Appendix B

Reports

2010 Annual Technical Report

SAN JOAQUIN RIVER
RESTORATION PROGRAM

April 2011

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Attachment 1: Sand Supply, Source, and Transport TM

Abbreviations and Acronyms

Act	San Joaquin River Restoration Settlement Act
ADCP	Acoustic Doppler Current Profiler
ATR	Annual Technical Report
CDEC	California Data Exchange Center
cfs	cubic feet per second
CSUF	California State University, Fresno
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board
CTK	Cottonwood Creek
Delta	Sacramento-San Joaquin Delta
DFG	California Department of Fish and Game
DO	dissolved oxygen
DPR	California Department of Pesticide Regulations
DWR	California Department of Water Resources
FMP	Fisheries Management Plan
FMWG	Fisheries Management Work Group
FWUA	Friant Water Users Authority
GBP	Grasslands Bypass Project
GIS	graphical information systems
GRF	Gravelly Ford
GPS	global positioning system
HEC-RAS	Hydrologic Engineering Centers River Analysis System
LDC	Little Dry Creek
mg	milligram
MIL	Millerton Lake gaging station
mm	millimeters
NAD	North American Datum
N/L	nitrogen per liter
NMFS	National Marine Fisheries Service
NRDC	Natural Resources Defense Council
Order	State Water Resources Control Board Order WR-2009-0058-DWR
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control

RA	Restoration Administrator
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RFID	radio frequency identification
RM	river mile
RTK	real-time kinematic
Secretary	Secretary of the U.S. Department of the Interior
Settlement	Stipulation of Settlement in NRDC, et al., v. Kirk Rodgers, et al.
SJR	San Joaquin River
SJRRP	San Joaquin River Restoration Program
SWAMP	Surface Water Ambient Monitoring Program
TMDL	total maximum daily load
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
WLR	water level recorder
WSE	water surface elevation
WY	Water Year

1.0 Introduction

Reports summarize results from SJRRP studies and reference to the appropriate ATR Data Appendices. Reporting includes presentation of methods, data, interpretation, and describing applicability and limitations of results. This evaluation leads to recommendation of a management action, future reevaluation, or no further action.

2.0 Millerton Lake Temperatures 2005-2010

2.1 Introduction

This report presents results of Temperature Monitoring for the Millerton Lake Cold Water Pool Study from 2005-2010 (refer to 2011 Agency Plan, Appendix A, section 14.0). Reclamation began collecting Millerton Lake temperature data in 2005 as background information in anticipation of the San Joaquin River Restoration Program. This monitoring investigated the effects of Friant Dam operations (with and without Interim Flows) on release temperatures to the San Joaquin River and the availability of the cold water pool to support recreational fisheries in Millerton Lake.

Water temperature exerts a substantial influence on the abundance, development, growth, and survival of fishes, including Chinook salmon (EPA, 1999, Myrick and Cech 2004). Temperature is critical to the timing of life-history events, especially reproduction (Fry 1971). High water temperatures result in physiological stress and increased metabolic demand, which may result in slower growth, increased susceptibility to disease, and lower survival rates. Understanding the longitudinal distribution of temperatures in relation to Restoration Flows on the SJR is critical to make flow schedule and stock selection recommendations.

In 2005 Reclamation deployed temperature sensors for monitoring the Millerton Lake inflow and outflow temperatures, and evacuation of the cold water pool. The data are used to calibrate and validate the CE-QUAL-W2 model of Millerton Lake temperatures providing Friant Dam release temperature inputs for the HEC-5Q model of San Joaquin River temperatures. The data inform management of the cold water pool for downstream release temperatures.

2.2 Methods

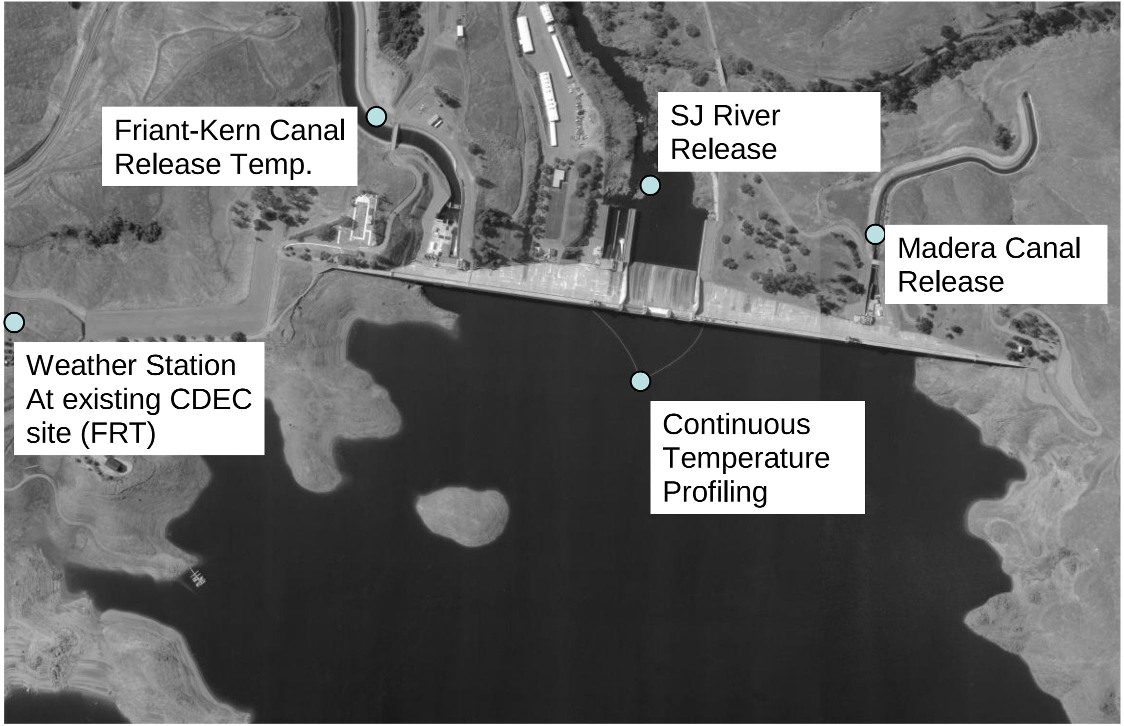
Hourly inflow temperatures were collected in the San Joaquin River Channel where it enters Millerton Reservoir and at release points below Friant Dam using ONSET temperature loggers. Hourly outflow temperatures were measured at the three release points from Friant Dam and from the fish hatchery and worm farm. In **Table B-1** and **Figure B-1** they are as described as follows:

Table B- 1
Millerton Lake Temperature Monitoring Locations

Name	String ID	Location	Notes
San Joaquin River outlet works	TW Temp	N36.99930, W119.70597	
Friant Forebay Temperature String	MLSTRNG	N37.00553°, W119.69492°	In the old river channel upstream from Friant Dam, a full depth string located near the Dam with 15 temperature loggers irregularly spaced to capture the detail in the epilimnion

Name	String ID	Location	Notes
			and metalimnion and to a lesser extent the hypolimnion.
Friant-Kern Canal	FKCANAL	N36.99697, W119.70453	
Madera Canal	MCTemp	N37.00220 W119.70769	
Main Outflow From Fish Hatchery/Worm Farm	FHTEMP	N36.98485, W119.72133	
Secondary outflow from Worm Farm	FH2	N36.98563,W119.72028	
Millerton Inflows below Kerckhoff #2 PP	HW-TEMP	N37.06938, W119.56102	
Finegold Temperature String	FGSTRNG	N37.04277°, W119.63910°	In the old river channel uplake from Finegold Creek, a full depth string with 15 temperature loggers irregularly spaced to capture the detail in the epilimnion and metalimnion and to a lesser extent the hypolimnion. This string was lost in 2009 and not replaced.

Figure B-1
Temperature Monitoring and Weather Station Locations near Friant Dam

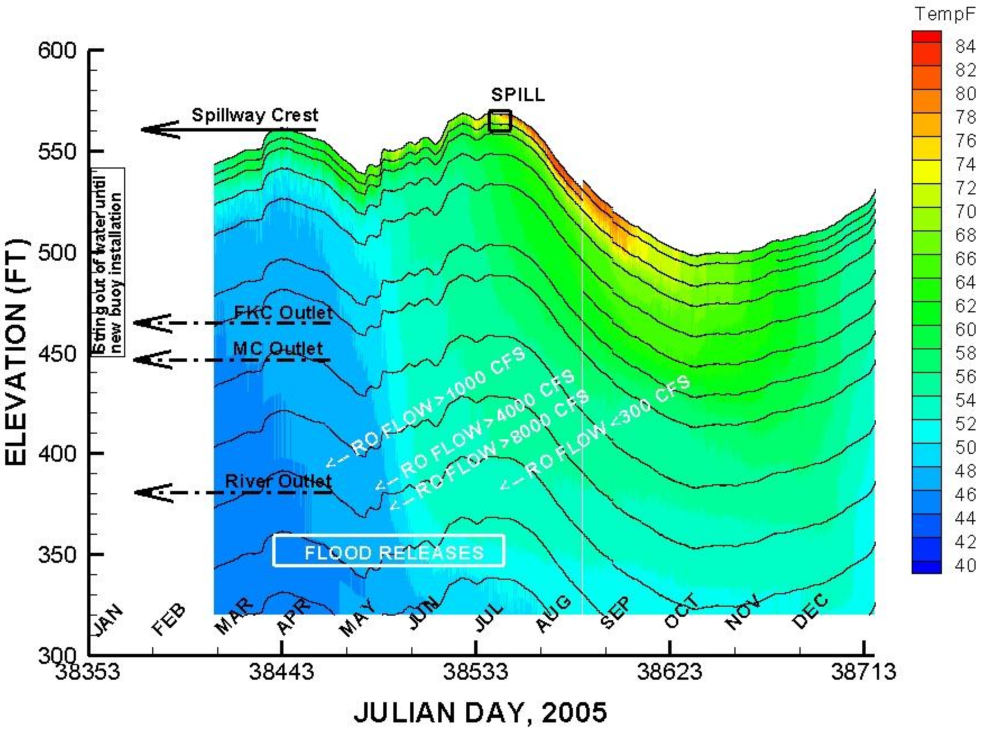


Sites not shown: Kerckoff Powerplant and Fish Hatchery Release Temperatures

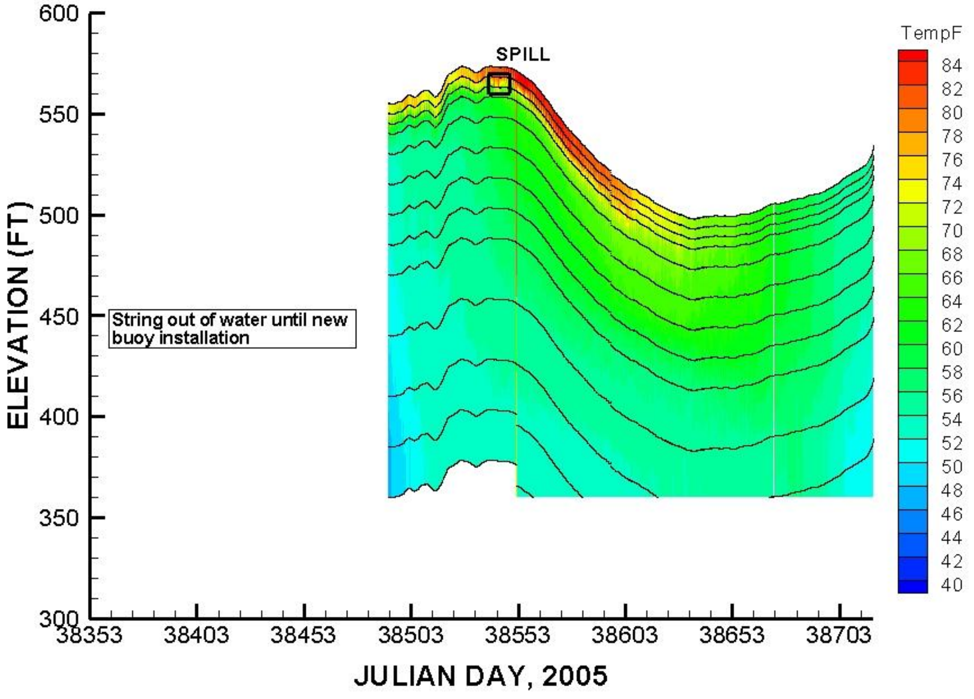
2.3 Results

Temperature profiles for Friant Dam Forebay and Finegold Bay are presented below in **Figures B-2** through **B-7**. Refer to the Temperature Atlas attached to this ATR for temperature results at other locations.

Figure B-2
2005 Millerton Reservoir Temperature Profiles



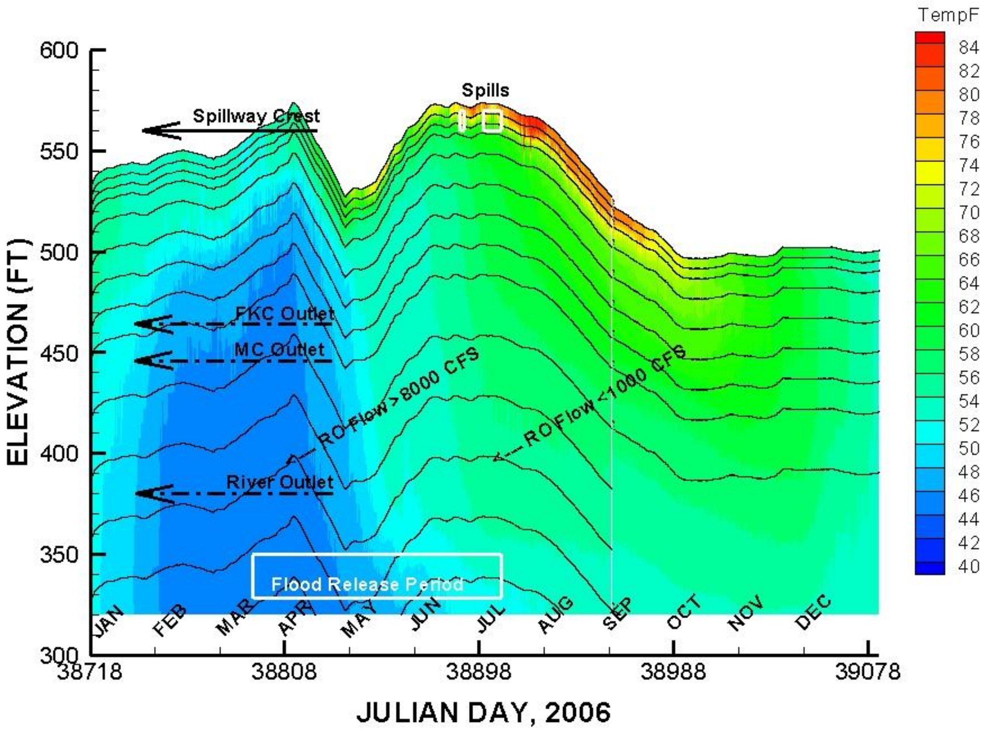
FRIANT DAM FOREBAY TEMPERATURE PROFILES



MILLERTON RESERVOIR AT FINEGOLD BAY PROFILES

Figure B-3
2006 Millerton Reservoir Temperature Profiles

FRIANT DAM FOREBAY TEMPERATURE PROFILES



MILLERTON RESERVOIR AT FINEGOLD BAY PROFILES

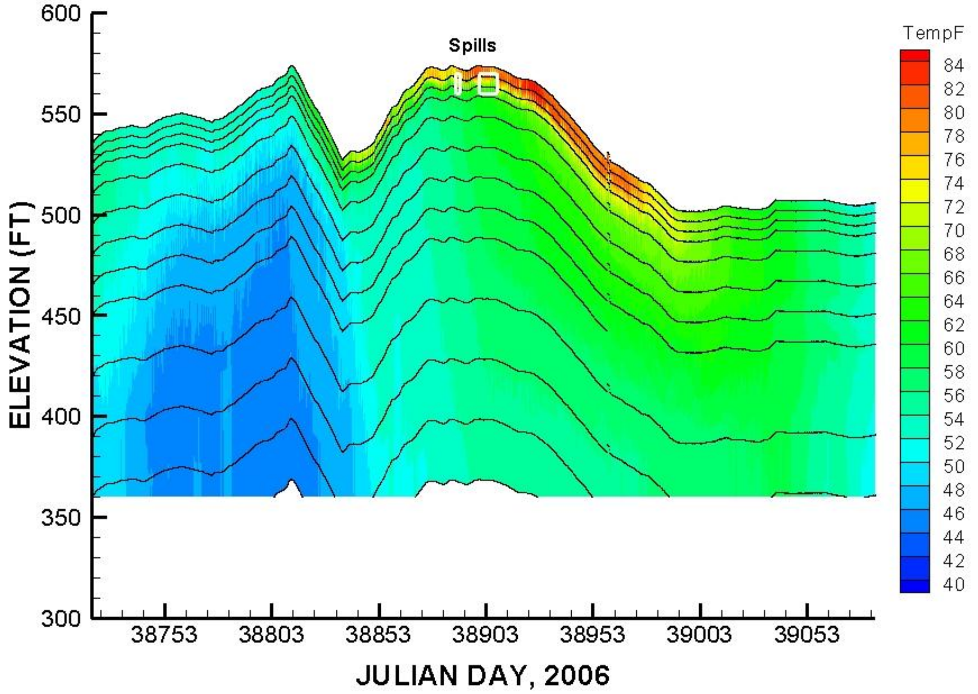
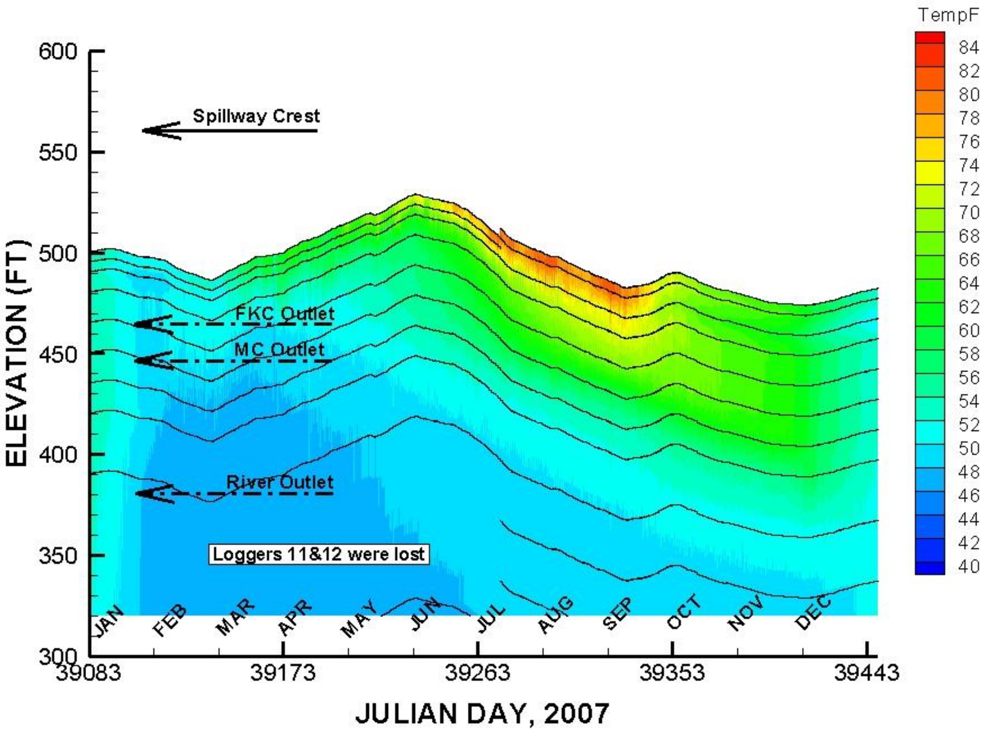


Figure B-4
2007 Millerton Reservoir Temperature Profiles

FRIANT DAM FOREBAY TEMPERATURE PROFILES



MILLERTON RESERVOIR AT FINEGOLD BAY PROFILES

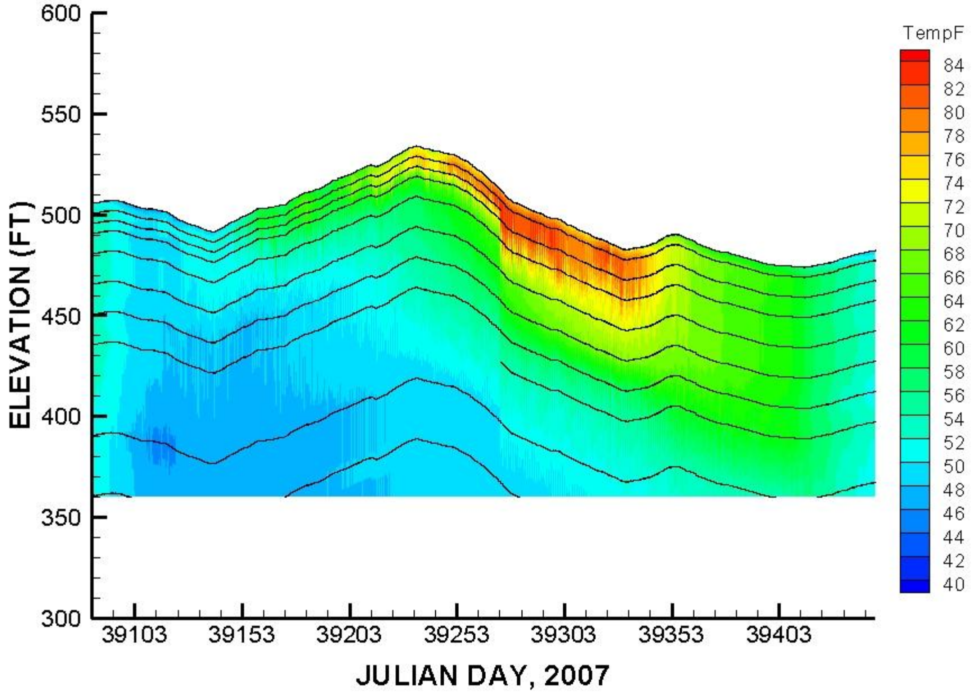
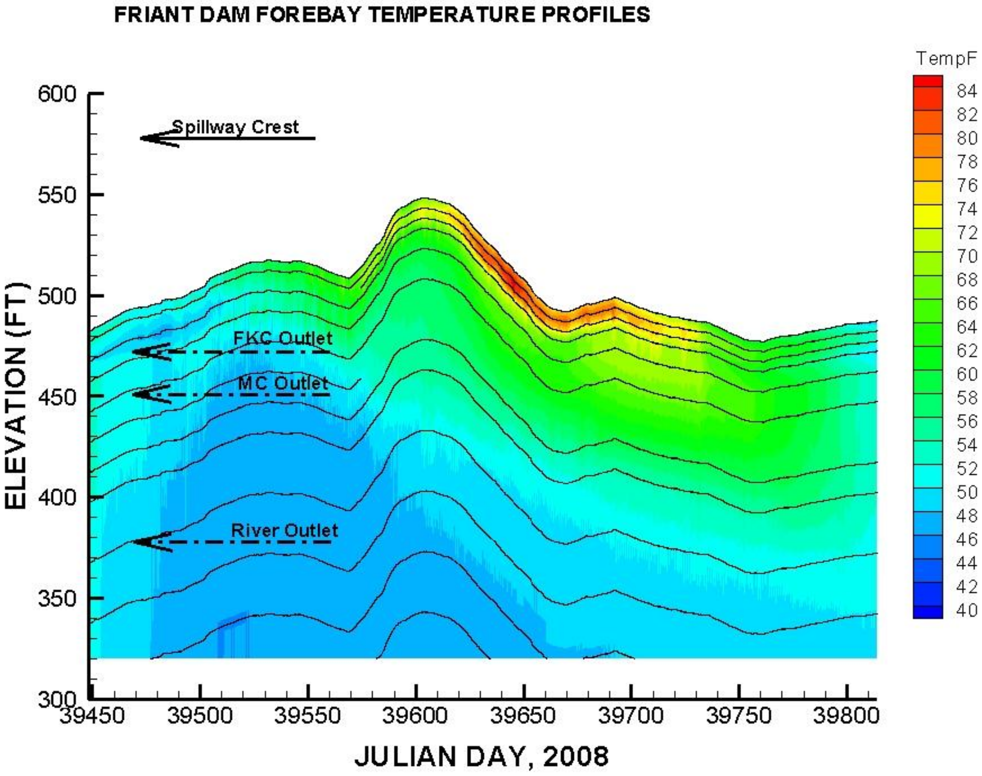


Figure B-5
2008 Millerton Reservoir Temperature Profiles



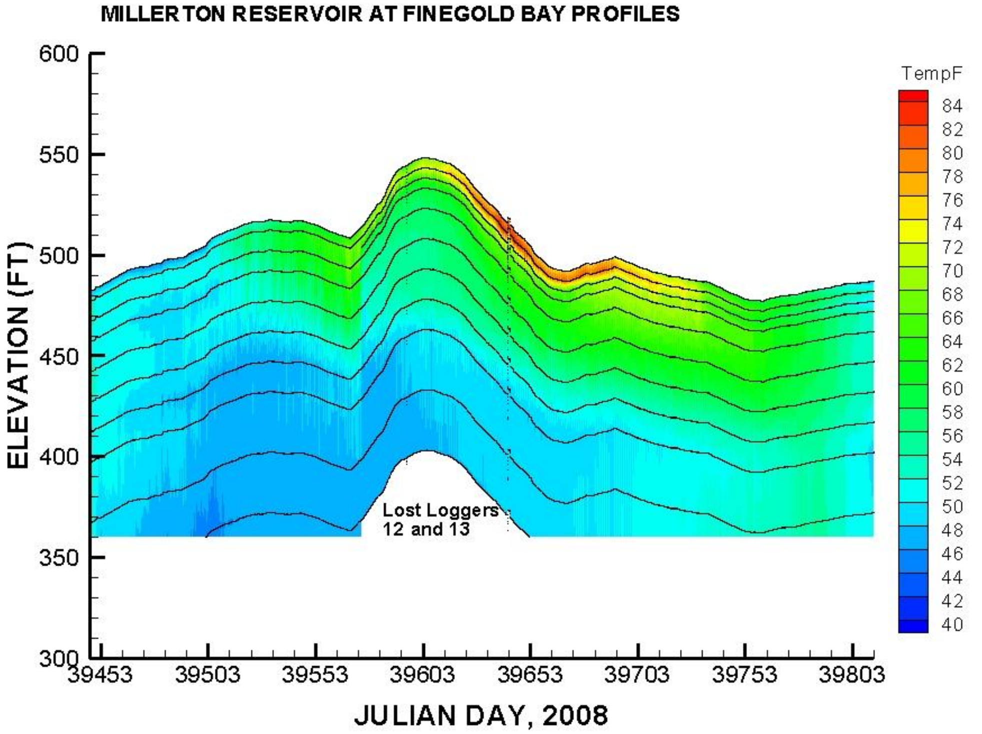
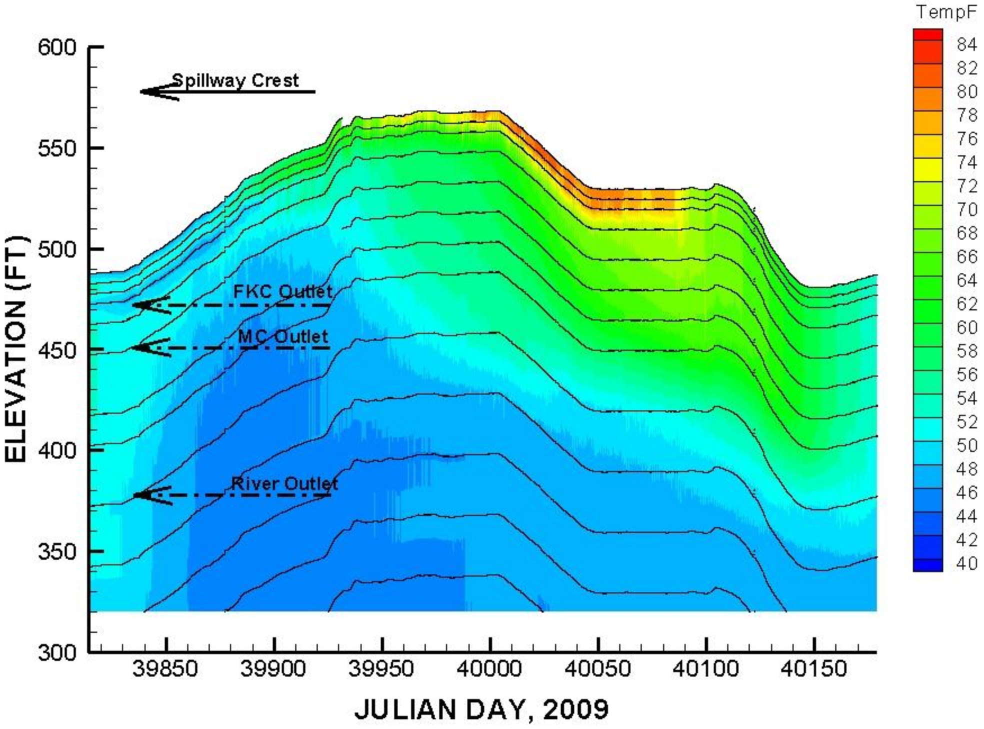


Figure B-6
2009 Millerton Reservoir Temperature Profiles

FRIANT DAM FOREBAY TEMPERATURE PROFILES



MILLERTON RESERVOIR AT FINEGOLD BAY PROFILES

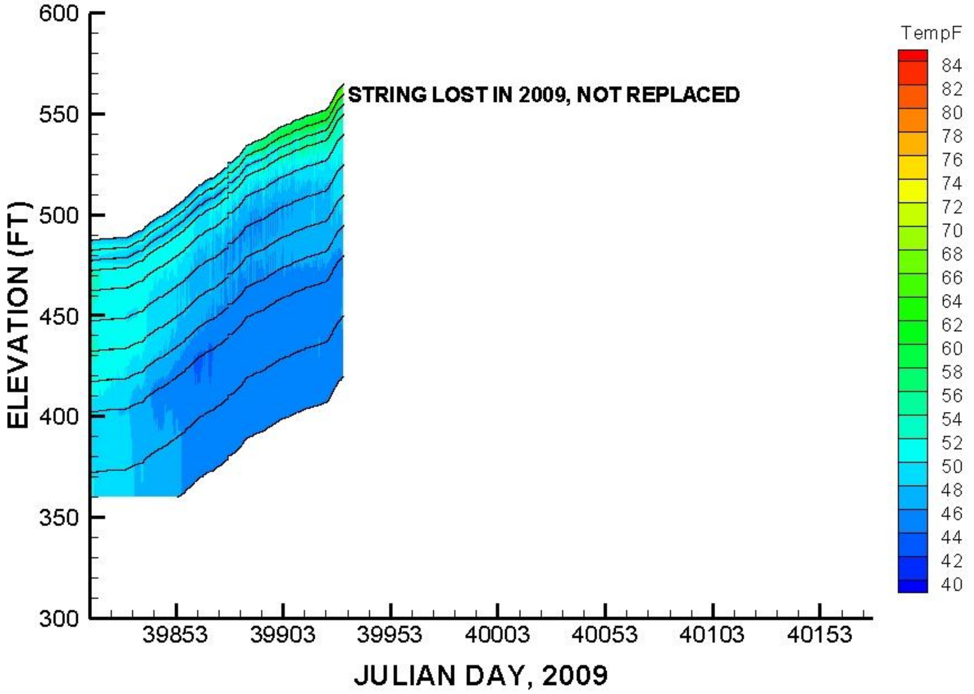
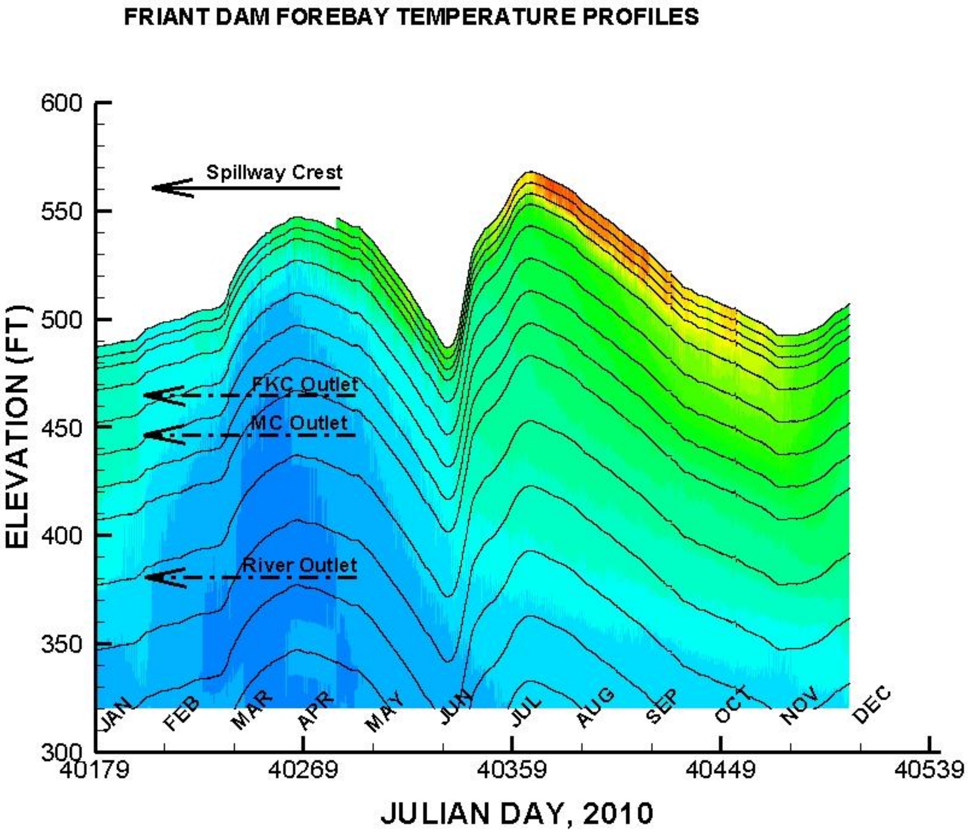


Figure B-7
2010 Millerton Reservoir Temperature Profiles



2.4 Discussion and Conclusions

Temperature profile results indicate a relationship between high flow years (2005, 2006, 2010 Interim Flows) and the hypolimnetic temperatures in Millerton Reservoir. When flood releases are made through the river outlets (El. 380 ft) the coldest water is released and it is replaced by SJR inflows to Millerton Reservoir. By late May and early June SJR inflows to Millerton Reservoir warm and cause warmer river outlet release temperatures. 2005 flood releases began in mid-April and river outlet releases temperatures exceeded 50 deg F on May 25. 2006 flood releases began in early April and river outlet releases temperatures exceeded 50 deg F on May 9. During 2010 Interim Flow releases the river outlet releases temperature exceeded 50 deg F on June 8.

The cold water depletion timing differences between these high flow years corresponds to differences in river outlet release timing. When deliveries to the higher elevation Friant-Kern and Madera Canals outlets are insufficient to maintain flood control storage, Reclamation releases flood flows from the cold water pool through the river outlet. Flood releases over the spillway are much warmer because this water comes from the reservoir surface.

2.5 References

Fry, F.E.J. 1971. The effects of environmental factors on the physiology of fish. Pp. 1–98 in W.S. Hoar and D.J. Randall, editors. Fish Physiology. Academic Press, New York.

Myrick, C. A., and J.J. Cech, Jr. 2001. Temperature effects on Chinook salmon and steelhead: a review focusing on California's Central Valley populations. Technical Publication 01-1. Published electronically by the Bay-Delta Modeling Forum at http://www.sfei.org/modelingforum/.

U.S. Environmental Protection Agency (USEPA). 1999. A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to Chinook salmon, EPA 910-R-99-010, 279 pp.

1

3.0 Summary of Meso-Habitat Monitoring Study for Reach 1B, Reach 2, and Reach 4A during the 2010 Interim Flow Period

Eric Guzman, California Department of Fish and Game, San Joaquin River Restoration,
Fisheries Management Work Group

3.1 Introduction

This report summarizes the San Joaquin River (SJR) Meso-Habitat Monitoring Study related to the 2010 Interim Flow Period (IFP) for the San Joaquin River Restoration Program (SJRRP). See **Table B-2** for time periods of flow release from Friant Dam and habitat study flows during the 2010 IFP. Meso-habitat monitoring consisted of mapping and characterizing SJR habitat units from the beginning of Reach 1B [Highway 99 (RM 243.1)] to the end of Reach 2 [Mendota Dam (RM 204.8)] and the beginning of Reach 4A [Sack Dam (RM 182)] to the end of Reach 4A [Sand Slough Control Structure (RM 168.3)]. This is continuation of the 2009 Meso-Habitat Monitoring Pilot Study that consisted of mapping and characterizing SJR Habitat Units (HU) from Friant Dam to the end of Reach 1A (Highway 99). Meso-habitat mapping began on July 12, 2010 and ended November 10, 2010. Recent aerial photographs (2010) were used to refine and expand Global Positioning System (GPS) data points into map polygons in Geographic Information System (GIS) depicting habitat units. Friant Dam releases were estimated at 350 cubic feet per second (cfs) at the time the photographs were taken (Appendix A: SJR Habitat Maps). This report presents the data collection methods, periods of data collection, and San Joaquin River (SJR) conditions. The purpose of this habitat monitoring is to document the longitudinal distribution of habitat units to plan for future design and data collection activities (microhabitat, holding, and spawning) and will be used to determine sampling locations for subsequent microhabitat measurements. All data contained within this report and appendices are preliminary and subject to revision.

Table B-2: Habitat Study Flows

Time window	**Reach**	**Friant Dam Release**	**Local CDEC Site Release**
Jul 12-14, 2010	1B	350 cfs	164-175 cfs (GRF)
Jul 28-29, 2010 Aug 3, 2010	2A+2B	347-355 cfs	121-137 cfs (GRF)
Nov 8, 2010 Nov 10, 2010	4A	353-355 cfs	220-292 cfs (MEN)

3.2 Methods

Crews of 2-6 individuals from the Department of Fish and Game floated the river in kayaks or waded in shallow habitats while taking measurements at each habitat unit (HU). Habitat Units were identified utilizing a classification system based upon those developed by Flosi and Reynolds (1998) and P.A. Bisson, et al. (1982). A main or side-channel HU (sub-habitat adjacent to the main channel HU) was identified when its length was equal to or greater than half the width of the river. If the area being sampled appeared to have some features that were not entirely consistent with the dominant HU and did not meet the above criteria (i.e. its channel length was less than half the width), that area was combined with the dominant mid-channel HU. **Table B-3** displays all of the potential habitat types that were considered likely to be present in the study area.

Table B-3: Potential Habitat Unit Types Within The SJR Restoration Area

RIFFLE	
Low Gradient Riffle	(LGR)
CASCADE	
Cascade	(CAS)
Bedrock Sheet	(BRS)
FLATWATER	
Pocket Water	(POW)
Glide	(GLD)
Run	(RUN)

Step Run	(SRN)
Edgewater	(EDW)*

MAIN CHANNEL POOL

Trench Pool	(TRP)
Mid-Channel Pool	(MCP)
Channel Confluence Pool	(CCP)
Step Pool	(STP)

SCOUR POOL

Corner Pool	(CRP)*
L. Scour Pool - Log Enhanced	(LSL)*
L. Scour Pool - Root Wad Enhanced	(LSR)*
L. Scour Pool - Bedrock Formed	(LSBk) *
L. Scour Pool - Boulder Formed	(LSBo)*
Plunge Pool	(PLP)

BACKWATER POOLS

Secondary Channel Pool	(SCP)*
Backwater Pool - Boulder Formed	(BPB)*
Backwater Pool - Root Wad Formed	(BPR)*
Backwater Pool - Log Formed	(BPL)*
Dammed Pool	(DPL)

ADDITIONAL UNIT DESIGNATIONS

Dry	(DRY)
Culvert	(CUL)
Not Surveyed	(NS)
Not Surveyed because of a marsh	(MAR)
In Channel Mine Pit	(ICMP)
Captured Mine Pit	(CMP)

* indicate side HU type

Habitat units were identified by visually estimating flow, depth, and substrate. Habitat units are relatively homogenous areas and are coarse in scale. They are discrete characterizations for relative estimations of continuous conditions and therefore difficult to quantify using qualitative criteria. It is common for smaller habitat patches to be present, especially in reaches with more complex channel features (riffle, run, pools complex). The complex transitional nature of channel features does not easily accommodate subjective decisions made by a group of surveyors; therefore, it was difficult to be entirely objective when delineating HU boundary points.

When a defined HU was encountered, a photograph was taken looking downstream from the upstream end. Wetted width, length, and mean depth were recorded at each HU. The boundaries of each HU were recorded using a GPS and a range finder was used to measure wetted widths and shorter HU lengths (typically runs, riffles, and pools). GPS points were used to measure longer HU lengths (typically long glides and large mine pits). Depth was measured by using a meter stick in shallower units and a SpeedTech SM-5 Depthmate Portable Sounder and Depth Meter in deeper water.

Discharge was recorded based upon the CDEC station records closest to the survey point. Polygons were created using field measurements and aerial photographs taken in the summer of 2010 (Appendix A: SJR Habitat Maps). The starting and ending GPS points from the survey provided the upstream and downstream boundary. The polygon was connected by following the wetted edge of the river on either the left or right bank and connecting the upstream to the downstream boundary. The area from each HU was calculated from the GIS polygons.

Each Reach was divided into sub-reaches. The first ten habitat units encountered in Reach 1B was recorded as sub-reach 1B.1, the next ten were recorded as 1B.2. This system continued through the entire Reach and subsequent Reaches. Each HU (including main- and side-channel) within each sub-reach were identified and recorded. Side-channel habitats (such as edgewater, backwater, etc.) determined to be distinct habitat units were recorded as distinct features associated within the main HU. Likewise, if a secondary channel HU had side channel habitat, then the side channel habitat would be recorded similarly. If the river was divided into two or more channels (braided channels), the dominant channel (the one with the highest discharge) was assigned the main HU number.

Mine pits that have the river flowing directly through them were classified as in-channel mine pits and were included in the survey. Mine pits that have connectivity to the river but the main channel does not flow through them were classified as off-channel mine pits and were not included in the survey. A GPS point was taken at the entrance point of off-channel mine pits. Mine pits that may be adjacent to the SJR but do not have connectivity were not identified in this study.

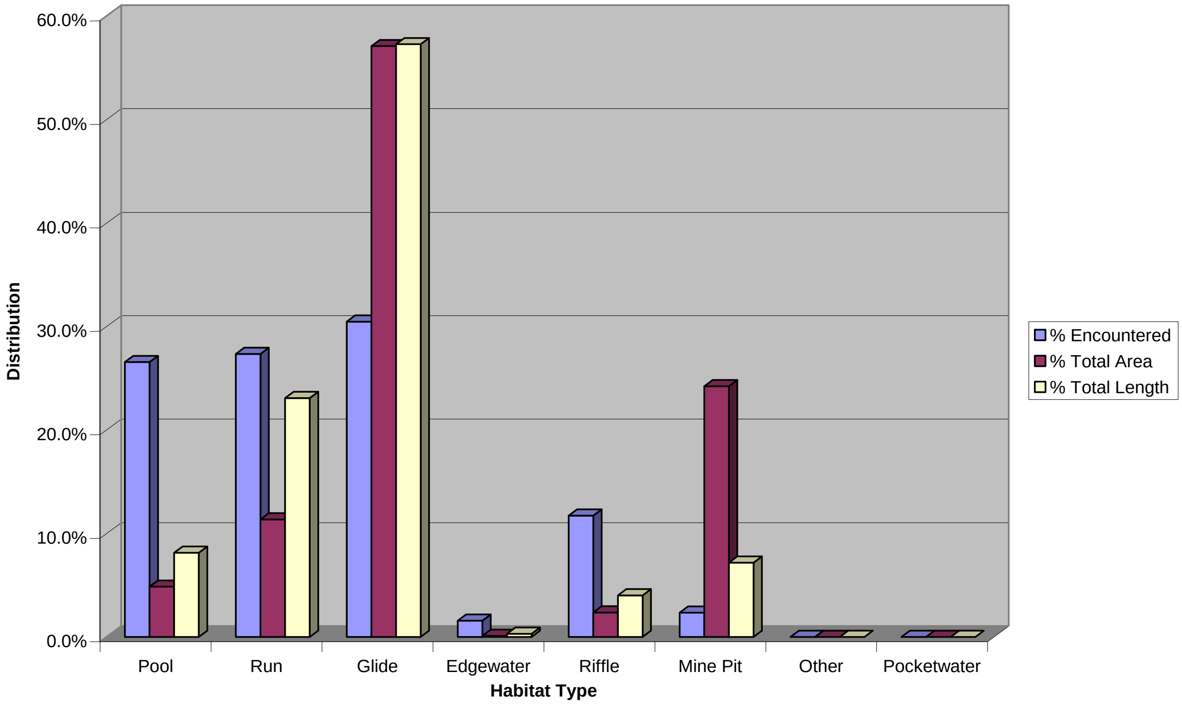
Results. In Reach 1B, 128 distinct habitat units were identified. Glides were the most dominant habitat type (30.5%), and consumed most (54.0%) of the area of the river that was surveyed (see **Table B-4** and **Figure B-8** for HU distribution details).

Table B-4:

Distribution of Habitat Units in Reach 1B

Type of Habitat	Quantity	% Encountered	Total Area (m2)	% Total Area	Total Length (m)	% Total Length
Pool	34	26.6%	31,483.76	4.9%	2,022.41	8.1%
Run	35	27.3%	73,539.55	11.4%	5,741.65	23.1%
Glide	39	30.5%	369,855.12	57.1%	14,242.56	57.3%
Edgewater	2	1.6%	642.95	0.1%	75.69	0.3%
Riffle	15	11.7%	15,274.21	2.4%	999.05	4.0%
Mine Pit	3	2.3%	156,930.78	24.2%	1,782.40	7.2%
Other	0	0.0%	0.00	0.0%	0.00	0.0%
Pocketwater	0	0.0%	0.00	0.0%	0.00	0.0%
Total	128	-	647,726.37	-	24,863.76	-

Figure B-8: Distribution of Habitat Types in Reach 1B



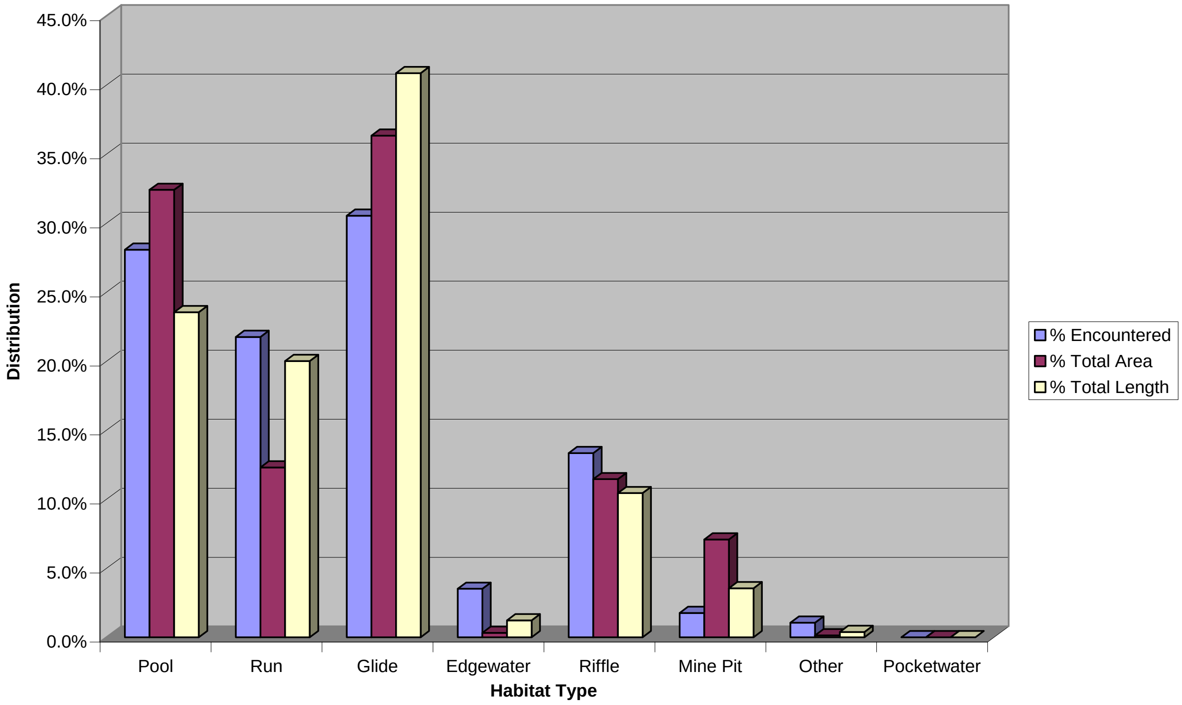
In Reach 2, 285 distinct habitat units were identified. Glides were again the most dominant habitat type (30.5%), and consumed most (36.3%) of the area of the river that was surveyed (see **Table B-5** and **Figure B-9** for HU distribution details).

