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Compliance with State Water Resources Control Board Order Nos. 98-05 and 98-07

May, 2000

Los Angeles Department of Water and Power

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1. INTRODUCTION

Pursuant to State Water Resources Control Board (SWRCB) Order No. 98-05 and 98-07 (Orders), the Department of Water and Power (LADWP) is to undertake certain activities in the Mono Basin to be in compliance with the terms and conditions of its water right licenses 10191 and 10192. In particular, the Orders state that LADWP is to undertake activities to restore and monitor the fisheries, stream channels, and waterfowl habitat. This summary provides an overview of all of the activities LADWP and its consultants completed during Runoff Year (RY) 1999 for compliance. The summary also provides a list of planned work/activities for RY 2000.

Runoff Year 1999 was the first full field season after the adoption of the Orders. As such, LADWP has initiated the implementation of its revised Stream and Stream Channel Restoration Plan, revised Grant Lake Operation and Management Plan, and revised Waterfowl Habitat Restoration Plan. This required, among other things, hiring consultants, scheduling field crews and other resources, coordinating with other agencies, preparing environmental documents, and obtaining permits and approvals. Even though there was much work to do and learn, LADWP was able to complete the required work/activities for compliance. The following details the work/activities undertaken:

2. WORK PERFORMED DURING RUNOFF YEAR 1999

2.1 Restoration Activities

2.1.1 Streams

In 1999, LADWP undertook and completed several stream restoration treatments that were outlined in the Mono Basin Stream and Stream Channel Restoration Plan (1996). The measures included:

- Placed large woody debris (LWD) in Rush and Lee Vining Creeks;
- Opened two overflow channels on Reach 3A of Rush Creek;
- Rewatered the former main channel of Rush Creek in Reach 3B;
- Closed several roads into the riparian areas of both Rush and Lee Vining creeks;
- Studied and planned the revegetation of Walker and Parker creeks;
- Coordinated and consulted with the Mono Lake Committee (MLC) for planting Jeffrey pines on lower Lee Vining Creek; and
- Coordinated and consulted with Caltrans on the restoration of the "Parker Plug".
- Met with Caltrans to discuss the culvert replacement project on Walker and Parker creeks at Highway 395;
- Commissioned a sediment bypass study on Lee Vining, Walker and Parker creeks;
- Met and consulted with the Department of Fish and Game on the necessity of installing fish screens;
- Continued with the grazing moratorium;
- Continued no irrigation policy;
- Continued efforts to rehabilitate the Rush Creek Return Ditch;
- Provided base flows, stream restoration flows, and export in accordance with the Orders; and
- Removed gravel bags from Lee Vining Creek;
- Started construction of a Web Page to display Mono Basin hydrology data.

Large Woody Debris: Site selection for Large Woody Debris (LWD) placement took place between May and October 1999. Each of the sections of both Rush and Lee Vining creeks were walked to identify areas of the stream that would benefit from either increased channel roughness or where habitat complexity could be increased. In addition to these efforts, Brian Tillemans contacted Bill Trush for his input as to where LWD should be placed. During the placement effort, Dr. Trush or one of his associates placed markers along the stream banks in the A4 complex to indicate where LWD should be placed. The majority (approximately 90 pieces) of the LWD was placed by helicopter to avoid disturbing the riparian zone and stream channel. (See Figures 1 and 2) The remainder of the LWD exceeded the lifting capacity of

Figure 1: Large woody debris being placed by LADWP helicopter in to Rush Creek. LWD placement was supervised by Brian Tillemans from the ground using a two-way radio to communicate with the pilot.

Figure 2: LWD after being placed in Rush Creek. The LWD is located about 200 yards above Highway 395.

the helicopter and had to be placed using a backhoe. Extreme caution was used to minimize disturbance within the floodplain.

Channel Rewatering (3A): Entrances of the two overflow channels in reach 3A of Rush Creek that were to be re-opened were visited several times in 1999 to gain an idea of what the area looked like at various stream discharges. Additionally, Steve McBain and David Martin of LADWP met on site with Scott McBain of McBain and Trush to discuss these restoration efforts. At this meeting, the original elevation of the channel openings and the best section of berm to be removed were identified. The section of the berms, identified for removal was located at an area on the bend that minimizes the likelihood that the newly opened channels would capture and divert the stream from its current channel. A large section of the berm was also left in place to protect the bank. Once an approach was decided upon, Dr. Martin and Steve McBain met with LADWP's construction forces to plan how these channels should be constructed. Scott McBain and Dr. Martin were present when the work was conducted to ensure that the work was performed as planned. (See Figures 3, 4, 5, and 6)

Channel Rewatering (3B): Planning for re-opening the former main channel in Reach 3B was conducted concurrently with the overflow channel work described in the previous section. Prior to the start of construction, Dr. Martin and Steve McBain met with Scott McBain in the field to discuss the construction plans. Mr. Tillemans and Dr. Martin were present in the field to oversee the construction work to ensure that it was performed as planned. (See Figures 7 and 8)

Road Closures: Site locations were identified in October at the conclusion of restoration activities. Road closures were placed at the interface of the upland vegetation and the riparian area. Locations for closure were selected so that adequate room was available for either parking or turning around and to decrease the likelihood that that the closure could be circumvented. Road closures are ongoing and will be completed in areas along the creeks where vehicle/equipment access is no longer necessary. On Rush Creek, all required road closures above Highway 395 and one below were completed. On Lee Vining Creek, the only required closure was completed. (See Figures 9 and 10)

Revegetation for Walker and Parker Creeks: Planning for revegetation of Walker and Parker creeks began in the fall of 1999 with a site visit by Mr. Tillemans, Boone Kaufman, and Bill Platts. Preliminary indications were that substantial natural recruitment of willows was occurring. A follow up field visit conducted in early March by Dr. Martin and Paula Hubbard confirmed that considerable recolonization was occurring on both creeks. John Bear and Dr. Trush indicated in discussions that they had also observed considerable recolonization on the creeks. They indicated that no transplanting of willow cuttings would be necessary.

Revegetation on Rush and Lee Vining Creek: Mr. Tillemans met with the Mono Lake Committee to discuss planting Jeffrey and Lodgepole pines in the floodplain of Lee Vining Creek. After consultation, it was agreed that the planting effort would concentrate on Reach 4A of Lee Vining Creek – the reach immediately below County Road. On May 26 and June

Figure 3: Brian Tillemans and Scott McBain are surveying the berm in the upper channel of Reach 3A of Rush Creek to determine the best location and approach to opening the overflow channel. Rush Creek is on the left side of the berm.

Figure 4: Upper channel of Reach 3A looking across Rush Creek after LADWP construction crews completed the removal of berm material down to the original floodplain.

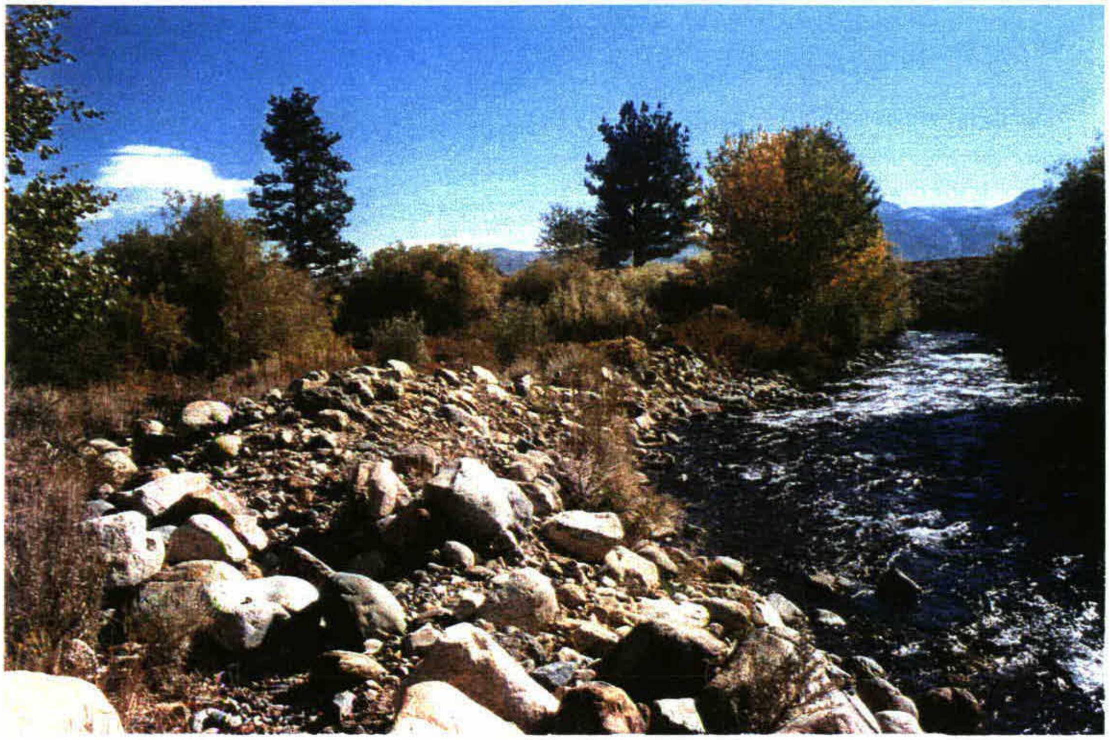


Figure 5: Looking downstream on Rush Creek; at the lower overflow channel berm in Reach 3A.

Figure 6: LADWP's backhoe removing a portion of the berm in the lower overflow channel in Reach 3A. Not shown in the photograph is Brian Tillemans supervising the work. The removal of material was completed similar to the upper berm.

Figure 7: Rewatered channel in Reach 3B of Rush Creek looking upstream. The photo was taken approximately four months (February) after the rewatering. The location is approximately 200 yards from the entrance.

Figure 8: Another view of the 3B channel taken from a different site looking upstream. Located in the center of the photograph is large woody debris placed by LADWP construction crews.

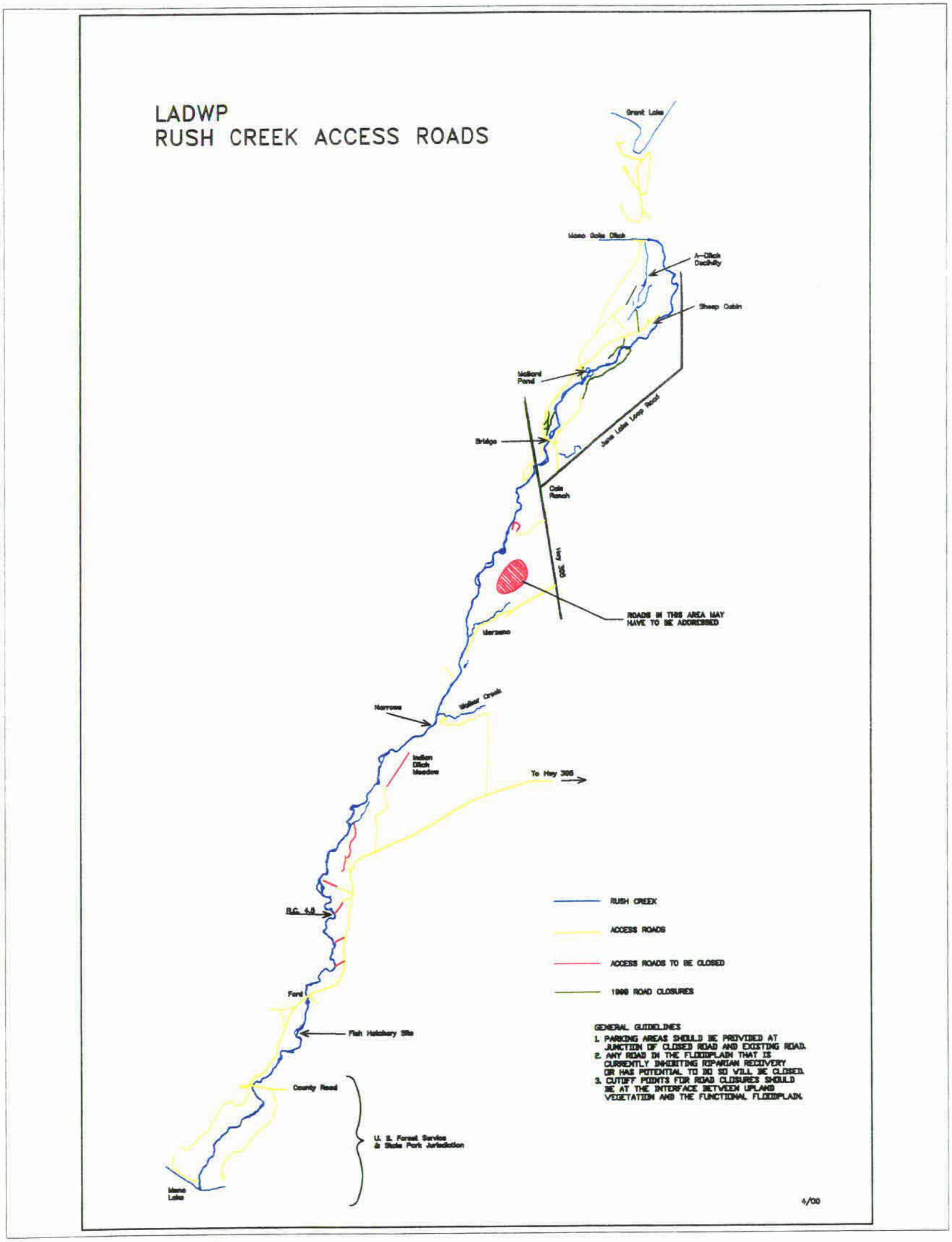


Figure 9: Location of Rush Creek road closures.

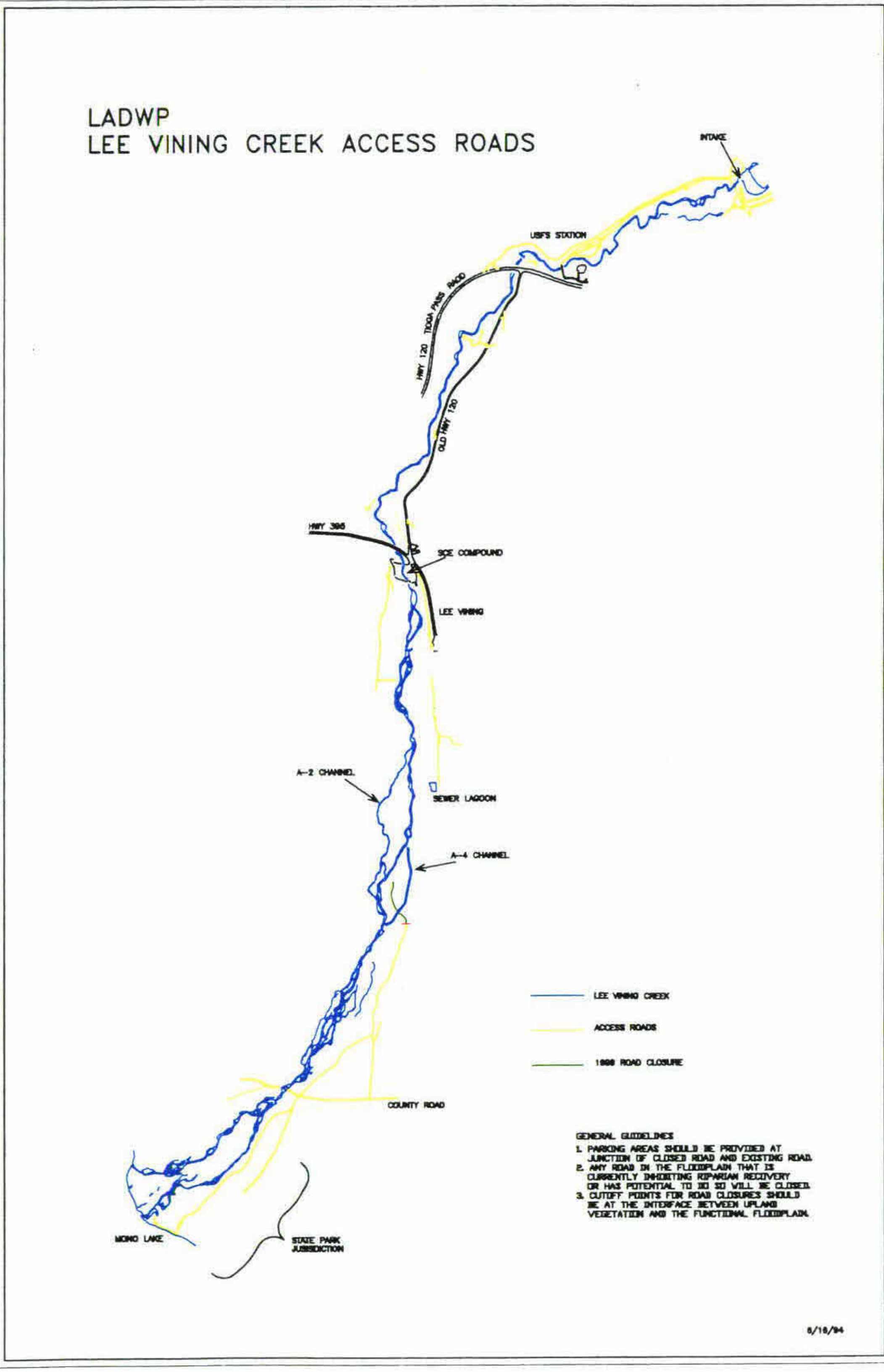


Figure 10: Location of Lee Vining Creek road closure.

7, 1999, the Mono Lake Committee planted 173 pine seedlings along Lee Vining Creek west of the main channel. Seedlings consisted of 104 Jeffrey Pine and 69 Lodgepole Pine. Mr. Tillemans chose the general location and Greg Reis (MLC) picked the specific spots. Volunteers, a class from Lee Vining Elementary School, and MLC staff planted the trees. The seedlings were donated by the USFS, grown at the Placerville nursery from seed collected locally (between Mammoth and Mono Lake). Jeffrey Pine were 2-year-old bare-root stock, Lodgepole were 3-year-old bare-root stock. (See Figure 11)

Parker Creek "Plug": Mr. Tillemans consulted with David Grah of Caltrans to develop the reclamation and restoration plan for the "Parker Plug". In particular, Mr. Tillemans reviewed and commented on Caltrans' SMARA reclamation plan focusing on reestablishment and monitoring of the riparian and floodplain vegetation. As part of Mr. Tillemans review, Dr. Trush was consulted. Grading of the site was completed in October 1999. (See Figures 12 and 13) LADWP staff also met with Caltrans' consultant, K and H Construction, to identify offsite areas for sources of willow and cottonwoods that could be used for planting. Sites were identified and cuttings were collected during the last week in March and planted during the first week of April. A field survey will be performed by LADWP's biologist this field season.

Culverts: LADWP staff met with Caltrans in June 1999 and obtained a set of construction drawings for their proposed project to widen Highway 395. In earlier communications with Caltrans, LADWP provided hydrologic records for Rush, Lee Vining, Walker and Parker creeks. The information was used to design the capacity of the culverts. Copies of the drawings were forwarded to Dr. Trush for his review.

Sediment Bypass Study: In March 1999, LADWP hired R2 Resource Consultants Inc. (R2) to analyze and design sediment bypass systems capable of bypassing sediment on a year round basis for LADWP's diversion structures on Walker Creek, Parker Creek, and Lee Vining Creek. The experts were also instructed to evaluate fish passage and the feasibility of rewatering Parker Creek and Walker Creek distributaries. R2 performed the conceptual analysis and design and prepared a report with recommendations. The report was completed in February and forwarded to the SWRCB. Copies of the report were also distributed to the parties.

Feasibility of Installing Fish Screens: LADWP and staff from DFG's Bishop office met on January 26, 2000 to discuss, among other things, the necessity of installing fish screens in the Mono Basin. At the end of the discussions, DFG concluded that fish screens are not necessary given LADWP's current operations and management practices in the Mono Basin. DFG however, reserved the right to require fish screens on irrigation diversions on Walker and Parker creeks below the Lee Vining Conduit if irrigation is to resume.

Grazing Moratorium: There was no grazing during RY 1999 on the floodplain 4 streams below the Lee Vining Conduit. The grazing moratorium is still in effect.

Irrigation Practices: No diversions occurred during the peak runoff period from Parker Creek for irrigation purposes. No irrigation occurred below the conduit.

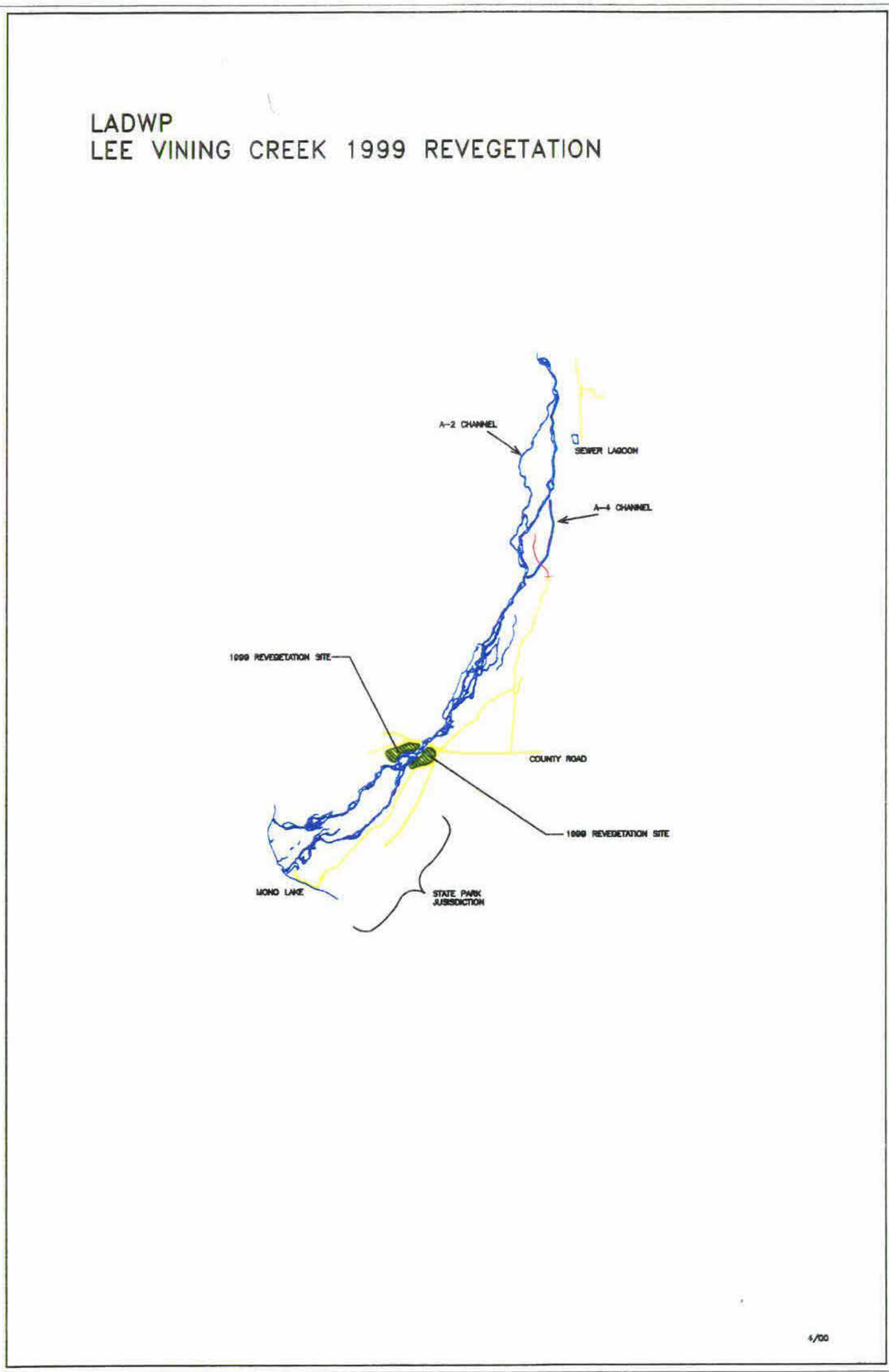


Figure 11: Location of Jeffery Pine revegetation site on lower Lee Vining Creek.

Figure 12: "Parker Plug" D8 Caterpillar grading the overburden from Caltrans' sand and gravel borrow pit.

Figure 13: Construction equipment removing overburden from the Parker Creek floodplain.

Rehabilitation of Rush Creek Return Ditch: Compliance with the California Environmental Quality Act (CEQA) and engineering and design was completed in 1998 ahead of the schedule shown in LADWP's plan. During 1999, LADWP met with DFG to address permitting issues. The permitting discussions are ongoing.

Base Flows and Stream Restoration Flows: During RY 1999, Lee Vining, Walker, and Parker creeks were maintained in "flow through" conditions and met all flow requirements. Rush Creek exceeded its base flow requirements. Since the Rush Creek Return Ditch has not yet been restored to its original capacity, LADWP provided peak flows to lower Rush creek by spilling Grant Lake reservoir. The reservoir was forced to spill to create a flow through condition when the peak occurred. The peak that occurred was 222 cfs. Exports from the basin began on July 20 after the peak had passed and continued until March 31, 2000. The rate of export ranged from 22 cfs to 40 cfs and the total export was 15,930 acre-feet.

Removal of Bags of Spawning Gravel: LADWP staff in early February opened and distributed one layer of bags (approximately 20 bags per layer) containing spawning gravel into Lee Vining Creek.

Web Page: Construction began on LADWP's Web Page to display Mono Basin hydrologic data. LADWP contracted with Beavins Systems and Psomas to assist LADWP in constructing the Web site.

2.1.2 Waterfowl

In 1999, LADWP initiated its waterfowl habitat restoration program. The following is a summary of activities and changes:

- Monitored Mono Lake elevation;
- Implemented a prescribed burn program; and
- Established vegetation transects.

Mono Lake: Mono Lake elevation was monitored on a weekly basis. There was very little change in Mono Lake's elevation. The lake elevation during 1999 ranged from 6,384.1 to 6,385.1 msl. On April 1, 1999 the elevation was 6,384.8 and on March 31, 2000 the elevation was 6,384.5 msl. The average surface area during 1999, based on the Pelagos Corp. 1986 bathymetric study, was approximately 72 sq. miles or 46,000 acres. The average salinity based on Jones & Stokes 1993 Mono Basin EIR was approximately 75 g/l. Salinity levels measured by UC Santa Barbara differed from the average in that the salinity levels are measured at several elevations and the lake is currently meromictic.

Prescribed burn program: During 1999, LADWP began development of its prescribed burn program for the Mono Basin. It involved identifying a suitable site for implementing the burn, developing a vegetation management plan, establishing transects, and taking inventory. The northern section of Warm Springs was selected and a burn is has been planned for early 2001. The California Department of Forestry has agreed to participate. Transects have been established and a vegetation inventory completed. A waterfowl survey was also conducted to document use and to establish baseline data.

Vegetation transects: Vegetation transects were established at Simon Spring, Warm Spring, DeChambeau Embayment, and the deltas of Rush and Lee Vining creeks. Base line data was collected and summarized in a report entitled "1999 Mono Lake Vegetation". The report can be found as an Appendix to the 1999 Waterfowl Habitat Restoration and Monitoring report.

2.2. Monitoring

2.2.1 Stream Channel

Contract and Scope of Work: In March 1999, LADWP contracted with Dr. Trush (McBain and Trush) to perform the stream channel monitoring program to monitor Rush, Lee Vining, Walker, and Parker creeks. A Scope of Work was developed to comply with the requirements of SWRCB Order No 98-07.

Monitoring and Reporting: McBain and Trush continued their monitoring program developed in RY 1997 and 1998 following the White and Blue book principles. There were three new planmap sites developed in 1999 – lower Rush Creek between the Ford crossing and County Road; Walker Creek between Highway 395 and the Lee Vining conduit; and Parker Creek between Highway 395 and the Lee Vining conduit. All planmap sites have been established per the White and Blue books. There are 3 sites on Rush Creek, 2 sites on Lee Vining Creek, 1 site on Walker Creek and 1 site on Parker Creeks. A report was prepared detailing the monitoring activities and requirements. The report is included in Section 4 of Compliance Reporting.

Reporting: A report entitled "Monitoring Summary for WY1997 and WY1998 for Rush Creek and Lee Vining Creek" was forwarded to the SWRCB in May 1999 describing the proposed operations and restoration and monitoring activities for 1999 and included a summary of the 1997 and 1998 stream monitoring. In addition, the report included recommendations for changes to the monitoring program, annual operations plan, and proposed stream restoration. (Note: The report title identifies the monitoring period as WY 1997 and WY 1998, although it covers the April to March period. Traditionally, the April to March period is called Runoff Year, whereas Water year refers to the October to September period.

2.2.2 Fishery

Contract and Scope of Work: In March 1999, LADWP contracted with Chris Hunter to perform fish population surveys on monitor Rush, Lee Vining, Walker, and Parker creeks. A Scope of Work was developed to comply with the requirements of SWRCB Order No. 98-07.

Monitoring and Reporting: Mr. Hunter continued the monitoring program developed in RY 1997 and 1998 following the White and Blue book principles. In addition to surveying the 4 planmap sites on Rush and Lee Vining creeks, Mr. Hunter also surveyed the 3 new planmap sites described above in the Stream Channel section. A report has been prepared detailing the fish population surveys and monitoring requirements.

Reporting: A summary of the fish population surveys and protocol were included in the report entitled "Monitoring Summary for WY1997 and WY1998 for Rush Creek and Lee Vining Creek".

2.2.3 Waterfowl

Contract and Scope of Work: In March 1999, LADWP hired David Chapin of R2 Resource Consultants Inc. and Don Paul to oversee the waterfowl restoration and monitoring program. A Scope of Work was developed to comply with the requirements of SWRCB Order Nos. 98-05.

Oversight of the Monitoring Program: During 1999, Dr. Chapin and Mr. Paul met with the researchers responsible for collecting data in the Mono Basin. Most of the meetings were in the field and included, in some cases, observing and/or participating with the researchers in collecting data. Dr. Chapin and Mr. Paul also had many phone conversations with the researchers. In addition, they reviewed historical data and reports.

Monitoring in the Mono Basin: During 1999, LADWP renewed the Mono Basin monitoring contracts with the following consultants to collect data as required by Order No. 98-05:

- UC Santa Barbara (John Melack and Robert Jellison) for monitoring limnology and secondary producers at Mono Lake; and
- Hubbs-Sea World Institute (Joseph Jehl) for waterfowl population survey at Mono Lake.

LADWP also contracted with I. K. Curtis Inc. and AirPhoto USA to provide aerial photography services to produce GIS compatible aerial photograph of the Mono Basin with a scale of 1:3,600 or 1 inch = 300 feet.

In addition, LADWP personnel collected hydrology data for the four streams and Mono Lake, performed a spring survey around the lake, and collected vegetation data in the lake fringing wetlands and stream deltas.

2.3. Informational Meetings

The LADWP sponsored two meetings during 1999 to provide an opportunity the experts and interested persons to present and discuss restoration and monitoring activities, hydrology and other issues related to the Mono Basin. The first was a two-day meeting held on April 19th and 20th in Sacramento and in the Mono Basin, respectively. The second meeting was held on November 16th in Sacramento.

April Meeting: This meeting provided an opportunity for the stream monitoring experts to present their 1997-98 monitoring activities and discuss their proposed 1999 scope of work. The meeting also provided an opportunity to introduce Mike Ramey, Dudley Reiser, and Dr. Chapin of R2 Resource Consultants Inc. and Mr. Paul. In addition, the 1999 runoff forecast was discussed.

Attendees in addition to LADWP personnel included the following: Experts – Dr. Trush, Mr. Hunter, Mr. Ramey, Dr. Reiser, Dr. Chapin, and Mr. Paul. Interested persons – Heidi Hopkins (MLC), Peter Vorster (MLC), Gary Smith (DFG), and Roger Porter (USFS).

November Meeting: This meeting provided an opportunity for the stream monitoring experts, waterfowl experts overseeing the waterfowl habitat monitoring program, and experts studying sediment bypass to present and discuss their 1999 activities. The meeting also provided an opportunity to provide an overview of the runoff recap for 1999.

Attendees in addition to LADWP personnel included the following: Experts – Dr. Trush, Mr. Hunter, Mr. Ramey, Dr. Reiser, Dr. Chapin, and Mr. Paul. Interested persons – Ms. Hopkins (MLC), Mr. Vorster (MLC), Mr. Reis (MLC), Mr. Smith (DFG), Jim Edmondson via conference call (CalTrout), and Jim Canaday (SWRCB).

3. ACTIVITIES PLANNED FOR RUNOFF YEAR 2000

3.1 Restoration

3.1.1 Streams

Permits and Approvals: LADWP will obtain the necessary permits and approvals from the Water Quality Control Board, Army Corp of Engineers, and from DFG. Environmental documents will be prepared to comply with the requirements of the California Environmental Act.

Channel Rewatering: In Reach 3D plans will be developed to restore the abandoned east side channel as the new main channel. No additional channel rewatering is contemplated for Rush Creek until Dr. Trush completes his evaluation on the effects of channel rewatering on the restoration process.

Revegetation: There are no plans this season for planting Jeffery pines on Lee Vining or Rush Creek. If the opportunity arises to plant Jeffery pines, LADWP will coordinate with the Mono Lake Committee.

Road Closures: There are no plans this season to close roads in the floodplain of Rush Creek. The remaining roads will be left open until restoration activities are completed. There are still needs to bring in equipment to some of the restoration sites.

Bags of Spawning Gravel: LADWP will distribute bags of gravel into Lee Vining Creek from the bags located immediately upstream of the old diversion dam.

Coordinate with Caltrans: LADWP will continue monitoring Caltrans progress on the installation of new culverts during the highway widening project, and the "Parker Plug" to ensure restoration and monitoring activities are proceeding as planned.

Return Ditch: LADWP will continue its discussions with DFG on the rehabilitation of the Return Ditch. If an agreement can be reached in the immediate future, LADWP will make every effort to complete the necessary work this season.

Web Page: Work continues on the development of the Web Page with the anticipation of having the site completed in RY 2000.

Sediment Bypass: LADWP will advise the Chief of the Division of Water Rights SWRCB by July 1st, 2000 which sediment passage it will construct.

3.1.2 Waterfowl

Prescribed Burn Program: In 1999, LADWP initiated a monitoring program to collect data for a control burn in the Warm Springs area. Transects were established and vegetation and wildlife was documented. This season LADWP will continue to monitor the site with plans to burn in January 2001.

Channel Rewatering: There are no plans to rewater the channels described in the waterfowl plan until Dr. Trush completes his evaluation on the effects of rewatering distributaries on the restoration of the stream system.

3.2 Monitoring

3.2.1 Streams

Dr. Trush will continue the monitoring program on Rush, Lee Vining, Walker, and Parker creeks. LADWP is currently processing an amendment to their contract, which would allow McBain and Trush to continue their work in the Mono Basin for three more years.

3.2.2 Fishery

Mr. Hunter will continue the fish population monitoring program on Rush, Lee Vining, Walker, and Parker creeks. LADWP is currently processing an amendment to Mr. Hunter's contract, which would allow Mr. Hunter to continue his work in the Mono Basin for three more years.

3.3.3 Waterfowl

Expert: Due to contractual issues, LADWP had to terminate contracts with Dr. Chapin and Mr. Paul. LADWP will be selecting a new expert(s) to oversee the waterfowl-monitoring program.

Limnology: LADWP is currently processing an amendment to UC Santa Barbara contract to allow Dr. Jellison and Dr. Melack to continue limnological monitoring in the Mono Basin for another three years.

Waterfowl Population Surveys: LADWP is currently processing an amendment to Hubbs-Sea World Institute contract to allow Dr. Jehl to continue waterfowl population surveys in the Mono Basin for another three years.

Aerial photography: LADWP is currently processing an Agreement with I. K. Curtis Inc., to provide aerial photography of the Mono Basin in a GIS compatible format.

Hydrology: LADWP will continue to monitor the elevation of Mono Lake and to collect hydrologic data in the Mono Basin.

3.3. Informational Meetings

Semi-annual Meetings: LADWP will host two meetings with the researchers and interested parties to discuss restoration and monitoring activities in the Mono Basin. As in previous years, the meetings will be held prior to and after the field season. The first meeting has been scheduled for April 27, 2000.

2

Mono Basin Operations for Runoff Year 2000-2001 - Preliminary

The April 1, 2000 Mono Basin forecast for the runoff[1] 2000-01 Runoff Year is 115,000 acre-feet or 94% of normal[2]. This year is a "normal" year, as defined by the State Water Resources Control Board (SWRCB) Order No. 98-05year-type designations. The Operation Plan based on the April 1st forecast is preliminary. The operations plan will be finalized once the May 1st forecast has been calculated. Unless there is a substantial difference, the Los Angeles Department of Water and Power (Department) will not submit a revised operations plan.

To meet the flow requirements of the SWRCB Order No. 98-05, the Department intends to follow "Planning Guideline D" (attached). Since the Mono Gate Return Ditch has not yet been rehabilitated to its design capacity of approximately 380 cfs, the Department will operate Grant Lake as flow-through with the intent of allowing the impaired peak flows to pass downstream of Grant Lake unimpeded. The Department will commence export operations from the basin after the peak flows in Rush Creek have occurred. This should ensure Grant Lake will be full and spilling when peak flows are occurring. The Department anticipates exporting its full entitlement at a constant rate after peak flows have passed.

A copy of the Statistical Summary output of the Grant Lake Operations Model (GLOM) is also attached. This summarizes the "educated guess" of distribution of monthly flows in the Mono Basin streams and Department facilities for the 2000-01 Runoff Year. These flows do not represent minimum or maximum flows, or target any kind: they merely provide a possible scenario of the flow distribution in the basin, assuming climatic conditions, subsequent to the forecast date, are average. The actual flows will likely be different.

The values of expected magnitude and timing of the peak flows in Rush, Lee Vining, Walker and Parker creeks were generated by a predictive model, and are as follows:

	Peak Flow Magnitude (cfs)	Timing
Rush Creek @ Damsite	222	June 10
Parker Creek above Conduit	47	June 18
Walker Creek above Conduit	35	June 13
Lee Vining Creek	245	June 6

1 Based on the April 1, 2000 runoff forecast.
2 Using the 1941-1990 average of 122,124 acre-feet.

The model uses regression analysis of historical data to predict future events. Since the actual values depend heavily on ambient temperatures that are difficult to accurately predict with any degree of certainty, it is more than likely that the values in the above table are not accurate. It is intended that they be used as an indicator of magnitude and timing of the peak flows. These predictions are based on the April 1, 2000 forecast, and assume median precipitation for the following six months.

On April 1, 2000, Mono Lake's water surface elevation measured 6,384.5-ft. amsl and storage in Grant Lake Reservoir was 36,691 acre-feet (77% of capacity). Given the most current forecast, and the proposed operations guideline, the elevation of Mono Lake is expected to be approximately 6385.2-ft. amsl at the end of the runoff year. This is graphically shown in the attached "Historical and Projected Mono Lake Elevation" graph. The estimate is derived from modeling, and includes a number of assumptions such as normal precipitation conditions for the remainder of the year. As such, the estimate is to be used only as a general indicator.

Grant Lake Operations Model - Statistical Summaries

2000 Runoff Year: Normal

Daily Flows

	Lee Vin. Creek Above Intake	Walker Creek Above Conduit	Parker Creek Above Conduit	Rush Creek @ Damsite	Lee Vin. Creek Release	Lee Vin. Conduit Diver.	Lower Walker Parker Flow	Lower Rush Cr. Release	Rush C. Bottom land Flow	Grant Lake Storage	Grant Lake Outflow	Grant Lake Spill	Mono Basin Export	Owens River Abv. E. Portal	Owens River Blw. E. Portal
	cubic feet/second									ac-ft	cubic feet/second				
Start										36,691					
Min	16	2	3	28	16	0	6	36	42	36,320	49	0	0	47	80
Ave	69	8	12	81	69	0	20	59	78	43,214	67	13	22	72	111
Max	318	40	58	255	318	0	96	193	253	47,580	90	144	44	139	156
End										38,380					

Monthly Average Flows

cubic feet/second	Lee Vin. Creek Above Intake	Walker Creek Above Conduit	Parker Creek Above Conduit	Rush Creek @ Damsite	Lee Vin. Creek Release	Lee Vin. Conduit Diver.	Lower Walker Parker Flow	Lower Rush Cr. Release	Rush C. Bottom land Flow	Grant Lake Storage (1st of Month)	Grant Lake Outflow	Grant Lake Spill	Mono Basin Export	Owens River Abv. E. Portal	Owens River Blw. E. Portal
Apr	29	4	5	53	29	0	9	49	58	36,691	59	0	11	66	93
May	106	7	17	116	106	0	24	49	73	36,750	49	0	0	82	99
Jun	219	27	38	203	219	0	66	98	164	41,350	49	49	0	121	138
Jul	106	18	27	142	106	0	45	135	180	47,580	49	86	0	93	110
Aug	36	8	12	105	36	0	19	71	90	47,580	81	22	32	81	130
Sep	37	6	12	58	37	0	18	48	66	47,580	76	4	32	81	130
Oct	26	9	7	61	26	0	16	44	60	46,100	76	0	32	67	116
Nov	39	5	6	52	39	0	11	44	55	45,050	76	0	32	55	104
Dec	72	3	4	56	72	0	8	44	52	43,840	76	0	32	56	105
Jan	60	3	4	49	60	0	7	44	51	42,850	76	0	32	55	104
Feb	50	3	4	42	50	0	7	42	49	41,470	74	0	32	54	103
Mar	51	3	4	36	51	0	7	36	43	39,970	67	0	31	53	101

Monthly Total Flows

acre-feet	Lee Vin. Creek Above Intake	Walker Creek Above Conduit	Parker Creek Above Conduit	Rush Creek @ Damsite	Lee Vin. Creek Release	Lee Vin. Conduit Diver.	Lower Walker Parker Flow	Lower Rush Cr. Release	Rush C. Bottom land Flow	Grant Lake Storage (Average)	Grant Lake Outflow	Grant Lake Spill	Mono Basin Export	Owens River Abv. E. Portal	Owens River Blw. E. Portal
Apr	1,715	216	317	3,169	1,715	0	533	2,890	3,423	36,508	3,531	0	641	3,905	5,557
May	6,490	450	1,043	7,143	6,490	0	1,494	3,013	4,506	38,246	3,013	0	0	5,035	6,081
Jun	13,054	1,627	2,280	12,078	13,054	0	3,907	5,833	9,740	45,639	2,916	2,917	0	7,177	8,188
Jul	6,508	1,110	1,642	8,709	6,508	0	2,752	8,310	11,062	47,580	3,013	5,297	0	5,724	6,769
Aug	2,228	470	714	6,447	2,228	0	1,184	4,351	5,535	47,580	4,981	1,338	1,968	4,956	7,969
Sep	2,192	366	728	3,468	2,192	0	1,094	2,832	3,926	47,092	4,522	214	1,904	4,832	7,747
Oct	1,580	554	412	3,774	1,580	0	966	2,705	3,671	45,456	4,673	0	1,968	4,129	7,142
Nov	2,311	313	348	3,068	2,311	0	661	2,618	3,279	44,486	4,522	0	1,904	3,272	6,188
Dec	4,409	213	271	3,448	4,409	0	484	2,705	3,190	43,527	4,673	0	1,968	3,413	6,426
Jan	3,689	179	252	2,997	3,689	0	430	2,705	3,136	42,180	4,673	0	1,968	3,362	6,375
Feb	2,777	159	215	2,315	2,777	0	373	2,333	2,706	40,775	4,110	0	1,777	2,992	5,713
Mar	3,115	173	250	2,195	3,115	0	423	2,214	2,637	39,264	4,116	0	1,902	3,286	6,233
Apr-Sep	32,188	4,239	6,724	41,014	32,188	0	10,964	27,229	38,192		21,975	9,766	4,512	31,628	42,311
Oct-Mar	17,881	1,590	1,747	17,798	17,881	0	3,337	15,281	18,618		26,767	0	11,486	20,453	38,077
Annual Total	50,069	5,829	8,471	58,812	50,069	0	14,300	42,510	56,810		48,742	9,766	15,999	52,081	80,387

Table 2

STATE WATER RESOURCES CONTROL BOARD
ORDER NO. 98-05 GUIDELINES

Hydrologic Year Type: Normal
Forecasted Volume of Runoff (acre-feet): 100,750 < - ≤ 130,670

LOWER RUSH CREEK

Instream Flows:

	Apr	May-Jul	Aug-Sept	Oct-Mar
Flow (cfs)	50	75	50	45

Minimum base flows are 47 cfs for the April through September period and 44 cfs for the October through March period, or the inflow to Grant Lake reservoir, whichever is less. If the inflow is less than the dry-year instream flow requirements, then dry year base flow requirements apply.

Stream Restoration Flows: 380 cfs for 5 days followed by 300 cfs for 7 days

- Begin ramping stream restoration flows on June 1.
- Ramping rate: 10% change ascending and descending, or 10-cfs incremental change, whichever is greater.

LEE VINING CREEK

Instream Flows:

	Apr-Sept	Oct-Mar
Flow (cfs)	54	40

Minimum base flows are those specified above or the stream flow at the point of diversion, whichever is less.

Stream Restoration Flows: Allow peak flow to pass point of diversion

- Begin ramping for stream restoration flows on May 15.
- Ramping rate: 20% change ascending and 15% change descending, or 10 cfs incremental change, whichever is greater.

Lee Vining Conduit Diversions:

- Divert flows in excess of base flows until May 15.
- Diversions may resume 15 days after peak flow.

WALKER AND PARKER CREEKS

Instream Flows:

	Apr-Sept	Oct-Mar
Parker Creek (cfs)	9	6
Walker Creek (cfs)	6	4.5

Minimum base flows are those specified above or the stream flow at the point of diversion, whichever is less.

Stream Restoration Flows: Allow peak flow to pass point of diversion

Lee Vining Conduit Diversions: None

MONO BASIN EXPORTS Start exports of 33 cfs after peak flows have passed. It is anticipated that would occur August 1st.

Figure 1

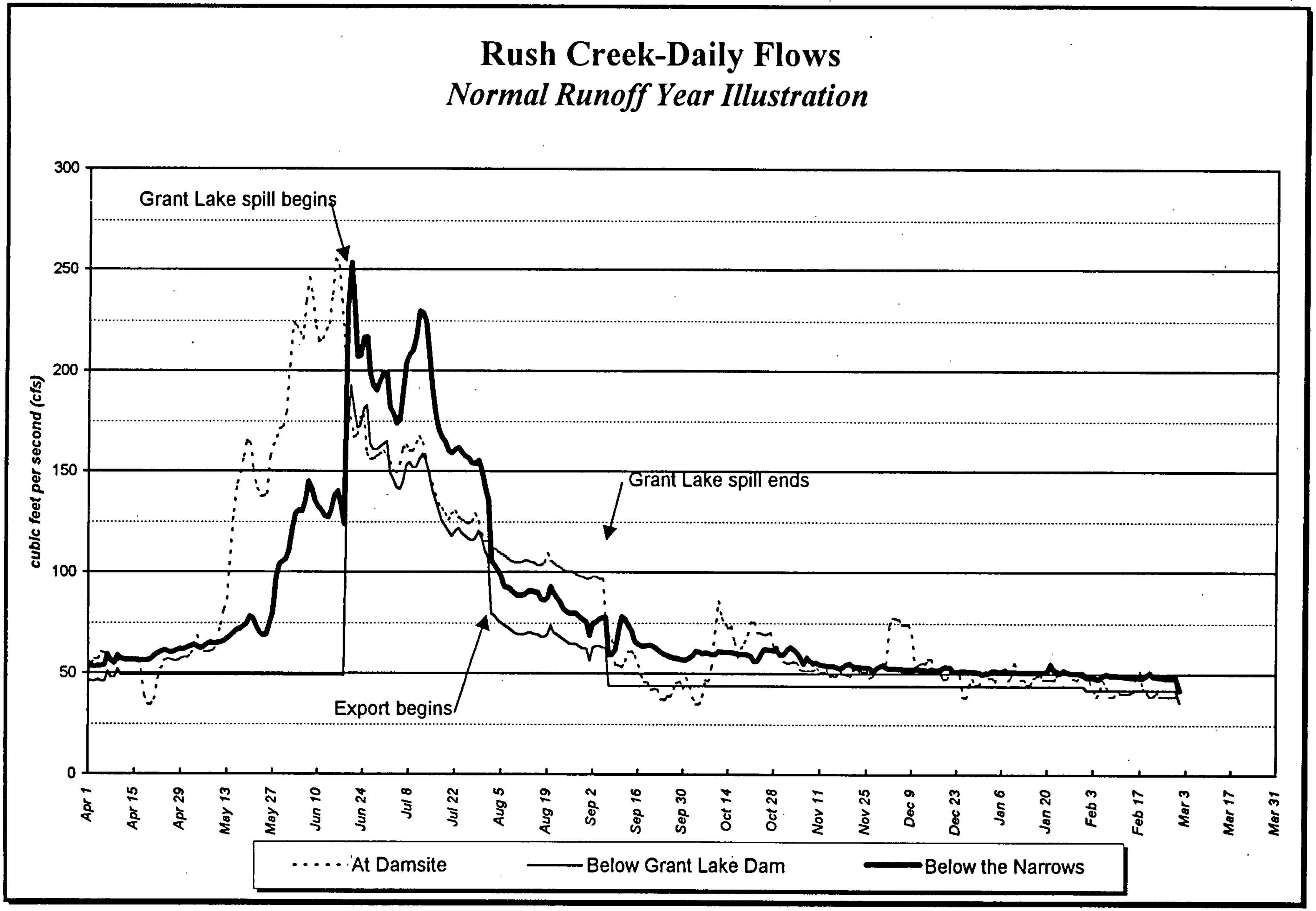


Figure 2

April, 2000

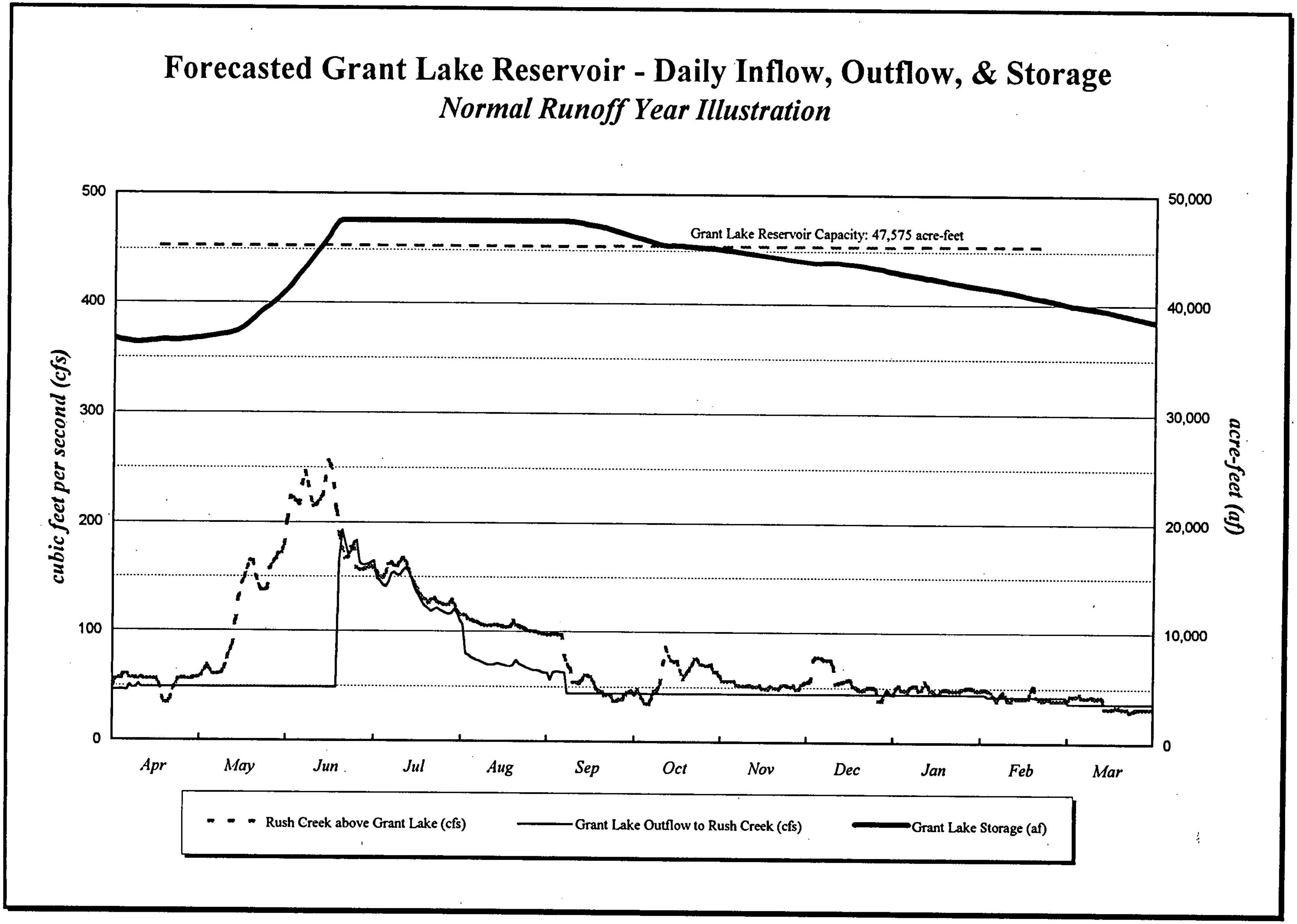
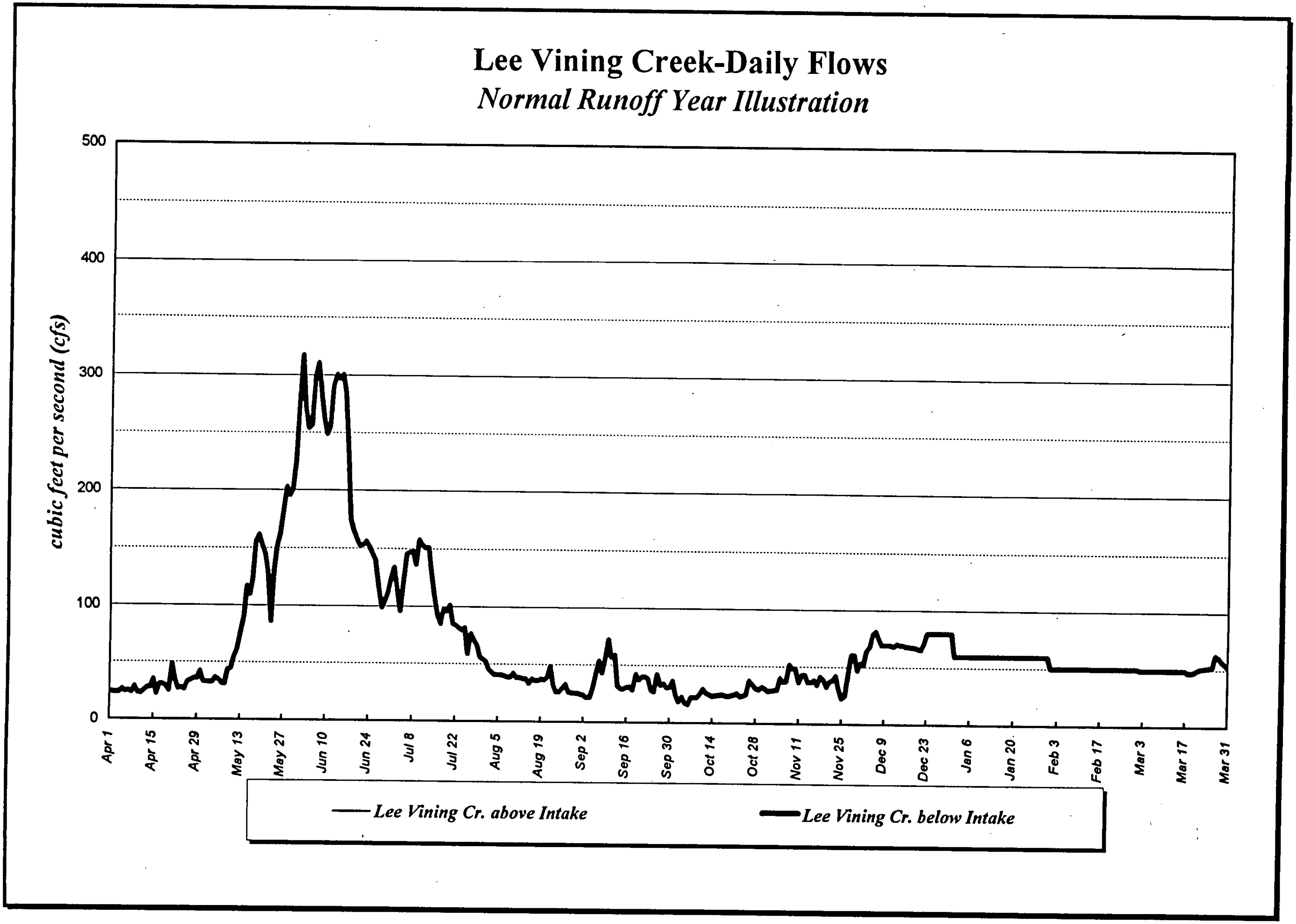


Figure 3

April, 2000



Lee Vining Creek-Daily Flows
Normal Runoff Year Illustration
cubic feet per second (cfs)
500
400
300
200
100
0
Apr 1
Apr 15
Apr 29
May 13
May 27
Jun 10
Jun 24
Jul 8
Jul 22
Aug 5
Aug 19
Sep 2
Sep 16
Sep 30
Oct 14
Oct 28
Nov 11
Nov 25
Dec 9
Dec 23
Jan 6
Jan 20
Feb 3
Feb 17
Mar 3
Mar 17
Mar 31
Lee Vining Cr. above Intake
Lee Vining Cr. below Intake

Figure 4

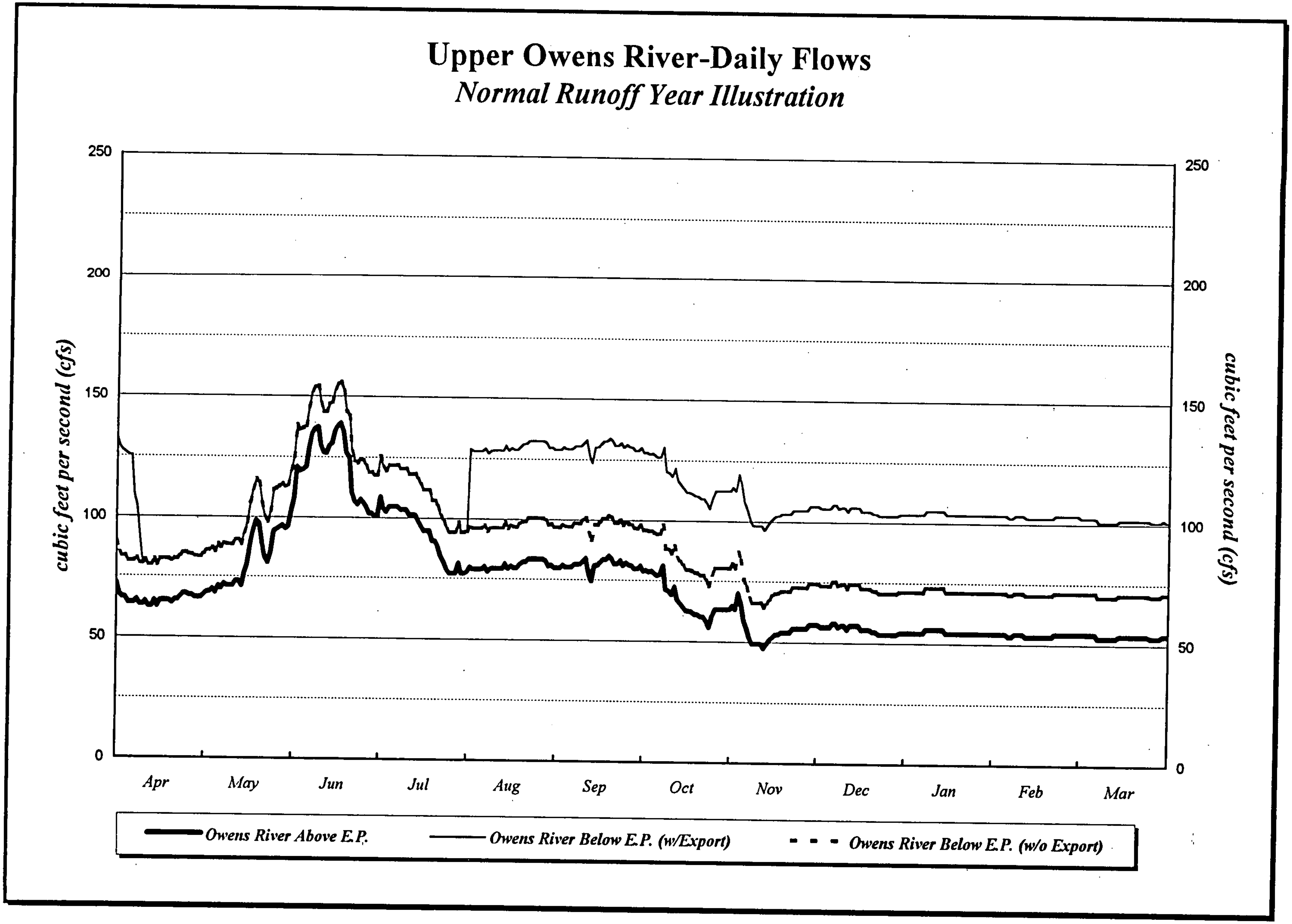
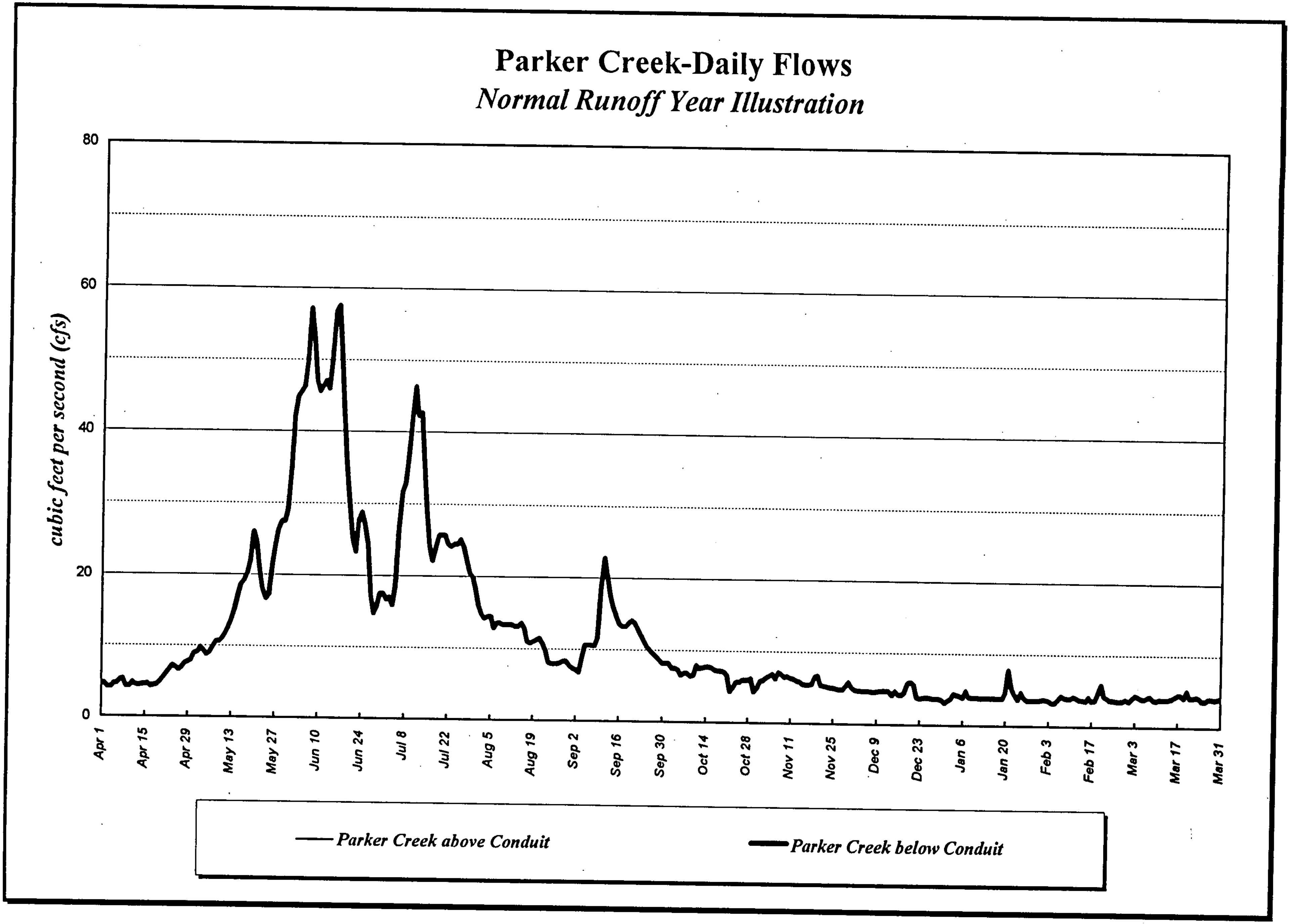


Figure 5

April, 2000



Parker Creek-Daily Flows
Normal Runoff Year Illustration
cubic feet per second (cfs)
80
60
40
20
0
Apr 1
Apr 15
Apr 29
May 13
May 27
Jun 10
Jun 24
Jul 8
Jul 22
Aug 5
Aug 19
Sep 2
Sep 16
Sep 30
Oct 14
Oct 28
Nov 11
Nov 25
Dec 9
Dec 23
Jan 6
Jan 20
Feb 3
Feb 17
Mar 3
Mar 17
Mar 31
Parker Creek above Conduit
Parker Creek below Conduit

Figure 6

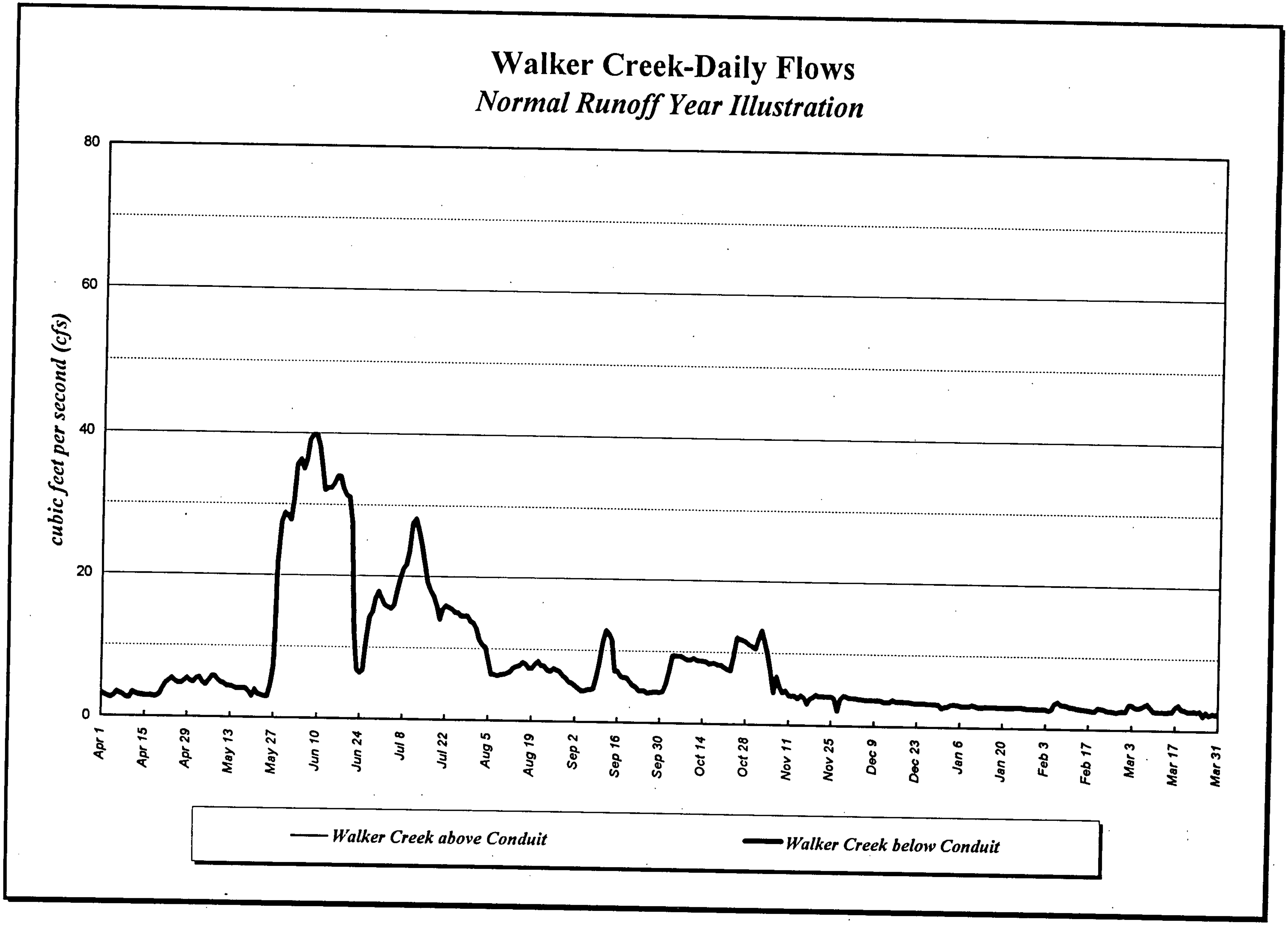

Walker Creek-Daily Flows
Normal Runoff Year Illustration
cubic feet per second (cfs)
80
60
40
20
0
Apr 1
Apr 15
Apr 29
May 13
May 27
Jun 10
Jun 24
Jul 8
Jul 22
Aug 5
Aug 19
Sep 2
Sep 16
Sep 30
Oct 14
Oct 28
Nov 11
Nov 25
Dec 9
Dec 23
Jan 6
Jan 20
Feb 3
Feb 17
Mar 3
Mar 17
Mar 31
Walker Creek above Conduit
Walker Creek below Conduit

Figure 7

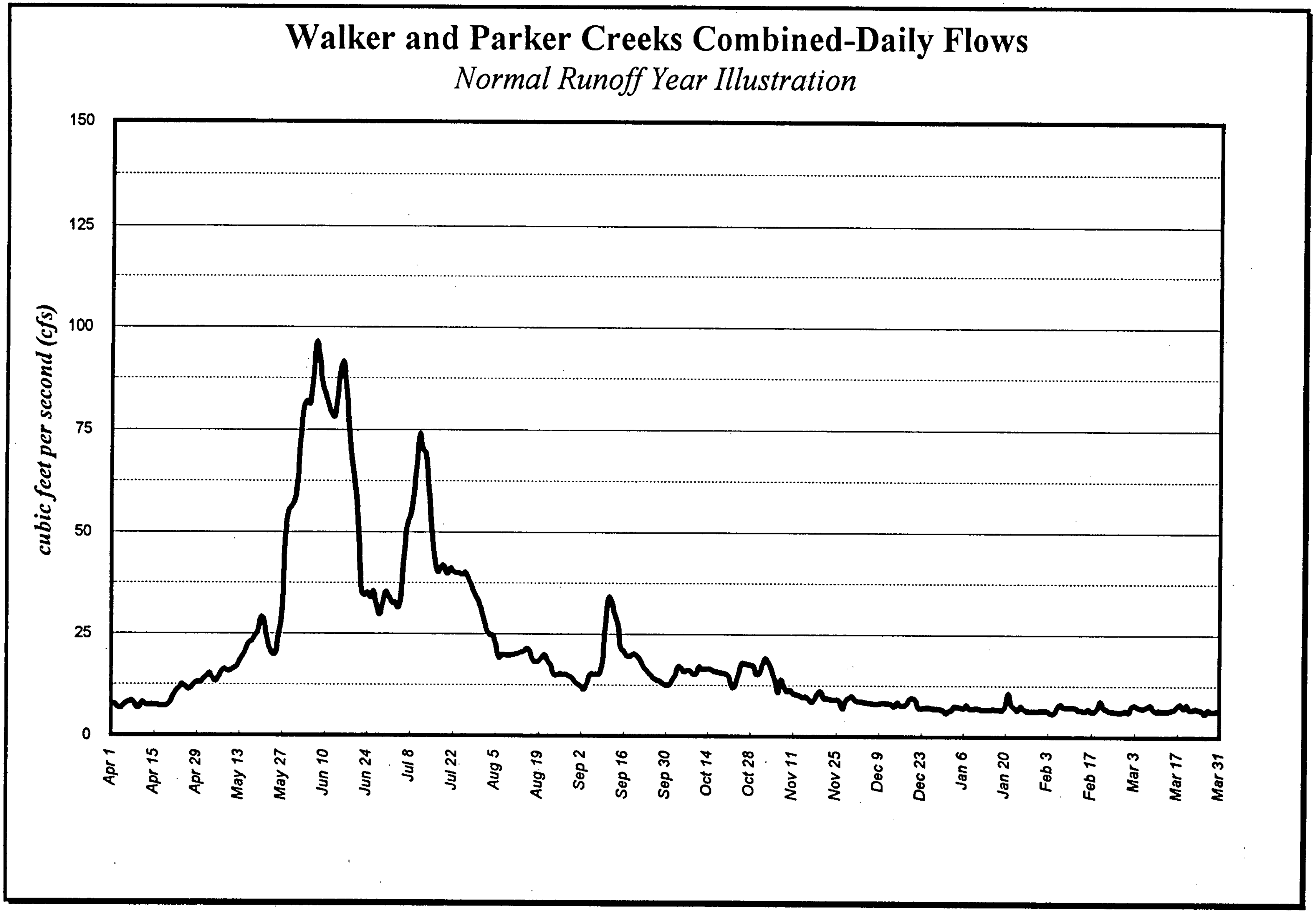
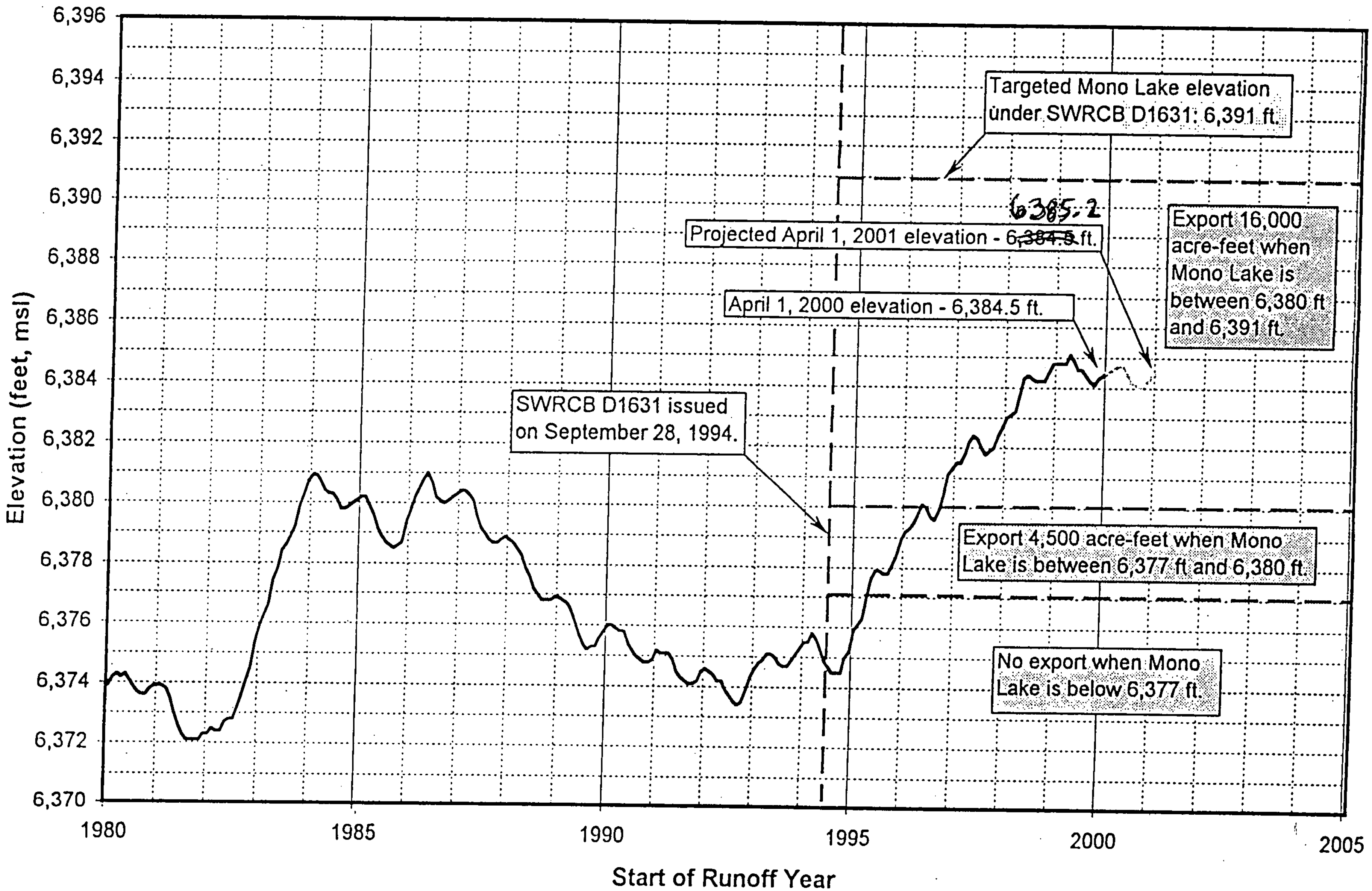


Figure 8

April, 2000

Mono Lake Elevation and Transition Period Exports



Note: The time until the Mono Lake elevation reaches 6,391 ft is called the "Transition Period". Export rules change at the end of that interval.
*Based on Runoff Forecast Model developed in 1993.

4/14/00 by Simon Hsu
Mono Lake Elevation.xls

Figure 9

3

4

Monitoring Results and Analyses for Water Year 1999: Lee Vining, Rush, Walker and Parker Creeks

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Pursuant to State Water Resource Control Board Decision 1631

April 6, 2000

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The river, then, is the carpenter of its own edifice.

Luna Leopold
1994

Introduction

A monitoring team was designated in SWRCB Order 98-05 to oversee implementation of a stream monitoring program. Purposes of this report are to: (1) present ongoing monitoring data collected in WY1999, (2) evaluate the termination criteria and recommend changes, additions, and/or deletions to the termination criteria, (3) determine whether termination criteria are needed for Parker Creek and Walker Creek, and (4) propose channel projects for WY2000 as stated in the Mono Basin Plan (LADWP 1996). Results from the WY1999 monitoring year will be presented first, followed by analyses of the termination criteria, and ending with proposed channel projects for WY2000.

WY1999 Monitoring Results

Introduction

WY1999 monitoring is the first complete year of monitoring as stipulated in SWRCB Order 98-05. Previous monitoring by LADWP in WY1997 and WY1998 (McBain&Trush and Hunter 1999) has generated important data on fluvial processes and served as a pilot study to refine sampling methodologies. Field methods employed in WY1999 are described in McBain&Trush and Hunter (1999). Changes and new/modified sampling locations are addressed within appropriate topic headings of this report.

New Sample Sites

In addition to four previously established study sites (first created in WY1997 or WY1998), we developed three new study sites along Walker, Parker, and Rush creeks in the summer of WY1999 (Figure 1). Concrete benchmarks with aluminum caps were installed at each. Monitoring consisted of cross sections, thalweg profile surveys, and planmapping. The Rush Creek study site is located between the County Road Ford and Test Station Road. The Walker and Parker Creek sites are located between the LADWP diversion structures and old Highway 395 (Figure 1). Each new study site extends at least two meander wavelengths and was monitored following established protocols (McBain &Trush and Hunter 1999; Harrelson et al 1994). Parker Creek was not planmapped (due to a problem with aerial photos, now corrected); a planmap will be made this summer.

Aerial Photography

With the exception of topographic work in 1991, previous field investigations on tributaries to Mono Lake have not established monitoring sites and cross sections under a standardized coordinate system. The intent of a "coordinate system" as applied to Mono Lake tributary investigations is to report all pertinent field data referenced to non-changing X, Y, and Z coordinates. For example, a given cross section headpin (and there are hundreds of them along the streams) currently has no coordinates, and with the exception of the memory of the person that installed or surveyed that headpin, no one else knows where it is. If that same headpin was accurately surveyed using an established coordinate system (say X=105239.96 ft, Y=658147.34 ft, Z=6257.76 ft), future surveys using accurate techniques (e.g., survey grade GPS or total stations) can locate and resurvey the cross section, allowing a precise comparison. Unfortunately, all horizontal coordinates (if used at all) and elevations used by most investigators to date have been arbitrary (no X,Y coordinates used, and arbitrary Z elevation used, e.g., 100.00 ft). Additionally, naming systems for cross sections and reaches have not been based on systematic referencing.

Cumulatively, this has caused great confusion in locating oneself, made it virtually impossible to compare data and trends over the years without a complex re-occupation and conversion of coordinate systems, and has resulted in inefficient use of resources and potential loss of valuable information. Standardization of coordinate systems and longitudinal stationing along streams were needed. Initiation of monitoring after the Water Board's final decision was the logical time to begin this transition. LADWP initiated this process by contracting a high altitude aerial photo flight to create an orthorectified air photo mosaic of Mono Lake and its tributaries. This air photo would be based on NAD 1927 for horizontal control (X and Y coordinates), and NAVD 1929 for vertical control (Z coordinate). There are three primary uses of these air photos: (1) provide an air photo base map with standardized coordinate system, (2) accurately document existing planform morphology and channel location, and (3) accurately document future evolution in planform morphology and channel location. However, the high altitude of this flight did not provide sufficient scale for our detailed field investigations, so we initiated a separate but lower altitude flight that would provide higher quality photographs of Rush, Lee Vining, Walker, and Parker creeks.

In 1998, we documented channel planform location and thalweg profiles without using a standardized coordinate system. Planform maps were constructed using tapes and compass; thalweg profiles used these planform maps and tapes to locate survey points, the elevation of which was measured with an engineers level. While these planform maps and thalweg profiles provided substantial detail, the compass and tape method for documenting location propagates significant horizontal error. In addition, concrete benchmarks installed at all sites were assigned arbitrary elevations of 100.00 ft; thalweg survey elevations were based on this arbitrary datum rather than on an established datum based on mean sea level. The State Water Resources Control Board's final decision, the availability of LADWP surveyors, and the pending aerial photographs presented the opportunity to standardize all monitoring data to a common coordinate system and datum.

Low altitude aerial photographs for Lee Vining, Rush, Parker, and Walker creeks were flown from their mouths' upstream to the LADWP diversion. Contract prints (and negatives) were produced at a 1"= 300' scale for the entire length of the four streams. Because Walker Creek and Parker Creek are much smaller than the others, 1"= 175' spot photos were taken at our detailed study sites on those two creeks. The 1"= 300' scale photos containing our detailed study sites on Lee Vining Creek and Rush Creek were enlarged to a scale of 1"= 30'; the 1"= 175' scale spot photos on Parker Creek and Walker Creek were enlarged to 1"= 20'. These contact prints and enlargements needed to be rubbersheeted or orthorectified to use in planmapping. Rubbersheeting is a process that removes much of the air photo distortion in two dimensions by differential "stretching" of the image to established ground control points, while orthorectifying removes much of the air photo distortion in three dimensions by stretching to control points and ground topography. Orthorectifying provides a more accurate product by using the topography to remove distortion.

Rubbersheeting control points were set-out in the field in August 1999, with the LADWP survey crew using survey grade GPS to document coordinates for each control point. Cross section headpins were also surveyed with the kinematic GPS to determine their coordinates. This GPS survey work documented coordinates using NAD 1927 for horizontal control and NAVD 1929 for vertical control. White targets were placed on each control point so that they would be easily observed on the aerial photographs. Softdesk CAD Overlay Civil Engineering software was used to rubbersheet scanned aerial photographs from the control points. While rubbersheeting corrects much of the photo distortion, we recommend that a specialized contractor use the 1991 photogrammetry-based topography to provide LADWP with digitally orthorectified aerial photographs to substantially improve accuracy of digital aerial photo basemaps.

Having LADWP surveyors assist future monitoring will not only simplify surveying, but also will greatly improve the accuracy and repeatability of surveys, particularly for longitudinal thalweg profiles. Our existing method of stringing tapes, taking bearings, and surveying elevations with an engineers level to document planform location and thalweg profile introduces substantial horizontal error, making year-to-year comparisons difficult. By using the LADWP kinematic GPS survey crew, we can survey very accurate planform location and thalweg elevations (± 0.1 ft).

Planmaps

The following McBain & Trush study sites were planmapped in WY1999 (Figure 1; Plates 1 to 9):

1. Upper Lee Vining Creek (main and A4 channel);
2. Lower Lee Vining Creek (main and B1 channel);

3. Upper Rush Creek;
4. Lower Rush Creek (main and 10 channel);
5. Rush Creek County Road Site;
6. Walker Creek.

Datums associated with all McBain & Trush concrete aluminum benchmarks have been converted from an arbitrary 100.00 ft elevation to an elevation relative to the 1929 vertical datum survey (see discussion on related work in the air photo narrative). Cross section rebar pins and previous years' survey data have been converted to reflect this change in datum.

Rubbersheeted 1999 low altitude aerial photographs served as base maps for the planmapping (Plates 1 to 9). WY1999 was the first year we planmapped directly from rubbersheeted aerial photographs; changes in our planmap reaches will be more easily quantified and compared to future maps. The planmaps provide greater geomorphic detail than our coarser vegetation-geomorphic unit mapping. All planmaps include location of cross sections and bed mobility experiments, as well as selected field notes.

Hydrology

WY1999 Annual Hydrographs and Instantaneous Peak Discharges

Annual hydrographs at LADWP gaging stations are presented for Lee Vining, Rush, Parker and Walker creeks (Figures 2 through 6) from WY1995 through WY1999. Annual hydrographs for Lee Vining Creek at the Intake (LADWP Gaging Sta. No. 5009) depict daily average flows through our Upper Lee Vining Creek and Lower Lee Vining Creek study sites. Annual hydrographs are available (or reconstructed) at three locations along Rush Creek: Rush Creek at the Dam site, Rush Creek below the Return Ditch, and Rush Creek below the Narrows. Rush Creek below the Narrows Annual hydrographs are synthetic: daily average discharges are derived by adding the gaging data for Rush Creek below the Return ditch (LADWP Gaging Sta. No. RCBR), to Walker Creek (LADWP Gaging Sta. No. 5002) and Parker Creek (LADWP Gaging Sta. No. 5003). Rush Creek Dam Site gaging station represents Rush Creek flows impaired by Southern California Edison (SCE) regulation only, contrasted to Rush Creek below the Return Ditch gaging site that represents impaired flow conditions caused by LADWP and SCE. Rush Creek below the Return Ditch provides the best discharge estimate through our Upper Rush Creek Study Site while Rush Creek below the Narrows provides the best daily average discharge estimate through our Lower Rush Creek and Rush Creek County Road study sites.

Flood Peaks and Annual Maximum Recurrence Intervals

Annual maximum flood frequency curves computed by Hasencamp (1994) were computed using the annual maximum daily average discharge. Frequency curves were developed for unimpaired (unregulated) and impaired (regulated) flow regimes for Lee Vining Creek and Rush Creek; only the impaired condition was evaluated for Walker Creek and Parker Creek. Instantaneous annual maximum discharges, maximum daily average discharges, and their respective recurrence intervals for recent years are presented in Table 1.

Flow Allocation Among Channels

In many instances the total daily average discharge measured at a given gaging station was distributed in more than one channel (e.g., Lee Vining mainstem and the A4 Channel). Synoptic gaging (measuring several flows at one time) was used to measure flow allocation among primary and secondary channels (Tables 2 and 3). Based on these measured flow allocations, we estimated daily average flow and peak instantaneous flows for a given channel by developing proportions of the total flow to the individual flows of specific channels. From WY1997 to WY1999, we synoptically gaged Rush Creek five times and Lee Vining Creek seven times to evaluate the proportion of total flow allocated to the primary and secondary channels (9207 gaging forms in Appendix A) at all multi-channel planmap sites.

Cross Sections

All cross sections, located on the planmaps, were re-surveyed in WY1999. Additional cross sections were surveyed in the new planmapped reaches. Cross sections required in the termination criteria analyses are presented in Appendix B; other cross sections for long-term monitoring are available on request. Aluminum tags on all rebar and benchmarks have not been replaced with the newly acquired coordinates using the kinematic GPS. This will be accomplished by late summer WY2000.

Thalweg Profiles

The thalweg is defined as the deepest part of a stream channel's cross section. Using an auto level and engineer's tape, mainstem and selected secondary channel thalwegs were surveyed through all McBain & Trush planmap sites in WY1999 (Figures 7 to 17). Thalweg measurements were taken at obvious slope breaks (i.e., not at equal increments along the channelbed) in the channelbed profiles. Water surfaces and high water marks also were surveyed for estimating water surface slopes over a wide range of discharges. Baseline thalweg profiles surveyed before WY1999 are compared to the WY1999 profiles (Figures 7 to 17). Thalweg profiles were surveyed at the new planmap sites: Rush Creek County Road site, Walker Creek, and Parker Creek. Trend analysis at all sites is premature until the thalwegs are surveyed over more years.

Channelbed Mobility

As described by Leopold (1994), "the moving water exerts a force on the bed which is available to push sediment grains downstream." This force, the bed shear stress (τ), is measured in lbs/ft^2. The greater the slope and/or deeper the water column, the more force is directed tangential to the channelbed (i.e., greater bed shear stress) and made available to push a rock downstream. If this shear stress exceeds frictional forces resisting movement, the rock moves downstream. The bed shear stress (τ) can be approximated by an equation labeled the "depth-slope product" defined simply as:

$$\tau = W * H * S \qquad \text{(equation 1)}$$

where:

W is the weight of water (62.4 lbs/ft^2),
H is water depth (ft),
S is water surface slope (ft/ft).

This equation requires stream channels with steady uniform flow where the streamflow changes little in the cross stream direction (Larsen 1992). Ideally the depth-slope product is applied only to straight riffle and run segments that exhibit uniform water depths and velocities. The shear stress equation for these uniform channel segments can be expressed as the bed averaged shear stress τ_b by:

$$\tau_b = W * d * S \qquad \text{(equation 2)}$$

where:

d is the average water depth (ft).

Other channel segments, such as pools and alternating bars, require considerably more sophisticated modeling to approximate τ_b (Larsen 1992).

Particle size of the streambed can be predicted by estimating τ_b based on the Shield's criterion for initial motion. The Shield's criterion is a ratio of the forces tending to move a rock (in the numerator) and the forces tending to keep the rock at rest (Larsen 1992). When this ratio reaches a critical value, the rock is on the threshold for movement. The shear stress just initiating incipient motion for a given rock size is labeled τ_{ci}, or critical shear stress. The Shield's ratio for incipient motion is calculated using the following formula:

$$\tau^*_{ci} = \tau_{ci} / g(\rho_s - \rho_w)D_i \qquad \text{(equation 3)}$$

where:

τ^*_{ci} is the dimensionless critical shear stress for rock size i,
g is gravitational acceleration (32.2 ft/sec^2)
ρ_s is the specific density of rock (2.65 g/cm^3),
ρ_w is the specific density of water (1.00 g/cm^3),

D_i is rock size (mm) at the given percentile i.

Dimensionless critical shear stress (identical units for force in the numerator and denominator cancel-out, i.e., "dimensionless") can be reduced to:

$$\tau^*_{ci} = dS/(1.65D_i) \qquad \text{(equation 4).}$$

To predict incipient motion for D_i, at a given discharge and cross section, a value for τ^*_{ci} is needed. Two analytical approaches are being used. Published values, experimentally estimated in the field and laboratory, to model incipient motion are available. The original Shield's value for τ^*_{ci} was 0.06 for a homogeneous laboratory setting. Field studies have since identified lower values of τ^*_{ci} for the D_{50} ranging from 0.035 to 0.045 as more representative of gravel bedded channels (Andrews 1983). We prefer to use $\tau^*_{ci} = 0.035$ to 0.040 for the D_{50} and $\tau^*_{ci} = 0.020$ to 0.025 for the D_{84} if no empirical data are available.

The second analytical approach is empirical. Marked (painted) rocks representing the D_{50} and D_{84} are set into the channelbed (in as natural a position as possible) along cross sections in uniform riffles. The percentage of rocks moved (more than 3 ft) since the last observation date is recorded, as well as the peak discharge (and stage height) since the last observation date. A graph is constructed to identify an interval of peak flows where the percentage of mobile rocks increases from 0% up to 100% mobility. Bed shear stress is then estimated at the flows just exceeding 0% and achieving 100% mobility. Both estimates of τ_b can be entered into the numerator of the dimensionless critical shear stress equation to bracket estimates of τ^*_{ci} for the D_{50} and D_{84} (d and S are also known).

The second approach requires several years of marked rock monitoring to accrue sufficient peak flows to narrow the window of flows just initiating movement and achieving 100% mobility. Although its extended field requirement may be considered a drawback, this approach allows us to identify mobility thresholds where simple equations cannot reliably predict mobility, e.g., in boulder eddies or constricted pool tails. Also, the second approach bolsters confidence in the modeling approach.

All marked rock results through WY1999 (WY1997 and WY1998 results initially presented in McBain & Trush and Hunter 1999) are summarized in Figures 18 to 22, with the percentage mobilized plotted as a dependent variable of peak discharge. The flow producing 10% mobility was considered the incipient threshold. The τ_b at peak discharge was calculated (using equation (2)) by estimating average depth (d) from the cross section and water surface slope from the field surveys. Computed τ_b was then entered into the numerator of equation (4) to back-calculate τ^*_{ci} for D_i (the D_{50} and D_{84}) at incipient mobility (Table 4). Only those sites providing reasonably decisive thresholds were analyzed. The most alluvial channel segment monitored, lower Rush Creek, produced the sharpest thresholds and the narrowest range in estimated τ^*_{ci} for the D_{50} and D_{84}. In contrast, the mainstem of Lee Vining Creek is the least alluvial and requires more flood peaks before estimating mobility thresholds. With more monitored events, τ^*_{ci} estimates are expected to change.

The channelbed in Lower Rush Creek achieved incipient mobility at approximately 110 cfs to 115 cfs for the D_{50} and 125 cfs to 130 cfs for the D_{84}. This narrow flow range spanning incipient conditions for the D_{50} and D_{84} is typical of alluvial channels. These two flow ranges are approximately 75% and 85% (respectively) of the regulated bankfull discharge ($Q_{1.5}$ = 150 cfs). Researchers are finding flow thresholds for incipient motion at 70% to 80% of $Q_{1.5}$ or even less (Rosgen 2000). Upper Rush Creek (XS05+45) exhibited a higher flow threshold for incipient mobility that is approximately 100% and 125% of regulated $Q_{1.5}$ for the D_{50} and D_{84} (Table 4). This discrepancy suggests Lower Rush Creek has adjusted morphologically (and alluvially) to its imposed regulated flow regime, whereas Upper Rush Creek has not (retaining characteristics of its pre-1941 channel morphology). If our preliminary threshold flows are compared to the unregulated $Q_{1.5}$ of 400 cfs, even the Lower Rush Creek threshold flow percentages of $Q_{1.5}$ (approximately 30% and 33% for the D_{50} and D_{84}) are considerably less than expected compared to contemporary alluvial streams.

Two important tasks are underway. While initial mobilization is an important threshold, we consider significant mobilization geomorphically more relevant. Using the marked rocks, mobility exceeding 80% was considered significant. Significant mobilization of the D_{84} in many alluvial channels we have examined occurs close to the bankfull discharge. This analysis will require more monitoring and analyses. Mobilization is not uniform throughout the channel. As indicated in the monitoring results, mobilization of alternate bar surfaces requires flows considerably higher, and less frequent, than the bankfull discharge. We hypothesize, based on contemporary alluvial channels, that the 5-yr to 10-yr flood will accomplish significant mobilization of alternate bars. This analysis also will require additional monitoring and analyses.

Vegetation and Geomorphic Unit Mapping

Vegetation in each stream corridor appears as a mosaic of distinctive plant stand types occupying a wide range of environmental conditions and gradients (Sawyer and Keeler-Wolf 1995). Riparian vegetation is composed of plant species that need considerable water and open space to germinate. These conditions are mostly created and sustained by streams, though other mechanisms may create them (e.g., irrigation ditch construction and maintenance, groundwater seeps, springs, etc.). Vegetation in the stream corridor has always been composed of desert, transitional, and riparian plant stand types in constantly varying ratios of abundance.

The riparian corridor has been traditionally defined as the zone of direct interaction between the terrestrial and aquatic system(s) or by the dominant plant species present (Gregory et al. 1991; Jones&Stokes 1993; Kaufman 2000). These definitions only consider the present channel location, and adjacent land only where the stream sustains a higher, off-channel groundwater table than would be available from local precipitation alone. But the riparian corridor should be synonymous with the stream corridor, including those areas where the channel once occupied and might in the future occupy. Often for small streams, such as the steep upper reaches and relatively flat bottomlands of Rush and Lee Vining creeks, a stream's corridor is simply bounded by its valley walls or very high ancient terraces. Occasionally some streams, such as Parker and Walker creeks below their diversion structures, have no definable valley walls. In these cases, boundaries for the stream corridor have been set at 300 ft from the present channel.

Riparian vegetation cover along Lee Vining, Rush, Walker and Parker creeks has been mapped from pre-1941 and post-1985 (approximately when watering was resumed) aerial photographs (Jones and Stokes 1993; Kaufman 2000). The first vegetation cover evaluation was part of the 1993 Environmental Impact Report (Jones and Stokes 1993). The EIR quantified pre-1941 and 1989 riparian vegetation cover along each stream. Rush Creek riparian vegetation was mapped again in 1996. We mapped vegetation cover within the Lee Vining Creek, Rush Creek, and Walker creek riparian corridors in the fall of 1999 (Plates 10 to 27). Parker Creek will be mapped in early summer 2000.

Our vegetation mapping and previous mapping were not entirely compatible. Individual stands, or patches, of vegetation on aerial photographs were mapped and labeled based on the dominant plant species in the canopy, then subjected to intensive groundtruthing. Each mapping study used a unique combination of spatial scale and vegetation classification system; ours was no different (Table 5). The common thread between studies is that individual stands have been defined by the dominant plant species identifiable in aerial photographs. The vegetation cover classification used in the EIR and our vegetation cover classification share a similar "crosswalk": the classification adopted by California Fish and Game's natural diversity data base (NDDB). Our plant stand types all have an equivalent NDDB stand classification, as do the EIR stand types (Table 5). The 1996 Rush Creek study (Kaufman 2000) still needs equivalent stand types developed.

As riparian vegetation recovers, accuracy of the acreage estimates becomes important for validating termination criteria. How well does the acreage of digitally delineated stands match acreage measured on the ground? Currently there are no estimates of accuracy for our 1999 vegetation maps, or for previous studies. Until 1999 there has not been a unified coordinate system for developing base maps. Consequently each study used different basemaps, making standardization among studies a real problem. Also, previous acreage has been estimated by planimetric analysis or using non-industry standard mapping software (i.e., Pagemaker rather than CAD or GIS type software); this may require re-entering all earlier riparian inventories.

Quantifying map accuracy is difficult because aerial photographs (serving as base maps) of similar scale were not corrected for camera lens curvature or for the curvature of the earth. Without using "corrected", or orthorectified, aerial photographs, acreage comparisons between years are flawed. The EIR mapping and our mapping use the 1991 topographic maps as base coordinates. We mapped vegetation with contact prints, originally at a scale of 1:9600, enlarged to a scale of 1:1,800. The 1996 study does not use the 1991 topographic maps (Kaufman 2000). Vegetation mapping efforts can be made compatible by converting previous base maps to the coordinate systems set up in 1999 and defining common valley wall boundaries for all studies. Different sets of aerial photographs orthorectified to the same base coordinate system used as base maps should, in theory, provide the same accuracy.

A plant stand is defined by the presence of a dominant species or co-dominance between a few species. Sometimes species dominance is unclear, or stand area seems too small to be considered a legitimate "stand." The minimum plant stand area we mapped was 233 sq. ft (Black Cottonwood) on Rush Creek, 114 sq. ft on Lee Vining Creek (Mountain Mahogany), and 35 sq. ft on Walker Creek (Shiny Willow).

Rather than use valley toeslopes to define the stream corridor, the EIR (Jones and Stokes 1993) quantified vegetation cover within an arbitrary distance from the stream; these rigid boundaries however always included all riparian vegetation. The EIR presents the total acres covered by mature riparian vegetation within predefined reaches. Mature riparian vegetation was defined using a combination of the dominant growth form (tree, shrub, herb), site hydrology (e.g., dry, riparian, wet), and plant species (black cottonwood, willow, Jeffery pine). No criteria were established to determine whether mapped "riparian vegetation" was produced by, or under the influence of, streamflow, irrigation, or groundwater seepage. The arbitrary limits were set to include all mapped "riparian" vegetation and in some cases, the total acreage attributable to mature riparian vegetation before diversion and in 1989 was overestimated. Differences in vegetation acreage can be corrected by redefining the 1993 arbitrary boundary of the EIR to include all acreage within the stream corridor (e.g., using our "valley wall" line).

We mapped 24 plant stand types and grouped them into four general types: aquatic, riparian, transition, and desert (Table 5). Stands dominated by aquatic plant species were classified as aquatic. Terrestrial wetland facultative and obligate plants dominated plant stands classified as the riparian group (*Populus balsamifera* ssp. *trichocarpa* and *Salix* spp.), while groups dominated or co-dominated by facultative plants were assigned to the transition group. Upland plants were assigned to the desert group (see Reed 1988 for a complete discussion of the wetland-upland classification).

There are inconsistencies in classification between our study and the EIR. Vegetation mapping by Jones and Stokes (1993) included three plant stand types in riparian vegetation that we considered transitional (i.e., buffaloberry, mixed riparian rose, rose). Transition vegetation is not considered in the riparian vegetation acreage presented in Tables 6 to 8. Transition vegetation does indicate elevated groundwater levels, and some recovery. However, transition vegetation does not necessarily indicate a shift to riparian conditions because species that compose transition vegetation can tolerate much dryer growing conditions and their seed germination does not rely on conditions created by the stream.

Aggradational Floodplains

Introduction

Floodplain aggradation is a key alluvial process in all Mono Basin stream channels perhaps best exemplified by Parker Creek. Its channel has been constructed on top a coarse glacial outwash fan and now functions almost independently of its original geomorphic setting. The straight downslope gradient of this fan at the planmap site is approximately 30% greater than the channel slope. Slope reduction (from the much steeper gradient of the outwash fan) affects water velocities and bed-averaged shear stresses, as well as physical channel complexity. Cross sections and field inspections clearly show the channel has become elevated, even precariously, above its valley floor. This alluvial "mound", labeled as floodplain, is composed almost entirely of sand and silt. And sedges! Generations of sedges have trapped thin 1 to 3 mm layers of aggrading sands with each overbank flood event (observed at Q > 50 cfs). Each episode of aggradation then required an even greater flood to overtop stationary banks. As segments of the channel bank migrate, the building process is renewed but in slightly displaced locations that follow a meander's path. As the radius of curvature for meanders tighten or an eroded tree collapses into the channel, the mainstem may avulse. Captured flow now traveling away from, and down from, the mainstem may parallel the mainstem channel far downstream before gaining a topographic depression that allows captured and mainstem flows to rejoin.

This brief description of Parker Creek's morphology highlights several key basinwide restoration considerations. First, vegetation does not simply influence channel morphology, it dominates channel morphology. Without sedge (and other plant taxa) colonization of the steep outwash fan, floodplain aggradation would not have occurred on Parker Creek. Second, an aggraded floodplain morphology is dynamic, resilient, but also fragile. A bulldozer scraping-off a few feet of sand and silts swiftly unravels centuries of construction. Third, high flows are critical for the channel to maintain its shape. As the channel migrates into its outer banks and undermines the aggraded floodplain, the channel must also aggrade its inner banks to maintain channel shape and confinement. High flow releases designed to scour gravels (at salmonid spawning sites), typically labeled flushing flows, cannot provide this function. With flushing flows as sole peak releases, the channel would continue to erode its outer banks but could not replenish its inner banks. The channel would continue to widen and degrade habitat. Frequent avulsions, that may have been a dominant rejuvenation process of channel morphology and woody riparian stands, also require flows capable of overtopping the channel banks.

The Parker Creek description, as well as the collective understanding of the other tributaries from years of numerous investigations in the Basin, also highlights that our understanding of contemporary alluvial channels provides an acceptable framework for how Mono Basin streams once functioned. No one was conducting bed mobility experiments in the early 1900's on Rush or Lee Vining creeks. But we can assert that the general channelbed once mobilized frequently and that formation and maintenance of point bars were important.

Historic Aggraded Floodplain

Our investigation of historic channel morphology had two primary purposes. First, if lower Lee Vining Creek and Rush Creek demonstrated geomorphic features common to alluvial stream channels, we could infer that many geomorphic processes governing contemporary alluvial stream channels also once applied to the two creeks. For example, alluvial channels typically construct floodplains just inundated by an annual maximum flood recurrence of 1.5 to 2.0 years called the bankfull flood. Did Lee Vining Creek and Rush Creek have "alluvial" floodplains? If so, then floodplain recovery would be an important goal for achieving sustainability. The second purpose was relief from the unexplained observation of numerous cottonwood stumps located well above the present stream channel in many locations. How could cottonwood stands have become established and thrived on terraces that received infrequent inundation (pre- and post-1941), unlike contemporary stands along similarly sized unregulated alluvial channels occupying surfaces inundated by 1.5-yr to 3.0-yr floods? Any attempt to create sustainable cottonwood stands needs an explanation.

Our first step in this investigation was to estimate the flood discharge that once formed the unaggraded floodplain under pre-1941 hydrologic conditions. We hypothesized this discharge would be the bankfull discharge having an unregulated 1.5-yr annual recurrence ($Q_{1.5}$). The unregulated $Q_{1.5}$ is approximately 265 cfs for lower Lee Vining Creek and 400 cfs for lower Rush Creek. To test this hypothesis, channel cross sections representative of the pre-1941 condition were needed, then: (1) identify bankfull stage on each cross section, (2) estimate the discharge using the Mannings equation, and (3) compute its unregulated recurrence interval.

The well-preserved channel morphology of the 1A Channel just downstream of the Narrows was our best choice (refer to Larsen (1994) for photographs and cross sections). Figure 23 depicts the actual cross section (labeled "pre-1941 berm") where "floodplain" corresponds to the stage height of the unregulated pre-1941 $Q_{1.5}$ peak discharge. This is the rudimentary floodplain if no aggradation occurred. However, colonization by woody riparian vegetation created an ideal depositional environment for fine particles with very slow settling velocities. A riparian berm formed, where fine sediment was rapidly winnowed by riparian vegetation along the main channel margin. Rather than being evenly deposited throughout the floodplain, a pronounced berm was constructed from the fine sediment. The riparian berm rests on coarser sand and gravel of the floodplain. Cores taken through the berm at Sta. No's. –03 ft and -09 confirmed a sharp interface between fine sand/silt and the coarser floodplain substrate at a stage height of 99.0 ft (Figure 23). The alluvial surface evident at a stage of 100.5 ft to 101.0 ft on the right bank is the surface of the pre-1941 aggraded floodplain. Approximately 1.5 ft of fine sand and silt had been deposited on this rudimentary floodplain surface.

Our first task was to estimate the discharge that just reached floodplain stage (99.0 ft) and the discharge that just overtopped the riparian berm crest. By using our empirical estimates for channel roughness and a surveyed thalweg profile (refer to Larsen 1994 who originally surveyed this site), we estimated both discharges (Figure 23). The floodplain had an unregulated discharge of approximately 350 cfs giving an annual maximum flood recurrence of 1.2 years, while the left bank riparian berm was just overtopped by a 65-yr event (1,200 cfs) giving an annual maximum flood recurrence of 65 years. Similar analyses were performed on two other ideal historic cross sections: lower Rush Creek Channel 14 and the A4 Channel in Lee Vining Creek.

These results do not state that the riparian berm in the 1A Channel cross section was formed in 65 years. Formation must have taken considerably longer. We have observed during floods that a minimum stage of approximately 0.5 ft deep flow is needed to cause measurable fine sediment deposition. As riparian vegetation became more dense, deposition would have been enhanced. In the sediment cores we noticed no distinctive banding of the sediments to indicate deposition depths for discrete flood events. At this junction in the investigation, we have not estimated how long berm formation requires.

But we can speculate on the following concerning riparian berms. First, higher berms probably required more time to form (height also was affected by channel slope; will present hypotheses/results in next year's report). As the berm grew, only higher and therefore rarer floods could increase berm height. Channels that remained stationary would be expected to have higher berms. Second, there must be a limit to berm height. To overtop a very high berm would require a several hundred year flood or greater (results to follow). The very largest floods were typically rain-on-snow events: high magnitude but very short duration. Therefore the very largest floods provided extremely short periods for deposition. The most important floods for berm construction probably were the intermediate high floods generated by unusually high snowmelt runoff: maybe not as high as rain-on-snow events, but much more common and of much longer duration per flood. While our sampling has not been exhaustive, the typical depth of fine sediment resting on coarser alluvium, as observed in the channel eroding into terraces or the pre-1941 floodplain, is from 1.5 ft to 2.0 ft. Although in the County Road planmap, the pre-1941 floodplain had one location with 4 ft of deposition on top the original floodplain. The importance of two feet is evident in the 1A Channel cross section. The distance from the floodplain stage height to the thalweg is 2.5 ft, whereas the distance from the floodplain stage height up to the top of the aggradational floodplain is approximately 1.5 ft. The channel has produced considerable confinement with the assistance from riparian vegetation.

Historic channels in lower Lee Vining and Rush creeks were hydraulically confined above the 1.5-yr flood stage height. Field inspection in 1999 of eroding banks indicated that approximately 2 ft of silt aggradation is common on historically aggraded floodplains. Some areas had even greater depths, e.g., at the Rush Creek County Road Site one site had 4 ft.

Silt deposition could occur very rapidly on the rudimentary floodplain. A 7 ft high dead willow was excavated from a pre-1941 aggraded floodplain in the County Road reach of lower Rush Creek. The excavation site is labeled on Plate 8. The excavated willow was 38 years old at the time of death. Diversions began 18 years after its initial germination, as evidenced by the sharp reduction in annual growth ring width. We used the placement and diameters of adventitious roots to determine the depositional history during this willow's lifespan; it survived three depositional events, the last exceeding 40 cm (15.75 inches) feet (Figure 32). It has been difficult to place a date on the year of each depositional event, however the fact that adventitious roots existed no more than 26 cm below the contemporary ground surface is strong evidence that significant depositional events occurred frequently (Figure 32).

Riparian berm formation must have had extreme consequences to woody riparian vegetation. As the berm grew, the stream was essentially isolating its mainstem channel (in time) from its floodplain by making inundation less frequent and less deep. For a species such as cottonwood that requires moist exposed sandy/silty substrate for germination, the opportunity to establish new cohorts probably decreased through time if the channel remained stationary (and built high berms). Age class distribution of the stumps can be used to indicate inundation dynamics. A varied age class structure indicates the occurrence of many floods within the relatively short lifespan of cottonwoods. We will propose estimating age class distributions this summer on lower Rush Creek and Lee Vining Creek. Most (only an observation at this time) of the large stumps do not exhibit adventitious roots, suggesting these cottonwoods established on top (or slightly beneath) the historic aggraded floodplain.

Contemporary Aggraded Floodplain

The contemporary (post-1941) floodplain discharge was identified by locating a baseline elevation underlying the sand/silt deposition of the contemporary aggraded floodplain, then estimating the discharge at this baseline elevation using a roughness factor. Occasionally a discharge had been measured at, or very near, the estimated elevation. We hypothesized that the $Q_{1.5}$ peak discharge in the regulated annual maximum flood frequency curve would equal the post-1941 floodplain discharge, i.e., that the post-1941 floodplain would form at the regulated $Q_{1.5}$ stage height. For Rush Creek (@ damsite) the regulated (i.e., impaired) $Q_{1.5}$ peak discharge for WY1941 to WY1991 (Table 9) was 165 cfs. Using another annual maximum flood frequency curve for WY1973 to WY1994, the regulated $Q_{1.5}$ peak discharge was 148 cfs. For Lee Vining Creek (above Intake), the regulated $Q_{1.5}$ peak discharge for WY1973 to WY1994 (Table 9) was 188 cfs. The unregulated $Q_{1.5}$ peak discharge for WY1973 through WY1994 (Table 9) was 265 cfs.

Cross sections with prominent contemporary floodplains were analyzed. No systematic sample of all contemporary floodplains was undertaken. Therefore only individual $Q_{1.5}$

estimates are presented (Table 4) without calculating means, etc. Until we better quantify hydraulic roughness and observe more peak flow events, the flow estimates are preliminary (Mannings n's are included). The post-1941 recurrence intervals for the flow just inundating the post-1941 floodplain were slightly lower (Table 4) than hypothesized. The results (pre-1941 and post-1941) support our underlying assumption that these stream channels function similarly to contemporary alluvial channels.

Berms are clearly growing in the contemporary channel. Lower Rush Creek planmap site provides the best examples. In XS 10+10 (Figure 33), the berm crest is approximately 0.5 ft high. Many cross sections show growing berms (Appendix B).

Channel Migration and Width Maintenance

Alluvial channels migrate. For lower Rush Creek and Lee Vining Creek, lateral channel migration will be a prominent mechanism for converting pre-1941 aggraded floodplain into contemporary aggraded floodplain. How long is required for a channel to re-occupy every location across its migration corridor? A coarse rule-of-thumb is that alluvial channels migrate 1 to 2 percent of their bankfull widths annually, i.e., 50 to 100 years to migrate one bankfull width. For lower Rush Creek, bankfull width is approximately 30 ft. Therefore, progressive lateral migration of a single channel from one valley wall, across a 1000 ft wide corridor, and to the opposite wall would minimally require 1,500 years. But the rate may be much higher.

Valleywide XS07+25 in lower Rush Creek (Plate 6) was centered through an actively migrating channel bend. This may not be the fastest migrating bend, but it must be one of the faster bends. Fortunately, the cross section was first surveyed in June 1995 (Figure 34), just before the 647 cfs peak flood (Channel 10 was not yet opened). Unfortunately, it was not resurveyed until late summer, following the WY1997 peak discharge (169 cfs). In June 1995, its w_{bf} was a very wide 61.0 ft. By late summer 1997 w_{bf} was 38.4 ft (Figure 34). We suspect the 1995 peak event caused significant outer bank erosion and that the 1996 peak event (293 cfs) significantly contributed to deposition on the inner bank. The 1997 event (only 169 cfs) had minor effect. However, another significant event in WY1998 (387 cfs) was sufficient to aggrade the inner point bar. The w_{bf} in late September 1998 was 29.0 ft. Bankfull width was being maintained by the annual flow regimes from WY1995 to WY1999, whereas the water years prior to WY1995 produced a much wider channel. Over the 4-yr period, the thalweg migrated 63 ft, for a rate of 52% w_{bf} annually. A 4-yr period is too short for estimating long-term migration rates, but this example illustrates the potential for migration and the ability of the channel to adjust w_{bf}.

How realistic is this estimate? We have not tackled this analysis yet. An answer probably is related to the height of riparian berm construction: the more stationary the channel, the higher the berm. Ash layering also will be an analytic tool. Our guess is that progressive channel migration (methodical floodplain construction with an advancing point bar) may have occurred faster than expected in the lowest gradient reaches of Rush Creek (e.g., from the lower Rush Creek planmap site and downstream). Avulsions, as opposed to progressive migration, may have allowed the mainstem to occupy much of its valley corridor faster than expected. Above Rt. 395, avulsion probably was the dominant mechanism.

The peak discharge in WY1995 also created floodplain aggradation above an elevation of 6490.0 ft shown on the WY1997 cross section (Figure 34); none of the subsequent floods attained this elevation. The flood, approximately 2 ft deep on the floodplain, deposited up to 1 ft of fine sand and silt within the dense willows occupying the floodplain.

Results from XS07+25 suggest that width maintenance requires two basic processes, erosion of the outer bank and deposition on the inner bank, that occur at different annual rates. Widening can occur from a very large flood or from a series of low flow years that cannot advance deposition on the inner bend but cumulatively cause outer bank erosion. Narrowing can occur during the intermediate floods ($Q_{1.5\text{-yr}}$ to $Q_{10\text{-yr}}$) capable of depositing coarser sediment on the flank and fine sediment on the crest of point bars, but not creating significant bank erosion on the outer bend. Annual flow regimes must provide the floods that balance the bank widening and narrowing in order to maintain channel width.

Floodplain Aggradation Model

We wanted to model floodplain aggradation to better understand physical processes. Can we recreate the depositional process and reproduce aggradational floodplains? We relied on our historic channel cross sections to provide a model template. Taking Channel 1A, and removing its berm down to the original floodplain, we can estimate the magnitude and recurrence of flood events needed to aggrade the floodplain. Figure 35 is the end product of this model, with the original cross section overlaid for comparison. The right side of the channel appeared slightly scoured in the field, from stations 26 ft to 45 ft. Figure 35 illustrates the flow magnitude and recurrence interval needed to inundate the floodplain to depths of 0.5 ft and 1.0 ft WITHOUT riparian vegetation on the floodplain (Manning's n is only 0.040). With riparian vegetation and initial deposition of 0.5 ft, the magnitude of flood needed to attain a given stage height is greatly reduced. A 1000 cfs event with a recurrence of 16 years is needed to inundate the floodplain without riparian vegetation to a stage height of 100 ft (Figure 35), but only a 750 cfs flood with a 5.7 year recurrence (Figure 36) is needed with riparian vegetation (encouraging 0.5 ft of depositional and providing hydraulic resistance to the flood flow). Other scenarios are presented (Figures 35 to 37). To achieve a 1.5 ft riparian berm (typical in lower Rush Creek) a 12-yr unregulated peak discharge of 950 cfs would be needed to attain a stage height of 100.5 ft (Figure 36).

In our simplified scenario, the floodplain remains hydraulically smooth. In reality, the floodplain becomes occupied by woody riparian vegetation that greatly increases resistance. The same discharge will attain a higher stage height with the hydraulically rough floodplain. Flows were estimated using three values for the Manning's n (e.g., Figures 35 to 37). As riparian vegetation matures, and eventually drops into, or erodes into, the mainstem channel, hydraulic roughness will increase. A Manning's n of 0.05 or greater (i.e., hydraulically rougher, therefore slowing water velocity) is very possible. Increased hydraulic roughness will decrease the flood's magnitude, and therefore the annual recurrence interval, required to attain a certain stage height. Using the previous example of a 1.5 ft high riparian berm (Figure 36), a Manning's n of 0.050 reduces the discharge from 950 cfs (using an n of 0.040) to 780 cfs (a 6.3-yr event).

Other historic cross sections were modeled: Channel 14 in lower Rush Creek (Figures 24 to 27), Yellow Bird reach below the Narrows (Figures 38 to 40), and the A4 Channel in Lee Vining Creek (Figures 28 to 30). The Channel 14 cross section indicated a more dynamic berm that was inundated more frequently (Figures 24 to 27). We initially hypothesized that height of the riparian berm was closely related to channel migration rate. A low berm, with supposedly frequent overtopping by peak flows, should indicate relatively rapid channel migration, i.e., the berm does not have sufficient time to grow before the channel moves on. In contrast, a relatively static channel (such as those found along the A4 and B1 channels in Lee Vining Creek, would be needed for a dense riparian stand capable of trapping sediment from many infrequent high floods to develop a high berm. However as the scenarios have illustrated, channels with lower gradients (s) can develop relatively high riparian berms but with relatively frequent recurrences of overtopping. Therefore, recurrence of overtopping probably is more an indicator of channel migration than berm height and is a function of channel gradient.

To build the highest 0.5 ft of a high berm (e.g., 1.5 or 2.0 ft) would require much more time than building the lowest 0.5 ft. The highest events are typically rain-on-snow floods that have very brief durations at their highest discharges. Their peak discharge durations may be measured in hours rather than in days (as for the highest magnitude discharges in snowmelt generated floods). If the depth of fine sediment deposition is significantly affected by duration, and we think deposition is, then the greatest snowmelt floods may be the most important events accomplishing floodplain deposition. These also are the most infrequent floods.

Extent of Downcutting and Headcutting

The aggradation models also provide insight into the extent of potential downcutting that has occurred since regulation. The Yellow Bird cross section has a pre-1941 floodplain at a stage height of 101.3 ft and a contemporary floodplain elevation (the stage height of the present day $Q_{1.5}$ flood) of 99.0 ft (Figure 38). The difference, 2.3 ft, is the extent of downcutting for this location in the Rush Creek lowlands. Restoration of the $Q_{1.5}$ flood will elevate the rudimentary floodplain to a stage height of 100.0 ft (Figures 38 and 39).

The influence of periodic downcutting and aggradation related to changing lake stage is undoubtedly a key factor in the pre-disturbance channel morphology. How much we can/will incorporate this phenomenon into our restoration vision is unclear as yet. However, the rapid downcutting in lower Lee Vining Creek in WY1998 and WY1999 above the washed-out County Road (i.e., not directly related to recent changes in lake elevation) demonstrates a necessary awareness with any proposed action.

Summary

Our restoration vision for lower Rush Creek is the development of a contemporary, sustainable aggradational floodplain incised within the pre-1941 aggradational floodplain (e.g., the "restored" condition of the Yellow Bird cross section in Figure 40). The only mechanism for repairing abandoned pre-1941 floodplain in the bottomlands is to tear it down and replace it with another aggradational floodplain constructed at a lower elevation. Lateral channel migration therefore is the wrecking ball that eventually mitigates lost aggradational floodplain.

However, several positive feedback mechanisms would, and probably did, prevent this leveling going unchecked. Surface fluctuations in Mono Lake may have been vital to initiate extensive filling and downcutting in the lower mainstems. This would have created a spatial diversity encouraging a wider range of habitats than if lake level remained stationary. Very large floods would have created channel avulsions that would have re-directed migration before reaching one valley wall or the other. Multiple channels may have shared high flows, and therefore slowed the migration rate for any single channel, thus extending the migration period and permitting other mechanisms (such as those just mentioned) to check migration in any one direction.

Complete restoration of the channel morphology will most likely require flood peak magnitudes throughout the range of 600 cfs and 1,000 cfs. Managing for large snowmelt floods (RI = 20 yrs and greater) must be a high restoration priority. The most vexing question (or challenging, depending on your perspective) is frequency. How often are these events needed? The safest recommendation is the natural unregulated frequency. Given suppression of flood peaks by SCE, followed downstream with additional alteration by LADWP, even estimation of unregulated flood frequencies has not been straightforward (Hasencamp 1994). SWRCB Mono Lake Basin Water Right Decision 1631 (1994) requires no peak flood magnitude greater than 300 cfs on Rush Creek and 160 cfs on Lee Vining Creek (refer to Tables 1 and 2 in LADWP February 29, 1996) though operational limitations would allow higher unplanned releases. Flood peaks higher than 300 cfs clearly will be needed for creating and maintaining a floodplain ecosystem.

Rush Creek snowmelt hydrographs will be difficult to manage. We recommend that LADWP estimate unregulated flood hydrographs as a first step toward refining management of large floods within their present infrastructure. This also was requested by Mono Lake Committee (via Peter Vorster) in the December'99 Sacramento meeting.

SCE's role overshadows many restoration actions for Rush Creek because their operations impose a major limitation on LADWP's potential for managing floods. An important use for our investigation will be to predict the geomorphic and ecological significance of an altered high flow regime.

How can we objectively recommend acceptable alterations to the natural flood regime? Clearly stating quantitative objectives is a start. To do this we must understand how major floods interact with changing channel morphology and riparian vegetation. One important direction is quantifying the physical role of channel confinement: Can a sustainable stream ecosystem, characterized by an aggradation floodplain, function as well with 1 ft rather than 2 ft of aggradation? We do not have an answer yet.

Termination Criteria: Analysis and Discussion

Introduction

SWRCB Order 98-08 establishes seven termination criteria to be used in determining when the stream monitoring program may be terminated. Each of these criteria is to specify specific pre-1941 stream conditions for Rush Creek and Lee Vining Creek. SWRCB Order 98-08 also stipulated that modifications to the restoration endpoints were possible: "*The monitoring team may, from time to time, reevaluate and if appropriate, recommend changes in the quantified forms of these criteria, on the basis of improved understanding of how to evaluate progress in restoring these streams.*" Given that one formal year, and two informal years, of monitoring have passed, this section evaluates the data and re-evaluates the first six termination criteria. The seventh, size and structure of fish populations, is addressed by Chris Hunter in a separate report. A table is presented in the Recommendations (Table 13) presenting the original termination criteria, proposed termination criteria, and WY1999 conditions.

Channel Gradient and Sinuosity

The restoration termination criteria recognize the importance of changes to channel gradient and/or sinuosity. These two morphologic variables are highly interrelated. If the main channel lengthens between two fixed points (i.e., stream corridor distance), then gradient decreases and sinuosity increases. Measurement of one is essentially measurement of the other.

The termination criteria for channel gradient and sinuosity are adequate on a large scale. Gradient and sinuosity for Rush Creek, from the Narrows and upstream, have remained essentially unchanged, as have both criteria for Lee Vining Creek above Rt. 395. Below the Narrows, channel straightening has occurred. In Reach 4A, coarse material from the quarry buried the historic channels. The new channel is relatively straight. The termination criterion of 1.19 is a reasonable expectation as the thalweg has already begun to develop a discrete meander (field observation). Lower channel segments of Reach 4B exceed the sinuosity criterion of 1.23 averaged over all Reach B (e.g., the Lower Rush Creek planmapped segment has a sinuosity of 1.55), whereas upper segments within Reach 4B do not achieve the average sinuosity. Reach 4B has a gradual slope transition from 0.011 to 0.007. Reach 4C should become highly sinuous given its pre-1941 morphology, although its major increase in slope (from the Channel 14 cutoff) could affect the outcome. We will be taking a closer inspection of this reach in summer 2000. The County Road planmap, containing most of Reach 5A (Ford to County Road), has a sinuosity of 1.33, close to the termination criteria of 1.39. Mainstems of lower Lee Vining Creek in the upper and lower planmaps both have a sinuosity of 1.08. The termination criteria of 1.15 to 1.20 are conservative. The A4 Channel (in the upper Lee Vining planmap) has a sinuosity of approximately 1.35.

Another approach to sinuosity is measuring curvature of individual channel bends. Radius of curvature approximately equals 2.0 to 3.0 times the bankfull width in alluvial rivers (Leopold 1994). An average radius of curvature (r_c), rather than sinuosity, may make better termination criteria for specific reaches. We have been calculating r_c values and meander amplitudes from historic aerial photos, old meander scars, and contemporary meander bends with the goal of substituting sinuosity with r_c and/or meander amplitude as termination criteria.

Lower Rush Creek planmap has several well-shaped meander bends (Plate 6) with radius of curvatures ranging from 85 to 105 ft. Old meander scars in the same planmap reach, evident in the 1999 aerial photos, also have similar r_c values. Development of cutoff channels on two of the contemporary meander bends suggests each is approaching a minimum r_c with meander cutoffs imminent. "Over-tightened" meander bends, exhibiting a high chance of being cut-off, generally have a r_c/w_{bf} ratio of approximately 1.5 or less (Leopold 1994). Using 30 ft for w_{bf}, the r_c/w_{bf} ratio is approximately 3.0 for contemporary lower Rush Creek meanders exhibiting potential cutoffs. This ratio for imminent cutoff differs sharply from the 1.5 ratio for typical alluvial rivers, and may be important in predicting channel cutoffs and avulsions.

Radius of curvature will not be constant throughout the long profile of Rush Creek of Lee Vining Creek. Candidate reaches that appear to have r_c's unlike recovering or historical channel segments are the same reaches exhibiting simplified thalweg profiles: the mainstem Lee Vining Creek, the upper half of the A4 Channel, mainstem Rush Creek below the Ford, and upper Rush Creek near the old Rt. 395 bridge. This is not surprising given tighter meanders generally produce more diverse thalweg profiles. Generalities require cautious application. Segments of the B1 Channel appear to have retained their original planform morphologies yet exhibit only minor curvature (e.g., immediately downstream of the B1 Connector), whereas other segments have much higher curvatures (e.g., the A4 Channel).

In summary, the termination criteria for gradient and sinuosity may be too robust. Much of the channel already meets the criteria. We recommend not changing the channel gradient criteria until a GPS survey is conducted this summer. R_c has the sampling advantage of being readily measurable from aerial photos. Parker and Walker creeks have not lost their meander curvatures and therefore should not require sinuosity or gradient termination criteria. We will be proposing an alternate approach for quantifying a historical or restored condition for channel curvature based in individual meander characteristics. Given recent advances in GPS, measuring the entire thalweg in three dimensions for the bottomlands of both creeks is practical and cost-effective.

Primary Channel Lengths

Increased primary channel length should be attainable by increasing sinuosity first, and then by creating other primary channels. Our historical analyses (later in this report) strongly indicate that primary channels required the entire flow regime for their creation. Stine (1992) shows two channels (1A and 1B) existed side-by-side immediately below the Narrows. Our analysis of a 1A historic cross section (1B is completely filled-in) concludes higher flows were needed to overtop the self-forming riparian berm and that the cross section's hydraulic geometry was proportioned to accommodate the entire annual flow regime (refer to Aggraded Floodplain sub-topic). If the 1A and 1B channels equally shared annual flows, dimensions of the A1 Channel should have been considerably smaller. We can only conclude that one channel was shaped, and then the other. Once both were formed, they could overlap in time and even equally share flow for a limited time. The present day 1A Channel, though isolated from the actively flowing Rush Creek mainstem, does have very slow moving water contributed from sub-surface flows. From the air, the 1A Channel clearly reflects light off its water surface. The A4 Channel also provided a useful historic prototype. Again, our analyses showed that the A4 Channel was proportioned originally to accommodate the entire annual flow regime. For tandem primary channels to exist, each required the entire flow regime for their original proportioning.

We are proposing a channel classification system for identifying process-oriented trends in channel evolution (Figure 41). This detailed level of channel analysis is not possible on the pre-1941 aerial photographs. Therefore a baseline channel condition developed from the proposed channel classification is not feasible. Scott Stine's (1992 and 1992) analysis of the pre-1941 channels remains the basic authority.

The first branch in the classification is whether a channel is *Primary*, *Secondary*, or *Tertiary*. The term "proportioned" requires the channel to exhibit floodplain development at approximately the bankfull discharge (with subsequent deposition onto the floodplain). A *Primary* channel therefore produces a floodplain and confines the bankfull discharge. If the unregulated flow regime were returned to an *Incised Primary* channel, its floodplain would still be constructed at a lower elevation than the pre-1941 floodplain.

A *Secondary* channel may exhibit an adjacent alluvial surface (at an elevation corresponding to bankfull stage or higher) but it does not contain the entire bankfull discharge as does a *Primary* channel. *Secondary* channels are often initially constructed on floodplains of *Primary* channels, but then can evolve into larger *Secondary* channels as meander cutoffs. *Secondary* channels are therefore proportioned for only a fraction of the total annual flow regime, though this fraction may change rapidly (as in an evolving meander cutoff). *Tertiary* channels direct high flow runoff over terraces (greater than bankfull discharge) and floodplains (high winter baseflows up to bankfull discharge) absent significant riparian colonization. *Tertiary* channels on floodplains can evolve into

Secondary channels, and possibly *Primary* channels, once riparian plants establish.

Primary channels that are "victims" of meander cutoffs or larger-scale channel avulsions can retain their original morphology (i.e., proportioned to accommodate the annual flow regime) while only receiving a portion of the annual flow regime. Once riparian vegetation colonizes the channelbed and greatly increases hydraulic roughness, fine sediment aggradation would aggrade the channel. Victimized *Primary* channels probably will evolve: from transporting a portion of the entire annual flow regime, to only transporting snowmelt baseflows and higher, and finally to transporting solely flood flows. Or being completely filled-in. Along lower Lee Vining Creek fine sediment plugs indicate former *Primary* channels commonly fill (noted on upper Lee Vining mainstem planmap, Plate 1).

The million dollar bend below the lower Rush Creek is a good test of the classification. The outside bend was an *Incised Primary* channel transporting the entire regulated annual flow regime prior to opening the 10-channel. The pre-1941 floodplain is approximately 2 ft higher than the contemporary floodplain. Once the 10-channel was opened, the outer bend remained an *Incised Primary* channel, but only as one conducting a fraction of the total annual flow regime. In 1998 the stream avulsed into the constructed and isolated this *Incised Primary* channel. The outer bend is still an *Incised Primary* channel but now one that receives flows only greater than Q_{ave}. The cutoff channel was originally constructed as a *Secondary* channel transporting a fraction of the total annual flow regime. Following avulsion its status remains unchanged. As long as the 10-channel (also a *Secondary* channel) continues to flow, the cutoff channel will remain a *Secondary* channel. If the cutoff channel continues to evolve, being proportioned to carry more of the annual flow regime (pirating more of the high flows from the outer bend), the outer bend will become colonized by willows (and possibly cottonwoods) and begin aggrading. Eventually the outer bend will not be proportioned to transport the entire annual flow regime. However the outer bend will remain an *Incised Primary* channel because it was originally proportioned for the entire annual flow regime. If the 10-channel is cutoff in the future (e.g., its entrance fills-in) and all flow passes through the cutoff channel (i.e., also assuming the outer bend has completely filled), then the cutoff channel would become an *Incised Primary* channel.

Total length of primary channels should increase with restoration as sinuosity increases. However, as the proposed channel classification distinguishes, a restoration goal will be to transform incised primary channels into un-incised primary channels. This transformation will encourage future floodplain dynamics similar to the pre-1941 dynamics. While we consider this goal achievable, we can only broadly predict morphological trends. If we could confidently predict trends, the transformation from incised to un-incised primary channel would make a good termination criterion.

Long secondary channels should decrease in number and individual lengths as both streams recover. Increasing hydraulic roughness of the floodplain and strengthening streambank integrity should encourage overbank deposition and fill-in long secondary channels exceeding ½ meander wavelengths. Short secondary channels, the cut-off channels on individual meander bends, should remain (or increase in number) and therefore comprise most of the future secondary channel length. The wild card will be channel avulsions. We do not know how, as yet, to predict the future role of avulsions in creating and maintaining a complex secondary channel network.

From a restoration perspective, these observations and conclusions will affect how future channel networks are managed. Restoration of a primary channel requires the entire annual flow regime minus a small (undefined) percentage diverted by secondary channels. The creation of an impenetrable riparian berm, where no flow escapes anywhere along the mainstem, is extremely unlikely. Two management actions, both approved by the RTC, have created side-by-side primary channels in Rush and Lee Vining creeks. The A4 Channel in Lee Vining may have been the only primary channel before diversions, whereas the present day adjacent mainstem was formed by the entire regulated annual flow regime. With the sanction of the RTC, reopening the A4 Channel was originally to redirect only a small portion of the total flow. However, the A4 Channel is now diverting increasingly more flow from the mainstem than originally intended. Restoration of either channel, by floodplain aggradation, is hampered significantly by this artificial arrangement. The same can be concluded for Channel 10 (a pre-1941 primary channel) and adjacent mainstem in lower Rush Creek (a post-1941 primary channel).

Basically we really do not know how channel entrances function. The unsettled dynamics of channel entrances recently observed may not reflect the long-term. With mature cottonwoods and willows established along the banks, future channel entrances may become more stable, thus permitting two primary channels to coexist more readily than today's. With significant floodplain aggradation accompanied by meander tightening, chances of meander cutoffs or major avulsions at the meanders' apices (or slightly farther downstream) should increase. More secondary channels, and occasionally primary, would be produced. Given the uncertainty, the A4 Channel and Channel 10 entrances should be kept open until woody riparian vegetation matures (reaches 1 ft diameter) even at the expense of hampering recovery of their respective mainstems.

The present termination criteria for primary (or "main") channel lengths will not be a decisive factor directing restoration. Other termination criteria already recognize morphological deficiencies, i.e., the low sinuosity in both channels and the high thalweg variance in 5A (thalweg variance not measured in the 4C channel). Recovering main channel in Reach 5A is expected, but complete recovery in Reach 4C may not. Cutting off the extensive Channel 14 loop greatly increased gradient. Lowering slope by increasing sinuosity alone may not be expected to compensate for this sudden gradient change imposed on the channel.

Inclusion of primary channels as reach-specific termination criteria (expressed in feet restored) needs overhauling or elimination. We favor the later, but do not object to keeping them as they are; only Reach 4C may have an unrecoverable channel length. We will be prepared at the end of this summer-fall sampling period to provide a specific number of feet for Reach 4C. Our proposed channel classification, undoubtedly to undergo revision, may get us closer to understanding the complex channel dynamics of the bottomlands. However, the detail of pre-1941 aerial photos is not sufficient to apply this classification system as termination criteria. Although recovery will be hampered, we are in favor of keeping the 10-channel and A4 channel entrances open until woody riparian vegetation matures.

Channel Complexity

Complexity of the thalweg profile was given as potential termination criteria. Measuring complexity seemed at first straightforward: quantify the variation of the residuals predicted from a linear regression fit to the thalweg profile. A thalweg profile was surveyed with measurements taken wherever a change in thalweg elevation was encountered. These profiles are provided for all planmap reaches in Appendix B. A linear regression was then fit to a thalweg profile, creating a set of residuals. A residual is the difference (in ft) between a predicted thalweg elevation (from the regression equation) and the observed thalweg elevation as portrayed in Figure 42. Positive residuals represent riffles, whereas negative residuals represent pools. Next a frequency distribution of the residuals was plotted. Simple statistics were calculated to describe this frequency distribution including the mean, variance, and standard error. We initially hypothesized that the thalweg's residual variance would be less in more altered channel segments, and that this variance could be used as a restoration endpoint. Recovering stream channels would not be considered "restored" until their thalweg variances equaled or exceeded a threshold variance associated with restored channels. In this way, thalweg variance would be a measure of channel complexity and a quantitative restoration endpoint.

Before testing this approach in the Mono basin, control channel reaches were required, i.e., channel segments representative of the pre-1941 morphology. Larsen (1994) was directed by the RTC to examine historic channel morphology in selected reaches that remained in their original configuration. The two most preserved sites were: the lower segment of the 1A Channel approximately 500 ft below the Narrows in Rush Creek and the lower segment of the A4 Channel in Lee Vining Creek (Plate 2). Larsen also identified another reach in Rush Creek, labeled "Yellow Bird", that was once the historic channel and remains the present day channel. This site is 500 ft downstream of the 1A Channel.

The 1A (Rush Creek) and A4 (Lee Vining) historic channel segments provided the best control segments needed to evaluate our initial hypothesis of using thalweg variance to measure complexity. Thalweg variances of the 1A and A4 channels were expected to exceed thalweg variances of nearby contemporary channels, i.e., pre-1941 channels were structurally more complex. The most ideal paired comparison was between the A4 Channel (Plate 2) and upper Lee Vining mainstem (Plate 1). Another was the comparison between Yellow Bird and the 1A Channel in lower Rush Creek.

Residual thalweg variances were calculated for all planmap reaches and control channels (Table10). Upper mainstem Lee Vining channel had a higher thalweg variance than the A4 Channel, opposite our prediction. Yellow Bird reach also had a higher variance than the 1A Channel. Other computed variances loosely conformed to a similar trend: historic channel morphology has a lower, not higher, thalweg variance. But lower Lee Vining Creek B1 and mainstem had the opposite relationship (Table 10). Perhaps the most intuitively clear distinction is the high variance of the County Road channel compared to lower variances of classically meandering channels (1A, Yellow Bird, and lower Rush Creek): 0.403, 0.566, and 0.492 respectively. Based on historic aerial photographs (Stine 1992), a restored lower Rush Creek County Road channel should be more meandering. Unlike the few other surviving B1 segments, upper Lee Vining B1 profile (not planmapped) is straight, narrow, and deeply incised. This reach's low variance (0.097) may be outside the norm. Channel 14 in lower Rush Creek was not surveyed for its thalweg profile, now mostly buried in sand. However, the upper portion is not buried (approximately 400 ft) and should be surveyed. Our field notes document a uniform channel, i.e., it would have a low thalweg variance.

Thalweg variance has promise as quantitative termination criteria. For example, the County Road channel probably should have a restored thalweg variance near 0.400 rather than its present 0.824 variance. This would require a more sinuous and confined channel than presently exists, fitting-in well with our vision of channel restoration. The method's greatest limitation is availability of control channels. Rather than relying on control channels, we are exploring ways to predict a restored thalweg profile using basic alluvial channel morphology. Also there are many ways to describe the frequency distribution of thalweg residuals other than as a sample variance. We are plotting frequency distributions for the negative residuals (pools) independent of the positive residuals (riffles) as another possibility for quantifying structural channel complexity.

Thalweg profiles have other uses beside termination criteria. By regressing a linear trend through the thalwegs of riffle crests, we can evaluate whether the channel is downcutting or aggrading. The change in the regression's intercept indicates the extent of downcutting or aggradation. Cross sections generally cannot document channelwide trends unless the change is dramatic. Three years of thalweg profiles regressed through the riffle crests in lower Rush Creek planmap site (Figure 43) show no downcutting. Yet, a 0.5 ft change or less would have been detectable. The change in positive and negative residuals also provides an objective methodology for documenting trends in pool and riffle abundance. The relatively low thalweg variance in meandering channels (compared to straight cobble reaches) suggests that structural complexity may have been more a product of LWD accumulation, rather than channelbed topography. This in turn suggests that hydraulic roughness of pre-1941 channels may have been very high, particularly for flood flows.

In summary, insufficient historic thalweg profiles make any detailed recommendation of thalweg variance as a termination criteria conditional at this stage of our investigation. However, lower variance is indicative of the pre-1941 channel condition. Thalwegs surveyed indicate maximum residual variances of 0.040 to 0.045 in lower Rush Creek and lower Lee Vining Creek are reasonable upper limits for a pre-1941 condition. Most contemporary reaches have higher variances, the most conspicuous being the County Road planmap reach and Lee Vining mainstem.

Channel Confinement

A channel with confinement can constrict high flow. There are several ways to permanently or temporarily constrict high flow: increasing bank roughness (hydraulic), bank aggradation, channel downcutting, and by ice formation. Hydraulic and aggradational confinement are highly interrelated. Dense vegetative growth on the floodplain increases resistance to flows to hydraulically keep most high flow in the main channel meanwhile creating an ideal environment for depositing fine sediment with very slow settling velocities on the banks and floodplain. The next flood encounters higher banks, and therefore greater confinement. During rain-on-snow floods, the sudden peak runoff can be confined by ice or dense snow along the stream banks. The same peak discharge without being "walled-in" by snow banks may be only half as deep in the main channel. Channel downcutting tends to create steeper banks (at least temporarily) and thus constrict higher flows.

Channel confinement is a process and therefore should be measurable as a rate. It is a force per unit area and can be quantified by the depth-slope product estimating τ_b (equation (2)). A uniform riffle that has the same slope and width (i.e., the same S and w_{bf}) but is narrower and deeper (i.e., a higher d) will have a greater τ_b at the same flow. Therefore, τ_b for a given flow magnitude or recurrence interval (e.g., $Q_{1.5}$) quantifies channel confinement; τ^*_{ci} can be used to predict changes in channelbed composition (the D_{50} and D_{84}) as τ_b changes. Bankfull width, although easy to measure off aerial photographs, is not a sufficient measure of channel recovery because it does not consider channel confinement. That is why we do not recommend channel widths as termination criteria. A contemporary channel with 0.5 ft banks and an historic channel with 2 ft banks may have the same (or similar) width but will function very differently.

The initial step in our investigation of channel confinement was to estimate τ_b for the unregulated $Q_{1.5}$ flood of 400 cfs in pre-1941 channel segments. The two historic sites in lower Rush Creek (XS02+03 in the 1A Channel and Channel 14) and XS06+80 in the A4 Channel of Lee Vining Creek had τ_b ranging from 0.40 lbs/ft^2 to 2.66 lbs/ft^2 (Table 11). XS05+45 in upper Rush Creek, with a cross section shape relatively unchanged from its pre-1941 morphology, had a similar τ_b value (1.52 lbs/ft^2) as the 1A Channel and Yellow Bird crossections (1.46 lbs/ft^2 and 1.30 lbs/ft^2) for the unregulated $Q_{1.5}$ and similar slopes (0.0145, 0.0110, and 0.0110 respectively). Whereas, XS05+07 in lower Rush Creek (with projected floodplain aggradation) had τ_b at unregulated $Q_{1.5}$ approximately double (1.49

lbs/ft^2) that of the Channel 14 cross section (0.40 lbs/ft^2), but also a higher slope (0.0092 compared to 0.0019).

The steeper the slope on Rush Creek, the higher τ_b at unregulated $Q_{1.5}$ (Figure 44). Only those contemporary cross sections that have minor morphological changes since 1941 (XS05+45 on upper Rush Creek) or can be reconstructed to a restored condition (i.e., aggraded 1.5 ft above its pre-1941 floodplain) were plotted. More points are needed before completely quantifying a slope-to-τ_b relationship for Rush Creek. However, the magnitude of change in τ_b between pre-1941 and contemporary morphology can be appreciated by computing τ_b at the contemporary regulated $Q_{1.5}$ of 150 cfs (for Rush Creek) and plotting computed τ_b as a function of slope. The difference in intercept of the two regression lines (Figure 44) helps quantify the restoration challenge ahead.

More work is needed to quantify a slope-to-τ_b relationship for Lee Vining Creek. When lower Lee Vining Creek lost its pre-1941 floodplain and terraces, the channel also lost its confinement. The same flow in the relatively narrow and deep pre-1941 channel morphology of lower Lee Vining Creek would have produced greater τ_b than the contemporary channel that is wider and shallower. A paired comparison between XS06+80 on the A4 Channel and XS13+92 on the adjacent mainstem illustrates the dynamics of channel confinement. The contemporary τ_b (at a regulated $Q_{1.5}$ flood of 180 cfs) for the mainstem XS (2.16 lbs/ft^2) is approximately 0.5 lbs/ft^2 less than τ_b for the A4 channel (2.66 lbs/ft^2) (at an unregulated $Q_{1.5}$ flood of 265 cfs). If a restored XS13+92 is projected by vertically aggrading the banks at stations 42 ft and 65 ft on the cross section, the water elevation producing a 265 cfs flood is 6540.0 ft (Figure 45). The τ_b at this elevation is 3.35 lbs/ft^2, substantially higher than the A4 channel at the same unregulated $Q_{1.5}$. Why the big difference, even though their average depths are 1.74 ft and 1.75 ft at unregulated $Q_{1.5}$? Slope of the A4 Channel is 0.0245, whereas slope of the adjacent mainstem is 0.0307. The A4 Channel is relatively sinuous; without sinuosity (i.e., the longitudinal profile does not trace the thalweg), an A4 Channel slope of 0.0300 would be similar to the mainstem slope. For Lee Vining Creek, increase in confinement and greater sinuosity will be required for channel restoration.

In summary, the intercept of a linear regression, with slope as the independent variable and τ_b as the dependent variable, could serve as a quantitative restoration endpoint. In Figure 44, the pre-1941 regression line would be the restoration endpoint for channel confinement; the contemporary regression line represents present-day confinement if the annual maximum flood frequency curve stays the same. Accurate slope measurement is critical to realistically estimate τ_b; distributing sample sites evenly throughout the channels would require a slope measurement for each, and consequently an extensive sampling program. Instead, cross section selections should be located within the planmapped sites where extensive slope estimates and cross section surveys have already been made. A few additional cross sections could be added that have slopes not encountered in the planmapped channels.

Individual cross sections will shift from their contemporary condition to the pre-1941 condition in Figure 44 several ways. Once the annual flow regime changes, the $Q_{1.5}$ flood will increase. Average depth at the new $Q_{1.5}$ will increase, and therefore so will τ_b. Some segments of Rush Creek should achieve their endpoint τ_b simply when releases of approximately 400 cfs occur at a frequency characteristic of the unregulated bankfull discharge (e.g., Upper Rush Creek). Other segments will require additional floodplain aggradation to increase confinement (e.g., lower Rush Creek). Still other Rush Creek segments (e.g., County Road planmap site) will require aggradation and greater sinuosity (to reduce high flow slope). On Lee Vining Creek mainstem, significantly more aggradation and greater sinuosity will be necessary to achieve the pre-1941 confinement condition (i.e., the pre-1941 regression line in Figure 44).

Confinement only has been presented relative to the bankfull stage, when flow theoretically begins to spill across an unaggraded floodplain. The bed averaged shear stress (τ_b) at bankfull stage significantly mobilizes the general channelbed. But the historic cross sections show constrained flow at higher stages. Did Rush Creek and Lee Vining Creek require much higher shear stresses to shape and maintain their channel morphology? Or did most floods overtop the banks then spread throughout an extensive floodplain, thus minimizing the increase of flow depth in the main channel and ultimately minimizing increases in shear stress? To answer these questions, we must gain a greater understanding of floodplain aggradation.

Riparian Vegetation Acreage

Lee Vining Creek

Along Lee Vining Creek, below the diversion structure and above Rt.395 (Reach 1 and Reach 2), quaking aspen, Jeffery and lodgepole pine dominate riparian plant stands. In 1989 riparian vegetation coverage was already within 0.5 acres of the SWRCB termination criteria in Reach 1, and 5.6 acres in Reach 2 (Table 6); for this reason we did not re-map vegetation within these reaches. We mapped riparian vegetation in Reach 3, downstream of Highway 395 within the valley wall (Plates 10 to 13). In Reaches 3A and 3B riparian vegetation recovery was within 10 acres of termination criteria and in Reach 3C riparian vegetation coverage was within 0.1 acre (Table 6).

Rush Creek

Unlike Lee Vining Creek, riparian vegetation along Rush Creek survived de-watering and was never exposed to catastrophic fire (Plates 14 to 20). Riparian vegetation cover has met the termination criteria in some reaches, while still requiring over 20 acres of cover in others (Table 7). Below the Narrows, the Rush Creek riparian corridor reaches its greatest width. Channel incision due to receding lake level becomes increasingly evident below the Narrows. Some pre-1941 riparian vegetation survived on former floodplain, now perched above the present floodplain; only increased ground water levels resulting from rewatering sustain it.

During vegetation mapping we defined 14 geomorphic units in the Rush Creek riparian corridor (Table 12). Lee Vining Creek geomorphic units were also mapped using similar definitions. Making up 17% of the total corridor area, portions of the riparian corridor have been created since 1941 and vegetated since 1987. Pre-1941 floodplain/low terrace, evidenced by the mature/senescent riparian vegetation covering these surfaces, currently makes up 36% of overall corridor area. Pre-1941 middle terraces and the remainder of the geomorphic units that fall within the valley are covered with desert vegetation and have not been historically fluvially active.

Rush Creek Reach 2 cuts through Tioga age glacial moraine. Riparian vegetation has passed the termination criteria coverage recommended by SWRCB (Table 7, Plate 20). Half of the mapped vegetation in this reach is a mixture of riparian vegetation (48%) and transition vegetation (4%). The riparian corridor is narrow, and riparian vegetation has few opportunities to expand in width.

Reach 3A is alluvial, beginning where Rush Creek leaves the Tioga moraine, and most mapped riparian vegetation within this reach survived the dewatering period (Plate 20). Riparian vegetation coverage is within 4.5 acres of the SWRCB termination criteria (Table 7), and comprises nearly 1/3 of the mapped vegetation in this reach. Vegetation coverage within the riparian corridor is a mixture of desert (66%), riparian (31%) and transition (2%) stand types. The width of riparian vegetation along the stream and its distributaries is 1 to 2 plants wide. At the rate of recovery since 1989, riparian vegetation cover within this reach should attain the termination criteria by 2009.

Reach 3B is characterized by the same channel characteristics as Reach 3A, however in this reach the riparian vegetation did not survive and much of the pre-1941 floodplain has been scoured and abandoned (Plates 19 and 20). Throughout Reach 3B most riparian vegetation has been planted or naturally recruited. Riparian vegetation cover is within 0.8 acres of the SWRCB riparian vegetation coverage termination criteria (Table 7). Historically however this reach had much more riparian vegetation cover (Stine 1992). LADWP has recently removed a berm and rewatered a channel, which should lead to a large increase in riparian vegetation cover along the rewatered channel. Currently within the valley walls riparian stand types (5.5%) and transition stand types (0.3%) vegetation comprises only 6% of the total vegetation cover, while desert stand types makes up the remaining 94%. This reach has effectively met the "recovered" riparian vegetation acreage, but this "recovered" coverage does not consider stand structural qualities or self sustaining plant populations. The re-watered reach presents an excellent opportunity to study riparian woody species recruitment requirements.

Human disturbance in combination with water diversion has influenced vegetation pattern in Reach 3C and 3D (Plates 18 and 19). The stream becomes more confined between valley walls and steeper (in many respects similar to Lee Vining Creek Reach 2). Desert vegetation is over 85% of the total riparian corridors vegetative cover. Riparian vegetation recovery within Reach 3C is within 3.1 acres of the SWRCB termination criteria (Table 7), and if current trends continue, is forecasted to reach this target by 2007. Riparian recovery in reach 3D is 5.3 acres from the termination criteria, and if current slow rate of vegetation recovery remain, this reach is forecasted not to fulfill the termination criteria until 2080. Reach 3D is the only reach within the Rush Creek corridor that will not reach termination criteria coverage by 2025.

Reach 4A-C begins downstream of the Narrows and extends to the County Road Ford (Plates 16 to 18). Below the Narrows the Rush Creek bottomlands begin and the riparian corridor reaches its greatest width. Most mature riparian vegetation is a remnant of the forests that covered this reach before diversion. Channel incision due to receding lake levels becomes increasingly evident downstream from the Narrows downstream. Although some pre-1941 riparian vegetation survived, it is now perched on a high terrace and sustained only be increased ground water levels from rewatering. Reach 4A-C ranges from 2.4 to 24 acres of the SWRCB termination criteria (Table 7), though current trends riparian vegetation recovery have been slow. Riparian (35%) and transition (17%) plant stands comprise 52% of vegetation coverage within the valley wall. Reach 4A-C has aquatic vegetation in pocket wetlands and in historic channels. Using the rate of riparian vegetation coverage increase since 1989, Reach 4A-C should attain the termination criteria by 2025.

Downstream of the County Road Ford in Reach 5A and 5B, Rush Creek is incising through volcanic ash; the rate of incision has exceeded 20 feet in some areas since 1981. Riparian vegetation recovery has been affected by patterns of channel incision and flood scour. Although there are many geomorphic units that could have supported riparian regeneration, channel incision rates have prevented significant colonization. Reach 5A, the last reach considered in the SWRCB riparian vegetation cover termination criteria, is still over 18 acres from meeting the criteria (Table 7). Riparian and transition plants stand types compose 42% of the total vegetation cover. If the current rate of recovery since 1989 continues, the termination criteria will be met by 2020.

Reach 5B is not included in SWRCB riparian vegetation cover termination criteria because it has been created since diversion began. However vegetation in this reach serves an important role for migrating waterfowl. Aquatic vegetation acreage is the highest of any Rush Creek reach (making up a little more than 3% of the total vegetation cover). The Rush Creek delta is a combination of narrowleaf willow thickets, grassland and aquatic vegetation (Plate 15).

Walker Creek

Walker Creek does not have well-defined riparian vegetation recovery criteria, nor a well-defined stream corridor. Grazing and streamflow diversion have influenced vegetation patterns and the subsequent recovery of riparian vegetation. Our riparian acreage data are not yet comparable to Jones and Stokes (Table 8). Riparian vegetation has its greatest coverage and width in reaches above old Highway 395 (Plates 21 to 24). Below new Highway 395, the riparian corridor is rarely more than two or three tree/shrubs wide on either side of the creek.

In summary, Tables 6 and 7 are our best riparian acreage assessment of recovery toward the termination criteria. As discussed, a variety of problems have prevented complete compatibility between all studies. The pre-1941 acreage, originally established in SWRCB Order 98-05, still serves adequately as termination criteria. Riparian vegetation cover acreage do not address the age structure, species diversity, canopy architecture, natural recruitment or other important vegetation "qualities" mandated in the SWRCB order. Measures of stand "quality" or development, such as canopy, species and age structure, are not currently considered as termination criteria, because quantifiable pre-1941 reference conditions do not currently exist. We are working on developing quantifiable criteria that define "self-sustaining" and "healthy" for the pre-1941 riparian corridor condition. This will be the focus of our upcoming field season, starting mid-May.

Parker and Walker Creek Termination Criteria

Establishing physical termination criteria for Parker and Walker Creeks is unwarranted. We anticipate no changes in main channel length, channel gradient, channel sinuosity, channel confinement, or variation in thalweg profile. However, planmap segments, aerial photos, thalweg profiles, and cross sections have been established in both creeks below the diversion points to establish long term monitoring sites. Restoration criteria for riparian acreage are appropriate, but have not been resolved. We have identified short segments of banks that had been impacted by human use, but are recovering. We need to better quantify potential restoration acreage to facilitate riparian recovery and report as termination criteria.

Channel Projects: Past and Future

WY1999 Channel Projects

The following channel projects were accomplished in WY1999 as outlined in the Mono Basin Stream and Stream Channel Restoration Plan (LADWP 1996):

(1) Two overflow channels in Reach 3A of upper Rush Creek, blocked by artificial boulder berms, were opened. Portions of both berms were excavated down to the original channelbed surface to create flow entrances. No modifications were made in either overflow channel, together totaling 980 ft;
(2) Flow entering the left side of the mid-channel island located immediately downstream of the Upper Rush Creek planmap (Plate 5) was diverted into the historic channel network of Reach 3B. Rather than diverting at the head of the island, a lower break in

the left bank closer to the bottom of the island became the diversion site. No modifications were made in the historic channel, given the purpose of the re-watered channel was groundwater recharge to promote riparian vegetation growth;

Stumps stored at the Cain Ranch, and originally obtained from a local highway widening project, were helicoptered into Rush Creek and Lee Vining Creek. A video documenting placement is available from LADWP.

WY2000 Channel Projects and Management Actions

We recommend the following near-term management actions for WY2000:

a) maintain the A4-mainstem entrance on lower Lee Vining Creek and the Channel 10 entrance on Lower Rush Creek as riparian trees mature, while recognizing the potential rate of floodplain aggradation (i.e., primary channel restoration) will be impaired;
b) allow the present bar dynamics of the Rush Creek mainstem, upstream of the planmapped reach, to continue. This may result in most flow being diverted into Channel 10, and possibly requiring a future maintenance decision on the mainstem's fate adjacent to Channel 10;
c) re-evaluate the restoration plan's mandate to open the Channel 4 link (LADWP 1996, p.70), though we presently are inclined against it. This project is not an issue of cost (very minor to make this linkage), but of purpose. This linkage was to improve recharge of the extensive pre-1941 floodplain containing the complex plumbing of the Channel 4 (Stine et al. 1994, p. 23). Recent aerial videos and field inspections show water availability has greatly improved in this area (via elevated groundwater contributions and some surface water flow during recent peak flow events). We are concerned that the proposed diversion of 10 cfs will have a negative cumulative effect on fishery baseflows. We are also sensitive to past efforts originally intending to divert a few cfs, but that eventually divert more;
d) not consider linking the 1A Channel to the present day mainstem as originally proposed in the restoration plan (LADWP 1996, p. 70). The entrance would likely capture a significant proportion of the total flow and significantly impede restoration elsewhere;
e) take no action on the proposed Channel 14 project (LADWP 1996, p. 71). Given recent developments (the 10-channel falls creating a backwater and diverting several cfs across the Channel 13 complex and into Channel 14), purposes of this project are presently being mostly satisfied (except for the lower half of Channel 14, which is not being re-watered);
f) design and permit the Reach 3D project in WY2000 as stated in the restoration plan (LADWP 1996, p.70);
g) evaluate the WY1999 projects and make physical changes, if needed.

Summary

The two primary restoration strategies will be releasing appropriate annual flow regimes and planting wherever natural recovery of the pre-1941 aggraded floodplain is unlikely. Continued elimination/restriction of livestock grazing also looms critical. Other lesser strategies may have major local impact. Maintenance of the County Road crossing in lower Rush Creek is extremely important in stabilizing grade control for a recovering alluvial channel.

Of them all, determination of "appropriate" annual flow regimes is the most critical to long term recovery. Annual flow regimes without peak floods exceeding the unregulated bankfull discharge ($Q_{1.5\text{-yr}}$) cannot achieve channel confinement. An aggrading point bar on the inside meander bend needs peak flows in excess of $Q_{1.5\text{-yr}}$ to encourage deposition. As the floodplain widens in our simplified aggradational floodplain model, greater and greater magnitude flows would be required to initiate point bar deposition. Without deposition above the bankfull stage, bankfull channel width cannot be maintained in the migrating channel.

Monitoring is demonstrating that Rush Creek and Lee Vining Creek, especially in their most impacted bottomlands, behave physically as contemporary alluvial channels. This will help considerably in formulating, and justifying, appropriate annual flow regimes. We mentioned that the "wrecking ball" of lateral channel migration will be nature's way to remove stranded floodplains (resulting from man-induced incision), then to rework the alluvium (of these former floodplains) into a new floodplain. There are several hitches to this expectation. The elevation of this new floodplain probably will not be as high as the pre-1941 floodplain throughout much of lower Rush Creek and Lee Vining Creek. The difference in elevation will depend on channel location and peak flow releases.

Part of our study and monitoring is to determine what happens geomorphically and ecologically with varying degrees of partial confinement. Can we translate lbs/ft^2 into ecological structure and function? Although riparian berms reached 2 ft or higher on the pre-1941 aggraded floodplain, would a 1.0 ft high or 1.5 ft high berm be satisfactory? Will the Yellow Bird reach be an acceptable restoration template: recreating a dynamic contemporary aggraded floodplain nestled within its former aggraded floodplain? At the Yellow Bird site, elevation of the restored aggraded floodplain would approximate the elevation of the pre-1941 floodplain. Provided this reach maintains its planform geometry (and therefore its slope), pre-1941 and restored bed averaged shear stress (τ_b) would be about the same if a 1.5 ft berm was maintained.

The last hitch is that natural recovery may take too long for many concerned people. Can we rebuild and repair Lee Vining Creek and Rush Creek faster than mother nature heals? Possibly, by accelerating certain processes. Placing large wood into the channels clearly compensates the relatively slow growth (relative to our human itch for change) of fast-growing cottonwoods. Female cottonwoods may be lacking in lower Rush Creek (with obvious consequences) based on our recent surveys. This can be remedied by planting. Even paying attention to the specific planting location of these female cottonwoods could accelerate recovery. As illustrated in Ridenhour et al (1995), trees planted 10 ft to 20 ft landward and downstream from a meander bend apex would permit sufficient time for significant growth (greater than 1 ft diameter) before the migrating channel undercuts and topples them into the channel. For example, a good planting location would be near the left bank pin of XS07+25 on the lower Rush Creek planmap site (Plate 6).

The pre-1941condition will not be achieved before Mono Lake reaches 6,392 feet, especially for lower Lee Vining Creek. One reason is that woody riparian vegetation requires more time to mature than is likely needed to fill Mono Lake. Lower Rush Creek is not as far from reaching a functional aggradational morphology, though the extent of aggradation needs considerable recovery still. Additional confinement must be expected of the stream restoration flows (SRF's). Real uncertainties in achieving restoration will be: (a) sustainability of the creek's multiple channel network as primary and/or secondary channels, (b) the continuing geomorphic response of Rush Creek's Reach 4B to major slope changes, (c) availability of fine sand and silt to adequately aggrade lower Lee Vining floodplains, and (d) the influence of large woody debris (LWD) on channel morphology and flood stages once the riparian forest matures. All are highly interdependent, dominant physical factors contributing to both streams' potential to sustain trout habitat.

The termination criteria are imperfect indicators of a functional and self-sustaining stream ecosystem or, more generally, of stream ecosystem integrity. There are no perfect measures. The criteria will not provide timely feedback (i.e., before Mono Lake fills) for evaluating and adjusting recommended SRF's. The desire to secure formal closure has merit for all concerned parties. But at the expense of this desire, we may be guilty of trying to fit round pegs into square holes. The pegs are the termination criteria, and the squares represent our educated guess of what these streams should look like and how they should behave. One way around this is to make the square so large that almost any peg will fit. Some termination criteria and restoration language fall into this solution. The healthy stream condition described in SWRCB Order 98-05 is too broad. A restoration program will not benefit from objectives and goals that are too general. It certainly will not provide closure.

So how small should the "square" be and how long should we wait before the peg fits? We doubt the square can be made significantly smaller given our ignorance. Luna Leopold (1994, pp. 280-281) sums it (our ignorance) gracefully in:

At any moment of time and at each location in the channel, if the available stress is greater than the resisting force, sediment in motion will be deposited. As these local events occur, the stress structure of the channel is altered until, as suggested by Gilbert, there is an equality of action along the channel. The steady state is an average condition:

the hydraulic parameters are constantly adjusting, rapidly and materially, as the water discharge and the sediment it caries vary through time. Low flow is followed by flood followed by low flow, each of different duration depending on the nature and location of the rainfall or snowmelt. To accommodate these various changes the interdependent hydraulic variables will change in any of several combinations of values.

There is not just one way these factors will change. The immutable physical laws of conservation of energy and conservation of mass can be satisfied by many combinations - in fact, the particular values that will exist at any moment of time and place are indeterminate. Moreover, adjustment to the initial perturbation takes time and may not be completed before another chance event disrupts the condition, causing readjustment to begin anew. Indeterminacy is a principle long recognized in physics, but applicable also to fluvial sciences.

The bottomline is that the channels, if given adequate flow regimes, may take a variety of only partially predictable pathways to recovery. The key to restoration is providing adequate annual flow regimes that will create and maintain a self-sustaining, aggraded floodplain ecosystem after Mono Lake fills, while recognizing we may not be able to predict the "final" dimensions of this dynamic floodplain ecosystem. The most important objective of our study is to identify and quantify these adequate annual flow regimes.

Planting can help heal alluvial surfaces that once were capable of sustaining riparian vegetation but are no longer capable. Part of our study is to give natural recovery time, but meanwhile identify where riparian plant recovery is very unlikely and why. Just below the Narrows, the pre-1941 floodplain was buried under quarry tailings deposited from a late-1960s flood along the east-side of the stream corridor. This surface would be an excellent candidate for creating (by planting) an extensive Jeffrey pine stand. It is a good choice because of its slow growth and riparian affinities, and has been slowly expanding downstream of the Narrows. Adopting this strategy recognizes that the pre-1941 condition is not a reasonable restoration goal. The cottonwood forest that once occupied this location has no chance of coming back anytime soon. Only re-working this coarse sediment into a contemporary floodplain via channel migration can accomplish cottonwood recovery here. In the meantime (many decades), a Jeffrey pine forest is a viable alternative.

Black cottonwood seedlings and saplings have begun to radiate from surviving populations along Lee Vining Creek, but not in the Rush Creek bottomlands. Black cottonwood stands are recovering in lower Lee Vining Creek, yet may not populate floodplains rapidly enough to promote sufficient deposition and channel confinement. Many black cottonwoods survived dewatering below the Narrows although very few are female. We seldom observed their seedlings or younger age classes. Has timing of peak flows been too altered and/or are there simply not enough viable seeds? If black cottonwood planting continues, special emphasis must be placed on selecting similar numbers of male and female cuttings.

For most alluvial surfaces in the bottomlands of Lee Vining Creek and Rush Creek, planted black cottonwoods will not re-establish self-sustaining stands. Without the exacting conditions for successful seedling establishment created by frequent flooding, only one age class will survive (the age class planted) on the pre-1941 aggraded floodplain. Suckering is a way of establishing new age classes absent periodic flooding, but probably does not sustain stands (more to say on this). But a rationale for planting the pre-1941 aggraded floodplain (and lower surfaces) can be sound. As lateral migration or avulsion eventually removes former floodplain, mature planted cottonwood and Jeffrey pine will be undermined and toppled into the channel as LWD. Establishment of a Jeffrey pine forest or black cottonwood stand will influence stream microclimate and encourage recruitment of understory species. The recent headcutting of lower Lee Vining Creek above the County Road blow-out has stranded even contemporary floodplains. These surfaces, once capable of establishing riparian vegetation under specific flow regimes, are now too high to flood frequently. Plantings in the early to mid-1990s anticipated timely mitigation to headcutting in the late-1990s.

Adding sediment to the channel may be the ultimate attempt to accelerate recovery in lower Lee Vining Creek. The restoration strategy, to date, has been to guarantee that coarse and fine sediment is available to the mainstems for redistribution downstream. Sediment addition would accelerate floodplain deposition (in conjunction with high flows) and greater channel confinement.

Recommendations

Additional Monitoring Recommendations for WY2000

- GPS entire thalweg profile for lower Rush and Lee Vining creeks, including several historic primary channels (e.g., Channel 10 and Channel 14)
- Explore the feasibility of installing a continuously recording gaging station in lower Rush Creek (near the Ford or County Road)
- Include additional XS's for developing a better slope-bed shear regression for use as termination criteria
- Continue tracking contemporary headcutting up Lee Vining Creek (mainstem and B1 Channel)

Termination Criteria Recommendations

- Channel Gradient and Sinuosity. Original termination criteria, proposed termination criteria, and WY1999 conditions for channel gradient and sinuosity are presented in Table 13. Recommended changes to the termination criteria were based on our inspection of the historic data developed by Stine, as well as on field inspections using recent aerial photos. Changes to the channel gradient criteria will be proposed at the end of this sampling season; we plan to survey thalweg elevations using GPS. Reach 4C in the Rush Creek bottomlands may have an unrecoverable pre-1941 channel gradient and sinuosity given its major change in slope caused by cutting-off Channel 14. We will be prepared at the end of this monitoring year to provide specific termination criteria for Reach 4C (i.e., this reach will require more than GPS surveying).

- Primary Channel Lengths. Original termination criteria, proposed termination criteria, and contemporary mainstem channel lengths are presented in Table 13. Recommended changes to the termination criteria were based on our inspection of the historic data developed by Stine, as well as on field inspections using recent aerial photos. Inclusion of primary channels as reach-specific termination criteria (expressed in feet restored) needs overhauling or elimination. We favor the later, but do not object to keeping the original termination criteria for primary channel lengths. Reach 4C in the Rush Creek bottomlands may have an unrecoverable pre-1941 primary channel length given its major change in slope caused by cutting-off Channel 14. We will be prepared at the end of this monitoring year to provide a specific channel distance for Reach 4C. We have proposed a channel classification protocol to better quantify primary and secondary channels, but need input from others before embarking on reach-wide channel classification. This protocol cannot be performed on early aerial photographs for all channel reaches; therefore, a complete set of pre-1941 channel distances (as termination criteria) based on this protocol would not be possible to quantify. Predicted trends in channel evolution might substitute as termination criteria. In part, some discrepancies in channel distance between the pre-1941 lengths and contemporary lengths are a product of aerial photo scale and the lack of orthorectification.

- Variation of Thalweg Profile. Adoption of thalweg profile variation as a measure of channel health or recovery is experimental. Surveyed thalweg profiles indicate residual variances of 0.040 to 0.045 in lower Rush Creek and lower Lee Vining Creek (Table 10) should serve as general termination criteria. More study is needed before recommending specific thalweg profile variances for each designated channel reach.

- Channel Confinement. Greater confinement, by simply aggrading the floodplain and making the streambanks higher, will increase shear stress (force per square foot) on the channelbed (Table 11). A linear regression, with slope as the independent variable and bed averaged shear stress (τ_b) (lbs/ft^2) of the pre-1941 channel morphology at unregulated bankfull discharge as the dependent variable, can serve as quantitative termination criteria. In Figure 44, the pre-1941 regression line for Rush Creek is the targeted average channelbed shear stresses (as a function of slope) while the regression line represents contemporary bed averaged shear stresses under a regulated bankfull discharge as the present condition. Satisfaction of the termination criteria, for a sustainable floodplain morphology, would require significant overlap of the two regression curves. Lee Vining Creek will require more investigation before recommending a similar paired regression comparison, and more points are needed for the Rush Creek regression to statistically define confidence limits (for the intercept and slope of both linear regressions).

- Acreage of Riparian Vegetation. Tables 6 and 7 are our riparian acreage assessments of recovery toward the termination criteria. As discussed, a variety of problems have prevented complete compatibility between all studies. The pre-1941 acreage, originally established in SWRCB Order 98-05, still serves adequately as termination criteria. Riparian vegetation cover acreage does not address the age structure, species diversity, canopy architecture, natural recruitment or other important vegetation "qualities" mandated in the SWRCB order. This will be the focus of our upcoming field season, starting mid-May.

- Parker Creek and Walker Creek. Establishing physical termination criteria for Parker and Walker Creeks is unwarranted. We anticipate no changes in main channel length, channel gradient, channel sinuosity, channel confinement, or variation in thalweg profile. Restoration criteria for riparian acreage are appropriate, but have not been resolved. We need to better quantify potential restoration acreage to facilitate riparian recovery, before recommending acreage as termination criteria.