Table B-5:

Distribution of Habitat Types in Reach 2

Type of Habitat	Quantity	% Encountered	Total Area (m2)	% Total Area	Total Length (m)	% Total Length
Pool	80	28.1%	798,463.82	32.4%	36,797.39	23.5%
Run	62	21.8%	302,993.07	12.3%	31,279.36	20.0%
Glide	87	30.5%	895,047.23	36.3%	63,869.99	40.9%
Edgewater	10	3.5%	7,714.42	0.3%	1,910.59	1.2%
Riffle	38	13.3%	282,013.53	11.4%	16,315.57	10.4%
Mine Pit	5	1.8%	174,399.64	7.1%	5,551.85	3.6%
Other	3	1.1%	3,230.09	0.1%	598.32	0.4%
Pocketwater	0	0.0%	0.00	0.0%	0.00	0.0%
Total	285	-	2,463,861.80	-	156,323.08	-

Figure B-9: Distribution of Habitat Types in Reach 2



Reach 4A consisted of 33 distinct habitat units were encountered with glides being the most abundant habitat type (42.4%) consuming (89.7%) of the area of the river that was surveyed (see **Table B-6** and **Figure B-10** for HU distribution details).

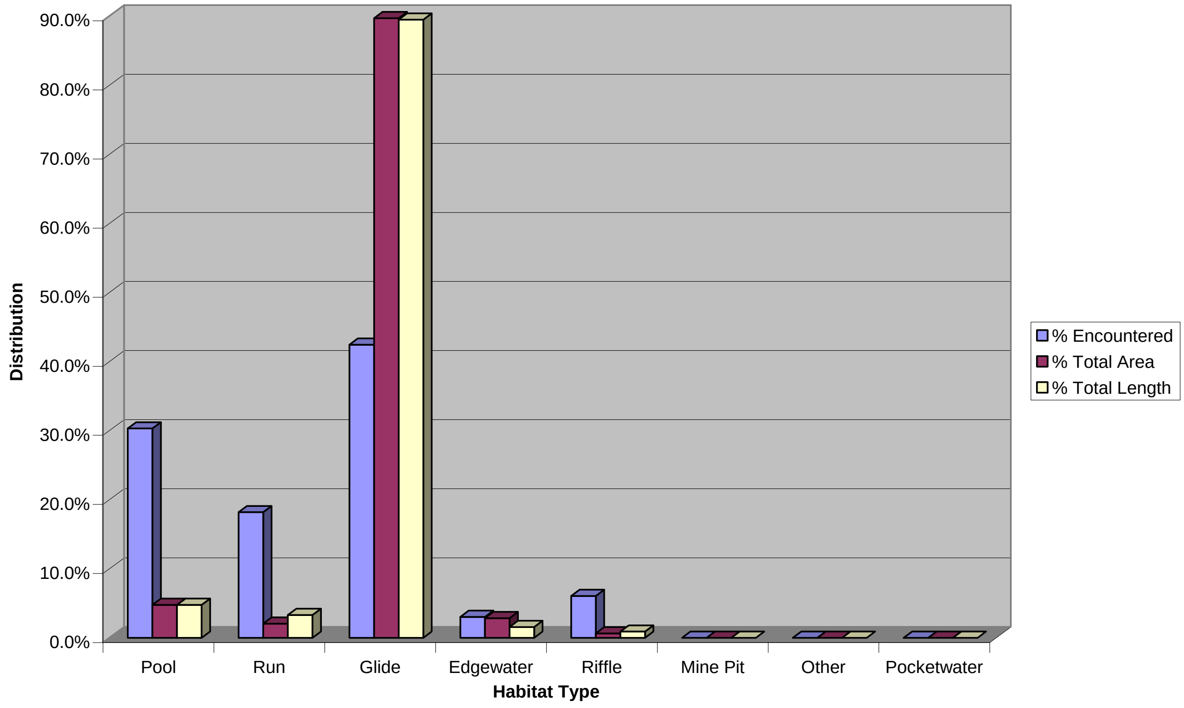
Table B-6:

Distribution of Habitat Units in Reach 4A

Type of Habitat	Quantity	% Encountered	Total Area (m2)	% Total Area	Total Length (m)	% Total Length
Pool	10	30.3%	33,190.59	4.8%	1,092.43	4.8%
Run	6	18.2%	14,245.01	2.0%	753.34	3.3%
Glide	14	42.4%	624,507.17	89.7%	20,462.27	89.5%
Edgewater	1	3.0%	19,750.63	2.8%	353.76	1.5%
Riffle	2	6.1%	4,491.70	0.6%	204.95	0.9%

Mine Pit	0	0.0%	0.00	0.0%	0.00	0.0%
Other	0	0.0%	0.00	0.0%	0.00	0.0%
Pocketwater	0	0.0%	0.00	0.0%	0.00	0.0%
Total	33	-	696,185.09	-	22,866.75	-

Figure B-10: Distribution of Habitat Types in Reach 4A



3.3 Discussion

The mapping time periods were dependent on the flow regime. DFG intended to map Program reaches when conveying flows prescribed by the Settlement, however, it was difficult to plan because full Settlement flows were not released because of seepage and water management issues. Additionally, Reach 4B was not mapped because of access issues. Habitat unit areas and distribution will be updated regularly (flow dependent) to document temporal changes.

3.4 Literature Cited

Bisson, P.A., J.L. Nielsen, R.A. Palmson, and L.E. Grove. 1982. A system of naming habitat types in small streams with examples of habitat utilization by salmonids during low stream flow. Symposium on acquisition and utilization of aquatic habitat inventory information. Western Division, American Fisheries Society. Bethesda, Maryland.

Flosi, G., and F.L. Reynolds. 1998. California Salmonid Stream Habitat Restoration Manual. California Department of Fish and Game, Technical Report, Sacramento.

4.0 Summary of Water Temperature Monitoring within the San Joaquin River Restoration Area during the 2010 Interim Flow Period

Eric Guzman, California Department of Fish and Game, San Joaquin River Restoration Program, Fisheries Management Work Group

4.1 Introduction. Water temperature substantially influences on the abundance, growth and survival of fishes. Temperature is critical to the timing of life-history events, especially reproduction (Fry 1971). High temperatures result in physiological stress and increased metabolic demand on fishes, which may result in slower growth, susceptibility to disease, and lower survival rates. Thermal distribution in a system is a major contributing factor that influences the physiology and biochemical mechanisms of Chinook salmon which in turn, cues their distribution and migration patterns. Bioenergetically, differing water temperature profile affects salmon swimming performance and food consumption, cascading into change in growth . Chinook salmon in California's streams encounter severe water temperature conditions throughout its geographic range (Moyle 2002). Understanding the longitudinal distribution of temperatures in relation to the Restoration Flows on the San Joaquin River is critical to our ability to successfully prepare the system for reintroduction of Chinook salmon (i.e., evaluate site specific alternatives, make recommendations on water allocations, make recommendations for stock selection and reintroduction strategies). See Exhibit A (Conceptual Models of Stressors and Limiting Factors for San Joaquin River Chinook Salmon) of the SJRRP Fisheries Management Plan for acceptable temperature ranges at each life stage of Chinook salmon and why suitable temperatures are important to salmonids at an individual and population level. The California Department of Fish and Game (DFG) began collecting water temperatures during the Fall 2009 Interim Flow Period. The purpose of this report is to summarize temperature data collected during the 2010 Interim Flow Period (IFP)

4.2 Methods. Temperature data loggers (HOBO Water Temp. Pro v2) were programmed to record temperature hourly and were placed at various locations beneath the water's surface, in a longitudinal array throughout the Restoration Area. Loggers were arrayed so that migration pathways and potentially suitable holding, rearing, and spawning habitats may also be evaluated (Appendix A: Temperature Monitoring Locations Maps). Location was dependant on legal access to the site, an appropriate anchor point, and the ability to conceal the loggers to reduce vandalism. Where possible, placement was made within the thalweg of the stream, or in an area where there is adequate year round flow and water depth to avoid measurement bias from the warmer stream edges or thermal stratification. Most loggers were deployed in runs, riffles, and glides along the right and left banks in the SJR. Typically loggers are cabled to trees, root wads, or permanent structures and would be located approximately 2 feet below the water surface in continuous flow. Loggers in depths less than 2 feet are located approximately 6 inches from the river bottom in continuous flow.

Loggers deployed in pool and mining pit sites are located in mid-channel. These sites contain loggers on vertical profiling stringers with a weight and float. Pools and mining pits with depths less than 8 feet have one logger attached to the stringer approximately one foot below the water surface. Pools and mining pits with depths greater than 8 feet have two loggers attached to the stringer. One logger is attached approximately one foot below the water surface on the stringer and the other logger is attached approximately 18 inches from the bottom on the stringer. Each mining pit site initially had two locations with vertical stringers (one stringer at the entrance of the pit and one stringer approximately in the center of the pit). Locations at the entrance of pits are not longer used as monitoring stations because of high vandalism.

Temperature loggers were deployed in off-channel mining pits that have connectivity to the SJR. Loggers were placed on stringers in two locations per mining pit. Stringers are located at the entrance and in the middle of the mining pits (typically the deepest section of the mining pit). Stringers located in depths less than 6 feet have only one logger attached just below the water surface. Stringers located in depths greater than 6 feet have one logger attached just below the water surface and one logger attached approximately two feet from the bottom of the pit. Microsoft Access is the database used for the temperature monitoring study. It is the responsibility of the DFG staff to ensure valid data; however, to aid the staff in this task the database is equipped with a QA/QC Utility to detect questionable data. The QA/QC Utility is designed to flag any data points that have a value in excess of a certain tolerance when compared with adjacent points. To minimize the possibility that erroneous data will migrate to other applications, the database will not allow the user to generate any reports or graphs until a QA/QC check is performed and all the data points tagged with QA/QC codes are cleared. Once processed, the data can be used for temperature model application purposes as well as to generate graphs and reports.

4.3 Results. Overall, 31 monitoring areas were operational prior to the 2010 IFP. All vertical stringers located at the entrance of the gravel pits were lost during the 2010 IFP. Several other monitoring sites had missing loggers because of vandalism and/or high flows. A description of monitoring sites and status of loggers is described in Appendix B: Temperature Logger Summary and Status. Raw temperature data for each monitoring location is located in Appendix C: Temperature Data. These data are preliminary and subject to revision.

4.4 Discussion. The specific locations of data loggers (i.e., near the stream margins versus main channel) may complicate our ability to make firm conclusions. More data should be gathered from these downstream habitats, and over multiple years, to better address our understanding of the temperature regimes in these locations. Water temperature and other physical and biological measurements of the hyporheic environment should also be assessed in potential spawning areas. As access becomes available, DFG intends to expand the temperature logger array by deploying loggers in Reach 4 and in the bypass system. Additionally, we will continue to monitor longitudinal temperatures patterns during future IFP to identify the annual variation in water temperatures throughout the Restoration Area. The Fisheries Management Work Group will continue to assess water temperatures during the spawning and incubation period and adjust the limiting factors analyses as appropriate.

Temperature monitoring data will be used to validate draft conceptual models of stressors and limiting factors for Chinook salmon and will be prepared for inclusion into the EDT (Ecosystem, Diagnosis, and Treatment) model and potentially other models used by the SJRRP. Analysis of temperature monitoring will be used to evaluate the relative importance of the various factors that combine to produce the observed stream temperatures, and to evaluate what impact changes in stream shade, channel geometry morphology, and flow may have on the stream temperature regime. Temperature monitoring evaluation will assist the SJRRP in developing TMDL standards and assist in making recommendations on specific actions relating to adaptive management of the SJRRP.

4.5 Literature Cited

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5.0 Water Surface Profile

5.1 Introduction

The data in this report was collected as part of the Channel Capacity Management study, Water Surface Elevations. Inundation levels, channel capacity and channel response to restoration releases requires knowledge of the water surface elevations and hydraulic conditions along the reach. Specific measurements of the water surface elevations at ~0.5-mile intervals that can be correlated with concurrent discharge measurements at known, steady-state discharges provide a means of assessing water surface elevations and associated hydraulic conditions, and the extent of inundation along the reach. These data provide a direct means of calibrating the hydraulic models to specific ranges of discharge.

5.2 Methods

5.2.1 Procedure

Water surface profiles were obtained using a survey grade GPS (3D quality of 0.1 foot) to record the water surface elevations along the river. The horizontal datum used was the California Coordinate System Zone 3, US Survey Feet, based on the California Geodetic Coordinates of 1983, Epoch 2007.0. The vertical datum used was the North American Vertical Datum of 1988. Orthometric heights were derived from RTK observations and application of GEOID03 to the RTK values. RTK observations were received from either the Fresno State or Tranquility base stations via a cell phone modem attached to the GPS receiver. Existing control points were used to validate the accuracy of the data. Near the DFG hatchery in Friant, thick vegetation prohibited the use of the GPS equipment. Control was set in an open area using GPS, and a total station was used to record the water level.

5.2.2 Timing

Below is **Table B-7** showing when each reach was surveyed. The 1A-2 survey was broken into two pieces because of heavy rains on April 20, 2010. The survey was stopped at about river mile 250 (Scout Island) on April 20, and restarted at the same location the following day.
Reaches 1A and 1B were measured during Friant releases of approximately 1,100cfs. On April 24, they were increased to approximately 1,350cfs and held constant for the duration of the surveys in Reaches 2A, 2B, and 3.

Table B-7: Timing for water surface elevation surveys

Date	Time	Activity
19-Apr	7:20	Start 1A-1 Survey
19-Apr	18:17	End 1A-1 Survey
20-Apr	7:24	Start 1A-2 Survey
20-Apr	9:43	End at Scout Island RM 250
21-Apr	8:46	Start at Scout Island RM 250
21-Apr	13:00	End 1A-2 Survey
22-Apr	6:41	Start 1B Survey
22-Apr	13:53	End 1B Survey
23-Apr	9:30	Start Hatchery Survey
23-Apr	10:30	End Hatchery Survey
26-Apr	9:31	Start 2A Survey
26-Apr	16:00	End 2A Survey
27-Apr	8:31	Start 2B Survey
27-Apr	14:21	End 2B Survey
28-Apr	9:02	Start 3-1 Survey
28-Apr	14:09	End 3-1 Survey
29-Apr	8:38	Start 3-2 Survey
29-Apr	14:38	End 3-2 Survey

5.2.3 Locations

Water surface elevations were obtained along reaches 1A through 3 (Friant Dam to Sack Dam). Please refer to the figures in **Appendix C** for locations and elevations. Survey locations were placed at the top and bottom of hydraulic controls, at the top and bottom end of long pools, and about 500 feet upstream, at and 500 feet downstream of discharge measurement cross-sections. An attempt was made to limit the drop between points to no more than half a foot. At Ledger Island, drop was limited to a quarter foot, and were gathered at both sides of the river.

5.3 Results

Water surface profile data points are shown with recorded elevations on maps in the Data Appendix. Data tables containing all of the survey point locations and elevations are contained on the data disk.

The number of data points collected for each reach is as follows:

- 1A- 194
- 1B – 82
- 2A – 92
- 2B – 37
- 3-72

5.4 Discussion

As established prior to the monitoring effort, the spacing of surveyed water surface points varied, as necessary, according to channel slope and local conditions. Longitudinal distances between survey points were often reduced significantly at specific locations in order to refine abrupt changes in the water surface profile by collecting data at the top and bottom of riffles and other hydraulic controls. Larger distances between points were used in the large pools and backwater areas without impacting the accuracy of the water surface profile.

A preliminary comparison of the surveyed and computed water surface profiles based on the current 1-D HEC-RAS model indicates that the majority of significant hydraulic controls were sufficiently characterized by the survey data, and that no noticeable gaps in the data exist. Brief comparisons of the survey data and current model results also indicate that additional model calibration is necessary and can now be performed in numerous locations where previous calibration data didn't exist.

The preliminary review of the data also indicates that, in general, no significant anomalies exist. However, an occasional subtle rise in water surface elevation in the downstream direction does exist, but the average magnitude of these instances is only approximately 0.1 feet and can be explained by a combination of error tolerance in the equipment and error in the exact placement of the survey rod. In some cases, it could also possibly be a hydraulic jump occurring after a steep riffle or weir.

5.5 Conclusions and Recommendations

5.5.1 Conclusions

Comparisons between predicted water surface elevations in the 1D model and measured water surface elevations have improved the model's performance, and will provide more certainty in predicted inundation levels, channel capacities and other channel responses to the restoration releases.

5.5.2 Recommendations

Trigger flows to conduct measurements that would best aide modeling are flows confined by the following indications: lowest commonly expected flow, flows wetting the bottom of the low flow channel, flows near the bank full flow that govern channel shape, flows that just wet the overbank floodplain areas, and flood flows that produce significant overbank flow. Additionally, flows should be of adequate duration to reach steady state.

Current trigger flows are based on restoration flow releases of 350, 1500, 2000, 2500, and 4000 cfs. For the existing channel it seems reasonable to look for the following (**Table B-8**) interim release ranges to identify the associated existing parts of the channel.

Table B-8. Hydraulic indicators, required flows from Friant, and reaches to be monitored

Indicator	Required Flow Out of Friant Dam (cfs)	Reaches to be Monitored
Lowest commonly expected flow	350	1B, 2B, 3
Flow wetting bottom of low flow channel	350-1,500	1B, 3
Bankfull Flow	2,000-2,500	All
Flows just wetting entire floodplain	3,000-4,000	All
Significant floodplain inundation	8,000	All

6.0 Discharge Measurements

6.1 Introduction

The data in this report was collected as part of the Channel Capacity Management study, Water Surface Elevations. Inundation levels, channel capacity and channel response to restoration releases requires knowledge of the water surface elevations and hydraulic conditions along the reach. Specific measurements of the water surface elevations at ~0.5-mile intervals that can be correlated with concurrent discharge measurements at known, steady-state discharges provide a means of assessing water surface elevations and associated hydraulic conditions, and the extent of inundation along the reach. These data provide a direct means of calibrating the hydraulic models to specific ranges of discharge.

6.2 Methods

Discharge measurements are collected using an ADCP. A bank-operated portable cableway is placed at most measurement locations. The water craft-mounted ADCP is then attached to the cableway. A steady, consistent pull is applied to the cableway to move the ADCP across the section to make up a transect. As per USGS standard, a minimum of four transects at each section are performed. If any single discharge measurement deviates from the average by more than 5 percent, an additional four transects are performed.

6.2.1 Procedure Modifications.

Communication difficulties between the Acoustic Doppler Current Profiler (ADCP) and laptop during the Spring 2010 Interim Flows measurements were common and resolved by either halting the craft on the transect until communications were restored, or abandoning the transect and starting a new transect to replace the faulty one. Location and travel of the ADCP were recorded from ADCP bed tracking data, and global positioning system (GPS) position and heading data. When a moving bed condition was observed, the GPS data were used to determine the distance traveled.

A few sites were measured without using a tagline or bank-operated cableway. Discharge sites D4, D12 split, D25 were conducted by towing the ADCP behind an inflatable kayak, which was paddled across the river between visually identified targets on either bank.

6.3 Results

6.3.1 QA/QC results

During many of the measurements, communications between the ADCP/GPS and laptop were discontinuous. When a pause in communications was noticed before the ADCP was moved significantly, the movement was halted until communications was restored. When more than a few minutes to restore communications were needed, or if the traveled distance without communications was excessive, the transect would be removed from the average and a new transect would be measured. After extensive office checks, it was determined that the USB-to-RS232 adapters were intermittent and alternative adapters would be necessary for future data collection.

Measurement files were checked in the office for completeness and consistency of details such as the survey team, site identification, and date. Starting bank location, distance to bank, bank shape, traveled distance and magnetic declination were also considered for correctness. Bottom track and GPS positions were compared for moving bed conditions and the applicable tracking method to calculate discharge was checked. Measured discharges were inspected to verify compliance with standards.

6.3.2 Summary results

Table B-9. Discharge measurement results

Scheduled Friant Release (cfs)	Measurement Site	Location (RM)	Date/Time	Flow Measured (cfs)	Equipment Used
Reach 1A					
1100	Discharge 4	263.6	04/19/2010 16:43-17:03	1,320	ADCP
1100	Discharge 6	261.5	04/19/2010 11:03-11:18	1,413	ADCP
1100	Discharge 7	260.8	04/19/2010 14:14-14:37	1,393	ADCP
1100	Discharge 8	260.5	04/19/2010 10:39-10:58	1,447	ADCP
1100	Discharge 8 split	260.4	04/19/2010 12:24-12:37	382	ADCP
1100	Discharge 11	255.1	04/19/2010 17:25-17:55	1,377	ADCP
1100	Discharge 11	255.1	04/20/2010 09:05-09:29	1,146	ADCP
1100	Discharge 12	251.2	04/20/2010 11:53-12:24	1,300	ADCP
1100	Discharge 12 split	251.1	04/20/2010 14:43-15:24	732	ADCP
1100	Discharge 16	248.3	04/21/2010 09:43-10:49	1,138	ADCP
1100	Discharge 17	245.2	04/21/2010 13:30-14:02	1,101	ADCP
Reach 1B					
1100	Discharge 18	237.7	04/22/2010 09:47-09:55	1,127	ADCP
1100	Discharge 19	232.5	04/22/2010 12:31-13:32	1,050	ADCP
Reach 2A					
1350	Discharge 22	222.0	04/26/2010 10:05-10:18	938	ADCP
1350	Discharge 23	218.3	04/26/2010 12:35-13:12	977	ADCP
Reach 2B					
1350	Discharge 24	214.0	04/27/2010 09:55-10:19	1,070	ADCP
1350	Discharge 25	212.2	04/27/2010 13:27-13:45	1,032	ADCP
Reach 3					
1350	Discharge 28	202.9	4/27/2010	595	ADCP
1350	Discharge 29	197.7	04/28/2010 12:27-13:01	574	ADCP
1350	Discharge 30	193.6	04/29/2010 09:40-10:06	848	ADCP
1350	Discharge 31	189.8	04/29/2010 11:32-12:11	837	ADCP
1350	Discharge 32	184.5	04/29/2010 14:59-15:16	826	ADCP

Key:
ADCP = Acoustic Doppler Current Profiler
cfs = cubic feet per second

6.4 Discussion

Discharge measurements were conducted following a week with planned Friant release of 1,600cfs to an adjusted release less than 1,350cfs before settling at 1,250cfs (refer to **Appendix G**). Reaches 1A and 1B were measured the week of April 19th, 2010 during Friant releases of approximately 1,250cfs. Measurements were conducted with the Friant release and included a natural component from a spring storm producing 0.67 inches of precipitation on April 20 and 0.36 inches of precipitation on April 21 in Fresno (California Irrigation Management Information System (CIMIS) Station No. 80). Reaches 2A, 2B, and 3 were measured during Friant releases of about 1,550cfs. Discharge measurements were conducted at the same time as the water surface profile survey.

In Reach 1A, access to discharge sites 8 and 8 split require access with time limitations dependant on public use. Because of potential precipitation, and other weather conditions and time requirements necessary to perform the discharge measurements, it was determined that one team would begin at this site and finish the day at discharge 4, upstream from this site.

As shown in **Table** , flow measurements generally indicate a decrease in total discharge in the downstream direction. However, as observed in the fall 2009 monitoring, measurements also indicated a slight increase in discharge between Ledger Island (Discharge 4) and Rank Island (Discharge 8). At the 1,250cfs release, this increase was approximately 127cfs (41cfs/mile). This increase is not attributable to inflow from Little Dry Creek which is recorded as discharging less than 5cfs on April 19th. The flow split into a secondary channel at Rank Island was also measured, indicating main channel flow was 1,447cfs and the secondary channel flow was 382cfs.

Discharge measurements below the Hwy 41 Bridge were complicated by a runoff from spring storm which likely increased the flow between the Hwy 41 Bridge and Sycamore Island by 154cfs. The timing of measurements allowed runoff approximately 3 hours more time to accumulate and flow down through the watershed at Sycamore Island than at Hwy 41. Because of difficulties caused by the weather, additional measurements after Sycamore Island were abandoned for the day. Between Discharge 16, near the Milburn unit, and Discharge 17 at the Highway 99 crossing, flow losses were 37cfs (12cfs/mile). In Reach 1B, at discharge 18, a 26cfs gain was observed, probably from responses to a spring storm earlier in the week. A 51cfs (4cfs/mile) loss occurred between Discharge 18 and Discharge 19.

Measurements in Reaches 2A and 2B yield a loss of 112cfs (11cfs/mile) at Discharge 22 followed by gains at discharge 23 and 24 for a total of 132cfs (17cfs/mile). Gains at discharge 23 and 24 are likely measurements of the rising limb of the increase in Friant releases to 1,550cfs. By discharge 25, flows had lost 38cfs (20cfs/mile), indicating the flow was stabilizing.

Five sites were added in Reach 3 for the 1,595cfs scheduled release at Friant. The locations were selected similarly to the previous sites and with a better understanding of optimal requirements for using an ADCP. Specific locations are listed by river mile in **Table** and shown in **Appendix G**. Operations at the Mendota Pool caused a flow discontinuity between measurements upstream from the pool and downstream from the pool. This discontinuity limits comparisons of the upstream and downstream measurements from channel losses without understanding how operations at the Mendota Pool control the flow.

In Reach 3 flow loss at discharge 29 was 21cfs (4cfs/mile), and flow gain at discharge 30 of 274cfs was probably contributed by Firebaugh Wasteway. Losses from Discharge 30 to 31 are 11cfs (3cfs/mile) and from Discharge 31 to 32 were 11cfs (2cfs/mile).

6.5 Conclusions and Recommendations

6.5.1 Conclusions

All of the discharges with the surface profile can be used as calibration for the model. However, because of the unsteady releases and weather events, Reaches 1 and 2 discharge measurements may not be usable for analysis of channel losses; however, they may provide insight into how the San Joaquin River watershed below Friant Dam responds as it flows through agricultural and urban land use areas.

Reach 3 discharges were much more stable, with a defined inconsistency where the Firebaugh Wasteway joins the river. Measuring the flow or installation of a transducer on the Firebaugh Wasteway may be helpful to better account for flow changes in the system.

6.5.2 Recommendations

Refer to the recommendations in Report 5.0: Water Surface Profile.

7.0 Additional Water Level Recorders

7.1 Introduction

The data reported in this section is related to the study "Additional Water Level Recorders" that specifically address needs related to Problem Statement 5, San Joaquin River Channel Capacity Management, and indirectly address certain aspects of other problem statements by providing a continuous record of water surface elevations at key locations during Restoration releases to calibrate hydraulic models being used to assess channel capacity, fishery habitat, channel bed stability and many other aspects of Restoration planning and design.

Five additional water-level recorders (Recorders 1 through 5) were installed at Reach 1A prior to the start of the 2009 Interim Flow releases and another one (Recorder 6) was installed at Reach 1B prior to the start of the 2010 Spring Interim Flow release. The stage data are continuously being collected from the dates of installations.

7.2 Methods

As shown in **Figure B-11**, this particular type of recorder, Global Water-WL16U, is an integrated unit consisting of a submersible transducer (pressure sensor) connected to the data logger with a standard 25-foot cable (longer cable lengths are available). The pressure transducer unit was installed in the channel bed and the data logger was installed at the shore to provide easy access to download the data. Refer to the 2009 ATR for more detailed information about installation methods.

Figure B-11. Water level recorder

The data from the recorders will be downloaded periodically at sufficient frequency to insure that storage capacity of individual data loggers is not exceeded. These water stage readings were used to compute WSE. As shown in **Figure** , the transducer was installed at the center of the 2-inch diameter PVC pipes anchored on the channel bed. The WSE was calculated by adding stage reading to the respective top of pipe elevation, which was surveyed using a total station, and subtracting a half of the outside diameter of the pipe.

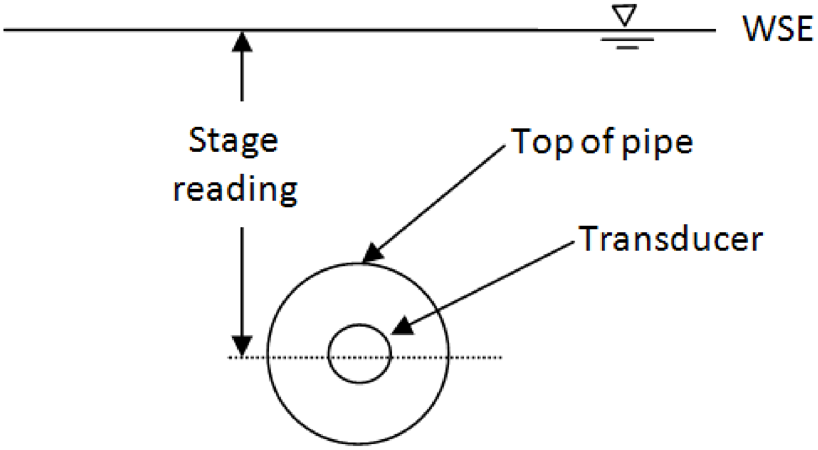

Figure B-12. Measured parameter

7.3 Results

Coordinates of recorder locations and the recording dates for 2010 are summarized in **Table** . The coordinates associated with each recorder refer the position of corresponding transducer located in channel bed.

Water stage readings that were stored in data loggers of all recorders were downloaded periodically using a field computer with Global Logger v2.0.6 software installed. Collected stage data were then converted as elevation data and presented in **Figure** through **Figure** , whereas the data before this period were reported in the 2009 ATR.

Table B-10. Location of water level recorders

Recorder	Location	River Miles	Northing	Easting	Elevation	Date Recorded
1	Head Ledger Island	263.4	1806574	6783091	289.21	1/1/2010 - 10/27/2010
2	Willow Unit Grade Control	261.5	1800801	6781533	284.93	
3	Rank Island Grade Control	260.4	1796241	6780278	274.85	
4	Sycamore Island Flow Split	251.1	1769843	6755779	245.70	
5	Milburn Unit	248.4	1769997	6747942	232.90	
6	R 1B-1_RM 237.7	237.7	1760168	6704615	206.91	1/28/2010 - 10/27/2010

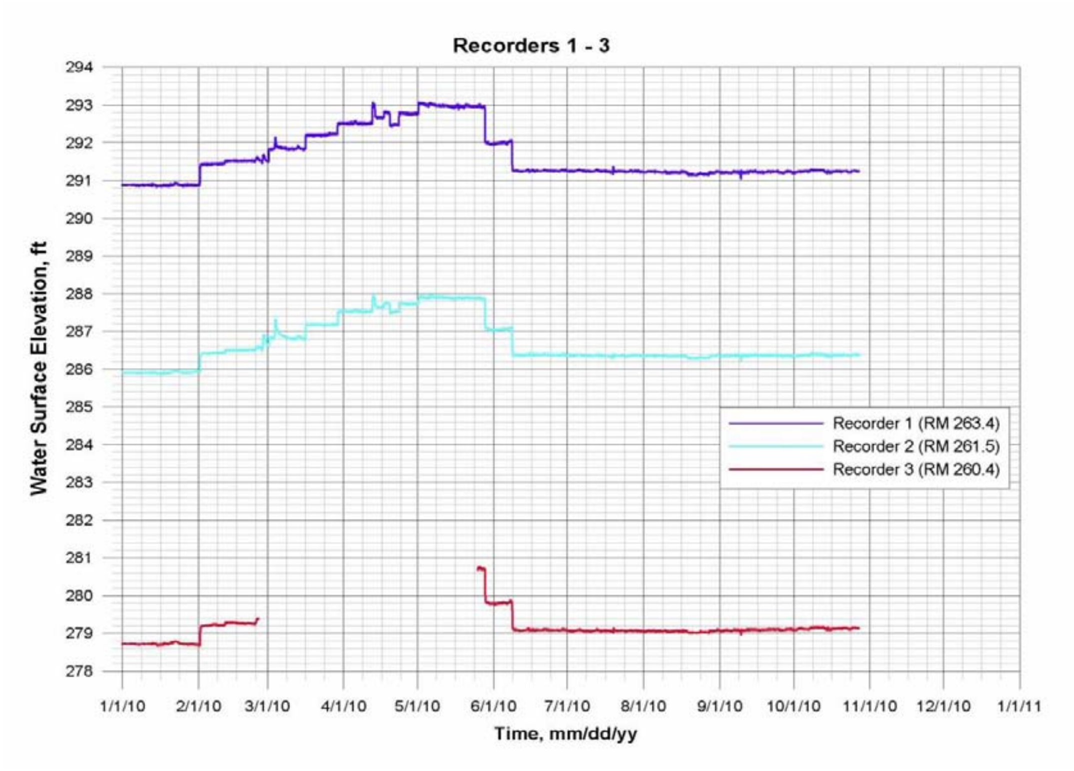

Figure B-13. Recorders 1, 2, & 3 elevation data

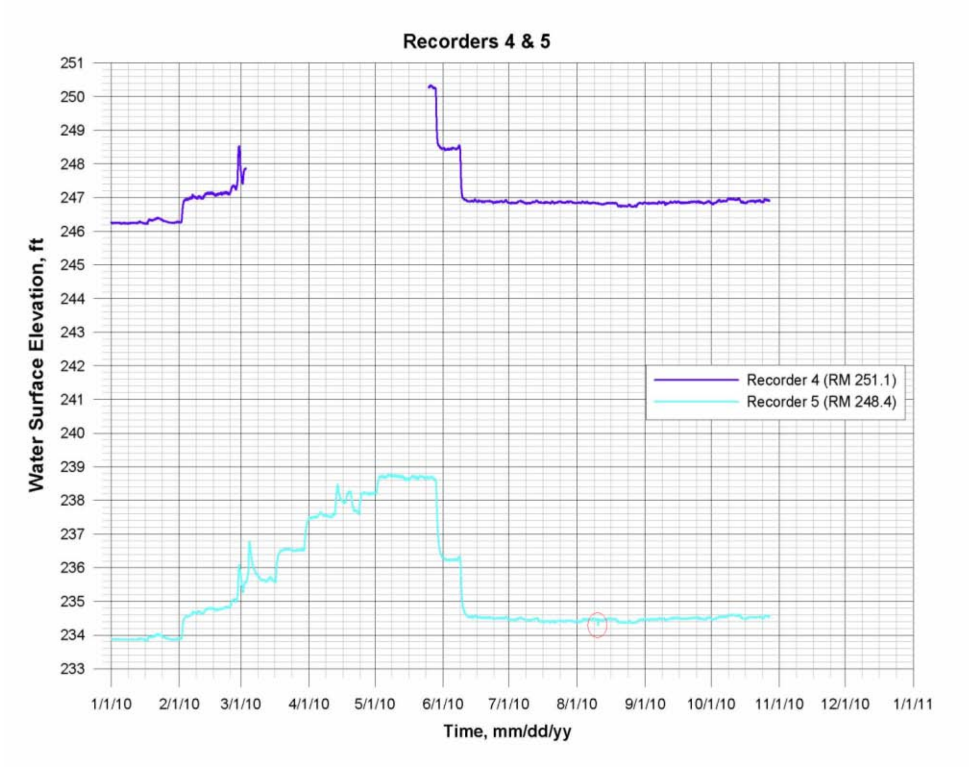

Figure B-14. Recorders 4 & 5 elevation data

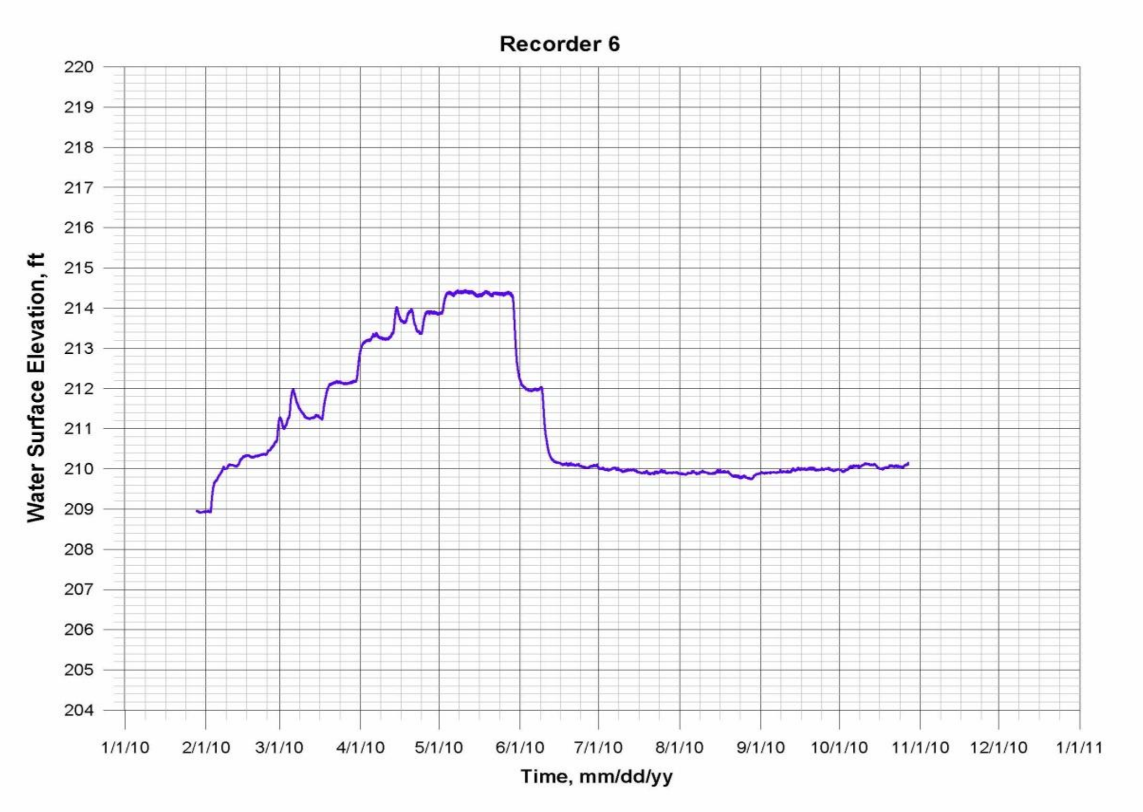

Figure B-15. Recorder 6 elevation data

7.4 Discussion

According to **Figure** through **Figure** , a discontinuity can be observed in the data from Recorders 3 and 4. During the data down load on May 25, 2010, it was observed that the Recorder 4 stopped functioning from March 3, 2010 because of unexpected battery exhaustion. In addition, Recorder 3 was found off-line and the data logger storage was empty. The actual reason for this loss of data has not been determined. These recorders were brought back on-line on May 25, 2010 with new batteries. Batteries for other recorders were also replaced with new ones and it was made sure that all the recorders were functioning well.

At the end of July 2010, it was noticed that the 2-inch diameter pipe that accommodated Recorder 5 and its cable was disconnected close to the right bank at an elbow because of suspected loss of one of the anchors. However, no movement was observed at the portion of the pipe adjacent to the transducer location. The pipe was re-connected and anchored back to the channel bed on August 10, 2010. There were no changes observed in the data before and after this repair work except a slight drop on 3 readings that were collected during the repair work.

Recorder 1 showed inconsistent changes during and after the 700cfs release in fall 2009 with respect to the other recorders (see 2009 ATR). Anchor movement was found as a possible reason for these inconsistent changes. The suspect anchors were reinforced and the data were continuously monitored. No further data problems have been observed.

7.5 Conclusions and Recommendations

Data from the transducers will be compared to routing model results, and adjustments will be made to the models, as necessary, to better match the data. The existing recorders should continuously be monitored and the data collection should be done periodically. It is recommended to evaluate the possibility of moving a recorder from Reach 1A or installing a few additional recorders in Reach 2 to provide wider spatial distribution of calibration data. We are currently reviewing possible options for relocation.

8.0 Bed Profile Surveys

8.1 Introduction

The data presented in this report are related to the study “Effects of Sand Mobilization on Water Surface Elevation” that specifically addresses needs related to Problem Statement 5, San Joaquin River Channel Capacity Management. Resulting data will be used to evaluate the changes in bed formation and by providing stage-discharge rating curves to assess the extent to which the change in bed formation affects channel capacity.

Two monitoring sites in Reach 2A were selected for this task and one cross section per each site was monumented. Cross sectional and longitudinal profiles at the selected cross section sites are repeatedly surveyed during various interim flow release benches. During each survey, a discharge measurement along with multiple water surface elevation measurements was also made.

8.2 Methods

8.2.1 Site Selection

The locations for the data collection sites was selected based on the previously established Vegetation Monitoring Sites M6 (River Mile (RM) 225.3) and M10 (RM 219.8) in Reach 2A. The M6 site was then moved to M6.5 (RM 223.8) because of the other monitoring activities being carried out by Reclamation at Site M6.5. The locations of the selected cross sections are shown in Figure .

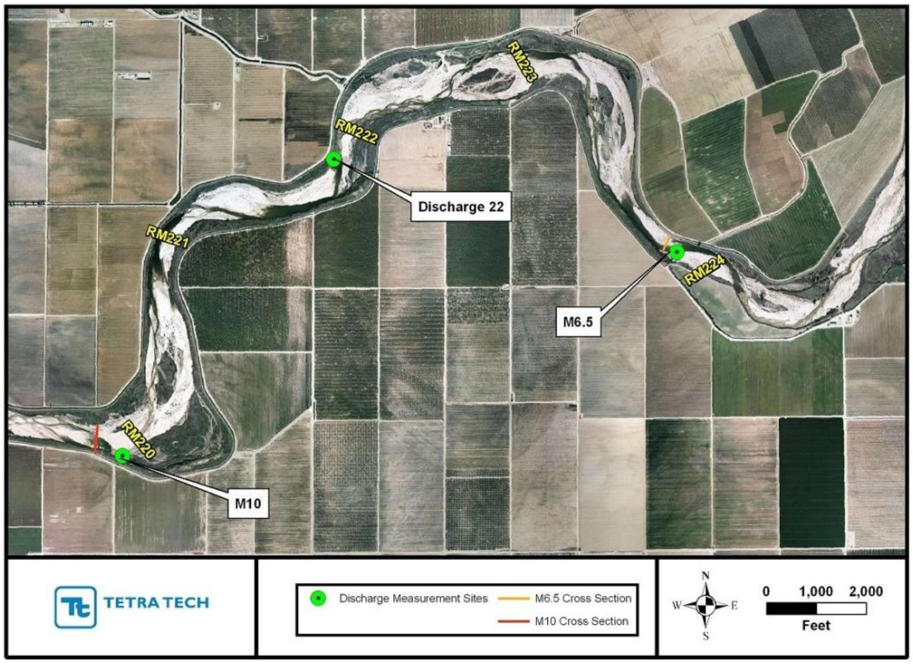

Figure B-16. General location of monitoring sites M6.5 and M10

8.2.2 Monitoring Activity

Bed profile surveys along with measurements of discharge and water surface elevations (WSE) were performed at each site during five interim flow release benches from Friant Dam that included 800 cfs, 1,100cfs, 1,100 cfs, 1,550 cfs, and 800 cfs (as per the data provided in **Table 2-1** in 2010 ATR). Even though some of the release benches were the same, the flows at monitoring sites were different during the time of each survey due to losses and tributary flow. The gauge located in SJR at Gravelly

Ford (~RM 227.6), which is approximately 4-miles upstream of Site M6.5, read average flows of 650 cfs, 950 cfs, 1,220 cfs, 1,350 cfs, and 590 cfs during each set of surveys, respectively. Each set of surveys took two days (one site per day) to complete. General order of the monitoring activities performed at each site was as follows:

- Set-up base GPS station for real-time kinematic (RTK)
- Measure WSE
- Measure discharge
- Measure WSE
- Survey bed profiles
- Measure WSE

8.2.3 Discharge and Water Surface Elevation Measurement

At each monitoring site, a cross section location for discharge measurement is selected according to USGS Techniques and Methods "Measuring Discharge with Acoustic Doppler Current Profilers (ADCP) from a Moving Boat”. The method for measuring discharge with an ADCP is described in the **Discharge Measurements** report. Leveling data, which is used to calculate water surface elevation, was also collected before and after each discharge measurement using Leica NA728 Auto Level.

Water surface elevations were determined from local control points surveyed by Provost and Pritchard Consulting Group and were derived from RTK observations and application of GEOID03 to the RTK values based on the North American Vertical Datum of 1988. Horizontal values for the control points are referenced to California Coordinate system Zone 3 (US Survey Feet), based on California Geodetic Coordinates of 1983, Epoch 2007.0.

8.2.4 Bed Profile Survey

The selected cross sections were surveyed to establish the prerelease channel geometry before the 2009 Interim Flow release. During the spring 2010 Interim Restoration Flow release benches, the monumented cross sections and the longitudinal sections extending approximately 2,500 feet of the channel at each site were repeatedly surveyed using a cataraft mounted “Sonarmite” echo sounder linked to Leica Viva GS15 survey-grade GPS rover (see Figure). The RTK corrections were provided with a temporarily established GPS base station at one of the existing local control points. The collected depth data were then converted to elevation data using water surface elevations (WSE) collected at the same time and location.

Multiple cross sections were surveyed by navigating the cataraft across the channel at the close vicinity of the selected monitoring cross-section at each site. Longitudinal profiles were surveyed by navigating in zigzag path from upstream to downstream of the selected cross-section. The travelling paths were kept consistent as much as possible at each set of survey. The xyz data was then converted to station elevation data using Microsoft Excel. Thalweg (a line connecting minimum elevation points) profiles were determined from the channel bed surveys and stationed on the Tetra Tech 2009 hydraulic model station line.

At the end of each bed profile survey, WSE data were also collected to monitor the changes in water level during the survey.

Figure B-17. Cataraft equipped with echo-sounder and survey-grade GPS rover

8.3 Results

The discharge was measured with DWR's TRDI Rio Grande ADCP during the first round of bed profile survey (March 25 and 26, 2010). Subsequent flows were measured using the TRDI River Ray provided by Tetra Tech.

The comparisons of cross-sectional profiles and the respective plan views for both sites are shown in the **Appendix E**. The comparison of plan and profile views of thalwegs at the both M6.5 and M10 sites for various flow release benches are presented in Figure through Figure .