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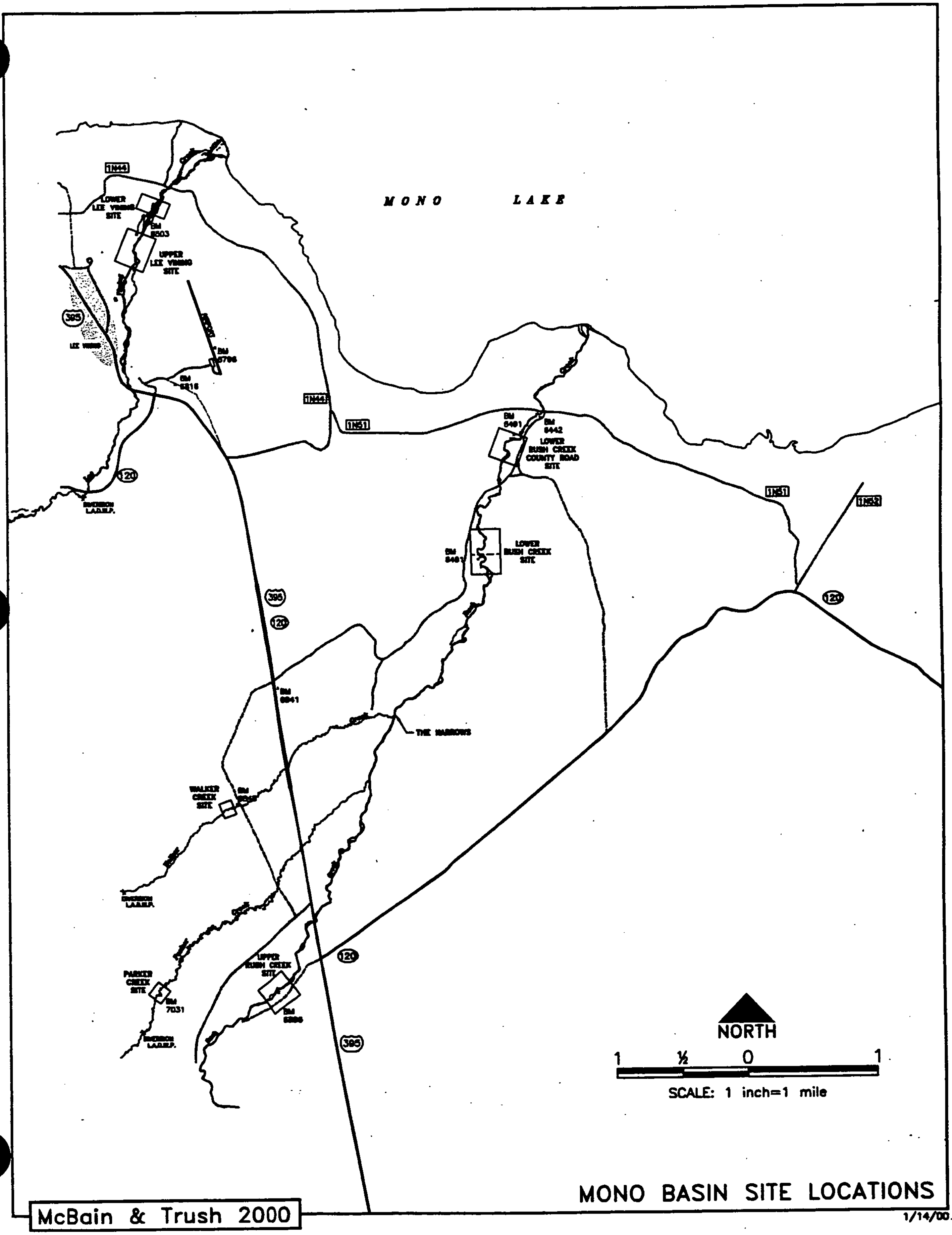


Figure 1. Mono Basin Study Site Location Map.

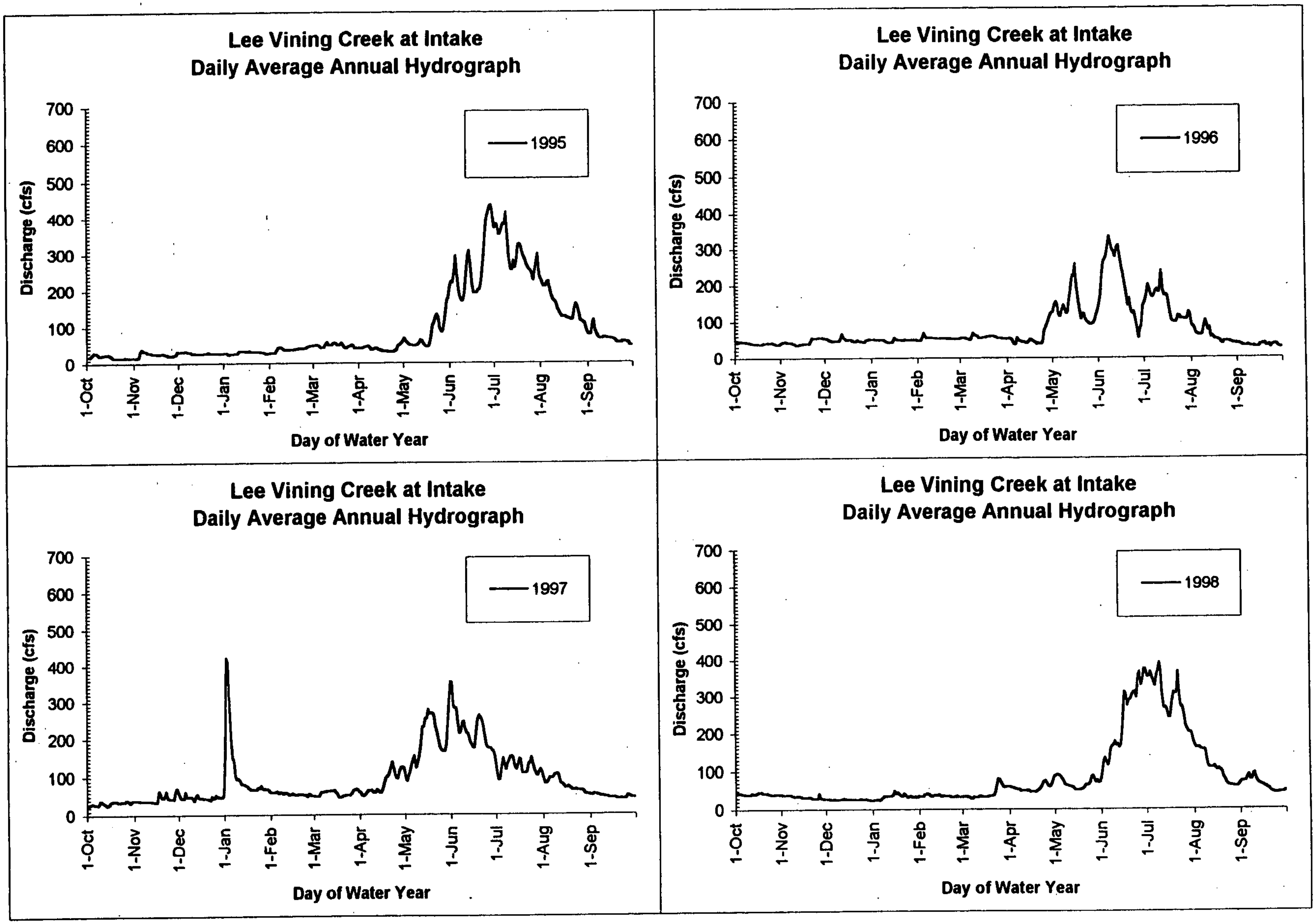
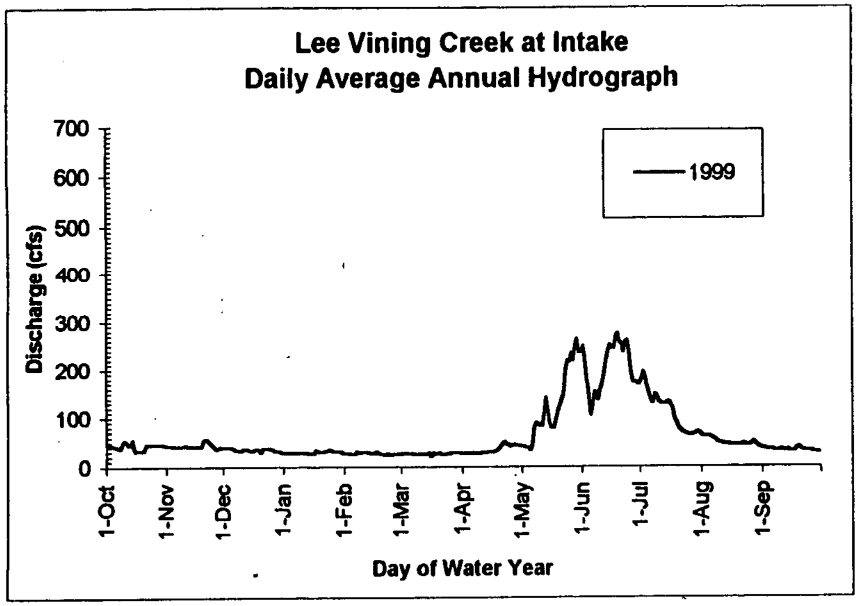


Figure 2. Daily Average Annual Hydrographs for Lee Vining Creek at Intake (LADWP Stn. 5009) for WY1995-99.



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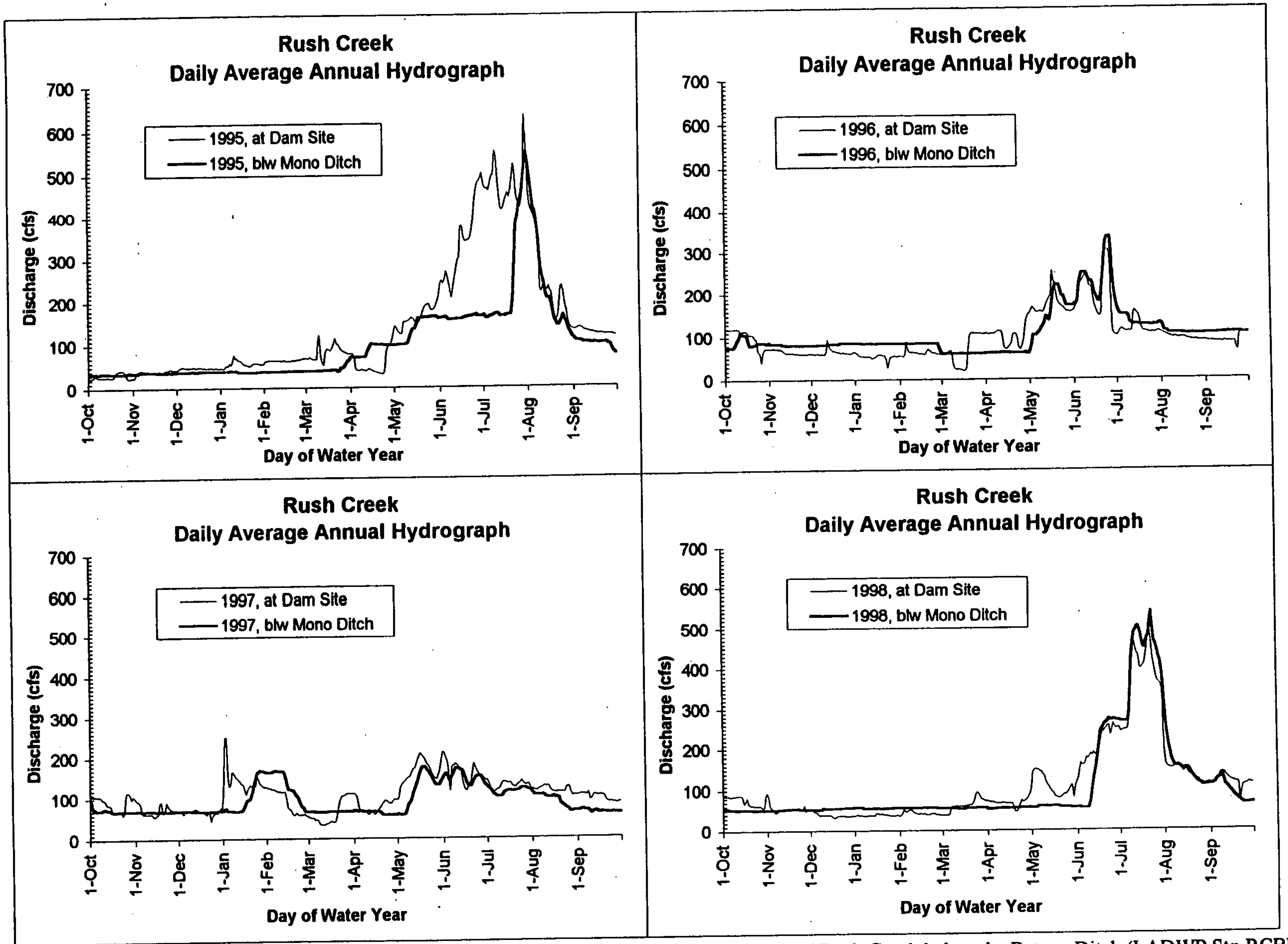


Figure 3. Daily Average Annual Hydrographs for Rush Creek at Dam Site (LADWP Stn. 5013) and Rush Creek below the Return Ditch (LADWP Stn RCBRD) for WY1995-99.

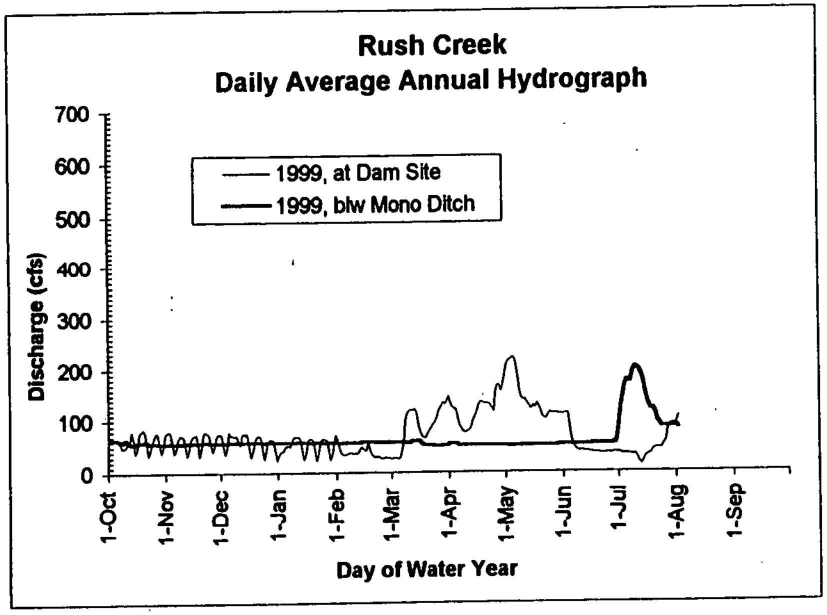


Figure 3. Daily Average Annual Hydrographs for Rush Creek at Dam Site (LADWP Stn. 5013) and Rush Creek below the Return Ditch (LADWP Stn RCBRD) for WY1995-99.

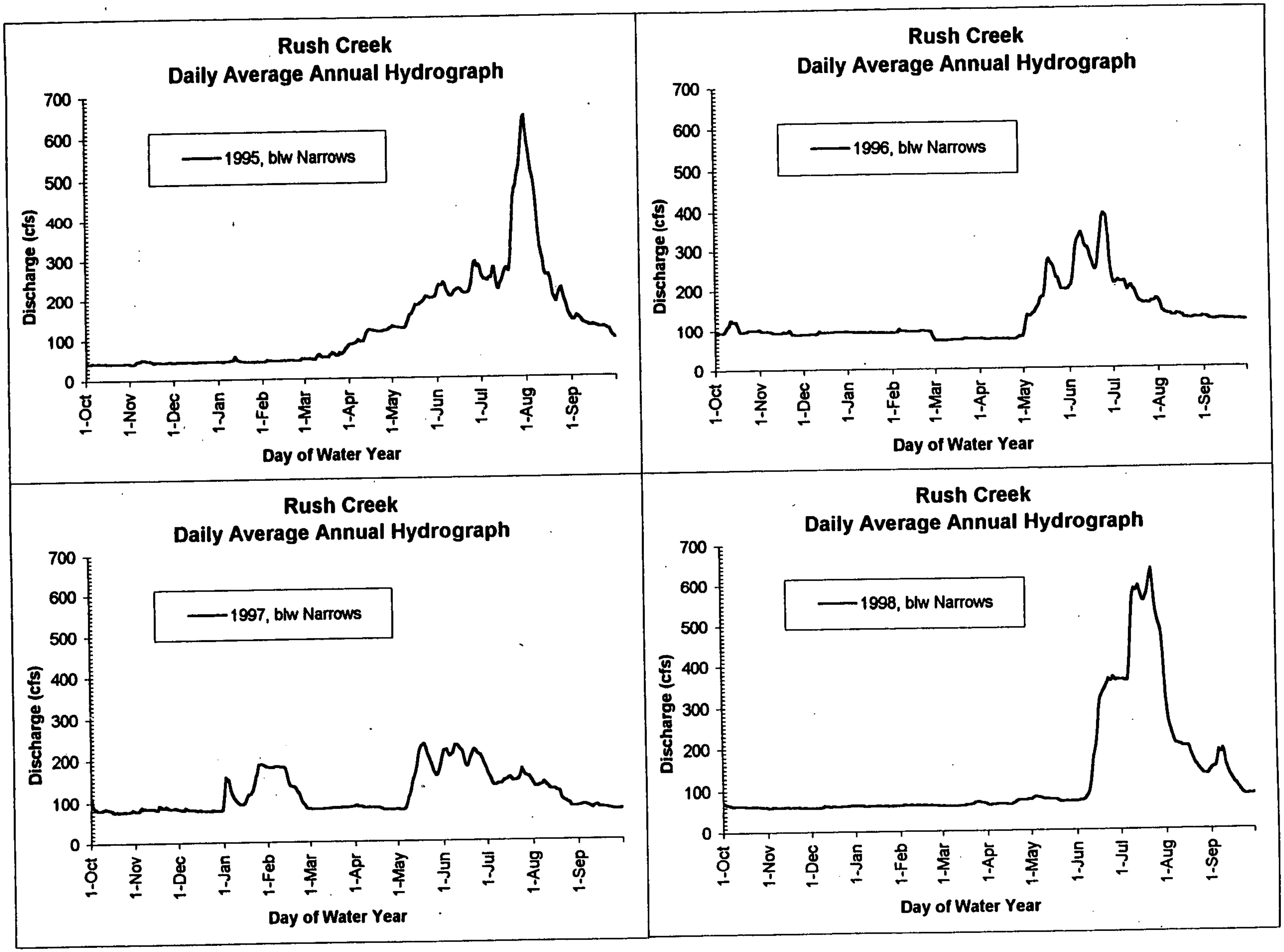


Figure 4. Daily Average Annual Hydrographs for Rush Creek below the Narrows for WY1995-99.

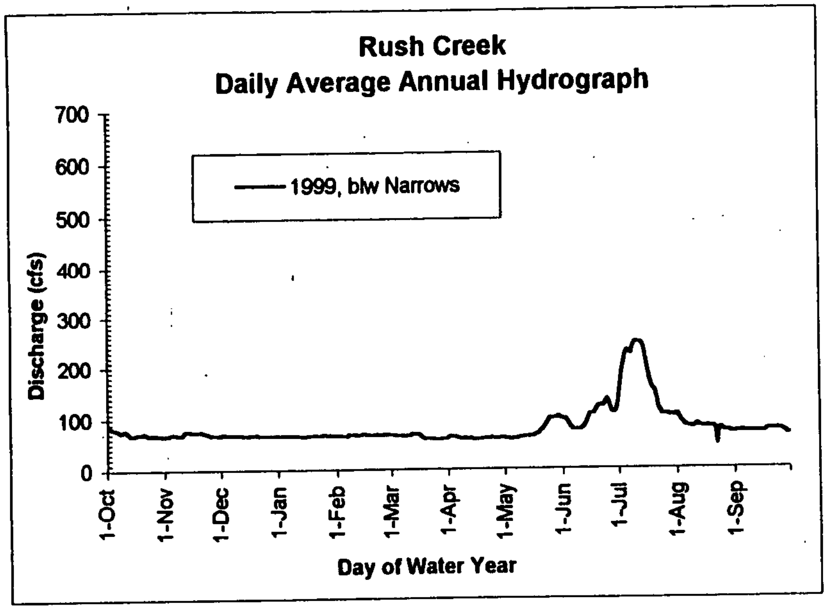


Figure 4. Daily Average Annual Hydrographs for Rush Creek below the Narrows for WY1995-99.

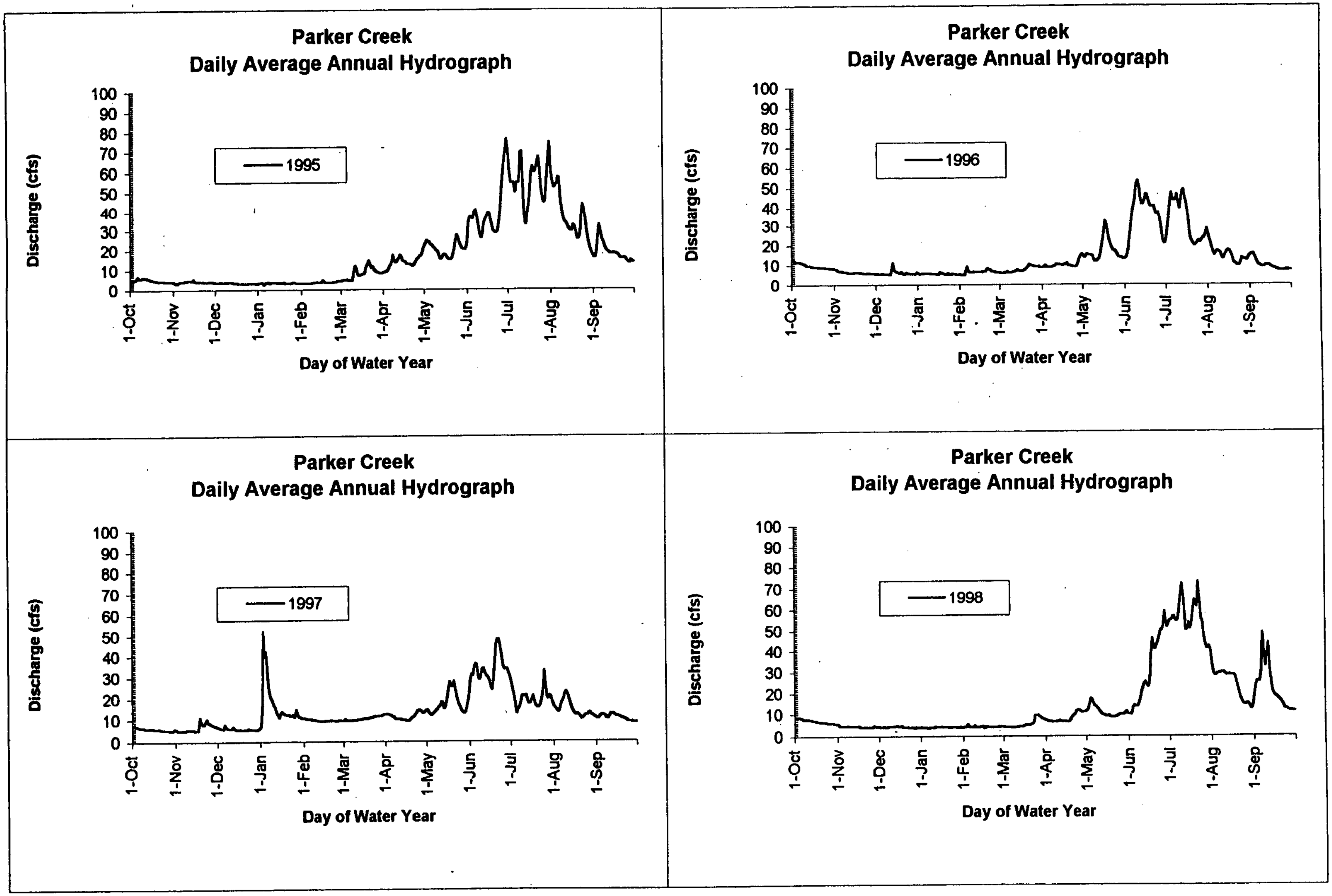


Figure 5. Daily Average Annual Hydrographs for Parker Creek under Conduit (LADWP Stn 5003) for WY 1995-99.

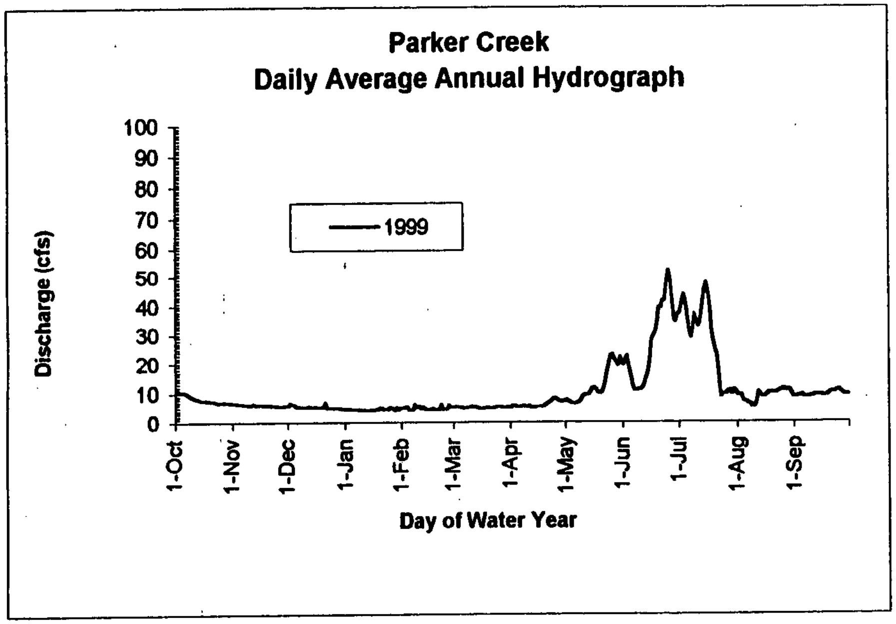


Figure 5. Daily Average Annual Hydrographs for Parker Creek under Conduit (LADWP Stn 5003) for WY 1995-99.

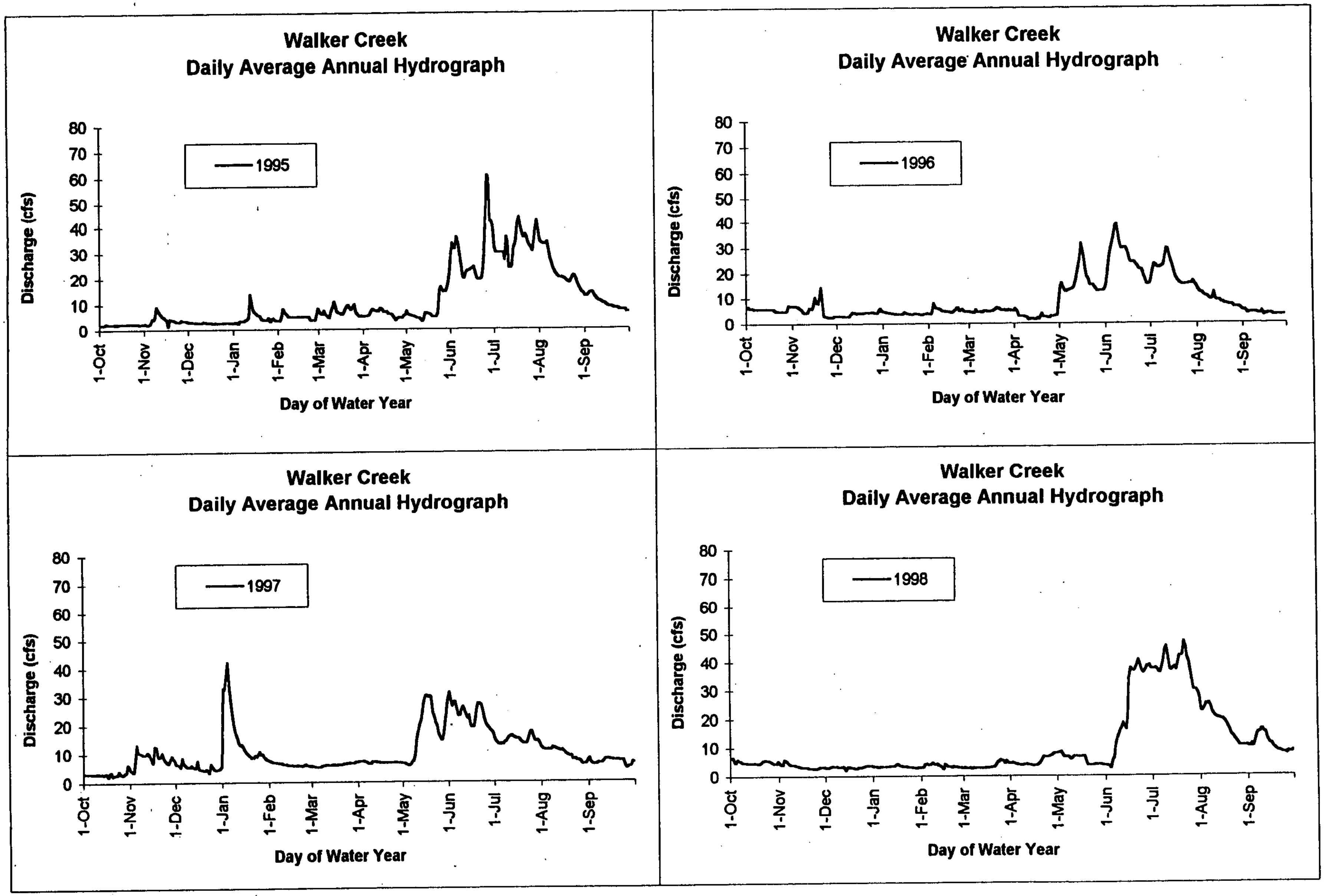


Figure 6. Daily Average Annual Hydrographs for Walker Creek under Conduit (LADWP Stn 5002) for WY 1995-99.

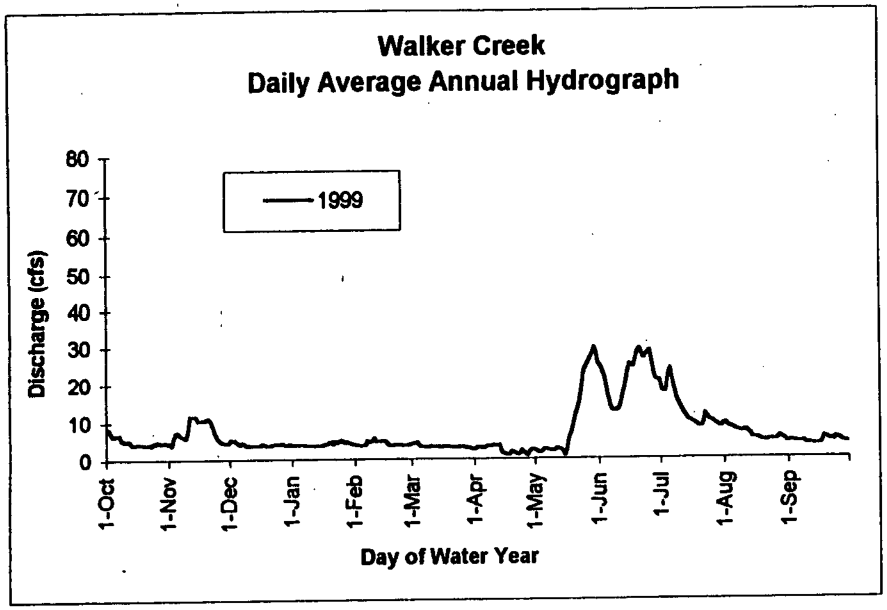


Figure 6. Daily Average Annual Hydrographs for Walker Creek under Conduit (LADWP Stn 5002) for WY 1995-99.

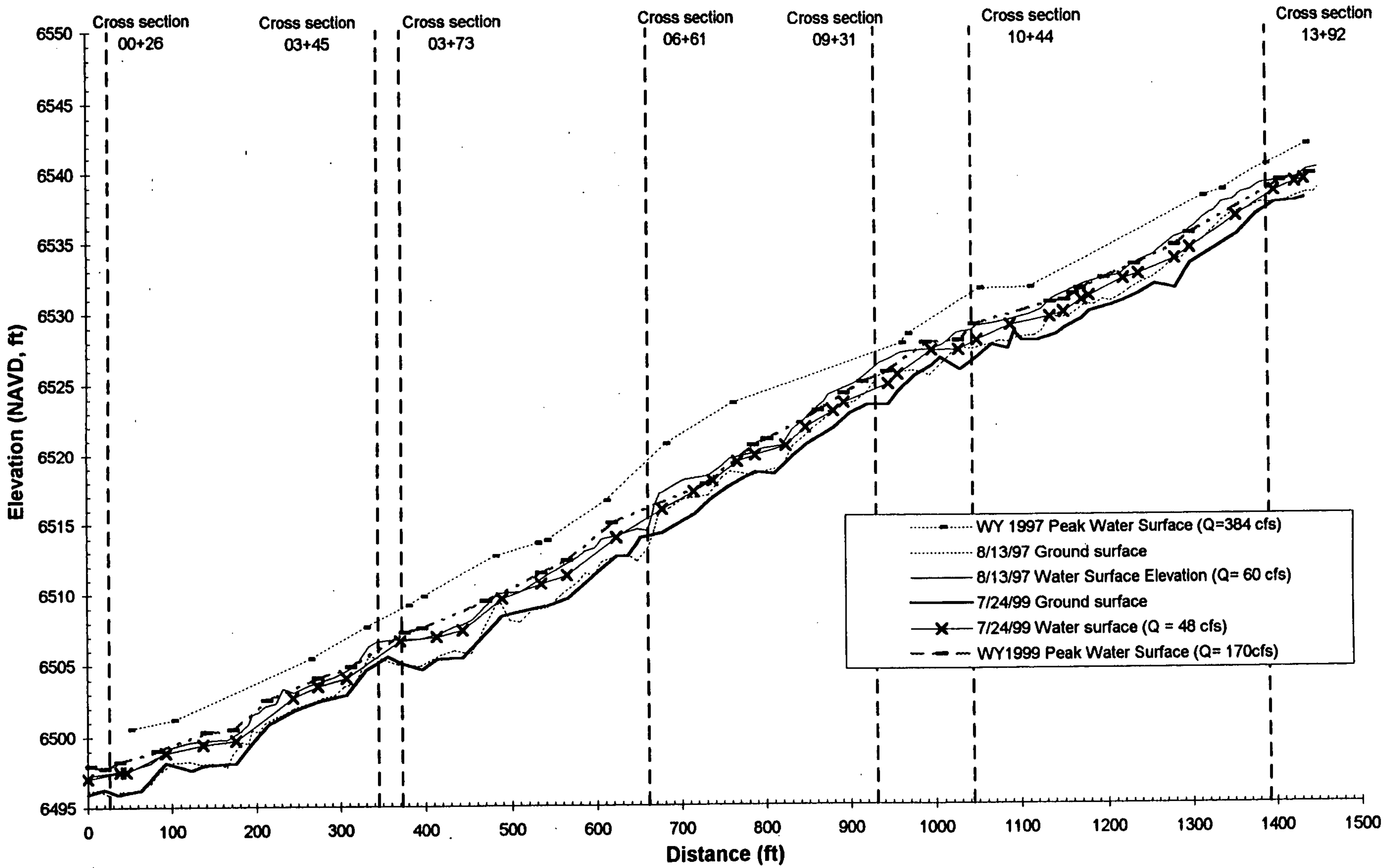


Figure 7. Upper Lee Vining Creek Main Channel, 1997 and 1999 Longitudinal Thalweg Profile.

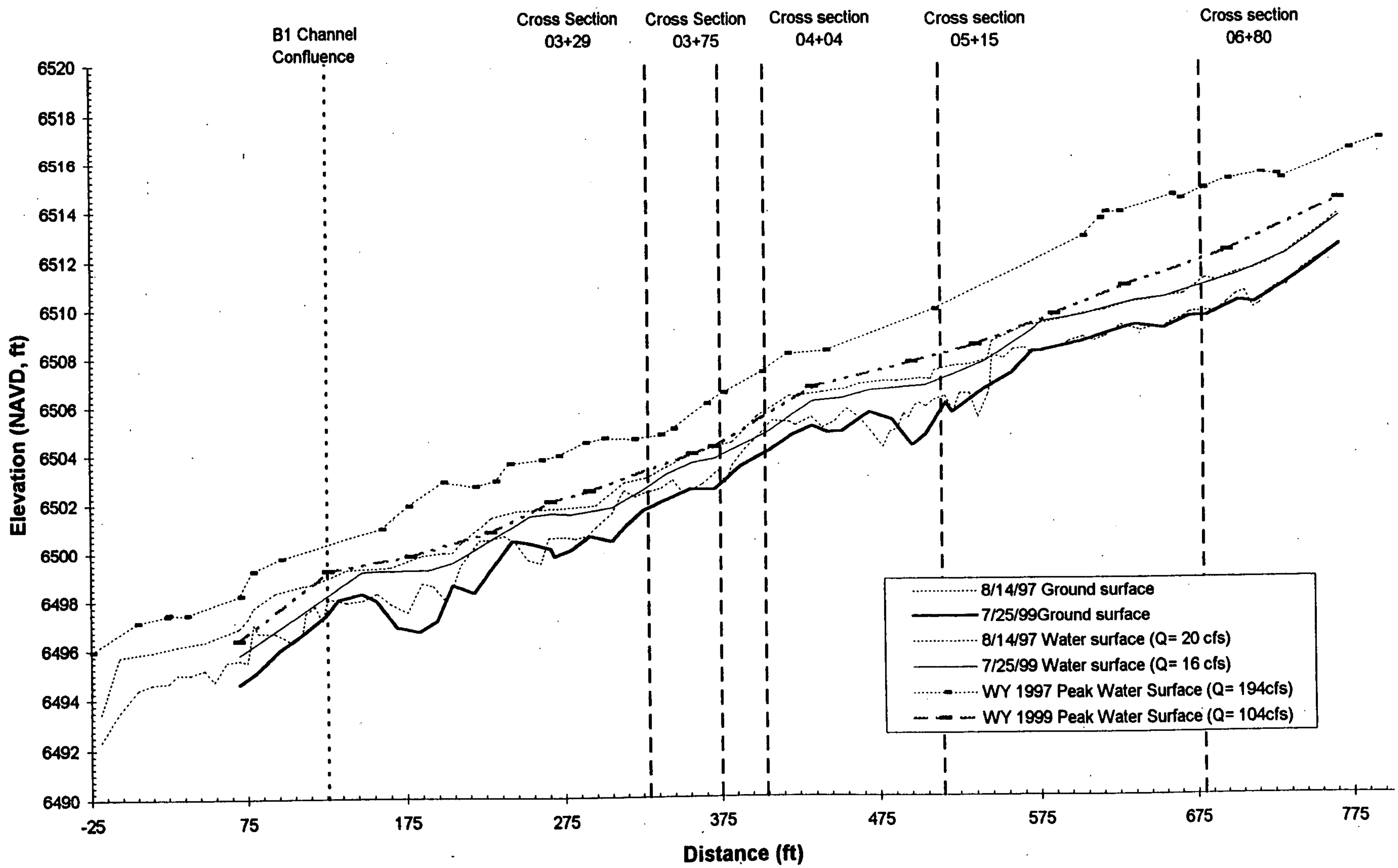


Figure 8. Upper Lee Vining Creek A4 Channel, 1997 and 1999 Longitudinal Thalweg Profile.

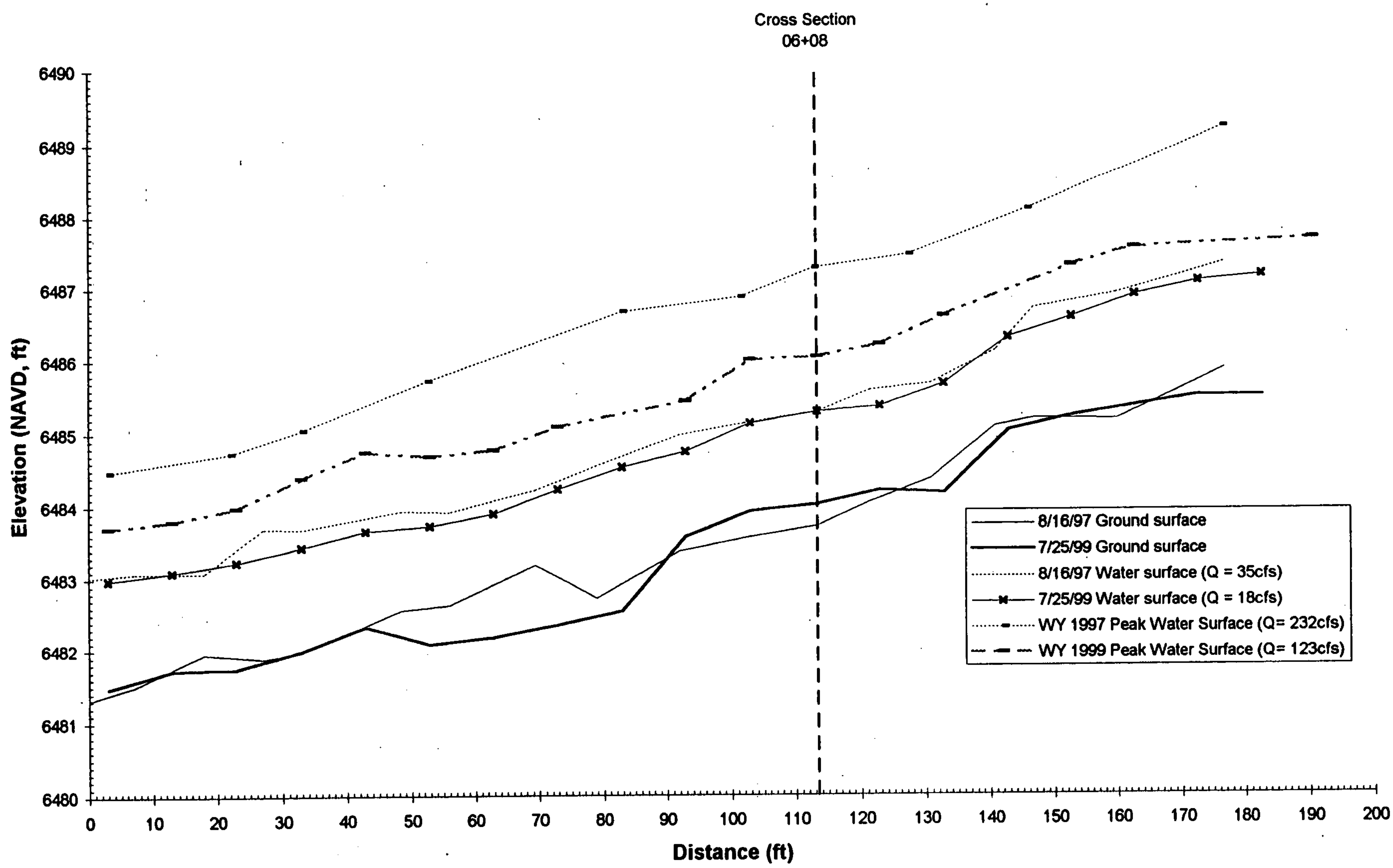


Figure 9. Upper Lee Vining Creek B1 Channel, 1997 and 1999 Longitudinal Thalweg Profile.

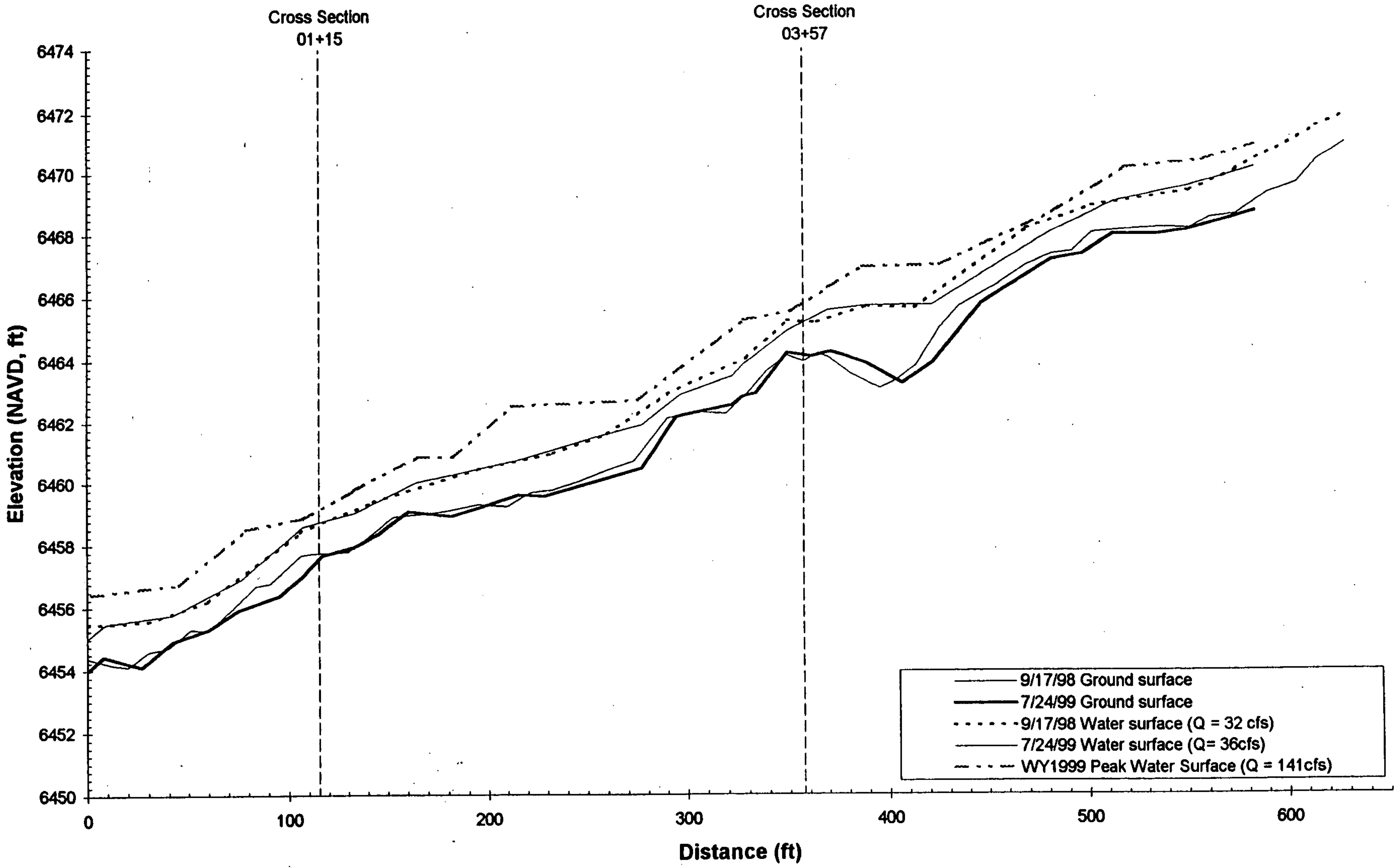


Figure 10. Lower Lee Vining Creek Main Channel, 1998 and 1999 Longitudinal Thalweg Profile.

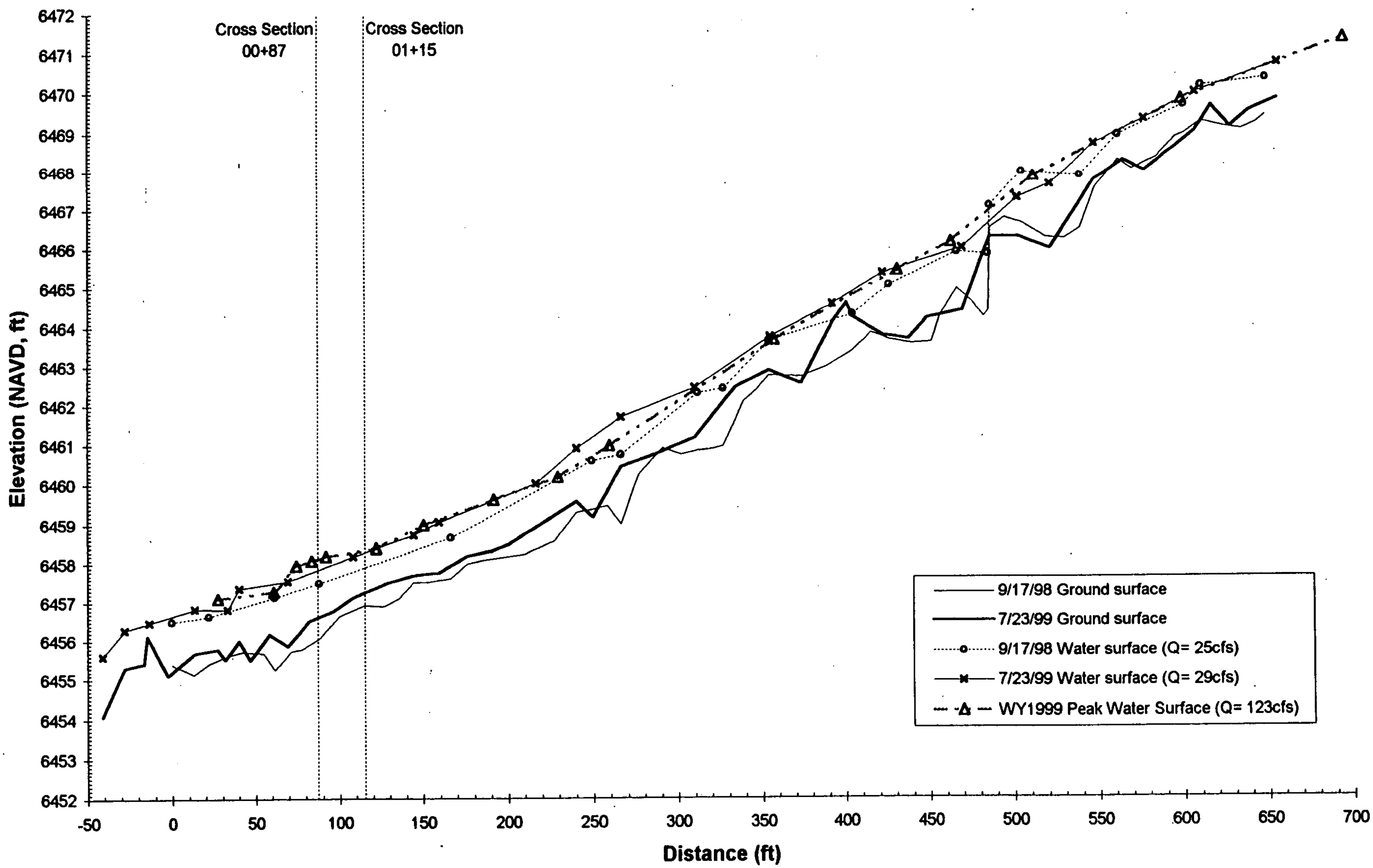


Figure 11. Lower Lee Vining Creek B1 Channel, 1998 and 1999 Longitudinal Thalweg Profile.

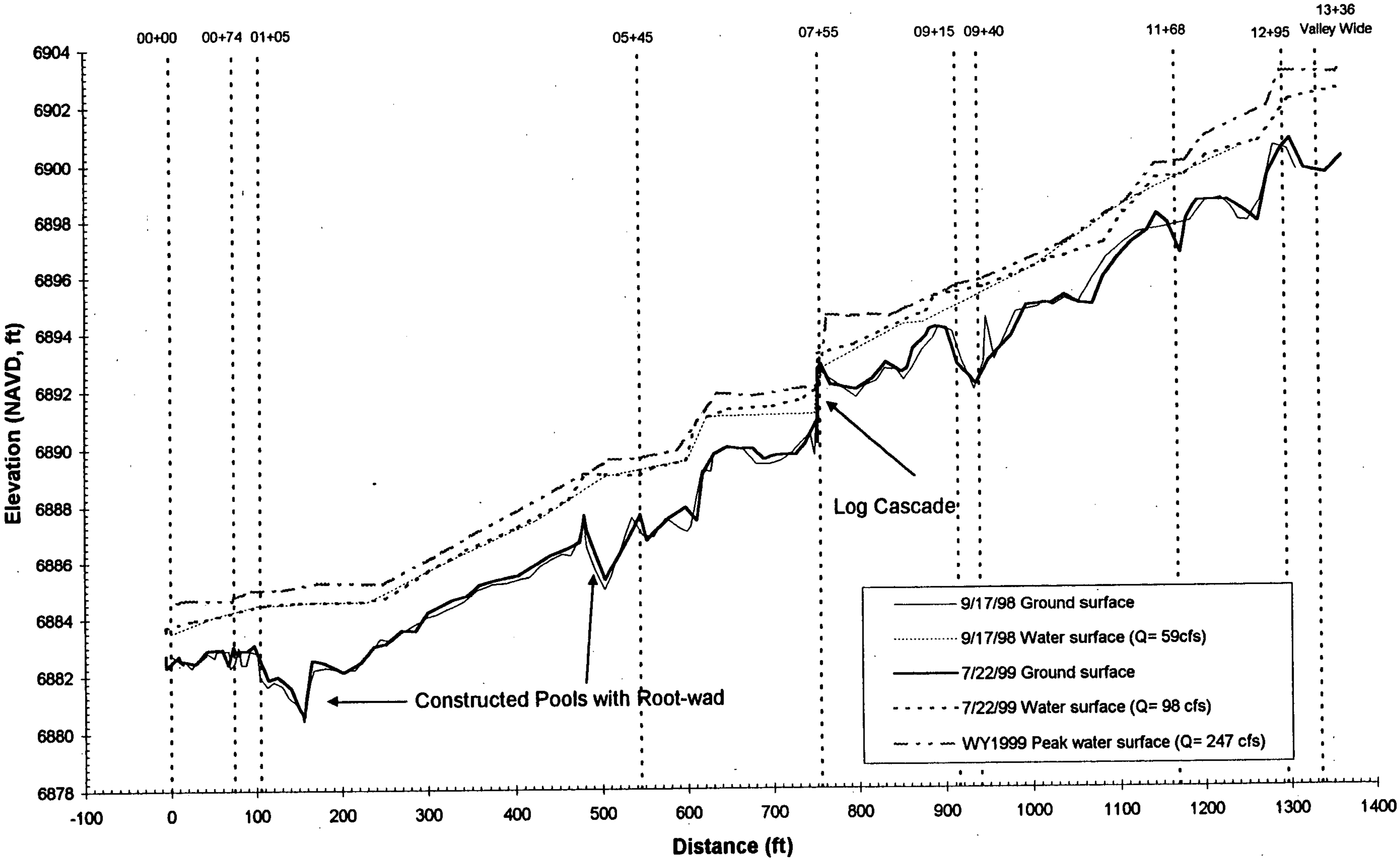


Figure 12. Upper Rush Creek, 1998 and 1999 Longitudinal Thalweg Profile.

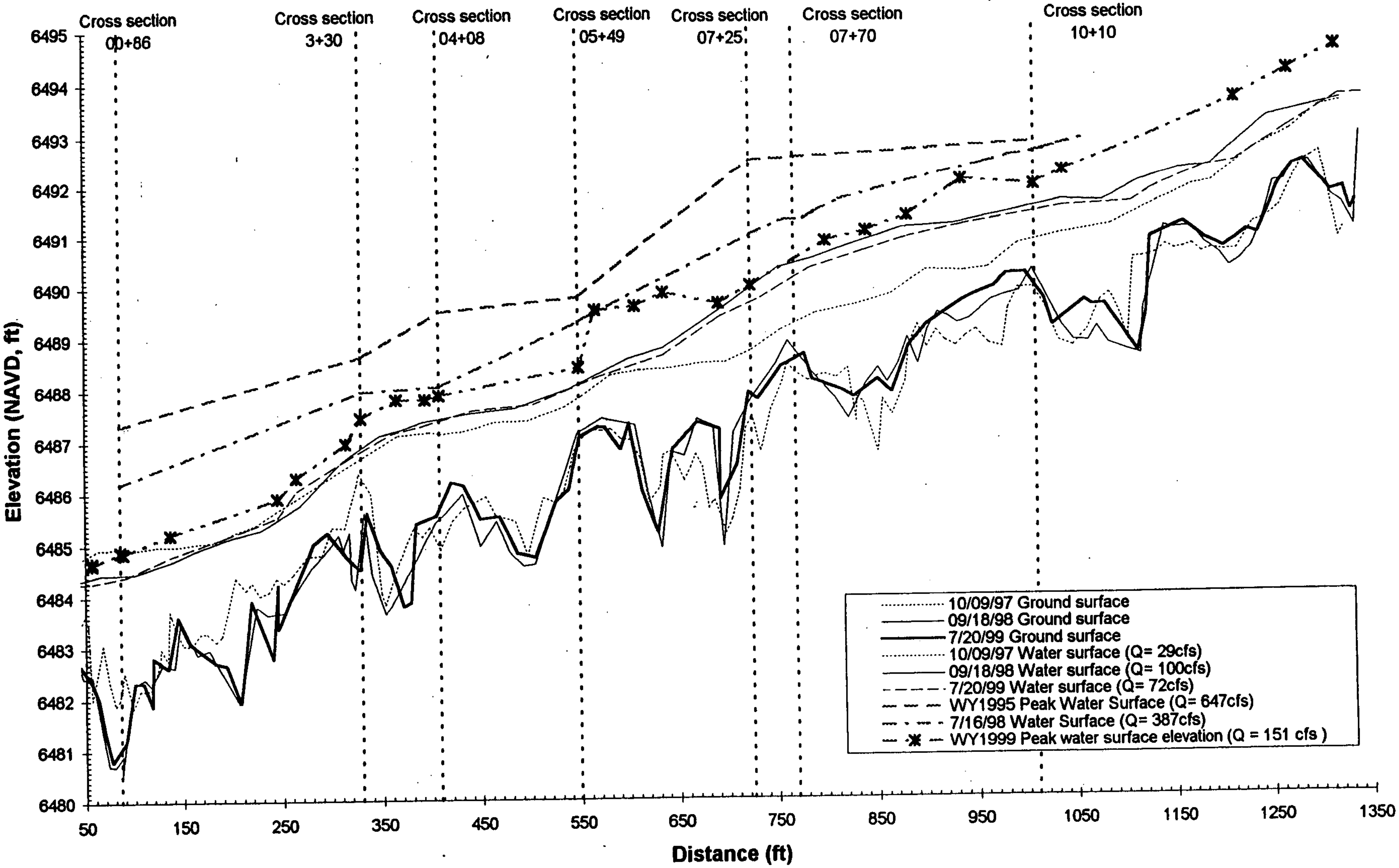


Figure 13. Lower Rush Creek Main Channel, 1997-1999 Longitudinal Thalweg Profile.

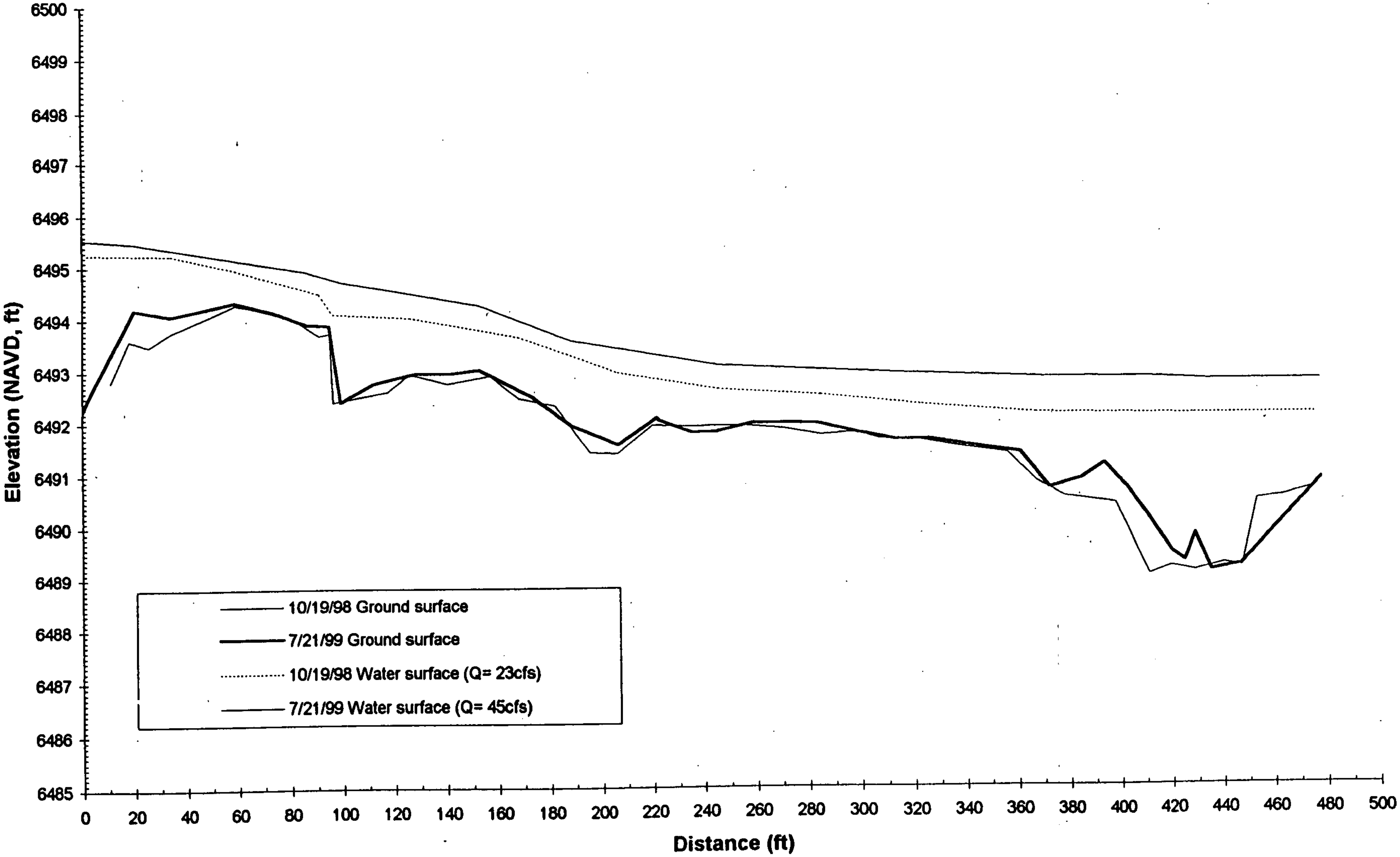


Figure 14. Lower Rush Creek 10 Channel, 1997-1999 Longitudinal Thalweg Profile.

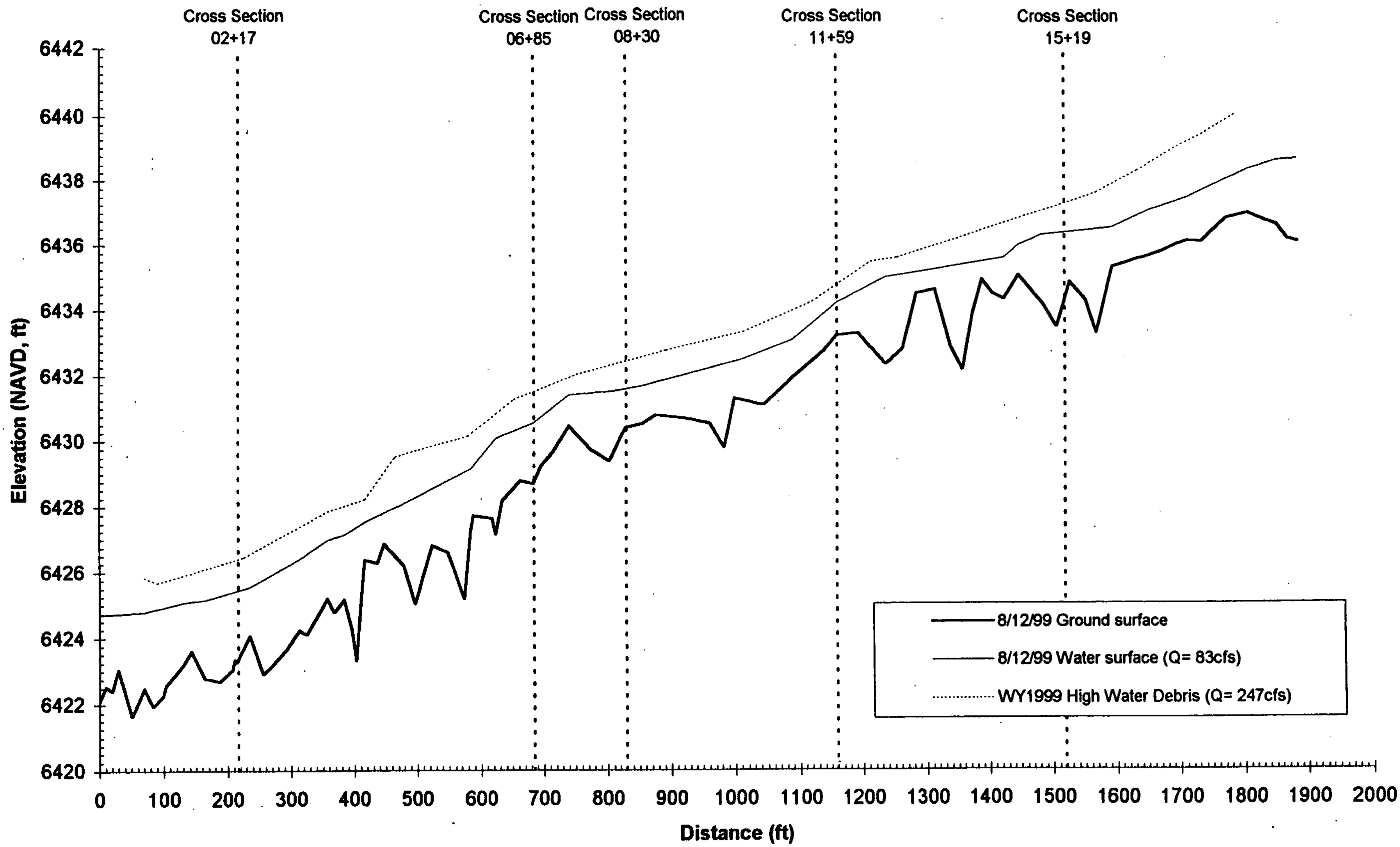


Figure 15. Rush Creek County Road, 1999 Longitudinal Thalweg Profile.

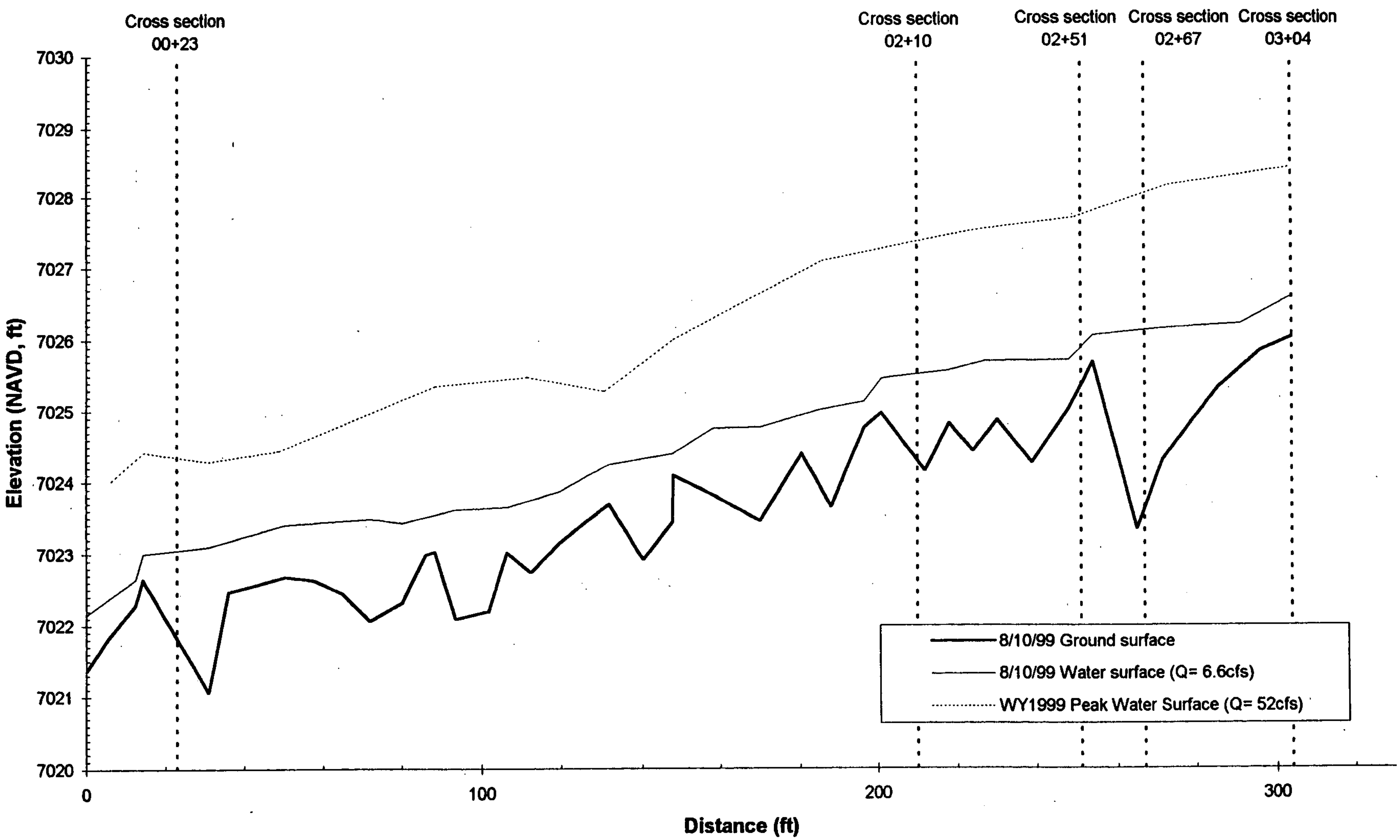


Figure 16. Parker Creek, 1999 Longitudinal Thalweg Profile.

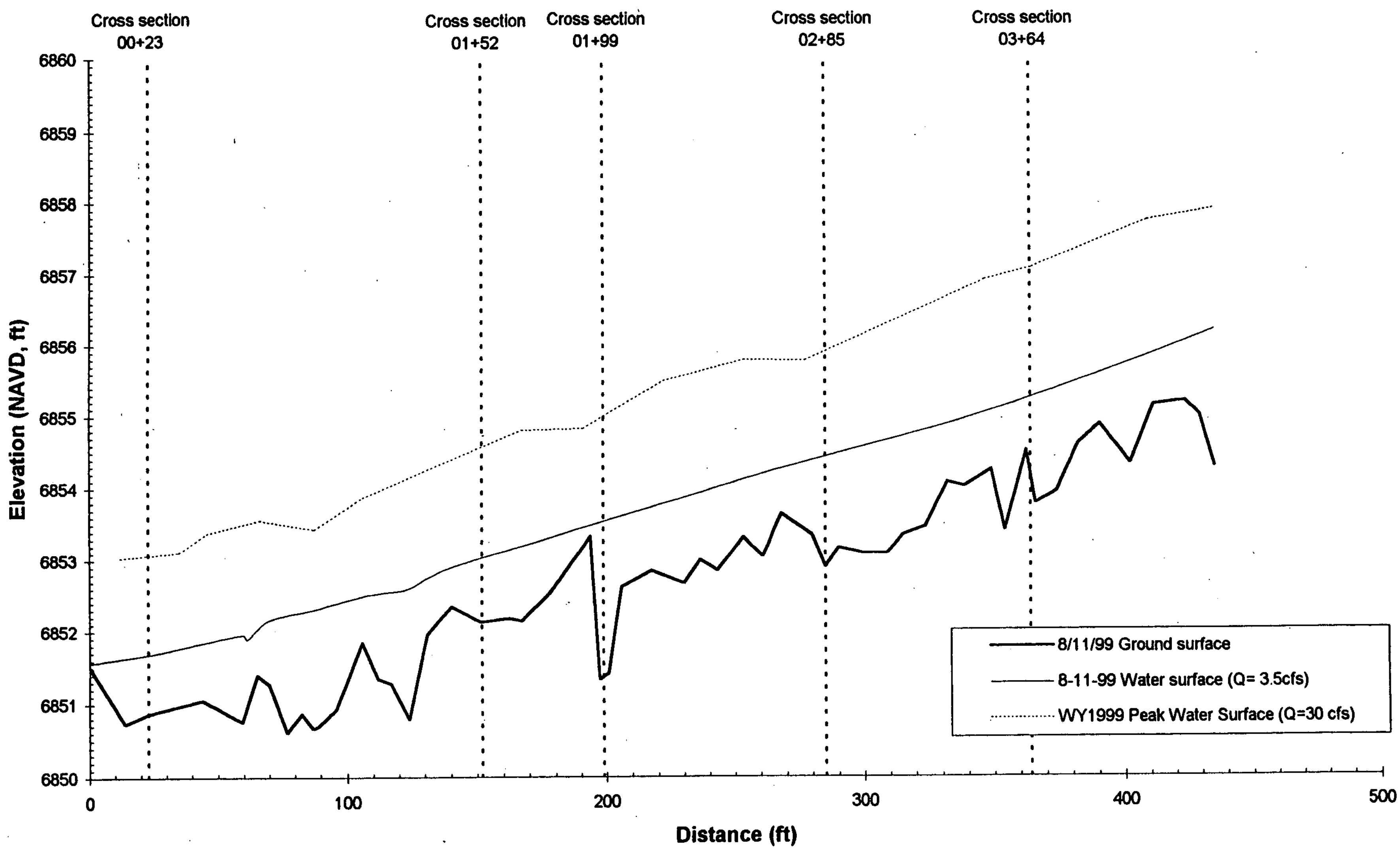


Figure 17 Walker Creek, 1999 Longitudinal Thalweg Profile.

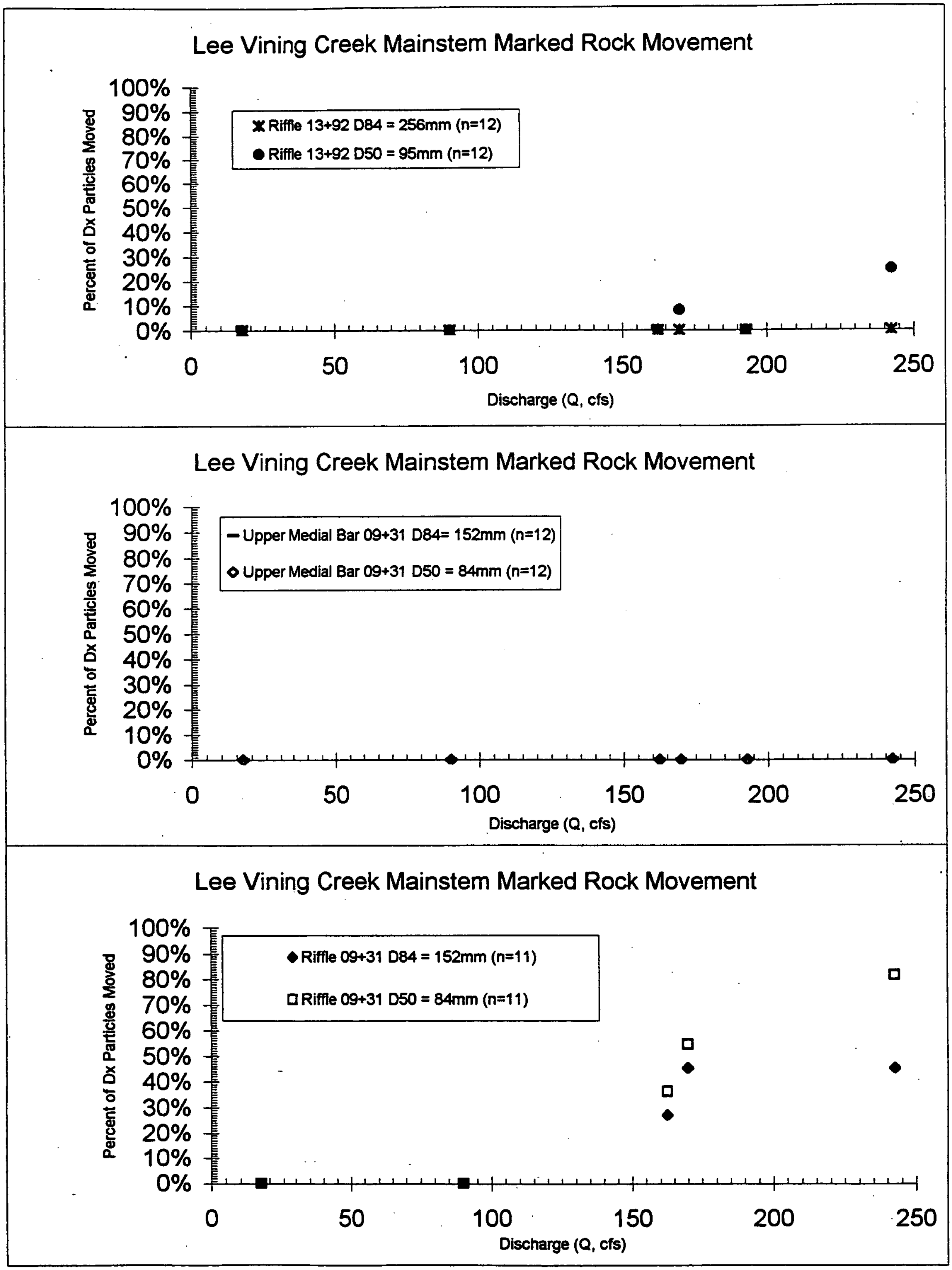
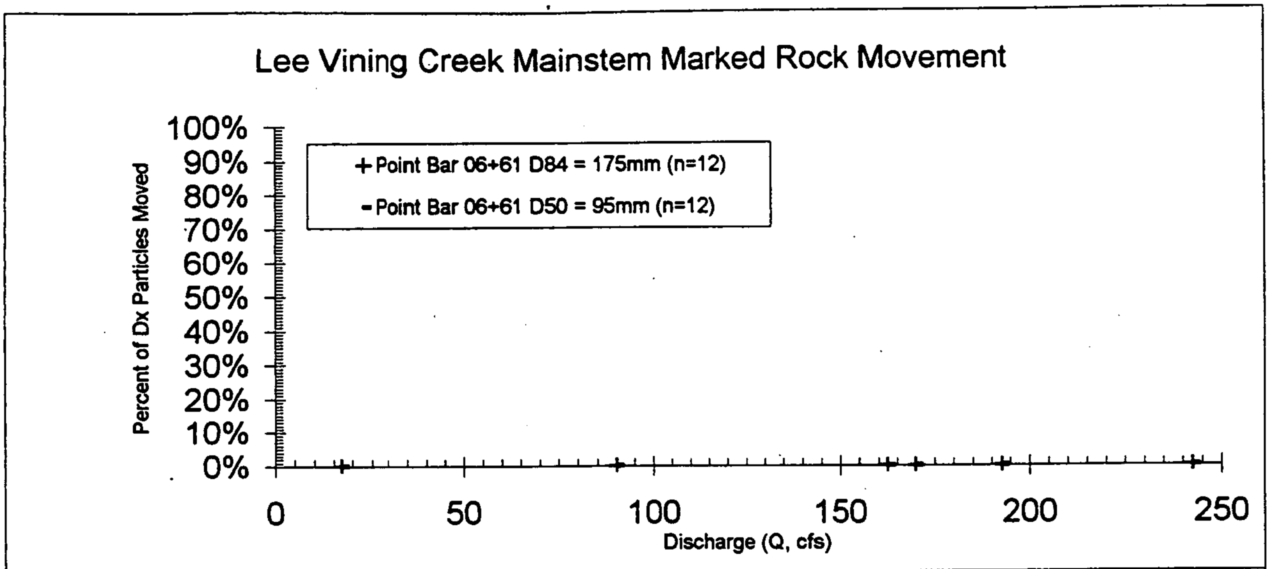


Figure 18. Upper Lee Vining Creek Main Channel, marked rock summary charts for WY 1998-99.



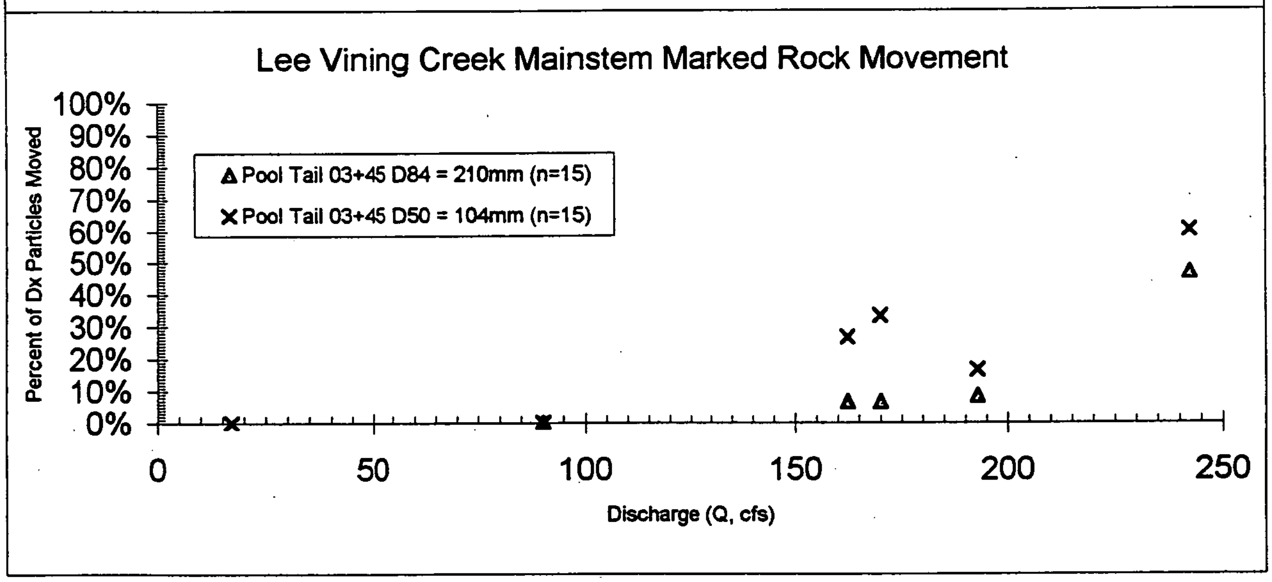


Figure 18. Upper Lee Vining Creek Main Channel, marked rock summary charts for WY 1998-99.

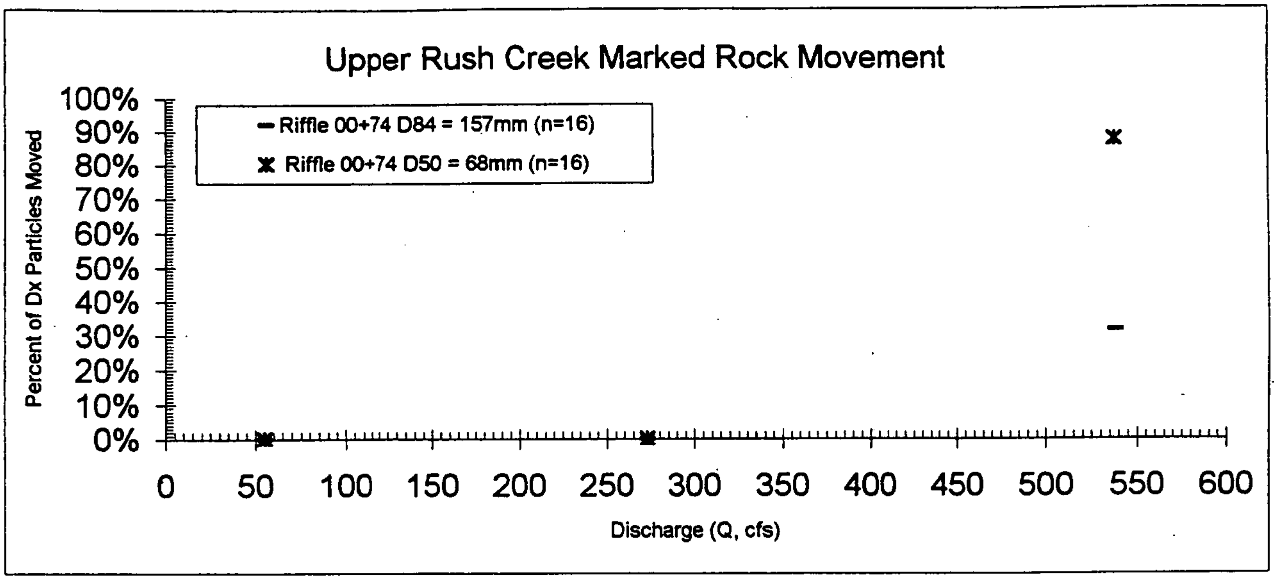
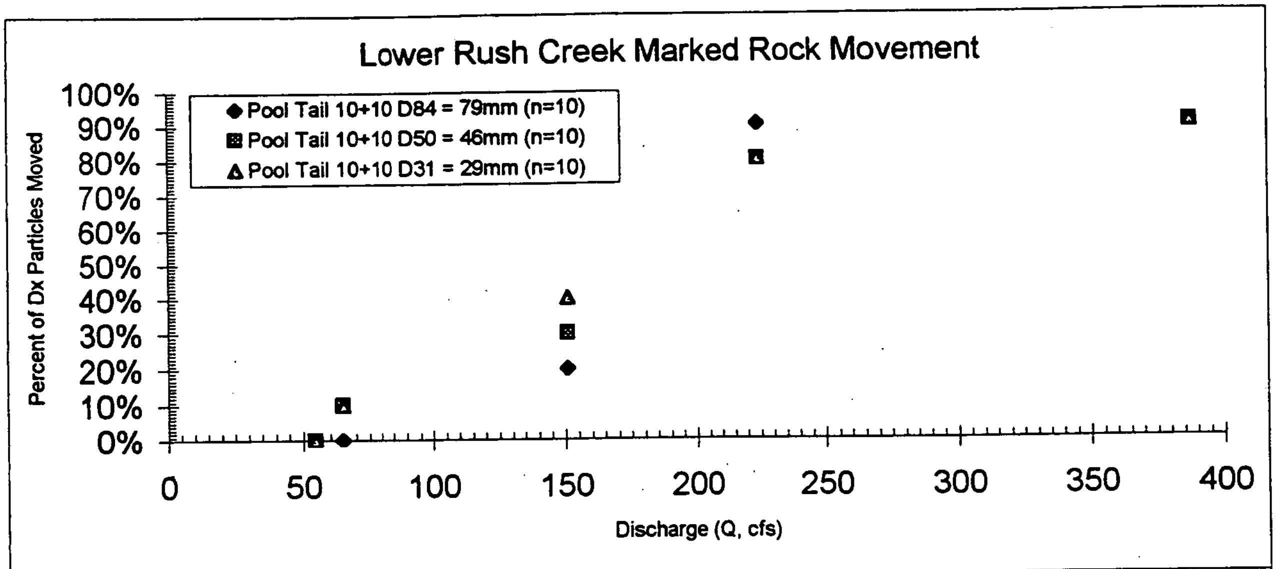
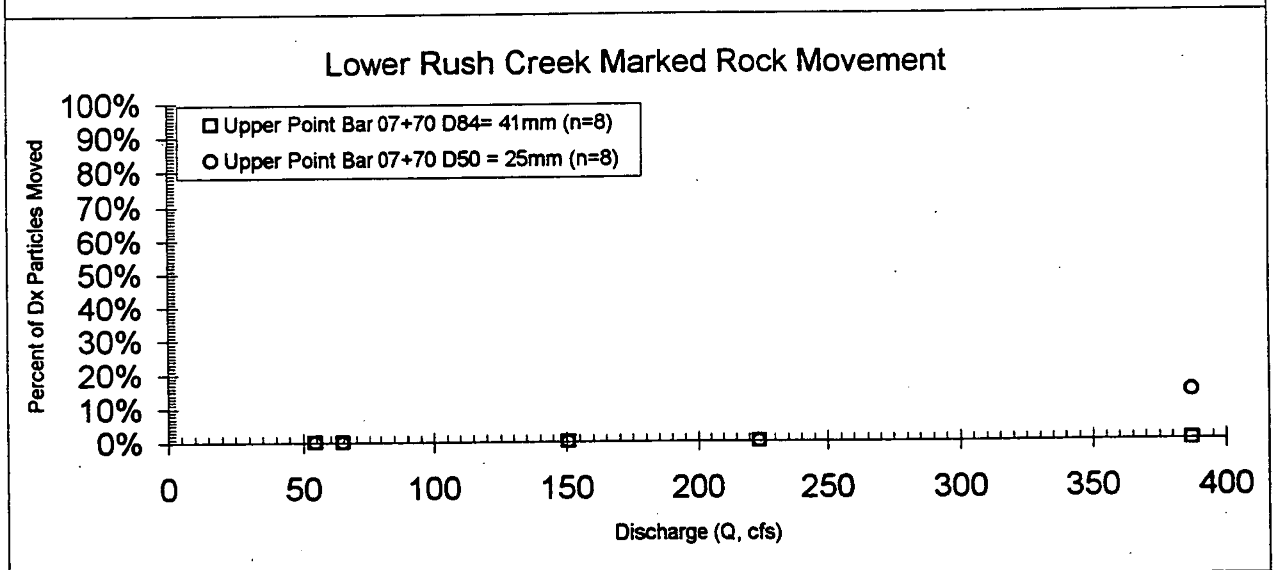


Figure 21. Upper Rush Creek, marked rock summary charts for WY 1998-99.





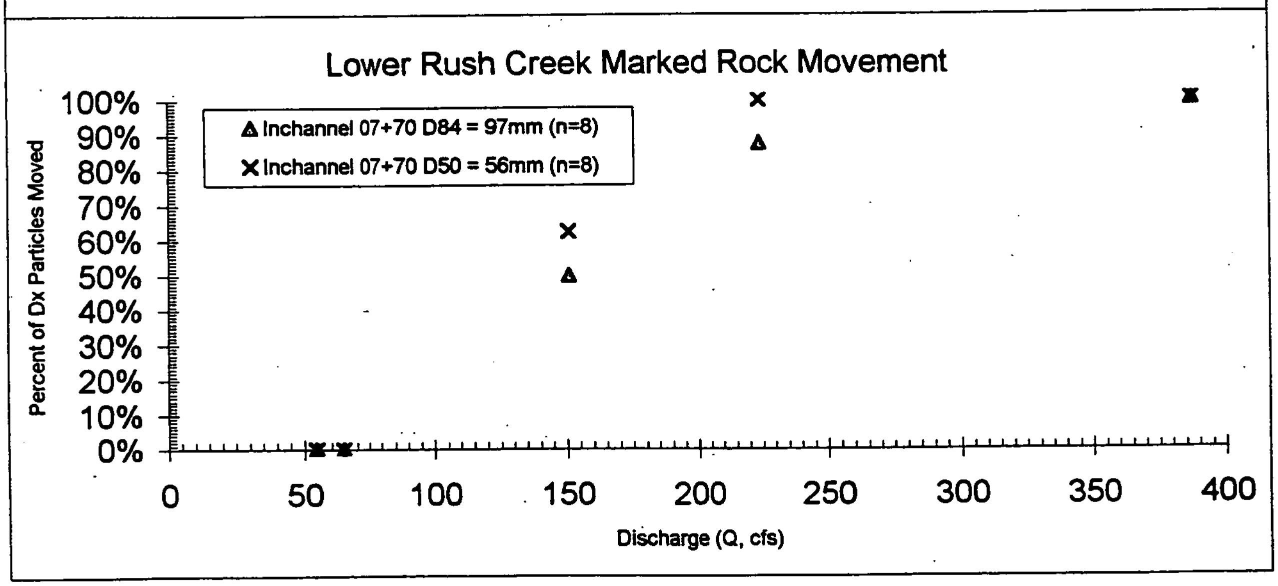


Figure 22. Lower Rush Creek Main Channel, marked rock summary charts for WY 1998-99.

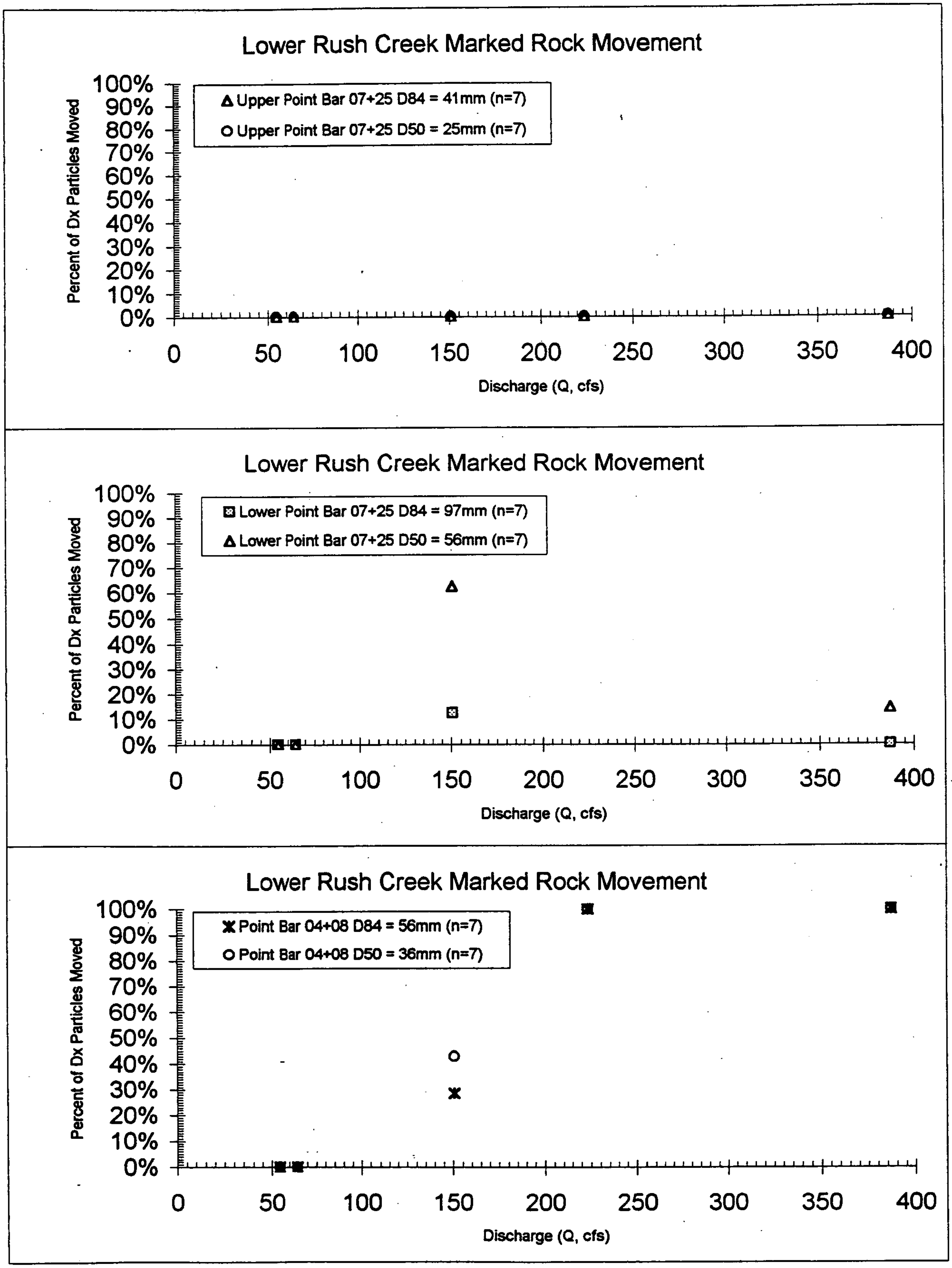
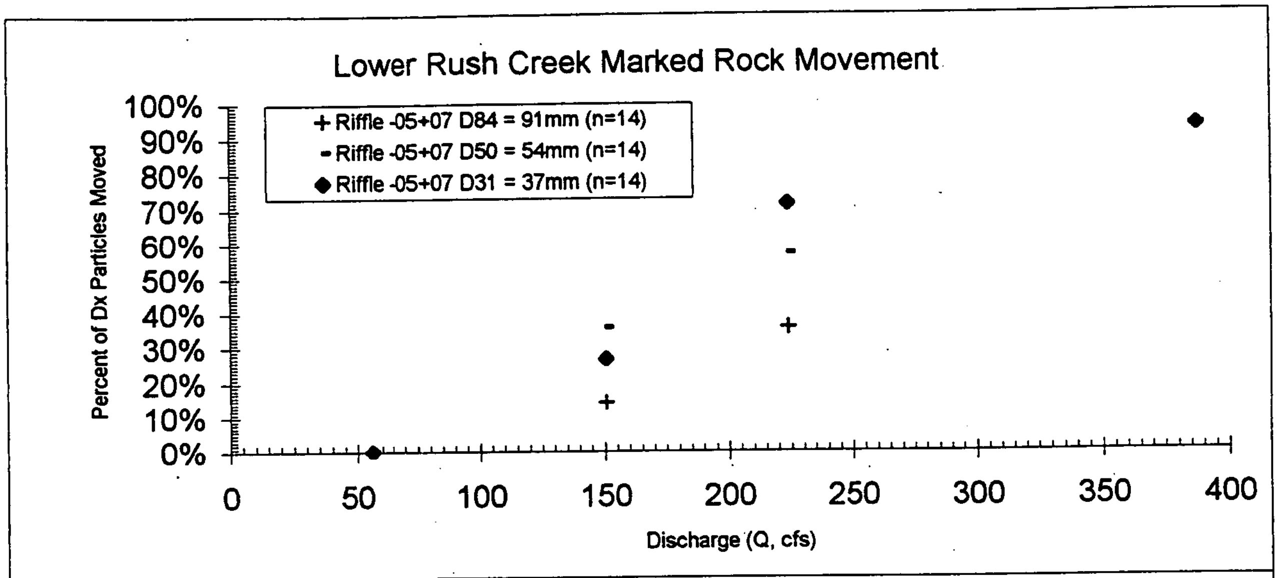


Figure 22. Lower Rush Creek Main Channel, marked rock summary charts for WY 1998-99.



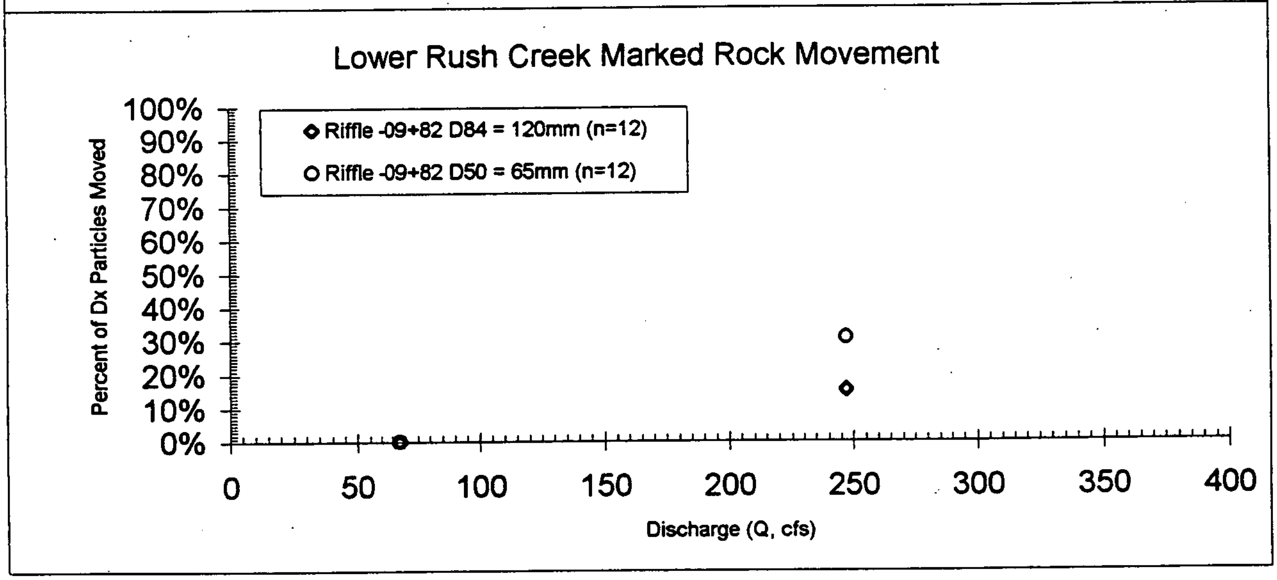
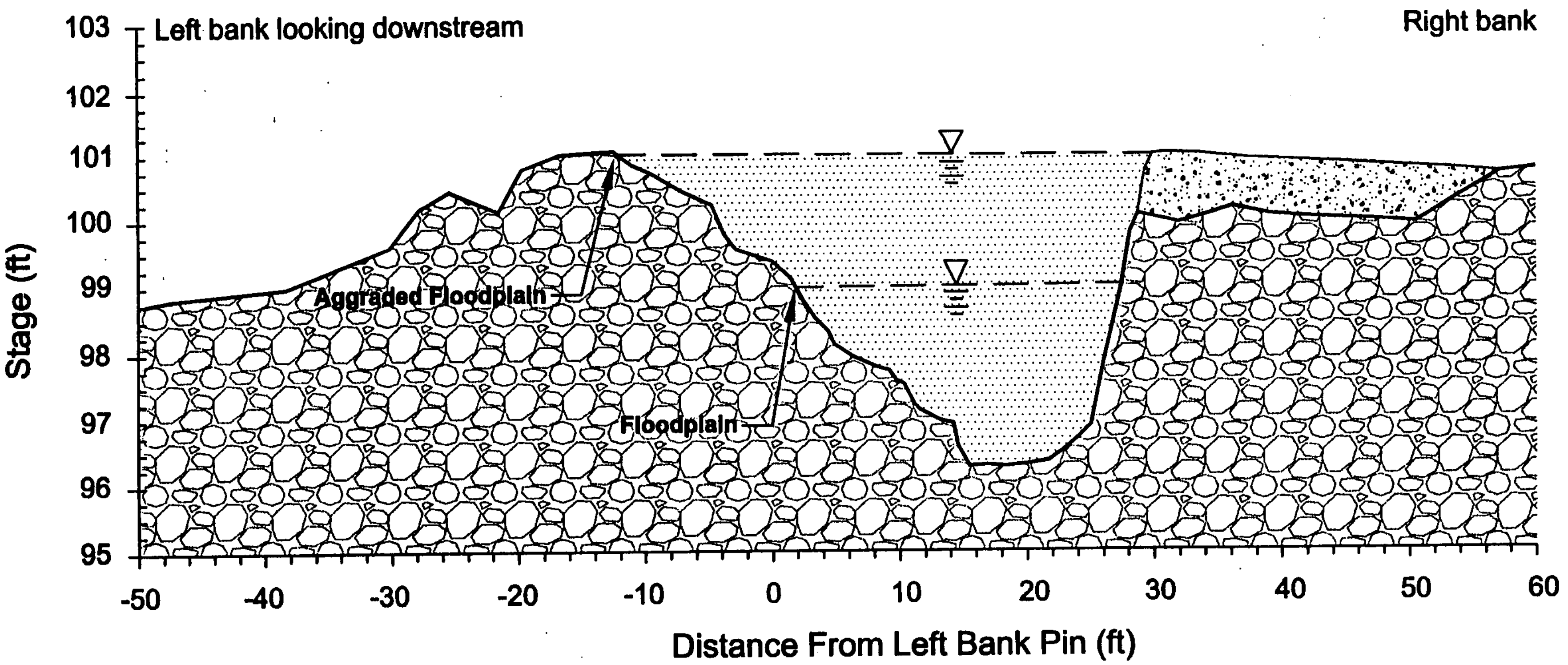


Figure 22. Lower Rush Creek Main Channel, marked rock summary charts for WY 1998-99.

Lower Rush Creek - Channel 1A

Original Cross Section with modified Right Bank



Floodplain	**Aggraded Floodplain**
350 cfs	1200 cfs
R.I.= 1.2 yrs.	R.I.= 65 yrs.
$\bar{d}_{main}$ = 2.12 ft	$\bar{d}_{main}$ = 3.513 ft
$\bar{u}_{main}$ = 6.41 ft/sec	$\bar{u}_{main}$ = 8.95 ft/sec

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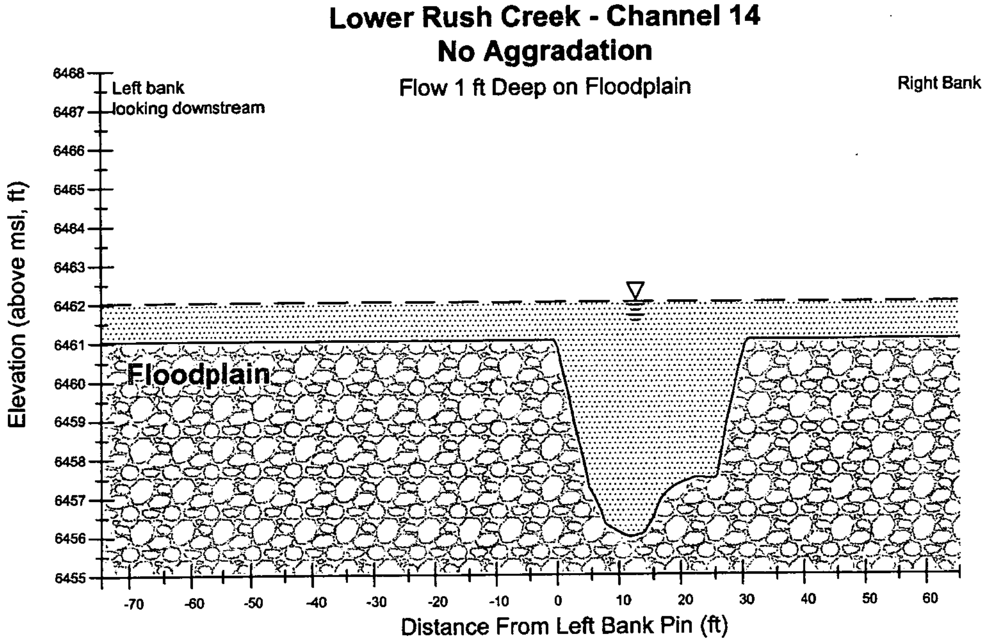
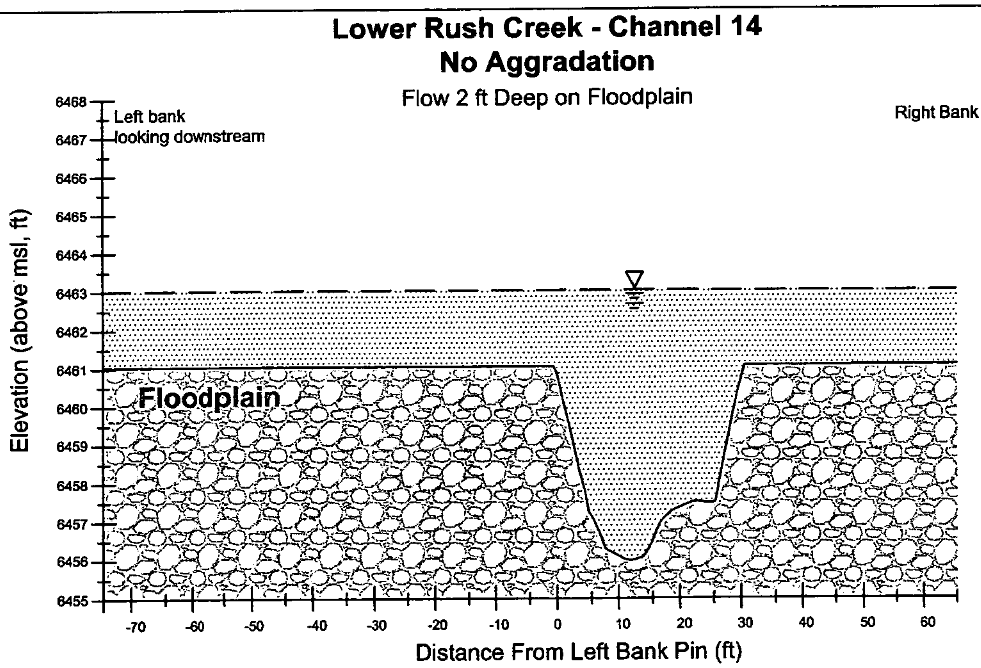
Figure 23. Lower Rush Creek Channel 1A, showing original cross section with pre-1941 berm and modified right bank.



590 cfs	740 cfs	880 cfs
R.I.= 3.1 yrs.	R.I. = 5.5 yrs	R.I. = 9.4 yrs
n_{main} = 0.05	n_{main} = 0.04	n_{main} = 0.032
$n_{floodplain}$ = 0.035	$n_{floodplain}$ = 0.035	$n_{floodplain}$ = 0.035
$\bar{d}_{main}$ = 4.33 ft	$\bar{d}_{main}$ = 4.33 ft	$\bar{d}_{main}$ = 4.33 ft
$\bar{u}_{main}$ = 3.50 ft/sec	$\bar{u}_{main}$ = 4.38 ft/sec	$\bar{u}_{main}$ = 5.48 ft/sec



1500 cfs
R.I. = 110 yrs
n_{main} = 0.032
$n_{floodplain}$ = 0.035
$\bar{d}_{main}$ = 5.33 ft
$\bar{u}_{main}$ = 6.29 ft/sec
$\bar{u}_{floodplain}$ = 3.01 ft/sec

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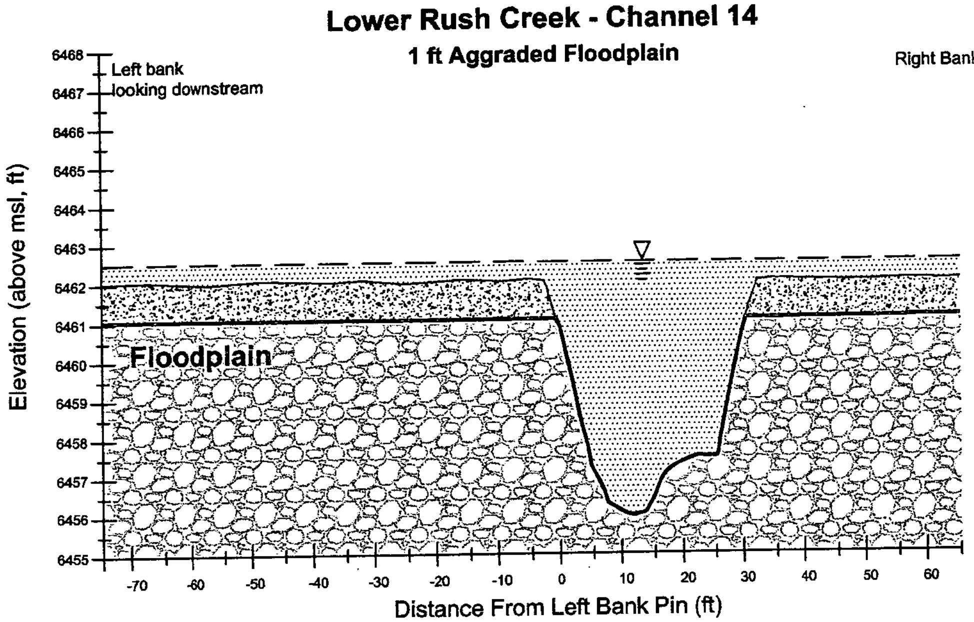
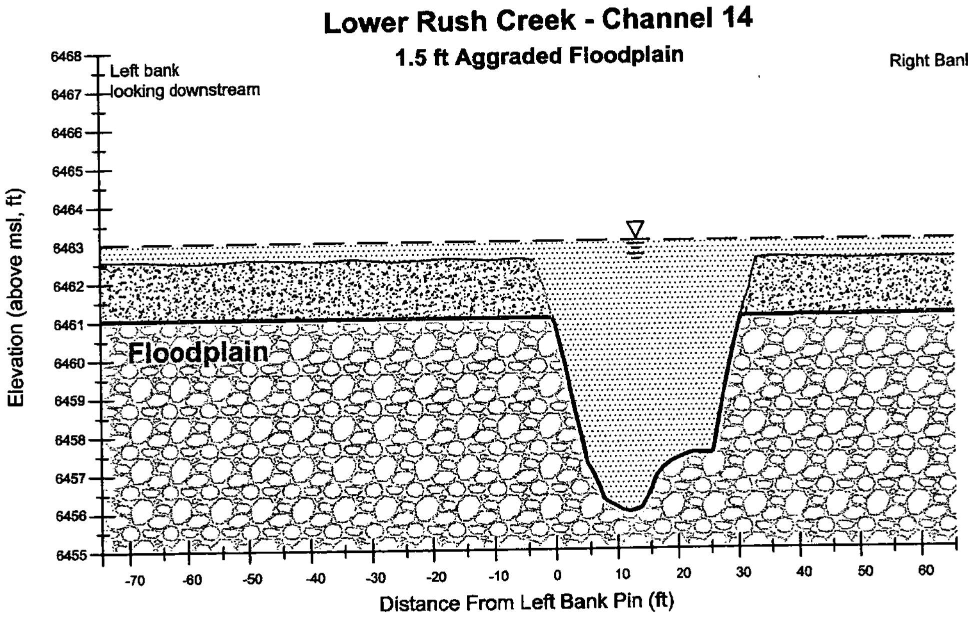
Figure 24. Lower Rush Creek Channel 14, showing the original cross section with no aggradation and two differing discharges.



890 cfs	720 cfs	590 cfs
R.I.= 9.7 yrs.	R.I. = 5.1 yrs	R.I. = 3.0 yrs
$n_{main} = 0.032$	$n_{main} = 0.04$	$n_{main} = 0.05$
$n_{floodplain} = 0.050$	$n_{floodplain} = 0.05$	$n_{floodplain} = 0.05$
$\bar{d}_{main} = 4.83$ ft	$\bar{d}_{main} = 4.83$ ft	$\bar{d}_{main} = 4.83$ ft
$\bar{u}_{main} = 5.89$ ft/sec	$\bar{u}_{main} = 4.71$ ft/sec	$\bar{u}_{main} = 3.77$ ft/sec



1100 cfs	830 cfs	670 cfs
R.I.= 21 yrs.	R.I. = 7.7 yrs	R.I. = 4.2 yrs
$n_{main} = 0.030$	$n_{main} = 0.04$	$n_{main} = 0.05$
$n_{floodplain} = 0.070$	$n_{floodplain} = 0.070$	$n_{floodplain} = 0.070$
$\bar{d}_{main} = 5.33$ ft	$\bar{d}_{main} = 5.33$ ft	$\bar{d}_{main} = 5.33$ ft
$\bar{u}_{main} = 6.71$ ft/sec	$\bar{u}_{main} = 5.03$ ft/sec	$\bar{u}_{main} = 4.02$ ft/sec

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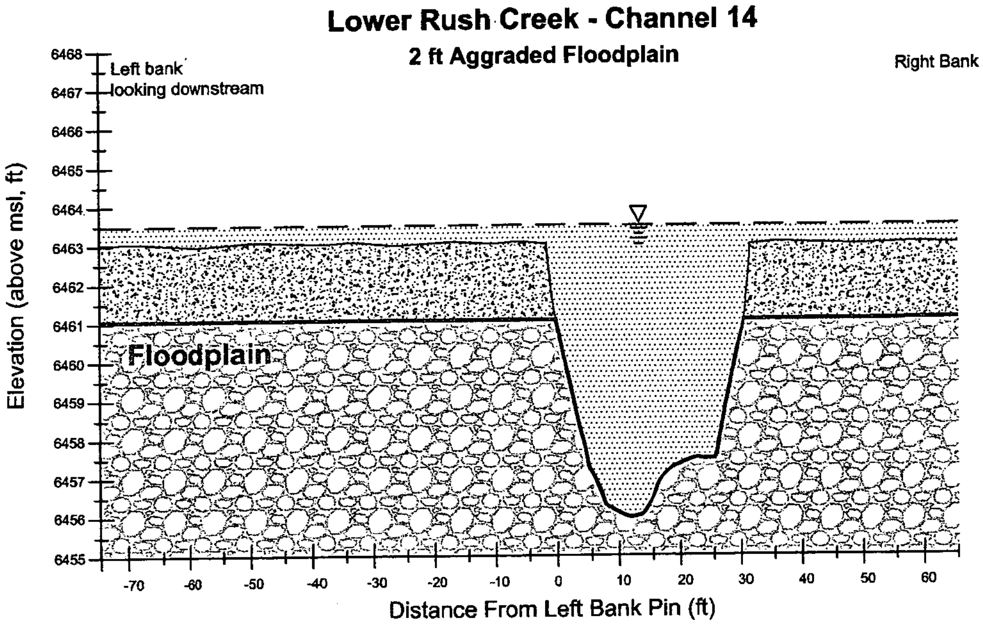
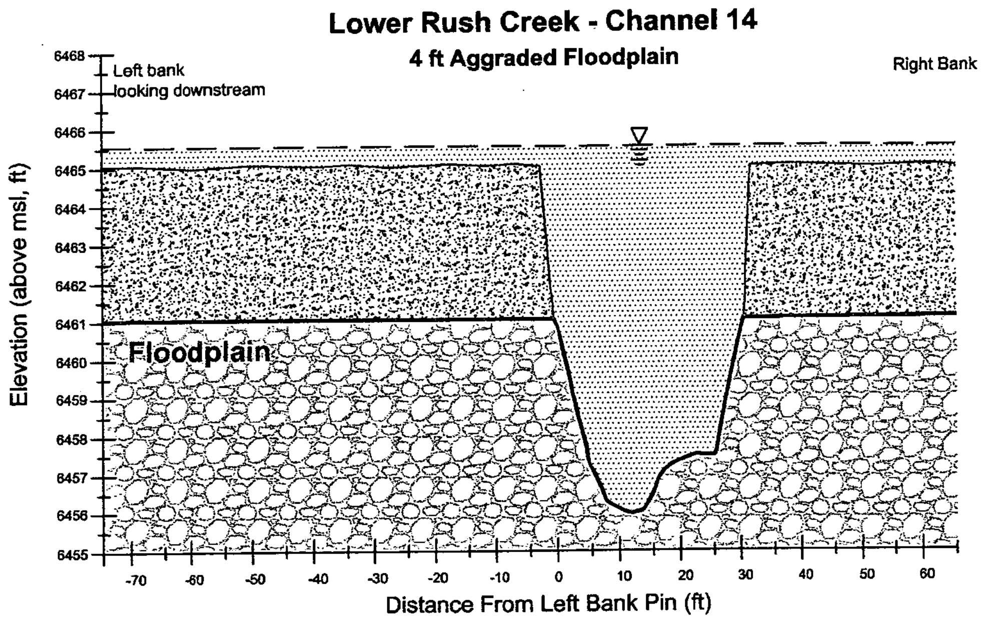
Figure 25. Lower Rush Creek Channel 14, showing the original cross section with 1 and 1.5 feet of aggradation.



1270 cfs	960 cfs	770 cfs
R.I.= 41 yrs.	R.I. = 13 yrs	R.I. = 6.2 yrs
$n_{main} = 0.03$	$n_{main} = 0.04$	$n_{main} = 0.05$
$n_{floodplain} = 0.07$	$n_{floodplain} = 0.07$	$n_{floodplain} = 0.07$
$\bar{d}_{main} = 5.83$ ft	$\bar{d}_{main} = 5.83$ ft	$\bar{d}_{main} = 5.83$ ft
$\bar{u}_{main} = 7.11$ ft/sec	$\bar{u}_{main} = 5.33$ ft/sec	$\bar{u}_{main} = 4.26$ ft/sec



2000 cfs	1600 cfs	1200 cfs
R.I.= 790 yrs.	R.I. = 120 yrs	R.I. = 37 yrs
$n_{main} = 0.03$	$n_{main} = 0.04$	$n_{main} = 0.05$
$n_{floodplain} = 0.07$	$n_{floodplain} = 0.07$	$n_{floodplain} = 0.07$
$\bar{d}_{main} = 7.83$ ft	$\bar{d}_{main} = 7.83$ ft	$\bar{d}_{main} = 7.83$ ft
$\bar{u}_{main} = 8.64$ ft/sec	$\bar{u}_{main} = 6.48$ ft/sec	$\bar{u}_{main} = 5.18$ ft/sec

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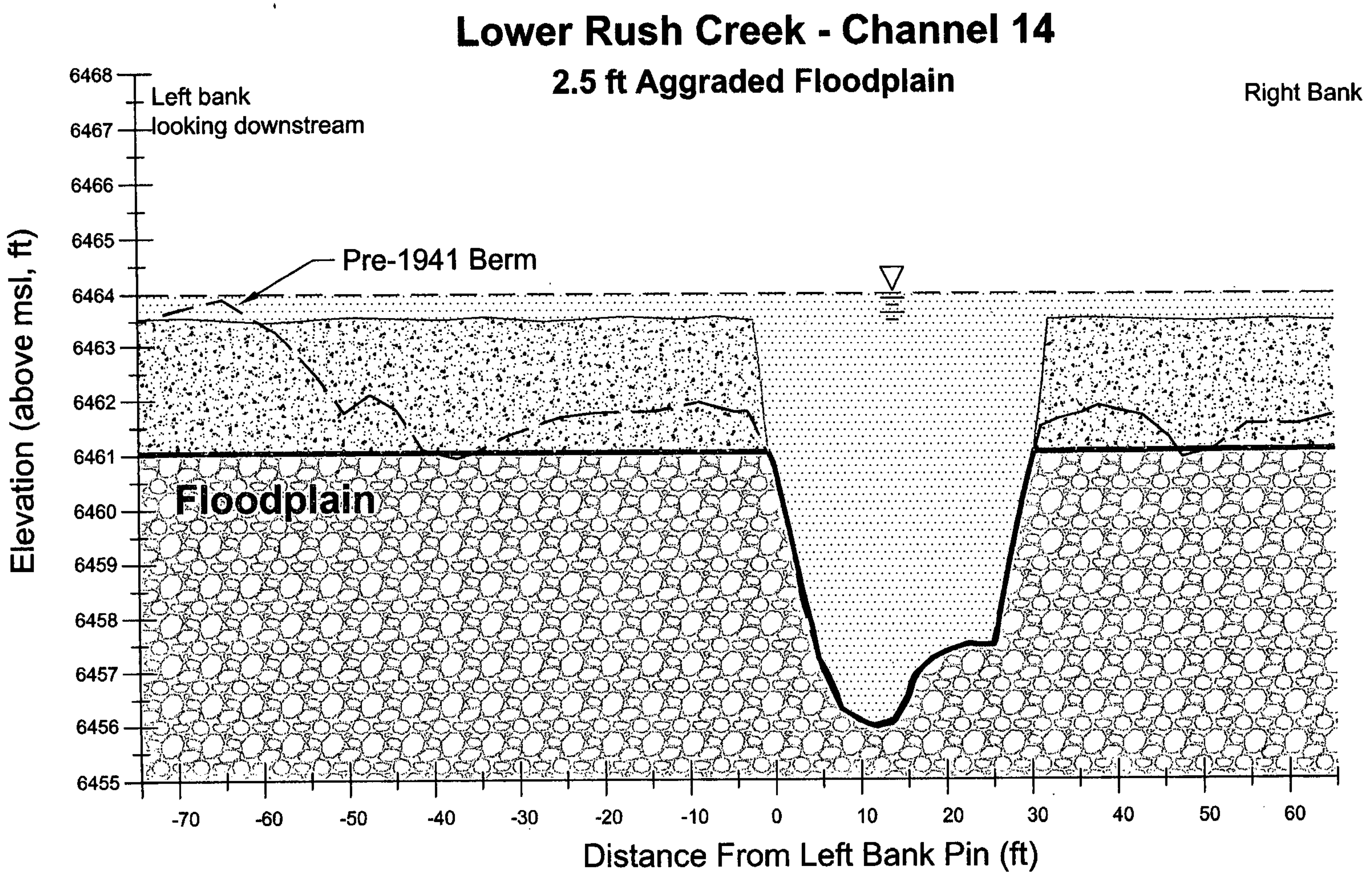
Figure 26. Lower Rush Creek Channel 14, showing the original cross section with 2 and 4 feet of aggradation.



1500 cfs	1100 cfs	830 cfs
R.I.= 81 yrs.	R.I. = 21 yrs	R.I. = 9.4 yrs
$n_{main} = 0.03$	$n_{main} = 0.04$	$n_{main} = 0.05$
$n_{floodplain} = 0.07$	$n_{floodplain} = 0.07$	$n_{floodplain} = 0.07$
$\bar{d}_{main} = 6.33$ ft	$\bar{d}_{main} = 6.33$ ft	$\bar{d}_{main} = 6.33$ ft
$\bar{u}_{main} = 7.51$ ft/sec	$\bar{u}_{main} = 5.63$ ft/sec	$\bar{u}_{main} = 4.50$ ft/sec

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Figure 27. Lower Rush Creek Channel 14, showing the original cross section with 2.5 feet of aggradation and two differing discharges.

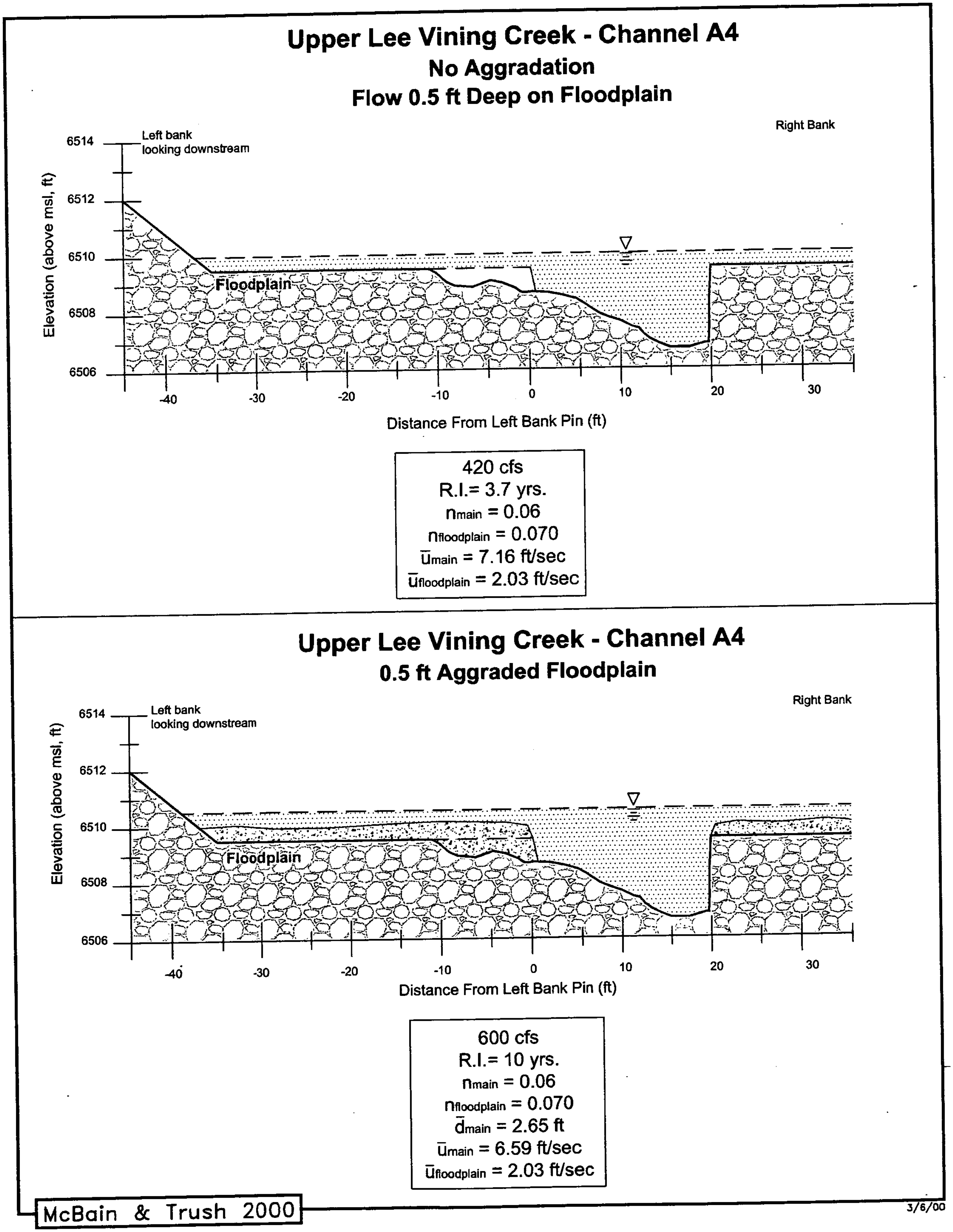
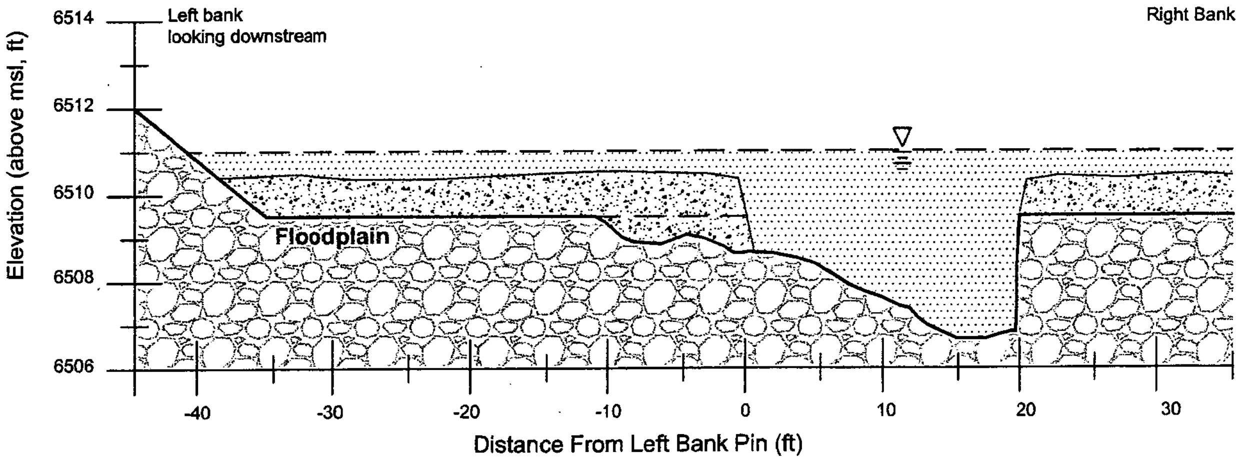


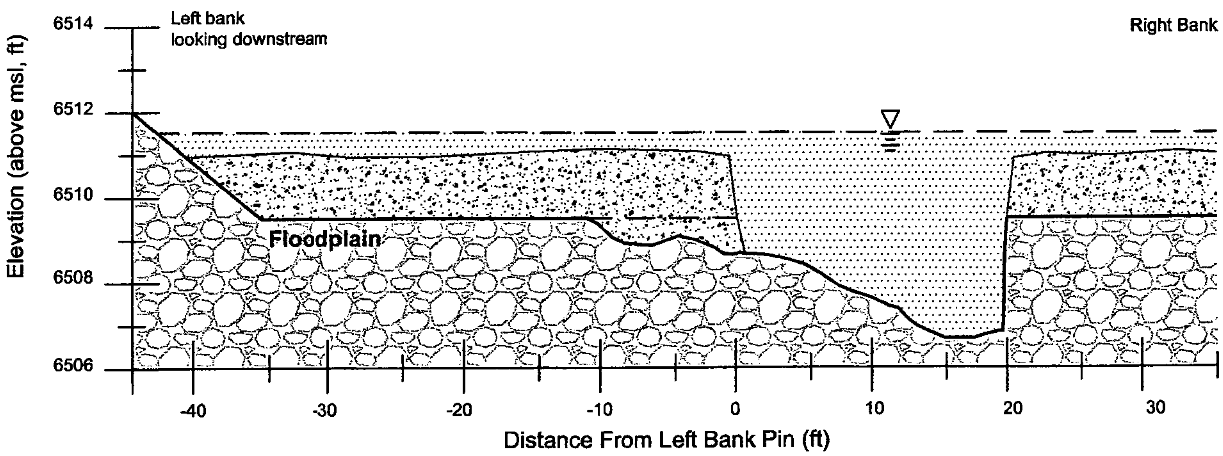
Figure 28. Upper Lee Vining Creek A4 Channel, showing the original cross section without aggradation and 0.5 ft of flow across floodplain, and with 0.5ft of aggradation on the floodplain.

Upper Lee Vining Creek - Channel A4
1.0 Aggraded Floodplain



790 cfs
R.I.= 31 yrs.
$n_{main} = 0.06$
$n_{floodplain} = 0.07$
$\bar{d}_{main} = 3.15$ ft
$\bar{u}_{main} = 8.02$ ft/sec
$\bar{u}_{floodplain} = 2.03$ ft/sec

Upper Lee Vining Creek - Channel A4
1.5 ft Aggraded Floodplain



1000 cfs
R.I.= 125 yrs.
$n_{main} = 0.06$
$n_{floodplain} = 0.07$
$\bar{d}_{main} = 3.67$ ft
$\bar{u}_{main} = 8.87$ ft/sec
$\bar{u}_{floodplain} = 2.03$ ft/sec

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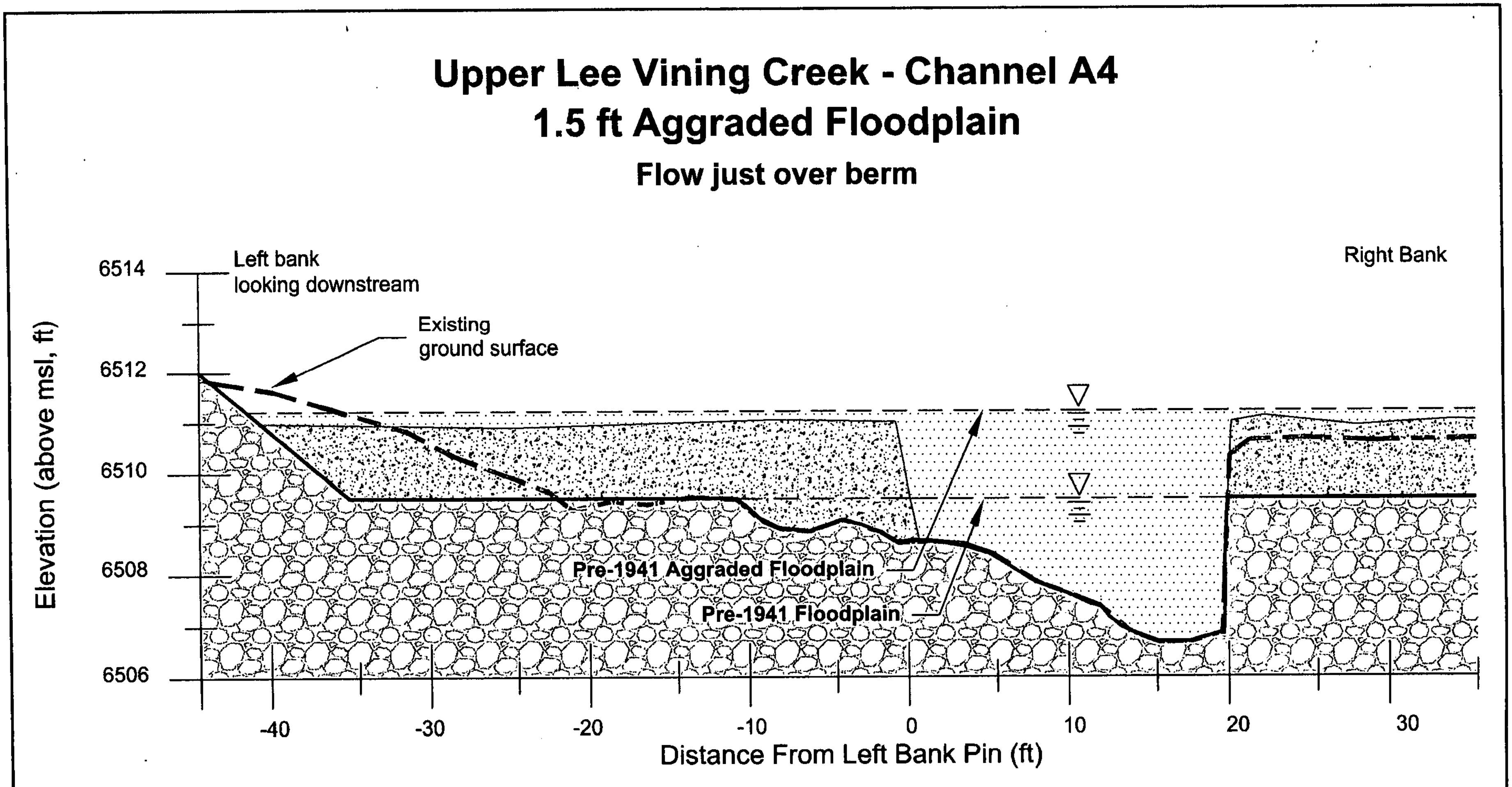
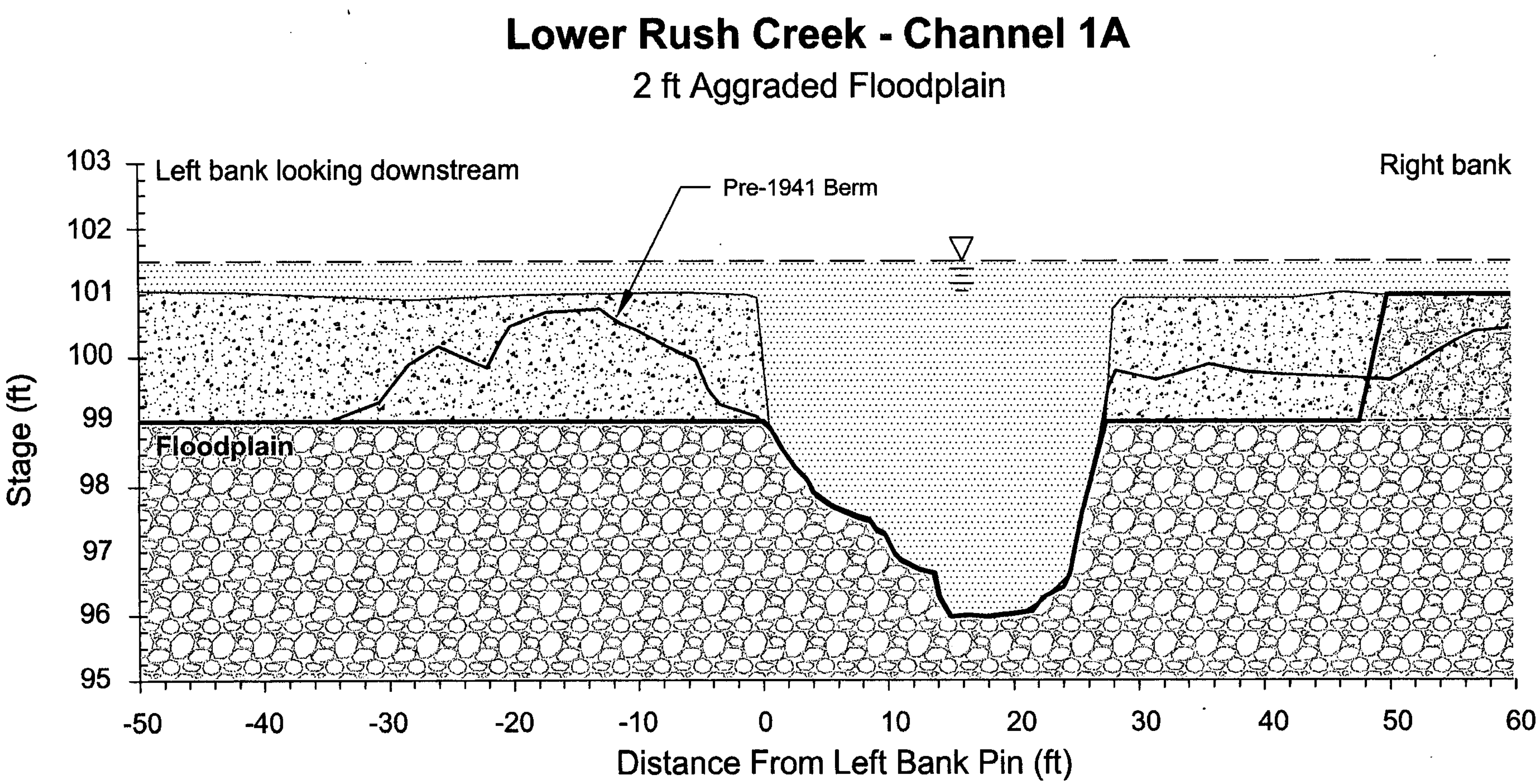
Figure 29. Upper Lee Vining Creek A4 Channel, showing the original floodplain with 1 and 1.5 feet of aggradation.



Floodplain	Aggraded Floodplain
270 cfs	660 cfs
R.I.= 1.5 yrs.	R.I. = 27 yrs
$\bar{n}_{main}$ = 0.06	$\bar{n}_{main}$ = 0.06
$\bar{d}_{main}$ = 1.74 ft	$\bar{d}_{main}$ = 3.17 ft
$\bar{u}_{main}$ = 5.42 ft/sec	$\bar{u}_{main}$ = 8.06 ft/sec

Figure 30. Upper Lee Vining Creek A4 Channel, showing the original floodplain with 1.5 feet of aggradation and flows just over the riparian induced berm.



1600 cfs	1400 cfs	1100 cfs
R.I.= 123 yrs.	R.I.= 60 yrs.	R.I.= 22 yrs.
$n_{main} = 0.035$	$n_{main} = 0.040$	$n_{main} = 0.050$
$n_{floodplain} = 0.070$	$n_{floodplain} = 0.070$	$n_{floodplain} = 0.070$
$\bar{d}_{main} = 4.46$ ft	$\bar{d}_{main} = 4.46$ ft	$\bar{d}_{main} = 4.46$ ft
$\bar{u}_{main} = 12.0$ ft/sec	$\bar{u}_{main} = 10.5$ ft/sec	$\bar{u}_{main} = 8.38$ ft/sec
$\bar{u}_{floodplain} = 1.41$ ft/sec	$\bar{u}_{floodplain} = 1.41$ ft/sec	$\bar{u}_{floodplain} = 1.41$ ft/sec

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Figure 31. Lower Rush Creek Channel 1A, showing original cross section with pre-1941 berm and 2 feet of aggradation.

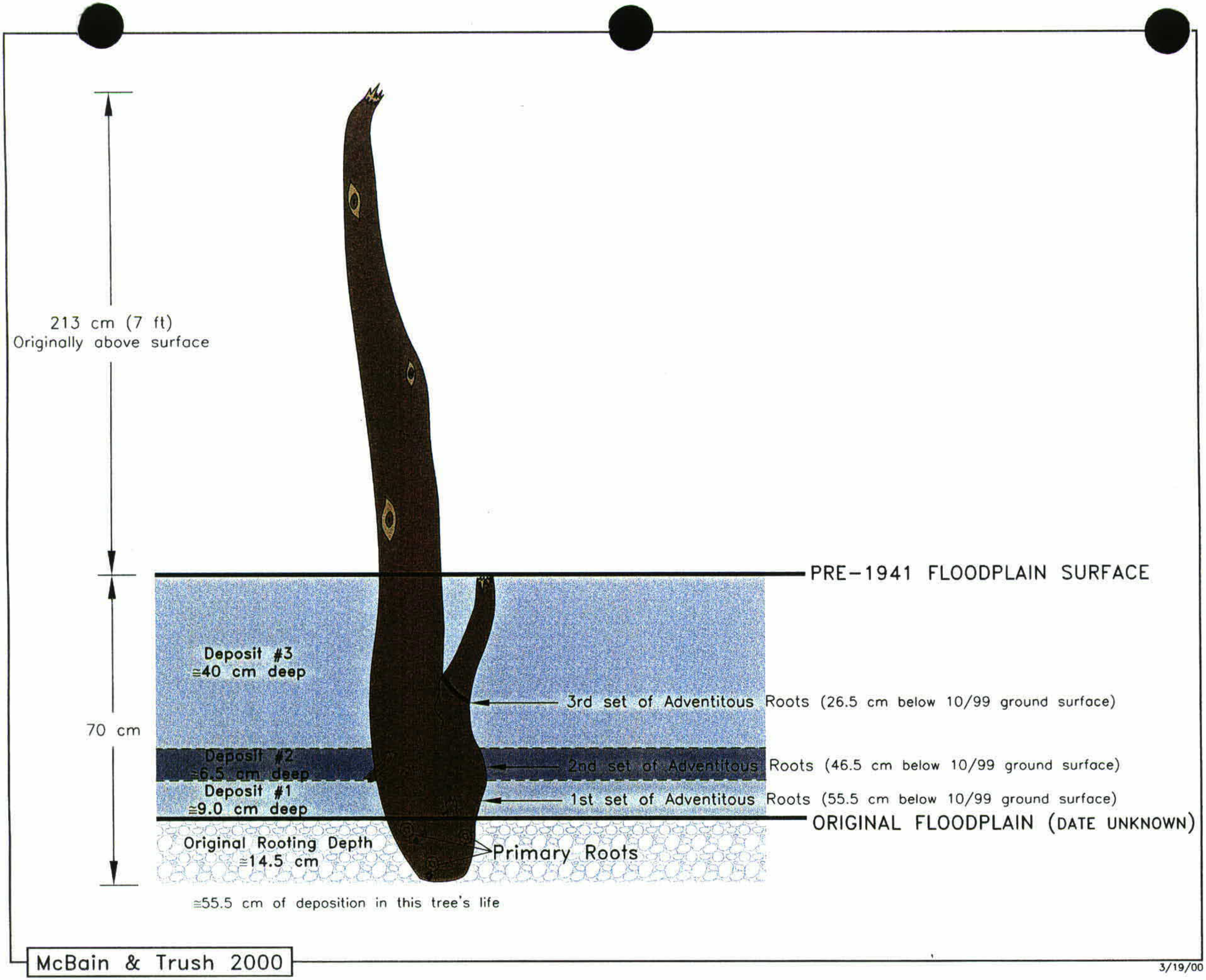


Figure 32. Diagram of 38 year old willow pole excavated from the pre-1941 floodplain at the Rush Creek County Road Site in WY1999.

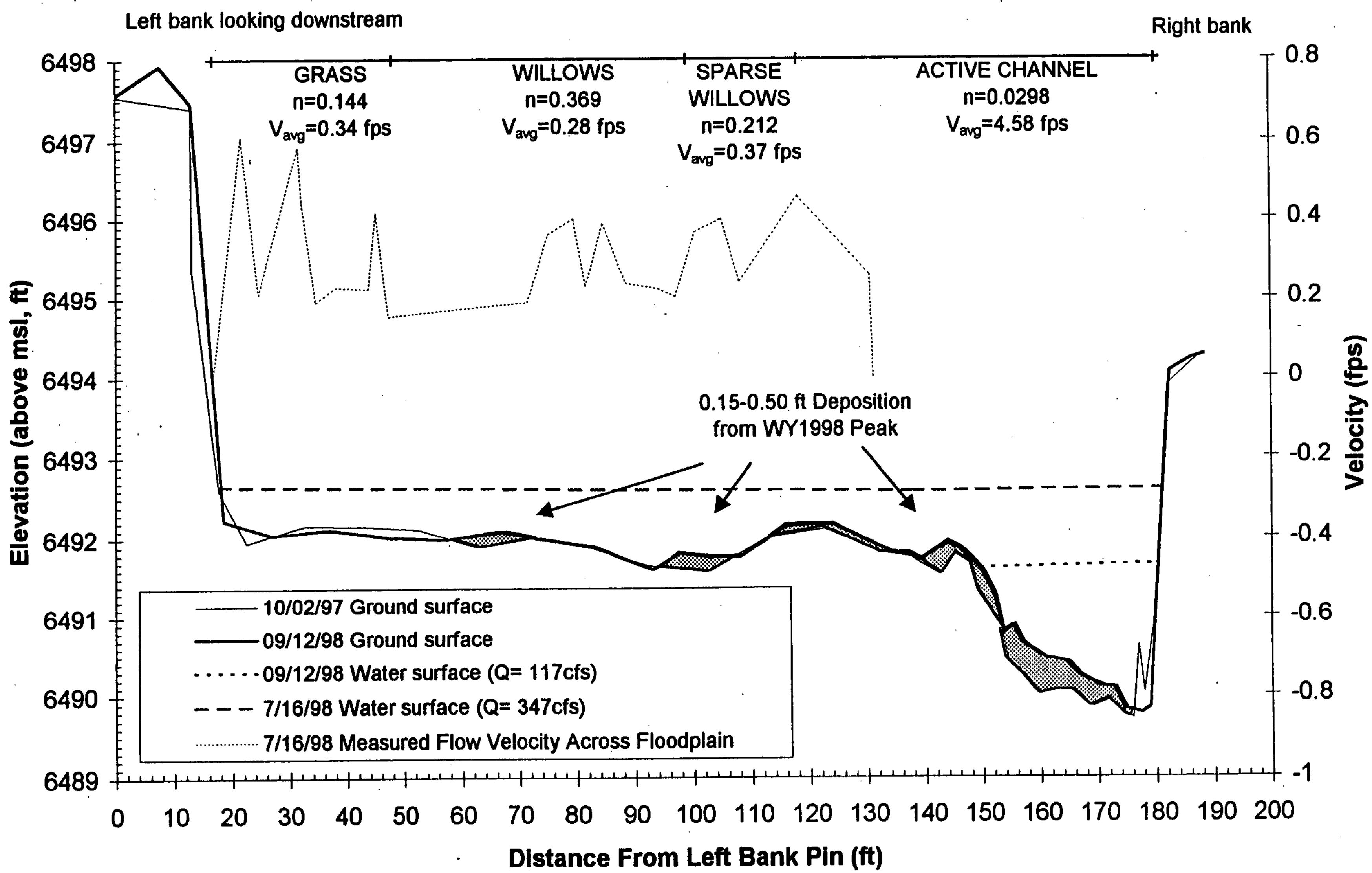


Figure 33. Lower Rush Creek Cross section 10+10, measured velocities, and estimated Manning's n values.

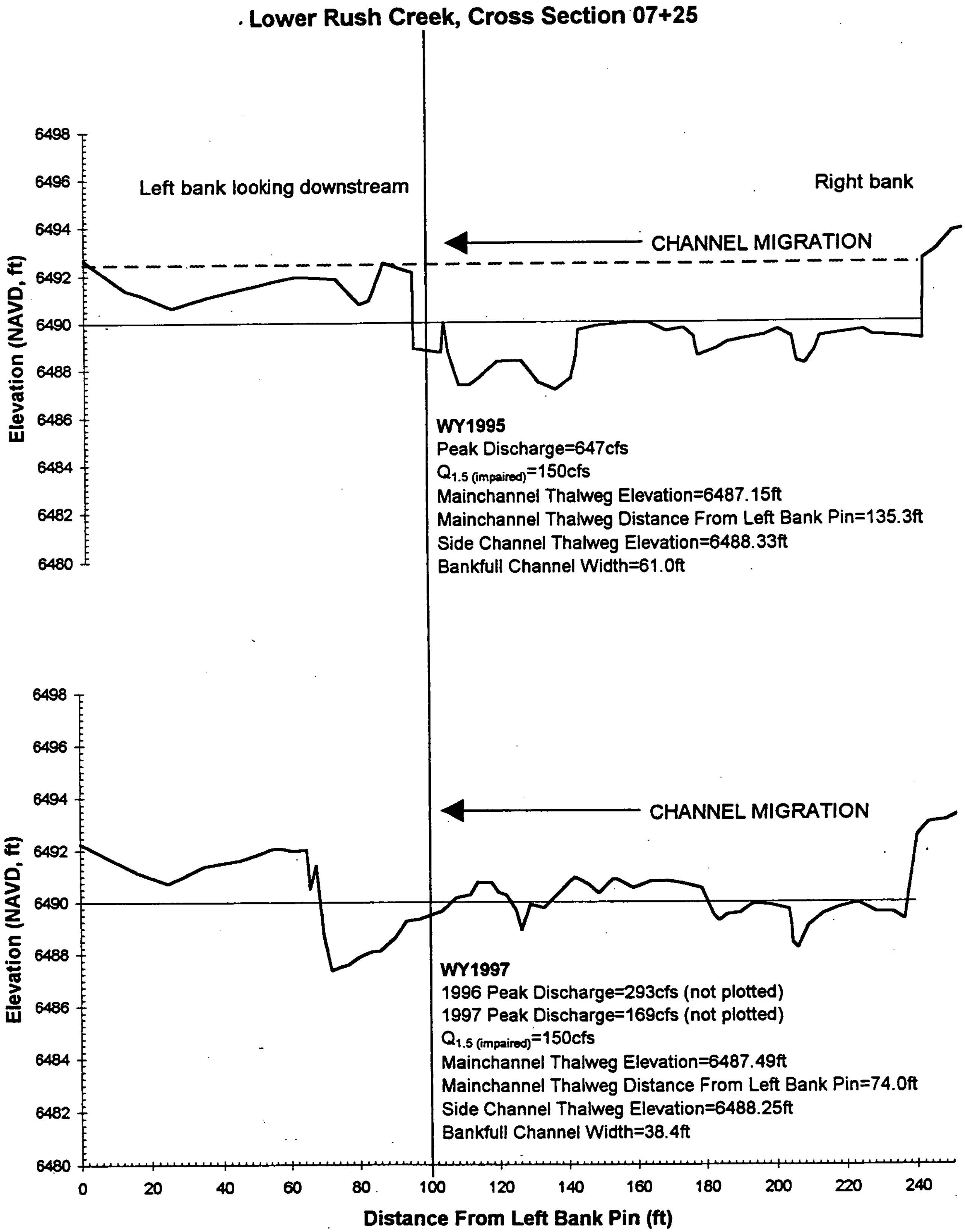


Figure 34. Lower Rush Creek Cross section 07+25 migration from WY1995 to WY1999.

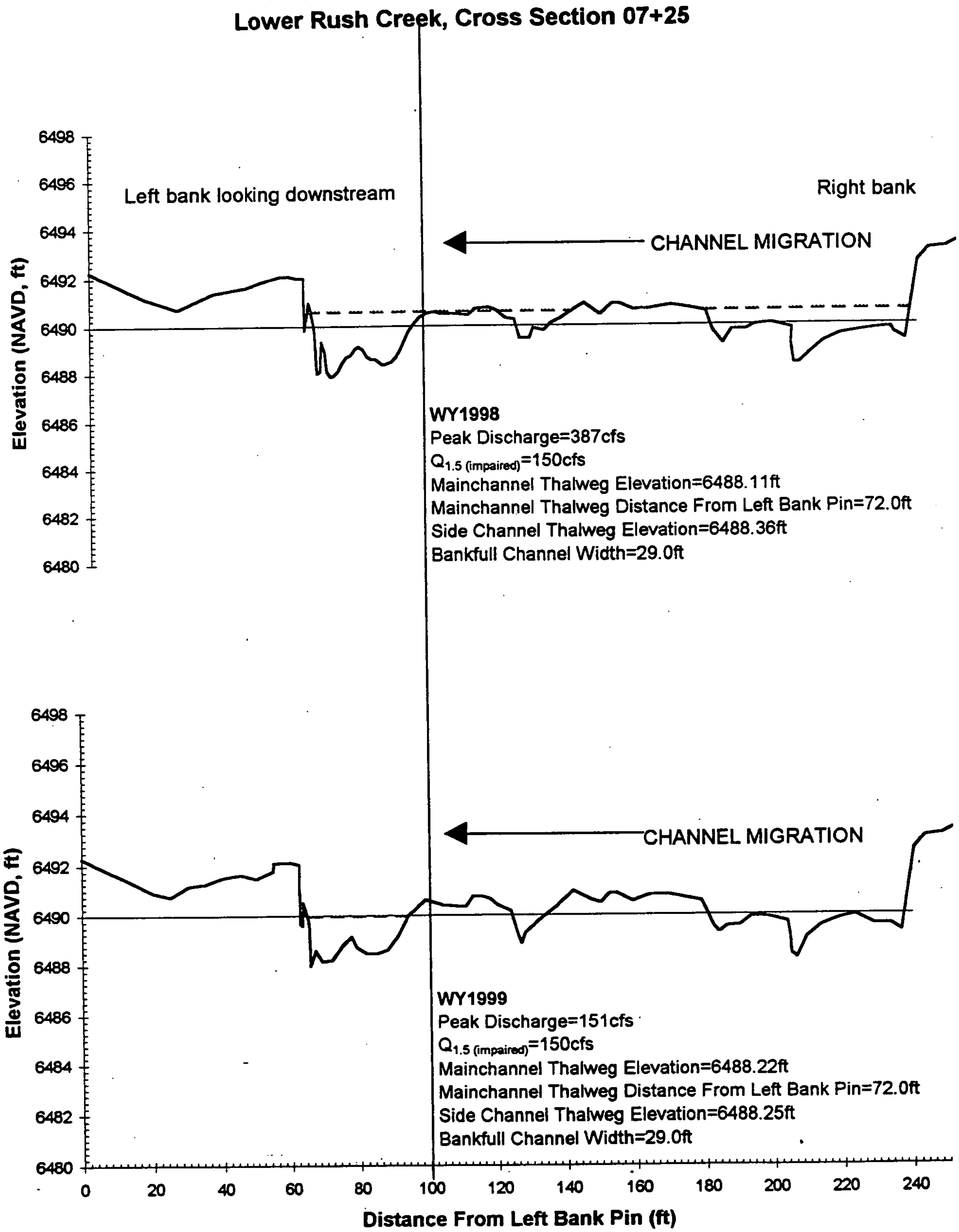
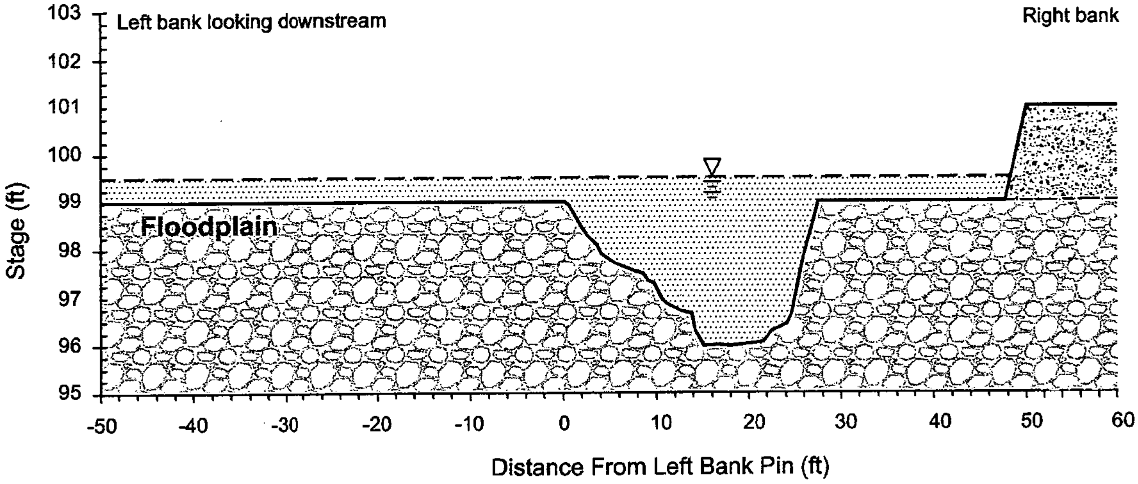


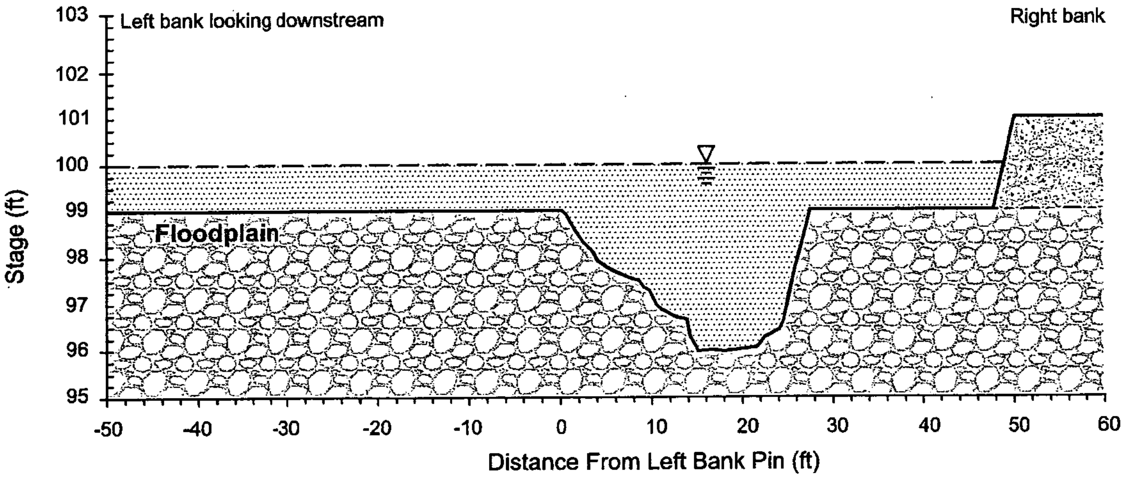
Figure 34. Lower Rush Creek Cross section 07+25 migration from WY1995 to WY1999.

Lower Rush Creek - Channel 1A
No Aggradation
Flow 0.5 ft Deep on Floodplain



650 cfs	580 cfs	480 cfs
R.I.= 3.8 yrs.	R.I.= 2.9 yrs.	R.I.= 2.0 yrs.
n_{main} = 0.035	n_{main} = 0.040	n_{main} = 0.050
$n_{floodplain}$ = 0.05	$n_{floodplain}$ = 0.050	$n_{floodplain}$ = 0.050
$\bar{d}_{main}$ = 2.46 ft	$\bar{d}_{main}$ = 2.46 ft	$\bar{d}_{main}$ = 2.46 ft
$\bar{u}_{main}$ = 8.08 ft/sec	$\bar{u}_{main}$ = 7.07 ft/sec	$\bar{u}_{main}$ = 5.66 ft/sec
$\bar{u}_{floodplain}$ = 1.98 ft/sec	$\bar{u}_{floodplain}$ = 1.98 ft/sec	$\bar{u}_{floodplain}$ = 1.98 ft/sec

Lower Rush Creek - Channel 1A
No Aggradation
Flow 1 ft Deep on Floodplain



1100 cfs	1000 cfs	880 cfs
R.I.= 22 yrs.	R.I.= 16 yrs.	R.I.= 9.4 yrs.
n_{main} = 0.035	η_{main} = 0.040	n_{main} = 0.050
$n_{floodplain}$ = 0.04	$\eta_{floodplain}$ = 0.040	$n_{floodplain}$ = 0.040
$\bar{d}_{main}$ = 2.96 ft	$\bar{d}_{main}$ = 2.96 ft	$\bar{d}_{main}$ = 2.96 ft
$\bar{u}_{main}$ = 9.15 ft/sec	$\bar{u}_{main}$ = 8.01 ft/sec	$\bar{u}_{main}$ = 6.41 ft/sec
$\bar{u}_{floodplain}$ = 3.91 ft/sec	$\bar{u}_{floodplain}$ = 3.91 ft/sec	$\bar{u}_{floodplain}$ = 3.91 ft/sec

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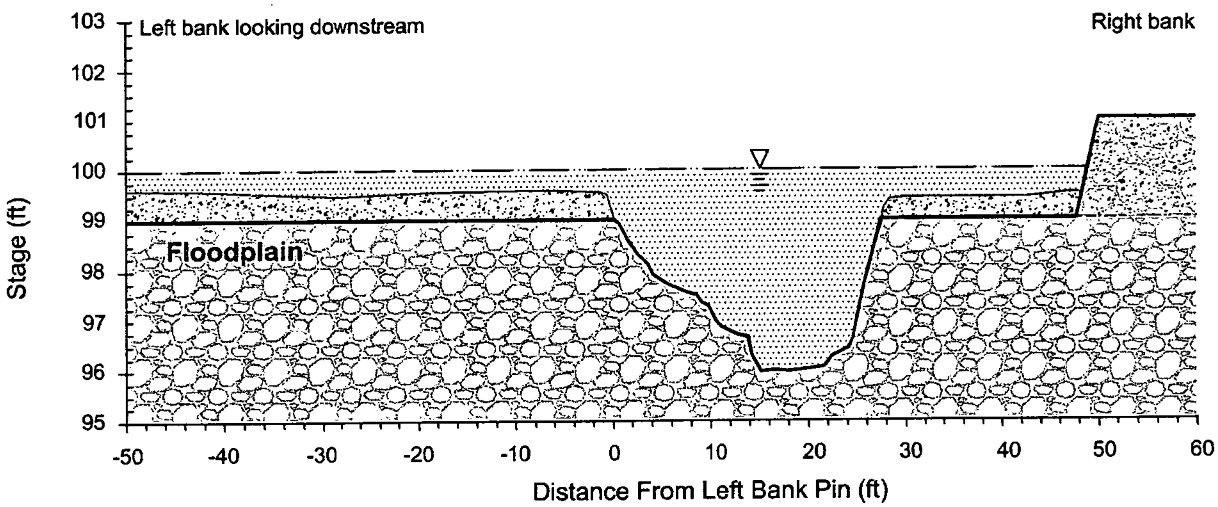
Figure 35. Lower Rush Creek Channel 1A, showing the existing floodplain with 0.5 and 1.0 ft flow depth.

Lower Rush Creek - Channel 1A

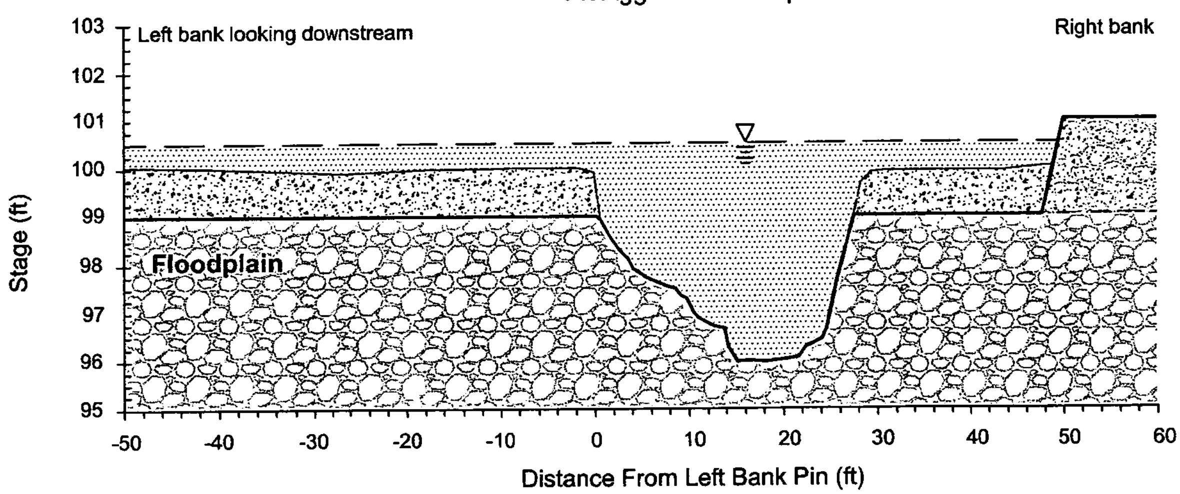
0.5 ft Aggraded Floodplain



850 cfs	750 cfs	620 cfs
R.I.= 8.2 yrs.	R.I.= 5.7 yrs.	R.I.= 3.5 yrs.
$n_{main} = 0.035$	$n_{main} = 0.040$	$n_{main} = 0.050$
$n_{floodplain} = 0.050$	$n_{floodplain} = 0.050$	$n_{floodplain} = 0.050$
$\bar{d}_{main} = 2.96$ ft	$\bar{d}_{main} = 2.96$ ft	$\bar{d}_{main} = 2.96$ ft
$\bar{u}_{main} = 9.15$ ft/sec	$\bar{u}_{main} = 8.01$ ft/sec	$\bar{u}_{main} = 6.41$ ft/sec

Lower Rush Creek - Channel 1A

1 ft Aggraded Floodplain



1100 cfs	950 cfs	780 cfs
R.I.= 19 yrs.	R.I.= 12 yrs.	R.I.= 6.3 yrs.
$n_{main} = 0.035$	$n_{main} = 0.040$	$n_{main} = 0.050$
$n_{floodplain} = 0.050$	$n_{floodplain} = 0.050$	$n_{floodplain} = 0.050$
$\bar{d}_{main} = 3.46$ ft	$\bar{d}_{main} = 3.46$ ft	$\bar{d}_{main} = 3.46$ ft
$\bar{u}_{main} = 10.1$ ft/sec	$\bar{u}_{main} = 8.87$ ft/sec	$\bar{u}_{main} = 7.09$ ft/sec
$\bar{u}_{floodplain} = 1.96$ ft/sec	$\bar{u}_{floodplain} = 1.96$ ft/sec	$\bar{u}_{floodplain} = 1.96$ ft/sec

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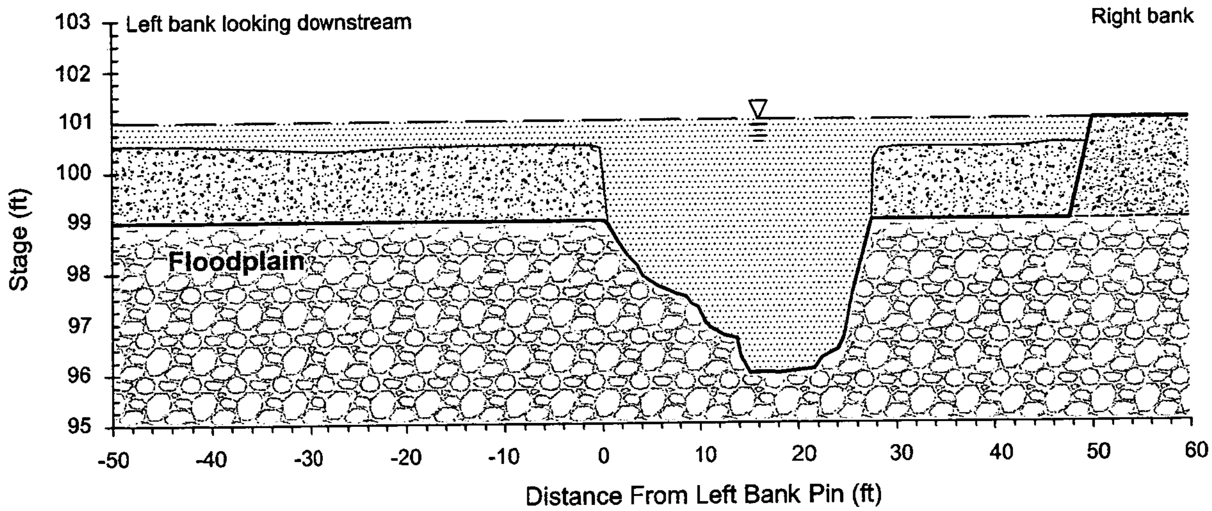
Figure 36. Lower Rush Creek Channel 1A, showing the original floodplain with 0.5 and 1.0 ft aggadation.

Lower Rush Creek - Channel 1A

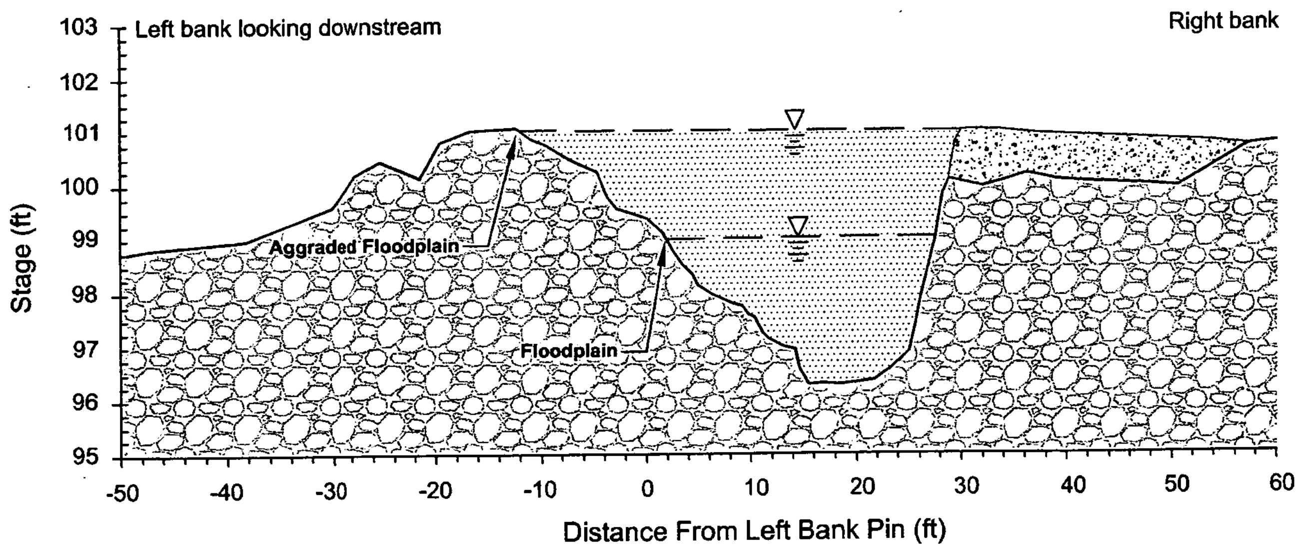
1.5 ft Aggraded Floodplain



1300 cfs	1100 cfs	920 cfs
R.I.= 45 yrs.	R.I.= 25 yrs.	R.I.= 11 yrs.
n_{main} = 0.035	n_{main} = 0.040	n_{main} = 0.050
$n_{floodplain}$ = 0.070	$n_{floodplain}$ = 0.070	$n_{floodplain}$ = 0.070
$\bar{d}_{main}$ = 3.96 ft	$\bar{d}_{main}$ = 3.96 ft	$\bar{d}_{main}$ = 3.96 ft
$\bar{u}_{main}$ = 11.1 ft/sec	$\bar{u}_{main}$ = 9.69 ft/sec	$\bar{u}_{main}$ = 7.75 ft/sec
$\bar{u}_{floodplain}$ = 1.41 ft/sec	$\bar{u}_{floodplain}$ = 1.41 ft/sec	$\bar{u}_{floodplain}$ = 1.41 ft/sec

Lower Rush Creek - Channel 1A

Original Cross Section with modified Right Bank



Floodplain	Aggraded Floodplain
350 cfs	1200 cfs
R.I.= 1.2 yrs.	R.I.= 65 yrs.
$\bar{d}_{main}$ = 2.12 ft	$\bar{d}_{main}$ = 3.513 ft
$\bar{u}_{main}$ = 6.41 ft/sec	$\bar{u}_{main}$ = 8.95 ft/sec

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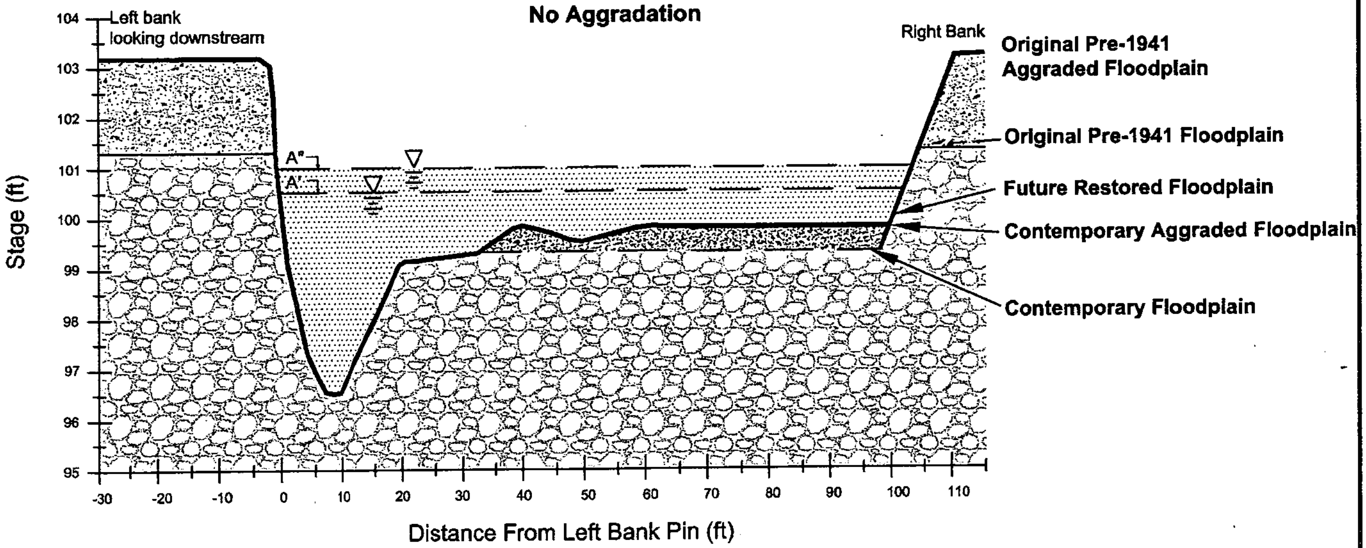
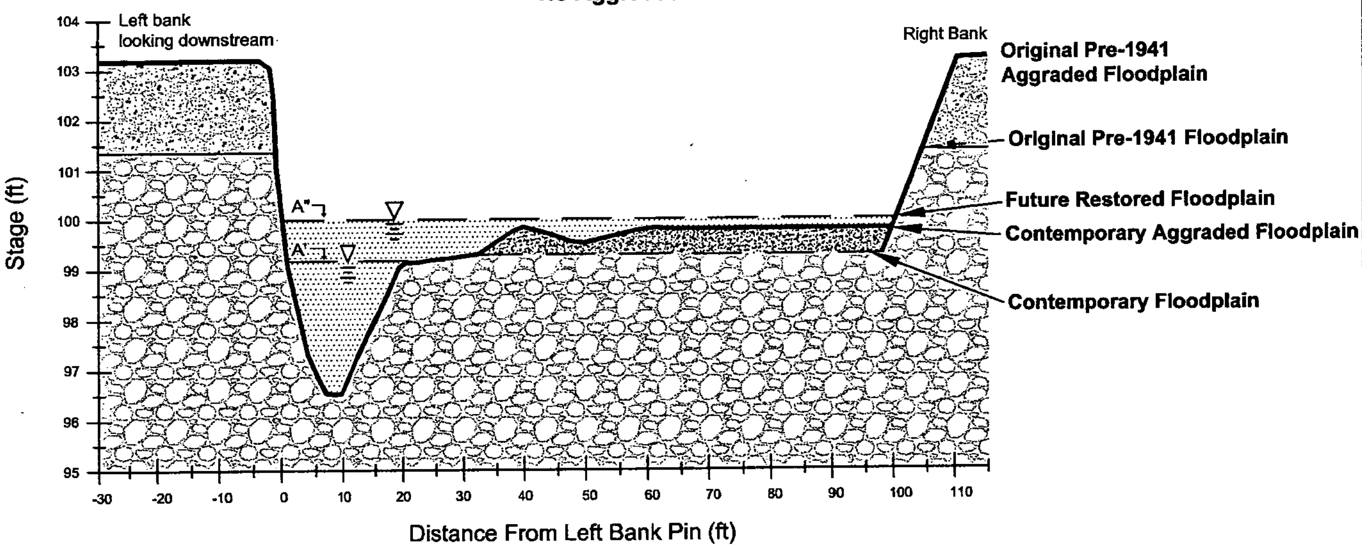
Figure 37. Lower Rush Creek Channel 1A, showing the original floodplain with 1.5 aggadation and original cross section with modified right bank.

Lower Rush Creek - Yellow Bird
No Aggradation



A' = 0.5 ft inundation			A" = 1.0 ft inundation		
650 cfs	580 cfs	480 cfs	1100 cfs	960 cfs	820 cfs
R.I.= 3.9 yrs.	R.I.= 3.0 yrs.	R.I.= 2.0 yrs.	R.I.= 21 yrs.	R.I.= 13 yrs.	R.I.= 7.4 yrs.
n_{main} = 0.035	n_{main} = 0.040	n_{main} = 0.050	n_{main} = 0.035	n_{main} = 0.040	n_{main} = 0.050
$n_{floodplain}$ = 0.04	$n_{floodplain}$ = 0.040	$n_{floodplain}$ = 0.040	$n_{floodplain}$ = 0.040	$n_{floodplain}$ = 0.040	$n_{floodplain}$ = 0.040
$\bar{d}_{main}$ = 2.28 ft	$\bar{d}_{main}$ = 2.28 ft	$\bar{d}_{main}$ = 2.28 ft	$\bar{d}_{main}$ = 2.78 ft	$\bar{d}_{main}$ = 2.78 ft	$\bar{d}_{main}$ = 2.78 ft
$\bar{u}_{main}$ = 7.68 ft/sec	$\bar{u}_{main}$ = 6.72 ft/sec	$\bar{u}_{main}$ = 5.38 ft/sec	$\bar{u}_{main}$ = 8.75 ft/sec	$\bar{u}_{main}$ = 7.66 ft/sec	$\bar{u}_{main}$ = 6.13 ft/sec
$\bar{u}_{floodplain}$ = 2.47 ft/sec	$\bar{u}_{floodplain}$ = 2.47 ft/sec	$\bar{u}_{floodplain}$ = 2.47 ft/sec	$\bar{u}_{floodplain}$ = 3.91 ft/sec	$\bar{u}_{floodplain}$ = 3.91 ft/sec	$\bar{u}_{floodplain}$ = 3.91 ft/sec

Lower Rush Creek - Yellow Bird
No Aggradation

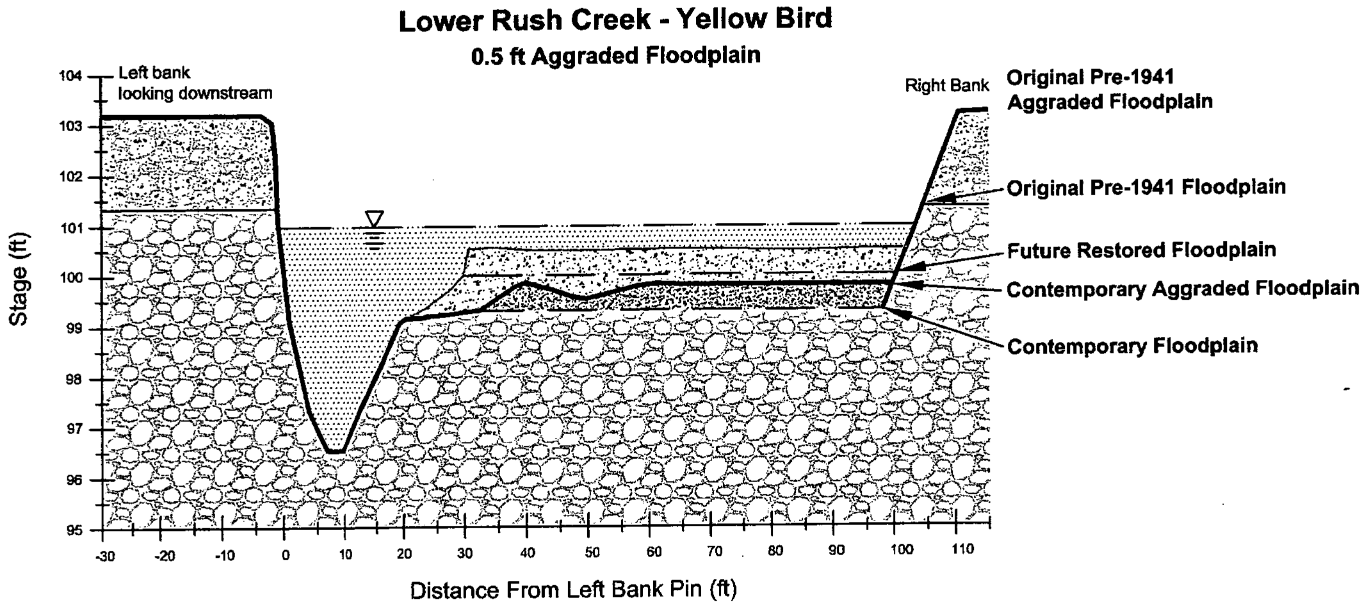


A'		A"	
200 cfs	130 cfs	370 cfs	330 cfs
n_{main} = 0.035	n_{main} = 0.040	n_{main} = 0.035	n_{main} = 0.040
$\bar{d}_{main}$ = 1.04 ft	$\bar{d}_{main}$ = 1.04 ft	$\bar{d}_{main}$ = 1.78 ft	$\bar{d}_{main}$ = 1.78 ft
$\bar{u}_{main}$ = 5.82 ft/sec	$\bar{u}_{main}$ = 4.00 ft/sec	$\bar{u}_{main}$ = 6.52 ft/sec	$\bar{u}_{main}$ = 5.70 ft/sec

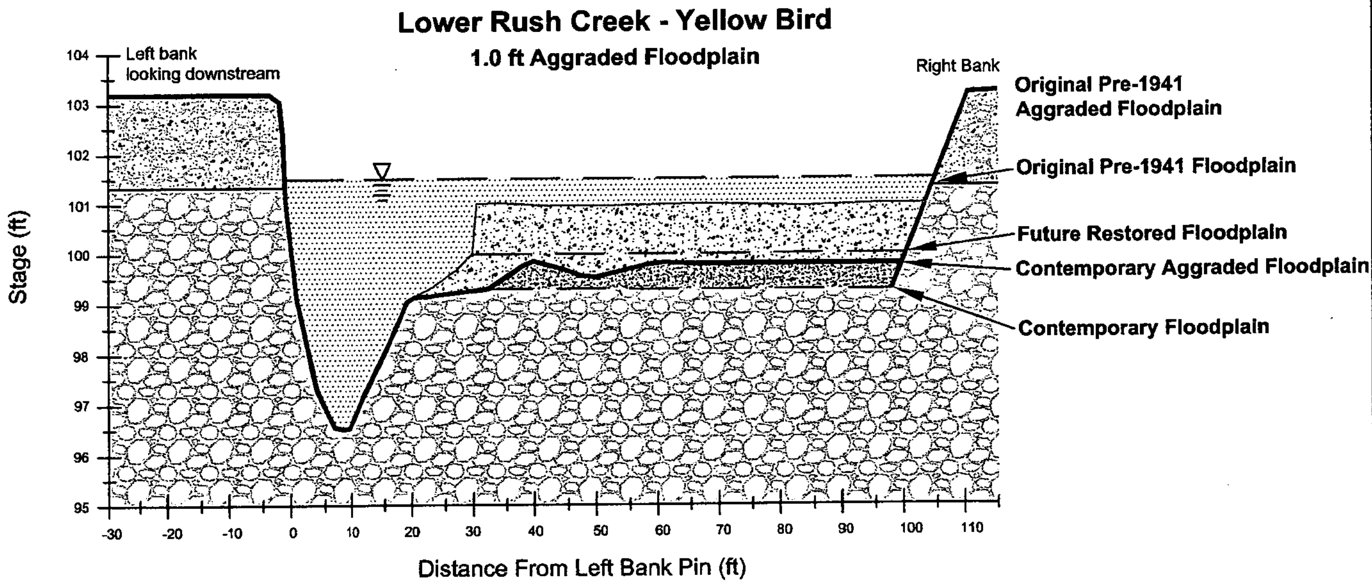
McBain & Trush 2000

3/6/00

Figure 38. Lower Rush Creek Yellow Bird channel, showing inundation on the original floodplain with no aggadation.



850 cfs	750 cfs	610 cfs
R.I.= 8.3 yrs.	R.I.= 5.7 yrs.	R.I.= 3.3 yrs.
n_{main} = 0.035	n_{main} = 0.040	n_{main} = 0.050
$n_{floodplain}$ = 0.050	$n_{floodplain}$ = 0.050	$n_{floodplain}$ = 0.050
$\bar{d}_{main}$ = 1.96 ft	$\bar{d}_{main}$ = 1.96 ft	$\bar{d}_{main}$ = 1.96 ft
$\bar{u}_{main}$ = 8.75 ft/sec	$\bar{u}_{main}$ = 7.66 ft/sec	$\bar{u}_{main}$ = 6.13 ft/sec
$\bar{u}_{floodplain}$ = 1.98 ft/sec	$\bar{u}_{floodplain}$ = 1.98 ft/sec	$\bar{u}_{floodplain}$ = 1.98 ft/sec

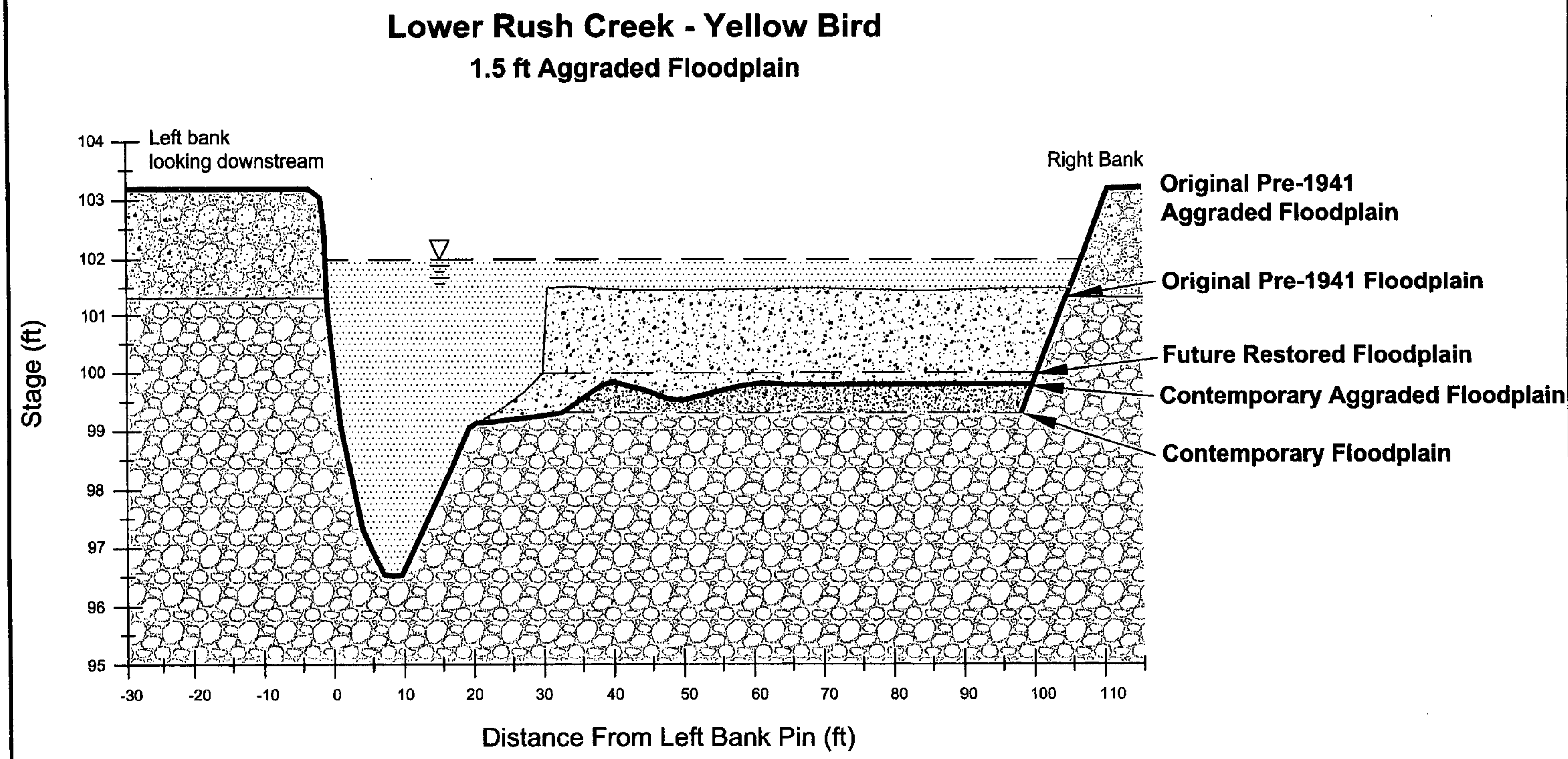


1100 cfs	950 cfs	770 cfs
R.I.= 19 yrs.	R.I.= 12 yrs.	R.I.= 6.2 yrs.
n_{main} = 0.035	n_{main} = 0.040	n_{main} = 0.050
$n_{floodplain}$ = 0.070	$n_{floodplain}$ = 0.070	$n_{floodplain}$ = 0.070
$\bar{d}_{main}$ = 3.28 ft	$\bar{d}_{main}$ = 3.28 ft	$\bar{d}_{main}$ = 3.28 ft
$\bar{u}_{main}$ = 9.78 ft/sec	$\bar{u}_{main}$ = 8.56 ft/sec	$\bar{u}_{main}$ = 6.48 ft/sec
$\bar{u}_{floodplain}$ = 1.41 ft/sec	$\bar{u}_{floodplain}$ = 1.41 ft/sec	$\bar{u}_{floodplain}$ = 1.41 ft/sec

McBain & Trush 2000

3/6/00

Figure 39. Lower Rush Creek Yellow Bird channel, showing the original floodplain with 0.5 and 1.0 ft aggadation.



1400 cfs	1200 cfs	960 cfs
R.I.= 66 yrs.	R.I.= 31 yrs.	R.I.= 13 yrs.
n_{main} = 0.035	n_{main} = 0.040	n_{main} = 0.050
$n_{floodplain}$ = 0.070	$n_{floodplain}$ = 0.070	$n_{floodplain}$ = 0.070
$\bar{d}_{main}$ = 3.78 ft	$\bar{d}_{main}$ = 3.78 ft	$\bar{d}_{main}$ = 3.78 ft
$\bar{u}_{main}$ = 10.8 ft/sec	$\bar{u}_{main}$ = 9.42 ft/sec	$\bar{u}_{main}$ = 7.53 ft/sec
$\bar{u}_{floodplain}$ = 1.41 ft/sec	$\bar{u}_{floodplain}$ = 1.41 ft/sec	$\bar{u}_{floodplain}$ = 1.41 ft/sec

McBain & Trush 2000

3/6/00

Figure 40. Lower Rush Creek Yellow Bird channel, showing the original floodplain with 1.5 aggadation.

Figure 41. Proposed primary, secondary, and tertiary channel classification scheme.

TERTIARY CHANNEL

Not Proportioned to Accommodate Perennial Fraction of Total Annual Flow Regime

Presently Transports Seasonally High Flow Fraction of Total Annual Flow Regime	Presently Transports None of Total Annual Flow Regime (Abandoned)

SECONDARY CHANNEL

Proportioned to Accommodate Perennial Fraction of Total Annual Flow Regime

Presently Transports Perennial Fraction of Total Annual Flow Regime (e.g., meander cut-off channels in Lower Rush)	Once Transported Perennial Fraction of Total Annual Flow Regime, Now Transports Only Greater Than Q_{ave} Fraction of Total Annual Flow Regime	Once Transported Perennial Fraction of Total Annual Flow Regime, Now Transports Only Greater Than Bankfull Flow Fraction of Total Annual Flow Regime (e.g., many segments of LV following recent headcutting)	Presently Transports None of Total Annual Flow Regime (Abandoned)

PRIMARY CHANNEL

Proportioned to Accommodate Total Annual Flow Regime

Presently Transports Total Annual Flow Regime: Not Incised Incised	Presently Transports Only Fraction of Total Annual Flow Regime: Not Incised Transports Perennial Flows Transports Q_{ave} and Greater Only Transports Bankfull Flow and Greater Only Incised Transports Perennial Flows (e.g. Lower Lee Vining B1) Transports Q_{ave} and Greater Only Transports Bankfull Flow and Greater Only (e.g., segments of LV B2)	Presently Transports None of Total Annual Flow Regime (Abandoned or Filled-In) Not Incised Incised (e.g., Lower Rush 14)

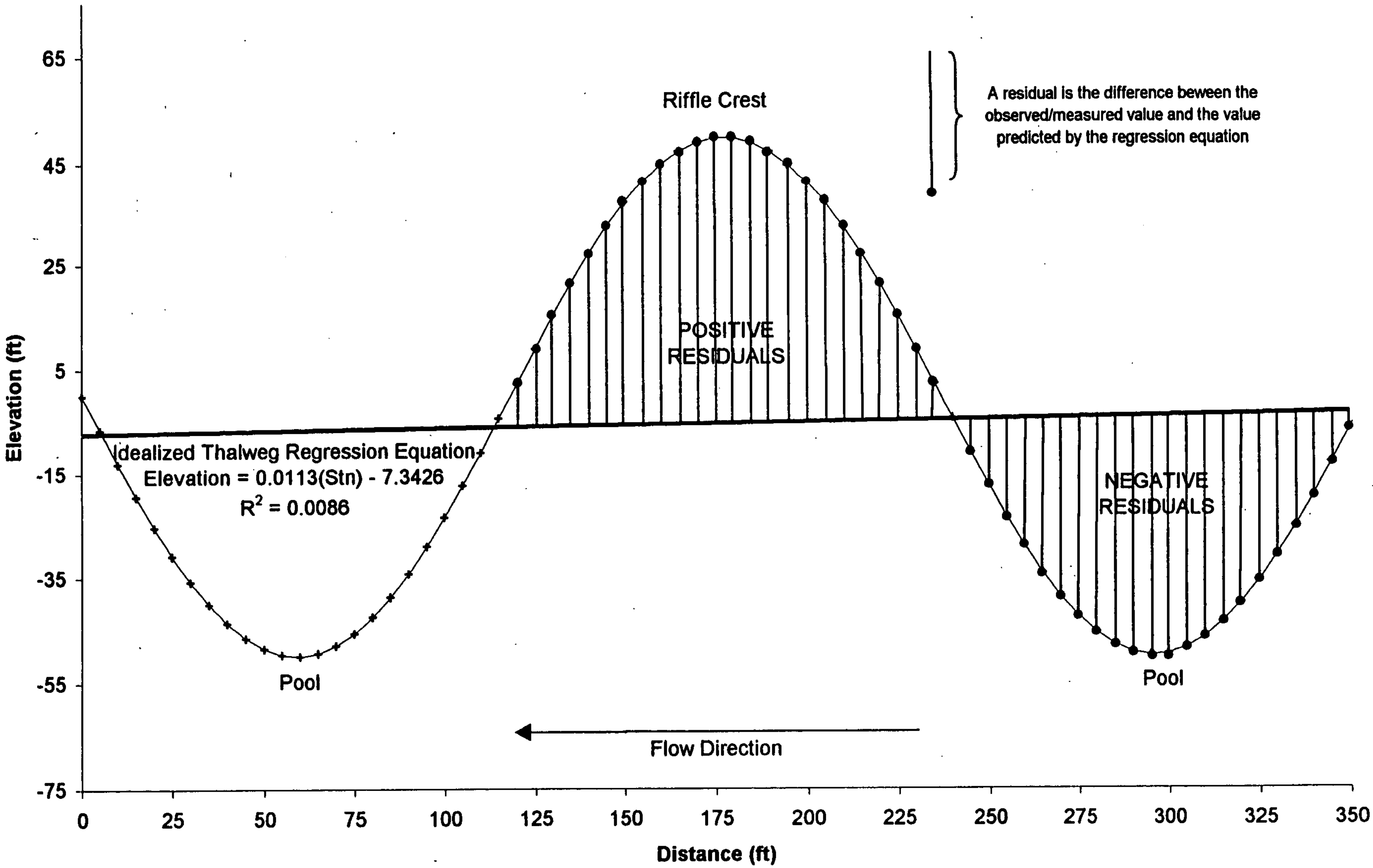


Figure 42. An idealized longitudinal thalweg profile (illustrated by a sine wave) showing the residual analysis components.

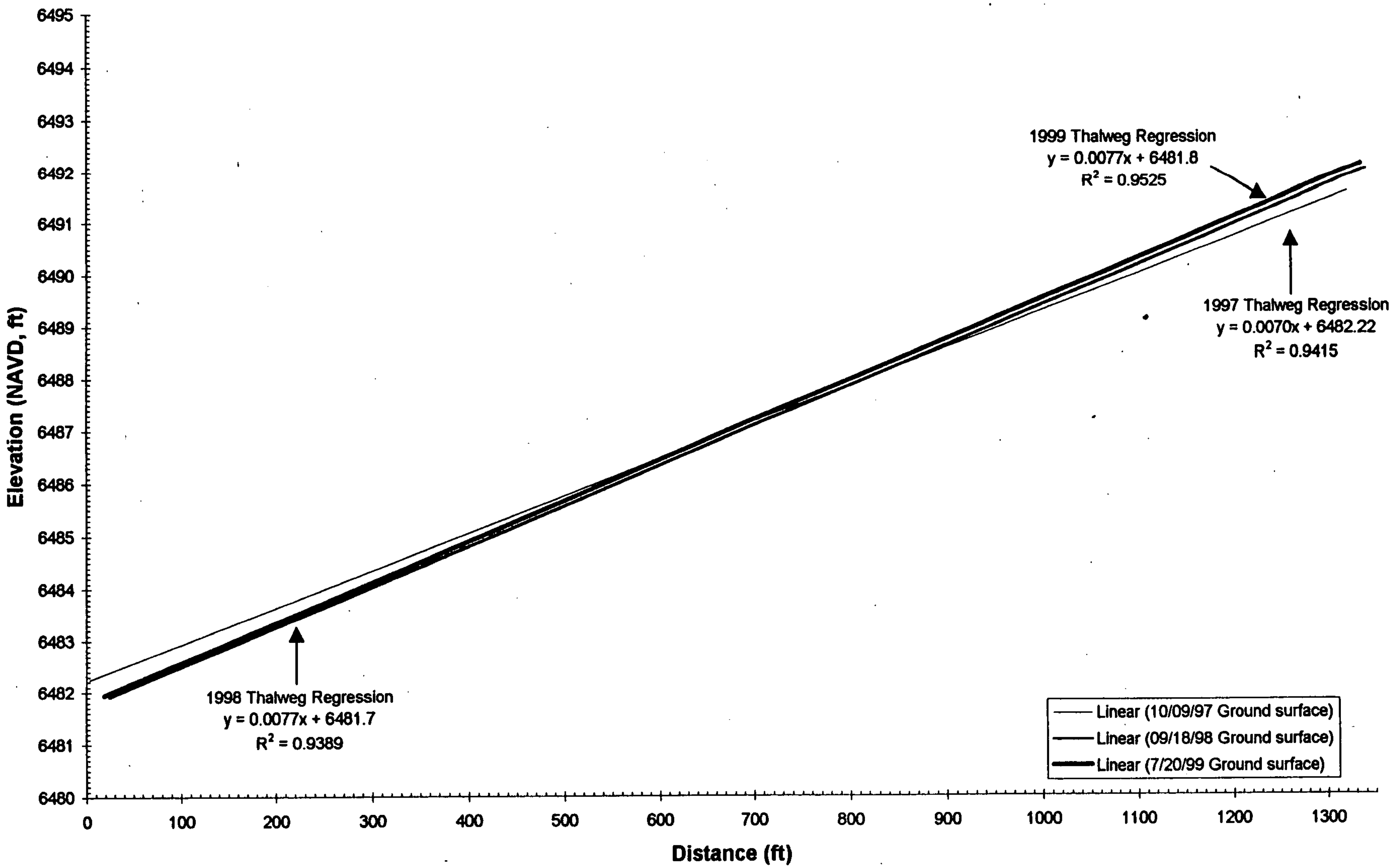


Figure 43. Lower Rush Creek longitudinal thalweg profile regression lines for WY1997-1999.

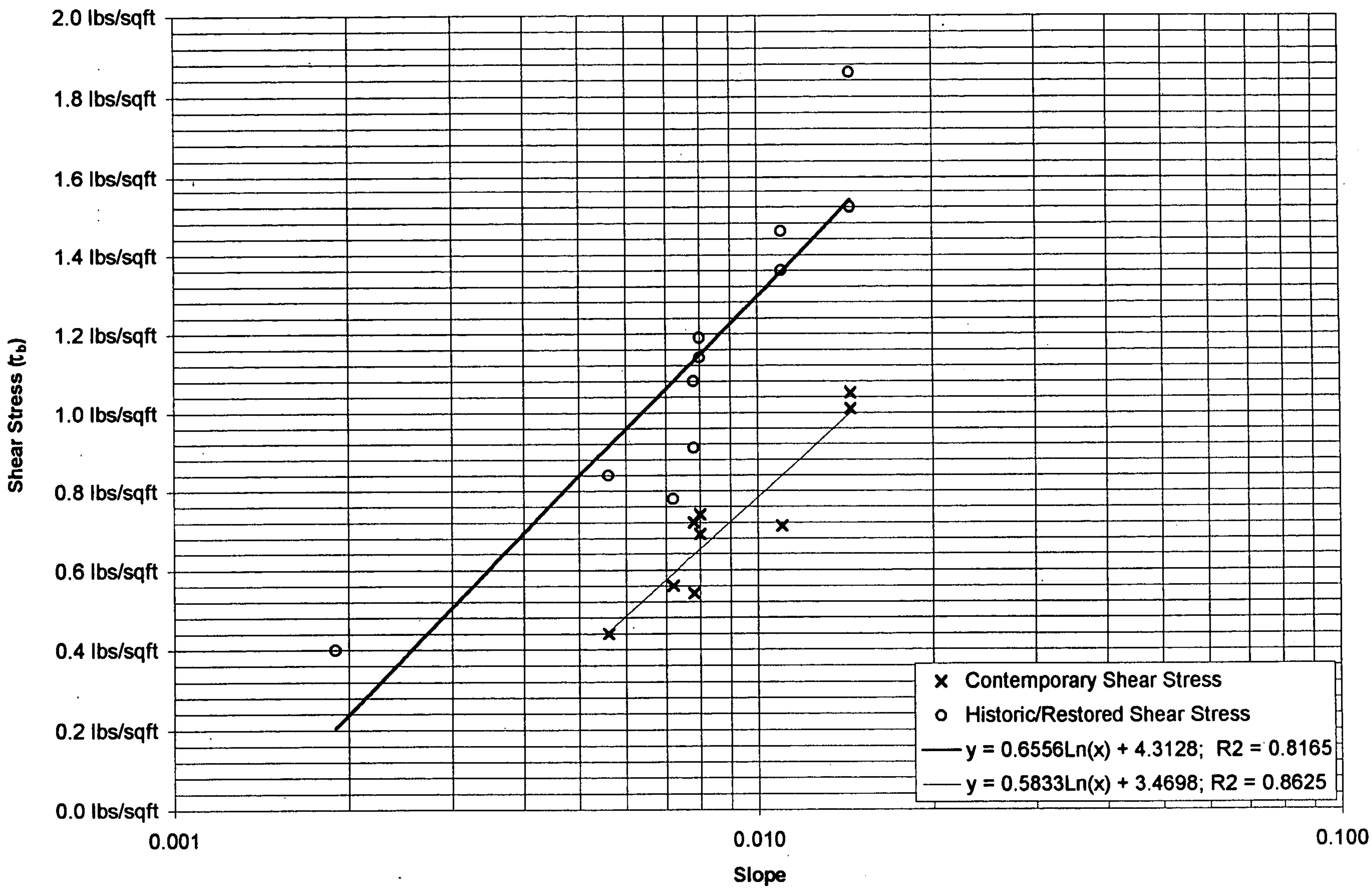


Figure 44. Lower Rush Creek shear stress at the Q1.5 impaired for contemporary cross sections and the shear stress at the Q1.5 unimpaired for historic/restored cross sections.

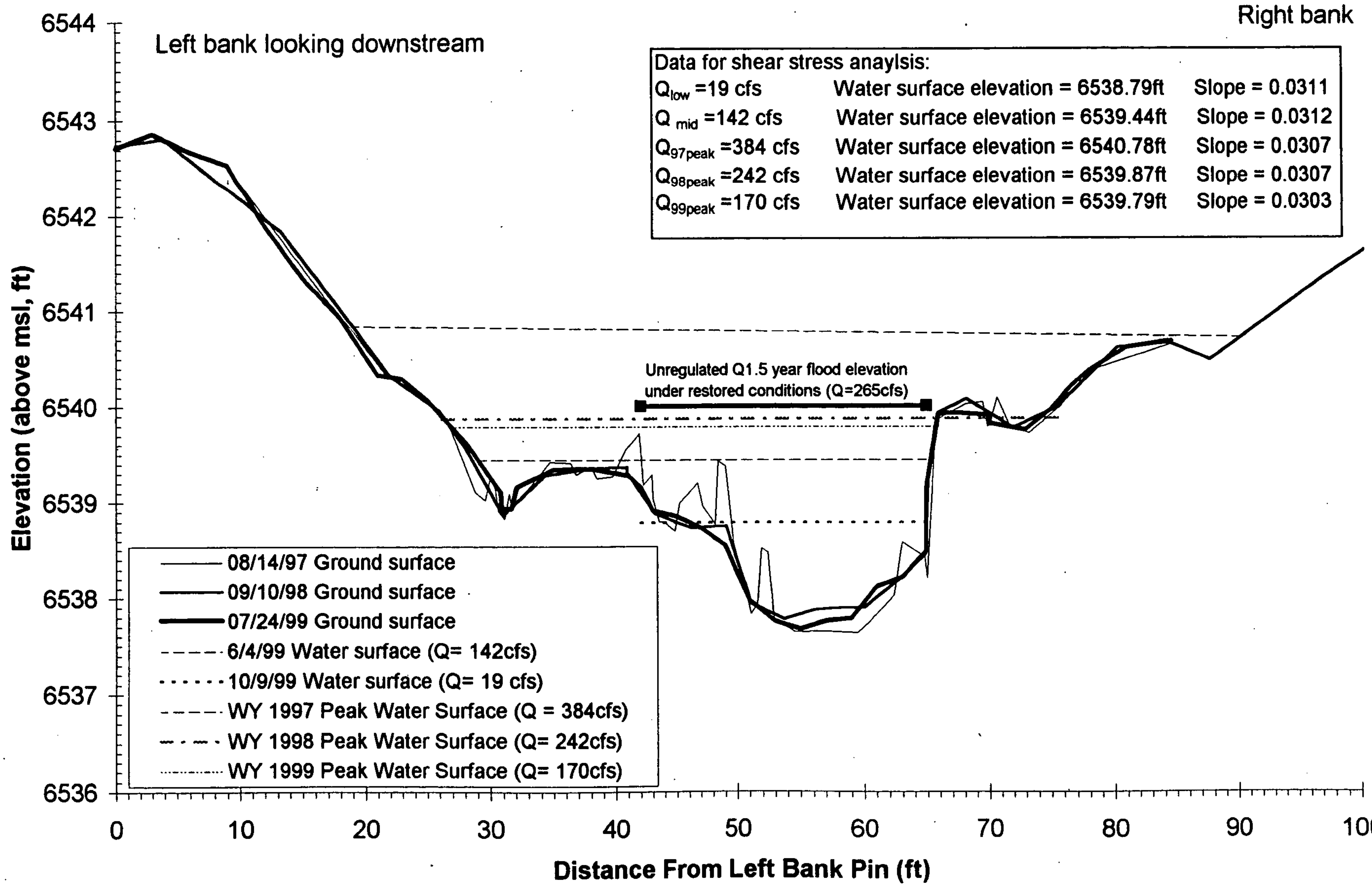


Figure 45. Upper Lee Vining Creek main channel cross section 13+92.

Table 1. Annual daily average peak discharges, and associated recurrence intervals (R.I.) for Walker, Parker, Lee Vining, Rush, Parker and Walker creeks. Annual Instantaneous maximum discharges are in parentheses where available.

LADWP Gaging Location	WY1995 Spring Snowmelt (cfs)	WY1996 Spring Snowmelt (cfs)	January-1997	WY1997 Spring Snowmelt (cfs)	WY1998 Spring Snowmelt (cfs)	WY1999 Spring Snowmelt (cfs)
Walker Creek under Conduit (5002)	61	39	42 (53)	34	47	30
Parker Creek under Conduit (5003)	76	54	52 (94)	48	72	52
Lee Vining Creek abv Intake (5008)	522 (583)	342 (362)	524 (740)	378 (404)	419 (451)	285 (288)
Lee Vining Creek at Intake (5009)	436 (480)	332 (357)	422 (578)	354 (399)	391 (391)	274
Rush Creek at Dam Site (5013)	634 (676)	306 (307)	250 (318)	211 (216)	495 (519)	147 (266)[2]
Rush Creek blw Return Ditch (RCBRD)	548	333	167	175	538	201
Rush Creek blw Narrows [1]	647	391	188	226	635	247

[1] Discharge calculated by adding RCBRD+Walker+Parker

[2] Annual instantaneous peak discharge and the Maximum daily average discharge did not occur on the same day

LADWP Gaging Location	WY1995 Annual Peak R.I.	WY1996 Annual Peak R.I.	WY1997 January Peak R.I.	WY1997 Spring Peak R.I.	WY1998 Annual Peak R.I.	WY1999 Annual Peak R.I.
Lee Vining at Intake (1973-1994 unimpaired)	5.20	2.56	9.15	3.26	3.11	1.58
Lee Vining at Intake (1973-1994 impaired)	12.05	5.01	24.27	6.76	6.38	2.77
Rush Creek at Dam Site (1941-1990 unimpaired)	5.16	0.94	0.99	0.62	2.50	0.78
Rush Creek at Dam Site (1941-1990 impaired)	38.66	3.70	3.97	2.08	14.25	2.85
Rush Creek at Dam Site (1973-1994 unimpaired)	31.68	3.76	4.01	2.22	12.80	2.97
Rush Creek at Dam Site (1973-1994 impaired)	4.28	1.06	1.11	0.75	2.37	0.91
Parker Creek above Conduit (1973-94 impaired)	9.24	3.09	22.63	2.30	7.58	2.80
Walker Creek above Conduit (1973-1994 impaired)	9.35	2.88	6.10	2.21	4.42	1.78

Table 2. Summary of Lee Vining Creek measured flow proportions:

Measurement Date	Lee Vining Creek @ Parshall Flume (cfs)*	Upper Lee Vining Creek Site Mainstem Discharge (cfs)	Upper Lee Vining Creek Site A4 Channel Discharge (cfs)	Upper Lee Vining Creek Site B1 Channel Discharge (cfs)	Upper Lee Vining Creek Site A4-B1 Connector Channel Discharge (cfs)	Measurments Total Combined Discharge
6/5/98	115.0	75.5	34.7	50.5	15.8	110.3
6/18/98	274.0	161.4	98.9	126.5	27.6	260.2
9/11/98	94.0	55.6	26.4	38.4	12.0	82.1
5/6/99	45.0	25.2	6.8	14.3	7.5	32.0
6/4/99	145.0	141.8	59.1	76.0	16.9	200.9
7/26/99	64.0	48.4	16.3	28.8	12.5	64.7
10/8/99	N/A	18.7	6.9	12.3	5.4	25.6

*Lee Vining Creek @ Parshall Flume is a daily average discharge and is included for reference only

Measurement Date	Upper Lee Vining Creek Site Mainstem Percent of Total Discharge	Upper Lee Vining Creek Site A4 Channel Percent of Total Discharge	Upper Lee Vining Creek Site B1 Channel Percent of Total Discharge	Upper Lee Vining Creek Site A4-B1 Connector Channel Percent of Mainstem's Total Discharge
6/5/98	69%	31%	46%	21%
6/18/98	62%	38%	49%	17%
9/11/98	68%	47%	47%	22%
5/6/99	79%	21%	45%	30%
6/4/99	71%	29%	38%	12%
7/26/99	75%	25%	44%	26%
10/8/99	73%	27%	48%	29%

Table 3. Summary of Rush Creek measured flow proportions.

Measurement Date	Rush Creek below the Return Ditch (cfs)*	Rush Creek below the Narrows (cfs)*	Lower Rush Creek Site Planmap Mainstem Discharge (cfs)	Lower Rush Creek Site 10 Channel Discharge (cfs)	Lower Rush Creek Site Below Planmap Mainstem Discharge (cfs)	Lower Rush Creek Site 10 Channel-Mainstem Connector Channel Discharge (cfs)
6/4/98	53.7	70.4	42.1	23.2	65.3	5.7
7/3/98	267.0	361.1	198.2	126.9	325.1	72.6
9/13/98	102.0	136.0	100.2	35.2	135.4	0.6
5/6/99	50.5	59.7	41.6	10.4	52.1	7.6
6/4/99	52.5	87.3	57.0	17.7	74.7	12.6
7/27/99	85.3	105.3	71.7	41.3	103.8	1.4
10/7/99	N/A	N/A	32.5	20.7	53.2	15.0

*Rush Creek below the Return Ditch is a daily average discharge and is included for reference only

Measurement Date	Lower Rush Creek Site Planmap Mainstem Percent of Total Discharge	Lower Rush Creek Site 10 Channel Percent of Total Discharge	Lower Rush Creek Site 10 Channel-Mainstem Connector Channel Percent of total 10 Channel Discharge
6/4/98	65%	35%	20%
7/3/98	61%	39%	36%
9/13/98	74%	26%	2%
5/6/99	80%	20%	42%
6/4/99	76%	24%	42%
7/27/99	69%	40%	3%
10/7/99	61%	39%	42%

Table 4. Summary τ^*_{cr} back calculations.

SUMMARY τ^*_{cr} BACKCALCULATIONS					
Site	**Estimated Q (Incipient D_{50})**	τ^*_{cr50}	**Estimated Q (Incipient D_{84})**	τ^*_{cr84}	**Slope**
Riffle Upper Rush Creek XS05+45	155 cfs (84mm)	0.036	185 cfs (119mm)	0.027	0.0145
Riffle Lower Rush Creek XS-05+07	110 cfs (54mm)	0.030	130 cfs (91mm)	0.026	0.0090
Pool Tail Lower Rush Creek 10+10	110 cfs (46mm)	0.033	130 cfs (79mm)	0.024	0.0072
Riffle Lee Vining Creek B1 Channel XS06+08	65 cfs (125mm)	0.043	90 cfs (240mm)	0.025	0.0249
Riffle Lee Vining Creek B1 Channel XS01+80	60 cfs (74mm)	0.063	100 cfs (153mm)	0.039	0.0230
Riffle Lower Rush Creek XS07+70	115 cfs (56mm)	0.028	125 cfs (97mm)	0.017	0.0072
Run Lower Rush Creek XS04+08	90 cfs (36mm)	0.040	110 cfs (56mm)	0.030	0.0072
Riffle Lee Vining Creek A4 Channel XS06+80	80 cfs (115mm)	0.048	100 cfs (?) (250mm)	0.024	0.0245

Table 5. Summary of plant stands mapped in WY1999 and their relationship to plant stand types identified by previous research.

MCBAIN & TRUSH (2000) PLANT STAND TYPES (ADAPTED FROM SAWYER 1994)	MCBAIN & TRUSH (2000) COARSE SCALE COVER TYPE	JONES & STOKES (1993) FINE SCALE VEGETATION COVER TYPE	JONES & STOKES (1993) COARSE SCALE VEGETATION COVER TYPE	NDDB DATA BASE/HOLLAND TYPE
1) Aquatic Vegetation	Aquatic	N/A	Aquatic vegetation	Montane Freshwater Marsh (52340 in part)
2) Bitterbrush	Desert	Decadent bitterbrush scrub	Great Basin scrub	Great Basin Mixed Scrub (35100)
		Mature bitterbrush scrub		
		Establishing bitterbrush scrub		
3) Black cottonwood	Riparian	Decadent cottonwood-willow	Mature floodplain vegetation	Montane Black Cottonwood Forest (61530)
		Mature cottonwood-willow		
		Establishing cottonwood-willow		
4) Buffaloberry	Transistion	Decadent mixed riparian scrub	Mature floodplain vegetation	Great Basin Mixed Scrub (35100)
		Mature mixed riparian scrub		
		Establishing mixed riparian scrub		
5) Cattail	Aquatic	N/A	Aquatic vegetation	Montane Freshwater Marsh (52340 in part)
6) Ephedra	Desert	N/A	Great Basin scrub	Great Basin Mixed Scrub (35100)
7) Great Basin grassland	Riparian	Mixed riparian meadow	Wet meadow	Great Basin Grasslands (43000 in part)
		Pasture		
8) Jeffery pine	Riparian	Decadent conifer-broadleaf	Mature floodplain vegetation	Jeffery Pine Forest (85100)
		Mature conifer-broadleaf		
		Establishing conifer-broadleaf		
9) Lupine	Riparian	Sparsely vegetated floodplain	N/A	Great Basin Grasslands (43000 in part)
10) Mixed desert rose	Transition	Decadent mixed riparian scrub	Mature floodplain vegetation	Great Basin Mixed Scrub (35100)
		Mature mixed riparian scrub		
		Establishing mixed riparian scrub		
11) Mixed riparian rose	Transition	Decadent willow scrub	Mature floodplain vegetation	Southern Willow Scrub (63320 in part)
		Mature willow scrub		
		Establishing willow scrub		
12) Mixed willow	Riparian	Decadent willow scrub	Mature floodplain vegetation	Southern Willow Scrub (63320 in part)
		Mature willow scrub		
		Establishing willow scrub		
13) Mountain mahogany	Desert	Decadent mixed riparian scrub	N/A	Semi-Desert Chaparral (37400 in part)
		Mature mixed riparian scrub		
		Establishing mixed riparian scrub		
14) Narrowleaf willow	Riparian	Decadent willow scrub	Mature floodplain vegetation	Southern Willow Scrub (63320 in part)
		Mature willow scrub		
		Establishing willow scrub		
15) Quaking aspen	Riparian	Decadent aspen	Mature floodplain vegetation	Aspen Riparian Forest (61520)
		Mature aspen		
		Establishing aspen		
		Establishing rabbitbrush scrub		

Table 5. Summary of plant stands mapped in WY1999 and their relationship to plant stand types identified by previous research. (continued)

MCBAIN & TRUSH (2000) PLANT STAND TYPES (ADAPTED FROM SAWYER 1994)	MCBAIN & TRUSH (2000) COARSE SCALE COVER TYPE	JONES & STOKES (1998) FINE SCALE VEGETATION COVER TYPE	JONES & STOKES (1998) COARSE SCALE VEGETATION COVER TYPE	NDDB DATA BASE/HOLLAND TYPE
16) Rabbitbrush	Desert	Decadent rabbitbrush scrub	Great Basin scrub	Rabbitbrush Scrub (35400)
		Mature rabbitbrush scrub		
		Establishing rabbitbrush scrub		
17) Rose	Transistion	Decadent mixed riparian scrub	Mature floodplain vegetation	Southern Willow Scrub (63320 in part)
		Mature mixed riparian scrub		
		Establishing mixed riparian scrub		
18) Sagebrush	Desert	Decadent sagebrush scrub	Great Basin scrub	Big Sagebrush (35210)
		Mature sagebrush scrub		
		Establishing sagebrush scrub		
19) Sagebrush-Black cottonwood	Transition	Decadent sagebrush scrub	Great Basin scrub	Great Basin Mixed Scrub (35100)
		Mature sagebrush scrub		
		Establishing sagebrush scrub		
20) Sagebrush-Great Basin grassland	Transition	Decadent sagebrush scrub	Great Basin scrub	Great Basin Mixed Scrub (35100)
		Mature sagebrush scrub		
		Establishing sagebrush scrub		
21) Sagebrush-Rabbitbrush	Transition	Decadent sagebrush scrub	Great Basin scrub	Great Basin Mixed Scrub (35100)
		Mature sagebrush scrub		
		Establishing sagebrush scrub		
22) Shiny willow	Riparian	Decadent cottonwood-willow	Mature floodplain vegetation	Southern Willow Scrub (63320 in part)
		Mature cottonwood-willow		
		Establishing cottonwood-willow		
23) Wet meadow	Riparian	Wet meadow	Wet Meadow	Wet Montane Meadow (45110 in part)
24) Yellow willow	Riparian	Decadent willow scrub	Mature floodplain vegetation	Southern Willow Scrub (63320 in part)
		Mature willow scrub		
		Establishing willow scrub		

Table 6. Acres of riparian vegetation mapped between Lee Vining Creek valley toeslopes.

Stream Segment (Trihey 1994)	Riparian AcreageTermination End Points (Ridenhour et al 1995)	Riparian Acres Pre-1941 (Jones & Stokes 1993)	1989 Riparian Acres (Jones & Stokes 1993)	1999 Riparian Acres (McBain & Trush 2000)
1	20.0	20.3	19.8	-
2	30.0	29.9	24.3	-
3a	22.2	23.2	6.9	12.9
3b	32.9	34.7	7.5	23.2
3c	4.0	4.3	3.3	4.1
3d	n/a	0.0	8.6	15.0
Total	109.1	112.4	70.4	55.2

Stream Segment (Trihey 1994)	Acreage Change from 1941-1989	Acreage Change from 1989-1999	Acreage difference between 1999 and the termination criteria
1	n/a	-	-
2	n/a	-	-
3a	-16.3	6.0	-9.3
3b	-27.2	15.7	-9.7
3c	-1.0	0.8	0.1
3d	8.6	6.4	n/a
Total	-35.9	28.9	-18.9

Table 7. Acres of riparian vegetation mapped between Rush Creek valley toeslopes.

Stream Segment (Trihey 1993)	Riparian AcreageTermination End Points (Ridenhour et al 1995)	Riparian Acres Pre-1941 (Jones & Stokes 1993)	1989 Riparian Acres (Jones & Stokes 1993)	1999 Riparian Acres (McBain & Trush 2000)
1	6.2	7.4	1.7	-
2	5.0	8.1	5.9	10.3
3a	21.5	24.8	12.7	17.0
3b	2.9	1.5	0.1	2.1
3c	11.2	10.8	4.1	8.1
3d	10.0	22.1	4.0	4.7
4a	26.0	149.6	90.0	23.5
4b	80.0	*combined with 4a*	*combined with 4a*	67.1
4c	38.7	*combined with 4a*	*combined with 4a*	14.7
5a	37.8	37.8	11.0	19.6
Total	239.3	262.1	129.5	167.0

Stream Segment (Trihey 1993)	Acreage Change from 1941-1989	Acreage Change from 1989 1999	Acreage difference between 1999 and the termination criteria	Projected Year when Termination Criteria will be met (with passive restoration)
1	-5.7	-	-	n/a
2	-2.2	4.4	5.3	n/a
3a	-12.1	4.3	-4.5	2009
3b	-1.4	2.0	-0.8	2003
3c	-6.7	4.0	-3.1	2007
3d	-18.1	0.7	-5.3	2080
4a	-59.6	15.2	-2.5	2025
4b	*combined with 4a*	*combined with 4a*	-12.9	*combined with 4a*
4c	*combined with 4a*	*combined with 4a*	-24.0	*combined with 4a*
5a	-26.8	8.6	-18.2	2020
Total	-132.6	37.5	-72.3	

Table 8. Acres of riparian vegetation mapped within Walker Creek riparian corridor.

Stream Segment (CDFG 1992)	1999 Riparian Acres (McBain & Trush 1999)
1	1.2
2	2.8
3	0.8
4	1.6
5	1.3
6	0.6
7	0.9
8	1.5
9	0.7
10	4.6
11	6.1
12	10.5
13	7.3
14	3.6
15	3.4
Total	46.7

Table 9. Flood recurrence interval regressions (from Hasencamp 1994) and common recurrence interval discharges for Lee Vining and Rush creeks.

Gaging Station	Regression Equations From Hasencamp (1994)
Lee Vining above Intake + SCE Storage Change (1973-1994 unimpaired)	Discharge = 194.3 + 173.3 (ln (Recurrence Interval)) -or- Recurrence Interval = $e^{(Discharge-194.3)/173.3}$
Lee Vining above Intake (1973-1994 impaired)	Discharge = 131.5 + 140.0 (ln (Recurrence Interval)) -or- Recurrence Interval = $e^{(Discharge-131.5)/140.0}$
Rush Creek at Dam Site + SCE Storage Change (1941-1990 Unimpaired)	Discharge = 319.5 + 217.3 (ln (Recurrence Interval)) -or- Recurrence Interval = $e^{(Discharge-319.5)/217.3}$
Rush Creek at Dam Site (1941-1990 impaired)	Discharge = 101.1 + 157.3 (ln (Recurrence Interval)) -or- Recurrence Interval = $e^{(Discharge-101.1)/157.3}$
Rush Creek at Dam Site + SCE Storage Change (1973-1994 unimpaired)	Discharge = 291.1 + 264.7 (ln (Recurrence Interval)) -or- Recurrence Interval = $e^{(Discharge-291.1)/264.7}$
Rush Creek at Dam Site (1973-1994 impaired)	Discharge = 77.5 + 173.2 (ln (Recurrence Interval)) -or- Recurrence Interval = $e^{(Discharge-77.5)/173.2}$
Parker Creek above Conduit (1973-94 impaired)	Discharge = 194.3 + 173.3 (ln (Recurrence Interval)) -or- Recurrence Interval = $e^{(Discharge-194.3)/173.3}$
Walker Creek above Conduit (1973-1994 impaired)	Discharge = 19.2 + 18.7 (ln (Recurrence Interval)) -or- Recurrence Interval = $e^{(Discharge-19.2)/18.7}$

Gaging Station	1.5 Year Flood	2 Year Flood	5 Year Flood	10 year Flood	25 Year Flood	50 Year Flood
Lee Vining at Intake (1973-1994 unimpaired)	265 cfs	314 cfs	473 cfs	593 cfs	752 cfs	872 cfs
Lee Vining at Intake (1973-1994 impaired)	188 cfs	229 cfs	357 cfs	454 cfs	582 cfs	679 cfs
Rush Creek at Dam Site (1941-1990 Unimpaired)	408 cfs	470 cfs	669 cfs	820 cfs	1,019 cfs	1,170 cfs
Rush Creek at Dam Site (1941-1990 Impaired)	165 cfs	210 cfs	354 cfs	463 cfs	607 cfs	716 cfs
Rush Creek at Dam Site (1973-1994 unimpaired)	398 cfs	475 cfs	717 cfs	901 cfs	1,143 cfs	1,327 cfs
Rush Creek at Dam Site (1973-1994 impaired)	148 cfs	198 cfs	356 cfs	476 cfs	635 cfs	755 cfs
Parker Creek above Conduit (1973-94 impaired)	39 cfs	45 cfs	64 cfs	78 cfs	96 cfs	110 cfs
Walker Creek above Conduit (1973-1994 impaired)	27 cfs	32 cfs	49 cfs	62 cfs	79 cfs	92 cfs

Gaging Station	100 Year Flood	500 Year Flood	1000 Year Flood
Lee Vining at Intake (1973-1994 unimpaired)	992 cfs	1,271 cfs	1,391 cfs
Lee Vining at Intake (1973-1994 impaired)	776 cfs	1,002 cfs	1,099 cfs
Rush Creek at Dam Site (1941-1990 Unimpaired)	1,320 cfs	1,670 cfs	1,821 cfs
Rush Creek at Dam Site (1941-1990 Impaired)	825 cfs	1,079 cfs	1,188 cfs
Rush Creek at Dam Site (1973-1994 unimpaired)	1,510 cfs	1,936 cfs	2,120 cfs
Rush Creek at Dam Site (1973-1994 impaired)	875 cfs	1,154 cfs	1,274 cfs
Parker Creek above Conduit (1973-94 impaired)	124 cfs	156 cfs	170 cfs
Walker Creek above Conduit (1973-1994 impaired)	105 cfs	135 cfs	148 cfs

Table 10. Longitudinal thalweg profile residual analysis summary table.

Site	WY1997 Thalweg Residual Variance	WY1997 Thalweg Slope	WY1997 High Water Slope
Upper Lee Vining Creek Mainstem	0.9419	0.0311	0.0307
Upper Lee Vining Creek A4 Channel	0.3445	0.0230	0.0258
Upper Lee Vining Creek B1 Channel	0.0528	0.0247	0.0268
Lower Rush Creek	0.4551	0.0070	0.0064

Site	WY1998 Thalweg Residual Variance	WY1998 Thalweg Slope	WY1998 High Water Slope
Lower Lee Vining Creek Mainstem	0.2990	0.0261	N/A
Lower Lee Vining Creek B1 Channel	0.3687	0.0236	N/A
Upper Rush Creek	1.1031	0.0144	0.0143
Lower Rush Creek	0.6524	0.0077	0.0070

Site	WY1999 Thalweg Residual Variance	WY1999 Thalweg Slope	WY1999 High Water Slope
Upper Lee Vining Creek Mainstem	0.8021	0.0305	0.0303
Upper Lee Vining Creek A4 Channel	0.3810	0.0238	0.0245
Upper Lee Vining Creek B1 Channel	0.0974	0.0252	0.0229
Lower Lee Vining Creek Mainstem	0.2848	0.0260	0.0259
Lower Lee Vining Creek B1 Channel	0.4023	0.0224	0.0225
Upper Rush Creek	1.0679	0.0142	0.0144
Lower Rush Creek	0.4918	0.0077	0.0078
Rush Creek County Road	0.8242	0.0084	0.0081
Lower Rush Yellowbird	0.5659	N/A	N/A
Lower Rush 1a	0.4029	N/A	N/A

Thalweg slope and high water slope are for the total planmap reach and do not represent local cross section slopes.

Table 11. Summary of contemporary τ_b and restored τ_b.

τ_b SUMMARY					
Site	Contemporary $Q_{1.5}$ τ	Contemporary $Q_{1.5}$ Average Depth	Contemporary Overbank τ	Contemporary Overbank Average Depth	Contemporary Slope (S_o)
Lower Rush Creek Cross Section -05+07	0.44 lbs/sqft	1.06 ft	0.72 lbs/sqft	2.05 ft	0.0056
Lower Rush Creek Channel 14	N/A	N/A	N/A	N/A	0.0019
Lower Rush Creek 1A Channel	N/A	N/A	N/A	N/A	0.0110
Lower Rush Creek Yellow Bird Reach Cross Section 01+45	0.71 lbs/sqft	1.04 ft	1.22 lbs/sqft	1.78 ft	0.0110
Lower Rush Creek Cross Section 10+10	0.56 lbs/sqft	1.24 ft	0.65 lbs/sqft	1.44 ft	0.0072
Lower Rush Creek Cross Section 07+70	0.72 lbs/sqft	1.48 ft	0.83 lbs/sqft	1.70 ft	0.0078
Rush Creek County Rd Cross Section 06+85	0.54 lbs/sqft	1.11 ft	0.61 lbs/sqft	1.26 ft	0.0078
Rush Creek County Rd Cross Section 15+19	0.74 lbs/sqft	1.49 ft	2.17 lbs/sqft	4.34 ft	0.0080
Upper Rush Creek Cross Section 05+45	1.01 lbs/sqft	1.12 ft	2.32 lbs/sqft	2.56 ft	0.0145
Upper Rush Creek Cross Section 13+36	1.05 lbs/sqft	1.16 ft	2.32 lbs/sqft	2.56 ft	0.0145
Rush Creek County Rd Cross Section 08+30	0.69 lbs/sqft	1.38 ft	1.03 lbs/sqft	2.06 ft	0.0080
Upper Lee Vining Creek A4 Channel Cross Section 06+80	N/A	N/A	N/A	N/A	0.0245
Upper Lee Vining Creek Mainstem Cross Section 13+92	2.16 lbs/sqft	1.13 ft	3.35 lbs/sqft	2.45 ft	0.0307
Upper Lee Vining Creek Mainstem Cross Section 00+26	1.62 lbs/sqft	0.85 ft	4.11 lbs/sqft	3.25 ft	0.0305

Table 11. Summary of contemporary τ_b and restored τ_b (continued).

τ_b SUMMARY					
Site	Historic/Restored $Q_{1.5}$ τ	Historic/Restored $Q_{1.5}$ Average Depth	Historic/Restored Overbank τ	Historic/Restored Overbank Average Depth	Contemporary Slope (S_o)
Lower Rush Creek Cross Section -05+07	0.84 lbs/sqft	2.40 ft	1.36 lbs/sqft	3.90 ft	0.0056
Lower Rush Creek Channel 14	0.4 lbs/sqft	3.33 ft	0.46 lbs/sqft	3.89 ft	0.0019
Lower Rush Creek 1A Channel	1.46 lbs/sqft	2.12 ft	2.41 lbs/sqft	3.51 ft	0.0110
Lower Rush Creek Yellow Bird Reach Cross Section 01+45	1.36 lbs/sqft	1.98 ft	2.25 lbs/sqft	3.28 ft	0.0110
Lower Rush Creek Cross Section 10+10	0.78 lbs/sqft	1.74 ft	1.46 lbs/sqft	3.24 ft	0.0072
Lower Rush Creek Cross Section 07+70	0.91 lbs/sqft	1.87 ft	1.64 lbs/sqft	3.37 ft	0.0078
Rush Creek County Rd Cross Section 06+85	1.08 lbs/sqft	2.22 ft	1.81 lbs/sqft	3.72 ft	0.0078
Rush Creek County Rd Cross Section 15+19	1.14 lbs/sqft	2.29 ft	1.89 lbs/sqft	3.79 ft	0.0080
Upper Rush Creek Cross Section 05+45	1.52 lbs/sqft	1.68 ft	2.32 lbs/sqft	2.56 ft	0.0145
Upper Rush Creek Cross Section 13+36	1.86 lbs/sqft	2.06 ft	3.22 lbs/sqft	3.56 ft	0.0145
Rush Creek County Rd Cross Section 08+30	1.19 lbs/sqft	2.39 ft	1.94 lbs/sqft	3.89 ft	0.0080
Upper Lee Vining Creek A4 Channel Cross Section 06+80	2.66 lbs/sqft	1.74 ft	4.85 lbs/sqft	3.17 ft	0.0245
Upper Lee Vining Creek Mainstem Cross Section 13+92	3.35 lbs/sqft	1.75 ft	6.23 lbs/sqft	3.25 ft	0.0307
Upper Lee Vining Creek Mainstem Cross Section 00+26	4.11 lbs/sqft	2.16 ft	6.97 lbs/sqft	3.66 ft	0.0305

Table 12. Geomorphic units mapped in WY1999 within Lee Vining and Rush creek riparian corridors.

Geomorphic Unit Number	Geomorphic Unit Name	Common Plant Stands Associated with Geomorphic Units	Description
0	Stream Channel	aquatic/emergent	active channel
1	Point, Transverse, and Medial Bars	Lupine	These active deposits may be mobilized frequently mobilized (< 10 year events) by smaller floods, and abandoned by incision during higher floods (<10 year events)
2	Floodplain	Lupine, mixed willow	Deposition is widespread across these surfaces during smaller events occasional scour by large floods; active floodplains
3	Low Terrace	Black cottonwood, mixed willow, yellow willow, narrowleaf willow, rose, Great Basin grassland	Channel incision, sediment plugging, and migration during 1995-97 floods scoured and abandoned these surfaces
4	Middle Terrace	Black cottonwood, narrowleaf willow, bitterbrush, rabbitbrush	Channel incision, sediment plugging, and migration during 1967-69 floods scoured and abandoned these surfaces
5	High Terrace, Pre 1941 Floodplain	Black cottonwood, mixed willow, yellow willow, narrowleaf willow, rose, buffalo berry, sage, bitterbrush	Active depositional surfaces prior to streamflow diversion
6	Pre-1941 Low Terrace	Sagebrush, bitterbrush, mixed willow	Cause for incision and abandonment unknown, presumed to be lake lowering related, potentially a floodplain prior to the end of the little Ice Age in 1850. Remnant willow stands indicate its hydrologic connectivity to streamflow prior to diversion
7	Pre-1941 Middle Terrace	Sagebrush, bitterbrush	Cause for incision and abandonment unknown, presumed to be climatically related
8	Pre-1941 High Terrace/ Climatic Low Terrace	Sagebrush, bitterbrush	Cause for incision and abandonment unknown, presumed to be climatically related
9	Climatic Middle Terrace	Sagebrush, bitterbrush	Cause for incision and abandonment unknown, presumed to be climatically related
10	Climatic High Terrace	Sagebrush, bitterbrush	Cause for incision and abandonment unknown, presumed to be climatically related
11	Tioga Age Glacial Till	Sagebrush, bitterbrush	Stream incision through these deposits occurred following the recession of Glaciers at the end of the last Ice Age
18	Cut Bank	open	Cut banks are result of channel migration and was mapped in association with geomorphic units 2-9
19	Human Disturbance	open	These sufaces are found throughout riparian corridors and are typicaly associated with parking areas and mining activites
21	Arroyo	Bitterbrush	Seasonal flow through these channels

Table 13. Summary of termination criteria and WY1999 measurements.

Rush Creek Main Channel Length			
Reach	Original Termination Criteria	Proposed Termination Criteria	WY1999
1	4,100 ft	N/A	N/A
2	4,820 ft	4,820 ft	4,813 ft
3A	3,800 ft	3,850 ft	3,850 ft
3B	3,100 ft	2,800 ft	2,494 ft
3C	6,940 ft	7,000 ft	7,000 ft
3D	3,370 ft	3,150 ft	2,888 ft
4A	3,070 ft	2,980 ft	2,756 ft
4B	7,810 ft	7,810 ft	6,825 ft
4C	4,360 ft	4,360 ft	4,069 ft
5A	7,320 ft	6,130 ft	5,206 ft

Rush Creek Main Channel Sinuosity			
Reach	Original Termination Criteria	Proposed Termination Criteria	WY1999
1	1.00	N/A	N/A
2	1.04	1.06	1.06
3A	1.06	1.08	1.08
3B	1.19	1.18	1.05
3C	1.07	1.07	1.07
3D	1.04	1.13	1.02
4A	1.19	1.20	1.11
4B	1.23	1.34	1.17
4C	2.11	N/A	1.33
5A	1.39	1.35	1.13

Rush Creek Main Channel Gradient			
Reach	Original Termination Criteria	Proposed Termination Criteria	WY1999*
1	?	N/A	N/A
2	0.0240	N/A	N/A
3A	0.0160	N/A	0.0142
3B	0.0140	N/A	N/A
3C	0.0230	N/A	N/A
3D	0.0220	N/A	N/A
4A	0.0140	N/A	N/A
4B	0.0100	N/A	0.0077
4C	0.0050	N/A	N/A
5A	<0.007	N/A	0.0084

Lee Vining Creek Main Channel Length			
Reach	Original Termination Criteria	Proposed Termination Criteria	WY1999
1	4,500 ft	N/A	N/A
2	7,400 ft	N/A	N/A
3A	3,500 ft	4,100 ft	3,894 ft
3B	4,200 ft	3,650 ft	3,185 ft
3C	1,360 ft	1,230 ft	1,015 ft

Lee Vining Creek Main Channel Sinuosity			
Reach	Original Termination Criteria	Proposed Termination Criteria	WY1999
1	1.42	N/A	N/A
2[1]	1.38	N/A	N/A
2[2]	1.16	1.16	1.08
3A	1.33	1.06	1.01
3B	1.15	1.20	1.05
3C	1.20	1.27	1.05

[1] = Reach 2 above Highway 395

[2] = Reach 2 below Highway 395

Lee Vining Creek Main Channel Gradient			
Reach	Original Termination Criteria	Proposed Termination Criteria	WY1999*
1	0.0110	N/A	N/A
2	0.0620	N/A	N/A
3A	0.0370	N/A	0.0305
3B	0.0250	N/A	0.026
3C	0.0210	N/A	N/A

*= Gradient calcuated from thalweg profiles in planmap reaches

APPENDIX A:

HYDROLOGY

DISCHARGE SUMMARY SHEET

LOCATION: Lee Vining Creek Main Channel near Lee Vining **STATION NUMBER:** **WATER YEAR:** 1998-2000

Measurement Number	Date	Made By	Meter Type	Meter Number	Width (feet)	Mean Depth (feet)	Area (ft²)	Mean Velocity (ft/sec)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Slope	Computed "n" value	Begin Gage Height (feet)	End Gage Height	Gage Ht change (feet)	Discharge (cfs)	Rating 1 Shift Adj.	Rating 1 Percent Diff	Method	No. of Msmt sections	Begin Time (hours)	End Time (hours)	Msmt Rating	Max % Q in any vertical	Water Temp (°C)	Air Temp (°C)	Crest Gage	Recorder level	Notes
9701	8/17/97	Worsley, Smith??	float	n/a	12.15	1.85	22.58	2.73			0.031		n/a	n/a	n/a	60.5			time-float	3									Time-float estimate
9801	06/05/98	Mierau, Merrill	AA	595	13.2	1.78	23.46	3.22	15.91	1.47	0.031	0.1055	n/a	n/a	n/a	75.53			0.6	20	11:50	12:20	fair	9.72%	n/a	n/a	n/a	n/a	unmonumented cross section
9802	06/18/98	McBain, Hopkins	AA	595	48	0.92	42.35	3.81	47.62	0.89	0.028	0.0605	n/a	n/a	n/a	161.37			0.6	26			fair	7.03%	n/a	n/a	n/a	n/a	
9803	07/02/98	Merrill, Bair	float													465			time-float				poor						Poor time-float msmt, see separate sheet
9804	07/17/98	Merrill, Bair	float													389			time-float				fair						Fair time-float msmt, see separate sheet
9805	09/11/98	McBain, Mierau	AA	595	35.5	0.91	32.25	1.73	36.82	0.88	0.031	0.1392	n/a	n/a	n/a	55.63			0.6	26	12:00	12:30	fair	6.37%	n/a	n/a	n/a	n/a	
9901	5/6/99	Mierau, Stecker	AA	595	32.6	0.65	21.15	1.19	37.00	0.57	0.031	0.1519	n/a	n/a	n/a	25.18			0.6	21	1600	1630	good	10.44%	52	n/a	n/a	n/a	
9902	6/4/99	Reis (MLC), Bair	AA	595	48	0.86	39.35	3.60	46.63	0.84	0.028	0.0618	n/a	n/a	n/a	141.84			0.6	22	n/a	n/a	good	9.01%	n/a	n/a	n/a	n/a	measurement taken at cross section 03+45
9903	7/26/99	Mierau, Worsley	MM	USFWS	34	0.83	28.17	1.72	34.46	0.82	0.031	0.1334	n/a	n/a	n/a	48.43			0.6	22	10:50	11:20	fair	8.07%	n/a	n/a	n/a	n/a	
0001	10/6/99	McBain, Bair	AA	595	22.6	0.92	20.71	0.90	22.54	0.92	0.031	0.274	n/a	n/a	n/a	18.74			0.6	23	n/a	n/a		7.58%	n/a	n/a	n/a	n/a	

DISCHARGE SUMMARY SHEET

LOCATION: Lee Vining Creek B Connector Channel near Lee Vining **STATION NUMBER:** **WATER YEAR** 1998-2000

Measurement Number	Date	Made By	Meter Type	Meter Number	Width (feet)	Mean Depth (feet)	Area (ft²)	Mean Velocity (ft/sec)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Slope	Computed "n" value	Begin Gage Height (feet)	End Gage Height	Gage Ht change (feet)	Discharge (cfs)	Rating 1 Shift Adj	Rating 1 Percent Diff	Method	No. of Msmt sections	Begin Time (hours)	End Time (hours)	Msmt Rating	Max % Q in any vertical	Water Temp (°C)	Air Temp (°C)	Crest Gage	Recorder level	Notes
9701		Worsley, Smith??	float													22.9			time-float										
9801	06/05/98	Mierau, Merrill	AA	595	11.6	0.57	6.56	2.41	12.27	0.534			n/a	n/a	n/a	15.8			0.6	21	12:28	12:55	fair	10.51%	n/a	n/a	n/a	n/a	unreferenced section
9802	06/18/98	McBain, Hopkins	AA	595'	13.5	0.58	7.78	3.55	13.90	0.559			n/a	n/a	n/a	27.6			0.6	24	n/a	n/a	fair/goo	9.65%	n/a	n/a	n/a	n/a	unreferenced section
9803	07/02/98	Merrill, Bair	float										n/a	n/a	n/a	25			time-float	n/a	n/a	n/a	poor	n/a	n/a	n/a	n/a	n/a	unreferenced section, time float poor msmt, see float sheet
9804	07/16/98	Merrill, Bair	float										n/a	n/a	n/a	21			time-float	n/a	n/a	n/a	fair	n/a	n/a	n/a	n/a	n/a	fair time-float msmt.
9805	09/11/98	McBain, Mierau	AA	595	12.8	0.40	5.16	2.32	13.15	0.392			0.67	0.7	0.03	11.99			0.6	18	10:00	10:30	fair	11.17%	n/a	n/a	n/a	n/a	unreferenced section
9901	6/6/99	Mierau, Stecker	AA	595	12.6	0.41	5.17	1.46	11.69	0.442			0.61	0.61	0	7.52			0.6	19	1530	1600	fair	11.76%	52	62	n/a	n/a	unreferenced section
9902	6/3/99	Reis (MLC), Bair	AA	595	18.7	0.41	7.65	2.21	19.11	0.400			0.71	0.71	0	16.92			0.6	31	n/a	n/a	fair/goo	7.82%	n/a	n/a	n/a	n/a	unreferenced section
9903	7/26/99	Mierau, Worsley	MM	USFWS	12.9	0.45	5.84	2.13	13.36	0.437			0.67	0.68	n/a	12.45			0.6	26	n/a	n/a	fair	11.84%	n/a	n/a	n/a	n/a	unreferenced section
0001	10/8/99	McBain, Bair	AA	595	12.4	0.34	4.25	1.27	11.93	0.356			n/a	n/a	n/a	5.41			0.6	17	n/a	n/a		13.76%	n/a	n/a	n/a	n/a	unreferenced section

DISCHARGE SUMMARY SHEET

LOCATION: Lee Vining Creek A4 Channel near Lee Vining **STATION NUMBER:** **WATER YEAR**1998-2000

Measurement Number	Date	Made By	Meter Type	Meter Number	Width (feet)	Mean Depth (feet)	Area (ft²)	Mean Velocity (ft/sec)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Slope	Computed "n" value	Begin Gage Height (feet)	End Gage Height	Gage Ht change (feet)	Discharge (cfs)	Rating 1 Shift Adj	Rating 1 Percent Diff	Method	No. of Msmt sections	Begin Time (hours)	End Time (hours)	Msmt Rating	Max % Q in any vertical	Water Temp (°C)	Air Temp (°C)	Crest Gage	Recorder level	Notes
9901	6/3/99	Bair, Reis (MLC)	AA	595	15	1.15	17.20	3.43	16.73	1.028	0.017	0.0576	n/a	n/a	n/a	59.07			0.6	24	n/a	n/a	fair	7.58%	n/a	n/a	n/a	n/a	cross section 6+80
0001	10/8/99	McBain, Bair	AA	595	12.8	0.57	7.26	0.95	13.21	0.549	0.24	0.5157	0.71	0.71	0	6.89			0.6	20	n/a	n/a	fair/goo	12.91%	n/a	n/a	n/a	n/a	unreferenced section

DISCHARGE SUMMARY SHEET

LOCATION: Lee Vining Creek B1 Channel near Lee Vining **STATION NUMBER:** **WATER YEAR**1998-2000

Measurement Number	Date	Made By	Meter Type	Meter Number	Width (feet)	Mean Depth (feet)	Area (ft^2)	Mean Velocity (ft/sec)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Slope	Computed "n" value	Begin Gage Height (feet)	End Gage Height	Gage Ht. change (feet)	Discharge (cfs)
9801	6/5/98	Mierau, Merrill	AA	595	14.3	1.10	15.66	3.23	15.84	0.9885	0.023	0.06949	n/a	n/a	n/a	50.53
9802	6/18/98	H. Hopkins S. McBain	AA	595	14.8	1.70	25.14	5.03	16.60	1.5145	0.022	0.05794	n/a	n/a	n/a	126.5
9803	7/2/98	Merrill, Bair	float										n/a	n/a	n/a	156
9804	7/17/98	Merrill, Bair	float										n/a	n/a	n/a	146
9805	9/11/98	McBain, Mierau	AA	595	11.5	1.24	14.27	2.69	12.90	1.106	0.024	0.09171	1.01	1.01	0	38.41
9901	6/8/99	Mierau, Stacker	AA	595	7.5	1.48	11.13	1.29	7.77	1.432	0.025	0.23213	n/a	n/a	n/a	14.34
9902	7/27/99	Mierau, Worsley	MM	USFWS	10.3	0.83	8.60	3.35	12.04	0.714	0.025	0.05824	0.4	n/a	n/a	28.76

Measurement Number	Rating 1 Shift Adj.	Rating 1 Percent Diff	Method	No. of Msmt sections	Begin Time (hours)	End Time (hours)	Msmt Rating	Max % Q in any vertical	Water Temp (°C)	Air Temp (°C)	Crest Gage	Recorder level	Notes
9801			0.6	20	13:00	13:30	fair	10.94%	n/a	n/a	n/a	n/a	Unreferenced cross section
9802			0.6	29	n/a	n/a	good	6.32%	n/a	70	n/a	n/a	Unreferenced cross section
9803			time-float	n/a	n/a	n/a	poor	n/a	n/a	n/a	n/a	n/a	Poor time-float msmt. See separate sheet
9804			time-float	n/a	n/a	n/a	fair	n/a	n/a	n/a	n/a	n/a	fair time-float msmt. See separate sheet
9805													
9901			0.6	13	1500	15:30	good	14.66%	52	n/a	n/a	n/a	
9902			0.6	18	13:30			9.01%	n/a	n/a	n/a	n/a	

DISCHARGE SUMMARY SHEET

LOCATION: Rush Creek Main Channel in Lower Planmap Site near Lee Vining **STATION NUMBER:** **WATER YEAR:** 1998

Measurement Number	Date	Made By	Meter Type	Meter Number	Width (feet)	Mean Depth (feet)	Area (ft²)	Mean Velocity (ft/sec)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Slope	Computed "n" value	Begin Gage Height (feet)	End Gage Height	Gage Ht. change (feet)	Discharge (cfs)	Rating 1 Shift Adj	Rating 1 Percent Diff	Method	No. of Measmt sections	Begin Time (hours)	End Time (hours)	Measmt Rating	Max % Q in any vertical	Water Temp (°C)	Air Temp (°C)	Crest Gage	Recorder level	Notes
9801	6/4/98	Merrill, Mierau	AA	595	15.5	0.92	14.26	2.55	16.01	0.89			n/a	n/a	n/a	36.40			0.6	14	15:24	15:45	fair	15.35%	n/a	n/a	n/a	n/a	unreferenced cross section above the 10 channel connector
9802	7/3/98	Merrill, Bair	AA	595	19.7	1.48	29.09	4.32	19.45	1.50	0.0053	0.033	n/a	n/a	n/a	125.56			0.6	21	n/a	n/a	fair	11.41%	n/a	n/a	n/a	n/a	unreferenced cross section above the 10 channel connector
9901	7/27/99	Mierau, Worsley	MM	USFW	37.8	0.79	29.74	2.41	38.05	0.78			n/a	n/a	n/a	71.72			0.6	19	17:13	17:32	good	10.64%	15.5	26.7	n/a	n/a	Cross section 10+10 below the 10 channel connector

DISCHARGE SUMMARY SHEET

LOCATION: Rush Creek Main Channel below Lower Planmap Site near Lee Vining **STATION NUMBER:** **WATER YEAR:** 1998

Measurement Number	Date	Made By	Meter Type	Meter Number	Width (feet)	Mean Depth (feet)	Area (ft²)	Mean Velocity (ft/sec)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Slope	Computed "n" value	Begin Gage Height (feet)	End Gage Height	Gage Ht. change (feet)	Discharge (cfs)	Rating 1 Shift Adj.	Rating 1 Percent Diff	Method	No. of Meas. sections	Begin Time (hours)	End Time (hours)	Meas. Rating	Max % Q in any vertical	Water Temp (°C)	Air Temp (°C)	Crest Gage	Recorder level	Notes
9701	10/10/97	Bair, Smith	float													33.2			time-float										unreferenced section
9801	9/13/98	Merau, McBain	AA	595	33.4	1.31	43.71	3.10	34.73	1.26			n/a	n/a	n/a	135.44			0.6	35	930	1000	good	6.13%	n/a	n/a	n/a	n/a	unreferenced section
9901	6/6/99	Merau, Stecker	AA	595	26.2	1.11	29.02	1.79	25.15	1.15			n/a	n/a	n/a	52.06			0.6	17	1700	1730	excellen	9.56%	n/a	n/a	n/a	n/a	upstream of XS-9+82
9902	6/4/99	Bair	AA	595	31.8	0.96	30.40	2.46	31.41	0.97			n/a	n/a	n/a	74.66			0.6	28	13:50	15:15	good	7.06%	n/a	n/a	n/a	n/a	XS-09+82
9903	7/27/99	Merau, Worsley	MM	USFW	27.5	1.39	38.23	2.72	28.91	1.32			n/a	n/a	n/a	103.84			0.6	27	17:13	17:32	good	4.85%	15.5	26.7	n/a	n/a	~90ft upstream from xs -09+82
0001	10/7/99	Mc Bain, Bair	AA	595	24.8	1.42	35.32	1.51	53.17	0.66			n/a	n/a	n/a	53.19			0.6	33	n/a	n/a		4.22%	n/a	n/a	n/a	n/a	

DISCHARGE SUMMARY SHEET

LOCATION: Rush Creek 10 Channel near Lee Vining **STATION NUMBER:** **WATER YEAR:** 1998-2000

Measurement Number	Date	Made By	Meter Type	Meter Number	Width (feet)	Mean Depth (feet)	Area (ft²)	Mean Velocity (ft/sec)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Slope	Computed "n" value	Begin Gage Height (feet)	End Gage Height	Gage Ht change (feet)	Discharge (cfs)	Rating 1 Shift Adj.	Rating 1 Percent Diff	Method	No. of Meas't sections	Begin Time (hours)	End Time (hours)	Meas't Rating	Max % Q in any vertical	Water Temp (°C)	Air Temp (°C)	Crest Gage	Recorder level	Notes
9701	10/10/97	Worsley, Smith??	float													23.1			time-float										
9801	6/4/98	Mierau, Merrill	AA	595	17.1	0.66	11.26	2.06	17.29	0.65			n/a	n/a	n/a	23.2			0.6	16	16:20	16:38	fair/good	12.14%	n/a	n/a	n/a	n/a	unreferenced section
9802	7/3/98	Merrill, Bair	AA	595	36.6	0.91	33.33	3.81	37.66	0.89			n/a	n/a	n/a	126.95			0.6	23			fair/good	9.02%	n/a	n/a	n/a	n/a	unreferenced section
9803	9/13/98	Mierau, McBain	AA	595	18.1	1.00	18.09	1.95	18.53	0.98			n/a	n/a	n/a	35.22			0.6	23	17:30	18:10	excellent	7.13%	n/a	n/a	n/a	n/a	unreferenced section
9901	6/6/99	Mierau, Stacker	AA	595	12.5	0.47	5.85	1.78	11.53	0.51			n/a	n/a	n/a	10.42			0.6	15	1730	1820	good	11.26%	n/a	n/a	n/a	n/a	unreferenced section
9902	6/4/99	Bair	AA	595	19.5	0.54	10.51	1.68	19.71	0.53			n/a	n/a	n/a	17.67			0.6	28	11:15	12:30	ood/excelle	5.12%	n/a	n/a	n/a	n/a	unreferenced section
9903 (a)	7/27/99	Mierau, Worsley	MM	USFWS	20.4	1.06	21.60	1.91	20.78	1.04			n/a	n/a	n/a	41.35			0.6	19	n/a	14:40	good	9.21%	15.5	26.7	n/a	n/a	
9903 (b)	7/27/99	Mierau, Worsley	AA	595	20.4	1.01	20.69	1.90	20.74	1.00			n/a	n/a	n/a	39.31			0.6	19	14:40	15:10	good	8.87%	15.5	26.7	n/a	n/a	
0001	10/7/99	Mc Bain, Bair	AA	595	12.2	0.98	11.93	1.73	18.00	0.66			n/a	n/a	n/a	20.66			0.6	24	n/a	n/a	fair	11.49%	n/a	n/a	n/a	n/a	

DISCHARGE SUMMARY SHEET

LOCATION: Rush Creek 10 Connector Channel near Lee Vining **STATION NUMBER:** **WATER YEAR:** 1998

Measurement Number	Date	Made By	Meter Type	Meter Number	Width (feet)	Mean Depth (feet)	Area (ft²)	Mean Velocity (ft/sec)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Slope	Computed "n" value	Begin Gage Height (feet)	End Gage Height	Gage Ht. change (feet)	Discharge (cfs)	Rating 1		Method	No. of Meas'd sections	Begin Time (hours)	End Time (hours)	Meas'd Rating	Max % Q in any vertical	Water Temp (°C)	Air Temp (°C)	Crest Gage	Recorder level	Notes
																	Shift Adj	Percent Diff											
9701		Worsley, Smith??	float													5.96			time-float										
9801	6/4/98	Mierau, Merrill	AA	595	8.2	0.57	4.68	1.22	8.54	0.5483			n/a	n/a	n/a	5.73			0.6	12	15:50	16:15		13.90%	n/a	n/a	n/a	n/a	unreferenced section
9802	7/3/98	Merrill, Bair	AA	595	12.4	1.39	17.24	4.21	13.73	1.2554			n/a	n/a	n/a	72.61			0.6	19				7.70%	n/a	n/a	n/a	n/a	unreferenced section
0001	10/7/99	McBain, Bair	AA	595	15	0.54	8.14	1.84	15.31	0.5317			n/a	n/a	n/a	14.95			0.6	23				5.99%	n/a	n/a	n/a	n/a	unreferenced section

Placeholder for Peter K. (LADWP)
WY1999 Operations Reports

APPENDIX B:

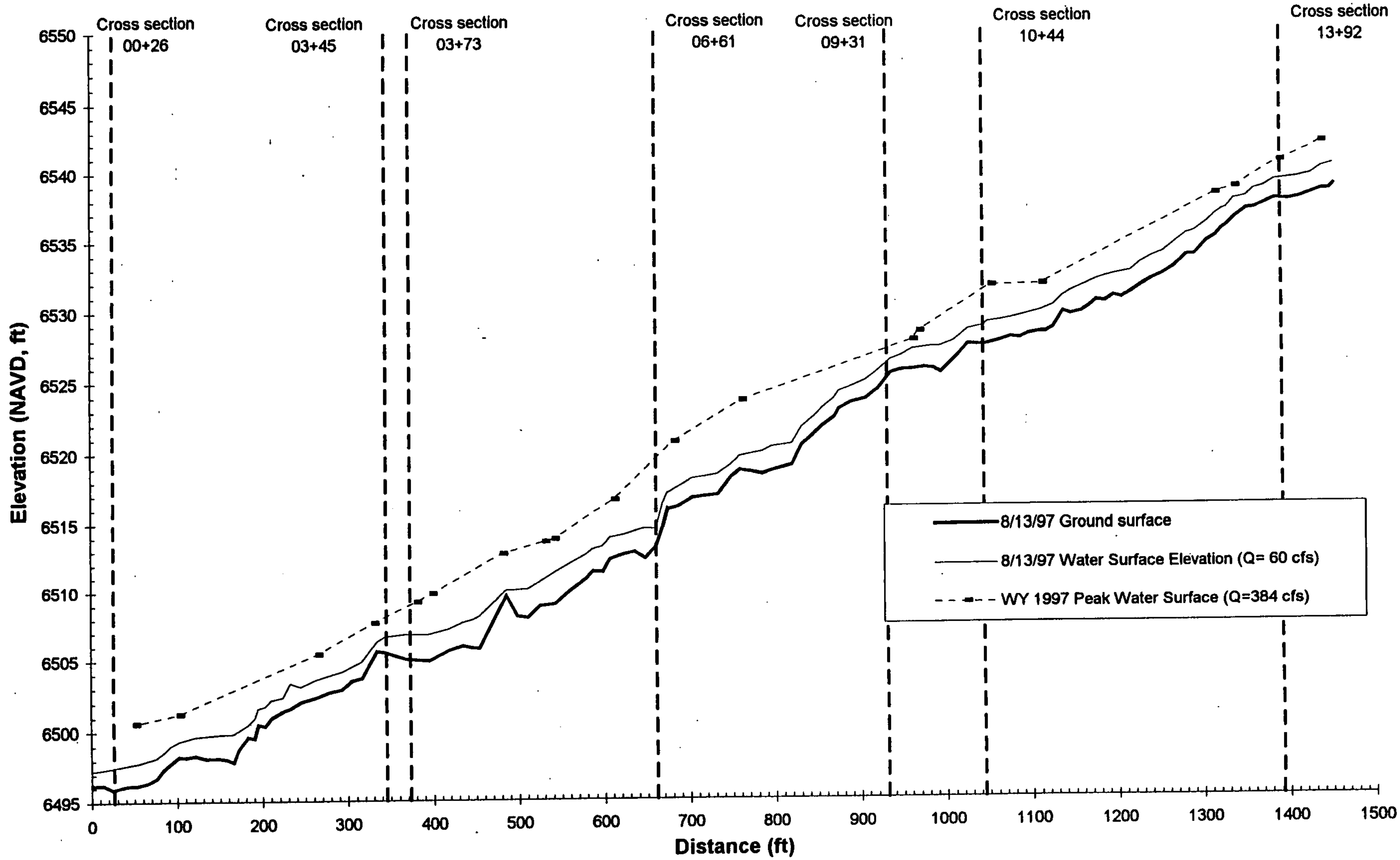
CROSS SECTIONS
AND
LONGITUDINAL THALWEG PROFILES

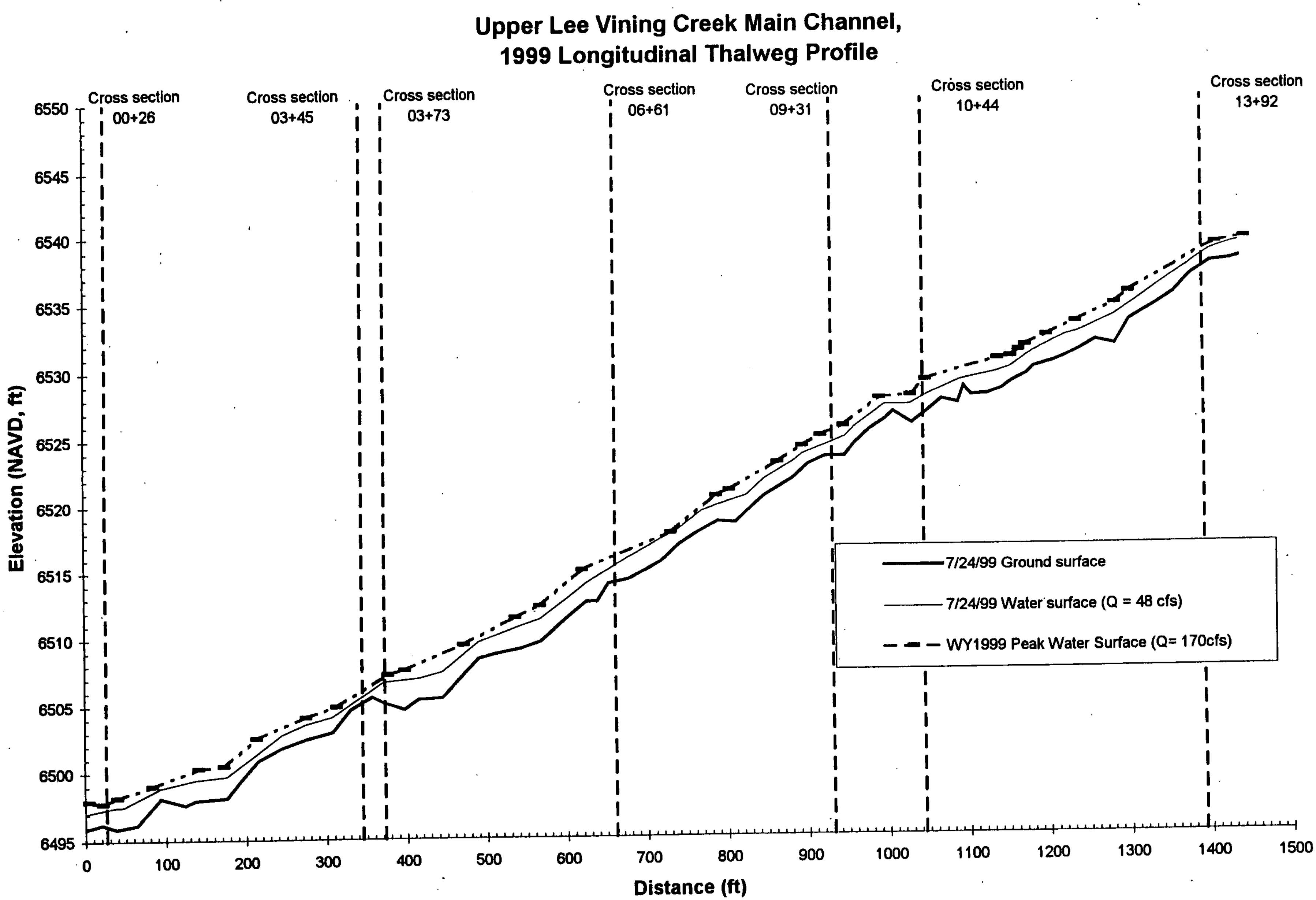
Lee Vining Creek Cross Section and Reference Pin Summary Sheet

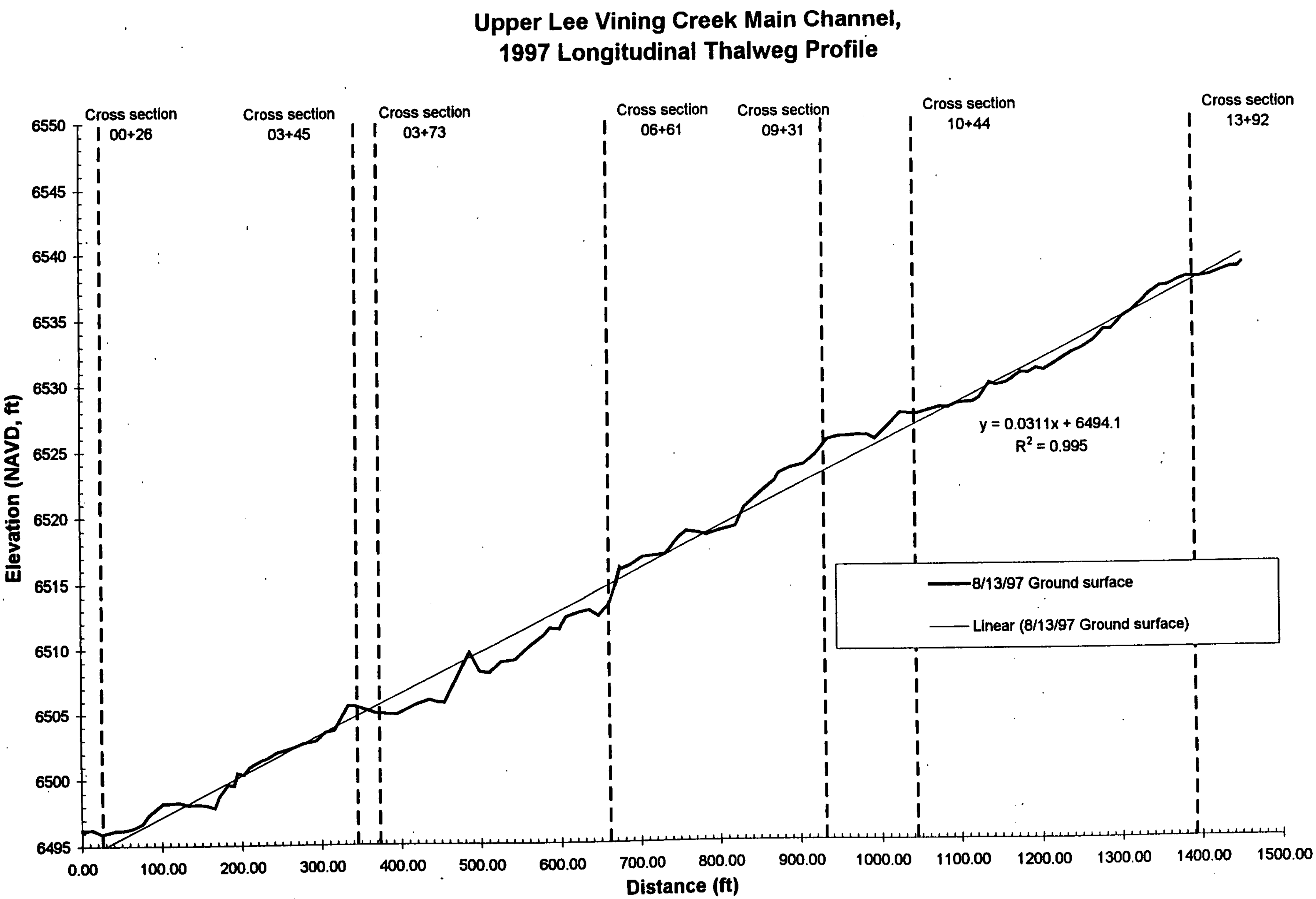
Note: links are updated as of 10/21/99

Site	Cross Section Label	Old Cross Section Label	Upper Left Bank Pin Elev. (ft)	Lower Left Bank Pin Elev. (ft)	Lower Right Bank Pin Elev. (ft)	Upper Right Bank Pin Elev. (ft)	Total Cross Section Length (ft)	Angle from LB pin to RB pin Degree	Cross Section Intersection with Long Profile (ft)	Long Profile Intersection with Cross Section (ft)	Fieldbook # and Page #'s	Notes
	BM1		6503.26									SITE BENCHMARK
Upper Main	00+26	00+25.6	6500.68	6499.01	none	6503.79	141.20	N/A	101.80	25.6	Fieldbook 2, page 4-15	
	03+45	03+35	6513.78	none	none	6511.08	105.40	123°	~75.00	344.6	Fieldbook 1, page 110-115	
	03+73	03+60	6511.41	none	none	6511.52	112.50	125°	~75.00	372.7	Fieldbook 1, page 116-119	
	06+61	06+61	N/A	6519.05	none	6520.19	79.80	111°	~36.9	661.4	Fieldbook 2, page 46	This cross section had an upper
	09+31	09+34	6530.00	none	none	6528.44	178.50	80°	~117.4	931.1	Fieldbook 1, page 122-129	
	10+44	12+62	6534.25	6530.15	6530.59	6534.68	233.30	87°	94.90	1044.3	Fieldbook 2, page 26	
	13+92	14+16	6543.03	none	none	6541.14	84.60	141°	44.80	1392	Fieldbook 2, page 16-25	
Upper A4	06+80	06+80	6514.70	none	none	6517.40	36.40	134°	22.00	679.6	Fieldbook 1, page 46-49	
	05+15	05+23	6511.96	6509.53	none	6511.60	83.30	57°	49.70	~515.3	Fieldbook 1, page 50-51; 56-57	
	04+04	04+02	6509.52	none	none	6509.52	70.70	151°	40.10	404.4	Fieldbook 1, page 68-71	
	03+75	TR1867	6507.90	none	none	6506.79	38.60	151°	17.20	374.6	Fieldbook 1, page 60-61	
	03+29	TR1912.5	6506.29	none	none	6505.36	58.00	138°	19.50	328.7	Fieldbook 1, page 62-65	
Upper B1	06+08	06+08	6493.78	none	none	6489.57	40.90	115°			Fieldbook 1, page 74-77	
Lower Main	01+15	XS-A	6462.55	none	none	6460.29	41.80	97°			Fieldbook 4, page 98	
	3+57	B Chevron	6466.66	6466.65	(Mid-channel)	6466.76	0.00	79°/123°			Fieldbook 8, page 40	
Lower B1	1+80	Y	6460.28			6461.25	0.00	156°			Fieldbook 8, page 38	
	0+87	Z	6458.46			6460.77	0.00	98°			Fieldbook 8, page 34	

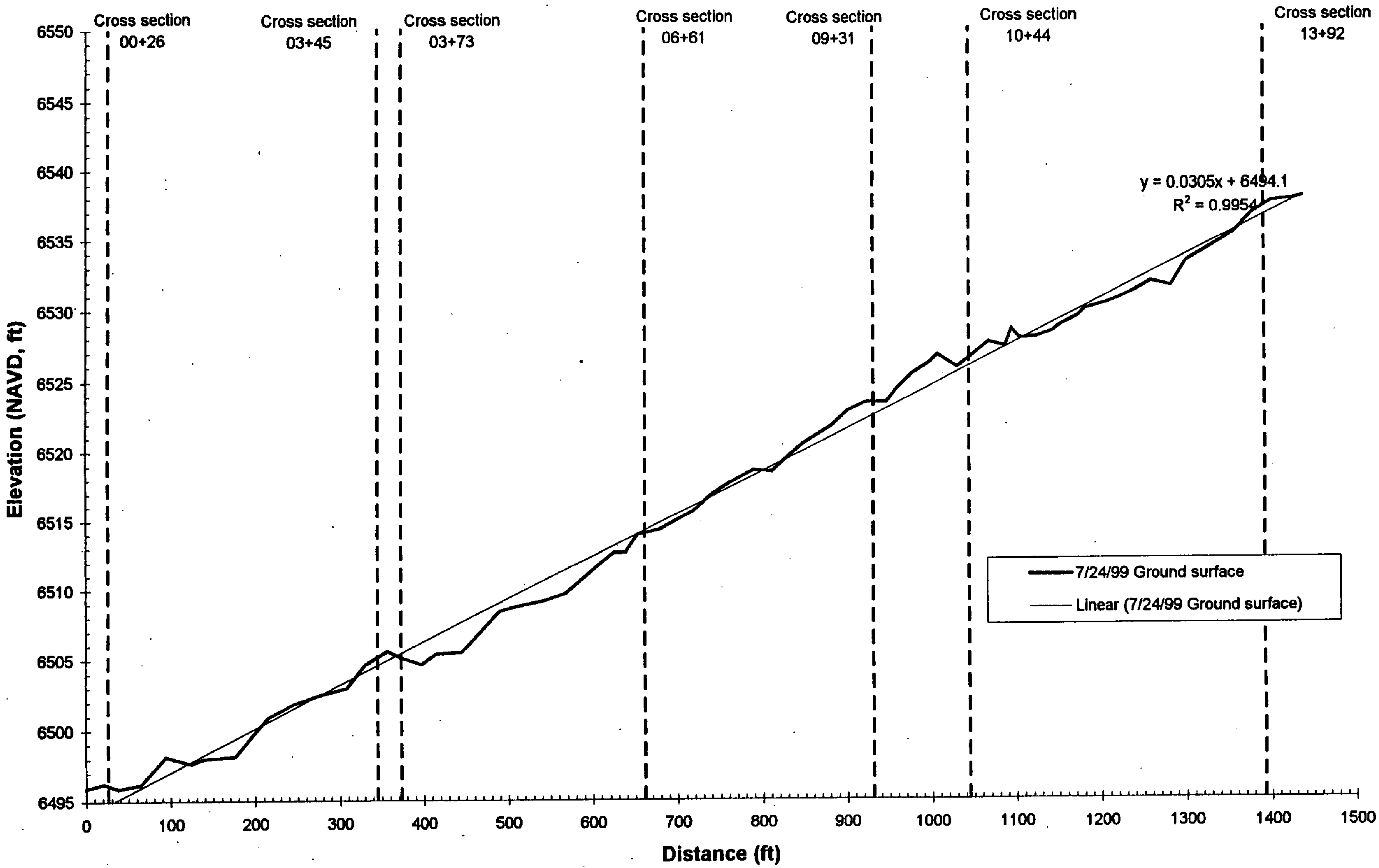
Upper Lee Vining Creek Main Channel, 1997 Longitudinal Thalweg Profile

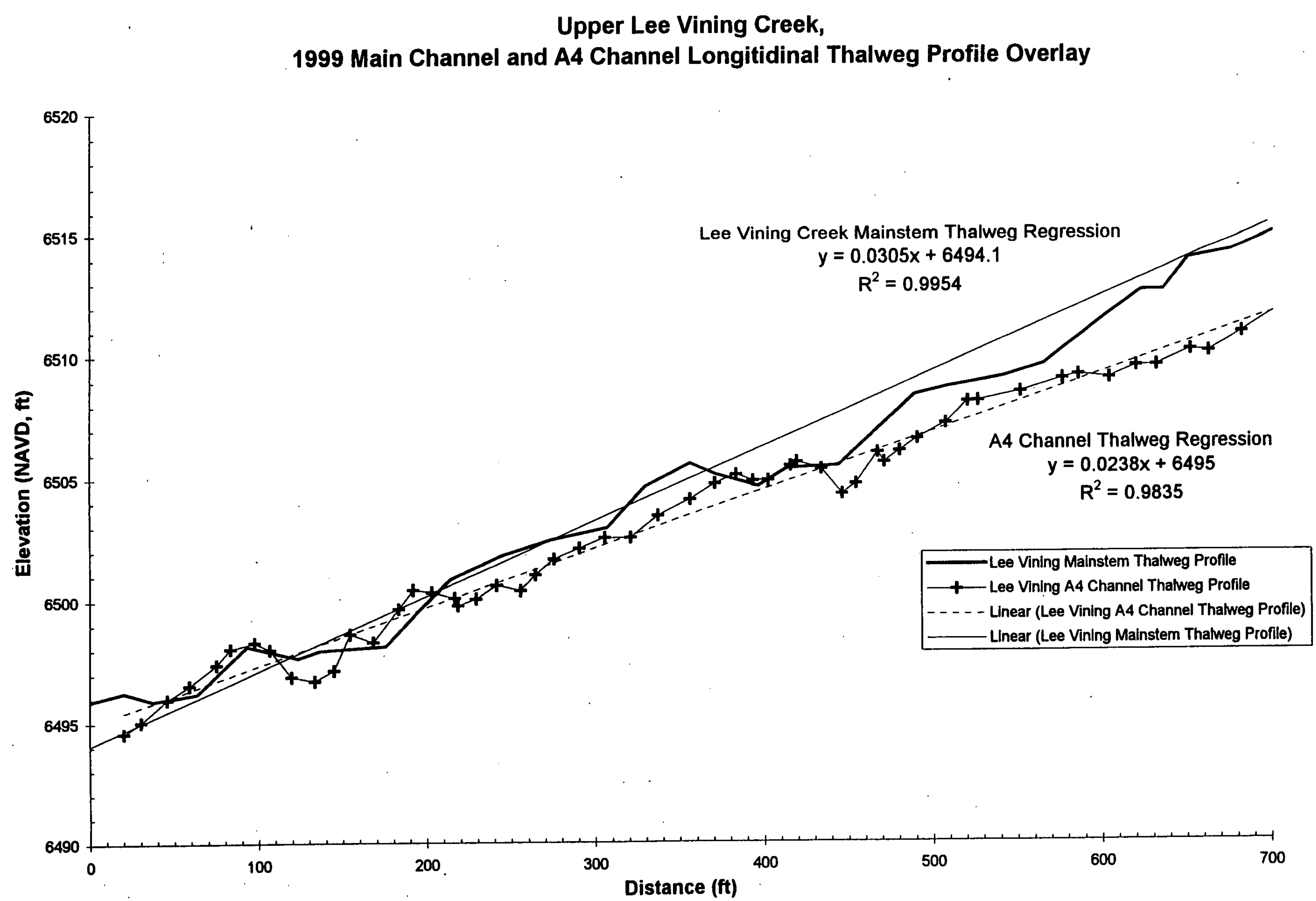


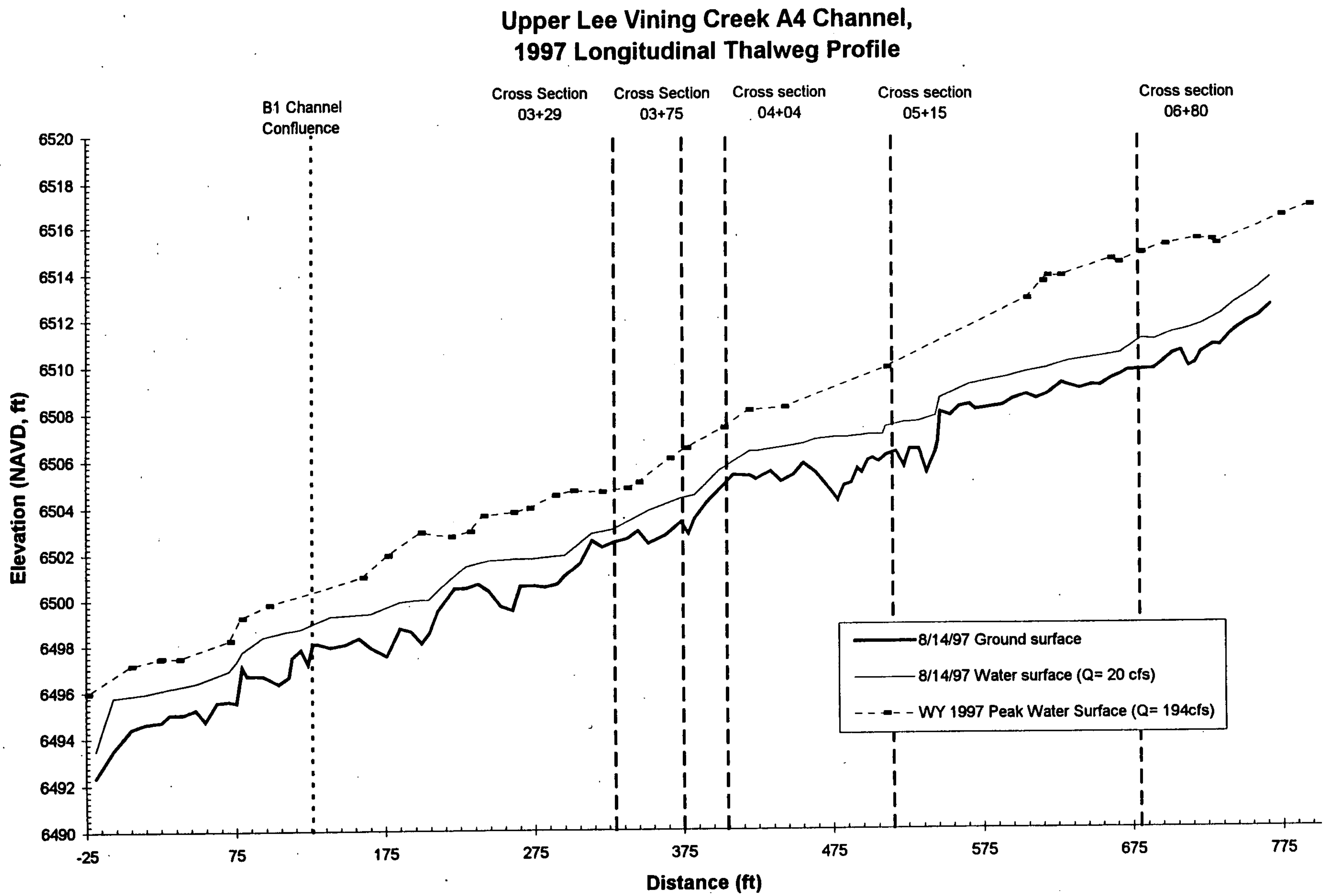

Upper Lee Vining Creek Main Channel,
1999 Longitudinal Thalweg Profile
Cross section 00+26
Cross section 03+45
Cross section 03+73
Cross section 06+61
Cross section 09+31
Cross section 10+44
Cross section 13+92
Elevation (NAVD, ft)
6550
6545
6540
6535
6530
6525
6520
6515
6510
6505
6500
6495
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
Distance (ft)
7/24/99 Ground surface
7/24/99 Water surface (Q = 48 cfs)
WY1999 Peak Water Surface (Q= 170cfs)


Upper Lee Vining Creek Main Channel,
1997 Longitudinal Thalweg Profile
Cross section 00+26
Cross section 03+45
Cross section 03+73
Cross section 06+61
Cross section 09+31
Cross section 10+44
Cross section 13+92
Elevation (NAVD, ft)
6550
6545
6540
6535
6530
6525
6520
6515
6510
6505
6500
6495
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
900.00
1000.00
1100.00
1200.00
1300.00
1400.00
1500.00
Distance (ft)
y = 0.0311x + 6494.1
R^2 = 0.995
8/13/97 Ground surface
Linear (8/13/97 Ground surface)

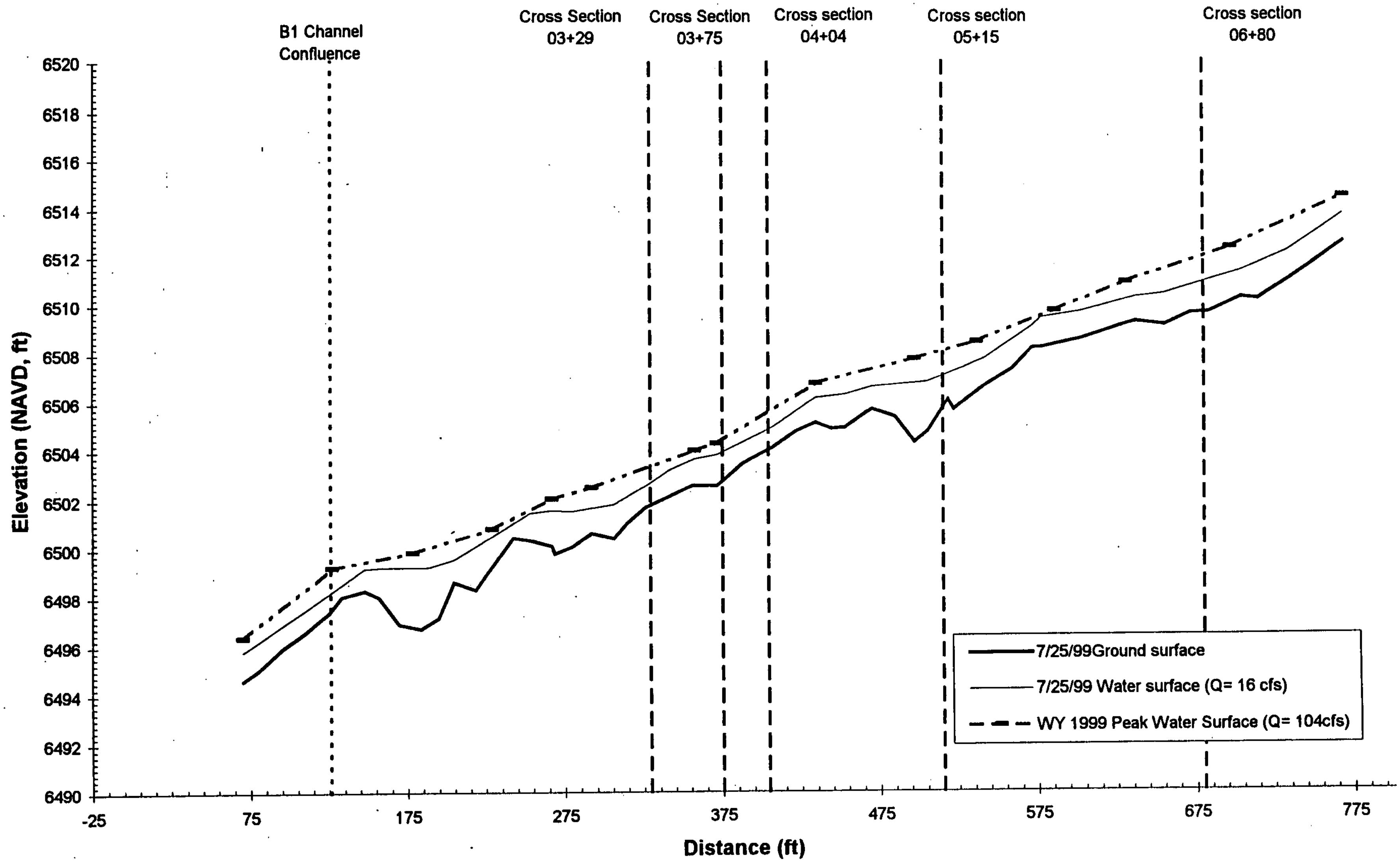
Upper Lee Vining Creek Main Channel, 1999 Longitudinal Thalweg Profile

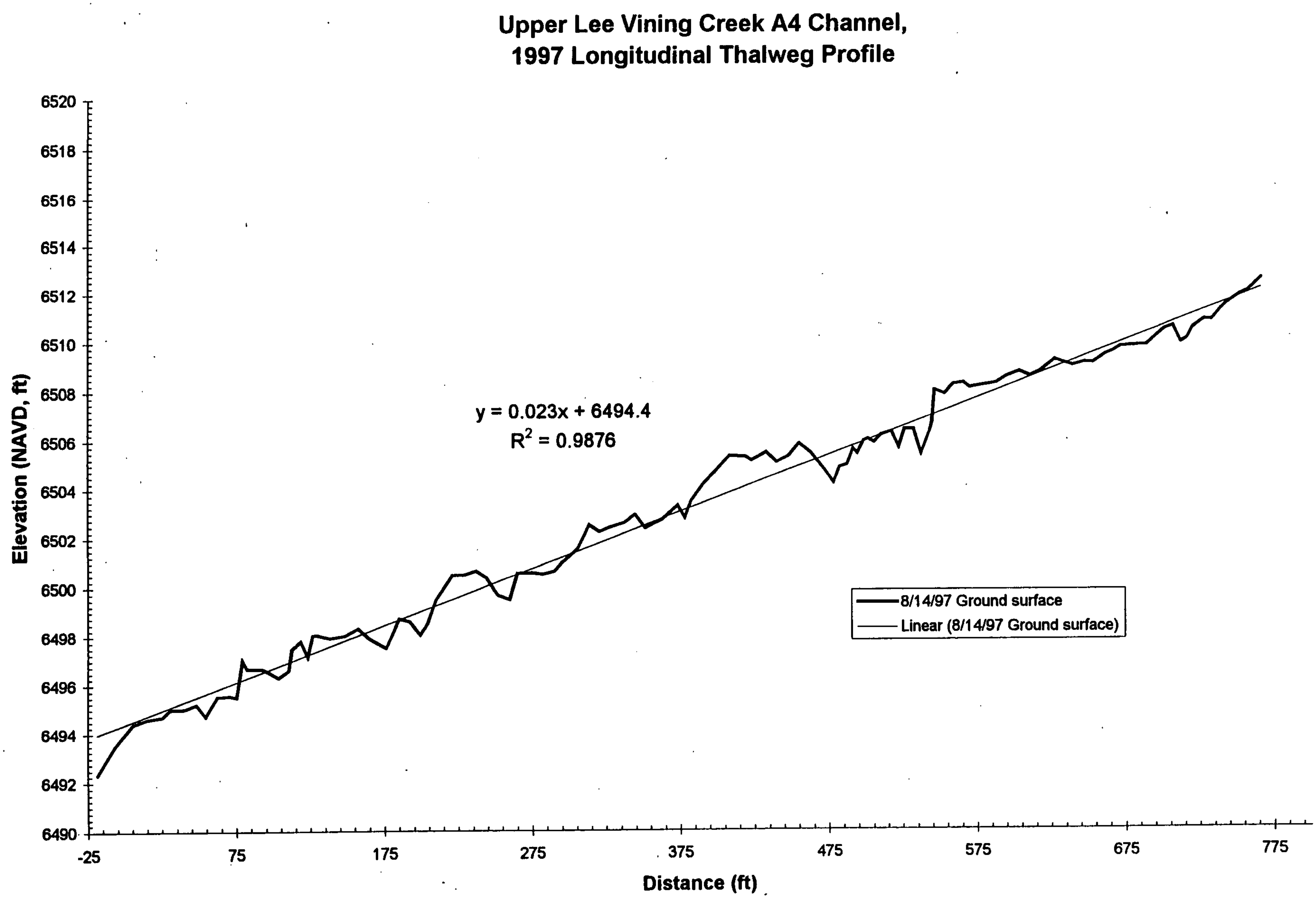



Upper Lee Vining Creek,
1999 Main Channel and A4 Channel Longitidinal Thalweg Profile Overlay
Lee Vining Creek Mainstem Thalweg Regression
y = 0.0305x + 6494.1
R2 = 0.9954
A4 Channel Thalweg Regression
y = 0.0238x + 6495
R2 = 0.9835
Lee Vining Mainstem Thalweg Profile
Lee Vining A4 Channel Thalweg Profile
Linear (Lee Vining A4 Channel Thalweg Profile)
Linear (Lee Vining Mainstem Thalweg Profile)
Elevation (NAVD, ft)
Distance (ft)
6520
6515
6510
6505
6500
6495
6490
0
100
200
300
400
500
600
700

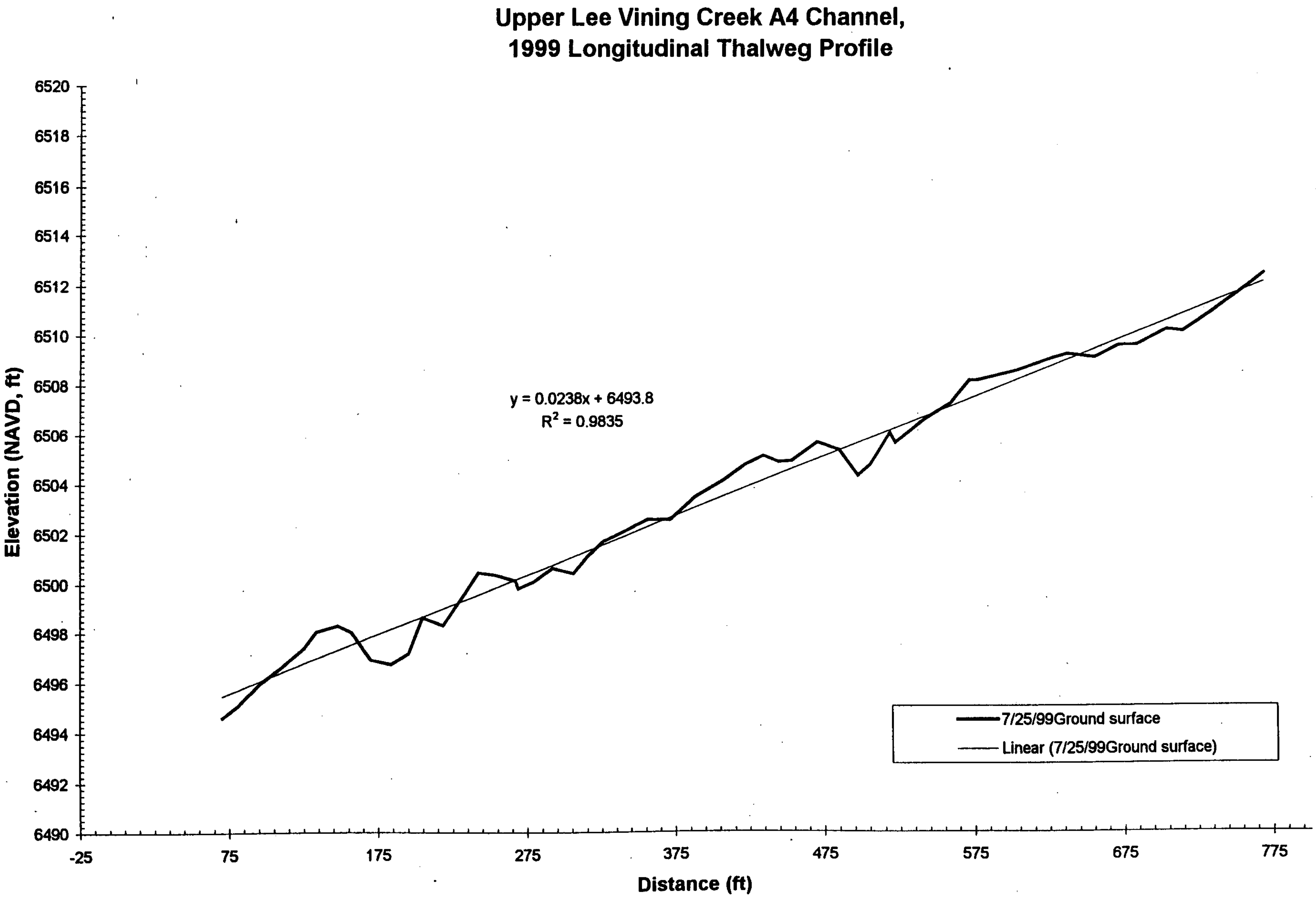

Upper Lee Vining Creek A4 Channel,
1997 Longitudinal Thalweg Profile
B1 Channel Confluence
Cross Section 03+29
Cross Section 03+75
Cross section 04+04
Cross section 05+15
Cross section 06+80
Elevation (NAVD, ft)
6520
6518
6516
6514
6512
6510
6508
6506
6504
6502
6500
6498
6496
6494
6492
6490
-25
75
175
275
375
475
575
675
775
Distance (ft)
8/14/97 Ground surface
8/14/97 Water surface (Q= 20 cfs)
WY 1997 Peak Water Surface (Q= 194cfs)

Upper Lee Vining Creek A4 Channel,
1999 Longitudinal Thalweg Profile

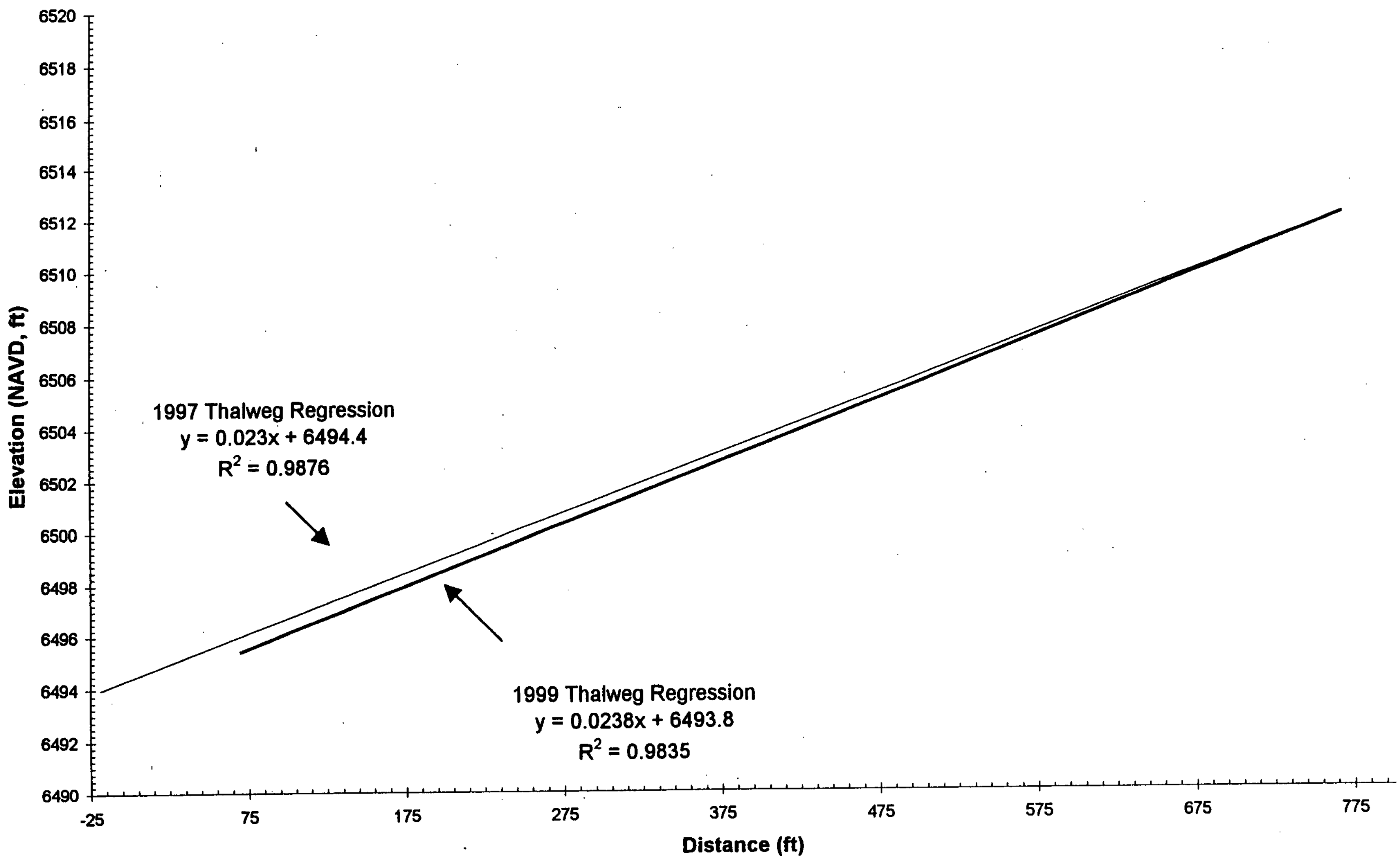


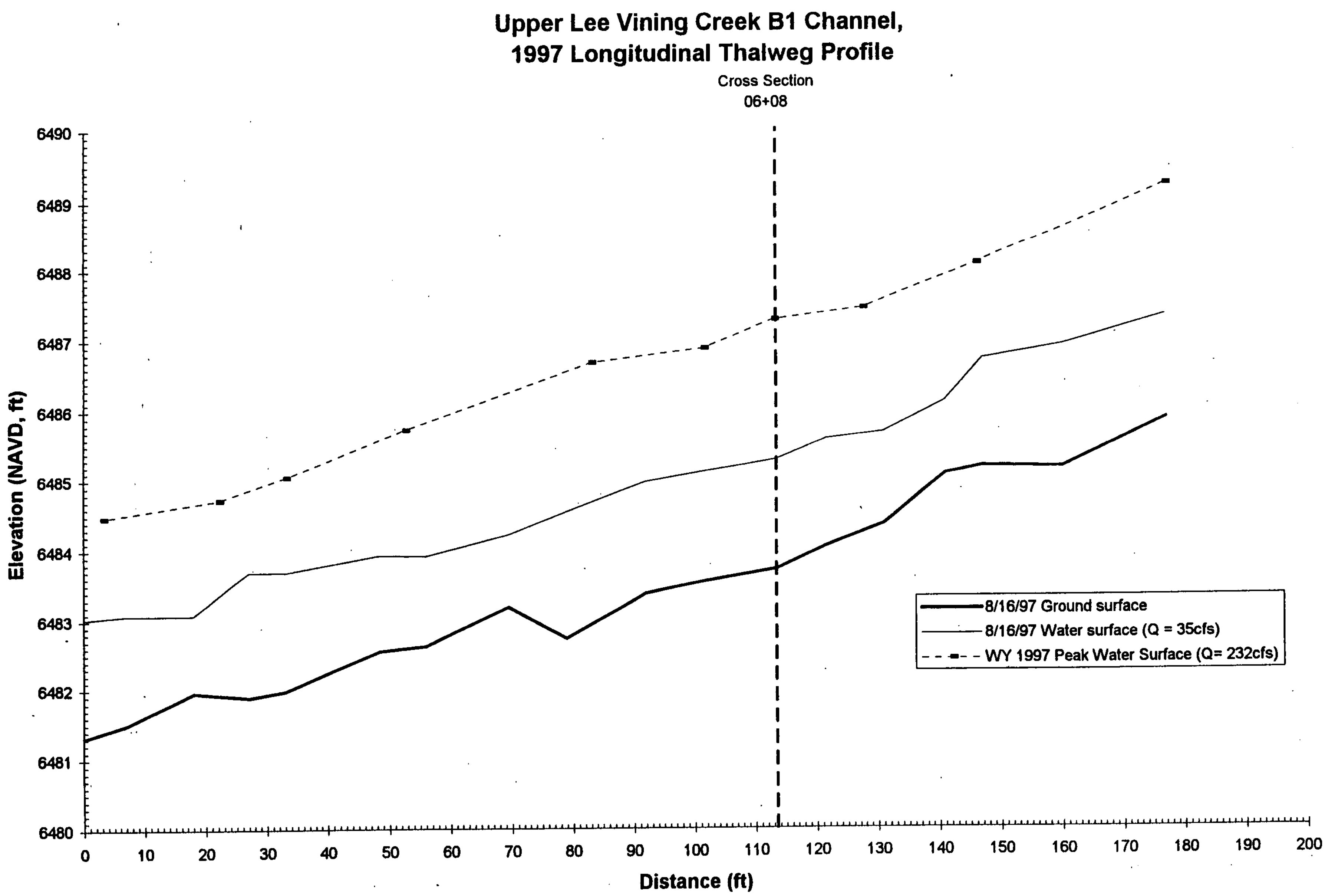


Upper Lee Vining Creek A4 Channel,
1997 Longitudinal Thalweg Profile
6520
6518
6516
6514
6512
6510
6508
6506
6504
6502
6500
6498
6496
6494
6492
6490
Elevation (NAVD, ft)
-25
75
175
275
375
475
575
675
775
Distance (ft)
y = 0.023x + 6494.4
R2 = 0.9876
8/14/97 Ground surface
Linear (8/14/97 Ground surface)


Upper Lee Vining Creek A4 Channel,
1999 Longitudinal Thalweg Profile
6520
6518
6516
6514
6512
6510
6508
6506
6504
6502
6500
6498
6496
6494
6492
6490
Elevation (NAVD, ft)
y = 0.0238x + 6493.8
R2 = 0.9835
7/25/99Ground surface
Linear (7/25/99Ground surface)
-25
75
175
275
375
475
575
675
775
Distance (ft)

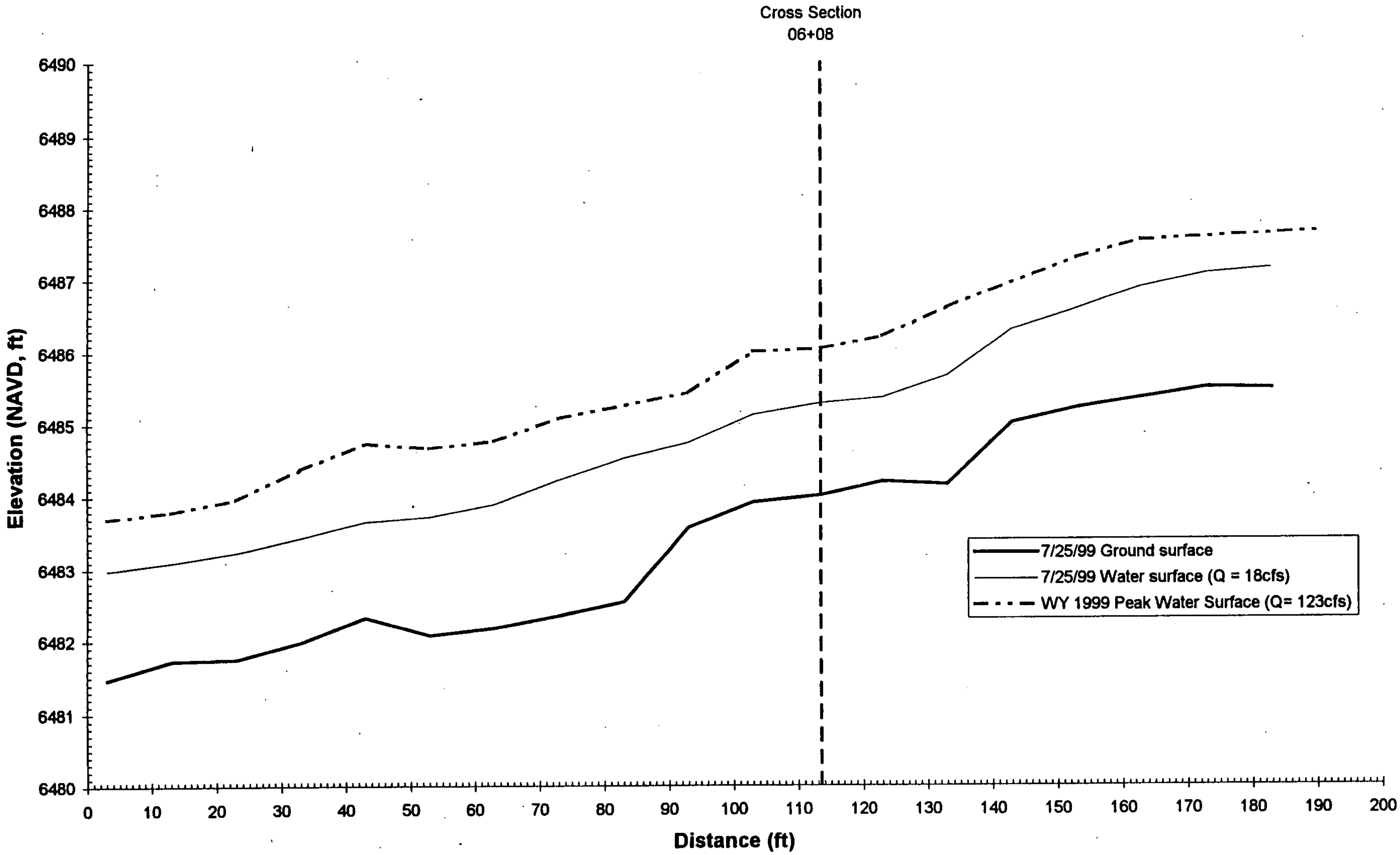
Upper Lee Vining Creek A4 Channel, 1997and 1999 Longitudinal Thalweg Profile Regressions

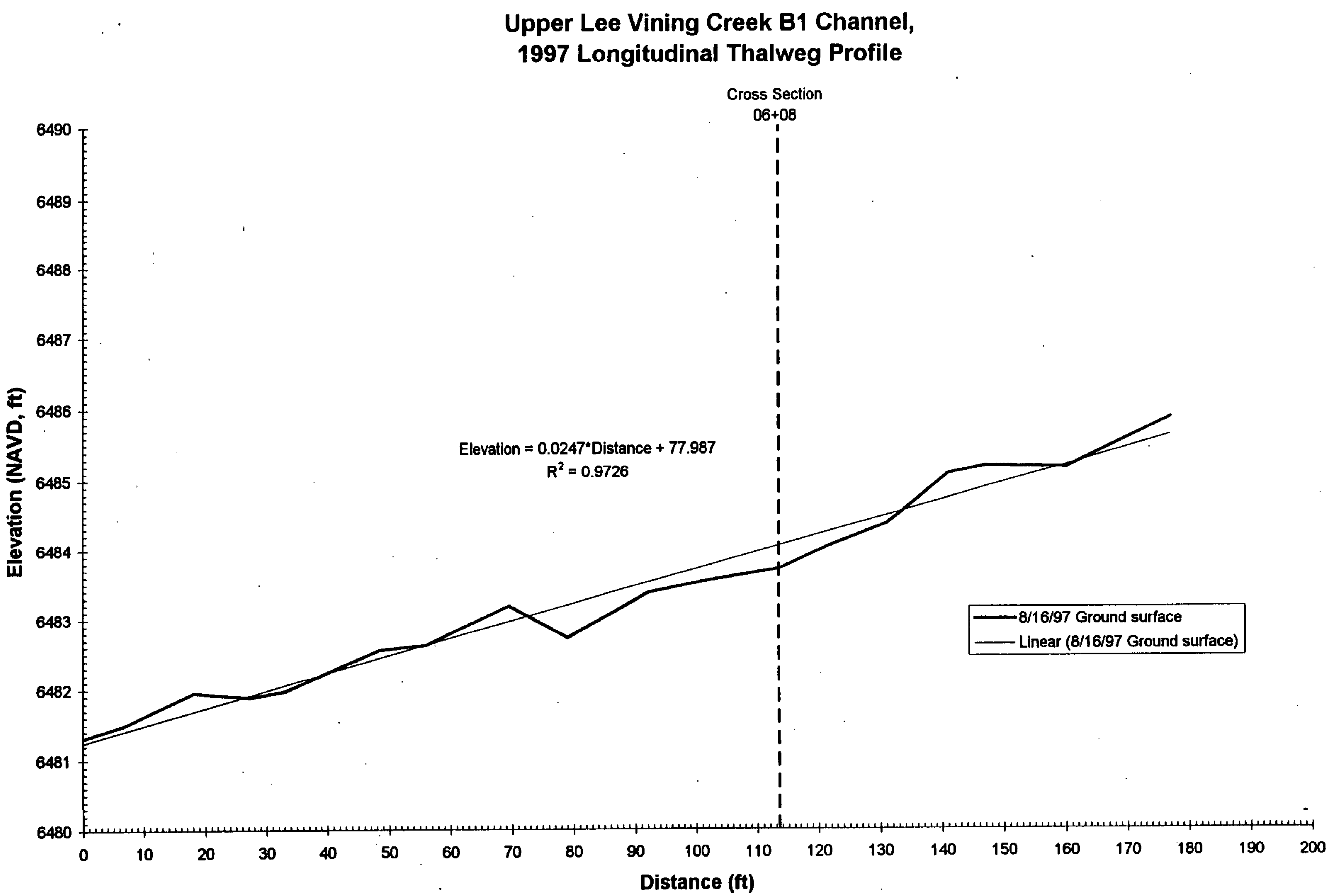




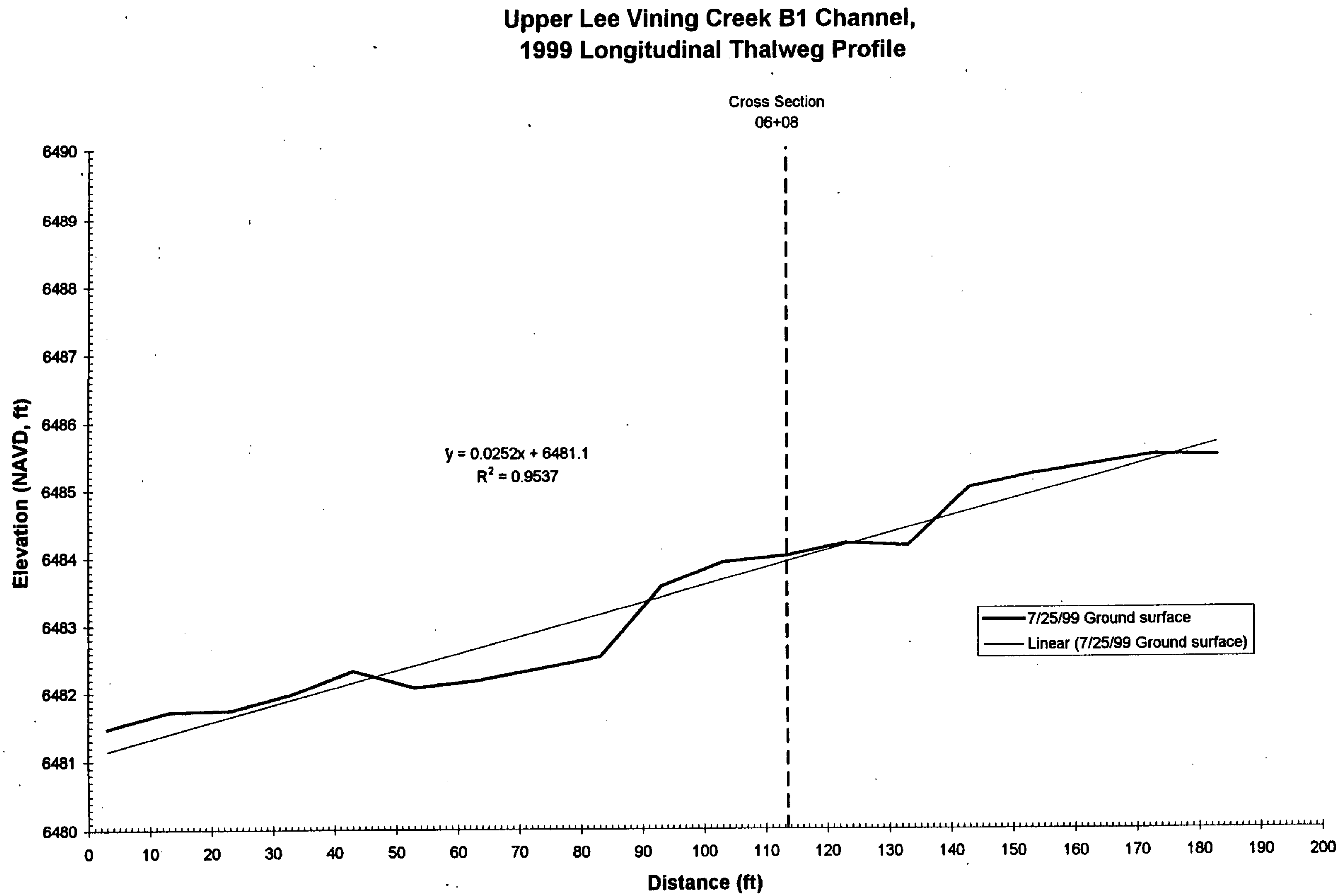
Upper Lee Vining Creek B1 Channel,
1997 Longitudinal Thalweg Profile
Cross Section
06+08
Elevation (NAVD, ft)
6490
6489
6488
6487
6486
6485
6484
6483
6482
6481
6480
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance (ft)
8/16/97 Ground surface
8/16/97 Water surface (Q = 35cfs)
WY 1997 Peak Water Surface (Q= 232cfs)

Upper Lee Vining Creek B1 Channel
1999 Longitudinal Thalweg Profile

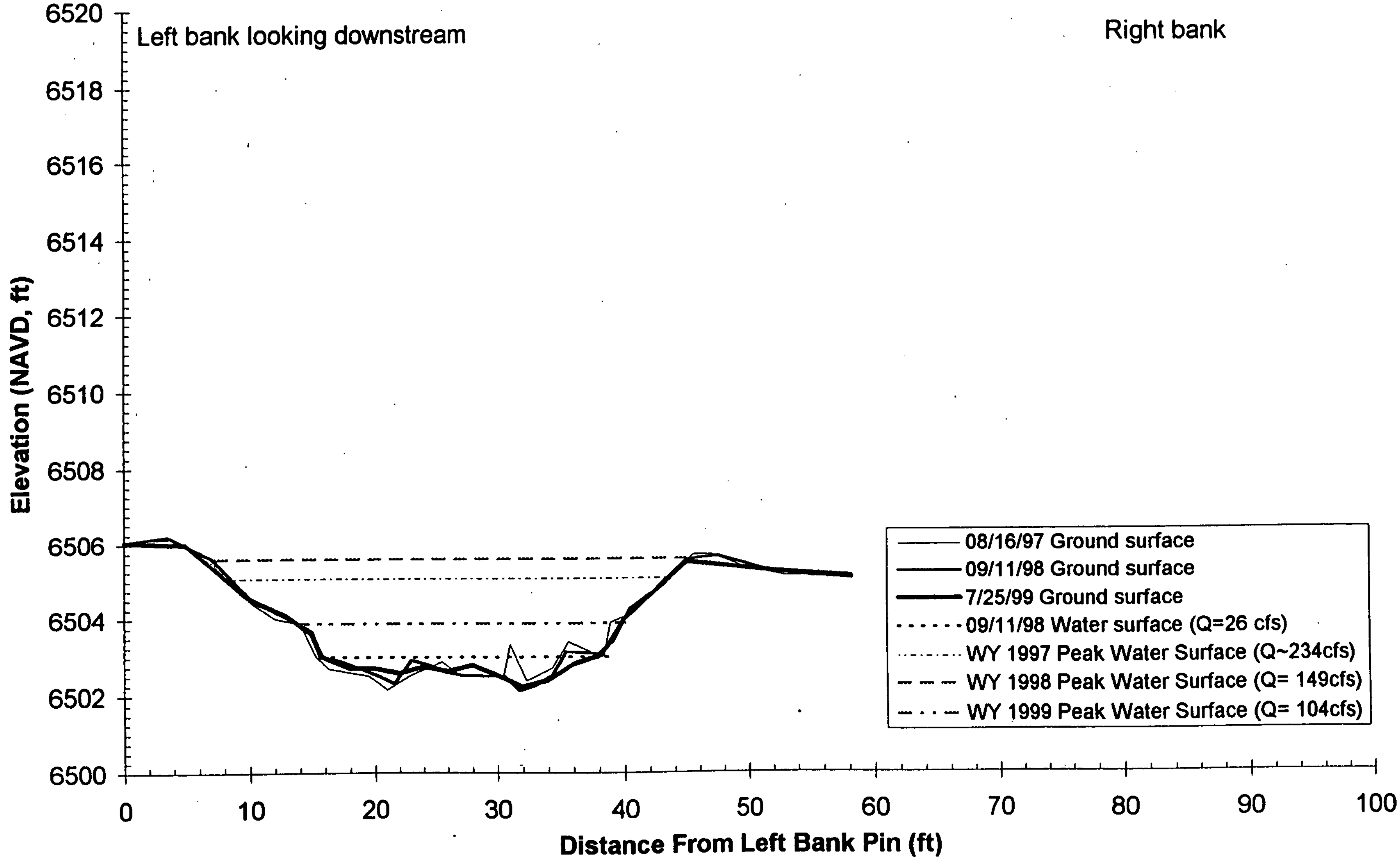


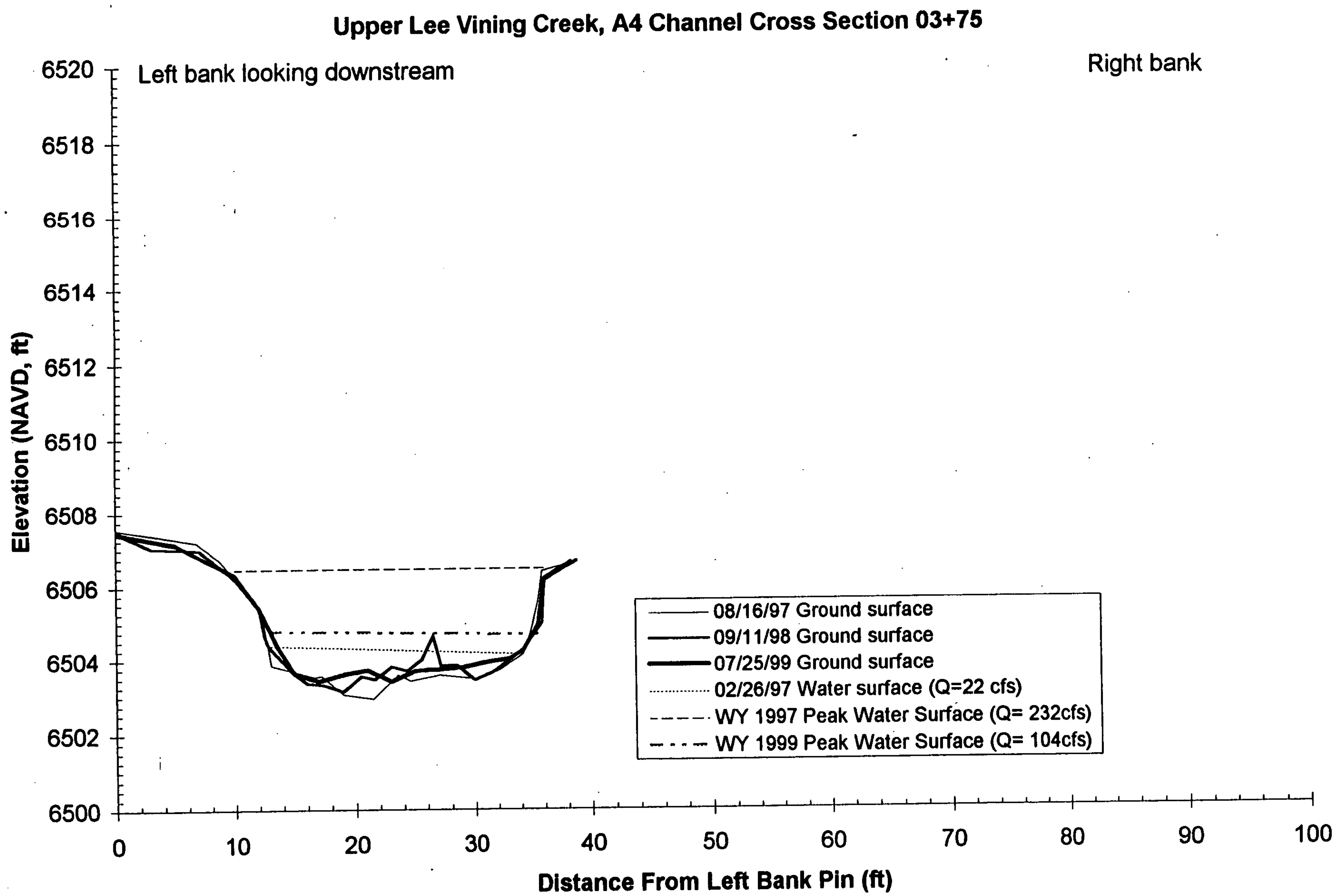


Upper Lee Vining Creek B1 Channel,
1997 Longitudinal Thalweg Profile
Cross Section
06+08
Elevation (NAVD, ft)
6490
6489
6488
6487
6486
6485
6484
6483
6482
6481
6480
Elevation = 0.0247*Distance + 77.987
R2 = 0.9726
8/16/97 Ground surface
Linear (8/16/97 Ground surface)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance (ft)

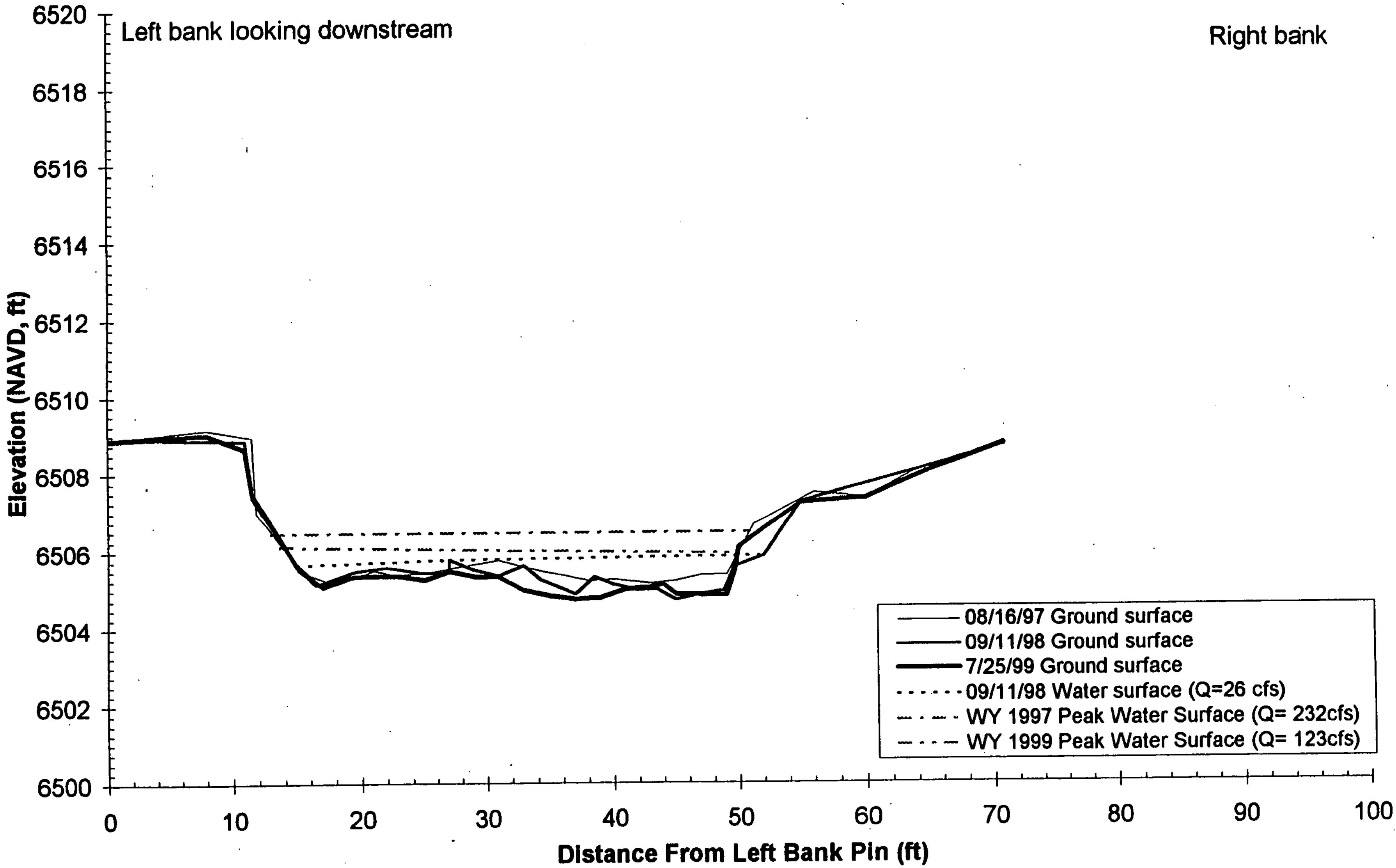

Upper Lee Vining Creek B1 Channel,
1999 Longitudinal Thalweg Profile
Cross Section
06+08
$y = 0.0252x + 6481.1$
$R^2 = 0.9537$
7/25/99 Ground surface
Linear (7/25/99 Ground surface)
Elevation (NAVD, ft)
Distance (ft)
6490
6489
6488
6487
6486
6485
6484
6483
6482
6481
6480
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

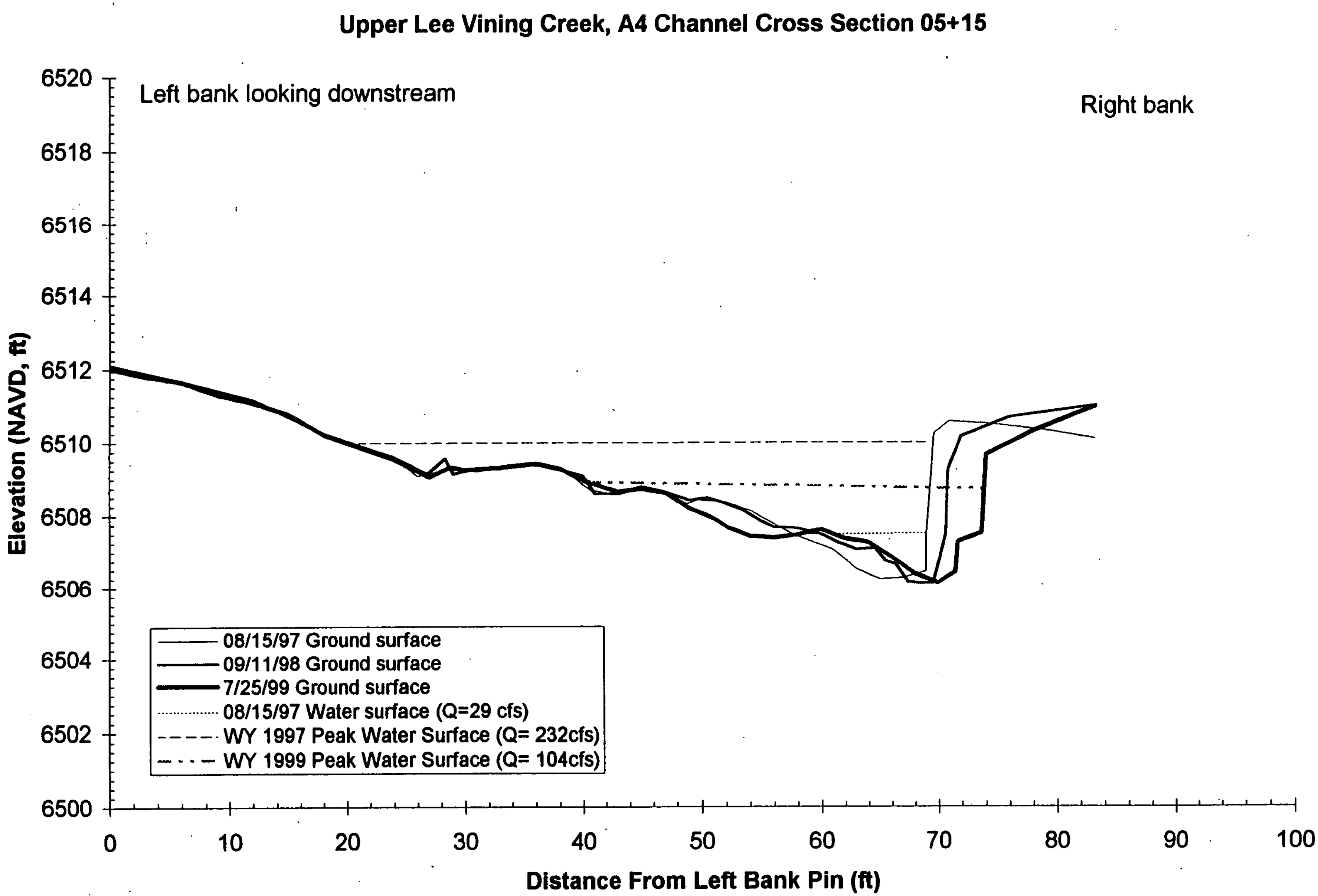
Upper Lee Vining Creek, A4 Channel Cross Section 03+29




Upper Lee Vining Creek, A4 Channel Cross Section 03+75
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6520
6518
6516
6514
6512
6510
6508
6506
6504
6502
6500
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)
08/16/97 Ground surface
09/11/98 Ground surface
07/25/99 Ground surface
02/26/97 Water surface (Q=22 cfs)
WY 1997 Peak Water Surface (Q= 232cfs)
WY 1999 Peak Water Surface (Q= 104cfs)

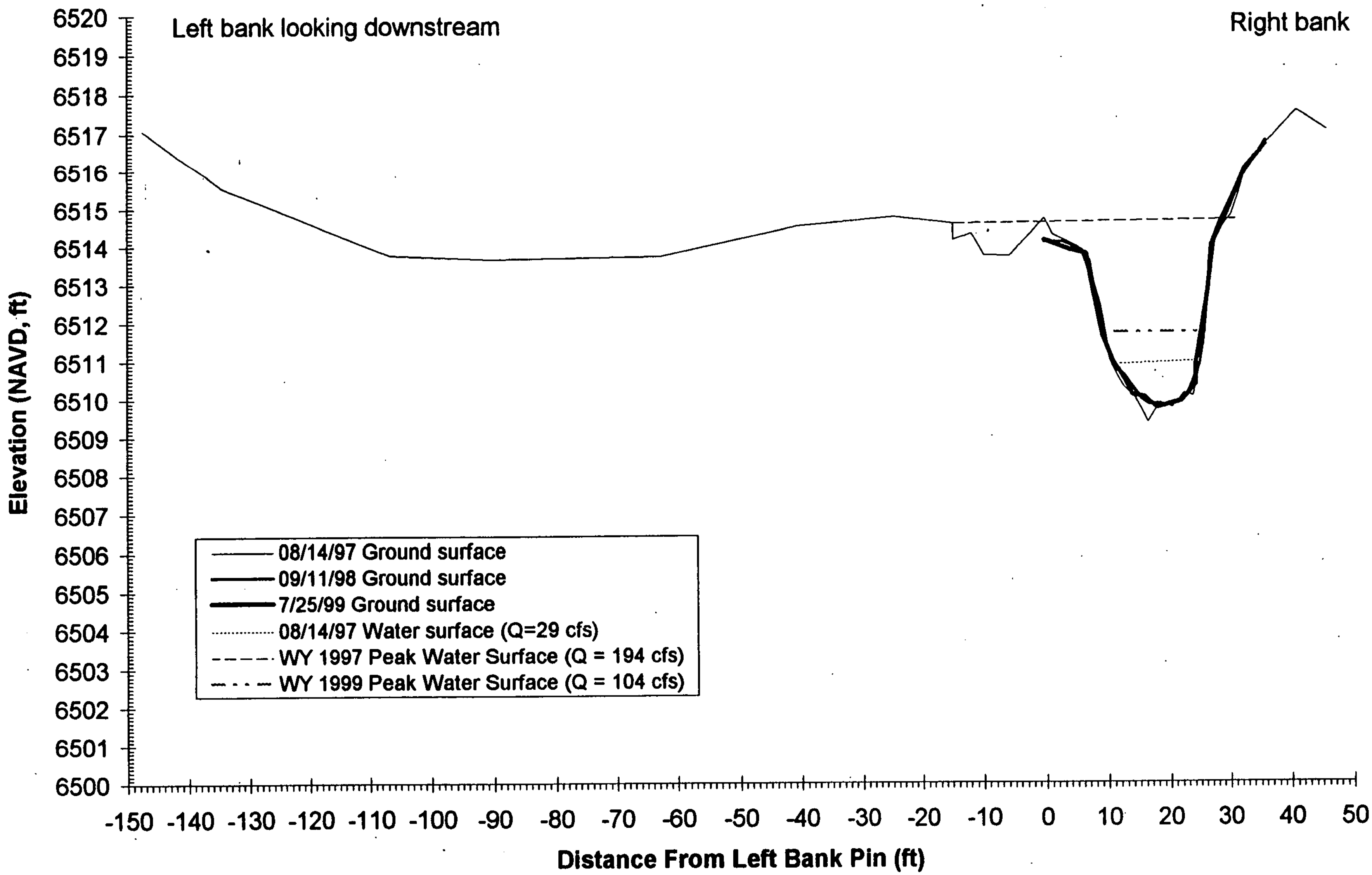
Upper Lee Vining Creek, A4 Channel Cross Section 04+04



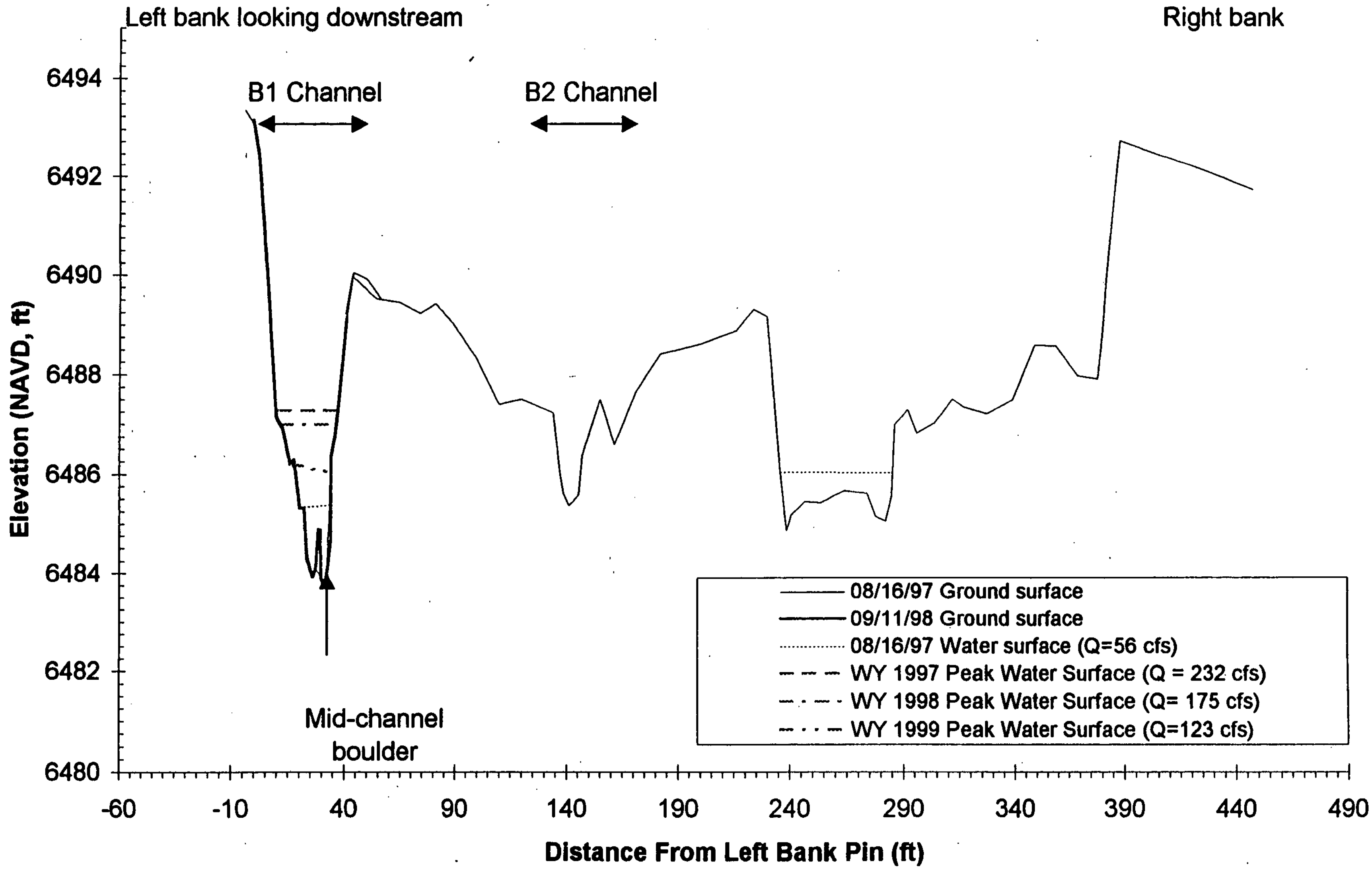


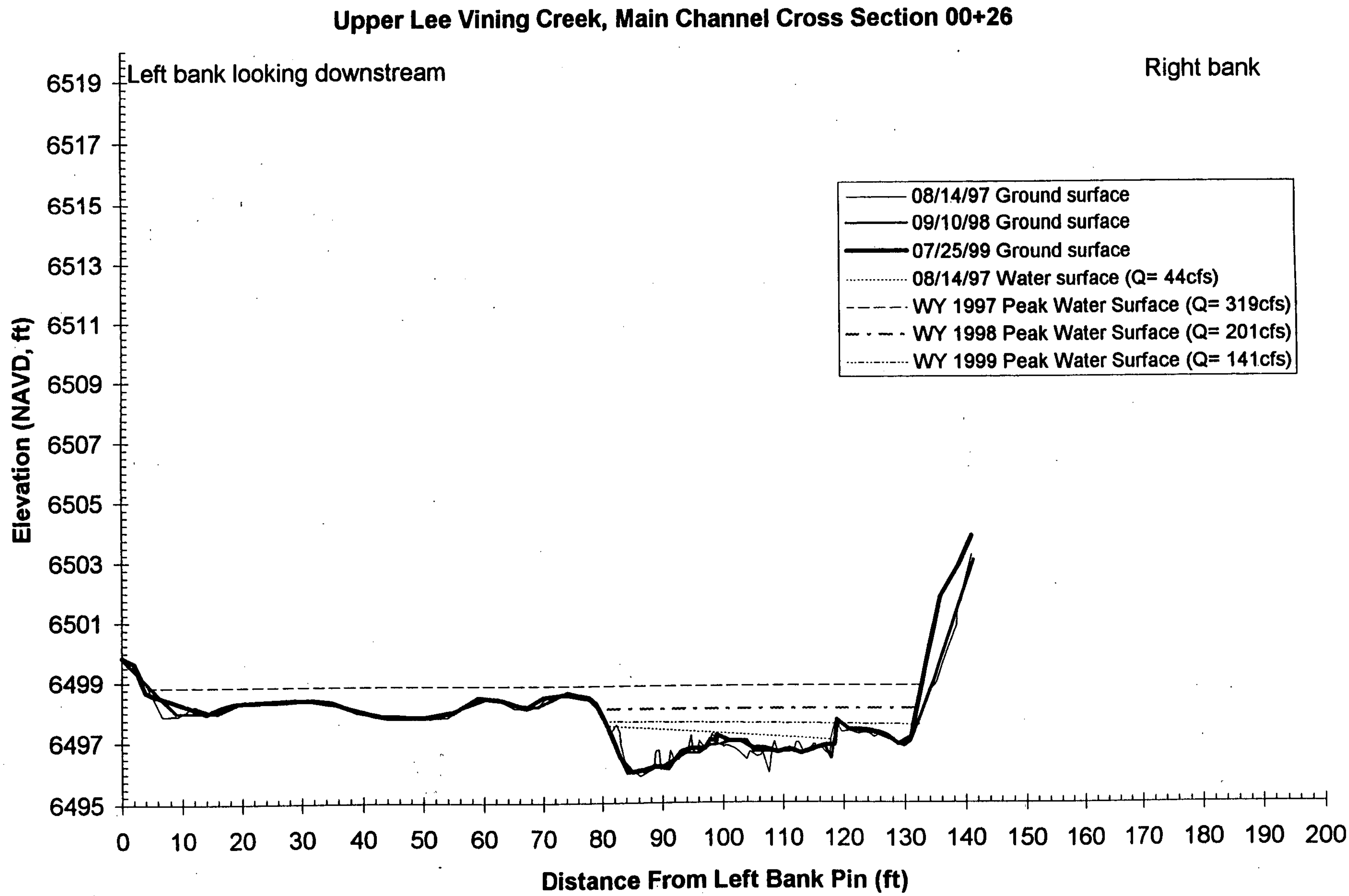
Upper Lee Vining Creek, A4 Channel Cross Section 05+15
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6520
6518
6516
6514
6512
6510
6508
6506
6504
6502
6500
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)
08/15/97 Ground surface
09/11/98 Ground surface
7/25/99 Ground surface
08/15/97 Water surface (Q=29 cfs)
WY 1997 Peak Water Surface (Q= 232cfs)
WY 1999 Peak Water Surface (Q= 104cfs)