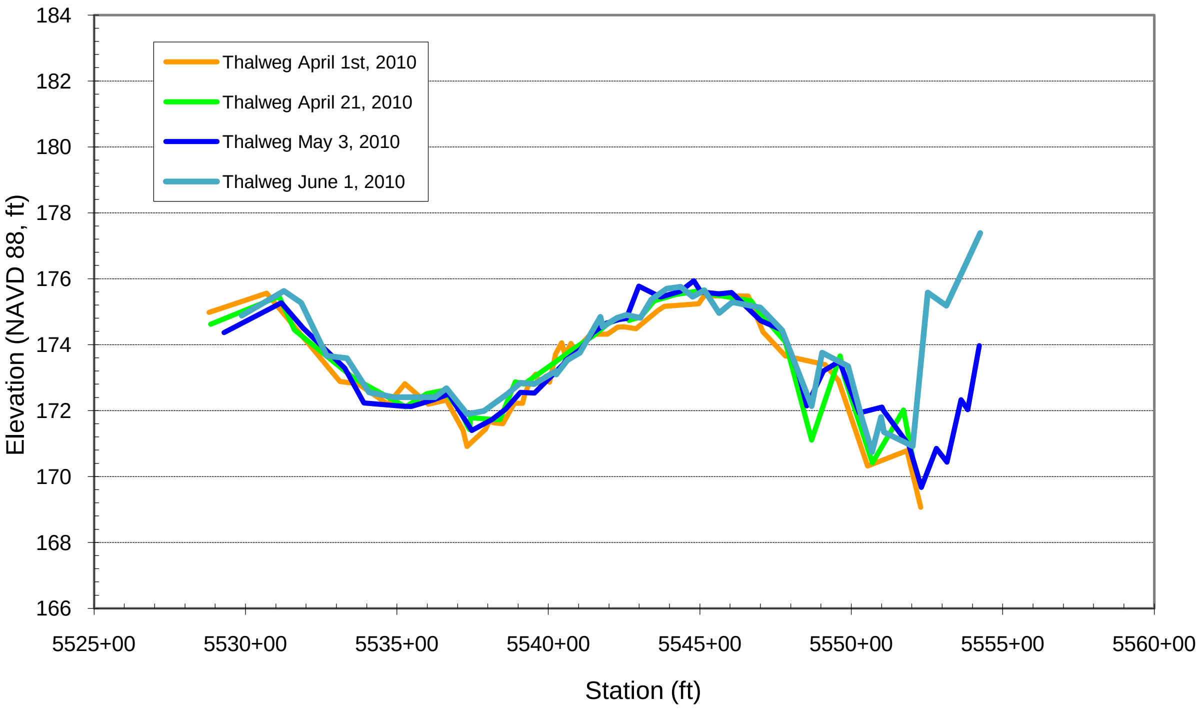

Figure B-18. Profile view of the thalweg during the spring 2010 bathymetric surveys at M6.5

Figure B-19. Plan view showing the location of the thalweg during the spring 2010 bathymetric surveys at M6.5

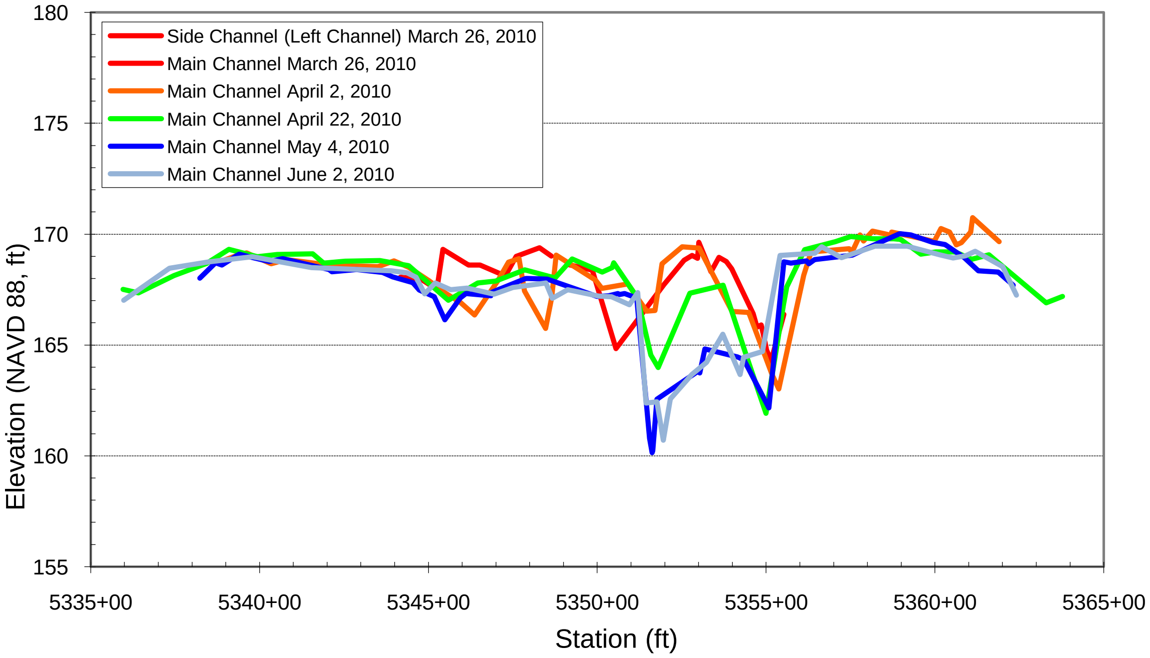

Figure B-20. Profile view of the thalweg during the spring 2010 bathymetric surveys at M10

Figure B-21. Plan view showing the location of the thalweg during the spring 2010 bathymetric surveys at M10

8.4 Discussion

In general, comparison of the bed elevation data shows that very little change in bed elevations or horizontal locations of thalwag occurred at Site M6.5 over the range of surveyed flows (**Figure** and **Figure**). Some aggradations occurred in the pool on river right (north) at the upstream end of the survey area at Site M6.5 between River Stations 5552+52 and 5554+25 between May 3 and June 1 (**Figure 18**). It is not known whether the formation of the pool prior to the March 25, 2010 survey was a natural occurrence or the result of in-channel earth work on river left (south).

The bed elevation data indicates that local scour and deposition occurred at Site M10 over the range of surveyed flows (**Figure** and **Figure**). Between River Stations 5351+00 and 5355+00, approximately 6 ft of local scour was measured over the period of survey (**Figure)**. The local scour can be attributed to the presence of a riprap spur on river left (south), and the subsequent contraction of flow and associated increasing velocities, as well as deposition on the bar on river right. Deposition occurred in the river left side channel downstream of the spur, between River Stations 5345+00 and 5350+00, most likely because of the local contraction scour at the spur. At the upstream and downstream ends of the surveyed area, outside the influence of the spur, only minor changes in elevation and location of the thalweg were measured.

8.5 Conclusions and Recommendations

General scour was not observed over the range of surveyed flows (600cfs to 1,250cfs). Local man-made influences at Sites M6.5 and M10 make it very difficult to measure general scour at these locations. If appropriate, based on more detailed analysis of the data, future data collection at these sites will most likely focus only on flow events exceeding 2,000cfs. The location of the sites should be re-evaluated prior to future monitoring activities to determine whether the sites should be shifted to locations where there is less influence from local man-made features.

8.6 References

Foley, M.G., 1975. Scour and fill in ephemeral streams, W.M. Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, Report No. KH-R-33, 202 pp.

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Powell, D.M., R. Brazier, J. Wainwright, A. Parsons and M. Nichols, 2006. Spatial patterns of scour and fill in dryland sand bed streams, Water Resources Research, v42, W08412, pp 1-11.

9.0 Scour Chains

9.1 Introduction

The data reported in this section is related to the study "Effects of Sand Mobilization on Water Surface Elevation" that specifically address needs related to Problem Statement 5, San Joaquin River Channel Capacity Management, by providing data on the extent to which the bed scours during higher flows. The information from this monitoring task, associated with the data from bed profile surveys, is used to determine if bed mobilization in the sand bed reaches affects rigid boundary hydraulic modeling results and other River Restoration aspects of San Joaquin River

All together eight scour chains were installed in two sites in Reach 2A that were selected for bed profile survey study to quantify amounts of scour and deposition that take place during each seasonal restoration flow release.

9.2 Methods

9.2.1 Site Selection

See site selection detail in the **Bed Profile Surveys** report (section 8.2.1).

9.2.2 Installation

The chains were installed using a 10-foot steel pipe, which had a small rectangular notch on its top edge, pounded into the sand using a post driver; this method limits the amount of impact to the surrounding soil. The galvanized chain was attached to a plugged bell reducer used to hold the chain in place (

Figure). The bell reducer was also used as a pointed head to help the pipe go into the ground more easily and also to cap the pipe to prevent sand from penetrating into it and to prevent the chain from shifting to the side and getting stuck.

An approximately 2-foot deep hole was dug before the pipe was driven into the ground. Then the pipe with the chain inside was pounded into the ground with a post driver keeping the free end of the chain inside the notch made at the edge of the pipe to prevent the chain from possible damage while pounding. The pipe was then pulled out, leaving the chain buried in the ground. The sand that was removed from the hole was then shoveled back into place to bring the surface back as close to original conditions as possible. The length of the excess chain above ground was measured to determine the length of the chain below the surface. Photos showing the process of installing the chains are shown in the 2009 ATR.

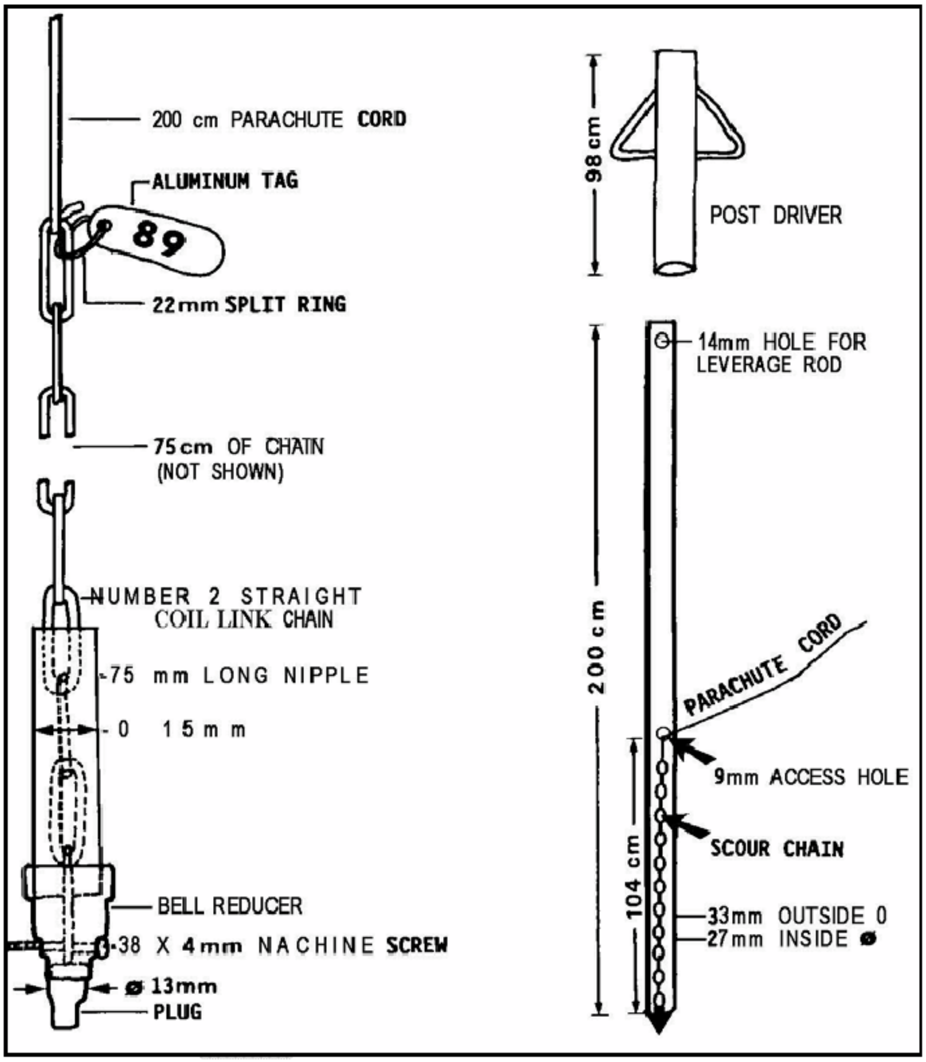


Figure B-22. Schematic showing the chain and pipe assembly

9.2.3 Monitoring

Chain sites were revisited each major restoration flow season for chain recovery. The recovery procedures are as follows:

- Chain location was identified using a Total Station.
- Channel bed was excavated carefully to find the new elbow of the chain (see Figure).
- Measurements were taken using a Total Station and a tape measure to get the amount of scour and fill because of the restoration flows.
- The excavation was backfilled while keeping the chain vertical.
- The excess chain above the ground was measured and laid on the bed with the free end facing upstream (see Figure).
- The exposed chain section was covered with a thin layer of bed surface material.

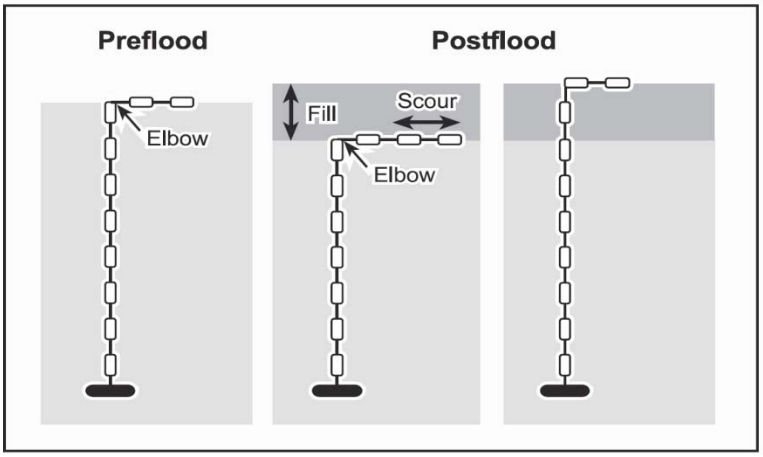


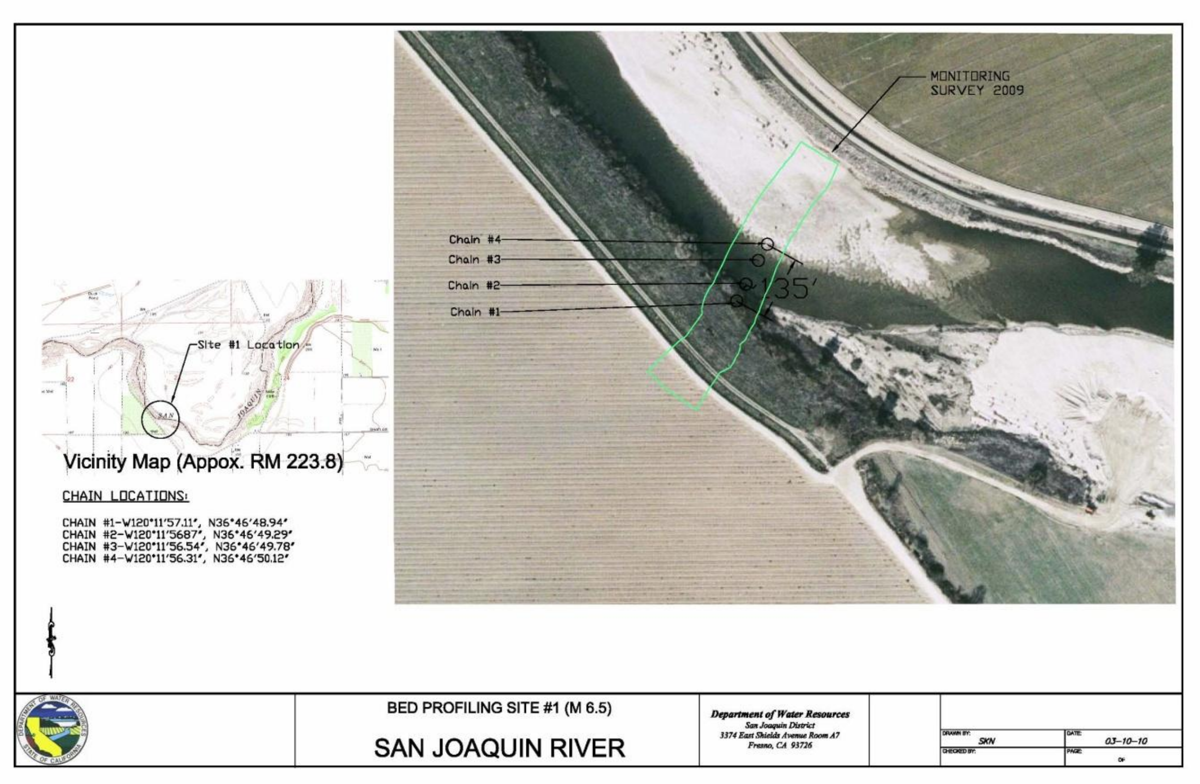
Figure B-23. Schematic showing fill and scour

9.3 Results

Eight chains were installed at the selected cross sections in August 2009 to verify depth of scour and re-deposition that takes place during particular flow releases. The buried depths of the chains vary from 8.20 and 9.10 feet, with the exception of one chain that was buried to a depth of 7.5 feet because of an obstacle at that depth that prevented the pipe from being driven deeper. At least one of the four chains in each cross section was placed in the low-flow channel. Based on the locally established control points referenced to North America Datum 1983 California Zone III (US Survey Feet) coordinate system, these chain locations were surveyed using a Total Station after installation. Locations and chain details are presented in **Table** as well as in **Figure** and **Figure** .

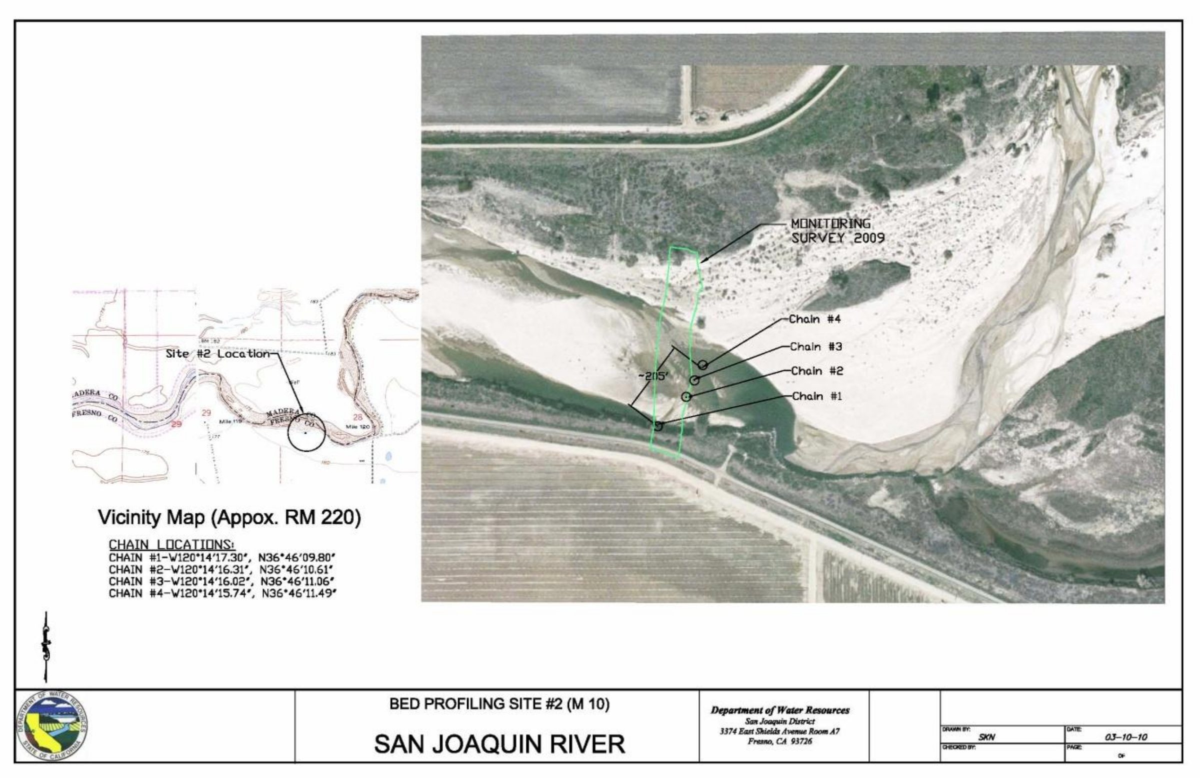
Table B-12. Scour chain information

Point Number	Longitude	Latitude	Date Installed	Total Length (ft)	Buried Depth (ft)
1-XS6.5	W120°11'57.19"	N36°46'48.96"	8/11/2009	9.90	8.40
2-XS6.5	W120°11'56.96"	N36°46'49.30"	8/11/2009	9.90	7.50
3-XS6.5	W120°11'56.64"	N36°46'49.80"	8/11/2009	9.50	8.80
4-XS6.5	W120°11'56.42"	N36°46'50.15"	8/11/2009	9.90	8.40
1-XS10	W120°14'17.30"	N36°46'09.80"	8/13/2009	9.80	8.50
2-XS10	W120°14'16.35"	N36°46'10.62"	8/13/2009	9.10	8.20
3-XS10	W120°14'16.07"	N36°46'11.08"	8/13/2009	9.35	8.35
4-XS10	W120°14'15.78"	N36°46'11.51"	8/19/2009	9.90	9.10



CHAIN LOCATIONS:
CHAIN #1-W120°11'57.11", N36°46'48.94"
CHAIN #2-W120°11'5687", N36°46'49.29"
CHAIN #3-W120°11'56.54", N36°46'49.78"
CHAIN #4-W120°11'56.31", N36°46'50.12"

Figure B-24. Location of scour chains at site M6.5 in Reach 2A



CHAIN LOCATIONS:
CHAIN #1-W120°14'17.30", N36°46'09.80"
CHAIN #2-W120°14'16.31", N36°46'10.61"
CHAIN #3-W120°14'16.02", N36°46'11.06"
CHAIN #4-W120°14'15.74", N36°46'11.49"

Figure B-25. Location of scour chains at site M10 in Reach 2A

The data collected in December 2009 were analyzed and presented in the 2009 ATR. The chain sites were revisited in October 19, 2010 and November 1, 2010 for the next set of data collection after spring 2010 Interim Flow Releases. Results are shown in **Table** below.

Table B-13. Post-flow scour chains inspection results

Date of visit		**Site and Chain #**							
		M 6.5				**M 10**			
		1	**2**	**3**	**4**	**1**	**2***	**3***	**4***
10/19/2010 and 11/01/2010	Initial exposed length (ft)	1.29	2.40	0.70	1.50	2.10	0.90	1.00	0.80
	Chain length to elbow (ft)	N/F	2.47	0.74	1.50	N/F	0.98	1.00	1.01
	Depth to kink (ft)		1.38	0.14	0.08		2.04	2.02	1.19
	New exposed length (ft)		1.25	0.59	1.38		3.87	4.27	3.38
	Amount of scour (ft)		0.07	0.04	0.00		0.08	0.00	0.21
	Total Deposition (ft)		1.38	0.14	0.08		2.04	2.02	1.19
	Net (-Scour, + Deposit) (ft)		**1.31**	**0.10**	**0.08**		**1.96**	**2.02**	**0.98**

* - Chains 2, 3, and 4 at Site M10 were extended by 4.95 ft, 5.25 ft, and 3.56 ft, respectively.
N/F – Not Found

9.4 Discussion

The data from Chain # 1 at Site M6.5 was not collected because of an active flow with an approximate depth of 1.5 ft in the channel. According to the differences in channel bed elevation, a net possible deposition of a foot or more may be estimated in this chain location. Chain # 1 in Site M10, which was not found, may have either been scoured away during high flows or removed by people.

Based on the data presented in Table , there was a very little or no scour occurred at the vicinity of the chains at both sites. In Site M6.5, there was not much deposition present at the right portion of the channel bed where vegetation cover was present; whereas, a significant amount of deposition was observed in the left portion. In Site M10, the middle portion of the channel bed had experienced relatively higher deposition compared to the right portion. Due to significant amounts of deposition in Site 10, Chains # 2, 3, and 4 were not long enough to reset for future measurements and were extended by 4.95, 5.25, and 3.56 ft, respectively.

9.5 Conclusions and Recommendations

There was not much local scour in the vicinity of chains at both sites M6.5 and M10 during the spring 2010 restoration flow releases (350cfs to 1,550cfs). However, significant amounts of local deposition were observed at the left channel bed at Site M6.5 as well as in the middle and right portion of the channel bed at Site M10.

Chain # 1 at Site M6.5 should be measured as the flow drops down to a workable level. A new chain needs to be installed next to Chain # 1 location at Site M10 in order to replace the one that was not found. All the chains should be monitored after each seasonal restoration flow releases. If there are any future changes in the locations selected for the monitoring task 0
8.0 Bed Profile Surveys, the chain sites should also be moved accordingly.

10.0 Sand Storage in Reach 1

10.1 Introduction

Data presented in this section were collected for the Sand Storage Assessment study under the Channel Capacity Management problem statement. The information presented in this report is a summary of activities and results based on the **Evaluation of Sand Supply, Storage, and Transport in Reaches 1A and 1B TM** by Tetra Tech available as **Attachment 1** to **Appendix B**. The purpose of this study is to assess existing conditions related to the availability of sand in Reaches 1A and 1B that could affect both the quality of instream habitat and the downstream sediment-transport balance by:

- quantifying the amount and location of sand storage in Reaches 1A and 1B
- identifying to the extent possible, the sources of the sand
- providing a basis for developing a longer-term sand-monitoring program

10.2 Methods

The data collections are as follows:

- Topographic Comparison
- Field Investigations
- Pit Surveys

10.2.1 Topographic Comparisons

Prior to conducting the field investigation, an analysis of volume change within the channel was conducted by comparing the 1997 post-flood topography with the 2008 DWR-surveyed topography. A cumulative net volume change curve was developed from the comparative data that extended from the Dam to Hwy 145.

10.2.2 Field Investigations

The field investigation was done by floating in an inflatable kayak, or a raft. Three field visits were conducted: 1) November 2009 at 700cfs, 2) March 2010 at 600cfs, 3) July 2010 at 350cfs. During the November 2009 visit locations of sand deposits within the channel were identified, located with a hand-held GPS and photographed.

For the March 2010 visit, several data were recorded. First, the locations of significant sand deposits in the riverbed were located. Once located a 10-foot long, ¼ -inch diameter rebar rod was driven into it to determine its thickness. The rebar was driven in several times along the sand deposit's centerline and the average depth was used for the volume calculations. A total of forty sites were measured. For six of the forty sites, the volume calculations were verified by detailed cross-channel transects. Also a sand sample was gathered at each of the transects and sent to a local Fresno testing lab for a gradation analysis. Several other overbank locations and alluvial fans were sampled and gradations determined. All locations where there was evidence of sediment supply to the river (bank erosion, tributaries, sand bars) were identified, located with a hand-held GPS and photographed. Channel margin areas that were disturbed (erosion and deposition) were identified and mapped on 1998 aerial photography. The surface area of margin areas within each subreach were calculated in

ArcGIS. During the March 2010 field visit, holes were dug in the channel margin areas. The minimum thickness encountered was 4 feet.

In March 2010, because of higher flows and increased turbidity, the bed-material size could not be identified at several sites. During the July 2010 visit, those sites were revisited and evaluated.

10.2.3 Pit Surveys

Active transport of sand was observed during the March 2010 field visit. Because it was not possible during the March 2010 visit to observe whether or not active transport was occurring through in-channel pits, it was decided to monitor four pits between Hwy 41 and Hwy 145. The geometry of these selected pits indicated that the trap efficiency should be high.

Detailed topographic and bathymetric surveys for the four pits were conducted in April 2010. The topographic surveys were done using conventional survey methods, while an ADCP was used to gather the bathymetry data. The ADCP was pulled back and forth in the pits using a cataraft and motor. The pits were resurveyed in June 2010. For at least 30 days between the two surveys, the flow in the river was at least 1600cfs.

10.3 Results & Discussions

Below show the results for the topographic comparisons, significant sand deposit investigation, and pit surveys.

10.3.1 In-Channel Sand Storage Loss from 1997 to 2008

Table B-14 that shows the net volume change within the channel by comparing the 1997 Ayres post-flood topography to the 2008 DWR-surveyed bathymetry.

Table B-14. Changes in in-channel volume by subreaches between years 1997 and 2008

Reach	RM-RM	Volume Change (cu.yd.)	Unit Change (cu.yd./mi)
Friant Dam - Hwy 41	267 - 255	-237,100	-19,400
Hwy 41 - Hwy 99	255 - 243	-775,900	-64,500
Hwy 99 - RM 236	243 - 236	-1,013,000	-41900

10.3.2 In-Channel Sand Storage

Table B-15 shows the estimated volume of sand stored in each subreach.

Table B-15. Estimated volumes of sand stored in the channel by subreach

		(cu.yd)	(cu.yd./ft)	Sites	(cu.yd./ft)
Friant Dam - Hwy 41	267 - 255	77,090	1.2	9	10.9
Hwy 41 - Hwy 99	255 - 243	99,980	1.6	18	6.3
Hwy 99 - RM 236	243 - 236	94,590	1.9	13	8.7

Based on the estimated volumes, about 271,600 cu.yd. of sand is stored within discrete sites in the channel between Friant Dam and Hwy 145. This estimate is believed to be conservatively small because there are numerous locations where there is a thin veneer of sand overlying gravel and cobble bed material, but thickness and lack of continuity of the deposits make measurement impractical.

Between 35 and 40 percent of the existing sand storage in the overall study reach is located in gravel pits. At the remaining measurement sites outside of the gravel pits, the unit storage volume averages about 7 cu.yd./ft of channel length.

10.3.3 Channel Margin Sand Availability

Table B-16 summarizes the areas of disturbance during the 1997 flood and provides a minimum estimate of the volume of sediment in storage along the channel margins by subreach.

Table B-16. Disturbed areas during the 1997 flood and estimated minimum sediment storage by subreach (based on estimate of 4-ft thickness of deposits)

Reach	RM	Disturbed Area (sq.yd.)	Minimum Estimated Storage Volume (cu.yd)	Unit Storage Volume (cu.yd./mi)
Friant Dam - Hwy 41	267-255	2,813,300	3,750,200	312,600
Hwy 41 - Hwy 99	255-243	2,112,400	2,816,400	234,600
Hwy 99 - Hwy 145	243-234	1,895,300	2,527,200	280,800
Total		6,821,000	9,094,800	275,700

10.3.4 Sediment Gradations

Table B-17 shows the gradations for the in-channel, tributary and overbank deposits.

Table B-17. Summary of the gradation parameters for in-channel, tributary, and overbank deposits

RM	D50 (mm)	D84 (mm)	D16 (mm)	Silt/Clay (%)
Bed Material Samples				
266.1	0.75	1.6	0.38	<1
263.0	1.80	13.0	0.60	<1
258.8	0.90	2.0	0.50	<1
250.1	0.75	2.0	0.36	<1
248.1	1.00	2.0	0.60	<1
241.7	1.00	2.0	0.60	<1
237.5	1.70	3.0	0.80	<1
Tributaries				
267.0	1.30	2.0	0.68	<1
264.9	0.75	1.5	0.38	2
257.6	0.60	1.3	0.20	7
Floodplain				
252.0	1.30	50.00	0.270	2
263.0	0.17	0.29	<0.075	20

10.3.5 Pit Deposition

Table B-18 showing the volume of sediment deposited in the four surveyed pits.

Table B-18. Measured depositional volumes in pits in Reach 1

General Location	RM	Depositional Volume (cu.yd)	Average Volume/Day (cu.yd./day)	Number of Days Between Surveys
Sycamore Island	252.5	19,423	303	64
Islewood GC	246.5	5,860	105	56
Camp Pashayan	243.7	3,718	60	62
Donny Bridge	240.5	1,688	30	56

10.4 Conclusions & Recommendations

A draft Technical Memorandum is currently in review. A final TM detailing the results and conclusions will be released in early 2011.

11.0 Topographic Surveys

11.1 Introduction

Data in this report were collected as part of the Monitoring Cross Section Resurveys study. Activities consist of taking measurements of the existing ground surface in the channel after specific flow events. The measurements create a topographic record of the channel which can be compared with previous records to measure channel shifts, deposits, scour and other channel characteristics. Variations between measurements are typically indicated as a volume difference between the surfaces and will be related as cut and fill which identify the material lost or gained respectively between the dates of measurements. Discharge events occurring between the dates of surveys are considered the active component of the variations between measurements, although other elements such as mining or maintenance for a traveled way may alter the channel also.

11.2 Methods

Measurements of the channel are taken using topographic surveying techniques that involve GPS and other traditional equipment. Sites are surveyed in a cross sectional approach, placing sections approximately 10 to 20 ft apart and extending from above the area wetted during the flow event, through the channel and to the other side equally. Around five to eight sections are surveyed in this manner at a site.

11.3 Results

Survey data maps are in the Data Appendix, where point locations are shown against aerial images. This illustrates the collection densities and location variations contrasted against the previous surveys. Initial analyses of the surveys are also shown in the form of sample line locations and the section views. Section views are generated by sampling topographic surfaces along the sample lines. Topographic surfaces were created from the survey data. Section views show representative lines approximating the topography found in each survey and an indication of scour and deposition occurring at specific locations along the sample line.

Volume changes for each site are shown in **Table** . The volume differences are over the intersecting areas of the surveys and don’t represent an average volume change per surface area.

Table B-19. Volume change per site, positive is deposition, negative is scour

Site	Volume Change from 07/2009 to 01/2010 (cu.yd.)	Volume Change from 01/2010 to 10/2010 (cu.yd.)
M1		0.3
M2		-637.6
M3	58.5	-219.1
M4	-69.7	-77.5
M5	7.7	-41.9
M6	-197.1	-270.3
M6.5	27.1	80.9
M7	-53.7	-89.3
M8	524.4	55.3
M9	16.2	1123
M10	-37.6	509.1
M11	25.0	407.4
M12	-28.6	131.4
M13	33.8	-595.6
M14		-145.7

11.4 Discussion

Section views make a visual comparison between topography before and after flows indicating where and how much change has occurred. Changes between July 2009 and January 2010 do not indicate much variation and imply the discharges during this time frame, with releases up to approximately 800cfs; are not sufficient to cause significant changes in the channel in Reach 2. Discharges between January 2010 and October 2010 peaked around 1,550cfs did produce significant changes in topography as indicated in the section views. Jan. 2010 to Oct. 2010 changes ranged up to around 2 ft of change in elevation. It will require additional analysis to determine if the recorded effects of 1,550cfs releases are significant to channel stability or even to resurvey the monitoring sections.

From July 2009 to January 2010, 7 sites showed a net deposition, and 5 sites showed a net scour. The largest scour was at M6 with a cut of 197 cubic yards. The largest deposition was at M8 with a fill of 524 cubic yards. From January 2010 to October 2010, 6 sites showed a net deposition and 9 sites showed a net scour. The largest deposition was at M9 with a fill of 1,123 cubic yards. The largest scour was at M2 with a cut of 637 cubic yards.

11.5 Conclusions and Recommendations

Measured differences after an approximately 800cfs discharge were inconclusive to net effects over the entire channel over the time period they were flowing. Channel changes from 800cfs discharges may require significantly more time for a discernable impact and seem unlikely to occur considering the current flow regime that is being applied. Differences in topography after approximately 1600cfs discharge seem to indicate measureable net differences in the channel and may lead to long term changes. Continued resurveys are recommended to better understand the effects at this flow.

Additional analysis of the existing survey data can be used to better understand the bed load transport rates and rates of change occurring with specific parts of the channel. Analysis would include focus on changes broken into characteristic areas that could be used to identify trends in the reach. The areas that could be easily identifiable are bed, bars, banks, and floodplain areas. This would identify features prone to change in the reach with a given flow history. Analysis could give insight into potential aggradational or degradational trends to characterize changes throughout the reach. Additional analyses could include earlier survey data from 1997 and 2008 to determine longer term trends. Until additional analysis is performed, it is prudent to continue resurveys at sequentially larger discharges, and reoccurrences in excess of 800cfs.

Additional monitoring section sites will be established in Reach 3, 4 and 5 if required. After a significant flow event where channel geometry changes are expected, the sections will be resurveyed. Analysis will require using the survey results to generate TIN surfaces and then finding the algebraic difference between them, which can be shown as a TIN volume surface. The volume surface will indicate gross changes indicating the amount of scour and deposition occurring and indicate spatially across the channel where these are occurring.

12.0 Bed Sampling

12.1 Introduction

Data in this report were collected as part of the Monitoring Cross Section Resurveys study. This monitoring task includes collecting and analyzing river bed samples at sand-bed reaches of San Joaquin River in order to improve understanding and validation of the sediment transport behavior of the river.

Channel bed samples from Reaches 1B, 2A, and 2B were collected at the survey sites after each interim flow release from Friant Dam. Bed samples were then analyzed in the DWR laboratory and the data are reported here.

12.2 Methods

12.2.1 Sampling Location

The riverbed samples were located between from River Mile 212 and River Mile 235. The sampling locations were selected within the selected topographic monitoring sections (see 0 **11.0 Topographic Surveys**) designated as M1, M2, M3, M4, M5, M6, M6.5 (6½), M7, M8, M9, M10, M11, M12, M13, and M14. The sampling locations are displayed in Figure . Samples that had significant sediment size variation within one section were designated M#-# (ex. M5-2).

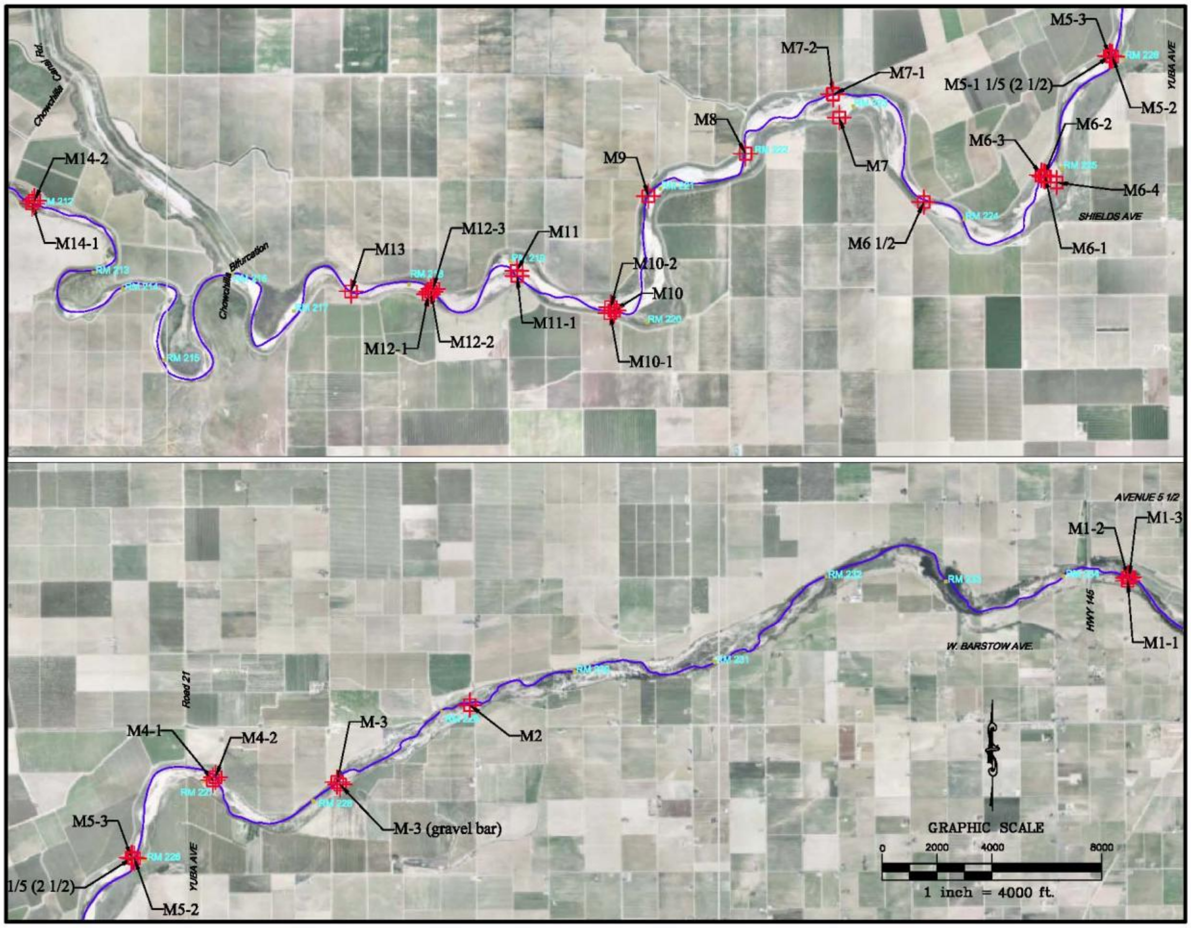


Figure B-26. Sampling location map

12.2.2 Sample Collection

The bed samples were collected at a minimum of one location at each site during monitoring cross section surveys performed after each seasonal interim flow releases from Friant Dam. During each set of sample collection, the sampling locations were kept as close as possible to the initial locations using a handheld GPS.

The coordinates of the new sampling locations were recorded using a total station right before sampling. The bed samples were collected using a shovel and placed in either 1-gallon Ziploc bags for sandy material or a 5-gallon plastic bucket for coarse material. Only the top six inches of the surface was taken from each sample location. When the sizes were more variable, the sample locations were chosen to represent the variation. Multiple samples (four maximum) were obtained from each section. Analyses were performed as described in the 2009 ATR.

12.2.3 Sample Analysis

Analyses were performed as described in the 2009 ATR.

Calculation - D84 and D50

- Calculate percentage passing through each sieve using cumulative weight retained in each sieve

- Using sizes of nominal sieve openings and percentage passing, calculate D84 and D50 particle sizes of each sample so that 84 and 50 percent of the particles in the sample are finer than D84 and D50, respectively

12.3 Results

Bed samples were initially collected in Reach 2A in summer 2009, before the winter 2009 interim flow release started. These sampling sites were revisited in January 2010, after the winter 2009 flow release, for sample collection and topographical cross-section survey. Bed sampling was then extended to Reaches 1B and 2B, and another set of sample collection was performed in fall 2010 after the spring 2010 interim flow releases.

The D84 and D50 values of the samples collected in summer 2009, before the fall 2009 interim flow releases, were computed and displayed in 2009 Data Report. The samples collected before and after spring 2010 interim flow releases were analyzed and the data were compared to the summer 2009 data. The summary of the above comparison is tabulated in Table .

Table B-20. Sample analyses results

Reach	RM	Cross Section	Before Winter 2009 Flow		Before Spring 2010 Flow		After Spring 2010 Flow	
			D84, mm	D50, mm	D84, mm	D50, mm	D84, mm	D50, mm
Reach 1B	234.4	M1-1					1.2	0.7
		M1-2					4.0	1.0
		M1-3					41.6	22.1
	229.2	M2					20.8	2.0
Reach 2A	228.1	M3 (gravel bar)	34.2	5.9	n/a	n/a	n/a	n/a
		M3	1.7	0.8	1.5	0.9	40.5	24.2
	227.0	M4-1	19.4	8.1	28.3	15.6	25.3	4.8
		M4-2	1.8	1.0	n/a	n/a	19.3	5.9
	226.0	M5-1.5	2.0	0.5	7.3	1.3	2.2	1.1
		M5-2	6.3	1.1	2.1	1.0	2.1	0.8
		M5-3	1.2	0.8	n/a	n/a	3.6	1.2
	224.9	M6-1	14.3	2.3	n/a	n/a	14.2	1.1
		M6-2	2.1	0.9	7.9	1.4	2.0	1.0
		M6-3	1.3	0.9	n/a	n/a	1.2	0.9
		M6-4			13.5	3.6	10.9	1.0
	223.8	M6 1/2	10.8	0.6	1.9	0.9	13.7	1.2
	222.9	M7	1.2	0.5	n/a	n/a	1.1	0.7
		M7-1			2.1	1.1	1.9	0.9
		M7-2			1.4	0.9	1.5	0.8
	222.0	M8-1&2	1.3	0.7	1.2	0.7	1.8	0.9
		M8-3	13.0	0.7	n/a	n/a	n/a	n/a
	220.9	M9	1.1	0.7	1.2	0.7	1.9	0.9
	219.9	M10	1.2	0.8	1.1	0.8	1.7	1.0
		M10-1					1.7	1.0
		M10-2					2.6	0.9
	219.0	M11	1.2	0.6	1.4	0.8	1.0	0.5
		M11-1					1.3	0.8
	218.2	M12-1	3.1	0.9	n/a	n/a	2.9	1.3
		M12-2	1.7	0.9	n/a	n/a	1.6	0.7
		M12-3					1.1	0.6
	217.5	M13	1.7	0.8	1.1	0.8	1.5	0.8
Reach 2B	212.0	M14-1					1.7	0.6
		M14-2					2.1	0.7

12.4 Discussion

12.4.1 Sample Collection before Spring 2010 Interim Flow

Some of the initial sampling locations (M3-gravel bar, M4-2, M5-3, M6-3, M7, M8-3, M12-1, and M12-2) remained undisturbed after the winter 2009 interim flow release and were not considered for re-sampling. Meanwhile, a few new sample locations were added in M6 and M7 sites based on the changes in channel bed formation during the flow events. According to the D84 and D50 values presented in Table , gravel patches (coarser materials) were observed in some locations. It was also observed that the Sites M4, M5, and M6 showed relatively higher D84 value compared to the other sites.

12.4.2 Sample Collection after Spring 2010 Interim Flow

Presence of gravel was noticed in some locations at Sites M1 and M2. Sampling locations M3 (gravel bar) and M8-3 remained undisturbed after spring 2010 flow release also and were not considered for re-sampling. In addition, a few more sampling locations in M10, M11 and M12 were added because of the changes in channel bed formation. Sites M3 and M4 showed considerable changes in D84 whereas the other sites exhibit slight or no changes. D84 values at the sampling locations M5-1.5, M6-2 and M6.5 showed some inconsistent changes after winter 2009 flow release and returned close to the initial values after spring 2010 flow release.

12.5 Conclusions and Recommendations

At some sampling locations in Sites M4, M5, and M6, bed materials collected before spring 2010 flow releases (after winter 2009 flow releases) were coarser than those collected before winter 2009 flow releases started, as compared to other sites. No significant changes in bed material were observed before and after spring 2010 flow releases except a few sampling locations in Sites M3, M5, M6, and M6.5. "

M5-1.5, M6-2 and M6.5 showed significant changes after winter 2009 flow releases and returned close to initial values after spring 2010 flow releases. Site M3 material sample median sizes showed a substantial increase after spring 2010 flow releases. The reason for these phenomena may be either due to coarse material movement from upper reaches or loss of fine material during high flows.

Sample collection should be performed in 2011 after spring flow releases from Friant Dam has subsided. Data should be analyzed to determine channel response at each location because of flow events and to try to identify trends. Depending on analysis results, future data collection may be triggered by higher flow events than the interim flow regime currently provides.

13.0 Bed Mobility

13.1 Introduction

Bed mobility is of importance to salmonids in that this action maintains conditions conducive to embryo survival. Adequate ventilation is required for delivery of dissolved oxygen to incubating embryos and removal of their metabolic wastes. If fine sediment accumulates between gravel framework particles, ventilation of the subsurface is reduced. Therefore, by mobilizing the coarse surface layer of the bed the fine matrix can be flushed from the gravel interstices thereby increasing ventilation.

Hydraulic and sediment transport analyses by MEI (2002) indicate that the river bed in Reach 1A is immobile for the range of flows in the Settlement Agreement, but there is some local reworking of the bed at flows in the 1,000 to 8,000 cubic feet per second (cfs) range. The analysis specifically indicated that bed mobilization would occur at flows less than 3,500 cfs at some riffle clusters that exist in the upper part of Reach 1A between Friant Dam and Highway 41. As one of the goals of this work it is intended that the MEI (2002) analysis will be validated and if necessary refined using the results from this bed mobility study.

In order to evaluate the mobility of the bed, the following tasks were performed:
topographic surveys,
bed material sampling,
bed photography,
tracer studies,
force gauge measurements, and
flow profiling.

The measurements associated with these tasks have been ongoing since summer 2009 and are described in this report. All data within this report are being presented for the first time since collection. Their relevance and intended uses are discussed in the 2010 Annual Technical Report's "Spawning Reach Bed Mobility Study Plan". The flow, bed mobility, and sediment transport models developed using these measurements for calibration and validating predictions will be further used as part of DWR's "Incubation Habitat Study Plan", "Enhanced Bed Mobility Study Plan", and "Effect of Altered Flow Regime on Channel Morphology in Reach 1A Study Plan".

13.2 Methods

Study sites

Two sites were selected for bed mobility measurements and monitoring activities (**Figure B-27**). They are located at river miles (RM) 260.7 and 261.6 and are denoted as Riffle Clusters 38 (RC38) and 40 (RC40), respectively (MEI, 2008). Bed mobility monitoring activities began at RC 38 and RC 40 beginning in the Summers of 2009 and 2010, respectively. These riffles are within Reach 1A where spawning activity is expected to occur. Additionally, MEI's (2002) predictions suggest that the bed at these sites should experience incipient motion at Restoration flow levels. At each of these sites 5 channel-spanning cross-sections were staked on both banks to stretch a tape measure across and define measurement locations. The cross-sections were selected to monitor and assess the upstream pool/glide tail, riffle head, middle riffle, lower riffle, and downstream pool morphological zones (Figures **B-28** and **B-29**). Locations of the staked channel spanning cross-section end points are provide in Attachment A1: Control Points and Cross-section Staked End Points.