Upper Lee Vining Creek, A4 Channel Cross Section 06+80



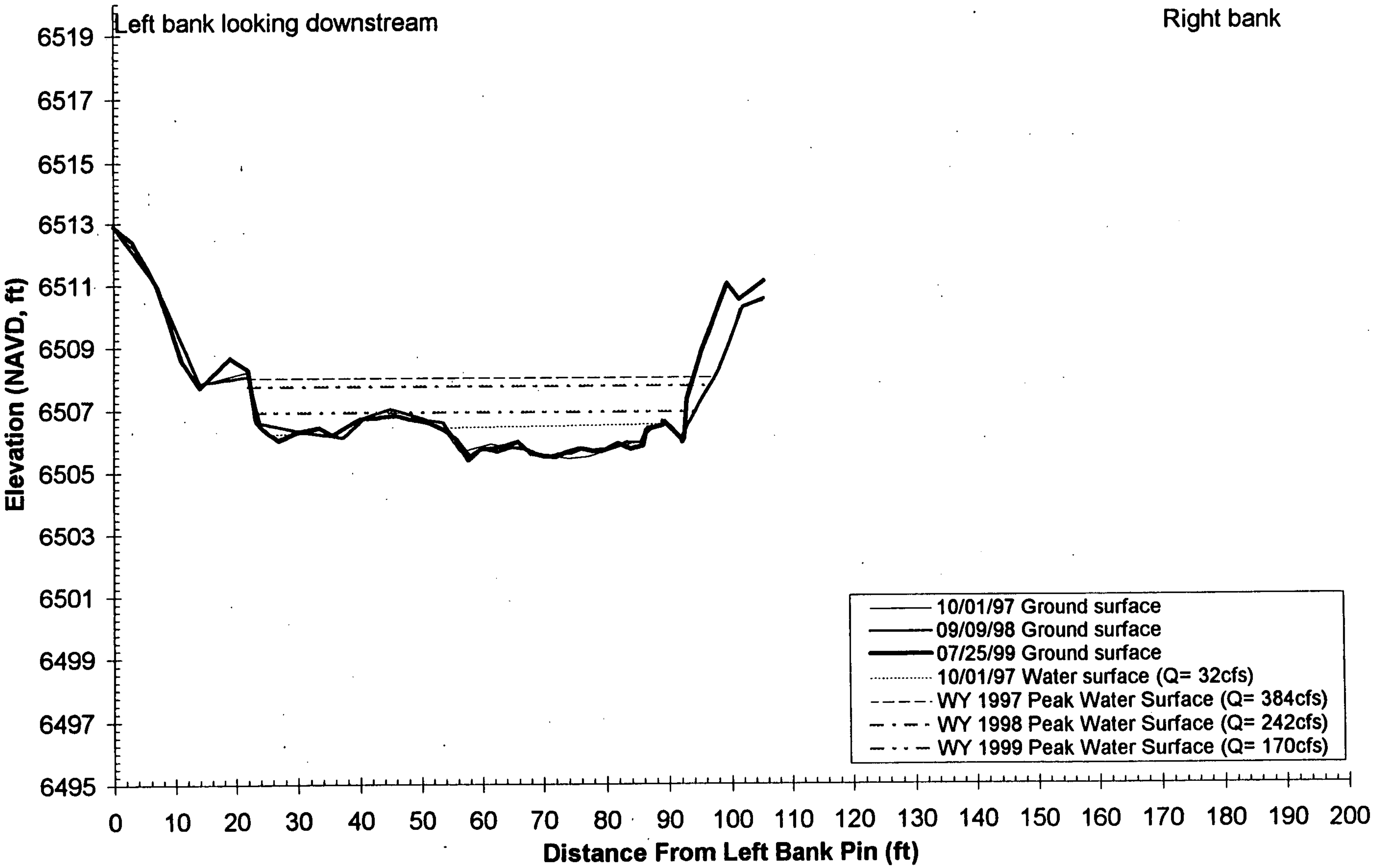
Upper Lee Vining Creek, B1 Channel Cross Section 06+08,
Bed Surface Mobility Modeling Cross Section

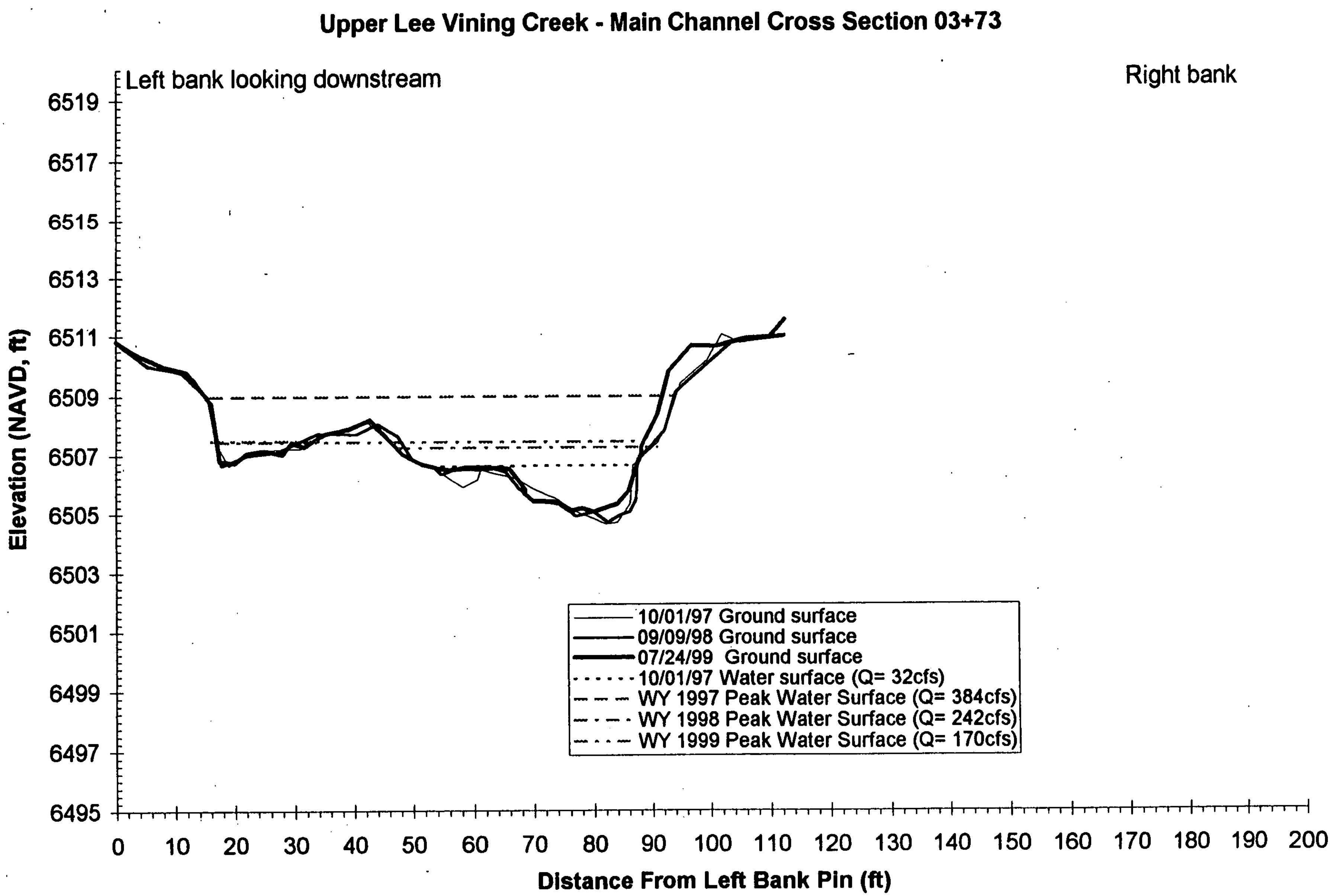




Upper Lee Vining Creek, Main Channel Cross Section 00+26
Left bank looking downstream
Right bank
08/14/97 Ground surface
09/10/98 Ground surface
07/25/99 Ground surface
08/14/97 Water surface (Q= 44cfs)
WY 1997 Peak Water Surface (Q= 319cfs)
WY 1998 Peak Water Surface (Q= 201cfs)
WY 1999 Peak Water Surface (Q= 141cfs)
Elevation (NAVD, ft)
6519
6517
6515
6513
6511
6509
6507
6505
6503
6501
6499
6497
6495
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance From Left Bank Pin (ft)

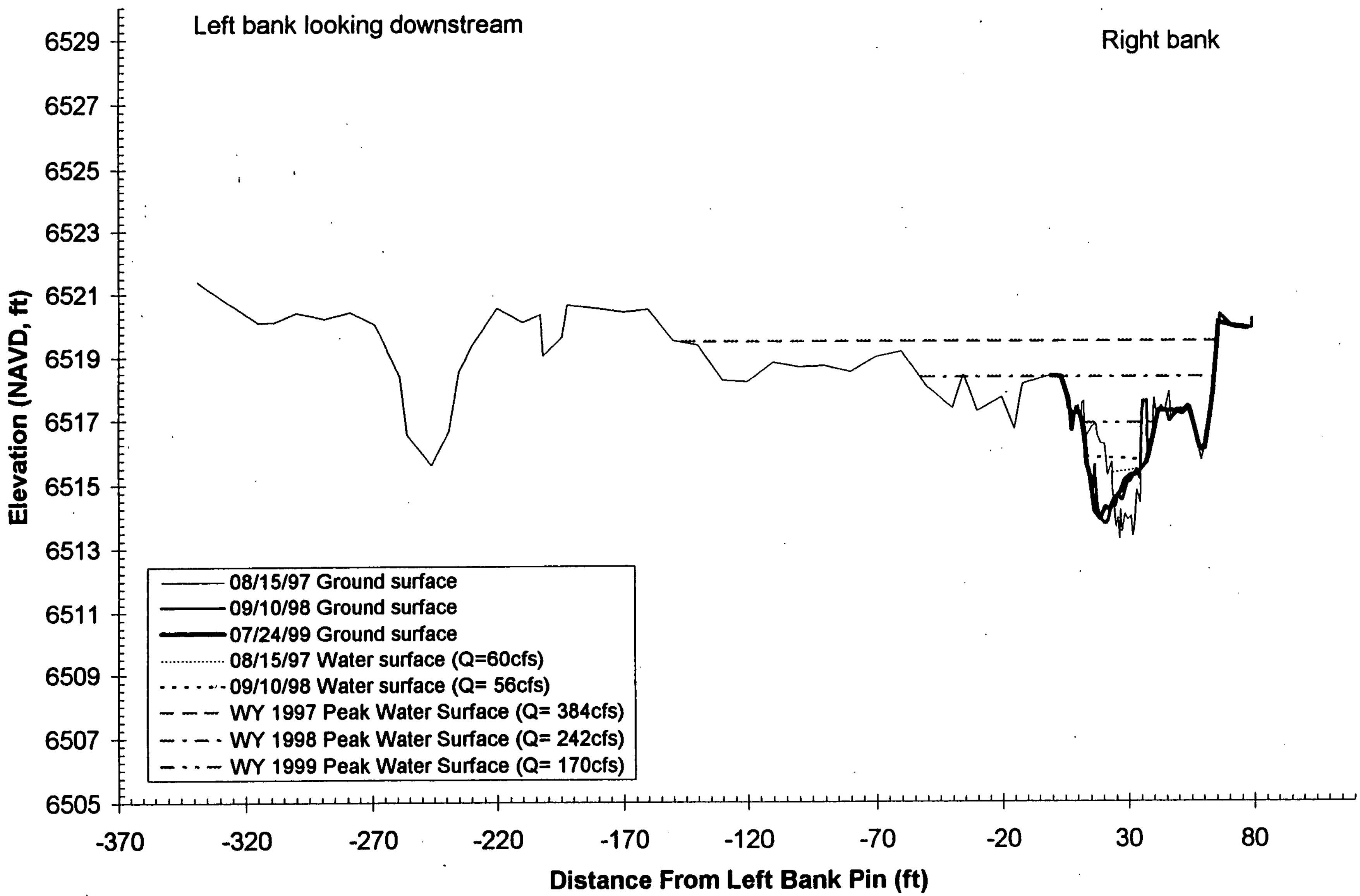
Upper Lee Vining Creek - Main Channel Cross Section 03+45

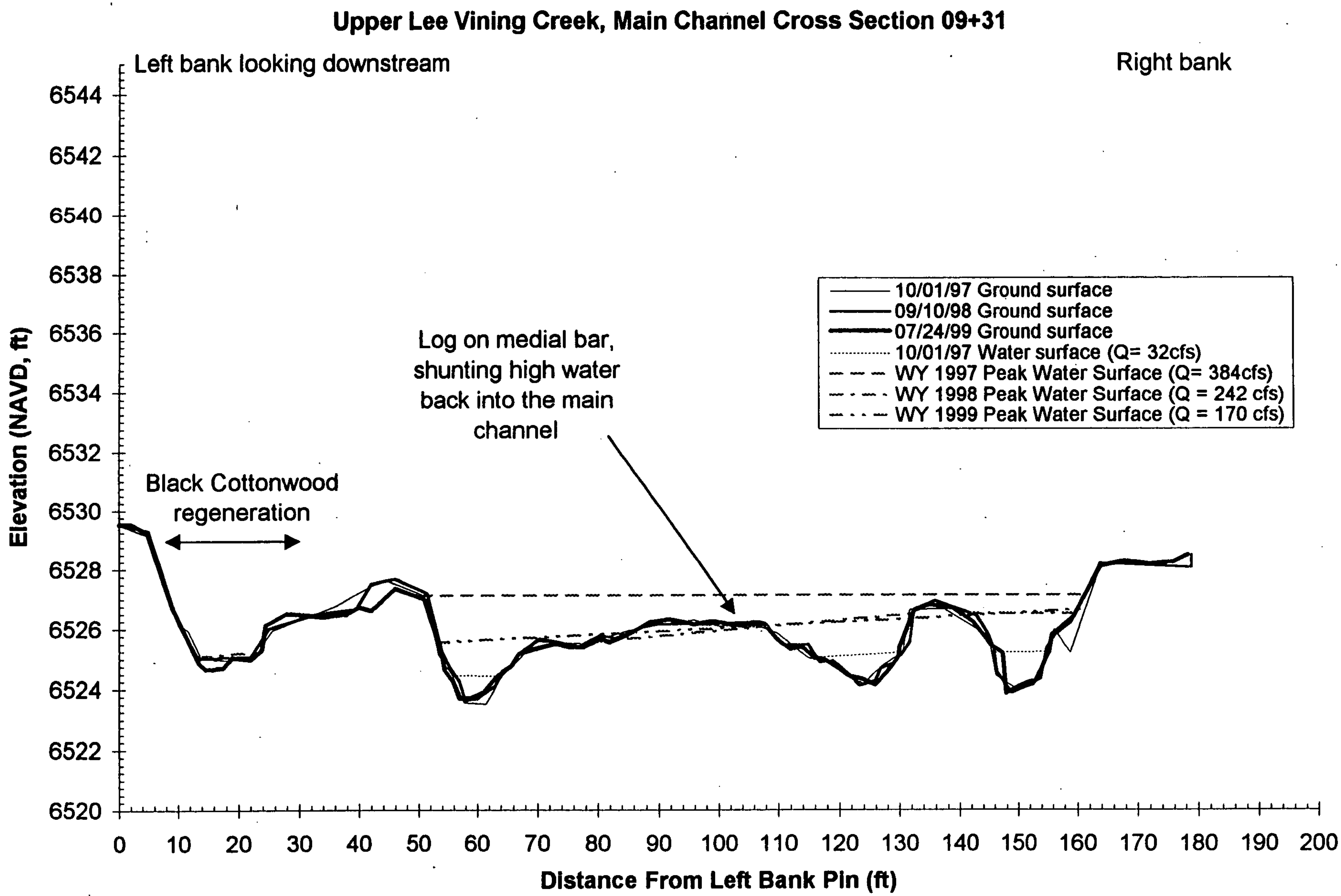




Upper Lee Vining Creek - Main Channel Cross Section 03+73
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6519
6517
6515
6513
6511
6509
6507
6505
6503
6501
6499
6497
6495
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance From Left Bank Pin (ft)
10/01/97 Ground surface
09/09/98 Ground surface
07/24/99 Ground surface
10/01/97 Water surface (Q= 32cfs)
WY 1997 Peak Water Surface (Q= 384cfs)
WY 1998 Peak Water Surface (Q= 242cfs)
WY 1999 Peak Water Surface (Q= 170cfs)

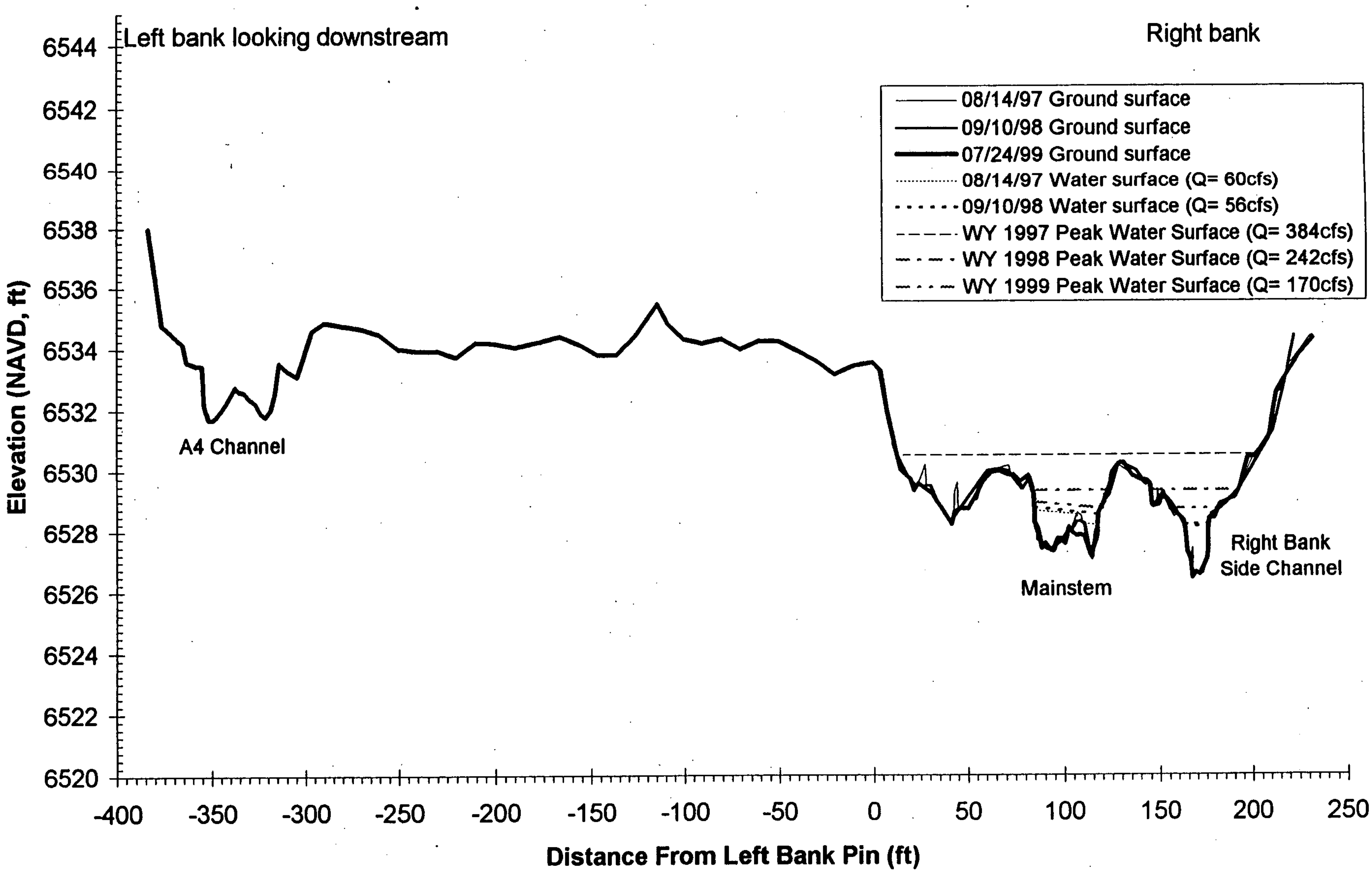
Upper Lee Vining Creek, Main Channel Cross Section 06+61

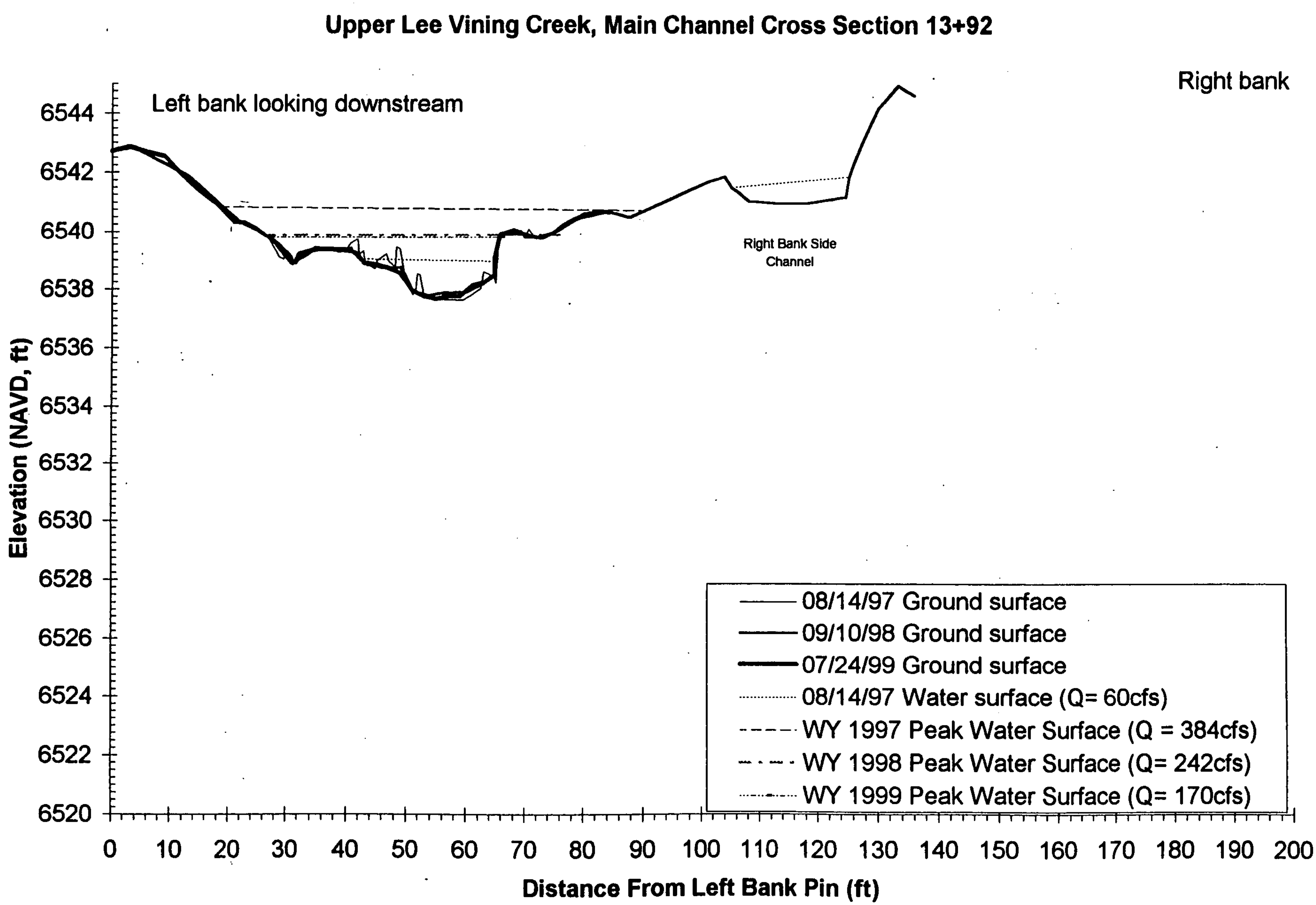




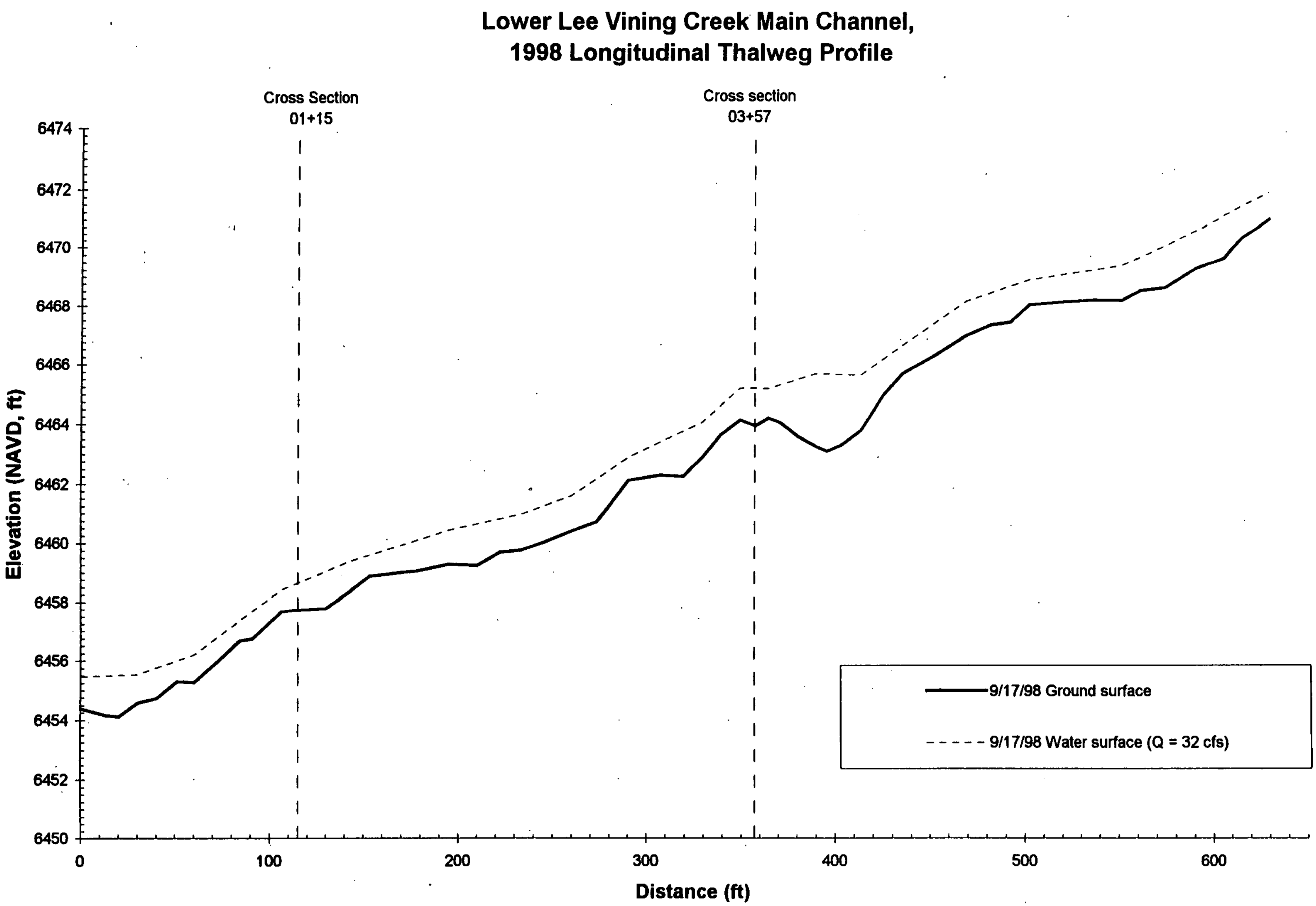
Upper Lee Vining Creek, Main Channel Cross Section 09+31
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6544
6542
6540
6538
6536
6534
6532
6530
6528
6526
6524
6522
6520
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance From Left Bank Pin (ft)
10/01/97 Ground surface
09/10/98 Ground surface
07/24/99 Ground surface
10/01/97 Water surface (Q= 32cfs)
WY 1997 Peak Water Surface (Q= 384cfs)
WY 1998 Peak Water Surface (Q = 242 cfs)
WY 1999 Peak Water Surface (Q = 170 cfs)
Log on medial bar, shunting high water back into the main channel
Black Cottonwood regeneration

Upper Lee Vining Creek, Main Channel Cross Section 10+44

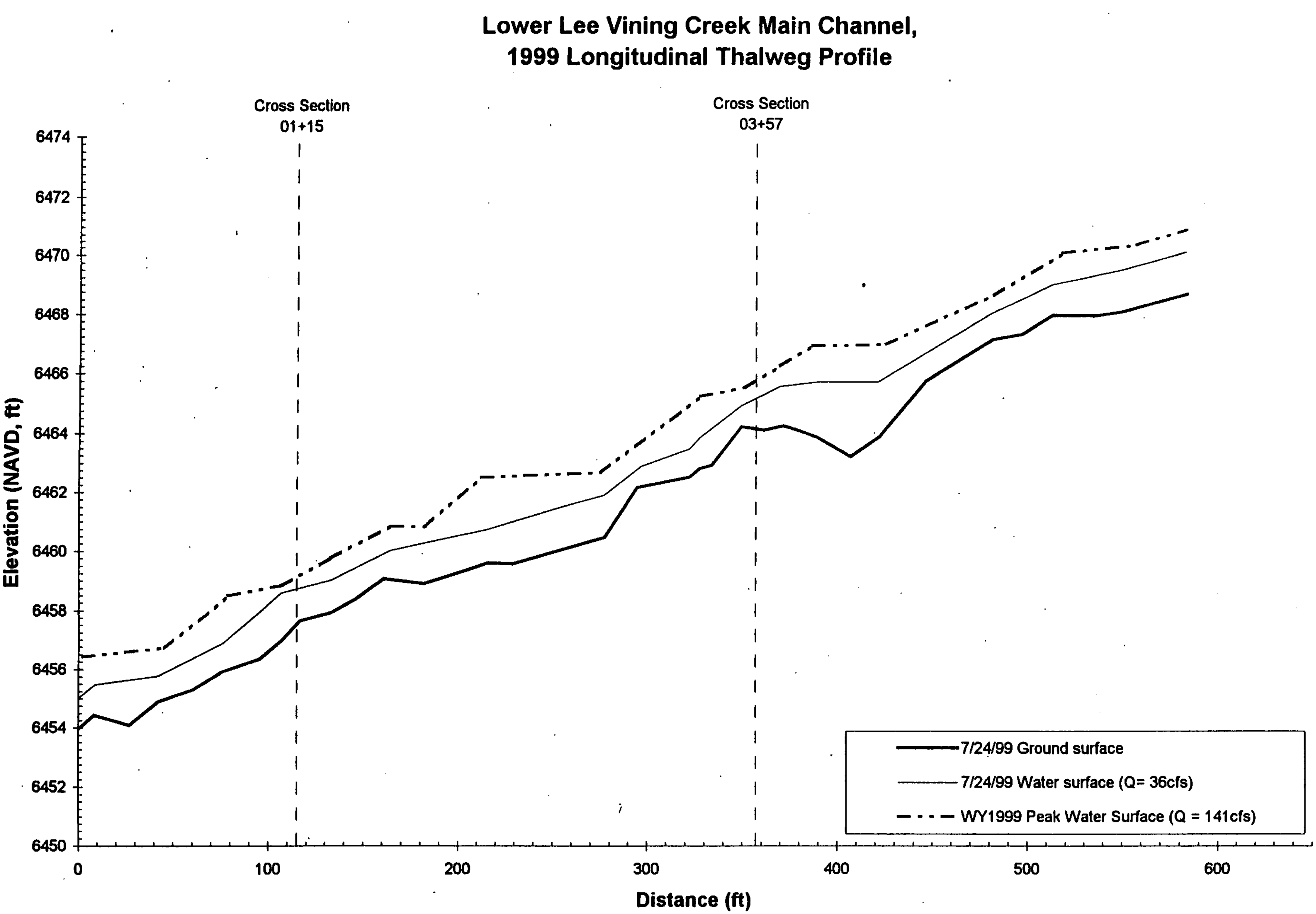


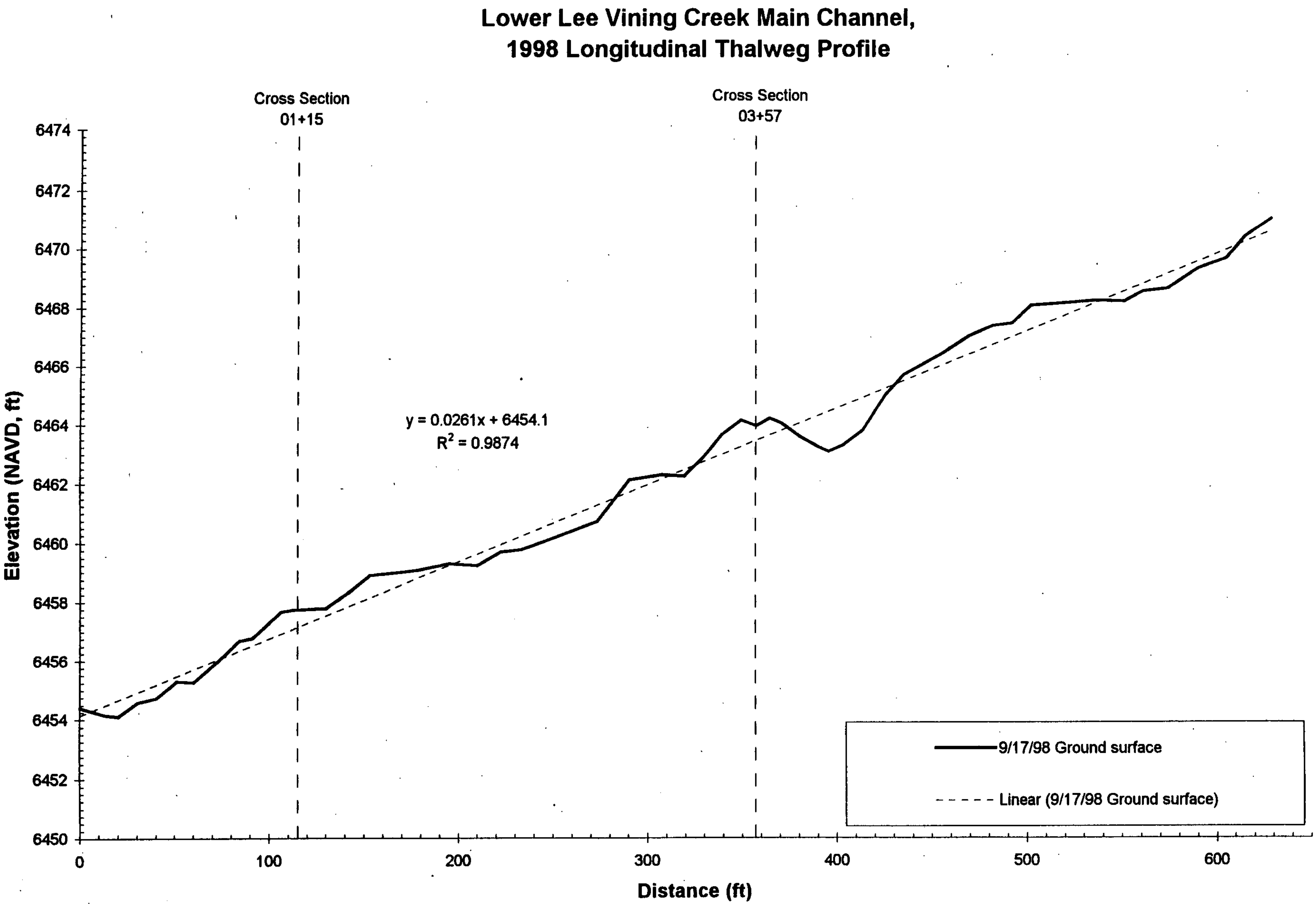


Upper Lee Vining Creek, Main Channel Cross Section 13+92
Left bank looking downstream
Right bank
Right Bank Side Channel
Elevation (NAVD, ft)
6544
6542
6540
6538
6536
6534
6532
6530
6528
6526
6524
6522
6520
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance From Left Bank Pin (ft)
08/14/97 Ground surface
09/10/98 Ground surface
07/24/99 Ground surface
08/14/97 Water surface (Q= 60cfs)
WY 1997 Peak Water Surface (Q = 384cfs)
WY 1998 Peak Water Surface (Q= 242cfs)
WY 1999 Peak Water Surface (Q= 170cfs)



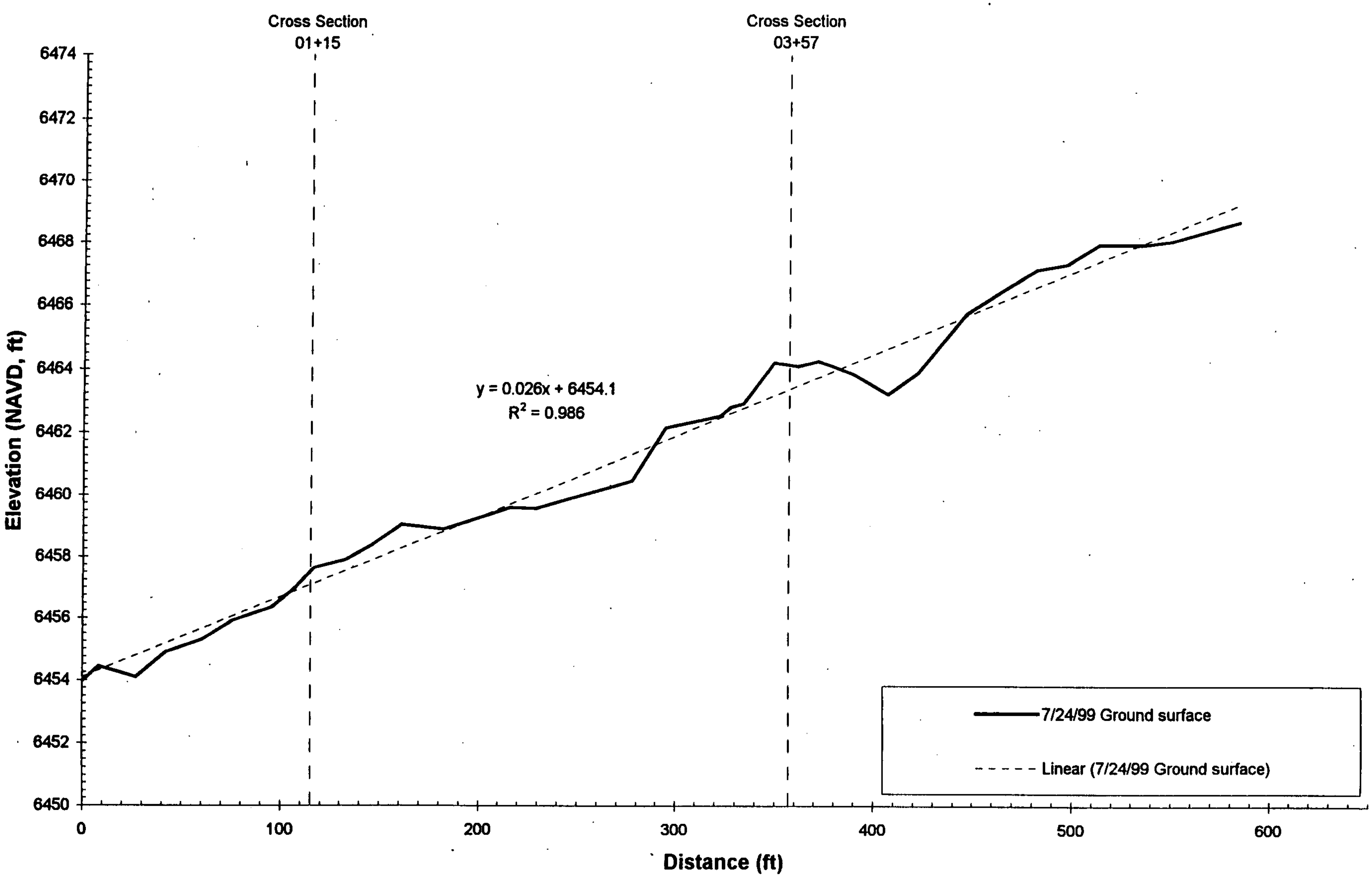
Lower Lee Vining Creek Main Channel,
1998 Longitudinal Thalweg Profile
Cross Section 01+15
Cross section 03+57
Elevation (NAVD, ft)
6474
6472
6470
6468
6466
6464
6462
6460
6458
6456
6454
6452
6450
0
100
200
300
400
500
600
Distance (ft)
9/17/98 Ground surface
9/17/98 Water surface (Q = 32 cfs)

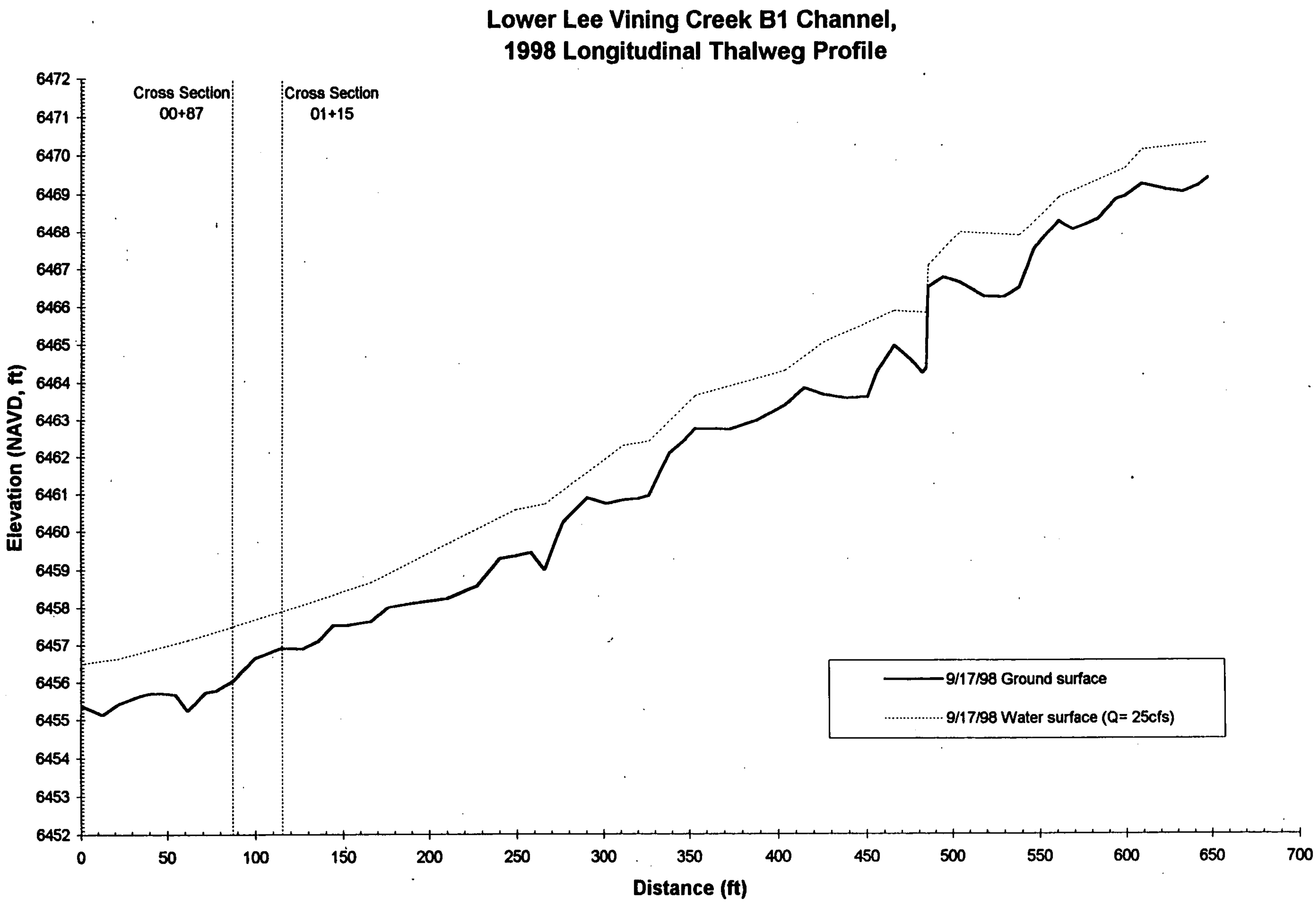

Lower Lee Vining Creek Main Channel,
1999 Longitudinal Thalweg Profile
Cross Section
01+15
Cross Section
03+57
Elevation (NAVD, ft)
6474
6472
6470
6468
6466
6464
6462
6460
6458
6456
6454
6452
6450
0
100
200
300
400
500
600
Distance (ft)
7/24/99 Ground surface
7/24/99 Water surface (Q= 36cfs)
WY1999 Peak Water Surface (Q = 141cfs)

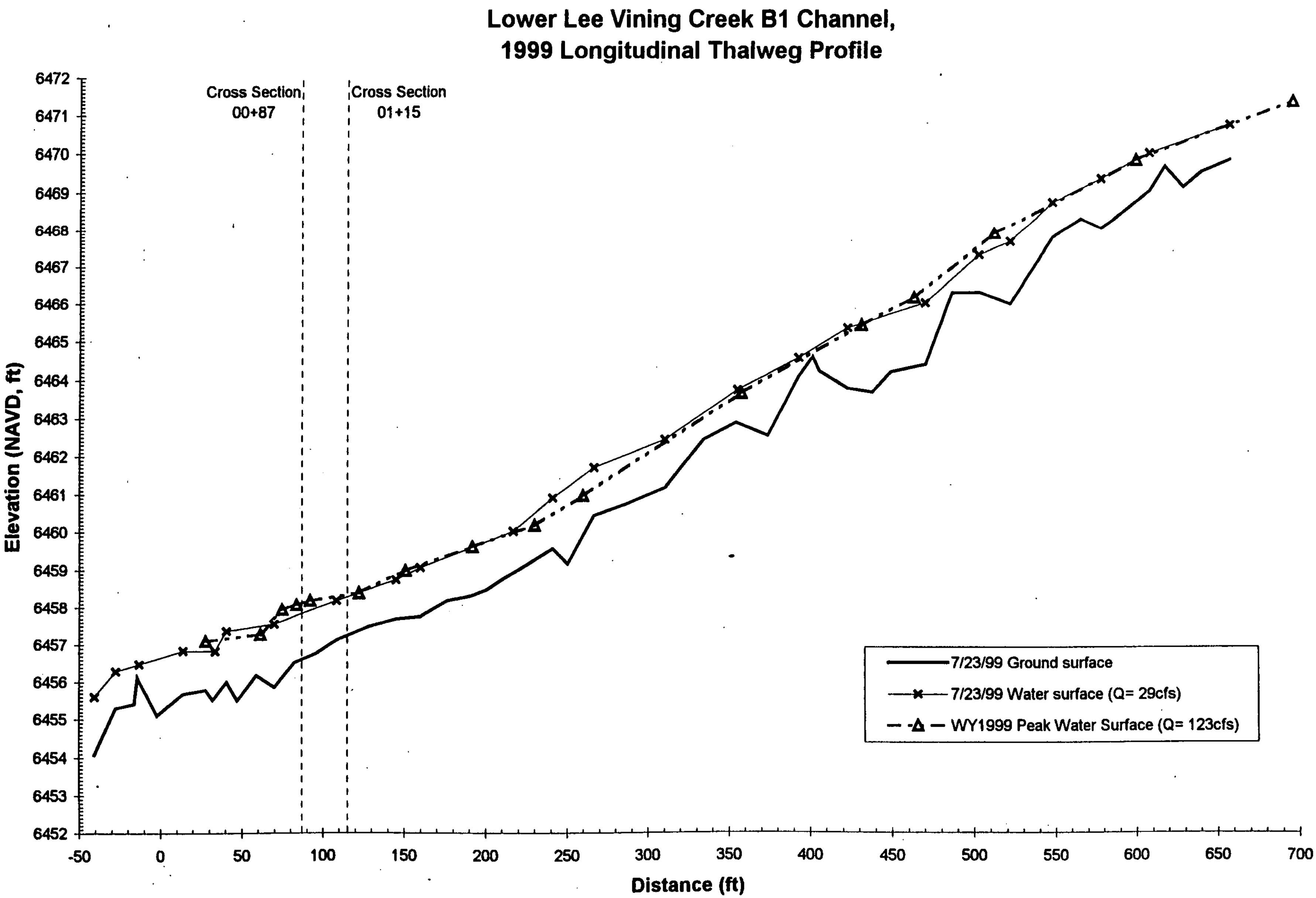


Lower Lee Vining Creek Main Channel,
1998 Longitudinal Thalweg Profile
Cross Section
01+15
Cross Section
03+57
6474
6472
6470
6468
6466
6464
6462
6460
6458
6456
6454
6452
6450
Elevation (NAVD, ft)
y = 0.0261x + 6454.1
R² = 0.9874
0
100
200
300
400
500
600
Distance (ft)
9/17/98 Ground surface
Linear (9/17/98 Ground surface)

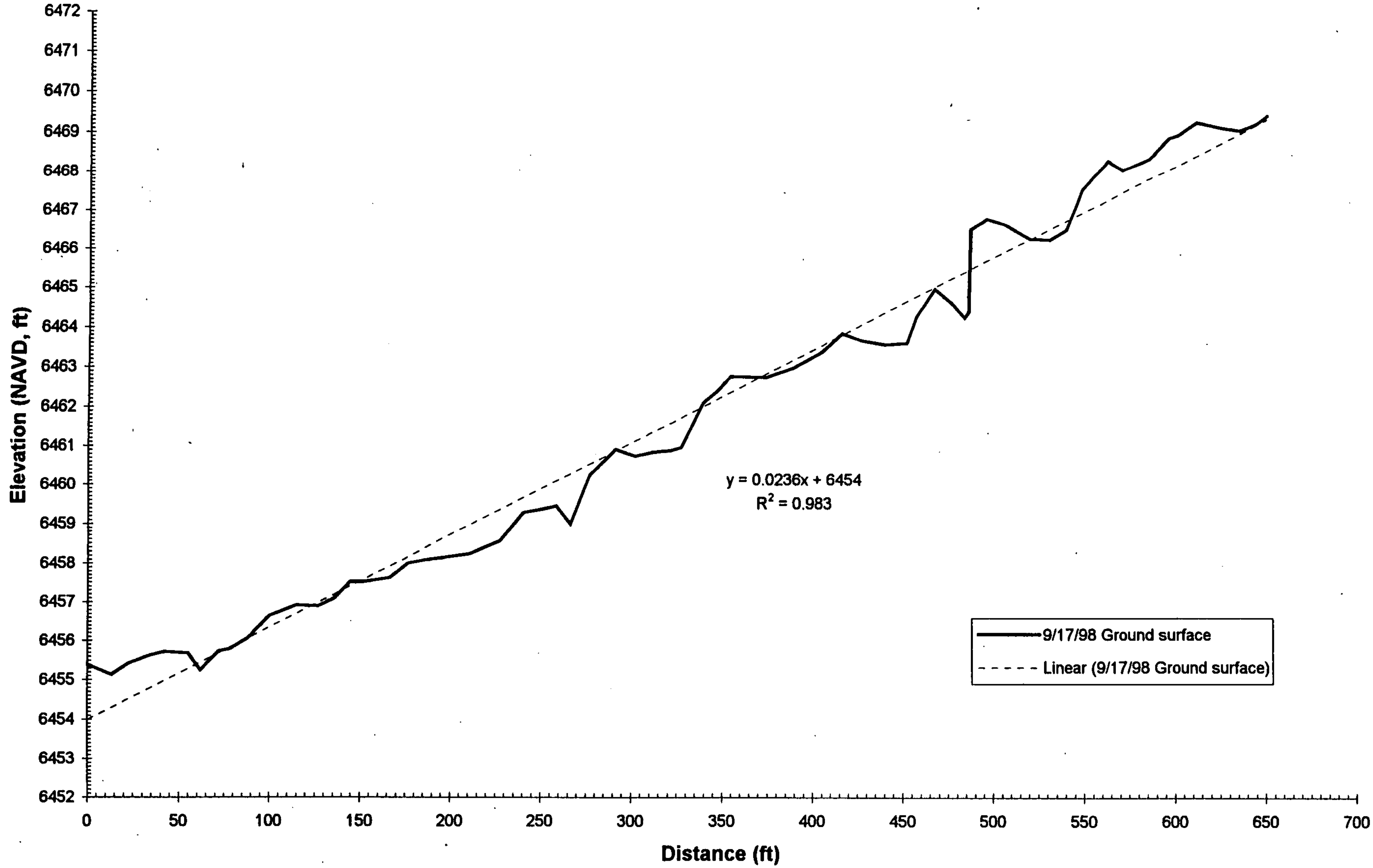
**Lower Lee Vining Creek Main Channel,
1999 Longitudinal Thalweg Profile**

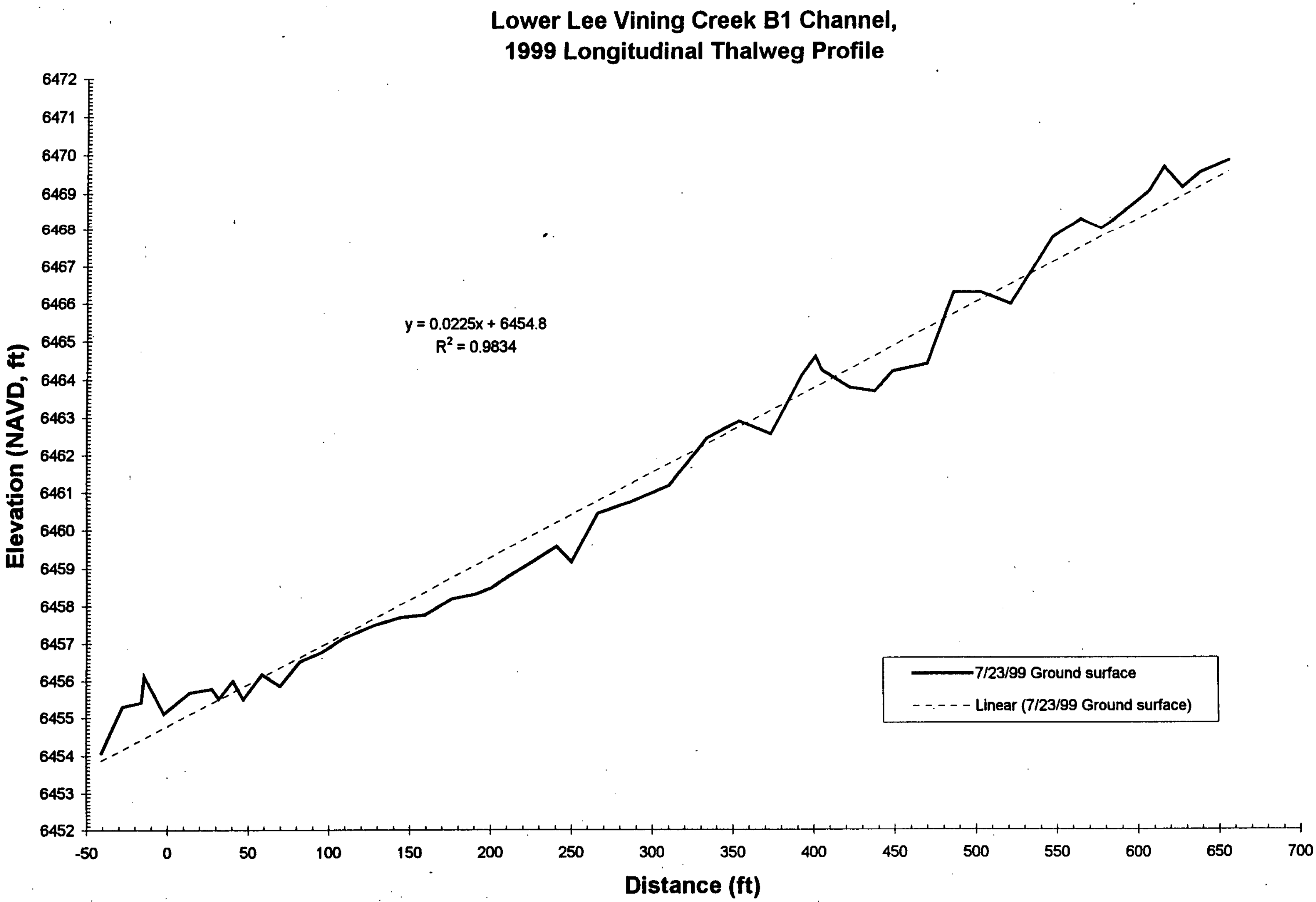


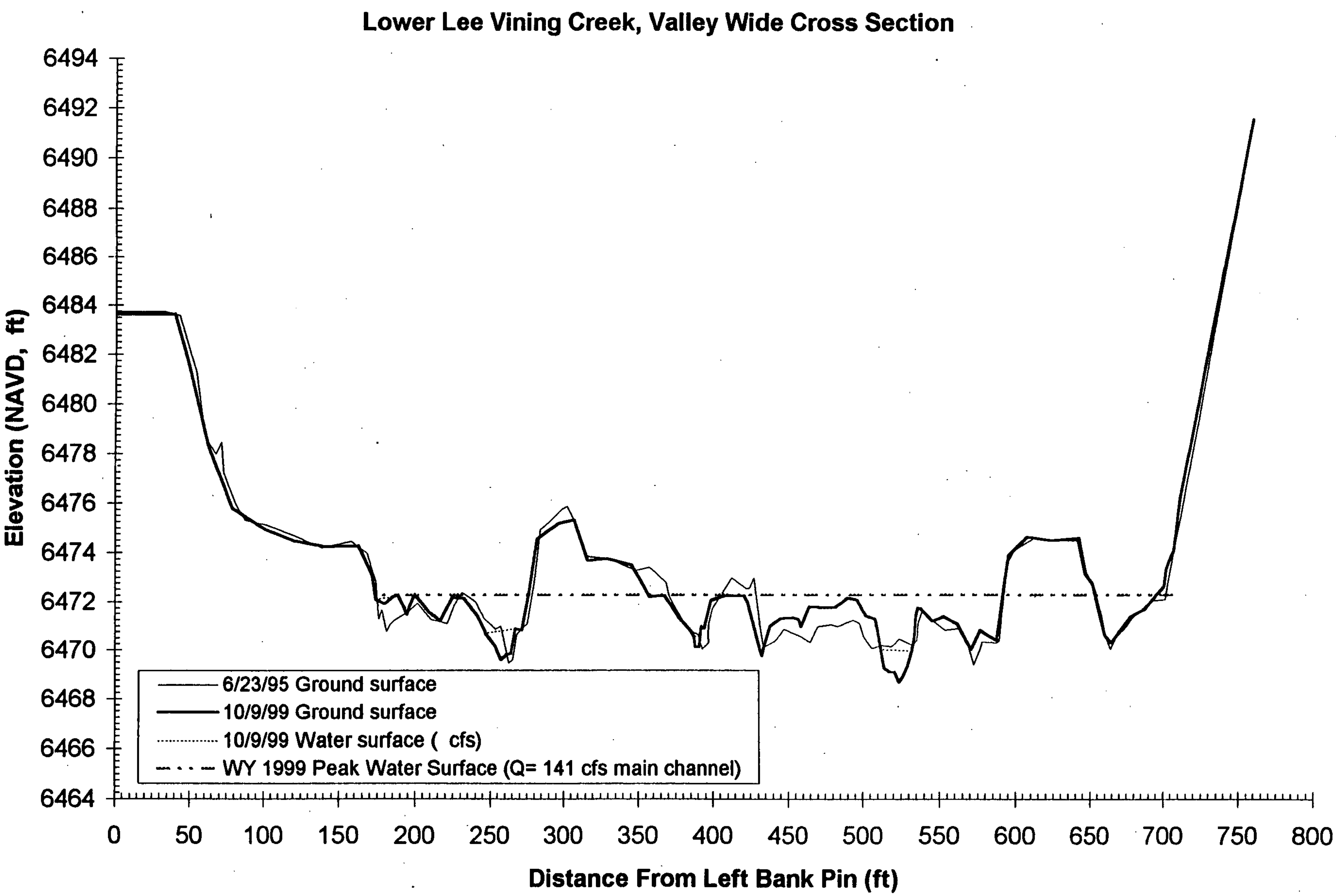

Lower Lee Vining Creek B1 Channel,
1998 Longitudinal Thalweg Profile
Cross Section 00+87
Cross Section 01+15
Elevation (NAVD, ft)
Distance (ft)
9/17/98 Ground surface
9/17/98 Water surface (Q= 25cfs)
6472
6471
6470
6469
6468
6467
6466
6465
6464
6463
6462
6461
6460
6459
6458
6457
6456
6455
6454
6453
6452
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700


Lower Lee Vining Creek B1 Channel,
1999 Longitudinal Thalweg Profile
Cross Section 00+87
Cross Section 01+15
Elevation (NAVD, ft)
Distance (ft)
6472
6471
6470
6469
6468
6467
6466
6465
6464
6463
6462
6461
6460
6459
6458
6457
6456
6455
6454
6453
6452
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
7/23/99 Ground surface
7/23/99 Water surface (Q= 29cfs)
WY1999 Peak Water Surface (Q= 123cfs)

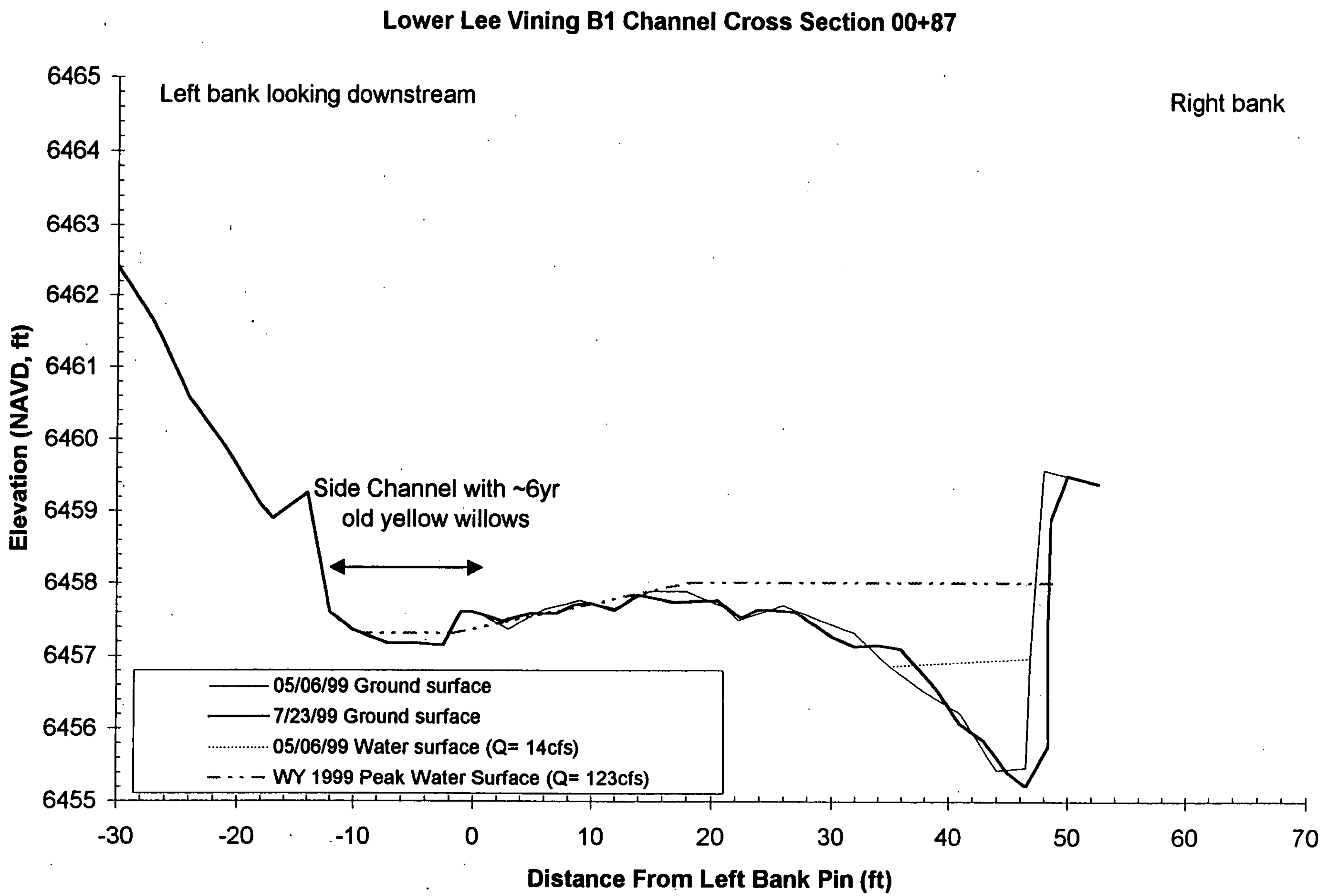
Lower Lee Vining Creek B1 Channel, 1998 Longitudinal Thalweg Profile



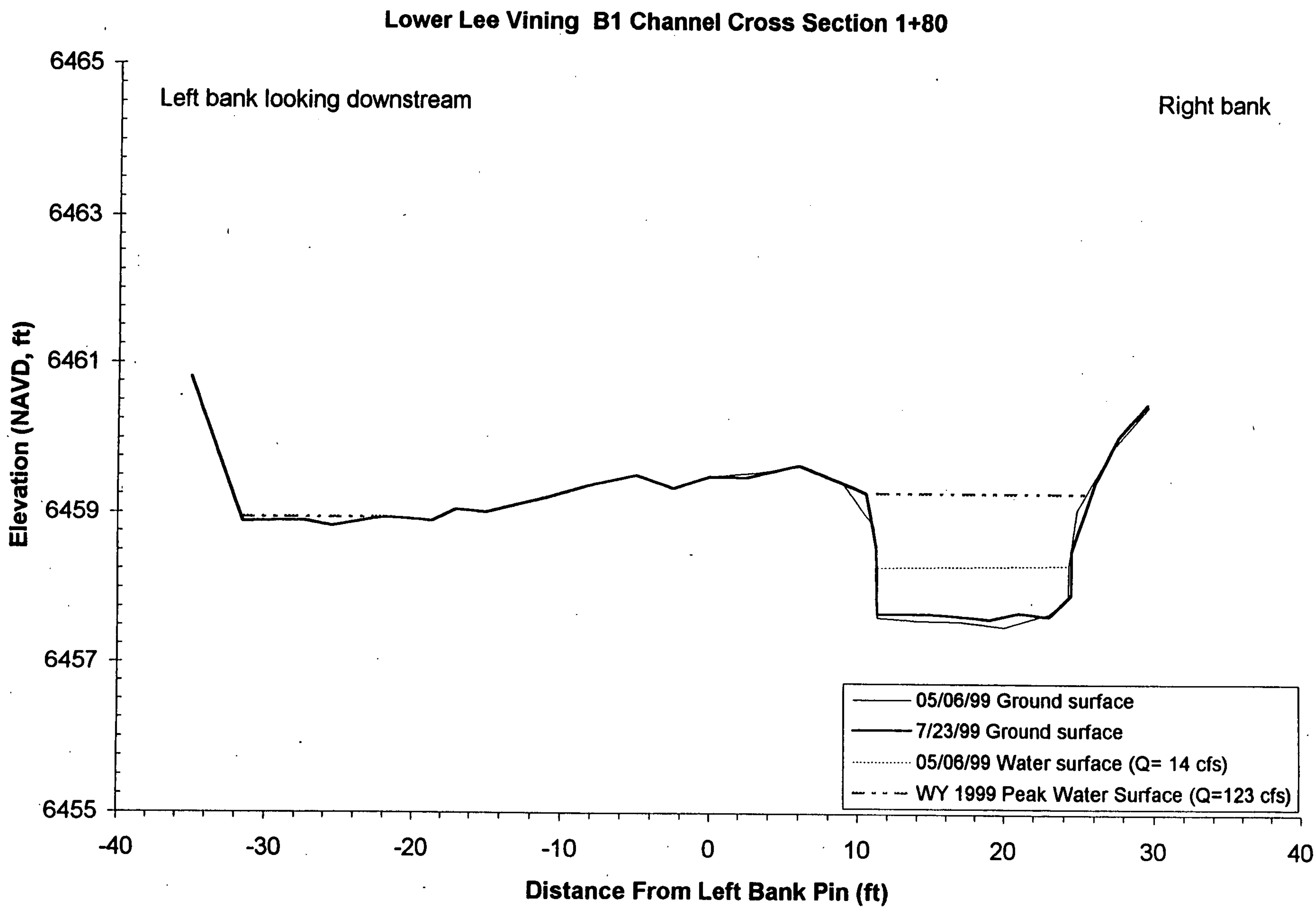

Lower Lee Vining Creek B1 Channel,
1999 Longitudinal Thalweg Profile
y = 0.0225x + 6454.8
R2 = 0.9834
7/23/99 Ground surface
Linear (7/23/99 Ground surface)
Elevation (NAVD, ft)
Distance (ft)
6472
6471
6470
6469
6468
6467
6466
6465
6464
6463
6462
6461
6460
6459
6458
6457
6456
6455
6454
6453
6452
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700



Lower Lee Vining Creek, Valley Wide Cross Section
Elevation (NAVD, ft)
6494
6492
6490
6488
6486
6484
6482
6480
6478
6476
6474
6472
6470
6468
6466
6464
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Distance From Left Bank Pin (ft)
6/23/95 Ground surface
10/9/99 Ground surface
10/9/99 Water surface (cfs)
WY 1999 Peak Water Surface (Q= 141 cfs main channel)

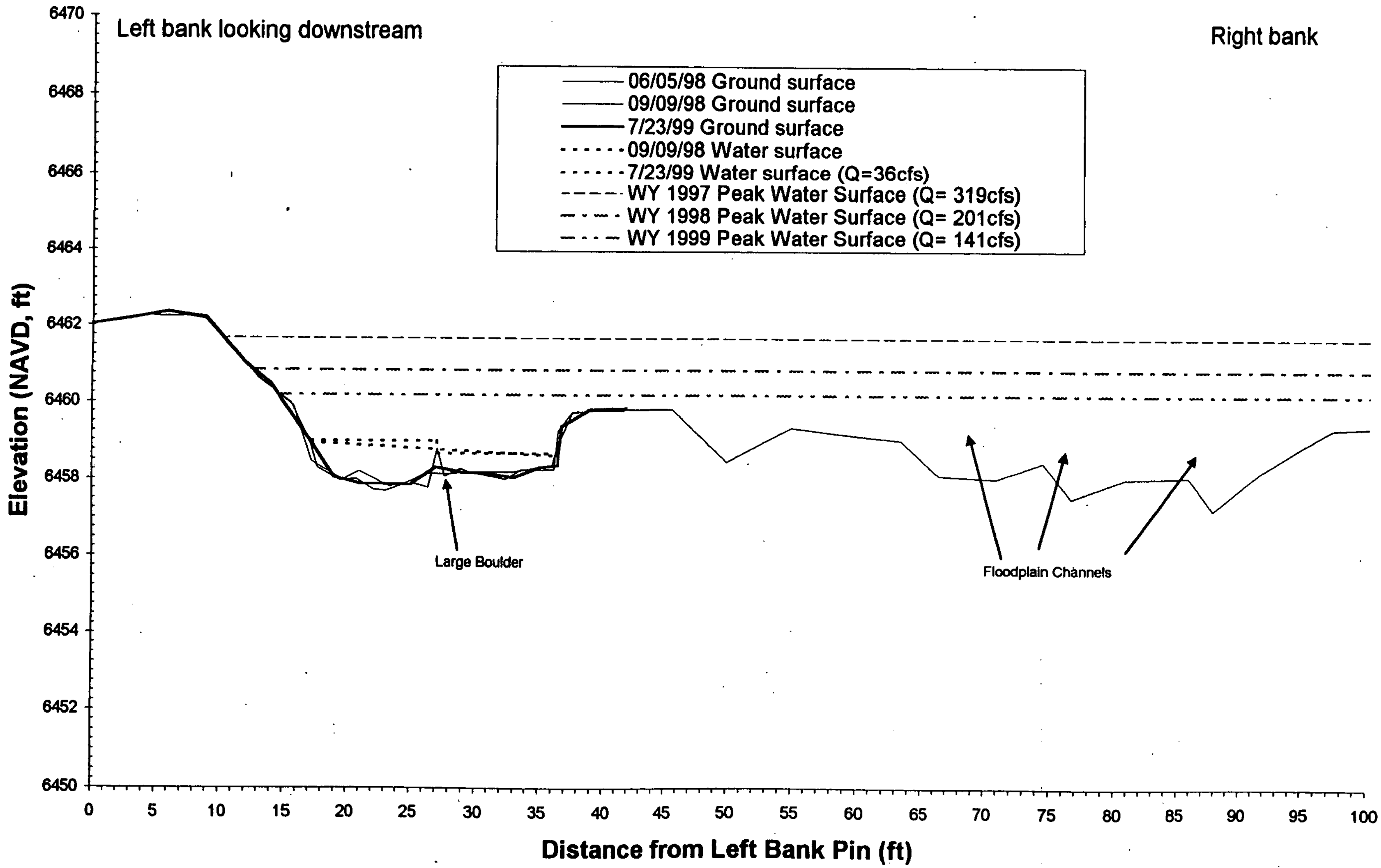


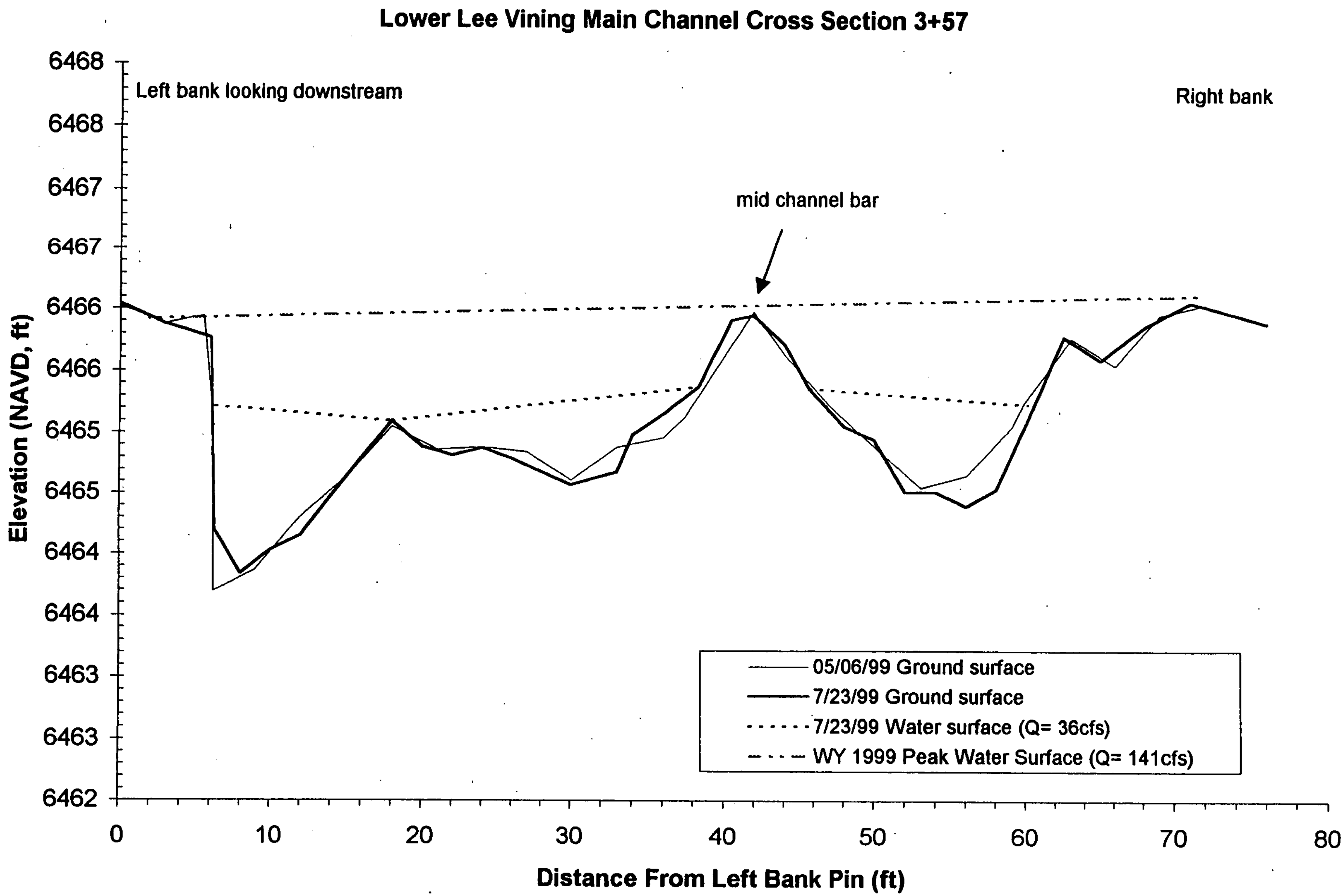
Lower Lee Vining B1 Channel Cross Section 00+87
Left bank looking downstream
Right bank
Side Channel with ~6yr old yellow willows
Elevation (NAVD, ft)
6465
6464
6463
6462
6461
6460
6459
6458
6457
6456
6455
-30
-20
-10
0
10
20
30
40
50
60
70
Distance From Left Bank Pin (ft)
05/06/99 Ground surface
7/23/99 Ground surface
05/06/99 Water surface (Q= 14cfs)
WY 1999 Peak Water Surface (Q= 123cfs)



Lower Lee Vining B1 Channel Cross Section 1+80
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6465
6463
6461
6459
6457
6455
-40
-30
-20
-10
0
10
20
30
40
Distance From Left Bank Pin (ft)
05/06/99 Ground surface
7/23/99 Ground surface
05/06/99 Water surface (Q= 14 cfs)
WY 1999 Peak Water Surface (Q=123 cfs)

Lower Lee Vining Creek Main Channel Cross Section 01+15





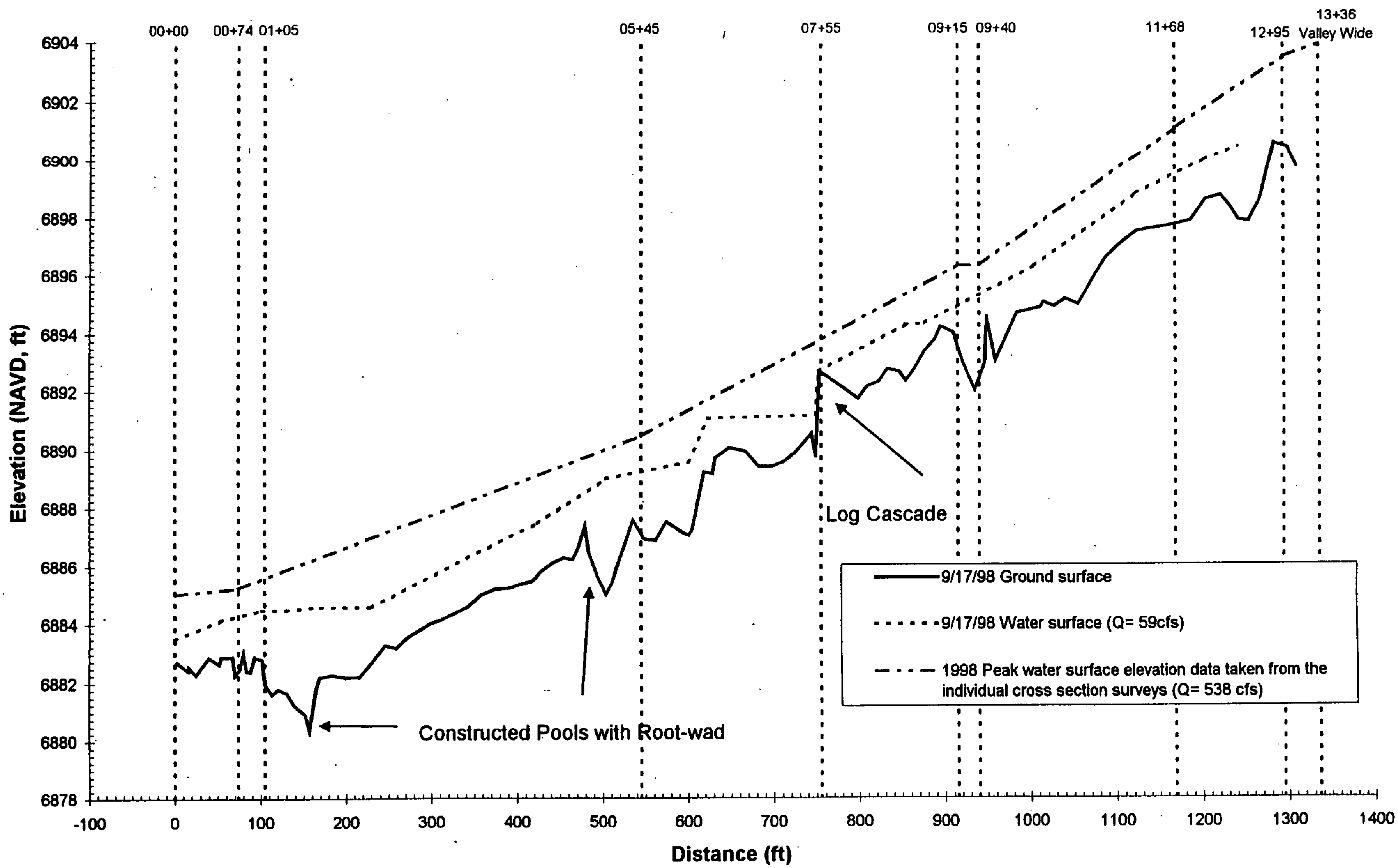
Lower Lee Vining Main Channel Cross Section 3+57
Left bank looking downstream
Right bank
mid channel bar
Elevation (NAVD, ft)
6468
6468
6467
6467
6466
6466
6465
6465
6464
6464
6463
6463
6462
0
10
20
30
40
50
60
70
80
Distance From Left Bank Pin (ft)
05/06/99 Ground surface
7/23/99 Ground surface
7/23/99 Water surface (Q= 36cfs)
WY 1999 Peak Water Surface (Q= 141cfs)

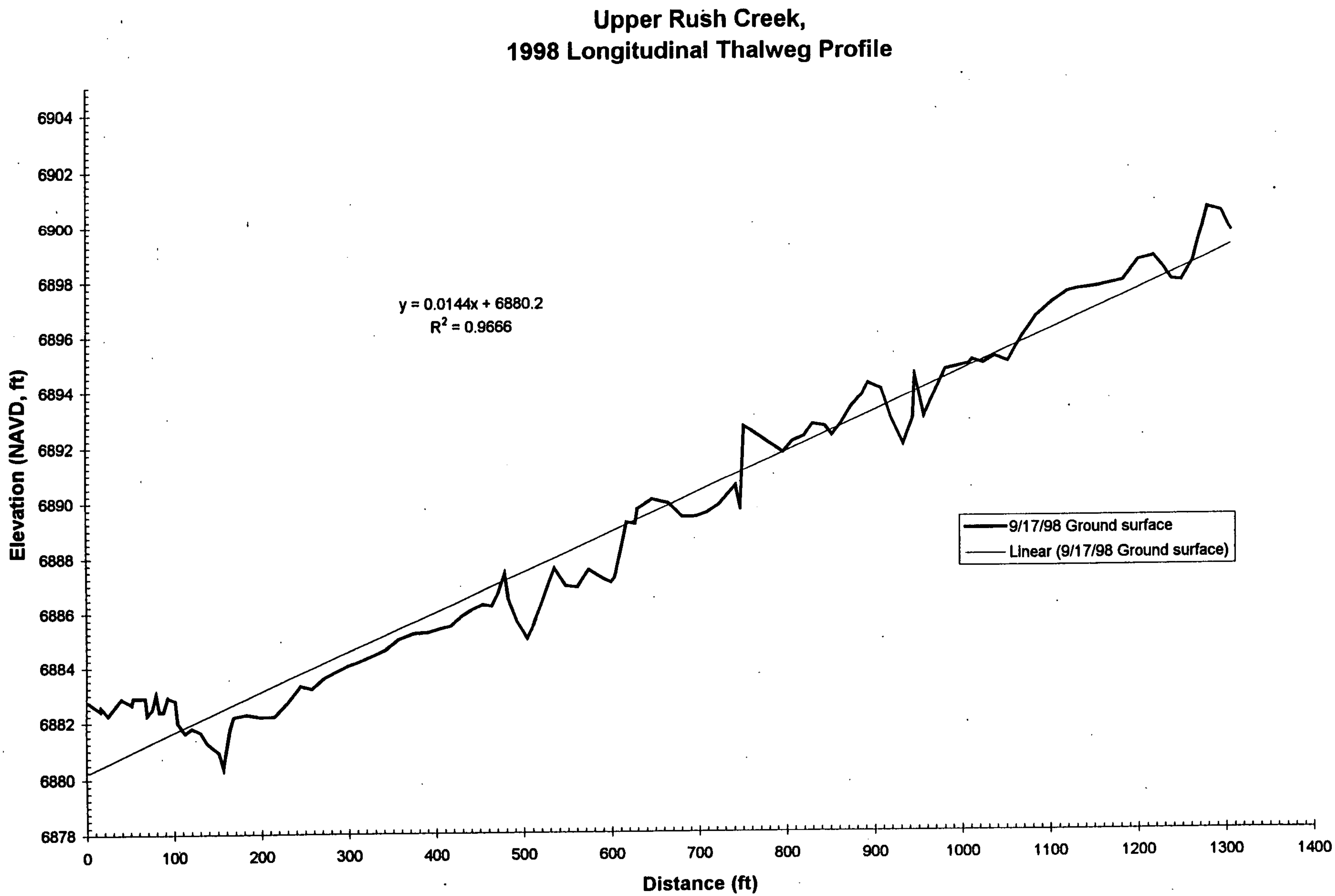
Rush Creek Cross Section and Reference Pin Summary Sheet

Site	Current Cross Section Label	Old Cross Section Label	Upper Left Bank Pin Elev. (ft)	Lower Left Bank Pin Elev. (ft)	Lower Right Bank Pin Elev. (ft)	Upper Right Bank Pin Elev. (ft)	Total Cross Section Length (ft)	Angle from LB pin to RB pin Degrees	Cross Section Intersection with 1997 Long Profile (ft)	1997 Long Profile Intersection with Cross Section (ft)	Fieldbook # and Page #'s	Notes
Lower	BM1		6491.407									SITE BENCHMARK
Lower	00+86	E		6490.07	6486.82		127.50	80	58.5	85.8	Fieldbook 3, page 138-139	
Lower	03+30	F		6488.67	6488.25		52.30	10	?	~330.2	Fieldbook 2, page 114-117	
Lower	04+08	D	6489.62	6489.22	6492.06		229.40	93	154.4	408.2	Fieldbook 3, page 130-135	there is another pin past the "upper" left bank pin, Top of pin elev.=6490.97 ft
Lower	05+49	none		6489.45	6489.55		58.50	25		~549.2	Fieldbook 2, page 134-139	
Lower	07+25	C	6492.47	6492.45	6491.26		154.50	?*	90.4	725.3	Fieldbook 3, page 126-129	
Lower	07+70	B	6494.13	6493.30	6491.27		155.50	82	83.0	770.3	Fieldbook 3, page 122-125	
Lower	10+10	A	6497.92	6492.10	6494.89		188.00	15	23.20	1009.5	Fieldbook 3, page 116-121	
Lower	-9+82	H		6477.75	6476.04		94.70	42	none	none	Fieldbook 2, page 124-133	Bed load mobility cross section
Lower	-5+07	D 7/98		6483.70	6481.26		119.50	80			Fieldbook 4, page 82-93	
Lower	-1+57	E 7/98		6484.34	6483.21		72.50	184			Fieldbook 4, page 82-93	
Upper	BM1		6896.181									SITE BENCHMRK
Upper	0+00	D U.S. 395		6885.45	6887.86		76.00				Fieldbook 5, page 138-143	
Upper	0+74	A U.S. 395		6887.99	6889.02		63.30	145			Fieldbook 5, page 134-137	
Upper	1+05	E U.S. 395		6888.14	6886.43		56.60				Fieldbook 5, page 144-147	
Upper	5+45	B U.S. 395		6891.70	6892.13	6896.45	166.70	192			Fieldbook 5, page 152-155	The upper right bank pin is also the upper right bank pin for cross section 07+55
Upper	7+55	none		6897.36	6896.45	6896.45	155.80				Fieldbook 7, page 2-9	
Upper	9+15	G U.S. 395		6896.99	6897.17		88.90				Fieldbook 6B, page 5-10	
Upper	9+40	none		6896.99	6897.17		51.90				Fieldbook 10, page 113-114	This cross section shares the same left bank and right bank as cross section 09+15
Upper	11+68	F U.S. 395		6900.47	6900.37		29.30				Fieldbook 6B, page 1-4	
Upper	12+95	C U.S. 395		6903.49	6904.40		47.00	167			Fieldbook 5, page 156-159	
Upper	13+36	none	6907.18	6903.92	6905.26	6905.16	324.80				Fieldbook 7, page 12-25	Valley Wide XS
10-Chan						6496.09					Ref Pin on RB hillslope above gravel bar	
County Rd	BM1		6434.142									SITE BENCHMRK
County Rd	02+17	none	6429.19	6428.15	6428.71	6430.67	224.20				Fieldbook 13, page 39-46	
County Rd	06+85	none	6432.81	6432.62	6432.32		171.00				Fieldbook 11, page 118-125	
County Rd	08+30	none	6440.09	6433.76		6437.26	285.90				Fieldbook 13, page 29-38	
County Rd	11+59	none		6439.11	6436.17		239.50				Fieldbook 11, page 136-145	
County Rd	15+19	none	6443.06	6443.41	6441.16	6446.76	318.50				Fieldbook 11, page 126-135	

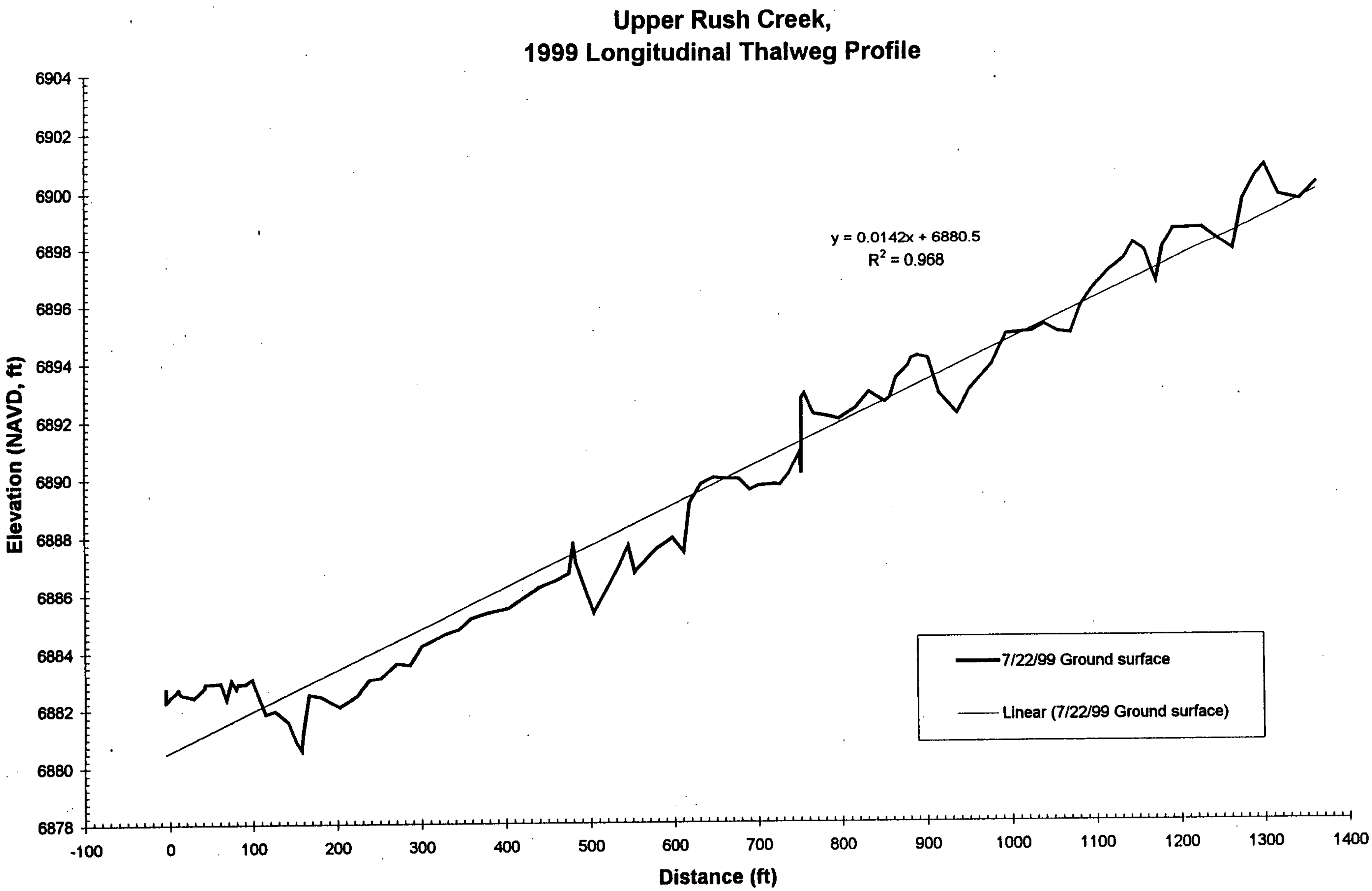
Cross sections do not use the same benchmarks. See cross section sheets or notebooks.

Upper Rush Creek, 1998 Longitudinal Thalweg Profile



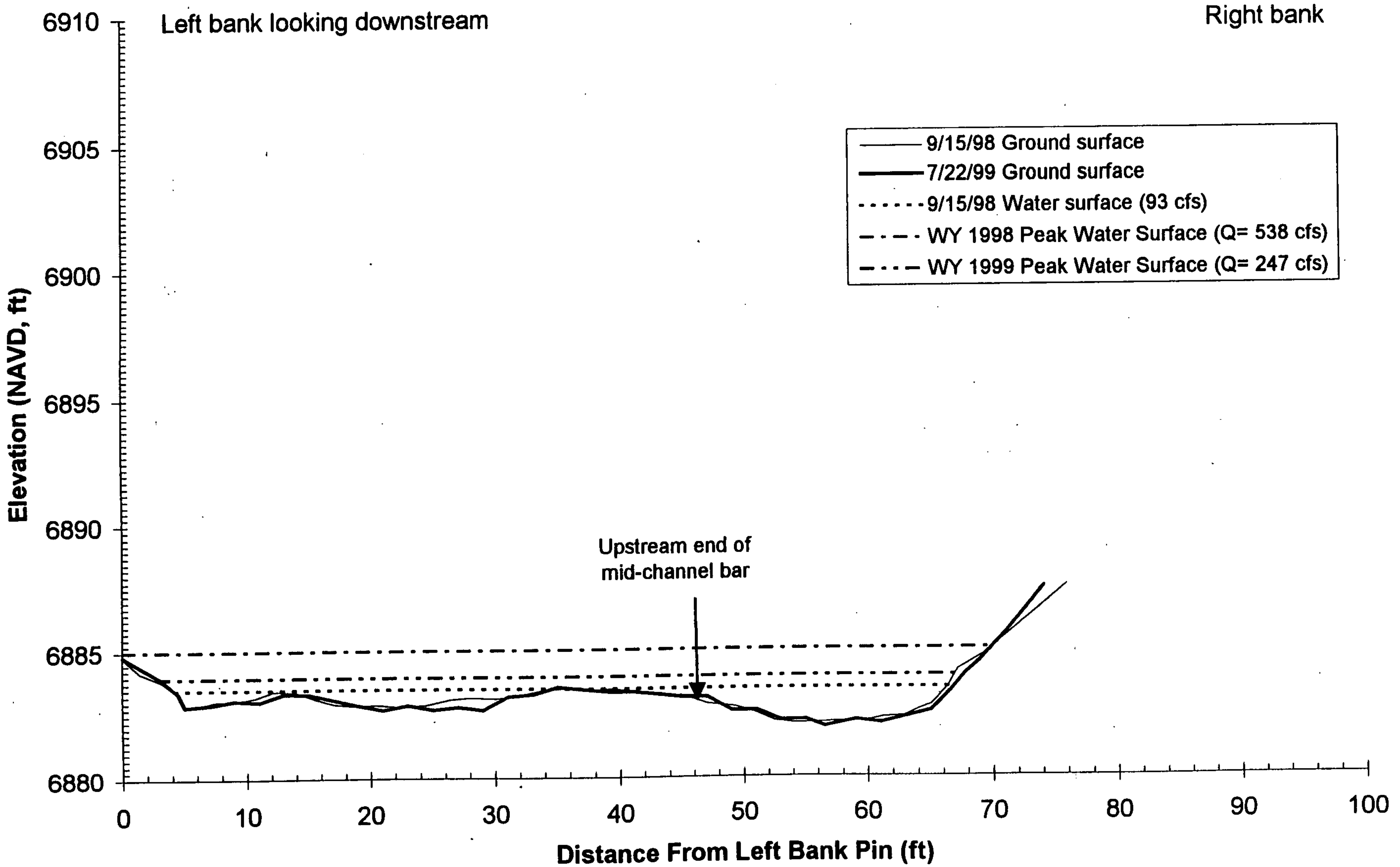


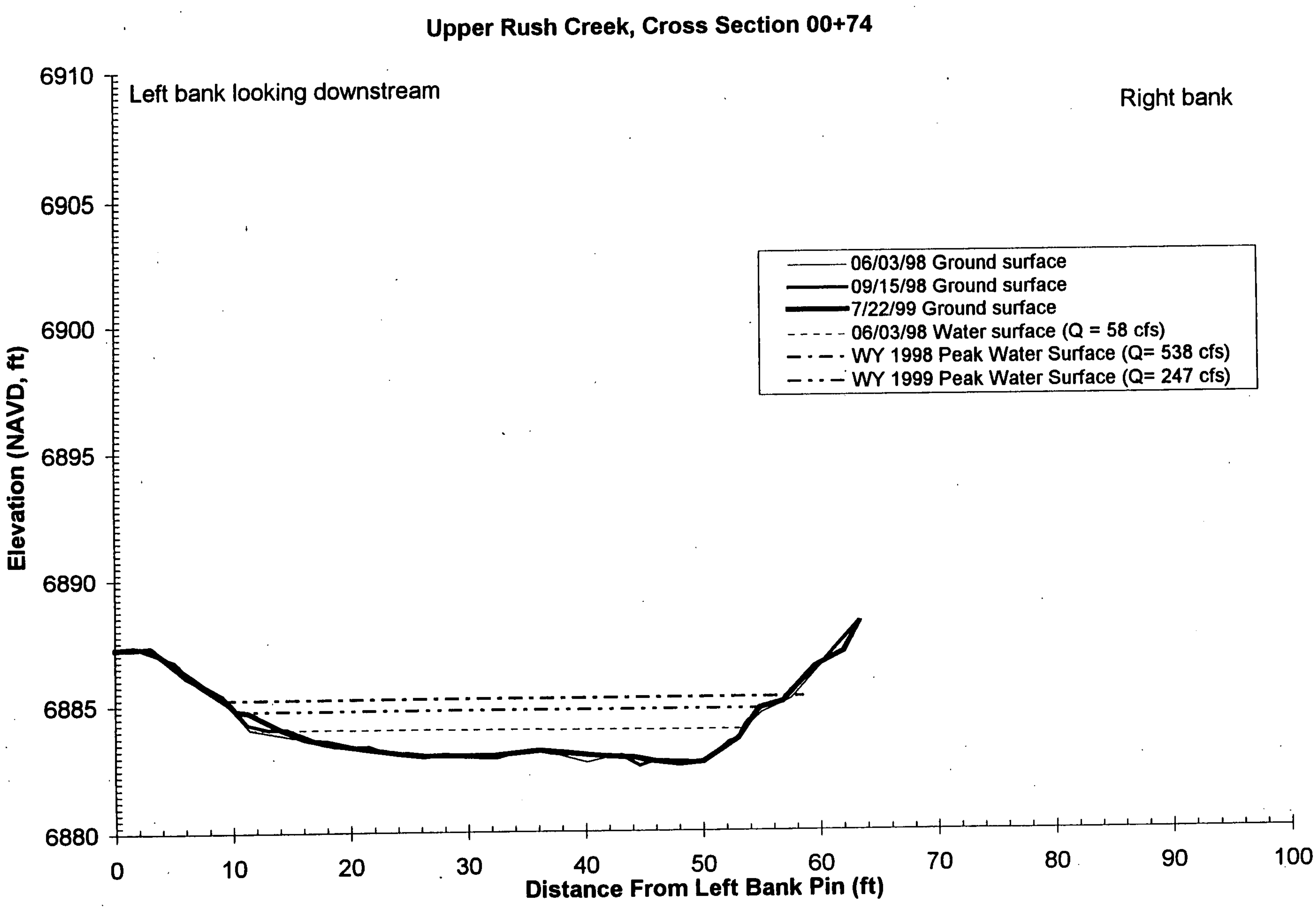
Upper Rush Creek,
1998 Longitudinal Thalweg Profile
y = 0.0144x + 6880.2
R^2 = 0.9666
Elevation (NAVD, ft)
6878
6880
6882
6884
6886
6888
6890
6892
6894
6896
6898
6900
6902
6904
Distance (ft)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
9/17/98 Ground surface
Linear (9/17/98 Ground surface)



Upper Rush Creek,
1999 Longitudinal Thalweg Profile
y = 0.0142x + 6880.5
R^2 = 0.968
7/22/99 Ground surface
Linear (7/22/99 Ground surface)
Elevation (NAVD, ft)
6904
6902
6900
6898
6896
6894
6892
6890
6888
6886
6884
6882
6880
6878
Distance (ft)
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400

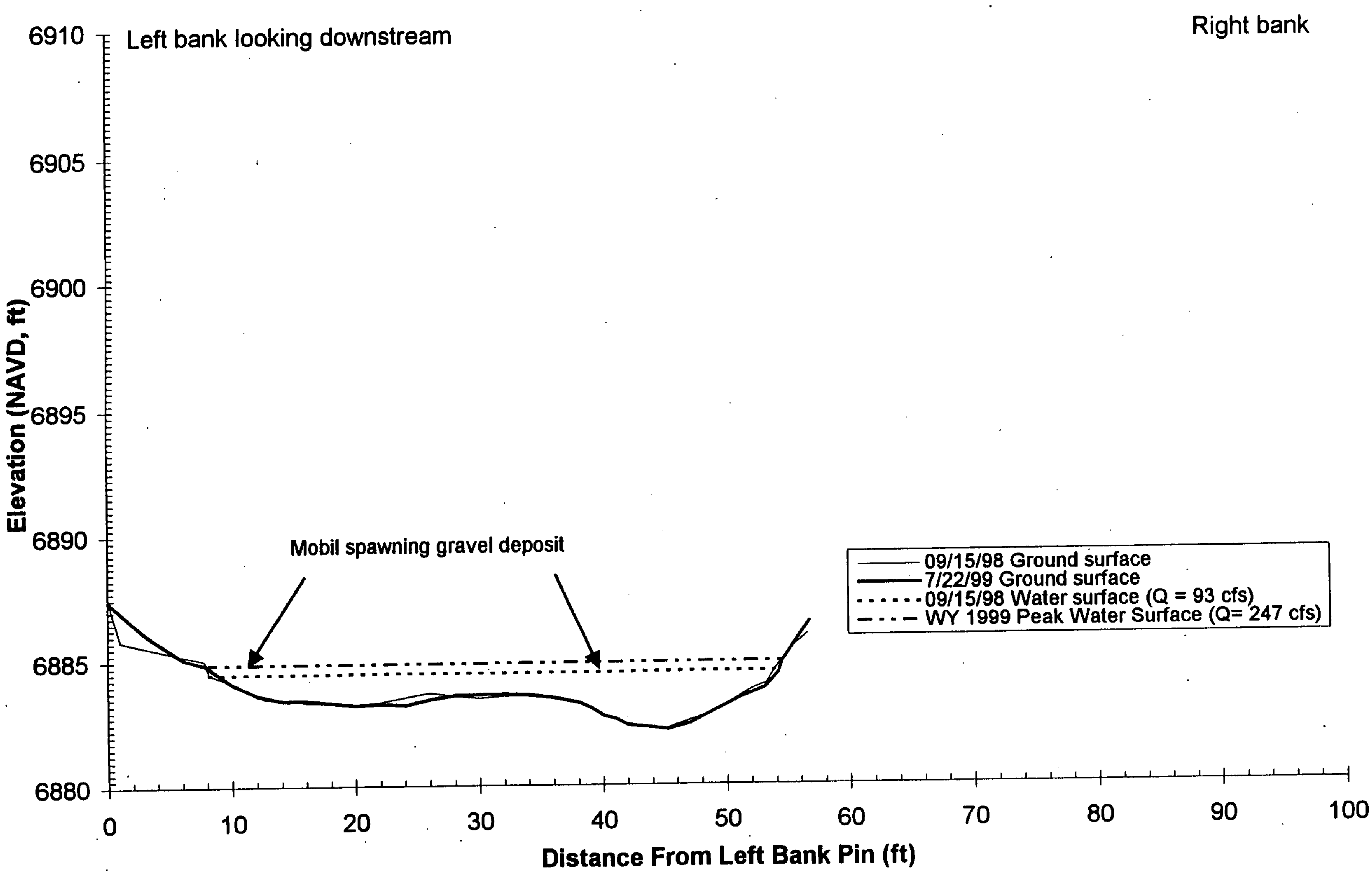
Upper Rush Creek, Cross Section 00+00

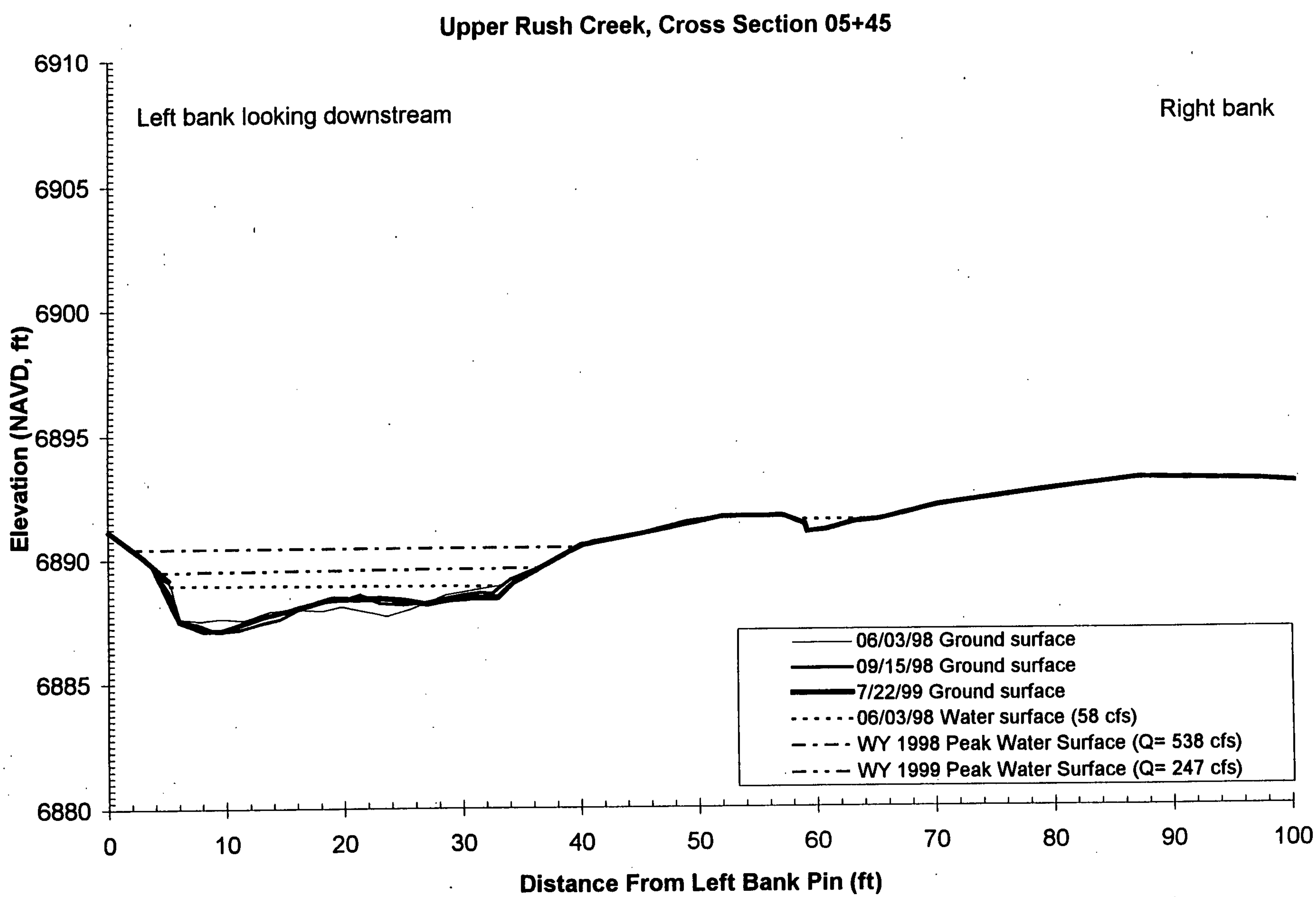


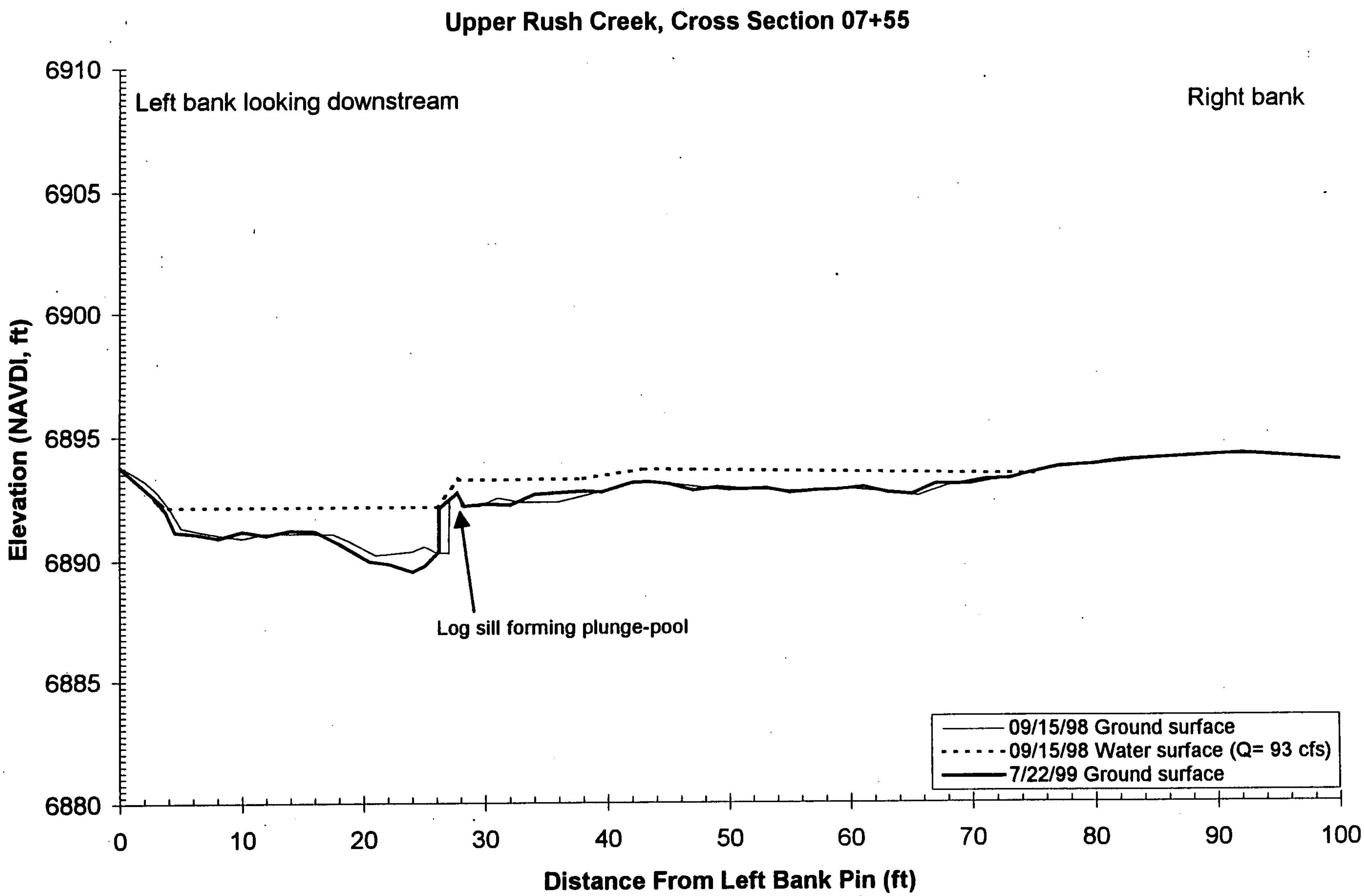


Upper Rush Creek, Cross Section 00+74
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
Distance From Left Bank Pin (ft)
6910
6905
6900
6895
6890
6885
6880
0
10
20
30
40
50
60
70
80
90
100
06/03/98 Ground surface
09/15/98 Ground surface
7/22/99 Ground surface
06/03/98 Water surface (Q = 58 cfs)
WY 1998 Peak Water Surface (Q= 538 cfs)
WY 1999 Peak Water Surface (Q= 247 cfs)

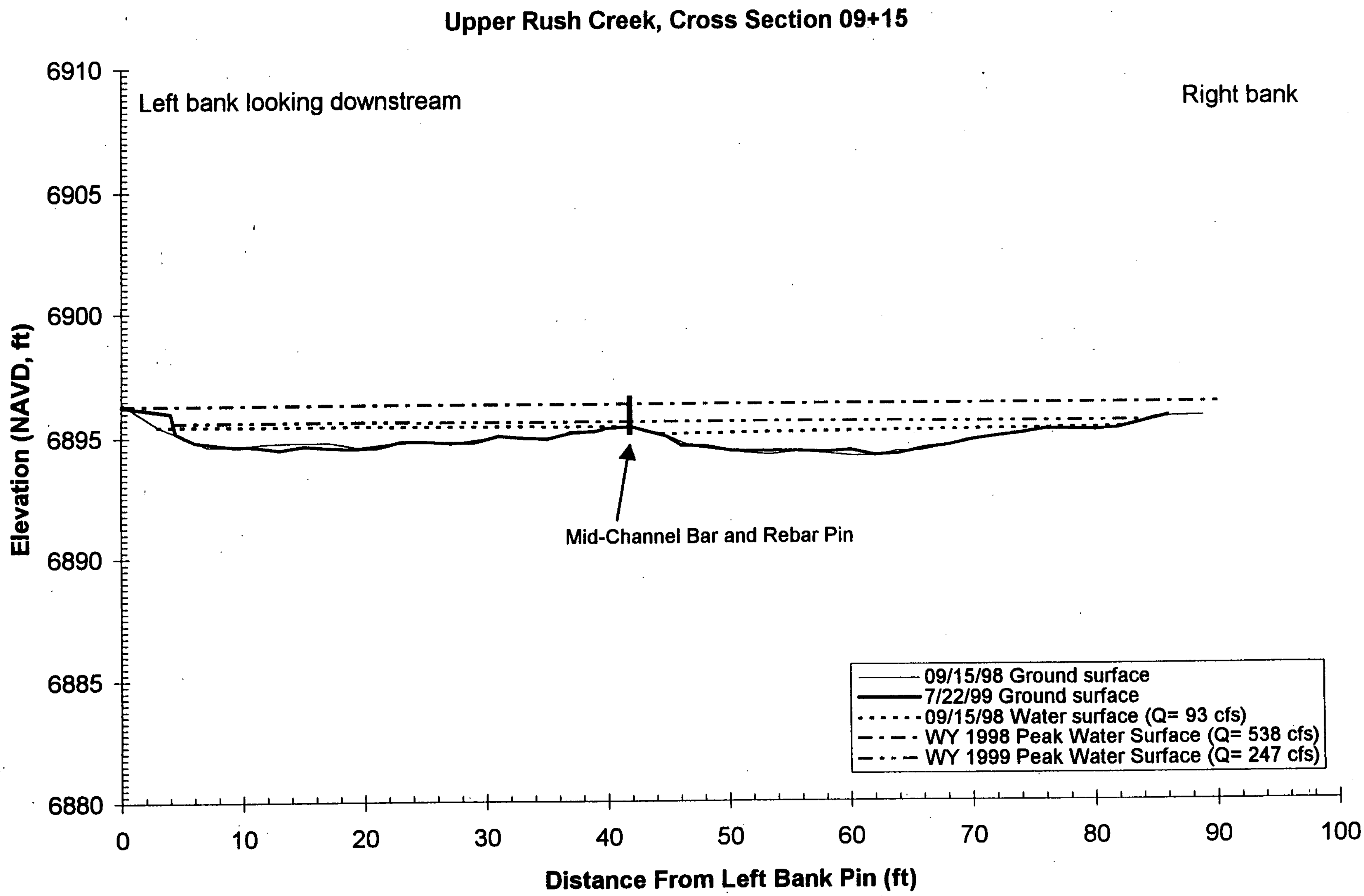
Upper Rush Creek, Cross Section 01+05

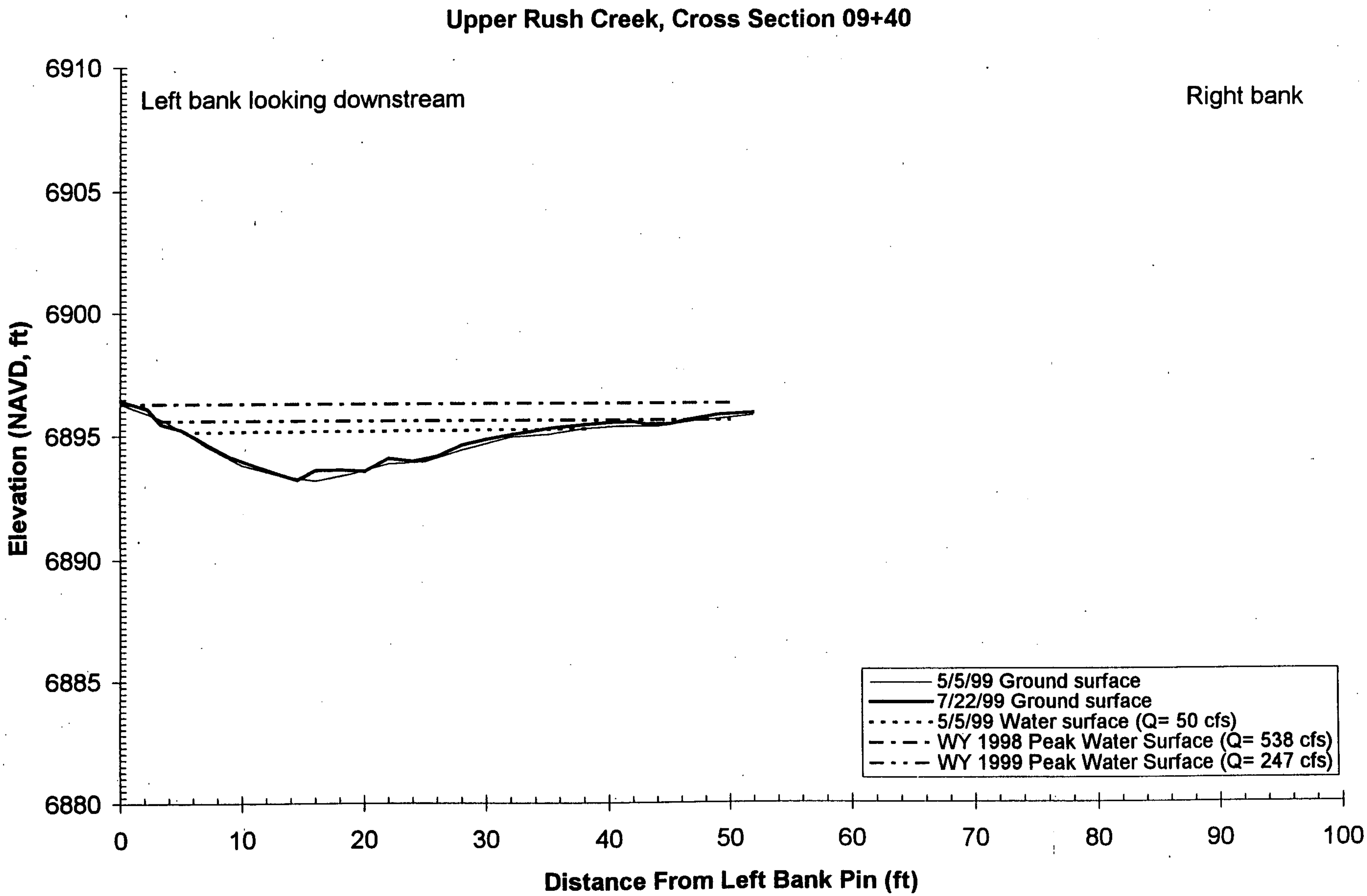


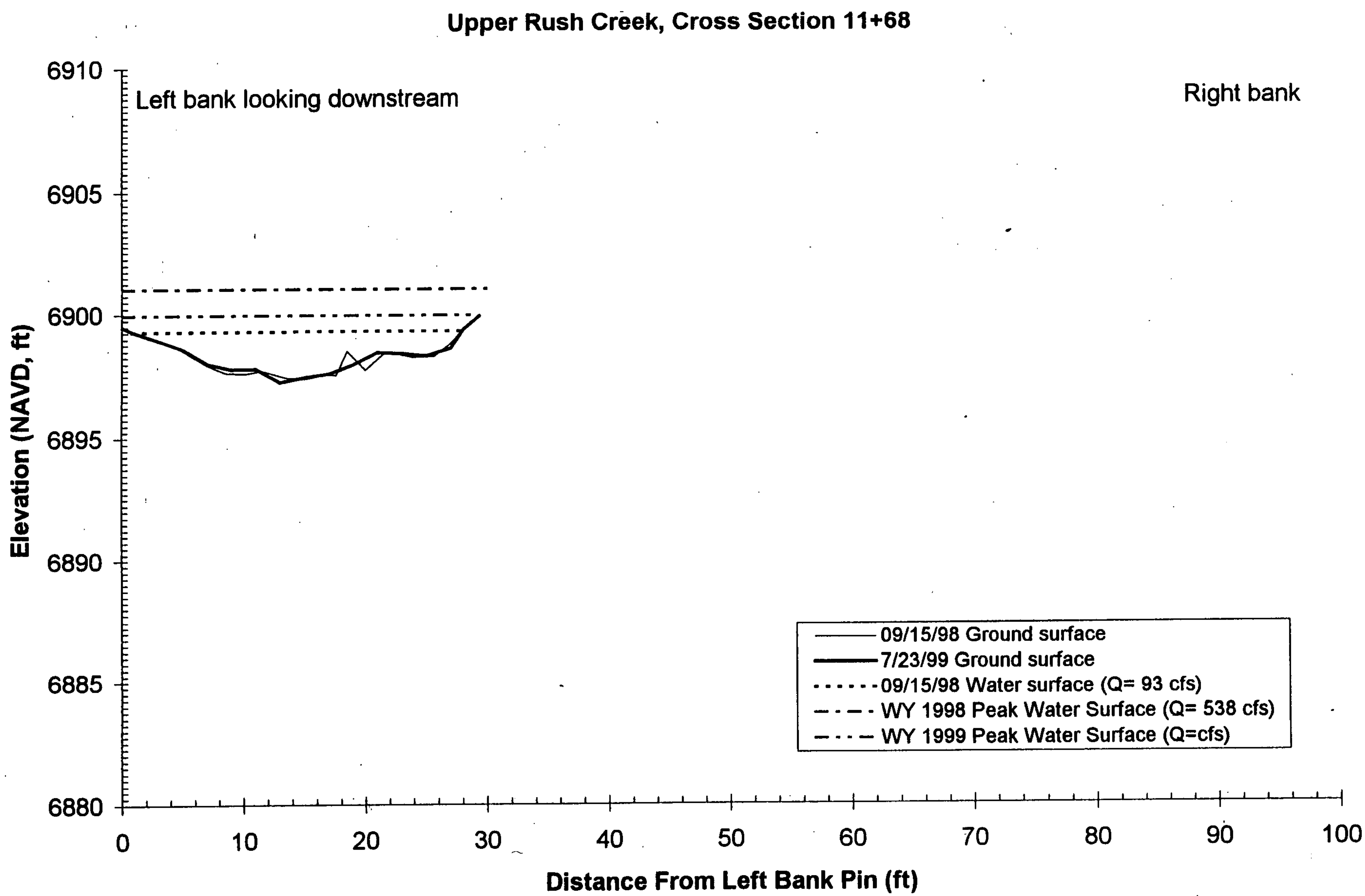

Upper Rush Creek, Cross Section 05+45
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6910
6905
6900
6895
6890
6885
6880
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)
06/03/98 Ground surface
09/15/98 Ground surface
7/22/99 Ground surface
06/03/98 Water surface (58 cfs)
WY 1998 Peak Water Surface (Q= 538 cfs)
WY 1999 Peak Water Surface (Q= 247 cfs)



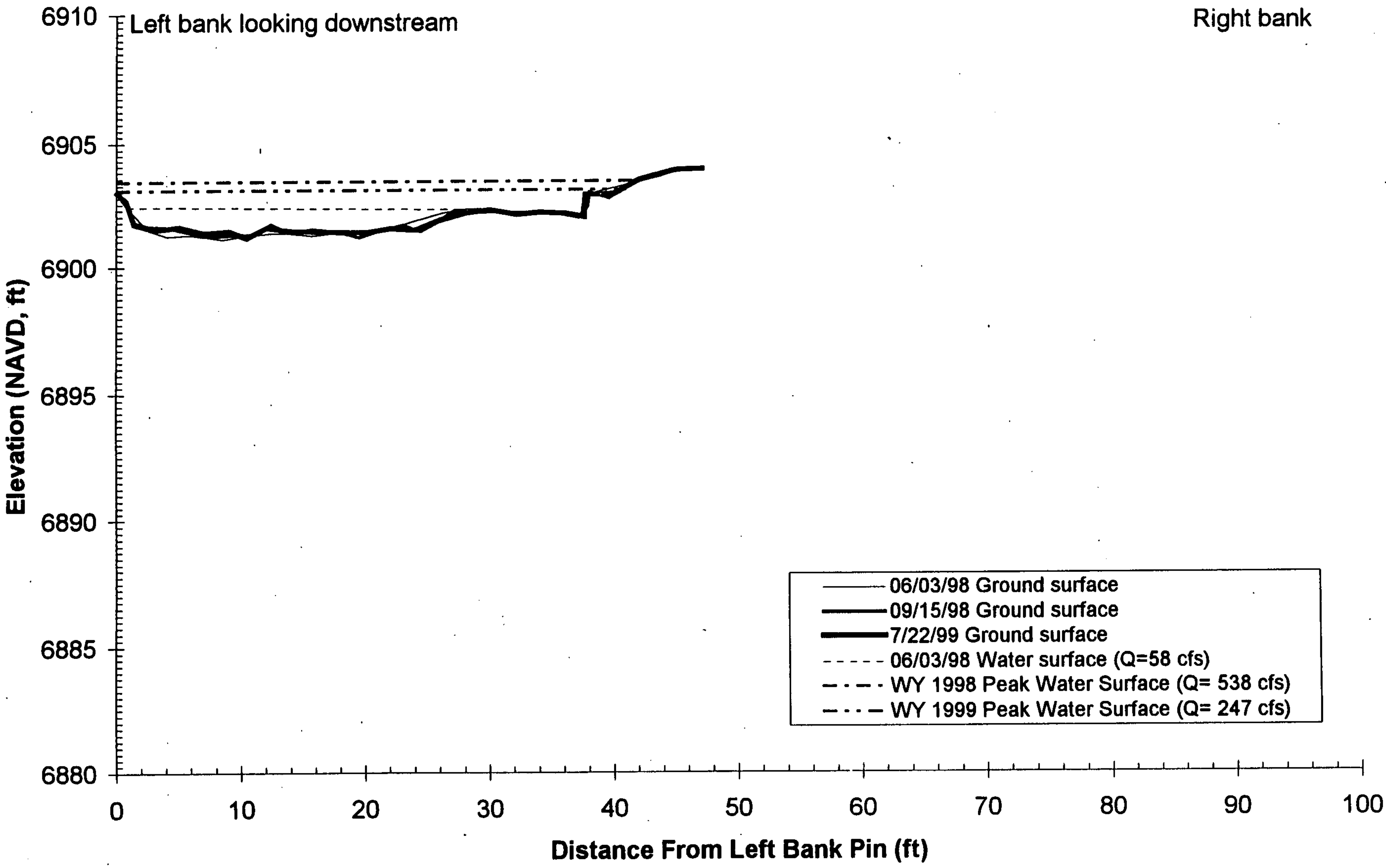
Upper Rush Creek, Cross Section 07+55
Left bank looking downstream
Right bank
Elevation (NAVDI, ft)
6910
6905
6900
6895
6890
6885
6880
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)
Log sill forming plunge-pool
09/15/98 Ground surface
09/15/98 Water surface (Q= 93 cfs)
7/22/99 Ground surface


Upper Rush Creek, Cross Section 09+15
Left bank looking downstream
Right bank
6910
6905
6900
6895
6890
6885
6880
Elevation (NAVD, ft)
Mid-Channel Bar and Rebar Pin
09/15/98 Ground surface
7/22/99 Ground surface
09/15/98 Water surface (Q= 93 cfs)
WY 1998 Peak Water Surface (Q= 538 cfs)
WY 1999 Peak Water Surface (Q= 247 cfs)
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)

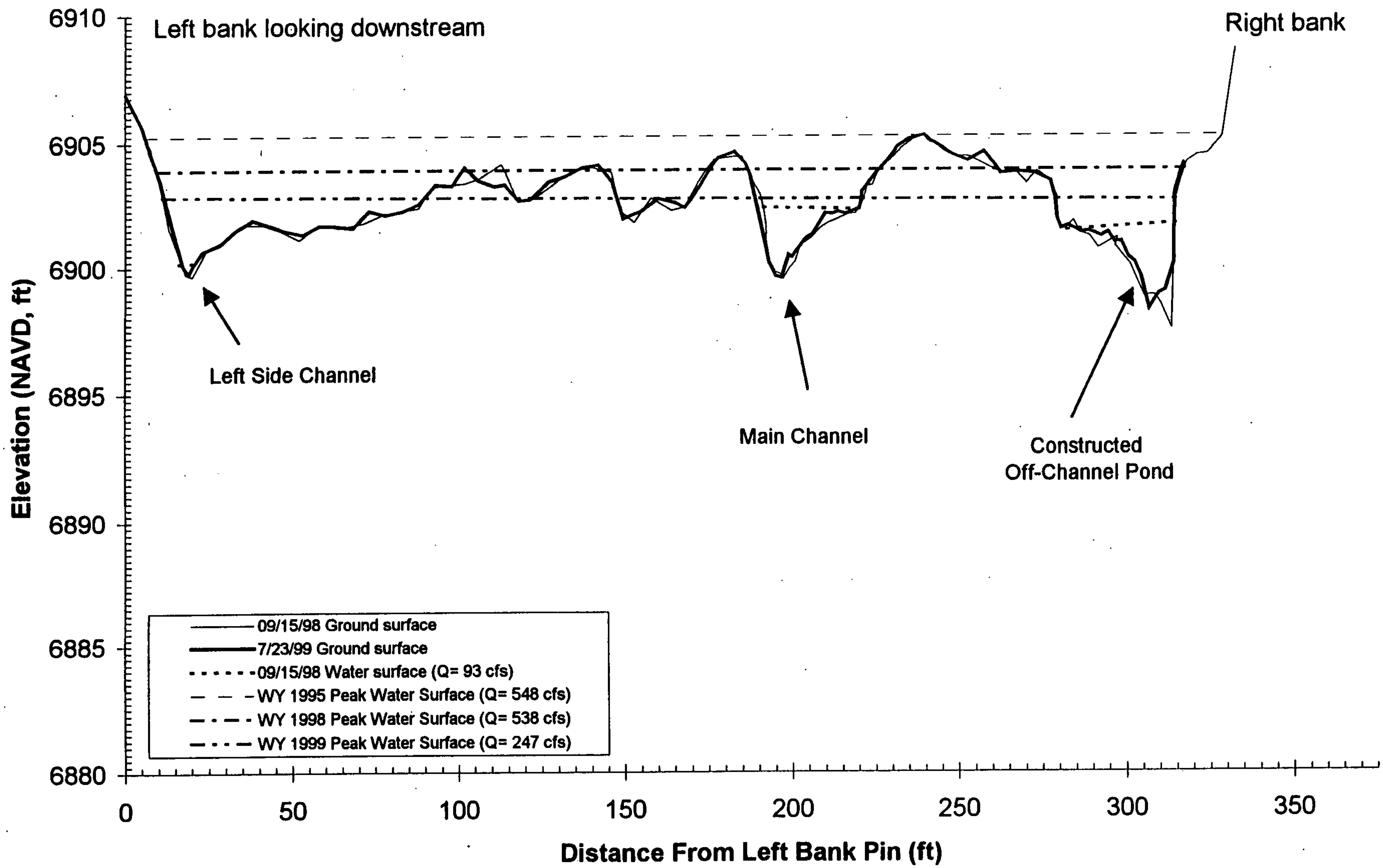

Upper Rush Creek, Cross Section 09+40
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6910
6905
6900
6895
6890
6885
6880
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)
5/5/99 Ground surface
7/22/99 Ground surface
5/5/99 Water surface (Q= 50 cfs)
WY 1998 Peak Water Surface (Q= 538 cfs)
WY 1999 Peak Water Surface (Q= 247 cfs)


Upper Rush Creek, Cross Section 11+68
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6910
6905
6900
6895
6890
6885
6880
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)
09/15/98 Ground surface
7/23/99 Ground surface
09/15/98 Water surface (Q= 93 cfs)
WY 1998 Peak Water Surface (Q= 538 cfs)
WY 1999 Peak Water Surface (Q=cfs)

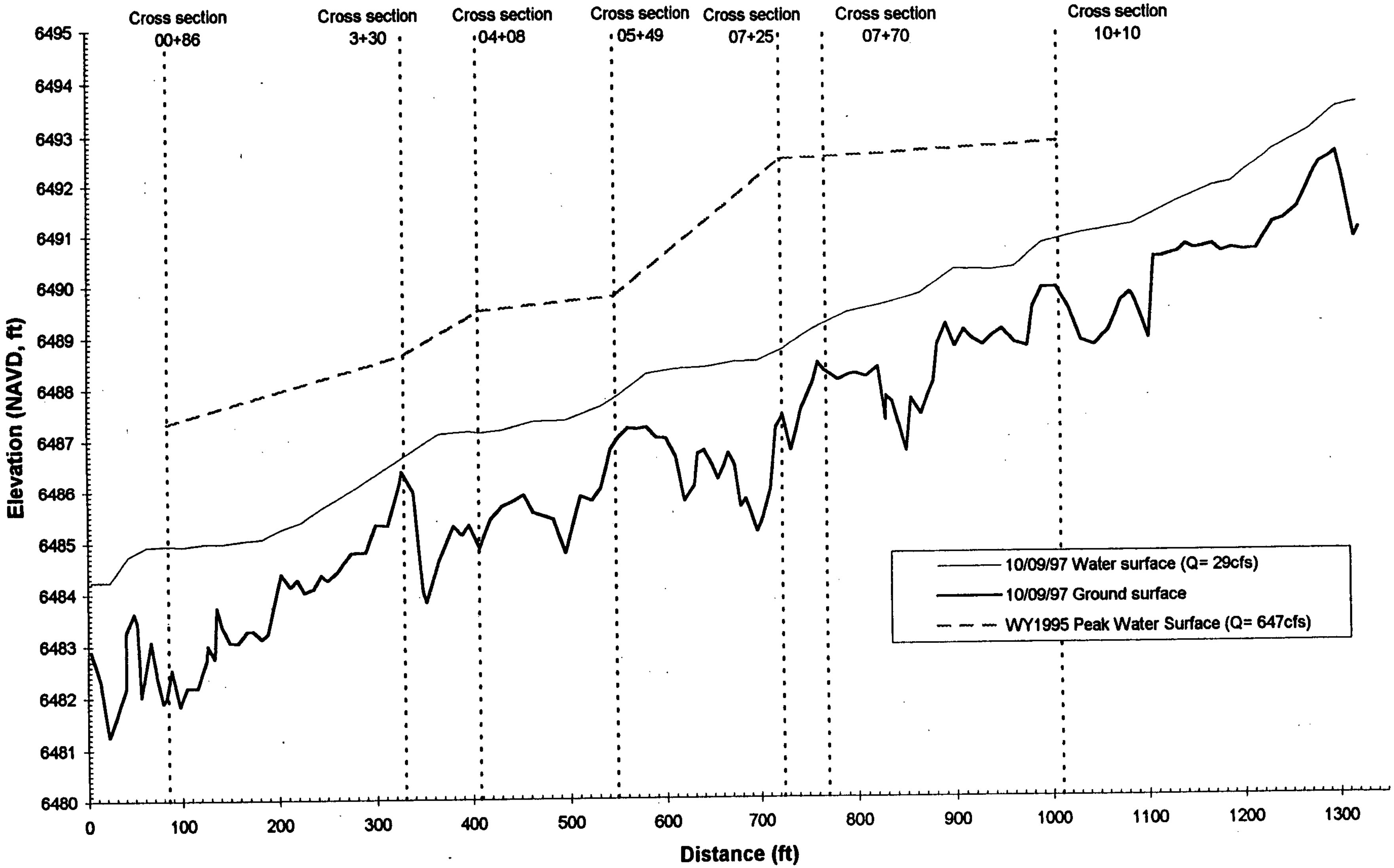
Upper Rush Creek, Cross Section 12+95



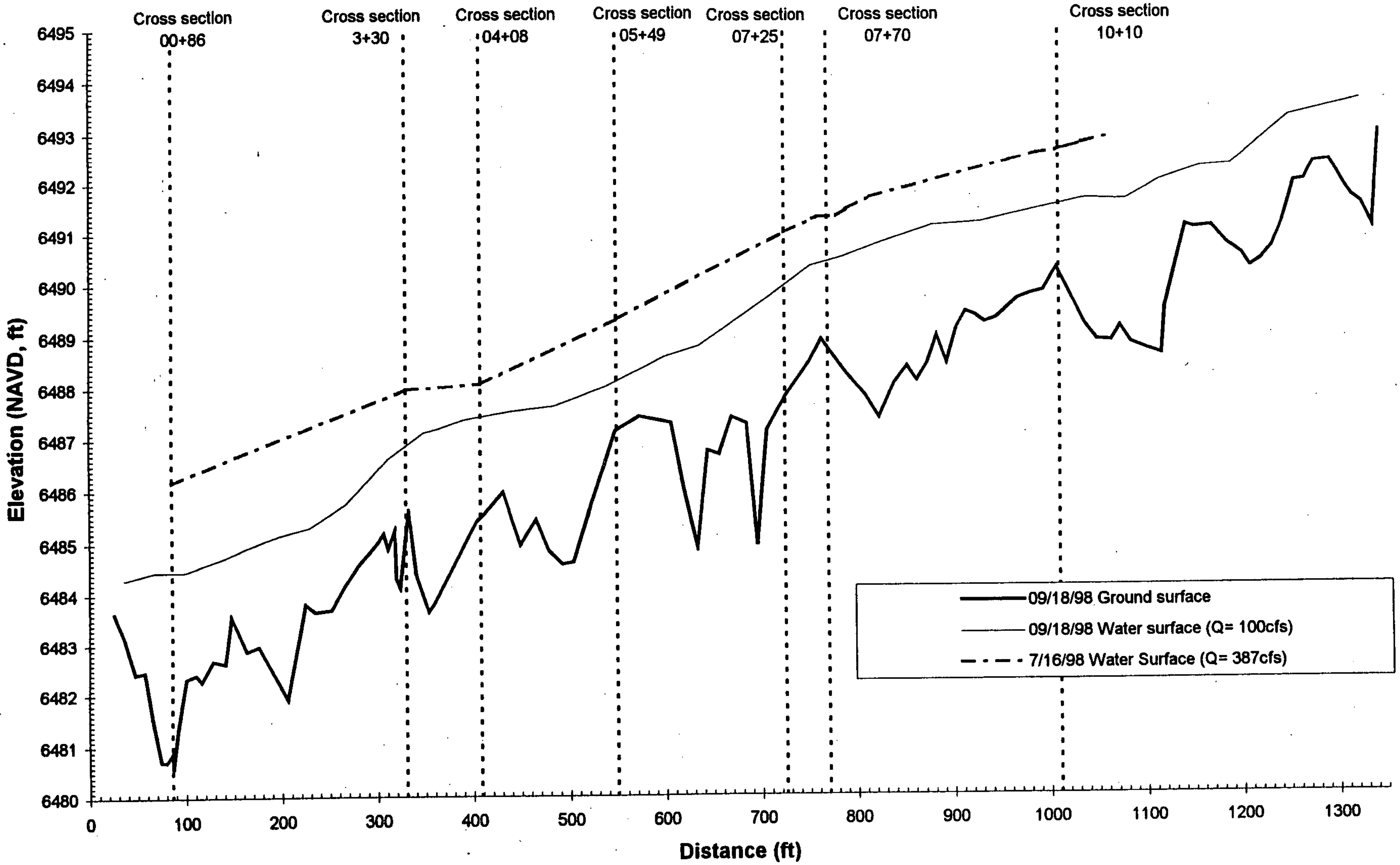
Upper Rush Creek, Valley-Wide Cross Section 13+36



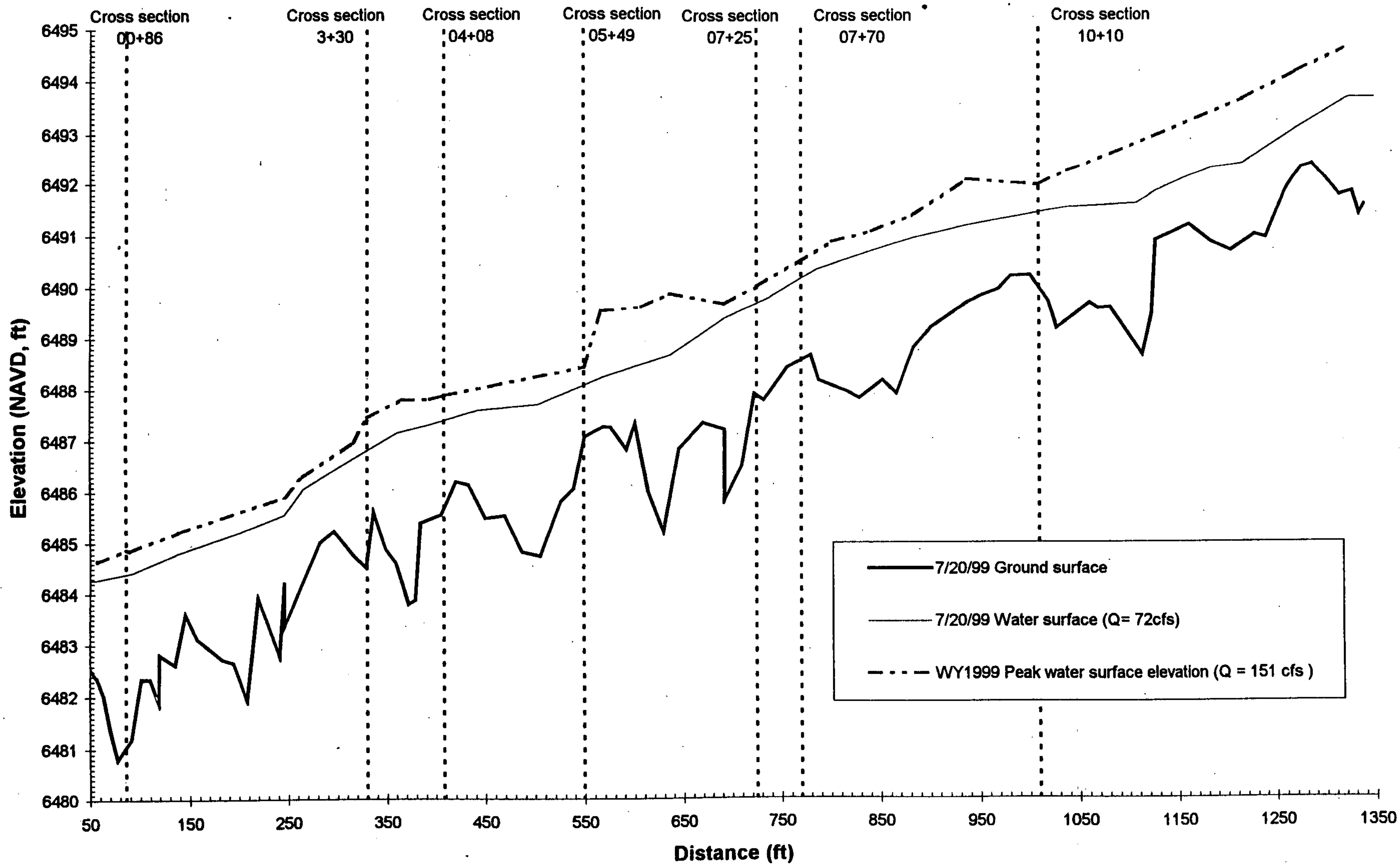
Lower Rush Creek Main Channel, 1997 Longitudinal Thalweg Profile

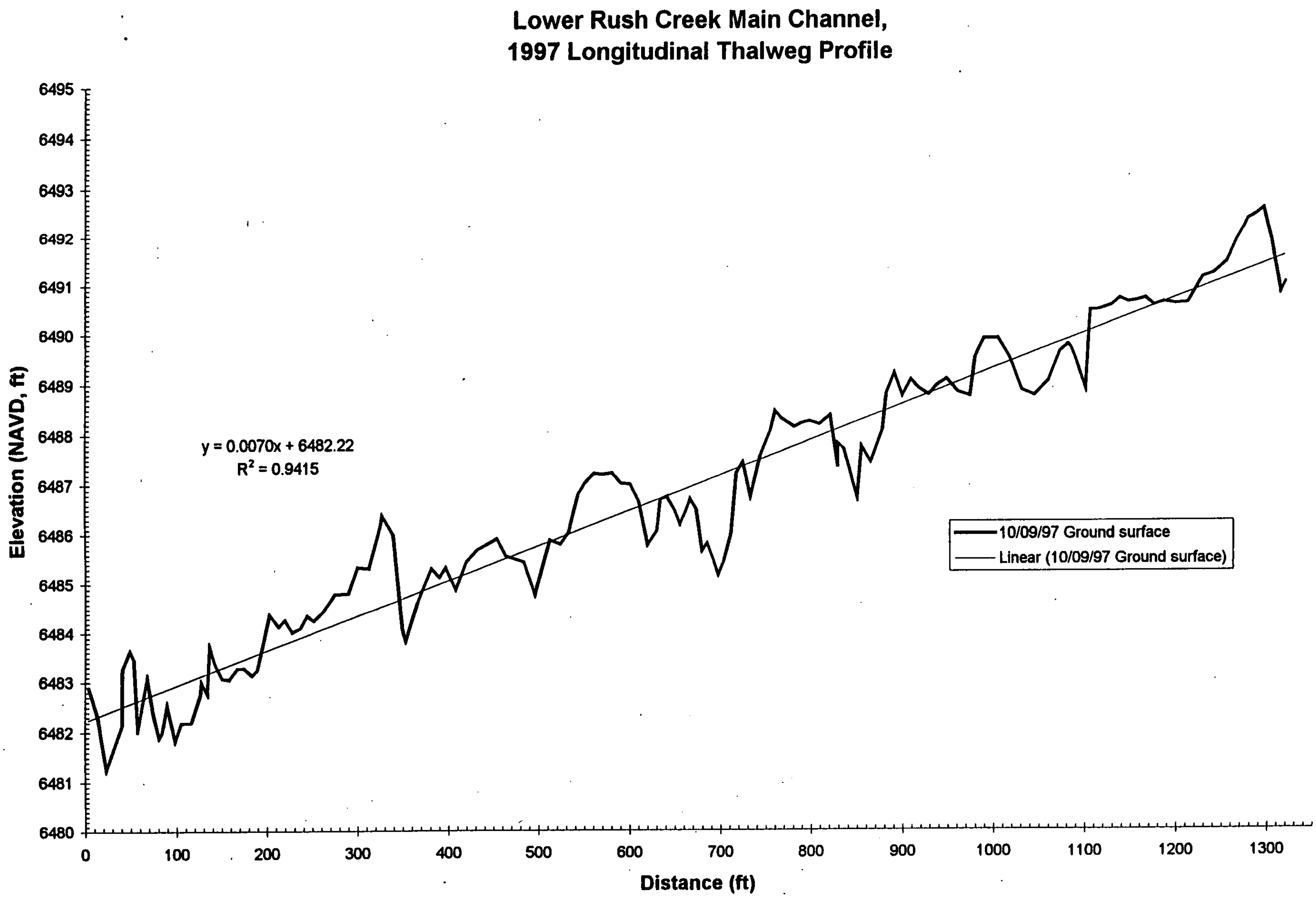


Lower Rush Creek Main Channel, 1998 Longitudinal Thalweg Profile

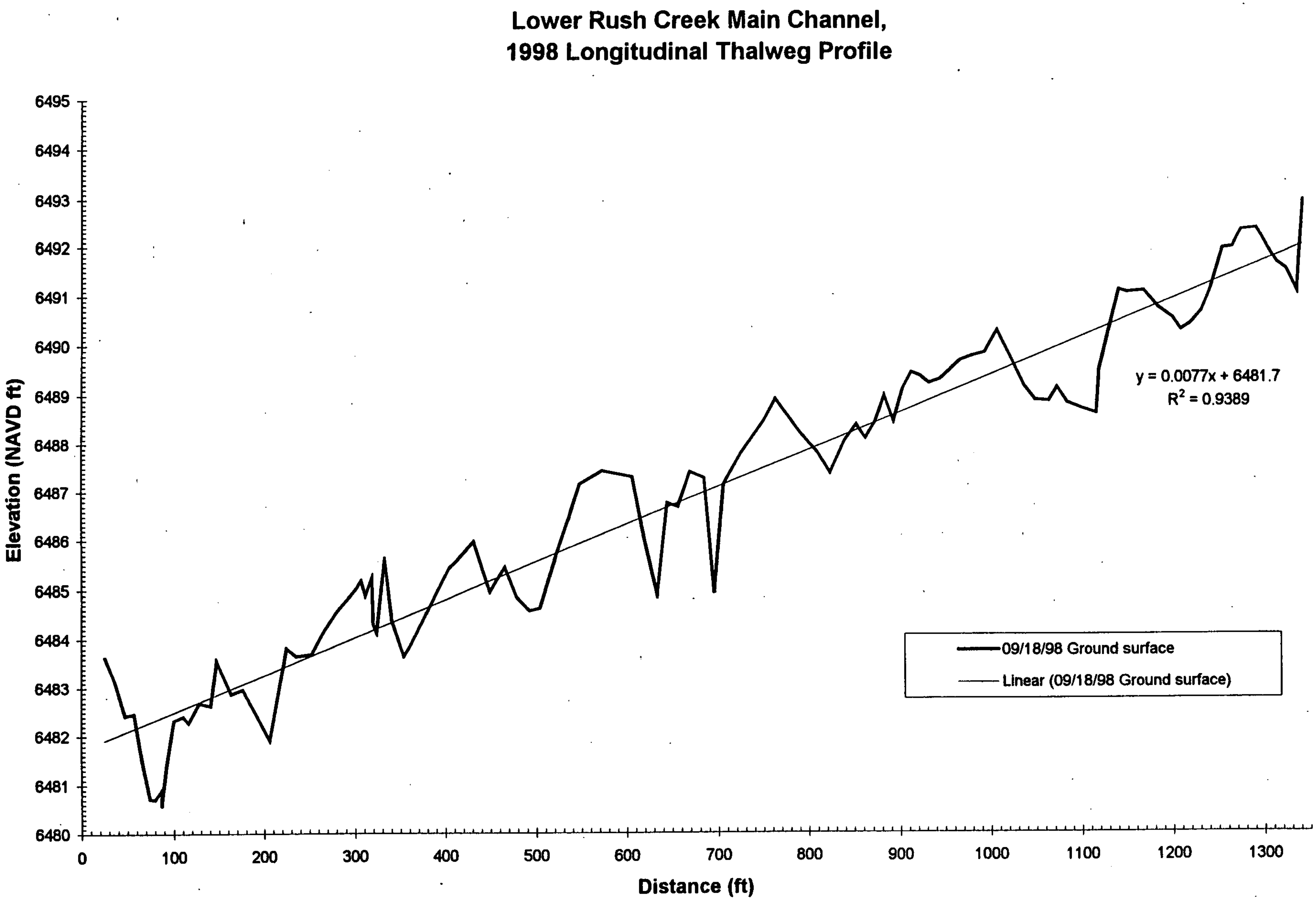


Lower Rush Creek Main Channel, 1999 Longitudinal Thalweg Profile

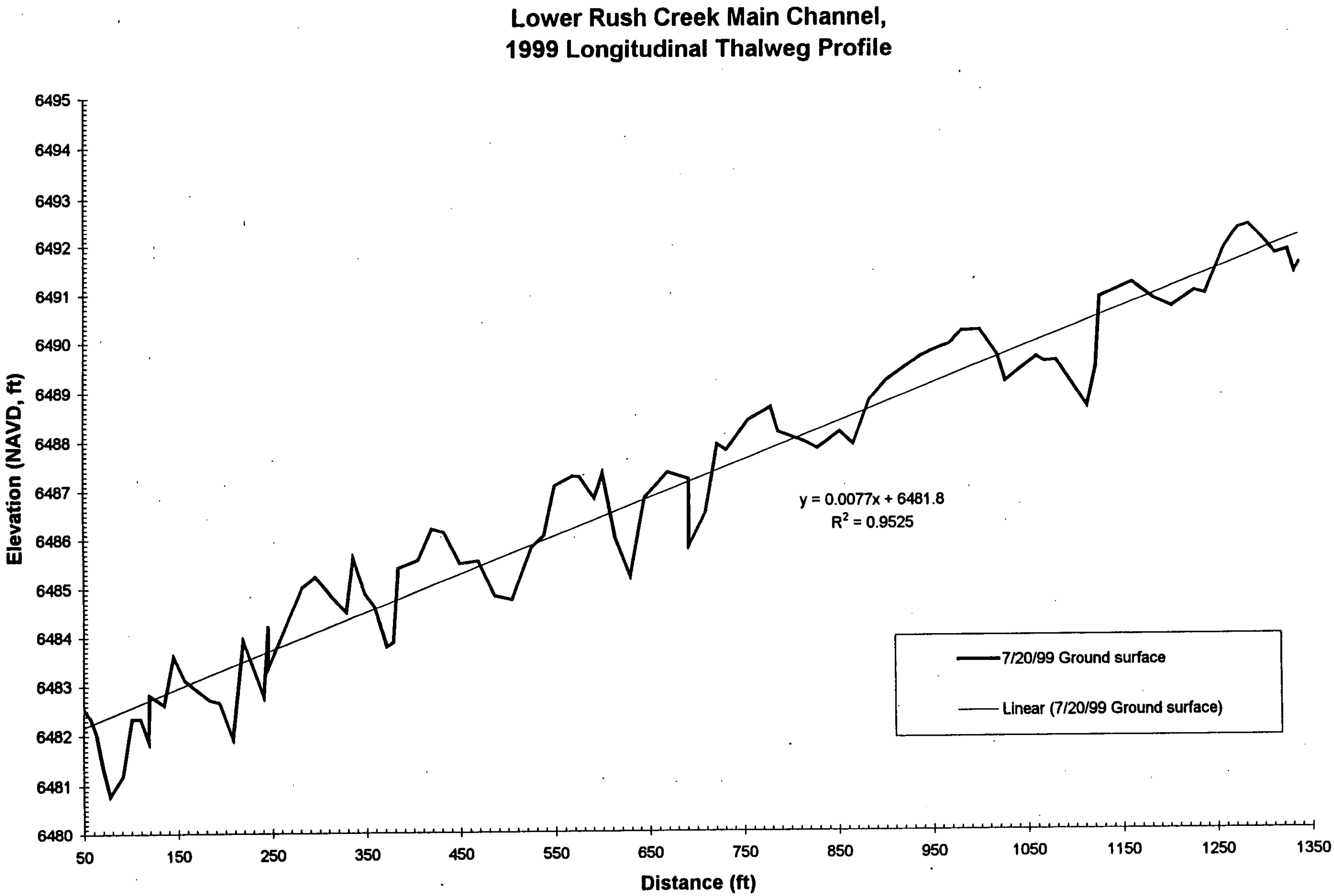




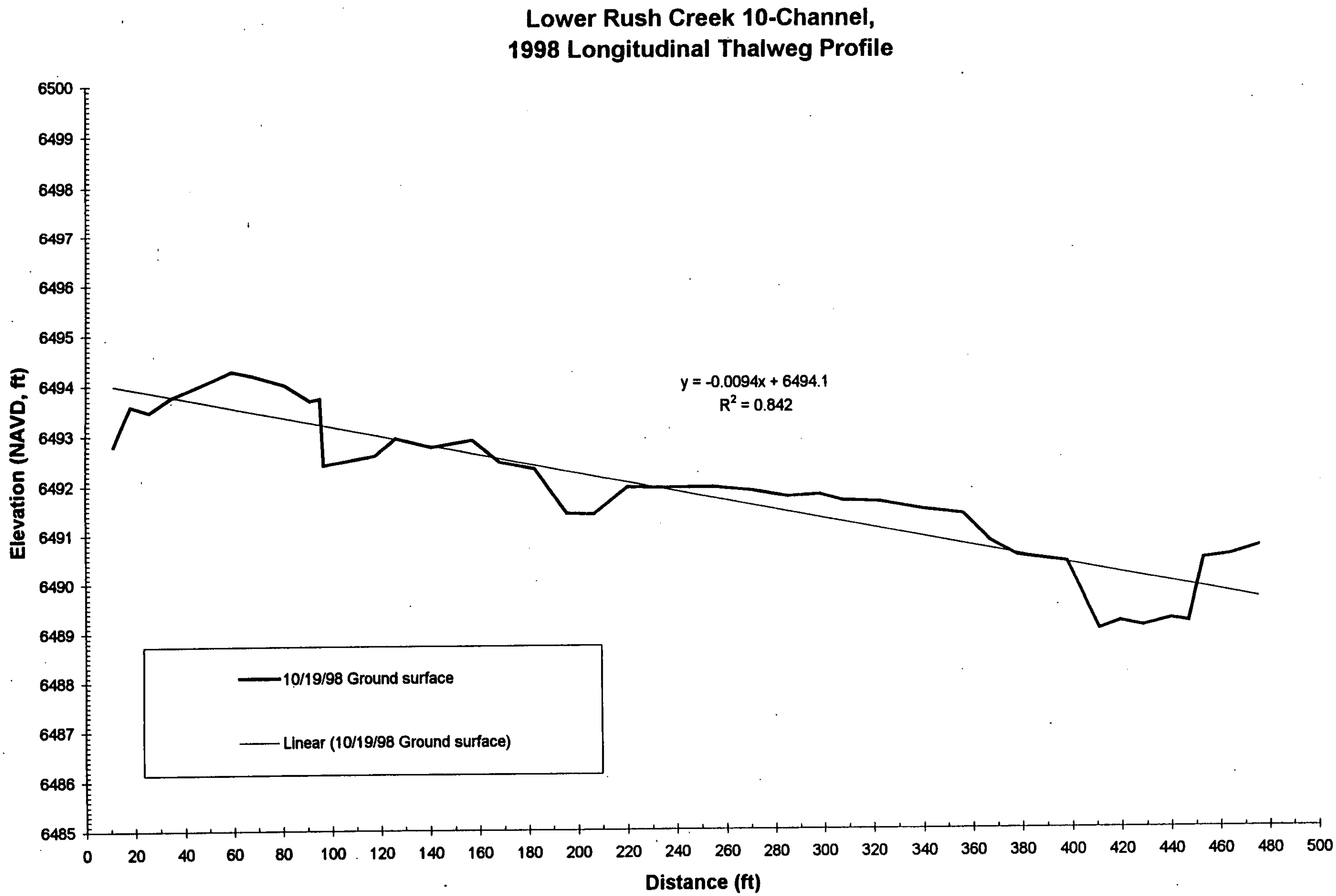
Lower Rush Creek Main Channel,
1997 Longitudinal Thalweg Profile
Elevation (NAVD, ft)
6495
6494
6493
6492
6491
6490
6489
6488
6487
6486
6485
6484
6483
6482
6481
6480
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Distance (ft)
y = 0.0070x + 6482.22
R^2 = 0.9415
10/09/97 Ground surface
Linear (10/09/97 Ground surface)



Lower Rush Creek Main Channel,
1998 Longitudinal Thalweg Profile
Elevation (NAVD ft)
6495
6494
6493
6492
6491
6490
6489
6488
6487
6486
6485
6484
6483
6482
6481
6480
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Distance (ft)
y = 0.0077x + 6481.7
R2 = 0.9389
09/18/98 Ground surface
Linear (09/18/98 Ground surface)

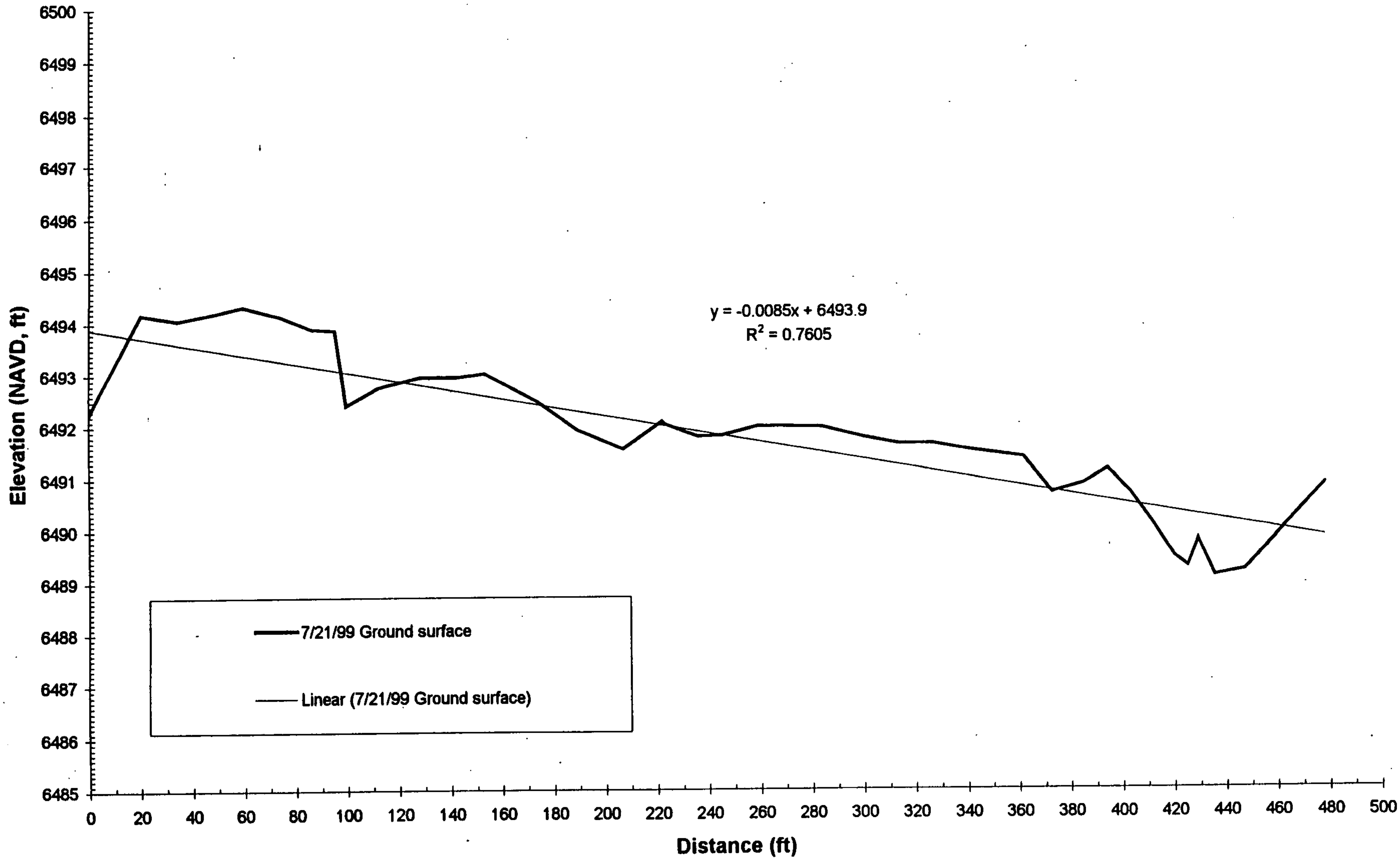


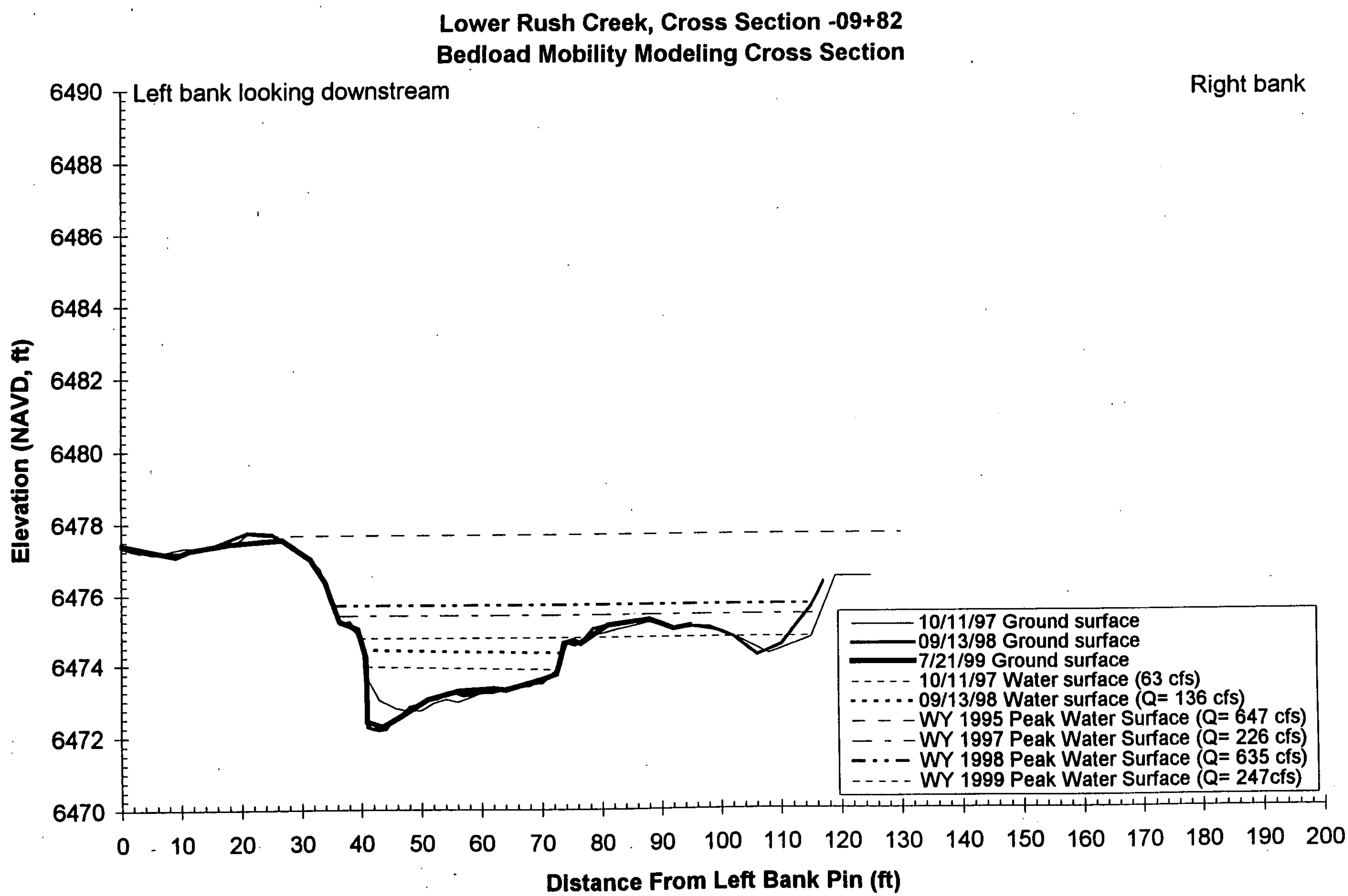
Lower Rush Creek Main Channel,
1999 Longitudinal Thalweg Profile
Elevation (NAVD, ft)
6495
6494
6493
6492
6491
6490
6489
6488
6487
6486
6485
6484
6483
6482
6481
6480
50
150
250
350
450
550
650
750
850
950
1050
1150
1250
1350
Distance (ft)
y = 0.0077x + 6481.8
R2 = 0.9525
7/20/99 Ground surface
Linear (7/20/99 Ground surface)



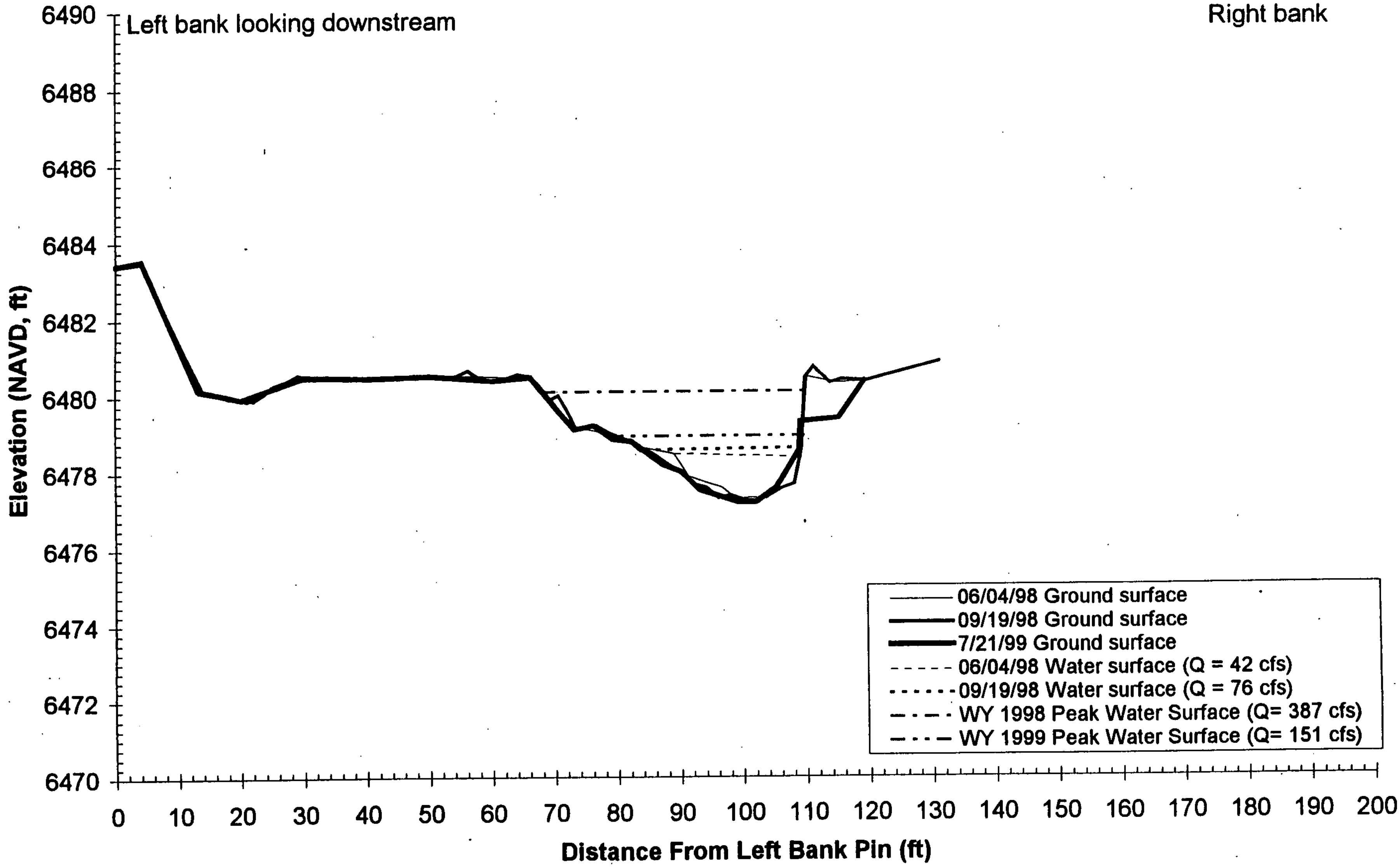
Lower Rush Creek 10-Channel,
1998 Longitudinal Thalweg Profile
Elevation (NAVD, ft)
6500
6499
6498
6497
6496
6495
6494
6493
6492
6491
6490
6489
6488
6487
6486
6485
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
Distance (ft)
y = -0.0094x + 6494.1
R2 = 0.842
10/19/98 Ground surface
Linear (10/19/98 Ground surface)

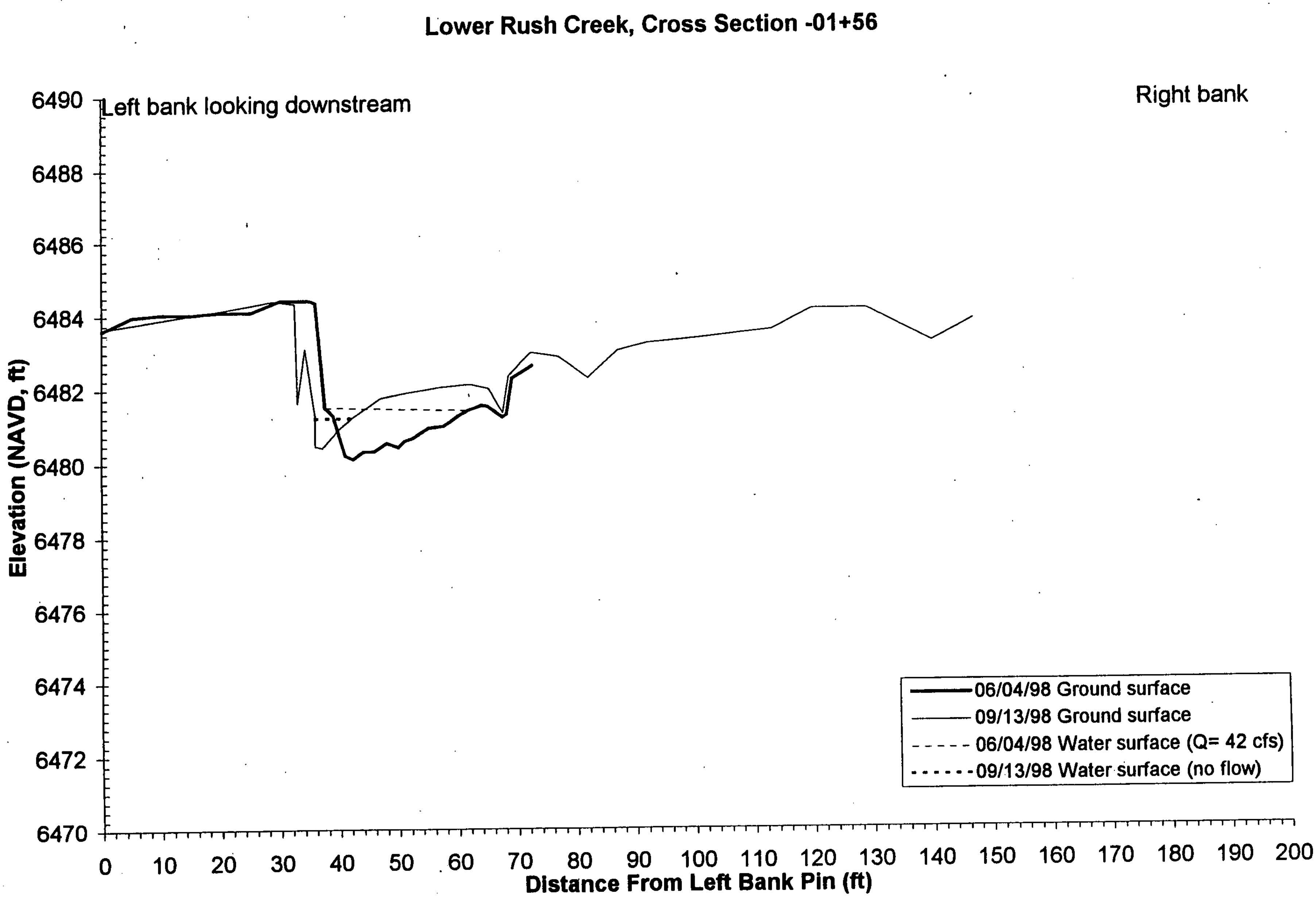
Lower Rush Creek 10-Channel, 1999 Longitudinal Thalweg Profile



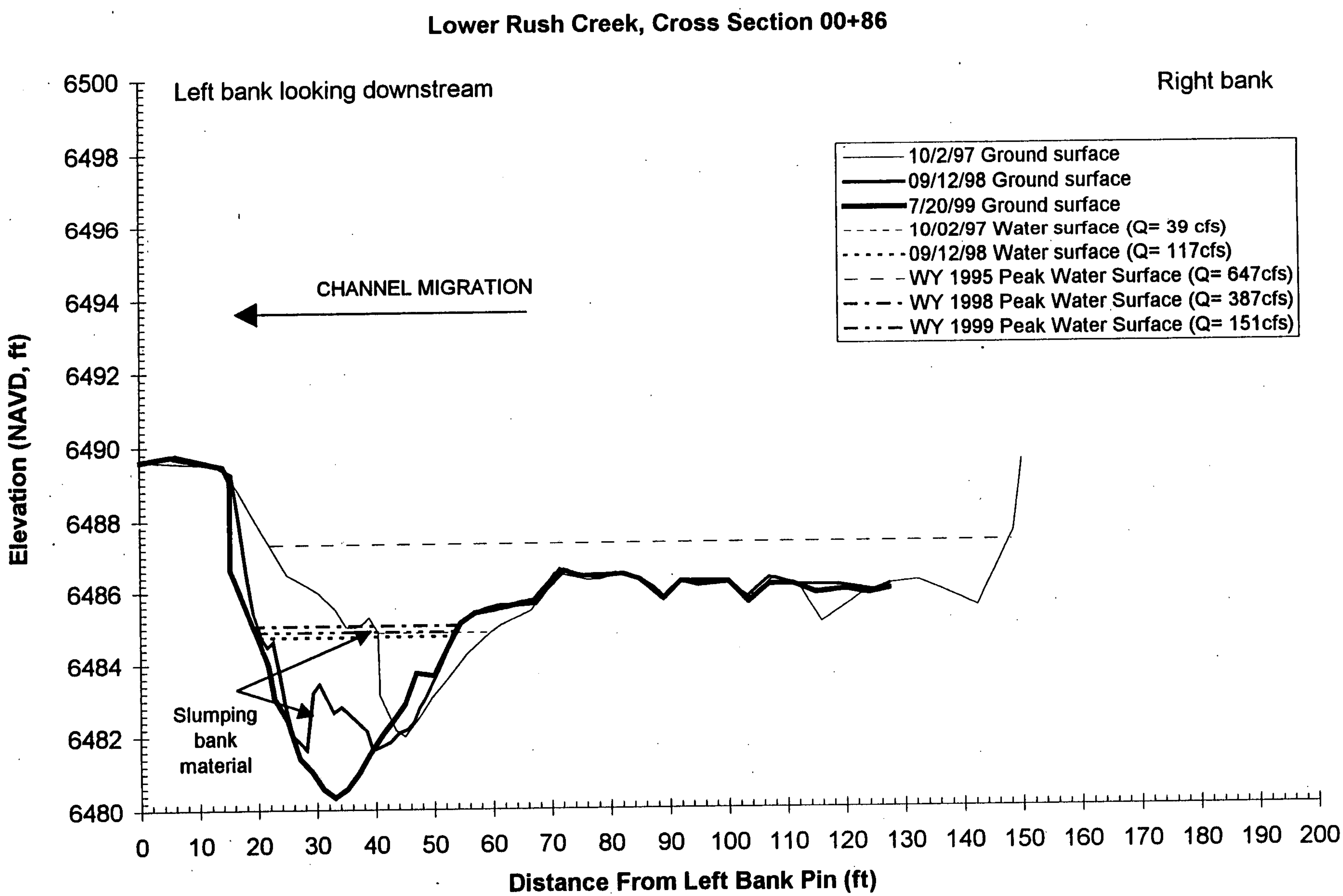

Lower Rush Creek, Cross Section -09+82
Bedload Mobility Modeling Cross Section
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6490
6488
6486
6484
6482
6480
6478
6476
6474
6472
6470
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance From Left Bank Pin (ft)
10/11/97 Ground surface
09/13/98 Ground surface
7/21/99 Ground surface
10/11/97 Water surface (63 cfs)
09/13/98 Water surface (Q= 136 cfs)
WY 1995 Peak Water Surface (Q= 647 cfs)
WY 1997 Peak Water Surface (Q= 226 cfs)
WY 1998 Peak Water Surface (Q= 635 cfs)
WY 1999 Peak Water Surface (Q= 247cfs)

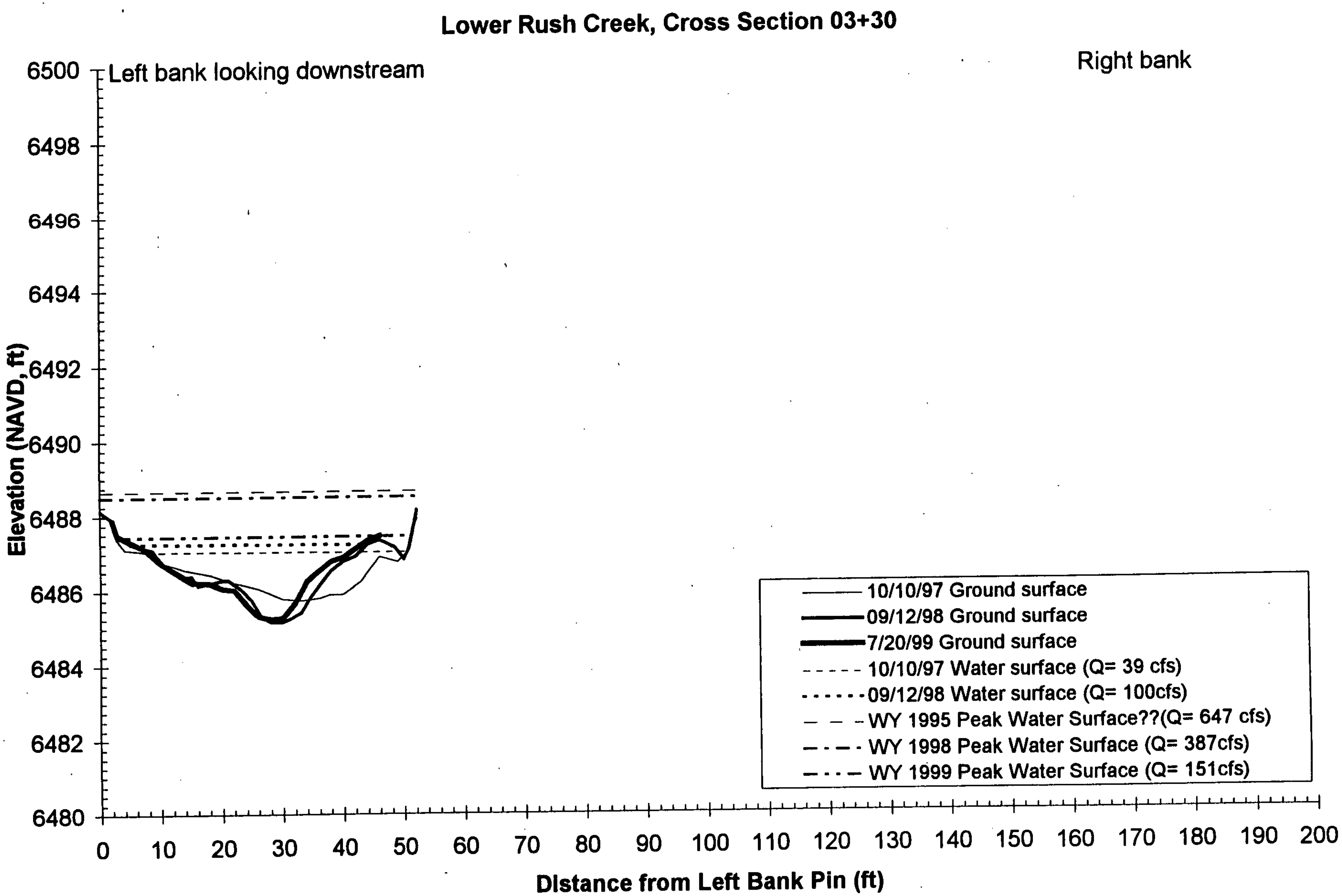
Lower Rush Creek, Cross Section -05+07



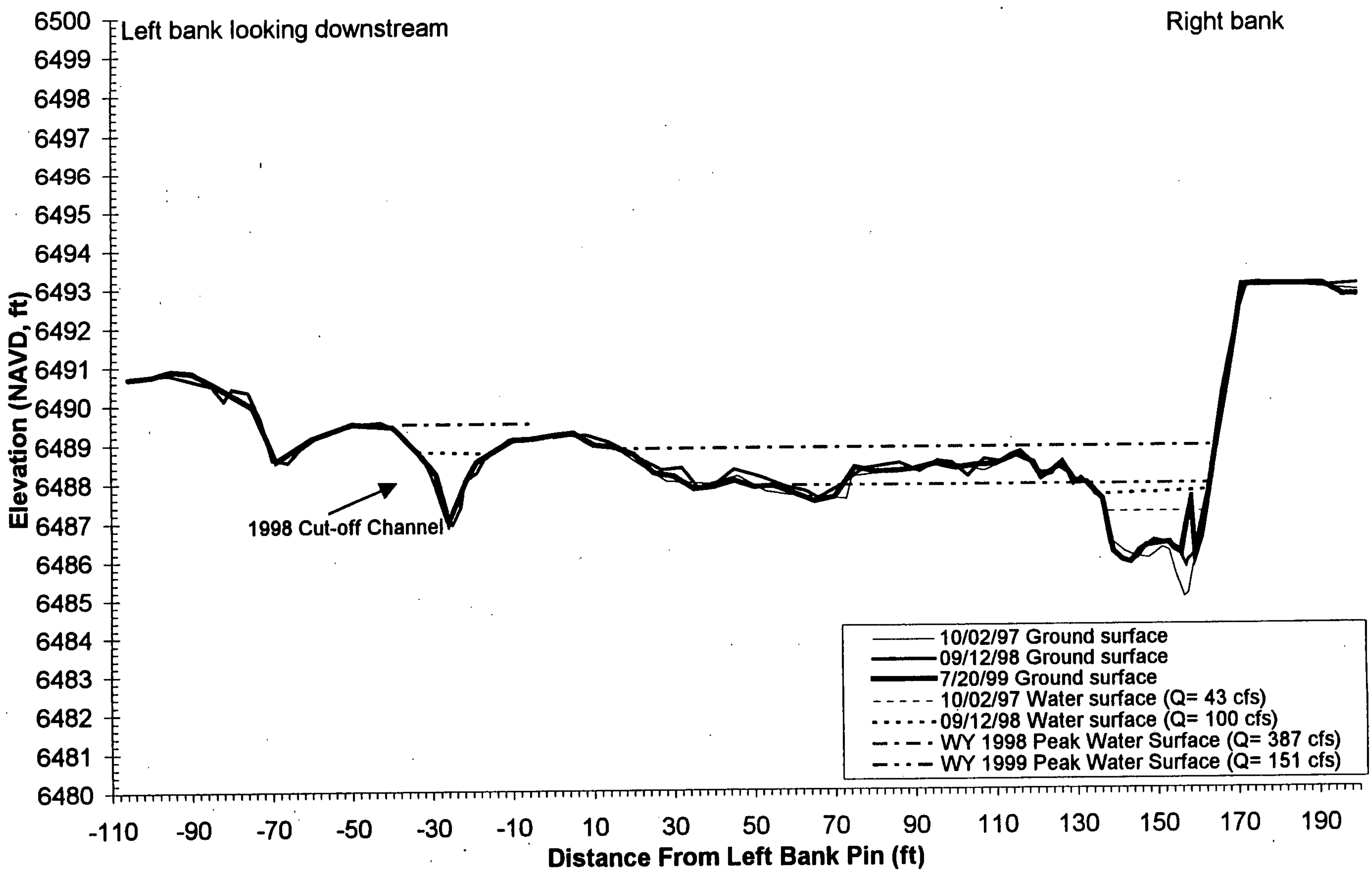


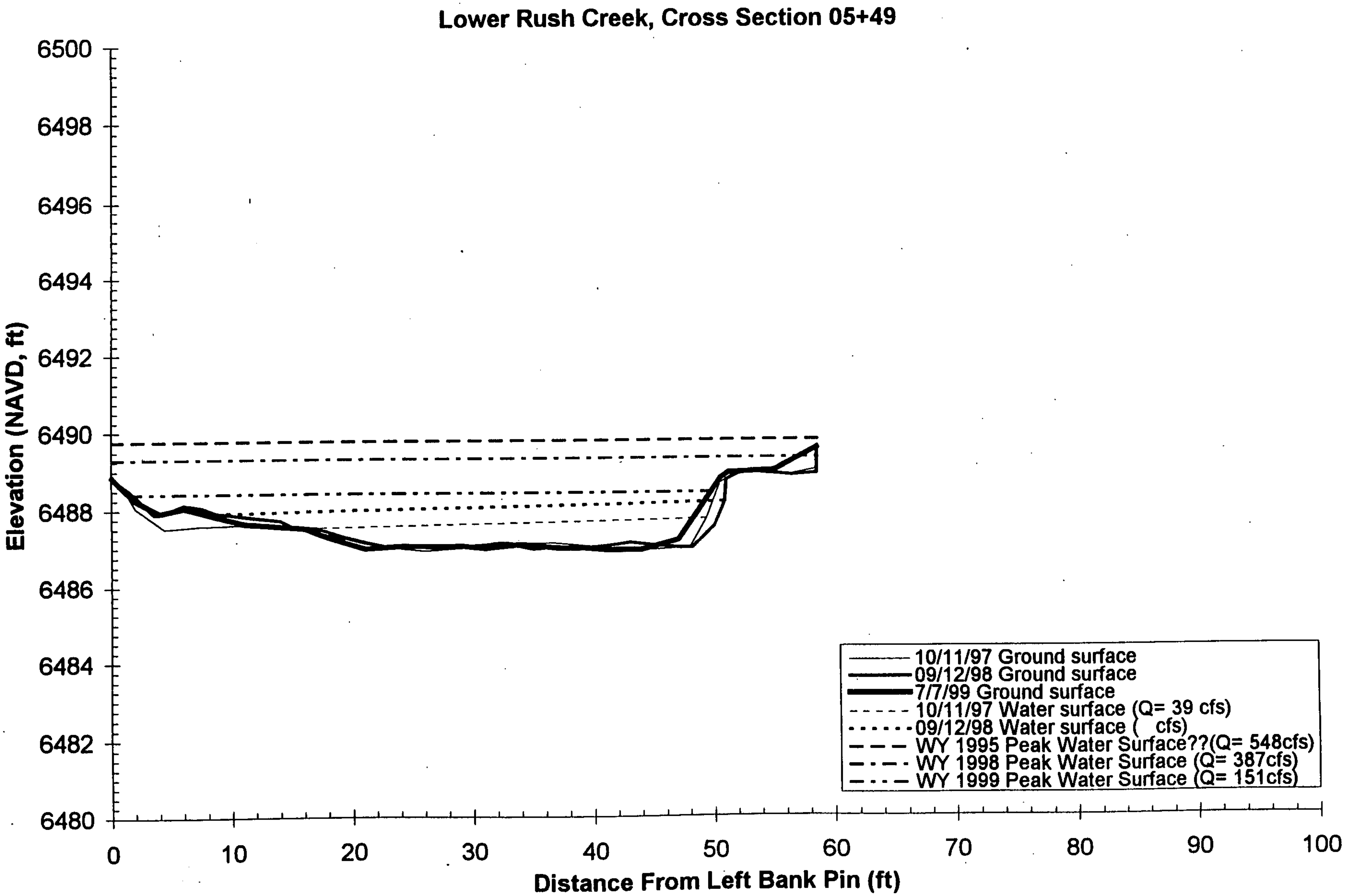
Lower Rush Creek, Cross Section -01+56
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6490
6488
6486
6484
6482
6480
6478
6476
6474
6472
6470
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance From Left Bank Pin (ft)
06/04/98 Ground surface
09/13/98 Ground surface
06/04/98 Water surface (Q= 42 cfs)
09/13/98 Water surface (no flow)

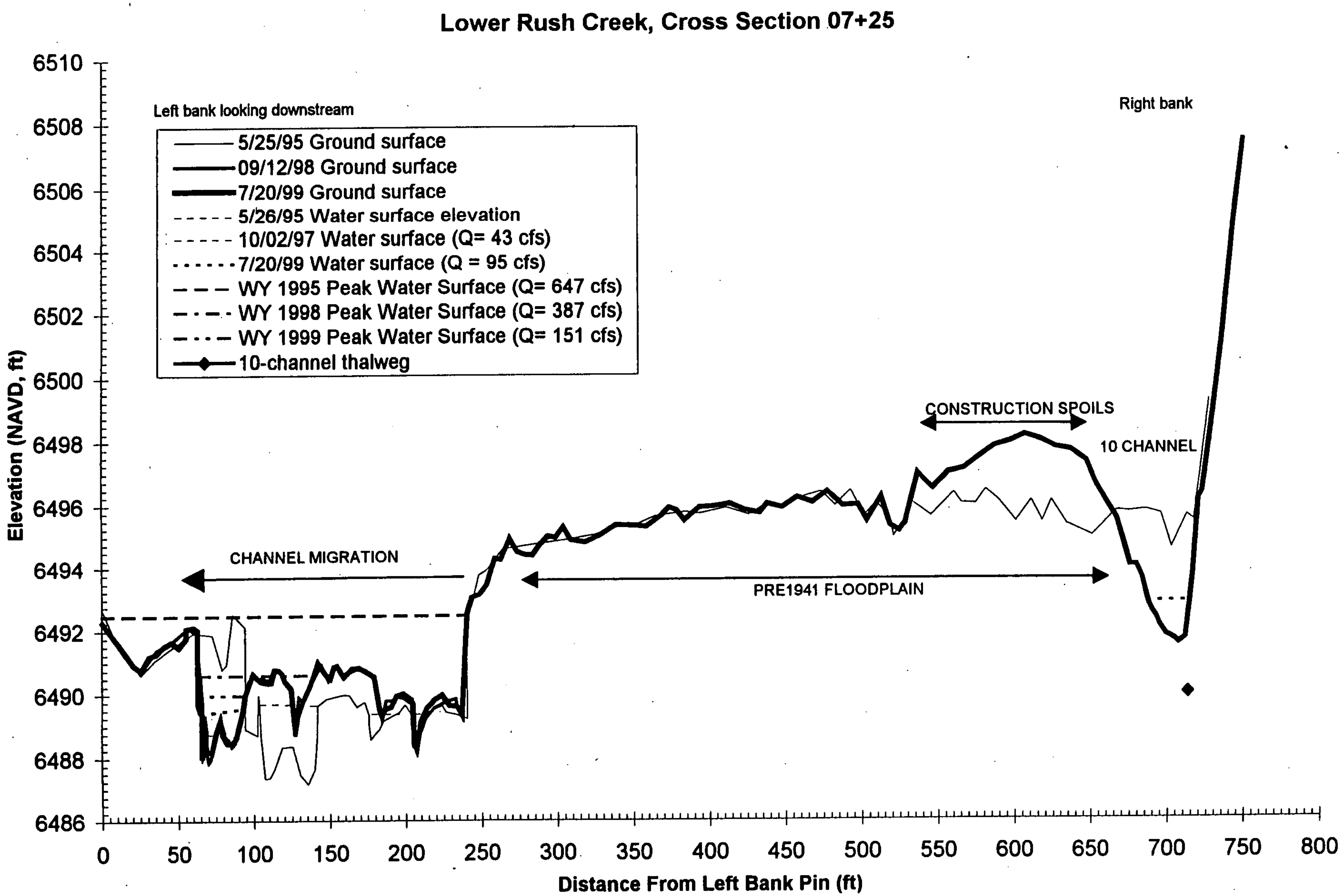

Lower Rush Creek, Cross Section 00+86
Left bank looking downstream
Right bank
10/2/97 Ground surface
09/12/98 Ground surface
7/20/99 Ground surface
10/02/97 Water surface (Q= 39 cfs)
09/12/98 Water surface (Q= 117cfs)
WY 1995 Peak Water Surface (Q= 647cfs)
WY 1998 Peak Water Surface (Q= 387cfs)
WY 1999 Peak Water Surface (Q= 151cfs)
CHANNEL MIGRATION
Slumping bank material
Elevation (NAVD, ft)
6500
6498
6496
6494
6492
6490
6488
6486
6484
6482
6480
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance From Left Bank Pin (ft)


Lower Rush Creek, Cross Section 03+30
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6500
6498
6496
6494
6492
6490
6488
6486
6484
6482
6480
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance from Left Bank Pin (ft)
10/10/97 Ground surface
09/12/98 Ground surface
7/20/99 Ground surface
10/10/97 Water surface (Q= 39 cfs)
09/12/98 Water surface (Q= 100cfs)
WY 1995 Peak Water Surface??(Q= 647 cfs)
WY 1998 Peak Water Surface (Q= 387cfs)
WY 1999 Peak Water Surface (Q= 151cfs)

Lower Rush Creek, Cross Section 04+08

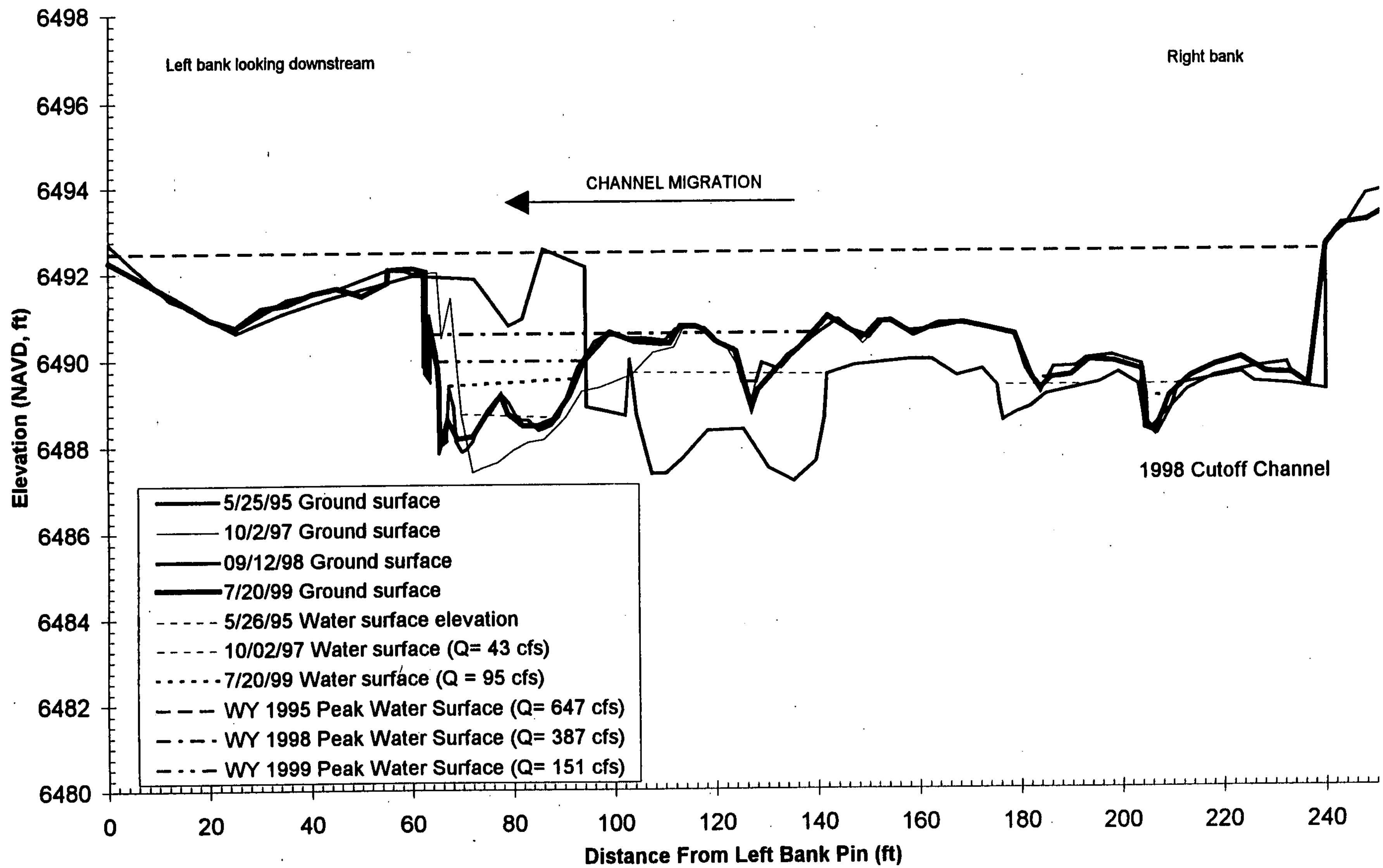



Lower Rush Creek, Cross Section 05+49
Elevation (NAVD, ft)
6500
6498
6496
6494
6492
6490
6488
6486
6484
6482
6480
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)
10/11/97 Ground surface
09/12/98 Ground surface
7/7/99 Ground surface
10/11/97 Water surface (Q= 39 cfs)
09/12/98 Water surface (cfs)
WY 1995 Peak Water Surface??(Q= 548cfs)
WY 1998 Peak Water Surface (Q= 387cfs)
WY 1999 Peak Water Surface (Q= 151cfs)

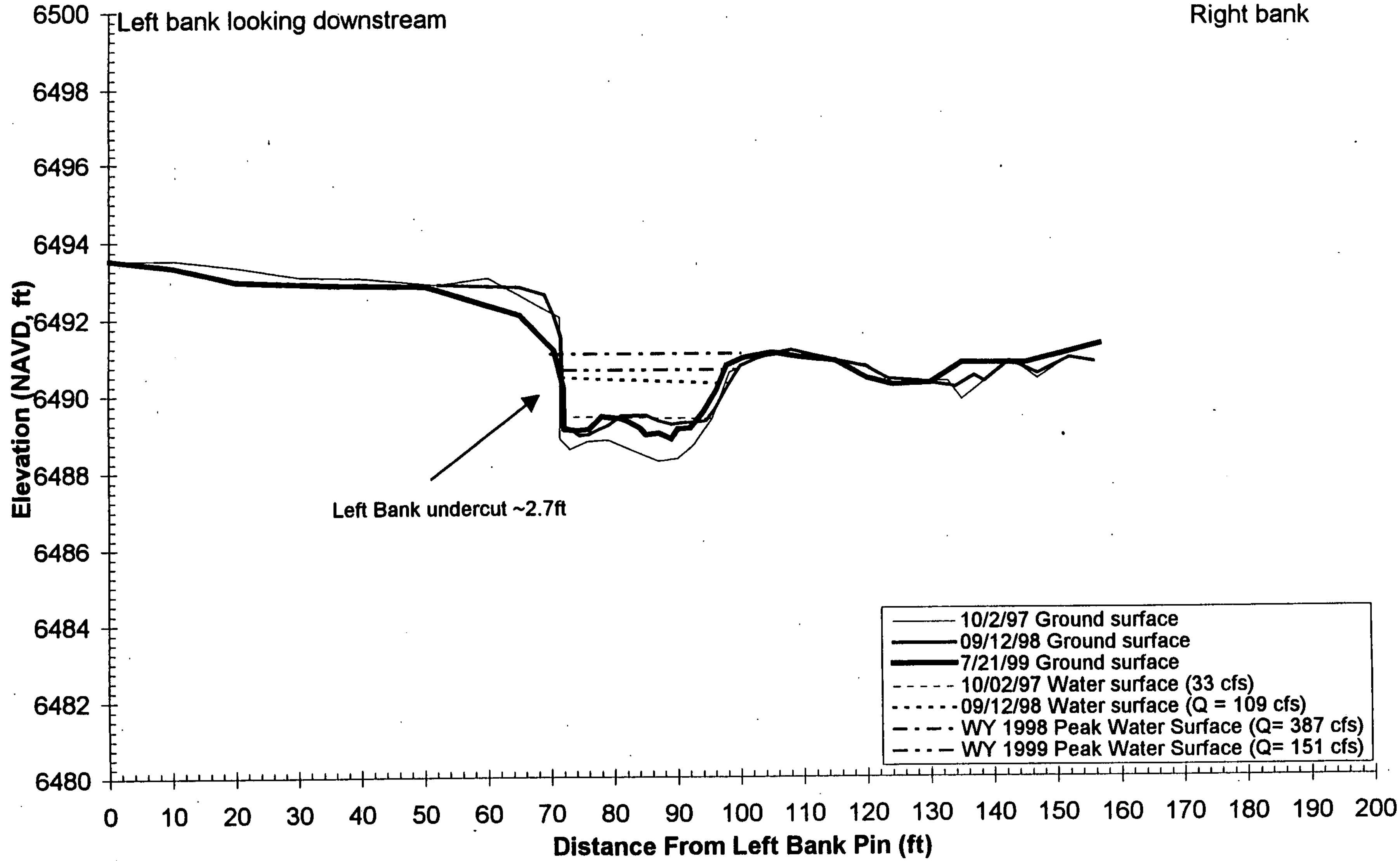


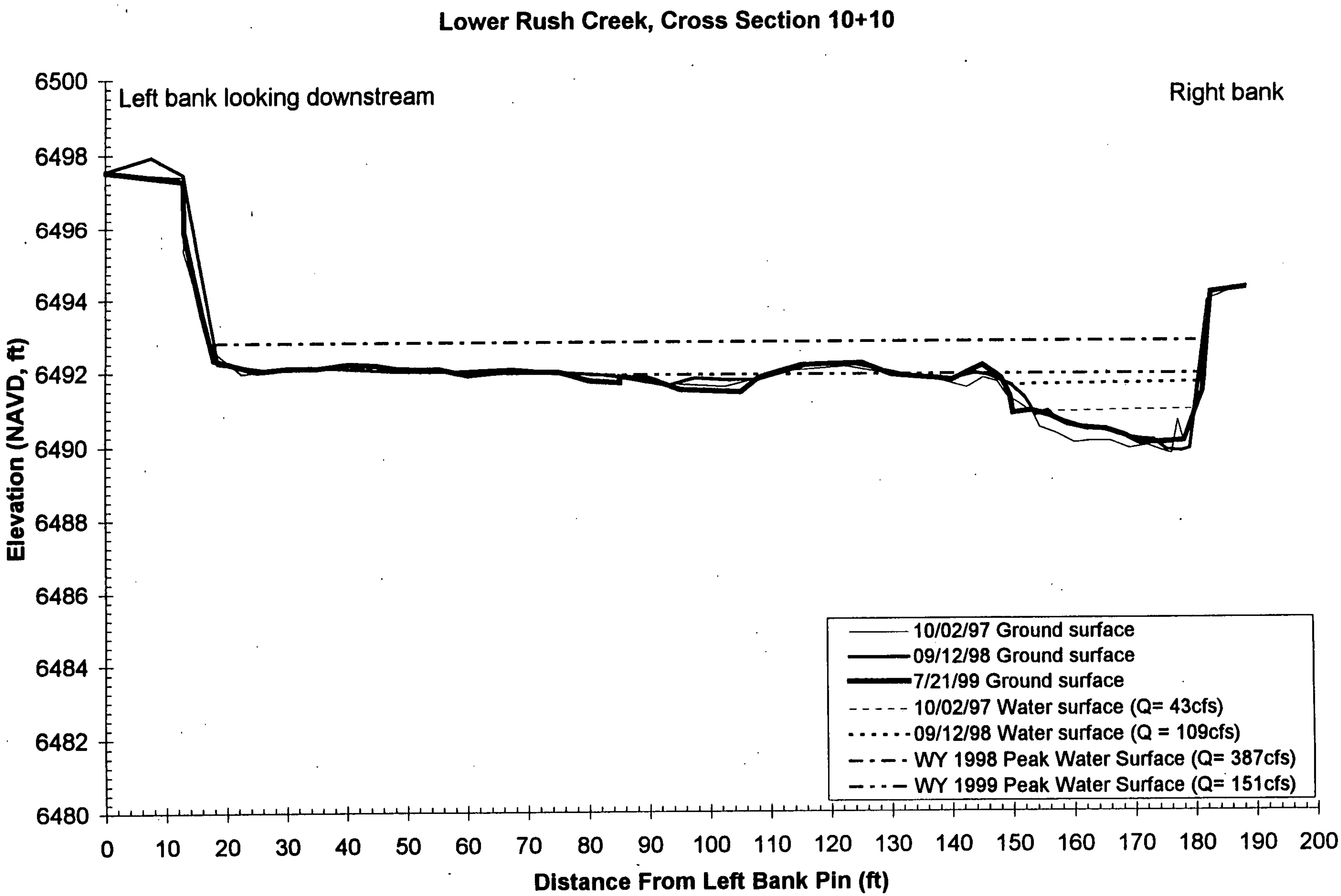
Lower Rush Creek, Cross Section 07+25
Left bank looking downstream
Right bank
5/25/95 Ground surface
09/12/98 Ground surface
7/20/99 Ground surface
5/26/95 Water surface elevation
10/02/97 Water surface (Q= 43 cfs)
7/20/99 Water surface (Q = 95 cfs)
WY 1995 Peak Water Surface (Q= 647 cfs)
WY 1998 Peak Water Surface (Q= 387 cfs)
WY 1999 Peak Water Surface (Q= 151 cfs)
10-channel thalweg
CONSTRUCTION SPOILS
10 CHANNEL
CHANNEL MIGRATION
PRE1941 FLOODPLAIN
Elevation (NAVD, ft)
6510
6508
6506
6504
6502
6500
6498
6496
6494
6492
6490
6488
6486
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Distance From Left Bank Pin (ft)

Lower Rush Creek, Cross Section 07+25

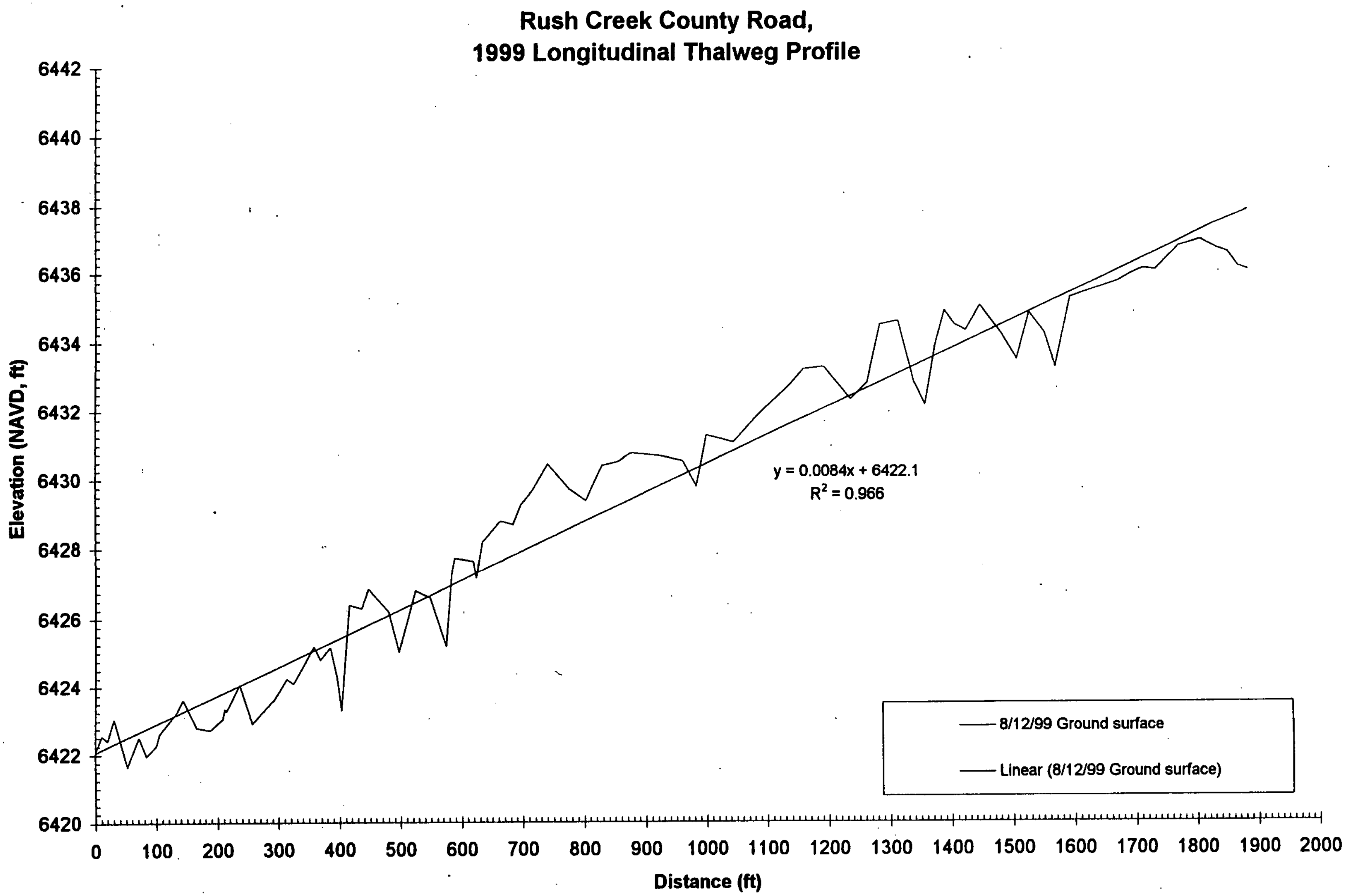


Lower Rush Creek, Cross Section 07+70

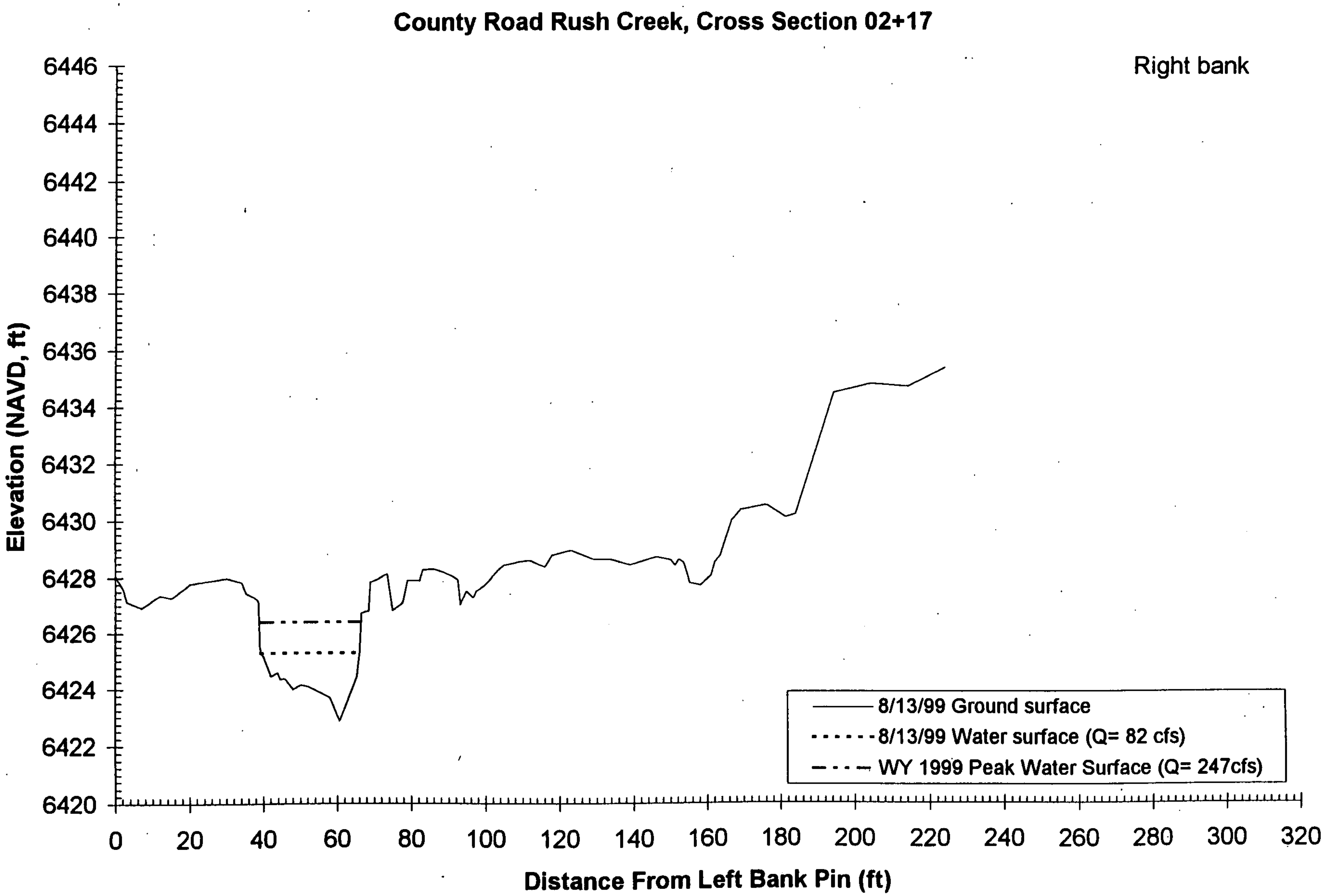


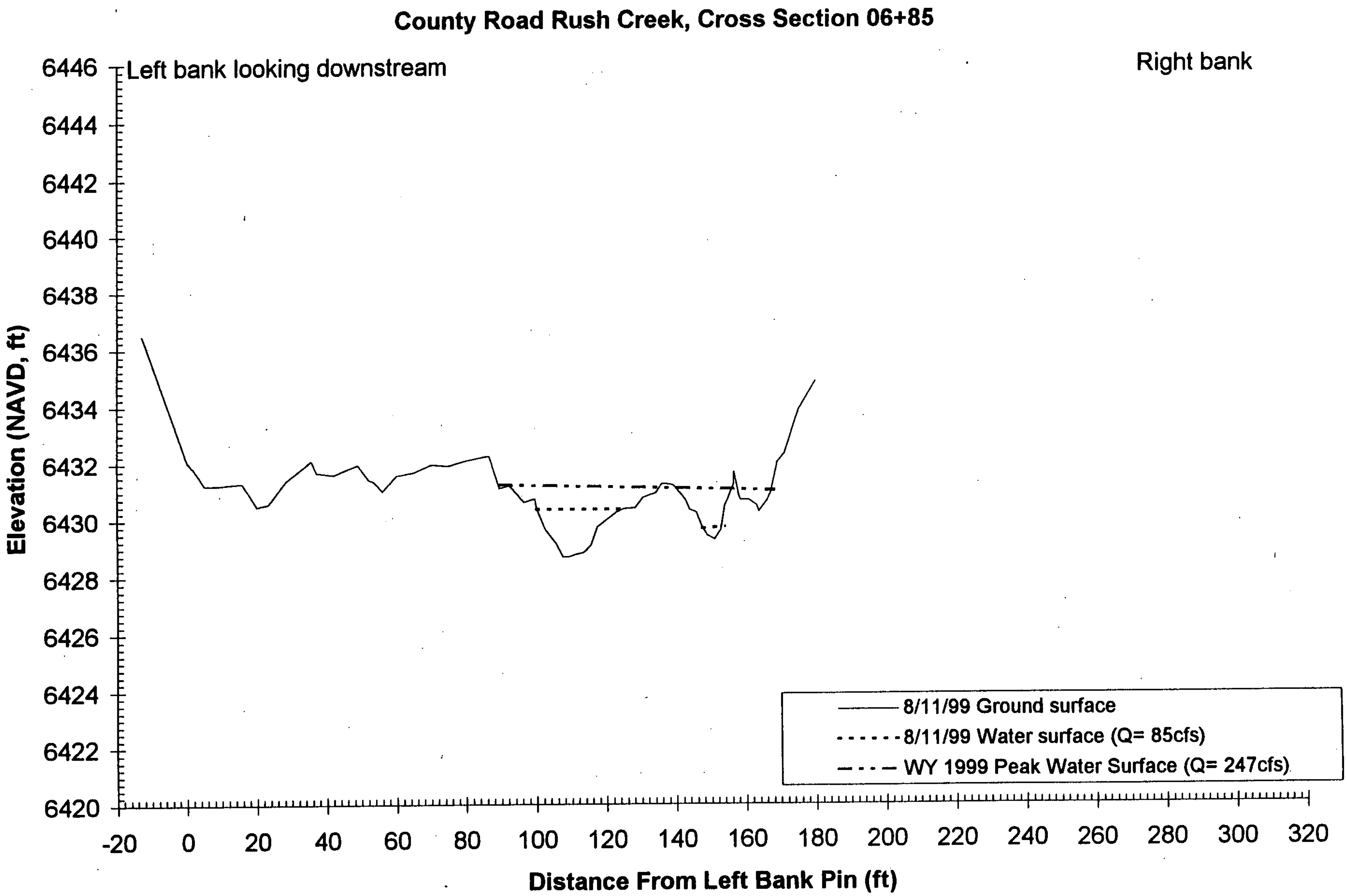


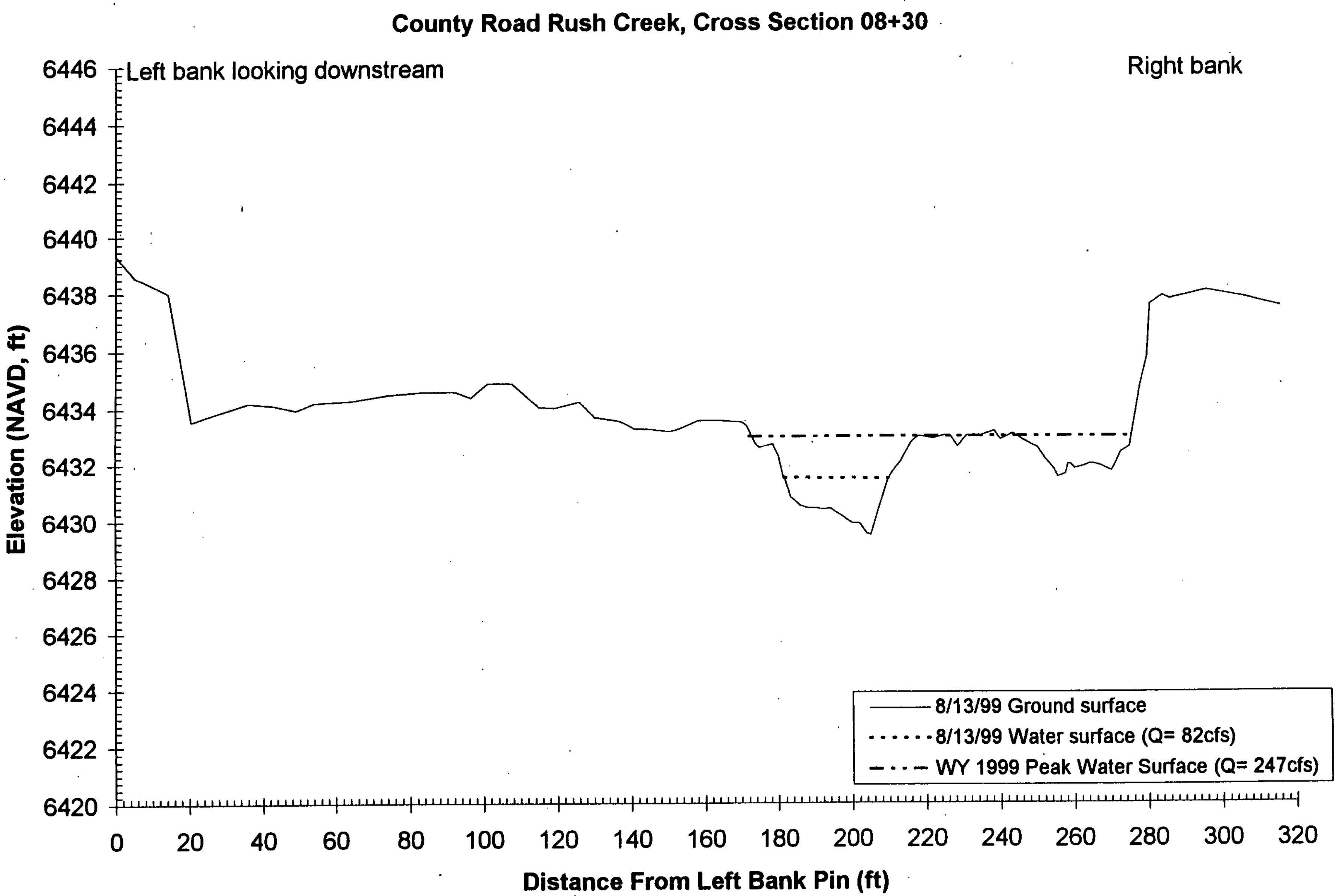
Lower Rush Creek, Cross Section 10+10
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6500
6498
6496
6494
6492
6490
6488
6486
6484
6482
6480
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance From Left Bank Pin (ft)
10/02/97 Ground surface
09/12/98 Ground surface
7/21/99 Ground surface
10/02/97 Water surface (Q= 43cfs)
09/12/98 Water surface (Q = 109cfs)
WY 1998 Peak Water Surface (Q= 387cfs)
WY 1999 Peak Water Surface (Q= 151cfs)

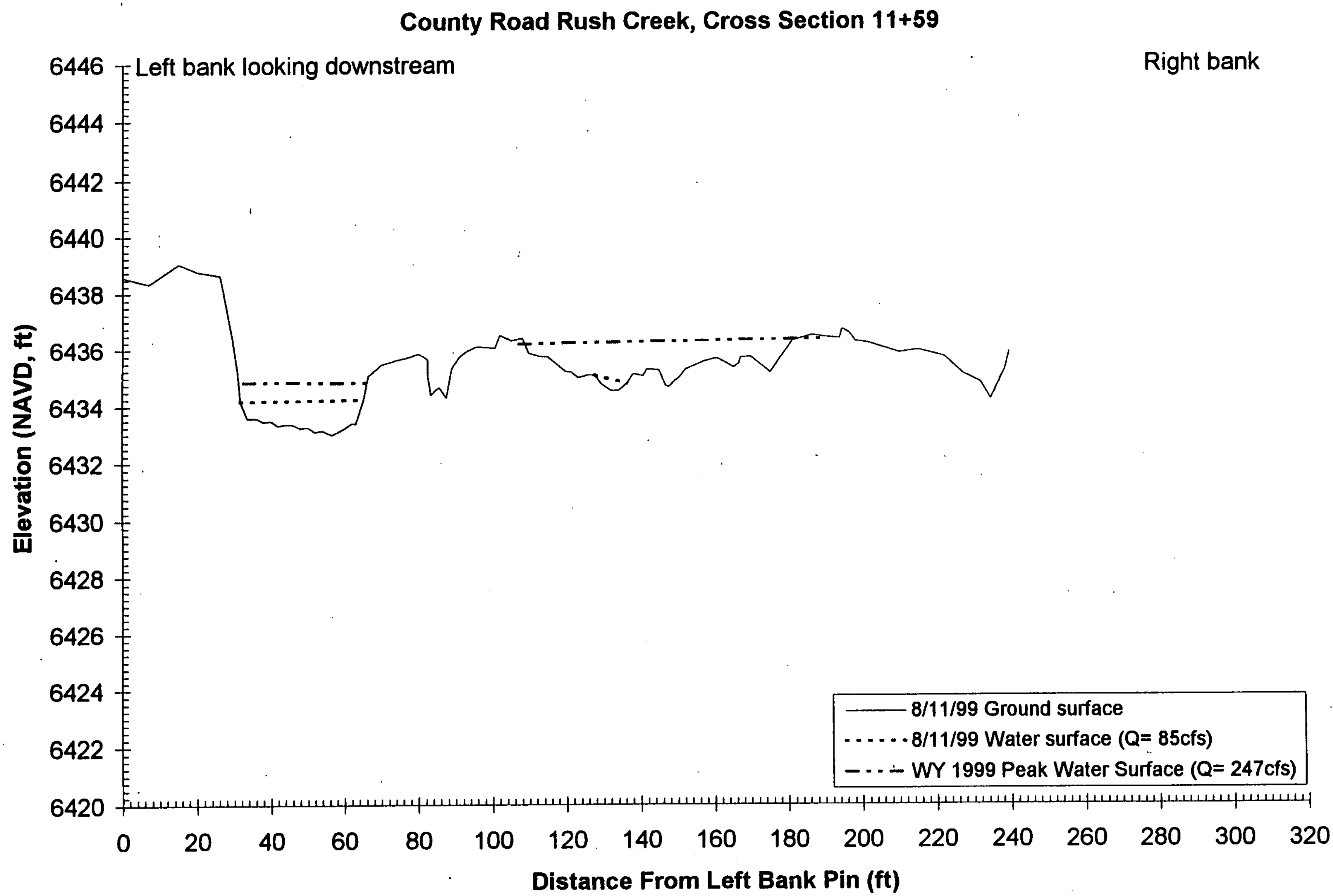


Rush Creek County Road,
1999 Longitudinal Thalweg Profile
Elevation (NAVD, ft)
6442
6440
6438
6436
6434
6432
6430
6428
6426
6424
6422
6420
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance (ft)
y = 0.0084x + 6422.1
$R^2 = 0.966$
8/12/99 Ground surface
Linear (8/12/99 Ground surface)

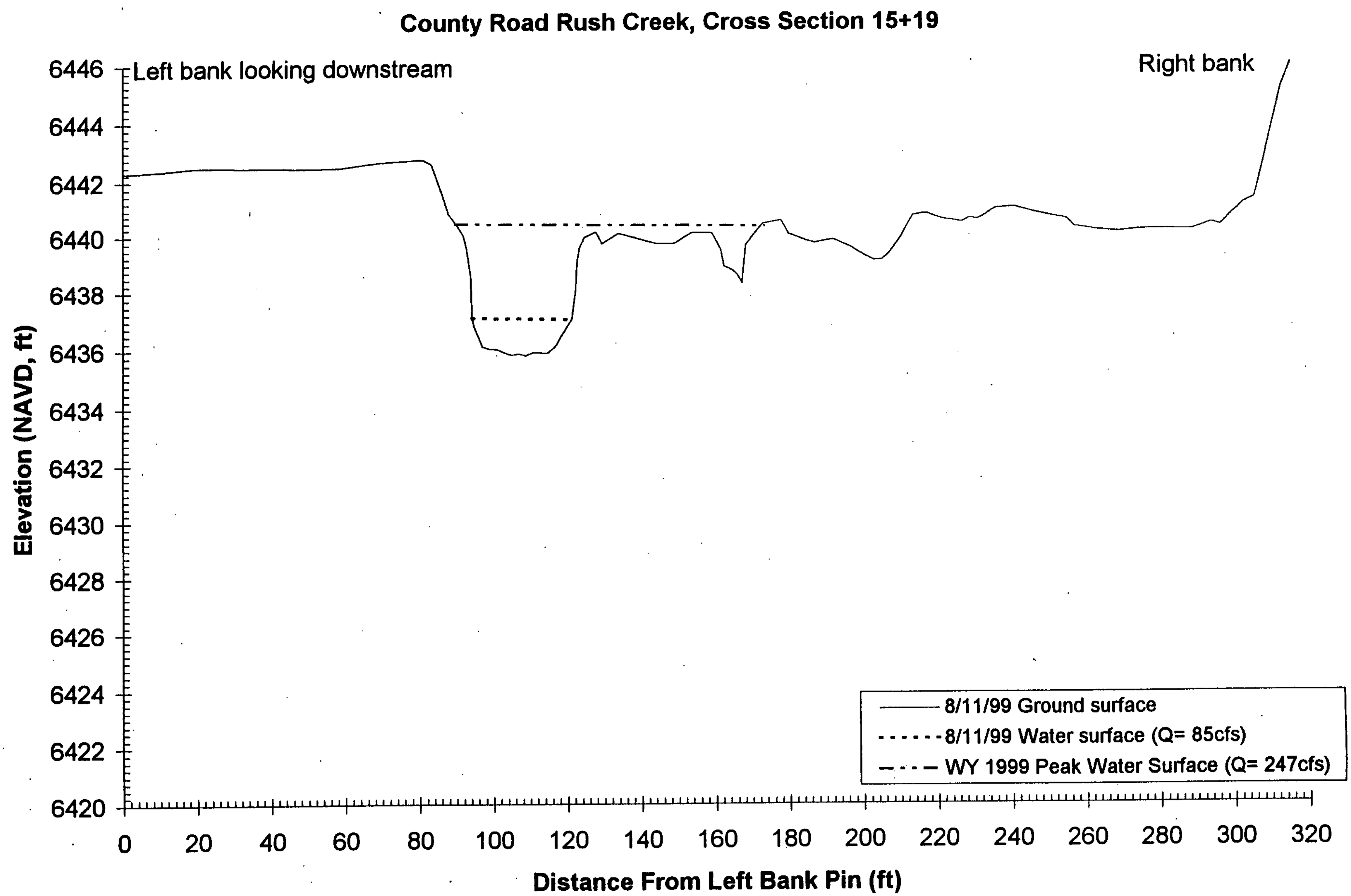

County Road Rush Creek, Cross Section 02+17
Right bank
Elevation (NAVD, ft)
6446
6444
6442
6440
6438
6436
6434
6432
6430
6428
6426
6424
6422
6420
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
Distance From Left Bank Pin (ft)
8/13/99 Ground surface
8/13/99 Water surface (Q= 82 cfs)
WY 1999 Peak Water Surface (Q= 247cfs)


County Road Rush Creek, Cross Section 06+85
Left bank looking downstream
Right bank
6446
6444
6442
6440
6438
6436
6434
6432
6430
6428
6426
6424
6422
6420
Elevation (NAVD, ft)
-20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
Distance From Left Bank Pin (ft)
8/11/99 Ground surface
8/11/99 Water surface (Q= 85cfs)
WY 1999 Peak Water Surface (Q= 247cfs)


County Road Rush Creek, Cross Section 08+30
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6446
6444
6442
6440
6438
6436
6434
6432
6430
6428
6426
6424
6422
6420
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
Distance From Left Bank Pin (ft)
8/13/99 Ground surface
8/13/99 Water surface (Q= 82cfs)
WY 1999 Peak Water Surface (Q= 247cfs)



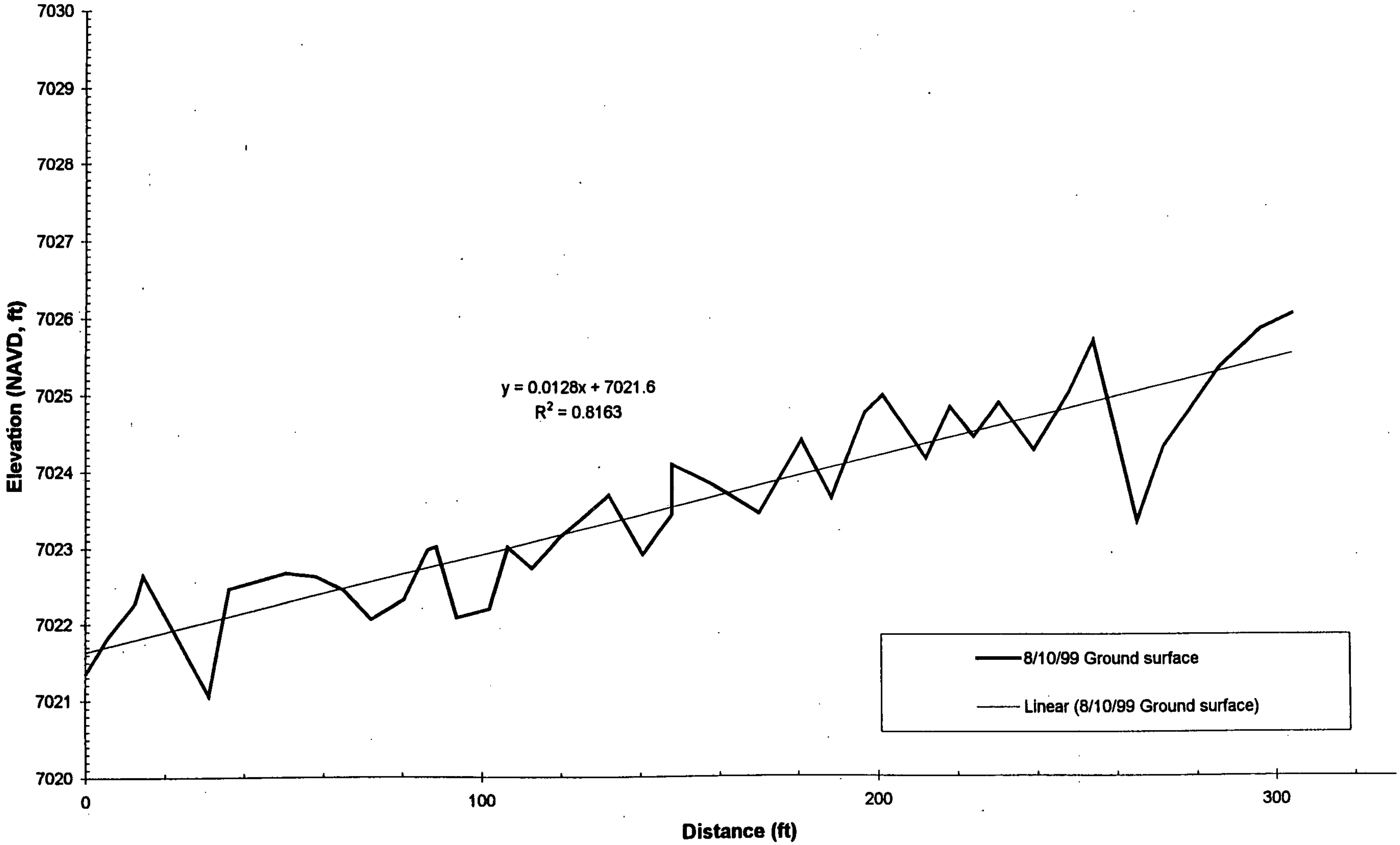
County Road Rush Creek, Cross Section 11+59
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6446
6444
6442
6440
6438
6436
6434
6432
6430
6428
6426
6424
6422
6420
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
Distance From Left Bank Pin (ft)
8/11/99 Ground surface
8/11/99 Water surface (Q= 85cfs)
WY 1999 Peak Water Surface (Q= 247cfs)

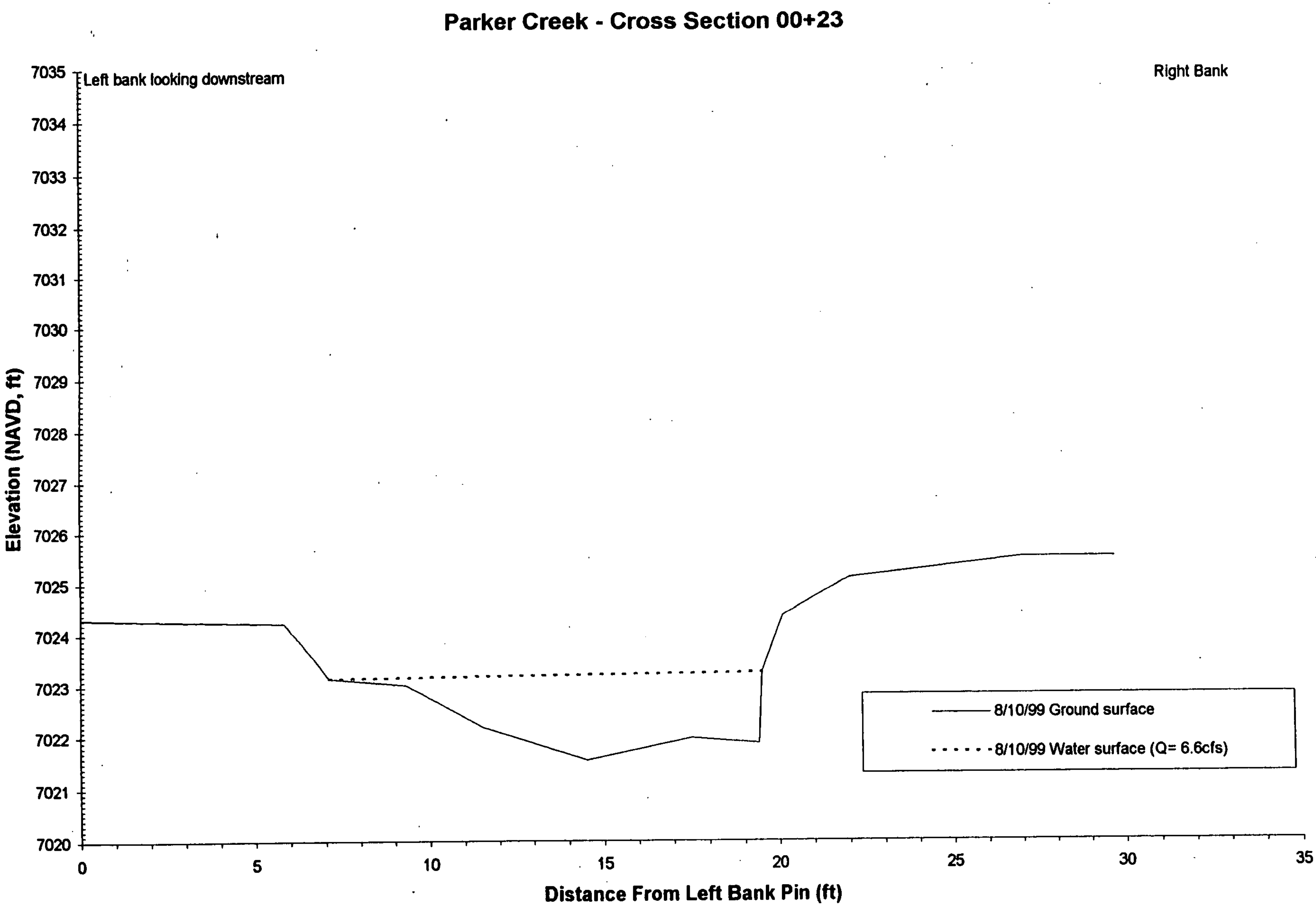

County Road Rush Creek, Cross Section 15+19
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6446
6444
6442
6440
6438
6436
6434
6432
6430
6428
6426
6424
6422
6420
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
Distance From Left Bank Pin (ft)
8/11/99 Ground surface
8/11/99 Water surface (Q= 85cfs)
WY 1999 Peak Water Surface (Q= 247cfs)

Parker Creek Cross Section and Reference Pin Summary Sheet

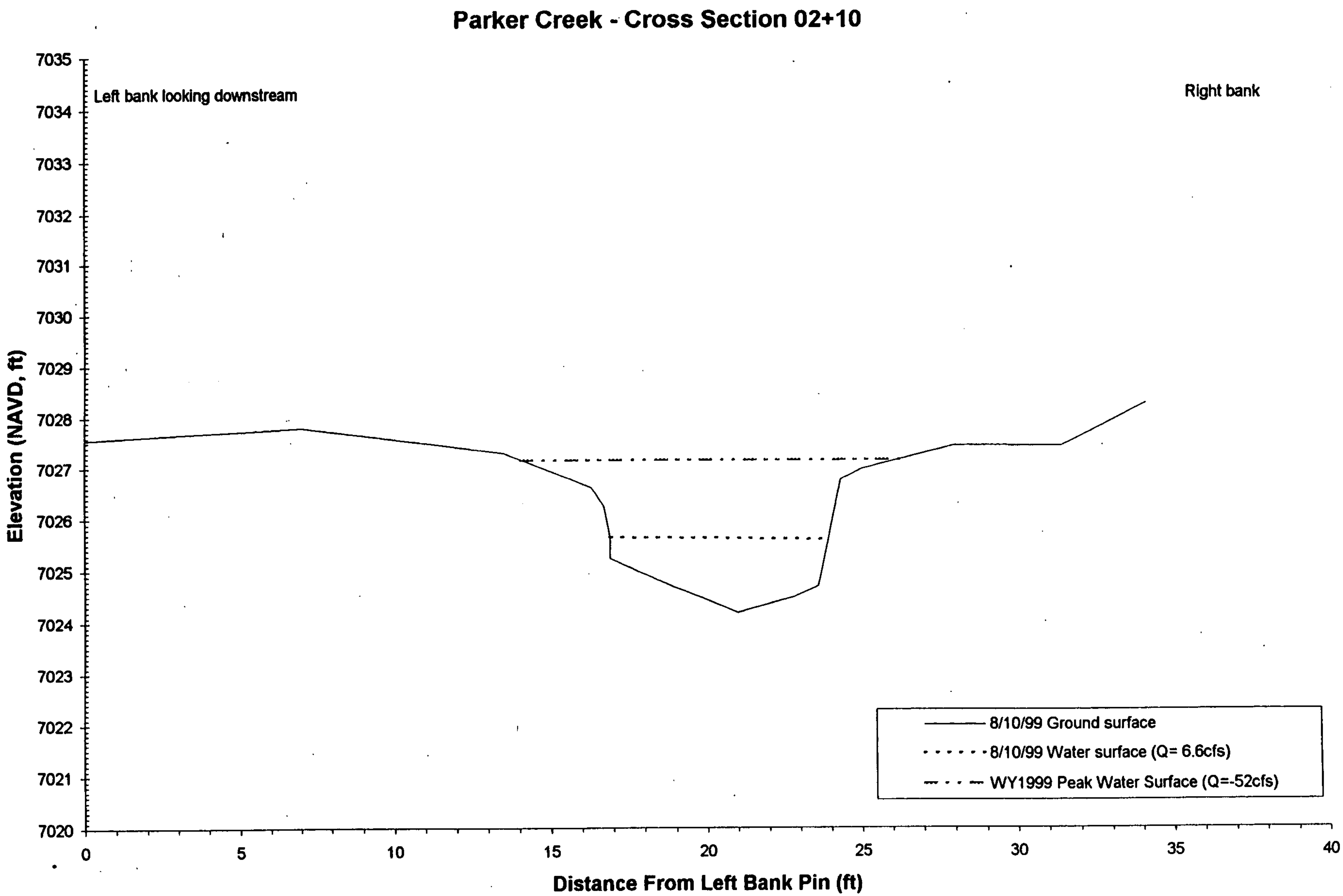
Site	Current Cross Section Label	Old Cross Section Label	Upper Left Bank Pin Elev. (ft)	Lower Left Bank Pin Elev. (ft)	Lower Right Bank Pin Elev. (ft)	Upper Right Bank Pin Elev. (ft)	Total Cross Section Length (ft)	Angle from LB pin to RB pin Degrees	Cross Section Intersection with Long Profile (ft)	Long Profile Intersection with Cross Section (ft)	Fieldbook # and Page #'s
Parker	BM1		**7031.49**	SITE BENCHMARK (Est 8-10-99, by M&T, GPS survey by LADWP)							Mono-Rush Creek #11, pg 82-83
Parker	00+23			7025.11	7026.09		29.70		7.8	23.4	Mono-Rush Creek #11, pg 94-95
Parker	02+10			7028.20	7028.93		34.10		22.9	209.8	Mono-Rush Creek #11, pg 96-97
Parker	02+51			7028.20	7029.01		24.20		15.8	250.6	Mono-Rush Creek #11, pg 98-99
Parker	02+67			7029.01	7028.23		32.00		13.1	266.7	Mono-Rush Creek #11, pg 100-10
Parker	03+04			7029.26	7029.15		21.00		10.5	304.1	Mono-Rush Creek #11, pg 102-10

Parker Creek,
1999 Longitudinal Thalweg Profile

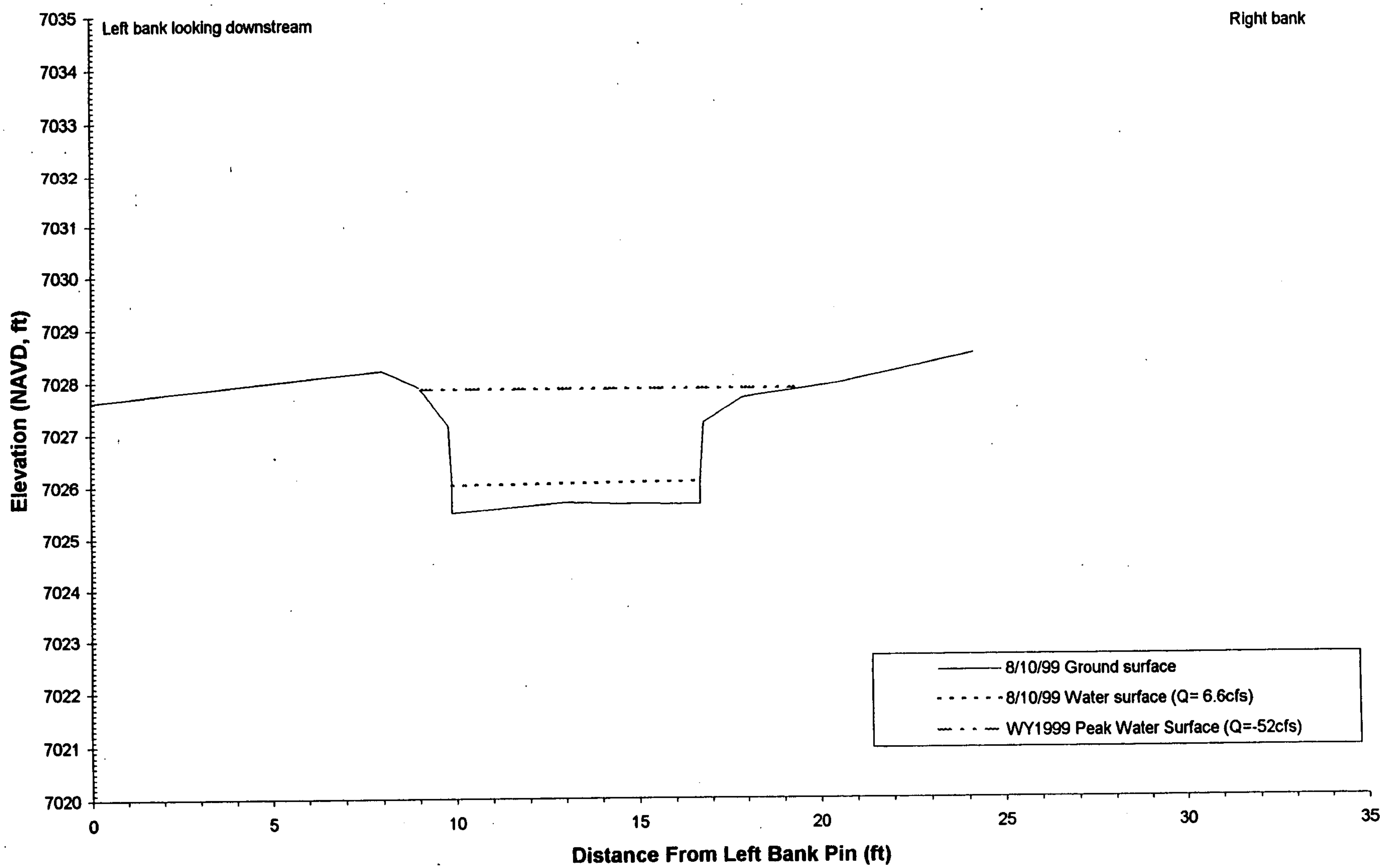




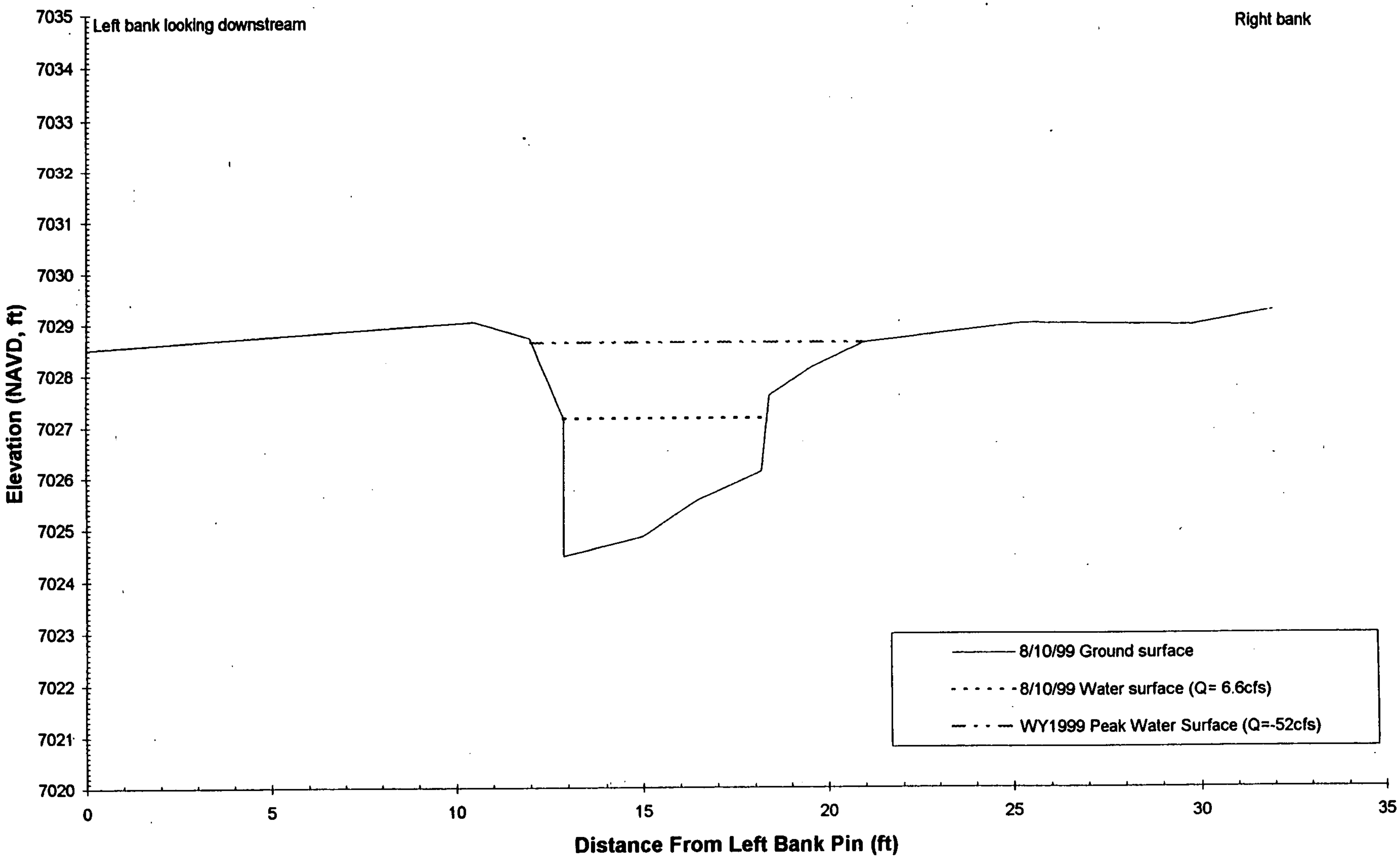
Parker Creek - Cross Section 00+23
Left bank looking downstream
Right Bank
Elevation (NAVD, ft)
7035
7034
7033
7032
7031
7030
7029
7028
7027
7026
7025
7024
7023
7022
7021
7020
0
5
10
15
20
25
30
35
Distance From Left Bank Pin (ft)
8/10/99 Ground surface
8/10/99 Water surface (Q= 6.6cfs)


Parker Creek - Cross Section 02+10
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
7035
7034
7033
7032
7031
7030
7029
7028
7027
7026
7025
7024
7023
7022
7021
7020
0
5
10
15
20
25
30
35
40
Distance From Left Bank Pin (ft)
8/10/99 Ground surface
8/10/99 Water surface (Q= 6.6cfs)
WY1999 Peak Water Surface (Q=-52cfs)

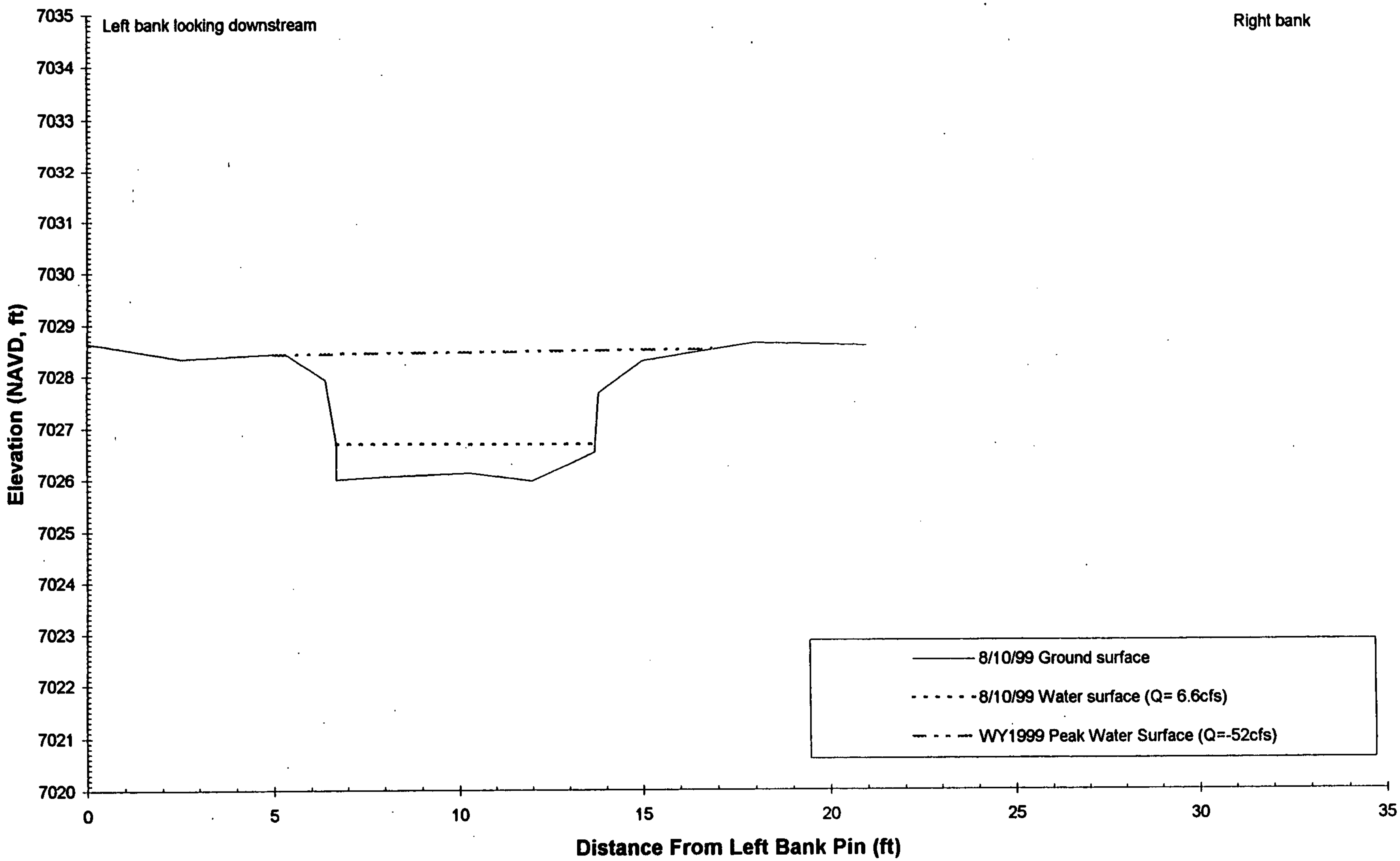
Parker Creek - Cross Section 02+51



Parker Creek - Cross Section 02+67



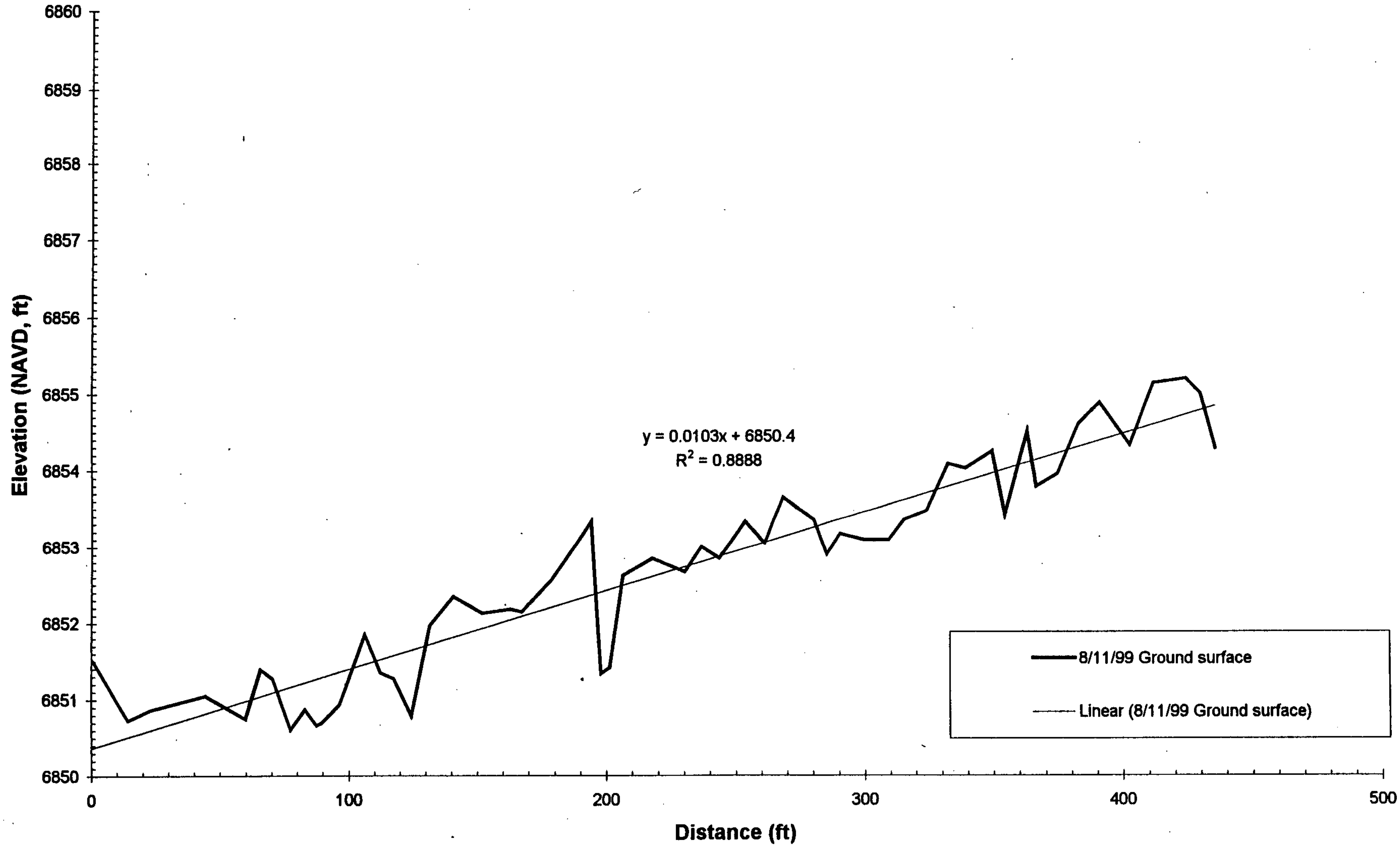
Parker Creek - Cross Section 03+04

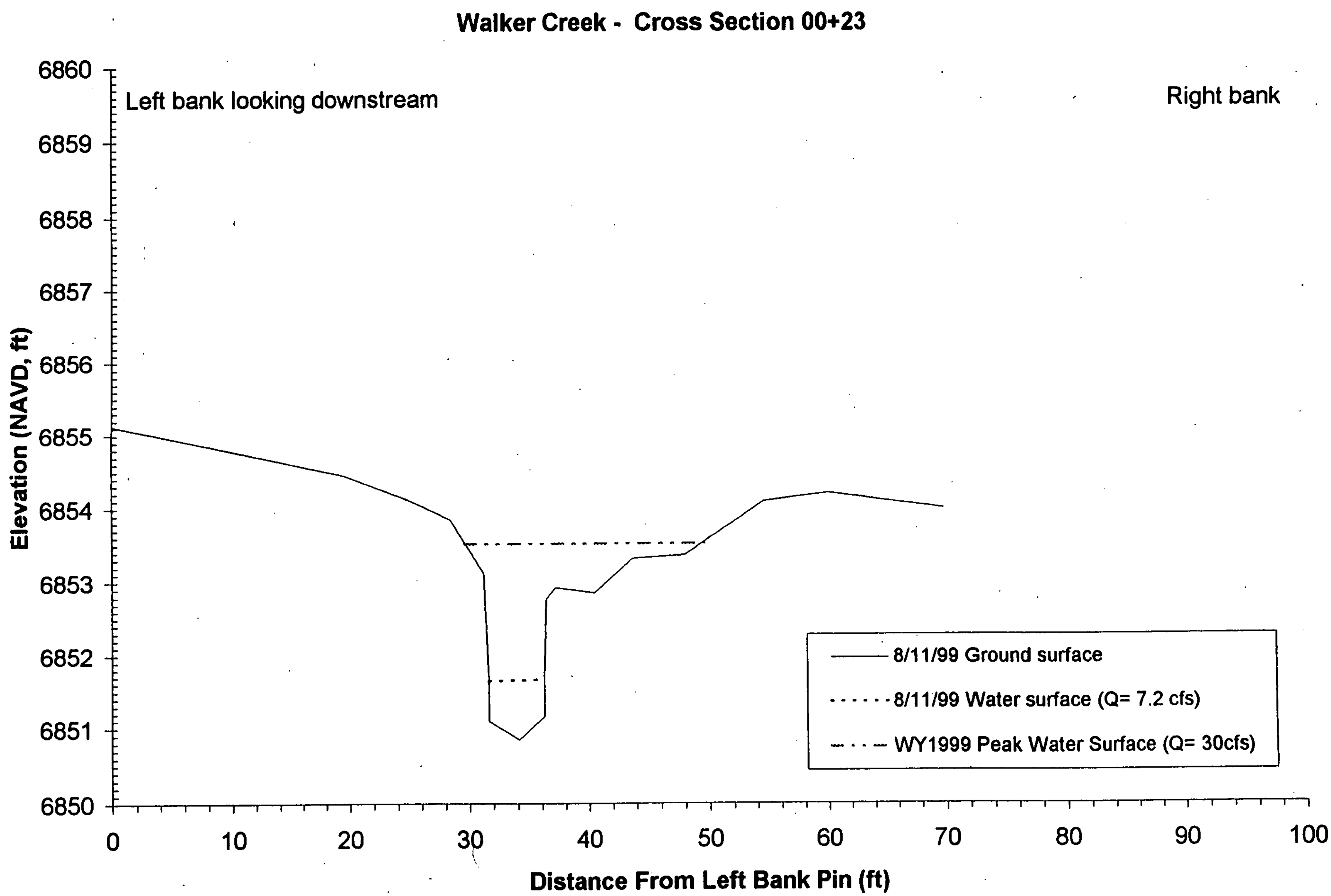


Walker Creek Cross Section and Reference Pin Summary Sheet

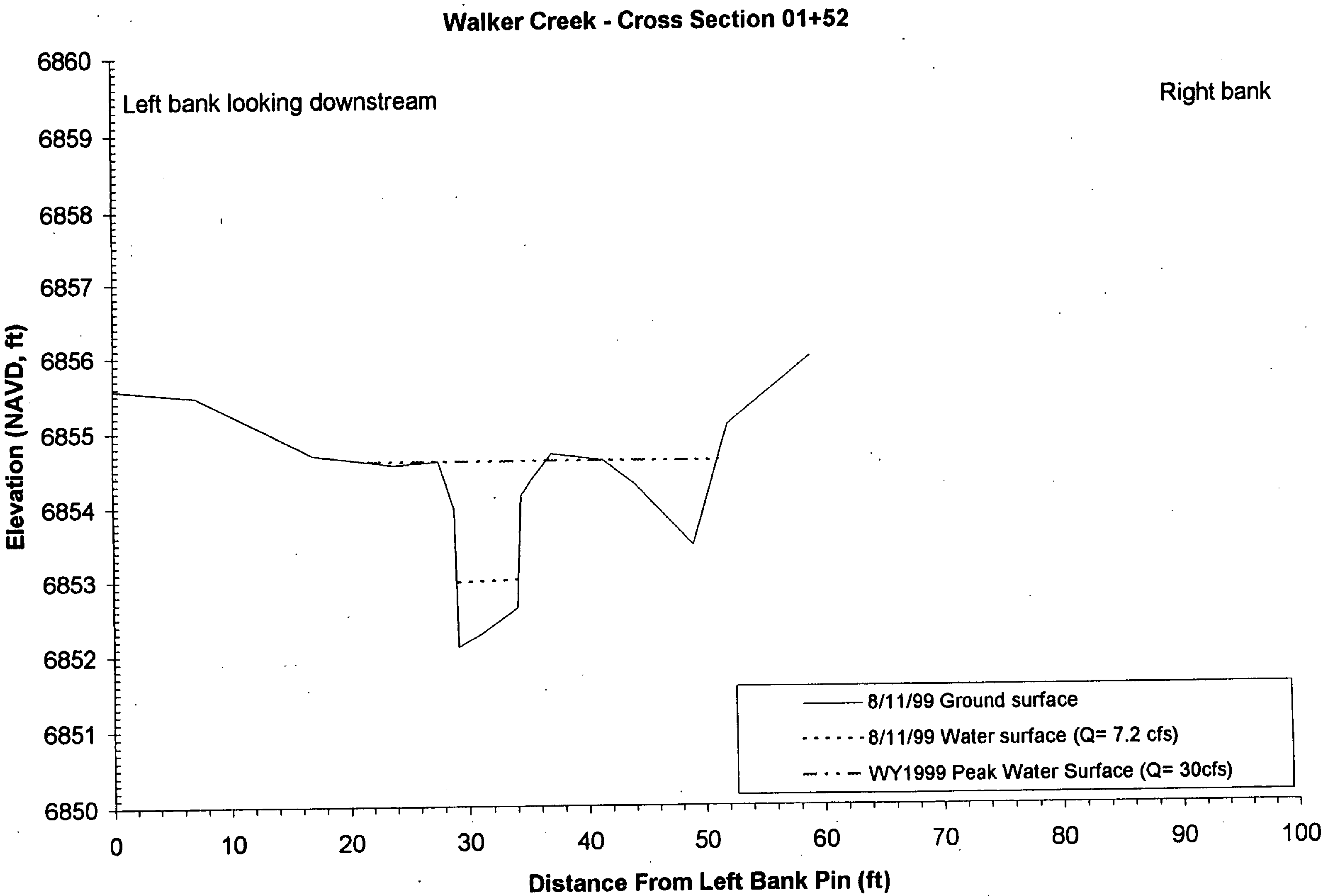
Site	Current Cross Section Label	Old Cross Section Label	Upper Left Bank Pin Elev. (ft)	Lower Left Bank Pin Elev. (ft)	Lower Right Bank Pin Elev. (ft)	Upper Right Bank Pin Elev. (ft)	Total Cross Section Length (ft)	Angle from LB pin to RB pin Degrees	Cross Section Intersection with Long Profile +	Long Profile Intersection with Cross Section (ft)	Fieldbook # and Page #'s
Walker	BM1		**6848.50**	SITE BENCHMARK (Est. 8-11-99, by M&T, GPS survey by LADWP)							Mono-Lee Vining #12, pg 92
Walker	00+23			6855.70	6855.11		69.80		35.2	23.0	Mono-Lee Vining #12, pg 92-95
Walker	01+52			6856.14	6856.84		64.30		33.9	151.6	Mono-Lee Vining #12, pg 96-99
Walker	01+99			6857.26	6858.71		92.80		30.9	198.8	Mono-Lee Vining #12, pg 100-10
Walker	02+85			6858.71	6859.02		91.70		36.7	285.1	Mono-Lee Vining #12, pg104-10
Walker	03+64			6859.49	6859.01		79.10		30.4	364.1	Mono-Lee Vining #12, pg 108-11

Walker Creek,
1999 Longitudinal Thalweg Profile

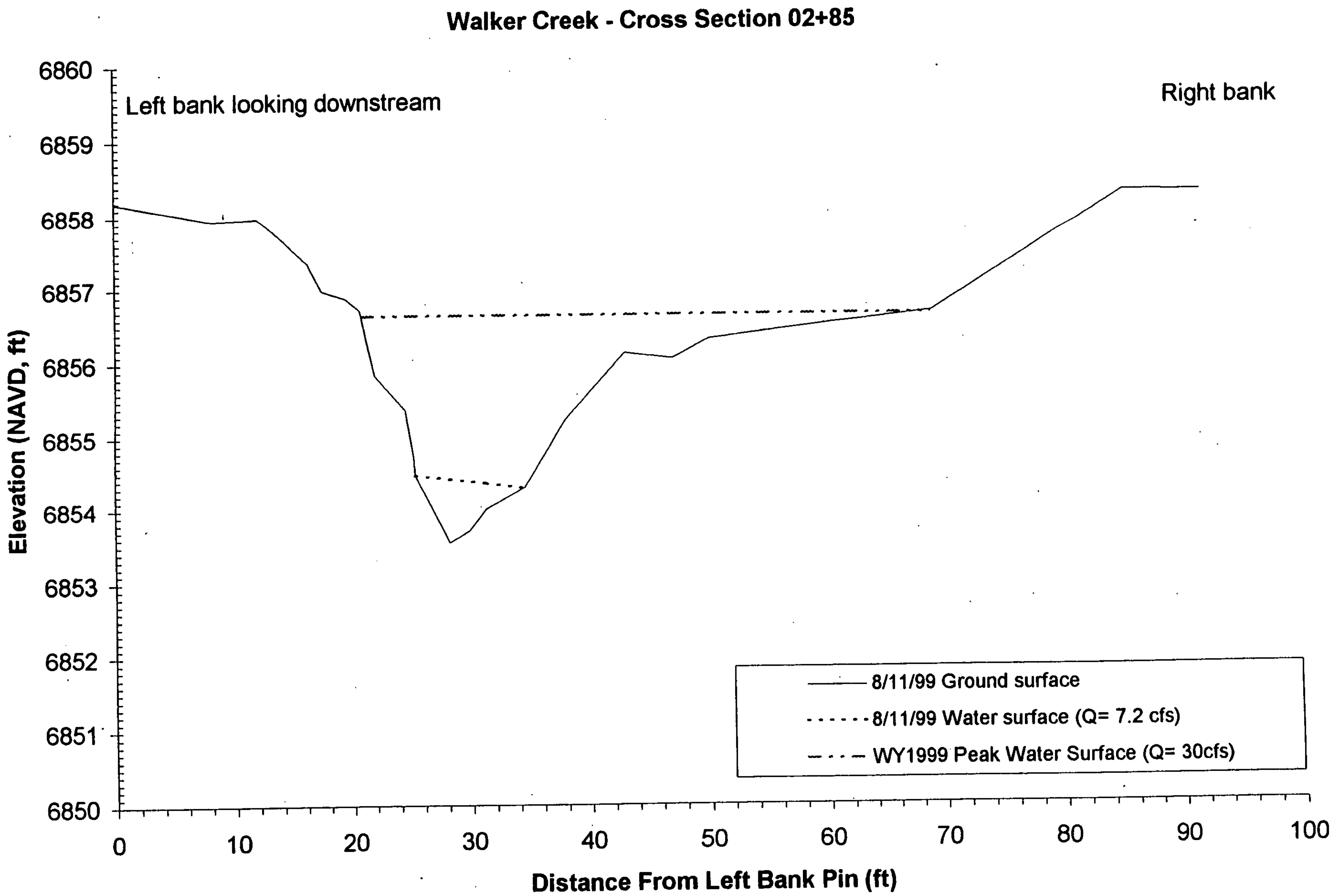




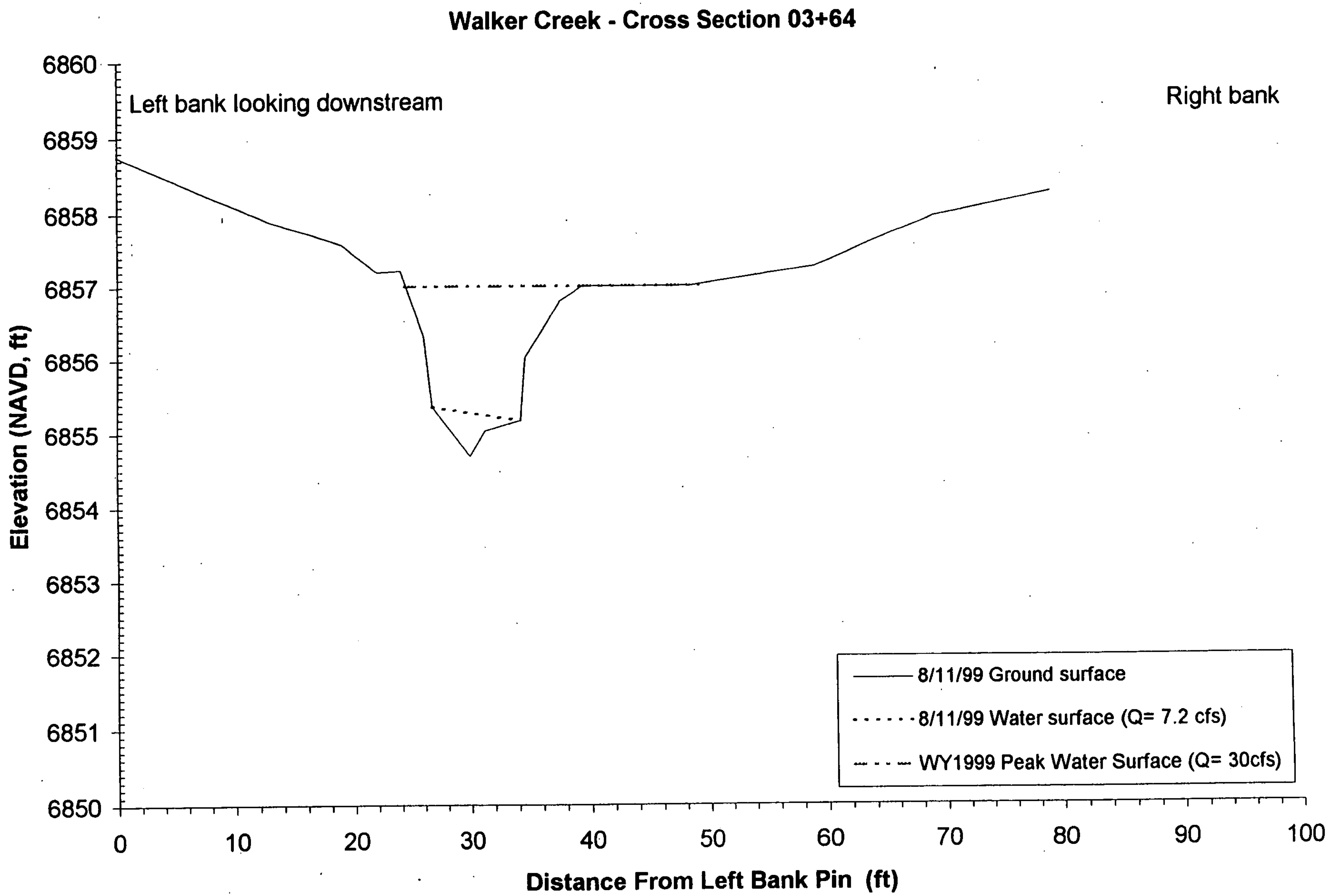
Walker Creek - Cross Section 00+23
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6860
6859
6858
6857
6856
6855
6854
6853
6852
6851
6850
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)
8/11/99 Ground surface
8/11/99 Water surface (Q= 7.2 cfs)
WY1999 Peak Water Surface (Q= 30cfs)



Walker Creek - Cross Section 01+52
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6860
6859
6858
6857
6856
6855
6854
6853
6852
6851
6850
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)
8/11/99 Ground surface
8/11/99 Water surface (Q= 7.2 cfs)
WY1999 Peak Water Surface (Q= 30cfs)



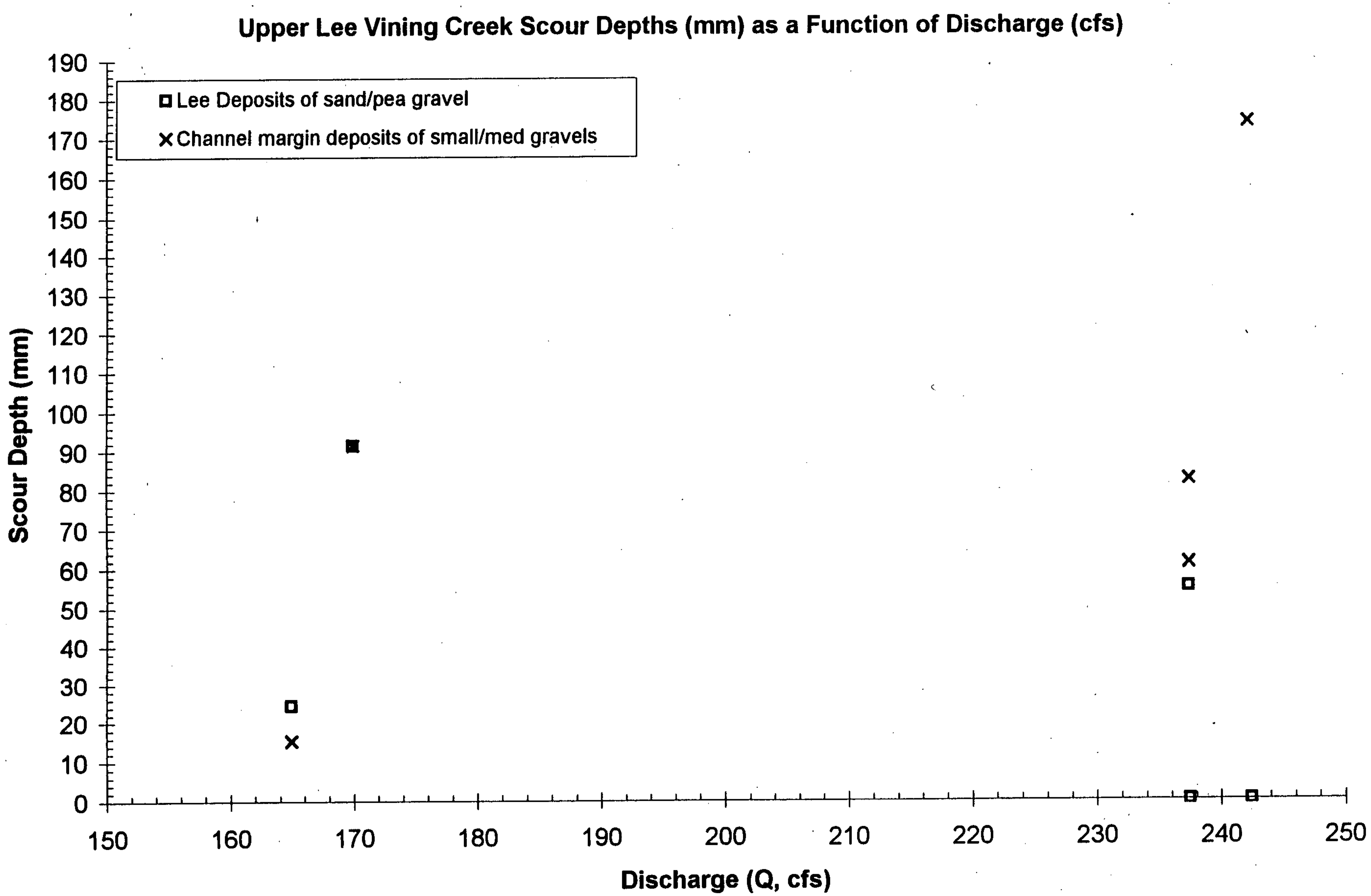
Walker Creek - Cross Section 02+85
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6860
6859
6858
6857
6856
6855
6854
6853
6852
6851
6850
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)
8/11/99 Ground surface
8/11/99 Water surface (Q= 7.2 cfs)
WY1999 Peak Water Surface (Q= 30cfs)



Walker Creek - Cross Section 03+64
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6860
6859
6858
6857
6856
6855
6854
6853
6852
6851
6850
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)
8/11/99 Ground surface
8/11/99 Water surface (Q= 7.2 cfs)
WY1999 Peak Water Surface (Q= 30cfs)

APPENDIX C:

WY1998-1999
SCOUR CORE SUMMARY


Upper Lee Vining Creek Scour Depths (mm) as a Function of Discharge (cfs)
Lee Deposits of sand/pea gravel
Channel margin deposits of small/med gravels
Scour Depth (mm)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
150
160
170
180
190
200
210
220
230
240
250
Discharge (Q, cfs)

UPPER LEE VINING CREEK MAINSTEM CROSS SECTION 13+92 SCOUR CORE SUMMARY

Scour inducing discharge (7/9/98) = 337 cfs		Water Slope 7/9/98 = 0.028	
7/9/98 Water Surface Elevation = 6539.33 ft	1998 D_{31}=58 mm	1998 D_{50}=104 mm	1998 D_{84}=260 mm
		Core #1	Core #2
Elevation of scour core tracer gravel (pre-flow)		6538.86 ft	6537.55 ft
Elevation of scour core tracer gravel (post flow)		6538.92 ft	6537.35 ft
Scour		0.00 ft	-0.20 ft
Scour		0 mm	-61 mm
Ground surface elevation above scour core (post flow)		6539.03 ft	6537.54 ft
Deposition		0.11 ft	0.19 ft
Deposition		34 mm	58 mm

UPPER LEE VINING CREEK MAINSTEM CROSS SECTION 10+44 SCOUR CORE SUMMARY

Scour inducing discharge (7/9/98) = 337 cfs		Water Slope 7/9/98 = 0.028	
7/9/98 Water Surface Elevation = 6529.30 ft	1998 D_{31}=84 mm	1998 D_{50}=111 mm	1998 D_{84}=208 mm
		Core #1	Core #2
Elevation of scour core tracer gravel (pre-flow)		not placed	not placed
Elevation of scour core tracer gravel (post flow)		not placed	not placed
Scour		not placed	not placed
Scour		not placed	not placed
Ground surface elevation above scour core (post flow)		not placed	not placed
Deposition		not placed	not placed
Deposition		not placed	not placed

UPPER LEE VINING CREEK MAINSTEM CROSS SECTION 03+73 SCOUR CORE SUMMARY

Scour inducing discharge (7/9/98) = 340 cfs		Water Slope 7/9/98 = 0.028	
7/9/98 Water Surface Elevation = 6507.24 ft	1998 D_{31}=84 mm	1998 D_{50}=111 mm	1998 D_{84}=208 mm
		Station 64	Station 68.5
Elevation of scour core tracer gravel (pre-flow)		6506.49 ft	6506.03 ft
Elevation of scour core tracer gravel (post flow)		6506.50 ft	6505.46 ft
Scour		0.00 ft	-0.57 ft
Scour		0 mm	-174 mm
Ground surface elevation above scour core (post flow)		6506.54 ft	6505.51 ft
Deposition		0.04 ft	0.05 ft
Deposition		12 mm	15 mm

UPPER LEE VINING CREEK MAINSTEM CROSS SECTION 13+92 SCOUR CORE SUMMARY

Scour inducing discharge (6/19/99) = 99 cfs	Water Slope 6/19/99 = 0.028		
6/19/99 Water Surface Elevation = 6539.79 ft	1998 D_{31}=58 mm	1998 D_{50}=104 mm	1998 D_{84}=260 mm
		Core #1	Core #2
Elevation of scour core tracer gravel (pre-flow)		6538.98 ft	6537.56 ft
Elevation of scour core tracer gravel (post flow)		6538.90 ft	6537.51 ft
Scour		-0.08 ft	-0.05 ft
Scour		-24 mm	-15 mm
Ground surface elevation above scour core (post flow)		6539.03 ft	6537.72 ft
Deposition		0.13 ft	0.21 ft
Deposition		40 mm	64 mm

UPPER LEE VINING CREEK MAINSTEM CROSS SECTION 10+44 SCOUR CORE SUMMARY

Scour inducing discharge (6/19/99) = 99 cfs	Water Slope 6/19/99 = 0.028		
6/19/99 Water Surface Elevation = 6528.69 ft	1999 D_{31}=84 mm	1999 D_{50}=111 mm	1999 D_{84}=208 mm
		Core #1	Core #2
Elevation of scour core tracer gravel (pre-flow)		6527.61 ft	6528.60 ft
Elevation of scour core tracer gravel (post flow)		6527.34 ft	6528.42 ft
Scour		-0.27 ft	-0.18 ft
Scour		-82 mm	-55 mm
Ground surface elevation above scour core (post flow)		6527.40 ft	6528.42 ft
Deposition		0.06 ft	0.00 ft
Deposition		18 mm	0 mm

UPPER LEE VINING CREEK MAINSTEM CROSS SECTION 03+73 SCOUR CORE SUMMARY

Scour inducing discharge (6/19/99) = 198 cfs	Water Slope 6/19/99 = 0.028		
6/19/99 Water Surface Elevation = 6507.43 ft	1998 D_{31}=84 mm	1998 D_{50}=111 mm	1998 D_{84}=208 mm
		Station 64	Station 68.5
Elevation of scour core tracer gravel (pre-flow)		6506.97 ft	6506.07 ft
Elevation of scour core tracer gravel (post flow)		6506.67 ft	6505.77 ft
Scour		-0.30 ft	-0.30 ft
Scour		-91 mm	-91 mm
Ground surface elevation above scour core (post flow)		6506.66 ft	6505.94 ft
Deposition		-0.01 ft	0.17 ft
Deposition		-3 mm	52 mm

LOWER LEE VINING CREEK MAINSTEM CROSS SECTION 01+15 SCOUR CORE SUMMARY

Scour inducing discharge (7/9/98) = 160 cfs	Water Slope 7/9/98 = 0.0261		
7/9/98 Water Surface Elevation = 6460.83 ft	1998 D_{31}=74 mm	1998 D_{50}=111 mm	1998 D_{84}=194 mm
	Core #1	Core #2	
Elevation of scour core tracer gravel (pre-flow)	6465.02 ft	6465.47 ft	
Elevation of scour core tracer gravel (post flow)	6465.01 ft	6465.46 ft	
Scour	-0.01 ft	-0.01 ft	
Scour	-3 mm	-3 mm	
Ground surface elevation above scour core (post flow)	6465.01 ft	6465.46 ft	
Deposition	0.00 ft	0.00 ft	
Deposition	0 mm	0 mm	

LOWER LEE VINING CREEK B1 CHANNEL CROSS SECTION 00+87 SCOUR CORE SUMMARY

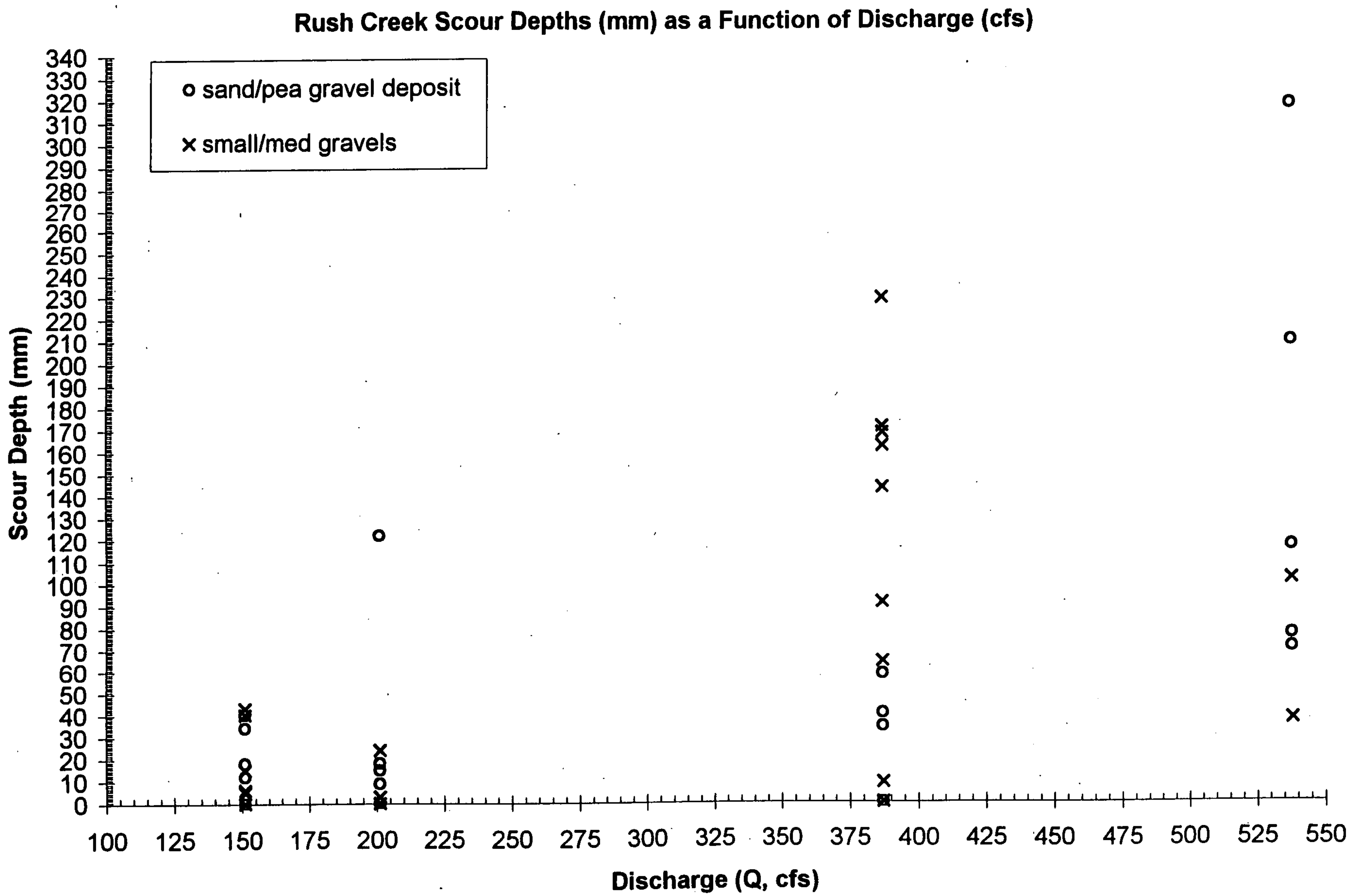
Scour inducing discharge (7/9/98) = 211 cfs	Water Slope 7/9/98 = 0.0236		
7/9/98 Water Surface Elevation =	1998 D_{31}=58 mm	1998 D_{50}=104 mm	1998 D_{84}=260 mm
		Station 29	
Elevation of scour core tracer gravel (pre-flow)		not placed	
Elevation of scour core tracer gravel (post flow)		not placed	
Scour		not placed	
Scour		not placed	
Ground surface elevation above scour core (post flow)		not placed	
Deposition		not placed	
Deposition		not placed	

LOWER LEE VINING CREEK MAINSTEM CROSS SECTION 01+15 SCOUR CORE SUMMARY

Scour inducing discharge (6/1/99) = 151 cfs	Water Slope 6/19/99 = 0.0261		
6/19/99 Water Surface Elevation = 6460.18 ft	1998 D_{31}=74 mm	1998 D_{50}=111 mm	1998 D_{84}=194 mm
	Core #1	Core #2	
Elevation of scour core tracer gravel (pre-flow)	6465.01 ft	6465.47 ft	
Elevation of scour core tracer gravel (post flow)	6465.04 ft	6465.45 ft	
Scour	0.00 ft	-0.02 ft	
Scour	0 mm	-6 mm	
Ground surface elevation above scour core (post flow)	6465.01 ft	6465.46 ft	
Deposition	-0.03 ft	0.01 ft	
Deposition	-9 mm	3 mm	

LOWER LEE VINING CREEK B1 CHANNEL CROSS SECTION 00+87 SCOUR CORE SUMMARY

Scour inducing discharge (6/1/99) = 124 cfs	Water Slope 6/19/99 = 0.0261		
6/19/99 Water Surface Elevation = 6458.01 ft	1998 D_{31}=58 mm	1998 D_{50}=104 mm	1998 D_{84}=260 mm
		Station 29	
Elevation of scour core tracer gravel (pre-flow)		6457.46 ft	
Elevation of scour core tracer gravel (post flow)		6457.36 ft	
Scour		-0.10 ft	
Scour		-30 mm	
Ground surface elevation above scour core (post flow)		6457.44 ft	
Deposition		0.08 ft	
Deposition		24 mm	


Rush Creek Scour Depths (mm) as a Function of Discharge (cfs)
sand/pea gravel deposit
small/med gravels
Scour Depth (mm)
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
550
Discharge (Q, cfs)

UPPER RUSH CREEK MAINSTEM CROSS SECTION 12+95 SCOUR CORE SUMMARY

Scour inducing discharge (7/23/98) = 538 cfs	Water Slope 7/23/98 = 0.0143	
7/23/98 Water Surface Elevation = 6903.39 ft	1998 D_{31}=52 mm 1998 D_{50}=76 mm	1998 D_{84}=147 mm
	Station 22	Station 32.1
Elevation of scour core tracer gravel (pre-flow)	6901.50 ft	6902.14 ft
Elevation of scour core tracer gravel (post flow)	6901.17 ft	6902.02 ft
Scour	-0.33 ft	-0.12 ft
Scour	-101 mm	-37 mm
Ground surface elevation above scour core (post flow)	6901.36 ft	6902.12 ft
Deposition	0.19 ft	0.10 ft
Deposition	58 mm	30 mm

UPPER RUSH CREEK MAINSTEM CROSS SECTION 05+45 SCOUR CORE SUMMARY

Scour inducing discharge (7/23/98) = 538 cfs	Water Slope 7/23/98 = 0.0143	
7/23/98 Water Surface Elevation = 6890.43 ft	1998 D_{31}=60 mm 1998 D_{50}=84 mm	1998 D_{84}=119 mm
	Station 28.5/Core #1	Core #2
Elevation of scour core tracer gravel (pre-flow)	6888.47 ft	6888.66 ft
Elevation of scour core tracer gravel (post flow)	6887.43 ft	6888.41 ft
Scour	-1.04 ft	-0.25 ft
Scour	-317 mm	-76 mm
Ground surface elevation above scour core (post flow)	6888.38 ft	6889.02 ft
Deposition	0.95 ft	0.61 ft
Deposition	290 mm	186 mm

UPPER RUSH CREEK MAINSTEM CROSS SECTION 01+05 SCOUR CORE SUMMARY

Scour inducing discharge (7/23/98) = 538 cfs	Water Slope 7/23/98 = 0.0143		
7/23/98 Water Surface Elevation = 6885.23 ft	1998 D_{31}=42 mm	1998 D_{50}=68 mm	1998 D_{84}=157 mm
	Core #1	Core #2	Core #3
Elevation of scour core tracer gravel (pre-flow)	6883.54 ft	6883.33 ft	6883.26 ft
Elevation of scour core tracer gravel (post flow)	6883.31 ft	6882.95 ft	6882.57 ft
Scour	-0.23 ft	-0.38 ft	-0.69 ft
Scour	-70 mm	-116 mm	-209 mm
Ground surface elevation above scour core (post flow)	6883.55 ft	6883.34 ft	6882.96 ft
Deposition	0.24 ft	0.39 ft	0.39 ft
Deposition	73 mm	119 mm	119 mm

UPPER RUSH CREEK MAINSTEM CROSS SECTION 12+95 SCOUR CORE SUMMARY

Scour inducing discharge (7/10/99) = 201 cfs	Water Slope 7/10/99 = 0.0145		
7/10/99 Water Surface Elevation = 6903.06 ft	1998 D_{31}=52 mm	1998 D_{50}=76 mm	1998 D_{84}=147 mm
		Station 22	Station 32.1
Elevation of scour core tracer gravel (pre-flow)		6901.22 ft	6902.13 ft
Elevation of scour core tracer gravel (post flow)		6901.23 ft	6902.05 ft
Scour		0.00 ft	-0.08 ft
Scour		0 mm	-24 mm
Ground surface elevation above scour core (post flow)		6901.51 ft	6902.05 ft
Deposition		0.28 ft	0.00 ft
Deposition		85 mm	0 mm

UPPER RUSH CREEK MAINSTEM CROSS SECTION 09+40 SCOUR CORE SUMMARY

Scour inducing discharge (7/10/99) = 201 cfs	Water Slope 7/10/99 = 0.0145		
7/10/99 Water Surface Elevation = 6895.60 ft	1999 D_{31}=30 mm	1999 D_{50}=48 mm	1999 D_{84}=91 mm
		Station 35.4	Station 43.3
Elevation of scour core tracer gravel (pre-flow)		6895.28 ft	6895.02 ft
Elevation of scour core tracer gravel (post flow)		6895.27 ft	6895.43 ft
Scour		-0.01 ft	0.00 ft
Scour		-3 mm	0 mm
Ground surface elevation above scour core (post flow)		6895.27 ft	6895.43 ft
Deposition		0.00 ft	0.00 ft
Deposition		0 mm	0 mm

UPPER RUSH CREEK MAINSTEM CROSS SECTION 05+45 SCOUR CORE SUMMARY

Scour inducing discharge (7/10/99) = 201 cfs	Water Slope 7/10/99 = 0.0145		
7/10/99 Water Surface Elevation = 6889.51 ft	1998 D_{31}=60 mm	1998 D_{50}=84 mm	1998 D_{84}=119 mm
		Station 28.5/Core #1	Core #2
Elevation of scour core tracer gravel (pre-flow)		6888.22 ft	6888.71 ft
Elevation of scour core tracer gravel (post flow)		6891.70 ft	6888.19 ft
Scour		0.00 ft	-0.52 ft
Scour		0 mm	-158 mm
Ground surface elevation above scour core (post flow)		0.00 ft	6888.38 ft
Deposition		-6891.70 ft	0.19 ft
Deposition		-2100590 mm	58 mm

UPPER RUSH CREEK MAINSTEM CROSS SECTION 01+05 SCOUR CORE SUMMARY

Scour inducing discharge (7/10/99) = 201 cfs	Water Slope 7/10/99 = 0.0145		
7/10/99 Water Surface Elevation = 6884.88 ft	1998 D_{31}=42 mm	1998 D_{50}=68 mm	1998 D_{84}=157 mm
	Core #1	Core #2	Core #3
Elevation of scour core tracer gravel (pre-flow)	6883.46 ft	6883.21 ft	6882.87 ft
Elevation of scour core tracer gravel (post flow)	6883.40 ft	6883.24 ft	6882.82 ft
Scour	-0.06 ft	0.00 ft	-0.05 ft
Scour	-18 mm	0 mm	-15 mm
Ground surface elevation above scour core (post flow)	6883.46 ft	6883.24 ft	6882.82 ft
Deposition	0.06 ft	0.00 ft	0.00 ft
Deposition	18 mm	0 mm	0 mm

LOWER RUSH CREEK MAINSTEM CROSS SECTION 07+70 SCOUR CORE SUMMARY

Scour inducing discharge (7/23/98) = 387 cfs — Water Slope 7/23/98 = 0.0070

7/23/98 Water Surface Elevation = 6491.07 ft — 1998 D_{31}=40 mm — 1998 D_{50}=56 mm — 1998 D_{84}=97 mm

	Station 103
Elevation of scour core tracer gravel (pre-flow)	6490.87 ft
Elevation of scour core tracer gravel (post flow)	6490.94 ft
Scour	0.00 ft
Scour	0 mm
Ground surface elevation above scour core (post flow)	6490.94 ft
Deposition	0.00 ft
Deposition	0 mm

LOWER RUSH CREEK MAINSTEM CROSS SECTION 07+25 SCOUR CORE SUMMARY

Scour inducing discharge (7/23/98) = 387 cfs — Water Slope 7/23/98 = 0.0070

7/23/98 Water Surface Elevation = 6490.59 ft — 1998 D_{31}=40 mm — 1998 D_{50}=56 mm — 1998 D_{84}=97 mm

	Station 116
Elevation of scour core tracer gravel (pre-flow)	6490.76 ft
Elevation of scour core tracer gravel (post flow)	6490.80 ft
Scour	0.00 ft
Scour	0 mm
Ground surface elevation above scour core (post flow)	6490.80 ft
Deposition	0.00 ft
Deposition	0 mm

LOWER RUSH CREEK MAINSTEM CROSS SECTION 05+49 SCOUR CORE SUMMARY

Scour inducing discharge (7/23/98) = 387 cfs — Water Slope 7/23/98 = 0.0070

7/23/98 Water Surface Elevation = 6489.30 ft — 1998 D_{31}= n/a — 1998 D_{50}= n/a — 1998 D_{84}= n/a

	Station 11	Station 21	Station 31	Station 41
Elevation of scour core tracer gravel (pre-flow)	6487.70 ft	6486.96 ft	6486.63 ft	6486.90 ft
Elevation of scour core tracer gravel (post flow)	6487.57 ft	6486.85 ft	6486.64 ft	6486.71 ft
Scour	-0.13 ft	-0.11 ft	0.00 ft	-0.19 ft
Scour	-40 mm	-34 mm	0 mm	-58 mm
Ground surface elevation above scour core (post flow)	6487.63 ft	6486.96 ft	6486.97 ft	6486.91 ft
Deposition	0.06 ft	0.11 ft	0.33 ft	0.20 ft
Deposition	18 mm	34 mm	101 mm	61 mm

LOWER RUSH CREEK MAINSTEM CROSS SECTION 04+08 SCOUR CORE SUMMARY

Scour inducing discharge (7/23/98) = 387 cfs — Water Slope 7/23/98 = 0.0070

7/23/98 Water Surface Elevation = 6488.85 ft — 1998 D_{31}=26 mm — 1998 D_{50}=36 mm — 1998 D_{84}=56 mm

	Station 142.7	Station 150.7
Elevation of scour core tracer gravel (pre-flow)	6485.92 ft	6486.12 ft
Elevation of scour core tracer gravel (post flow)	6485.36 ft	6485.59 ft
Scour	-0.56 ft	-0.53 ft
Scour	-171 mm	-162 mm
Ground surface elevation above scour core (post flow)	6485.84 ft	6486.44 ft
Deposition	0.48 ft	0.85 ft
Deposition	146 mm	259 mm

NO TRACER GRAVEL RECOVERED (PROBABLY DID NOT DIG DEEP ENOUGH)

LOWER RUSH CREEK MAINSTEM CROSS SECTION 03+30 SCOUR CORE SUMMARY

Scour inducing discharge (7/23/98) = 387 cfs — Water Slope 7/23/98 = 0.0070

7/23/98 Water Surface Elevation = 6488.50 ft — 1998 D_{31}= n/a — 1998 D_{50}= n/a — 1998 D_{84}= n/a

	Station 13	Station 20	Station 27
Elevation of scour core tracer gravel (pre-flow)	6486.56 ft	6486.23 ft	6486.08 ft
Elevation of scour core tracer gravel (post flow)	6486.09 ft	6485.68 ft	6485.33 ft
Scour	-0.47 ft	-0.55 ft	-0.75 ft
Scour	-143 mm	-168 mm	-229 mm
Ground surface elevation above scour core (post flow)	6486.40 ft	6486.23 ft	6485.33 ft
Deposition	0.31 ft	0.55 ft	0.00 ft
Deposition	94 mm	168 mm	0 mm

NO TRACER GRAVEL RECOVERED (scour exceeded depth of scour core placement)

LOWER RUSH CREEK MAINSTEM CROSS SECTION 00+86 SCOUR CORE SUMMARY

Scour inducing discharge (7/23/98) = 387 cfs — Water Slope 7/23/98 = 0.0070

7/23/98 Water Surface Elevation = 6485.06 ft — 1998 D_{31}= n/a — 1998 D_{50}= n/a — 1998 D_{84}= n/a

	Station 51	Station 57	Station 72	Station 82
Elevation of scour core tracer gravel (pre-flow)	6483.28 ft	6484.47 ft	6486.59 ft	6486.46 ft
Elevation of scour core tracer gravel (post flow)	6482.98 ft	6484.26 ft	6486.56 ft	6486.46 ft
Scour	-0.30 ft	-0.21 ft	-0.03 ft	0.00 ft
Scour	-91 mm	-64 mm	-9 mm	0 mm
Ground surface elevation above scour core (post flow)	6483.75 ft	6485.40 ft	6486.56 ft	6486.46 ft
Deposition	0.77 ft	1.14 ft	0.00 ft	0.00 ft
Deposition	235 mm	347 mm	0 mm	0 mm

LOWER RUSH CREEK MAINSTEM CROSS SECTION 10+10 SCOUR CORE SUMMARY

Scour inducing discharge (7/10/99) = 151 cfs — Water Slope 7/10/99 = 0.0078

7/10/99 Water Surface Elevation = 6491.92 ft — 1998 D_{31}=29 mm — 1998 D_{50}=46 mm — 1998 D_{84}=79 mm

	Station 24.6	Station 30.1
Elevation of scour core tracer gravel (pre-flow)	6490.30 ft	6490.15 ft
Elevation of scour core tracer gravel (post flow)	6490.26 ft	6490.09 ft
Scour	-0.04 ft	-0.06 ft
Scour	-12 mm	-18 mm
Ground surface elevation above scour core (post flow)	6490.41 ft	6490.20 ft
Deposition	0.15 ft	0.11 ft
Deposition	46 mm	34 mm

LOWER RUSH CREEK MAINSTEM CROSS SECTION 07+70 SCOUR CORE SUMMARY

Scour inducing discharge (7/10/99) = 151 cfs — Water Slope 7/10/99 = 0.0078

7/10/99 Water Surface Elevation = 6491.27 ft — 1998 D_{31}=40 mm — 1998 D_{50}=56 mm — 1998 D_{84}=97 mm

	Station 103
Elevation of scour core tracer gravel (pre-flow)	6490.87 ft
Elevation of scour core tracer gravel (post flow)	6490.94 ft
Scour	0.00 ft
Scour	0 mm
Ground surface elevation above scour core (post flow)	6490.94 ft
Deposition	0.00 ft
Deposition	0 mm

LOWER RUSH CREEK MAINSTEM CROSS SECTION 07+25 SCOUR CORE SUMMARY

Scour inducing discharge (7/10/99) = 151 cfs — Water Slope 7/10/99 = 0.0078

7/10/99 Water Surface Elevation = 6489.97 ft — 1998 D_{31}=40 mm — 1998 D_{50}=56 mm — 1998 D_{84}=97 mm

	Station 116
Elevation of scour core tracer gravel (pre-flow)	6490.76 ft
Elevation of scour core tracer gravel (post flow)	6490.74 ft
Scour	-0.02 ft
Scour	-5 mm
Ground surface elevation above scour core (post flow)	6490.74 ft
Deposition	0.00 ft
Deposition	0 mm

LOWER RUSH CREEK MAINSTEM CROSS SECTION 05+49 SCOUR CORE SUMMARY

Scour inducing discharge (7/10/99) = 151 cfs — Water Slope 7/10/99 = 0.0078

7/10/99 Water Surface Elevation = 6488.41 ft — 1998 D_{31}= n/a — 1998 D_{50}= n/a — 1998 D_{84}= n/a

	Station 11	Station 21	Station 31	Station 41
Elevation of scour core tracer gravel (pre-flow)	6487.70 ft	6486.96 ft	6486.63 ft	6486.90 ft
Elevation of scour core tracer gravel (post flow)	6487.57 ft	6486.85 ft	6486.64 ft	6486.71 ft
Scour	-0.13 ft	-0.11 ft	0.00 ft	-0.19 ft
Scour	-40 mm	-34 mm	0 mm	-58 mm
Ground surface elevation above scour core (post flow)	6487.63 ft	6486.96 ft	6486.97 ft	6486.91 ft
Deposition	0.06 ft	0.11 ft	0.33 ft	0.20 ft
Deposition	18 mm	34 mm	101 mm	61 mm

LOWER RUSH CREEK MAINSTEM CROSS SECTION 04+08 SCOUR CORE SUMMARY

Scour inducing discharge (7/10/99) = 151 cfs — Water Slope 7/10/99 = 0.0078

7/10/99 Water Surface Elevation = 6487.88 ft — 1998 D_{31}=56 mm — 1998 D_{50}=36 mm — 1998 D_{84}=26 mm

	Station 147.2	Station 153.3
Elevation of scour core tracer gravel (pre-flow)	6486.11 ft	6486.33 ft
Elevation of scour core tracer gravel (post flow)	6486.06 ft	6486.20 ft
Scour	-0.05 ft	-0.13 ft
Scour	-15 mm	-40 mm
Ground surface elevation above scour core (post flow)	6486.26 ft	6486.20 ft
Deposition	0.20 ft	0.00 ft
Deposition	61 mm	0 mm

LOWER RUSH CREEK MAINSTEM CROSS SECTION 03+30 SCOUR CORE SUMMARY

Scour inducing discharge (7/10/99) = 151 cfs — Water Slope 7/10/99 = 0.0078

7/10/99 Water Surface Elevation = 6487.44 ft — 1998 D_{31}= n/a — 1998 D_{50}= n/a — 1998 D_{84}= n/a

	Station 13	Station 20
Elevation of scour core tracer gravel (pre-flow)	6486.33 ft	6486.21 ft
Elevation of scour core tracer gravel (post flow)	6486.28 ft	6486.07 ft
Scour	-0.05 ft	-0.14 ft
Scour	-15 mm	-43 mm
Ground surface elevation above scour core (post flow)	6486.42 ft	6486.21 ft
Deposition	0.14 ft	0.14 ft
Deposition	43 mm	43 mm

LOWER RUSH CREEK MAINSTEM CROSS SECTION 00+86 SCOUR CORE SUMMARY

Scour inducing discharge (7/10/99) = 151 cfs	Water Slope 7/10/99 = 0.0078		
7/10/99 Water Surface Elevation = 6484.88 ft	1998 D_{31}= n/a	1998 D_{50}= n/a	1998 D_{84}= n/a
	Station 57	Station 72	Station 82
Elevation of scour core tracer gravel (pre-flow)	6485.41 ft	6486.56 ft	6486.46 ft
Elevation of scour core tracer gravel (post flow)	6485.39 ft	6486.56 ft	6486.46 ft
Scour	-0.02 ft	0.00 ft	0.00 ft
Scour	-6 mm	0 mm	0 mm
Ground surface elevation above scour core (post flow)	6485.39 ft	6486.56 ft	6486.45 ft
Deposition	0.00 ft	0.00 ft	-0.01 ft
Deposition	0 mm	0 mm	-3 mm