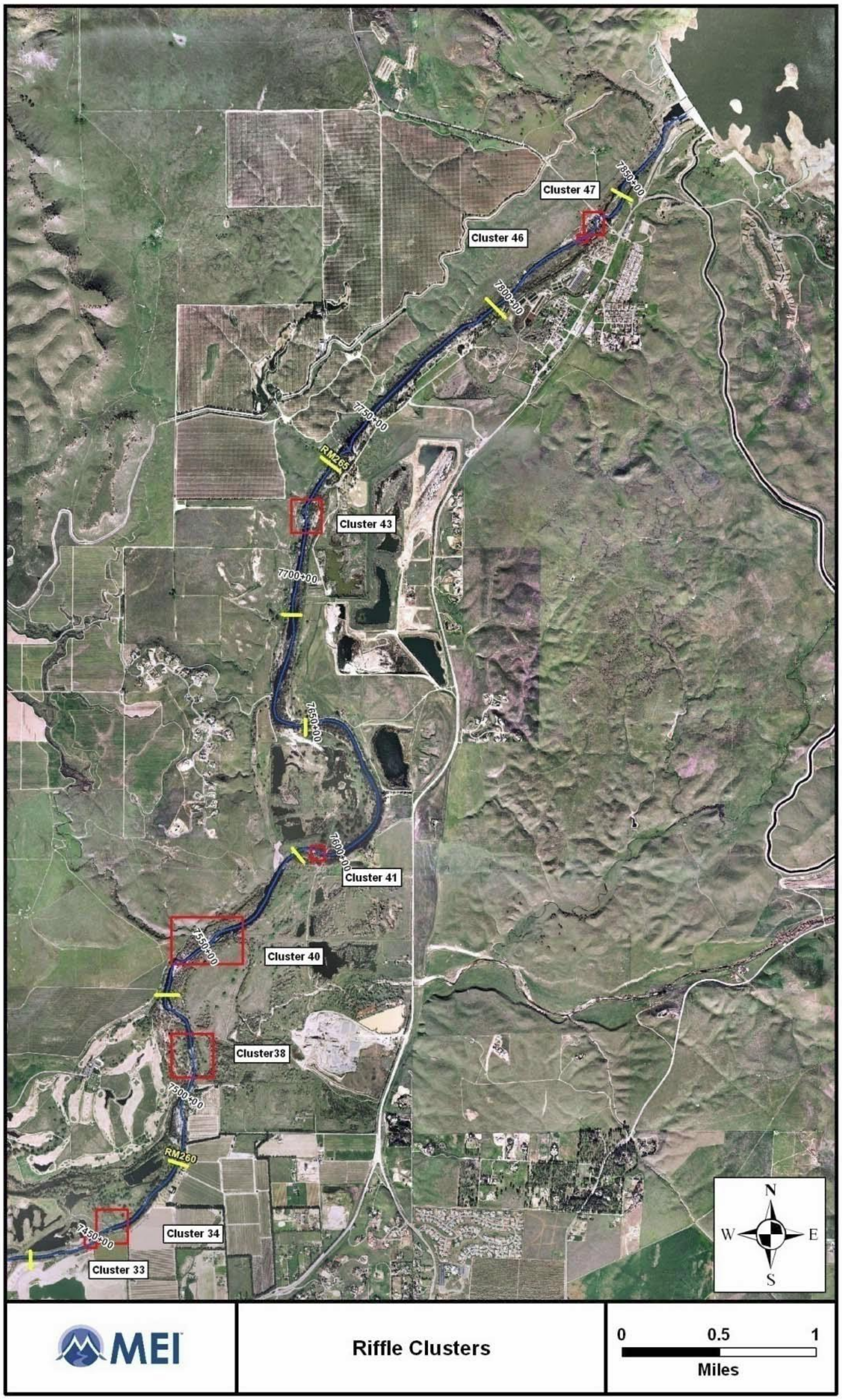


Figure B-27: Map showing Riffle Cluster areas where gravel mobilization studies were proposed. Sites selected for this study are labeled 38 and 40 (Source: MEI 2008).

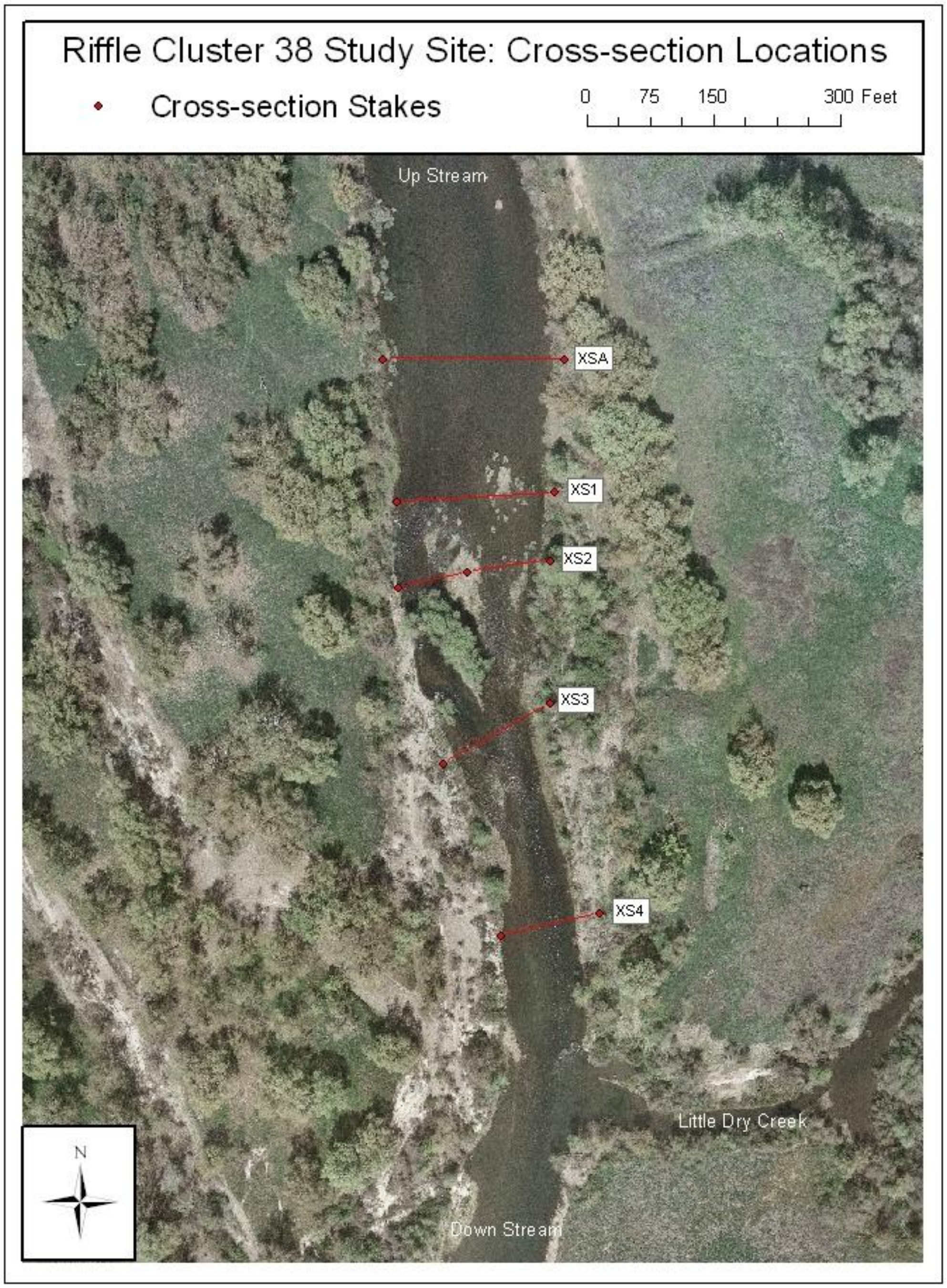


Figure B-28: Map showing Riffle Cluster 38 study site's staked cross-sections XSA, XS1, XS2, XS3, and XS4.

Figure B-29: Map showing Riffle Cluster 40 study site's staked cross-sections XSA, XS1, XS2, XS3, and XS4.

Topographic Survey

A real-time kinematic (RTK) global position system (GPS) is used as the primary method of horizontally and vertically surveying the site. In situations where riparian canopy cover was too dense to maintain a satisfactory signal with GPS satellites a conventional total station and survey rod were used. All surveys are tied to the 2007/2008 established control points local to each study site. The horizontal datum used is the California Coordinate System Zone 3, US Survey Feet, based on California Geodetic Coordinates of 1983, Epoch 2007.0. The vertical datum used is the North American Vertical Datum of 1988. Established control points are presented in Attachment A1: Control Points and Cross-section Staked End Points.

Existing control points are used to validate the accuracy of the data. At the commencement of a survey, several times per day, and at day's end the accuracy of the survey readings are verified by positioning the rover on a control point to make certain that the horizontal and vertical location is within 0.01 and 0.1 ft, respectively.

Topographic Change Monitoring

At least twice a year, the 5 cross sections at each study site are topographically surveyed (Figures 2 and 3). The intention is to measure change in the elevation of the bed after erosion and/or deposition producing flow events. It is necessary, therefore, to survey along the same line each time. As mentioned previously the ends of each cross-section are monumented with steel stakes between which a tape measure is stretched thereby creating a straight line that can be duplicated for each survey. The rover is positioned tangentially to the tape and vertical with use of a bull's eye spirit level. Equal intervals are maintained with use of the tape as well. Typically, 2 to 3 ft intervals are used while traversing the channel with shorter intervals used at grade breaks and in the vicinity of the water's edge. The results from these repeated channel spanning topographic surveys are presented in Attachment A2: Repeated Channel Spanning Topographic Surveys.

Channel Bathymetry

Higher resolution bathymetry data is anticipated to be useful for modeling the flow within the intensively monitored study sites. To accomplish this task the RTK GPS is used to survey the channel bed, banks, bars, floodplain, and levees. Given the bank full width of the channel being approximately 150 ft, surveys were performed by recording horizontal and vertical measurements at approximately 10 ft intervals laterally across the channel and repeating approximately every 75 ft (1/2 bank full width) longitudinally to about 300 ft beyond the upstream-most and downstream-most cross-sections (Figures 2 and 3). The channel's horizontal and vertical survey measurements are presented as Attachment A3: Channel Bathymetry Survey Data.

Roughness Polygons

To incorporate the effect of roughness variation on flow patterns the RTK GPS rover was used to delineate the boundaries of locations that exhibit elements differing from the majority of the channel. Such elements typically included large woody debris (LWD) and vegetation (e.g. reeds, willow bushes, alder trees, and grass) on bars exposed during low flow conditions. The outer limits of each roughness element was surveyed and noted as to the type of roughness element (e.g. willows) it contained thereby creating many "polygons" of differing size and shape that each would be expected to have a roughness value similar to one with the same element. This information will be used to calibrate the flow model. The roughness polygon boundary horizontal and vertical survey measurements are presented as Attachment A4: Roughness Polygons Survey Data.

Water's Edge

Water's edge measurements were surveyed during the course of other topography and flow profiling surveys. This data will be useful for calibrating the flow model and comparing its results with the measurements from the acoustic Doppler current profiler. For each water's edge survey the day's discharge from the USGS Friant gauge (11251000) was noted from the DWR's CDEC website (DWR). Prior to use of these water's edge measurements, comparison with actual discharge measurements made locally or other agency's (e.g. USBR) calculations will be made to verify the discharge level. Water's edge survey recordings, recording date, and discharge are presented in Attachment A5: Water's Edge Survey Data.

Bed Material Characterization

Bed material was measured and photographed for the purpose of characterizing its size distribution. This information will be useful for developing (1) a flow model by providing a parameter [i.e. the particle size for which 90% of the sampled bed area is finer than (D_{90})] for calculating bed roughness; and (2) a sediment transport model by providing required parameters [i.e. packing and median particle size (D_{50})] for determining the critical shear stress.

Pebble Counts

Pebble counts were performed at regular intervals along each cross-section in a manner that would allow subsequent measurements for comparison. Pebble counts were performed 5 to 20 ft downstream of each cross-section at lateral-to-flow intervals of 10 to 20 ft. Each pebble count sampled approximately 100 particles by random selection using a point-to-the-bed while not looking approach. After two particles were selected the sampler would sidestep and select two more particles thereby zigzagging over the 15 ft by 10 to 20 ft area without duplication of a previous sampled location. For each sample interval the distance along the cross-section from the left bank stake was noted for both ends of the interval. The interval width for each cross-section was chosen to capture the trends in particle size distributions amongst differing morphologic features (i.e. side channel, bar chute, bar toe, thalweg, against banks, etc.). Pebble count data and the sample statistics are presented in Attachment A6: Pebble Count Data & Sample Statistics.

Bed Photography

Photographs were taken of the channel bed using in-house developed equipment. A Nikon D700 digital single lens reflex (SLR) camera with a 35 mm lens was used for its ability to capture details in low light settings. The camera was positioned with its lens in a device that allows better viewing of the bed surface under water. Two different such devices were used and each was designed in-house. The first is what we call the "photocone" and the second we call the "viewing bucket" (Figure 4). The photocone is a cone shaped scope with a plexiglass lens fitted to the larger end of the cone. The camera is positioned through the smaller end of the cone. Similarly, the viewing bucket has a lens on one end of a 5-gallon bucket while the lidded end has a circular hole cut into it of the same diameter as the camera lens. The viewing bucket device is fitted with a bracket for holding the camera to the bucket to allow for greater ease of photography (Figure 5).

Figure B-30: Bed photography surveying using the photocone device. The yellow stretched tape is used to note each photograph's position along the cross-section. The umbrella is used to block light from entering both around the edges of the cone as well as into the hole behind the camera. Two people are needed to carry and hold the photocone in position while the third person takes photographs and records notes. Note the size of the photocone relative to the viewing bucket shown in the lower left corner of this figure.

Figure B-31: The viewing bucket photographing device. The bottom of the viewing bucket is made of plexiglass, while the top lid has a circular hole the same size as the camera's lens thereby preventing light from entering the bucket from around the lens and producing a glare. The camera is fitted to a bracket on the bucket's lid (right photo) for ease of photographing (left photo) while in difficult flow conditions.

The photocone is better suited in areas where its size is not problematic. Since the photocone is large and made of sheet metal it can be difficult to manage in swift flows (>3 ft/s). However, the photocone's larger bottom diameter allows for a larger area (~3 ft by 2 ft) to be captured within a photograph and the shading effect of the photocone creates a more even lighting that makes it easier to capture details in areas that would otherwise be lost in the shadows (Figure 6). The viewing bucket device is smaller and lighter making it easier to use in swift flows and deeper areas but has the drawback of light unevenness and smaller bed area photos.

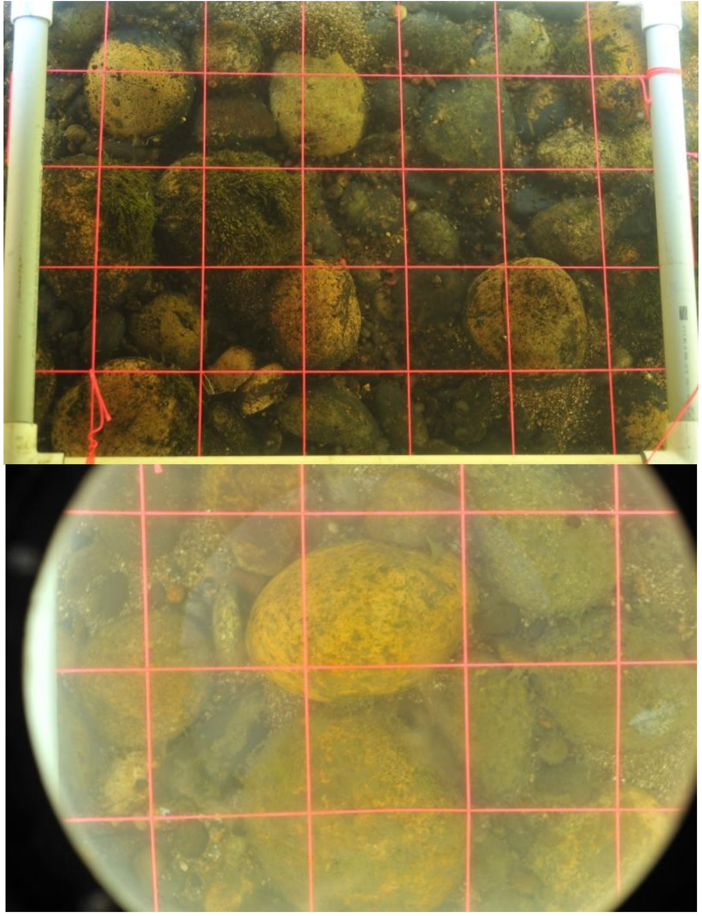


Figure B-32: Bed photographs taken from the photocone (above) and viewing bucket (below). Note the grid formed by the pink string is 10 cm by 10 cm. These photographs are reduced in size, the original larger images allow for detecting finer details (e.g. sand grains).

Bed photographs are taken tangentially to the upstream side of each of the study site's five cross-sections (**Figures B-28** and **B-29**) by following a tape measure stretched between staked end points. To photograph the bed material the lens of the photocone/viewing bucket is pressed below the surface of the water thereby removing the unevenness of the water surface from the photograph. Glare is reduced by blocking light from behind the camera using an umbrella and other shielding. Glare is further reduced with the use of a circular polarizing camera lens filter. A weighted PVC frame approximately 671 cm by 466 cm threaded with string tied taught forming a 10 cm by 10 cm grid pattern is placed on the bed for each photograph (Figure 6). The grid, as well as the string width

(1.5 mm) and PVC pipe width (33 mm) can be used as scale references within the photographs. A tape measure stretched between the cross-sections's staked end points is used to note the location of each photograph by measuring the distance of each end of the PVC frame to the nearest 0.5 ft. An index of the bed photographs is presented in Attachment A7: Bed Photography Index. Due to the large number of photographs, their large file sizes, and the necessity to maintain image quality for the sake of their usefulness the individual photographs are not provided with this report. Instead, contact Matt Meyers at mmeyers@water.ca.gov for bed photograph acquisition.

Pilot Tracers

In July 2009 a pilot tracer study began. This report presents the data collected to date from this study but the reader is referred to DWR's "Fall 2009 Interim Flows Monitoring Data Report for the San Joaquin River Restoration Program" (2010) for more complete information regarding the methods used in their implementation. The size class, number, and location of all painted tracers originally sized, painted, and placed along RC38's XS1, XS2, and XS3 are presented as Attachment A8: Pilot Tracer Study – Initial Location, Size, and Count.

Unmobilized Pilot Tracers

During Summer 2010 tracers that did not move beyond the cross-section line were counted, weighed, size classed (22.6, 32, 45, 64, 90, 128, and 180 mm), and had their smallest, intermediate, and largest axes measured. Similar to their placement, the location of each tracer along the cross-section was recorded by 2 ft wide increments (bins). Due to time constraints axes were not measured for some of the unmobilized tracers along XS1. To measure and record tracer attributes each tracer was moved to the bank and as a result the natural positioning was compromised and therefore all located unmobilized tracers were removed from the channel at the conclusion of this study. These measurements are presented in Attachment A9: Pilot Tracer Study – Unmobilized Tracers.

Mobilized Pilot Tracers

Pilot tracers that mobilized as a result of Fall 2009 and Spring 2010 elevated flow events were sought in January 2010 and throughout Summer 2010. Located mobilized tracers positions were recorded using the RTK GPS rover. During the January 2010 survey located tracer's size class was measured and recorded but otherwise left insitu. During the Summer 2010 survey located tracers were measured for weight, size class, and their three axes which were recorded with the survey point id. Due to the need to move each tracer to the bank for measurements the natural positioning was compromised and therefore all located tracers were removed from the low flow channel during the Summer 2010 survey. These measurements are presented in Attachment A10: Pilot Tracer Study – Mobilized Tracers.

Discharge Patterns

The pilot tracers were deployed from July 2009 through Summer 2010. During this period two distinct peaks in stream discharge occurred. The first peak was reached on November 10, 2009 at a provisional peak discharge of 726 cfs (USGS). The second peak was reached in May 6, 2010 at a provisional peak discharge of 1,700 cfs (USGS). Mobilization of the pilot tracers is viewed as not only the result of the peak flows but the cumulative discharges above the threshold necessary to mobilize them. Future analyses will hone in on those thresholds. See **Figure B-33** for a plot of the discharge at the USGS's Friant gauge during pilot tracer deployment.

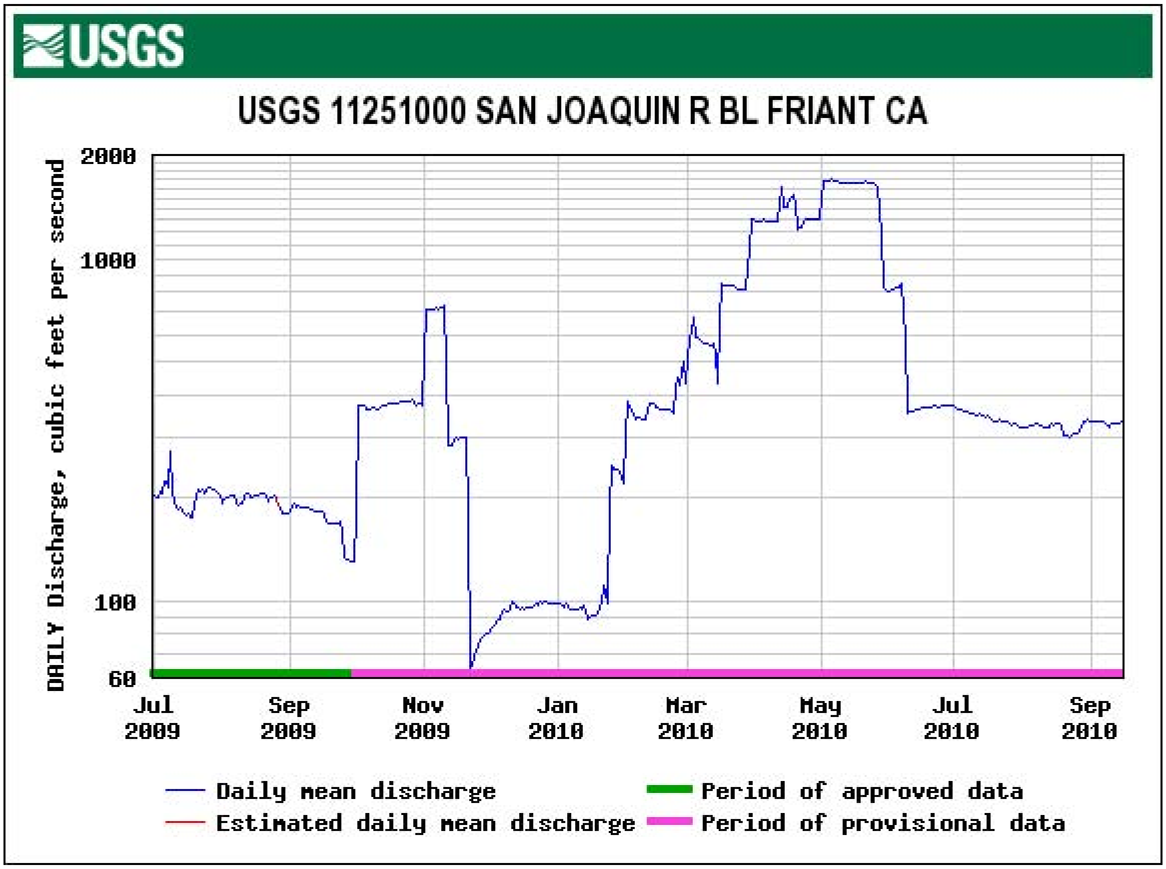


Figure B-33: Mean daily discharge at the USGS Friant gauge (11251000) during pilot tracer deployment (USGS). USGS reports data from October through Summer 2010 as provisional. It is recommended that all discharge measurements be verified with other's calculations and direct measurements.

RFID Tracers

Beginning in January 2010 an alternative tracer method was implemented that requires less time to install and has the potential to provide useful information after each high flow event for many years. This method uses gravel particles from the selected study areas as tracers by inserting passive transponders into them. When located with an antenna in the field the transponders are capable of relaying a unique identifying code via radio frequencies which can be read from a portable field computer.

RFID Tracer Installation

Several steps were followed to prepare the RFID tagged tracers. First, natural gravel particles greater than 32 mm in intermediate diameter were randomly collected from the study area to ensure similarity in particle traits found at the study area. Collected particles were then transported for further preparation and measurement. Each particle had a hole drilled in it just deep enough to create a cavity into which a RFID tag was completely inserted and sealed. The size of the hole depended on the size of the gravel particle. RFID tags currently come in 3 sizes (12 mm x 2.15 mm diameter, 23 mm x 3.85 mm diameter and 32 mm x 3.85 mm diameter). Larger tags have the advantage of a longer read range with the antenna. A drill bit with a 3/16 inch diameter was used to create a cavity to insert the tag and seal with a thin layer of silicone. Each particle was then scrubbed and washed for preparation before painting. The purpose of painting is to make future locating easier and less time consuming. Additionally, in order to measure the depth in which the tracers are buried the paint is needed to differentiate from native gravels (i.e. the small hole is not obvious). The unique RFID identifier was then recorded for each particle along with the respective particle weight, description of roundness, and the length of its smallest, intermediate, and largest axes. Additionally, a unique alternate identification (Alt Id) number is marked on each tracer and recorded with the other information for ease of identification without the antenna/reader.

Procedures were developed to place the RFID tracers on the stream bed. First, the cross-sections described previously were used to define the downstream limit of placement and to space across the channel's width. The tracers were placed with at least one of each size class at every 20 ft across the channel. Their placement was between 2 and 7 ft upstream of the cross-section's stretched tape measure. The 5 ft wide area was necessary to find locations for positioning the tracers such that they replace particles of similar size and shape. Prior to placing a tracer the bed was carefully scanned for particles of similar size and shape. Upon locating a suitable particle it was carefully plucked and the tracer was positioned in the same location with a diligent effort made to simulate the plucked particle's orientation and relationship with neighboring particles.

Upon placement each tracer was then surveyed horizontally and vertically using the rover GPS equipment with an RTK GPS base station. Each tracer's survey point ID is recorded along with the RFID number and orientation of the particle's axes relative to flow direction and vertical. Tracers from the 32 mm, 45 mm, 64 mm, 90 mm, and 128 mm size classes were spaced within the bank full channel in areas exhibiting unvegetated and coarse surface materials.

RFID Tracer Surveys

RFID tracer surveys were conducted to locate unmobilized and mobilized RFID tracers after elevated flow events. These surveys occurred in Summer 2010 and December 2010. Tracers were located visually using their paint as well as using the RFID antenna. Upon locating, the tracer's identification code was read with the antenna/reader and recorded with its GPS surveyed position information. Each RFID code and survey point number was also recorded in a field book. If the alternate identification number was legible it too was recorded in the field book. In the event that the RFID antenna/reader system was malfunctioning the alternate identification number and/or size class was recorded with the surveyed position information. In the event that a RFID tracer was located with the antenna and buried typically it was uncovered and its depth noted by surveying the bed surface before and after disturbing the bed. The difference in elevation is the burial depth. Additionally noted was the predominate size class of the material overlying the tracer. In the event that unmobilized tracers close to one another were buried some were left with overlying material undisturbed if the others within close proximity that were uncovered were thought to have representative burial depth. In such a case the depth of burial was noted as that found nearby (within 10 ft). The intention of leaving overlying material undisturbed is to maintain the surface structure in its natural deposited state as best as possible.

Force Gauge Measurements

In order to quantify the degree to which the bed material is resistant to movement direct measurements were made. This was accomplished using spring resisting force gauges to quantify the force necessary to move bed surface particles in the downstream direction. The force gauge has a maximum reading pointer that records the maximum force applied. Six different sized force gauges were used. Each gauge has a different capacity as well as level of accuracy. The maximum capacity was 18 kg with an accuracy of 0.2 kg. The smallest force gauge is capable of detecting a minimum recording of 5 g. Selection of the appropriate gauge for each particle measurement was based on the size of the particle as well as its relationship with the surrounding particles. Prior to each force gauge measurement the gauge was zeroed.

Force gauged areas were selected 10 to 30 ft upstream of the cross-sections so as not to disturb the tracers. The width of the areas were based on the size of the morphologic feature that was being measured. As a result, their size varied and were between 15 ft (RC38 XS2 bar chute) and 100 ft

(RC40 XS1 riffle head) wide. The position relative to cross-section end point stakes was recorded for each area. The difference in the area's size also depended on the availability of particles in each size class. Typically, the smaller 32 mm and even more- so the larger 128 mm size class particles were more difficult to locate and so the area may have expanded to measure their resistance as best as possible. Typically, as more particles for an area were measured some size classes began to be sampled more than others. When approximately 20 measurements were collected from a few size classes the other remaining size classes were selected less randomly. Often particles of the remaining size classes had to be sought out. In some instances 20 particles could not be found within an area that was considered representative of the morphological feature that was being attempted to be representatively measured.

Once the area to be measured was delineated we assessed the best approach to use so as to avoid disturbing the bed particles and minimize the area required to collect measurements of undisturbed particles. Each particle was selected randomly by gently pointing down while averting or closing one's eyes until the first gravel particle was touched with the right edge of one's index fingernail. Using this random selection process enabled a measure of the condition of the bed without a selection bias for more preferentially accessible particles. In order to avoid disturbing the bed from turbulence caused by the measurer's presence in swifter flow (>2 ft/s) measurements were made while standing downstream of the particle. In slower flow (<2 ft/s) measurement were made while positioned upstream of the particle.

After each particle was selected notes were taken to categorize the particles' relative support and/or protrusion provided by its position relative to neighboring particles from the force of the flowing water. Categorization of this structure included clustered (C), imbricated (I), embedded (E), protected in a pocket (P), and loosely exposed (L). Additionally, the axes parallel to the primary flow direction and to the depth were noted. The measurement was then made by pushing the force gauge from the upstream side of the particle, parallel to flow and the bed surface, and through the centroid of the particle. If after the measurement the particle was observed to have different than anticipated geometry the recorded orientation was corrected. When the particle was pushed with the tip of the force gauge it would either pivot and roll, slide without rotation over the bed material downstream of it, or both. After pushing, the maximum force gauged and its movement type was recorded and the particle was retained for further measurements. Using a caliper with millimeter accuracy, the smallest, intermediate, and largest axes were measured and recorded. For particles weighing less than 6,000 grams (g) a digital scale was used to weigh each particle to the nearest gram. Larger particles required weighing using a hanging scale to the nearest 100 g. Finally, using a gravel-o-meter with ½- phi sized square openings, the particle's size class was recorded. Force gauge measurements were made at RC38's XSA, XS1, XS2, and XS3 and RC40's XSA, XS1, XS2, and XS3.

Flow Profiling

Attributes of flow were measured at RC38 on October 28 and 29, 2009 at 377 cfs; November 3 and 5, 2009 at 709 cfs; April 14, 2010 at 1,420 cfs; April 23, 2010 at 1,280 cfs; November 17 and 18, 2010 at 730 cfs and RC40 on November 16 and 17, 2010 at 730 cfs. These discharge values are from the USGS Gauge 11251000 (USGS). Surveys that spanned more than one day are approximated based on the range in flows reported for those days. However, the range never appeared to exceed ± 10 cfs and is therefore believed to have negligible effect on comparison between such measurements.

Flow was measured using a Sontek^{TM}/YSI^{TM}, Inc. acoustic Doppler current profiler (ADCP) mounted aboard a small trimaran. The trimaran was tethered to a pulley system that was stretched tight between fence post stakes across the channel's width approximately 10 ft upstream of the each cross-section. The tether line was adjusted in length to allow the ADCP to record flow data over the RFID tracer lines. The pulley system allowed the ADCP to traverse the channel while recording flow characteristics without interference of the stream flow. The pulley system consisted of a looped 3/8" nylon rope with a pulley on both sides of the channel latched to the fence posts. A manual ratcheting winch was used to tighten the pulley line. The tightened pulley line allowed a near linear cross-sectional flow profile to be measured. However, eddies and higher flow velocity still adversely affected the linearity of the ADCP path. In order to traverse the channel the pulley line was manually pulled by persons on both side of the channel at a steady rate that was no more the 50% of the average flow velocity. Approximately 4 channel traversing velocity profiles were conducted at each cross-section during each survey event. The summarized flow profile data are presented in Attachment A13: Flow Profile Summary Data.

13.3 Results

Topographic Change Monitoring

Net change in bed elevation is being monitored using topographic surveys along 10 cross-sections at the study sites (**Figures B-28** and **B-29**). Monitoring began at RC38's XS1, XS2, and XS3 in July 2009. Additional cross-sections were added at RC38 (XSA and XS4) and RC40 (XSA, XS1, XS2, XS3, and XS4) in Summer 2010. At these times baseline surveys were performed for future comparison. Since then, repeat surveys occurred in January, Summer, and December 2010. These surveys bracketed 3 peak flows that occurred on November 10, 2009 (726 cfs), May 6, 2010 (1,700 cfs), and November 21, 2010 (721 cfs) (USGS). See **Figure B-34** for mean daily discharge during this time period.

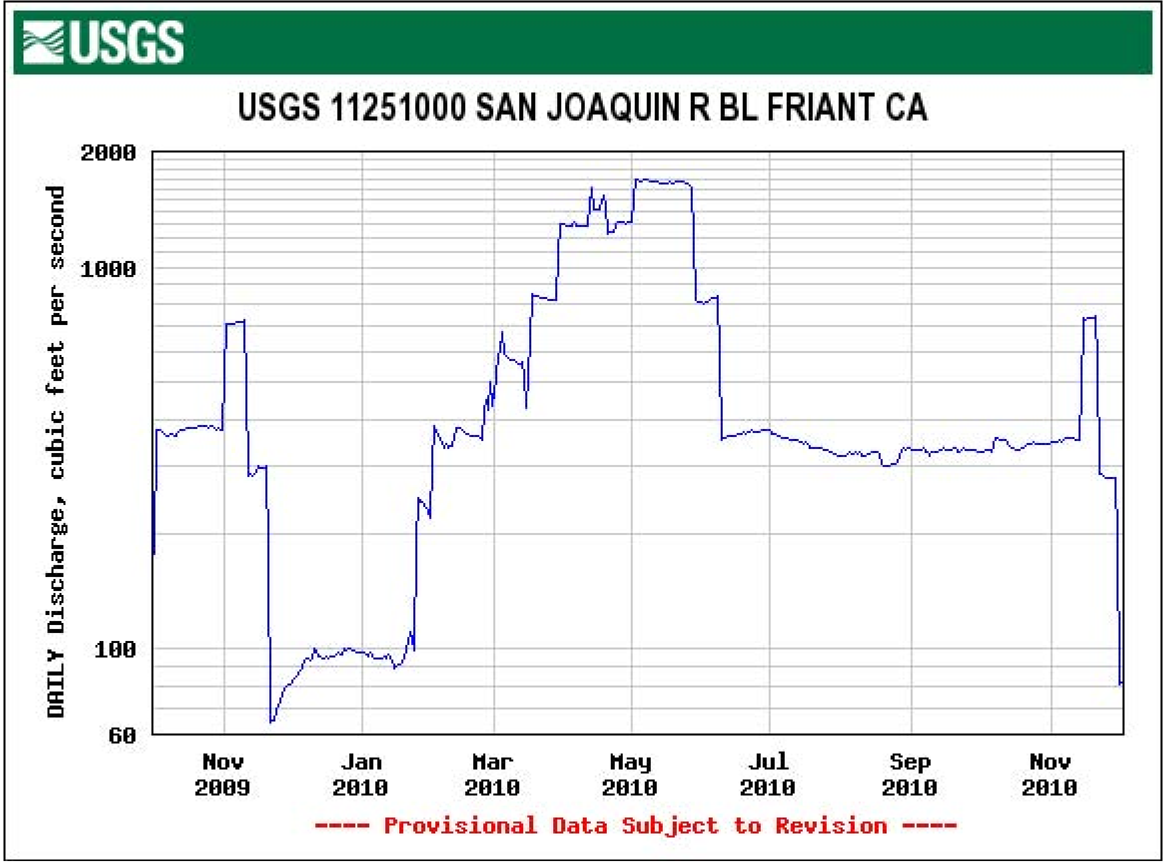


Figure B-34: Mean daily discharge at the USGS Friant gauge (11251000) from October 1, 2009 through December 1, 2010.

Results varied with location and discharge event. At RC38 XS2 up to 1.5 ft of net scour, 0.5 ft of net deposition, and 6 ft of bank erosion were measured after the Spring 2010 flows (**Figure B-35**). At

RC38 XS3, on the other hand, primarily net deposition with only a minor amount of net scour was measured after the Spring 2010 flows (**Figure B-35**). Results from the remaining cross-sections show little change and are presented in Attachment A2: Repeated Channel Spanning Topographic Surveys.

Figure B-35. SJR RC38 XS2, ReTopo Surveys

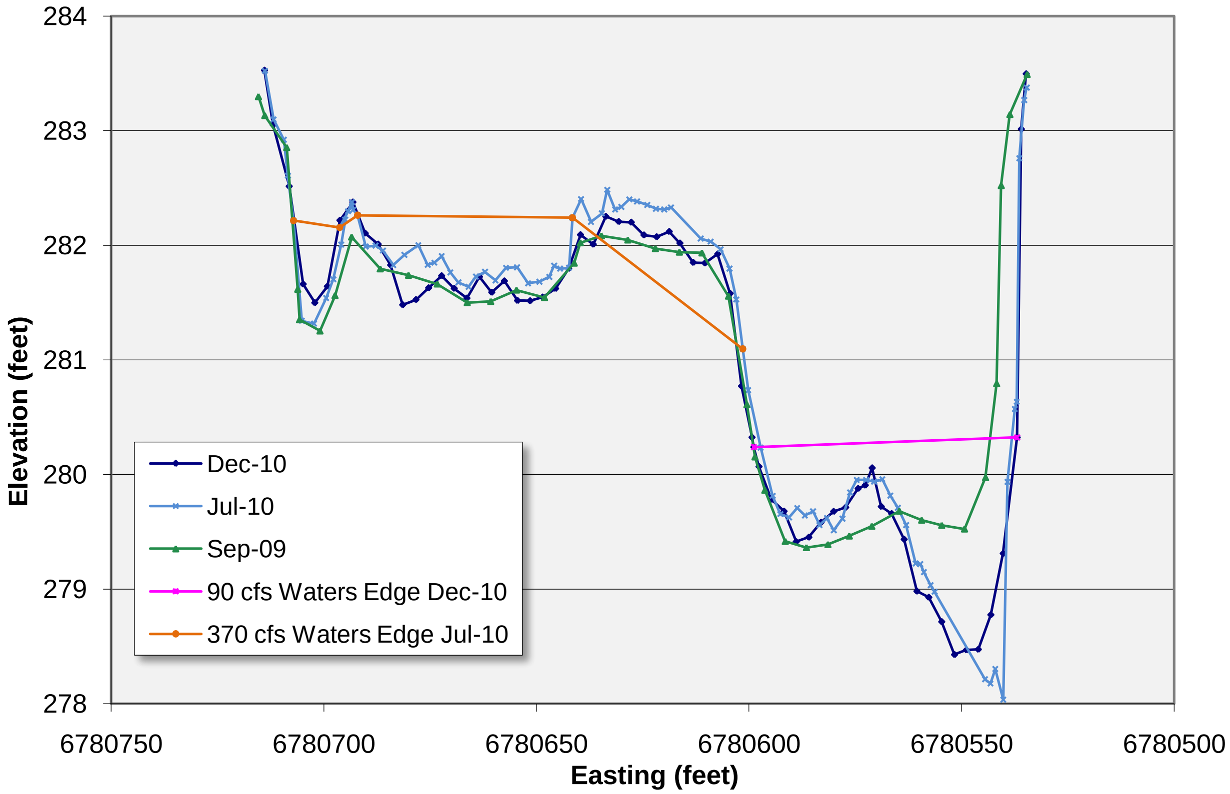


Figure B-35: Bed elevation change illustrated from 3 topographic surveys of Riffle Cluster 38's XS2 from September 2009 through December 2010. The low flow channel and thalweg are seen from 6780600 to about 6780560 ft and display the most dynamic response with up to 0.5 ft of net deposition, up to 1.5 ft of net scour, and 6 ft of bank retreat by July 2010. Bed elevation change on the bar, between 6780700 and 6780600 ft, is attributed to building and removal of debris piles.

Figure B-36. SJR RC38 XS2, ReTopo Surveys

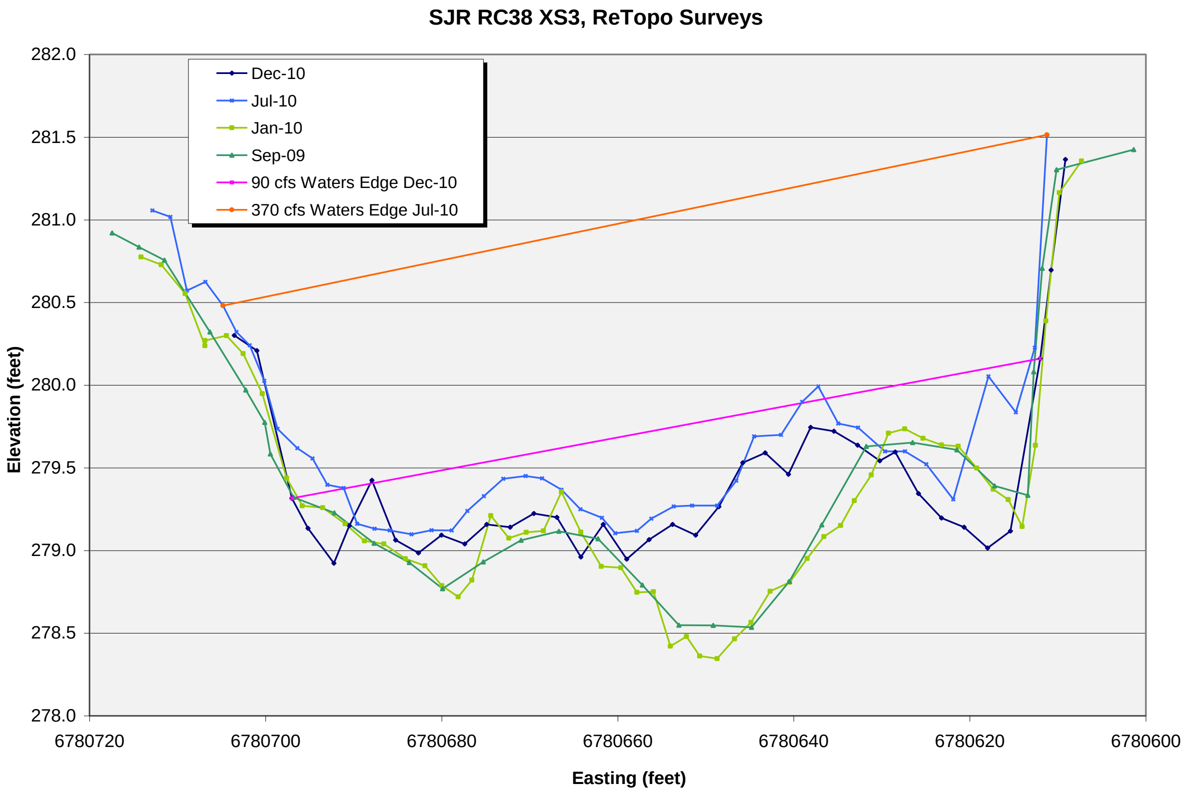


Figure B-36: Bed elevation change illustrated from 4 topographic surveys of Riffle Cluster 38's XS3 from September 2009 through December 2010. The thalweg is seen between 6780640 and 6780670 ft. This area displays the largest elevation change with up to 1 ft of net deposition after January 2010. This bed elevation change is associated with a large woody debris pile that was deposited approximately 10 to 40 ft upstream of XS3 between approximately 6780660 and 6780630 ft.

Pebble Count Results

Bed material sampling using the pebble count technique were performed at the RC38 XS1, XS2, and XS3 during Summer 2009 and January 2010, and along XS3 again in December 2010. Pebble counts were also performed at the RC38's XSA and XS4 and RC40's XSA, XS1, XS2, XS3, and XS4 during Summer 2010. Results showed variability in grain size statistics with lateral and longitudinal location. In addition, samples collected along RC38 XS3 showed coarsening along the right bank where in Summer 2009 there was a sandy head of a bar chute (Figure B-37). The complete statistical summary from each pebble count is presented in Attachment A6: Pebble Count Data and Sample Statistics.

Figure B-37. RC38 XS3 Grainsize Variation Across Channel Width

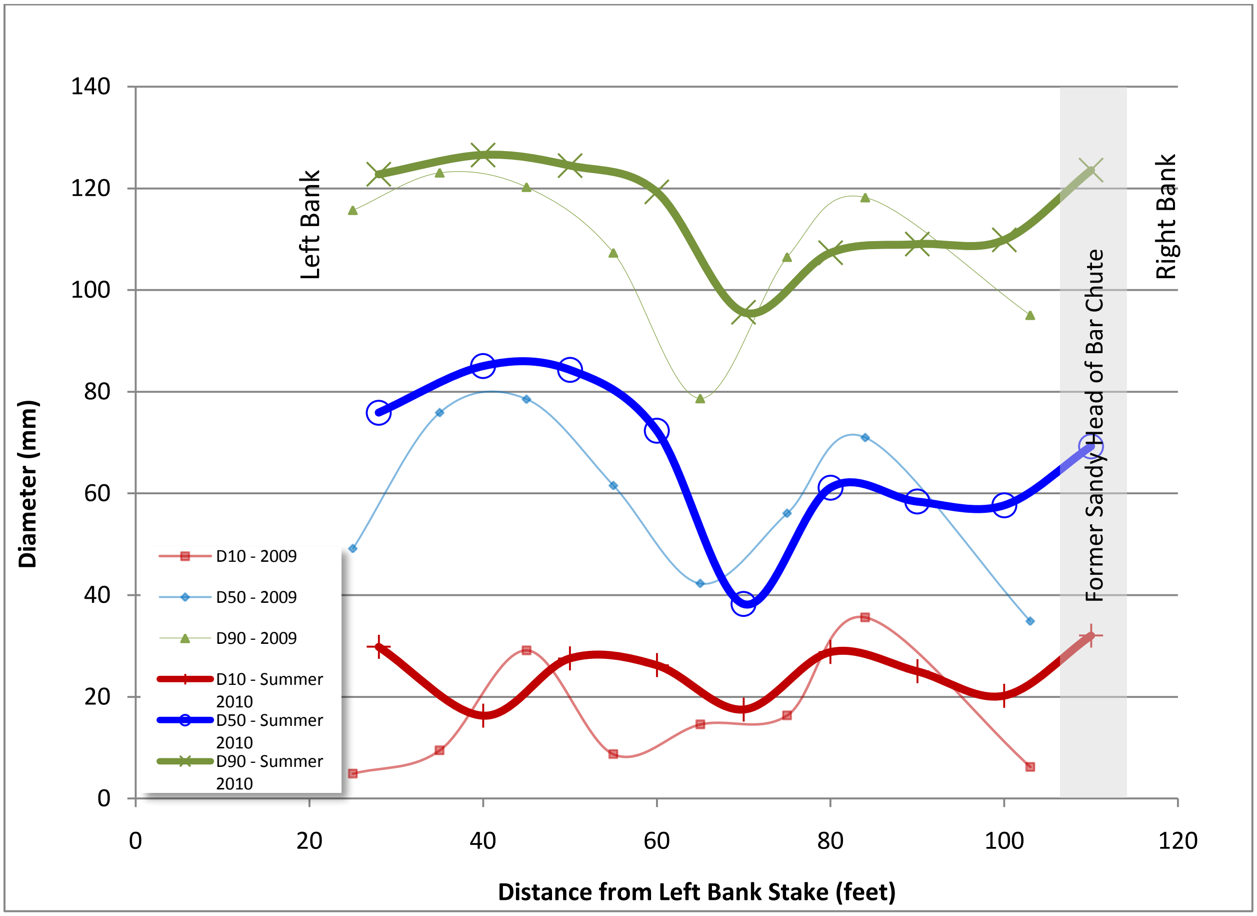


Figure B-37: A comparison of pebble count results from RC38 XS3. Thin lines show trends in sample statistics from the baseline Summer 2009 pebble counts. Thick lines show trends in follow-up Summer 2010 pebble counts. Symbol locations indicate the center of each pebble count sample, which were 10 ft wide. Note the change from a sandy margin to a coarser surface along the right bank.

Pilot Tracer Study Results

Painted gravel tracers placed in Summer 2009 were surveyed in January 2010 and again in Summer 2010. Table 1 shows the number of tracers originally placed by size class at each cross-section. Figures 12 through 14 illustrate the number of tracers painted per size class with position along their cross-sections.

Table B-21: Count of tracers placed during Summer 2009.