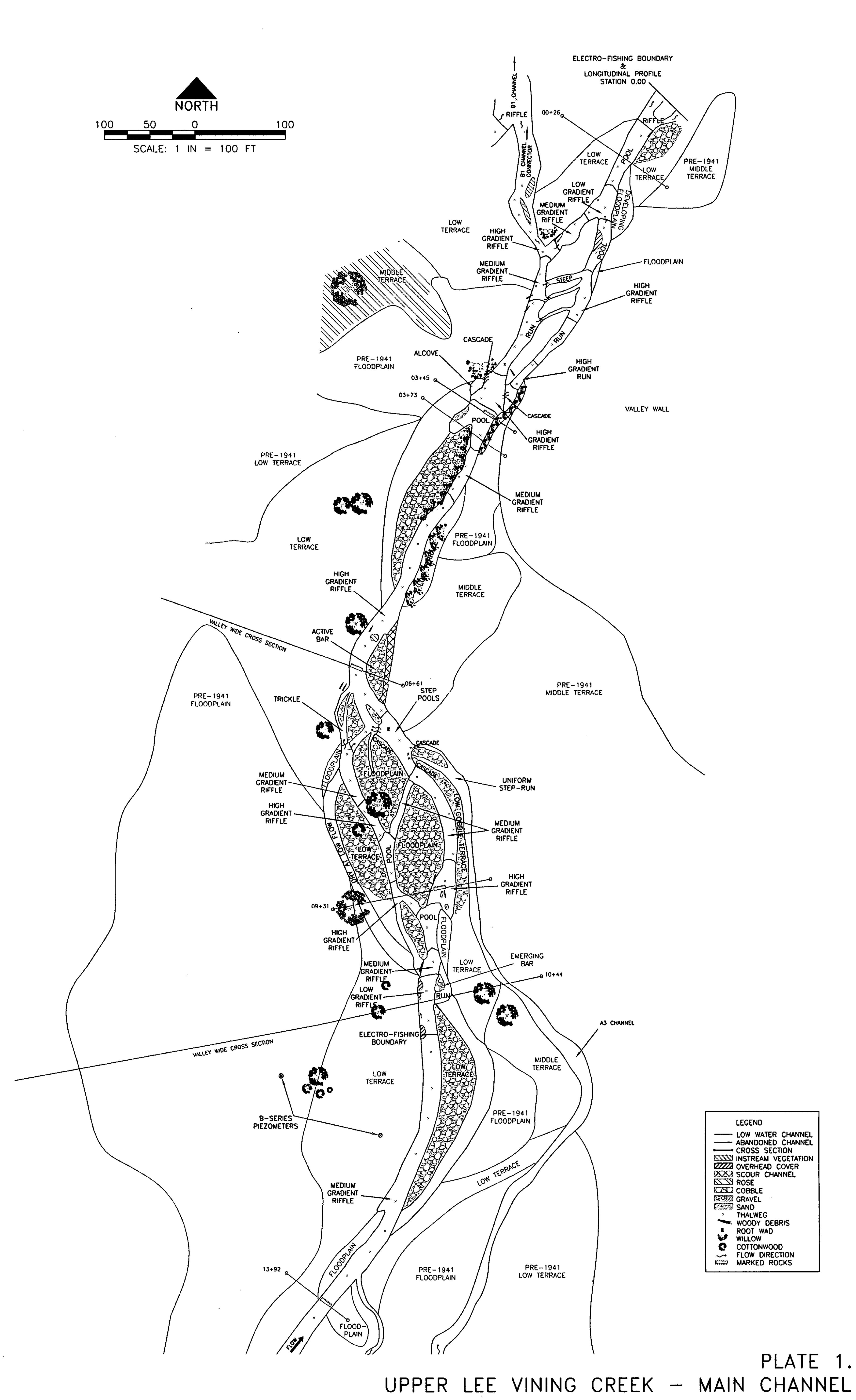


PLATE 1.
UPPER LEE VINING CREEK – MAIN CHANNEL
1999 PLANFORM

McBain & Trush 2000

3/17/00

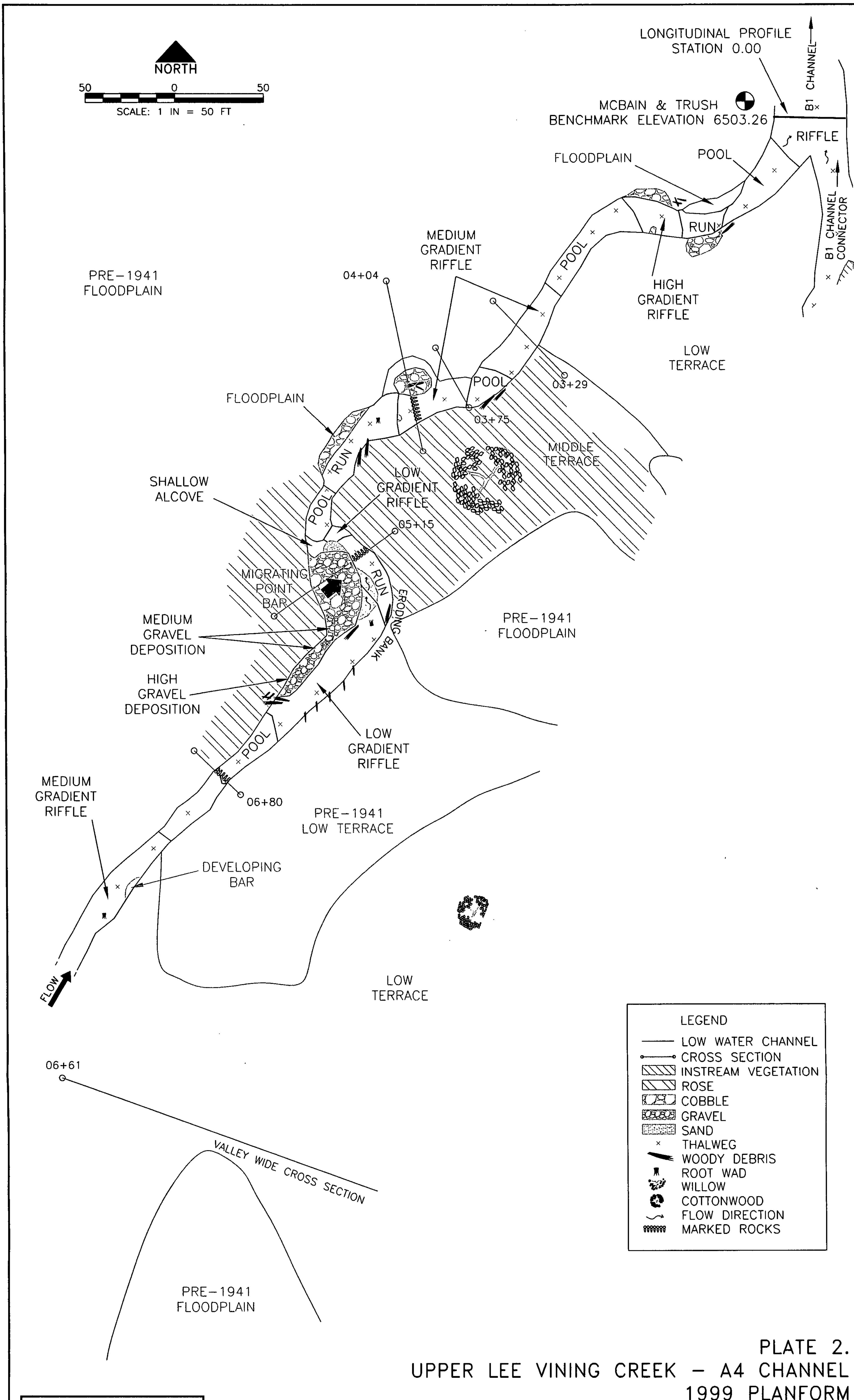


PLATE 2.
UPPER LEE VINING CREEK – A4 CHANNEL
1999 PLANFORM

McBain & Trush 2000

3/17/00

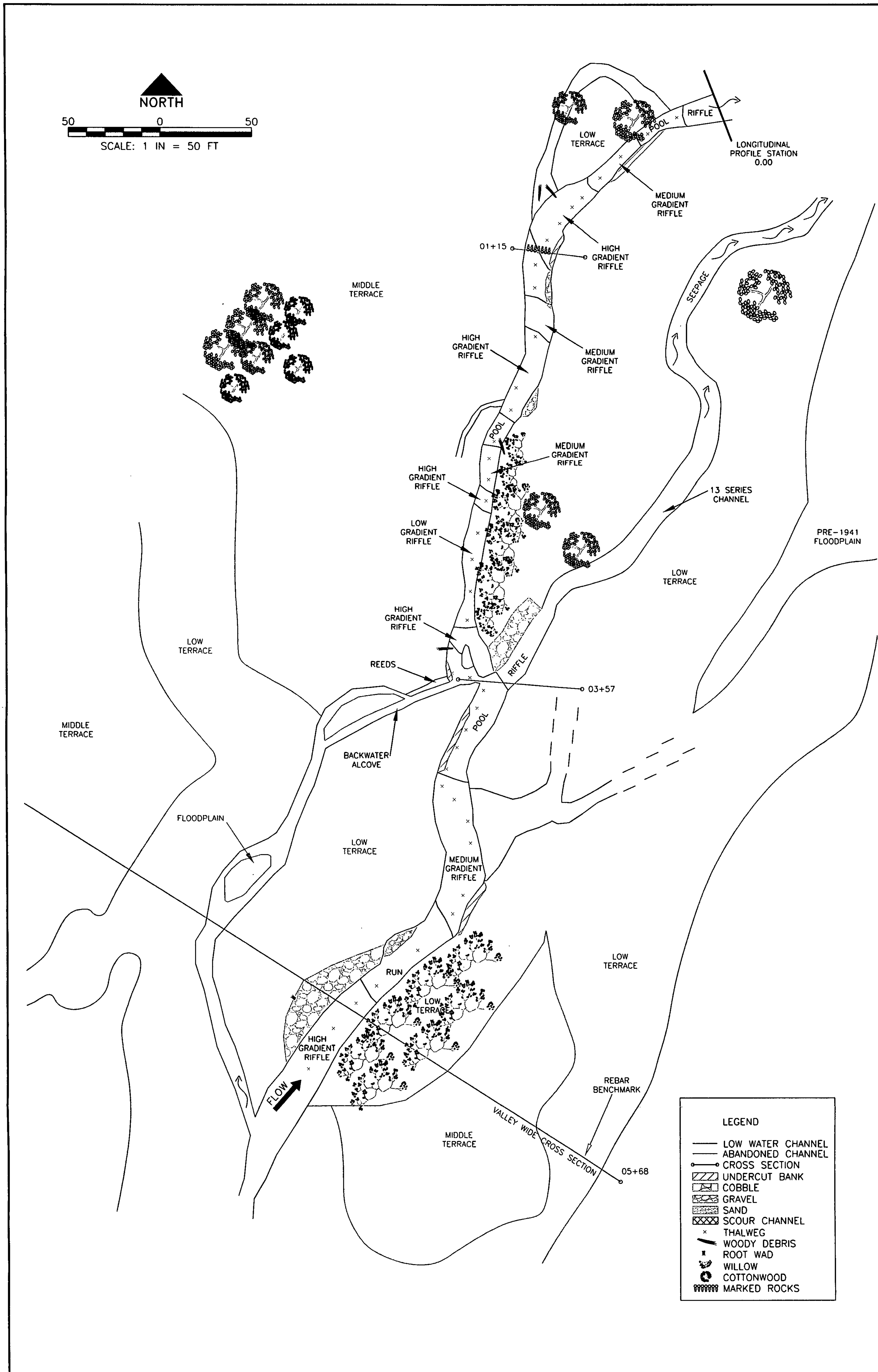


PLATE 3.
LOWER LEE VINING CREEK– MAIN CHANNEL
1999 PLANFORM

McBain & Trush 2000

3/17/00

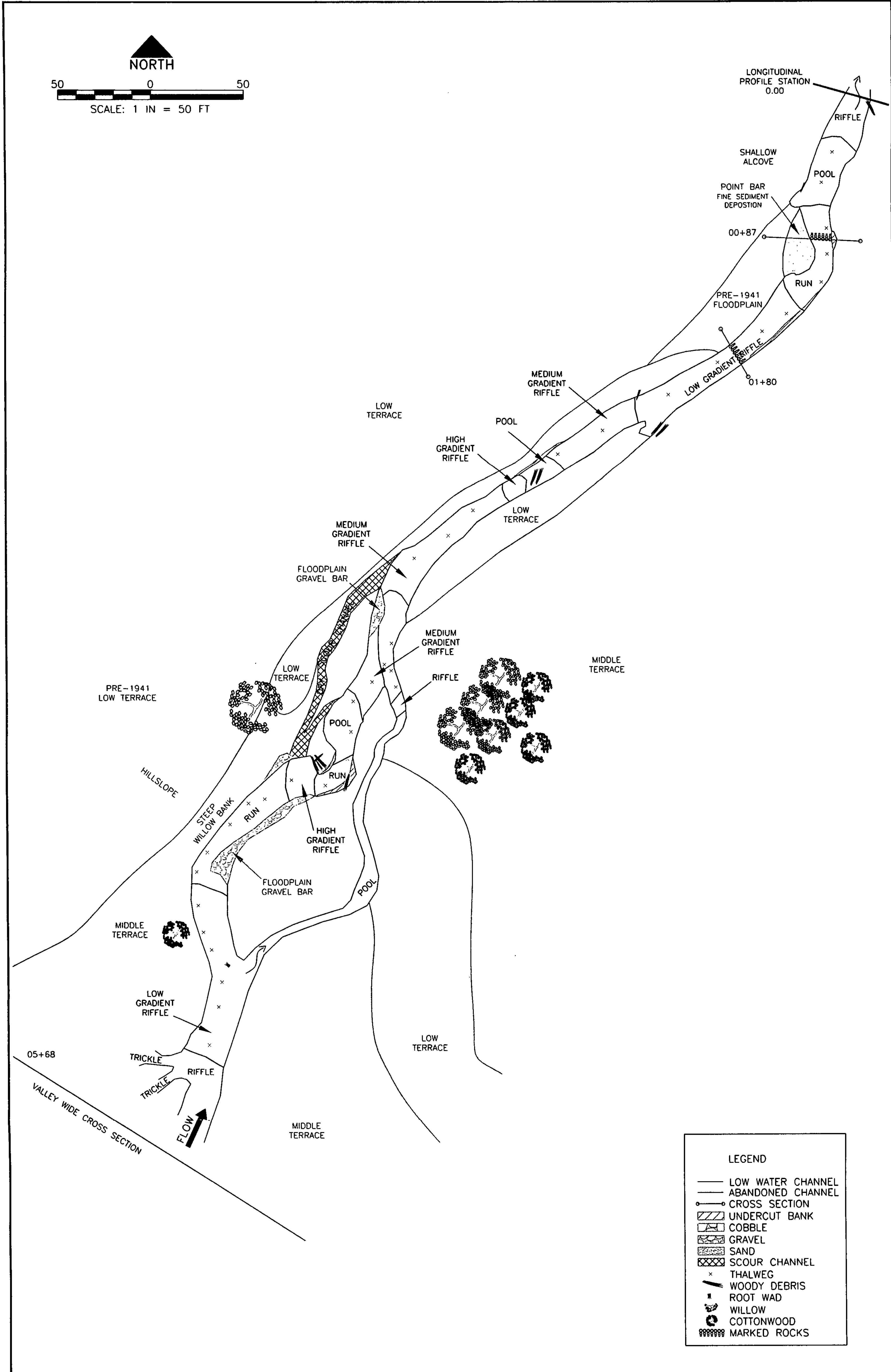


PLATE 4.
LOWER LEE VINING CREEK- B1 CHANNEL
1999 PLANFORM

McBain & Trush 2000

3/17/00

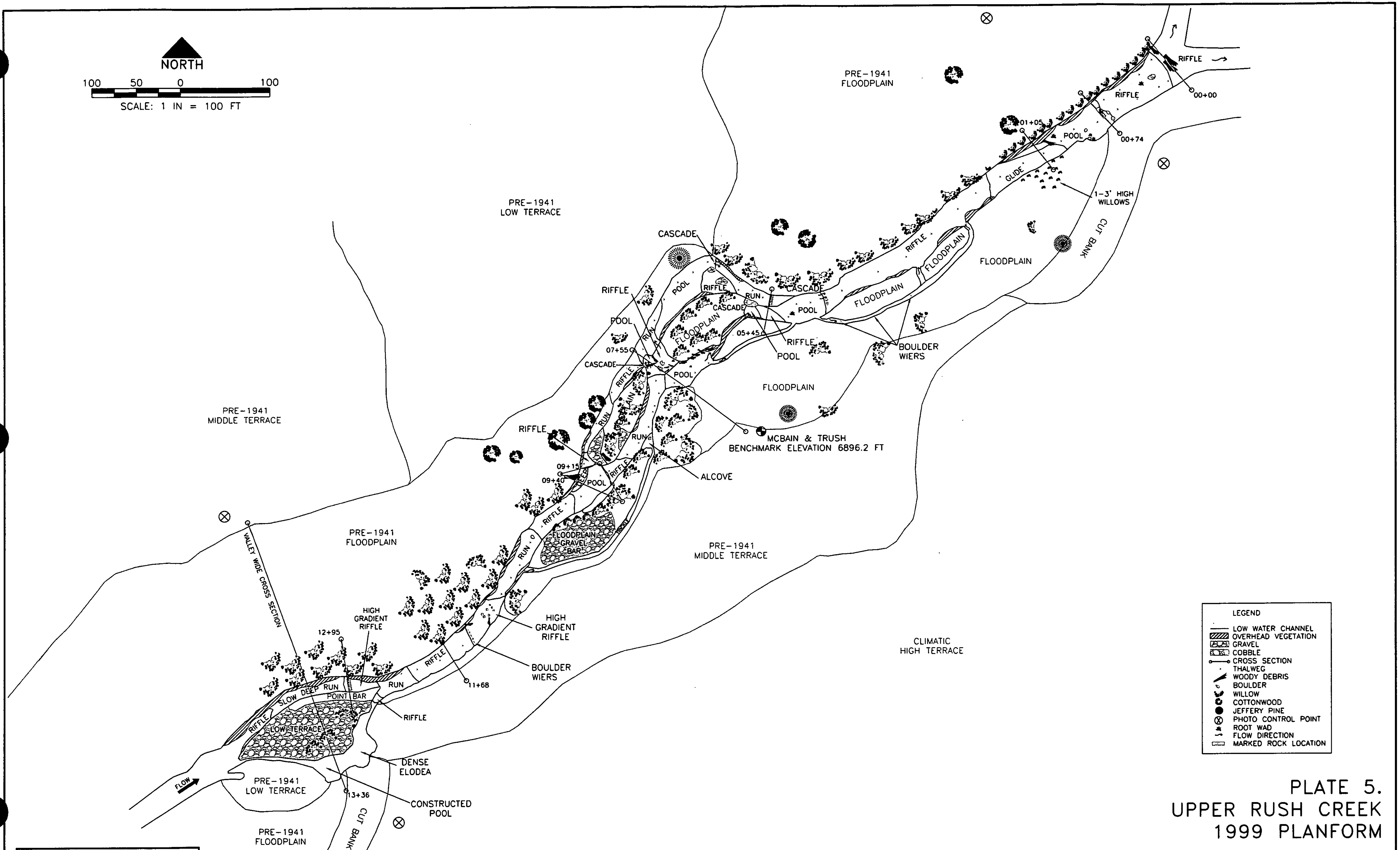


PLATE 5.
UPPER RUSH CREEK
1999 PLANFORM

McBain & Trush 2000

3/17/00

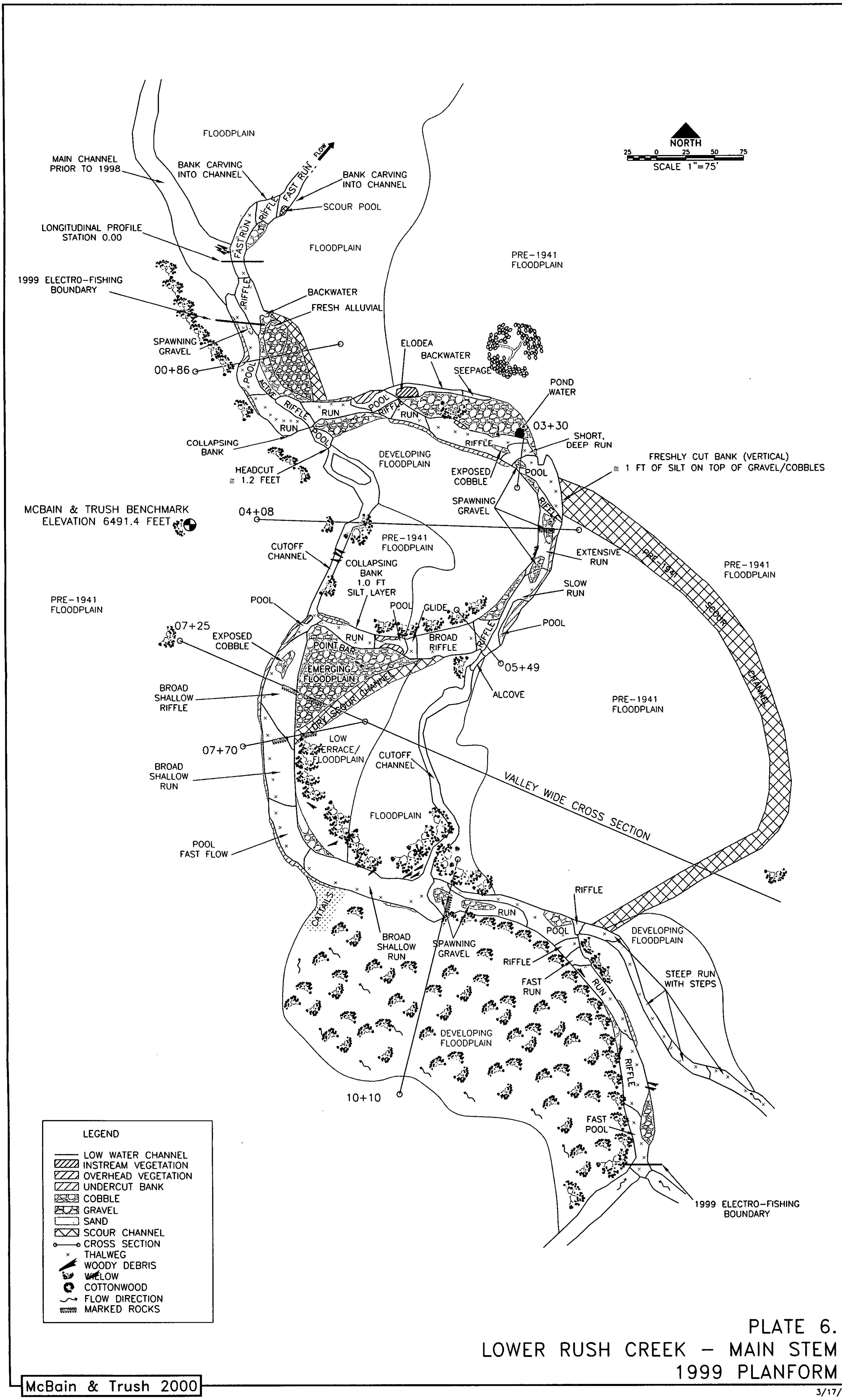


PLATE 6.
LOWER RUSH CREEK - MAIN STEM
1999 PLANFORM

McBain & Trush 2000

3/17/00

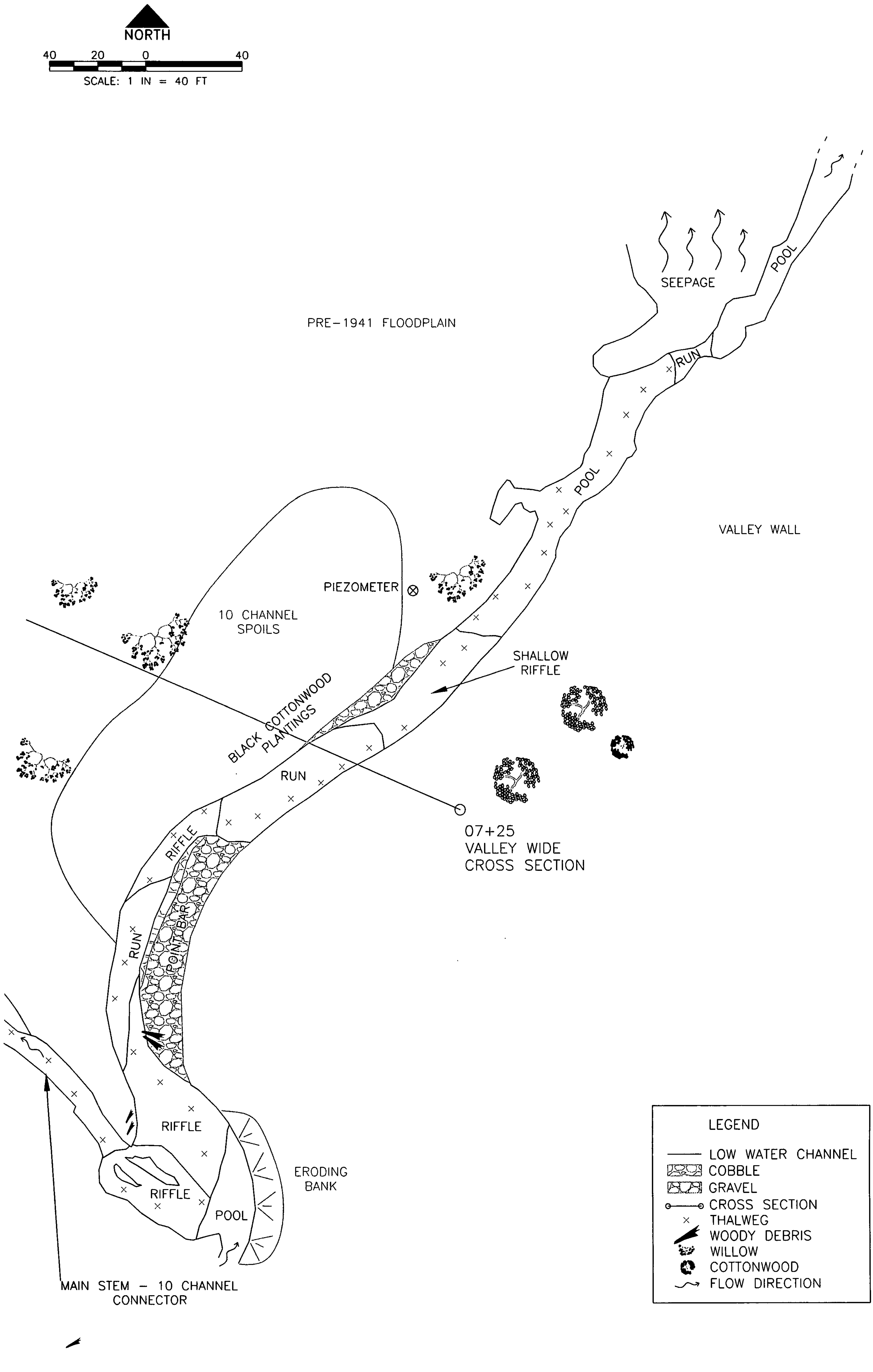


PLATE 7.
LOWER RUSH CREEK - 10 CHANNEL
1999 PLANFORM

McBain & Trush 2000

3/17/00

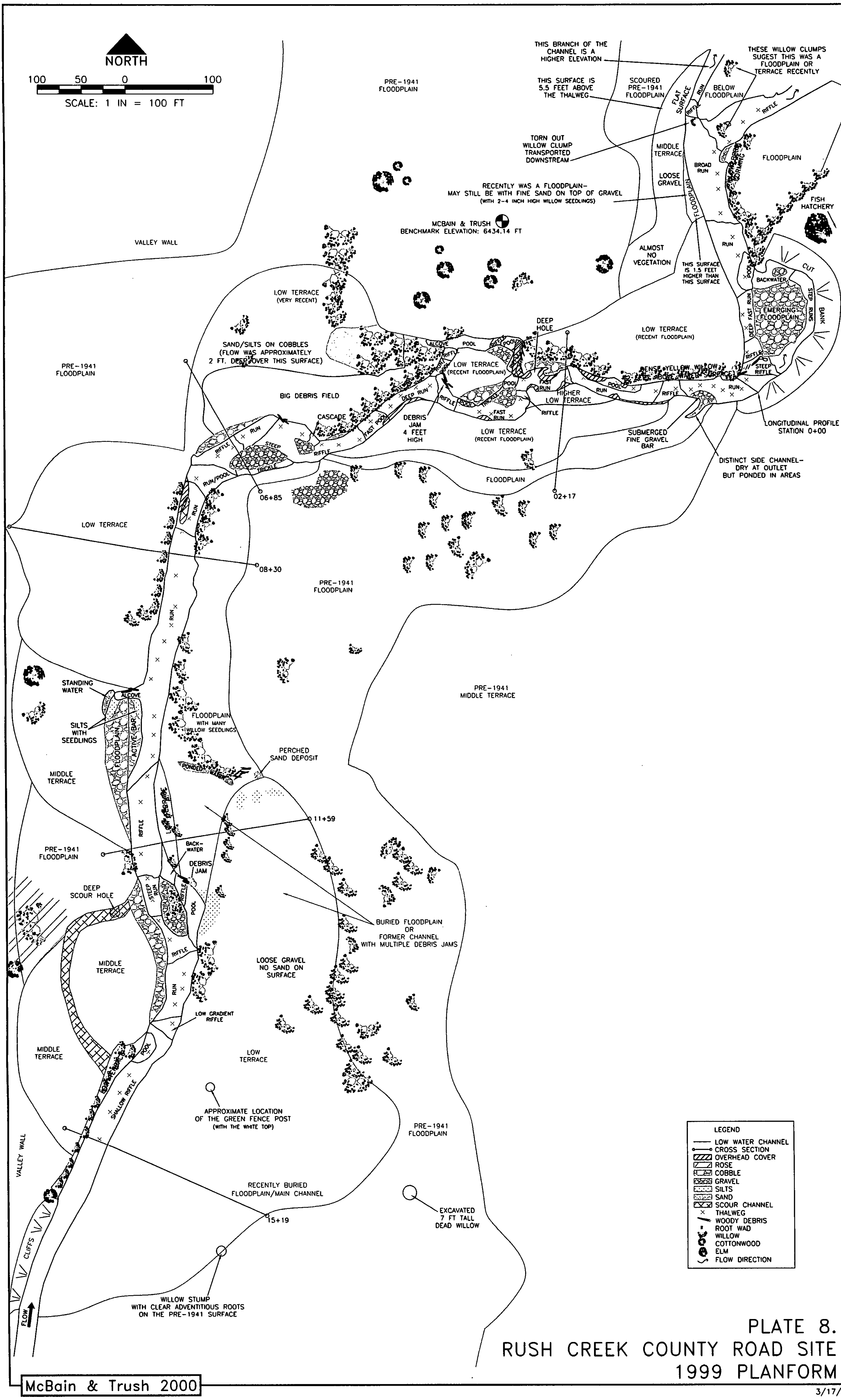


PLATE 8.
RUSH CREEK COUNTY ROAD SITE
1999 PLANFORM

McBain & Trush 2000

3/17/00

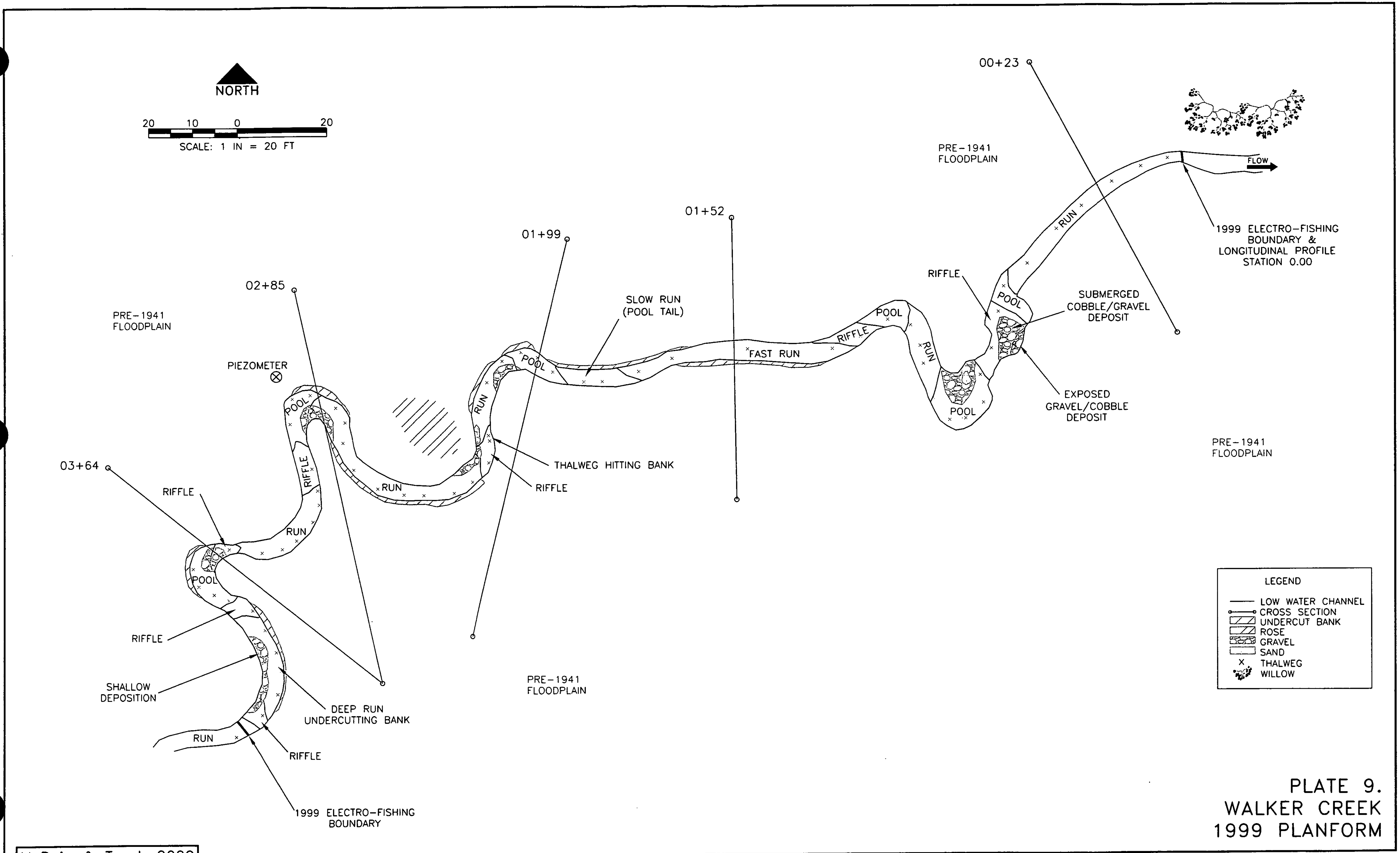


PLATE 9.
WALKER CREEK
1999 PLANFORM

McBain & Trush 2000

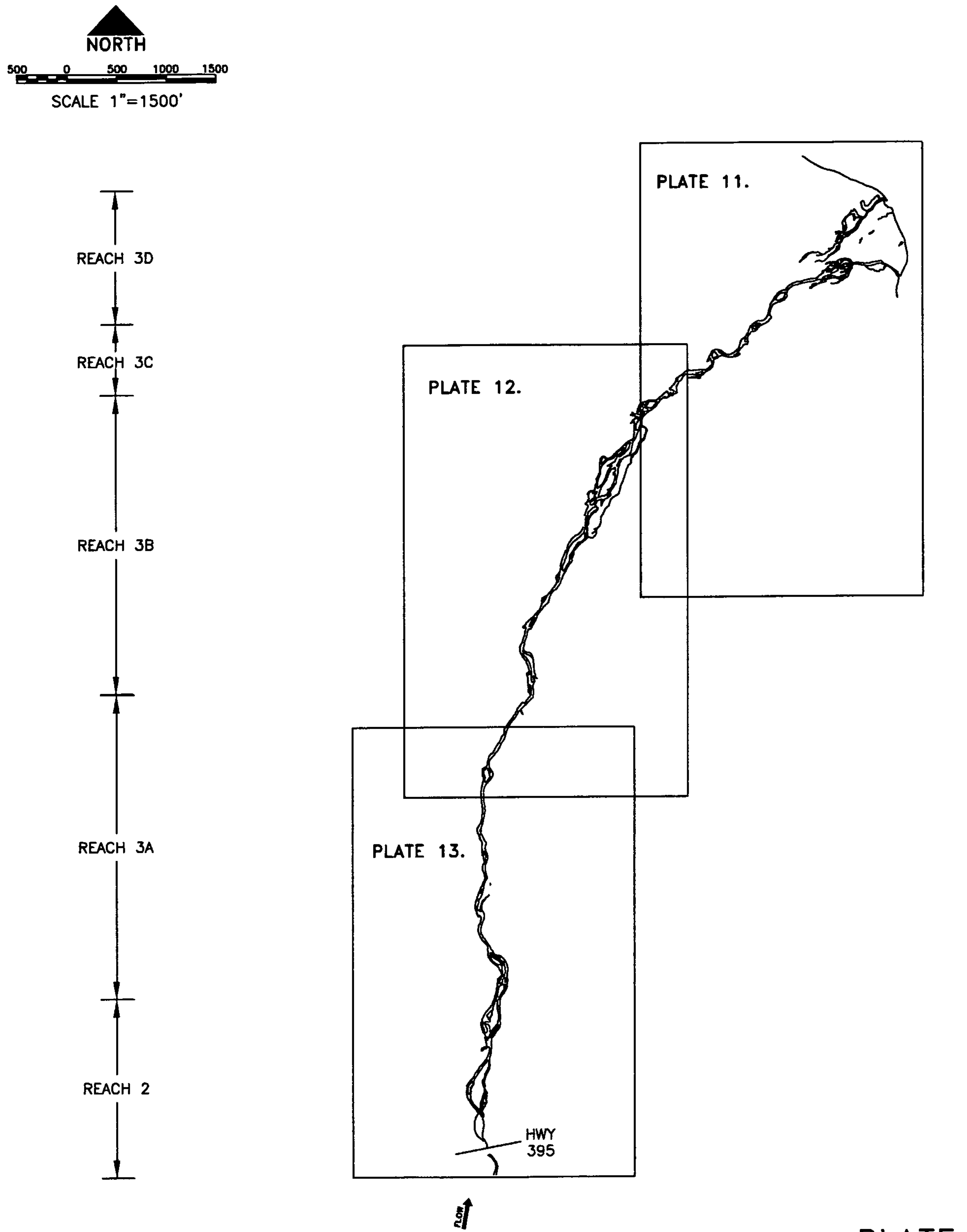


PLATE 10.
LEE VINING CREEK
1999 PLATE ATLAS

McBain & Trush 2000

2/8/00

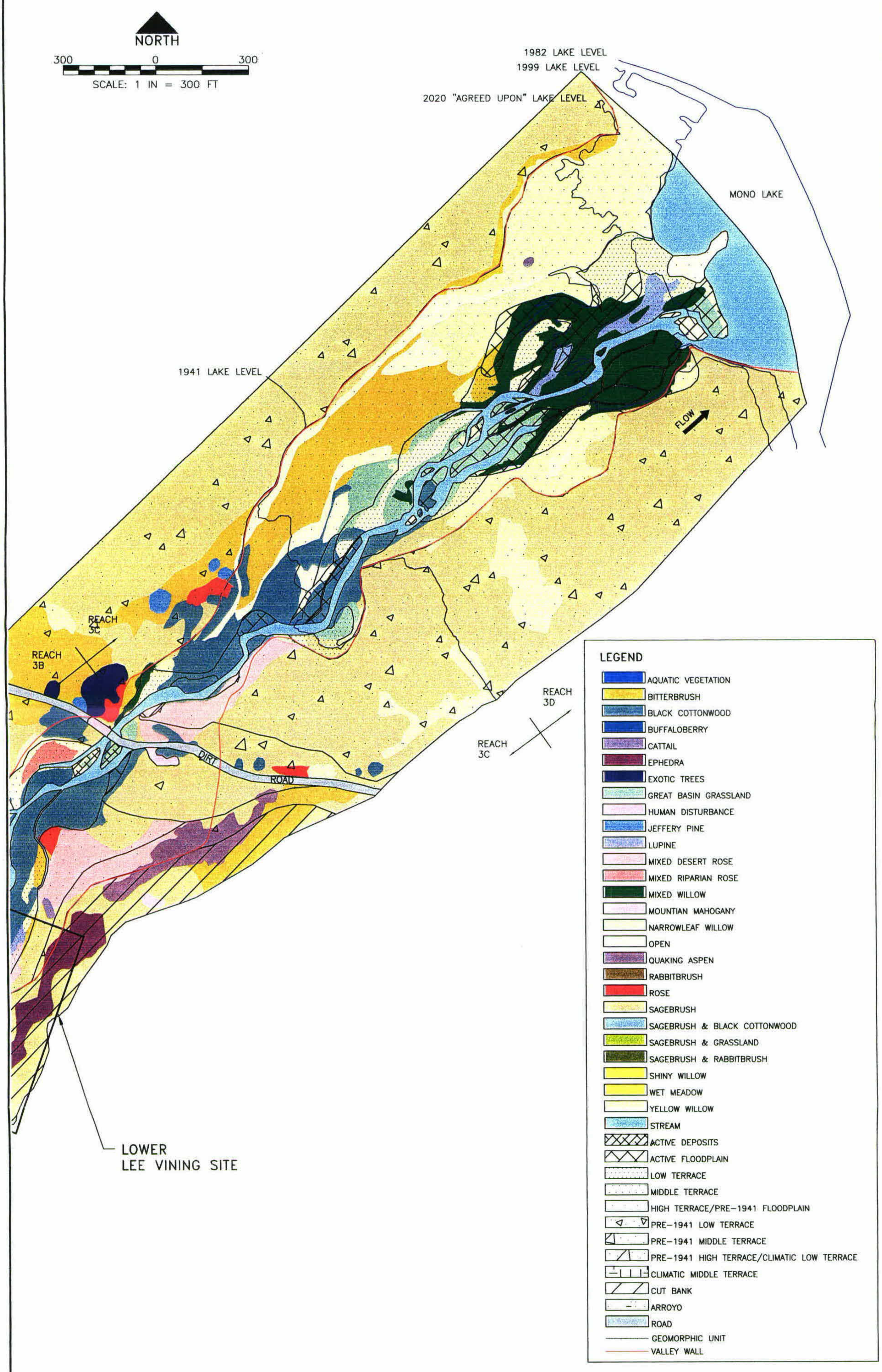


PLATE 11.
1999 LEE VINING CREEK VEGETATION & GEOMORPHIC UNITS

McBain & Trush 2000

2/8/00

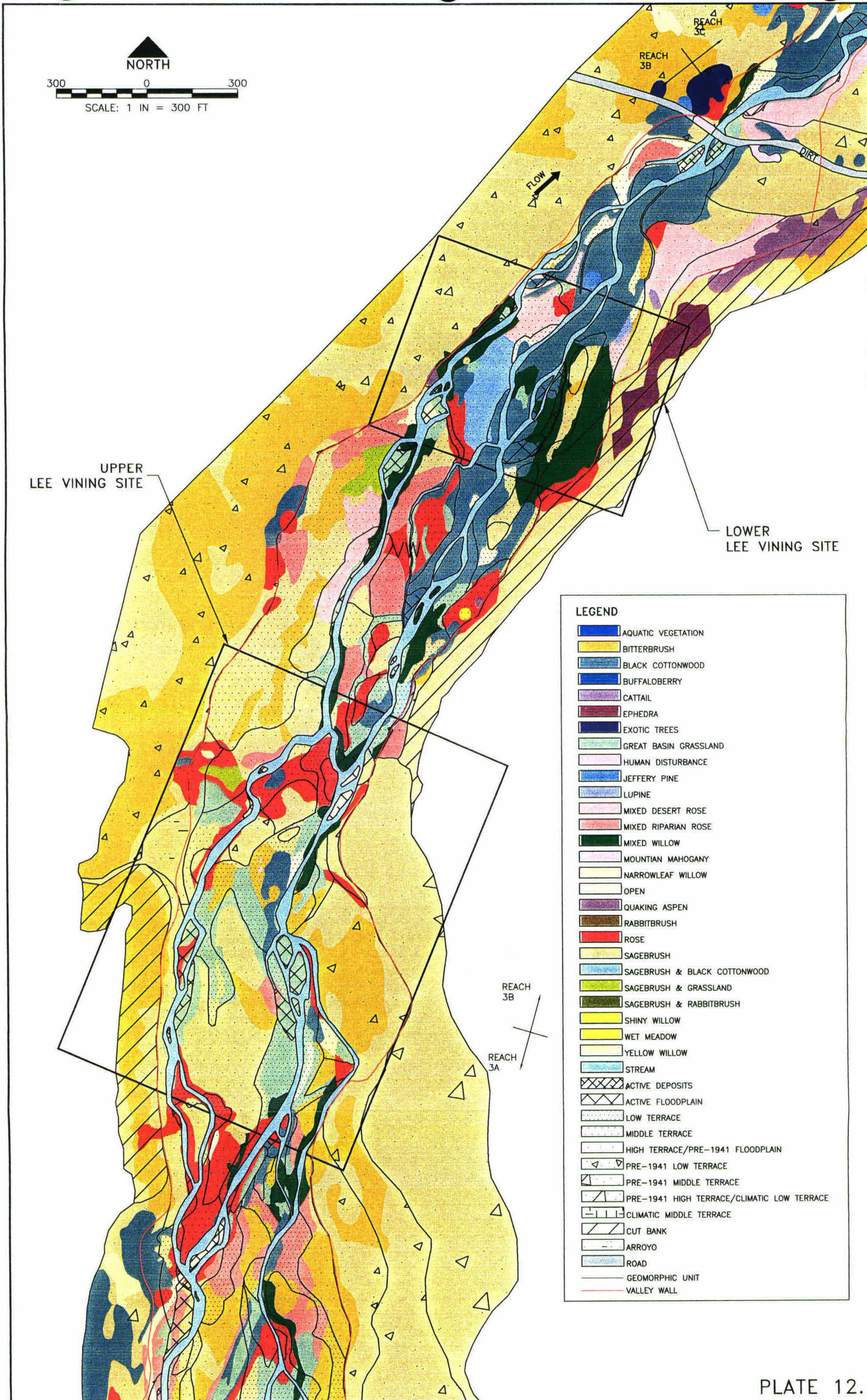


PLATE 12.
1999 LEE VINING CREEK VEGETATION & GEOMORPHIC UNITS

McBain & Trush 2000

2/8/00

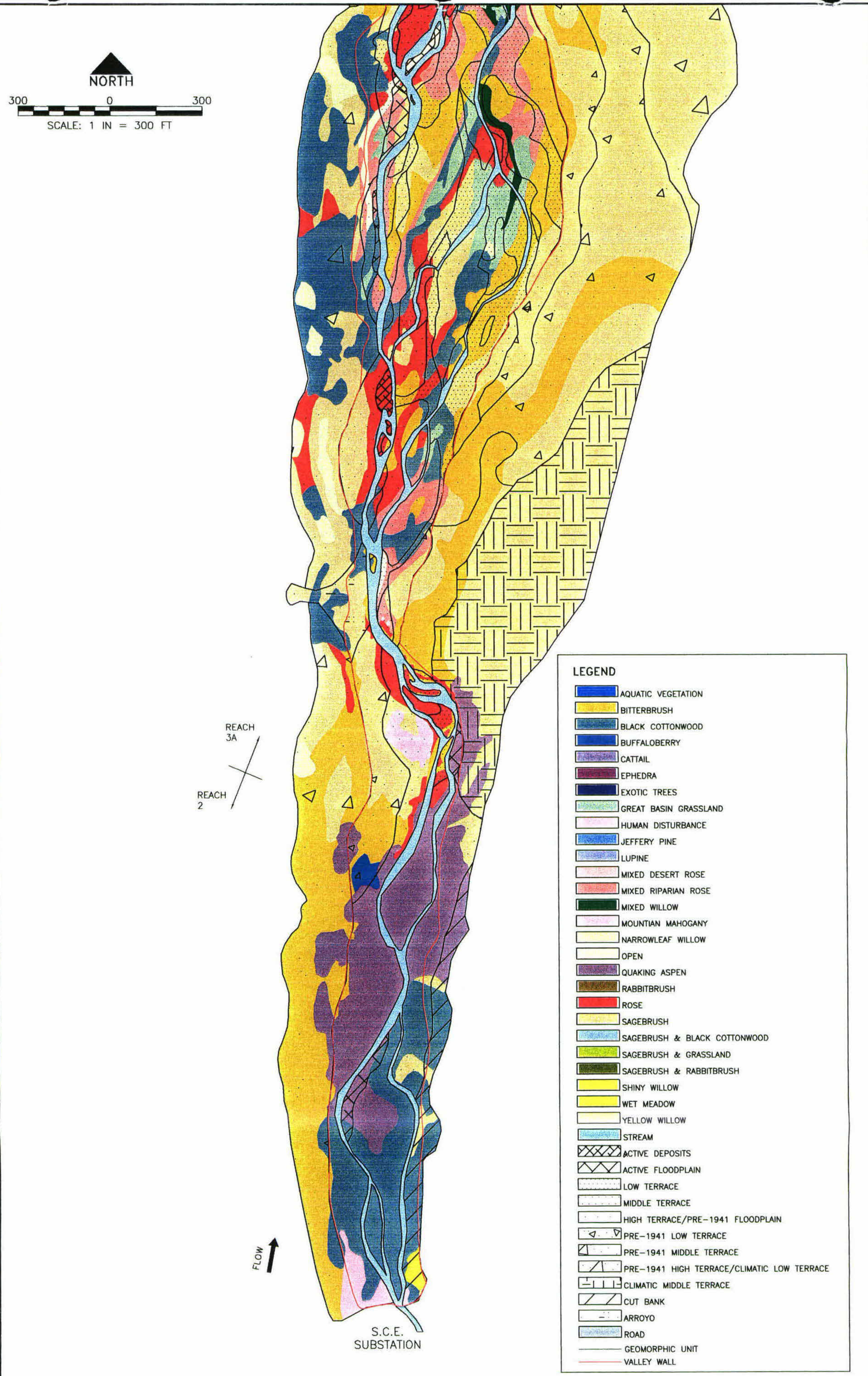


PLATE 13.
1999 LEE VINING CREEK VEGETATION & GEOMORPHIC UNITS

McBain & Trush 2000

2/8/00

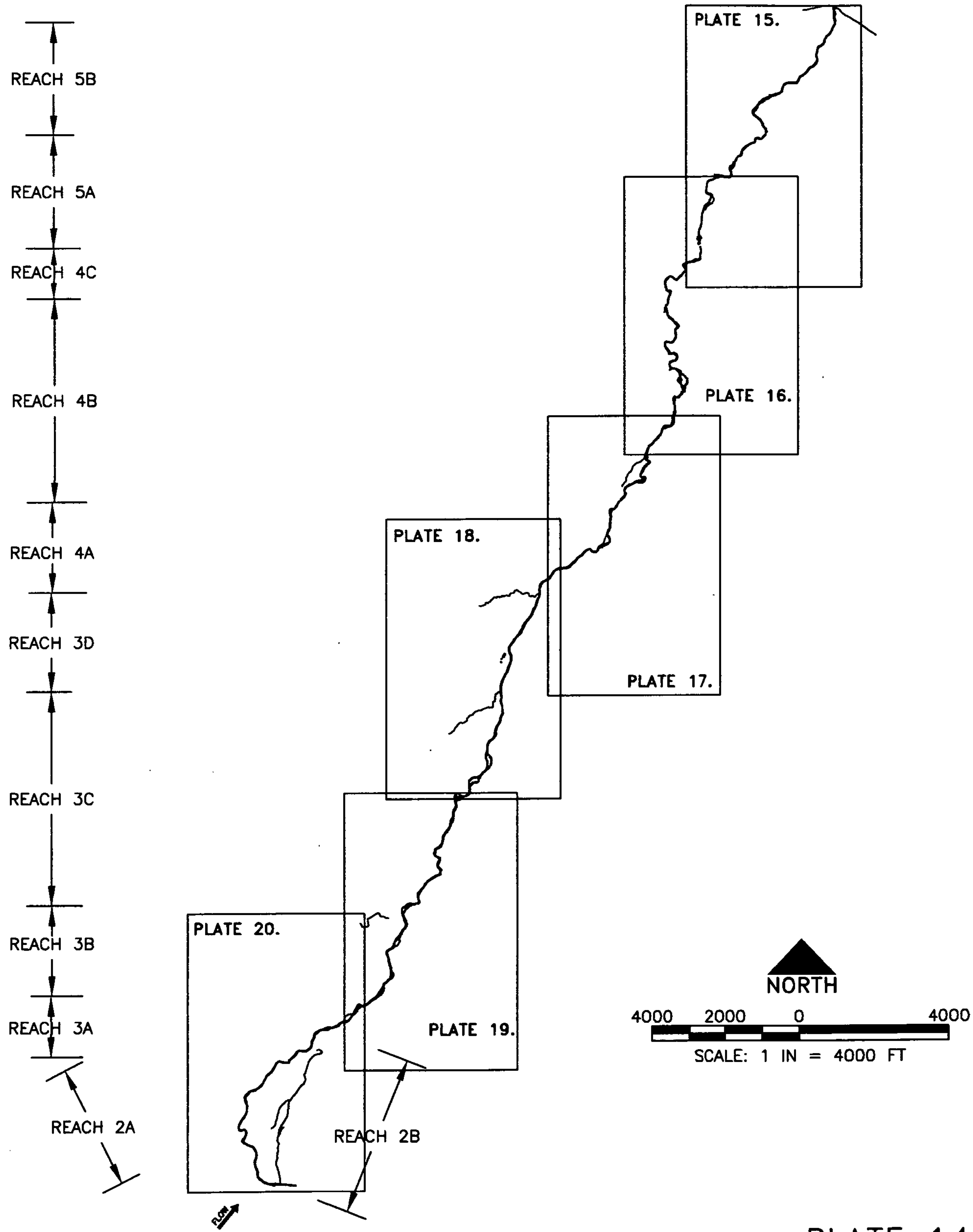


PLATE 14.
RUSH CREEK
1999 PLATE ATLAS

McBain & Trush 2000

1/14/00

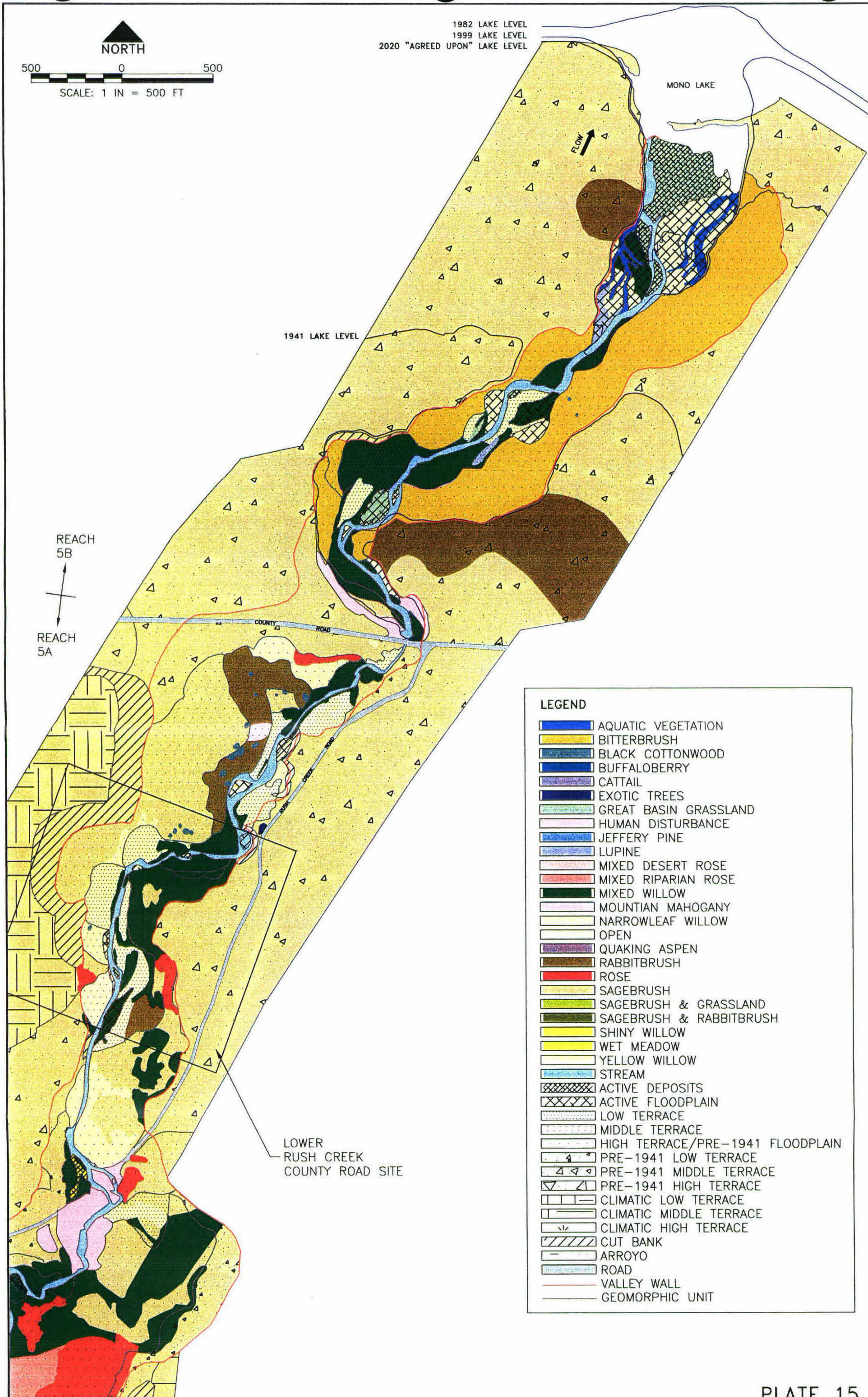


PLATE 15.
1999 RUSH CREEK VEGETATION & GEOMORPHIC UNITS

McBain & Trush 2000

1/17/00

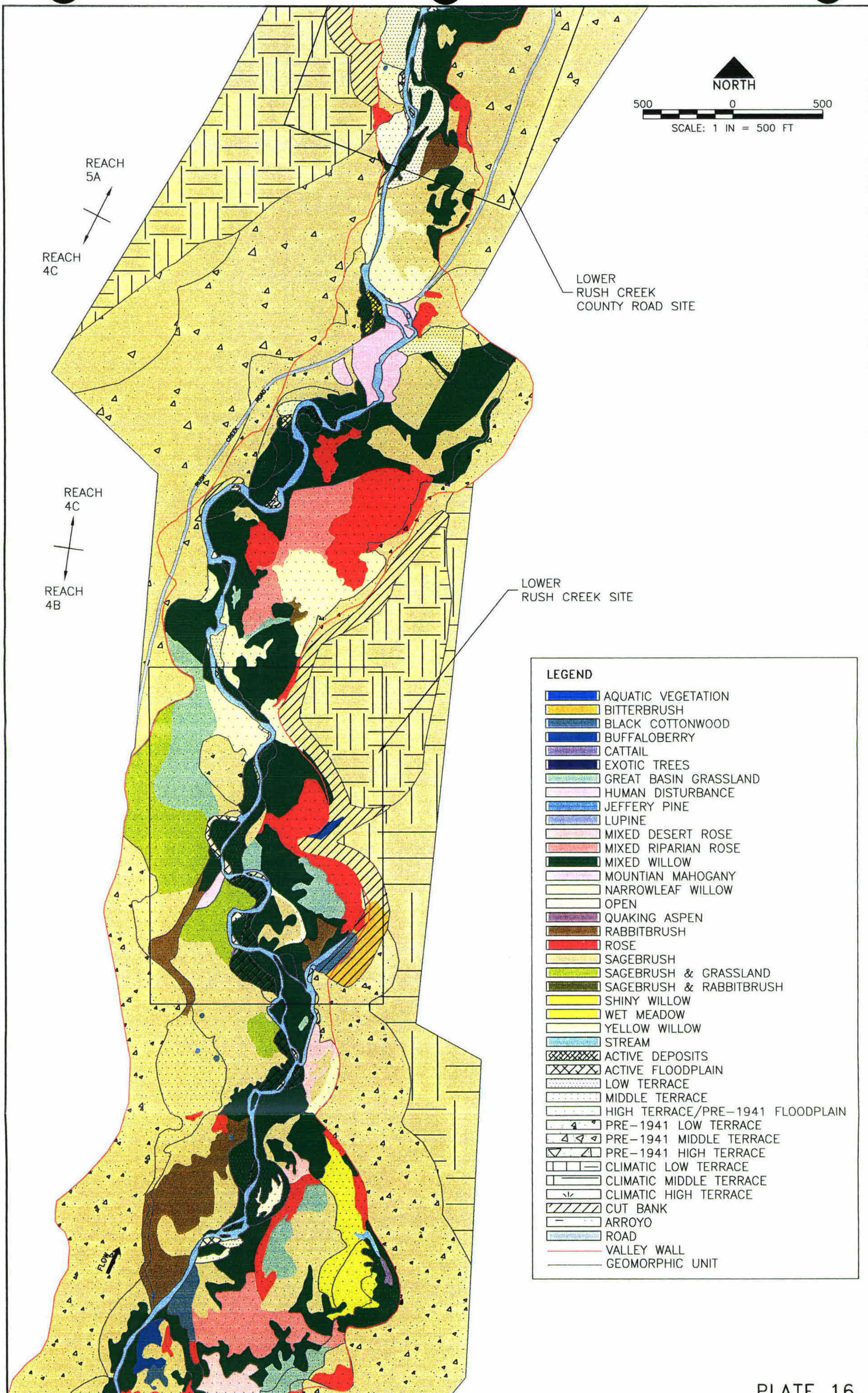


PLATE 16.
1999 RUSH CREEK VEGETATION & GEOMORPHIC UNITS

McBain & Trush 2000

1/17/00

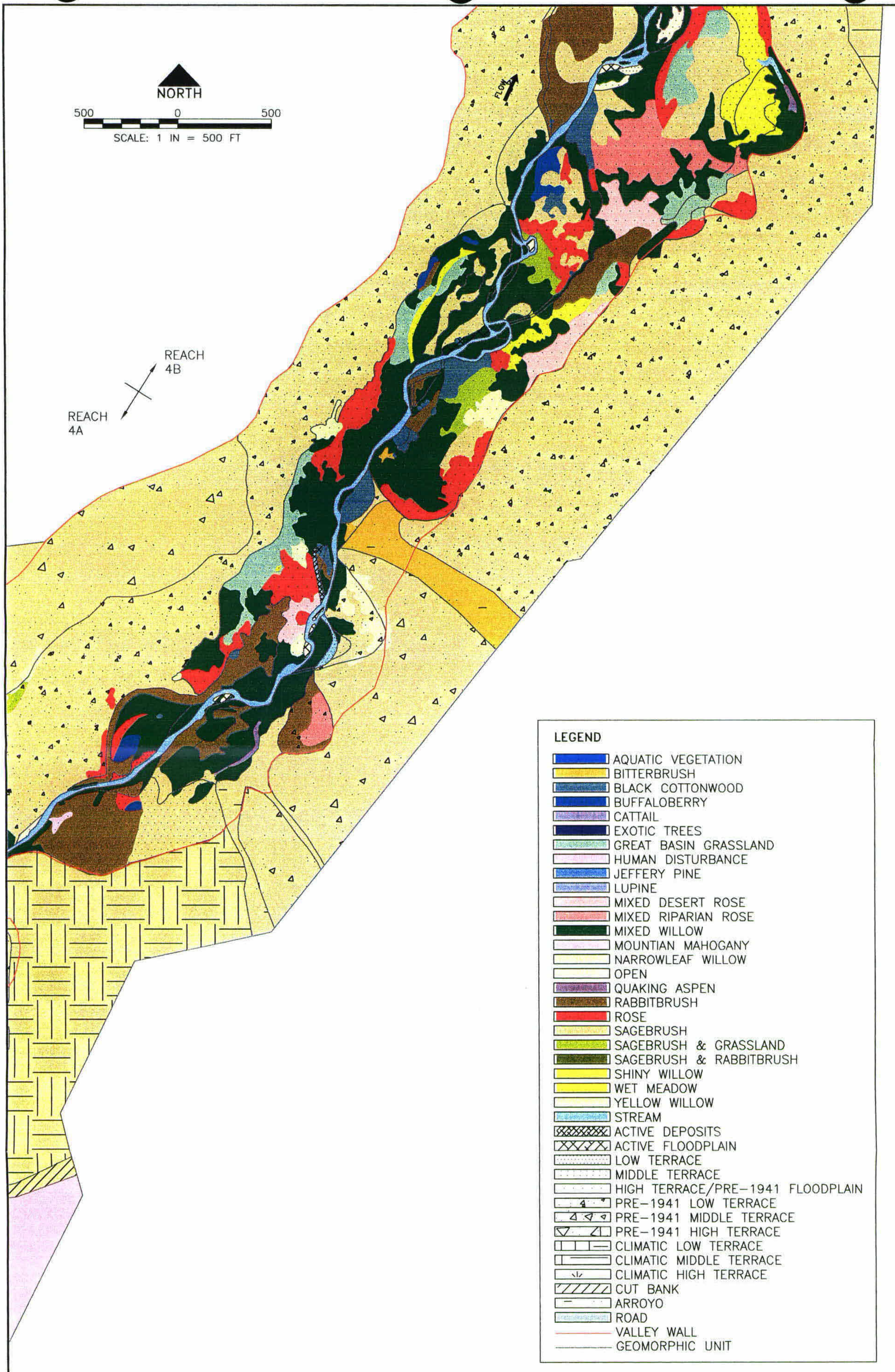


PLATE 17.
1999 RUSH CREEK VEGETATION & GEOMORPHIC UNITS

McBain & Trush 2000

1/17/00

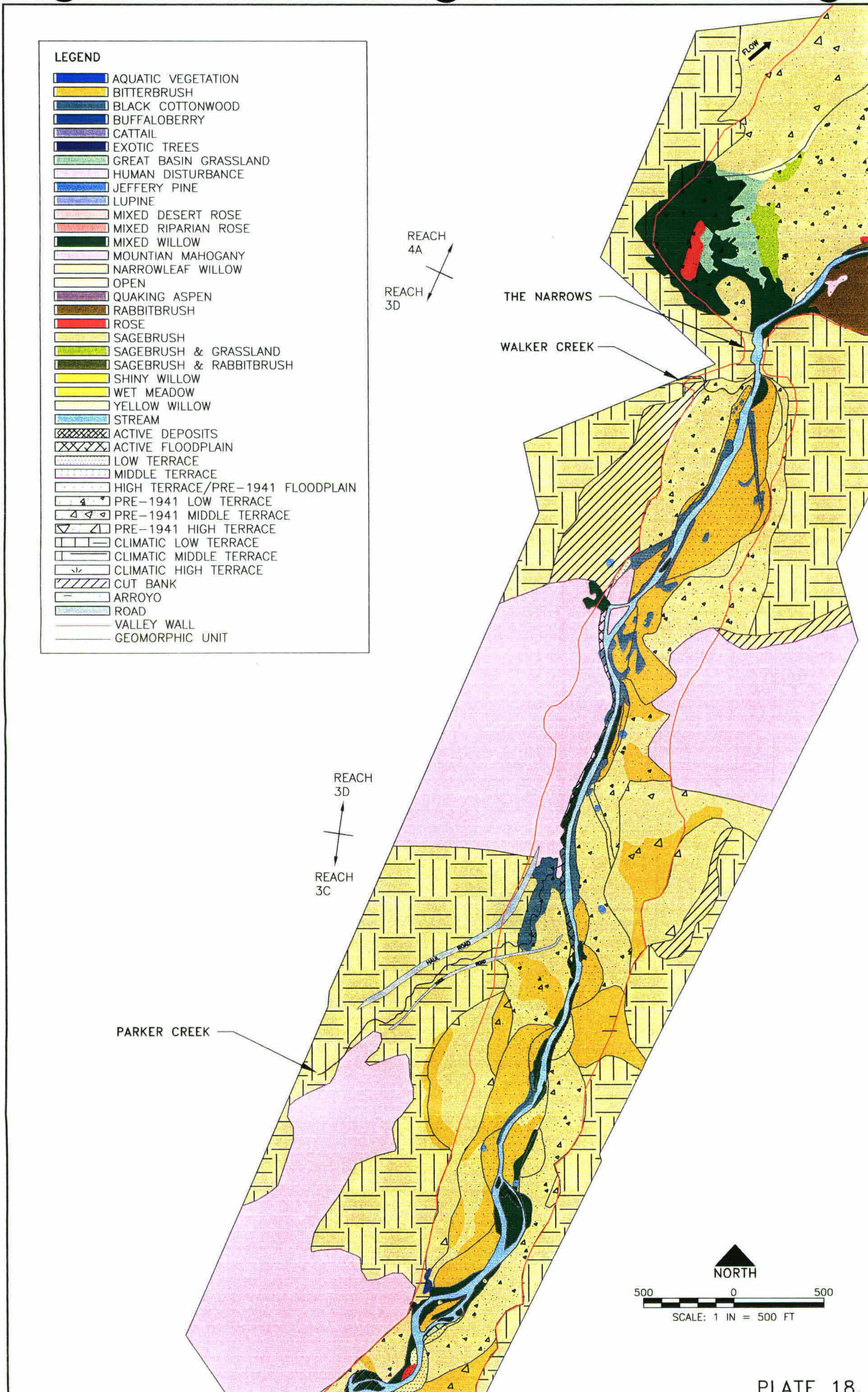


PLATE 18.
1999 RUSH CREEK VEGETATION & GEOMORPHIC UNITS

McBain & Trush 2000

1/17/00

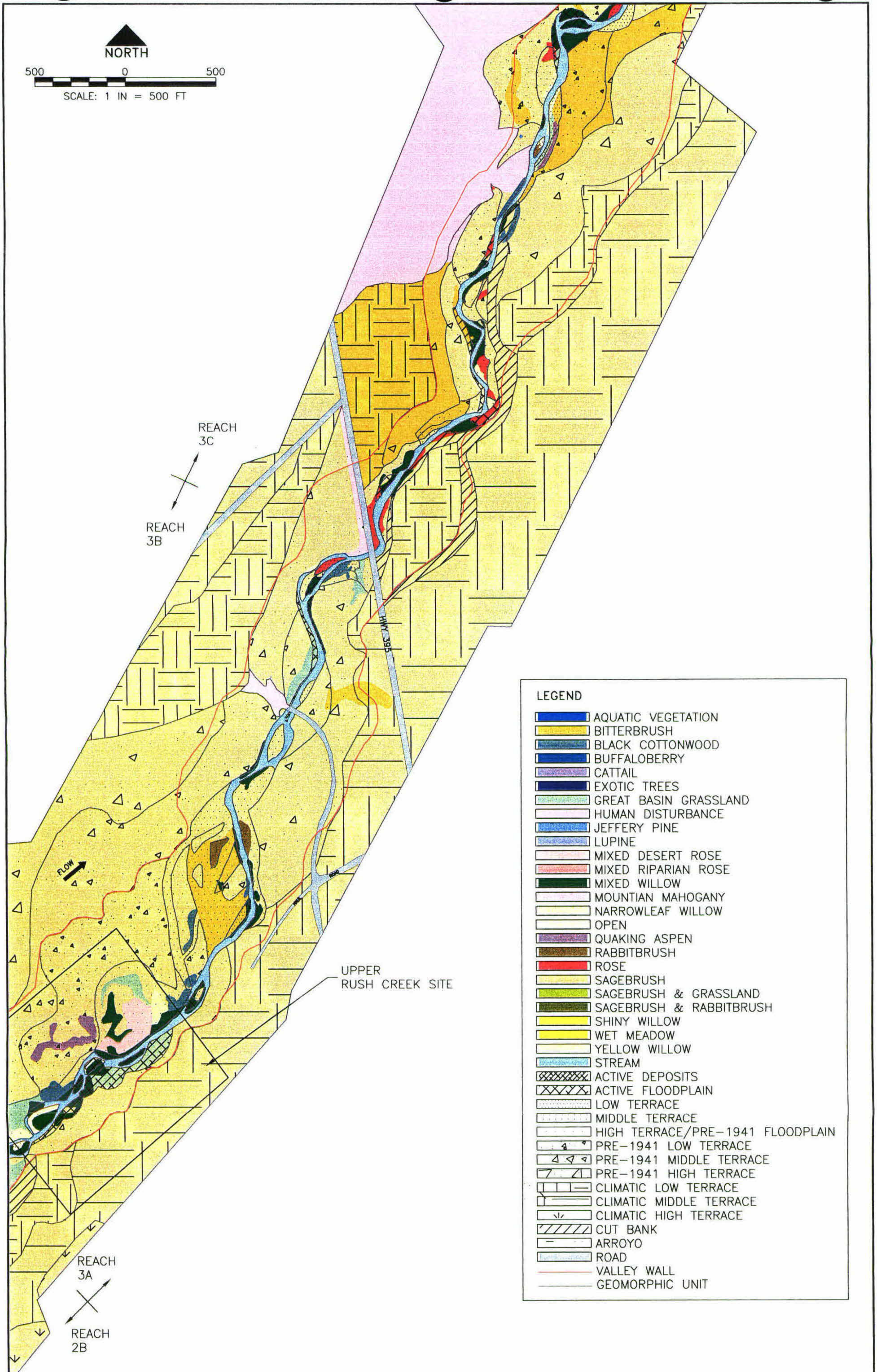


PLATE 19.
1999 RUSH CREEK VEGETATION & GEOMORPHIC UNITS

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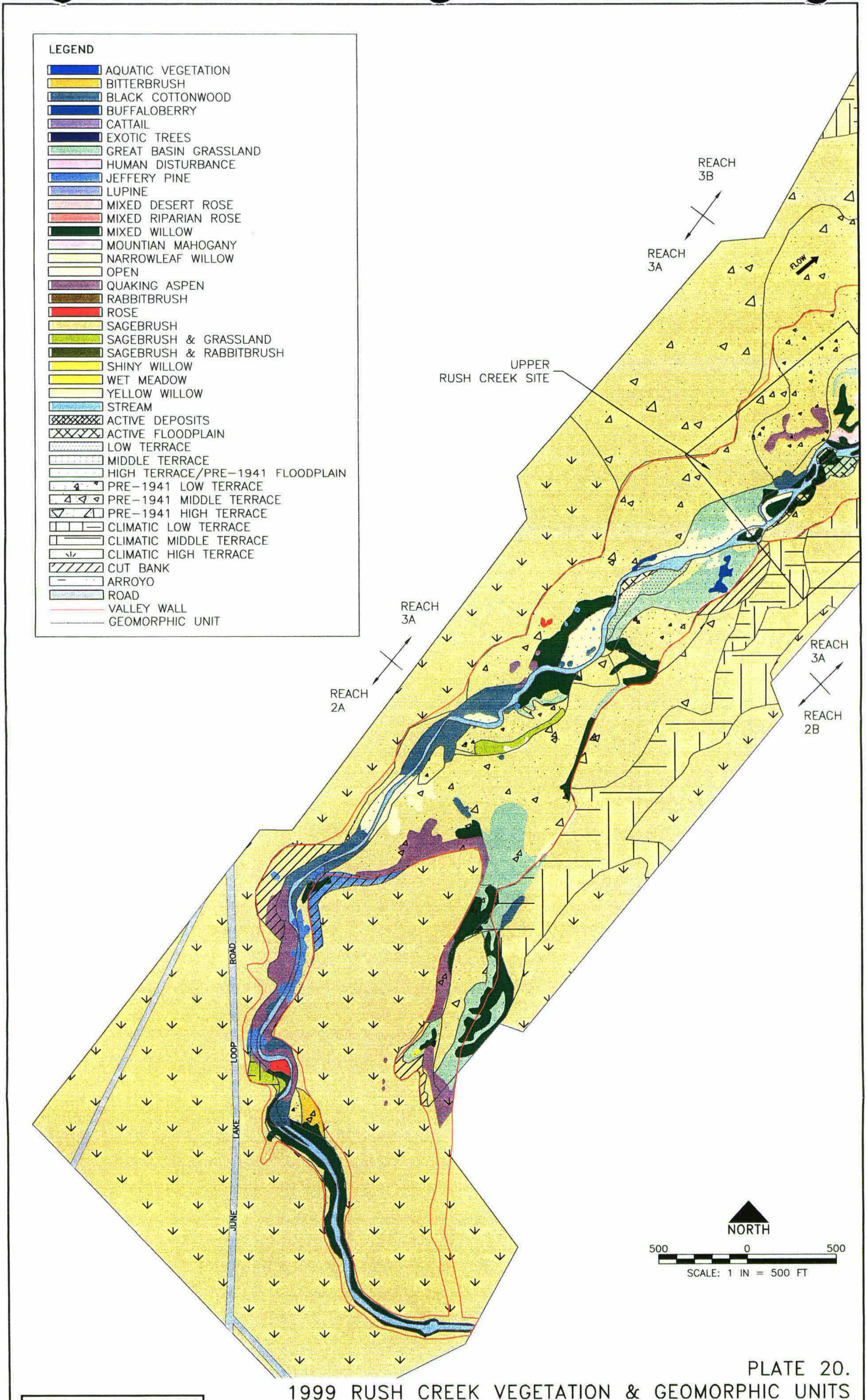

PLATE 20.
1999 RUSH CREEK VEGETATION & GEOMORPHIC UNITS

McBain & Trush 2000

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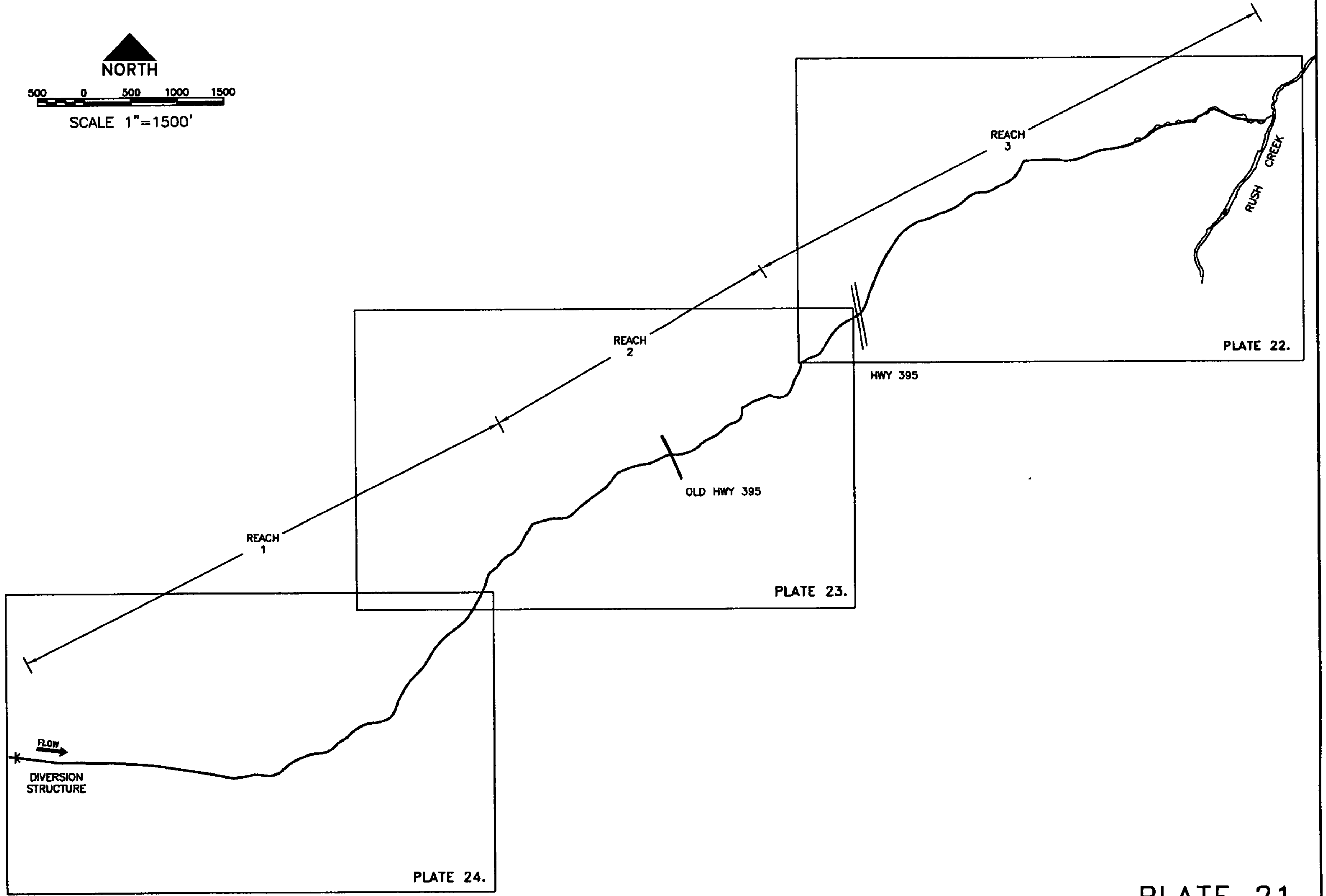

PLATE 21.
WALKER CREEK
1999 PLATE ATLAS

McBain & Trush 2000

2/4/00

PLATE 22.
1999 WALKER CREEK VEGETATION

McBain & Trush 2000

2/7/00

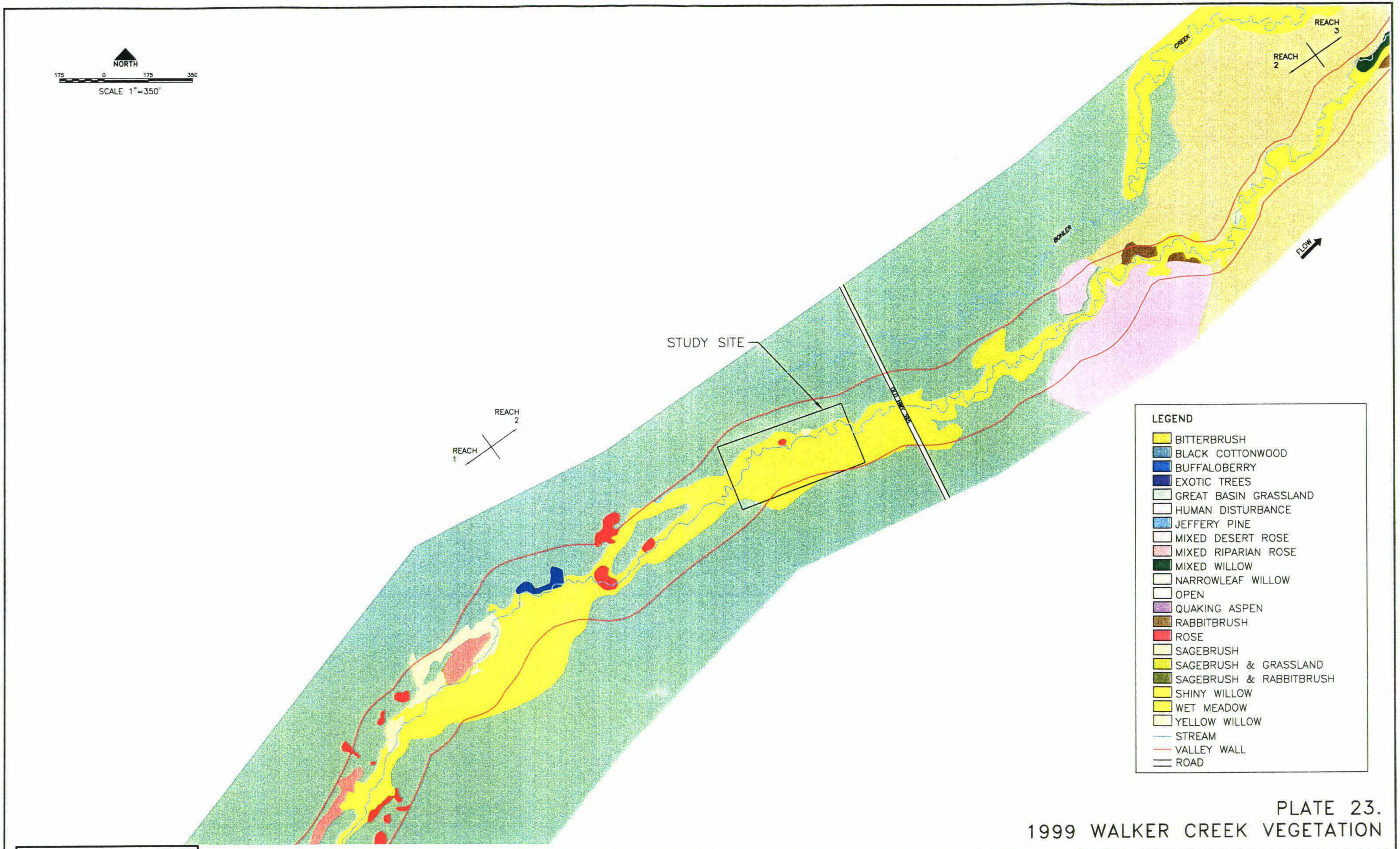

PLATE 23.
1999 WALKER CREEK VEGETATION

McBain & Trush 2000

2/7/00

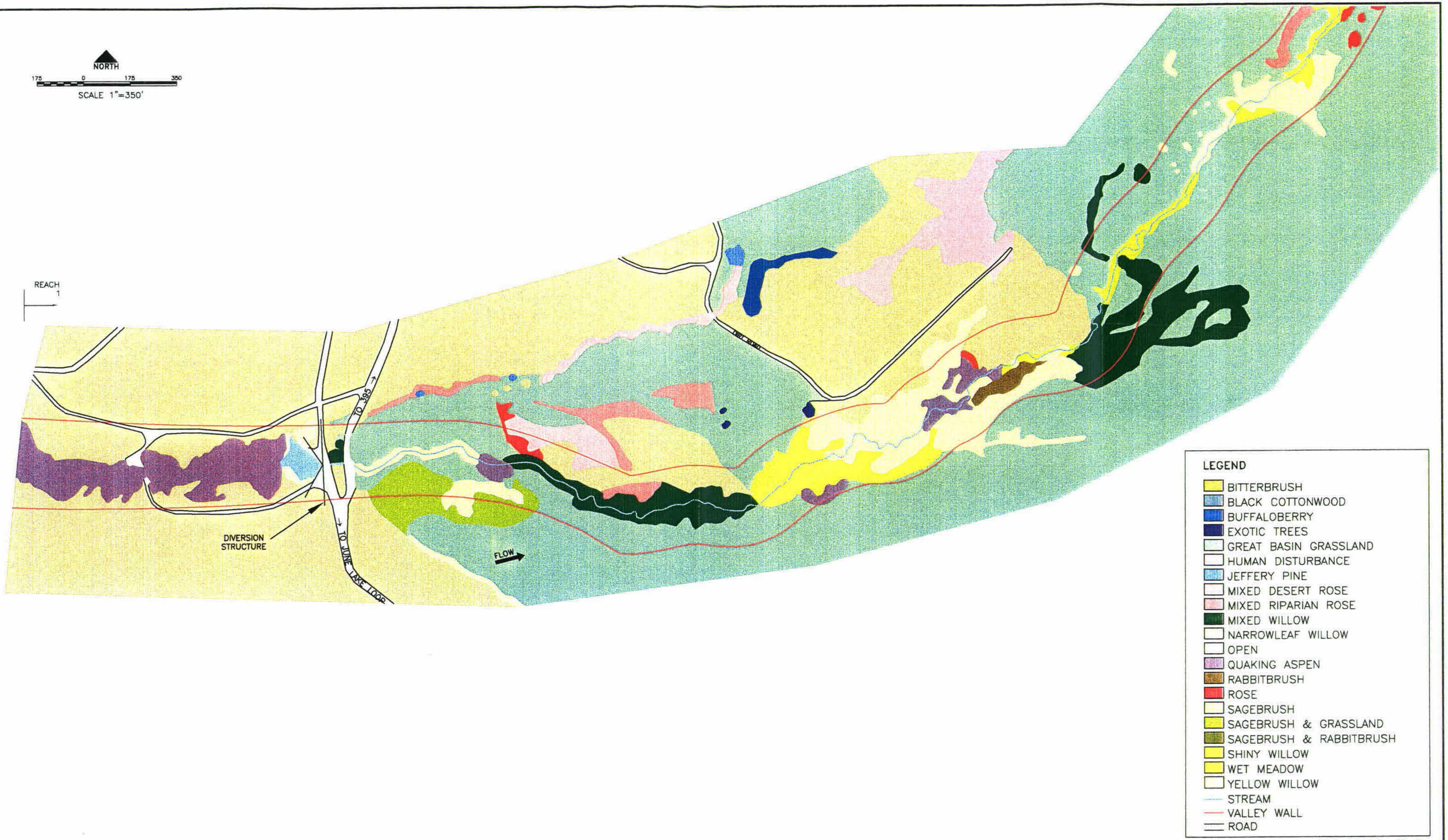

PLATE 24.
1999 WALKER CREEK VEGETATION

McBain & Trush 2000

2/7/00

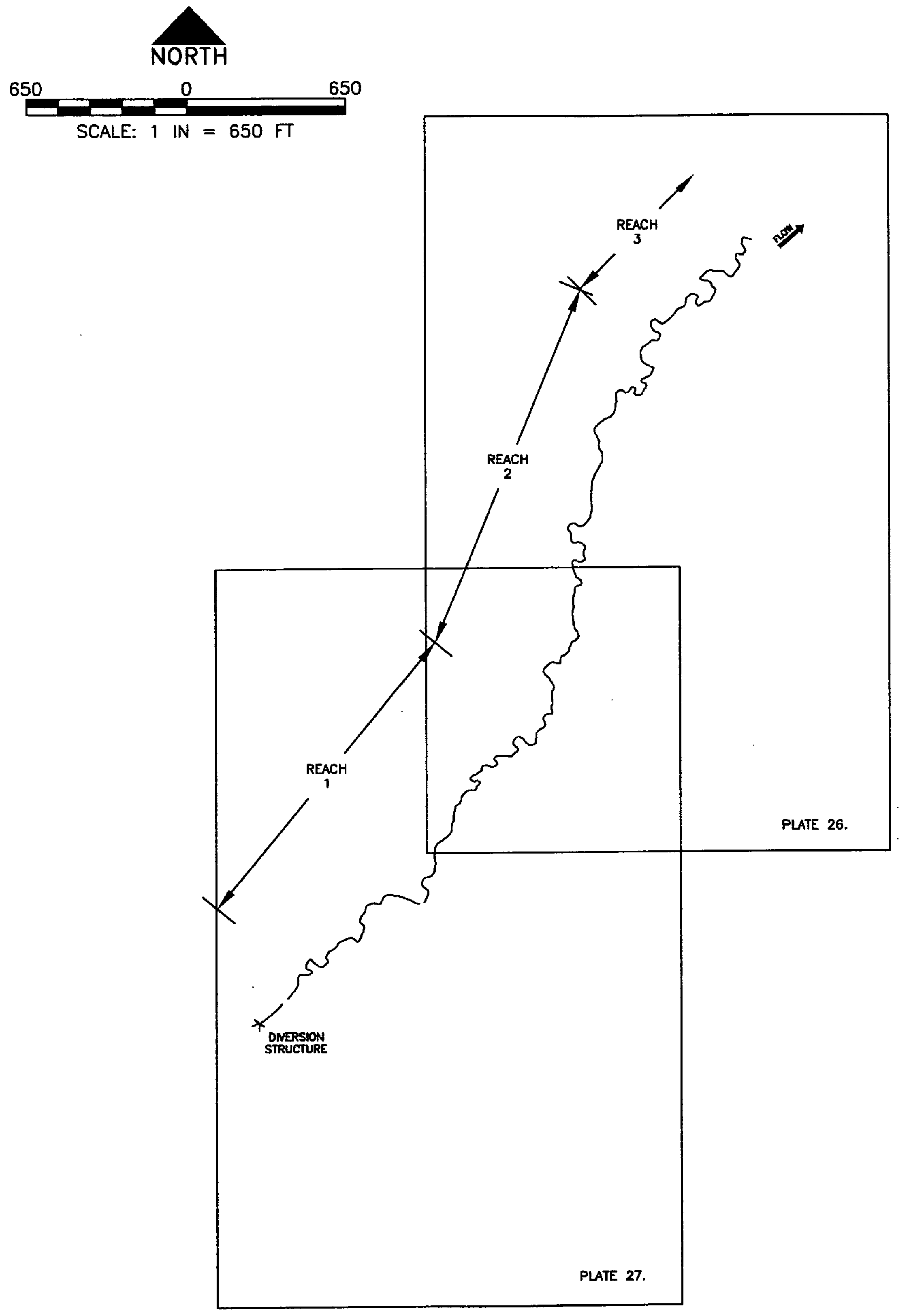

PLATE 25.
PARKER CREEK
1999 PLATE ATLAS

McBain & Trush 2000

2/4/00

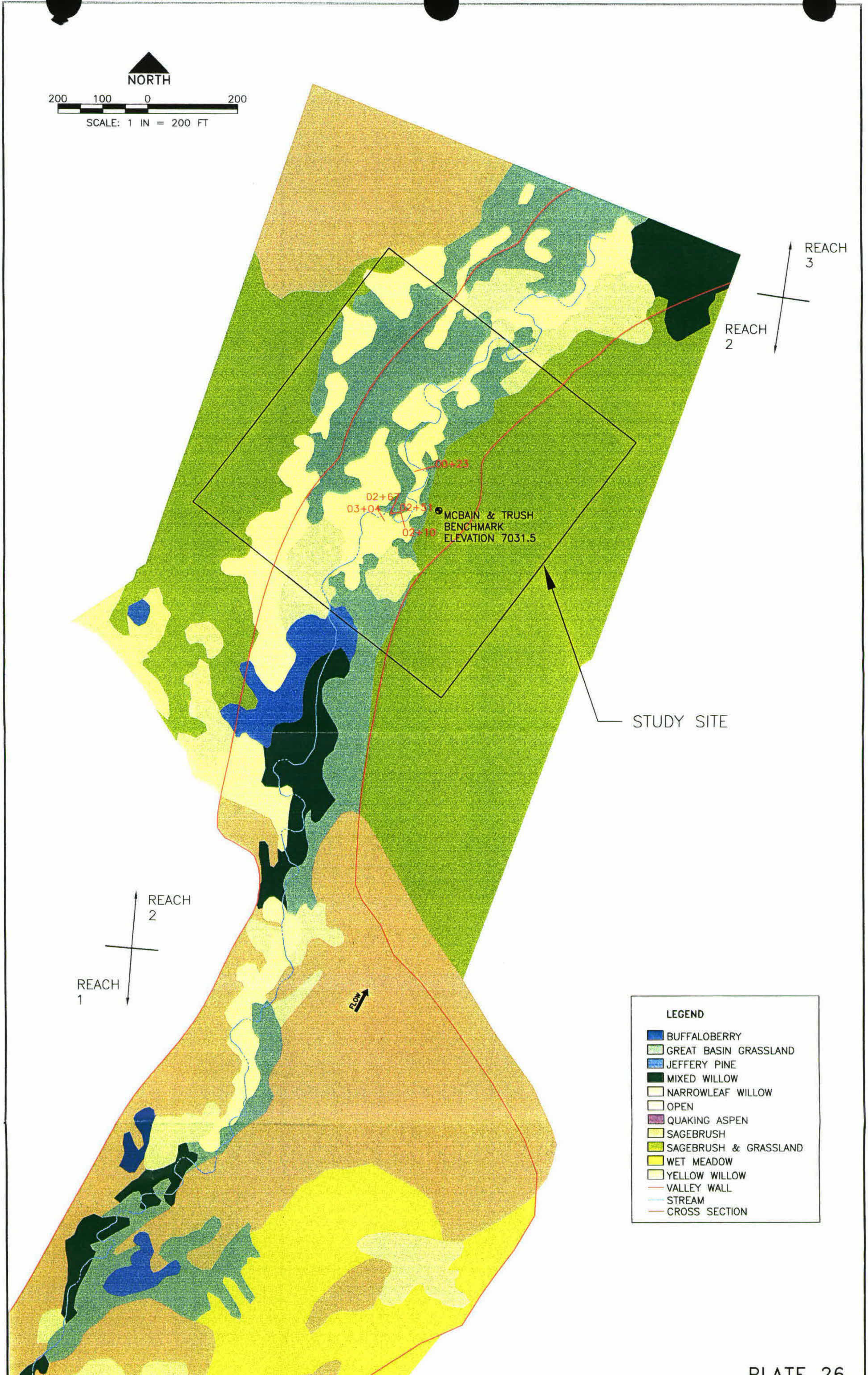

PLATE 26.
1999 PARKER CREEK VEGETATION MAP

McBain & Trush 2000

2/7/00

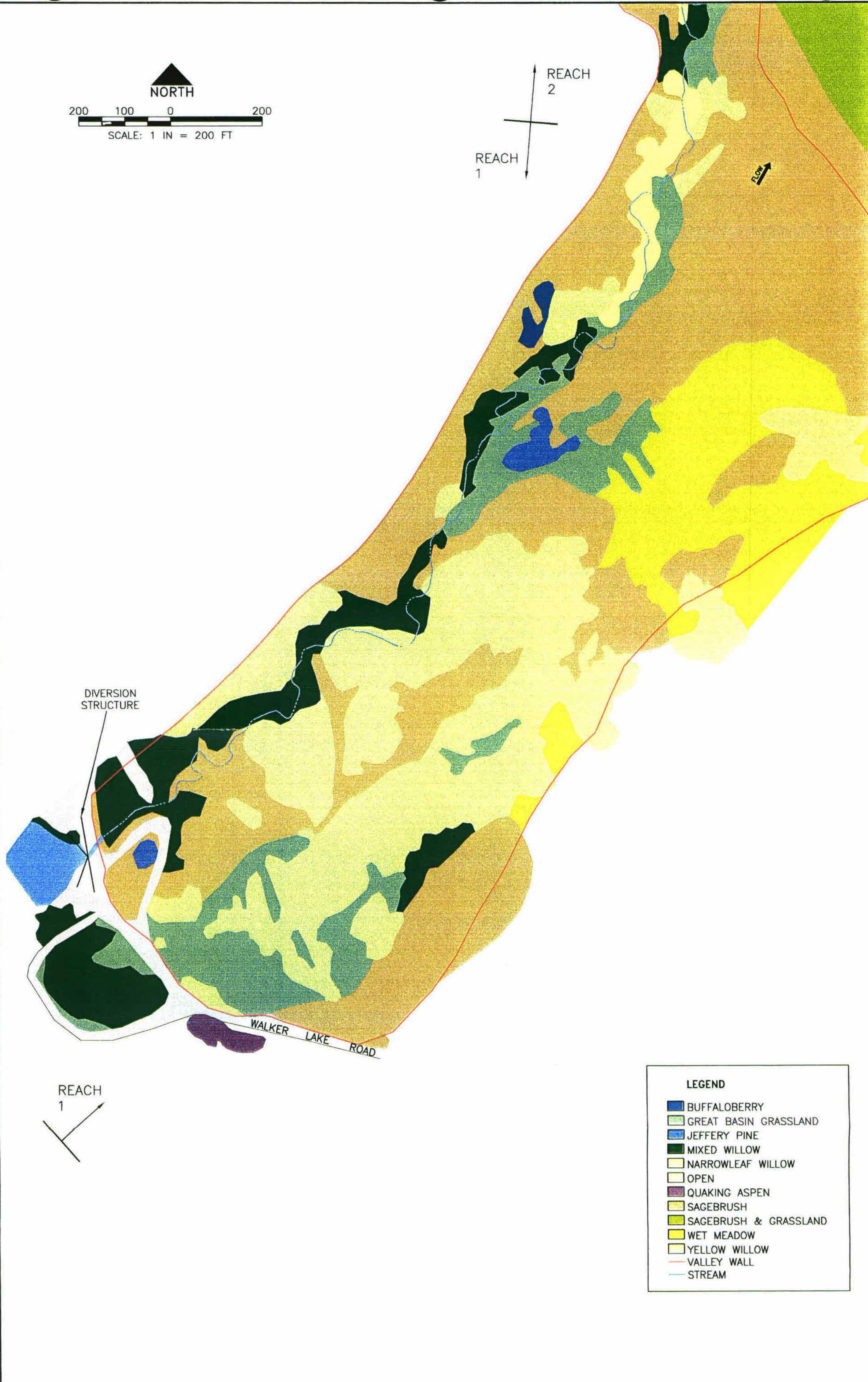

PLATE 27.
1999 PARKER CREEK VEGETATION MAP

McBain & Trush 2000

2/7/00

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1999-2000 Mono Basin Waterfowl Habitat and Population Monitoring Report

April, 2000

Los Angeles Department of Water and Power

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Appendices

I. Summary of LADWP's operations and runoff in the Mono Basin for Water Year 1999-00, (Letter dated November 9, 1999)

II. 1999 Mono Basin Spring Survey

III. 1999 Annual Report – "Mixing and Plankton Dynamics in the Mono Lake, California

IV. 1999 Mono Lake Vegetation Monitoring Report

V. 1999 Mono Basin Vegetation and Habitat Mapping

VI. Waterfowl Population at Mono Lake, California, 1999

1. INTRODUCTION

This report presents a synthesis and review of monitoring data collected in 1999 and prior years to evaluate the restoration of waterfowl habitat and use in the Mono Basin. The report primarily covers restoration and monitoring since September 1994, when Mono Lake Basin Water Rights Decision 1631 was adopted by the California State Water Resources Control Board (SWRCB); a summary of previous restoration and monitoring is also presented. This report is the first in a series of annual reports that will document monitoring results in and around Mono Lake with respect to waterfowl habitat and use.

1.1 Background – Water Right Decision 1631 And Order 98-05

Mono Lake Basin Water Right Decision 1631 set the stabilization lake level for Mono Lake at 6,392 feet above mean sea level amsl, which is a 20 feet increase in level from its post-diversion low stand of 6,372 feet in 1981. One of the considerations put forth in Decision 1631 for setting the stabilization lake level at 6,392 feet was to restore waterfowl habitat lost as a result of the decline in Mono Lake's water level. However, this level is predicted to only partially restore habitat conditions as they existed prior to diversions in 1940. To mitigate the difference in waterfowl habitat between pre-diversion conditions and those at a lake level of 6,392 feet, Decision 1631 required that a waterfowl restoration plan be developed and implemented. Decision 1631 also specified that the restoration plan include a monitoring program to evaluate changes in waterfowl habitat resulting from rising lake level and other restoration actions.

In response to Decision 1631, Los Angeles Department of Water and Power (LADWP) retained three waterfowl experts to develop a waterfowl restoration plan for the Mono Basin. Based largely on a 1995 report by these experts, LADWP submitted the Mono Basin Waterfowl Habitat Restoration Plan to the SWRCB in February 1996. The waterfowl experts' report is Appendix I of the Waterfowl Habitat Restoration Plan.

The SWRCB issued Order 98-05 in 1998, which addressed stream and waterfowl restoration and Grant Lake operations and management. In addition to the restoration of waterfowl habitat brought about by the increase in lake level to 6,392 feet, Order 98-05 prescribed several waterfowl habitat restoration measures for the Mono Basin that were presented in the 1996 Mono Basin Waterfowl Restoration Plan. These measures included:

- rewatering of distributaries in Rush Creek;
- creation or enhancement of waterfowl habitat at County Ponds, Black Point area, or in shallow scrapes in wetland areas near Mono Lake; and
- implementation of a prescribed burn program in lake fringing marshes.

Order 98-05 also specified that LADWP conduct a monitoring program that includes monitoring of hydrology, lake limnology and secondary producers, vegetation in riparian and lake-fringing wetland habitat, and waterfowl population surveys and studies in accordance with the provisions of the Waterfowl Habitat Restoration Plan dated February 29, 1996.

Order 98-05 required that the monitoring program be carried out under the direction of a waterfowl expert or experts approved by the SWRCB Chief of the Division of Water Rights. Mr. Don S. Paul and Dr. David M. Chapin, were contracted by LADWP and approved by the SWRCB as waterfowl experts to oversee the waterfowl monitoring program and to report annually on its results. Several individuals, either contracted or employed by LADWP, are currently involved in collecting monitoring data, including Dr. Joseph Jehl (waterfowl population counts and activity budgets), Dr. Robert Jellison (limnological data), and Drs. David Chapin and David Martin (vegetation data and aerial photography interpretation).

1.2 Objectives Of Report

The primary goal of this report is to document waterfowl habitat and population monitoring and restoration in the Mono Basin as of December 1999. Following the requirements of Order 98-05, the specific objectives are to report on:

A. The status of waterfowl habitat restoration projects

B. The recovery of waterfowl habitat from increased streamflow and lake level

C. The results of waterfowl population surveys and studies

D. Other information relevant to restoration/recovery of wildlife habitat

In addition to these required objectives, this first annual waterfowl restoration report includes one other objective:

E. summarize previous monitoring data and efforts

1.3 Organization Of Report

Section 2 summarizes previous research and monitoring studies relevant to the restoration of waterfowl habitat in the Mono Basin (Objective E). Section 3 documents the results of all 1999 monitoring activities, including subsections on hydrology, limnology, vegetation and habitat, and waterfowl populations surveys and studies. This section addresses Objective C while giving an overview of the entire monitoring effort. Section 4 provides a status of waterfowl habitat restoration projects (Objective A), and Section 5 presents information on the recovery of waterfowl habitat from increased streamflow and lake level.

In addition to the main report, we have attached several appendices. These appendices consist of individual monitoring reports authored by the investigators responsible for each monitoring component, including hydrology, limnology, vegetation and habitat, and waterfowl populations surveys (Objective D).

2. SUMMARY OF RESTORATION MEASURES AND WATERFOWL MONITORING ACTIVITIES PRIOR TO 1999

This section summarizes the status of waterfowl habitat restoration measures and reviews monitoring and research related to waterfowl habitat that have taken place prior to 1999. Waterfowl habitat restoration measures include actions resulting from Decision 1631 and those conducted outside of Decision 1631 requirements. Waterfowl monitoring studies can be most broadly defined as any previous research that pertains to the Mono Lake ecosystem or more narrowly defined to include only studies specifically addressing waterfowl populations and habitat conditions prior to and following the initiation of restoration actions. This summary will focus on the more narrow definition of monitoring, although other ecosystem-level studies will be mentioned where relevant.

2.1 Restoration Measures

Waterfowl habitat restoration measures in the Mono Basin initiated prior to 1999 include increases in lake level and stream flows and modifications of surrounding habitat. Increases in stream flows and lake level will be described in Section 2.2 below.

2.1.1 Stream Flow and Lake Level

The flow in Rush Creek was maintained year round at 19 cfs following high flows in 1983 and were subsequently increased as a result of Decision 1631. The flow in Lee Vining Creek was maintained at 4 cfs following high flows in 1986 and were subsequently increased as a result of Decision 1631. A defined flow regime for both streams has been specified in Order 98-05 that takes into account flows needed for stream restoration and fish habitat, as well as increasing lake level.

From the recent low stand of 6,373.4 feet occurring in December 1992, the lake level generally increased through December 1998. At the end of 1998, the water surface of Mono Lake reached 6,384.3 feet. During 1995 a rise in the lake level of 3.3 feet resulted in a stratified lake condition known as meromixis, which has continued to the present. Salinity in Mono Lake at the 6,384.4 feet lake level is approximately 80 to 85 g/l total dissolved solids. To reach the stabilization lake level of 6,392 feet established by Decision 1631, the lake level needs to rise another 6.7 feet.

2.1.2 DeChambeau/County Ponds Complex

The DeChambeau Ponds were originally created in 1915, when an oil test well tapped an aquifer of hot artesian water. The water was directed into a series of three ponds, and as many as seven ponds once existed. The ponds had deteriorated over several decades up to 1992 and their habitat value to waterfowl had diminished considerably.

In 1992, the U.S. Forest Service (USFS), Caltrans, the Mono Lake Committee (MLC), and Ducks Unlimited collaborated on a project to restore three degraded ponds and create two more ponds. The project was largely completed in September 1995, although work has continued since then to improve the functioning of the ponds. The project consisted of rebuilding dikes below old ponds, construction of a new check dam and dike to create new ponds, installation of water control structures, sealing of ponds with bentonite, and constructing a new well, pump, pumphouse, and pipeline. As a result of the original project, four ponds were created (one with an island), while one pond was considered too expensive to line with bentonite. The new well was found to be too expensive to run and consequently not used. The USFS has subsequently reworked the hot water artesian well and pipeline to increase the flow of water to 180 gallons per minute, which is maintaining approximately 9 acres of water surface at DeChambeau Ponds and also providing water to the County Ponds.

The County Ponds below the DeChambeau Ponds are natural basins that were inundated by Mono Lake prior to diversions in 1941. Following their exposure from the receding lake, they periodically filled with water during high runoff periods and provided ephemeral freshwater waterfowl habitat. In 1997 water diverted from Mill Creek to the DeChambeau Ranch was directed to the West County Pond via a ditch and the pond filled to a depth of 3.6 feet with a surface area of approximately 3 acres. In 1998 the ditch from DeChambeau Pond #5 was replaced with a pipe, and flow was directed to the east County Pond. However, the East County Pond did not hold water, and it subsequently drained.

2.1.3 Experimental Burning

An experimental burn program of Mono Lake wetlands was initiated in 1995 under the direction of the California Department of Parks and Recreation. These actions were implemented prior to Order 98-05, which requires LADWP to conduct a burn program in lake-fringing wetlands (subject to the Chief of the Water Rights Division, SWRCB, approval).

In November 1995 approximately 12 acres of marsh were burned near Simons Springs in two different patches, one along the lakeshore and the other inland. The intensity of the burn was variable, depending on what species were dominant. In February 1997 a second burn was conducted at Simons Springs along the lakeshore. No formal documentation of these experimental burns was available for review as of February 2000.

2.1.4 Rewatering Rush Creek Distributaries

There has been no activity to rewater the distributaries identified in the Waterfowl Habitat Restoration Plan. The original goal was to rewater two to three distributaries for stream as well as waterfowl habitat restoration purposes per year. Three were rewatered on Rush Creek above Highway 395 in 1999. Those distributaries were done in accordance with the Stream and Stream Channel Restoration Plan and provide limited waterfowl habitat. Dr. Bill Trush, the stream monitoring expert, recently expressed his opinion that rewatering distributaries on Rush Creek should be discontinued until the effects on the stream can be further evaluated.

2.1.5 Other Measures

Other than those mentioned above, we are aware of no other Mono Basin waterfowl restoration measures that have been implemented prior to 1999. Other waterfowl restoration measures identified in Order 98-05 include using shallow scrapes to make open water areas within lake-fringing wetlands.

2.2 Monitoring Activities

2.2.1 Stream Flow and Lake Level

Monitoring of stream flow in the Mono Basin is conducted by LADWP for Rush, Lee Vining, Walker, and Parker creeks and by Southern California Edison for Mill and Wilson creeks. Stream flow measurements recorded by LADWP are available and will be accessible through an Internet web page in the near future.

In addition, a monitoring program for stream restoration was specified in Order 98-05, which is being conducted by Bill Trush of McBain and Trush and Chris Hunter, an independent consultant, under contract to LADWP. This monitoring program includes detailed assessment of changes in stream geomorphology resulting from changes in flow and specific restoration actions. The monitoring program also includes fish population surveys.

The lake level is monitored biweekly by LADWP from a staff gage located near the month of Lee Vining Creek on the shore of Mono Lake. Lake level is recorded as elevation (in feet) above mean sea level (amsl). A correction factor of 0.4 feet is added to the gage reading to make the elevation consistent with U.S. Geological Survey datum. Both LADWP and the MLC maintain records of the lake level.

2.2.2 Limnology

There has been considerable research on the Mono Lake aquatic ecosystem, largely beginning with Mason's 1967 study of Mono Lake limnology. A thorough description of Mono Lake limnological and aquatic ecology studies is found in the Mono Basin EIR and in Jellison et al. Only a brief overview will be presented here.

Mason in 1967 documented abiotic and biotic conditions in Mono Lake, including a description of the plankton communities. An interdisciplinary study led by David Winkler in 1977 was the next major effort made toward understanding the Mono Lake ecosystem. The group led by Winkler studied the ecology of phytoplankton, brine shrimp, and alkali flies, emphasizing the interactions with nutrient levels and salinity.

Starting in 1979, scientists from the University of California, Santa Barbara (UCSB) Marine Science Institute began an intensive study of limnology at Mono Lake. John Melack and Robert Jellison have been the principal investigators of the UCSB group and have had several collaborators. Early in the UCSB program, Lenz (1982, 1984) studied Mono Lake brine shrimp populations using systematic sampling techniques and examined brine shrimp food-web relationships. In 1982, the UCSB group initiated a much broader sampling effort and array of studies that continue today. Their work has produced a durable, systematic set of physical and biological data from standardized locations around Mono Lake. The work of the UCSB group has resulted in a detailed, not necessarily complete, understanding of life history, development, growth, grazing rates, production, abundance, and salinity tolerance of brine shrimp. In addition, to the UCSB group's work, LADWP has carried out limited surveys of phytoplankton and brine shrimp since 1974. The UCSB group has produced annual monitoring reports of Mono Lake limnology since 1987.

Since 1995, and previously in the mid 1980s, a considerable amount of monitoring and research in Mono Lake have been directed at the effects of meromictic conditions on brine shrimp dynamics and production (Table 1). Because meromictic conditions result in no annual vertical mixing of the lake, nutrient dynamics (especially nitrogen) and their effects on algal biomass and productivity have been an important component of limnological studies. The effects of meromixis have been of increasing concern because meromictic conditions are projected to persist for as long as several decades due to greater than expected runoff in lake tributaries in 1995 and continued freshwater inputs.

Beginning in 1991, a dynamic reservoir simulation model (DYRESM) was developed and applied at Mono Lake by Jellison et al. The DYRESM was used to simulate the likelihood of meromixis among five lake elevations and assess the effects of prolonged drought and runoff variability. Efforts to refine DYRESM are ongoing.

Investigation of plankton dynamics is ongoing and has included several approaches. Initial studies utilized long-term laboratory experiments and were directed primarily at effects of increasing salinity. However, these laboratory studies did not predict the magnitude of changes observed in field studies. A cohort model of *Artemia* population dynamics was also developed to explain field data. Modeling of plankton dynamics have subsequently been improved by coupling *Artemia* dynamics with nitrogen fluxes, incorporating results from additional laboratory experiments, and application of multi-transfer models.

David Herbst has been responsible for much of the research to date on alkali fly populations at Mono Lake. Herbst and his collaborators have investigate such questions as how alkali fly abundance varies with depth, fly use of different substrates and open water, salinity effects on alkali fly productivity, and the numerical abundance of the alkali fly on different substrate types. Modeling of alkali fly productivity and abundance at different lake levels was conducted by Jones and Stokes Associates as part of the Mono Basin EIR impacts analysis.

2.2.3 Waterfowl Habitat

Waterfowl habitat conditions around Mono Lake prior to diversions were based on interpretation of 1940 aerial photographs.

Post-diversion vegetation around Mono Lake was sampled and classified by Burch et al. resulting in the description of several vegetation or community types and their relation to various environmental factors. Mapping of lake-fringing vegetation around Mono Lake in the 1980s was conducted by Drummer and Cowell in 1985 and Hargis in 1986. Vorster (1985) also sampled vegetation transects along the Mono Lake shoreline during this period. None of these vegetation mapping efforts emphasized waterfowl habitat, although they do provide information useful in characterizing waterfowl habitat.

Mapping of point-of-reference conditions (August 22, 1993) for lake-fringing wetlands around Mono Lake was completed by Jones and Stokes Associates for the Mono Basin. The Jones and Stokes study was based on aerial photographs taken on May 23, 1991 and on extensive ground truthing, in which each wetland was surveyed on foot. Qualitative descriptions of waterfowl habitat around Mono Lake both before and after diversions were also provided in the Mono Basin EIR.

Since Decision 1631 in 1995 and prior to 1997, there has been no systematic monitoring of waterfowl habitat around Mono Lake. However, some incidental descriptions of waterfowl habitat in certain areas around the lake were provided in waterfowl monitoring reports conducted by J. Jehl and W. Lin.

Pre-diversion channel and riparian conditions along the Rush Creek bottomlands have been characterized in the Mono Basin EIR. Stine described riparian and channel conditions based on 1930 and 1940 aerial photographs, historical ground photographs, and interviews with local residents. He concluded that prior to diversions the Rush Creek bottomlands had multiple channels within an extensive cottonwood-willow riparian woodland. Although Beschta did not address riparian conditions of the Rush Creek bottomlands in detail, he did assess the question of multiple channels. He concluded that prior to 1941, Rush Creek had a single channel, with segments of relic channels present within the floodplain and with numerous rills that collected water from seeps and springs and conveyed it to Rush Creek. While the geomorphic and hydrologic basis of waterfowl habitat conditions in the Rush Creek bottomlands is not entirely clear, both Beschta's and Stine's studies indicate that there were areas of standing or flowing water within the cottonwood-willow woodland. These areas would likely have been attractive to small numbers of breeding waterfowl and to migrating waterfowl from Mono Lake during inclement weather.

Post-diversion riparian conditions in the Rush Creek bottomlands were characterized by Patten and Stromberg-Wilkins described Rush Creek riparian conditions as they existed in the 1980s. The Mono Basin EIR also provided a description of channel and riparian conditions and quantified areas of major vegetation types.

2.2.4 Waterfowl Populations

Mono Lake provides a permanent, saline, shallow to deep waterway body for migratory waterfowl traveling through the expansive arid Great Basin during the fall. It is especially attractive to species that exploit hyper-saline environments. Of these species the ruddy duck (*Oxyura jamaicensis)* and northern shoveler *(Anas clypeata)* are most abundant at Mono Lake. Systematic surveys have only recently been conducted for migratory populations of waterfowl and are essentially non-existent for breeding ducks at Mono Lake. Prior to 1948 only journal and personal recollections of waterfowl abundance exist in the record.

In 1948, Walter Dombrowski conducted the first systematic waterfowl survey reported for Mono Lake. There were no systematic waterfowl surveys for Mono Lake through the 1950s, 1960s, and early 1970s. In September of 1976, a waterfowl survey was conducted by Winkler et al. Various individuals and groups through the 1970s and 1980s have collected additional, sporadic waterfowl data. A professional wildlife biologist who has hunted Mono Lake for waterfowl hundreds of times during the 1980s and early 1990s estimates the current lake wide fall population at about 11,000 ducks. Joseph Jehl estimated the population in recent years at 15,000 ducks. Both Taylor and Jehl observed that ruddy ducks and northern shovelers continue to predominate in the fall population. A National Research Council (NRC) study in the mid 1980s summarized existing information about the Mono Lake ecosystem. With respect to birds, the NRC study focussed on phalaropes and gulls, with virtually no mention of waterfowl.

In the 1990s several systematic waterfowl surveys were conducted. The California Department of Fish and Game (CDFG) has collected some data using aircraft. Fall CDFG aerial waterfowl surveys were conducted in 1993,1998 and 1999. The Mono Lake Committee has surveyed the entire Mono Lake for all birds using a cadre of volunteers since 1997.

Joseph Jehl of Hubbs Sea World Research Institute under contract with LADWP, has conducted the most comprehensive waterfowl surveys at Mono Lake. These surveys have been conducted since 1995. Surveys have consisted of aerial (except 1995), ground, and boat counts at different intervals between summer and late fall. The 1996, 1997, 1998, and 1999 effort also included aerial surveys of waterfowl populations at Bridgeport Reservoir and Crowley Lake. Waterfowl time budget studies were conducted during the same survey periods, with a major effort in 1997.

3. RESULTS OF 1999 MONITORING ACTIVITIES

Results of monitoring activities that occurred in 1999 are summarized in this section. In most cases, specific reports have been produced that address these activities in more detail. These reports on lake limnology, vegetation sampling, and waterfowl habitat mapping, and waterfowl populations are included as appendices to this report.

3.1 Hydrology

Mono Lake elevations began and ended the 1999 calendar year at essentially the same elevation (Table 2). Lake level was 6384.2 feet on January 5, 1999 and 6384.1 feet on December 30, 1999 (data from LADWP using USGS datum). Peak lake level was 6,385.1 feet in July 1999. Lake level in January 1999 was 2.3 feet higher than the previous January (1998), however lake level at the end of 1999 was 0.2 feet lower than the end of 1998. At a 6,384-foot lake level, estimated lake area is 45,665 acres and estimated volume is 2,641,837 acre feet.

Stream flows in Rush, Walker, Parker, and Lee Vining creeks by month for all of 1999 are shown in Table 3. Peak flows for major Mono Basin streams gaged by LADWP were:

- Rush Creek: 222 cfs on July 2 at the dam site and 257 cfs July 11 below the narrows,
- Walker Creek: 29 cfs on May 29 and 29 cfs on June 20,
- Parker Creek: 52 cfs on June 24 and 47 cfs on July 14, and
- Lee Vining Creek: 262 cfs on May 29 and 274 cfs on June 19.

Water was diverted for export from Rush Creek from January to early April. Diversions for export were suspended from early April until July 20 to provide peak flows in Rush Creek. After July 20, exports were resumed at an average flow rate of 33 cfs. There were no diversions from Walker Creek, Parker Creek, or Lee Vining Creek for export during 1999. The report is attached as Appendix I.

Personnel from the Mono Lake Committee collected data from a network of piezometer stations located in the stream complexes of Rush and Lee Vining creeks. Nineteen ninety-five was the fifth year of data collection to assess the change in ground water depth as the stream restoration program takes place. There are six piezometer wells in Rush Creek and ten in Lee Vining Creek.

LADWP conducted surveys of springs and creeks within the Mono Basin complex on September 13 and 14, 1999 as required under Order 98-05. This survey was conducted to assess the condition of springs and streams that were first surveyed in August 1992, which consisted of 34 separate springs and one creek. Increased lake elevation of 10.5 feet since 1992 resulted in the inundation of some previously surveyed springs, and only sixteen springs and one creek were subsequently located and surveyed in 1999. The 1999 report contains information on stream location (GPS coordinates), photographs, tufa conditions, and data on water quantity (flow), temperature, conductivity, and clarity. The report is attached as Appendix II.

3.2 Lake Limnology

Limnology monitoring data in 1999, as in previous years, was collected by Robert Jellison and his collaborators at the Marine Science Institute, University of California, Santa Barbara. A detailed account of 1999 mixing and plankton dynamics in Mono Lake can be found in Jellison et al. (2000), which is included as Appendix III to this report. Their 1999 research continues the long-term investigations into the highly variable and dynamic Mono Lake aquatic environment.

Limnological monitoring indicated that meromictic conditions present since 1996 in Mono Lake continued in 1999. However, a decline of 0.1 feet in lake level since 1998 appeared to moderate effects of meromixis on several physical, chemical, and biological parameters of lake conditions.

As of the end of 1999, meromictic conditions have been present in Mono Lake for five consecutive years. During this time there has been no fall overturn, when the lake normally mixes to the bottom. Consequently, nitrogen has accumulated in the monimolimnion (below the chemocline) and been depleted in the mixolimnion (above the chemocline). Reduced nitrogen availability has led to reduced phytoplankton productivity and biomass, which continued in 1999.

The 1999 data show a slight moderation of meromixis since 1998 (Table 4). Some notable differences between 1999 and the immediate previous years of meromictic condition include:

- the midsummer density gradient due to chemical stratification declined from 1998 to 1999;
- epilimnetic chlorophyll concentrations in 1999 were as high as in 1998 and higher than in 1996 and 1997;
- estimated primary production was higher in 1999 than in the previous three years;
- midsummer *Artemia* abundance was slightly higher and female *Artemia* length slightly longer;
- mean annual biomass of *Artemia* was higher in 1999 than in the previous three years; and
- total annual *Artemia* cyst production increased from 1998 to 1999.

Despite some amelioration of meromictic conditions in 1999 compared to 1996 to 1998, 1999 still showed considerably lower chlorophyll concentrations, primary production rates, abundance and biomass of *Artemia,* and total *Artemia* cyst production compared to most previous monomictic years of 1989 to 1995.

Limnological parameters that have showed little to no change in 1999 compared to 1996 through 1998 include:

- a single late-summer peak *Artemia* compared to two peaks typical of monomictic years;
- daily ranges of primary production; and
- mean *Artemia* brood size.

Of direct importance to waterfowl and other water birds is the spatial and temporal occurrence of adult *Artemia* at Mono Lake. Vertical distribution of *Artemia* in the water column may play a role on food availability for waterfowl, especially for dabbling duck species. Mean weight of *Artemia* individuals may also have some bearing on meeting avian energetic demands. *Artemia* biomass has remained relatively constant in Mono Lake from 1993 to 1999 (approximately 8 to 9 g m^{-2} dry weight), except for a noticeably lower biomass in 1997 (< 6 g m^{-2}). *Artemia* biomass, however, was much higher during 1987 through 1990 (11 to 18 g m^{-2}), which included both the end of a meromictic period (1987-1988) and several monomictic years (1989-1990). Mean length of adult females, a measure of *Artemia* size, was slightly longer in 1999 compared to 1998, but similar to 1996 and 1997. These data suggest that *Artemia* biomass and individual size is not showing a progressive decline during the latest meromictic period, but rather is remaining fairly stable. It is uncertain whether this pattern of stability will continue if the current period of meromixis continues for a several years or even decades, as predicted.

3.3 Vegetation and Habitat

There are several elements for waterfowl habitat monitoring in the Mono Basin. As required by Order 98-05, vegetation transects were established and sampled, and aerial photography was acquired and used for habitat mapping. Other vegetation monitoring pertaining to waterfowl habitat includes monitoring associated with experimental burning and monitoring of riparian and channel habitat in Rush Creek bottomlands.

3.3.1 Vegetation Transects

Vegetation monitoring of lake-fringing and delta wetlands in 1999 included the establishment and sampling of five sets of transects by LADWP, under the direction of David Martin (Martin 2000, Appendix IV). Transects were located at Simons Springs, Warm Springs, DeChambeau Embayment, Rush Creek delta, and Lee Vining Creek delta. In the lake fringing wetland areas, three transects were set up perpendicular to the shoreline and the locations recorded with a Global Positioning System (GPS). From these transects, 50-meter point intercept transects were extended parallel to the shoreline. In the deltas, transects were established parallel to the shoreline (i.e., perpendicular to the channel), the locations recorded with a GPS, and sampled using the point-intercept method.

The vegetation transect sampling resulted in documented vegetation conditions in various locations around Mono Lake in 1999, including species composition and cover. Photographs of transect endpoints were also taken during the sampling.

Based on data presented in Martin (2000), dominant species found in 1999 can be compared to mapping of 1989 lake-fringing wetland vegetation conducted by Jones and Stokes. Such a comparison is tentative because of the difficulty in accurately identifying either 1999 transect locations on aerial photographs and difficulty in identifying the location of polygons mapped in Jones and Stokes EIR, which lack features that can be used to relate polygon locations to the aerial photographs.

This comparison suggests that there has been considerable change in vegetation from 1989 to 1999 in some areas but not in others. The area sampled by these transects that appears to have changed the most is Warm Springs. At that location, much of the vegetation within approximately 600 meters of the current lake shoreline has changed from alkali lakebed and dry meadow to marsh dominated by three-square (*Scirpus pungens*), alkali bulrush (*S. maritimus*), and Nevada bulrush (*S. nevadensis*). There have also been substantial changes at the transect locations in the DeChambeau Embayment. The lake has risen to within about 100 meters of the bare, Black Point sands. Vegetation between the sands and the water is now dominated by a mixture of marsh dominated by three-square and dry meadow dominated by meadow barely (*Hordeum jubatum*); in 1989 this area was alkali lakebed and alkali meadow. In contrast to changes at these locations, vegetation at Simons transects is very similar between 1989 and 1999. It also appears that vegetation types in the Rush and Lee Vining creek deltas has not changed substantially in type over the 10-year period, although there may have been changes in density or height of willow (*Salix* spp.) dominating the floodplain in the delta areas.

3.3.2 Aerial Photography and Habitat Mapping

The mapping of vegetation in the Mono Basin waterfowl habitat is described in Appendix V. The task consisted of three separate steps, each completed by a separate company under contract to LADWP. The first step consisted of the aerial photography, which was completed by I. K. Curtis Inc. of Burbank, CA. The second step involved the conversion of the aerial photography into a digital, geo-rectified, composite image, which was done by AirPhoto USA of Phoenix, AZ. The final step included the interpretation of vegetation classes and mapping of vegetation polygons into a GIS database, which was completed by David Chapin of R2 Resource Consultants, Redmond, WA.

Methods

Aerial photography was taken on September 2, 1999. The scale of photography was 1 inch = 3,000 feet, or 1:36,000 (original scale on 9 inch x 9 inch negatives or contact prints). The aerial photography was converted from negatives to a digital, composite image by AirPhoto USA using their proprietary "Stable Earth Digital Ortho Rectification Process." Pixel size of the digital image was 1 meter and planimetric accuracy was 40 feet (90% of pixels within 40 feet of real location), although AirPhoto USA claimed that real accuracy was generally within 1 meter of control points. Optimum resolution on the digital composite image was indicated to be at a scale of 1 inch = 300 feet, or 1:3,600. A GIS database of cover class polygons was developed with ESRI ArcView software, using on-screen digitizing over a backdrop of imported images from the AirPhoto USA digital, composite image.

Classes of major vegetation types mapped in the 1999 mapping and a brief description of each class were as follows:

Marsh. Dominated by tall emergent species such as hard-stem bulrush (*Scirpus acutus*), cattail (*Typha latifolia*), three-square (*Scirpus pungens*), alkali bulrush (*Scirpus maritimus*) and beaked sedge (*Carex utriculata*).

Wet meadow. Dominated by lower stature herbaceous plant species, such as sedges (*Carex* spp.), rushes (*Juncus* spp.), spikerushes (*Eleocharis* spp.), and some forbs.

Alkaline wet meadow. Similar in stature to the wet meadow class but occuring in areas clearly affected by saline or alkaline soils. Dominated by dense stands of Nevada bulrush (*Scirpus nevadensis*), Baltic rush (*Juncus balticus*), and/or saltgrass (*Distichlis spicata*).

Dry meadow/forb. Moderately dense to sparse (at least 15 percent) cover of herbaceous species, including a variety of grasses and forbs and some sedges (e.g., *Carex douglasii*).

Riparian and wetland scrub. Dominated by willows (*Salix* spp) or willow mixed with small amounts of buffalo berry *(Shepardia argentea*) and Wood's rose (*Rosa woodsii*).

Great Basin scrub. Scattered to dense stands of sagebrush (*Artemesia tridentata*), rabbitbrush (*Chrysothamnus nauseosus*), and/or bitterbrush (*Purshia tridentata*).

Classes of aquatic habitats. Included freshwater-stream, freshwater-ria, freshwater-pond, ephemeral brackish lagoon, and ephemeral hypersaline lagoon.

Other cover classes. Included riparian forest and woodland, unvegetated, and man-made.

Results

Most of the 1999 marsh habitat in lake fringing wetlands around Mono Lake were in the Simons Springs area, (165 acres), with Warm Springs (66 acres) and DeChambeau Embayment (26 acres) also having substantial marsh areas. Wet meadow (probably equivalent to "mixed marsh" of Jones and Stokes EIR) was most abundant in the County Park (44 acres), Mill-Wilson Delta (21 acres), and DeChambeau Embayment and DeChambeau Ponds (19 acres) areas. Extensive alkaline wet meadow areas were mapped in the Warm Springs (233 acres), Simons Springs (179 acres), and East Beach (106 acres) areas.

Small amounts of freshwater ponds were identified in Simons Springs, East Beach, and Black Point areas (< 1 acre each), and there were 7.1 acres of pond habitat mapped in the DeChambeau/County Ponds complex. Extensive areas of ephemeral brackish lagoon were mapped in the Warm Springs (30 acres), South Beach (24 acres), and North Beach (21 acres) areas. North Beach also had a large amount of hypersaline lagoon (105 acres). There were 2.4 and 0.5 acres mapped as ria in the Rush Creek and Lee Vining Creek deltas, respectively.

3.3.3 Rush Creek Riparian Monitoring

Riparian vegetation in the Rush Creek bottomlands, as well as in several other riparian areas in the Mono Basin, was mapped in 1999 by John Bair of McBain and Trush, Arcata, California. The riparian mapping was done primarily to meet monitoring requirements of stream restoration, but the results are also useful for characterizing waterfowl habitat in the Rush Creek bottomlands.

Bair used 1:9,600 scale natural color aerial photographs enlarged to a scale of 1:1,800. Since the purpose of mapping was to quantify the amount of riparian vegetation present and compare to pre-diversion and pre-restoration estimates, Bair's classification was oriented towards identifying the major riparian plant communities in contrast to upland communities also present. Cover classes most relevant to waterfowl habitat included aquatic vegetation, cattail, wet meadow, and stream.

Based on an examination of the maps in Bair's report, the only area of aquatic vegetation in the Rush Creek bottomlands were in rias of the delta. There were a few scattered patches of cattail (presumably *Typha latifolia*), two of which were below the County Road and two of which were in bank channel areas along the east valley wall. Following the orientation of the channels, they were all generally linear in shape. There appeared to be no wet meadow areas mapped.

There were two significant back channel areas (mapped as stream) along the east valley wall, one towards the lower end of Reach 4B and another one upstream near the boundary between Reaches 4A and 4B. There was also a smaller isolated back channel in Reach 4B, again along the east valley wall. The creek was generally mapped as one channel, with braiding present in scattered reaches up to 300 feet in length.

During a reconnaissance visit to the Mono Basin in June 1999, Don Paul and David Chapin examined a portion of the Rush Creek bottomlands. They found that a back channel along the east valley wall (Channel 10) harbored a relatively small amount of waterfowl habitat. The area contained slow moving water with pools in some portions and isolated pools of standing water apparently fed by springs or a high water table. Vegetation adjacent to the channel consisted mostly of willow thickets, but also included wet meadows and grassy areas. A few cinnamon teal were flushed from the area and an active cinnamon teal nest was found, indicating the area was being used by breeding waterfowl.

3.3.4 Experimental Burning

Monitoring reported for experimental burn areas in 1999 consisted only of the vegetation transects at Simons Springs sampled by Martin (2000), which were described in Section 3.2.3.1. Since no results of any previous sampling of these transects were available at the time of this report, the 1999 data cannot be compared to either pre-burn or earlier post-burn conditions.

3.3.5 DeChambeau/County Ponds Habitat Creation and Enhancement

Monitoring of habitat at the DeChambeau/County ponds complex included qualitative observations by Larry Ford and relatively small scale mapping conducted by David Chapin as part of the lake wide habitat mapping. Mapping based on the 1999 aerial photography identified approximately 4.1 acres of open water, 20 acres of marsh and wet meadow delineated at DeChambeau Ponds; and 0.5 acres of open water and 17 acres of wet meadow at the West County Pond. The East County Pond was dry during 1999.

3.4 Waterfowl Population Surveys

Joseph Jehl of Hubbs Sea World Research Institute, under contract to LADWP, carried out waterfowl population monitoring at Mono Lake in 1999. Jehl's work continues a waterfowl monitoring effort by himself and associates that has been conducted annually since 1995. The 1999 summary presented here is drawn from Jehl (2000), which is included as Appendix VI to this report.

Several methods were employed in 1999 to assess waterfowl populations at Mono Lake and nearby lake and wetland complexes, including boat, aerial, and foot surveys at multiple times during the year. Data collected at Mono Lake in 1999 included numbers of breeding waterfowl, migratory waterfowl, and waterfowl utilizing the DeChambeau/County ponds complex. Observations of waterfowl using prescribed burn areas (Simons Springs) hypopycnal zones, wetland and lagoon areas were also made. All-lake, aerial surveys were conducted to determine total waterfowl present at Mono Lake, Bridgeport Reservoir, and Crowley Lake. Survey activities were conducted for the period of May through late November with emphasis on the period between mid-July and November.

3.4.1 Mono Lake: Breeding Waterfowl

The only waterfowl species consistently found to occur, as a breeder within the lake-bordering wetlands, was the gadwall. In 1999, 22-25 pairs of gadwall nested along the lake itself. Two to three pairs nested at the DeChambeau Pond area. In addition to Jehl's data and observations, Don Paul and David Chapin found a single nest and observed several cinnamon teal hens in flight at Rush Creek during June 1999.

The 1999 total nesting population of breeding waterfowl in Mono Lake and associated wetlands was estimated by Jehl to be 30 to 35 pairs. The main hatching period was July 10 to 15, and broods were generally large (8-10). On August 15, Jehl estimated 205 locally produced juveniles to be present at the lake. Ten adults and 13 juvenile gadwall were captured and banded in 1999 as part of a study on various aspects of gadwall biology.

3.4.2 Mono Lake: Migrating Waterfowl

Boat survey was the principal method used to collect waterfowl estimates at Mono Lake (see Jehl [2000] for details of survey methodology). In 1999, 20 species of ducks, geese, and allied waterbirds were recorded within the Mono Lake ecosystem. The mallard, northern shoveler, green-winged teal, and northern pintail were the most common dabbling ducks. Northern shoveler was the most common dabbler in September; mallards and northern pintails were most common in October, and green-winged teal were most common in November.

Ruddy ducks (in the stiff-tailed duck tribe) is the most abundant migrating duck species at Mono Lake. Numbers of ruddy duck were estimated to be 4,000 in mid-October, which was the peak of ruddy duck numbers at Mono Lake in 1999. This count is likely an underestimate, with the true number of ruddy ducks in October probably closer to 5,000. Ruddy ducks are difficult to count at Mono Lake because they occur in association with large numbers of staging eared grebes. The peak total waterfowl count (all species) was 10,657 in mid-October. There were >19,000 individual ducks total recorded for all survey periods, however it is not known how many of these ducks were present from one survey period to the next.

3.4.3 DeChambeau/County Ponds Surveys

Pond surveys concentrated on the DeChambeau/County ponds complex. The total waterfowl count by month and pond is summarized in Table 5. This summary also includes the eared grebe, pied-billed grebe, and western grebe, which are not considered waterfowl species. As mentioned above, three pairs of breeding gadwall were found at the DeChambeau Ponds. The peak waterfowl count at DeChambeau/County ponds complex was 152 on October13, with most of the ducks located at County Pond 1 (the west pond). Of the two County Ponds, only County Pond 1 had water in 1999; Pond 2 (the east pond) was dry.

3.4.4 Surveys of Lagoons and Ponds in Navy Beach to Simons Springs Area

Other ponds and lagoons along the shoreline were surveyed in 1999, primarily to collect behavioral data on waterfowl. Special attention was given to ponds forming on the south shore between Navy Beach and Simons Springs. Jehl indicated in this 1999 report that these data will be presented in future reports. According to Jehl, these ponds were being used by only a handful of migratory ducks (< 20) when he visited them in 1999.

3.4.5 Aerial and Other All-Lake Censuses

Aerial waterfowl surveys were conducted on September 17 and October 14, 1999 over Mono Lake, Bridgeport Reservoir, and Crowley Lake. The aerial survey counts for September 17 were 10,716 total waterfowl at Crowley Lake, 8,350 at Bridgeport Reservoir, and 3,576 at Mono Lake. On October 14, there were much larger numbers of mallards and pintails present at Mono Lake (10,657) compared to Bridgeport Reservoir (4,948) and Crowley Lake

(4,562). Aerial census data since 1996 will be compared between the three surveyed water bodies and discussed in Section 5 below.

The California Fish and Game Department (CDFG) carried out an aerial survey in 1999 that included Mono Lake, Crowley Lake, and Bridgeport Reservoir. The data from the CDFG survey were not available for this report. The Mono Lake Committee sponsored a spring and fall all-lake bird survey that includes waterfowl in 1999. On April 25 they counted 2,137 ducks and geese, and on August 21 they counted 1,486.

3.4.6 Waterfowl Use of Prescribed Burn Areas

Observations were made of two prescribed burn sites in the Simons Springs area. Jehl indicated that observations from both plane and boat revealed no evidence of waterfowl use of the burn areas.

3.4.7 Waterfowl Use of Hypopycnal Stratified Areas

Using a refractometer, the extent of hypopycnal stratification was mapped at the mouth of Lee Vining Creek between April and November. The five mapping sessions included waterfowl counts and distribution. Visits were also made to other areas of stream discharge and seep activity near the lake. With one exception, Jehl reported that waterfowl were using these areas for loafing in proximity to fresh water marsh feeding areas. Jehl indicated that data from several years would be summarized elsewhere.

3.4.8 Behavioral Studies

S. I. Bond of Hubbs-Sea World Research Institute, under the direction of Joseph Jehl, spent a week (September 28 through October 30) at Mono Lake observing the distribution and behavior of ducks. Observational data included activity budget, habitat use, and daily movements of waterfowl on the lake. These data add to behavioral data collected during other waterfowl monitoring efforts in recent years. Jehl said that these data will be incorporated in future reports.

4. STATUS OF RESTORATION MEASURES

Several ongoing restoration measures pertaining to waterfowl took place in 1999. The lake level continued to increase (at least through part of the year), enhancement work continued on the DeChambeau/County Ponds complex, and experimental burning took place.

4.1 Lake Level

The average lake level for 1999 was 6,384.7 feet (using the level at the beginning of each month). This is a 10.1-foot increase toward the target lake level of 6,391 feet since the 1994 Decision 1631. The lake level needs to rise another 6.3 feet from the 1999 average lake level to reach the target lake level.

4.2 DeChambeau/County Ponds Complex

Restoration activities conducted during 1999 by the USFS at the DeChambeau/County Ponds Complex included construction of 2000 feet of pipe to transport excess water from DeChambeau Ponds to the County Ponds. The west County Pond maintained approximately 3.3 acres of surface water through diversions of water from the DeChambeau Pond and a diversion from Wilson Creek. In addition to this addition to the infrastructure of the DeChambeau/County Ponds complex, the USFS carried out ongoing management and maintenance of ponds and water supply system during 1999. The USFS developed plans to burn part of the DeChambeau meadow to remove thatch and open up surface water in depression areas.

4.3 Experimental Burning

LADWP did not conduct any experimental burning in 1999 but carried out planning for a proposed burn in winter 2000-2001. The intended location of the 2000-2001 burn is in the Warm Springs area. David Chapin participated in a field visit to the proposed burn area with David Martin and other personnel from LADWP in October. It was decided that a possible winter 1999-2000 burn would be postponed a year until appropriate wildlife and vegetation baseline monitoring could be conducted in 2000.

The California Department of Parks and Recreation (CDPR) directed experimental burns in the Simons Springs area in January and on December 16, 1999. The only information we have available concerning these burns is a description of the December 16 burn provided by Jim Barry. Although area burned was not indicated by Barry, vegetation and thatch was totally consumed down to the water line in areas burned 4 years ago, and was patchy in areas burned 1 year ago. Barry indicated that documentation of the 1999 or previous burns (1995, 1997) had not yet been compiled.

4.4 Rewatering of Rush Creek Distributaries

There were no direct actions taken toward rewatering distributaries in Rush Creek during 1999. Bill Trush, one of the scientists directing stream restoration and monitoring in the Mono Basin, recommended that decisions to open up channels 8 and 11 of Rush Creek be delayed to see how the channels in the Rush Creek bottomlands respond naturally to the current flow regime.

There was some placement of large woody debris in the Rush Creek channel and floodplain by LADWP during October 1999. This material consisted of root wads from 1 to 3-foot diameter Jeffery pine trees. Since large woody debris can have a significant effect on channel processes, this action may affect what channels are active, formation of pools within active channels, and how water is distributed across the floodplain during floods, all of which can affect waterfowl habitat.

5. RECOVERY OF WATERFOWL HABITAT

This section summarizes the recovery of waterfowl habitat in the Mono Basin. The habitat being monitored includes the lake, ephemeral brackish lagoons and open water ponds, lake-fringing wetlands, freshwater ria and stream deltas, and distributaries of Rush Creek.

5.1 Lake Level

Mono Lake elevations began and ended the 1999 calendar year at essentially the same elevation (Table 2). Lake level was 6384.2 feet on January 5, 1999 and 6384.1 feet on December 30, 1999 (data from LADWP using USGS datum). Peak lake level was 6,385.1 feet in July 1999. Lake level in January 1999 was 2.3 feet higher than the previous January (1998), however lake level at the end of 1999 was 0.2 feet lower than the end of 1998. At a 6,384-foot lake level, estimated lake area is 45,665 acres and estimated volume is 2,641,837 acre feet.

5.2 Ephemeral Brackish Lagoons

Ephemeral brackish lagoons along the shore at South Beach, Simons Spring, East Beach, Warm Springs, North Beach, Black Point, Bridgeport Creek (east of DeChambeau Embayment), and Mill-Wilson delta totaled over 100 acres in 1999, indicating that this type of habitat was relatively abundant and widely distributed around the lake.

Emphemeral brackish lagoons changed markedly from 1989 to 1999. Only 1 acre of "ponds and lagoons" were mapped by Jones and Stokes (1993) under point-of-reference conditions. In contrast, 109 acres of ephemeral brackish lagoons and 8.5 acres of freshwater ponds were mapped in 1999. However, the 1999 mapping included 7.1 acres of freshwater ponds within the DeChambeau/County Ponds complex, which were not included by Jones and Stokes (1993). Brackish lagoons mapped in 1999 include ponds and lagoons formed by extensive littoral bars and, in the South Beach area, inundation of pre-existing swales, which may have been deflationary features formed since the lake receded after 1941. Although most of these brackish lagoons are likely to be transient, they nonetheless are potentially important as waterfowl habitat until an equilibrium lake level is reached

5.3 Lake-Fringing Wetlands and Marshes

One of the most prominent changes anticipated with increasing the lake level was an overall decrease in marsh area, primarily due to inundation of marsh areas by the rising lake and "spring-line sapping" (i.e., desiccation of wetland supported by springs as beveling cuts an escarpment at a higher equilibrium shoreline). Marsh area mapped in 1999 totaled 302 acres. This area, however, should likely be combined with wet meadow mapped in 1999 (83 acres) to compare to Jones and Stokes (1993) point-of-reference marsh area. Combined 1999 marsh and wet meadow area at a lake level of 6,384.6 feet was 385 acres compared to 988 acres of marsh mapped at a lake level of 6,376 feet. This decrease occurred in most areas where marsh was present in lake-fringing wetlands. Warm Springs, however, was an exception and showed an increase in marsh area between 1989 and 1999.

There was also a decrease in alkaline wet meadow from point-of-reference conditions, assuming that the 1999 wet alkaline meadow type is roughly equivalent to Jones and Stokes (1993) alkali meadow formation. There were 1,521 acres of alkali meadow mapped in 1989 and 582 acres of wet alkaline meadow mapped in 1999. Again, decreases occurred in most areas around the lake; Warm Springs and East Beach were two exceptions, as alkaline wet meadow increased in these two areas.

The overall area of wetland/riparian scrub increased from point-of-reference conditions (236 acres) to 1999 (335 acres). Increases were most apparent in the Wilson-Mill creek delta areas and Horse Creek Embayment, although there were also smaller increases in Rush Creek Delta and Lee Vining Creek Delta.

5.4 Rush Creek Distributaries

As a result of increased flows in Rush Creek, actions to open up Channel 10, and natural processes, there are several places in Rush Creek bottomlands that provide favorable habitat. Rewatering Channel 10 does appear to have benefited waterfowl habitat in the Rush Creek bottomlands. The abandoned or active channels along the eastern valley wall seem to be conducive to the development of small areas of good habitat, particularly for small breeding birds. Rewatering in these areas along the eat valley appears to be a function of high water table and spring activity, as well as opening up Channel 10.

5.5 Freshwater Rias and Riparian Habitat in Stream Deltas

Ria habitat has developed in the deltas of both Rush and Lee Vining Creek. Freshwater ria habitat was 2.5 acres in Rush Creek and 0.5 in Lee Vining Creek. There were also shoreline bars present across the months of Mill and Wilson creek that likely resulted in freshwater to brackish conditions there.

Table 1. Mono Lake Mixing History 1964-Present

1964-1982	1983-1987	1988-1989	1990-1994	1995	1996-Present
Monomictic	Meromictic	Transition	Monomictic	Transition/ Meromictic	Meromictic

Table 2. 1999 Mono Lake Monthly Elevations in (feet amsl) LADWP Bishop Aqueduct Data.

Jan 5	Feb 4	Mar 11	Apr 5	May 6	Jun 10	Jul 1	Aug 5	Sep 2	Oct 7	Nov 4	Dec 9
6384.2	6384.5	6384.8	6384.8	6384.8	6384.9	6385.1	6384.5	6384.6	6384.5	6384.3	6384.1

Table 3. Mean monthly discharge (cfs) in Lee Vining, Rush, Walker, and Parker Creeks for 1999[1].

Month	Lee Vining Creek	Rush Creek	Walker Creek	Parker Creek	Rush Creek below Narrows (estimated)
January	29.50	57.90	4.00	4.42	66.32
February	27.00	57.48	4.07	4.81	66.36
March	26.20	52.25	3.24	4.98	60.47
April	34.70	52.20	2.28	6.10	60.58
May	128.00	51.93	10.50	12.80	75.23
June	203.00	53.59	21.80	27.60	102.99
July	112.00	134.16	12.70	26.80	173.66
August	48.80	60.80	6.03	8.90	75.73
September	33.40	53.61	4.25	9.28	67.14
October	30.20	45.39	3.06	6.73	55.18
November	34.30	43.78	5.75	4.88	54.41
December	29.80	45.41	3.74	4.41	53.56

[1] All flow data from LADWP. Flows at Lee Vining Creek are spill from intake, at Rush Creek below dam (plus spillway); at Walker and Parker creeks under conduit. Estimated flow in Rush Creek below Narrows is sum of Rush, Walker, and Parker creeks.

Table 4. 1999 Mono Lake Limnological Characteristics and Comparison to Recent Meromictic Years and the Last Monomictic Period.

Characteristic	1999	1998	1997	1996	1990-1995
Year end January lake elevation	6384.1	6384.3	6380.4	6378.1	6373.4 to 6377.8
Significant inverse thermal stratification (mid depth)	Present	Present	Present	Present	Absent
Holomixis	Absent	Absent	Absent	Absent	Present
Monimolimnetic temperature pattern	Constant throughout year	Constant throughout year	Constant throughout year	Constant throughout year	1990-1994 variant through year
Maximum mixolimnetic Conductivity/ salinity trend	Decreased slowly	Decreased	Decreased	Decreased	Stable to increasing
Monimolimnetic conductivity/ salinity trend	Small decrease from 1998	Decrease from 1997	Decrease from 1996	Decrease from 1995	Stable to increasing
Density Stratification trend	Strong but weaker than 1998	Strong	Strong	Strong	Moderate to weak
Transparency Secchi depth range (m)	2.1-11.5	1.9-12.0	2.0-9.6	1.5-10.9	1.4-8.3 (1994)
Dissolved oxygen: Above chemocline	Within range of previous years				Water column oxygenated during holomixis
Below chemocline	Anoxic	Anoxic	Anoxic	Anoxic	
Nutrient (ammonium): ephotic ammonium	Low except June and Sept.	Low except June and Sept.	Low all year	Highest mid-summer	High but not as high as 1985
benthic ammonium	Increase over 1998	Increase over 1997	Increase over 1996	Increase over 1990-1995	Distributed in water column (holomixis)
Mixolimnetic algal biomass (chlorophyll *a*): December – March	Higher than 1996-1998				
Rest of year pattern	Similar to 1996-1998 but lower than 1990-1995	Similar to 1996-1998 but lower than 1990-1995	Similar to 1996-1998 but lower than 1990-1995	Similar to 1996-1998 but lower than 1990-1995	Planktonic primary production significantly higher
Monimolimnetic algal biomass (chlorophyll *a*)	Similar to 1998-1996	Similar to 1997-1996	Similar to 1996	Average 33.5 µg chl *a* l^{-1}	?
Artemia population dynamics	Single mid-July adult peak small 2nd generation	Single mid-July adult peak small 2nd generation	Single mid-August adult peak small 2nd generation	Single mid-July adult peak small 2nd generation	First population peak spring, 2nd population summer
Artemia adult peak abundance (m^{-2})	38,439 (07-15-99)	33,968 08-10-98	27,312 08-21-97	?	06-93 =27,000 07-22-93 =21,000 07-22-94 = 29,000 07-03-95 = 24,400
Artemia mean annual biomass (mg m^{-2})					

Table 5. Summary of Waterfowl Counted at the Dechambeau and County Pond Complex (Jehl 2000).

Dates (1999)	Total Number of Species on Each Date		Total Waterfowl (number of adults)	Total Other Water Birds (number of adults)	Total All Water Birds (number of adults)
	DeChambeau Ponds	County Ponds			
June 2	3	3	20	16	36
July 15,	1	0	1	7	8
July 29,	2	2	18	3	21
August 12,	2	6	96	55	151
September 3,	3	4	2	6	29
September 20,	2	3	20	27	47
September 29,	0	5	49	38	87
October 2,	1	4	39	46	85
October 13,	1	3	152	229	381
November 7,	2	0	5	77	82
November 24,	4	0	17	75	92
Total Season Count			440	579	1019

APPENDIX I

SUMMARY OF LADWP'S OPERATIONS AND RUNOFF IN THE MONO BASIN FOR RUNOFF YEAR 1999-00

(Letter dated November 9, 1999)

file

November 9, 1999

To Enclosed Distribution List:

Update on Mono Basin Operations During 1999-2000 Runoff Year

This year's runoff for the Mono Basin (Figure 1) could be termed "typical" with no significant events occurring. The peaks on most of the creeks came later than forecasted and the magnitude for three of the four creeks was higher than forecasted, but not significantly. The total volume of water that has been measured however, is considerably less than forecasted. The forecasted volume for the April-through-September period was 97,000 acre-feet and the measured was 69,900 acre-feet.

The following is a summary of LADWP's operations to date in the Mono Basin for the 1999-2000 runoff year:

- Mono Basin Exports: Exports were suspended in early April to assure a Grant Lake spill, and were curtailed until the peak had passed on Rush Creek. Exports were resumed on JULY 20th at an average flow rate of 23 cfs (Figure 2). The exports will continue through the remainder of the runoff year, and are expected to conclude in late March 2000. The flow rate will be increased to approximately 40 cfs to provide LADWP its allowable maximum export of 16,000 acre-feet.

- Walker Creek: There were no diversions for export during the year. The creek experienced two peaks. The first peak occurred May 29th with a magnitude of 29 cfs (average daily) and the second peak also a magnitude of 29 cfs occurred on June 20th. The peaks did not exceed the forecasted magnitude (Figure 3).

- Parker Creek: There were no diversions for export during the year. The creek experienced two peaks. The first peak occurred June 24th with a magnitude of 52 cfs (average daily) and the second peak occurred July 14th with a magnitude of 47 cfs. The first peak exceeded the forecasted magnitude of 47 cfs (Figure 4).

- Lee Vining Creek: There were no diversions for export during the year. There were two peaks on Lee Vining Creek measured below the Conduit. The first peak occurred on May 29th with a peak of 262 cfs (average daily) which was slightly higher than forecasted. The second peak occurred on June 19th with a magnitude of 274 cfs (Figure 5).

  No water was diverted from Lee Vining Creek through the Lee Vining Conduit to the conduit spillway to augment Rush Creek flow.

- Rush Creek: Grant Lake's elevation on April 1, 1999 was 7,122.4 ft amsl, 7.6 ft below the lip of the spillway, providing another opportunity to spill and pass the peak to lower Rush Creek. To promote the spill and assure that the spill would be occurring when the peak flow was most likely to arrive, releases to Mono Gate Return Ditch were maintained slightly above Rush Creek minimum flows. In addition, exports to the Owens River were suspended in early April. A peak inflow into Grant Lake (Rush Creek at Damsite) of 201 cfs was forecasted to occur the week of June 7th. On June 30th, Grant Lake reservoir began to spill. Rush Creek at Damsite experienced its peak on July 2nd with a magnitude 222 cfs (average daily) (Figure 6, 7, and 8).

  Rush Creek below the confluence of the Mono Gate Return Ditch and Grant Lake spill experienced a flow of 202 cfs (average daily) on July 11th. In early July when it became evident that the spill was not likely to increase, LADWP decided to ramp up the ditch to its current maximum safe operating flow of 160 cfs to provide Rush Creek with the highest possible flows under the current circumstances. The decision resulted in Rush Creek receiving a flow magnitude approximately 10% higher than what would have occurred had no change been made (Figure 7).

  Rush Creek below the narrows experienced on July 11th a magnitude of 247 cfs (average daily) (Figure 8).

- Grant Lake Reservoir: Releases from the reservoir to Rush Creek were maintained slightly above the minimum and exports were suspended on April 7th to facilitate a spill. Grant Lake began spilling on June 30th and continued until early August, achieving a maximum spill of 121 cfs on July 5th (Figure 9).

- Mono Basin Runoff: The timing of the Mono Basin runoff occurred one to three weeks later than predicted and three of the four creeks experienced flow magnitudes greater than those forecasted. The table below compares April 22nd forecasted magnitudes and timing to the flows that were actually measured:

	Predicted		Measured	
	Magnitude	Timing	Magnitude	Timing
Rush Creek @ Damsite	201 cfs	June 7	222 cfs	July 2
Parker Creek	47 cfs	June 18	52 cfs	June 24
Walker Creek	35 cfs	June 13	29 cfs	May 29
Lee Vining Creek	247 cfs	June 6	274 cfs	June 19

If you have any questions or need additional information regarding operations, please contact me at (760) 873-0225.

Sincerely,

ORIGINAL SIGNED BY
GENE L. COUFAL

GENE L. COUFAL
Manager
Aqueduct Business Group

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Mr. Marshall S. Rudolph
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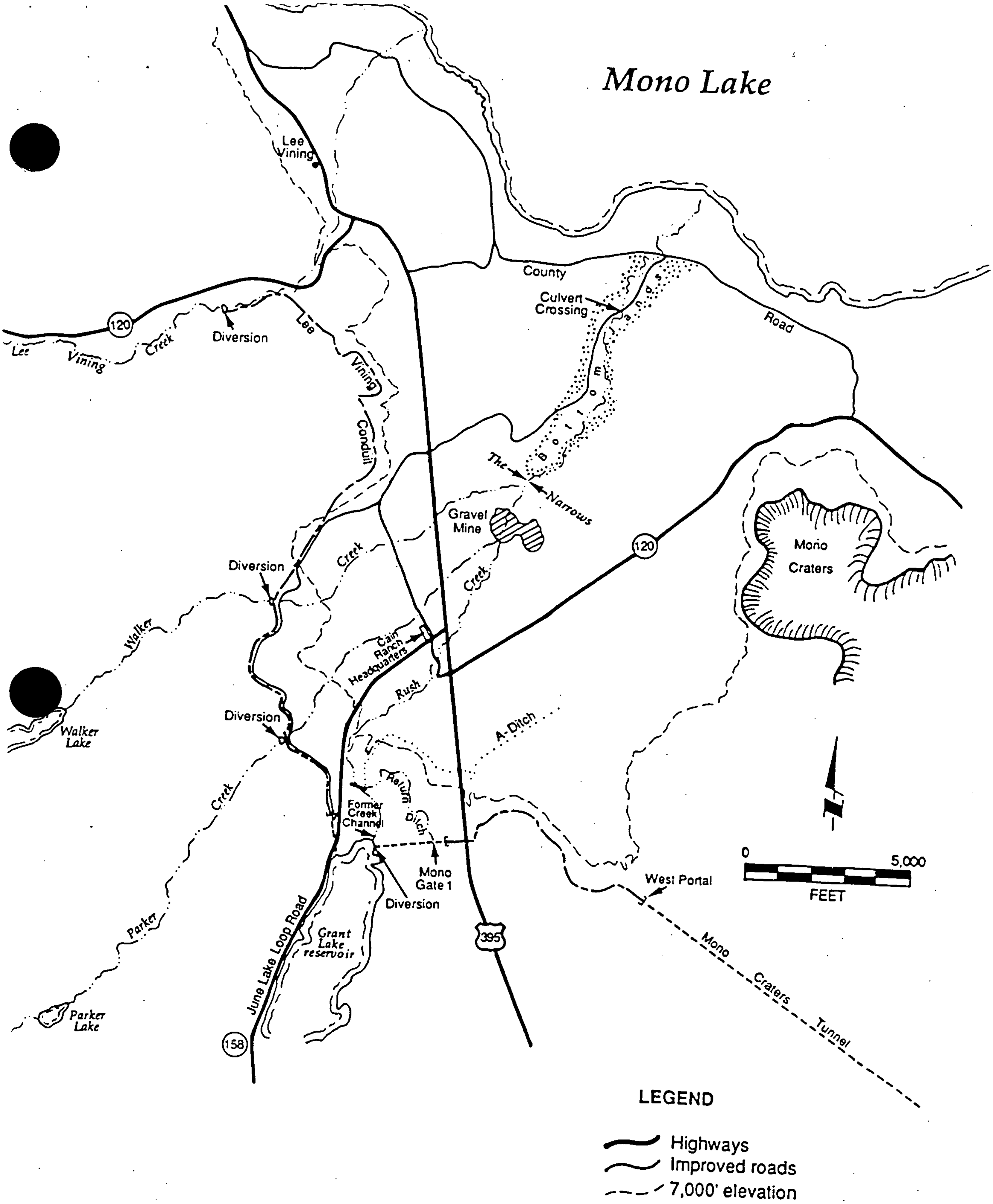

Mono Lake
Lee Vining
County
Culvert Crossing
Road
Bottomlands
120
Lee Vining Creek
Diversion
Lee Vining Conduit
The Narrows
Gravel Mine
Mono Craters
Diversion
Walker Creek
Walker Lake
Creek
Creek
Cain Ranch Headquarters
Rush
Diversion
A-Ditch
Return Ditch
Former Creek Channel
Parker Creek
Mono Gate 1
Diversion
West Portal
0
5,000
FEET
June Lake Loop Road
Grant Lake reservoir
395
158
Mono Craters Tunnel
Parker Lake
LEGEND
Highways
Improved roads
7,000' elevation

Figure 1

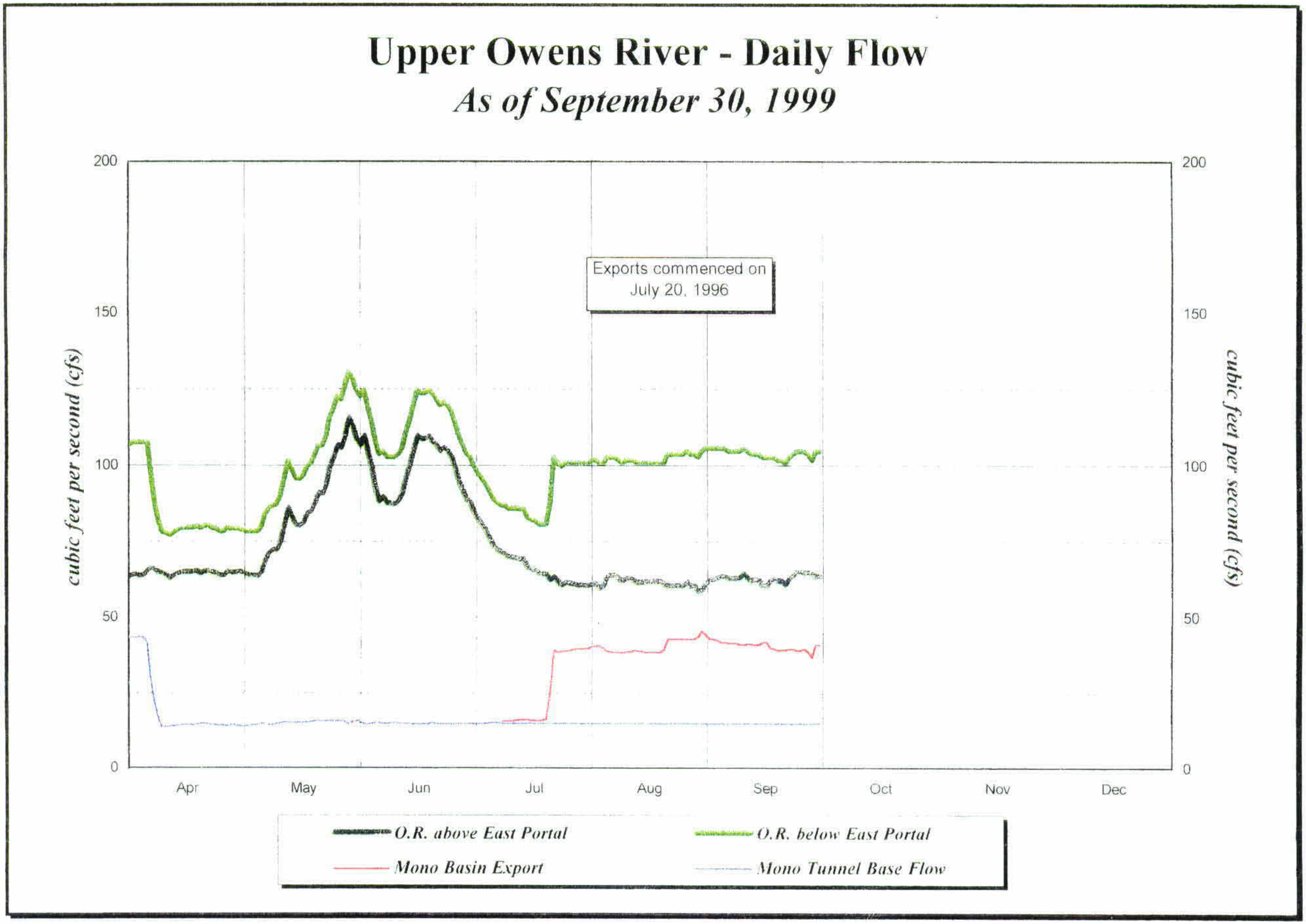

Upper Owens River - Daily Flow
As of September 30, 1999
Exports commenced on July 20, 1996
cubic feet per second (cfs)
0
50
100
150
200
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
O.R. above East Portal
O.R. below East Portal
Mono Basin Export
Mono Tunnel Base Flow

Figure 2

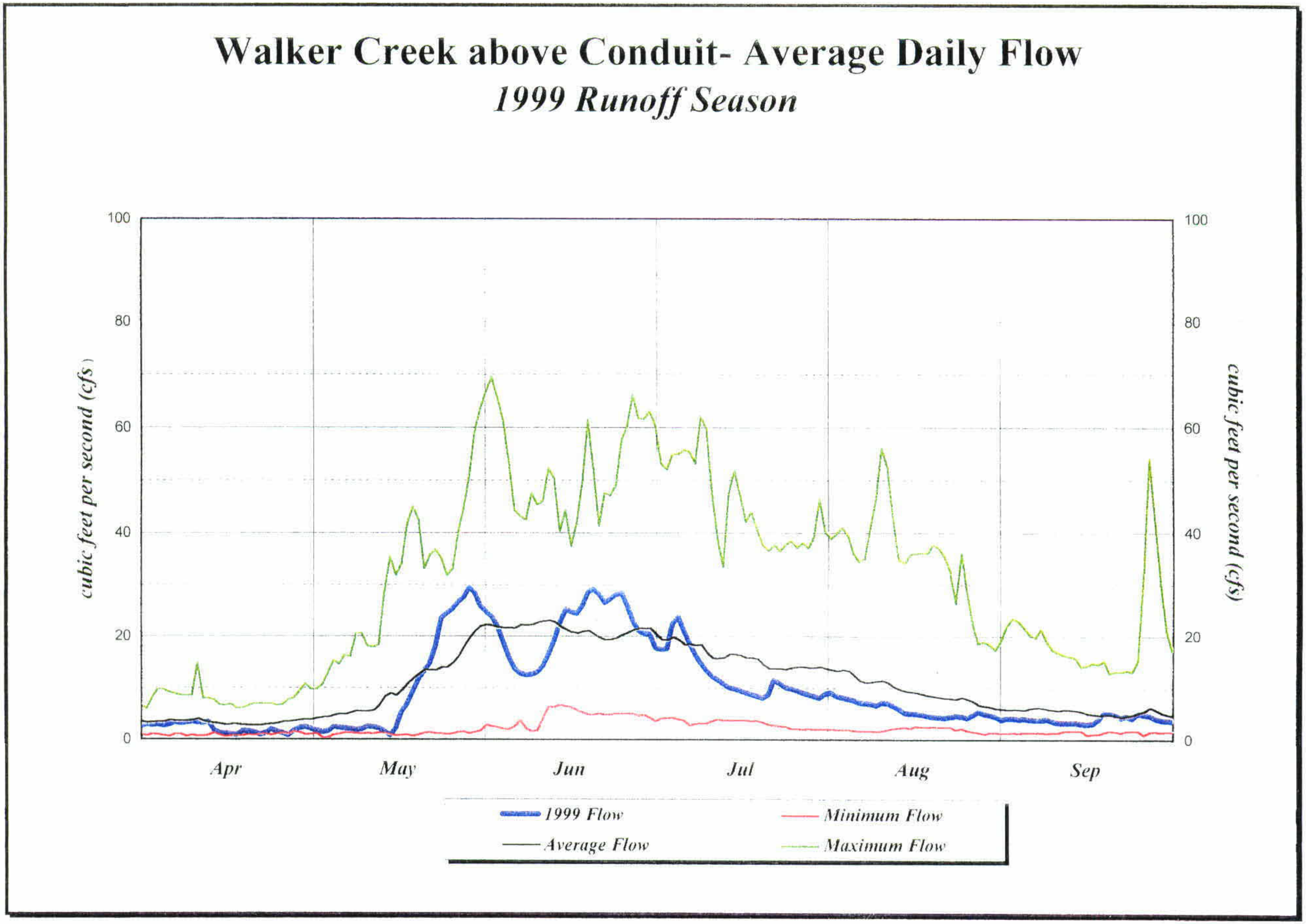

Walker Creek above Conduit- Average Daily Flow
1999 Runoff Season
100
80
60
40
20
0
cubic feet per second (cfs)
Apr
May
Jun
Jul
Aug
Sep
1999 Flow
Minimum Flow
Average Flow
Maximum Flow

Figure 3

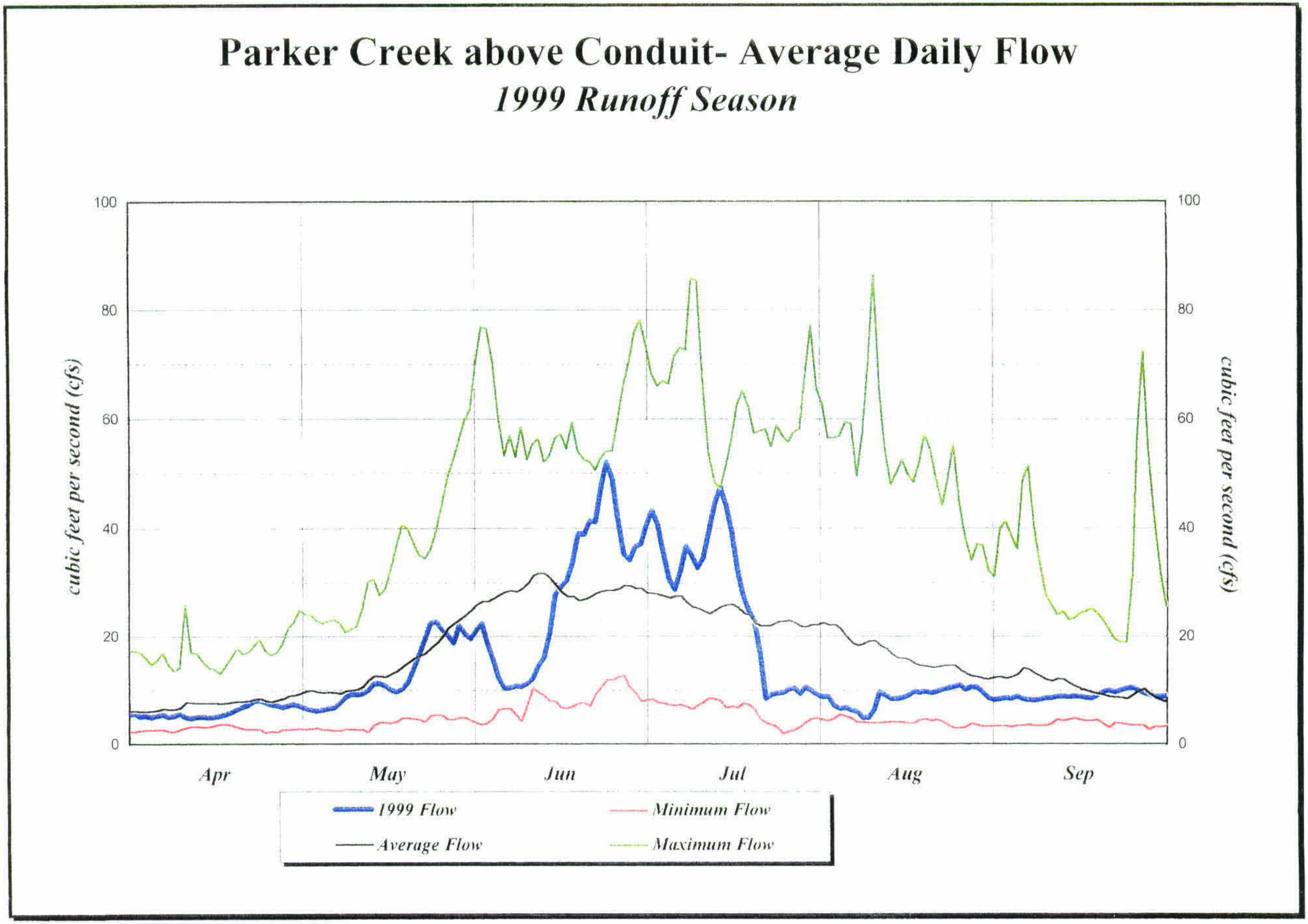

Parker Creek above Conduit- Average Daily Flow
1999 Runoff Season
cubic feet per second (cfs)
cubic feet per second (cfs)
100
80
60
40
20
0
Apr
May
Jun
Jul
Aug
Sep
1999 Flow
Minimum Flow
Average Flow
Maximum Flow

Figure 4

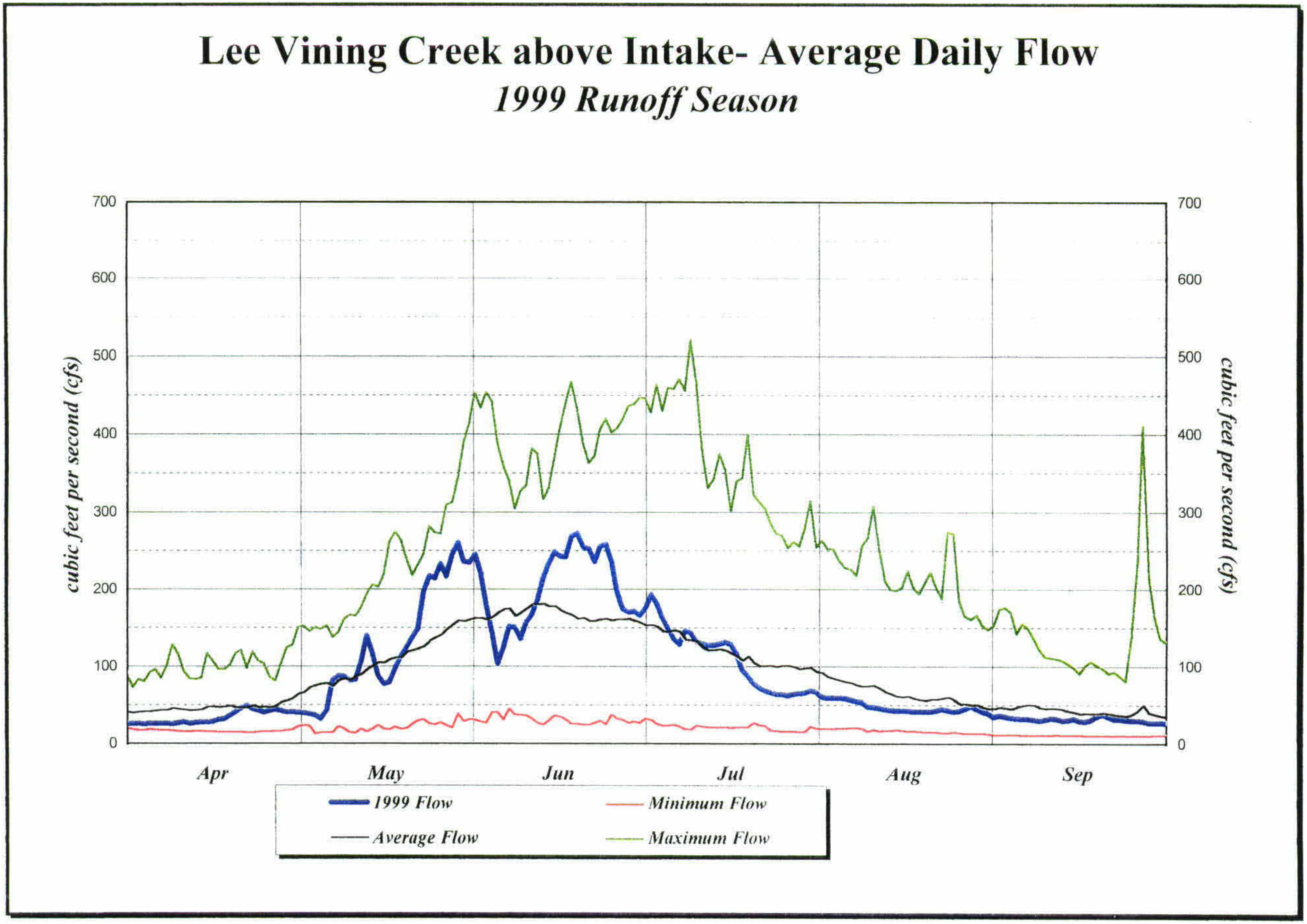
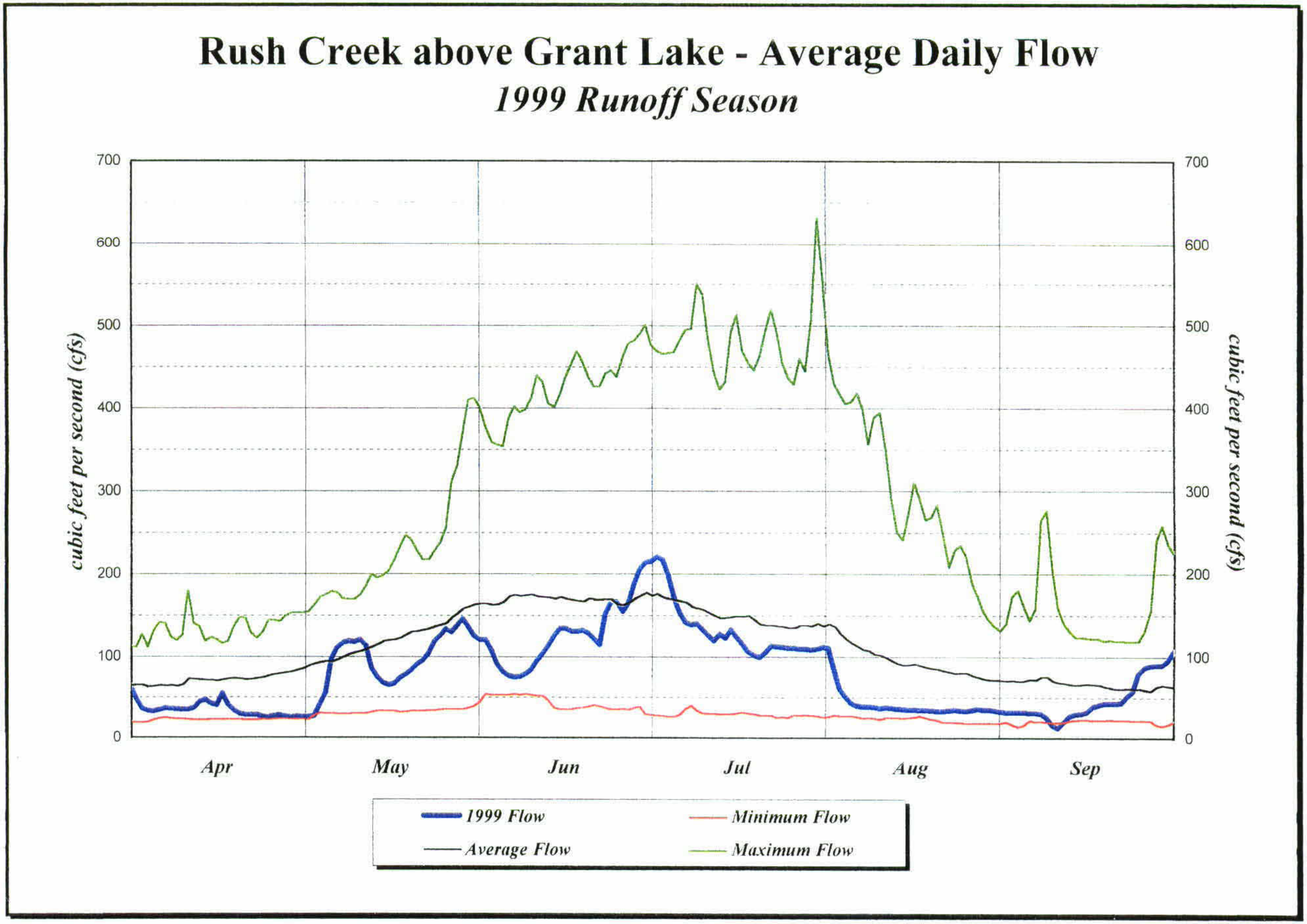
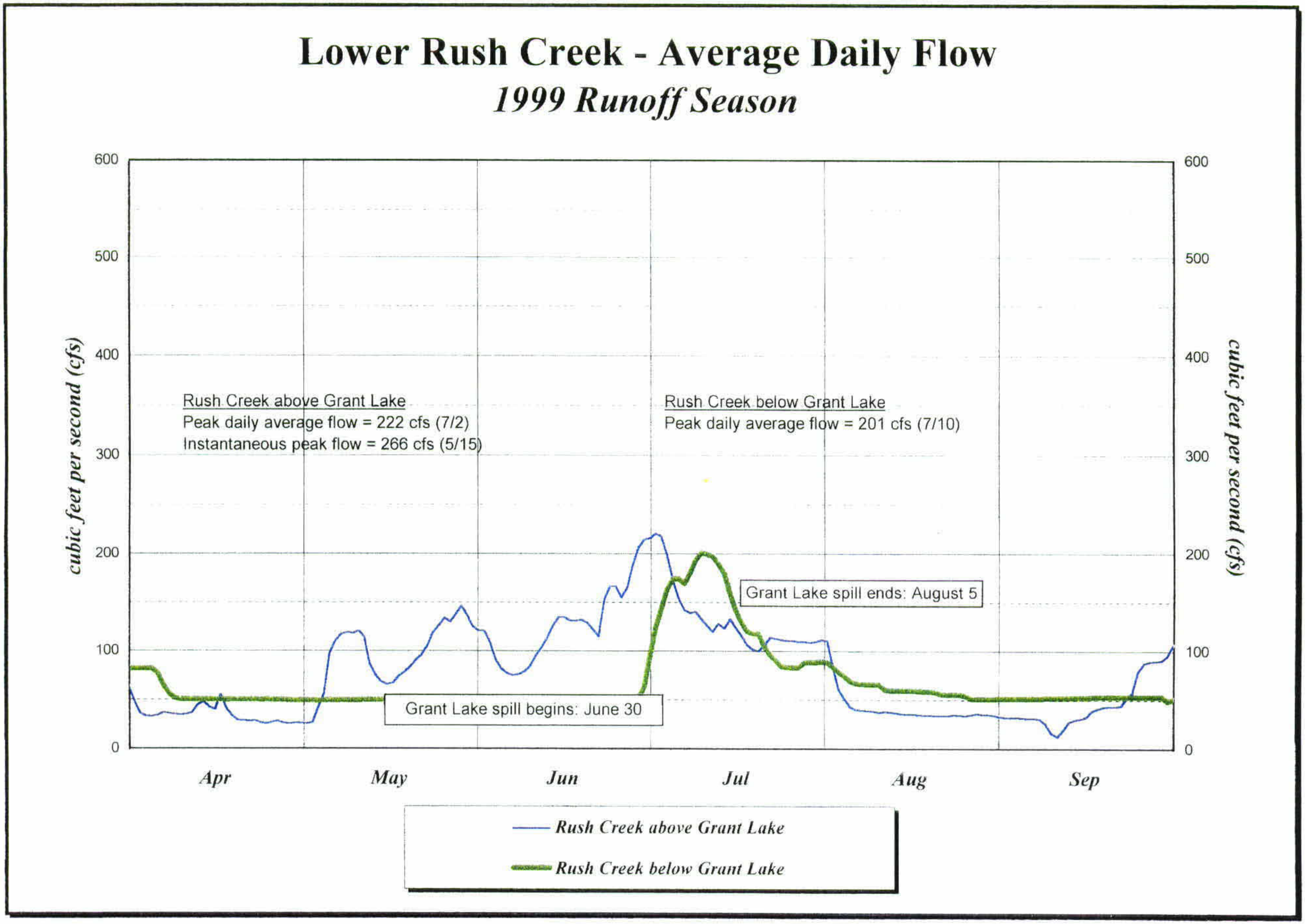

Lee Vining Creek above Intake- Average Daily Flow
1999 Runoff Season
700
600
500
400
300
200
100
0
cubic feet per second (cfs)
Apr
May
Jun
Jul
Aug
Sep
1999 Flow
Minimum Flow
Average Flow
Maximum Flow

Figure 5



Rush Creek above Grant Lake - Average Daily Flow
1999 Runoff Season
700
600
500
400
300
200
100
0
cubic feet per second (cfs)
Apr
May
Jun
Jul
Aug
Sep
1999 Flow
Minimum Flow
Average Flow
Maximum Flow

Figure 6



Lower Rush Creek - Average Daily Flow
1999 Runoff Season
cubic feet per second (cfs)
Rush Creek above Grant Lake
Peak daily average flow = 222 cfs (7/2)
Instantaneous peak flow = 266 cfs (5/15)
Rush Creek below Grant Lake
Peak daily average flow = 201 cfs (7/10)
Grant Lake spill ends: August 5
Grant Lake spill begins: June 30
600
500
400
300
200
100
0
Apr
May
Jun
Jul
Aug
Sep
Rush Creek above Grant Lake
Rush Creek below Grant Lake

Figure 7

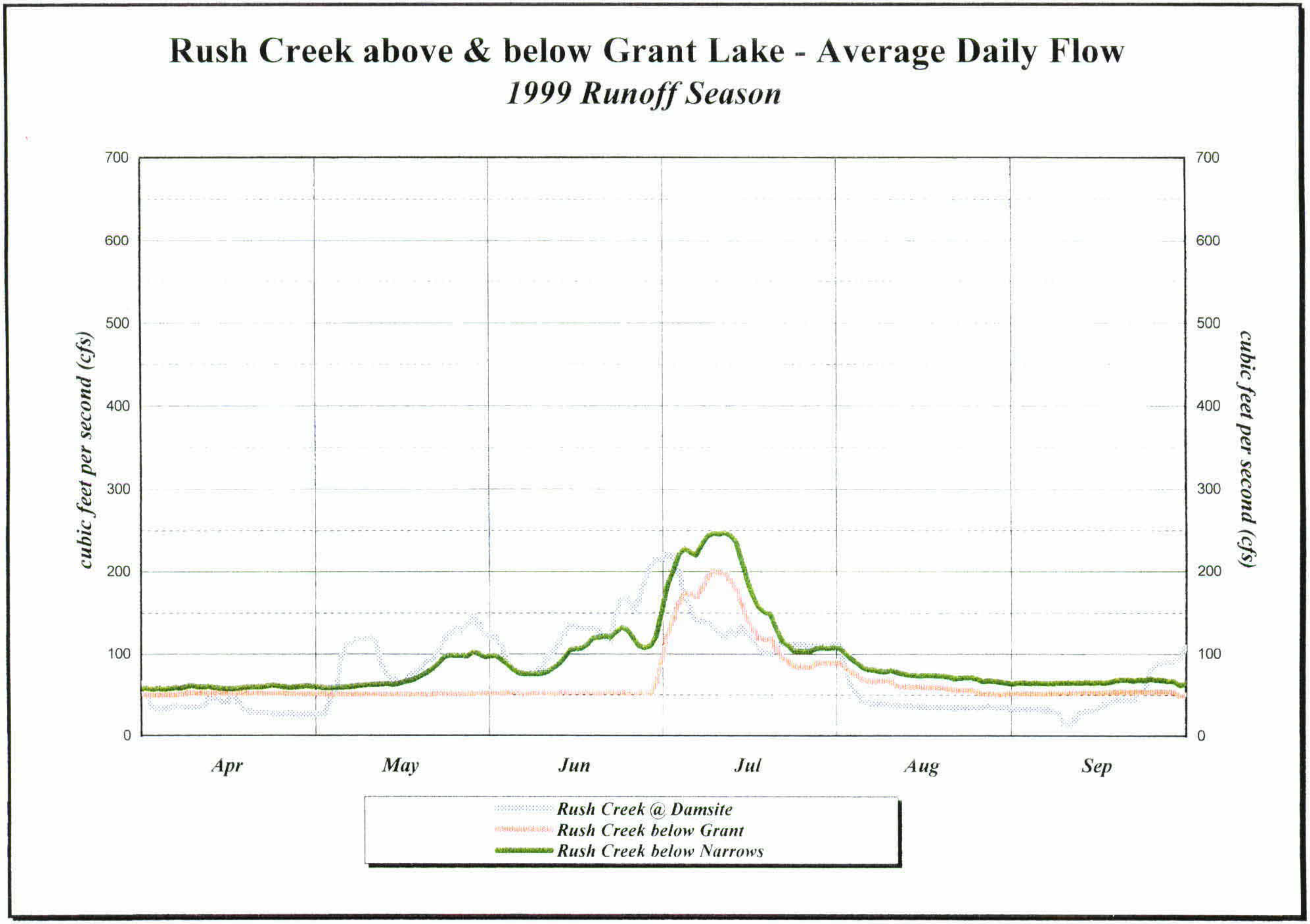
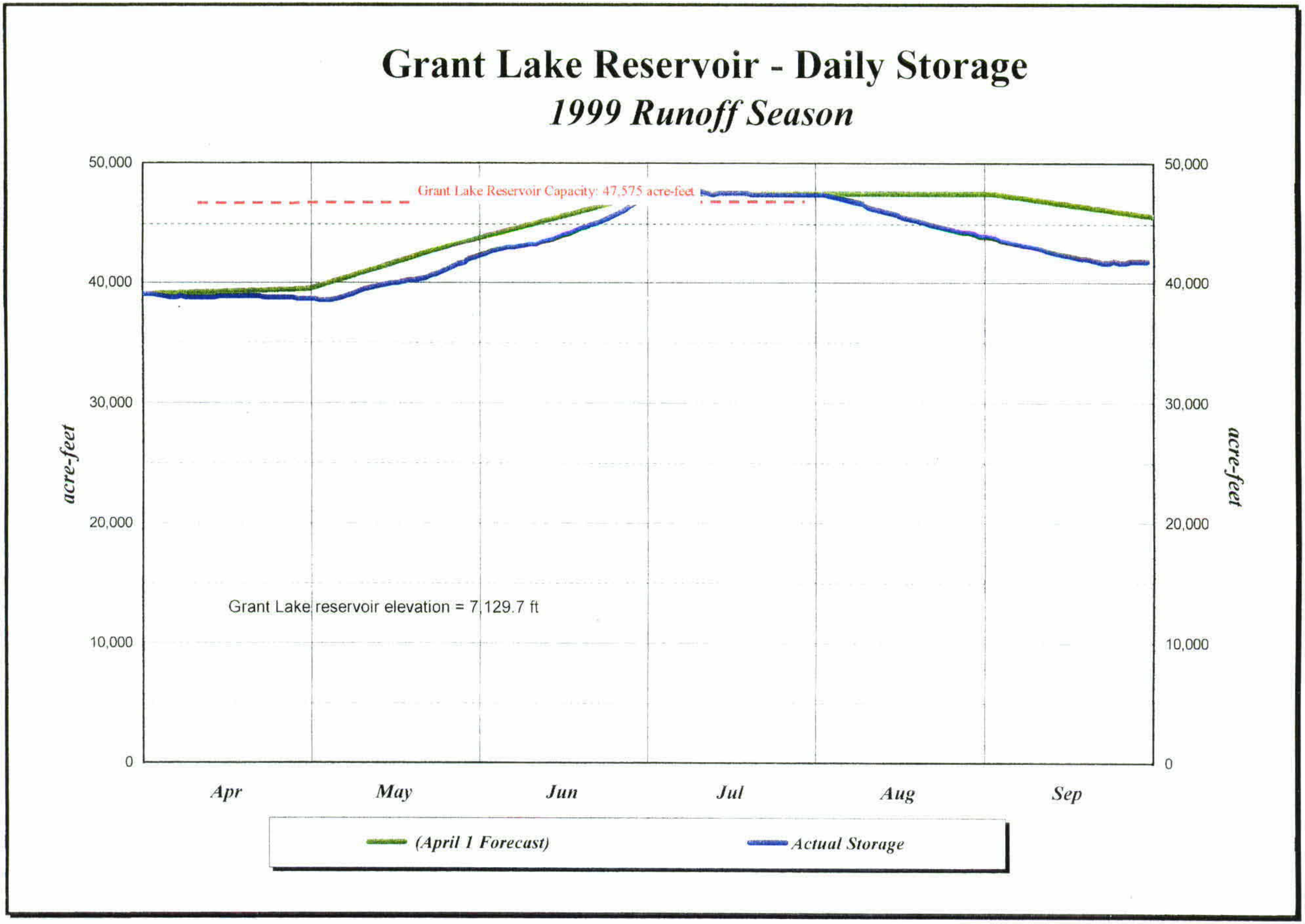

Rush Creek above & below Grant Lake - Average Daily Flow
1999 Runoff Season
cubic feet per second (cfs)
0
100
200
300
400
500
600
700
Apr
May
Jun
Jul
Aug
Sep
Rush Creek @ Damsite
Rush Creek below Grant
Rush Creek below Narrows

Figure 8



Courtesy Los Angeles Department of Water and Power
Figure 9

APPENDIX II

1999 MONO BASIN SPRING SURVEY

1999 Mono Basin Spring Survey

Prepared by: Los Angeles Department of Water and Power

September 1999

Code 8701147
Rev. 9-91

MEMORANDUM

MEMO BY Peter Kavounas TO Thomas Erb DATE September 27, 1999

FILE TITLE 1999 Mono Basin Spring Survey

The Mono Basin Spring Survey was conducted September 13 and 14, 1999 by Peter Kavounas and Steve McBain of the Water Resources Business Unit, and Chuck F. Maurer and Robert W. Taylor of the Aqueduct Business Unit. The survey was performed to comply with the terms and conditions of our water right Licenses Nos. 10191 and 10192 as set forth in the State Water Resources Control Board Order Nos. 98-05 and 98-07.

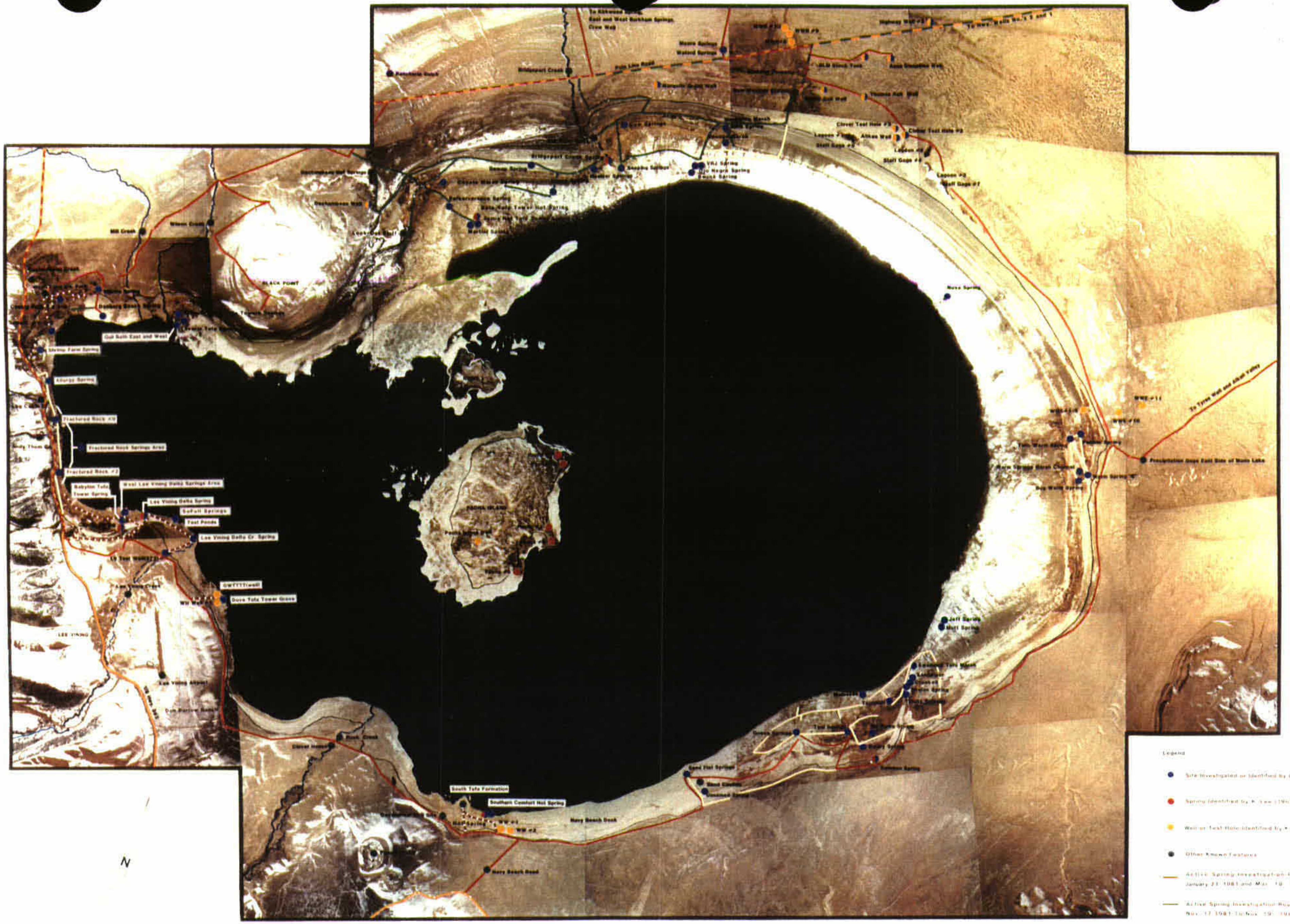
The purpose of the survey is to collect spring data at several locations around the lake for the waterfowl directors to consider in their annual Mono Basin Waterfowl Habitat Monitoring report. The spring survey report includes an aerial view of Mono Lake including approximate spring locations, drawings showing the spring survey sub areas and the County Park springs, data sheets, and photos.

The original plan was to survey thirty-four springs and one creek. However, due to the rising lake level many of the springs and/or monitoring sites have been inundated. As such, only 16 spring sites and one creek were surveyed. In addition to the higher lake level, most of the spring areas were choked with dense vegetation, making it extremely difficult to access and locate the spring source. Due to the rapid changes occurring at the lake and the difficulty in locating many of the springs, all of the accessible sites were surveyed using a hand held Global Positioning System (GPS). For each site, longitude and latitude coordinates were recorded.

The springs and their measured parameters, along with associated information, are listed in table 1. Photographs and data sheets pertaining to the 1999 spring survey have also been included.

The lake elevation during the survey was 6384.6 (USGS Datum), 10.5 feet higher than the August 1992 spring survey. Visual observations made during this survey indicate that many of the 16 spring sites visited this year will also be inundated with a slight rise in the lake elevation of one to two feet. Most of the springs are expected to be inundated when the lake reaches an average elevation of 6392 feet.

The next survey is scheduled for September 2004.



MONO LAKE

Legend

Site Investigated or Identified by LADWP

Spring Identified by K. Lee (1967-1969)

Well or Test Hole Identified by K. Lee

Other Known Features

Active Spring Investigation Route January 21 1981 and Mar. 18, 1981

Active Spring Investigation Route Nov. 17 1981 to Nov. 19, 1981

Active Spring Investigation Route Feb. 16 and 17, 1982

Active Spring Investigation Route July 13, 14 and 15, 1982

MARCH 28 1980

LAKE SURFACE ELEVATION 6373.5 Ft.

Table 1
Mono Basin 1999 Spring Survey

Spring	Flow	Measuring Device	Temperature	Electrical Conductivity	Sulfur Strands	H_2S Gas	Tufa Tower	Clarity	Photo	Coordinates	
										Latitude	Longitude
Northwest Shore											
Gull Bath (E)	Underwater		No	No	No	No	No	N/A	No	N38 01.085"	W119 07.170"
Gull Bath (W)	Underwater		No	No	No	No	No	N/A	No	N38 01.085"	W119 07.170"
County Park #1-8	Underwater		No	No	No	No	No	N/A	No		
Villette	0.33 cfs	Parshall	50 F	540 uMHOS	No	No	Yes	Clear	Yes	N38 01.142"	W119 08.361"
West Shore											
Shrimp Farm	0.42 cfs	1' Cipp Wier	52 F	150 uMHOS	No	No	No	Clear	Yes	N38 00.300"	W119 08.876"
Sunset #1	Underwater		No	No	No	No	No	N/A	No		
Sunset #2	Underwater		No	No	No	No	No	N/A	No		
Sunset #3	Underwater		No	No	No	No	No	N/A	No		
Fractured Rock	0.34 cfs	Metered	64 F	280 uMHOS	No	No	No	Clear	Yes	N37 59.038"	W119 08.311"
Andy Thom Creek	2.7 cfs	Est.	44 F	550 uMHOS	No	No	No	Clear	Yes	N37 59.420"	W119 08.522"
Southwest Shore											
Lee Vining Delta	0.30 cfs	1' Cipp Wier	50 F	310 uMHOS	No	No	Yes	Clear	Yes	N37 58.769"	W119 06.950"
Babylon	0.45 cfs	Est.	52 F	140 uMHOS	No	Yes	Yes	Clear	Yes	N37 58.747"	W119 07.241"
Charlie's	Seep		51 F	100 uMHOS	No	No	No	Clear	Yes	N37 58.708"	W119 07.205"
South Shore											
Southern Comfort	Underwater		No	No	No	No	No	N/A	No		
Hot Tufa Tower	Underwater		No	No	No	No	No	N/A	No		
Southeast Shore											
Sand Flat	0.5 cfs	Est.	No	No	No	No	Yes	Clear	Yes	N37 57.376"	W118 58.571"
Sandpiper	Flowing		58 F	860 uMHOS	No	No	No	Clear	Yes	N37 59.024"	W118 55.861"
Goose (E)	1.79 cfs	Metered	54 F	540 uMHOS		Yes	Yes	Clear	Yes	N37 58.132"	W118 57.229"
Goose (N)	Dry						Yes			N37 58.132"	W118 57.229"
Goose (W)	Dry						Yes			N37 58.132"	W118 57.229"
Teal	0.34 cfs	Metered	58 F	440 uMHOS	No	No	Yes	Poor	Yes	N37 58.282"	W118 56.503"
East Shore											
Warm "B"	0.53 cfs	90 V-Notch	86 F	2300 uMHOS	No	No	No	Clear	Yes	N38 04.765"	W118 54.249"
Warm Springs Marsh Ch.	0.05 cfs	Metered	62 F	3600 uMHOS	No	No	No	Clear	Yes	N38 01.777"	W118 54.430"
Twin Warm	Pond		92 F	2700 uMHOS	No	Yes	Yes	Clear	Yes	N38 02.136"	W118 54.562"
Pebble	Pond		66 F	1600 uMHOS	No	Yes	No	Algae	Yes	N38 02.246"	W118 54.448"
North Shore											
Perseverance	Under water or vegetation									N38 03.238"	W119 04.023"
Solo Hot Tufa Tower	Underwater										

FS-2700-25 (9/96)
OMB No. 0596-0082

U.S. DEPARTMENT OF AGRICULTURE
Forest Service

TEMPORARY SPECIAL - USE PERMIT
(FSH 2709.11, sec. 54.6)

AUTHORITY: Act of June 4, 1897

This authorization is revocable and nontransferable and is a license for the use of federally-owned land. It does not grant any interest in real property.

Holder No.	Issue Date	Expir. Date
1078-01	04-16-99 ~~01-01-1999~~	12-31-2001
Type Site(s)	**Authority**	**Auth. Type**
422	02	22
Region/Forest/District		**State/County**
05/04/51		06/051
Cong. Dist.	**Latitude**	**Longitude**
04		

Los Angeles Department of Water and Power, Glenn C. Singley hereinafter called the Holder, is hereby authorized to use, subject to the terms and conditions of this permit, National Forest System land identified within the unit area and described as the Mono Basin National Forest Scenic Area. This authorization covers approximately .5 acres and/or n/a miles.

The holder is authorized to conduct the following activities on the permitted area:
Monitoring and collecting of spring and surface waters on a biannual basis and recording all data collected.

The holder is authorized to install the following temporary improvements on the permitted area:
measuring devices installed at Villette, Sulfer Pond, Sand Flat, Warm Spring "B", Teal, Lee Vining Delta, and Sandpiper springs.

TERMS AND CONDITIONS

1. Use under this permit shall begin on 01-01-1999 and end on 12-31-2001 The permit shall not be extended.
2. The fee for this use is $ free use / CFR 251.57(b)(3) It shall be paid in advance and is not refundable.
3. The holder shall conduct the authorized activities according to the attached approved plans and specifications, Exhibit(s) exhibits 1 and 2
4. The holder shall not install any improvements not specifically identified and approved above.
5. No soil, trees, or other vegetation may be destroyed or removed from National Forest System lands without specific prior written permission from the authorized officer.
6. The holder shall comply with all Federal, State, county, and municipal lows, ordinances, and regulations which are applicable to the area or operations covered by this permit.
7. The holder shall maintain the improvements and premises to standards of repair, orderliness, neatness, sanitation, and safety acceptable to the authorized officer. The holder shall full repair and bear the expenses for all damage, other than ordinary wear and tear, to National Forest System lands, roads and trails caused by the holder's activities.
8. The holder shall be liable for any damage suffered by the United States resulting from or related to use of this permit, including damages to National Forest resources and costs of fire suppression.
9. The holder has the responsibility of inspecting the use area and adjoining areas for dangerous trees, hanging limbs, and other evidence of hazardous conditions which would pose a risk of injury to individuals. After securing permission from the authorized officer, the holder shall remove such hazards.
10. The holder shall hold harmless the United States from any liability from damage to life or property arising from the holder's occupancy or use of National Forest lands under this permit.
11. The holder agrees to permit the free and unrestricted access to and upon the premises at all times for all lawful and proper purposes not inconsistent with the intent of the permit or with the reasonable exercise and enjoyment by the holder of the privileges thereof.
12. This permit is subject to all valid existing rights and claims outstanding in third parties.
13. This permit may be revoked upon breach of any of the conditions herein or at the discretion of the authorized officer. Upon expiration or revocation of this permit, the holder shall immediately remove all improvements except those owned by the United States, and shall restore the site within 14 days, unless otherwise agreed upon in writing. If the holder

fails to remove the improvements, they shall become the property of the United States, but that will not relieve the holder of liability for the cost of their removal and restoration of the site.

14. This permit is not transferrable. The holder shall not subject occupancy of the authorized premises and improvements to third parties.
15. Any changes to this permit, its provisions or requirements my be subject to appeal per 36 CFR 251.
16. This permit is accepted subject to the conditions set forth herein, condition(s) n/a and Exhibit(s) 1+2 attached to and made a part of this permit.
17. The above clauses shall control if they conflict with additional clauses or provisions.

HOLDER	Glenn C. Singley	**U. S. DEPARTMENT OF AGRICULTURE** **Forest Service**	
By:	Glenn C. Singley	By:	for/ Rick Murray, Lands - Special Us
Address:	City of Los Angeles 300 Mandich St. Bishop, CA 93514	Name	Ron Keil
		Title:	Ass't. Forest Supervisor (Authorized Officer)
Phone #:	(760) 873-0370		
Date:		Date:	April 16, 1999

According to the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0596-0082.

This information is needed by the Forest Service to evaluate requests to use National Forest System lands and manage those lands to protect natural resources, administer the use, and ensure public health and safety. This information is required to obtain or retain a benefit. The authority for that requirement is provided by the Organic Act of 1897 and the Federal Land Policy and Management Act of 1976, which authorize the Secretary of Agriculture to promulgate rules and regulations for authorizing and managing National Forest System lands. These statutes, along with the Term Permit Act, National Forest Ski Area Permit Act, Granger-Thye Act, Mineral Leasing Act, Alaska Term Permit Act, Act of September 3, 1954, Wilderness Act, National Forest Roads and Trails Act, Act of November 16, 1973, Archeological Resources Protection Act, and Alaska National Forest Lands Conservation Act, authorize the Secretary of Agriculture to issue authorizations for the use and occupancy of National Forest System lands. The Secretary of Agriculture's regulations at 36 CFR Part 251, Subpart B, establish procedures for issuing those authorizations.

The Privacy Act of 1974 (5 U.S.C. 552a) and the Freedom of Information Act (5 U.S.C. 552) govern the confidentiality to be provided for information received by the Forest Service.

Public reporting burden for collection of information, if requested, is estimated to average 1 hour per response for annual financial information; average 1 hour per response to prepare or update operation and/or maintenance plan; average 1 hour per response for inspection reports; and an average of 1 hour for each request that may include such things as reports, logs, facility and user information, sublease information, and other similar miscellaneous information requests. This includes the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Department of Agriculture, Clearance Officer, OIRM, AG Box 7630, Washington D.C. 20250; and to the Office of Management and Budget, Paperwork Reduction Project (OMB #0596-0082), Washington, D.C. 20503.

revised 12/98

Exhibit 1

Mono Basin Spring Survey Schedule for 1999 through 2001

SPRING NAME	ACCESS METHOD
Northwest Shore	
Gull Bath Spring (E)	walk (see note #1)
Gull Bath Spring (W)	walk
County Park Spring #1 through #8	walk
Villette Spring	walk
West Shore	
Shrimp Farm Spring	walk (see note #2)
Sunset Spring #1	walk
Sunset Spring #2	walk
Sunset Spring #3	walk
Fractured Rock Spring	walk
Andy Thom Ck.	walk
Southwest Shore	
Lee Vining Delta Spring	walk
Babylon Spring	walk
Charlie's Spring	walk
South Shore	
Southern Comfort Spring	walk
Hot Tufa Tower Spring	walk
Southeast Shore	
Sand Flat Spring	walk
Sandpiper Spring	walk
Goose Spring (E)	walk
Goose Spring (N)	walk
Goose Spring (W)	walk
Teal Spring	walk
East Shore	
Warm Springs "B"	walk
Warm Springs Marsh Ch.	walk
Twin Warm Springs	walk
Pebble Spring	walk
North Shore	
Perserverence Spring	ATV
Solo Hot Tufa Tower	ATV

N.B. -- data collection one to two times each year

Note #1: walk - driving to nearest open road access and walking to spring
Note #2: ATC access to north and west shore springs is permitted when necessary to transport heavy equipment, notify Larry Ford (760) 647-3004 in advance of work.

revised 12/98

Exhibit 2

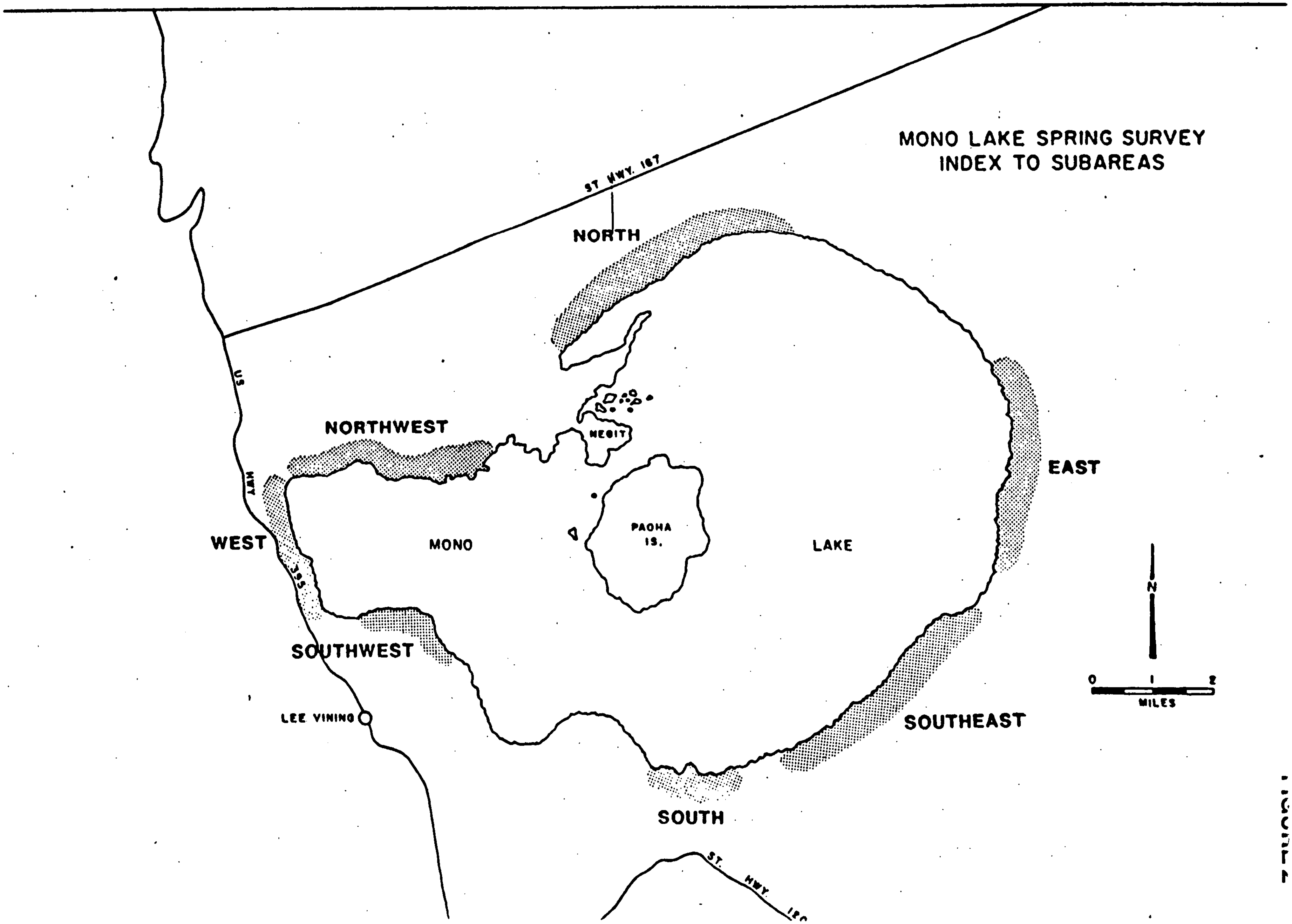
The letter from the Department of Water and Power dated November 19, 1998 and signed by Glenn C. Singley states that data will be collected one or two times each year through the period of the permit which expires on 31 December 2001 and will be made part of this permit.

The hydrologist will notify the Forest Service office (647-3004) seven (7) days in advance of the dates of data collection and will adhere to the access requirements contained in exhibit 1. Any changes must be approved by the Forest Service in advance of data collection.

The hydrologist will call the Forest Service (647-3004) and leave a message on the day of the survey.

Use of OSV's (i.e. snow cats) will not be allowed on relicted lands but may be used in the north and east sections of the basin, above relicted lands, to access rain gages in heavy snow year.

The hydrologist doing the monitoring and collection of data will be notified of the stipulations of the permit and have a copy of the permit, with attachments, in his possession while completing work within the Mono Basin National Forest Scenic Area.


MONO LAKE SPRING SURVEY
INDEX TO SUBAREAS
ST HWY. 167
NORTH
NORTHWEST
NEGIT
US
HWY
395
WEST
MONO
PAOHA
IS.
LAKE
EAST
SOUTHWEST
LEE VINING
SOUTHEAST
SOUTH
ST. HWY.
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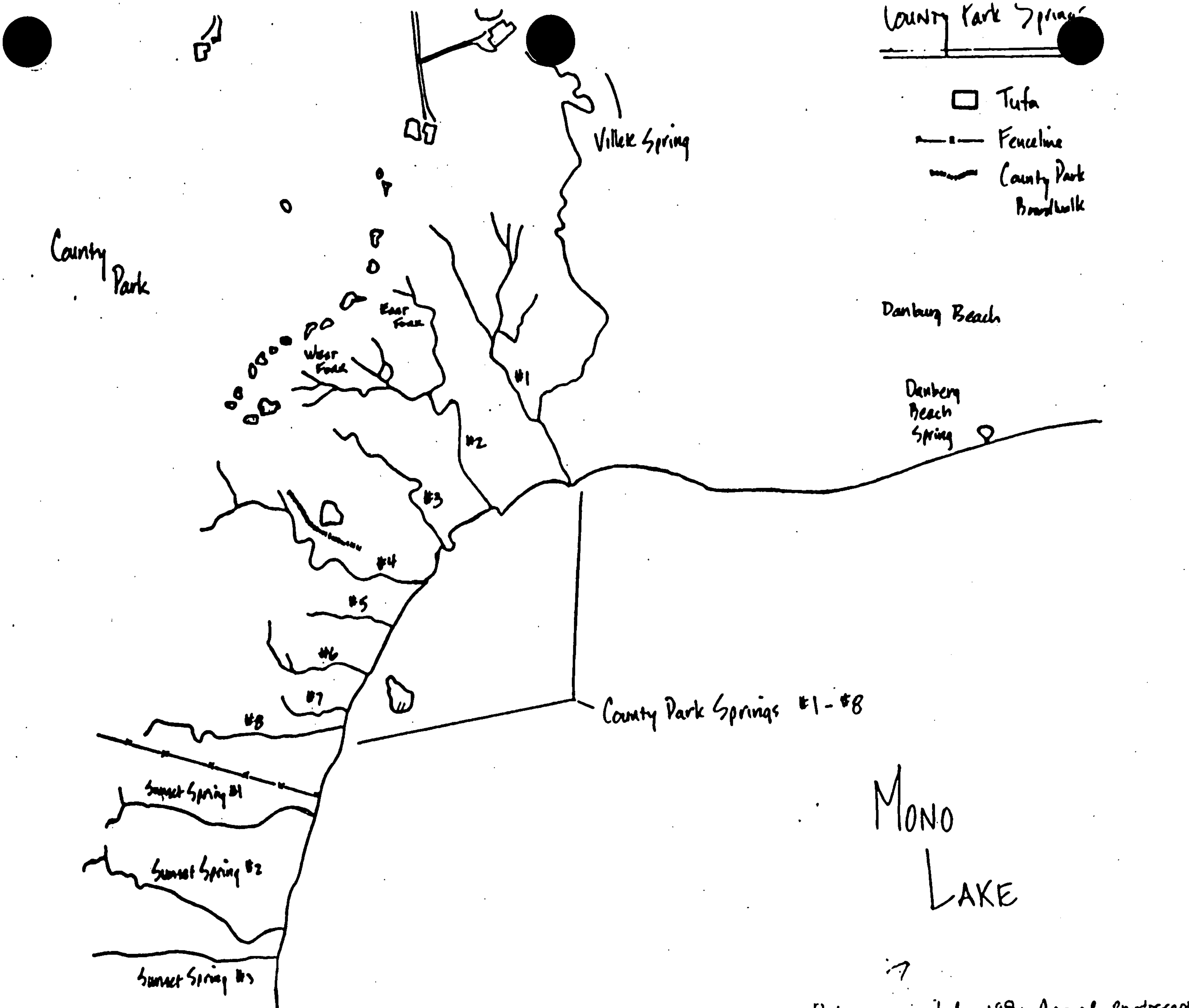
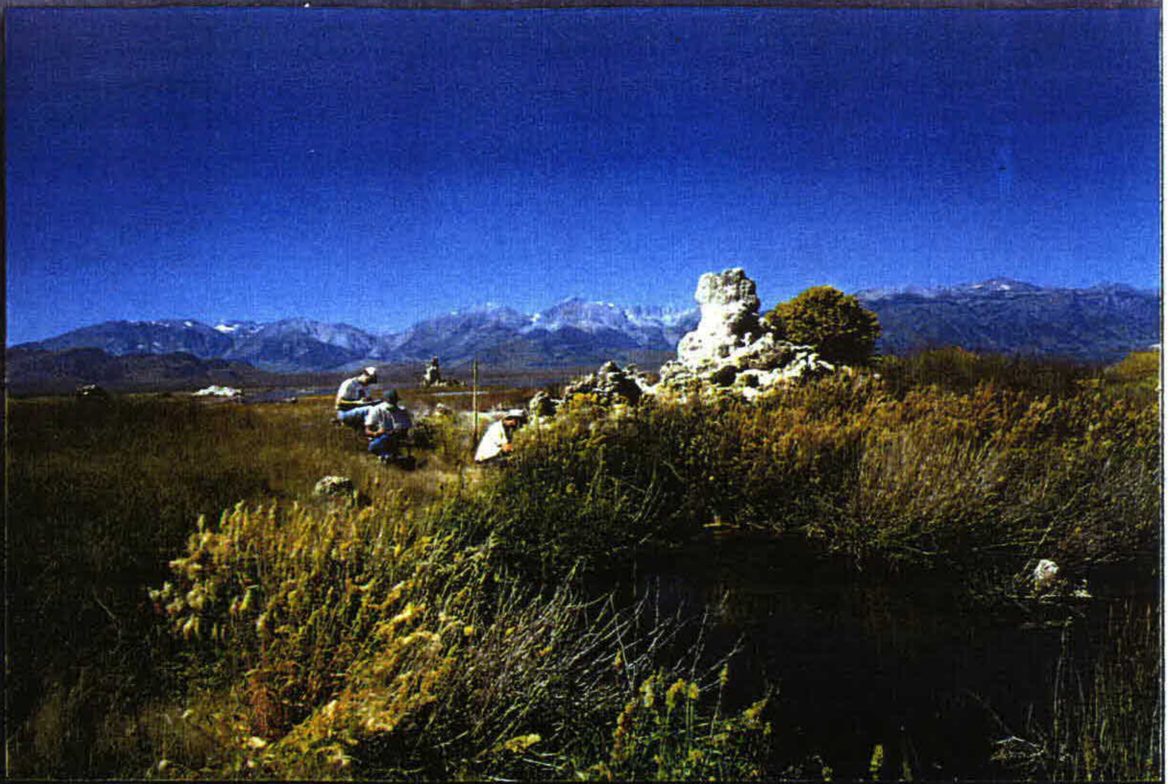


FIGURE 3

Reference: July 1981, Aerial Photographs

Sand Flat

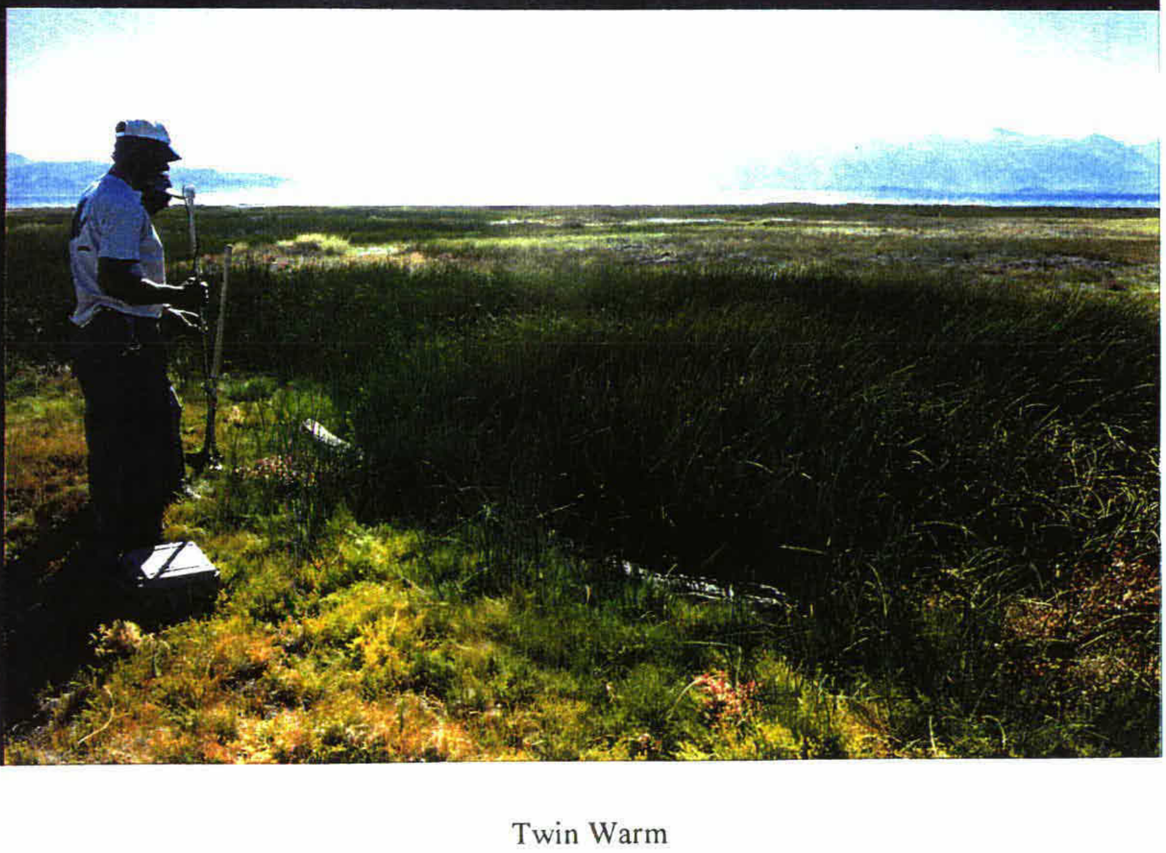


Goose (East)

Teal

Sand Piper

Pepple



Twin Warm

Babylon

Shrimp Farm

Villette

APPENDIX III

1999 Annual Report
Mixing and Plankton Dynamics in the Mono Lake, California

1999 ANNUAL REPORT

MIXING AND PLANKTON DYNAMICS IN MONO LAKE, CALIFORNIA

Robert Jellison and John M. Melack

Marine Science Institute
University of California
Santa Barbara, CA 93106

1999 ANNUAL REPORT

MIXING AND PLANKTON DYNAMICS IN MONO LAKE, CALIFORNIA

Robert Jellison and John M. Melack

Marine Science Institute

University of California

Santa Barbara, CA 93106

Submitted: 1 March 2000

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DRAFT EXECUTIVE SUMMARY

Mono Lake research activities in 1999 focused on continued limnological monitoring and analysis of the annual plankton dynamics and nutrient limitation. This report includes a review of research conducted at Mono Lake prior to 1999 (Chapter 1), a detailed description of the limnological data collected during 1999 (Chapter 2), estimates of primary production and mean annual *Artemia* biomass (Chapter 3), and a description of the abundance of rotifers (Chapter 4).

Chapter 2 describes the results of our limnological monitoring program during 1999. Meromixis continued but weakened slightly in 1999 as the net change in surface elevation over the course of the year was -0.1 ft. The midsummer difference in density between 2 and 28 m attributable to chemical stratification declined from 14.9 kg m^{-3} in 1998 to 12.2 kg m^{-3}. The lack of holomixis during the past four winters has resulted in depleted inorganic nitrogen concentrations in the mixolimnion and reduced abundance of phytoplankton. In 1999, the spring (February–April) epilimnetic chlorophyll *a* concentrations at 2 m (10–16 μg chl *a* l^{-1}) were similare to those observed in 1998 and higher than the two previous years of meromixis, 1997 (~2–3 μg chl *a* l^{-1}) and 1996 (~5–8 μg chl *a* l^{-1}). However, they are considerably lower than those observed during the spring months during the last period of monomixis, 1989–95 (~15–153 μg chl *a* l^{-1}). As in all of the three immediately preceding years of meromixis, 1996–98, the *Artemia* population dynamics in 1999 were characterized by a single late-summer peak in adults with little evidence of recruitment of second generation *Artemia* into adults. The peak midsummer adult abundance (38,000 m^{-2}) was slightly higher than 1996 (32,200 m^{-2}), 1997 (27,300 m^{-2}), and 1998 (34,000 m˙2). The mean length of adult females was slightly longer (10.0–10.7 mm) than 1998 (9.6–10.3 mm) and similar to 1996 (10.1–10.7 mm) and 1997 (9.9–10.4 mm), while the range of mean brood sizes (27–48 eggs $brood^{-1}$) was similar (22–50 eggs $brood^{-1}$; 1996–98).

In chapter 3, primary production and mean annual biomass of *Artemia* were calculated and compared to previous years. The estimated primary production in 1999 (297 g C m^{-2} yr^{-1}) was higher than any of the preceding three meromictic years; 1996 (221 g C m^{-2} yr^{-1}), 1997 (149 g C m^{-2} yr^{-1}), 1998 (228 g C m^{-2} yr^{-1}) but still well below the mean annual production (508 g C m^{-2} yr^{-1}) estimated for the 5-yr period of monomixis from 1990 to 1994. The mean annual biomass of *Artemia* (8.88 g m^{-2}) was also higher than any of the previous three years (8.2 g m^{-2}, 1996; 5.3 g m^{-2}, 1997; 8.03 g m^{-2}, 1998) but still below the long-term (1983–98) of 9.8 g m^{-2}. The highest estimated mean annual biomass (17.6 g m^{-2}) occurred in 1989 just after the breakdown of meromixis during a period of elevated phytoplankton nutrients (ammonium) and phytoplankton. Total annual cyst production in 1999 also increased from 2.8 x 10^6 m^{-2} in 1998 to 4.17 x 10^6 m^{-2}, but remaining slightly below the long-term (1983–1998) mean of 4.8 x 10^6 m^{-2}.

In 1998, several observations suggested the effects of meromixis on primary and secondary productivity were beginning to lessen. This trend was more pronounced in 1999, as primary production, annual *Artemia* biomass, fecundity, and cyst production all increased further. Further, a significant autumn algal bloom occurred after significant deepening of the mixed-layer occurred in November. Although all of the above measures of productivity increased in 1999, the spring *Artemia* population matured slowly as observed in 1998, and thus potentially impacted breeding gull populations.

Chapter 4 describes the re-appearance and seasonal abundance of two rotifer species, *Hexarthra jenkinae* and *Brachionus plicatilis*. Abundant (100,500 m^{-2}) *H. jenkinae* were first noted in late 1997 but then declined to 670 m^{-2} by March 1998. *H. jenkinae* remained at low numbers in 1998 and largely disappeared by 1999. *B. plicatilis* first appeared in September 1998 samples and increased to 15,100 m^{-2} by October 1998. Although absent or in low abundance during February through June 1999, the population increased to 2,000, 7,000, and 12,000 m^{-2} in October, November, and December, respectively. Sampling of less saline pools adjacent to the lake indicate high abundance of rotifers and it is hypothesized that these are acting to seed the planktonic population.

ACKNOWLEDGEMENTS

Laboratory work was performed at the Sierra Nevada Aquatic Research Lab and University of California, Santa Barbara. Pete Kirchner and Darla Heil assisted with field sampling and laboratory analyses while Heather Adams assisted in enumeration and identification of rotifer samples. This work was supported by a grant from the Los Angeles Department of Water and Power and National Science Foundation (NSF-DEB95-08733) grants awarded to R. Jellison and J. M. Melack

CHAPTER 1

REVIEW OF PREVIOUS RESEARCH

Our present understanding of the Mono Lake ecosystem draws from limnological research extending over 30 years. The dynamic interactions between the abiotic and biotic components of the ecosystem have been examined in various scientific studies utilizing monitoring, experimental, and theoretical techniques. During the 1980s, an extended period persistent chemical stratification (meromixis) resulted from high inputs of freshwater into Mono Lake in 1982 and 1983 and created a "natural experiment" which provided insights into ecosystem function which would have been difficult to obtain through experimental manipulations. In 1995, a second period of meromixis, which has persisted through the present, was initiated by high runoff and reduced diversions. Scientific monitoring and study during this second episode of meromixis will further our understanding of the Mono Lake ecosystem.

Mixing and plankton dynamics

Previous research at Mono Lake can be divided into five periods defined by the vertical mixing regime of the lake: monomictic (one annual period of complete vertical mixing), 1964–82; meromictic (no annual period of complete vertical mixing), 1983–87; transition from meromictic to monomictic, 1988–89; monomictic, 1990–94; and meromictic , 1995-present.

Monomictic and declining lake levels, 1964–82

The limnology of Mono Lake, including seasonal plankton dynamics, was first documented in the mid 1960s (Mason 1967). Mono Lake was characterized by declining lake levels, increasing salinity, and a monomictic thermal regime. No further limnological research was conducted until 1976 (Winkler 1977). Subsequent studies (Lenz 1984; Melack 1983, 1985) beginning in 1979 further described the seasonal dynamics of the plankton. During the period 1979–81, Lenz (1984) documented a progressive increase in the ratio of peak summer to spring abundances of adult brine shrimp. The smaller spring generations resulted in greater food availability and much higher ovoviviparous production by the first generations. Thus, leading to larger second generations. Therefore, changes in the size of the spring hatch can result in large changes in the ratio of the size of the two generations.

In 1982, an intensive limnological monitoring program funded by LADWP was established to monitor changes in the physical, chemical, and biological environments in Mono Lake. This monitoring program has continued to the present. A detailed description of the results of the monitoring program are contained in a series of reports to LADWP (Dana *et al.* 1986, 1992; Jellison *et al.* 1988, 1989, 1990, 1991, 1994, 1995, 1996, 1997, 1998, 1999) and are summarized below.

Meromixis, 1983–87

In 1983, a large influx of freshwater into Mono Lake resulted in a condition of persistent chemical stratification (meromixis). A decrease in surface salinities resulted in a chemical gradient of ca. 15 g total dissolved solids l^{-1} between the mixolimnion (the mixed layer) and monimolimnion (layer below persistent chemocline). In subsequent years evaporative concentration of the surface water led to a decrease in this gradient and in November 1988 meromixis was terminated.

Following the onset of meromixis, ammonium and phytoplankton were markedly affected. Ammonium concentrations in the mixolimnion were reduced to near zero during spring 1983 and remained below 5 μM until late summer 1988. Accompanying this decrease in mixolimnetic ammonium concentrations was a dramatic decrease in the algal bloom associated with periods when the *Artemia* are less abundant (November through April). At the same time, ammonification of organic material and release from the anoxic sediments resulted in a gradual buildup of ammonium in the monimolimnion over the six years of meromixis to 400 to 500 μM. Under the previous monomictic conditions, ammonium, which accumulated beneath the thermocline during the summer, was mixed into the upper water column during the autumn overturn.

Artemia dynamics were also affected by the onset of meromixis. The size of the first generation of adult *Artemia* in 1984 (31,000 m^{-2}) was nearly ten times as large as observed in 1981 and 1982, while peak summer abundances of adults were much lower. Following this change, the two generations of *Artemia* were relatively constant during the meromictic period from 1984 to 1987. The size of the spring generation of adult *Artemia* only varied from 23,000 to 31,000 m^{-2} while the second generation of adult *Artemia* varied from 33,000 to 54,000 m^{-2}. The relative sizes of the first and second generation are inversely correlated. This is at least partially mediated by food availability as a large first generation results in decreased algal levels for second generation nauplii and vice versa. During 1984 to 1987, recruitment into the first generation adult class was a nearly constant but small percentage (about 1 to 3%) of the cysts calculated to be available (Dana *et al.* 1990). Also, fecundity showed a significant correlation with ambient algal concentrations (r^2, 0.61).

In addition to annual reports submitted to Los Angeles and referenced herein, a number of published manuscripts document the limnological conditions and algal photosynthetic activity during the onset, persistence, and breakdown of meromixis, 1982–90 (Jellison *et al.* 1992; Jellison and Melack 1993a, 1993b; Jellison *et al.* 1993; Miller *et al.* 1993).

Response to the breakdown of meromixis, 1988–89

Although complete mixing did not occur until November 1988, the successive deepening of the mixed layer during the period 1986–88 led to significant changes in the plankton dynamics. By spring 1988, the mixed layer included the upper 22 m of the lake and included 60% of the area and 83% of the lake's volume. In addition to restoring an annual mixing regime to much of the lake, the deepening of the mixed layer increased the nutrient supply to the mixolimnion by entraining water with very high ammonium concentrations

(Jellison *et al.* 1989). Mixolimnetic ammonium concentrations were fairly high during the spring (8–10 μM), and March algal populations were much denser than in 1987 (53 vs. 15 μg chl *a* l^{-1}).

The peak abundance of spring adult *Artemia* in 1988 was twice as high as any previous year from 1979 to 1987. This increase could have been due to enhanced hatching and/or survival of nauplii. The pool of cysts available for hatching was potentially larger in 1988 since cyst production in 1987 was larger than in the four previous years (Dana *et al.* 1990) and significant lowering of the chemocline in the autumn and winter of 1987 allowed oxygenated water to reach cysts in sediments which had been anoxic since 1983. Cysts can remain dormant and viable in anoxic water for an undetermined number of years. Naupliar survival may also have been enhanced since chlorophyll *a* levels in the spring of 1988 were higher than the previous four years. This hypothesis is corroborated by the results of the 1988 development experiments (Jellison *et al.* 1989). Naupliar survival was higher in the ambient food treatment relative to the low food treatment.

Mono Lake returned to its previous condition of annual autumnal mixing from top to bottom with the complete breakdown of meromixis in November 1988. The mixing of previously isolated monimolimnetic water with surface water affected biotic components of the ecosystem. Ammonium, which had accumulated to high levels (600 μM) in the monimolimnion during meromixis, was dispersed throughout the water column raising surface concentrations above previously observed values (>50 μM). Oxygen was diluted by mixing with the anoxic water and consumed by the biological and chemical oxygen demand previously created in the monimolimnion. Dissolved oxygen concentration immediately fell to zero. *Artemia* populations experienced an immediate and total die-off following deoxygenation. Mono Lake remained anoxic for a few months following the breakdown of meromixis in November 1988. By mid-February 1989, dissolved oxygen concentrations had increased (2–3 mg l^{-1}) but were still below those observed in previous years (4–6 mg l^{-1}). The complete recovery of dissolved oxygen concentrations occurred in March when levels reached those seen in other years.

Elevated ammonium concentrations following the breakdown of meromixis led to high chlorophyll *a* levels in spring 1989. Epilimnetic concentrations in March and April were the highest observed (40–90 μg chl *a* l^{-1}). Subsequent decline to low midsummer concentrations (<0.5–2 μg chl *a* l^{-1}) due to brine shrimp grazing did not occur until late June. In previous meromictic years this decline occurred up to six weeks earlier. Two effects of meromixis on the algal populations, decreased winter-spring concentrations and a shift in the timing of summer clearing, are clearly seen over the period 1982–89.

The 1989 *Artemia* population exhibited a small first generation of adults followed by a summer population over one order of magnitude larger. A similar pattern was observed from 1980–83. In contrast, the pattern observed during meromictic years was a larger first generation followed by a summer population of the same order of magnitude. The timing of hatching of *Artemia* cysts was affected by the recovery of oxygen. The initiation of hatching occurred slightly later in the spring and coincided with the return of oxygenated conditions. First generation numbers in 1989 were initially high in March (ca. 30,000 individuals m^{-2}) and within the range seen from 1984–88, but decreased by late spring to 4,200 individuals m^{-2}. High mortality may have been due to low temperatures, since March lake temperatures (2–6°C) were lower than the suspected lethal limit (ca. 5–6°C) for *Artemia* (Jellison *et al.* 1989). Increased mortality may also have been associated with elevated concentrations of toxic compounds (H_2S, NH_4^+, As) resulting from the breakdown of meromixis.

High spring chlorophyll levels in combination with the low first generation abundance resulted in a high level of fecundity which led to a large second generation of shrimp. Spring chlorophyll *a* concentrations were high (30–44 μg chl *a* l^{-1}) due to the elevated ammonium levels (27–44 μM) and are typical of pre-meromictic levels. This abundant food source (as indicated by chlorophyll *a*) led to large *Artemia* brood sizes and high ovigerity during the period of ovoviviparous reproduction and resulted in the large observed summer abundance of

Artemia (peak summer abundance, 93,000 individuals m^{-2}). Negative feedback effects were apparent when the large summer population of *Artemia* grazed the phytoplankton to very low levels (<0.5–2 μ g chl *a* l^{-1}). The low algal densities led to decreased reproductive output in the shrimp population. Summer brood size, female length, and ovigerity were all the lowest observed in the period 1983–89.

Small peak abundance of first generation adults were observed in 1980–83, and 1989. However, the large (2–3 times the mean) second generations were only observed in 1981, 1982, and 1989. During these years, reduced spring inflows resulted in less than usual density stratification and higher than usual vertical fluxes of nutrients thus providing for algal growth and food for the developing *Artemia* population.

Monomictic conditions with relatively stable lake levels, 1990–94

Mono Lake was monomictic from 1990 to 1994 (Jellison *et al.* 1991, Dana *et al.* 1992, Jellison *et al.* 1994, Jellison *et al.* 1995) and lake levels (6374.6 to 6375.8 ft asl) were similar to those in the late 1970s. Although the termination of meromixis in November 1988 led to monomictic conditions in 1989, the large pulse of monimolimnetic ammonium into the mixed layer led to elevated ammonium concentrations in the euphotic zone throughout 1989, and the plankton dynamics were markedly different than 1990–94. In 1990–94, ammonium concentrations in the euphotic zone decreased to levels observed prior to meromixis in 1982. Ammonium was low, 0–2 μM, from March through April and then increased to 8–15 μM in July. Ammonium concentrations declined slightly in late summer and then increased following autumn turnover. This pattern of ammonium concentrations in the euphotic zone and the hypolimnetic ammonium concentrations were similar to those observed in 1982. The similarities among the years 1990–94 indicate the residual effects of the large hypolimnetic ammonium pulse accompanying the breakdown of meromixis in 1988 were gone. This supports the conclusion by Jellison *et al.* (1990) that the seasonal pattern of ammonium concentration is returning to that observed before the onset of meromixis.

Spring and summer peak abundance of adult *Artemia* were fairly constant throughout 1990 to 1994. Adult summer population peaks in 1990, 1991, and 1992 were all 35,000 m^{-2} despite the large disparity of second generation naupliar peaks (280,000, 68,000, and 43,000 m^{-2} in 1990, 1991, and 1992, respectively) and a difference in first generation peak adult abundance (18,000, 26,000, and 21,000 m^{-2} in 1990, 1991, and 1992, respectively). Thus, food availability or other environmental factors are more important to determining summer abundance than recruitment of second generation nauplii. In 1993, when freshwater inflows were higher than usual and thus density stratification enhanced, the summer generation was slightly smaller (21,000 m^{-2}). Summer abundance of adults increased slightly (29,000 m^{-2}) in 1994 when runoff of lower and lake levels declining.

Meromictic conditions with rising lake levels, 1995–present

The winter (1994/95) period of holomixis injected nutrients which had previously accumulated in the hypolimnion into the upper water column prior to the onset of thermal and chemical stratification in 1995 (Jellison *et al.* 1996). During 1995, above normal runoff in the Mono Basin coupled with the absence of significant water diversions out of the basin led to rapidly rising lake levels. The large freshwater inflows resulted in a 3.4 ft rise in surface elevation and the onset of meromixis, a condition of persistent chemical stratification with less saline water overlying denser more saline water. Due to holomixis during late 1994 and early 1995, the plankton dynamics during the first half of 1995 were similar to those observed during the past four years (1991–94). Therefore 1995 represents a transition from monomictic to meromictic conditions. In general, 1995 March mixed-layer ammonium and chlorophyll *a* concentrations were similar to 1993. The peak abundance of summer adult *Artemia* (24,000 m^{-2}) was intermediate to that observed in 1993 (21,000 m^{-2}) and 1994 (29,000 m^{-2}). The effects of increased water column stability due to chemical stratification only became evident later in the year. As the year proceeds a shallower mixed layer, lower mixed-layer ammonium and chlorophyll *a* concentrations, slightly smaller *Artemia,* and smaller brood sizes compared to 1994 are all observed. The full effects of the onset of meromixis in 1995 are not evident until 1996.

Chemical stratification persisted and strengthened throughout 1996 (Jellison *et al.* 1997). Mixolimnetic (upper water column) salinity ranged from 78 to 81 g kg^{-1} while monimolimnetic (lower water column) were 89–90 g kg^{-1}. The maximum vertical density stratification of 14.6 kg m^{-3} observed in 1996 was larger than any year since 1986. During 1996, the annual maximum in Secchi depth, a measure of transparency, was among the highest observed during the past 18 years and the annual minimum was higher than during all previous years except 1984 and 1985 during a previous period of meromixis. While ammonium concentrations were <5 μM in the mixolimnion throughout the year, monimolimnetic concentrations continued to increase. The spring epilimnetic chlorophyll *a* concentrations (~5–23 μg chl *a* l^{-1}) were similar to those observed in previous meromictic years, but were much lower than the concentrations observed in March 1995 before the onset of the current episode of meromixis. During previous monomictic years, 1989–94, the spring maximum epilimnetic chlorophyll *a* concentrations ranged between 87–165 μg chl *a* l^{-1}.

Artemia population dynamics in 1996 were characterized by a single mid-July peak in adults with little evidence of recruitment of second generation *Artemia* into the adult population during late summer. The peak abundance of first generation adults was observed on 17 July (34,600 m^{-2}), approximately a month later than in previous years. The percent ovigery during June 1996 (42%) was lower than that observed in 1995 (62%), and much lower than that observed 1989–94 (83–98%). During the previous meromictic years (1984–88) the female population was also slow to attain high levels of ovigery due to lower algal levels. The maximum of the mean female length on sampling dates through the summer, 10.7 mm, was shorter than those observed during 1993, 1994, and 1995 (11.7, 12.1, and 11.3 mm, respectively). In 1996, brood size ranged from 29 to 39 eggs $brood^{-1}$ during July through November. The summer and autumn brood sizes were smaller than those observed during

1993–95 (40 to 88 eggs brood^{-1}), with the exception of September 1995 (34 eggs brood^{-1}) when the brood size was of a similar size to September 1996 (33 eggs brood^{-1}).

Chemical stratification continued to increase in 1997 as the surface elevation rose an additional 1.6 ft during the year. The midsummer difference in density between 2 and 28 m attributable to chemical stratification increased from 10.4 kg m^{-3} in 1996 to 12.3 kg m^{-3} in 1997. The lack of holomixis during the previous two winters resulted in depleted nutrient levels in the mixolimnion and reduced abundance of phytoplankton. In 1997, the spring (February–April) epilimnetic chlorophyll *a* concentrations at 2 m (~2–3 µg chl *a* l^{-1}) were lower than those observed during 1996 (~5–8 µg chl *a* l^{-1}), and other meromictic years 1984–89 (1.6–57 µg chl *a* l-1), and much lower than those observed during the spring months in the last period of monomixis, 1989–95 (~15–153 µg chl *a* l^{-1}). Concommittant increases in transparency and the depth of the euphotic zone were also observed. As in 1996, the *Artemia* population dynamics in 1997 were characterized by a single mid-July peak in adults with little evidence of recruitment of second generation *Artemia* into adults. The peak midsummer adult abundance (27,300 m^{-2}) was slightly lower than 1996 but similar to 1995 (24,400 m^{-2}). The mean length of adult females was 0.2–0.3 mm shorter than the lengths observed in 1996 and the brood sizes lower, 26–33 eggs brood^{-1} in 1997 compared to 29 to 53 eggs brood^{-1} in 1996.

In 1998 the surface elevation of the lake rose 2.2 ft. The continuing dilution of saline mixolimnetic water and absence of winter holomixis led to increased chemical stratification. The peak summer difference in density between 2 and 28 m attributable to chemical stratification increased from 12.3 kg m^{-3} in 1997 to 14.9 kg m^{-3} in August 1998. The 1998 peak density difference due to chemical stratification was higher than that seen in any previous year, including 1983–84. The lack of holomixis during the previous three winters resulted in depleted nutrient levels in the mixolimnion and reduced abundance of phytoplankton. Chlorophyll *a* concentrations at 2 m generally decreased from 14.3 µg chl *a* l^{-1} in February to 0.3 µg chl *a* l^{-1} in June, when the seasonal chlorophyll *a* concentration minimum was reached.

After that it increased to 1–2 μg chl *a* l^{-1} during July–October and to ~8 μg chl *a* l^{-1} in early December. In general, the seasonal pattern of mixolimnetic chlorophyll *a* concentration was similar to that observed during the two previous meromictic years, 1996 and 1997, in which the spring and autumn algal blooms are much reduced compared to monomictic years.

As in 1996 and 1997, the *Artemia* population dynamics in 1998 were characterized by a single mid-July peak in adults with little evidence of recruitment of second generation *Artemia* into adults. The peak abundance of adults observed on 10 August (34,000 m^{-2}) was slightly higher than that observed in 1997 (27,300 m^{-2}) and, while similar to the timing in 1997, approximately two weeks to a month later than in most previous years. The mean female length ranged from 9.6 to 10.3 mm in 1998 and was slightly shorter than observed in 1996 (10.1–10.7 mm) and 1997 (9.9–10.4 mm). Mean brood sizes in 1998 were 22–50 eggs $brood^{-1}$. The maximum brood size (50 eggs $brood^{-1}$) was within the range of maximums observed in 1995–97 (62, 53, and 33 eggs $brood^{-1}$, respectively), but significantly smaller than has been observed in any other previous year 1987–94 (81–156 eggs $brood^{-1}$).

Primary Productivity and Average Annual *Artemia* Biomass

The availability of dissolved inorganic nitrogen or phosphorus have been shown to limit primary production in a wide array of aquatic ecosystems. Soluble reactive phosphorus concentrations are very high (>400 μM) in Mono Lake and thus will not limit growth. However, inorganic nitrogen varies seasonally, and is often low and potentially limiting to algal growth. A positive response by Mono Lake phytoplankton in ammonium enrichments performed during different periods from 1982 to 1986 indicated inorganic nitrogen will potentially limits the standing biomass of algae (Jellison 1992). In Mono Lake, the two major sources of inorganic nitrogen are brine shrimp excretion and vertical mixing of ammonium-rich monimolimnetic water.

Algal photosynthetic activity was measured from 1982 to 1992 (Jellison and Melack, 1988, 1993a; Jellison *et al.* 1994) and clearly shows the importance of variation in vertical mixing of nutrients to annual primary production. Algal biomass during the spring and autumn decreased following the onset of meromixis and annual photosynthetic production was reduced (269–462 g C m^{-2} yr^{-1}; 1984 to 1986) compared to non-meromictic conditions (499–641 g C m^{-2} yr^{-1}; 1989 and 1990) (Jellison and Melack 1993). Also, a gradual increase in photosynthetic production occurred even before meromixis was terminated because of increased vertical flux of ammonium due to deeper mixing and the buildup of ammonium in the monimolimnion. Annual production was greatest in 1988 (1,064 g C m^{-2} yr^{-1}) when the weakening of chemical stratification and eventual breakdown of meromixis in November resulted in large fluxes of ammonium into the euphotic zone.

Estimates of annual primary production integrate annual and seasonal changes in photosynthetic rates, algal biomass, temperature, and insolation. Although measurements of photosynthetic rates were discontinued in 1992, most of the variation in photosynthetic rates can be explained by regressions on environmental covariates (i.e. temperature, nutrient, and light regimes) (Jellison and Melack 1993a, Jellison *et al.* 1994). Therefore, estimates of annual primary production using previously derived regressions and current measurements of algal biomass, temperature, and insolation are included as part of the limnological monitoring program (see chapter 3). These estimates of annual primary production indicate a period of declining productivity (1994–1997) associated with the onset of meromixis and increasing chemical stratification, followed by an increasing production during 1998 and 1999 despite continuing meromixis.

The mean annual biomass of *Artemia* was estimated from instar-specific abundance and length-weight relationships for the period 1983–98. The mean annual biomass has varied from 5.34 to 17.6 g m^{-2} with a 16-yr mean of 9.8 g m^{-2}. The highest estimated mean annual biomass (17.6 g m^{-2}) occurred in 1989 just after the breakdown of meromixis during a period of elevated phytoplankton nutrients (ammonium) and phytoplankton. The lowest annual estimate was in 1997 following two years of meromixis and increasing density stratification. Mean annual biomass was somewhat below the long-term mean during the first 3 years of the

1980s episode of meromixis and then above the mean the next 3 years as meromixis weakened and ended. The lowest annual biomass of *Artemia* (5.3 g m^{-2}) was observed in 1997, the second year of the current episode of meromixis. However, annual biomass increase in 1998 and 1999 to near the long-term mean.

Dynamic reservoir simulation model (DYRESM)

The development and testing of a dynamic reservoir simulation model, DYRESM (Imberger and Patterson 1981), for use at Mono Lake began in 1990. Following modifications appropriate to saline lakes, DYRESM successfully reproduced the observed thermal and conductivity structure for most of 1990 (Jellison *et al.* 1991). In 1991, installation of new meteorological sensors at Mono Lake, which measure required DYRESM inputs, improved the analysis of the seasonal vertical mixing dynamics and further verified DYRESM.

DYRESM was used to simulate the likelihood of meromixis among five lake elevation management alternatives (point of reference, 6372 ft, 6377 ft, 6383 ft, 6390 ft, 6410 ft). A monthly water balance model of the Mono Lake basin (Los Angeles Aqueduct Model) generated fifty year stream discharge and surface elevation records for each elevation management alternative. Simulation inputs included the 50 year monthly elevations for each alternative and the 1990 meteorology. The 6372 ft alternative was predicted to be susceptible to meromixis, the 6377 and 6383 ft alternatives were predicted to be a prone to meromixis for exceptionally high runoff years, and the 6390 ft alternative was predicted not to be susceptible to meromixis.

In 1994, a bubble plume algorithm was incorporated into DYRESM to determine methane ebullition could account for the observed higher than predicted rates of hypolimnetic heating (Romero *et al.* 1996). Application of the one dimensional vertical mixing model, DYRESM, to hypersaline Mono Lake reproduces mixed layer dynamics well but hypolimnetic heating is underestimated. One possible source of increased hypolimnetic heating is vertical mixing caused by a bubble plume of methane rising from the sediments where a large reservoir exists. Estimates of vertical mixing from methane seepage in Mono Lake were made with the inclusion of a bubble plume algorithm. A methane ebullition rate three hundred times greater than the maximum Mono Lake estimate was required to simulate the observed hypolimnetic heating. Other potential sources or mechanisms for hypolimnetic heating are currently being considered.

DYRESM was also used to assess the effect of predicted prolonged regional droughts due to global warming on the occurrence of meromixis in Mono Lake (Romero and Melack 1996). Lake levels, salinities, and vertical mixing of closed-basin lakes can undergo large changes due to variations in regional climate. To examine the influences of changes in lake level and salinity on the seasonal mixing regime, we applied a one-dimensional vertical mixing model to Mono Lake and incorporated hydrological data for 50 years (1940 to 1990). The frequency and duration of meromixis for three runoff conditions (0%, 12.5% and 25% reductions of the past 50 years of precipitation and streamflow) were simulated. The frequency of meromixis was forecast to increase with higher inter-annual streamflow and precipitation variability, particularly if lake levels remain near present elevations. The effect of earlier snowpack melt on vertical mixing was modeled to be a shorter period of winter holomixis.

Subsequent limnological monitoring and data analysis have highlighted the importance year-to-year differences in the stratification regime to explaining among year differences in the plankton dynamics. For this reason, continued efforts at modifying, refining, testing, and applying DYRESM have continued to the present.

Modeling plankton dynamics

Dana and Lenz (1986) studied the effects of salinity on the *Artemia* population with a long-term laboratory experiment. They found that with increasing salinity, adult size, growth rates, and brood sizes decreased, and female mortality during reproduction increased. In addition, hatching of diapause eggs was delayed and total percent hatch decreased as salinity increased. Although these results are qualitatively consistent with changes observed in the *Artemia* population during a period of salinity increase in Mono Lake, they do not predict the magnitude of the changes observed in the field monitoring.

In 1991, relationships between *Artemia monica* life history characteristics and salinity were re-analyzed using data from four published studies and three experiments (Dana *et al.* 1993). Salinity explained 40 to 93% of the variation in ten life-history characteristics. Reduction in hatching success, survival, length, weight, ovigery, and brood size were observed as salinity increased from 76 to 168 g l^{-1}. Inter-brood duration, and time to hatching and reproduction were protracted as salinity was elevated. Salinity effects on life history characteristics appeared to be gradual and continuous rather than exhibiting thresholds. The one exception was naupliar survival, which was constant between 76 and 133 g l^{-1} followed by a decrease above 133 g l^{-1}.

In 1987, an initial attempt to derive life-history parameters was made using a model of the shrimp dynamics (Jellison 1987). The assumptions contained in traditional methods of cohort analysis were not met by the data and thus could not be usefully applied. As an alternative, a state-space model of the shrimp dynamics was constructed. Analysis of Mono Lake data using a state-space model was only partially successful. Although individual years could be fairly well simulated, data from different years yielded different parameter estimates. Because the analysis of field data was made difficult by the need to estimate many unknown model parameters, development rates were estimated independently from laboratory experiments which mimicked conditions found in the lake during both monomictic and meromictic periods. A model was successfully employed to estimate instar specific development and mortality rates in these experiments (Jellison *et al.* 1989).

A cohort model of the *Artemia* population dynamics was developed to analyze the field data collected from 1983–88 (Jellison *et al.* 1990). Results from the *Artemia* development experiments conducted in 1988 were incorporated into the model. Initially, the field data was analyzed with a cohort model which explicitly included ovoviviparous reproduction. Poor results led to revisions which utilized empirical data to describe ovoviviparous reproduction and used the model to estimate six life-history parameters from the field data: a base mortality rate for nauplii, juveniles, and adults; an effect of low food on survival; an effect of low temperature on survival; and the % hatch of cysts lying in the oxygenated sediments. Although 1984–89 were fairly well simulated with parameters estimated from the field data, 1983 was poorly described by the model.

The cohort model of the *Artemia* dynamics was coupled with a description of the major nitrogen fluxes and used to assess the effects of changing lake levels on the *Artemia* population. While the model described the general characteristics of the plankton dynamics and the seasonal partitioning of nitrogen among various pools, instar-specific abundances were not well simulated and a better understanding of *Artemia* mortality rates is required. It was also concluded a multi-layered model formulation is needed to accurately model nitrogen fluxes as opposed to the simple two-layer formulation used in the analysis. In general, the model was most sensitive to factors affecting nitrogen availability and thus the importance of nutrient limitation was highlighted.

The analysis of the relationships between *Artemia* life history parameters and salinity were combined with the model to predict the effects of different lake levels. A 40 to 60% change in mean annual *Artemia* biomass (per unit volume) was predicted for lake level changes of 15 ft. The expected changes are 20 to 30% greater on a total lakewide basis when area and volume changes are included. While cyst production was strongly affected, it appears to have little relevance to the dynamics of subsequent years as illustrated by the low sensitivity to 20-fold changes in hatching success. These predicted effects are much less than would be predicted by multiplying together the effects of salinity on individual life history parameters. Changes in life history characteristics are not translated directly through to the population level due to interactions among other limiting factors.

In 1993, previously conducted laboratory experiments were re-analyzed to determine the effects of different natural regimes of temperature and food on survival, growth, and development of *Artemia* (Dana *et al.* 1995). Each year, two generations of *Artemia monica* develop under different environmental conditions in Mono Lake. The first generation develops during spring when food levels are high and temperatures are low and warming slowly. The second generation develops during summer at low food levels and higher initial temperatures which continue to warm. Development, growth, and survival of first and second generation *Artemia* were determined under laboratory conditions which tracked the natural temperature and food regimes in the lake. Two food treatments were administered to first generation shrimp representing the high levels usually found during the spring and reduced food levels observed during a recent six-year period of meromixis.

Development to adulthood and the onset of reproduction occurred five days sooner in high food treatment than in the low food treatment of the spring experiment. Also, development and onset of reproduction were two to three times faster in the warmer low food summer treatment. Under spring, high food conditions, shrimp experienced a higher survival to adulthood (46%) and lower daily mortality rate (0.012 d^{-1}) than shrimp in the spring, low food treatment, which had 30% survival and a 0.015 d^{-1} mortality rate. Survival to adulthood of summer, low food animals (49%) was similar to that in spring, high food, however, the daily mortality rate was twice as high (0.029 d^{-1}). While instar-specific length did not vary among treatments, instar-specific weights of juvenile and adults were lower in the summer, low food treatment than in the other two treatments. The cumulative secondary production of single cohorts was lowest in the summer (0.32 mg dry weight individual^{-1}) due to low individual weights and highest under spring, high food conditions (1.1 mg dry weight individual^{-1}).

In 1993, several methods of cohort analysis were compared and a new method used to analyze the *Artemia* development experiments (Jellison *et al.* 1995). The linear-transfer and lag-Manly models of zooplankton cohort development were examined using data generated from a third more realistic model. The more realistic multi-transfer model included variance in development rate among individuals. The linear-transfer model produced highly biased estimates of development rate under conditions of rapidly changing recruitment. Although its performance was improved by increasing the number of modeled stages and thus decreasing the rate of change in recruitment compared to stage duration, a positive bias remained. The lag-Manly model also produced positively biased estimates of stage duration given non-zero variance in development rates. A comparison of the models' performances under different simulated sampling regimes recommended the multi-transfer model.

Use of the multi-transfer model was illustrated by determining the development and mortality rates of the brine shrimp, *Artemia monica*, reared under three different conditions of food and temperature corresponding to natural regimes in Mono Lake, California. The experimental conditions and sampling regime resulted in high relative standard errors (mean, 33%) in stage abundance estimates not atypical of zooplankton sampling regimes in lakes. A Monte Carlo analysis was used to determine the uncertainty in estimated parameters and determine the level of stage aggregation which maximized the amount of information derived from the experiments. A similar analysis is planned for weekly *Artemia* population data collected during summer 1993 after which the new method will be applied to previously collected field data in an attempt determine year to year and seasonal changes in *Artemia* mortality.

Other research activities

The efficiency of the plankton sampling program was evaluated in 1990 by analyzing the spatial and analytical variation in chlorophyll *a* and *Artemia* field data (Jellison *et al.* 1991). The results indicate that although the sampling program was reasonable for evaluating spatial and temporal variability in the plankton and describing functional relationships within and among the plankton communities, it was not the most efficient design for evaluating inter-annual population change. Based on this analysis, the number of stations sampled for *Artemia* was doubled while replicate tows taken at each station reduced. In 1994 LADWP-funded limnological monitoring at Mono Lake was further reduced. While much reduced, the limnological monitoring was modified to estimate key features of the seasonal plankton dynamics which enable comparisons to previous years.

In 1993 several sediment cores were collected from a central deep station in Mono Lake (Jellison *et al.* 1996). Finely-laminated sediments of Mono Lake provide a detailed paleolimnological record of organic matter accumulation during a period of large fluctuations in salinity resulting from climatic variation and water diversions. In sedimentary profiles representing the last 170 years, organic carbon content of the sediments varied from 6.6% to 16.1%. The accumulation rate of organic carbon at a sedimentation rate of 0.7 cm yr^{-1} varied from 76 to 164 g C m^{-2} yr^{-1}. The most notable change was a gradual increase in 10-yr mean accumulation rate from 93 g C m^{-2} yr^{-1} to 145 g C m^{-2} yr^{-1} as salinity increased from ca. 48 to 97 g l^{-1} during water the recent period of water diversions (1941–82). While the correlation between organic matter accumulation and salinity during the recent period may be due, in part, to the slow decay of organic matter under hypersaline conditions, a positive correlation between accumulation rates and estimated lake salinities at time of burial exists throughout the 170-yr record.

To determine how long the current episode of meromixis is likely to persist, the vertical mixing model, DYRESM (Imberger and Patterson 1981), which had been previously modified for use at Mono Lake (Romero and Melack 1996), was used in conjunction with 50 years of historical runoff data (1940–90) and the allowable diversion schedule (Jellison *et al.* 1998). Simulations predict that the current management policy of rapidly raising the lake level by restricting diversions is likely to result in a multi-decade period of meromixis at Mono Lake. The median estimate of the duration of the current episode of meromixis ranges from 44 to 63 years due to uncertainty in the eddy diffusivity parameter coefficient. However, the predicted duration is highly dependent on the starting year of the runoff sequence. Starting the runoff sequence with the high runoff observed in 1982 leads to a predicted duration of 62 years while beginning with the drought conditions observed in 1987 predicts the breakdown of meromixis after 17 years.

In 1999, temperature and salinity profiles from DYRESM simulations for the period 1996 – 1999 were compared to observed profiles for the same period. Analyses indicate DYRESM is not predicting the full extent of the observed freshening of the monimolimnion. Although subsurface inflows not modeled by DYRESM can account for a portion of the observed discrepancy, it is clear that DYRESM does not fully account for the observed vertical mixing. Thus, the earlier predictions of the expected duration of meromixis are overestimates. Modifications of DYRESM and further analysis are being pursued.

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CHAPTER 2

PHYSICAL, CHEMICAL, AND BIOLOGICAL CONDITIONS IN MONO LAKE, 1999

Introduction

Long-term monitoring of the plankton populations in Mono Lake and their physical, chemical, and biological environment is essential to understanding the effects of rising lake levels on ecosystem dynamics. Measurements of the vertical distribution of temperature, oxygen, conductivity, and nutrients are requisite for interpreting how variations in these variables affect the plankton populations. Consistent methodologies were employed during the 21-yr period, 1979–99, and have yielded a standardized data set from which to analyze seasonal and year to year changes in the plankton. Lakewide monitoring was conducted during ten surveys in 1999, once each month during February–October and December. A survey of lakewide brine shrimp abundance was also conducted in November to better describe the autumn decline in *Artemia* abundance.

The intensity and duration of limnological research at Mono Lake during the past 21 years is unique among limnological studies of large hypersaline lakes and has resulted in detailed understanding of many aspects of the plankton dynamics. Many of these are described in the review of previous research and in numerous publications (see Chapter 1). Differences among years in the 1980s and early 1990s are described in previous annual reports and publications.

Limnological monitoring at Mono Lake can be divided into several periods each with fundamentally different mixing and nutrient regimes. These different regimes correspond to two different annual circulation patterns, meromixis and monomixis, and the transition between them (see Chapter 1). During 1995, above normal runoff coupled with the current reduced volume of Mono Lake resulted in the second largest annual lake level rise this century. The large influx of freshwater initiated a period of persistent chemical stratification or meromixis. Strong chemical stratification has continued through the present as diversions of freshwater streams out of the Mono Basin have been minimal and the surface elevation of the lake has continued to rise. A previous episode of meromixis that was initiated by record runoff in 1982-83 ended 6 years later when the salinity of the mixolimnion (surface mixed layer) eventually became greater than that of the monimolimnion (bottom layer beneath chemocline) due to evaporative concentration and low inputs of freshwater. Given the management goal of raising the lake level to 6391 ft, the current episode of meromixis is likely to continue much longer (Jellison *et al.* 1998). In this chapter, we describe the physical, chemical, and biological conditions in Mono Lake during 1999, the fifth year of what is likely to be an extended period of meromixis.

Methods

Ten lakewide surveys were conducted in 1999 at approximately monthly intervals. During winter the plankton dynamics change relatively slowly and a survey was not conducted during January. An additional *Artemia* survey was conducted in November to better describe the autumn decline in *Artemia* as this may be important to understanding Eared Grebe abundance and staging behavior. *Artemia*, temperature, conductivity, oxygen, ammonium, chlorophyll *a*, and Secchi depth were sampled on every survey except in November when oxygen, ammonium and chlorophyll *a* were not measured. A complete set of meteorological data was also continuously collected at meteorological stations located on Paoha Island and at Cain Ranch.

Physical Environment

Water temperature and conductivity were measured at eight buoyed, pelagic stations (4, 6, ET5.6, S10, S30, 8, 9, and 11) (Fig. 2.1) with a high-precision, conductivity-temperature-depth profiler (CTD) (Sea-Bird Electronics, model Seacat SBE 19). The CTD was deployed with a free-fall rate of ~0.25–0.35 m s^{-1} and records temperature and conductivity every 0.5 seconds. Raw temperature data were shifted upward 1.6 scans (~800 ms) relative to the pressure data to allow for the slower response of the thermistor. Conductivity readings at in situ temperatures (C_t) are standardized to 25°C (C_{25}) using

$$C_{25} = \frac{C_t}{1 + 0.02124(t - 25) + 9.16 \times 10^{-5}(t - 25)^2}$$

where t is the in situ temperature. The CTD was calibrated in June 1998 by Sea-Bird Electronics. To describe the general seasonal pattern of density stratification, the contributions of thermal and chemical stratification to overall density stratification were calculated based on conductivity and temperature differences between 2 and 28 m at station S30 and the following density equation:

$$\rho(t, C_{25}) = 1.0034 + 1.335 \times 10^{-5} t - 6.20 \times 10^{-6} t^2 + 4.897 \times 10^{-4} C_{25} + 4.23 \times 10^{-6} C_{25}^2 - 1.35 \times 10^{-6} t C_{25}$$

The relationship between total dissolved solids and conductivity for Mono Lake water is given by:

$$TDS\left(g\ kg^{-1}\right) = 3.386 + 0.564 \times C_{25} + 0.00427 \times C_{25}^2.$$

To obtain TDS in grams per liter, multiply the above expression by the density at 25°C for a given standardized conductivity given by:

$$\rho_{25}(C) = 0.99986 + 5.2345 \times 10^{-4} C + 4.23 \times 10^{-6} C^2$$

A complete description of the derivation of these relationships is given in Chapter 4 of the 1995 Annual Report.

Throughout 1999 light attenuation and dissolved oxygen were measured at one centrally-located station (S30). Light attenuation was measured with a LI-COR light meter (LI-COR, model LI-189 - February–October, model LI-250 - December) equipped with a submersible PAR light sensor (LI-COR, model LI-192S). Dissolved oxygen concentration was measured with a Yellow Springs Instrument temperature-oxygen meter (YSI, model 58) and probe (YSI, model 5739) during 1999. The LI-COR light meter (LI-COR, model LI-189) and submersible PAR light sensor (LI-COR, model LI-192S) were calibrated on 4 January 1999 by LI-COR Inc. The LI-COR light meter (LI-COR, model LI-250) was purchased in November 1999. The oxygen electrode is calibrated at least once each year against Miller titrations of Mono Lake water (Walker *et al.* 1970).

Chlorophyll and Nutrients

Chlorophyll and nutrient samples were collected from seven to eleven depths at one centrally-located station (S30). In addition, 9-m integrated samples for chlorophyll *a* determination and nutrient analysis were collected with a 2.5 cm diameter tube at five stations (2, 6, 10, 11, and S30) (Fig. 2.1). Samples for nutrient analyses were filtered immediately upon collection through Gelman A/E glass-fiber filters, and kept chilled and dark until returned to the lab. Water samples used for the analysis of chlorophyll *a* were filtered through a 120-μm sieve to remove all stages of *Artemia*, and kept chilled and dark until filtered in the laboratory.

Ammonium concentrations were measured using the indophenol blue method (Strickland and Parsons 1972). Internal standards were used since the molar extinction coefficient is less in Mono Lake water than in distilled water.

Upon return to the laboratory, chlorophyll samples were filtered onto 47 mm Gelman A/E filters and kept frozen until the pigments were analyzed. Chlorophyll *a* was extracted and homogenized in 90% acetone at room temperature in the dark. Following clarification by centrifugation, absorption was measured at 750 and 663 ηm on a spectrophotometer (Milton Roy, model Spectronics 301) calibrated once a year by Milton Roy Company. The sample was then acidified in the cuvette, and absorption was again determined at the same wavelengths to correct for phaeopigments. Absorptions were converted to phaeophytin-corrected chlorophyll *a* concentrations with the formulae of Golterman (1969). During periods of low phytoplankton concentrations (<5 μg chl *a* l^{-1}), the fluorescence of extracted pigments was measured on a fluorometer (Sequoia-Turner, model 450) which was calibrated against the spectrophotometer using large-volume lake samples and fresh lettuce.

Artemia

The *Artemia* population was sampled by one net tow from each of twenty stations (Fig. 2.1). Samples were taken with a plankton net (1 m x 0.30 m diameter, 120 μm Nitex mesh) towed vertically through the water column. Samples were preserved with 5% formalin in lake water, and counted under a stereo microscope (6x or 12x power). Depending on the density of shrimp, counts were made of the entire sample or of subsamples made with a Folsom plankton splitter. Samples were split so that a count of 150 to 200 animals was obtained. Shrimp were classified into adults (instars > 12), juveniles (instars 8–11), and nauplii (instar 1–7) according to Heath's classification (Heath 1924). Adults were sexed, and the adult females were divided into ovigerous and non-ovigerous. Ovigerous females included egg-bearing females and females with oocytes. Adult ovigerous females were further classified according to their reproductive mode, ovoviviparous or oviparous. A small percentage of ovigerous females were unclassifiable if eggs were in an early developmental stage. Nauplii at six stations (6, 15, 9, 11, S10, and S30), representing the east, west, and south sectors of the lake (Fig. 2.1), were further classified as to instars 1–7.

Live females were collected for brood size and length analysis from the ten buoyed stations (Fig. 2.1) with 20-m vertical net tows and kept cool and in low densities during transport to the laboratory. Immediately on return to the laboratory, females were randomly selected, isolated in individual vials, and preserved. Brood size was determined by counting the number of eggs in the ovisac including those dropped in the vial, and egg type and shape were noted. Female length was measured from the tip of the head to the end of the caudal furca (setae not included).

Results and Discussion

Surface Elevation

The surface elevation of Mono Lake rose during the first half of the year and peaked at 6385.1 ft asl (USGS datum) on 16 July 1999. This was 0.6 ft above the 1998 high point. After mid-July 1999, the surface elevation declined due to evaporative loss to 6384.1 ft asl by the end of the year (Fig. 2.2). The 1998–99 increase in peak surface elevation (0.6-ft) resulted from a year of near normal runoff following four consecutive years of above normal runoff with restricted water diversions out of the basin. While the peak surface elevation was 0.6 ft higher in 1999 than in 1998, the surface elevation actually declined 0.1 ft between 5 January 1999 (6384.2 ft asl) and the end of the year (6384.1 ft asl). This was the first net annual decline in surface elevation in 5 years. In 1995, exceptionally high runoff led to a 3.5 ft net annual rise in surface elevation, whereas the 1996, 1997, and 1998 runoff resulted in 2.0, 2.3, and 2.2 ft. net annual rises, respectively.

Temperature

The annual pattern of thermal stratification in Mono Lake results from seasonal variations in climatic factors (e.g. air temperature, solar radiation, wind speed, humidity) and their interaction with density stratification. The timing and magnitude of freshwater inputs, primarily precipitation and inflowing streams which mix into the upper portion of the water column, strongly affect the seasonal pattern of thermal stratification. The annual pattern of seasonal thermal stratification observed at Mono Lake during monomictic conditions (1989–94), in which strong thermal stratification during the summer is followed by holomixis in late autumn, is typical of large temperate lakes. This pattern was altered in 1995–99 (Fig. 2.3, Table 2.1) due to vertical salinity gradients associated with ongoing meromixis.

Aside from the absence of a winter period of holomixis, the most notable difference in the thermal regime during 1996–99 compared to monomictic years is the presence of significant inverse thermal stratification at mid-depths. This inverse thermal stratification was observed from December 1995 through April 1996 and from November 1996 through May 1999 (throughout 1997 and 1998). In the February 1999 profile, temperatures increased from a minimum of 2.1°C at 5-17 m depth to a maximum of 5.1°C at 22-23 m, an increase of 3.0°C below the mixolimnion (Table 2.1). During 1999 this thermal signature was observed only through mid-May, and at greater depths and with less warming than was observed in February. The temperature increase below the mid-depth temperature minimum gradually decreased from 3.0°C in February to ~0.3°C in May before virtually disappearing (< 0.05°C increase) by mid-June. The mid-depth minimum temperatures ranged from 2.1°C in February to 4.7°C in May, and their depth increased from 5-17 m in February to 21 m in May (Table 2.1).

The almost constant monimolimnetic temperatures represent the second significant difference from more typical monomictic thermal patterns. In a typical monomictic year, hypolimnetic temperatures warm slowly throughout the year until overturn in late autumn, when the lake mixes to the bottom. After holomixis occurs, isothermal conditions prevail with temperatures decreasing through the winter months. The lowest temperatures in the hypolimnion typically occur in February before the onset of seasonal stratification. In 1993–95 the lowest temperatures in the hypolimnion occurred January–April, (1.8-1.9°C in 1993, 2.5-2.7°C in 1994, and 2.9°C in 1995), and the warmest temperatures occurred in December (4.6°C in 1993, 5.0°C in 1994, and 4.1°C in 1995) near the time of holomixis. Because no period of holomixis occurred in late 1995 through 1999, hypolimnetic temperatures were slightly warmer than usual and changed little throughout the year. Hypolimnetic temperatures remained between 4.9–5.0°C throughout 1999, slightly cooler and more constant than those observed in 1997 and 1998 (5.0-5.2°C and 4.9-5.1°C, respectively).

During February and March no thermocline was observed above the monimolimnion. However, by mid-April a seasonal thermocline had formed below 3 m.

This thermocline persisted and gradually deepened to 11 m by mid-June. In mid-July a secondary seasonal thermocline had formed at 9-10 m. This secondary thermocline persisted throughout the summer and autumn, gradually deepening to 18-19 m by mid-November. In December, the water column was nearly isothermal at 7.4°C above the monimolimnion at 21-22 m. In December 1999, the mixed layer temperature was ~2°C warmer and the top of the monimolimnion was 5 m deeper than was observed in December 1998.

Mean epilimnetic temperatures were cool during February and March 1999 (2.1 and 4.0°C, respectively) above the inverse temperature gradient at 18–19 m depth. By mid-April when the shallow seasonal thermocline had formed, near surface mean temperatures warmed to 6.7°C similar to April 1998. The mean epilimnetic temperature warmed further to 11.8°C by mid-May, which was ~2°C warmer than observed during May 1998, and continued to warm until the maximum was reached in mid-July (20.7°C). The maximum water temperature for 1999 was recorded in mid-July at 5-m depth (21.0°C). The mean epilimnetic temperature maximum in 1999 occurred a month earlier than that observed in 1998 and was ~1.2°C cooler, but is within the range observed in previous years. Autumnal cooling of the epilimnion proceeded slowly in 1995–99 compared to 1993 and 1994. Slower rates of cooling in 1995–99 were caused in part by reduced entrainment of colder metalimnetic water due to strong chemical stratification. On 6 December 1999, the upper 21 m of the water column were ~7.4°C, warmer than observed in early December 1996–98 (~6.6, 6.4 and 5.6°C, respectively) and ~1.5°C cooler than observed on 7 December 1995, probably reflecting the warmer than average autumn ambient temperatures in 1999. The December 1999 mixed-layer temperatures were much warmer than in 1993 (4.7°C) and 1994 (5.0°C) before the onset of this period of meromixis.

Conductivity and Salinity

Salinity, expressed as total dissolved solids, can be calculated from conductivity measurements corrected to a reference temperature (see Methods). Because total dissolved solids are conservative at the current salinities in Mono Lake, salinity decreases as the volume of the lake increases due to inputs of freshwater in excess of evaporative losses.

During 1999, conductivities in the mixolimnion (2 m) decreased from 77.5 mS cm^{-1} in February to 76.8 mS cm^{-1} in July (Fig. 2.4, Table 2.2) during maximum snowmelt runoff. Subsequent evaporative concentration resulted in a conductivity increase to 78.7 mS cm^{-1} by early December. Thus, in 1999 the mixolimnetic salinity (TDS) ranged from 71.9 to 74.2 g kg^{-1}. The minimum conductivity and salinity observed in 1999 was slightly higher than the minimums observed in 1998 (~75 mS cm^{-1}, 69.9 g kg^{-1}), but the maximum conductivity and salinity was lower (~80 mS cm^{-1}, 75.8 g kg^{-1} in 1998). This continues a 5-yr trend of decreasing maximum mixolimnetic conductivities and salinities. In 1995, 1996, and 1997 mixolimnetic conductivities ranged from 84 to 86, 81 to 84, and 78 to 81 mS cm^{-1} each year, respectively, and mixolimnetic salinities ranged from 81 to 87, 78 to 81, and 74 to 77 g kg^{-1}, respectively. Although evaporative concentration during autumn resulted in a slight increase in mixolimnetic conductivities during August–December 1999, significant density stratification remained at the end of the year.

Monimolimnetic conductivities during 1999 were ~87.5 mS cm^{-1} (~85.4 g kg^{-1} TDS) in February and exhibited a small decrease by year's end, reaching ~87.3 mS cm^{-1} (~85.1 g kg^{-1}) in December. Monimolimnetic conductivities and salinities have decreased slightly each year during this period of meromixis. Conductivities and salinities ranged from 91.0 mS cm^{-1} (90.1 g kg^{-1}) in March to 90.3 mS cm^{-1} (89.1 g kg^{-1}) in December during 1995, from 90.2 mS cm^{-1} (89 g kg^{-1}) in February to 89.6 mS cm^{-1} (88.2 g kg^{-1}) in December during 1996, from ~89.6 mS cm^{-1} (88.2 g kg^{-1}) in February to ~88.8 mS cm^{-1}

(87.1 g kg^{-1}) in December during 1997, and from ~88.6 mS cm^{-1} (86.9 g kg^{-1}) in February to ~87.7 mS cm^{-1} (~85.7 g kg^{-1}) in December during 1998. This indicates a small amount of vertical mixing or the presence of subsurface freshwater inflows.

During 1999 conductivities generally appear well-mixed above the monimolimnion and the salinity gradient at the chemocline appears significantly steeper and sharper than in previous meromictic years (Table 2.2, Figure 2.4). The chemocline deepened throughout the year from ~18 m in February to ~ 20-21 m in December.

Density Stratification: Thermal and Chemical

The large seasonal variation in freshwater inflows associated with a temperate climate and year-to-year climatic variation leads to complex patterns of seasonal density stratification. Much of the year-to-year variation in the plankton dynamics observed during the past 21 years at Mono Lake can be attributed to marked differences in chemical stratification resulting from variation in freshwater inflows.

Strong density stratification was present throughout the year during 1999 (Fig. 2.5, Table 2.3), though the stratification was slightly weaker than in 1998 due to a lower volume of freshwater inputs in 1999. Density ranged from a maximum of 1.077–1.078 g cm^{-3} for water near the bottom (below 28 m) throughout the year to a minimum of 1.061 g cm^{-3} in near surface (1-4 m) water during July. The minimum densities observed in 1999 were more than the minimums observed August 1998 (1.059 g cm^{-3}), but less than in July and August 1995 (1.068 g cm^{-3}), 1996 (1.066 g cm^{-3}), and 1997 (1.064 g cm^{-3}). The slight rise in minimum densities in 1999 reflects a slight increase in evaporative concentration of the mixolimnion with a year of slightly below normal precipitation and lower freshwater inflows.

The highest density gradients (greater than 0.0015 g cm^{-3} m^{-1}) occurred at intermediate depths between mixolimnion and the perennially isolated monimolimnion (Fig. 2.5). The density gradient at the top of the monimolimnion was extremely sharp and steep throughout 1999 (an increase of ~0.0040-0.0060 g cm^{-3} within a meter). The depth of this sharp density gradient increased from 18-19 m in February to 20-21 m in December.

A comparison of the density differences between 2 and 28 m due to thermal versus chemical stratification indicates chemical density stratification continued to predominate throughout 1999 (Fig. 2.6, Table 2.4). At the peak of thermal stratification during July, chemical stratification contributed about three times as much as temperature to the overall density stratification (12.2 versus 4.1 kg m^{-3}). A comparison of the density differences between 2 and 28 m during 1998–99 indicates that chemical density stratification weakened slightly during 1999. Annual peaks in density differences due to chemical stratification increased each year 1995–98 (from 8.1 kg m^{-3} in August 1995, to 10.4 kg m^{-3} in July 1996, to 12.3 kg m^{-3} in July 1997, to 14.9 kg m^{-3} in August 1998), but in 1999 the annual peak decreased to near 1997 levels (12.2 kg m^{-3} in July 1999, Fig. 2.6). During the 1999 December survey the density stratification due to salinity was 9.9 kg m^{-3} compared to 0.4 kg m^{-3} due to temperature. The December density stratification due to salinity was lower in 1999 than in 1998 (11.7 kg m^{-3}), but higher than any other year since 1995 (6.0 kg m^{-3}, 1995; 7.9 kg m^{-3}, 1996; 9.7 kg m^{-3}, 1997). During 1999, the only survey in which temperatures showed an inverse gradient between 2 and 28 m was 19 February, when the density difference due to temperature was -0.38 kg m^{-3} and the density difference due to salinity was 11.7 kg m^{-3}.

December conductivity profiles from 1994–99 (Fig. 2.7) show that in 1999 there was an increase in mixolimnetic conductivities due to summer evaporative concentration of surface water while monimolimnetic conductivities showed a slight decrease, resulting in an overall decrease in chemical stratification during 1999. The overall maximum density stratification due to both thermal and chemical effects observed in 1999 was 16.3 kg m^{-3}, a decrease from the 1998 maximum of 19.4 kg m^{-3}, but similar to the maximum observed in 1997 (16.4 kg m^{-3}) (Fig. 2.6, Table 2.4).

Summer thermal stratification regularly contributes 4 to 5 kg m^{-3} of density stratification between 2 and 28 m, as was observed in 1997–99. During most monomictic years, the density stratification due to temperature is lessened by inverse salinity stratification due to evaporative concentration of surface water during late summer. This inverse salinity stratification promotes vertical mixing of nutrients and late summer deepening of the mixed layer. During meromictic years, density stratification is enhanced by salinity stratification, and late summer vertical fluxes of nutrients and deepening of the mixed layer are inhibited.

Transparency and Light Attenuation

In 1999 average lakewide transparencies, as determined by Secchi depth, remained between 1.8-1.9 m during February–April. In mid-May as *Artemia* instar abundance reached its spring maximum, mean Secchi depth increased to 2.8 m. This spring increase in lake transparency occurred one month later than in 1998. The mean Secchi depth increased rapidly to 9.9 m by mid-June, as the first generation of *Artemia* matured, and then reached an annual maximum of 11.5 m in mid-July. This maximum annual Secchi depth is 0.4 m shallower than the maximum observed in 1998, but nearly 2 m deeper than the maximum observed in 1997 and 0.6 m deeper than that observed in 1996 (Fig. 2.8). The timing of the summer transparency maximum was the same as that in 1996–98 and over a month earlier than in 1995. In 1999, Secchi depths remained high into August and September (11.2 and 9.8 m, respectively), then decreased to 5.9 m on 20 October and further to 2.7 m on 11 November. Average lakewide transparencies, as determined by Secchi depth, reached their annual minimum (1.5 m) in December (Table 2.5). This annual minimum Secchi depth was 0.4 m shallower than that in 1997, and occurred in December instead of in the spring as observed in 1995–98. The mean transparency in December 1999 was shallower than the range observed during December 1995–98 (2.0–2.8 m), and similar to Secchi readings during December in 1993–94 before the onset of this period of meromixis (1.5-1.6 m). Reduced upward flux of nutrients accompanying meromixis reduces the annual autumn algal bloom during periods of meromixis. However, in 1999 significant deepening of the mixed layer presumably entrained nutrient-rich water and led to the observed algal bloom and shallower Secchi readings during December. Throughout the rest of the year transparencies were higher than observed in previous monomictic years.

Secchi depth is an integrative measure of light attenuation within the water column. Because absorption is exponential with depth, the long-term variation in Secchi depth is most appropriately viewed on a logarithmic scale. During 1999, the annual maximum in Secchi depth was higher than that observed during the past 21 years, except 1985, 1989, and 1998 and greater than that observed during any of the previous monomictic years (Fig. 2.9). The annual minimum Secchi depth was between those observed in 1997–98 and those observed in 1995–96 and was similar to the minimum observed in 1985 during the previous episode of meromixis. These changes reflect decreased availability of nitrogen and thus phytoplankton as a result of increasing chemical stratification and the absence of a winter period of holomixis.

The attenuation of PAR within the water column varies seasonally, primarily as a function of changes in algal biomass. In 1999, the depth of the euphotic zone, operationally defined as the depth at which only 1% of the surface insolation is present, varied from 7-10 m in the spring and winter to a maximum of 19 m in June (Fig. 2.10). From its maximum in June, the depth of the euphotic zone decreased slowly through October (~15 m), and then more rapidly, reaching the annual minimum in December (~7.5 m). In 1999, with one exception, the depth of the euphotic zone was generally ~3-4 meters deeper than observed during the last two monomictic years (1994–early1995), reflecting decreased algal biomass. However, during December 1999 the depth of the euphotic zone was nearly the same as that in December 1994 and was 2-3 m shallower than in December 1995 at the beginning of this period of meromixis.

Dissolved Oxygen

Dissolved oxygen concentrations are primarily a function of salinity, temperature, and the balance between photosynthesis and overall community respiration. In the euphotic zone of Mono Lake, dissolved oxygen concentrations are typically highest during the spring algal bloom. As the water temperature and *Artemia* population increase through the spring, dissolved oxygen concentrations decline. Beneath the euphotic zone, bacterial processes deplete the oxygen once the lake stratifies.

On the first survey of the year, 19 February 1999, dissolved oxygen was high in the mixolimnion (~5-6 mg l^{-1}) and depleted below 20 m (Fig 2.11, Table 2.6). In March the dissolved oxygen concentration in the mixolimnion reached the year's maximum (~6.9–7.4 mg l^{-1} above 10 m) while the water below 20 m was anoxic. Mixolimnetic dissolved oxygen concentrations gradually decreased through April–June, and by mid-July dissolved oxygen concentrations in the upper 7 m were 4.6–4.7 mg l^{-1}. Mixolimnetic dissolved oxygen remained near that concentration through October. Dissolved oxygen concentrations increased slightly to 4.8–5.2 mg l^{-1} in the mixolimnion during early December. The water column was depleted of dissolved oxygen below 19–20 m depth February–October. In December the depth of the anoxic zone (defined by dissolved oxygen concentration of <0.5 mg l^{-1}) deepened to below 22 m. The absence of any winter period of holomixis results in permanently anoxic conditions beneath the chemocline. The maximum oxygen concentration observed during 1999 was in mid-March at 4 m (7.4 mg l^{-1}). Mid-depth oxygen concentration maxima were also observed at 4–7 m depth during April and 8–10 m in May (6–7 mg l^{-1}), at 12 m in June and July (5–6 mg l^{-1}), at 15 m during August, and at 12–13 m in October (~5 mg l^{-1}). These dissolved oxygen values are within the range observed in previous years.

Nutrients (Ammonium)

Nitrogen is the primary limiting macronutrient in Mono Lake as phosphate is in super-abundance (350-450 μM) throughout the year (Jellison *et al.* 1994). External inputs of nitrogen are low relative to recycling within the lake (Jellison *et al.* 1993). Ammonium concentrations in the euphotic zone reflect the dynamic balance between excretion by shrimp, uptake by algae, upward vertical fluxes through thermo- and chemocline(s), release from sediments, ammonia volatilization, and small external inputs. Because a large portion of particulate nitrogen, in the form of algal debris and *Artemia* fecal pellets, sink to the bottom and are remineralized to ammonium in the hypolimnion (or monimolimnion during meromixis), vertical mixing controls much of the internal recycling of nitrogen.

During 1999, ammonium concentrations in the euphotic zone were low (0.6–1.1 µM) during February–May, July–August and October–December (Fig. 2.12, Table 2.7). Euphotic zone ammonium concentrations were slightly higher in the upper 12 m of the water column during June (1.4–2.4 µM) and September (0.8–2.0 µM) due to *Artemia* grazing and excretion. *Artemia* grazing results in decreased phytoplankton and thus algal ammonium uptake. This pattern is similar to that observed in 1998 when concentrations increased slightly each month from April to June then decreased in July and were generally very low the rest of the year, except that in 1999 the ammonium at 2 m was slightly elevated in October (1.1 µM). In 1996, the euphotic zone ammonium concentrations reached a higher mid-summer peak June–August (2.2–3.7 µM), whereas in 1997, the ammonium concentrations in the euphotic zone remained low all year (0.4–0.9 µM) and never reached a mid-summer peak. Ammonium concentrations at 2 m depth were similar during February and March 1996–99 (0.6–0.7 µM). However, during May–July 1997 ammonium concentrations at 2 m depth (0.4–0.5 µM) were significantly lower than in 1996 and 1998–99 (0.8–3.5 µM). During September–December, ammonium concentrations were similar at 2 m in 1996–99 (0.6–0.9 µM).

Ammonium concentrations have continued to increase in the bottom waters. During February 1999, ammonium concentrations in the bottom waters were 369–394 µM at 28–35 m compared to 286–334 µM at 28–35 m in 1998, 181 µM at 28 m in 1997 and 73 µM at 24 m in 1996). Monimolimnetic ammonium concentrations generally increased throughout the year with concentrations at 28 m reaching 483 μM by December (compared with 164, 276 and 403 μM at 28 m in December of 1996, 1997 and 1998, respectively). At 35 m ammonium concentrations were over 500 μM in December 1999. The observed seasonal accumulation is higher than during monomictic years, but similar to that observed during the 1983–88 episode of meromixis. During the mid-80s period of meromixis, ammonium built up to ~600 μM over 6 years (Jellison *et al.* 1989).

Algal Biomass (Chlorophyll a)

Algal biomass, as characterized by chlorophyll *a*, varied in the mixolimnion from 0.9 to 24.6 μg chl *a* l^{-1} (Table 2.8, Fig. 2.13) in 1999. Chlorophyll *a* concentrations at 2 m increased from ~11 μg chl *a* l^{-1} in February to ~16 μg chl *a* l^{-1} in March then decreased to 0.9 μg chl *a* l^{-1} by mid-June, when the seasonal chlorophyll *a* concentration minimum was reached. After that it increased to 1–3 μg chl *a* l^{-1} during July–October. By early December chlorophyll *a* concentration at 2 m increased to the annual mixolimnetic maximum, ~25 μg chl *a* l^{-1}. The highest mixolimnetic chlorophyll *a* concentrations were observed during the early spring and winter months, February, March and December and were higher than the maximums observed in 1996, 1997, and 1998 (at 2 m ~5-8, 3-10, and 8-14 μg chl *a* l^{-1}, respectively). While the seasonal pattern of mixolimnetic chlorophyll *a* concentration was generally similar to that observed during the three previous meromictic years, 1996–98, the high December concentrations represent a significant difference.

Prominent mid-depth maxima were observed at 24 m in February–May (32-35 μg chl *a* l^{-1}), at 20 m June through September (~48-104 μg chl *a* l^{-1}), and at 22 m in December (~40 μg chl *a* l^{-1}). It is clear that large populations of photosynthesizing organisms may develop at the top of the nutricline. Our current sampling program does not attempt to accurately monitor these populations which may have very limited vertical extent. It is likely that this population consists of a recently identified novel phytoplankton (C. Roesler pers. commun.) adapted to very low light levels.

Monimolimnetic (24-28 m) concentrations of chlorophyll *a* were relatively constant, ranging between ~29 and 38 μg chl *a* l^{-1}, and within the range observed in previous years.

Artemia Population Dynamics

Population Overview

Artemia population dynamics in 1999 were characterized by a single mid-July peak in adults with little recruitment of second generation *Artemia* during late summer – early autumn (Fig. 2.14, Table 2.9-10). The first adults had not appeared by mid-May but some had matured by mid-June and were producing second-generation nauplii. Given adequate food, second-generation individuals mature rapidly at warm summer temperatures. However, during meromictic years (1996–99), algal biomass is reduced and development and maturation of second generation shrimp retarded. This results in formation of broader, more indistinct adult population peaks, and merging of the first and summer generation adult peaks into one. Thus, the single annual population peak in mid-July 1999 is composed of 1st and 2nd generation adults. In 1999, beginning with the 15 July survey, the absence of middle instar stages of nauplii (instars 3 or 4–6 or 7) indicated recruitment into the adult population had nearly stopped (Table 2.10). This pattern continued through September when instars 5–7 were not observed. In October–December all instars were present, indicating late fall recruitment of instars into the adult population could have occurred. In 1999, the peak abundance of adults was observed on 15 July (38,400 m^{-2}). Subsequent surveys indicated that the adult population declined each month to <30 m^{-2} by early December.

Nauplii (Instars 1-7)

Hatching of over-wintering cysts occurs in oxygenated sediments as water temperatures warm following an obligatory cold dormancy period (Dana 1981). In Mono Lake, these requirements result in hatching from January through May with most of the hatching occurring in March and April. In all previously sampled years hatching had begun by late February, with the exception of 1989 when anoxic conditions following the breakdown of meromixis delayed the beginning of the spring hatch until the beginning of March. In 1999, significant hatching had occurred by 19 February as naupliar abundance was ~18,600 m^{-2} on that date (Fig. 2.14, Table 2.9–10). Naupliar numbers then increased each month until they reached their spring peak abundance on 12 May (60,600 m^{-2}). Naupliar numbers declined rapidly to 11,200 m^{-2} by 15 June and generally continued to decrease each month until 6 December when naupliar numbers reached the lowest lakewide abundance of the year (~600 m^{-2}). It is clear that the nauplii that were observed in early spring 1999 hatched from over-wintering cysts, because no adult females were present February–May. The spring naupliar peak abundance in 1999 (~60,600 m^{-2}), similar to that in 1998 (~64,400 m^{-2}), was less than the unusually large peak observed in 1996 (82,600 m^{-2}), but greater than the range observed during 1989–94 (13,000–35,000 m^{-2}) and 1997 (36,700 m^{-2}). Data were not collected in April and May 1995.

During April and May 1999, naupliar numbers (42,000–60,600 m^{-2}) were significantly higher than were observed during those months during 1993–94 (11,500–28,300 m^{-2}) and fall within the range observed in 1996–98 (26,600–82,600 m^{-2}). Spring naupliar numbers peaked in May 1999 at the same time as in 1998, a month later than the spring peak was observed in 1993–94 and 1996–97.

In 1999, production of second generation nauplii by ovoviviparous females occurred during June–September when brood sizes were moderate (27–48 eggs $brood^{-1}$) (Fig. 2.15, Tables 2.11-12). Ovoviviparously reproducing females comprised 8% of fecund females with differentiated egg masses in June, the annual maximum in percent ovoviviparity, and comprised less than 1% of fecund females with differentiated egg masses July–September. The mean brood size on 15 June 1999 (48 eggs $brood^{-1}$) was similar to June 1998 (50 eggs $brood^{-1}$). During 1998 and 1999, the June brood sizes were the largest of the year and within the range observed during June 1990–95 and 1998 (28–

124 eggs brood^{-1}), and larger than were observed during June 1996–97 (33–36 eggs brood^{-1}). During the meromictic years 1984–1988, as well as 1991–92 and 1994, early summer brood sizes were moderate (20–70 eggs brood^{-1}), smaller than the large broods observed in 1983, 1989, and 1990 (90–156 eggs brood^{-1}). Differences in brood size are largely related to algal abundance and individual size.

Naupliar abundance, which reached its first generation peak on 12 May (60,600 m^{-2}), exhibited a much smaller second generation peak on 15 June (11,200 m^{-2}) (Fig. 2.14, Table 2.9) during the period of maximum ovoviviparous reproduction. Production of nauplii declined by 15 July as females switched to oviparous reproduction (Fig. 2.15). Algal biomass, already depleted to levels of ~1 µg chl *a* l^{-1} by 15 June, rose no higher than ~2 µg chl *a* l^{-1} through September and low food levels most likely account for lack of recruitment of second generation nauplii into the summer population of adults. From July to September, between 3 and 5 consecutive instar stages (3–7) were absent in *Artemia* samples (Table 2.10) illustrating the lack of naupliar recruitment into the adult population. A similar pattern has been observed in other years (1984, 1987, 1989, 1990–91, 1996–98). The pattern in 1999 was less pronounced than that observed in 1996.

<u>Juveniles (Instars 8–11)</u>

In 1999 juvenile numbers reached their annual peak on 15 June (35,600 m^{-2}), as the first generation of *Artemia* matured (Fig. 2.14, Table 2.9). The timing of maximum juvenile abundance, similar to that in 1998, was a month later than observed in 1993–94 and 1996–97. The annual juvenile peak was greater in 1999 than the range in peaks observed 1993–98 (9,700–32,200 m^{-2}). The abundance of juvenile stages decreased drastically each month from June (35,600 m^{-2}) through September (~20 m^{-2}), then increased to ~400 m^{-2} by November indicating that some recruitment into the adult population may have occurred during the autumn algal bloom. Juvenile numbers then decreased to ~80 m^{-2} by December as water temperatures cooled. This pattern is generally similar to that seen in 1993–98; except that the annual maximum was higher than in 1993–98 and the annual minimum (~20 m^{-2}) was lower than any of those years (30–270 m^{-2}) except 1998 (<10 m^{-2}).

Adults

In 1999, adults were even slower to mature than in 1998. By 15 June adults represented only 27% of total *Artemia* numbers (June 1998, 32% of total *Artemia*) (Table 2.9), whereas juveniles represented 55% of the total (42% of the total in 1998). In 1999, similar to 1998, the mid-July survey was the first one in which a majority of first generation adults had matured, with adults representing 73% of total *Artemia* numbers. The timing of the maturation of the majority of *Artemia* in 1998–99 is up to a month later than in 1996–97, and nearly two months later than was observed in 1993–94. The maturation of *Artemia* is dependent on water temperature and the abundance of algae for food. In mid-June 1999 the mean mixolimnetic temperature was 14.8°C, more than a degree warmer than in June 1995 and 1998 (13.6 and 13.7°C, respectively), but within the range observed during June 1993–94 and 1996–97 (14.6–18°C). The mixolimnetic water temperature in 1999 allowed swift maturation of shrimp between mid-June and mid-July.

The peak abundance of adults was observed on 15 July (38,400 m^{-2}, Fig. 2.14, Table 2.9), a month earlier than in 1997–98 and similar in timing to most previous years. The annual adult peak abundance was greater in 1999 than during 1990–98 (24,400–34,900 m^{-2}, Fig. 2.16). There was remarkably little variation in annual adult peak abundance during the 1990's, compared to variations observed 1979–89 prior to and during the previous period of meromixis. Adult abundance declined from its peak in July to <30 m^{-2} in December. The abundance of adults in December was within the range observed during December 1993–98 (20–90 m^{-2}).

In 1999, first generation ovigerous females were not observed at Mono Lake until 15 June (1,000 m^{-2}) when they comprised 14% of all adult females (Fig. 2.15, Table 2.11).

In 1999, similar to 1998, the appearance of ovigerous females was one month later than in 1993–94 and 1996–97. The number of ovigerous females increased to ~10,300 m^{-2} by 15 July (62% of all adult females), and to the year's maximum, 10,400 m^{-2} by 18 August (83% of all adult females) and decreased only slightly to 10,200 m^{-2} by 23 September (99% ovigery, the year's maximum). Numbers of ovigerous females continued to decline to 4,100 m^{-2} on 20 October (98% ovigery), to 600 m^{-2} (91% ovigery) on 11 November, and to only 1 m^{-2} (13% ovigery) on 6 December.

The percent ovigery during mid-June 1999 (14%) was lower than the range observed during mid-June 1995–98 (20–62%) and much lower than observed in mid-June 1989–94 (71–98%). Lower ovigerity early in the year reflects the slower maturation rates resulting from the lower spring algal levels during this period of meromixis. During the previous meromictic years (1984–88) the female population was also slow to attain high levels of ovigery due to lower algal levels. During July 1999, percent ovigery (62%) was similar to the same time period in 1996 and 1998 (60 and 63%, respectively) and lower than the range observed during July 1991–95 and 1997 (72–92%). During August 1999, percent ovigery (83%) was within the range observed in August 1991–98 (67–93%). In September the percent ovigery (99%) had peaked and was greater than the range observed during September 1990–98 (85–97%). By October the percent ovigery (98%) was within the range observed during that month in previous years. During summer and autumn, female reproductive characteristics followed a pattern similar to other years, though delayed by about a month, with percent ovigery generally increasing from June to September–October (14 to 99%) (Fig. 2.15, Table 2.11).

Ovoviviparity in first generation adult females was at its spring peak (8%) on 15 June when percent ovigery was low (14%), but brood size was at its annual maximum (48 eggs $brood^{-1}$, Fig. 2.15, Tables 2.11–12). Most females switched to oviparous reproduction by 15 July and the percent ovoviviparity remained low (0–1%) throughout the rest of the year (Fig. 2.15, Table 2.11). The peak in percent ovoviviparity in 1999 was at the lower end of the range observed during 1990–98, when the peak in percent ovoviviparity ranged from 7–70%.

The mean female length ranged from 10.0 to 10.7 mm in 1999 (Table 2.12), somewhat longer than in 1997 (9.9–10.4 mm) and 1998 (9.6–10.3 mm), but similar to 1996 (10.1–10.7 mm). The mean female length decreased from 10.3 mm in June to 10.0 mm in July and August, indicating the maturation of a component of smaller female adults between the June and July surveys. Mean female length increased to 10.3 mm in September and reached the annual maximum length (10.7 mm) in October. The maximum female length observed in 1999 was at the top end of the range of maximums observed in 1996–98 (10.3–10.7 mm), but was significantly shorter than the maximum mean female lengths measured in previous years 1987–95 (11.6 to 13.7 mm). Shorter lengths of fecund females in 1996–99 reflect lower ambient food (phytoplankton) concentrations during those summers.

Mean brood sizes in 1999 ranged from 27 to 48 eggs brood^{-1} (Fig. 2.15, Table 2.12) which were within the ranges observed in 1996–98 (22–53 eggs brood^{-1}). The maximum brood size (48 eggs brood^{-1}) was within the range of maximums observed 1995–98 (62, 53, 33, and 50 eggs brood^{-1}, respectively), but significantly smaller than was observed in 1987–94 (81–156 eggs brood^{-1}). As in 1997–98, the largest mean brood size was observed in June as the first generation of *Artemia* matured. Smaller brood sizes in 1996–99 resulted from the reduced algal mass during this period of meromixis.

Year to year variation in climate, hydrological conditions, vertical stratification, food availability, and possibly salinity have led to significant differences in the seasonal *Artemia* dynamics. During years when the first generation was small due to reduced hatching, high mortality, or delayed development, (1981, 1982, and 1989) the second generation peak of adults was 2-3 times the long term average (Fig. 2.16). However, in most years the seasonal peaks of adult abundance were similar and the seasonal (1 May to November 30) mean of adult abundance is remarkably constant among all years except

1981, 1982, and 1989 (Fig. 2.17). During most years, the seasonal distribution of adult abundance was nearly normal or lognormal. However, in several years the seasonal abundance was not described well by either of these distributions and therefore the abundance-weighted centroid of temporal occurrence was calculated to compare overall seasonal shifts in abundance. The center of the temporal distribution of adults varied from day 190 (9 July) to 253 (10 September) from 1979 to 1998 (Fig. 2.18). During 1999, the center of the distribution was on day 225, almost identical to 1998 (day 226), and very close to the long-term mean of day 222. This centroid is three weeks later than the center of temporal distribution in 1997 (day 204) and 8-15 days later than in 1992–96.

Interaction Among Nutrients, Phytoplankton, and Artemia

Primary production in Mono Lake is limited by nitrogen availability (Jellison and Melack 1993). Because external inputs of nitrogen are low, sustained high levels of primary productivity are dependent on internal recycling of nitrogen. Internal recycling takes place on several different spatial and temporal scales. Under monomictic conditions, ammonium, which has accumulated in the hypolimnion due to bacterial remineralization of detrital material, is mixed throughout the water column during winter holomixis. Thus, the euphotic zone is replenished with nutrients on an annual basis. During monomictic conditions, ammonium concentrations within the euphotic zone are highest immediately following autumn overturn and during the winter. The onset of thermal stratification in spring limits the vertical fluxes of nitrogen and as phytoplankton populations increase they usually deplete the available nitrogen to <1 μM. As the first generation of *Artemia* mature during April and May, they covert particulate nitrogen in the form of phytoplankton to ammonium via grazing and excretion, and ammonium concentrations increase to non-limiting concentrations (>5 μM). Thus by increasing supply through excretion and limiting demand by reducing algal populations, *Artemia* relieve nutrient limitation. However, they also export a significant amount of nitrogen to the hypolimnion via rapidly sinking fecal pellets and ammonium concentrations decline through the summer. In autumn, deepening of the mixed layer accompanying seasonal cooling entrains nutrients accumulated in the hypolimnion and, as the *Artemia* population declines, an algal bloom occurs. This general pattern was observed during the 5-yr period of monomixis, 1990–94.

During episodes of meromixis following high runoff years, chemical stratification modifies this seasonal pattern. Rapid lake level rise in 1995 resulted in chemical stratification early in the year and ammonium and chlorophyll *a* concentrations were reduced compared to monomictic years (e.g. 1994, Fig. 2.19). Continually rising lake levels throughout the rest of 1995 and into 1996 prevented winter holomixis and thus initiated meromixis. Because the mixolimnion deepened only marginally during autumn cooling, winter holomixis was prevented and the autumn phytoplankton bloom and winter increase in ammonium concentrations within the euphotic zone were absent. Under continuing meromictic conditions, mixolimnetic ammonium and chlorophyll concentrations were reduced in 1996 through 1999 (Fig 2.19). However, a prominent increase in chlorophyll was observed in December 1999 and may indicate a lessening of the effects of meromixis similar to that observed in the 1980s episode of meromixis.

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Table 2.1. Temperature at Station S-30, 1999 (°C)

	Dates										
Depth (m)	2-19	3-18	4-15	5-12	6-15	7-15	8-18	9-23	10-20	11-11	12-6
1	2.47	5.09	6.31	11.93	15.73	20.63	18.32	17.93	14.76	11.89	7.47
2	2.28	4.99	6.82	11.96	15.68	20.82	18.58	17.95	14.75	11.81	7.44
3	2.21	4.58	6.83	11.84	15.59	20.92	18.60	17.95	14.77	11.79	7.43
4	2.15	4.37	5.75	11.27	15.56	20.96	18.59	17.95	14.77	11.80	7.45
5	2.10	4.16	5.32	10.67	15.53	21.01	18.53	17.95	14.78	11.81	7.46
6	2.08	4.20	4.93	10.13	15.55	20.93	18.51	17.95	14.78	11.79	7.46
7	2.07	4.10	4.63	9.24	14.80	20.75	18.50	18.00	14.83	11.75	7.46
8	2.07	3.98	4.60	8.72	14.57	20.28	18.50	18.25	14.87	11.77	7.46
9	2.07	3.87	4.53	8.05	13.97	19.69	18.52	18.38	14.88	11.82	7.44
10	2.07	3.86	4.52	7.80	13.22	18.45	18.54	18.27	14.99	11.74	7.44
11	2.07	3.82	4.60	7.39	12.70	16.90	18.70	18.00	15.09	11.74	7.43
12	2.09	3.80	4.57	7.20	10.35	13.89	18.08	17.86	15.06	11.77	7.42
13	2.12	3.76	4.61	6.87	8.63	10.12	16.13	17.18	15.03	11.77	7.36
14	2.10	3.70	4.61	6.51	7.68	9.07	13.25	15.43	15.01	11.73	7.33
15	2.08	3.62	4.65	6.05	7.02	8.55	10.85	11.93	14.68	11.66	7.30
16	2.08	3.55	4.61	5.63	6.41	8.00	9.10	9.77	13.65	11.61	7.29
17	2.10	3.44	4.55	5.39	5.94	7.25	7.99	8.61	10.23	11.48	7.28
18	2.17	3.33	4.53	5.14	5.90	6.91	7.45	8.15	8.97	11.03	7.27
19	3.74	3.33	4.49	4.98	5.75	6.54	7.20	7.55	7.82	9.44	7.25
20	4.87	4.15	4.44	4.82	5.51	6.19	6.65	7.11	7.02	7.71	7.16
21	5.02	4.72	4.54	4.70	5.18	5.68	5.97	6.22	6.35	6.41	6.84
22	5.07	4.91	4.82	4.78	4.89	5.12	5.36	5.56	5.63	5.73	6.19
23	5.07	4.98	4.93	4.91	4.90	4.98	5.06	5.20	5.27	5.30	5.59
24	5.03	4.99	4.97	4.96	4.92	4.93	4.97	5.08	5.09	5.14	5.28
25	4.96	4.97	4.96	4.97	4.94	4.95	4.97	5.00	5.02	5.04	5.15
26	4.93	4.95	4.95	4.97	4.94	4.98	4.96	4.96	4.98	4.98	5.04
27	4.93	4.93	4.94	4.96	4.93	4.95	4.96	4.96	4.97	4.96	5.01
28	4.92	4.92	4.93	4.96	4.93	4.96	4.97	4.96	4.95	4.96	4.98
29	4.91	4.91	4.93	4.95	4.93	4.96	4.95	4.94	4.95	4.95	4.97
30	4.90	4.90	4.92	4.95	4.93	4.96	4.96	4.94	4.94	4.94	4.96
31	4.90	4.90	4.92	4.95	4.94	4.94	4.97	4.93	4.94	4.93	4.95
32	4.89	4.89	4.92	4.94	4.93	4.94	4.95	4.94	4.93	4.93	4.95
33	4.89	4.89	4.92	4.93	4.92	4.93	4.98	4.93	4.93	4.93	4.94
34	-	-	-	-	-	4.92	4.94	4.92	4.93	4.93	4.93
35	-	-	-	-	-	4.96	4.98	4.93	4.92	4.93	4.93
36	-	-	-	-	-	-	-	4.93	4.94	4.92	4.92
37	-	-	-	-	-	-	-	4.92	-	4.92	-

Table 2.2. Conductivity (mS/cm at 25°C) at Station S-30, 1999

Depth (m)	2-19	3-18	4-15	5-12	6-15	7-15	8-18	9-23	10-20	11-11	12-6
					Dates						
1	77.43	77.09	77.28	77.31	76.68	76.57	77.14	77.31	78.07	78.35	78.62
2	77.53	77.43	77.52	77.30	76.97	76.80	77.48	77.61	78.08	78.35	78.68
3	77.55	77.27	77.59	77.35	77.02	76.86	77.48	77.61	78.09	78.38	78.71
4	77.56	77.35	77.50	77.40	77.03	76.90	77.48	77.61	78.09	78.40	78.74
5	77.56	77.44	77.59	77.52	77.03	76.93	77.49	77.62	78.10	78.41	78.74
6	77.57	77.56	77.57	77.42	77.23	76.95	77.50	77.62	78.11	78.42	78.74
7	77.58	77.55	77.57	77.43	77.29	77.10	77.51	77.65	78.17	78.42	78.76
8	77.58	77.60	77.62	77.46	77.40	77.09	77.51	77.87	78.17	78.45	78.76
9	77.58	77.60	77.63	77.46	77.40	77.08	77.54	77.95	78.19	78.47	78.76
10	77.58	77.63	77.65	77.51	77.36	76.93	77.59	77.93	78.41	78.45	78.77
11	77.58	77.62	77.69	77.50	77.46	76.96	77.73	77.93	78.43	78.46	78.78
12	77.62	77.63	77.68	77.64	77.05	76.96	77.53	77.92	78.43	78.47	78.77
13	77.63	77.63	77.72	77.59	77.49	77.09	77.43	77.75	78.44	78.49	78.77
14	77.62	77.63	77.72	77.59	77.58	77.54	77.22	77.66	78.46	78.49	78.78
15	77.63	77.64	77.75	77.58	77.66	77.69	77.22	77.45	78.45	78.49	78.79
16	77.64	77.72	77.72	77.67	77.81	77.87	77.59	77.61	78.24	78.51	78.80
17	77.66	77.74	77.75	77.73	78.07	78.02	77.82	77.95	78.03	78.59	78.81
18	77.69	77.76	77.78	77.88	78.42	78.31	78.38	78.35	78.22	78.70	78.82
19	82.33	78.34	77.97	78.20	78.64	78.74	78.81	78.79	78.83	78.67	78.82
20	84.35	83.61	81.62	81.49	79.54	79.41	79.57	79.41	79.83	79.30	78.82
21	85.09	84.95	84.59	84.37	83.72	82.92	83.13	82.98	83.05	83.39	82.28
22	85.40	85.88	85.80	85.67	86.06	85.47	85.28	85.34	85.40	85.44	85.00
23	86.22	86.54	86.43	86.41	86.47	86.23	86.20	86.08	86.13	86.18	85.77
24	86.79	86.91	86.74	86.64	86.69	86.72	86.61	86.33	86.46	86.53	86.29
25	87.16	87.16	86.94	86.86	86.90	86.92	86.80	86.66	86.75	86.79	86.58
26	87.33	87.31	87.13	87.03	87.04	87.09	86.90	86.93	86.91	87.04	86.81
27	87.37	87.42	87.25	87.14	87.19	87.23	86.99	87.04	87.04	87.18	86.95
28	87.43	87.51	87.31	87.20	87.29	87.25	87.04	87.11	87.13	87.26	87.08
29	87.50	87.58	87.35	87.26	87.36	87.34	87.12	87.20	87.19	87.30	87.15
30	87.53	87.64	87.40	87.30	87.39	87.40	87.17	87.25	87.25	87.37	87.20
31	87.54	87.69	87.43	87.35	87.44	87.49	87.22	87.30	87.30	87.41	87.24
32	87.61	87.71	87.45	87.39	87.50	87.52	87.27	87.33	87.34	87.42	87.28
33	87.65	87.77	87.47	87.43	87.56	87.55	87.27	87.36	87.36	87.44	87.31
35	-	-	-	-	-	87.57	87.38	87.40	87.37	87.45	87.34
36	-	-	-	-	-	87.52	87.48	87.40	87.38	87.42	87.36
37	-	-	-	-	-	-	-	87.42	87.38	87.49	87.38
	-	-	-	-	-	-	-	87.47	-	87.50	-

Table 2.3. Density (g/cm3) at Station S-30, 1999

Depth (m)	2-19	3-18	4-15	5-12	Dates 6-15	7-15	8-18	9-23	10-20	11-11	12-6
1	1.0664	1.0657	1.0657	1.0646	1.0629	1.0612	1.0626	1.0629	1.0647	1.0658	1.0670
2	1.0666	1.0661	1.0659	1.0646	1.0632	1.0614	1.0629	1.0632	1.0647	1.0658	1.0671
3	1.0666	1.0659	1.0659	1.0646	1.0633	1.0614	1.0629	1.0632	1.0647	1.0658	1.0671
4	1.0666	1.0661	1.0660	1.0648	1.0633	1.0615	1.0629	1.0632	1.0647	1.0658	1.0671
5	1.0666	1.0662	1.0662	1.0651	1.0633	1.0615	1.0629	1.0633	1.0647	1.0658	1.0671
6	1.0666	1.0663	1.0662	1.0651	1.0635	1.0615	1.0629	1.0633	1.0647	1.0659	1.0672
7	1.0666	1.0663	1.0663	1.0653	1.0638	1.0617	1.0630	1.0633	1.0648	1.0659	1.0672
8	1.0666	1.0664	1.0663	1.0654	1.0640	1.0619	1.0630	1.0634	1.0648	1.0659	1.0672
9	1.0666	1.0664	1.0664	1.0656	1.0642	1.0621	1.0630	1.0635	1.0648	1.0659	1.0672
10	1.0666	1.0665	1.0664	1.0657	1.0643	1.0623	1.0630	1.0635	1.0650	1.0659	1.0672
11	1.0666	1.0665	1.0664	1.0657	1.0646	1.0628	1.0631	1.0636	1.0650	1.0659	1.0672
12	1.0667	1.0665	1.0664	1.0659	1.0646	1.0637	1.0631	1.0636	1.0650	1.0659	1.0672
13	1.0667	1.0665	1.0665	1.0659	1.0655	1.0647	1.0636	1.0636	1.0650	1.0659	1.0672
14	1.0667	1.0665	1.0665	1.0660	1.0658	1.0655	1.0641	1.0641	1.0651	1.0660	1.0672
15	1.0667	1.0665	1.0665	1.0661	1.0660	1.0657	1.0647	1.0647	1.0651	1.0660	1.0672
16	1.0667	1.0666	1.0665	1.0662	1.0663	1.0661	1.0655	1.0654	1.0652	1.0660	1.0672
17	1.0667	1.0666	1.0665	1.0663	1.0666	1.0664	1.0660	1.0660	1.0658	1.0661	1.0673
18	1.0668	1.0667	1.0665	1.0666	1.0671	1.0668	1.0667	1.0666	1.0663	1.0664	1.0673
19	1.0719	1.0674	1.0668	1.0669	1.0673	1.0673	1.0673	1.0672	1.0672	1.0667	1.0673
20	1.0742	1.0734	1.0710	1.0708	1.0684	1.0681	1.0683	1.0680	1.0685	1.0677	1.0673
21	1.0750	1.0749	1.0745	1.0742	1.0734	1.0723	1.0725	1.0723	1.0724	1.0728	1.0714
22	1.0754	1.0760	1.0759	1.0758	1.0762	1.0755	1.0752	1.0752	1.0753	1.0753	1.0747
23	1.0764	1.0768	1.0767	1.0766	1.0767	1.0764	1.0764	1.0762	1.0762	1.0763	1.0758
24	1.0771	1.0772	1.0770	1.0769	1.0770	1.0770	1.0769	1.0765	1.0767	1.0768	1.0764
25	1.0775	1.0775	1.0773	1.0772	1.0772	1.0773	1.0771	1.0769	1.0770	1.0771	1.0768
26	1.0778	1.0777	1.0775	1.0774	1.0774	1.0775	1.0772	1.0773	1.0772	1.0774	1.0771
27	1.0778	1.0779	1.0777	1.0775	1.0776	1.0776	1.0773	1.0774	1.0774	1.0776	1.0773
28	1.0779	1.0780	1.0777	1.0776	1.0777	1.0777	1.0774	1.0775	1.0775	1.0777	1.0774
29	1.0780	1.0781	1.0778	1.0777	1.0778	1.0778	1.0775	1.0776	1.0776	1.0777	1.0775
30	1.0780	1.0781	1.0778	1.0777	1.0778	1.0778	1.0776	1.0777	1.0777	1.0778	1.0776
31	1.0780	1.0782	1.0779	1.0778	1.0779	1.0780	1.0776	1.0777	1.0777	1.0779	1.0776
32	1.0781	1.0782	1.0779	1.0778	1.0780	1.0780	1.0777	1.0778	1.0778	1.0779	1.0777
33	1.0782	1.0783	1.0779	1.0779	1.0780	1.0780	1.0777	1.0778	1.0778	1.0779	1.0777
34	-	-	-	-	-	1.0781	1.0778	1.0778	1.0778	1.0779	1.0778
35	-	-	-	-	-	1.0780	1.0779	1.0778	1.0778	1.0779	1.0778
36	-	-	-	-	-	-	-	1.0779	1.0778	1.0780	1.0778
37	-	-	-	-	-	-	-	1.0779	-	1.0780	-

Table 2.4. Temperature, conductivity, and density stratification (x 0.0001 g/cm3) at Station S30, 1999

Date	Temperature 2 m	Temperature 28 m	Conductivity 2 m	Conductivity 28 m	Density Difference due to Temperature	Density Difference due to Conductivity	Density Difference due to Both
2-19	2.28	4.92	77.53	87.43	-3.8	117.0	113.2
3-18	4.99	4.92	77.43	87.51	0.1	119.0	119.1
4-15	6.82	4.93	77.52	87.31	3.2	115.3	118.6
5-12	11.96	4.96	77.30	87.20	14.2	116.2	130.4
6-15	15.68	4.93	76.97	87.29	24.2	120.8	145.0
7-15	20.82	4.96	76.80	87.25	40.8	121.8	162.6
8-18	18.58	4.97	77.48	87.04	33.2	111.8	145.0
9-23	17.95	4.96	77.61	87.11	31.2	111.3	142.4
10-20	14.75	4.95	78.08	87.13	21.6	106.3	127.9
11-11	11.81	4.96	78.35	87.26	13.9	105.1	118.9
12-6	7.44	4.98	78.68	87.08	4.3	99.3	103.6

Table 2.5. Secchi Depths (m), 1999

	Dates										
Depth (m)	2-19	3-18	4-15	5-12	6-15	7-15	8-18	9-23	10-20	11-11	12-6
Eastern sector:											
2	1.80	1.70	1.60	2.45	11.30	11.25	11.25	9.70	3.70	2.55	1.70
4	1.90	1.70	1.90	2.40	9.00	10.00	11.00	8.80	4.00	2.40	1.50
6	1.90	1.80	1.85	3.75	10.30	11.50	10.95	10.75	3.50	2.25	1.30
ET5.6	1.70	1.80	1.90	3.00	7.50	10.50	11.40	10.25	5.20	2.90	1.25
15	1.80	1.75	1.95	3.90	11.00	11.10	13.00	9.95	4.40	2.90	1.50
16	1.90	1.90	2.05	3.10	12.50	11.75	12.50	10.50	4.00	3.15	1.30
17	2.10	1.75	1.75	2.50	13.50	11.00	12.75	9.00	3.75	3.00	1.25
18	1.75	1.90	1.80	2.50	13.80	11.55	12.25	9.35	3.75	2.75	1.45
19	1.75	1.70	1.90	2.75	13.50	11.60	11.30	9.75	4.10	2.55	1.35
20	1.80	1.95	1.90	2.50	13.50	-	10.70	8.00	4.75	2.55	1.45
Avg.	1.84	1.80	1.86	2.89	11.59	11.14	11.71	9.61	4.12	2.70	1.41
S.E.	0.04	0.03	0.04	0.17	0.68	0.19	0.26	0.27	0.17	0.09	0.05
n	10.00	10.00	10.00	10.00	10.00	9.00	10.00	10.00	10.00	10.00	10.00
Southern sector:											
13	2.10	2.05	1.80	2.45	8.00	11.70	11.00	10.00	7.80	2.45	1.70
14	2.00	1.90	1.90	2.65	8.00	10.65	11.90	9.15	8.50	2.50	1.70
S-10	1.90	1.90	2.10	3.00	8.25	12.45	11.50	9.75	5.90	2.70	1.50
S-30	1.80	1.70	1.70	2.95	9.10	12.00	9.50	10.95	7.50	2.75	1.80
Avg.	1.95	1.89	1.88	2.76	8.34	11.70	10.98	9.96	7.43	2.60	1.68
S.E.	0.06	0.07	0.09	0.13	0.26	0.38	0.53	0.37	0.55	0.07	0.06
n	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Western sector:											
8	1.95	2.00	2.00	2.70	8.00	11.50	9.55	9.80	7.00	2.70	1.70
9	1.90	1.75	2.30	2.75	7.25	11.00	11.00	9.50	7.75	2.45	1.50
10	2.10	1.70	2.05	2.13	9.25	12.00	10.65	11.10	8.50	2.35	1.50
11	1.90	1.80	1.80	2.50	7.80	12.00	10.75	10.25	8.50	2.90	1.50
12	2.00	1.90	1.90	2.70	7.75	12.15	10.95	10.20	7.75	2.95	1.60
21	2.10	1.90	1.95	2.55	8.00	12.00	10.65	9.50	7.75	2.20	1.50
Avg.	1.99	1.84	2.00	2.56	8.01	11.78	10.59	10.06	7.88	2.59	1.55
S.E.	0.04	0.05	0.07	0.09	0.27	0.18	0.22	0.25	0.23	0.12	0.03
n	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Total Lakewide:											
Avg.	1.91	1.83	1.91	2.76	9.87	11.46	11.23	9.81	5.91	2.65	1.50
S.E.	0.03	0.02	0.03	0.10	0.53	0.14	0.20	0.17	0.44	0.06	0.04
n	20.00	20.00	20.00	20.00	20.00	19.00	20.00	20.00	20.00	20.00	20.00

Table 2.6. Dissolved oxygen (mg/l) at Station S-30, 1999

	Dates									
Depth (m)	2-19	3-18	4-15	5-12	6-15	7-15	8-18	9-23	10-20	12-6
0	5.9	6.9	6.8	5.7	4.9	4.6	4.7	4.6	4.9	5.2
1	5.9	7.1	6.8	5.6	4.9	4.6	4.6	4.6	4.7	5.2
2	5.8	7.2	6.6	5.6	4.9	4.6	4.6	4.6	4.6	5.2
3	5.8	7.2	6.7	5.6	4.9	4.6	4.6	4.6	4.6	5.1
4	5.8	7.4	6.9	5.8	4.9	4.6	4.7	4.6	4.6	5.0
5	5.8	7.2	6.9	5.9	4.9	4.6	4.7	4.6	4.6	5.0
6	5.7	7.0	6.9	6.0	4.7	4.6	4.7	4.6	4.8	5.0
7	5.7	6.9	6.9	6.2	4.6	4.7	4.7	4.6	4.9	4.9
8	5.7	6.9	6.4	6.3	4.6	4.9	4.7	4.6	4.9	4.9
9	5.6	6.9	6.2	6.3	4.6	4.8	4.6	4.6	4.9	4.8
10	5.6	6.8	5.9	6.3	4.7	4.9	4.6	4.6	4.7	4.8
11	5.6	6.7	5.8	6.2	5.2	5.1	4.6	4.3	5.3	4.9
12	5.6	6.6	5.6	5.7	5.3	5.5	4.5	4.1	5.4	4.8
13	5.6	6.5	5.4	5.2	5.4	5.3	4.4	4.0	5.4	4.8
14	5.6	6.2	5.2	4.9	4.6	4.6	4.6	3.7	5.2	4.8
15	5.6	6.0	5.2	4.2	3.9	4.3	4.8	3.2	5.2	4.8
16	5.5	5.9	5.2	4.0	2.6	3.6	3.9	1.6	5.3	4.8
17	5.4	5.0	4.9	3.6	0.9	1.3	1.5	1.3	3.0	4.8
18	5.1	4.5	4.7	3.2	0.6	0.9	1.3	1.1	0.6	4.9
19	1.7	2.9	4.3	1.8	0.5	0.6	1.1	0.6	0.5	4.9
20	0.5	0.5	1.4	0.5	0.4	0.4	0.4	0.4	0.4	4.9
21	0.4	0.4	0.4	0.4	<0.5	<0.5	<0.5	<0.5	<0.5	5.0
22	<0.5	<0.5	0.4	0.4	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
23	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.4

Table 2.7. Ammonium at Station S-30, 1999 (µM)

Depth (m)	2-19	3-18	4-15	5-12	Dates 6-15	7-15	8-18	9-23	10-20	12-6
1	-	-	-	-	-	-	-	-	-	-
2	0.6	0.6	0.6	0.8	2.3	1.1	0.6	0.8	1.1	0.5
3	-	-	-	-	-	-	-	-	-	-
4	-	-	0.6	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	1.0	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	0.6	0.6	0.7	0.9	2.4	0.7	0.5	0.9	0.6	0.5
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	0.7	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-
12	0.8	0.7	1.1	0.9	1.4	0.8	1.1	2.0	0.7	0.6
13	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	3.6	-	-
15	-	-	-	-	-	-	-	-	-	-
16	0.9	0.7	0.8	1.1	3.6	0.9	0.7	3.9	1.2	0.7
17	-	-	-	-	-	-	-	-	-	-
18	1.7	1.3	1.1	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-
20	64.8	41.3	0.2	5.8	14.4	24.4	3.4	14.7	1.1	0.6
21	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	96.8	-	304.7
23	-	-	-	-	-	-	-	-	-	-
24	267.4	319.7	267.2	-	355.5	377.1	-	368.0	411.9	428.6
25	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	443.4	-
27	-	-	-	-	-	-	-	-	-	-
28	369.4	374.0	315.3	375.1	416.5	417.2	392.3	-	472.3	483.1
29	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	473.0	-
31	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-
35	393.7	404.0	333.6	396.5	452.5	437.7	417.3	451.2	499.2	517.8
9-m int.	0.5	0.5	0.5	1.2	2.0	0.9	1.0	0.8	1.5	0.4

Table 2.8. Chlorophyll a (µg/l) at Station S-30, 1999.

	Dates									
Depth (m)	2-19	3-18	4-15	5-12	6-15	7-15	8-18	9-23	10-20	12-6
1	-	-	-	-	-	-	-	-	-	-
2	11.2	15.9	9.7	2.9	0.9	1.5	2.1	1.4	2.8	24.6
3	-	-	-	-	-	-	-	-	-	-
4	-	-	11.2	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	5.6	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	12.7	16.8	18.4	6.6	1.4	1.4	2.2	1.6	4.7	24.6
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	1.7	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-
12	11.6	17.3	24.1	15.6	1.2	1.5	1.6	1.6	6.3	24.2
13	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	1.4	-	-
15	-	-	-	-	-	-	-	-	-	-
16	13.9	22.7	20.9	26.1	0.9	2.1	1.7	1.9	6.8	24.3
17	-	-	-	-	-	-	-	-	-	-
18	12.8	15.8	21.2	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-
20	31.5	20.1	23.8	32.2	103.9	48.2	47.9	62.2	2.9	24.0
21	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	33.1	-	40.4
23	-	-	-	-	-	-	-	-	-	-
24	35.4	33.0	32.2	-	35.6	38.2	-	31.5	30.5	29.6
25	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	31.0	-
27	-	-	-	-	-	-	-	-	-	-
28	30.7	30.7	29.3	31.2	31.6	32.7	34.3	-	32.7	28.8
29	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	33.1	-
9-m int.	13.1	17.1	12.2	4.4	1.2	1.4	2.1	1.5	3.6	24.2

Table 2.9a. Artemia lake and sector means, 1999.

	Instars 1-7	Instars 8-11	adult male	adult fem ?	adult fem e	adult fem c	adult fem n	adult fem tot	adult total	total
Lakewide Mean:										
2/19	26,156	0	0	0	0	0	0	0	0	26,156
3/18	34,683	0	0	0	0	0	0	0	0	34,683
4/15	41,974	0	0	0	0	0	0	0	0	41,974
5/12	60,596	105	0	0	0	0	0	0	0	60,700
6/15	11,191	35,646	10,221	696	6,322	274	24	7,316	17,537	64,374
7/15	5,408	9,199	21,795	2,857	6,310	7,413	64	16,644	38,439	53,046
8/18	3,042	584	22,644	2,181	2,121	8,229	16	12,547	35,191	38,817
9/23	1,551	24	19,634	471	121	9,690	4	10,286	29,920	31,495
10/20	1,138	91	7,975	178	74	3,949	0	4,201	12,176	13,405
11/11	1,346	378	2,107	34	59	565	0	659	2,766	4,490
12/6	610	83	21	0	7	1	0	8	29	722
Eastern Sector Mean:										
2/19	40,048	0	0	0	0	0	0	0	0	40,048
3/18	59,111	0	0	0	0	0	0	0	0	59,111
4/15	57,368	0	0	0	0	0	0	0	0	57,368
5/12	89,441	193	0	0	0	0	0	0	0	89,634
6/15	14,036	60,523	11,525	386	8,306	419	0	9,111	20,636	95,195
7/15	4,990	8,676	18,656	3,300	6,600	6,906	97	16,901	35,557	49,224
8/18	3,252	475	16,845	2,028	1,763	9,843	0	13,634	30,479	34,205
9/23	1,815	16	13,706	475	129	9,996	8	10,608	24,314	26,145
10/20	1,551	133	4,054	42	20	863	0	926	4,980	6,664
11/11	1,805	362	779	8	34	46	0	89	867	3,034
12/6	1,074	104	16	0	6	2	0	8	24	1,203
Southern Sector Mean:										
2/19	11,826	0	0	0	0	0	0	0	0	11,826
3/18	7,636	0	0	0	0	0	0	0	0	7,636
4/15	12,646	0	0	0	0	0	0	0	0	12,646
5/12	39,638	0	0	0	0	0	0	0	0	39,638
6/15	8,451	15,533	10,906	1,087	4,668	201	81	6,036	16,942	40,926
7/15	6,358	10,221	27,887	3,300	6,519	9,095	0	18,914	46,801	63,380
8/18	2,374	1,006	36,620	3,743	3,501	9,779	40	17,063	53,682	57,062
9/23	1,248	81	29,618	684	81	10,302	0	11,067	40,684	42,012
10/20	1,006	101	9,397	161	181	5,896	0	6,237	15,634	16,741
11/11	971	559	2,797	35	85	1,308	0	1,429	4,226	5,755
12/6	181	60	35	0	0	0	0	0	35	277
Western Sector Mean:										
2/19	12,556	0	0	0	0	0	0	0	0	12,556
3/18	12,002	0	0	0	0	0	0	0	0	12,002
4/15	35,869	0	0	0	0	0	0	0	0	35,869
5/12	26,493	27	0	0	0	0	0	0	0	26,519
6/15	8,276	7,592	7,593	952	4,118	81	27	5,178	12,770	28,638
7/15	5,473	9,390	22,965	1,824	5,688	7,136	54	14,702	37,666	52,529
8/18	3,139	483	22,991	1,395	1,798	4,507	27	7,726	30,718	34,339
9/23	1,315	0	22,857	322	134	8,773	0	9,229	32,086	33,401
10/20	537	13	13,562	416	94	7,793	0	8,303	21,864	22,415
11/11	832	285	3,860	77	84	936	0	1,097	4,956	6,073
12/6	121	64	20	0	13	0	0	13	33	218

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii (na): missing data

Table 2.9b. Standard errors of Artemia sector means (Table 9a), 1999.

	Instars 1-7	Instars 8-11	adult male	adult fem ?	adult fem e	adult fem c	adult fem n	adult fem tot	adult total	total
SE of Lakewide Mean:										
2/19	4,384	0	0	0	0	0	0	0	0	4,384
3/18	8,657	0	0	0	0	0	0	0	0	8,657
4/15	7,497	0	0	0	0	0	0	0	0	7,497
5/12	12,266	70	0	0	0	0	0	0	0	12,315
6/15	1,138	7,129	946	152	942	90	18	1,011	1,802	9,375
7/15	566	944	1,695	350	456	675	30	1,162	2,676	3,735
8/18	413	89	2,639	317	235	1,046	11	1,428	3,616	3,788
9/23	191	18	2,073	82	39	956	4	1,012	2,588	2,574
10/20	189	22	1,299	60	28	1,059	0	1,118	2,368	2,267
11/11	267	49	417	11	9	161	0	174	564	588
12/6	152	19	4	0	3	1	0	4	6	164
SE of Eastern Sector Mean:										
2/19	6,092	0	0	0	0	0	0	0	0	6,092
3/18	13,386	0	0	0	0	0	0	0	0	13,386
4/15	10,753	0	0	0	0	0	0	0	0	10,753
5/12	19,390	137	0	0	0	0	0	0	0	19,488
6/15	1,789	8,455	1,350	172	1,596	167	0	1,753	2,994	12,024
7/15	578	1,394	1,644	467	641	1,015	49	1,558	3,079	4,078
8/18	707	80	2,090	327	262	1,478	0	1,926	3,897	4,431
9/23	265	16	1,857	113	58	1,380	8	1,460	3,181	3,373
10/20	293	27	790	14	6	149	0	160	838	867
11/11	487	77	172	3	10	12	0	19	176	674
12/6	220	37	4	0	4	2	0	6	8	248
SE of Southern Sector Mean:										
2/19	2,272	0	0	0	0	0	0	0	0	2,272
3/18	1,346	0	0	0	0	0	0	0	0	1,346
4/15	7,242	0	0	0	0	0	0	0	0	7,242
5/12	21,500	0	0	0	0	0	0	0	0	21,500
6/15	1,079	5,202	2,785	331	749	77	81	1,171	3,135	8,152
7/15	2,145	3,199	6,642	1,103	1,535	2,038	0	4,405	10,736	15,787
8/18	433	325	8,848	1,087	582	2,843	40	4,091	11,891	12,171
9/23	282	81	4,870	212	81	2,380	0	2,588	4,007	3,806
10/20	302	76	3,035	68	102	2,085	0	2,144	5,179	4,995
11/11	347	66	1,021	17	13	467	0	480	1,414	1,447
12/6	26	20	17	0	0	0	0	0	17	21
SE of Western Sector Mean:										
2/19	1,172	0	0	0	0	0	0	0	0	1,172
3/18	3,407	0	0	0	0	0	0	0	0	3,407
4/15	11,957	0	0	0	0	0	0	0	0	11,957
5/12	4,958	27	0	0	0	0	0	0	0	4,983
6/15	964	882	867	310	847	36	27	989	1,590	2,737
7/15	1,018	1,063	1,460	329	586	741	54	769	1,979	2,814
8/18	718	93	2,559	142	201	333	27	495	2,561	2,846
9/23	414	0	2,738	138	77	1,830	0	1,886	4,601	4,359
10/20	171	13	2,043	162	53	2,398	0	2,533	4,536	4,471
11/11	64	64	659	28	13	221	0	253	834	866
12/6	39	18	7	0	7	0	0	7	12	56

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii (na): missing data

Table 2.9c. Percentage in different classes for Artemia sector means (Table 9a), 1999.

	Instars 1-7	Instars 8-11	adult male	adult fem ?	adult fem e	adult fem c	adult fem n	adult fem tot	adult total	total
Lakewide (%):										
2/19	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
3/18	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/15	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
5/12	99.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
6/15	17.4	55.4	15.9	9.5	86.4	3.7	0.3	11.4	27.2	100.0
7/15	10.2	17.3	41.1	17.2	37.9	44.5	0.4	31.4	72.5	100.0
8/18	7.8	1.5	58.3	17.4	16.9	65.6	0.1	32.3	90.7	100.0
9/23	4.9	0.1	62.3	4.6	1.2	94.2	0.0	32.7	95.0	100.0
10/20	8.5	0.7	59.5	4.2	1.8	94.0	0.0	31.3	90.8	100.0
11/11	30.0	8.4	46.9	5.2	9.0	85.7	0.0	14.7	61.6	100.0
12/6	84.5	11.5	2.9	0.0	87.5	12.5	0.0	1.1	4.0	100.0
Eastern Sector (%):										
2/19	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
3/18	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/15	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
5/12	99.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
6/15	14.7	63.6	12.1	4.2	91.2	4.6	0.0	9.6	21.7	100.0
7/15	10.1	17.6	37.9	19.5	39.1	40.9	0.6	34.3	72.2	100.0
8/18	9.5	1.4	49.2	14.9	12.9	72.2	0.0	39.9	89.1	100.0
9/23	6.9	0.1	52.4	4.5	1.2	94.2	0.1	40.6	93.0	100.0
10/20	23.3	2.0	60.8	4.5	2.2	93.2	0.0	13.9	74.7	100.0
11/11	59.5	11.9	25.7	9.0	38.2	51.7	0.0	2.9	28.6	100.0
12/6	89.3	8.6	1.3	0.0	75.0	25.0	0.0	0.7	2.0	100.0
Southern Sector (%):										
2/19	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
3/18	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/15	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
5/12	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
6/15	20.6	38.0	26.6	18.0	77.3	3.3	1.3	14.7	41.4	100.0
7/15	10.0	16.1	44.0	17.4	34.5	48.1	0.0	29.8	73.8	100.0
8/18	4.2	1.8	64.2	21.9	20.5	57.3	0.2	29.9	94.1	100.0
9/23	3.0	0.2	70.5	6.2	0.7	93.1	0.0	26.3	96.8	100.0
10/20	6.0	0.6	56.1	2.6	2.9	94.5	0.0	37.3	93.4	100.0
11/11	16.9	9.7	48.6	2.4	5.9	91.5	0.0	24.8	73.4	100.0
12/6	65.3	21.7	12.6	0.0	0.0	0.0	0.0	0.0	12.6	100.0
Western Sector (%):										
2/19	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
3/18	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/15	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
5/12	99.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
6/15	28.9	26.5	26.5	18.4	79.5	1.6	0.5	18.1	44.6	100.0
7/15	10.4	17.9	43.7	12.4	38.7	48.5	0.4	28.0	71.7	100.0
8/18	9.1	1.4	67.0	18.1	23.3	58.3	0.3	22.5	89.5	100.0
9/23	3.9	0.0	68.4	3.5	1.5	95.1	0.0	27.6	96.1	100.0
10/20	2.4	0.1	60.5	5.0	1.1	93.9	0.0	37.0	97.5	100.0
11/11	13.7	4.7	63.6	7.0	7.7	85.3	0.0	18.1	81.6	100.0
12/6	55.5	29.4	9.2	0.0	100.0	0.0	0.0	6.0	15.1	100.0

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii (na): missing data
The fem-?,e,c,n percentages are of the total females.

Table 2.10. Lakewide Artemia instar analysis, 1999.

	Instars 1	2	3	4	5	6	7	8-11	adults	total
Mean:										
2/19	18,645	40	0	0	0	0	0	0	0	18,685
3/18	33,126	1,123	0	0	0	0	0	0	0	34,249
4/15	12,327	29,390	107	0	0	0	0	0	0	41,824
5/12	4,078	9,363	12,247	12,542	24,588	16,566	8,102	322	0	87,807
6/15	3,863	2,039	644	537	899	657	738	23,608	14,514	47,498
7/15	2,790	2,924	27	0	0	0	54	11,000	42,629	59,423
8/18	1,100	1,047	0	0	0	0	0	510	36,271	38,927
9/23	617	1,208	27	54	0	0	0	54	34,769	36,727
10/20	94	332	194	60	60	24	13	97	11,586	12,462
11/11	258	486	308	164	171	84	107	523	4,071	6,174
12/6	121	74	10	30	34	20	37	47	20	393
Standard error of mean:										
2/19	3,484	27	0	0	0	0	0	0	0	3,501
3/18	22,493	663	0	0	0	0	0	0	0	23,021
4/15	3,464	9,510	49	0	0	0	0	0	0	12,800
5/12	1,048	3,899	4,896	4,677	8,625	5,862	3,399	220	0	30,287
6/15	745	480	181	129	287	212	300	9,289	2,137	11,671
7/15	830	774	27	0	0	0	54	1,920	7,029	10,068
8/18	289	269	0	0	0	0	0	113	7,229	7,182
9/23	87	310	27	54	0	0	0	54	3,740	3,603
10/20	58	70	45	25	41	20	8	48	4,270	4,229
11/11	125	297	151	85	59	42	53	78	1,338	1,345
12/6	65	58	10	26	26	13	25	19	10	222
Percentage in different age classes:										
2/19	99.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
3/18	96.7	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/15	29.5	70.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	100.0
5/12	4.6	10.7	13.9	14.3	28.0	18.9	9.2	0.4	0.0	100.0
6/15	8.1	4.3	1.4	1.1	1.9	1.4	1.6	49.7	30.6	100.0
7/15	4.7	4.9	0.0	0.0	0.0	0.0	0.1	18.5	71.7	100.0
8/18	2.8	2.7	0.0	0.0	0.0	0.0	0.0	1.3	93.2	100.0
9/23	1.7	3.3	0.1	0.1	0.0	0.0	0.0	0.1	94.7	100.0
10/20	0.8	2.7	1.6	0.5	0.5	0.2	0.1	0.8	93.0	100.0
11/11	4.2	7.9	5.0	2.7	2.8	1.4	1.7	8.5	65.9	100.0
12/6	30.8	18.8	2.5	7.6	8.7	5.1	9.4	12.0	5.1	100.0

Table 2.11a. Artemia reproductive summary, lake and sector means, 1999.

	Adult Females Total	Ovig	e	?	c	n
Lakewide Mean:						
2/19	0	0	0	0	0	0
3/18	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/12	0	0	0	0	0	0
6/15	7,316	994	6,322	696	274	24
7/15	16,644	10,334	6,310	2,857	7,413	64
8/18	12,547	10,427	2,121	2,181	8,229	16
9/23	10,286	10,165	121	471	9,690	4
10/20	4,201	4,127	74	178	3,949	0
11/11	659	599	59	34	565	0
12/6	8	1	7	0	1	0
Eastern Sector Mean:						
2/19	0	0	0	0	0	0
3/18	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/12	0	0	0	0	0	0
6/15	9,111	805	8,306	386	419	0
7/15	16,901	10,302	6,600	3,300	6,906	97
8/18	13,634	11,871	1,763	2,028	9,843	0
9/23	10,608	10,479	129	475	9,996	8
10/20	926	905	20	42	863	0
11/11	89	54	34	8	46	0
12/6	8	2	6	0	2	0
Southern Sector Mean:						
2/19	0	0	0	0	0	0
3/18	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/12	0	0	0	0	0	0
6/15	6,036	1,369	4,668	1,087	201	81
7/15	18,914	12,394	6,519	3,300	9,095	0
8/18	17,063	13,562	3,501	3,743	9,779	40
9/23	11,067	10,986	81	684	10,302	0
10/20	6,237	6,057	181	161	5,896	0
11/11	1,429	1,343	85	35	1,308	0
12/6	0	0	0	0	0	0
Western Sector Mean:						
2/19	0	0	0	0	0	0
3/18	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/12	0	0	0	0	0	0
6/15	5,178	1,060	4,118	952	81	27
7/15	14,702	9,014	5,688	1,824	7,136	54
8/18	7,726	5,929	1,798	1,395	4,507	27
9/23	9,229	9,095	134	322	8,773	0
10/20	8,303	8,209	94	416	7,793	0
11/11	1,097	1,013	84	77	936	0
12/6	13	0	13	0	0	0

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii (na): missing data

Table 2.11b. Standard errors of Artemia reproductive summary (Table 11a), 1999.

	Total	Ovigery	Adult Females e	?	c	n
Standard Error of Lakewide Mean:						
2/19	0	0	0	0	0	0
3/18	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/12	0	0	0	0	0	0
6/15	1,011	190	942	152	90	18
7/15	1,162	886	456	350	675	30
8/18	1,428	1,269	235	317	1,046	11
9/23	1,012	1,006	39	82	956	4
10/20	1,118	1,103	28	60	1,059	0
11/11	174	167	9	11	161	0
12/6	4	1	3	0	1	0
Standard Error of Eastern Sector Mean:						
2/19	0	0	0	0	0	0
3/18	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/12	0	0	0	0	0	0
6/15	1,753	268	1,596	172	167	0
7/15	1,558	1,279	641	467	1,015	49
8/18	1,926	1,706	262	327	1,478	0
9/23	1,460	1,437	58	113	1,380	8
10/20	160	157	6	14	149	0
11/11	19	12	10	3	12	0
12/6	6	2	4	0	2	0
Standard Error of Southern Sector Mean:						
2/19	0	0	0	0	0	0
3/18	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/12	0	0	0	0	0	0
6/15	1,171	462	749	331	77	81
7/15	4,405	3,070	1,535	1,103	2,038	0
8/18	4,091	3,686	582	1,087	2,843	40
9/23	2,588	2,534	81	212	2,380	0
10/20	2,144	2,054	102	68	2,085	0
11/11	480	471	13	17	467	0
12/6	0	0	0	0	0	0
Standard Error of Western Sector Mean:						
2/19	0	0	0	0	0	0
3/18	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/12	0	0	0	0	0	0
6/15	989	350	847	310	36	27
7/15	769	588	586	329	741	54
8/18	495	412	201	142	333	27
9/23	1,886	1,924	77	138	1,830	0
10/20	2,533	2,524	53	162	2,398	0
11/11	253	243	13	28	221	0
12/6	7	0	7	0	0	0

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii (na): missing data

Table 2.11c. Artemia percentages in different reproductive categories (Table 11a), 1999.

	Total	Ovigery	Adult e	Females ?	c	n
Lakewide Mean (%):						
2/19	0.0	0.0	0.0	0.0	0.0	0.0
3/18	0.0	0.0	0.0	0.0	0.0	0.0
4/15	0.0	0.0	0.0	0.0	0.0	0.0
5/12	0.0	0.0	0.0	0.0	0.0	0.0
6/15	100.0	13.6	86.4	70.0	91.9	8.1
7/15	100.0	62.1	37.9	27.6	99.1	0.9
8/18	100.0	83.1	16.9	20.9	99.8	0.2
9/23	100.0	98.8	1.2	4.6	100.0	0.0
10/20	100.0	98.2	1.8	4.3	100.0	0.0
11/11	100.0	90.9	9.0	5.7	100.0	0.0
12/6	100.0	12.5	87.5	0.0	100.0	0.0
Eastern Sector Mean (%):						
2/19	0.0	0.0	0.0	0.0	0.0	0.0
3/18	0.0	0.0	0.0	0.0	0.0	0.0
4/15	0.0	0.0	0.0	0.0	0.0	0.0
5/12	0.0	0.0	0.0	0.0	0.0	0.0
6/15	100.0	8.8	91.2	48.0	100.0	0.0
7/15	100.0	61.0	39.1	32.0	98.6	1.4
8/18	100.0	87.1	12.9	17.1	100.0	0.0
9/23	100.0	98.8	1.2	4.5	99.9	0.1
10/20	100.0	97.7	2.2	4.6	100.0	0.0
11/11	100.0	60.7	38.2	14.8	100.0	0.0
12/6	100.0	25.0	75.0	0.0	100.0	0.0
Southern Sector Mean (%):						
2/19	0.0	0.0	0.0	0.0	0.0	0.0
3/18	0.0	0.0	0.0	0.0	0.0	0.0
4/15	0.0	0.0	0.0	0.0	0.0	0.0
5/12	0.0	0.0	0.0	0.0	0.0	0.0
6/15	100.0	22.7	77.3	79.4	71.3	28.7
7/15	100.0	65.5	34.5	26.6	100.0	0.0
8/18	100.0	79.5	20.5	27.6	99.6	0.4
9/23	100.0	99.3	0.7	6.2	100.0	0.0
10/20	100.0	97.1	2.9	2.7	100.0	0.0
11/11	100.0	94.0	5.9	2.6	100.0	0.0
12/6	0.0	0.0	0.0	0.0	0.0	0.0
Western Sector Mean (%):						
2/19	0.0	0.0	0.0	0.0	0.0	0.0
3/18	0.0	0.0	0.0	0.0	0.0	0.0
4/15	0.0	0.0	0.0	0.0	0.0	0.0
5/12	0.0	0.0	0.0	0.0	0.0	0.0
6/15	100.0	20.5	79.5	89.8	75.0	25.0
7/15	100.0	61.3	38.7	20.2	99.2	0.8
8/18	100.0	76.7	23.3	23.5	99.4	0.6
9/23	100.0	98.5	1.5	3.5	100.0	0.0
10/20	100.0	98.9	1.1	5.1	100.0	0.0
11/11	100.0	92.3	7.7	7.6	100.0	0.0
12/6	100.0	0.0	100.0	0.0	0.0	0.0

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii (na): missing data
Total, ovigery, and e given as percentages of total number of females.
? given as percentage is of ovigerous females.
Cyst and naup given as percentages of individuals with differentiated egg masses.

Table 2.12. Artemia fecundity summary, 1998.

	#eggs/brood mean	SE	%cyst	%indented	female length mean	SE	n
Lakewide Mean:							
6/15	47.7	2.6	95.0	1.0	10.3	0.1	10
7/15	37.1	1.7	100.0	43.0	10.0	0.1	10
8/18	27.2	1.4	100.0	52.0	10.0	0.1	10
9/23	36.9	1.6	100.0	54.0	10.3	0.1	10
10/20	47.2	2.6	100.0	53.0	10.7	0.1	10
Eastern Sector Mean:							
6/15	42.0	4.3	100.0	3.0	9.8	0.1	4
7/15	39.2	1.9	100.0	48.0	10.2	0.2	4
8/18	27.8	1.5	100.0	58.0	10.2	0.1	4
9/23	37.8	2.0	100.0	50.0	10.3	0.0	4
10/20	47.6	5.8	100.0	58.0	10.7	0.1	4
Southern Sector Mean:							
6/15	52.7	4.3	88.0	0.0	10.4	0.3	2
7/15	36.9	3.0	100.0	40.0	9.9	0.4	2
8/18	27.7	0.2	100.0	40.0	9.8	0.2	2
9/23	32.5	5.9	100.0	45.0	10.4	0.2	2
10/20	53.7	4.8	100.0	55.0	10.7	0.1	2
Western Sector Mean:							
6/15	50.9	3.0	94.0	0.0	10.6	0.1	4
7/15	35.1	3.8	100.0	40.0	9.9	0.1	4
8/18	26.3	3.3	100.0	53.0	10.0	0.2	4
9/23	38.1	2.1	100.0	63.0	10.3	0.2	4
10/20	43.6	1.9	100.0	48.0	10.6	0.2	4

n in the last column refers to number of stations averaged together.
Ten females were collected and measured from each station.

Table 2.13. Summary Statistics of Adult Artemia Abundance from 1 May through 30 November, 1979–99

Year	Mean	Median	Peak	Centroid*
1979	14118	12286	31700	216
1980	14643	10202	40420	236
1981	32010	21103	101670	238
1982	36643	31457	105245	252
1983	17812	16314	39917	247
1984	17001	19261	40204	212
1985	18514	20231	33089	218
1986	14667	17305	32977	190
1987	23952	22621	54278	226
1988	27639	25505	71630	207
1989	36359	28962	92491	249
1990	20005	16775	34930	230
1991	18129	19319	34565	226
1992	19019	19595	34648	215
1993	15025	16684	26906	217
1994	16602	18816	29408	212
1995	15584	17215	24402	210
1996	17734	17842	34616	216
1997	14389	16372	27312	204
1998	19429	21235	33968	226
1999	20221	21547	38439	225

*Centroid calculated as the abundance-weighted mean day of occurrence.

Figure Captions

Figure 2.1. UCSB sampling stations at Mono Lake. Solid circles represent permanently moored buoys.

Figure 2.2. Mono Lake surface elevation (ft asl), 1979–98, USGS datum.

Figure 2.3. Temperature (°C) at station S30, 1998.

Figure 2.4. Conductivity (mS cm^{-1} corrected to 25°C) at station S30, 1998.

Figure 2.5. Density – 1000 (kg m^{-3}) at station S30, 1998.

Figure 2.6. Density difference (10^{-4} g cm^{-3}) between 2 and 28 m at station S30 due to temperature and chemical stratification from 1983 through 1998.

Figure 2.7. Winter salinity stratification, 1994–98.

Figure 2.8. Mean lakewide Secchi depth (m), 1994–98. Error bars show standard errors of the lakewide estimate based on twenty stations.

Figure 2.9. Mean lakewide Secchi depth ($\log_{10}$ m) 1979–98.

Figure 2.10. Light attenuation (% of surface) at station S30, 1998. Dots denote the dates and depths of samples.

Figure 2.11. Dissolved oxygen concentration (mg O_2 l^{-1}) at station S30, 1998.

Figure 2.12. Ammonium concentration (µM) at station S30, 1998. Dots denote the dates and depths of samples.

Figure 2.13. Concentration of chlorophyll *a* (µg chl *a* l^{-1}) at station S30, 1998. Dots denote the dates and depths of samples.

Figure 2.14. Lakewide *Artemia* abundance during 1998: adults (instars 12+, top), juveniles (instars 8-11, middle), and nauplii (instars 1-7, bottom).

Figure 2.15. Reproductive characteristics of *Artemia* during 1998: lakewide mean abundance of total females and ovigerous females (top), percent of females ovoviviparous and ovigerous (middle), and brood size (bottom). Vertical lines are the standard error of the estimate.

Figure 2.16. Lakewide estimates of adult *Artemia* based on 3-20 stations, 1979–98 (see Methods). The mean relative error of the lakewide estimates for all years is 23%.

Figure 2.17. Summary statistics of the seasonal (1 May through 30 November) lakewide abundance of adult *Artemia*, 1979–98.

Figure 2.18. Temporal center of abundance-weighted centroid of the seasonal (1 May through 30 November) distribution of adult *Artemia*, 1979–98.