Size Class (mm)	XS1	XS2	XS3	Total at RC38
32 – 45	528	289	171	988
45 – 64	610	335	283	1,228
64 – 90	299	262	261	822
90 – 128	99	113	126	338
128 – 180	8	9	18	35
180 – 256	0	0	1	1
256 – 360	0	0	1	1
Sum	1,544	1,008	861	3,413

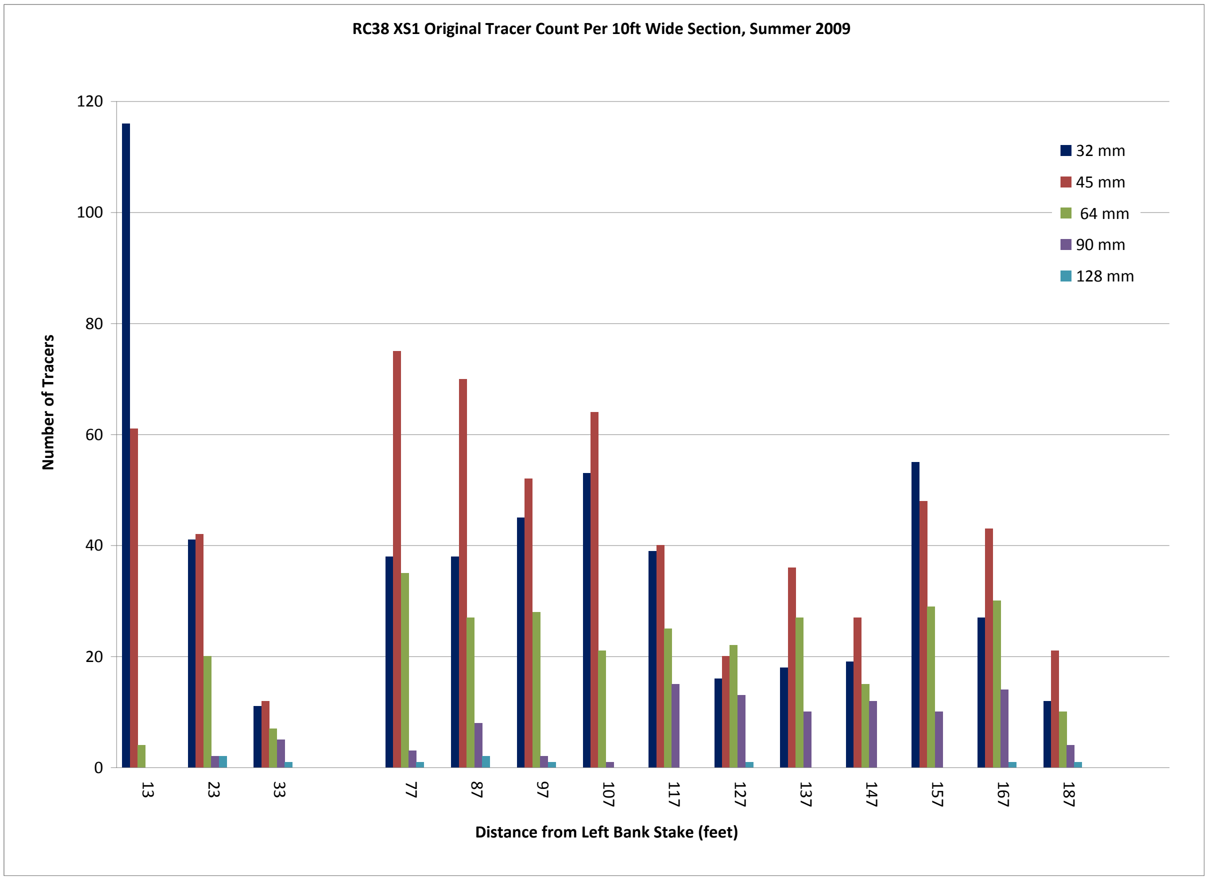


Figure B-38: The number of tracers by size class placed along XS1 in ~10 ft sections. The distance indicated along the horizontal axis indicates the midpoint of each section. The difference in the number of tracers in each 10 ft section is a reflection of the flow conditions. Higher flow conditions had fewer tracers due to attempts to reduce presence of personnel's disturbance of the bed. Relative proportion of each size class is a reflection of the change in bed texture along the cross-section. The gap from 38 to 72 ft is because of the presence of vegetation patches.

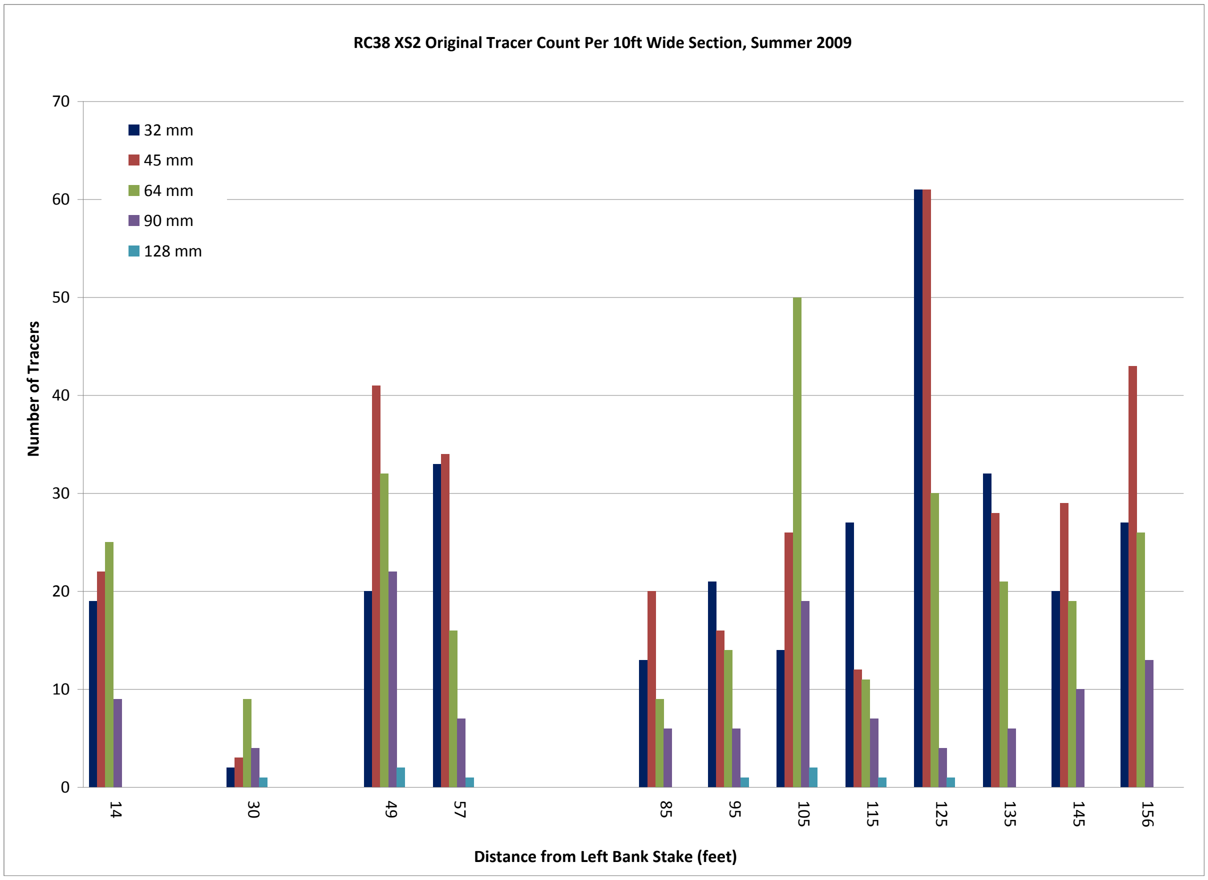


Figure B-39: The number of tracers by size class placed along XS2 in ~10 ft sections. The distance indicated along the horizontal axis indicates the midpoint of each section. The gaps from 19 to 25 ft, 35 to 44 ft, and 62 to 80 ft are because of the presence of vegetation patches.

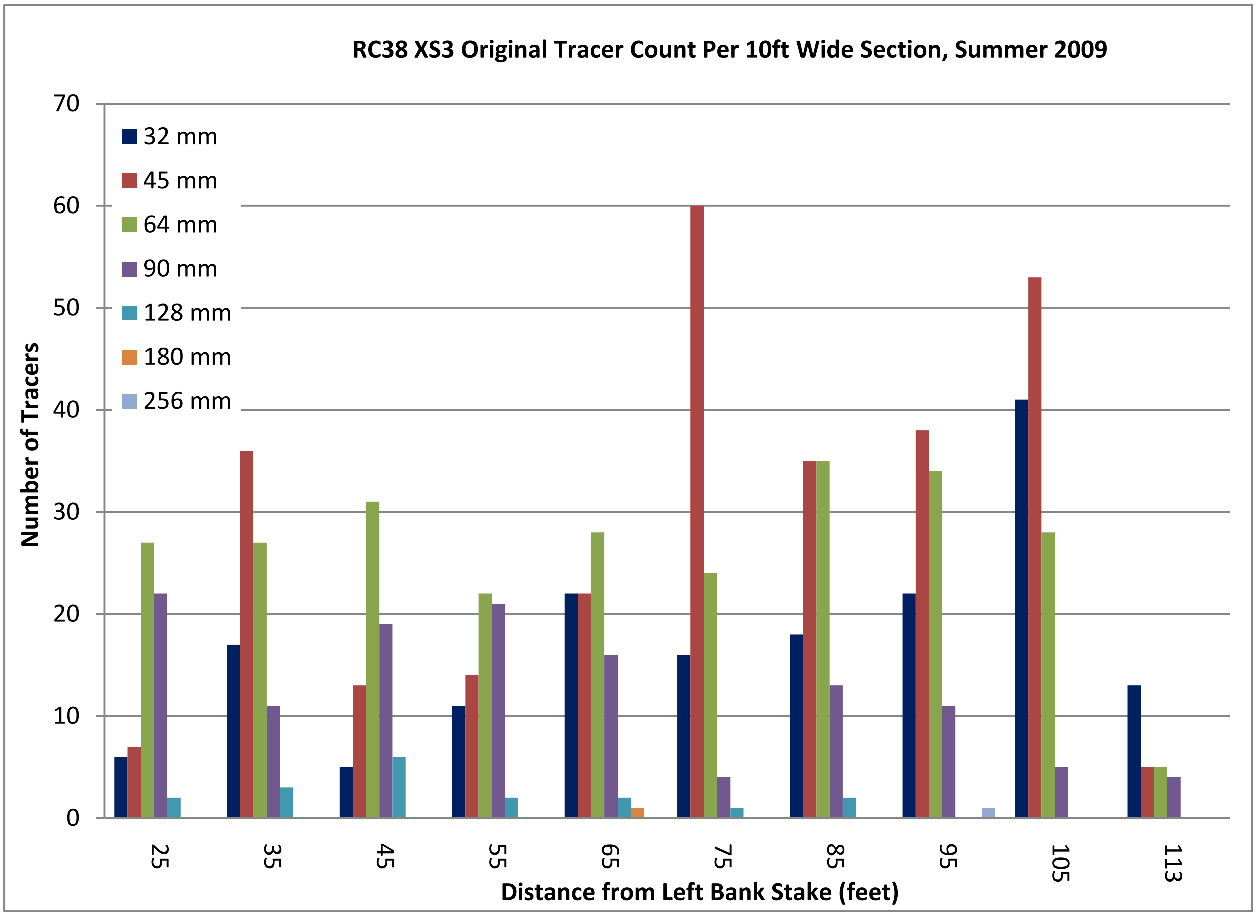


Figure B-40: The number of tracers by size class placed along XS3 in ~10 ft sections. The distance indicated along the horizontal axis indicates the midpoint of each section.

The January 2010 survey located 246 mobilized pilot tracers out of 3,413 that were placed. Table 2 shows the number of each size class that mobilized and were located for each cross-section and as a percentage of those that were originally placed. Figures 15 through 17 illustrate the percentage of tracers mobilized as a function of position along the cross-sections.

Table B-22: Count of located pilot tracers and percent relative to the total placed that mobilized >3 ft by January 2010.

Size Class (mm)	Mobilized at XS1	Mobilized at XS2	Mobilized at XS3	Total Mobilized at RC38
32 – 45	28 (5%)	6 (2%)	32 (19%)	66 (7%)
45 – 64	39 (6%)	11 (3%)	44 (16%)	94 (8%)
64 – 90	24 (8%)	3 (1%)	38 (15%)	65 (8%)
90 – 128	10 (10%)	1 (1%)	9 (7%)	20 (6%)
128 – 180	1 (13%)	0	0	1 (3%)
128 – 256	NA	NA	0	0 (0%)
256 – 360	NA	NA	0	0 (0%)
Sum	102 (7%)	21 (2%)	123 (14%)	246 (7%)

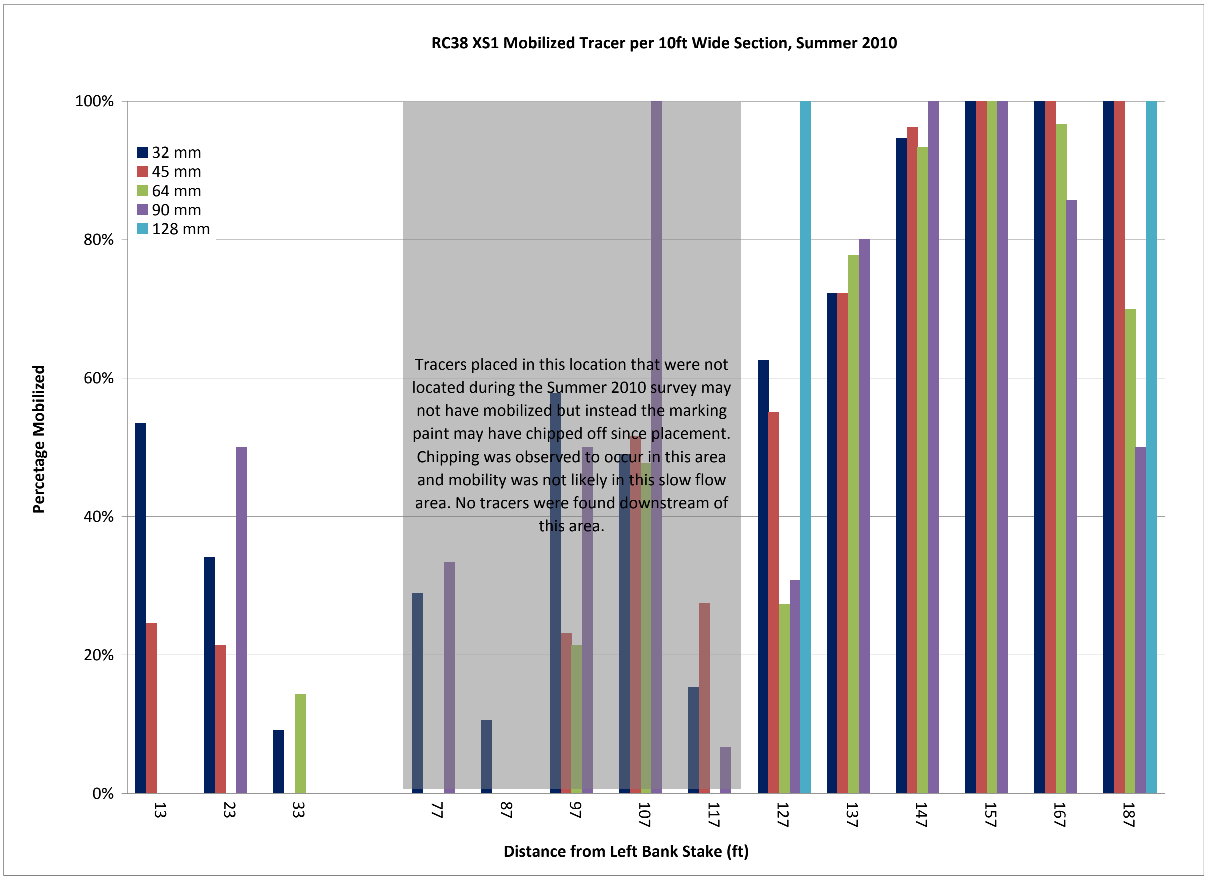


Figure B-41: The percent of absent tracers during the Summer 2010 survey as compared to the original number placed by size class along XS1. The distance indicated along the horizontal axis indicates the midpoint of each section. The thalweg along the right bank (right side of graph) suggests general mobility occurred since placement of the tracers. Partial mobility is indicated away from the thalweg area. However, absence of tracers between 77 to 107 ft from the left bank stake may be the result of paint chipping rather than mobility. Therefore, the mobility predicted by the absence of such tracers in this area should be considered an overestimate.

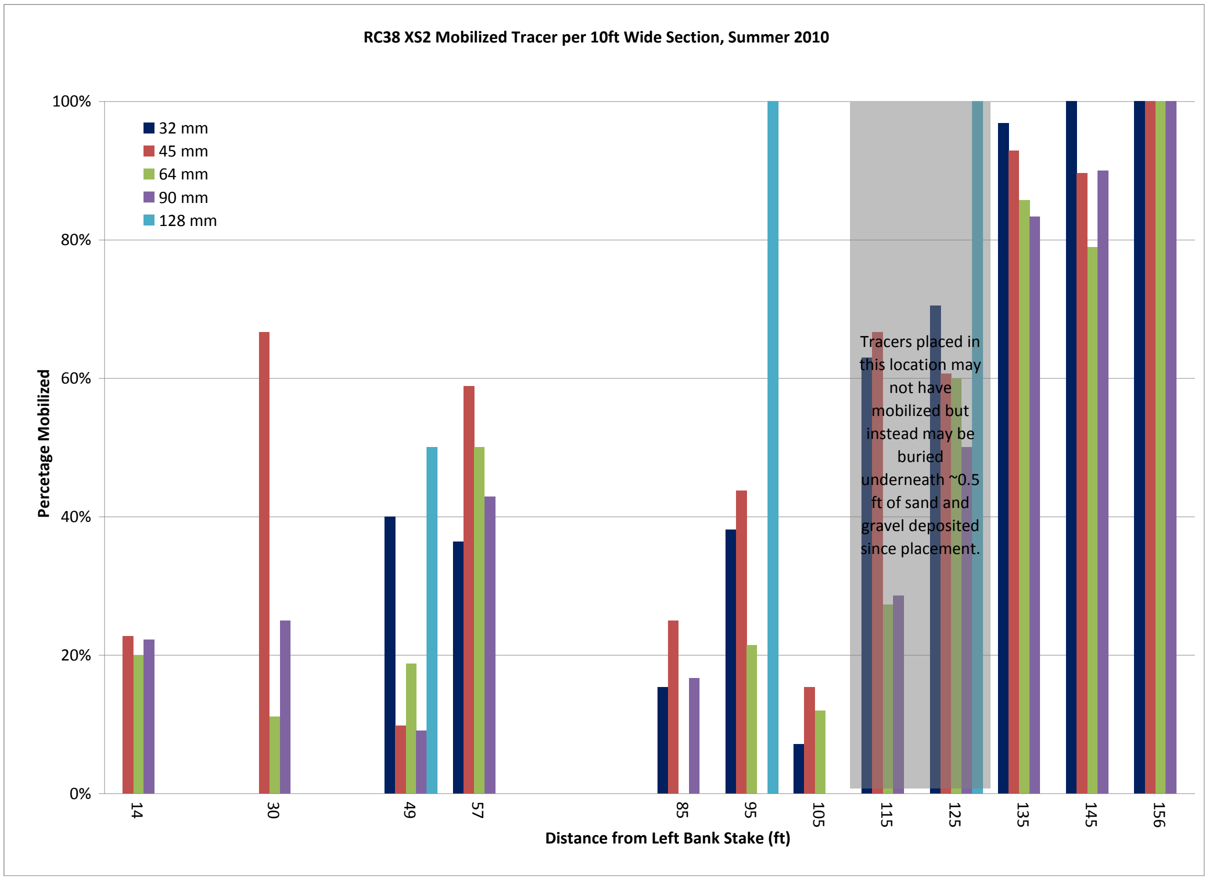


Figure B-42: The percent of absent tracers during the Summer 2010 survey as compared to the original number placed by size class along XS2. The thalweg along the right bank (right side of graph) shows general mobility occurred since placement of the tracers. Partial mobility is indicated away from the thalweg area. However, absences of tracers from between 110 to 130 ft may be the result of burial by sand and gravel since placement. Those particles located in this buried area were located beneath up to 0.5 ft of sediment. Therefore, apparent mobility indicated by the absence of tracers in this area should be considered an overestimate.

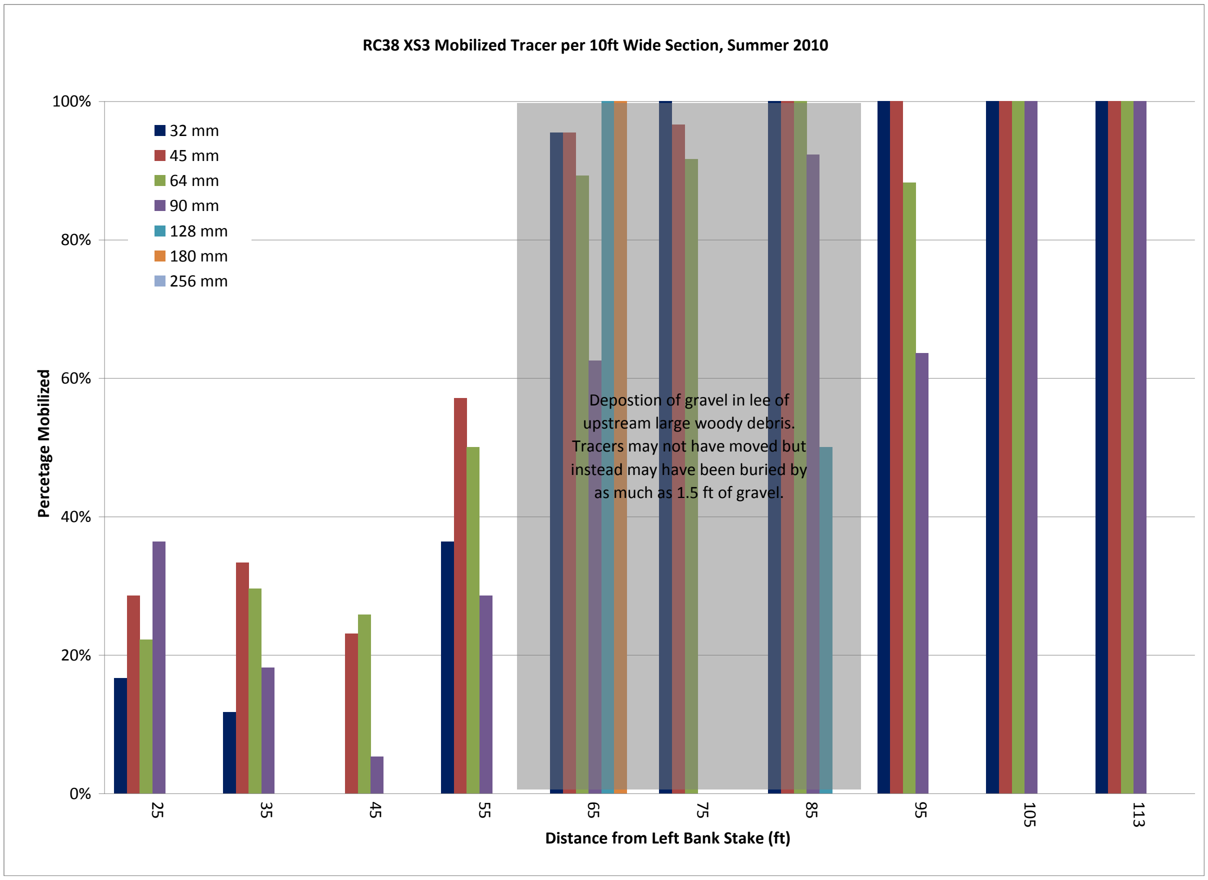


Figure B-43: The percent of absent tracers during the summer 2010 survey as compared to the original number placed by size class along XS3. The thalweg along the right bank shows general mobility occurred since placement of the tracers. Partial mobility is indicated away from the thalweg area. However, absence of tracers from between 60 to 90 ft from the left bank stake may be the result of burial by as much as 1 ft of gravel since placement. Therefore, apparent mobility indicated by the absence of tracers in this area should be considered an overestimate.

Located mobilized tracers were surveyed in January 2010 and summer 2010. Their locations are illustrated on Figures 18 and 19. The distance they traveled since placement is illustrated on Figures 20 and 21.

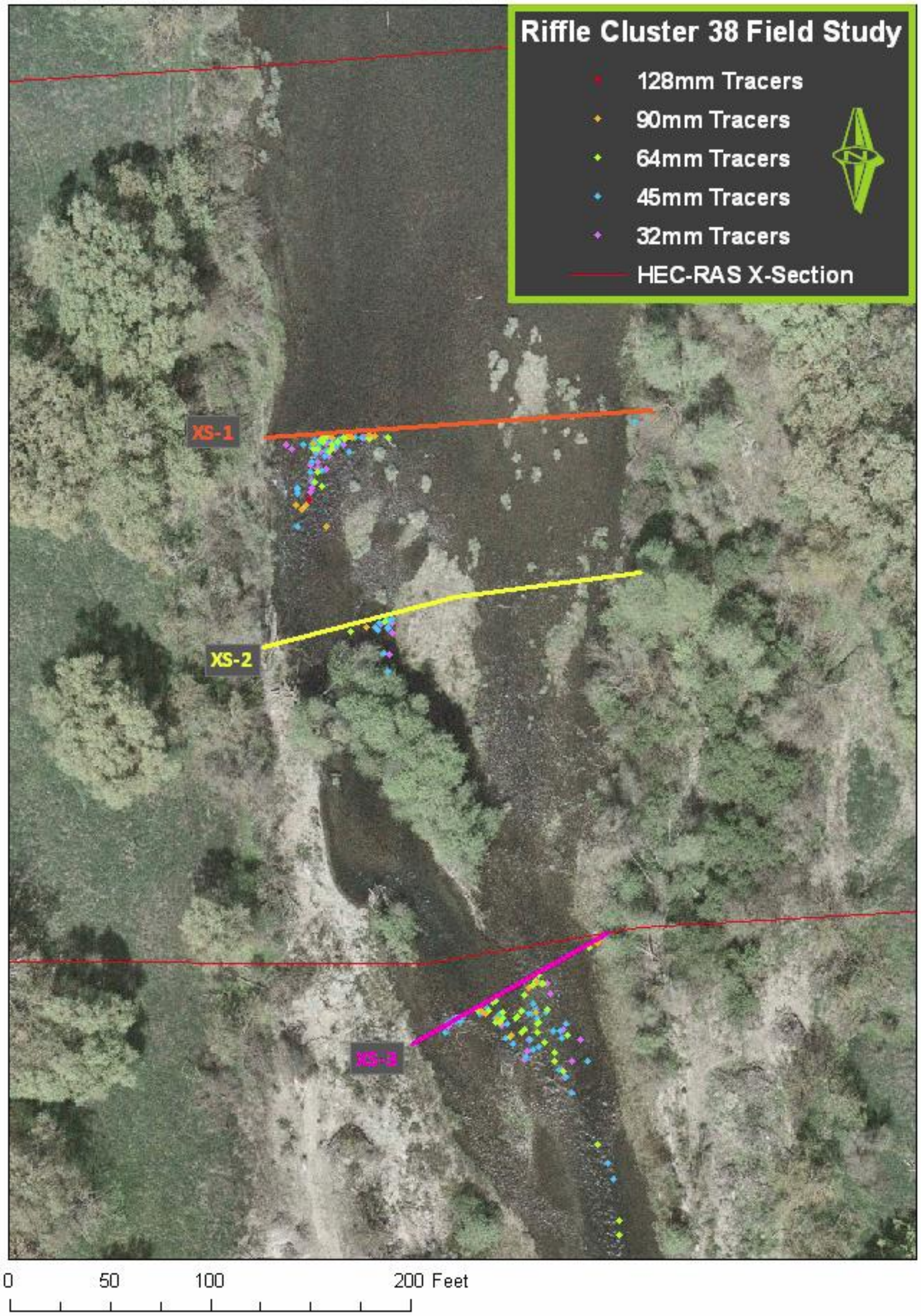


Figure B-44: Pilot tracer survey results showing mobilized tracers as of January 2010. Orange, yellow, and pink lines indicate original lines of placement. Dots indicate located mobilized tracers with the color indicating size class.

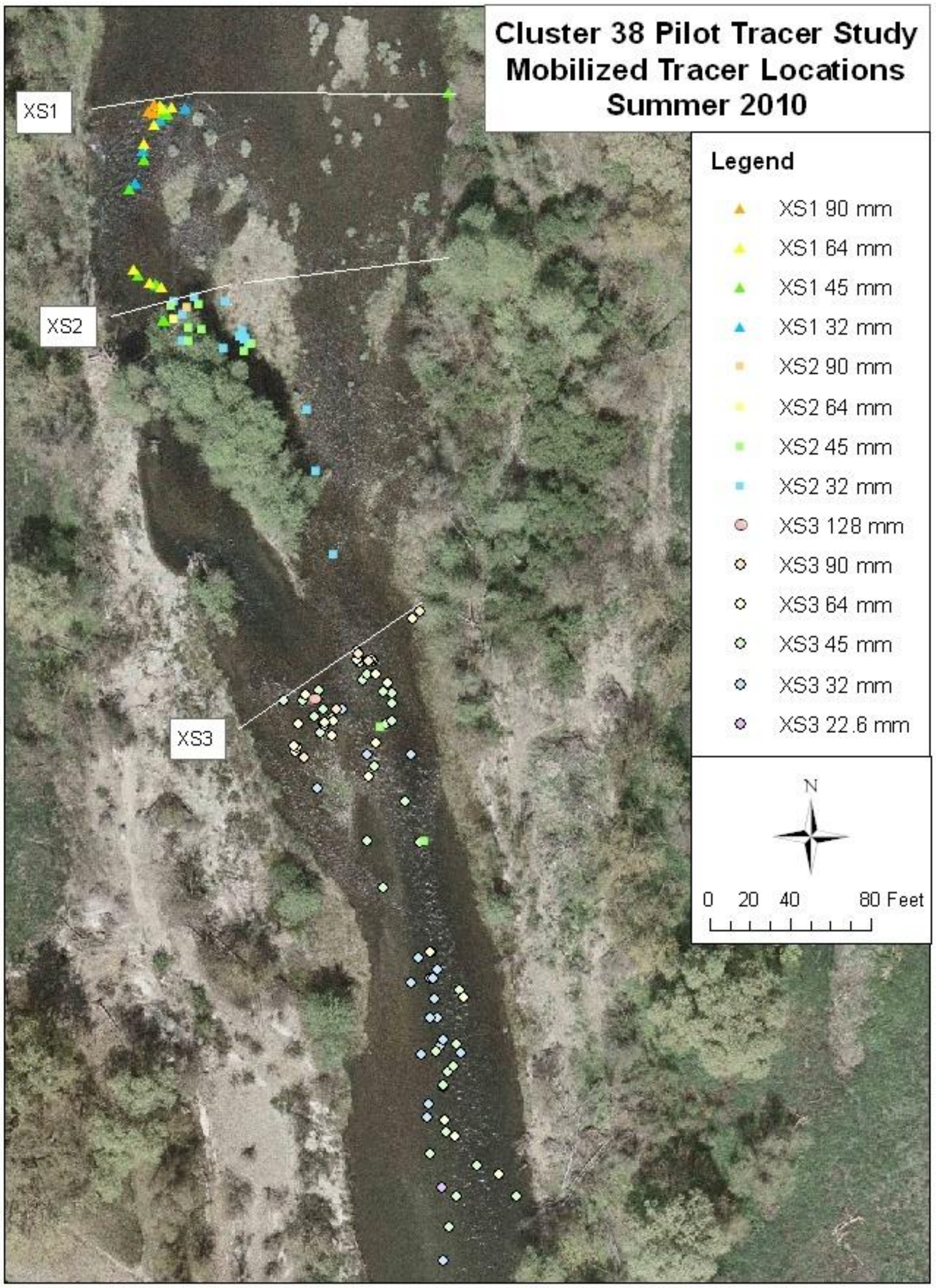


Figure B-45: Pilot tracer survey results showing mobilized tracer positions as of Summer 2010. White lines indicate original lines of placement. Triangle, square, and dot symbols indicate tracers from XS1, XS2, and XS3, respectively, and color indicates size class.

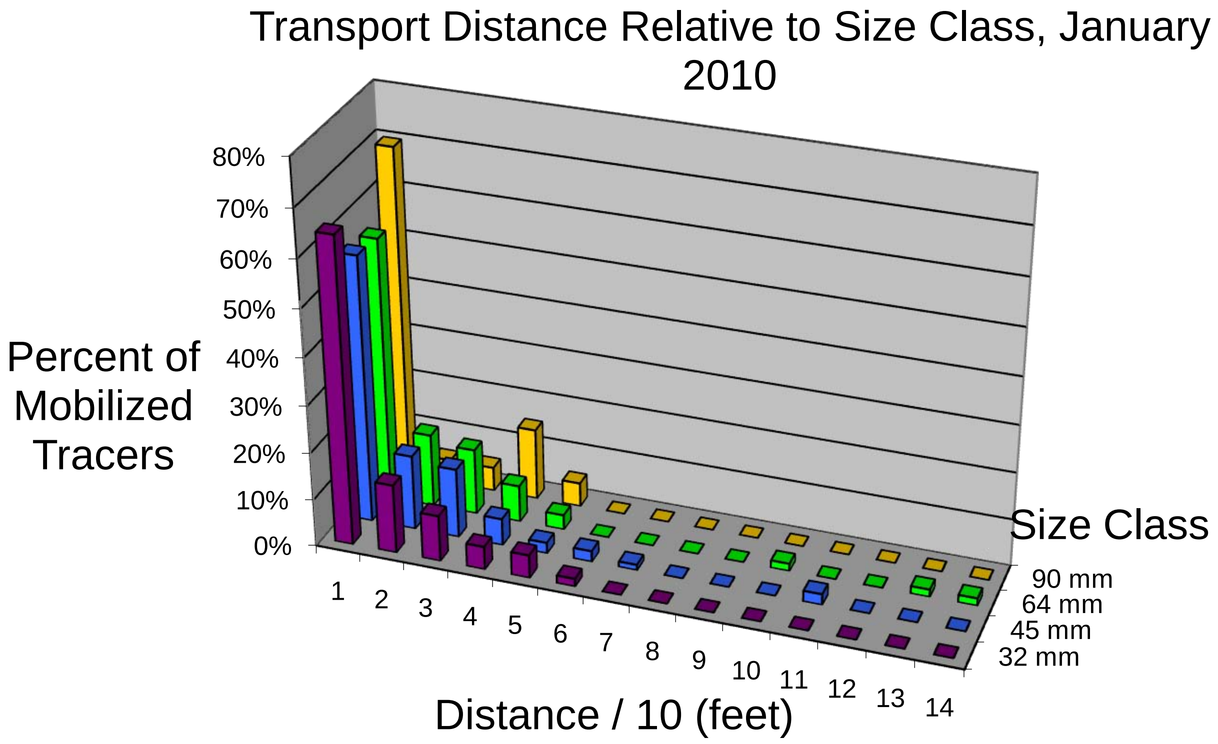


Figure B-46: January 2010 Riffle Cluster 38 tracer transport distance relationships since placement with relative number of mobilized tracers divided into size classes (32, 45, 64, and 90 mm). Travel distance is binned into 10 ft intervals with the first bin (1) being 0 to 10 ft from the cross-section.

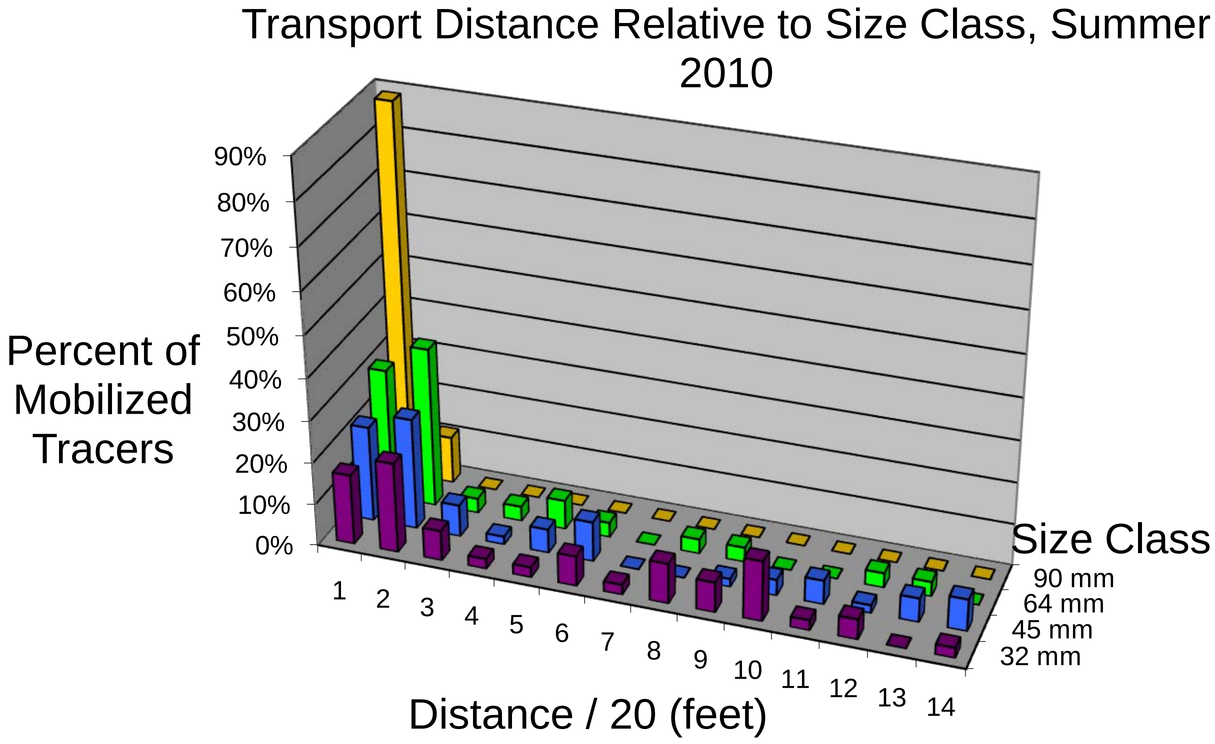


Figure B-47: Riffle Cluster 38 tracer transport distance relationships with relative number of mobilized tracers divided into size classes (32, 45, 64, and 90 mm) after the Spring 2010 flows. Travel distance is binned into 20 ft intervals with the first bin (1) being 0 to 20 ft from the cross-section.

RFID Tracer Results

In January 2010, 47, 42, and 61 tracers were placed at RC38’s XS1, XS2, and XS3, respectively (**Figure B-48**). Further break down in numbers of each size class for each cross-section is shown in Table 3. The smaller size classes (32 mm and 45 mm) were not as well represented because of difficulty drilling without destroying the particle. Recent developments in the RFID technology have created the smaller of the RFID tags as mentioned previously. These tags were released in large scale production in Fall 2010. Future tracer studies should include a greater representation of these smaller sized tracers.

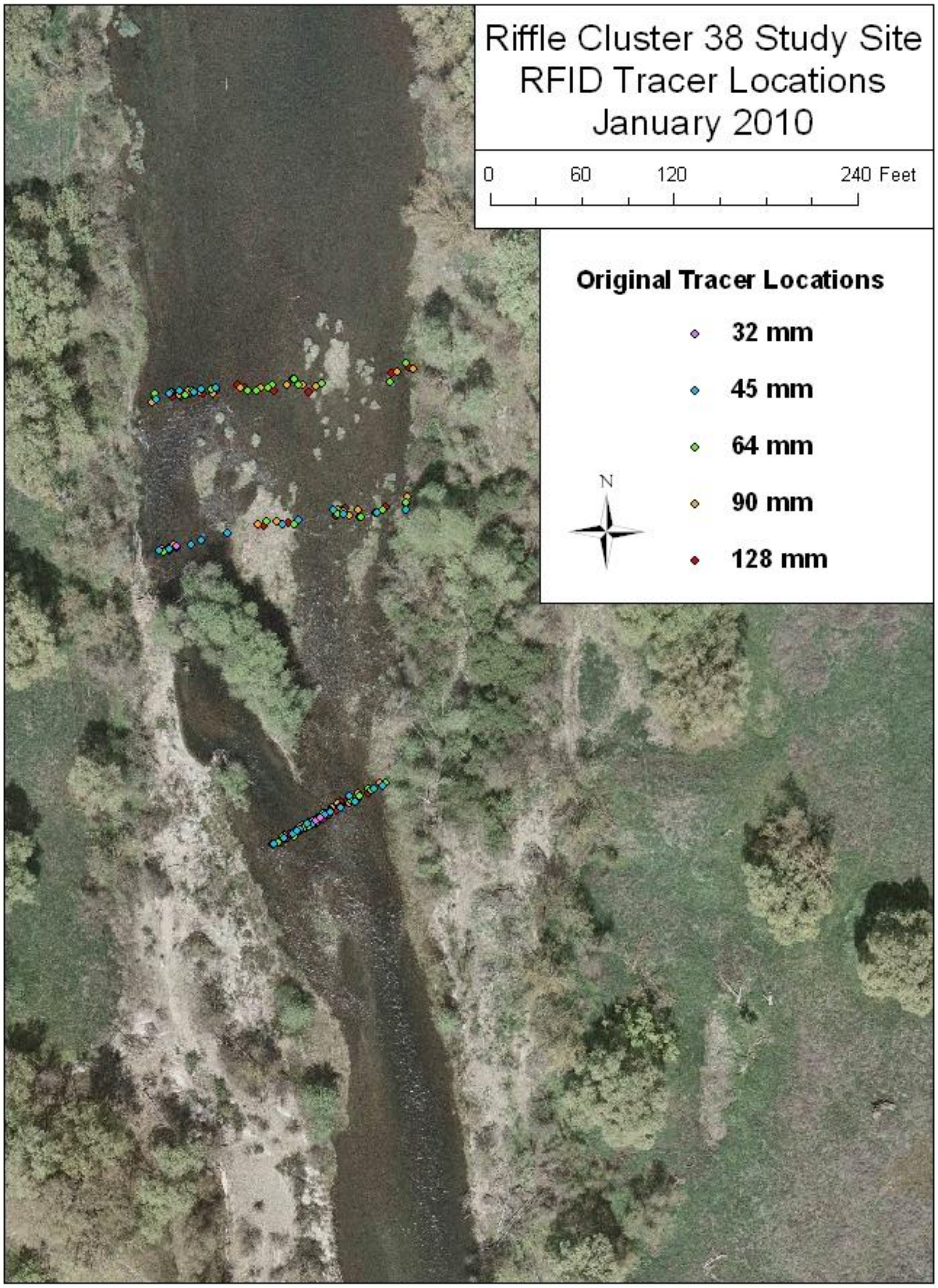


Figure B-48: Riffle Cluster 38 RFID tracer locations as placed in January 2010. Three lines of tracers are 2 to 7 ft upstream of cross-section lines shown in Figure 2. Dots represent tracers and colors represent size class.

Table B-23: Total number of RFID tracers deployed at Riffle Cluster 38 in January 2010.

Size Class (mm)	**XS1**	**XS2**	**XS3**	**Total at RC38**
32 - 45	0	1	2	3
45 - 64	6	12	15	33
64 - 90	15	9	16	40
90 - 128	13	11	14	38
128 - 180	13	9	14	36
Sum	47	42	61	150

During Summer 2010 the RC38 was scanned for tracers. At this time a total of 124 tracers (82%) were located. Of these, 39 tracers (26% of those located) were noted to have moved at least 1.5 ft from their previously surveyed location. The Summer 2010 positions of the tracers are illustrated on Figure 23. Further cross-section specific details are provided in **Table B-24**.

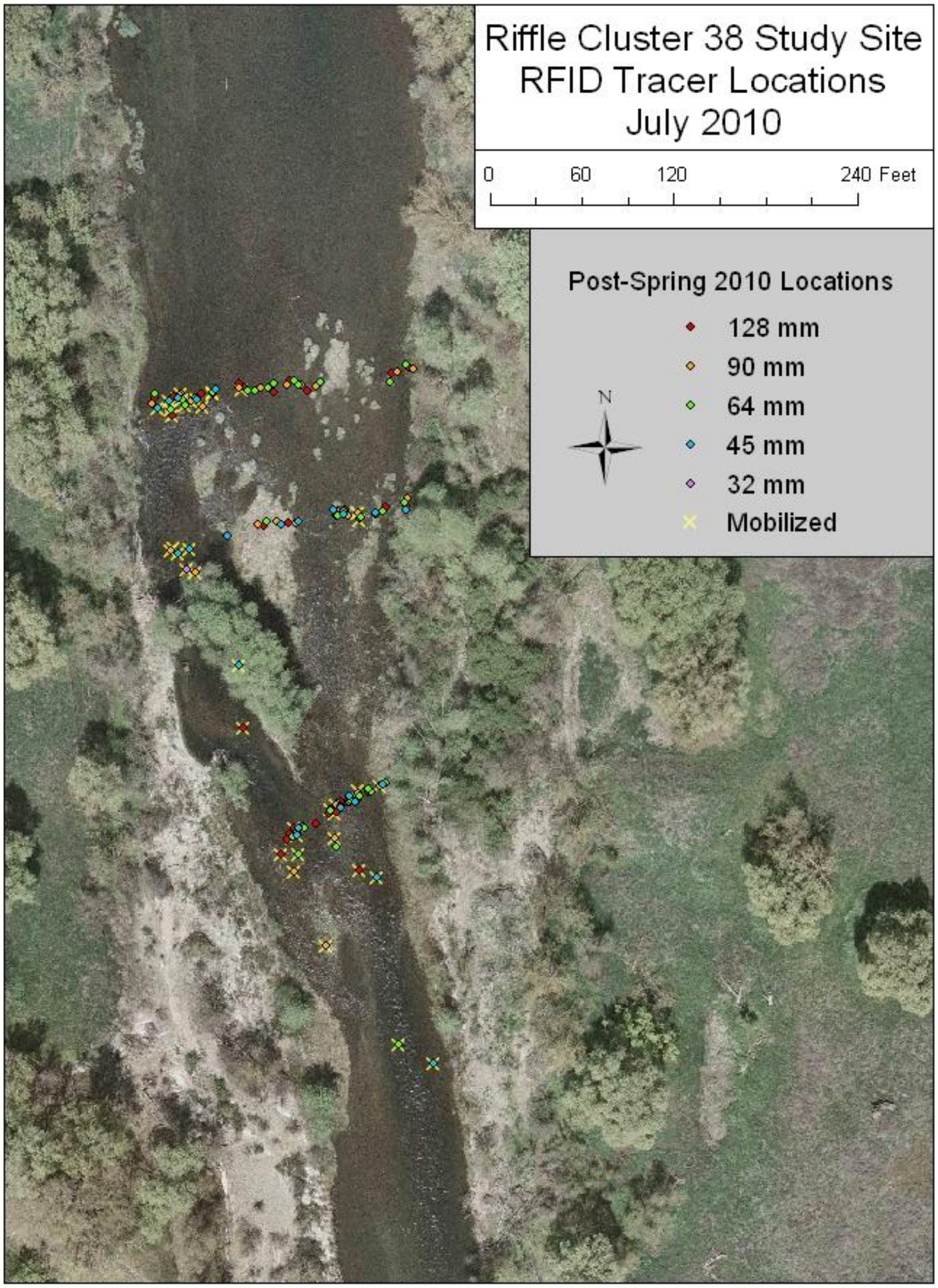


Figure B-49: Riffle Cluster 38 RFID tracer locations after Spring 2010 flows that reached a peak of 1,700 cfs (USGS). Yellow crosses indicate those tracers that moved >1.5 ft since January 2010.

Table B-24: Total number of RFID tracers mobilized in Spring 2010 and

percent of total placed at Riffle Cluster 38.

Size Class (mm)	XS1	XS2	XS3	Total at RC38
32 - 45	NA	1 (100%)	0 (0%)	1 (33%)
45 - 64	4 (67%)	3 (25%)	3 (20%)	10 (30%)
64 - 90	4 (27%)	1 (11%)	3 (19%)	8 (20%)
90 - 128	4 (31%)	3 (27%)	6 (43%)	13 (34%)
128 - 180	2 (15%)	1 (11%)	4 (29%)	7 (19%)
Sum	14 (30%)	9 (21%)	16 (26%)	39 (26%)

Of the 40 tracers that moved after Spring 2010 the mean travel distance was 20 ft. However, this result is deceiving because the majority of particles traveled a much shorter distance as suggested by the relatively large standard deviation (34 ft) of the sample. The median travel distance is 6 ft and is a much more accurate descriptor of the travel distance of the population. See **Figure B-50** for an illustration Spring 2010 travel distance per size class as well as for the sample population. The summary statistics for the travel distances for each size class and all tracers is shown in Table 5.

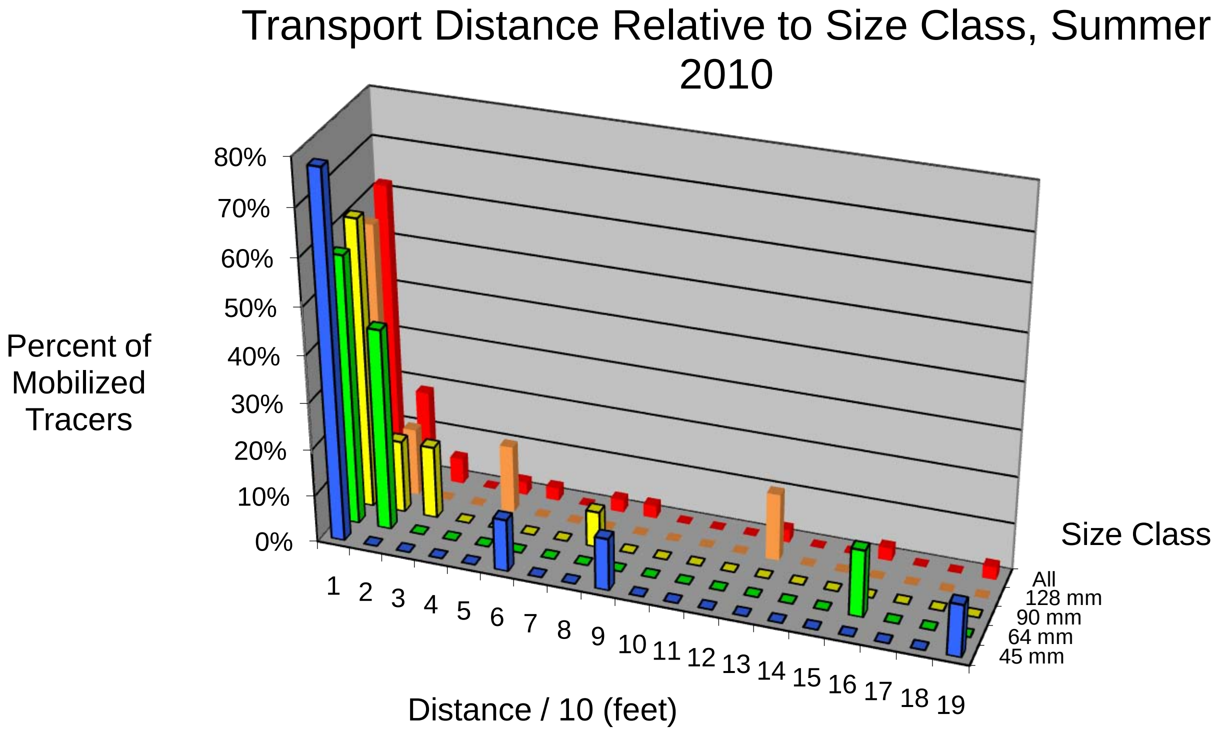


Figure B-50: Riffle Cluster 38 tracer transport distance relationships with relative number of mobilized tracers divided into size classes (45, 64, 90, and 128 mm) after the Spring 2010 flows. Travel distance is binned into 10 ft intervals with the first bin (1) being 0 to 10 ft from the cross-section.

Table B-25: Statistical summary of Riffle Cluster 38 Spring 2010 tracer travel distances for each size class and the total sampled population.

	32 mm	45 mm	64 mm	90 mm	128 mm	All
Maximum	17 ft	153 ft	24 ft	88 ft	16 ft	153 ft
Mean	17 ft	51 ft	9 ft	13 ft	5 ft	20 ft
Median	17 ft	32 ft	6 ft	5 ft	3 ft	6 ft
Mode	NA	NA	NA	2 ft	2 ft	2 ft
Standard Deviation	NA	53 ft	7 ft	23 ft	5 ft	34 ft
Sample Size	1	10	8	13	7	40

By October 2010, RC38's XSA and XS4 were used to position 45 and 25 tracers, respectively. In addition, new tracers were installed to replace mobilized tracers at XS1, XS2, and XS3 (5, 10, and 22 tracers, respectively) (Figure 25). The size class distribution among the new and replacement tracers for each cross-section is shown in Table 6.

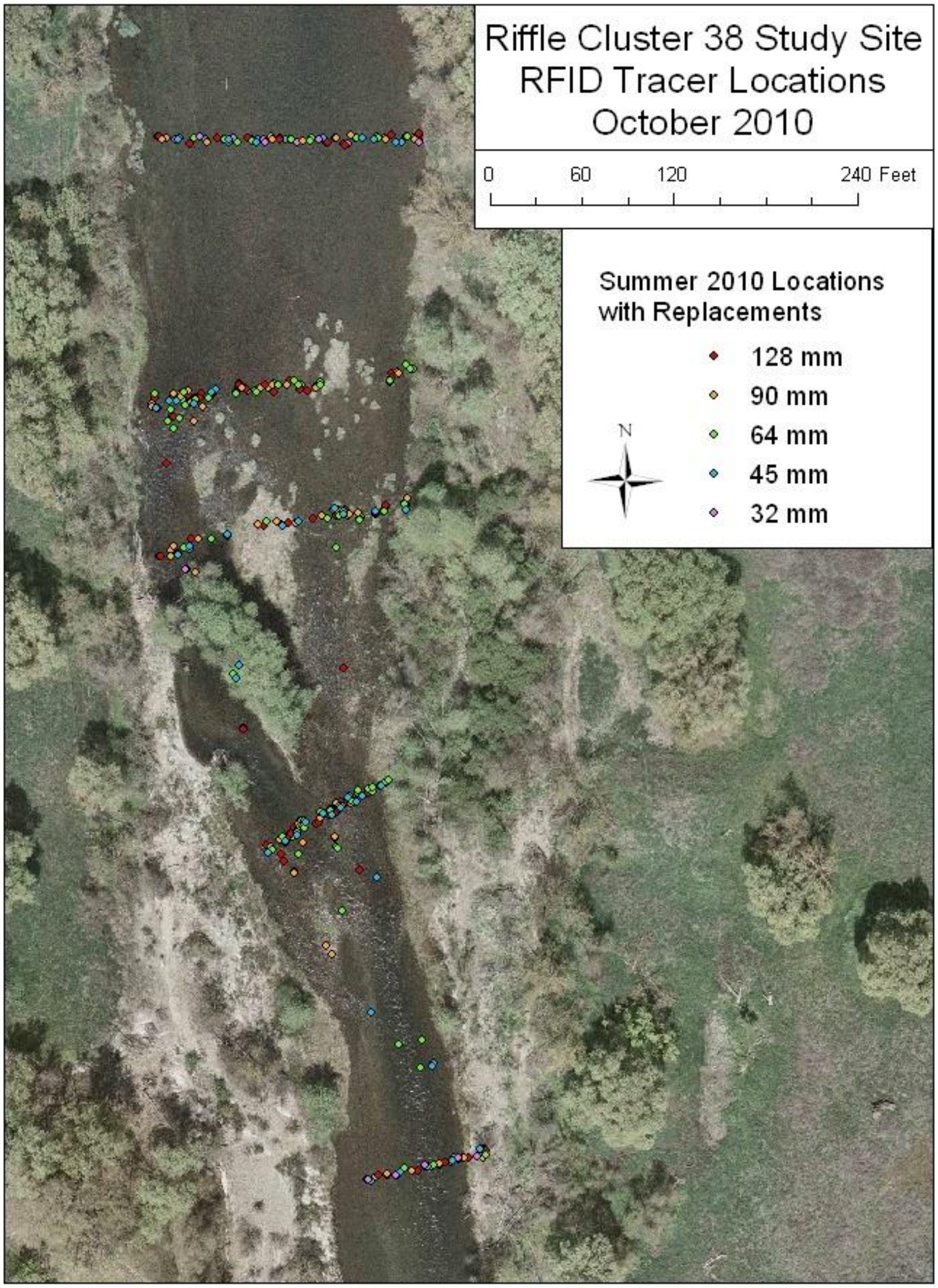


Figure B-51: Riffle Cluster 38 RFID tracer locations by October 2010 including: mobilized, unmobilized, and replacement tracers along XS1, XS2, and XS3; and newly deployed tracers along XSA and XS4.

Table B-26: Total number of RFID tracers newly deployed during Summer 2010 at Riffle Cluster 38 study site.

Size Class (mm)	XSA	XS1	XS2	XS3	XS4	Total
32 - 45	8	0	0	0	5	13
45 - 64	10	0	0	7	5	22
64 - 90	9	2	3	7	5	26
90 - 128	9	1	3	5	5	23
128 - 180	9	2	4	3	5	23
Sum	45	5	10	22	25	107

In December 2010 RC38 was again surveyed for tracers. At this time a total of 208 tracers (81% of the 257 total deployed) were located (Figure 26). Of these, 30 tracers (14% of the 208 located or 12% of the 257 that are deployed) were noted to have moved at least 1.5 ft from their previously surveyed location (**Table B-27**).

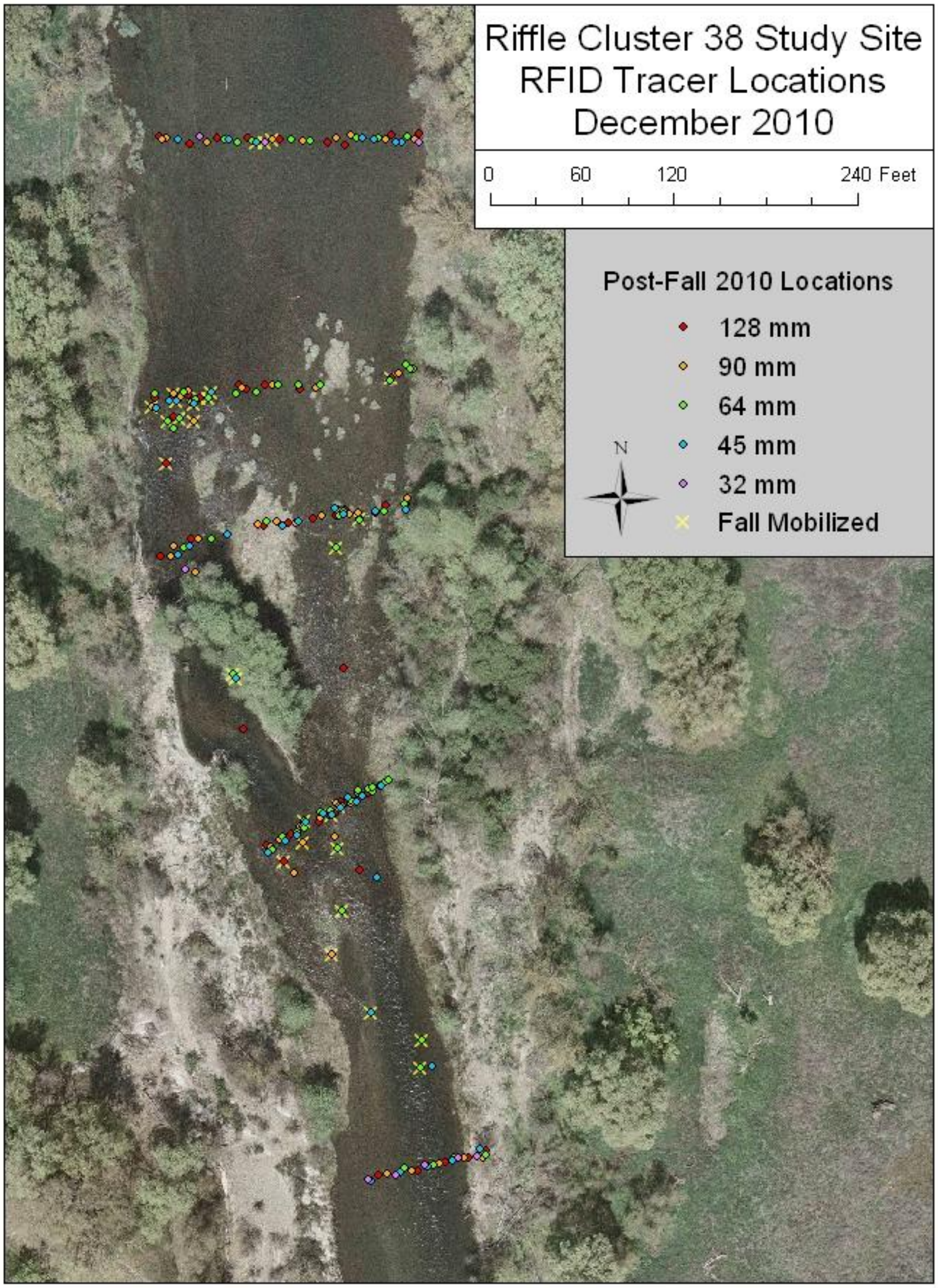


Figure B-52: Riffle Cluster 38 RFID tracer locations after the Fall 2010 flows, which reached a peak of 721 cfs (USGS). Yellow crosses indicate those tracers that moved >1.5 ft since surveyed in Summer 2010.

Table B-27: Total number of RFID tracers mobilized in Fall 2010 and percent of total deployed at Riffle Cluster 38.

Size Class (mm)	XSA	XS1	XS2	XS3	XS4	Total
32 - 45	1 (13%)	NA	0 (0%)	0 (0%)	0 (0%)	1 (6%)
45 - 64	1 (10%	3 (50%)	1 (8%)	2(9%)	0 (0%)	7 (13%)
64 - 90	0 (0%)	3 (18%)	2 (17%)	5 (22%)	0 (0%)	10 (15%)
90 - 128	1 (11%)	3 (21%)	0 (0%)	3 (16%)	0 (0%)	7 (11%)
128 - 180	0 (0%)	3 (20%)	1 (8%)	1 (6%)	0 (0%)	5 (8%)
Sum	3 (7%)	12 (23%)	4 (8%)	11 (13%)	0 (0%)	30 (12%)

The Fall 2010 median travel distance was 5 ft. See Figure 27 for an illustration of Fall 2010 travel distance per size class as well as for all tracers. The summary statistics for the travel distances for each size class are shown in Table 8.

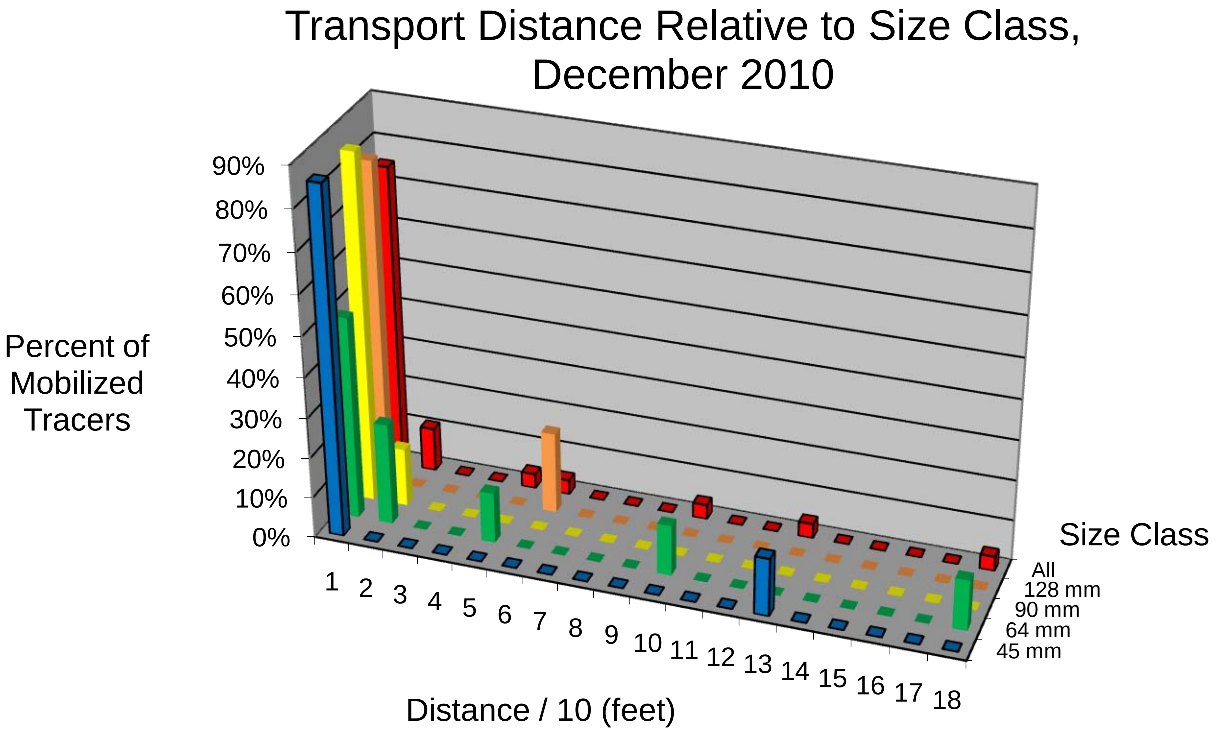


Figure B-53: Fall 2010 Riffle Cluster 38 tracer transport distance relationships with relative number of mobilized tracers divided into size classes (45, 64, 90, and 128 mm). Travel distance is binned into 10 ft intervals with the first bin (1) being 0 to 10 ft from the cross-section.

Table B-28: Statistical summary of Fall 2010 tracer travel distances for each size class and the total sample population.

	32 mm	45 mm	64 mm	90 mm	128 mm	All
Maximum	2 ft	127 ft	175 ft	12 ft	5 ft	175 ft
Mean	2 ft	29 ft	38 ft	6 ft	3 ft	21 ft
Median	2 ft	3 ft	14 ft	5 ft	3 ft	5 ft
Mode	NA	3 ft	2 ft	2 ft	3 ft	2 ft
Standard Deviation	NA	55 ft	56 ft	4 ft	1 ft	41 ft
Sample Size	1	5	10	7	4	30

Some tracers were observed to be embedded or buried by as much as 0.5 ft and by particles as large as ~128 mm intermediate diameter. After the Spring 2010 flows these tracers were located in areas of net deposition along RC38's XS3 (Figure 28). Later, after the Fall 2010 flows, embedded and buried tracers were observed in areas where some of the Spring 2010 deposition was eroded but not enough to remove the previously buried tracers (XS2 and XS3). In addition, embedded tracers were found along the thalweg of XS4 and the low flow margins of XS1 (Figure 29).

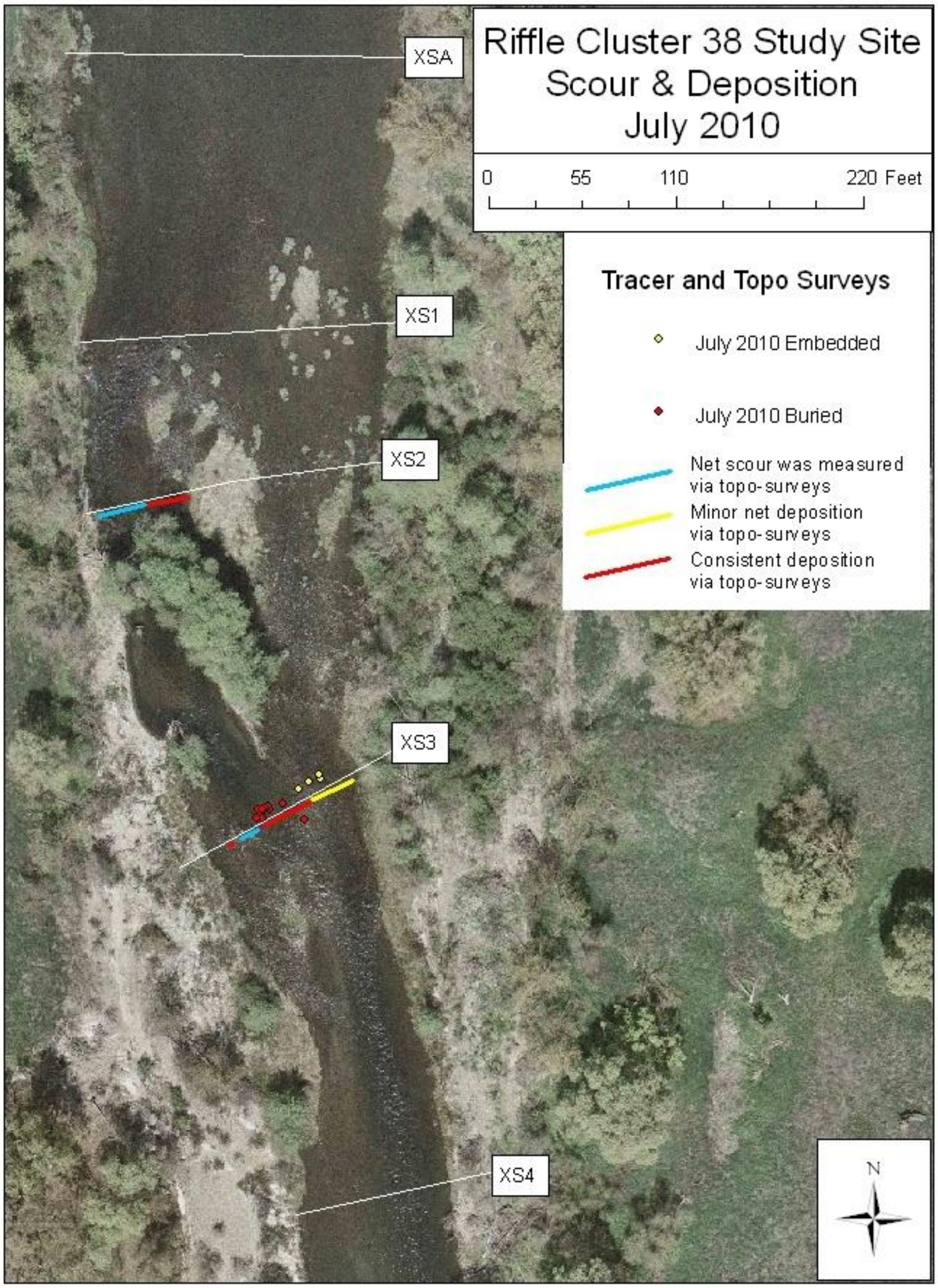


Figure B-54: Buried and embedded RFID tracers after Spring 2010 flows that reached a peak of 1,700 cfs (USGS). Yellow indicates minor net deposition and embeddedness, red indicates substantial net deposition and burial, and blue indicates net scour.

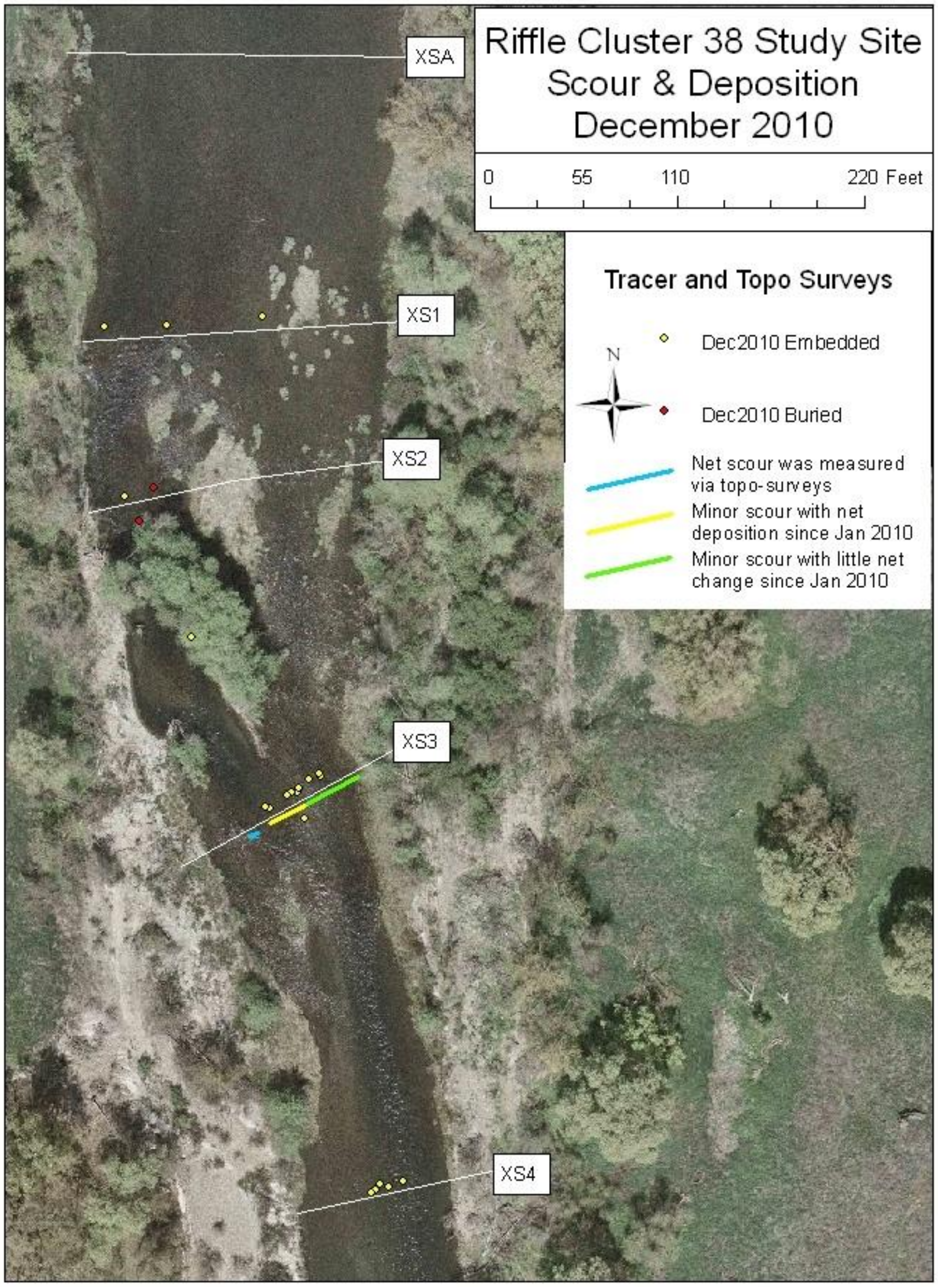


Figure B-55: Buried and embedded RFID tracers after Fall 2010 flows that reached a peak of 721 cfs (USGS). Yellow indicates minor scour but net deposition and embeddedness, green indicates minor bed elevation loss with only slight net change since January 2010, blue indicates net scour, and red indicates burial.

RFID tagged tracers were also installed at the RC40 study site along 4 cross-sections (XSA, XS1, XS2, and XS3) by the end of Summer 2010 and one more (XS4) in December 2010. Of those placed in Summer 2010 only one tracer was observed to have moved (approximately 65 ft) during Fall 2010. Due to the size (90 mm size class and > 2kg) and original position (channel margin) of this tracer its December 2010 apparent movement is likely the result of manual disturbance. Therefore, results suggest the absence of bed mobility during the peak 721 cfs discharge event at the RC40 study site.

Compromised RFID Tracers

Upon arriving at the RC38 study site in Summer 2010 several of the RFID tracers locations were observed to have been compromised. Many were located in a pile located near a dry, exposed bar and others appeared to have been tossed into vegetation patches or elsewhere. As a result, those tracers that were obviously tampered with were returned to the office for identification, noted to have been removed from the channel, and prepared for re-use. Further work was required to decipher anomalies in tracer locations likely to have been caused by similar compromising activities. This work was completed by comparing position information via ArcGIS™. Future surveys that locate deployed tracers that have to-date not been relocated will be similarly scrutinized so as to validate their mobility or lack thereof. For now, the reported RFID tracers positions are complete and future reports will include the historic RFID locations with revisions if necessary. The RFID tracer descriptions and location information is included as Attachment A11: RFID Tagged Tracer Data.

Force Gauge Measurement Results

Direct force gauging surveys of the channel’s bed surface particles were performed beginning in January 2010 at both the RC38 and RC40 study sites. A total of 7 areas at RC38 were delineated for measurement samples. Each area is intended to be representative of a local geomorphic feature. These features include:

1) Pool/Glide Tailout along XSA
2) Bar head along XS1
3) Riffle head Bar toe along XS1
4) Riffle head Thalweg along XS1
5) Bar along XS2
6) Mid-Riffle Thalweg along XS2
7) Riffle Tail Thalweg along XS3

In addition, the thalweg along XS3 was resampled in Summer 2010. The purpose of resampling was to investigate for a change in bed surface resistance that may have resulted from scour and deposition associated with large woody debris (LWD) that built up in the area during Spring 2010. The calculated phi angles are presented in **Figures B-56** and **B-57** for the pre-LWD and post-LWD force gauge measurements, respectively.

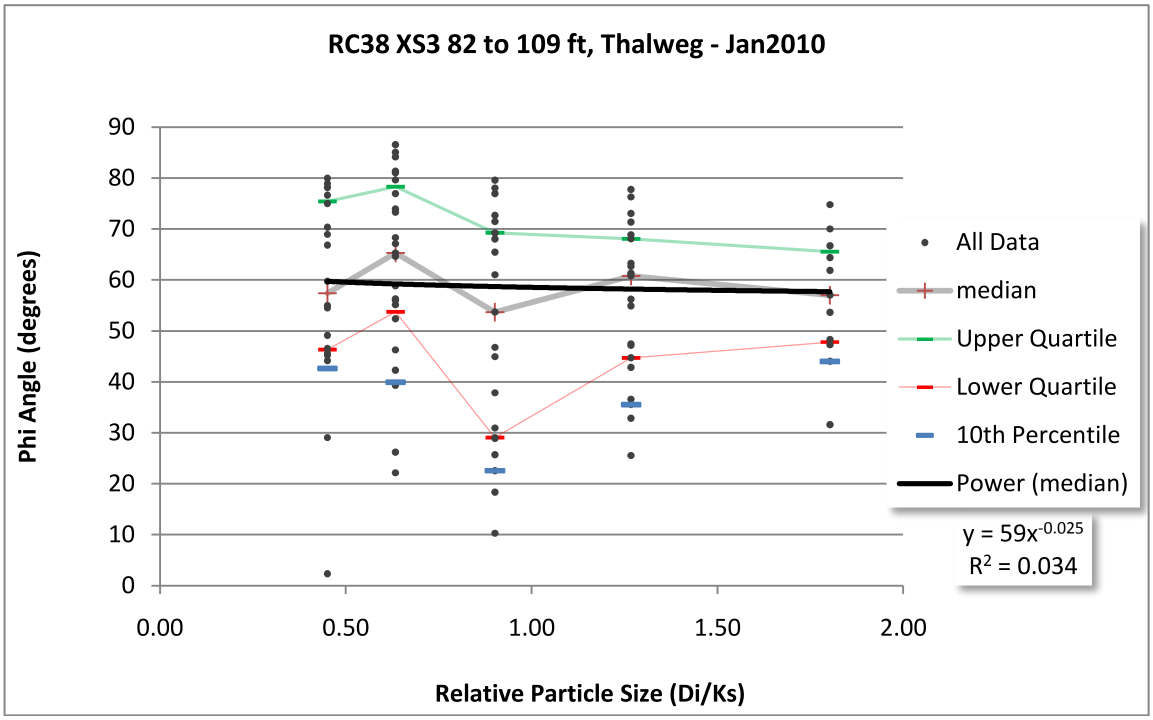


Figure B-56: Phi angle trends with size class (Di) relative to the median particle size (Ks) within the thalweg area of RC38 XS3 before LWD altered the channel surface. Note the consistent median phi angle of greater than 55 degrees across all size classes.

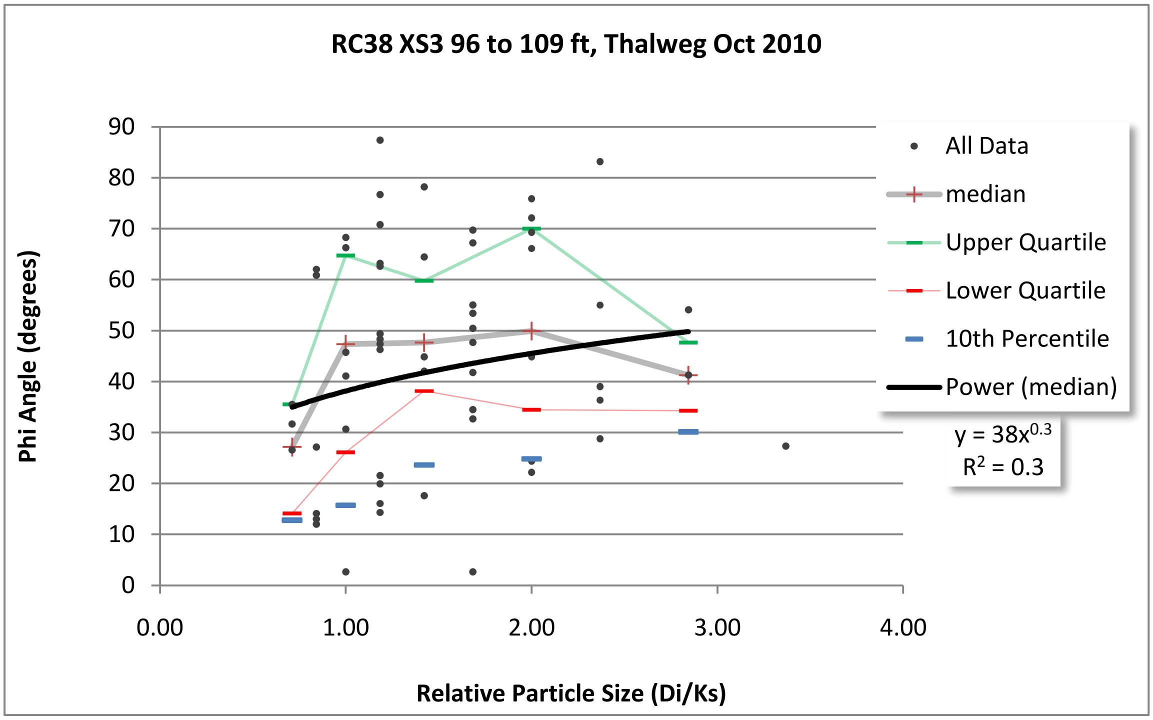


Figure B-57: Phi angle trends with size class (Di) relative to the median particle size (Ks) within the thalweg area of RC38 XS3 after LWD has altered the channel surface. Note the reduced phi angles to less than 50 degrees.

Similarly, a total of 6 areas at RC40 were delineated for measurement samples. Each area was intended to be representative of a local geomorphic feature. These features include:

1) Pool/Glide tail along XSA
2) Riffle head along XS1
3) Mid-riffle/left channel along XS2
4) Mid-riffle thalweg along XS2
5) Riffle tail thalweg along XS3
6) Riffle tail/right channel along XS3

Overall, force gauge measurements show substantial variance between individual measurements as well as when comparing averages sampled from different geomorphic areas. The variance between individual measurements is illustrated in Figure 27 which shows the most heavily sampled area (RC40 XS1: the riffle head). In this case, the spread in phi angles for a given size class appears evenly spread between the minimum and maximum values if not skewed towards the extremes.

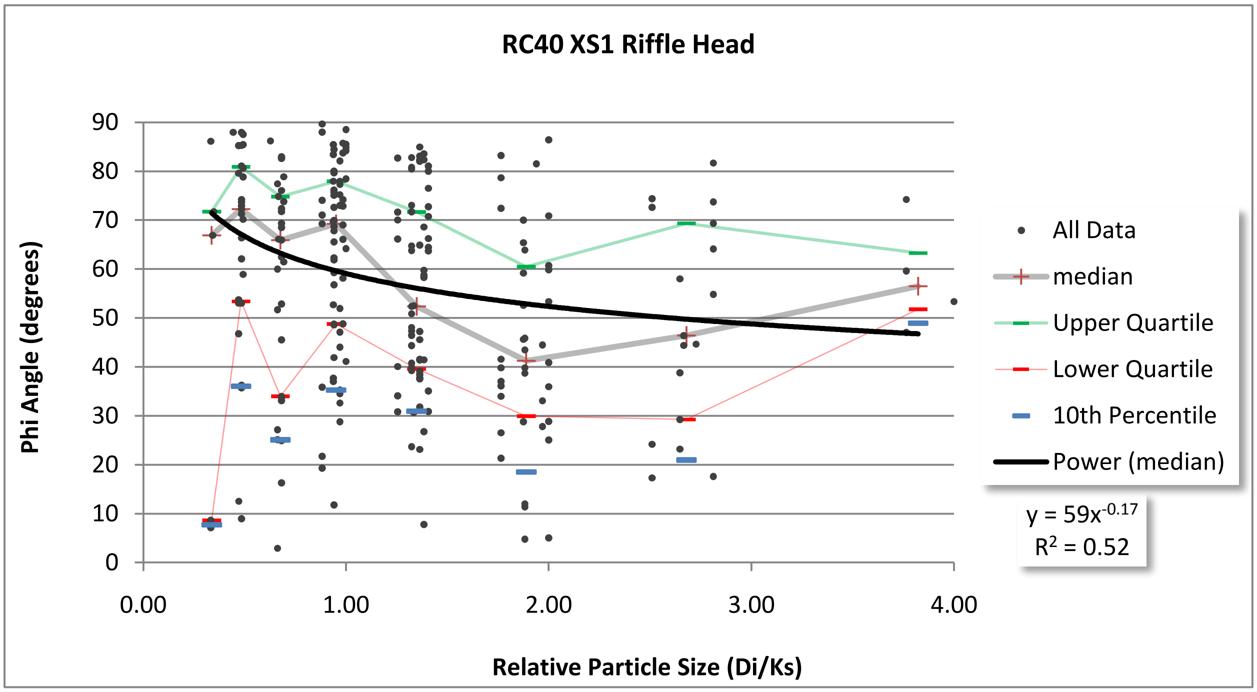


Figure B-58: Phi angles calculated from force gauge measurements across the entire channel at RC40 XS1. Note the variance in individual measurements about the median.

Comparison of median phi angle trends per geomorphic area also show variablity. This is illustrated in Figure 33 which shows each separately measured area's median phi angle trends combined for RC38.

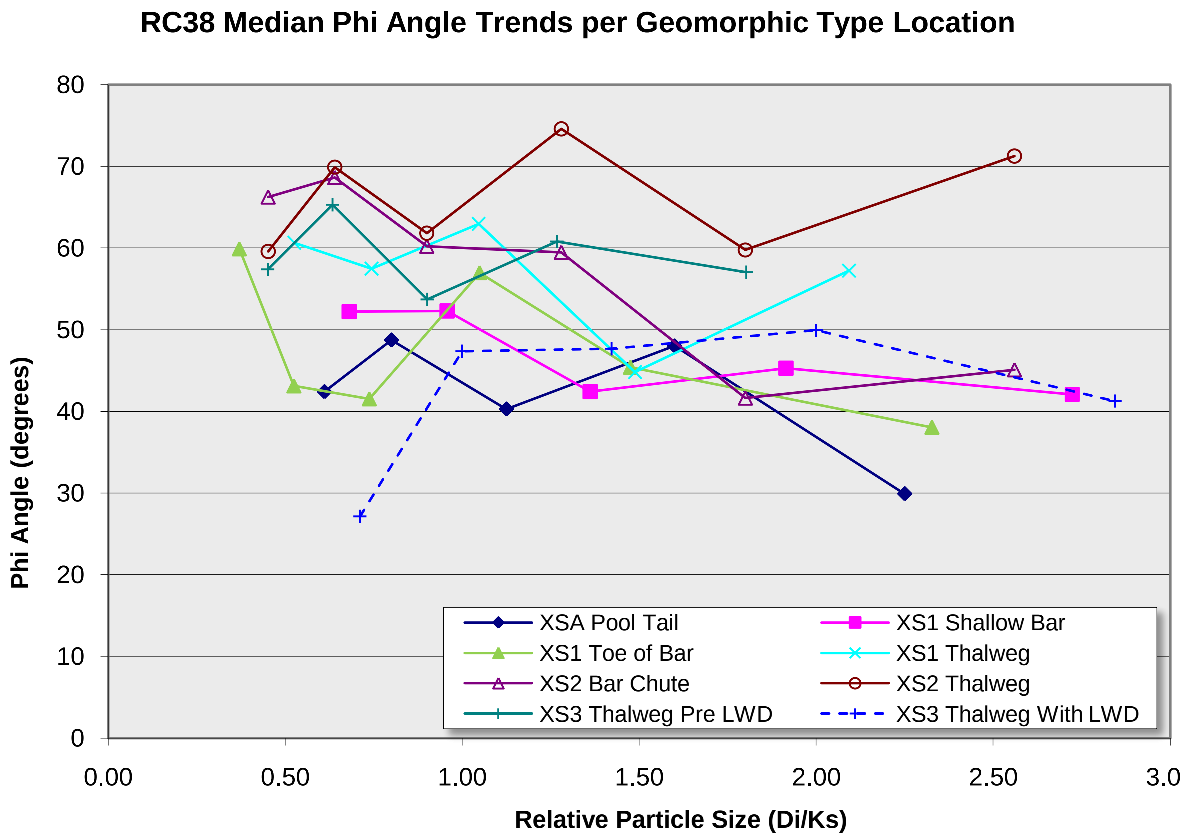


Figure B-59: Median phi angle trends relative to the normalized particle size from force gauge measurements at all RC38 sample areas. Note the variance in median phi angle trends per sample area.

Flow Profiling Results

Flow profile results from RC38 at XS1, XS2, and XS3 were available at the time of this report's preparation. Section XS1 was measured at 375 cfs, 708 cfs, and 1,420 cfs. Sections XS2 and XS3 were measured at 375 cfs, 708 cfs, and 1,280 cfs. Trends in the maximum depth averaged speed differed between all three cross-sections. The maximum mean speed at XS1 decreased from 6.8 to 6.4 ft/s as the discharge increased (Table 9). The maximum speed peaked at 8.5 ft/s during the medium range flow of 708 cfs while the lower and higher flows had reduced maximum mean speeds of 7.1 and 7.0, respectively (Table 10). The maximum mean speed at XS3, though, increased from 5.4 to 7.7 ft/s with increasing discharge.

Table B-29: Summarized results from the flow profiling measurements at Riffle Cluster 38 cross-section 1 in the main channel. These measurements do not include the flows in smaller bar chutes or vegetated areas. Note: the "Max Mean Speed" is the maximum depth averaged flow speed measured along the channel.

Date	UGSG Gauged Discharge (Q)	Transects	Mean Width	Mean Area	Mean Depth	Max Depth	Mean Speed	Max Mean Speed	Speed StDev	Mean Q	Q StDev
	mean daily cfs	#	ft	ft2	ft	ft	ft/s	ft/s	ft/s	cfs	cfs
10/29/2009	375	4	115	117	1.0	1.5	1.8	6.8	0.075	29	10

11/5/2009	708	6	128	198	1.6	2.4	3	6.7	0.059	604	13
4/14/2010	1420	4	198	342	1.7	3.0	3.6	6.4	0.057	1236	20

Table B-30: Summarized results from the flow profiling measurements at Riffle Cluster 38 cross-section 2 in the main channel. These measurements do not include the flows in smaller bar chutes or vegetated areas.

Date	UGSG Gauged Q	Transects	Mean Width	Mean Area	Mean Depth	Max Depth	Mean Speed	Max Mean Speed	Speed StDev	Mean Q	Q StDev
	mean daily cfs	#	ft	ft2	ft	ft	ft/s	ft/s	ft/s	cfs	cfs
10/29/2009	375	4	61	77	1.4	1.8	3.7	7.1	0.71	286	54
11/5/2009	708	4	66	144	2.3	3.5	4.4	8.5	0.071	631	12
4/23/2010	1280	4	85	216	2.0	5.0	4.1	7.0	0.11	876	27

Table B-31: Summarized results from the flow profiling measurements at Riffle Cluster 38 cross-section 3 in the main channel. These measurements include the entire channel.

Date	UGSG Gauged Q	Transects	Mean Width	Mean Area	Mean Depth	Max Depth	Mean Speed	Max Mean Speed	Speed StDev	Mean Q	Q StDev
	mean daily cfs	#	ft	ft2	ft	ft	ft/s	ft/s	ft/s	cfs	cfs
10/29/2009	375	5	115	118	1.1	1.7	2.1	5.4	0.05	245	5.9
11/5/2009	708	4	118	188	1.7	2.5	3.3	7.4	0.27	624	37.0
4/23/2010	1280	2	153	295	1.9	3.3	4.0	7.7	0.14	1172	15.0

The measured cross-sectional average speed produces slightly different trends from the maximum mean speeds. At XS1 and XS3 the average speed increased with discharge from 1.8 to 3.6 ft/s and 2.1 to 4.0 ft/s, respectively. However, XS2 continued to show a peak (4.4 ft/s) in the overall cross-sectional average speed at the mid range flow relative to the lower (3.7 ft/s) and higher (4.1 ft/s) discharges.

13.4 Discussion

13.4.1 Interpretation

From the force gauge measurements the friction angle (phi angle) is shown to vary considerably. Furthermore, the results suggest the channel bed's resistance to motion may depend on lateral (e.g. along a cross-section) and longitudinal (e.g. between cross-sections) position and/or geomorphic feature. These force gauge measurements agree with the variability in bed mobility as demonstrated from the tracer movement patterns. However, further work is necessary to compare the resistance of the bed to flow relative to the forces exerted on the bed by the flow. Using the results presented in this report to develop, calibrate, and validate a flow, bed mobility, and sediment transport model, we will be able to investigate this question. The results will then be used to quantify the extent of bed mobilization throughout the spawning reach under Restoration flow scenarios, thereby providing an estimate of bed area capable of maintenance through flushing flows. If mobile bed area appears to be a limitation in the success of the spawning activities and/or incubation, immobile locations can be predicted for remedial management actions.

From the force gauge measurements made before and after the LWD at RC38 XS3 the friction angle was shown to decrease. This variation in resistance with time is interpreted to be the result of a local contribution in sediment supply likely to have been in the form of sand, gravel, and cobble.

The sediment source is believed to be from both bank and bed erosion. The source of the LWD was from a tree and other jammed LWD along the right bank approximately 40 to 60 ft upstream of XS3. The bank in this area eroded with the removal of the tree/debris pile providing sediment to the channel. As the LWD migrated to its present position scour of the bed material occurred to a minimum depth of 4 ft below grade, based on casual field observation. If this depth is assumed to be an average depth associated with the LWD imposed scour, the areal extent of the LWD induced scour is 20 ft by 20 ft (estimated from the measured area of the debris pile to be 15 ft by 20 ft), we can conservatively assume approximately 1,600 ft^3 (4 ft x 20 ft x 20 ft) of sediment was supplied downstream of this area. The addition of this sediment reduced local bed material friction angles by about 15% while at the same time coarsening the bed surface (see 96 to 109 ft section on Figure 11). Further work will be done to refine this sediment volume estimate from bank surveys and channel surveys.

No tracer movement was measured along RC38 XS4 after Fall 2010 flows which peaked at 721 cfs. At the same time several of the tracers along XS4's thalweg became embedded. This cross-section is meant to monitor the mobility and dynamics of bed elevation changes in the pool environment. Although this monitored flow event was not as large as those monitored upstream when measured bed alteration occurred it was sufficient to produce bed mobility in those locations. Therefore, any mobilized bed particles delivered to this pool would not have conveyed through this section. The consequence of this may be for the pool to shallow and possibly for the riffle to lengthen as material is delivered downstream from the riffle environment.

Upstream flows on the order of 700 cfs were capable of producing local general mobility at XS1, XS2 and XS3 of RC38 (Figures 18 and 23). This flow level though was not capable of generating significant net scour or net deposition (Figure 10). However, flows on the order of 1,700 cfs were capable of causing up to 1.5 ft of scour (RC38 XS2), 1 ft of deposition (RC38 XS3), and 6 ft of bank erosion (RC38 XS2) (Figures 9 and 10). Additional channel widening was observed through the bank erosion associated with the LWD movement. Meanwhile, at RC40 no movement was measured from 700 cfs flows. These results illustrate the conditions of mobility and channel change at the two study sites.

13.4.2 Applicability

These measurements are intended for the development of a flow, mobility, and sediment transport model as described in the "Spawning Reach Bed Mobility Study Plan". This model will be calibrated and validated from these measurements and used to make predictions as part of DWR's "Incubation Habitat Study Plan", "Enhanced Bed Mobility Study Plan", and "Effect of Altered Flow Regime on Channel Morphology in Reach 1A Study Plan". Extrapolation of these results to other study sites, reaches, or river systems will require additional details on sediment supply, hydrology, and channel form not provided in this document.

13.4.3 Limitations

The pilot tracer study data may overestimate the width of the channel that experienced full to partial mobility during a 700 cfs peak flow event. The areas in question are shaded on Figures 15 through 17. After a similar sized peak flow event RFID tracers suggest that in the case of XS1 and XS2 the areas in question are immobile. After the same flow event the RFID tracers at XS3 within the area in question showed partial mobility (Figure 21).

The RFID tracer study was compromised to a certain degree. Therefore, the results likely express a maximum degree of mobility. Future work will assist in validating these results. Additionally, as tracers that have not yet been relocated are found, their whereabouts will provide additional clues. As a result, RFID tracer results released after the release of this report should be sought for the most current and accurately compiled information available.

USGS reported provisional as well as approved data were used to compare the discharge level at USGS Friant gauge 11251000 to the conditions experienced at the sites. This gauge is located at RM 268.1 approximately 7.4 and 6.5 miles upstream of RC38 and RC40, respectively. This data is of limited use based on the fact that the gauge is not calibrated regularly. Additional sources should be used to verify discharge levels, preferably closer to the study sites, when using discharge dependant data reported herein (e.g. water’s edge surveys, flow profile measurements, scour and deposition induced bed elevation changing flow levels).

13.5 Conclusions and Recommendations

The sediment supplied to the vicinity of RC38 XS3 provides an opportunity to investigate its influence on bed mobility. A bulk sample (14C) collected Summer 2008 approximately 30 ft from the LWD’s present location will provide a reasonable approximation of the supplied sediment’s composition (DWR 2010). Future work should investigate the difference in bed mobility that occurred at this location and monitor its affect with time to better determine the extent of how augmenting sediment supply will enhance mobility both over time and space. Such an understanding will be useful for designing remedial strategies with the intention of enhancing bed mobility for the purpose of increasing spawning and incubation habitat. A similar study is proposed as part of DWR’s “Enhanced Bed Mobility Study Plan”.

The bed form and channel geometry adjustments associated with scour, deposition, and bank erosion suggest that the channel adjusts to moderate flow levels. Additionally, though it is still premature to make any conclusions, there is the beginning of evidence to suggest that longitudinal processes may be encouraging pool filling and/or riffle lengthening. Therefore, altering the hydrograph for Restoration purposes or otherwise is shown to have at least a local affect on channel geometry and flow patterns. Continued monitoring of channel geometry in critical habitat areas is requisite so as to determine trends in the channel form and to predict changes to aquatic environment relating to flow conditions (i.e. velocity and depth) that result from Restoration flows. Therefore, it is recommended that channel form monitoring continue and if observed trends persist through future flows DWR’s “Effect of Altered Flow Regime on Channel Morphology in Reach 1A Study Plan” should be implemented.

Net bed scour (up to 1.5 ft) and deposition (up to 1 ft) were measured at sites expected to be some of the most suitable for spawning and incubation success. These results were from a flow level of 1,700 cfs. These observations are of sufficient depth to impact incubating eggs and emerging fry. However, significant scour and deposition were not measured at either study site at the 700 cfs peak flows. Considering that spawning flows are anticipated to be on the order of 350 cfs, and peak flows during incubation will be in the range of 700 cfs, there is no evidence that incubation or emergence should be impacted as a result of scour or coarse sediment (i.e. gravel and cobble) deposition. Though repeat topographic surveys only measure the net bed elevation change there is no evidence from field observations to suggest that the lower flow conditions would produce excessive scour or deposition. DWR's "Incubation Habitat Study Plan" suggests adding scour chains as well as artificial redd studies to the monitoring schedule. Both are intended to answer these questions related to incubation and emergence. For now we recommend implementing the artificial redd study so as to investigate the impact of fine sediment to the redd environment during incubation season flow levels as soon as possible. If it is predicted that higher flows (>700 cfs) will occur during the incubation season(s) monitoring with scour chains should be implemented to investigate occurrence and extent that these flows reduce the incubation habitat area and emergence.

Bed mobility is variable between riffle cluster areas and at riffle cluster sites both laterally and longitudinally. Simply assuming a length of channel (such as a riffle cluster) will exhibit mobile bed conditions under restoration flow levels is inaccurate. Spawning area estimates made in such a manner will be an overestimate and may prove detrimental to the success of the Restoration effort. Continued monitoring activities (e.g. tracers, scour chains, repeated topographic surveys, grain size analysis, etc.) will assist in quantifying thresholds for mobility and in developing a model to predict flow level consequence. Further work should refine the estimated spawning area based on the ability of the bed to be mobilized and therefore maintained with flushing flows. It is our recommendation that future efforts be made to model flow, mobility, and sediment transport processes within Reach 1A to quantify the affects of Restoration flows; areas likely to be maintained as suitable spawning/incubation habitat; and potential sites for enhancement activities.

13.6 References

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14.0 Water Quality and Fish

14.1 Introduction

Water quality results have been reported in previous San Joaquin River Restoration Program (SJRRP) Annual Technical Reports (ATR), but little attention has been given to interpreting these results in terms of possible effects on salmon and other native fish species that live within the San Joaquin River. The purpose of this report is to summarize and assess water quality data collected along the river between Friant Dam and the Merced River for the San Joaquin River Restoration Program during 2009-2010. This summary and assessment considers sampling frequency for adequate characterization of variability, sampling locations for sufficient characterization of the sampling reach, and sampling methods for appropriate media (water, sediment, tissue) and detection levels. A discussion of the water quality data and how it compares to available criteria and thresholds for salmonids, native fishes, and other aquatic organisms is also included.

14.2 Water Quality Methods

As described in Appendix C of the 2009 Annual Technical Report, water and sediment samples were collected by U.S. Bureau of Reclamation (USBR) personnel. All collection was done in accordance with Section 22 of the SWRCB Division of Water Rights Order WR 2009-0058-DWR and corrected WR 2010-0029-DWR.

Samples were collected, preserved, and handled according to USBR quality assurance practices, which included the incorporation of blank, reference, duplicate, and spiked samples to verify laboratory and field measurements. Bacteria, chlorophyll A, dissolved organic carbon, total organic carbon, nitrates, and total suspended solids samples were shipped from the field directly to laboratories. Grab samples were collected from the stream bank in a churn-splitter and then deposited directly into sample bottles. Water samples were collected from the surface at each location. Sediment samples were collected from the top 5 cm at each location.

In order to summarize and assess the accumulated water quality data for this report, data were first compiled and organized by location and date so that meaningful comparisons could be made. The results were compared to thresholds and criteria obtained from literature sources for effects of water quality on aquatic organisms. This report specifically discusses the results of the Programs' water quality monitoring and how those results might affect the fish community within the Program's restoration reach. Detailed information about each sample's constituent results, location, and collection date is available in Appendix D of the ATR. Constituents that were not detected during SJRRP sampling were not discussed unless recommendations were made to lower current reporting detection limits.

14.3 Results

All available water quality data beginning with interim flows in fall 2009 through October 2010 were used in this summary and analysis. No samples were collected in November 2010, and results are pending for samples collected in December 2010.

Sampling frequency

During fall 2009, 44 water samples (from 11 sites) and 12 sediment samples (from 10 sites) were collected for analysis (Figure 1). Baseline water quality was measured in samples collected prior to the arrival of Interim flows at each site. Water samples were collected approximately once per week through November 2010. Sediment was collected at four sites before the arrival of Interim flow water, and at seven sites in December upon completion of Interim flows.

During 2010, 55 water samples and seven sediment samples were collected from seven sampling sites. Water samples were collected once per week in February and March, twice in April and once per month from June – December. No samples were collected in May and November 2010 due to staff limitations. Sediment samples were collected once in April from seven monitoring sites.

In total, 99 water samples (from 11 sites) have been collected for the SJRRP water quality monitoring program during 2009-2010 Each water sample was analyzed for 153 different constituents (Table 4). During the same period, nineteen sediment samples were collected (from 10 sites), with each sample being measured for 54 constituents (Table 5).

Sampling locations

In 2009, water samples were taken from three locations in reach 1A, one location in reach 2A, 2B, 3, 4A, and 4B, and two locations in reach 5 (Table 1; Figure 1). Sediment samples were taken from two locations in reach 1A, one location in reach 2A, 3, and 4B, and 4 locations in reach 2B.

In 2010, water samples were taken from two locations each in reach 1A, 2A, and 5, and from one location in reach 3 and 4B. Sediment samples were taken from two locations in reach 1A and one location in reach 2A, 2B, 3, 4B, and 5.

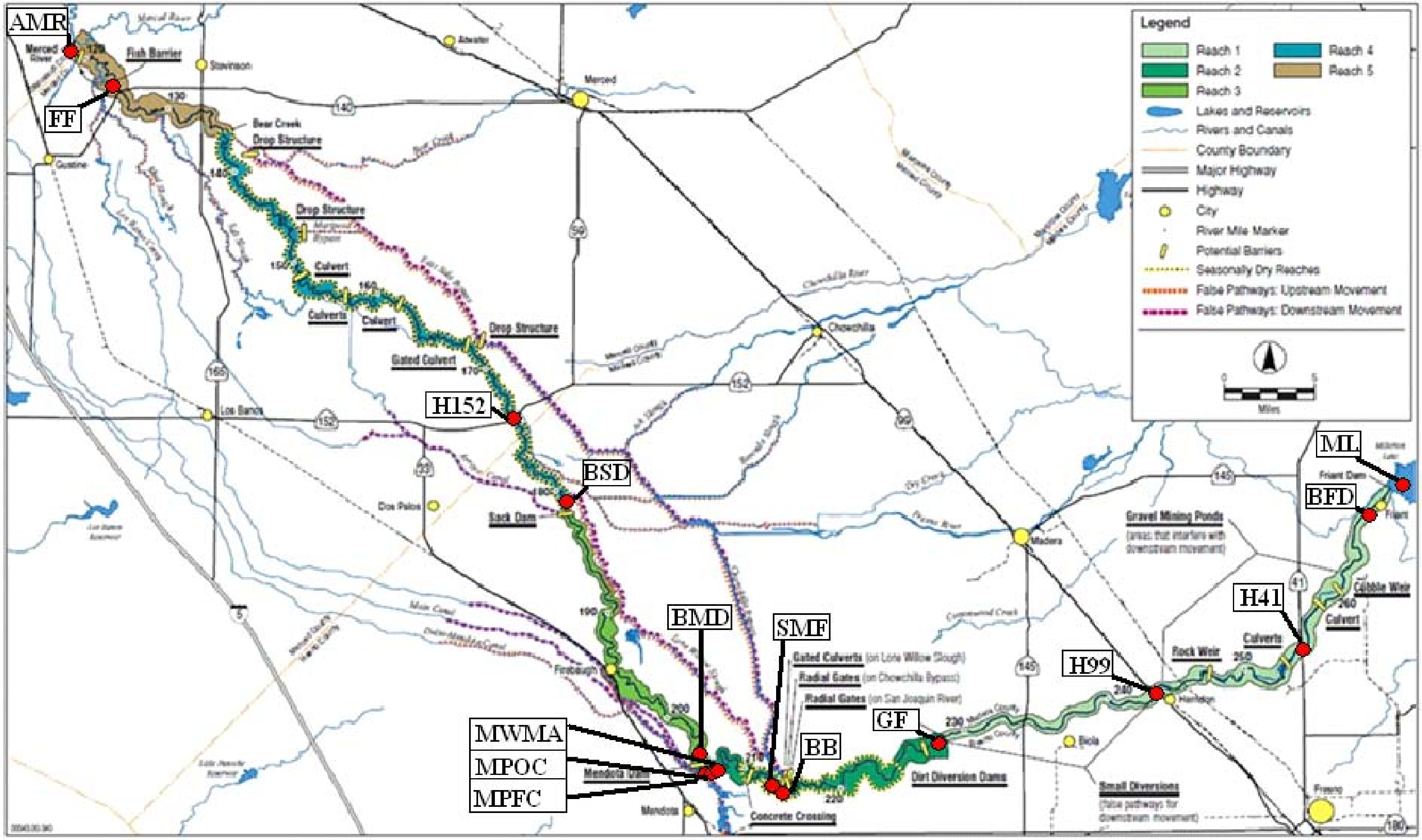

Figure B-60: Water quality and sediment sampling site locations. Refer to **Table B-32** for site codes and descriptions.

Table B-32: Water quality and sediment monitoring site locations
Media: wq = water quality sites, s= sediment sites, wq/s= both water quality and sediment sites

River Mile	Site code	Monitoring Site	Reach	Media	Year Collected
268	ML	Millerton Lake		wq	09
266	BFD	SJR below Friant Dam (Lost Lake Park)	1A	wq/s	09/10
255	H41	SJR at HWY 41	1A	wq	09
243	H99	SJR near HWY 99 (Camp Pashayan)	1A	wq/s	09/10
227	GF	SJR at Gravelly Ford	2A	wq/s	09/10
213	BB	SJR below Bifurcation	2B	wq	09
211.9	SMF	SJR at San Mateo Ford	2B	s	09
206	MWMA	Mendota Wildlife Management Area	2B	s	09/10
205.5	MPOC	Mendota Pool (CCID Outside Canal)	2B	s	09
205.2	MPFC	Mendota Pool (Firebaµgh Canal WD Intake Canal)	2B	s	09
205	BMD	SJR below Mendota Dam	3	wq/s	09/10
182	BSD	SJR below Sack Dam	4A	wq	09
174	H152	SJR at HWY 152	4AB	wq/s	09/10
125	FF	SJR at Fremont Ford	5	wq	09/10
118	AMR	SJR above Merced River (Hills Ferry)	5	wq/s	09/10

Sample media

Water and bed sediment are the types of media currently being sampled as part of the Program's water quality monitoring.

Detection limits

Water quality goals for the Program were defined using the water quality objectives for beneficial uses as defined by the Central Valley Regional Water Quality Control Board. Where no goals currently exist, minimum lab detection limits were used (Table 4 and 5). These detection limits may not detect sub-lethal concentrations (discussed further below) and some are above recommendations for detection of biological effects on fishes (Table 6).

Concentrations found and comparisons to criteria

Approximately 75 percent of the lab analyses of water and sediment samples were below minimum lab detection limits. Results for constituent samples above lab detection limits are listed in Table 2 (water) and Table 3 (sediment). A complete list of constituents measured in water and the laboratory reporting limits is provided in Table 4. A complete list of constituents measured in sediment and the laboratory reporting limits is provided in Table 5.

Of results that were above reporting limits, high sediment concentrations of bifenthrin and lambda-cyhalothrin, both pyrethroid pesticides, are of concern. Both of these samples come from the sampling site "San Joaquin River at San Mateo" on October 1, 2009. The collected sediment sample contained a bifenthrin concentration of 23 µg/kg (ppb). A study on the effects of sediment bound bifenthrin on gizzard shad (*Dorosoma cepedianum*) found that an eight day exposure to a bifenthrin concentration of 7.75 ppb induced complete mortality. Partial mortality and stress behaviors occurred at concentrations between 0.185-1.55 ppb. The gizzard shad is of the same family (Clupeidae) as the threadfin shad, which is a member of the 'deep-bodied' fish assemblage, including Sacramento perch, hitch, and Sacramento blackfish (SJRRP, Background Report, Chapter 7). The gizzard shad is a filter feeder on zooplankton similar to threadfin shad, Sacramento blackfish and hitch. Therefore, although the gizzard shad does not exist on the San Joaquin River, comparable fishes do. This example is meant to illustrate the potential effects of bifenthrin on fishes and as few such studies currently exist, information must be drawn from available sources. In the same study, copepod nauplii experienced significant mortality across concentrations (0.090-7.75 ppb) on day four and seven of exposure (Drenner et al. 1992). Copepods are a group of zooplankton that are likely food for zooplankton-consuming fishes. Also, the larvae of almost all fishes consume zooplankton, including copepods, for at least a short time as they grow. These results highlight the fact that bifenthrin readily binds to sediment and is of particular concern for organisms that feed on organic matter as do some aquatic invertebrates, thus contaminating food sources for organisms that feed on invertebrates, such as salmon. The lambda-cyhalothrin sediment concentration was 21 µg/kg, a sediment-bound concentration harmful to aquatic invertebrates (Amweg et al. 2005; Weston et al. 2004).

Copper levels in water were above laboratory reporting limits (Table 2) in approximately 70 samples. Results for dissolved copper ranged from 7.0 - < 0.5 µg/L. A total of 42 water samples had copper concentrations greater than 1.11 µg/L, which is EPA’s Office of Pesticide Programs (OPP) aquatic-life chronic benchmark for invertebrates. Thirty samples were above the acute benchmark for invertebrates (1.8 µg/L) (EPA 2011). Aquatic life benchmarks are extracted from the most current publicly available risk assessment data which is based on the most sensitive toxicity data for each aquatic taxa. Each benchmark is an estimates of the concentration below which pesticides are not expected to harm the organism. The highest copper samples come from the sites; SJ River above Merced River, SJ River below Mendota Dam, and SJ River at Fremont Ford.

Dissolved copper naturally occurs in the environment, but elevated ambient levels can cause negative effects on the food web that salmon and other fish depend on as well as lethal and sub lethal effects to the fish themselves. Sources of copper that can elevate ambient background levels include fertilizers, herbicides, acid mine drainage, and urban runoff. Sub lethal effect of copper have been shown to impair olfaction, interfere with migration, reduce response to predators, depress immune response, and interfere with brain function of salmonids (Lorz and McPherson, 1977; Baker et al. 1983). For example, Baldwin et al. 2003 found that a 2.3-3.0 µg/L increase in copper levels above background levels, for 30- 60 minutes, affected olfactory related behaviors in juvenile coho salmon regardless of water hardness levels. All other constituents sampled in water and sediment were below EPA's available water quality criteria standards for surface water (EPA 2009; EPA 2001; EPA 1986).

Table B-33: Results of water quality constituents above lab reporting limits

Constituent				
General Water Quality	**Max**	**Min**	**Reporting Limit**	**Units**
Alkalinity	200	12	5.0	mg/l
Bicarbonate	190	15	5.0	mg/l
Bicarbonate alkalinity	200	12	5.0	mg/l
E.coli	240	2	1.0	MPN/100mL
Fecal coliform	300	2	2.0	MPN/100mL
Ph	7.8	7.1	0.1	PH
Total coliform	1600	13	2.0	#/100ml
Metals				
Arsenic	6.2	0.5	0.5	µg/l
Boron	790	10	10	µg/l
Chromium	5.3	0.5	0.5	µg/l
Copper	7.0	0.5	0.5	µg/l
Lead	56	0.5	0.5	µg/l
Magnesium	37	1	1.0	mg/l
Mercury	.017	.0022	2.0	µg/l
Nickel	16	1	1.0	µg/l
Selenium	2.3	0.4	0.4	µg/l
Zinc	640	2	2.0	µg/l
Ions				
Calcium	68	2	1.0	mg/l
Carbonate	7	7	5.0	mg/l
Chloride	230	1.1	0.2	mg/l
Potassium	6.6	1	1.0	mg/l
Sodium	170	2	1.0	mg/l
Sulfate	240	0.72	0.4	mg/l
Biological				
Chlorophyll A	6.5	2.4	2.0	µg/l
DOC	8	2	0.3	mg/l
TKN	1.6	0.2	0.2	mg/l
TOC	8.2	2	0.3	mg/l
TSS	85	1.1	1.0	mg/l
Pesticides				
Dacthal	0.014	0.013	0.002	µg/l
Diuron	0.024	0.024	0.005	µg/l
Molybdenum	9.2	0.8	0.5	µg/l
Nutrients				
Ammonia as N	3.5	0.05	0.05	mg/l
Nitrate + Nitrite as N	1.4	0.055	0.05	mg/l
Nitrate as N	1.5	0.05	0.05	mg/l
Nitrite as N	0.04	0.03	0.03	mg/l
Phosphorus, Total as P	0.39	0.05	0.05	mg/l

Table B-34: Results of sediment sample constituents above lab detection limits

Constituent	Max	Min	Reporting Limit	Units
Metals				
Chromium	15	1.2	0.5-1.0	µg/g
Copper	23	1.2	0.5-1.0	µg/g
Lead	53	0.98	0.5-1.0	µg/g
Nickel	34	1.3	1.0	µg/g
Zinc	62	5.5	1.5-2.0	µg/g
Pesticides				
Bifenthrin	23	<0.013	1.2-17.0	µg/g
Lambda-cyhalothrin	21	<0.013	2.3-17.0	µg/g

Table B-35. Summary of all constituents measured in water with laboratory reporting limits.

Pesticides	**Reporting limit**	**Carbamates**	**Reporting limit**		**Reporting limit**
Organochlorine scan		3-hydroxycarbofuran	0.5 µg/L	Total Suspended Solids	1.0 mg/L
2,4'-DDD	0.002 µg/L	Aldicarb	0.005 µg/L	Total Organic Carbon	0.3 µg/L
2,4'-DDE	0.002 µg/L	Aldicarb sulfone	0.5 µg/L	Dissolved Organic Carbon	0.3 µg/L
2,4'-DDT	0.002 µg/L	Aldicarb sulfoxide	0.5 µg/L	**Nutrients**	
2,4,5-T	0.1 µg/L	Baygon	0.5 µg/L	Ammonia as N	0.05 mg/L
2,4,5-TP	0.2 µg/L	Captan	0.005 µg/L	Chlorophyll A	2.0 µg/L
2,4-D	0.1 µg/L	Carbaryl	0.2 µg/L	Nitrate and nitrite as N	0.05 µg/L
2,4-DB	2.0 µg/L	Carbofuran	0.001 µg/L	Nitrate as N	0.05 mg/L
3,5-Dichlorobenzoic Acid	0.5 µg/L	Diuron	0.005 µg/L	Nitrite as N	0.05 mg/L
4,4'-DDD	0.002 µg/L	Linuron	0.005 µg/L	Phosphorus, total as P	0.05 mg/L
4,4'-DDE	0.002 µg/L	Methiocarb	0.005 µg/L		
4,4'-DDMU	0.002 µg/L	Methomyl	0.001 µg/L	**Bacteria**	
4,4'-DDT	0.005 µg/L	Oxamyl	0.5 µg/L	E. Coli	1.0 MPN/100mL
Acifluorfen	0.2 µg/L	**Organophosphates**		Fecal coliform	2.0 MPN/100mL
Aldrin	0.002 µg/L	Aspon	0.05 µg/L	Total coliform	2.0 #/100ml
Bentazon	0.5 µg/L	Azinphosmethyl	0.02 µg/L	**Trace elements, cations**	
Chlordane	0.05 µg/L	Azinphos ethyl	0.05 µg/L	Calcium	1.0 mg/L
Chlordane-alpha	0.002 µg/L	Bolstar	0.05 µg/L	Magnesium	1.0 mg/L
Chlordane-gamma	0.002 µg/L	Carbophenthion	0.05 µg/L	Potassium	1.0 mg/L
Dachtal	0.002 µg/L	Chlorfenvinphos	0.05 µg/L	Sodium	1.0 mg/L
Dalapon	1.0 µg/L	Chlorpyrifos	0.005 µg/L	**Trace elements, anions**	
Dicamba	0.1 µg/L	Chlorpyrifos, methyl	0.05 µg/L	Alkalinity	5.0 mg/L
Dichlorprop	0.5 µg/L	Ciodrin	0.05 µg/L	Bicarbonate alkalinity	5.0 mg/L
Dieldrin	0.002 µg/L	Coumaphos	0.05 µg/L	Carbonate alkalinity	5.0 mg/L
Dinoseb	0.2 µg/L	Demeton	3.0 µg/L	Chloride	0.2 mg/L
Endosulfan I	0.002 µg/L	Demeton-o	1.0 µg/L	Hydroxide	5000 µg/L
Endosulfan II	0.002 µg/L	Demeton-s	0.05 µg/L	Sulfate	0.4 mg/L
Endosulfan sulfate	0.002 µg/L	Diazinon	0.005 µg/L	**Trace elements, total**	
Endrin	0.002 µg/L	Dichlorfenthion	0.05 µg/L	Arsenic	0.5 µg/L

Endrin aldehyde	0.005 µg/L	Dichlorvos	0.05 µg/L	Boron	10.0 µg/L
Endrin ketone	0.005 µg/L	Dicrotophos	0.05 µg/L	Chromium	0.5 µg/L
Gamma-bhc	0.002 µg/L	Dimethoate	0.03 µg/L	Copper	0.5 µg/L
HCH-Alpha	0.002 µg/L	Dioxathion	0.05 µg/L	Lead	0.5 µg/L
HCH-Beta	0.002 µg/L	Disulfoton	0.02 µg/L	Mercury	2.0 ng/L
HCH-Delta	0.002 µg/L	Epn	1.2 µg/L	Molybdenum	0.5 µg/L
Heptachlor	0.002 µg/L	Ethion	0.05 µg/L	Nickel	1.0 µg/L
Heptachlor epoxide	0.002 µg/L	Ethoprop	0.05 µg/L	Selenium	0.4 µg/L
Hexachlorobenzene	0.001 µg/L	Famphur	0.05 µg/L	Zinc	2.0 µg/L
Methoxychlor	0.002 µg/L	Fenitrothion	0.05 µg/L		
Mirex	0.002 µg/L	Fensulfothion	0.05 µg/L		
Nonachlor, cis	0.002 µg/L	Fenthion	0.05 µg/L		
Nonachlor, trans	0.002 µg/L	Fonophos	0.05 µg/L		
Oxadiazon	0.002 µg/L	Glyphosate	6.0 µg/L		
Oxychlordane	0.002 µg/L	Leptophos	0.05 µg/L		
Pentachlorophenol	0.04 µg/L	Malathion	0.02 µg/L		
Picloram	0.1 µg/L	Merphos	0.05 µg/L		
Tedion	0.002 µg/L	Methidathion	0.02 µg/L		
Total DCPA Mono & Diacid Degradates	0.1 µg/L	Mevinphos	0.05 µg/L		
Toxaphene	0.5 µg/L	Naled	0.05 µg/L		
Trichloronate	0.05 µg/L	O,O,O-Triethylphosphorothioate	0.5 µg/L		
		Parathion, ethyl	1.0 µg/L		
Pyrethroid scan		Parathion, methyl	4.0 µg/L		
Bifenthrin	0.001 µg/L	Phorate	0.02 µg/L		
Cyfluthrin	0.002 µg/L	Phosmet	0.02 µg/L		
Cypermethrin	0.002 µg/L	Phosphamadon	0.05 µg/L		
Deltamethrin	0.5 µg/L	Ronnel	0.05 µg/L		
Esfenvalerate	0.5 µg/L	Sulfotep	0.05 µg/L		
Fenpropathrin	0.002 µg/L	Terbufos	0.05 µg/L		
Lambda-cyhalothrin	0.5 and 0.0005 µg/L	Tetrachlorvinphos	0.05 µg/L		
Permethrin (total)	0.5 µg/L	Thionazin	0.05 µg/L		
Permethrin, cis	0.003 µg/L	Tokuthion	0.05 µg/L		
Permethrin, trans	0.003 µg/L	Trichlorfon	0.05 µg/L		

Table B-36. Summary of all constituents measured in sediment with laboratory reporting limits

Pesticides	Reporting limit	Pyrethroid scan	Reporting limit
Organochlorine scan		Bifenthrin	1.2-17.0 ng/g
2,4'-DDD	1.1-3.3 ng/g	Cyfluthrin	4.7-17.0 ng/g
2,4'-DDE	2.2-3.3 ng/g	Cypermethrin	4.7 ng/g
4,4'-DDD	0.65-1.1 ng/g	Esfenvalerate	13-17 ng/g
4,4'-DDE	2.2-3.3 ng/g	Fenpropathrin	4.7 ng/g
4,4'-DDMU	3.4 ng/g	Lambda-cyhalothrin	2.3-17.0 ng/g
4,4'-DDT	0.65-5.6 ng/g	Permethrin (total)	13-17 ng/g
Aldrin	1.1 ng/g	Permethrin, Cis	5.8 ng/g
Chlordane, technical	3.3 ng/g	Permethrin, Trans	5.8 ng/g
Chlordane-Alpha	1.1 ng/g	**Organophosphates**	
Chlordane-Gamma	1.1 ng/g	Chlorpyrifos	0.46 ng/g
Dachtal	1.1 ng/g	**Trace elements, total**	
Dieldrin	0.56-0.65 ng/g	Arsenic	0.5-1.0 µg/g
Endosulfan I	2.2 ng/g	Chromium	0.5-1.0 µg/g
Endosulfan II	6.8 ng/g	Copper	0.5-1.0 µg/g
Endosulfan sulfate	5.5 ng/g	Lead	0.5-1.0 µg/g
Endrin	0.65-2.2 ng/g	Mercury	0.0117-0.3 µg/g
Gamma-BHC	0.56-13 ng/g	Nickel	1.0 µg/g
HCH-alpha	0.56 ng/g	Selenium	2.5 µg/g
HCH-beta	1.1 ng/g	Zinc	1.5-2.0 µg/g
Heptachlor	1.1 ng/g	Total Organic Carbon	100-2500 µg/g
Heptachlor epoxide	0.65-1.1 ng/g	Dissolved Organic Carbon	2000 µg/g
Hexachlorobenzene	0.77 ng/g	Percent solids	
Methoxychlor	3.4 ng/g	Pecent moisture	
Mirex	1.7 ng/g	H. azteca survival	
Nonachlor, Cis	1.1 ng/g	H. azteca dry weight	
Nonachlor, Trans	1.1 ng/g		
Oxadiazon	1.1 ng/g		
Oxychlordane	1.1 ng/g		

14.4 Discussion and Recommendations

- Sampling frequency

Water quality sampling during 2010 generally occurred once per month for water, and once per year for sediment, in different months. No samples were collected in May and November 2010 due to limited availability of staff. Continuation of monthly water sampling as was done for most of 2010 is recommended so that a thorough understanding of the effects of interim flows can be developed. Routine sediment sampling should be considered, meaning that sediment sampling should be collected at the same time each year, ideally before increases in fall flow releases.

Storm sampling should be considered in order to determine if there are pulses of sampled constituents in the Restoration Area during storm events. In-stream concentrations of constituents that come primarily from surface runoff, such as pesticides, can increase dramatically during a storm event and may have toxic effects on aquatic organisms. A study by Kratzer (1999) found that concentrations of the pesticide diazinon are highly variable during winter storms, with some pulses high enough to be acutely toxic to aquatic invertebrates. Thus, it is important to sample water quality during both base-flow and high-flow events in order to accurately monitor the water quality of the river (Hladik et al. 2009; Weston et al. 2004; Orlando et al. 2003). Storm sampling is labor intensive and requires careful planning. A recommendation and design for a storm sampling study should be developed separately from this report by experts in the field.

- Sampling locations

Sampling is occurring in at least two locations in every reach, with the exception of Reach 3 and 4, where access to the river is restricted. Distribution of sampling locations is fairly even, with the exception of Reach 4. To help remedy this, it is recommended that water and sediment sampling sites be added above and below the confluence of Bear Creek with the San Joaquin River. Even distribution of sampling locations is important in order to develop an accurate representation of the water quality throughout the restoration reach.

- Sample media

Tissue samples of resident fish species would be a very valuable asset to the Program. Tissue samples can help address questions regarding bioaccumulation and food web transfer of contaminates as such questions are difficult to address with only data from water and sediment. Tissue sampling has been conducted on the San Joaquin River as part of the Graslands Bypass Project for selenium and boron (Reach 5) and for mercury (Davis et al. 2008).

Another method for addressing the bioavailability of hydrophobic organic chemicals to aquatic organisms involves the use of semi-permeable membrane devices (SPMDs). This passive sampling technique can mimic the uptake of contaminates through biological membranes (Kot et al. 2000). They have been used to passively sample organochlorine pesticides in aquatic environments and can be used as a surrogate tissue sample to evaluate bioconcentration from water in aquatic organisms (Esteve-Turrillas et al. 2008). Bioaccumulation of contaminants through the food web cannot be addressed with SPMDs.

Bioassays conducted on aquatic invertebrates can indicate if important food web organisms are affected by the presence of contaminates in the sediment or water column. Previous bioassay studies have identified pesticide related toxicity in invertebrates in the San Joaquin River (Kuivila and Foe 1995; Foe and Connor, 1991). It is recommended that the Program consider conducting bioassays on sediment with benthic invertebrates (e.g., Hyallela sp., Chironomus sp.) and on water with water column oriented invertebrates (e.g., Ceriodaphnia sp.) as food web surrogates to better understand the possible lethal and sub-lethal effects of contaminates on food web organisms in the Restoration Area. Bioassays have been conducted on invertebrates, fish and algae as part of the Grasslands Bypass Project, but none of these tests were conducted at locations within the San Joaquin River. These bioassays were conducted in Mud Slough and Salt Slough, both inputs to the San Joaquin River in reach 5 of the SJRRP.

- Sample processing

Approximately three percent of constituent analyses from both sampling years exceeded their hold times for lab processing, which can reduce the accuracy of the results. Hold times exceedances ranged from 24 hours to 40 days, with the majority of samples exceeding either their 24 hour (47%) or 14-day hold times (44%). Samples that exceeded 24-hour hold times were primarily bacteria (coliform and E.coli), while those that exceeded 14-day hold times consisted of a variety of constituents including pesticides and general water quality parameters. Seven DOC and one TOC samples were not preserved correctly upon collection. Forty-five chlorophyll A samples were not filtered within the correct amount of time following collection. It is recommended that sample processing protocols, including holding times, be improved upon and applied to the current sampling effort.

- Detection limits

Detection limits are mostly sufficient for detecting concentrations potentially toxic to aquatic biota, with some acceptations. It is recommended that arsenic, boron, chlordane, DDD, DDE, and DDT be tested with lower detection limits than currently utilized (Table 6). It is also important to note that some pesticides such as chlorpyrifos, diazinon, malathion, and bifenthrin can be detected at lower concentrations than possible with laboratory analyses presently being used by the Program. Detection of toxic constituents at low levels can be important for identification and investigation of sub-lethal effects of both salmon and resident native fishes (discussed further below). A review of existing literature indicates that the detection levels currently being used by the Program appear to be sufficient for monitoring biological effects of harmful constituents within the river, with the exception of those present at a sub-lethal concentration.

Table B-37: Recommended detection limits for biological effects on fishes from the 2009 SJRRP Water Quality Monitoring Plan

Constituent	Current detection limit	Recommended detection limit
Arsenic	0.5 µg/L	0.014 µg/L
Boron	10.0 µg/L	0.8 µg/L
Chlordane	0.05 µg/L	0.0043 µg/L
DDD	0.002 µg/L	0.00031 µg/L
DDE	0.002 µg/L	0.00022 µg/L
DDT	0.005 µg/L	0.001 µg/L

- Thresholds

Review of the water quality data collected to date for the Program shows few constituents present at concentrations that exceed aquatic life thresholds. However, other water quality studies conducted on the San Joaquin River have found elevated levels of constituents, such as selenium and methyl-mercury in the system that may pose threat to aquatic organisms. Thus, it is important to maintain regular and consistent sampling in the Restoration Area to understand possible changes associated with natural factors, such as seasonal differences, storm events, as well as anthropogenic factors, such as changes in restoration flows, restoration of floodplain, and changes in agricultural practices. Monitoring results should be evaluated in the context of current research on the effects of pollutants in surface waters on aquatic biota. Such evaluation can guide refinements in the water quality monitoring program.

The SJRRP manages for Chinook salmon and other native fish that are linked through a food web. The water quality program will not adequately utilize existing results until the translation of water quality effects up the food web is investigated and better understood. This investigation should rely on conclusions from existing studies and address these information gaps. For example, there is little information about toxic effects of pesticides on aquatic invertebrates and how such effects translate up the food web (Macneale et al. 2010). Of the work that has been done in this area, results show that applications of pesticides can have a strong negative effect on the food web. In a study done by Relyea and Diecks (2000) that looked at food web effects of the insecticide malathion, findings showed that all levels of application (10-250 µg/L) over short periods of time (1-4 days) caused a decline in zooplankton, which caused a cascading decline in all other species in the study. They also found that repeated applications of low doses caused a greater negative response than a single application of a high dose. These and other studies highlight the importance of quantifying pesticide exposure in aquatic habitats due to pesticide-use patterns, combined effects of multiple pesticides, and how the fate of various pesticides change in relation to degradation times, uptake rates and binding ability of soils (Laetz et al. 2009; Oros and Werner, 2005; Nowell et al. 1999).

A variety of research has been done on pesticides and their various effects on fish. Organophosphates and carbamates are two classes of pesticides that are of particular concern as both target the nervous system (Fulton and Key 2001). For example, a two hour exposure to the organophosphate insecticide diazinon has been found to decrease olfactory-mediated alarm responses in Chinook salmon at concentrations of 1.0 µg/L. A 24 hour exposure to diazinon at concentrations ranging from 0.1-10.0 µg/L disrupts homing in Chinook salmon males (Scholz et al. 2000). Another currently used pesticide that is commonly applied in the San Joaquin Valley, chlorpyrifos, has been shown to inhibit acetylcholinesterase (AChE), an important chemical in the transmission of nerve impulses, in the nervous system and muscles of juvenile steelhead and coho salmon at concentrations of 510.0 mg/L. Reduction in AChE activity has been linked to decreased swimming behavior and prey consumption by juvenile salmon (Sandahl et al. 2005; Sandahl and Jenkins 2002). The presence of these and other pesticides are well documented on the San Joaquin River and its tributaries (Domagalski et al. 2010; Orlando et al. 2004) and SJRRP monitoring should continue.

Sub-lethal effects of pesticides, such as those discussed above, are of particular concern for aquatic organisms in the San Joaquin River. Sub-lethal effects include reductions in growth, swimming behavior, reproductive success, and immune system response in aquatic fish and invertebrates, often at much lower than lethal concentrations (Oros and Werner, 2005). The pesticide carbofuran is thought to have sub-lethal effects on reproduction in Atlantic salmon (Waring and Moore, 1997). To date, the results from the Program’s water quality sampling show few exceedances, yet it is possible that aquatic organisms within the river are exposed to concentrations of both pesticides and other potentially harmful constituents that are sufficient to cause important sub-lethal effects. It may be valuable to test for some of the most toxic constituents, particularly pesticides, at the lowest available detection limits so that a sub-lethal baseline can be established. If sub-lethal effects occur with exposures in the part per trillion range, then they are not currently being detected since the Program’s laboratories detection levels are in the part per million or part per billion range. This type of testing may lead to a better understanding of how present persistent pollutants affect the San Joaquin River fish fauna.

Summary of recommendations

- Continue monthly water quality sampling throughout the year
- Consider sampling sediment at the same time each year, before increases in flow releases (i.e. September).
- Evaluate desirability of storm sampling
- Add sample site above and below Bear Creek confluence
- Evaluate desirability of tissue sampling
- Consider using SPMDs for passive pesticide sampling
- Consider conducting bioassays above Reach 5
- Change detection limits to those listed in Table 6
- Evaluate the likelihood of sub lethal effects based on existing data and literature review

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15.0 April 2010 Bathymetric Surveys of the San Joaquin River

15.1 Overview

In April, 2010, Reclamation conducted bathymetric surveys along San Joaquin River and bypasses from Mendota Dam to the Merced River confluence. Surveys were conducted from April 9th to April 15th during the spring 2010 interim flow period, in which flow releases from Friant Dam were approximately 1275 cfs. However, flows in reaches below Mendota Dam had not yet approached steady state conditions and there was likely significant variability in space and time throughout the surveyed reaches below Mendota Dam. In addition, several irrigation diversions and return flow sources were present throughout the surveyed region, which caused further fluctuations in flows. The variability in flow does not affect the accuracy of the bathymetric data collected.

Data collected in Reach 3 supplements existing bathymetric surveys and provides bed elevation information in areas where bed elevations had previously not been obtained. Data collected in Reach 4A, 4B2, the Eastside Bypass, and Reach 5 were the first bathymetric surveys conducted in recent years and provide bed elevations and water surface elevations for use in monitoring and modeling efforts. The bathymetric data collected as part of this investigation will be combined with existing LiDAR to develop complete surface models of the San Joaquin River Restoration Program Area.

15.2 Methods

The bathymetric survey data were collected using a Teledyne RD Instruments 1200 kHz Workhorse Rio Grande Acoustic Doppler Current Profiler (ADCP). Accurate horizontal and vertical position information for the survey was achieved by linking the ADCP to a Trimble R8 GPS system operating with a Real Time Kinematic (RTK) survey.

The GPS and ADCP were mounted on an aluminum frame raft with inflatable pontoons and connected to a field computer, which processes information from both instruments. The GPS receiver on the raft was mounted in close proximity to the ADCP mounting pole and was set to export the GGA NMEA data string. This data string exports the GPS position data directly to the computer. The computer program WinRiver (Version 10.06, RD Instruments, San Diego, CA) reads the GGA data string and uses it to determine the position of the ADCP. The ADCP was set to a depth of 0.67 feet during the survey. The magnetic variation varied along the river but was generally around 13.77 degrees. Bottom type was set to sand, and water mode 12SB and bottom mode 7 were used. The ADCP self test and compass calibration programs were executed each day of the survey. During the survey, the depth of the ADCP was adjusted so that the top of the mounting plate was just at the water surface. The instrument height for the GPS with this configuration was 4.1 feet from the water surface to the center of bumper. During the boat surveys, GPS observations were taken to measure the water surface elevation every 20 feet. These measurements were later used to assign a water surface elevation to each ADCP measurement.

15.2.1 Data Processing

Data collected in the data controller (on the boat) and in the base station receiver were downloaded to Trimble Business Center (TBC version 2.2). Data logged at the base stations were submitted to OPUS (http://www.ngs.noaa.gov/OPUS/) for post processing. The control point coordinates were adjusted based on these results. Horizontal positions were reported in NAD 83 State Plane California 3; and vertical positions were reported in NAVD 88. Elevations were derived from GEOID 03. After these adjustments were made, the water surface observations were exported in shapefile format for further use in ArcMap (Version 9.3.1, ESRI, Redlands, CA).

ADCP data require several processing steps. First, the ADCP raw data files are exported in ASCII format using WinRiver (playback mode). The second step in processing is to use AdMap (Dave Mueller, USGS version 1.8, 2008) to export bathymetric data. AdMap can export several types of bathymetry data, but for the purposes of this project, only the multibeam bathymetry data, depth and position for each of the four ADCP beams, were exported. Beam depths were obtained by creating a water surface file within AdMap in which the water surface elevation at each transect was set equal to zero. AdMap processed files were exported in text file format and included position data in UTM coordinates. With a small amount of manipulation these files were imported into ArcMap.

Once the ADCP multibeam bathymetry data and the GPS water surface elevation data were imported into ArcMap, bed elevations for the ADCP measurements could be determined. The GPS water surface elevations were used to create a water surface TIN (Triangulated Irregular Network). Using the Functional Surface Tool in 3D analyst, the ADCP multibeam bathymetry points were assigned a water surface elevation based on each point's position relative to the water surface TIN. Once this process was completed, fields for horizontal position (x,y), water surface elevation, and bed elevation were created and populated in the attribute table of the new 3D feature class.

15.3 Results

Figure through **Figure** illustrate the locations of data collected during the April 2010 surveys. The background photography is from 2004. In addition, plots of bed profiles and water surface elevations are also provided for each of the reaches where surveys were conducted (**Figure** through **Error! Reference source not found.**).

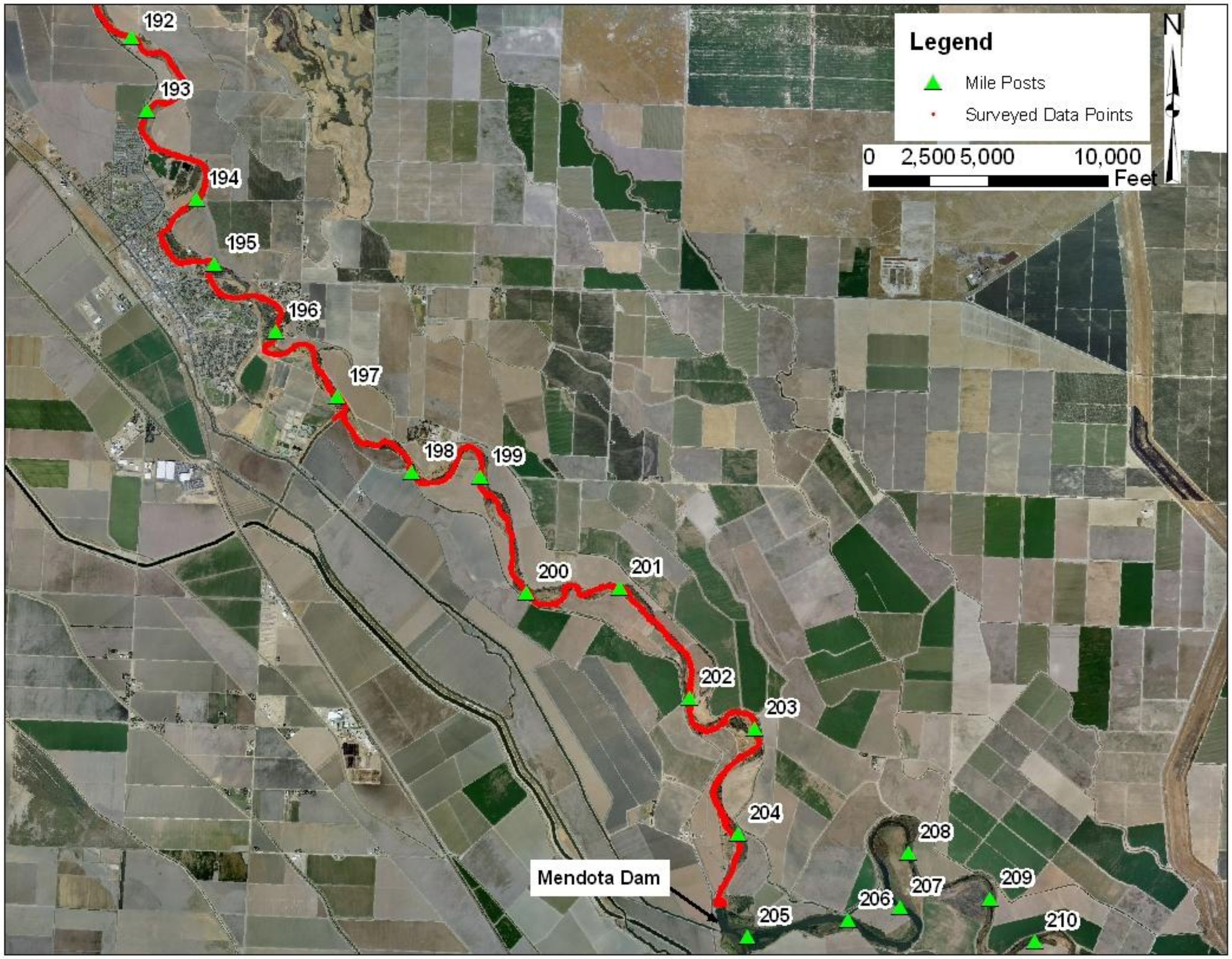

Figure B-61. Reach 3 bathymetric surveyed data points from Mendota Dam to MP 192. Data were collected on April 9, 2010.

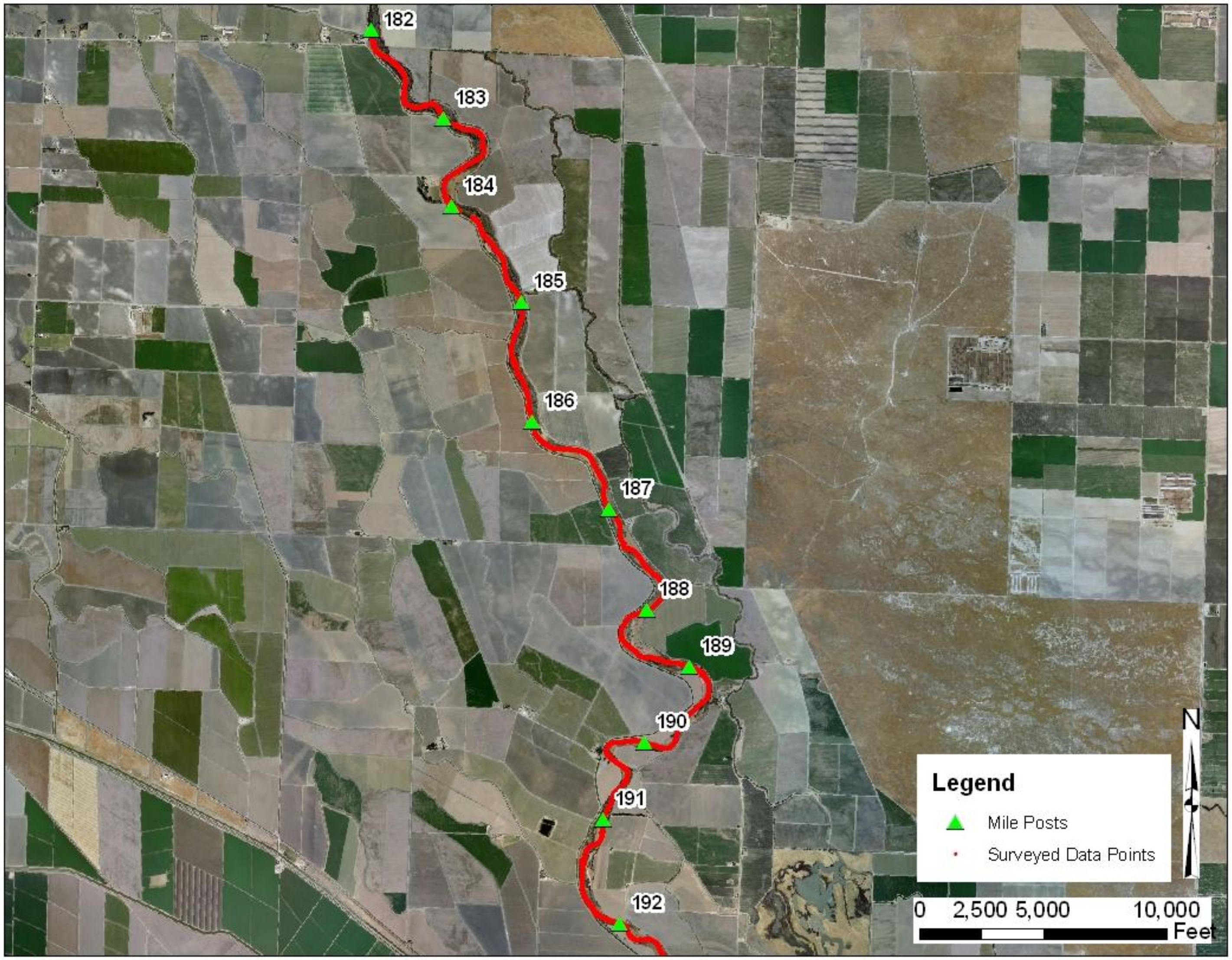

Figure B-62. Reach 3 bathymetric surveyed data points from RM 192 to Sack Dam (MP 182). Data were collected on April 9, 2010.

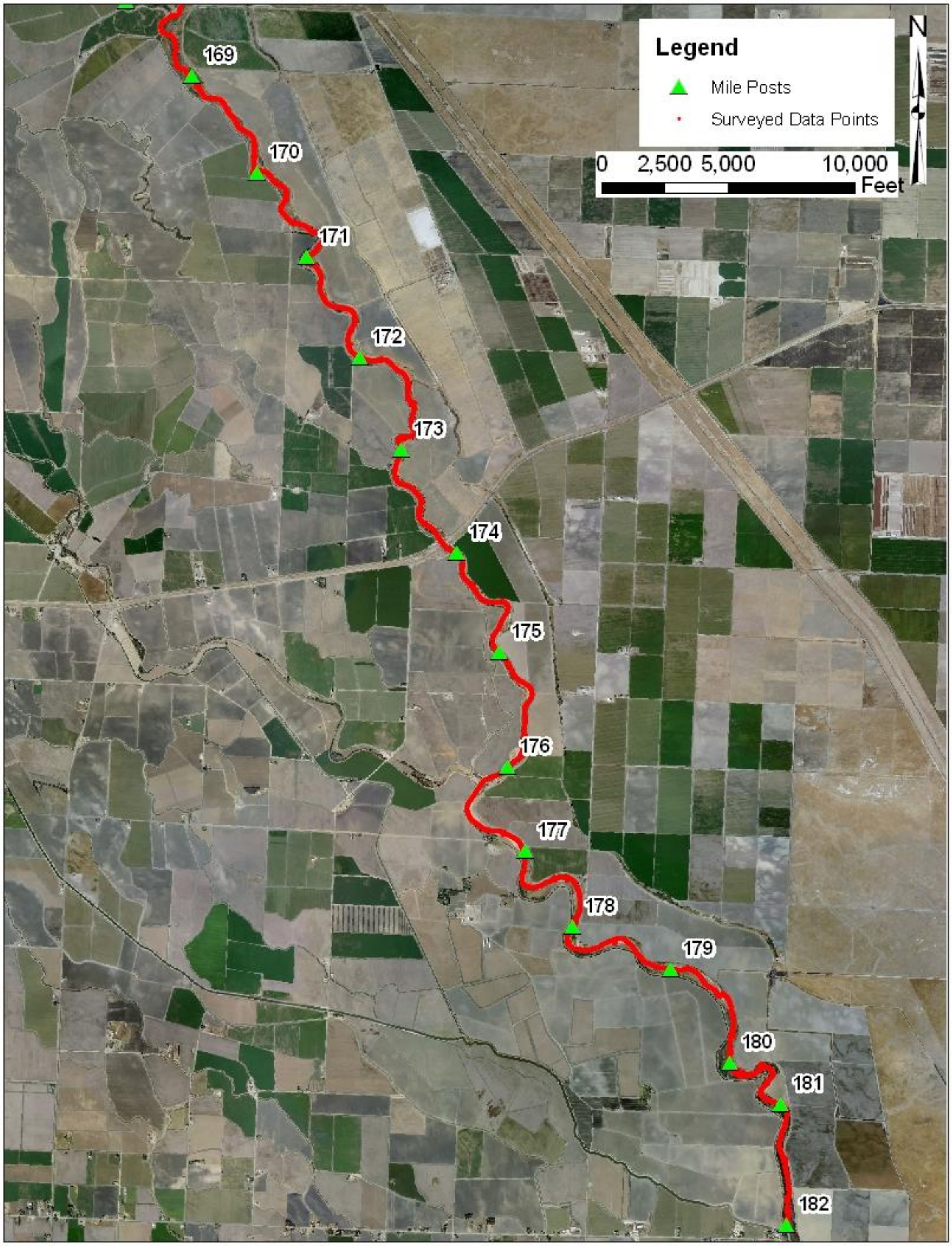

Figure B-63. Reach 4a bathymetric surveyed data points from Sack Dam (MP 182) to Sand Slough (MP 168.5). Data were collected on April 10, 2010.

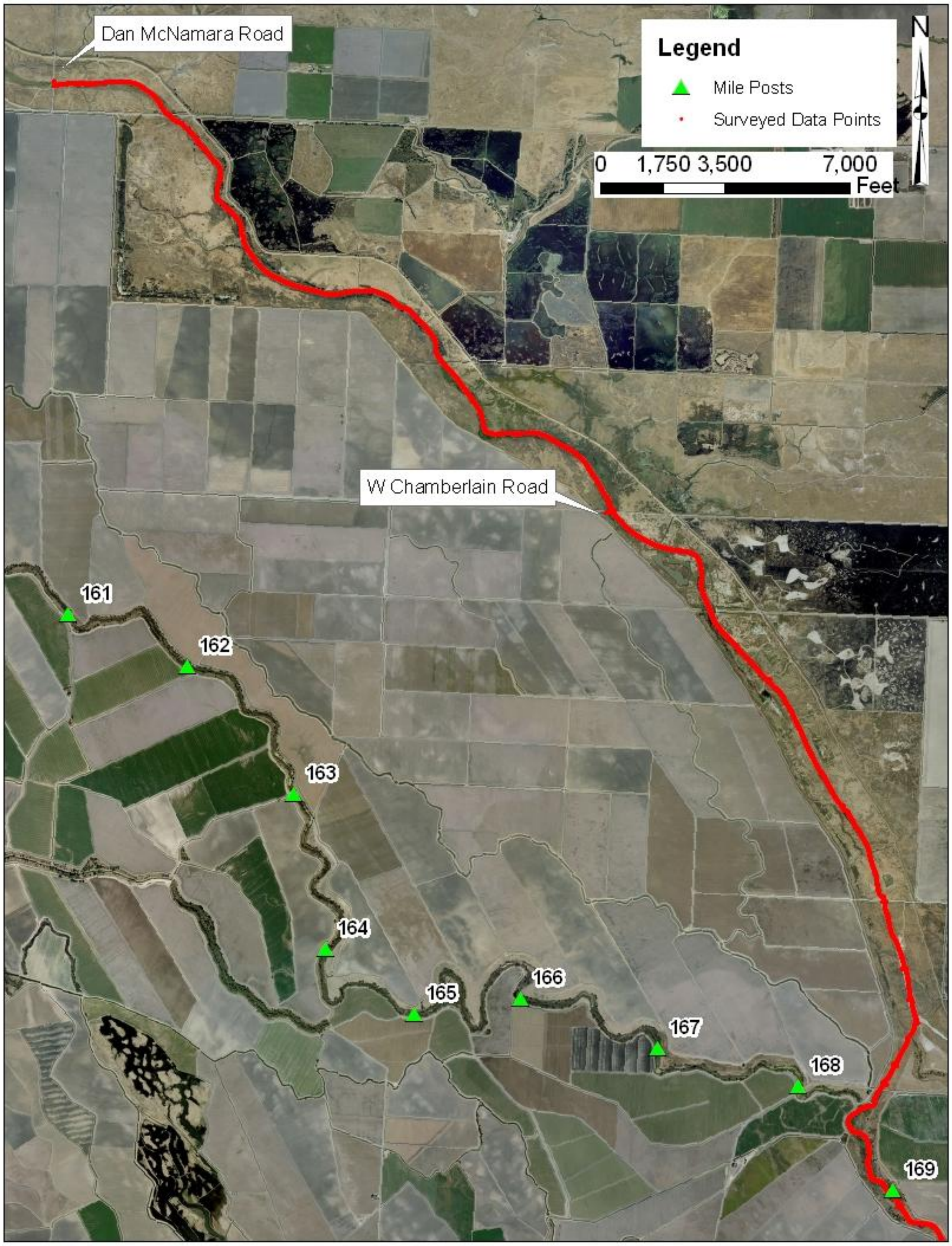

Figure B-64. Eastside Bypass bathymetric surveyed data points from Sand Slough (MP 168.5) to Dan McNamara Road. Data were collected on April 10, 2010.

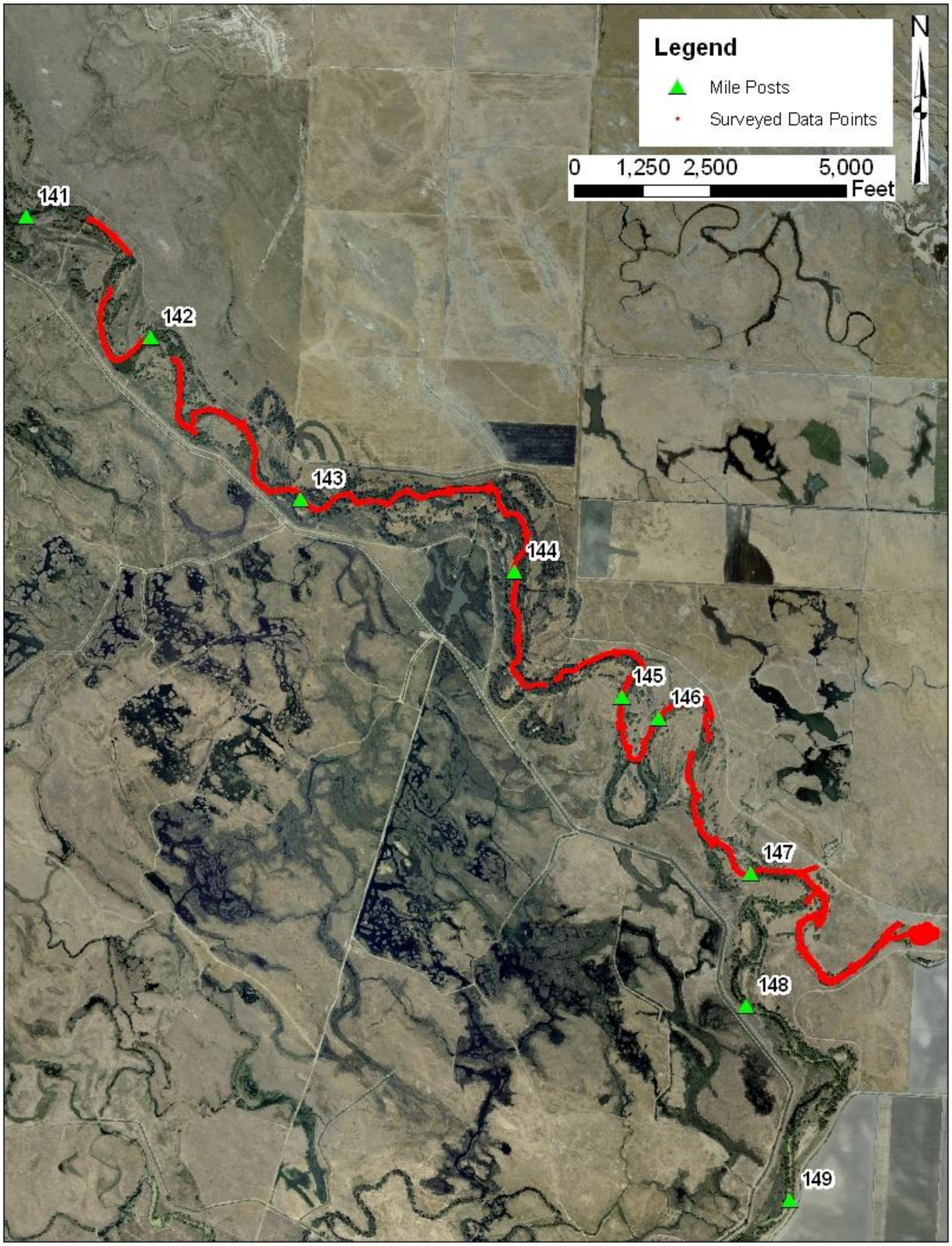

Figure B-65. Reach 4b2 bathymetric surveyed data points from the Mariposa Bypass (MP 147.5) to MP 141. Data were collected on April 13, 2010.

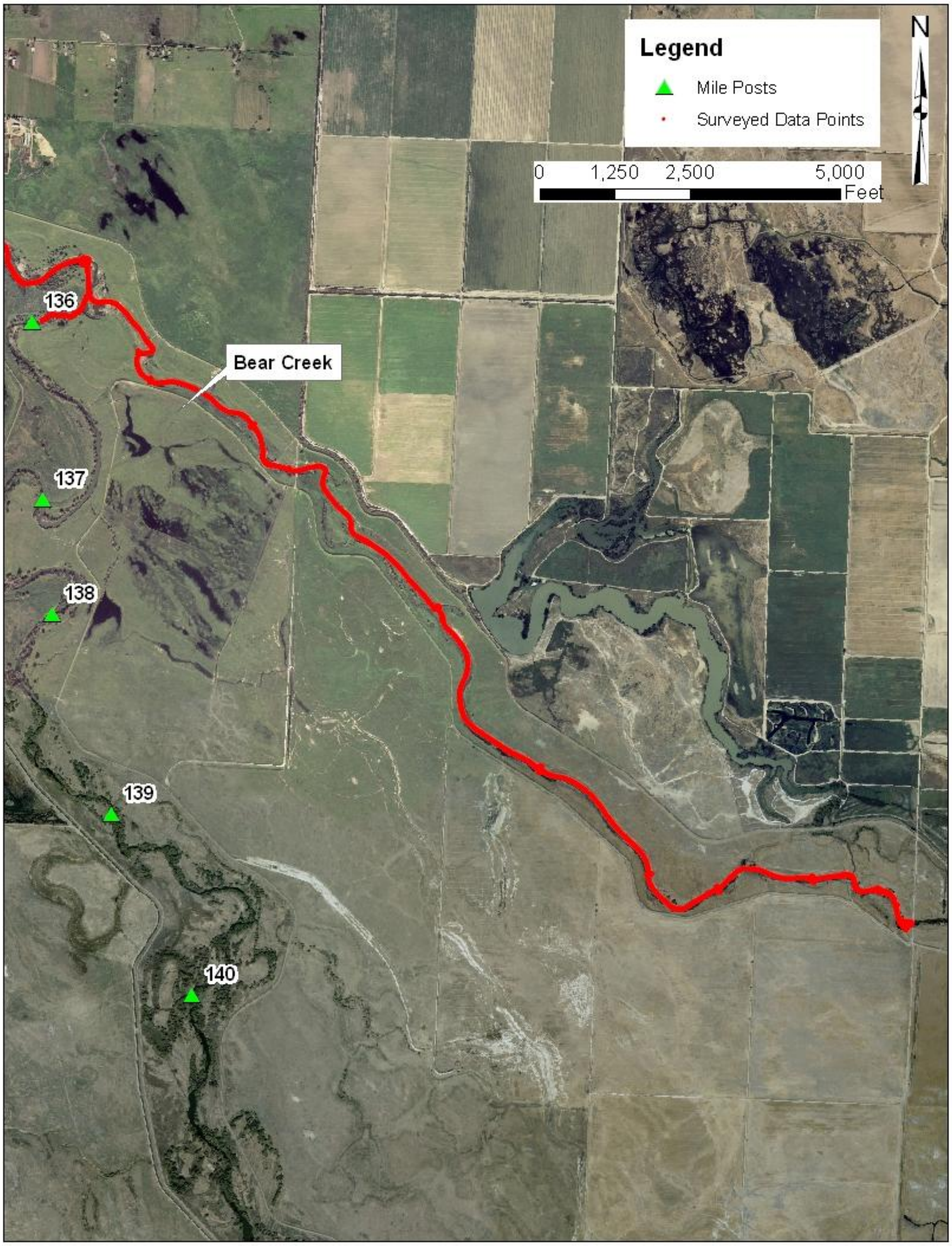

Figure B-66. Bear Creek/Eastside Bypass bathymetric surveyed data points just upstream of the confluence with the San Joaquin River at MP 136. Data were collected on April 14, 2010

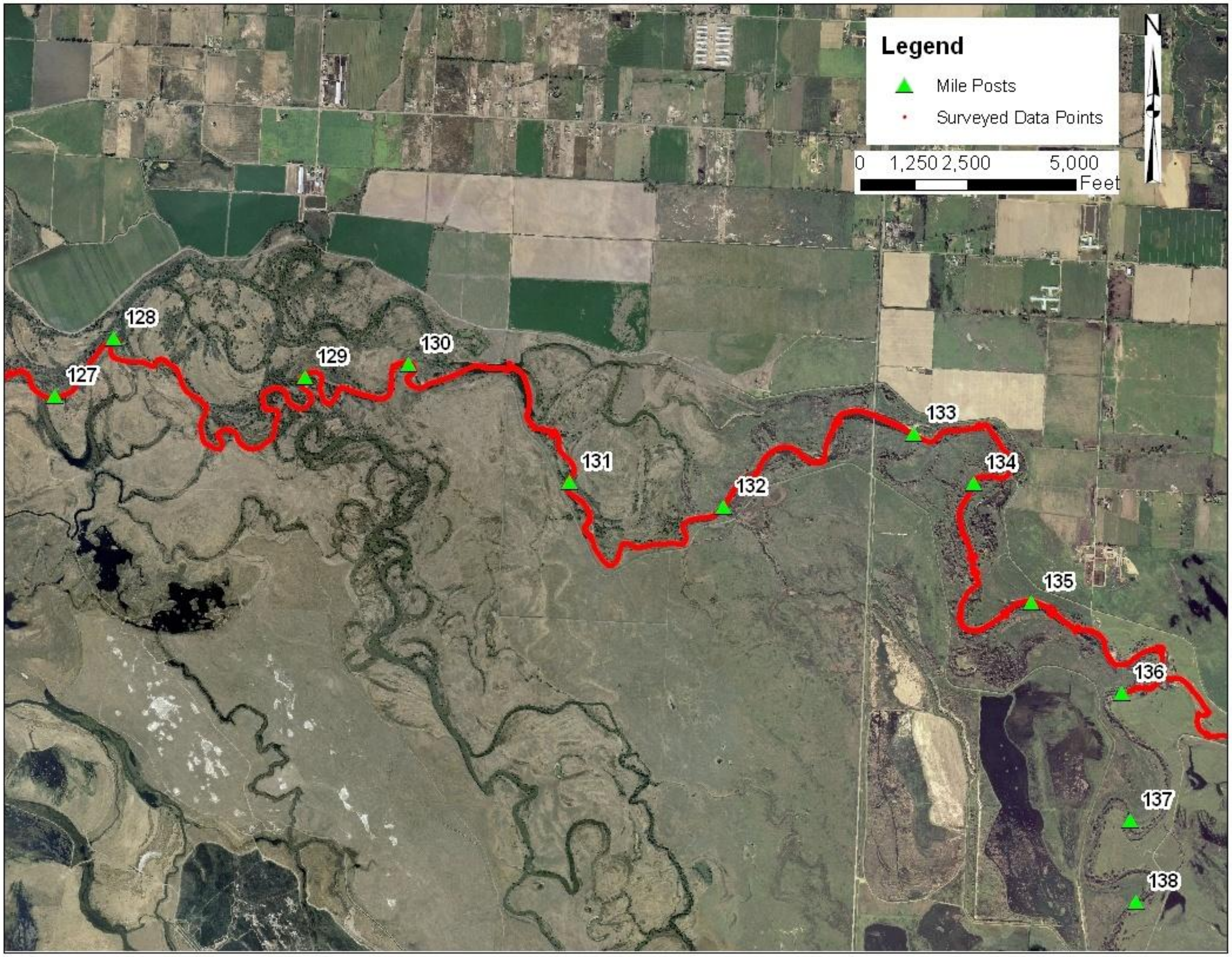

Figure B-67. Reach 5 bathymetric surveyed data points from MP 136 to MP 127. Data were collected on April 14, 2010.

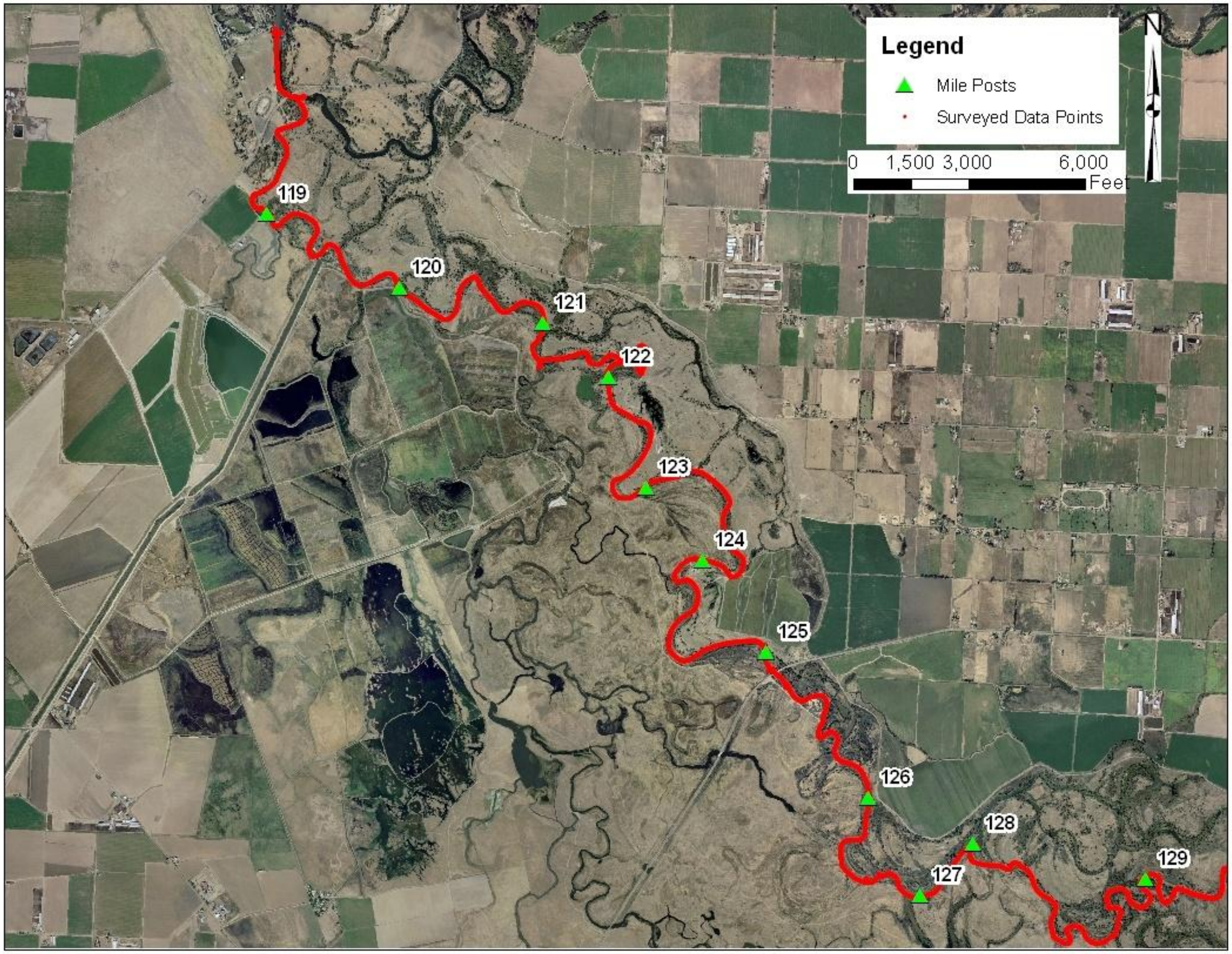

Figure B-68. Reach 5 bathymetric surveyed data points from MP 127 to confluence with the Merced River. Data were collected on April 14, 2010.

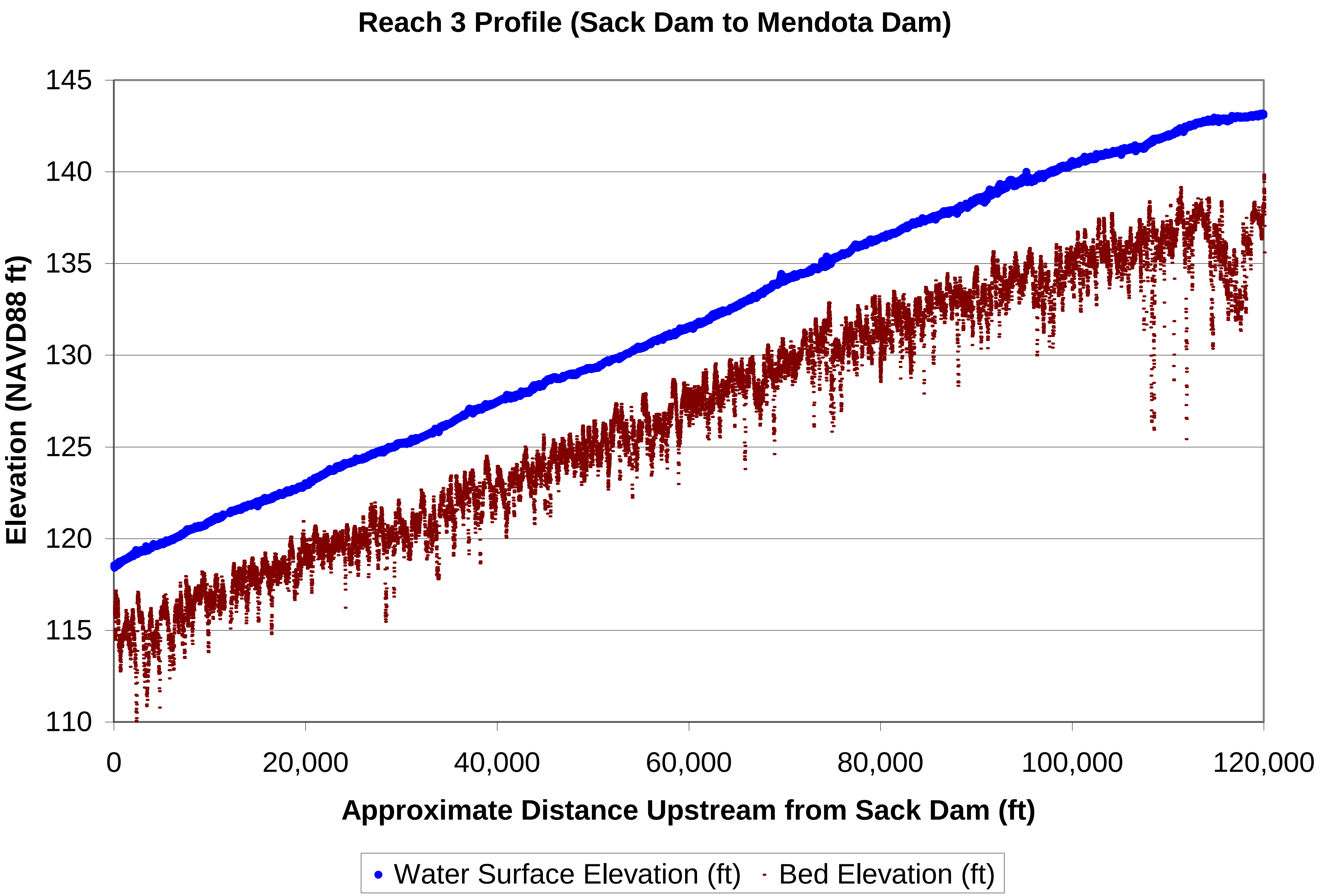

Figure B-69. Profile of survey collected in Reach 3 on 04/09/2010.

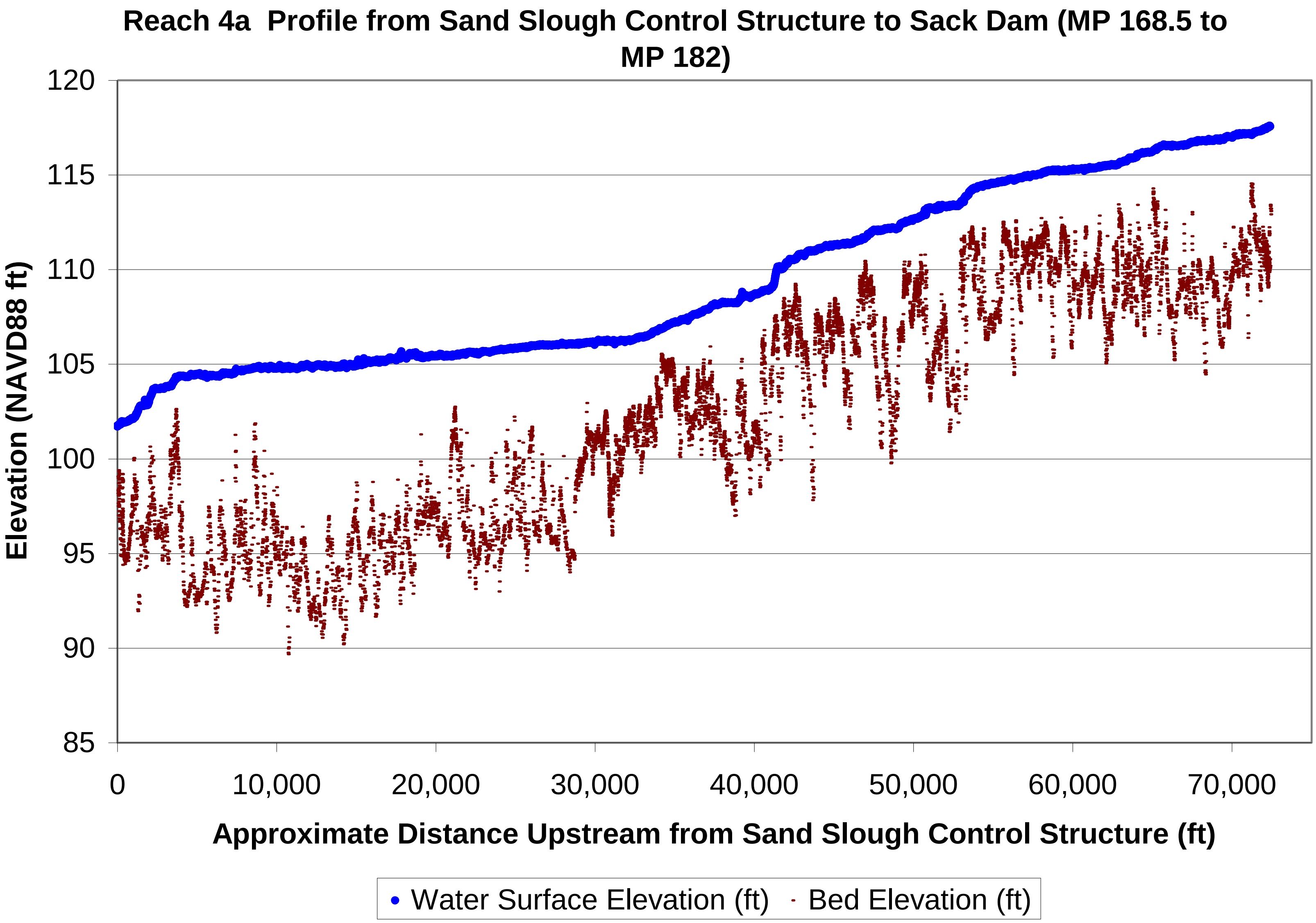

Figure B-70. Profile of survey collected in Reach 4a on 04/10/2010.

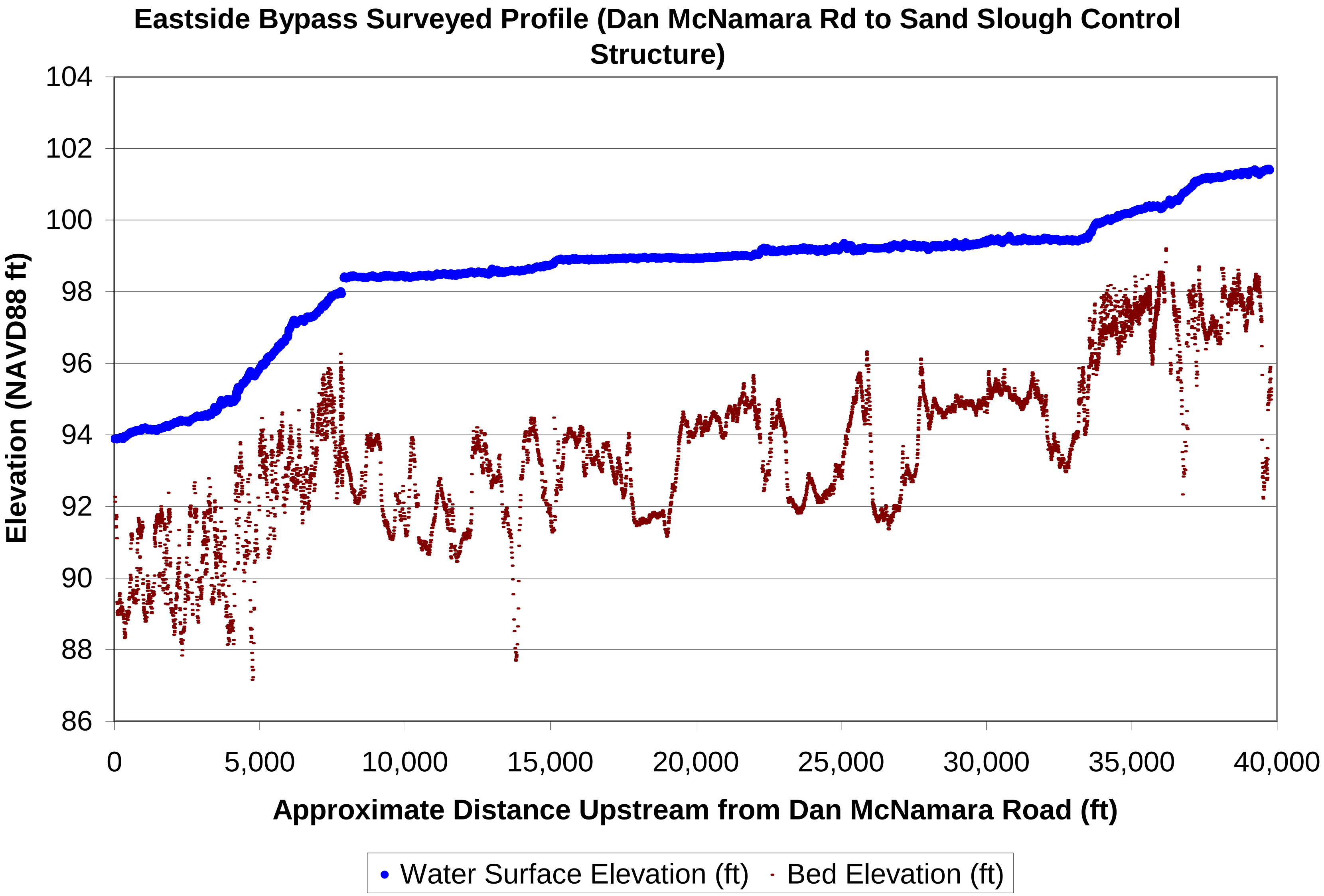

Figure B-71. Profile of survey collected along the Eastside Bypass on 04/10/2010.

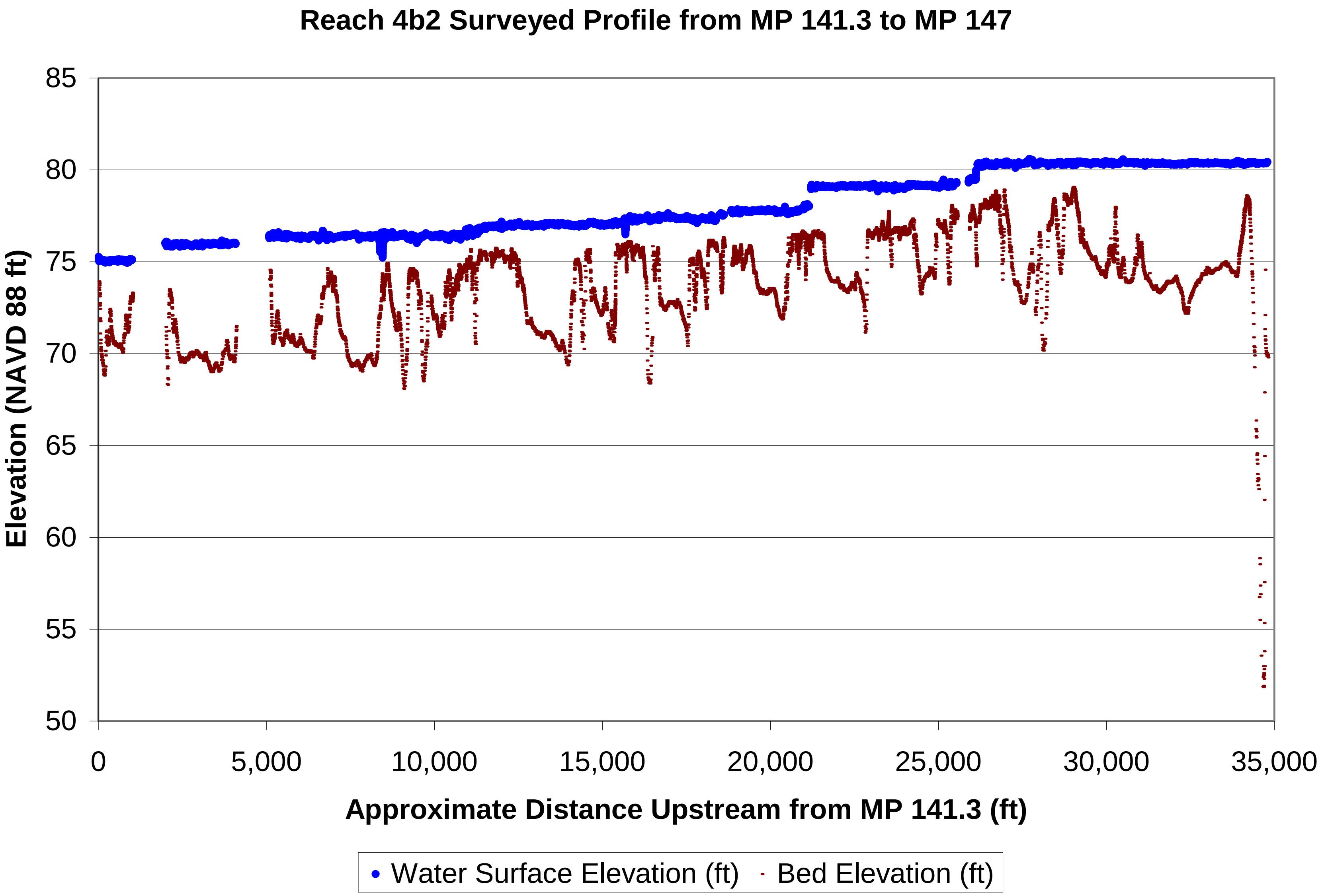

Figure B-72. Profile of survey collected in Reach 4B2 on 04/13/2010

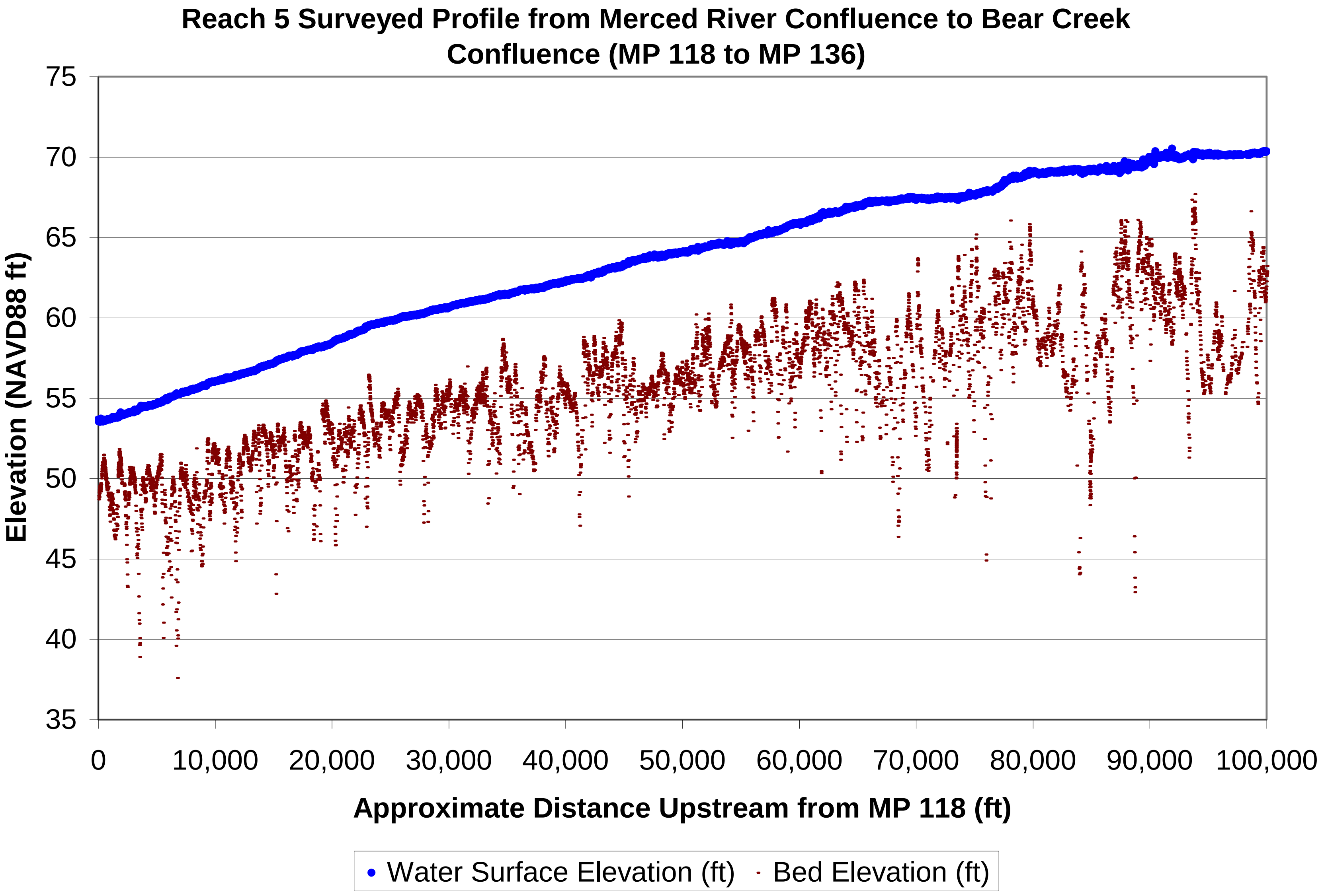

Figure B-73. Profile of survey collected in Reach 5 on 04/14/2010.

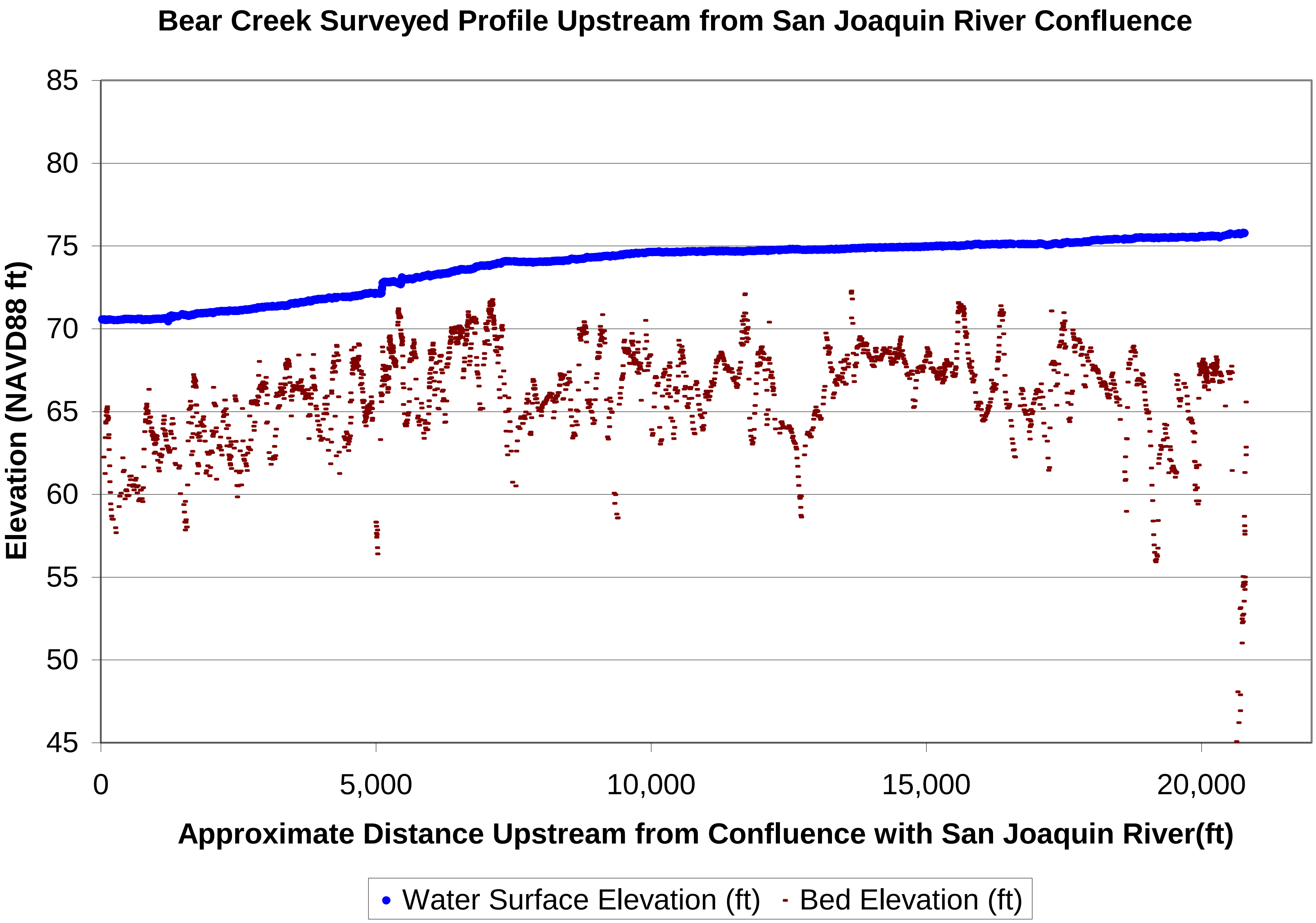

Figure B-73. Profile of survey collected in Bear Cree