Figure 2.19. Ammonium concentration (μM), algal biomass (chlorophyll *a*, 10^1 μg chl *a* l^{-1}), and *Artemia*

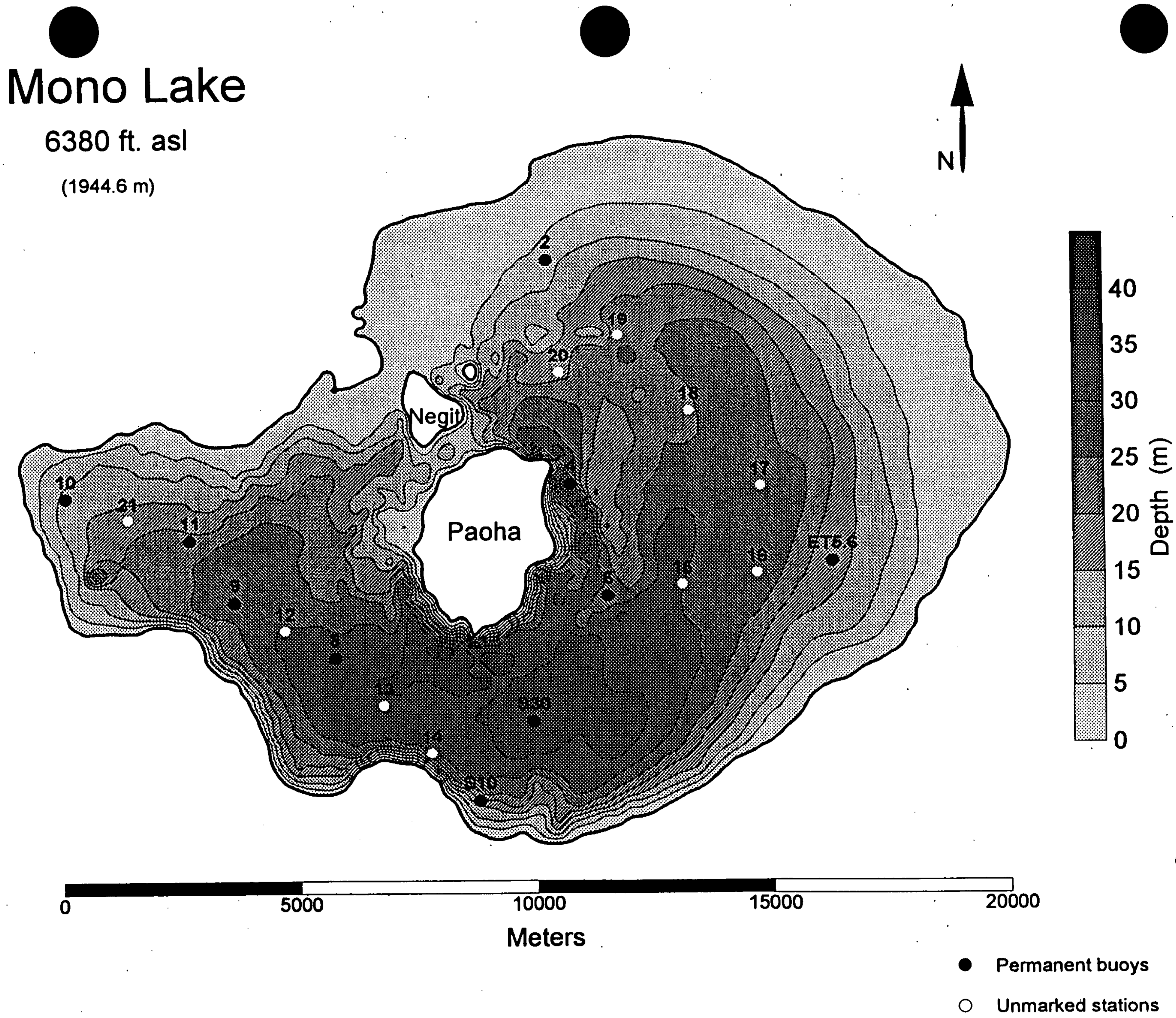

Mono Lake
6380 ft. asl
(1944.6 m)
N
Negit
Paoha
2
19
20
18
17
10
21
11
ET5.6
16
15
6
9
12
5
13
9.30
14
9.10
40
35
30
25
20
15
10
5
0
Depth (m)
0
5000
10000
15000
20000
Meters
Permanent buoys
Unmarked stations

Figure 2.1

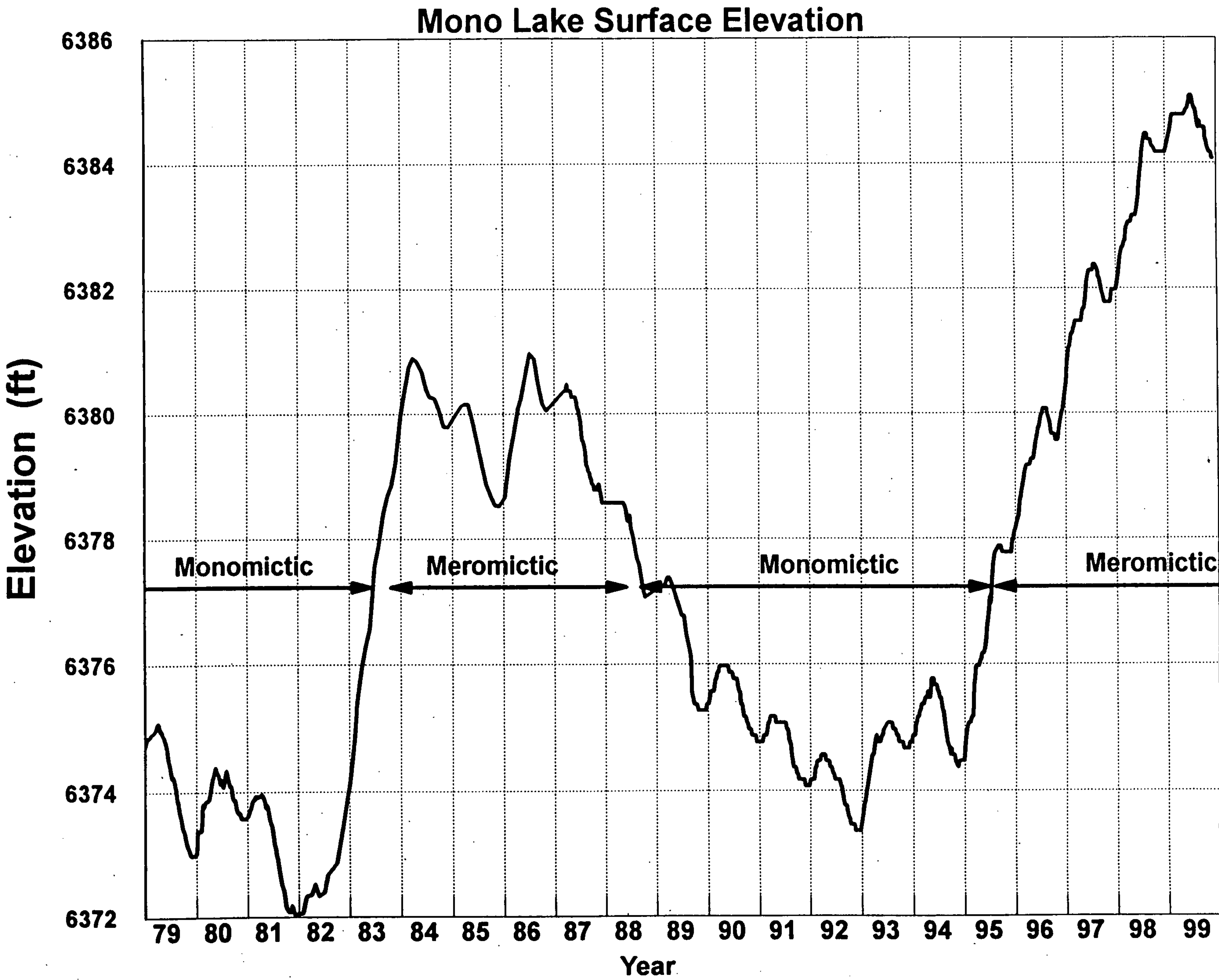
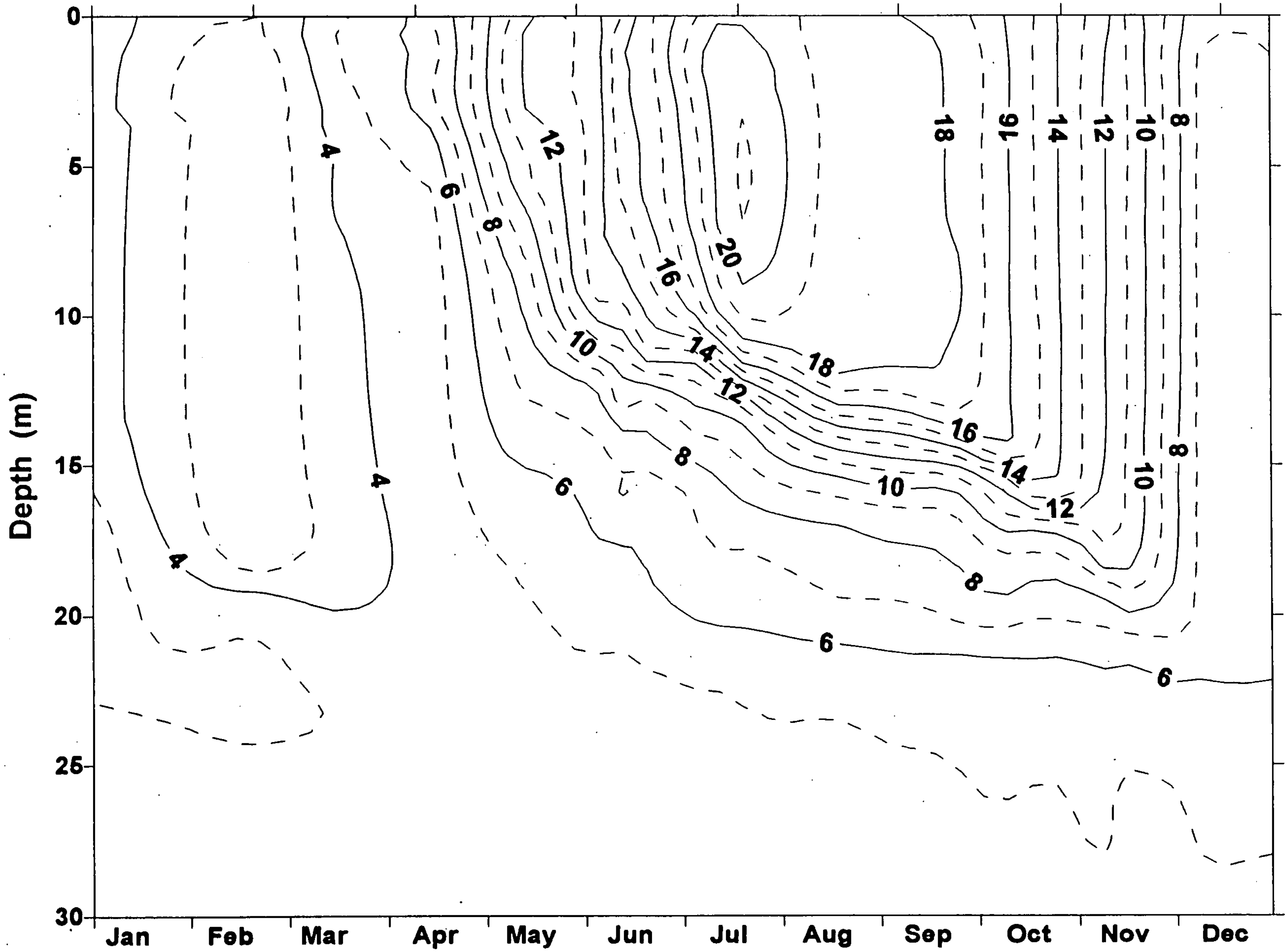

Mono Lake Surface Elevation
Elevation (ft)
6386
6384
6382
6380
6378
6376
6374
6372
Monomictic
Meromictic
Monomictic
Meromictic
79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99
Year

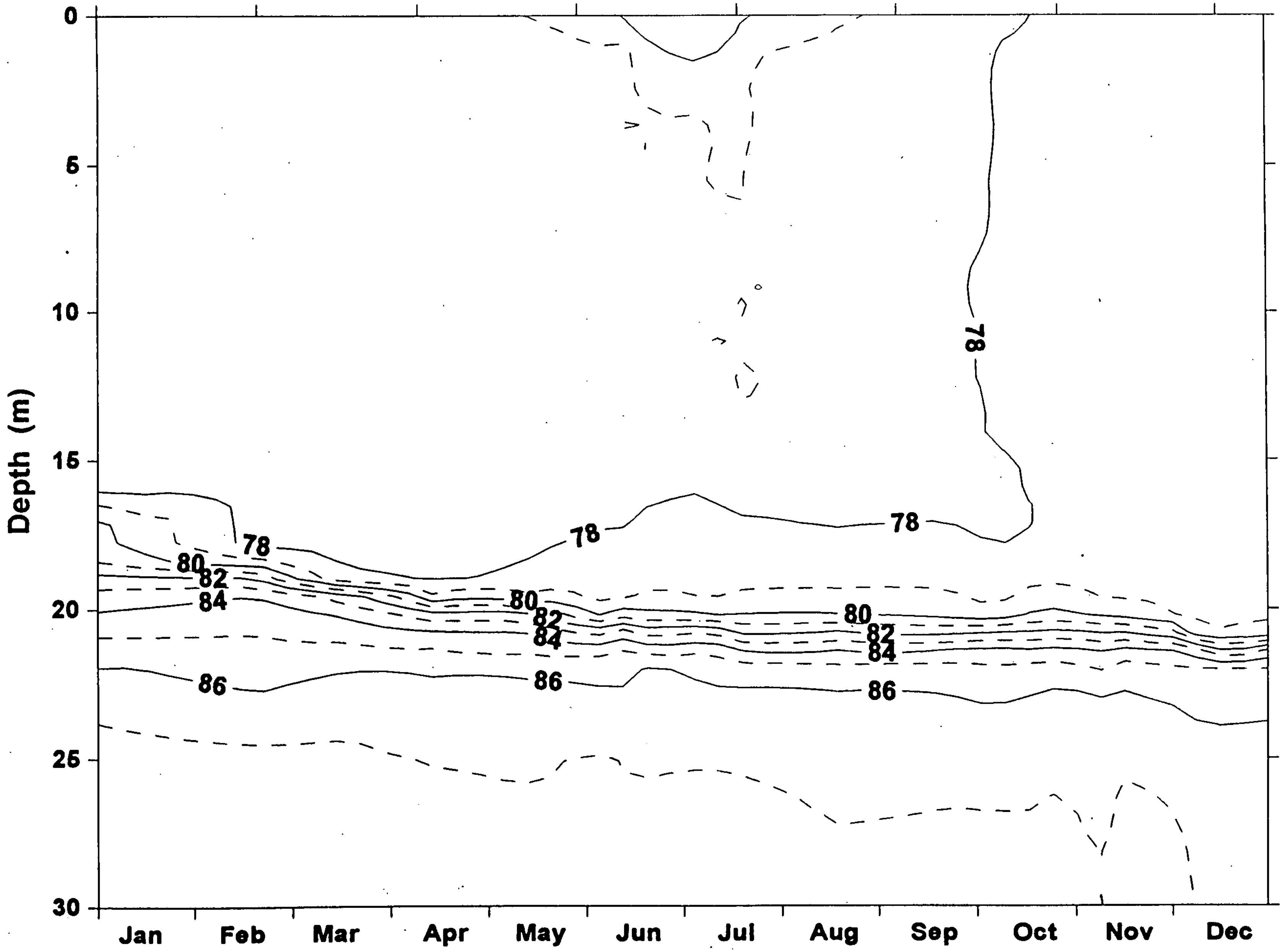
Figure 2.2



Temperature (C) at S30, 1999

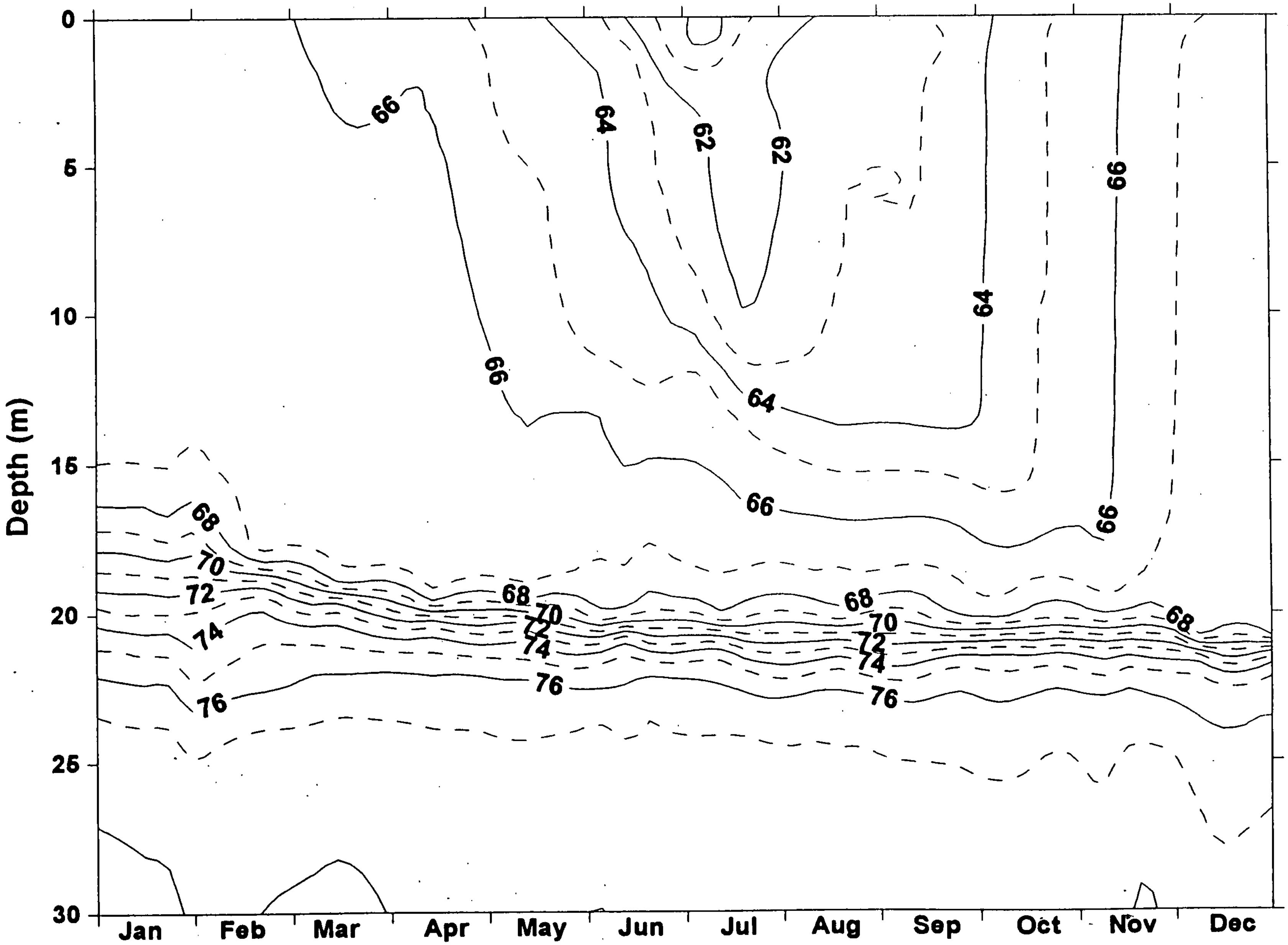
2.47

Figure 2.3



Conductivity (mS/cm) at S30, 1999

Figure 2.4



Density (1000 kg/m3) at S30, 1999

Figure 2.5

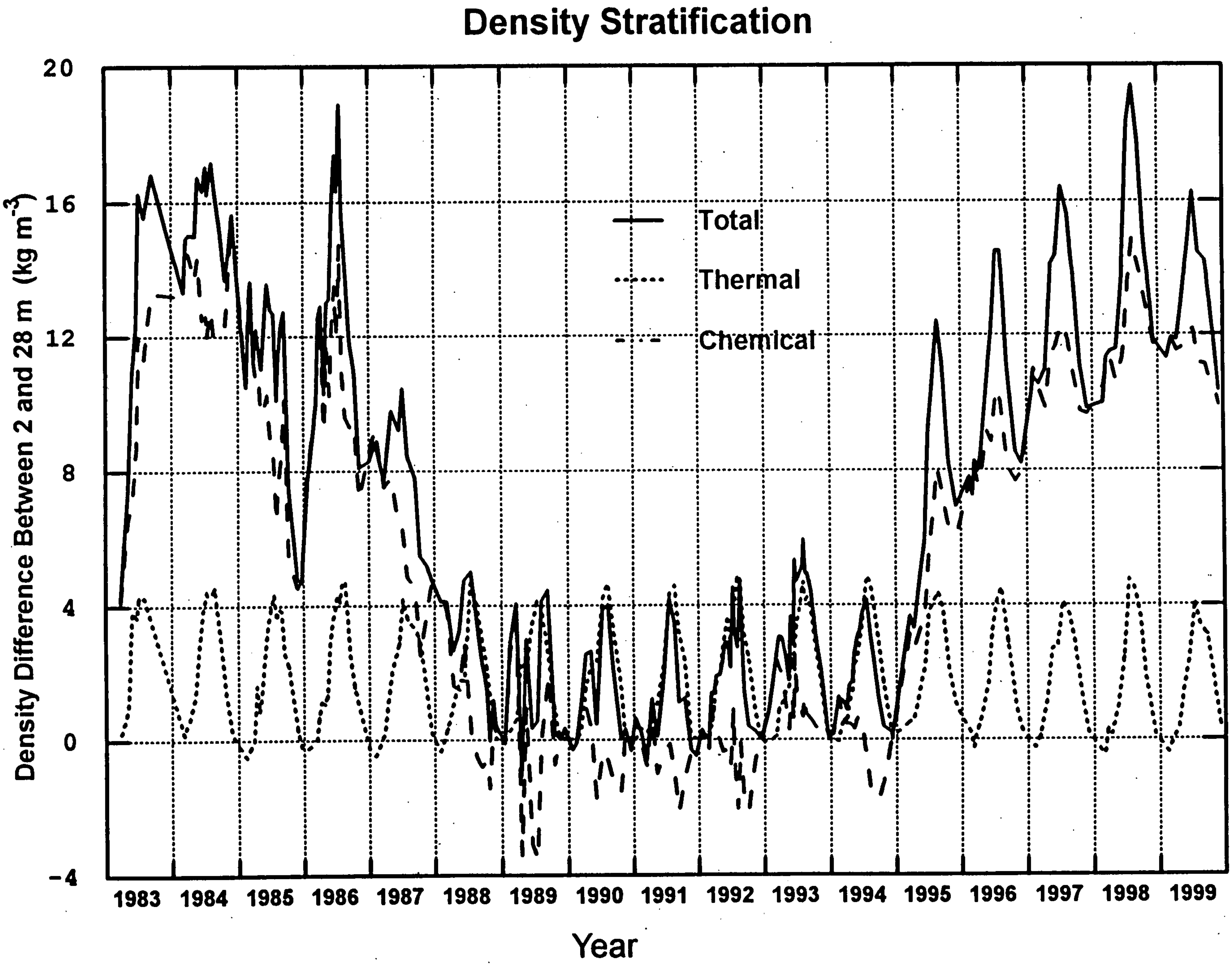

Density Stratification
Total
Thermal
Chemical
Density Difference Between 2 and 28 m (kg m^{-3})
20
16
12
8
4
0
-4
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Year

Figure 2.6

December Chemical Stratification in Mono Lake

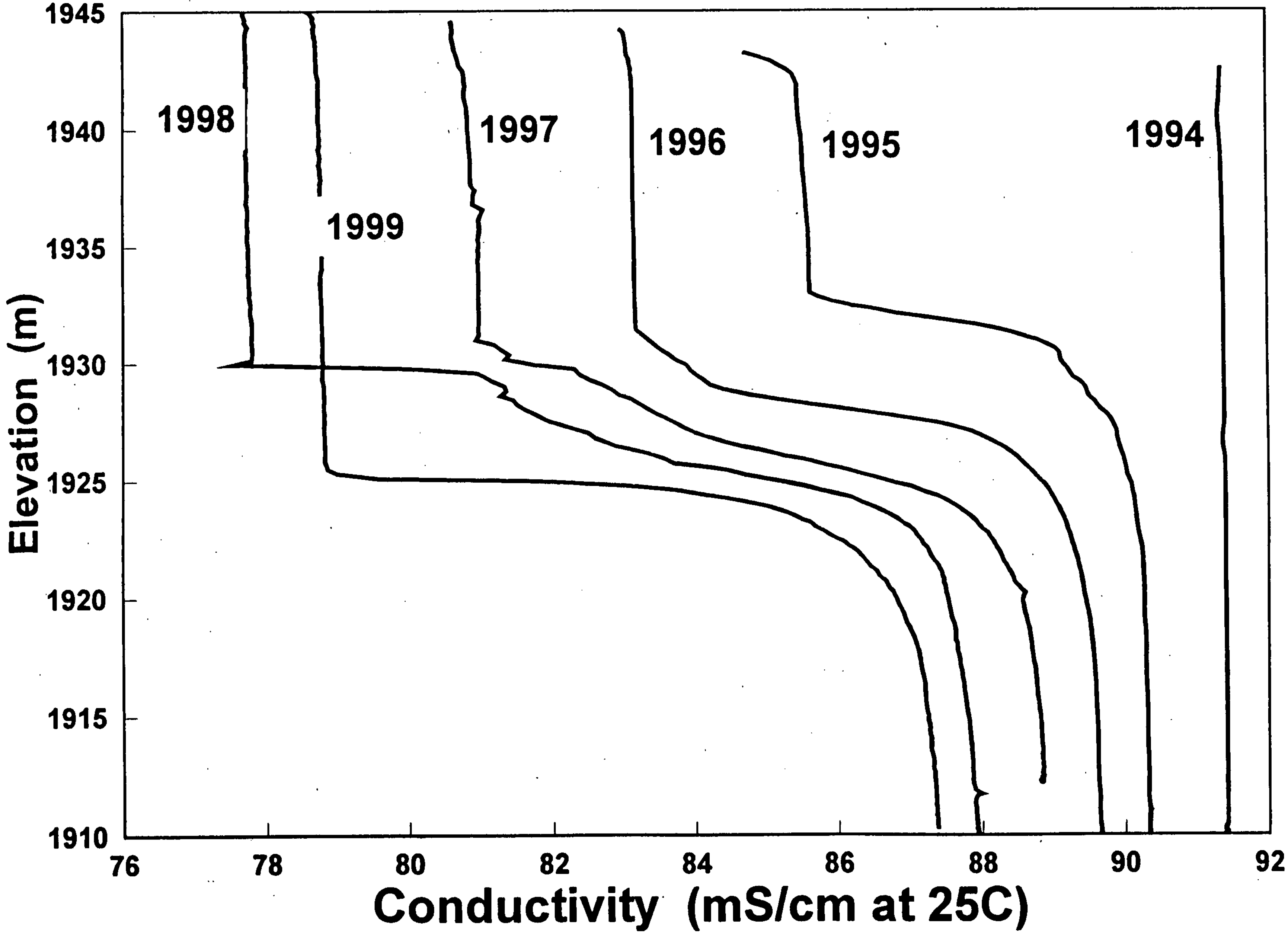
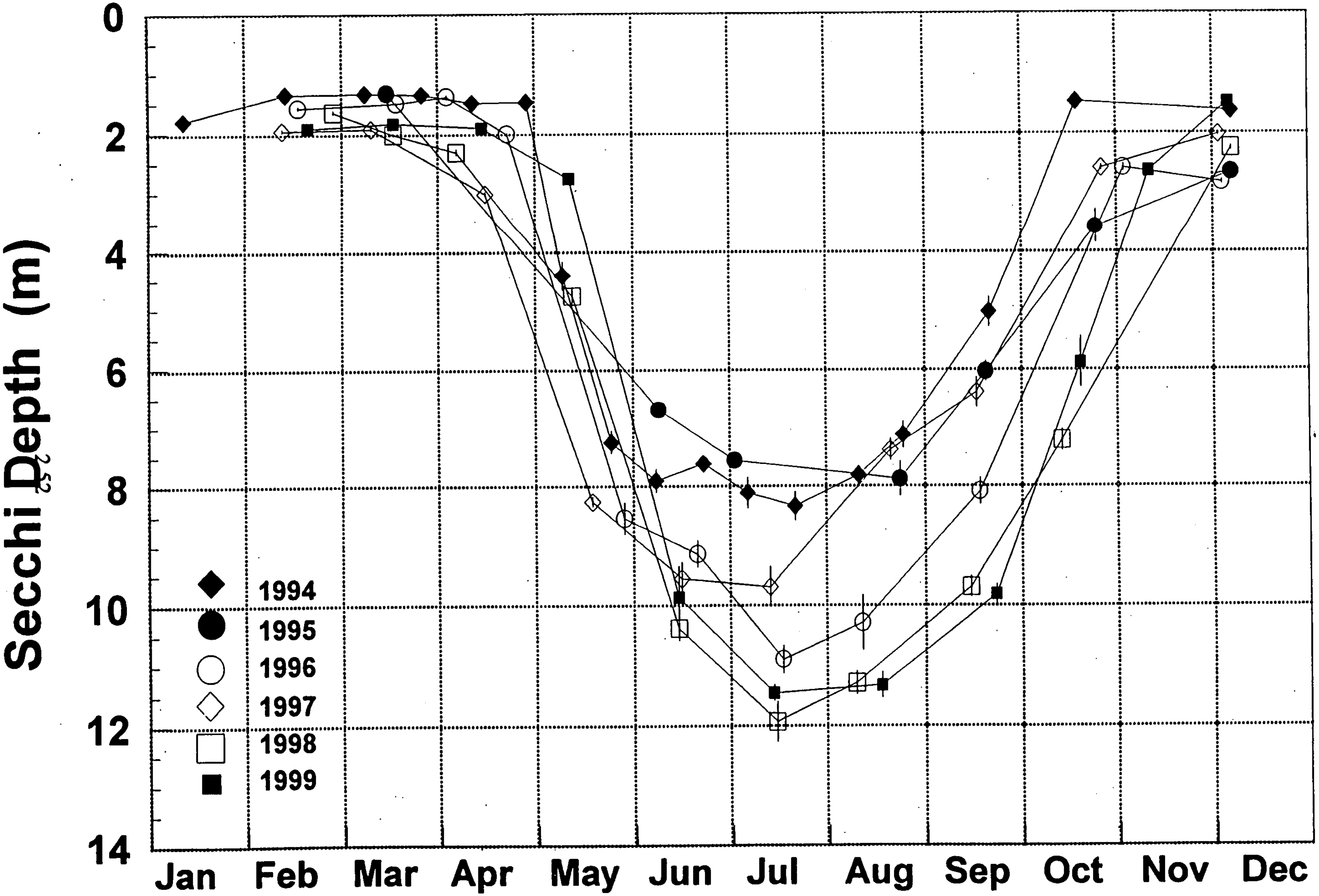


Figure 2.7



Mono Lake Transparency

Figure 2.8

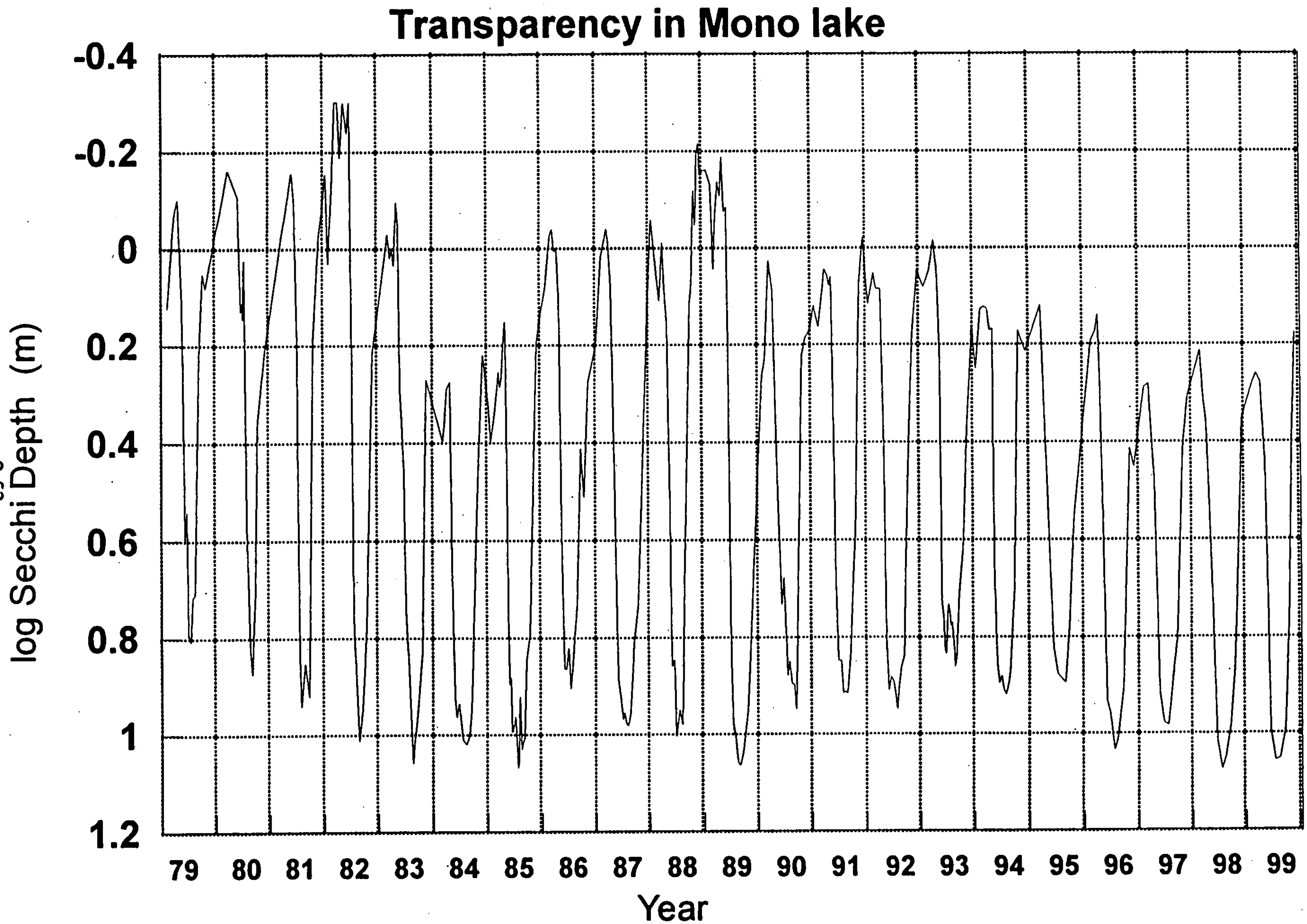
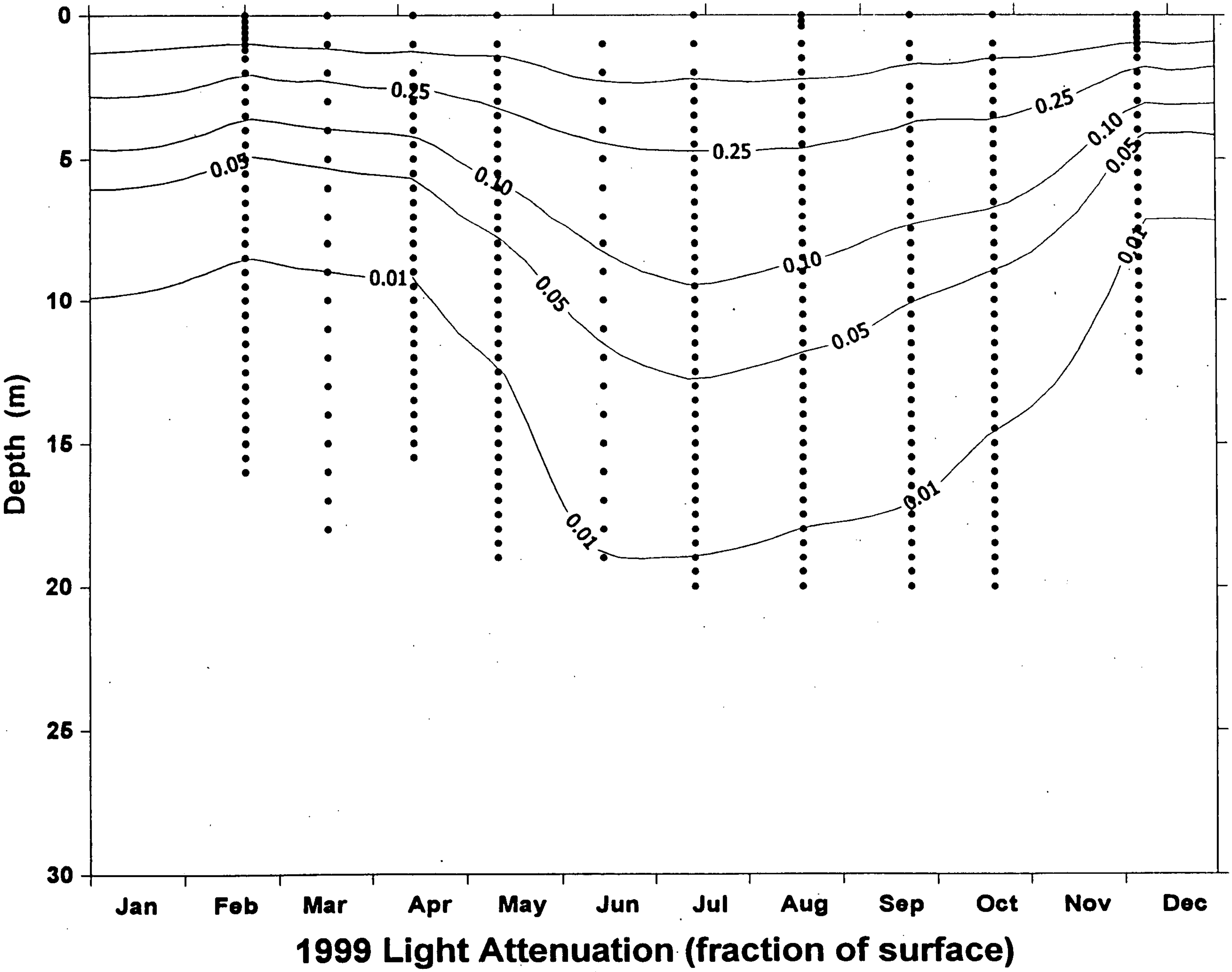
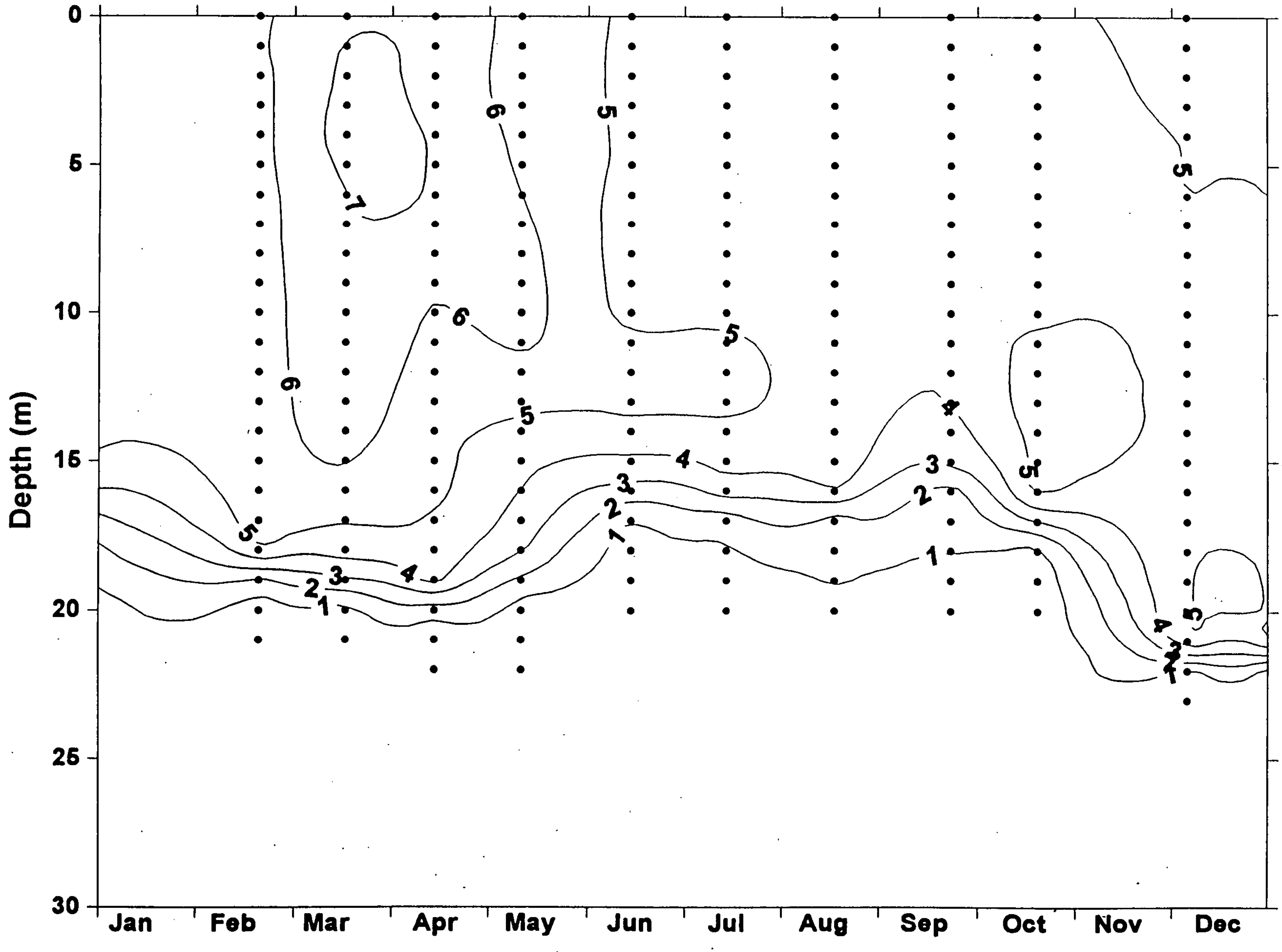

Transparency in Mono lake
log 2.53 Secchi Depth (m)
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99
Year

Figure 2.9



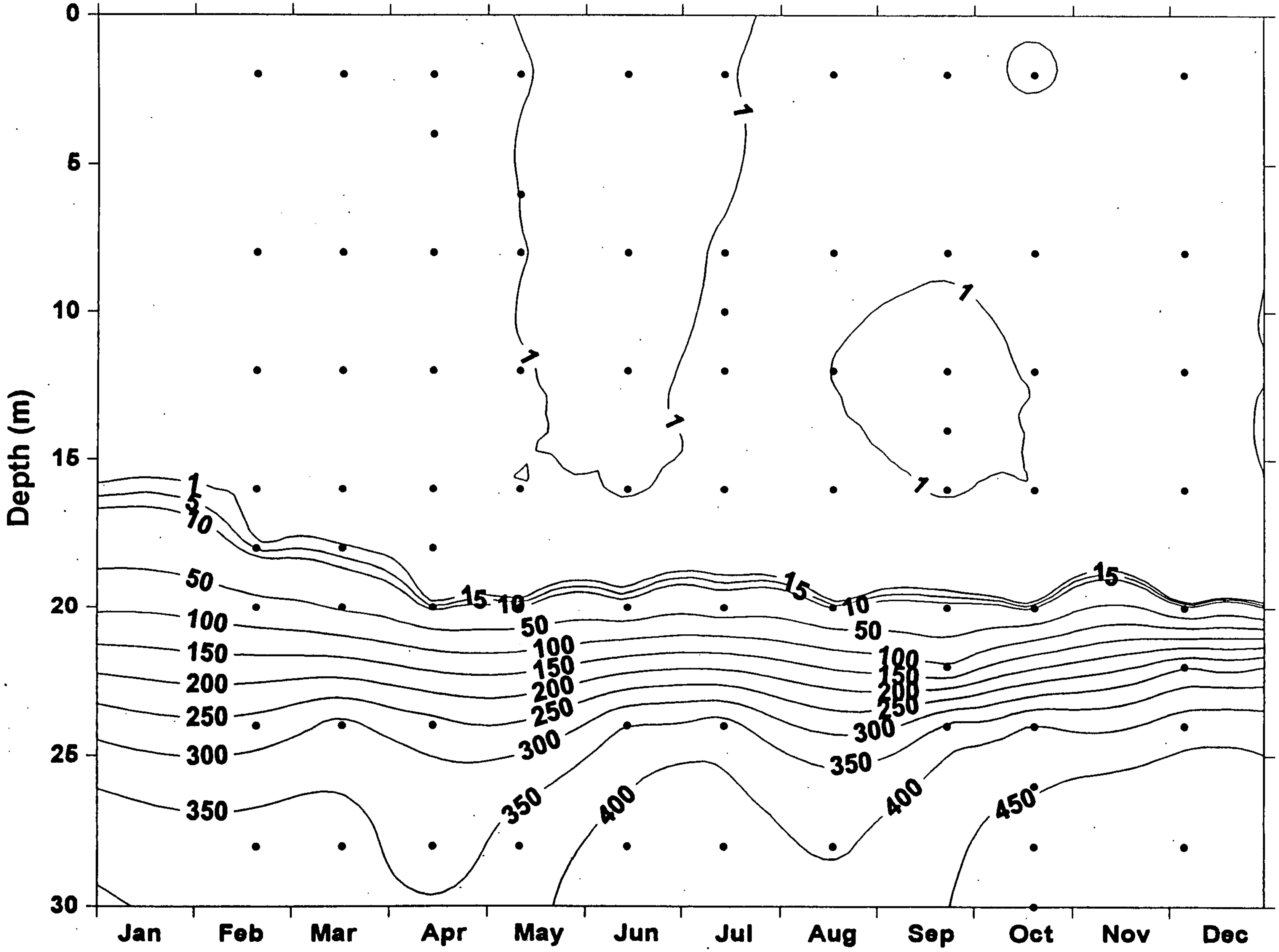
2.54

Figure 2.10



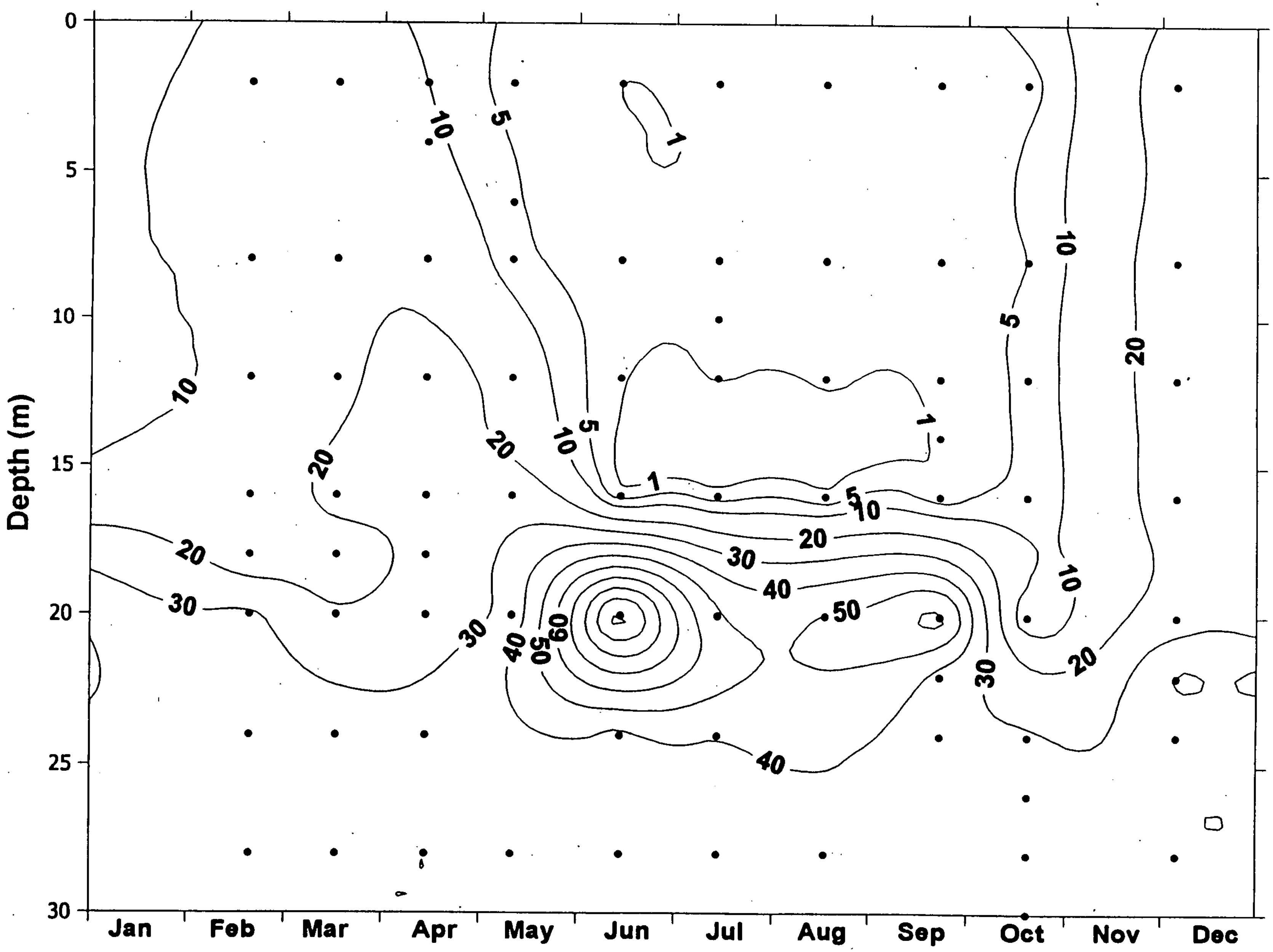
Dissolved Oxygen (mg/l) at S30, 1999

Figure 2.11



Ammonium (uM) at S30, 1999

Figure 2.12

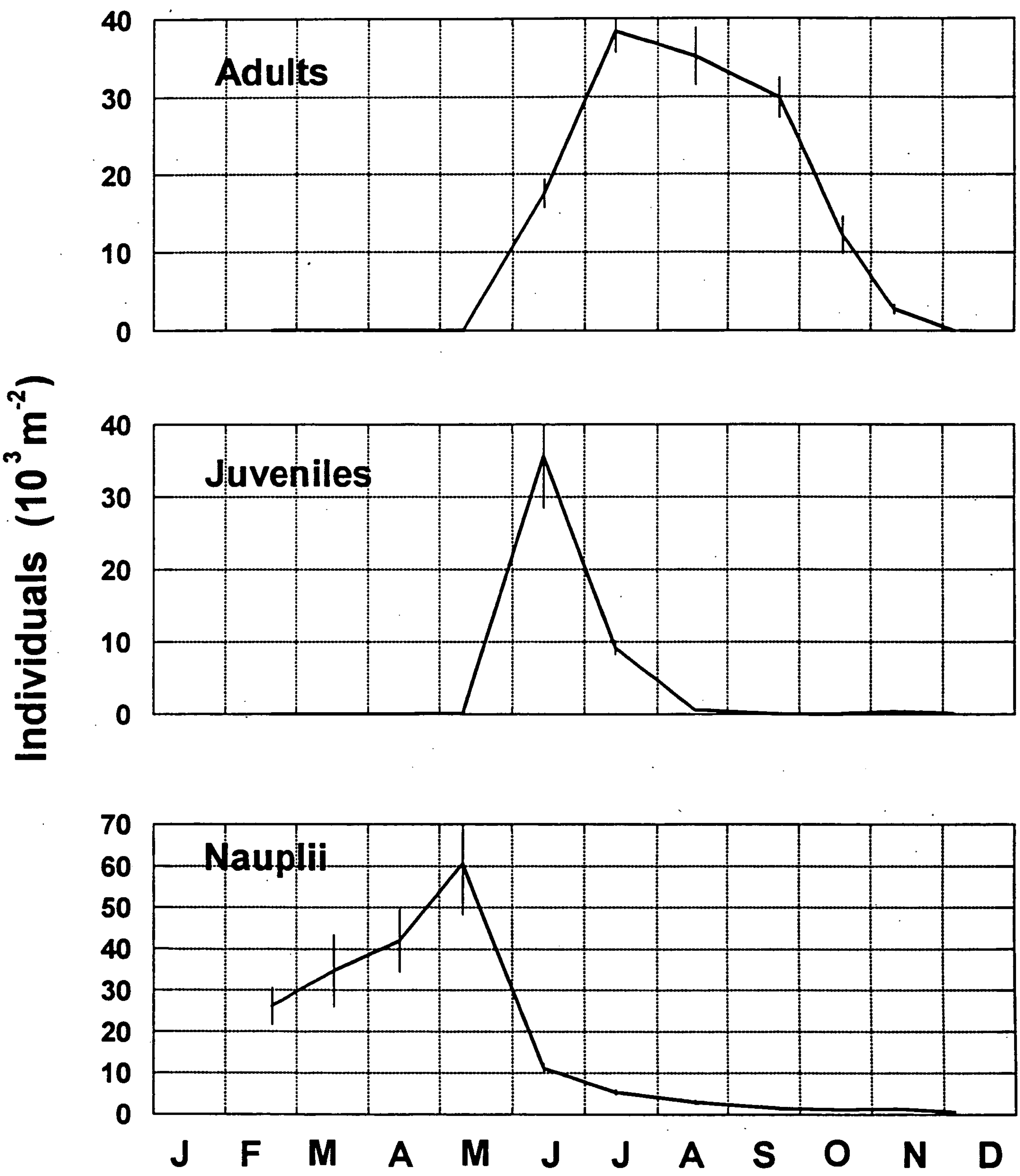


Chlorophyll a (ug/l) at S30, 1999

2.57

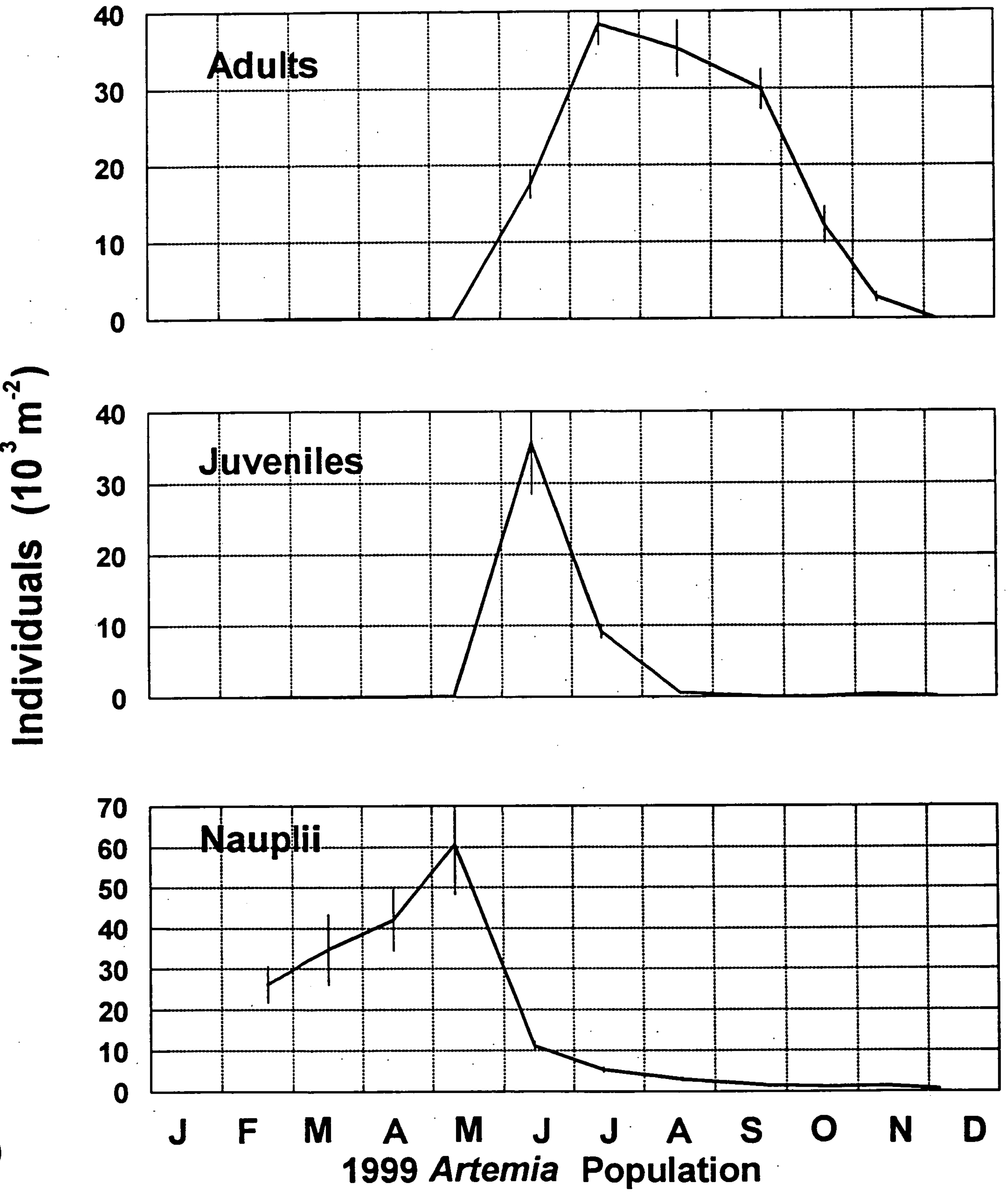
Figure 2.13

Figure 2.14



1999 *Artemia* Population

Figure 2.15


Individuals ($10^3 m^{-2}$)
Adults
40
30
20
10
0
Juveniles
40
30
20
10
0
Nauplii
70
60
50
40
30
20
10
0
J F M A M J J A S O N D
1999 *Artemia* Population

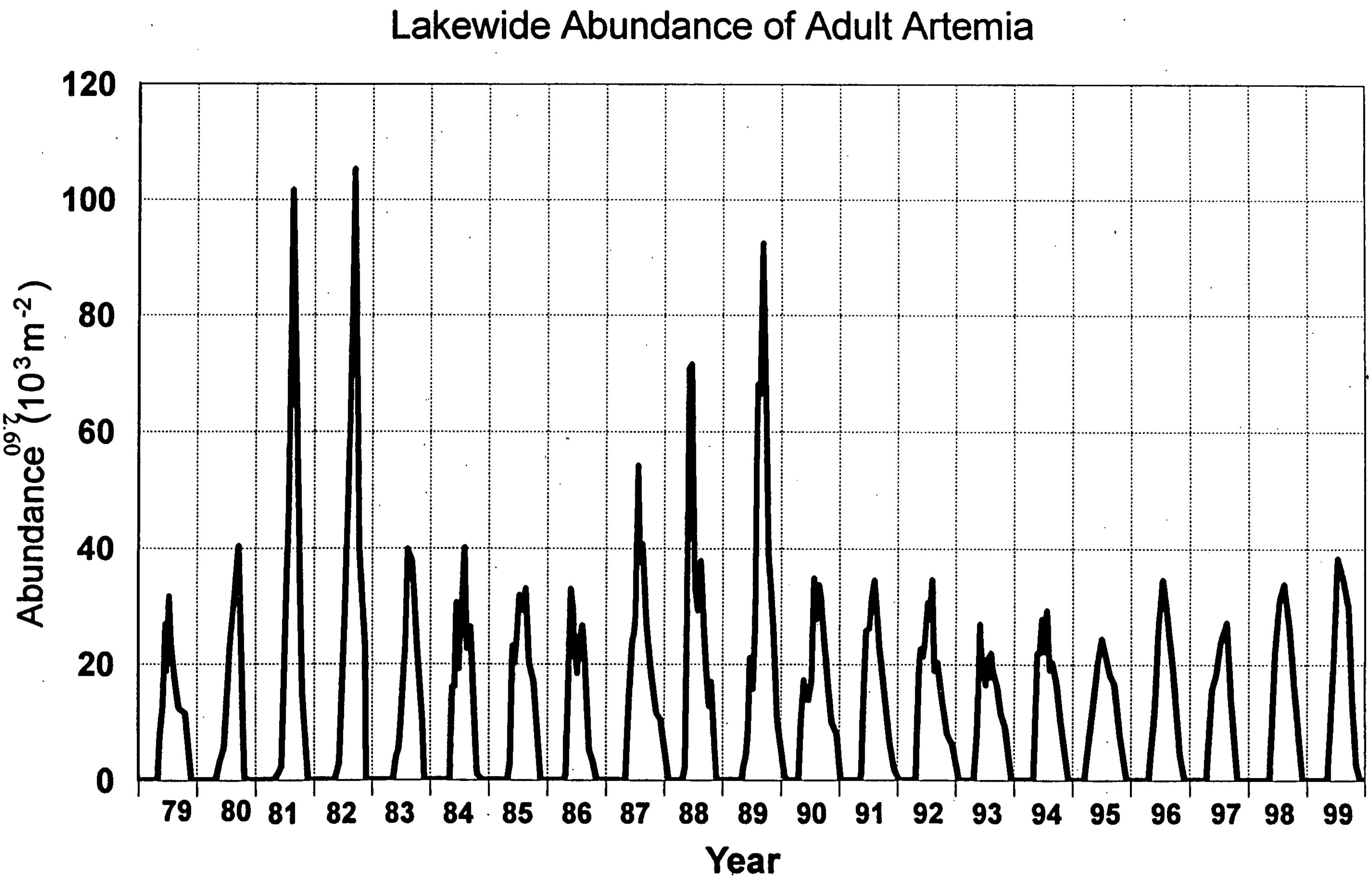

Lakewide Abundance of Adult Artemia
Abundance $(10^3 m^{-2})$
0
20
40
60
80
100
120
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
Year

Figure 2.16

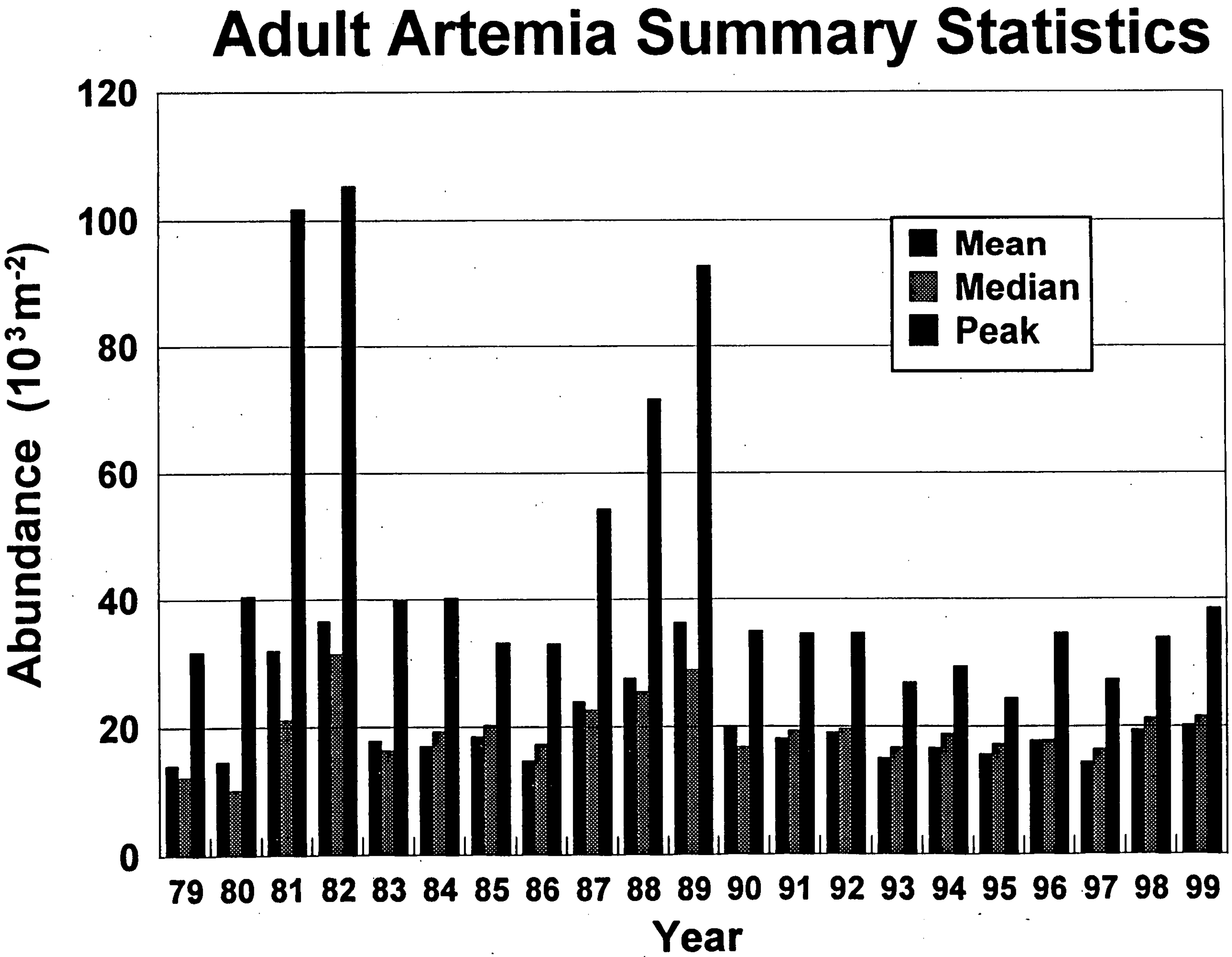

Adult Artemia Summary Statistics
Abundance (10³m⁻²)
0
20
40
60
80
100
120
Mean
Median
Peak
79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99
Year

Figure 2.17

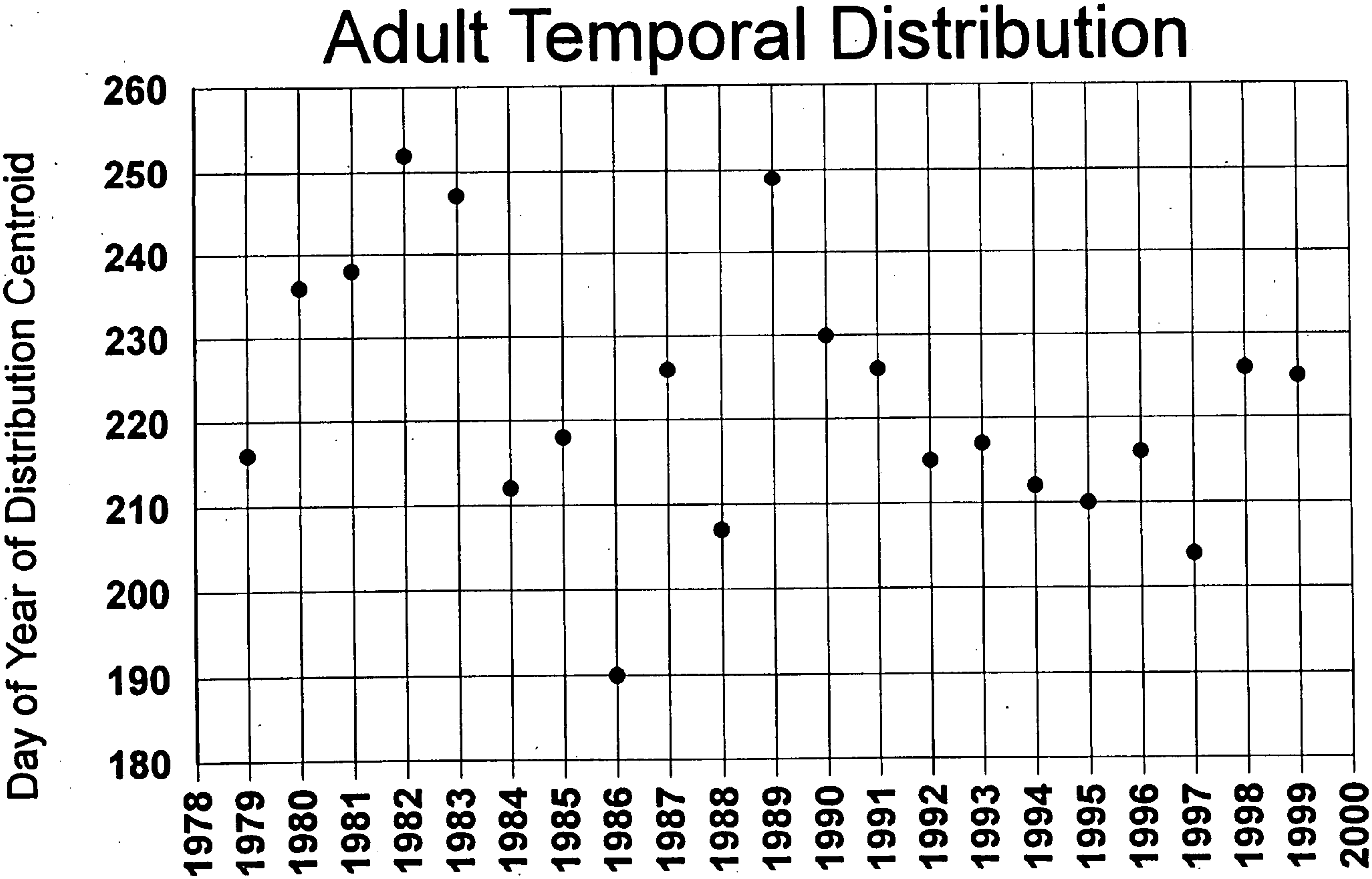

Adult Temporal Distribution
Day of Year of Distribution Centroid
260
250
240
230
220
210
200
190
180
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000

Figure 2.18

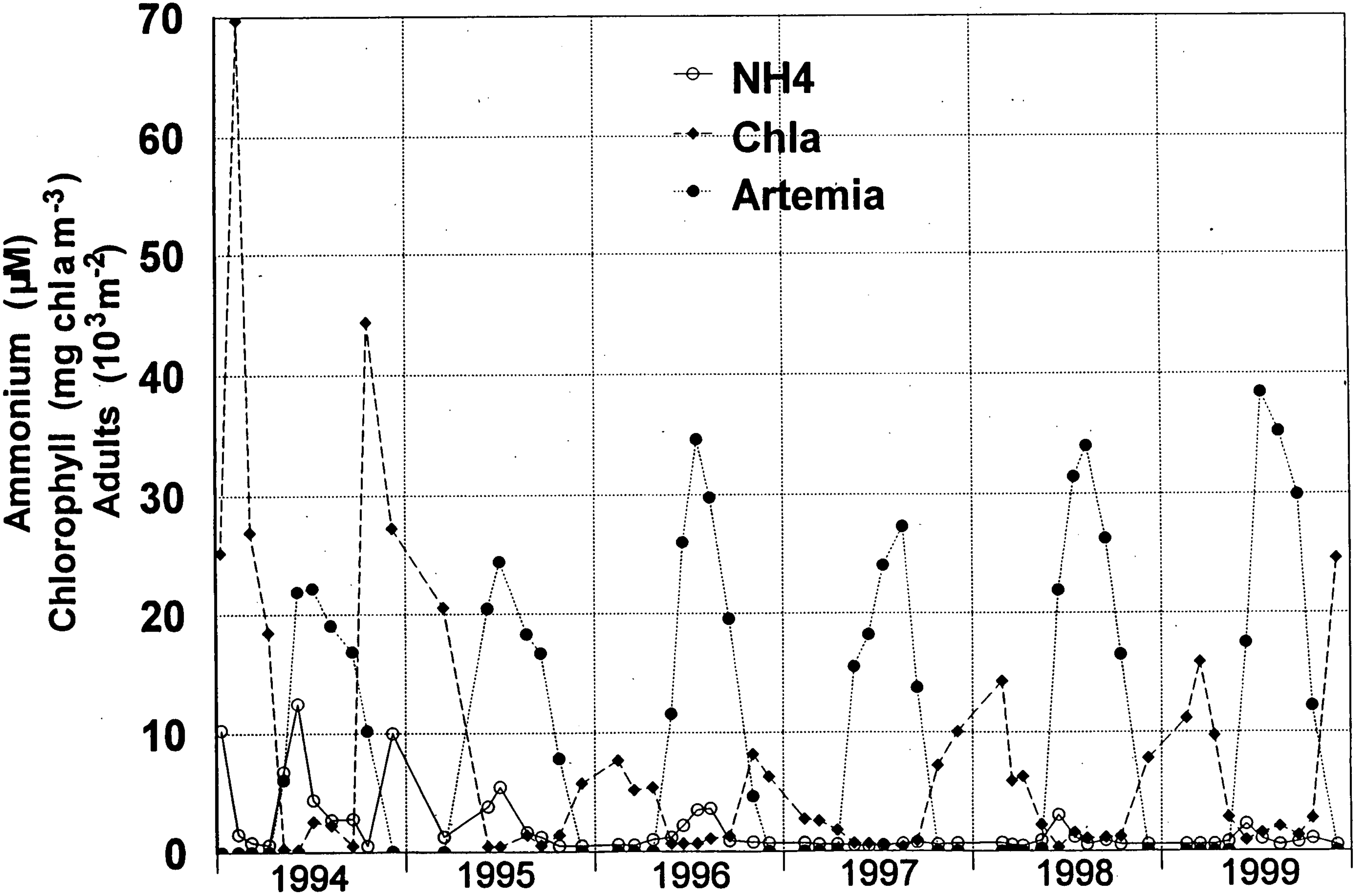

NH4
Chla
Artemia
Ammonium (µM)
Chlorophyll (mg chl a m^{-3})
Adults (10^{3}m^{-2})
70
60
50
40
30
20
10
0
1994
1995
1996
1997
1998
1999

Figure 2.19

CHAPTER 3

ANNUAL PRIMARY AND *ARTEMIA* BIOMASS

Introduction

Worldwide the volume of inland saline waters is approximately equal to that of freshwater lakes (Wetzel 1983). Despite this, seasonal and long-term studies of plankton dynamics in saline lakes are few and have only begun in the last few decades. These studies indicate that many saline ecosystems are highly productive at several trophic levels often culminating in large breeding and migrating populations of birds (see Hammer 1986). Mono Lake, California, is noted for its large populations of migrating eared grebes (*Podiceps nigricollis*) and phalaropes (*Phalaropus spp.*) and nesting colonies of California gulls (*Larus californicus*) (Patten et al. 1987). Of major importance to these populations are two invertebrate species; the alkaline fly, *Ephydra hians*, which has a benthic larval stage and an endemic brine shrimp, *Artemia monica*. Both these invertebrate populations reach high abundances supported by high rates of algal primary production.

Measurements of primary production in saline lakes vary over two orders of magnitude on an areal basis (Hammer 1981) and include some of the highest recorded daily values for natural lakes (Talling et al. 1973; Melack and Kilham 1974). Previous measurements of algal photosynthetic activity at Mono Lake indicate high annual rates of primary production (269–1063 g C m^{-2} yr^{-1}) which vary several-fold over different hydrological regimes (Jellison & Melack 1993).

While variation in photosynthetic production among lakes is large and well documented, few studies of saline lakes are of sufficient duration to assess year to year variation. In several lakes, large interannual differences due to climatic variation have been noted. In shallow Lake Elmenteita (Kenya), photosynthesis declined dramatically as lake levels dropped and salinity increased over a 16-month period (Melack 1981). In large Great

Salt Lake (Utah, USA), algal populations increased as the lake expanded and salinity decreased, and a different zooplankton community became established (Wurtsbaugh 1990).

At Mono Lake, diversion activities and climatic variation have led to changes in salinity and the annual patterns of thermal and chemical stratification. Diversions of freshwater streams out of the Mono Basin beginning in 1941 led to a 14 m decline in the surface elevation of the lake by 1982 and an approximate doubling of lake water salinities (Los Angeles Department of Water and Power (LADWP) 1984). In 1983, exceptionally high runoff initiated an extended period (1983–1988) of chemical stratification (meromixis) in which internal recycling of nutrients was significantly altered. While drought conditions and continued diversions led to the termination of meromixis in 1988, a second episode of meromixis was initiated in 1995 following curtailment of diversions and above average runoff. This second episode of meromixis has continued through 1998 and is expected to last several decades.

The effects of changing size and salinity on the lake ecosystem are difficult to determine and have been the subject of several studies (Patten *et al.* 1987, Jones and Stokes Associates 1993). During research conducted over the past two decades, the effects of changing salinity on productivity have been obscured by the effects of changes in internal nutrient cycling that accompany year to year variation in chemical stratification. Annual primary production initially declined during the 1980s episode of meromixis, but recovered as vertical mixing was enhanced and nutrient-rich monimolimnetic water was entrained during a period of declining lake level (Jellison and Melack 1993). Primary production was higher immediately following the breakdown of meromixis due to increased availability of ammonium. The current episode of meromixis initiated in 1995 led to a similar initial decline in productivity. However, in contrast to the previous episode of meromixis, primary productivity has remained low as the lake level continues to rise. Data from 1999, the 4th year of the current episode of meromixis, indicate the effects of meromixis on primary production may by weakening.

A long-term record of limnological measurements over periods of different salinities and annual mixing regimes is necessary to assess the impacts of changing salinity and interpret changes in the observed plankton dynamics. Here, we employ measurements of seasonal changes in algal biomass, temperature, and light coupled with previously derived regressions of photosynthetic uptake rates to estimate annual primary productivity for the entire period, 1982–1999.

Differences in secondary production would be expected to accompany changes in primary production. However, secondary production is difficult to estimate because knowledge of individual growth rates of *Artemia* is required. In several previous annual reports, we estimated secondary production based on *Artemia* abundance and size, water temperature, sub-adult growth rates observed in laboratory experiments under different conditions, and estimates of adult growth rates based on the increase in average length of adults during late summer. As long as adult growth rates did not vary significantly from year to year, this provided a valid comparison among years. Analysis of data collected during the current episode of meromixis provides evidence of substantially different growth rates among years. With the onset of meromixis in 1995, the mean length of adult *Artemia*, individual fecundity, and rate of maturation have all decreased. Thus, inferring a significant decrease in individual growth rates. While it may be possible using detailed cohort analyses to estimate growth rates and then calculate secondary productivity, such analysis is outside the scope of this report. Instead, we analyze two proxy measures of secondary productivity; average daily biomass of the *Artemia* population and annual reproduction. These provide integrative measures of the *Artemia* population which incorporate seasonal and year to year changes in abundance, mean length of adults, reproductive characteristics, instar distribution, water temperature, and stratification regime.

Methods

Primary Production

Photosynthetically available radiation (PAR, 400-700 nm) was recorded continuously at Cain Ranch, seven kilometers southwest of the lake, from 1982 to present and on Paoha Island in the center of the lake beginning in 1991 with a cosine-corrected quantum sensor. Attenuation of PAR within the water column was measured at 0.5-m intervals with a submersible quantum sensor. Temperature was measured at 1-m intervals with a thermistor and wheatstone bridge circuit calibrated against a certified thermometer and accurate to 0.05°C prior to 1992 and with a conductivity-temperature-depth profiler (Seabird, SB19) from 1992 to 1999 (see methods, Chapter 2).

Phytoplankton samples were filtered onto Gelman A/E filters and kept frozen at -14°C until pigments were analyzed. A subset of samples from various depths were selected on each date and the filtrate from the Gelman A/E filter was filtered through a Whatman GF/F filter to determine the amount of algae passing through the Gelman A/E filters. Chlorophyll *a* values given here were not corrected by this amount. Except during periods of low biomass, chlorophyll *a* was determined by spectrophotometric analysis with correction for phaeopigments (Golterman 1969), after a 45-min extraction of the macerated filters in 90% acetone at room temperature in the dark. Low chlorophyll *a* concentrations (<5 mg Chl *a* m^{-3}) were measured on a fluorometer which was calibrated against spectrophotometric measurements using large-volume lake samples and fresh lettuce.

Photosynthetic parameters were estimated based on regression of 1991 and 1992 photosynthetic parameters against temperatures. The chlorophyll-normalized light-saturated uptake rates from carbon uptake measurements performed in 1991 and 1992 were highly correlated with water temperature. The exponential equation:

$$P_m^B = 0.237 \times 1.183^T \qquad n=42,\ r^2=0.86$$

where T is temperature (°C) explained 86% of the overall variation. As found in previous analyses (Jellison and Melack 1993), there was a strong correlation between light-limited and light-saturated rates. A linear regression on light-saturated rates explained 82% of the variation in light-limited rates:

$$\alpha^B = 2.69 + (1.47 \times P_m^B) \qquad n=42,\ r^2=0.82$$

Both light-limited and light-saturated carbon uptake rates are within the range reported in other studies. During 1995, rising lake levels and greater salinity stratification most likely reduced the vertical flux of nutrients and thus may have affected the photosynthetic rates. However, previous regression analyses (Jellison and Melack 1993), using an extensive data set collected during periods of different nutrient supply regimes, indicates little of the observed variance in photosynthetic rates can be explained by simple estimate of nutrient supply. The above regressions explain most of the variance in photosynthetic rates and thus provide a reasonable alternative to frequent, costly field and laboratory measurements using radioactive tracers. The differences in annual phytoplankton production throughout the period, 1982–1992, resulted primarily from changes in the amount of standing biomass; year to year changes in photosynthetic parameters during the years they were measured (1983–92) were not correlated with annual production. While photosynthetic parameters were not measured in 1993–99, other major factors determining primary production were measured throughout the year.

Estimates of daily integral production were made using a numerical interpolative model (Jellison and Melack 1993). Inputs to the model include the estimated photosynthetic parameters, insolation, the vertical attenuation of photosynthetically available irradiance and vertical water column structure as measured by temperature at 1 m intervals and chlorophyll *a* from samples collected at 4–6 m intervals. Chlorophyll-specific uptake rates based on temperature were multiplied by ambient chlorophyll *a* concentrations interpolated to 1-m intervals. The photosynthetically available light field was calculated from hourly-integrated values at the onshore monitoring site, measured water column attenuation, and a calculated albedo. The albedo was calculated based on hourly solar declinations. All parameters, except insolation that was recorded continuously, were linearly interpolated between sampling dates. Daily integral production was calculated by summing hourly rates over the upper 18 m.

Artemia biomass and reproduction

Average daily biomass and annual cyst and naupliar production provide integrative measures of the *Artemia* population allowing simple comparison among years. *Artemia* sampling and enumeration methods (see chapter 2) have been consistently applied over the entire period, 1982–99. Instar-specific abundance, adult size, sex, fecundity, and type of reproduction were collected monthly at 6 to 20 stations depending on the type of measurement (see Chapter 2). Here, we calculate lakewide estimates of biomass and cyst and naupliar production. As the instar distribution within the naupliar stages (1-7) was determined at two stations in each of the eastern, southern, and western sectors of the lake, we assume the naupliar instar distributions at other stations are similar. Likewise, fecundity and adult female length, which were determined on 10 individuals from each of 10 stations, are assumed to be representative of the 20 stations from which abundance data were collected.

To estimate biomass from population data requires the use of appropriate weight-length regressions. Instar-specific weights vary as a function of temperature and food availability during growth. Because weight measurements are not routinely collected, instar-specific weights from laboratory experiments simulating in situ food and temperature were used to estimate instar-specific weights of individuals collected in the field (Dana et al. 1995). Two experimental treatments were conducted which simulated the development of the first generation under gradually warming spring water temperatures, one at high food levels corresponding to monomictic conditions and one at low food levels corresponding to meromictic conditions. A third treatment simulated summer development under warm temperatures and low food conditions. Food consisted of phytoplankton collected at regular intervals from the lake during the course of the experiments. Instar-specific weights and weight-length regressions were calculated from these experiments. To use this data for estimating biomass in the field, field samples were classified into one of the three categories:

spring-high, spring-low, summer-low, and appropriate instar-specific weights applied to the abundance data.

Although summer conditions are superficially similar during both monomictic and meromictic mixing regimes, previous research (Jellison et al. 1993, Romero et al. 1998) indicates vertical mixing rates are lower at the thermocline during meromixis. Thus, changes in summer primary productivity could cause the summer weight-length relationships of *Artemia* to vary among years. The weights of 3 adult males and 3 adult females from each of 10 buoyed stations were determined on eight dates during summer 1996 and 1997 to determine if significant differences in the weight-length relationships were occurring among sampling dates. In 1998, 8 individuals ranging from late naupliar instars (5-7) to adults were randomly selected from each of three stations (ET5.6, S30, 10) and weighed to determine if their weight-length relationships differed significantly from the previously derived ones. In 1999, individual weight-length relationships were determined on 12 May, 15 June, and 20 October.

The resulting biomass estimates are approximate because actual instar-specific weights may vary within the range observed in the laboratory experiments. However, classifying the field samples into one of the three categories will be more accurate than using a single instar-specific weight-length relationship. Because length measurements of adult females are routinely made, they are used to further refine the biomass estimates. The adult female weight is estimated from the mean length on a sample date and one of the three weight-length regressions determined in the laboratory development experiments. As the lengths of adult males are not routinely determined, the average ratio of male to female lengths determined from individual measurements on 15 dates from 1996 and 1999 was used to estimate the average male length of other dates.

Naupliar and cyst production was calculated using a temperature-dependent brood interval, ovigery, ovoviviparity versus oviparity, fecundity, and adult female abundance data for each date.

Results & Discussion

Planktonic primary production

Daily estimates of primary production in 1999 ranged from 0.5 to 1.5 g C m^{-2} d^{-1}. This range is the same as observed during 1996–98, and within the previously reported range (Jellison and Melack 1988, 1993; Jellison *et al.* 1994, Jellison *et al.* 1995, Jellison *et al.* 1996, Jellison *et al.* 1997). The estimated total annual production of 297 g C m^{-2} yr^{-1} in 1999 represents a 30% increase over the 1998 estimate of 228 g C m^{-2} yr^{-1} and is significantly higher than that observed in 1996 (221 g C m^{-2} yr^{-1}) and 1997 (149 g C m^{-2} yr^{-1}) (Fig. 3.1). Although higher than the previous four years, the 1999 estimated planktonic primary production is still significantly lower than the mean annual production (508 g C m^{-2} yr^{-1}) during the recent 5-yr period of monomixis (1990–94) and indicates the continuing effect of nutrient reduced availability accompanying meromixis.

There are no comparable long-term studies of algal production in other large, deep hypersaline lakes. The annual estimates of planktonic photosynthesis found in this study (149–1063 g C m^{-2} yr^{-1}) are generally higher than other hypersaline lakes in the Great Basin: Great Salt Lake (southern basin), 145 g C m^{-2} yr^{-1} (Stephens and Gillespie 1976); Soap Lake, 391 g C m^{-2} yr^{-1} (Walker 1975); and Big Soda, 500 g C m^{-2} yr^{-1} (350 g C m^{-2} yr^{-1} phototrophic production) (Cloern *et al.* 1983).

Artemia biomass and reproduction

Artemia biomass is estimated from instar-specific population data and previously derived weight-length relationships (see Methods and 1997 Annual Report). In 1999, twenty-four individual *Artemia* were measured and weighed during May, June, and October to determine if previously derived weight-length relationships from laboratory experiments approximated those in the field (Figs. 3.2-4). In general, individual adults were heavier than predicted by the appropriate (Spring-Low for May and June, Summer-Low for October) laboratory regressions. The weights of individual adults collected from the field on the June survey were 12% heavier than predicted by the spring, low food treatment and the adults collected in October were 18% heavier than predicted by the summer, low-food laboratory treatments. Individual adults were 6% and 9% heavier than predicted in 1996 and 1997, respectively, and 7% lighter than predicted by the laboratory data in 1998. Weight-length regressions for previous years are not available (except summer 1980) and thus the laboratory weight-length regressions were applied to all the years (1983-1999) to allow comparison among years. However, the fact that the individual weights on any survey may differ by as much as 18% from predicted weights means this long-term comparison is likely to underestimate year to year differences.

In 1999, *Artemia* biomass was always dominated by adult stages and varied from near zero (0.06 g dry weight m^{-2}) in February to 25.3 g m^{-2} on 15 June. The annual mean biomass of 8.88 g m^{-2} was slightly higher than any of the past five years (5.3 to 8.6 g m^{-2}) but still below the 1983–1998 16-yr mean of 9.8 g m^{-2} (Fig. 3.5). The highest estimated mean annual biomass (17.6 g m^{-2}) occurred in 1989 just after the breakdown of meromixis during a period of elevated phytoplankton nutrients (ammonium) and phytoplankton. Mean annual biomass was somewhat below the long-term mean during the first 3 years of the 1980s episode of meromixis and then above the mean during the next 3 years as meromixis weakened and ended. Except for the lower values in 1997, *Artemia* biomass has remained relatively constant since 1993 and was only slightly higher during 1990–1992.

Weight-to-length data have been collected on individual shrimp from selected surveys from 1996 through 1999. Thus, a more accurate estimate of mean annual biomass is possible for these years. While applying a year-specific correction factor to the weight-length relationship in calculating total *Artemia* biomass results in only minor differences in the estimate (Fig. 3.6), this more accurate estimate does indicate a larger increase this past year. As year-specific weight-length data are only available for the last four years, it is not utilized for the long-term comparison of *Artemia* biomass.

Oviparous (cyst) reproduction is much higher than ovoviviparous (live-bearing) reproduction in all years, 1983–99 (Fig. 3.7). In 1999, total annual cyst production was estimated to be 4.17 x 10^6 m^{-2}, a 50% increase of 1998. While this is still 13% below the long-term (1983–1998) mean of 4.81 x 10^6 m^{-2}, it was substantially higher than during any of the past three years of meromixis (2.5–3.6 x 10^6 m^{-2}, 1996–1998). In general, cyst production was lower during meromictic periods and highest just after the breakdown of the 1980s episode of meromixis.

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Figure Captions

Figure 3.1. Annual phytoplankton production estimates (g C m^{-2}), 1982–99.

Figs. 3.2–4. Comparison of the dry weight of individual *Artemia* collected on field surveys during May (Fig. 3.2), June (Fig. 3.3), and October (Fig. 3.4) compared to that predicted by different weight-length regressions. The regression lines from highest to lowest are 1) the spring, high-food treatment, 2) spring, low-food treatment, 3) summer, low-food treatment, and 4) summer 1980 field population.

Figure 3.5. Mean annual *Artemia* biomass, 1983–99.

Figure 3.6. Comparison of calculated mean annual *Artemia* biomass with and without year-specific weight-length relationships, 1996–99.

Figure 3.7. Annual Artemia reproduction, ovoviviparous (live-bearing) and oviparous (cyst-bearing), 1983–99.

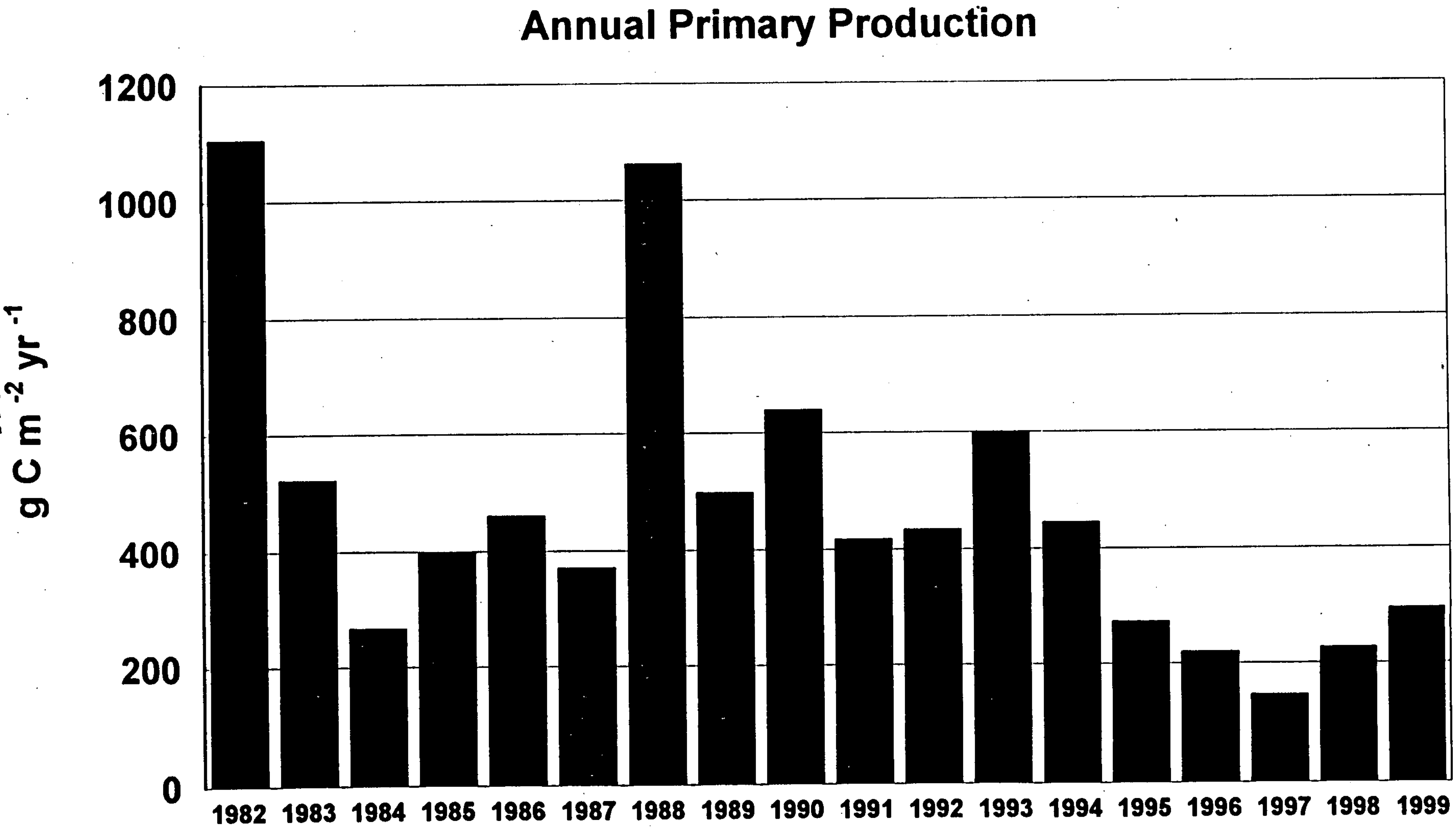

Annual Primary Production
g C m -2 yr -1
1200
1000
800
600
400
200
0
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999

Figure 3.1

Artemia Weight versus Length

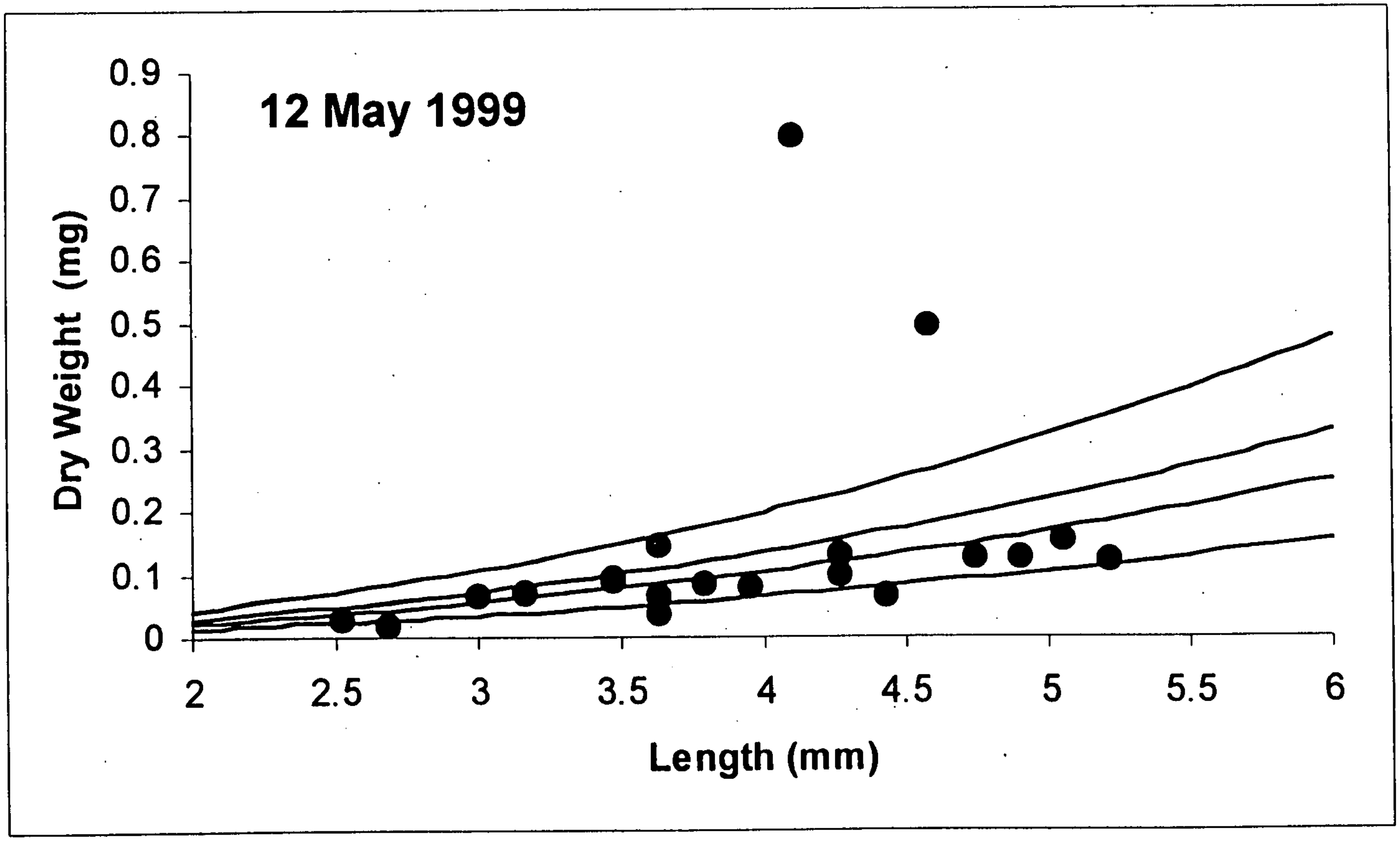


Figure 3.2

Artemia Weight versus Length

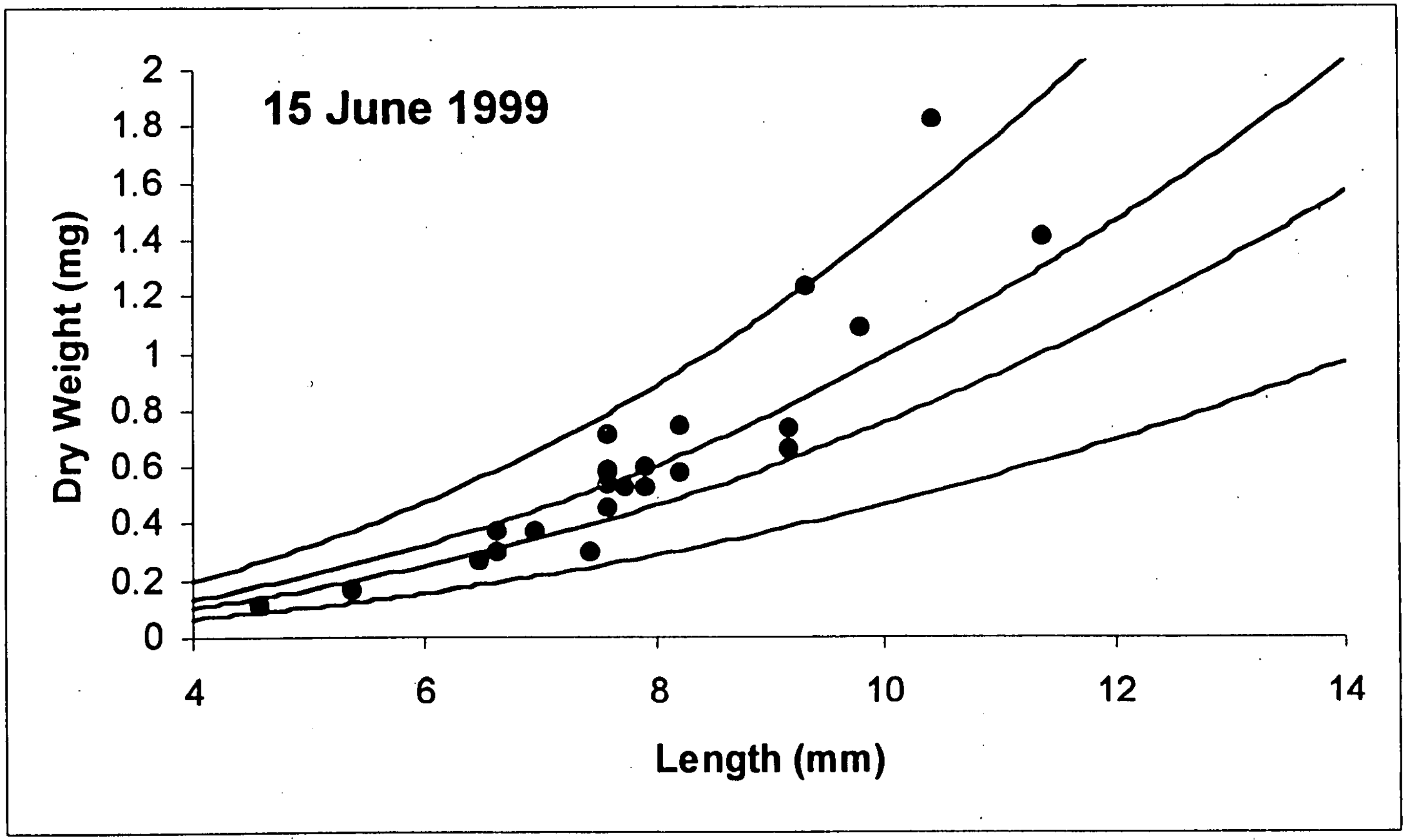


Figure 3.3

Artemia Weight versus Length

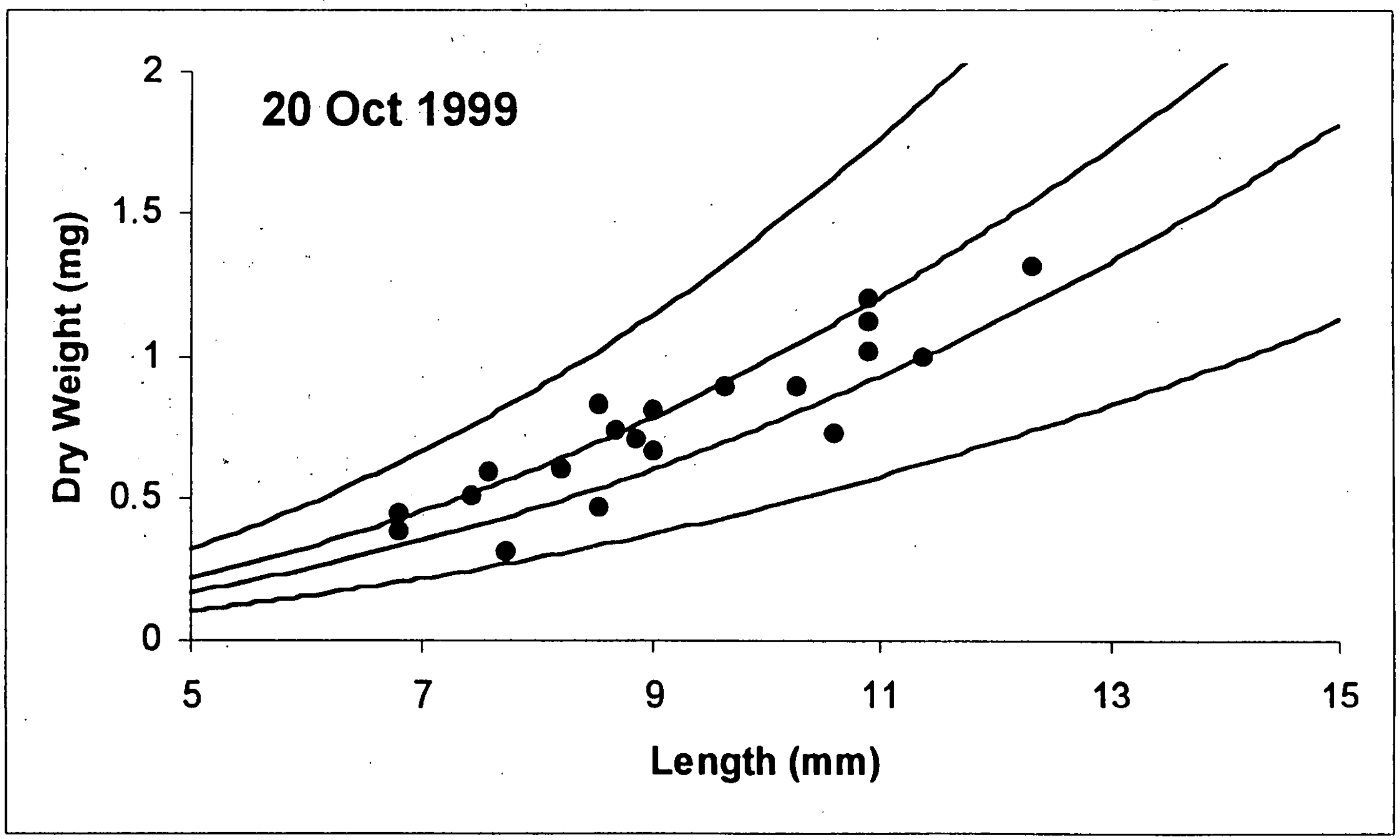
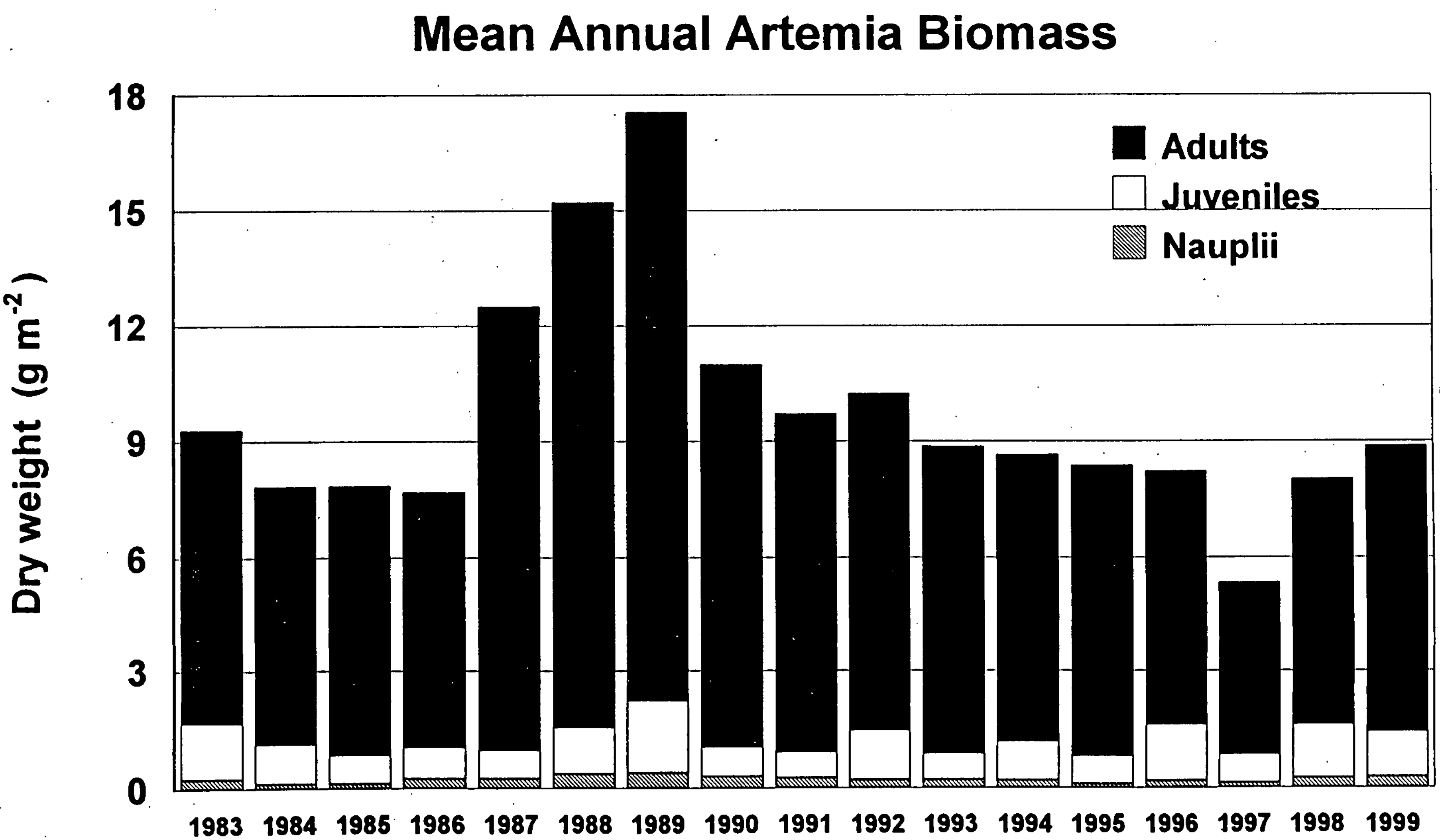


Figure 3.4



3.19

Figure 3.5

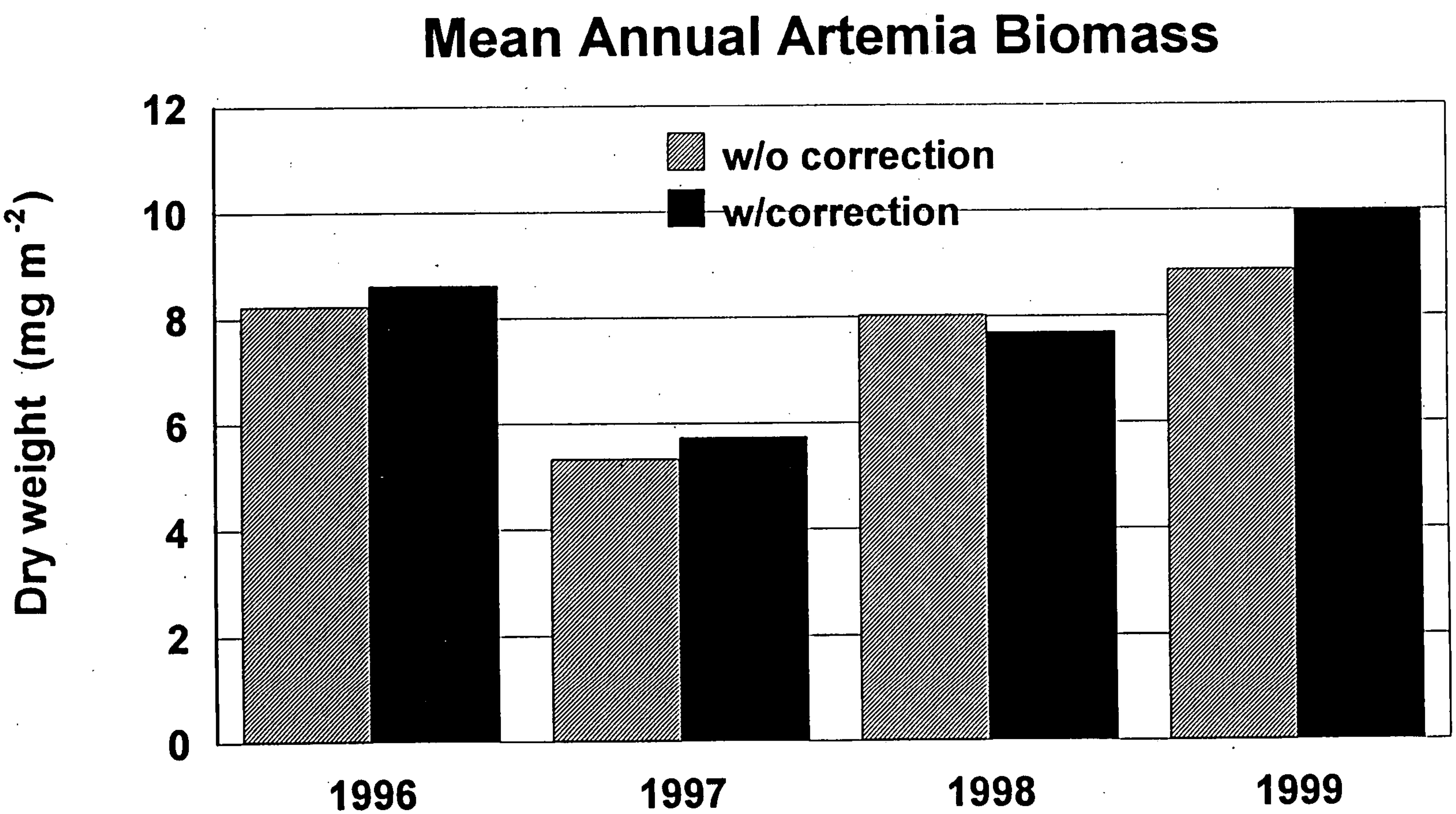

Mean Annual Artemia Biomass
w/o correction
w/correction
Dry weight (mg m -2)
12
10
8
6
4
2
0
1996
1997
1998
1999

Figure 3.6

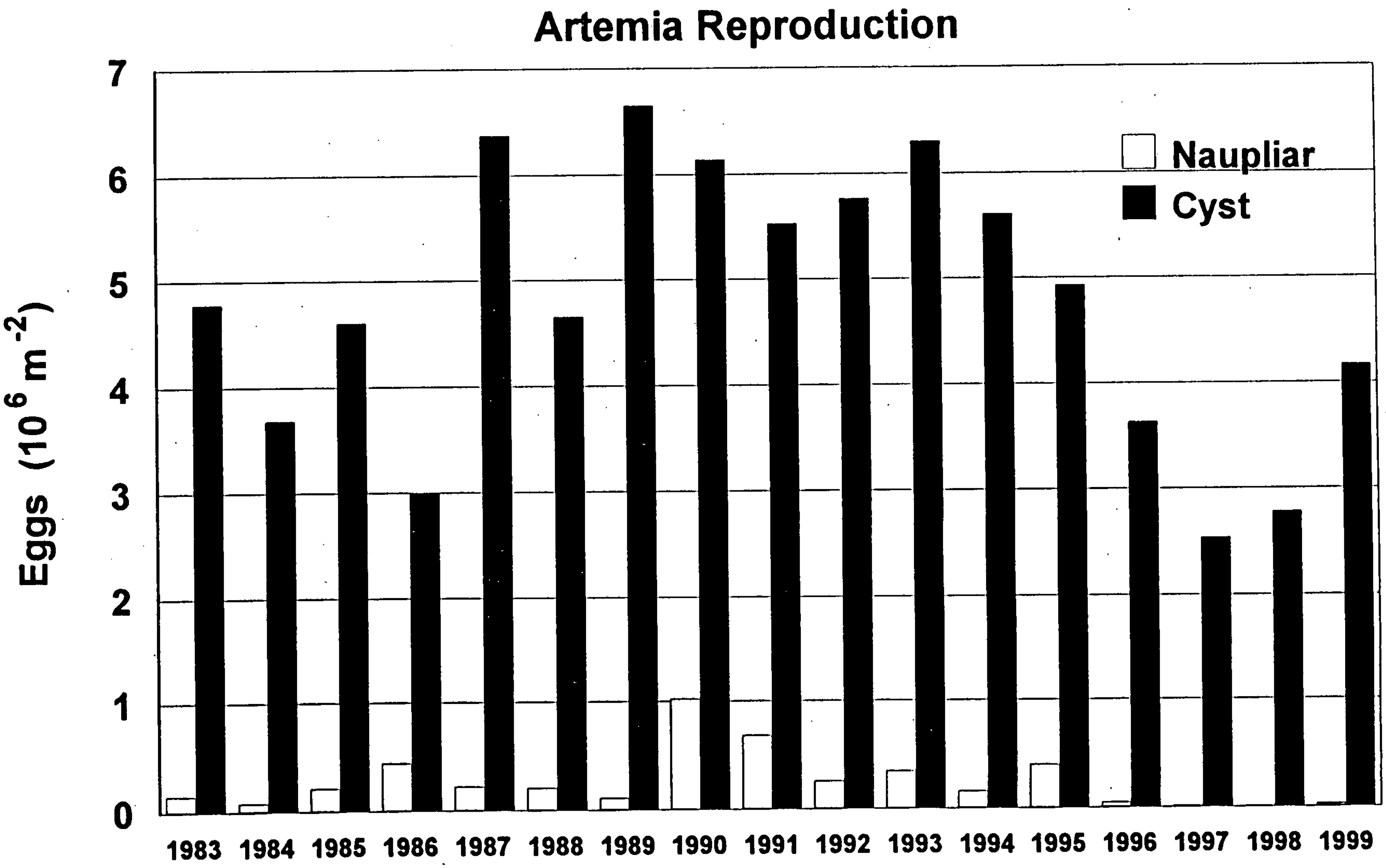

Artemia Reproduction
Naupliar
Cyst
Eggs (10^6 m^-2)
0
1
2
3
4
5
6
7
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999

Figure 3.7

CHAPTER 4

ROTIFER ABUNDANCE IN MONO LAKE

Introduction

The zooplankton communities of hypersaline (>50 g l^{-1}) lakes are much less diverse than in less saline lakes and freshwaters. During limnological surveys of Mono Lake in the mid-1960s, Mason (1967) noted several species of protozoans; the two rotifers, *Hexarthra jenkinae* and *Brachionus plicatilis*; and the endemic brine shrimp, *Artemia monica*. Although Mason (1967) is widely quoted for noting the winter abundance of the two species of rotifers in Mono Lake, his winter observations are from a single collection made in mid-December 1959. During summer surveys in 1963 and 1964, Mason (1967) observed rotifers twice in phytoplankton settling chambers but conducted no winter sampling. Subsequent to these early observations, both species of rotifers disappeared from the pelagic plankton community as water diversions continued and the salinity of the lake rose. However, the date or salinity at which the rotifers disappeared cannot be ascertained with certainty. Hammer (1986) incorrectly cites Winkler (1977) as noting the presence of rotifers at 90‰. In other high salinity lakes such as lakes found northeast of Lake Chad, upper salinity limits for *B. plicatilis* have been found to be 70‰ and for *H. jenkinae*, 50‰ with maximum populations at salinities from 10-20‰ (Iltis and Duwait 1971).

In the 1990s strict limits on water diversions from the basin and several high runoff years have led to rapidly rising surface elevation and decreasing salinity and the re-appearance of rotifers. *H. jenkinae* were first observed during October 1997 when mixolimnetic salinities were ~80 g l^{-1}. *Hexarthra* numbered 18,000 m^{-2} on 27 October and then increased to 101,000 m^{-2} on 3 December 1997. In 1998, *Brachionus plicatilis* re-appeared in autumn plankton samples.

Here, we describe rotifer abundance during 1997-1999.

Methods

The macrozooplankton community of Mono Lake, consists of a single zooplankter, the brine shrimp, *Artemia monica*. The brine shrimp population is sampled throughout the year at twenty stations distributed around the lake. Samples are taken with a plankton net (1 m x 0.30 m diameter, 120 μm Nitex mesh) towed vertically through the water column at approximately 0.5 m s^{-1}. Samples are preserved with 5% formalin in lakewater, and counted under a stereo microscope (6x power). While samples were not explicitly examined for the presence of rotifer species, the presence of abundant rotifers was noted in October 1997 samples.

Therefore, beginning in October 1997 samples were saved following enumeration of *Artemia* and examined for the presence of rotifers. Samples were concentrated to 25-70 ml depending on the abundance of rotifers by filtering through a fine sieve and then rinsing individuals into a sample container. Samples were thoroughly mixed and then three or four 1-ml subsamples removed for counting under an inverted microscope (Olympus BX40) with an attached video camera and monitor. In October and December 1997 samples, individual lengths were measured using Optimus 5.2 software specifically designed for the microscope and camera.

Beginning in May 1998, a 50-μm net lowered to a depth of 5 m was used to collect a separate sample for rotifer enumeration. Low observed abundances during May and June, prompted a change in sampling protocol. Beginning in July and continuing through mid-1999, rotifer samples were collected with both 120-μm and 50-μm nets. Both vertical tows extended to 20 m depth, but the 50-μm net was raised much slower (approximately 10 cm s^{-1}).

The efficiency of vertical net tows varies as a function of mesh size, shape, ascent rates, and the plankton community. Data reported here assume a 70% net efficiency. This efficiency was derived from previous comparisons of *Artemia* abundance collected by vertical net tows and a Schindler-Patalas trap. The current low abundance of rotifers does not allow a similar comparison to be made for deriving a rotifer net efficiency.

Results & Discussion

Net Mesh Size

Rotifer samples were collected with both a 50 and 120 μm mesh net during July 1999 through July 1999. *H. jenkinae* abundance was too low throughout the period for comparison of the efficiency of the two different nets. However, comparison of *B. plicatilis* abundance indicated the 120 μm net hauled vertically at ~0.5 m s^{-1} collected significantly more (Wilcoxon signed rank test with n=18; $p < 0.05$) individuals than the 50 μm net hauled vertically at ~0.1 m s^{-1}. For this reason, the 50-μm net tows were discontinued.

Abundance

The abundance of *H. jenkinae* declined from 100,500 m^{-2} on 3 December 1997 to 670 m^{-2} on 18 March 1998 (Fig. 4.1). Numbers of *H. jenkinae* remained low throughout the rest of the year never exceeding 1,700 m^{-2}. Assuming they are distributed throughout the oxic portion of the water column, the 1998 areal estimates translate to <1 $liter^{-1}$. In 1999, no *H. jenkinae* were observed in plankton samples although a few individuals were observed in ponds adjacent to the lake.

B. plicatilis first appeared in September 1998 samples when abundance was 4,600 m^{-2}. *B. plicatilis* was more abundant on 14 October (15,100 m^{-2}) and then declined by 7 December (400 m^{-2}). In 1999, *B. plicatilis* was absent from samples collected during February through June, but re-appeared at low abundances (40–300 m^{-2}) in July through September plankton samples. The population then increased to 2,000, 7,000, and 12,000 m^{-2} in October, November, and December, respectively. Assuming the rotifers are distributed over the oxic portion of the water (upper 12-15 m), this abundance is quite low for a rotifer population (~1 $liter^{-1}$).

The low abundance of both these species throughout 1998 and 1999 indicates sub-optimal conditions in the lake and suggests the possibility that the pelagic rotifer population is being "seeded" from less saline nearshore environments where freshwater springs and seeps occur. Mason's (1967) reports of *H. jenkinae* and *B. plicatilis* in his 1959 mid-winter sample provided the extreme upper range for these species and thus they are likely at the limit of their physiological tolerance. According to Epp and Winston (1978), rotifers are osmoconformers that respond to any change in osmotic concentration by decreasing their metabolism. Lubzens et al (1985) found no mixis, sexual reproduction, at salinities greater than 35‰ and postulated that there would be a lower amount of energy allocated to reproduction due to the increased energy requirement of osmoregulation. Lower reproduction would affect the number of resting eggs available for hatching.

Rotifers were present in Mono Lake during December 1959. Based on the surface elevation of 6399 ft during December 1959, the salinity is estimated to have been 62 g l^{-1}. Mason noted their presence while counting phytoplankton samples on two occasions in summer 1964 when the lake was ~70 g l^{-1}. The salinity rose to 97 g l^{-1} at the lake's historic low of 6372 ft. asl in 1982, after which salinity decreased with increasing lake size. Abundant rotifers were again first observed October 1997 at mixolimnetic salinities of 80 g l^{-1}. Given their potential significance to plankton dynamics, plankton samples for rotifer enumeration have been routinely collected beginning in 1998. Rotifers were virtually absent during February-June of both 1998 and 1999 and only increased to low abundance (~1 liter^{-1}) late in the year.

If the low abundances observed at the three pelagic sampling stations were due to persisting populations drifting in from less saline pools along the shore, the implications would be quite different than if the rotifers were hatching from resting eggs found in the sediments. The conditions necessary for hatching of *Brachionus plicatilis* resting eggs have been studied by Minkoff *et al* (1983). Light was found to be the only obligatory cue for hatching, thus only resting eggs from sediments of the littoral region would be expected to hatch. This result was confirmed by Hagiwara *et al* (1995) and may be due to light induced peroxide formation in salt water. Minkoff *et al.* (1983) found optimal hatching temperature to be 10-15°C. This was the surface temperature at which the large abundances of rotifers were found at Mono. Optimal salinity was 16‰. The highest salinity tested was 40‰, at which over half of the eggs remained dormant and only approximately 15% hatched within the 11-day incubation period. However, these results were based on a single clone. Ito (1960) has suggested that the salt concentration during the formation of resting eggs may be the optimal salinity for their hatching. Since no work has been done with rotifer resting eggs at Mono Lake, the hatching conditions can not be determined at this location.

The absence of significant numbers of rotifers during all but late in the year may reflect seeding from less saline ponds immediately adjacent to the lake. In each of the past 3 years (1997—99), the surface elevation of the lake has risen during January through July after which it has declined ~1 ft. late in the year. During this period of decline, connected ponds immediately adjacent to the lake would drain into the lake. In 1997, *H. jenkinae* appeared late in the year but disappeared immediately thereafter and has remained virtually absent through the present. However, *B. plicatilis* appeared in significant numbers late in the year in both 1998 and 1999 during the period of surface elevation decline. The absence of significant numbers of rotifers except late in the year may also result from competition with the much larger and efficient filter-feeding *Artemia*. The increase in rotifers coincides with the autumn decline in the *Artemia* population.

The effects of the current rotifer population on energy flow and trophic dynamics is low given their small numbers. Rotifer clearance rates are commonly between 1 and 10 $\mu l\ hr^{-1}$ (Wallace and Snell 1991), although rates as high as 50 $\mu l\ hr^{-1}$ have been reported (Bogdan et al. 1980). Assuming clearance rates of 10 $\mu l\ hr^{-1}$ for 24 hours a day yields 0.24 ml d^{-1} and given 2-10 $liter^{-1}$ observed in October and December 1997 gives a population clearance rate of less than 3 ml d^{-1}. The clearance rates of individual *Artemia* are 100–200 ml d^{-1} and typical summer abundances are 2–5 $liter^{-1}$. However, much higher *H. jenkinae* abundances have been reported in other saline lakes (e.g. 17,000 $liter^{-1}$ in Red Rock Tarn; Hammer 1981). At these abundances, *H. jenkinae* would certainly make a major contribution to overall zooplankton grazing rates. Also, other factors may increase the significance of rotifers on the plankton dynamics including effects of species-specific grazing and their patterns of seasonal abundance (e.g. present in winter when *Artemia* are absent).

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Figure captions

Figure 4.1. Rotifer abundance (10^3 m^{-2}) in Mono Lake, 1997–99.

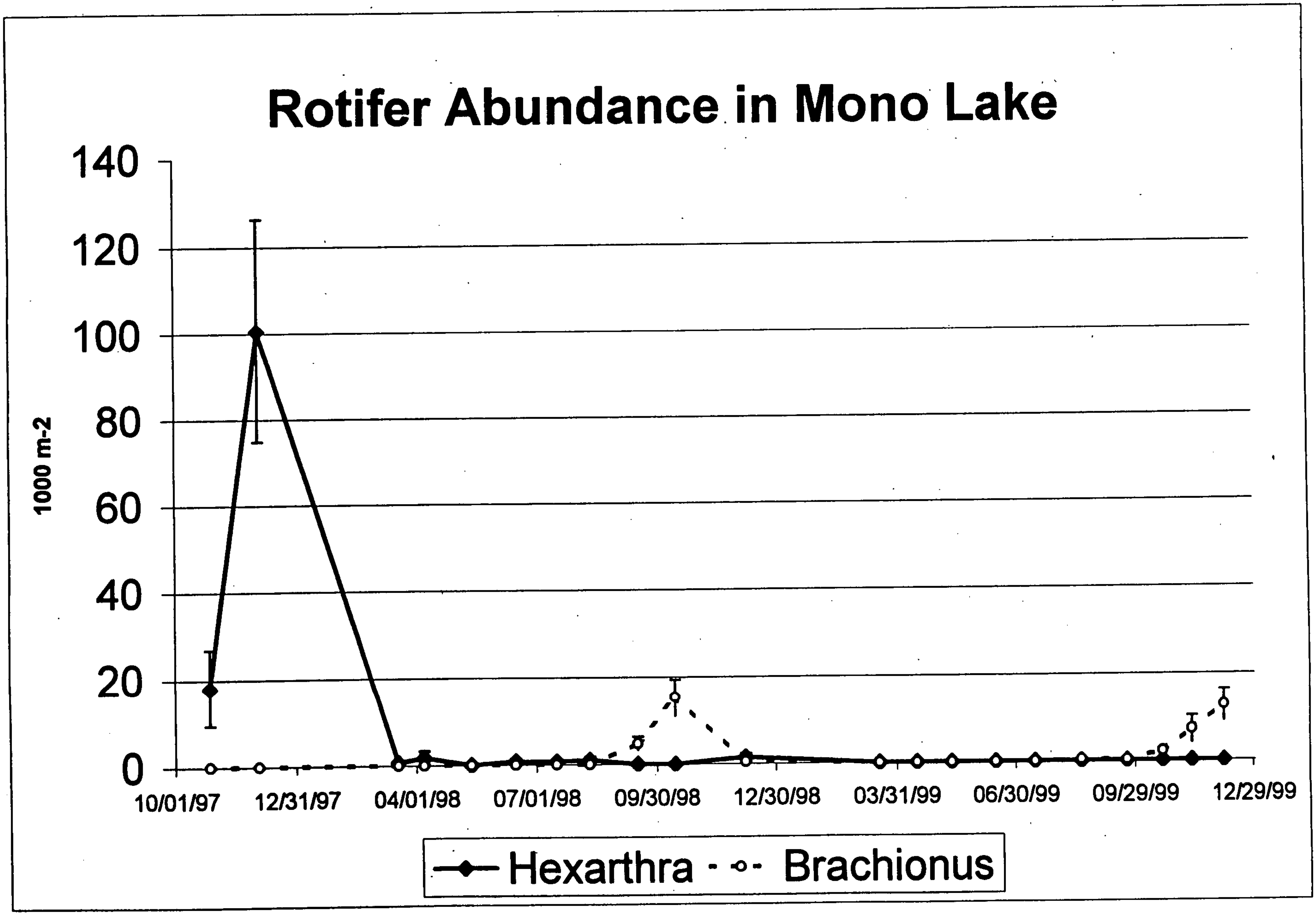
Rotifer Abundance in Mono Lake
140
120
100
80
60
40
20
0
1000 m-2
10/01/97
12/31/97
04/01/98
07/01/98
09/30/98
12/30/98
03/31/99
06/30/99
09/29/99
12/29/99
Hexarthra
Brachionus

Figure 4.1

TAB

11

APPENDIX IV

1999 MONO LAKE VEGETATION MONITORING REPORT

1999

Mono Lake Vegetation

Monitoring Report

Prepared by

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Mono Lake Vegetation Monitoring

The Los Angeles Department of Water and Power (LADWP) conducted vegetation-monitoring activities in lake fringing wetlands surrounding Mono Lake and in tributary stream deltas during the 1999-growing season. These efforts were undertaken to fulfill LADWP's State Water Resources Control Board (SWRCB) obligations prescribed in SWRCB Order No. 98-05. Monitoring protocol was developed working closely with the waterfowl monitoring consultants hired to oversee the LADWP's Mono Basin waterfowl habitat monitoring program. The objective of these monitoring efforts is to determine wetland changes as the lake level rises and how those changes may relate to waterfowl activity in the region. Monitoring will also be used to determine the effectiveness of a burning program that is in the developmental phase.

Wetland Monitoring

Wetland monitoring sites were established at three locations in the Mono Lake Basin; Sammon Springs, Warm Springs, and Dechambeau Embayment (Figure 1). Vegetation monitoring was conducted along permanent transects using the point intercept method to determine species composition and cover for each site. Caution was taken to minimize disturbance to extant vegetation along the permanent transects. Horizontal coordinates of each monitoring site and permanent transects were determined with GPS.

Sammon Springs

At Sammon Springs, 3 transects established by California State Parks biologists were utilized to determine species composition and cover (Figure 2). These transects were utilized in order to minimize the number of permanent markers visible at this popular tufa viewing site. Transects varied in length with 2 being 100 m long while the third was 75 m. Approximately 84% of this site was vegetated and approximately 1% was open water. Species composition and cover values are presented in Table 1.

Warm Springs

At Warm Springs, three permanent transects were established perpendicular to the Mono Lake shoreline (Figure 3). Transects were randomly located within the marsh areas at each site. Transects extended from the current lake elevation (6385 ft) to approximately 6392 ft (□ 550 m). At 100 m intervals along each permanent transect, 50 m long sampling transects were established (n=6) parallel to the lake shore. Sampling transects ran either north or south from the permanent transect. The direction was randomly chosen. Average cover and species composition presented in Table 2. Values are averages of the three sampling points of approximately equal distance from the lake shore.

Dechambeau Embayment

At Dechambeau Embayment, three permanent transects were established perpendicular to the Mono Lake shoreline (Figure 4). Transects were randomly located within the marsh areas at each site. Transects extended approximately 100 m from the current lake shore. At each end, and the mid-point of each permanent transect, a 50 m long sampling transect was established (n=3). Sampling transects ran either north or south from the permanent transect. The direction randomly chosen. Average cover and species composition presented in Table 3 are averages of the sampling points of approximately equal distance from the lake shore.

Tributary Delta Monitoring

Six transects were established within the delta areas of both Lee Vining and Rush Creeks (Figures 1, 5, and 6). The first transect was located near the mouth of each delta and extended upstream at approximately 100 m intervals. Vegetation monitoring was conducted using the point intercept method to determine species composition and cover for each site. These data are presented in Tables 4 and 5. Horizontal coordinates of each sampling transect were determined with GPS. GPS readings were also taken at approximately 10 m intervals along each sampling transect.

With all sampling, caution was taken to disturb existing monitoring areas as little as possible.

Data collected during the 1999 growing season will be utilized as baseline data for comparison of future monitoring data. Additionally, data from Warm Springs will be utilized to examine the effectiveness of prescribed burns that are in the planning stages for the winter of 2000-2001.

Table 1. Species list and average cover (%) of each for the three sampling transects at the Sammon Springs Wetland Vegetation monitoring area.

	Transect 1	Transect 2	Transect 3
Bare	6.33	2	12
Litter	6.33	2	7
Water	--	2	--
Casteleja spp.	--	2	--
Chrysothamnus nauseosus	--	--	6
Disticilis spicata	10.67	3	7
Epilobium spp.	2.67	--	--
Eleocharis macrostachya	28.00	6	5
Hordeum jubatum	--	--	2
Mimulus glabrata	--	2	--
Juncus balticus	13.33	34	17
Muhlenbergia asperifolia	--	2	2
Poa pratensis	--	--	2
Scirpus acutis	--	27	1
Scirpus pungens	28.00	8	10
Scirpus nevadensis	5.33	--	23
Solidago spectablis	--	3	4
Typha latifolia	--	7	2

Table 2. Species list and average cover (%) of each for the Warm Springs Wetland Vegetation monitoring area. Values are averages of sampling points of approximately equal distance from the lake shore. Transect 1 is closest to the lake while transect 6 is furthest from the lake.

	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Transect 6
Bare	10.67	3.33	6.67	20.67	1.33	2.00
Litter	10.67	16.00	11.33	15.33	7.33	--
Water	3.33	0.67	10.67			--
Disticilis spicata	--	--	--	15.33	2.00	--
Juncus balticus	--	--	1.33	--	3.33	3.33
Scirpus acutis			16.67	--	--	2.66
Scirpus pungens	--	18.00	5.33	--	13.33	74.00
Scirpus maritimus	--	58.67	4.00	--	--	--
Scirpus nevadensis	64.67	--	33.33	46.00	62.66	16.00
Unk annual forb	--	--	--	--	0.66	--
Unk mustard	10.67	3.33	10.67	2.67	2.66	2.00

Table 3. Species list and average cover (%) of each for the Dechambeau Embayment Wetland Vegetation monitoring area. Values are averages of sampling points of approximately equal distance from the lake shore. Transect 1 is closest to the lake while transect 3 is furthest from the lake.

	Transect 1	**Transect 2**	**Transect 3**
Litter	8	--	0.67
Water	20.67	--	--
Bare	2	--	--
Allenrolfea occidentalis	0.66	--	--
Bassia hyssopifolia	0.67	6	1.33
Carex rostrata	0.66		--
Descuriania pinnata	1.33	3.33	18
Disticilis spicata	22	14.67	6
Juncus balticus	1.33	--	0.67
Hordeum jubatum	1.33	44	8
Muhlenbergia apserifolia	1.33	--	--
Muhlenbergia spp.	0.67	--	--
Poa secunda	4	14	--
Polypogon monspeliensis	--	1.33	4.67
Salix exigugua	--	--	0.67
Salsola tragus	--	--	2.67
Sarcobatus vermiculatus	--	--	0.67
Scirpus acutis	--	--	1.33
Scirpus pungens	31.33	16	27.33
Triglogin concinna	4.67	--	
Typha latifolia	--	--	2.67
Veronica perigrina	--	--	1.33
Unk Chenepod	--	--	8
Unk Mustard	--	--	6

Table 4. Species list and average cover (%) of each for the Lee Vining Delta vegetation monitoring transects.

	T1	T2	T3	T4	T5	T6
Bare	17.4	9.6	29.1	51.8	57.6	42.9
Liter	8.7	9.6	12.6	5	8.5	14.7
Water	13	6.7	6.8	21.6	7.3	6.1
Agrostis stolonifera	4.4	--	--	--	--	--
Artemesia ludoviciana	--	2.9	3.9	3.6	1.7	1.9
Artemesia tridentata	4.3	0.96	--	0.7	2.3	0.6
Valeriana californica	--	--	2.9	2.9	1.1	--
Chrysothamnus nauseosus	--	--	--	--	0.56	--
Deschampsia cespitosa	--	0.96	0.97	--	--	--
Disticiclis spicata	--	0.96	--	--	4.5	1.8
Juncus balticus	--	--	--	--	--	0.6
Juncus nevadensis	--	6.7	--	2.9	--	--
Lupinus spp.	4.3	3.8	5.8	2.2	1.1	3.7
Melalotis alba	8.7	4.8	0.97	--	--	1.8
Medicago lupulina	--	--	--	0.7	--	--
Muhlenbergia spp.	4.3	--	--	2.2	--	2.5
Poa pratensis	--	--	1.9	1.4	0.6	0.6
Poa secunda	--	--	--	--	1.7	--
Populus trichocarpa	--	0.96	--	--	4.5	12.3
Pursia tridentata	--	--	--	--	2.3	--
Rosa woodsii	--	--	0.97	--	3.95	3.1
Rumex crispus	--	--	0.97	--	--	--
Salix spp.	4.4	--	--	--	--	--
Salix exigua	13	45.2	23.3	5	2.3	2.5
Salix exigua (dead)	17.4	--	2	--	--	--
Salix lutea	--	4.8	6.8	--	--	4.9
Solidago spectablis	--	1.9	--	--	--	--

Table 5. Species list and average cover (%) of each for the Rush Creek Delta vegetation monitoring transects.

	T1	T2	T3	T4	T5	T6
Bare	17	13.8	16.9	9.5	17.6	21.7
Liter	3	2.7	3.4	--	--	3.6
Water	17.5	22.2	8.5	15.9	29.4	31.3
Artemesia tridentata	--	--	--	--	--	1.42
Carex aquatilis	--	1.1	--	--	--	--
Carex nebrascensis	0.5	--	--	--	3.9	2.4
Carex praegracilis	0.5	--	0.6	--	5.9	--
Chrysothamnus nauseosus	--	--	1.1	1.6	2	--
Deschampsia cespitosa	2	--	--	--	--	--
Disticiclis spicata	--	--	--	--	--	2.4
Juncus balticus	11	23.8	14.7	12.7	13.7	8.4
Juncus bufonis	1.5	--	--	--	--	--
Juncus longistylus	3.5	3.3	2.8	1.6	--	--
Lupinus spp.	--	0.6	1.1	17.5	--	--
Melalotis alba						
Medicago lupulina						
Muhlenbergia asperina	--	--	0.6	--	--	--
Muhlenbergia spp.	3	1.1	1.2	--	--	--
Poa secunda	--	--	2.3	--	--	--
Potentilla biennis	0.5	--	--	--	--	--
Pursia tridentata	--	--	0.6	--	--	--
Rosa woodsii						
Rumex crispus						
Salix exigua	32.5	27.8	39.5	39.7	19.6	28.9
Salix exigua (dead)	6	--	--	--	--	--
Salix lutea	--	2.8	6.2	--	3.9	--
Tamarix rammosisima	0.5	--	--	--	3.9	--
Triglochin maritimus	0.5	0.6	--	--	--	--
Unk Annual Forb	0.5	--	--	--	--	--
Verbascum thapsus						

Figure 1. Airphoto of Mono Lake. Wetland and stream delta sampling areas are noted.

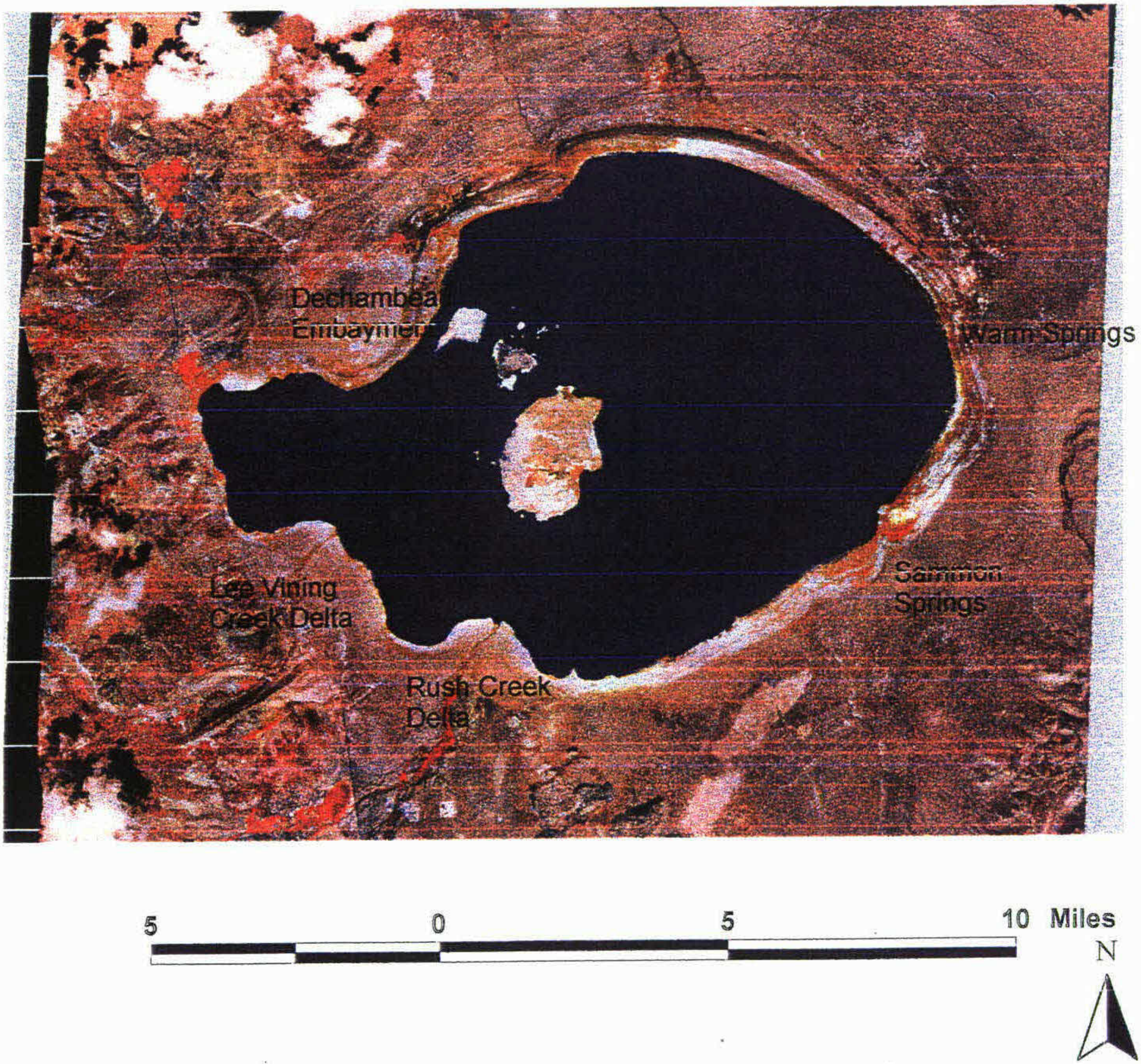


Figure 2. Sammon Springs wetland vegetation monitoring transects. Transect endpoints are marked. Values presented in Table 1 are averages for each transect.

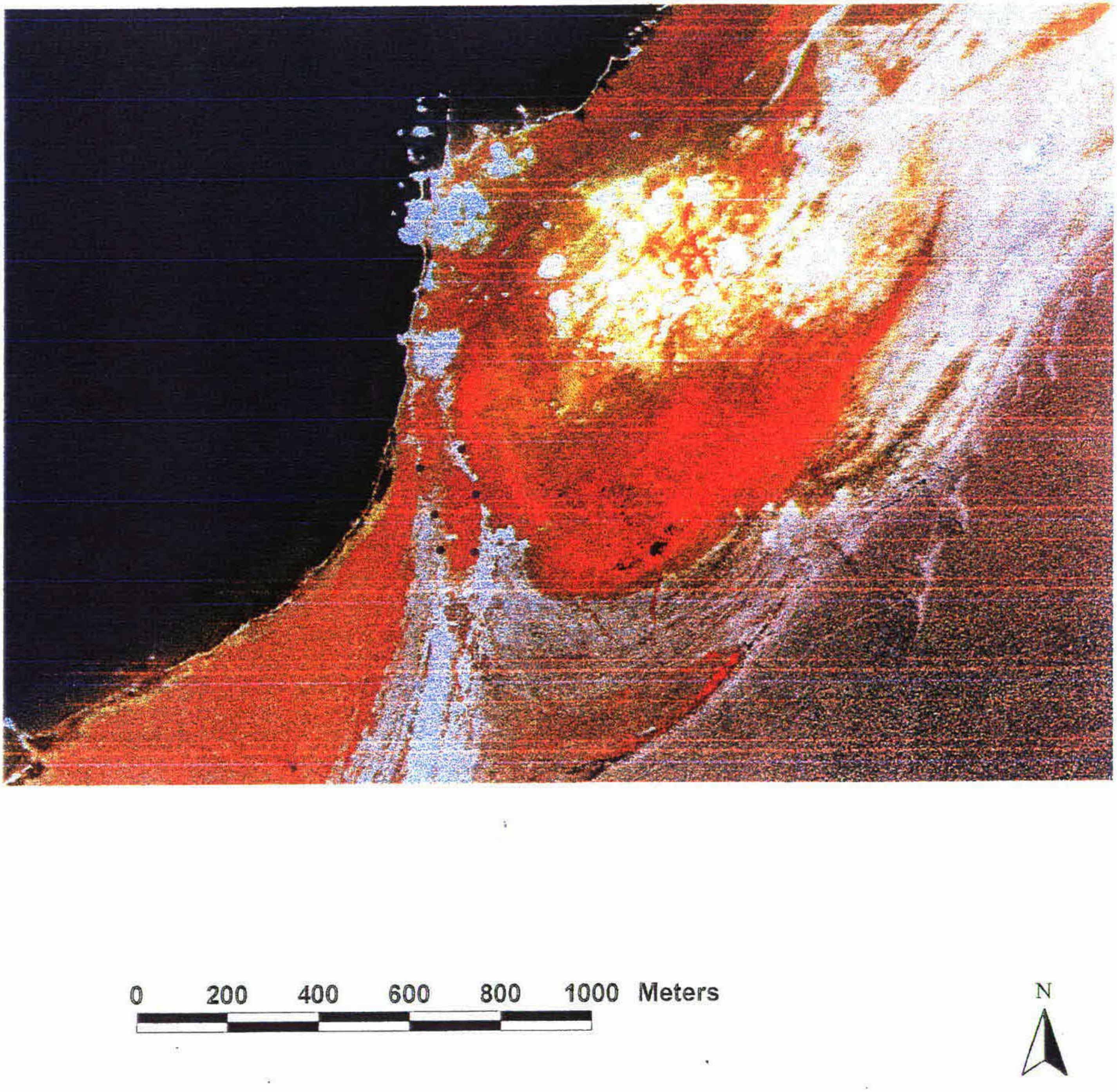


Figure 3. Warm Springs vegetation monitoring site. Marked locations indicate sampling transect enpoints. Values presented inTable 2 are averages of sample transects of approximate equal distance from the lake shore.

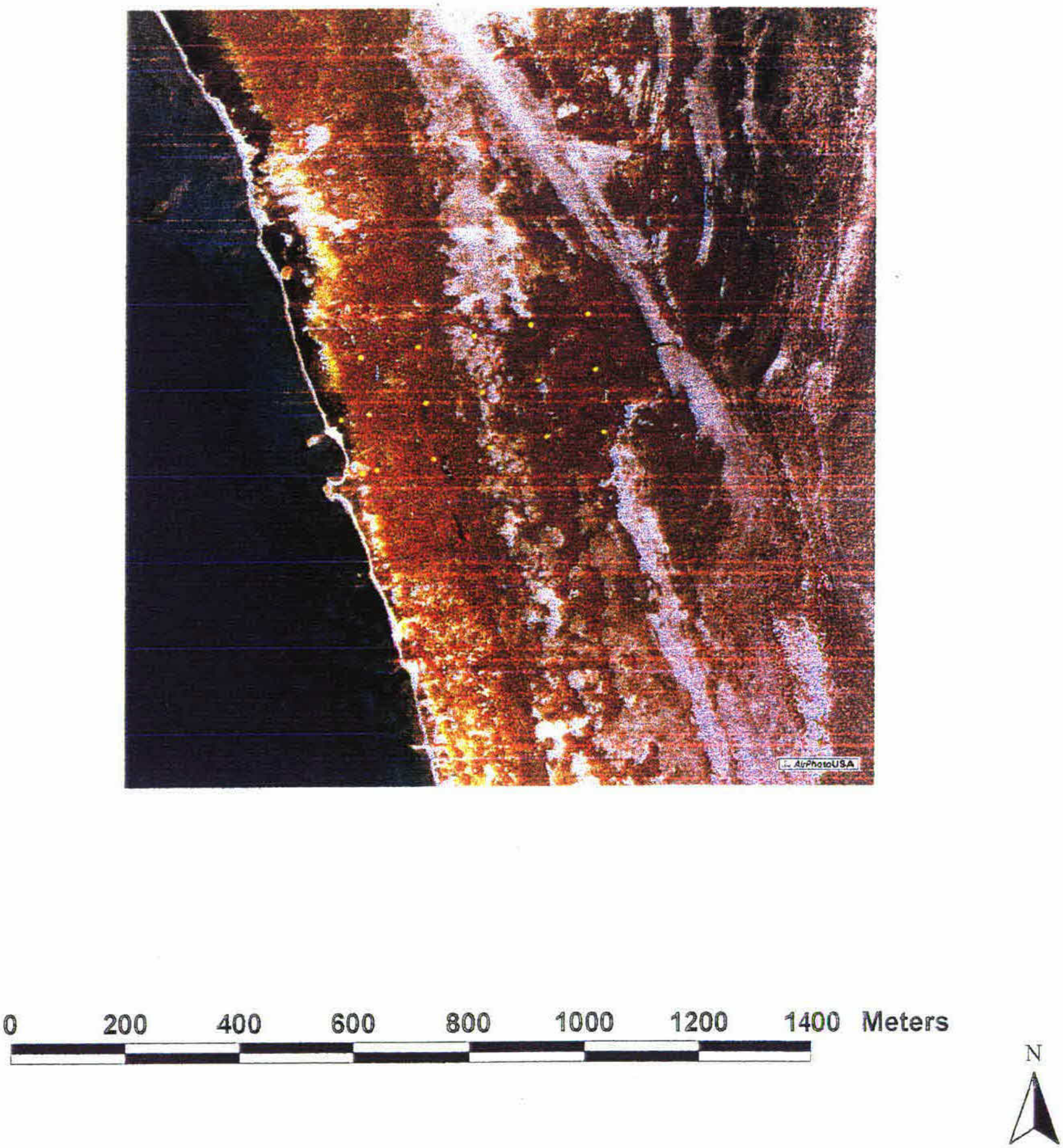
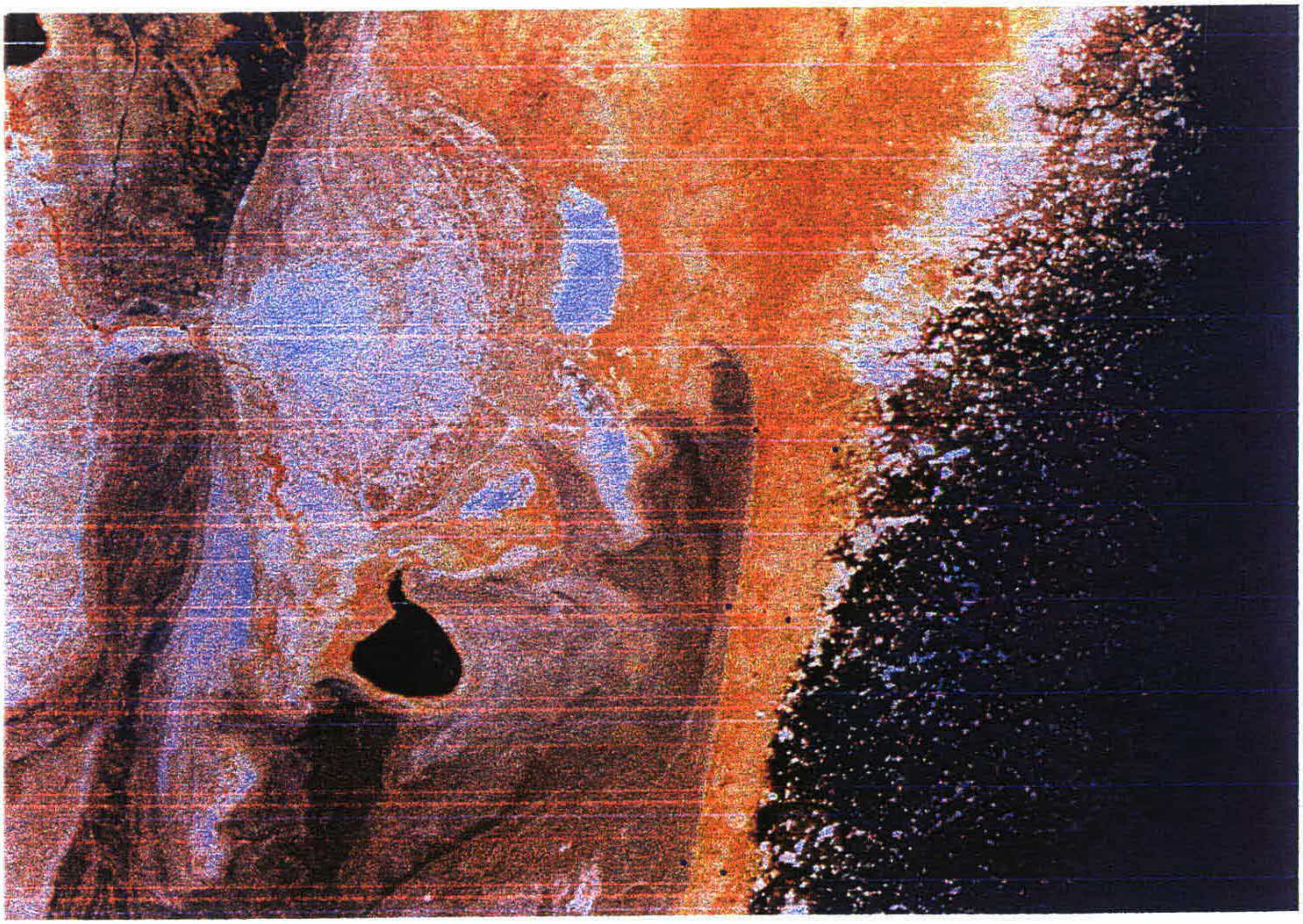


Figure 4. Wetland vegetation monitoring transects at Dechambeau Embayment. Values presented in Table 3 are averages of points of approximately equal distance from the lake shore.



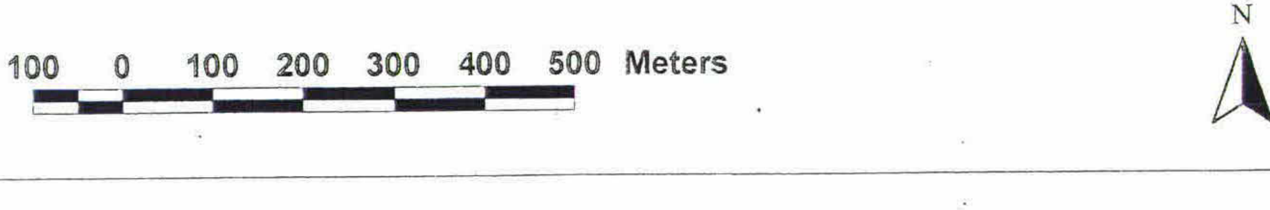


Figure 5. Rush Creek delta vegetation monitoring transects.

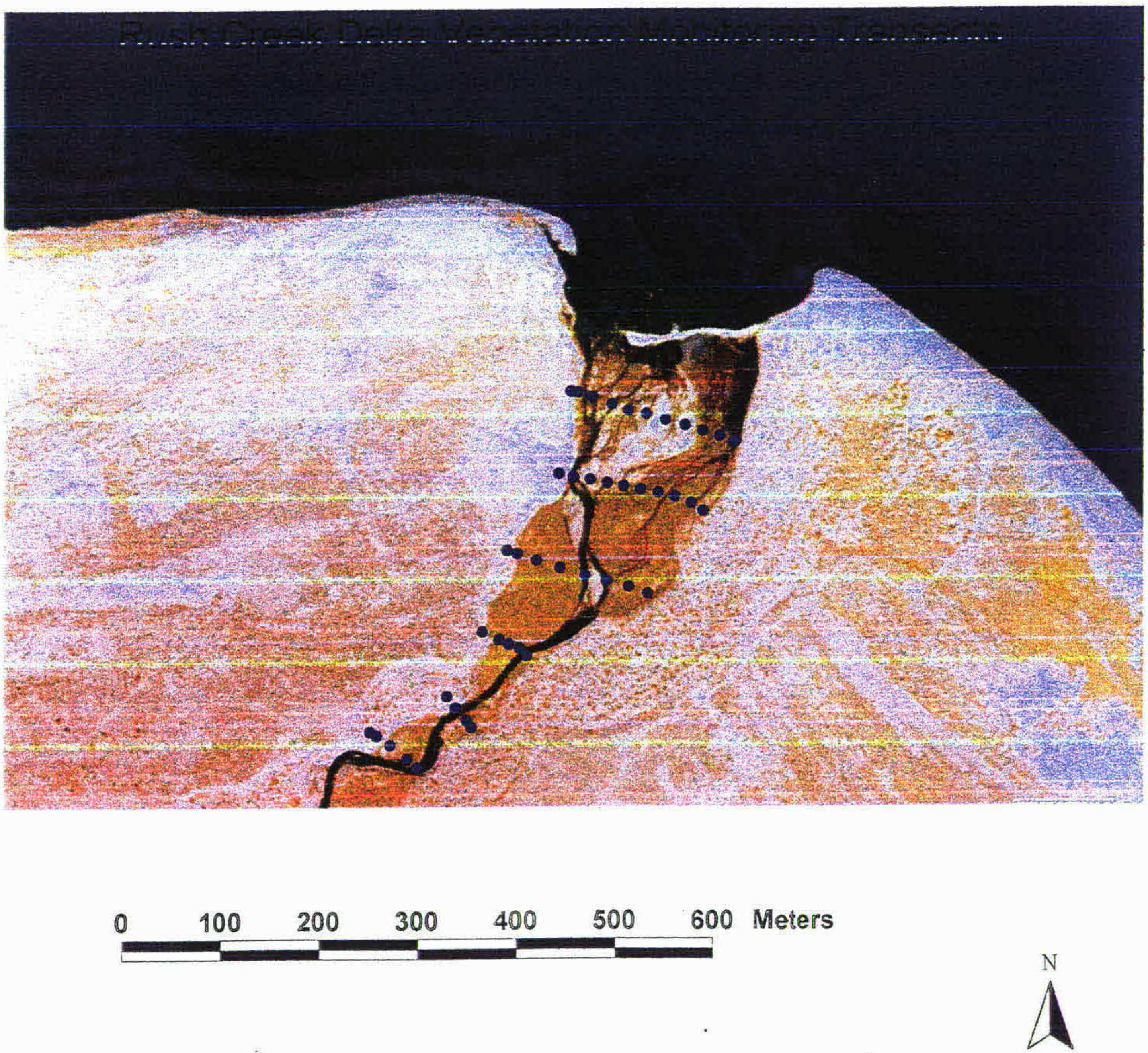
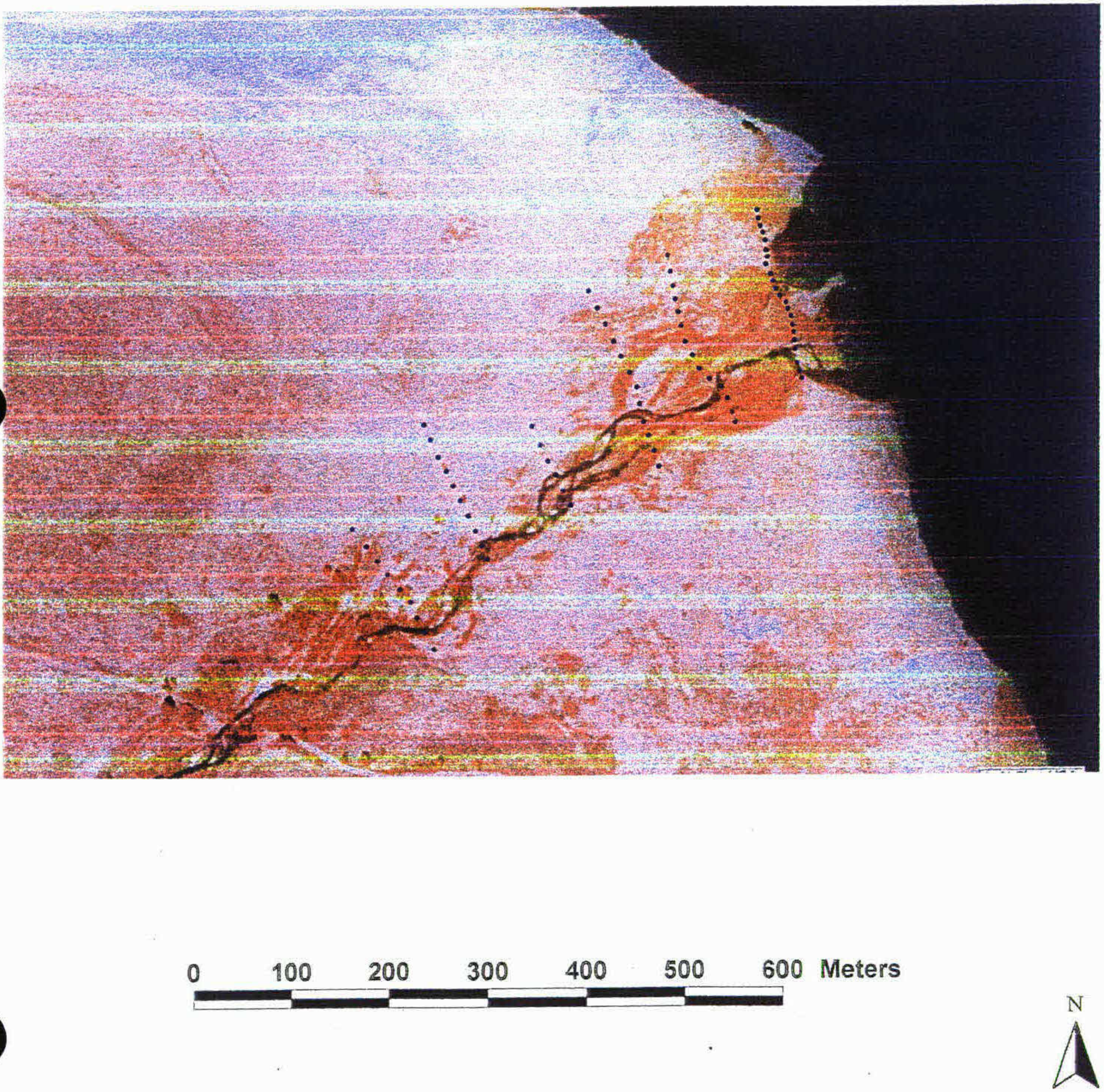


Figure 6. Lee Vining delta vegetation monitoring transects.



APPENDIX V

1999 MONO BASIN VEGETATION AND HABITAT MAPPING

1999 Mono Basin Vegetation and Habitat Mapping

May, 2000

Los Angeles Department of Water and Power

1. Introduction

As one component of waterfowl restoration monitoring described in Section 4.d(2) of Order 98-05, Los Angeles Department of Water Power (LADWP) is required to undertake annual aerial photography of waterfowl habitat. The aerial photography needs to be "...sufficient for use in annual waterfowl population studies and sufficient to identify annual changes in vegetation in waterfowl habitat areas."

This report documents the aerial photography of Mono Lake shoreline areas and the waterfowl habitat quantified in 1999.

2. Methods

The aerial photography and mapping of vegetation in Mono Basin waterfowl habitat was comprised of three separate steps each completed by a separate company under contract to LADWP. The first step consisted of the aerial photography, which was completed by I.K. Curtis of Burbank, CA. The second step involved the conversion of the aerial photography into a digital, geo-rectified, composite image, which was done by AirPhoto USA of Phoenix, AZ. The final step included the interpretation of vegetation classes and mapping of vegetation polygons into a GIS database, which was completed by David Chapin of R2 Resource Consultants, Redmond, WA.

2.1 Aerial Photography

Aerial photography was taken on September 2, 1999 between 10:00 AM and 2:00 PM using color infrared (CIR) film (Kodak2443 CIR) with a Leica RC20 camera having a 6 inch focal length lens. The aircraft was flown at an approximate altitude of 18,000 feet above the earth surface. Scale of photography was 1 inch = 3,000 feet or 1:36,000 (original scale on 9 inch x 9 inch negatives or contact prints). The CIR film was processed to negatives, from which contact prints were made. The photography resulted in 37 frames taken along 5 flight lines that covered much of the Mono Basin. Adjacent frames were viewable as stereo-pairs.

2.2 Digital Image Production

The aerial photography was converted from negatives to a digital composite image by AirPhoto USA using their proprietary "Stable Earth Digital Ortho Rectification Process" (See Appendix A for a description). The production of the digital composite image using this process consisted of four basic steps (J. R. Robertson, AirPhoto USA, personal communication with David Chapin, 4 January 2000):

- Image was scanned at 1200 dpi optically, resulting in a digital image with 1 meter pixel size. During the scanning, the negative is "developed" into a positive through computer processing;
- Each frame was computer processed using various algorithms to take out any distortion from camera;

- The frames were put together as a mosaic; color differences between frames were radiobalanced;
- Georeferencing was done using U.S. Geological Survey (USGS) digital elevation models (DEM) and location of features on USGS 1:24,000 quads for ground control. Planimetric accuracy is 40 feet (90% of pixels within 40 feet of real location), but according to AirPhoto USA, real accuracy was generally within 1 meter of control points.

The digital composite image of the Mono Basin CIR photography was delivered on CD-ROM and could be viewed using the AirPhoto USA proprietary software (called PhotoMapper) included on the CD. The PhotoMapper software also has a utility for exporting digital images in various formats from the composite image, including formats compatible with ArcInfo and ArcView GIS software. Optimum resolution on the digital composite image was indicated to be at a scale of 1 inch = 300 feet, or 1:3,600.

2.3 Habitat Classification, Mapping, and GIS database development

2.3.1 Classification

The selection of a vegetation classification for the 1999 habitat mapping and monitoring was based on three basic criteria. First, the classification used for monitoring should be compatible with previous vegetation mapping conducted around Mono Lake. Second, the cover classes needed to distinguish structurally different habitat types utilized differently by waterfowl. Third, the cover classes used for monitoring habitat changes needed to be individually discriminated using the 1999 CIR aerial photography and digital image.

The classification used in the Mono Basin EIR consisted of 37 different cover classes (to the vegetation series level), not all of which were discriminated using the 1999 CIR aerial photography. Stine's (1995) table of pre-diversion, point-of-reference, and predicted future waterfowl habitat at Mono Lake utilized six different habitat classes:

- freshwater marsh,
- seasonally wet meadow,
- freshwater pond,
- perennial brackish lagoon,
- ephemeral brackish lagoon, and
- hypopycnal ria (plus bottomlands)

Stine's "freshwater marsh" and "seasonally wet meadow" classes were composites of several individual vegetation classes identified for the Mono Basin EIR.

The classification used for the 1999 mapping and monitoring of waterfowl habitat included all of Stine's (1995) classes, some subdivisions of Stine's classes to facilitate interpretation, and a few other classes that were useful in distinguishing surrounding vegetation or cover that was not considered waterfowl habitat. However, for several reasons discussed below in Section 3.2, all of the classes used in the 1999 mapping are not exactly comparable between the two classification systems. The classes used in the 1999 mapping and a brief description of each class are as follows:

Marsh

Areas with surface water usually present all year and dominated by tall emergent species such as hard-stem bulrush (*Scirpus acutus*), cattail (*Typha latifolia*), three-square (*Scirpus pungens*), alkali bulrush (*Scirpus maritimus*) and beaked sedge (*Carex utriculata*).

Wet meadow

Vegetation with seasonally or permanently wet ground dominated by lower stature herbaceous plant species, such as sedges (*Carex* spp.), rushes (*Juncus* spp.), spikerushes (*Eleocharis* spp.), and some forbs (e.g. monkey flower [*Mimulus* spp.], paintbrush [*Castilleja exilis*]). Wet meadow vegetation was in areas where alkaline or saline soils did not appear to be present. This class included the "mixed marsh" series from Jones and Stokes 1993 mapping.

Alkaline wet meadow

This type was similar in stature to the wet meadow class but occurred in areas clearly affected by saline or alkaline soils. Vegetation was typically dominated by dense stands of Nevada bulrush (*Scirpus nevadensis*), Baltic rush (*Juncus balticus*), and/or saltgrass (*Distichlis spicata*). The high density and lushness of the vegetation indicated that it had a relatively high water table with at least seasonal inundation and distinguished it from the dry meadow vegetation class. Distinction between alkaline wet meadow and dry meadow was not always clearcut, both in classifying polygons in the 1999 mapping and making comparisons to the Jones and Stokes 1993 mapping.

Dry meadow /forb

This vegetation class included moderately dense to sparse (at least 15 percent) cover of herbaceous species, including a variety of grasses and forbs and some sedges (e.g., *Carex douglasii*). As with the alkaline wet meadow type above, comparison to vegetation series in Jones and Stokes (1993) was sometimes problematic due to difficulty in distinguishing dry meadow from wet meadow types.

Riparian and wetland scrub.

Areas dominated by willows (*Salix* spp.) comprised most of the vegetation classified as riparian/wetlands scrub. Small amounts of buffalo berry (*Shepardia argentea*) and Wood's rose (*Rosa woodsii*) usually mixed with willow also were included in this class.

Great Basin scrub

Scattered to dense stands of sagebrush (*Artemesia tridentata*), rabbitbrush (*Chrysothamnus nauseosus*), and/or bitterbrush (*Purshia tridentata*) were classified as Great Basin scrub. This vegetation type included a range of soil moisture conditions, as rabbitbrush was often found in moist areas close to the lakeshore and sagebrush was typically in arid upland areas.

Riparian forest and woodland

Aspen (*Populus tremuloides*) and black cottonwood (*Populus trichocarpa*) were the two tree species most common in the riparian forest/woodland vegetation type.

Freshwater-stream

This class included the channels of streams that were watered at the time of the aerial photography. Generally, a channel had to be > 10 feet wide to be mapped.

Freshwater- ria

Surface water at the mouths of streams that likely had some salt/fresh water stratification were mapped as ria. Since the distance to which rias extended up the stream channel was difficult to determine from the aerial photography, the boundary between ria and stream was subjectively interpreted.

Freshwater-pond

This type included ponds fed by springs within marsh areas or artificially by diversions from streams (e.g. DeChambeau/County ponds

Ephemeral brackish lagoon

If an extensive area of marsh or wet meadow indicating the presence of springs was present landward, lagoons along the shoreline created by the formation of littoral bars were mapped as ephemeral brackish lagoons. In some cases, lagoons were not completely cut off from lake water, but were judged to still have brackish water due to freshwater input and reduced mixing.

Ephemeral hypersaline lagoon

If an extensive area of marsh or wet meadow was not present landward, lagoons along the shoreline created by the formation of littoral bars were mapped as ephemeral hypersaline lagoons. These were presumed to contain concentrated brine due to evaporation.

Unvegetated

Barren to sparsely vegetated (< 15 percent cover) areas were classified as unvegetated. This class included sandy areas, alkaline flats, tufa, and delta outwash deposits.

Man-made

Areas classified as man-made included buildings, parking areas, larger roads, farm houses, and compounds. Stands of horticulturally established tree species (e.g. black locust, Siberian elm) usually growing near houses or farms were also usually classified as man-made.

2.3.2 Photointerpretation, Mapping, and GIS Database Development

Photointerpretation and mapping of cover class polygons consisted of several steps. Ground information about vegetation in marshes, deltas, and other potential waterfowl habitat areas was obtained from several trips to the Mono Basin, including five days in the field during early October using prints of the digital composite image. Based on the October ground-truthing field visit, and using photographs and notes from previous field visits, signatures on the CIR imagery were identified that corresponded to cover classes. Using these signatures, cover class polygons were mapped into a GIS database directly from the composite digital image.

The GIS database was developed using ESRI ArcView software. A series of tiles (small sections) from the composite digital image that covered the entire Mono Lake shoreline area were exported using PhotoMapper and brought into the GIS database. Using these imported images as a backdrop, cover class polygons were delineated on the computer screen as ArcView shape files (often referred to as "heads-up digitizing"). Polygons were mapped by subarea, which corresponded to the set of subareas used by Jones and Stokes (1993) and Stine (1995) (e.g., Warm Springs, South Tufa, Mill-Wilson Delta). Generally, all areas shoreward of the surrounding Great Basin scrub vegetation were mapped.

Minimum polygon size was generally 0.5 acre, although in extensive dry meadow, Great Basin scrub, and unvegetated areas minimum polygon size was approximately 1.0 acre. Most delineation was conducted at an onscreen scale of 1 inch = 300 feet (1:3,600), although along shorelines, in delta areas, and around ponds a scale of 1 inch = 150 feet (1:1,800) was used to obtain finer mapping detail.

Verification of polygon classification was conducted using a series of stratified, randomly selected transects that were distributed around the lake shoreline. Transects were sampled during the October field visit and consisted of (1) establishing location with a Trimble GeoExplorer GPS unit with submeter horizontal accuracy; (2) recording of dominant species and percent cover; and taking a ground photograph at regular intervals (100 to 150 meters depending on distance of transect). Information from the transects used for post-mapping verification was not used during the mapping process.

3. Results and Discussion

The classification and mapping of vegetation and other cover classes presented here documents areas of different waterfowl habitat types at Mono Lake in 1999. The areal quantification of these vegetation and cover classes provides a basis for comparison to point-of-reference and future waterfowl habitat conditions as lake level changes. Since this was the first effort to acquire aerial photography and use it to map waterfowl habitat conditions for the purposes of meeting Order 98-05 monitoring requirements, an evaluation of its adequacy for monitoring should provide useful information for future monitoring efforts.

3.1 Accuracy of Cover Type Classification

To evaluate the accuracy of polygon classification, vegetation data were collected on the ground along 12 separate transects selected in a stratified random manner and located around the entire lake shoreline. Data from these locations were compared to the vegetation type classified at the same location, using the GPS coordinates for the sample point to identify the sample point location on the vegetation GIS datalayer. At each location, a classification type was determined from plant cover data and a photograph taken of the general area. These classifications were compared to those mapped in the vegetation datalayer. Of the 86 points used in the verification process, 71 (83 percent) were correct. It should be noted, however, that a check of GPS points to nearby landmarks indicated that there was up to a 20 meter error compared to the location in the georectified digital, mosaic image. It is not known how this error affected the accuracy evaluation.

3.2 Areas of Waterfowl Habitat Types

Most of the marsh habitat in lake fringing wetlands around Mono Lake were in the Simons Springs subarea, (165 acres), with Warm Springs (66 acres) and DeChambeau Embayment (26 acres) also having substantial marsh areas (Table 1). Wet meadow (probably equivalent to "mixed marsh" of Jones and Stokes [1993]) was most abundant in the County Park (44 acres), Mill-Wilson Delta (21 acres), and DeChambeau Embayment and DeChambeau Ponds (19 acres) subareas. Extensive alkaline wet meadow areas were mapped in the Warm Springs (233 acres), Simons Springs (179 acres), and East Beach (106 acres) subareas.

Small amounts of freshwater ponds were identified in Simons Springs, East Beach, and Black Point subareas (< 1 acre each), and there were 7.1 acres of pond habitat mapped in the DeChambeau/County Ponds complex. Extensive areas of ephemeral brackish lagoon were mapped in the Warm Springs (30 acres), South Beach (24 acres), and North Beach (22 acres) subareas. North Beach also had a large amount of hypersaline lagoon (105 acres). There were 2.4 and 0.5 acres mapped as ria in the Rush Creek and Lee Vining Creek deltas, respectively.

3.3 Comparison to Point-of-Reference Habitat (Jones and Stokes 1993)

For the Mono Basin EIR, Jones and Stokes (1993b) mapped and quantified areas of vegetation types under point-of-reference conditions (August 29, 1989, 6,376 feet lake surface elevation). As the lake level rises, a variety of changes to lake-ringing vegetation were predicted. Because the geomorphic and hydrologic processes affecting marsh extent and vegetation composition are complex, transitional conditions present as the lake level rises are not necessarily indicative of conditions at the target lake level of 6,391 feet elevation. Consequently, this comparison serves only to document the changes in the extent and characteristics of lake-fringing wetlands at a transitional lake-level intermediate between the point-of-reference and the target lake level.

One of the most prominent changes anticipated with increasing the lake level was an overall decrease in marsh area, primarily due to inundation of marsh areas by the rising lake and "spring-line sapping" (i.e., desiccation of wetland supported by springs as beveling cuts an escarpment at a higher equilibrium shoreline). Marsh area mapped in 1999 totaled 302 acres (Table 1). This area, however, should likely be combined with wet meadow mapped in 1999 (83 acres) to compare to Jones and Stokes (1993) point-of-reference marsh area. Combined 1999 marsh and wet meadow area at a lake level of 6,384.6 feet was 385 acres compared to 988 acres of marsh mapped at a lake level of 6,376 feet. This decrease occurred in most areas where marsh was present in lake-fringing wetlands. Warm Springs, however, was an exception and showed an increase in marsh area between 1989 and 1999.

There was also a decrease in alkaline wet meadow from point-of-reference conditions, assuming that the 1999 wet alkaline meadow type is roughly equivalent to Jones and Stokes (1993) alkali meadow formation. There were 1,521 acres of alkali meadow mapped in 1989 and 582 acres of wet alkaline meadow mapped in 1999. Again, decreases occurred in most areas around the lake; Warm Springs and East Beach were two exceptions, as alkaline wet meadow increased in these two areas.

The increase in both marsh and alkaline wet meadow in the Warm Springs area and alkaline wet meadow in the nearby East Beach area suggests that changes in spring activity may be resulting in wetter lake-fringing conditions than occurred their previously. Since some of the marsh and meadow in these areas has been inundated by rising lake level, an increase in marsh and alkaline wet meadow at higher elevations along the shoreline makes this explanation even more likely. Future monitoring should pay particular attention to vegetation changes in this area.

In addition to these major vegetation changes, ephemeral brackish lagoons also changed markedly from 1989 to 1999. Only 1 acre of "ponds and lagoons" were mapped by Jones and Stokes (1993) under point-of-reference conditions. In contrast, 109 acres of ephemeral brackish lagoons and 8.5 acres of freshwater ponds were mapped in 1999. However, the 1999 mapping included 7.1 acres of freshwater ponds within the DeChambeau/County Ponds complex, which were not included by Jones and Stokes (1993). Brackish lagoons mapped in 1999 include ponds and lagoons formed by extensive littoral bars and, in the South Beach area, inundation of pre-existing swales, which may have been deflationary features formed since the lake receded after 1941. Although most of these brackish lagoons are likely to be transient, they nonetheless are potentially important as waterfowl habitat until an equilibrium lake level is reached

The overall area of wetland/riparian scrub increased from point-of-reference conditions (236 acres) to 1999 (335 acres) (data not included in Table 1). Increases were most apparent in the Wilson-Mill creeks delta area and Horse Creek Embayment, although there were also smaller increases in Rush Creek Delta and Lee Vining Creek Delta.

Other changes in vegetation cover types also likely occurred between 1989 and 1999. However, they will not be discussed here either because the cover types are not comparable between the two mapping efforts or they are not relevant to waterfowl.

3.4 Adequacy of 1999 Waterfowl Habitat Mapping for Restoration Monitoring

The acquisition of aerial photography and the mapping of waterfowl habitat in 1999 was the first time this aspect of Order 98-05 waterfowl monitoring has been done. As such, it is useful to evaluate the methods and results of the habitat monitoring to identify areas where it can be improved to better meet monitoring objectives.

3.4.1 Classification and Mapping

As described in Section 2.3.1, the classification system for the 1999 mapping was partly determined by what vegetation types could be differentiated in the aerial photographs and by the relevant habitat types to waterfowl. Comparison of this classification to the previous classification and vegetation mapping conducted by Jones and Stokes (1993) was somewhat problematic due to differences between the two systems.

Mapping the entire lake-fringing wetland area is a large task and is not necessary on an annual basis. It would be more beneficial to use the 1999 mapping as a characterization of early restoration conditions and to do another full-scale mapping in 5 or 10 years. In the interim, monitoring would continue on an annual basis to track changes in several specific areas that are most likely to change in the short-term. This would be especially important for the ephemeral brackish lagoon areas that could potentially appear or disappear from one year to the next. The areas identified for annual mapping include the area from Navy Beach to Warm Springs, DeChambeau Embayment and Lee Vining and Rush Creek deltas.

Literature Cited

Jones and Stokes Associates. 1993. Auxillary Report No. 27, Mono Basin Water Rights EIR: Lake-fringing wetland vegetation and substrate classification, description, and mapping. Prepared for the California Water Resources Control Board, Division of Water Rights, Sacramento, California. May.

Stine, S. 1995. Historical and future waterfowl habitat at Mono Lake, California. A report to the California State Lands Commission and the California Department of Parks and Recreation. April.

Table 1. Area of lake-fringing vegetation types at Mono Lake, California in 1989 (point-of-reference conditions, 6,376 feet lake surface elevation) as listed by Stine (1995) and in 1999 (6,384 feet lake surface elevation).

	Marsh	Wet Meadow	Alkaline Wet Meadow -	Freshwater-Pond	Perennial Brackish Lagooon	Ephemeral Brackish Lagoon	Hypersaline Lagoon	Ria	Freshwater-Stream
"North, East, and South Shores"									
Simons Springs									
6,376 feet (point-of-reference)	496.0	2.0	200.0	1.5	0.0	minor			
6,384 feet (1999 mapped)	165.3		179.0	0.5		8.7	0.0	0.0	0.0
Warm Springs									
6,376 feet (point-of-reference)	55.0	0.0	134.0	2.5	0.0	0.0			
6,384 feet (1999 mapped)	66.1	0.0	233.0	0.4	0.0	29.7	0.0	0.0	0.0
South Tufa									
6,376 feet (point-of-reference)	3.0	0.0	30.0	0-minor	0.0	0.0			
6,384 feet (1999 mapped)	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
"Northwestern Shore near Black Point"									
Mill-Wilson Delta									
6,376 feet (point-of-reference)	43.0	0.0	4.0	0.0	0.0	<0.1		0.0	
6,384 feet (1999 mapped)	0.0	20.5	0.4	0.1	0.0	2.0	0.0	0.0	2.6
County Park									
6,376 feet (point-of-reference)	83.0	7.0	33.0	0.0	0.0	0-minor			
6,384 feet (1999 mapped)	0.0	44.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DeChambeau Embayment									
6,376 feet (point-of-reference)	68.0	0.0	208.0	0.0	0.0	minor			
6,384 feet (1999 mapped)	25.5	18.8	0.0	7.1	0.0	1.0	0.0	0.0	0.0
"Rush and Lee Vining Creek Deltas"									
Rush Creek Delta									
6,376 feet (point-of-reference)	2.0	0.0	0.0	0.0	0.0	0.0		0.0	
6,384 feet (1999 mapped)	0.0	0.0	0.0	0.0	0.0	0.2	0.0	2.4	5.9
Horse Creek Embayment									
6,376 feet (point-of-reference)	27.0	0.0	0.0	0.0	0.0	minor			
6,384 feet (1999 mapped)	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0

Table 1. (continued)

	Marsh	Wet Meadow	Alkaline Wet Meadow -	Freshwater-Pond	Perennial Brackish Lagooon	Ephemeral Brackish Lagoon	Hypersaline Lagoon	Ria	Freshwater-Stream
Lee Vining Creek Delta									
6,376 feet (point-of-reference)	6.0	0.0	0.0	minor	0.0	minor		0.0	
6,384 feet (1999 mapped)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5
Lee Vining Tufa									
6,376 feet (point-of-reference)	43.0	1.0	0.0	0.0	0.0	minor			
6,384 feet (1999 mapped)	4.3	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
"Other Perennial Lagoons of the Mono Shorelands"									
Bridgeport Creek									
6,376 feet (point-of-reference)	20.0	14.0	255.0	0.0	0.0	0.0			
6,384 feet (1999 mapped)	9.1	0.0	0.0	0.0	0.0	12.2	1.6	0.0	0.0
North Beach									
6,376 feet (point-of-reference)	1.0	0.0	122.0	0.0	0.0	0.0			
6,384 feet (1999 mapped)	1.2	0.0	20.3	0.0	0.0	22.1	105.2	0.0	0.0
"Other Marshlands of the Mono Shorelands"									
Black Point									
6,376 feet (point-of-reference)	1.0	0.0	187.0	0.0	0.0	0.0			
6,384 feet (1999 mapped)	0.9	0.0	9.8	0.4	0.0	5.5	3.6	0.0	0.0
South Beach									
6,376 feet (point-of-reference)	6.0	0.0	242.0	0.0	0.0	0.0			
6,384 feet (1999 mapped)	0.0	0.0	7.6	0.0	0.0	23.6	0.0	0.0	0.0
Sierran Escarpment									
6,376 feet (point-of-reference)	125.0	27.0	16.0	0.0	0.0	minor			
6,384 feet (1999 mapped)	10.7	0.0	24.5	0.0	0.0	0.0	0.0	0.0	0.0
East Beach									
6,376 feet (point-of-reference)	6.0	0.0	90.0	0.0	0.0	0.0			
6,384 feet (1999 mapped)	15.0	0.0	105.7	0.4	0.0	3.4	0.0	0.0	0.0
Paoha Island									
6,376 feet (point-of-reference)	3.0	0.0	0.0	0.0	0.0	0.0			
6,384 feet (1999 mapped)	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total									
6,376 feet (point-of-reference)	988.0	51.0	1521.0	4.4	0.0	minor		0.0	
6,384 feet (1999 mapped)	302.0	83.3	581.9	8.5	0.0	109.1	110.4	2.9	9.0

APPENDIX VI

WATERFOWL POPULATION AT MONO LAKE, CALIFORNIA, 1999

WATERFOWL POPULATIONS AT MONO LAKE, CALIFORNIA, 1999

Joseph R. Jehl, Jr.

Hubbs-Sea World Research Institute

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NOTICE

WATERFOWL POPULATIONS AT MONO LAKE, CALIFORNIA, 1999

Joseph R. Jehl, Jr.

Abstract.--This report summarizes observations on waterfowl populations at Mono Lake, CA in 1999. It is based on detailed biological studies, which incorporate foot, boat, and aerial surveys of the lake and adjacent areas during the breeding and fall migration seasons.

The fall migration extends from mid-August-early December. On eight all-lake censuses conducted between 14 July and 23/27 November, we encountered about 19,000 waterfowl of 20 species; Shovelers, Ruddy Ducks, Mallards and Green-winged Teal comprised 92% of those identified to species, and > 98% of the total. Peak numbers (> 10,000) were recorded in mid-October. Freshwater ponds along the north shore provide foraging and breeding habitat for a few waterfowl, but contributed little to overall abundance. Only small numbers or ducks were found there on 12 surveys between early May and late November (peak 152 on 13 October).

Habitat conditions along the lake shore continued to change as a result of the lake's continued rise. The most noticeable was the further development of several freshwater ponds along the south shore between Navy Beach and Sammann's Springs. There was no indication that marshland burned at Sammann's Springs were used by waterfowl. Overall, waterfowl numbers and distribution did not differ importantly from that found in other recent years.

Introduction

In 1980 Hubbs-Sea World Research Institute initiated a long-term program on the biology, ecology, and status of waterbirds at Mono Lake. We gathered data on all species, emphasizing those that are most strongly associated with highly saline environments: California Gull, Eared Grebe, Wilson's Phalarope, Red-necked Phalarope.

In 1995 the State Water Resources Control Board requested detailed information on waterfowl, to include migration periods, population size, distribution and behavior, and comparative data from nearby lakes. This and other collateral information is relevant to evaluating efforts to promote the restoration of Mono Lake to pre-diversion conditions.

We determine the size of the waterfowl population by making lakewide censuses at approximate 3-week intervals in the breeding and fall migration periods. We use a small boat to circumnavigate of the lake, cruising 150-300 m offshore. As necessary, and when conditions permit, we also expand coverage to include forays to the mouths of the major streams, shore-based observations, and foot surveys in marshy areas (e.g., Sammann's Spring, Wilson/Mill creek) that may hold breeding ducks. Because ducks are closely associated with freshwater situations, and except when disturbed occur within 50 m or less of the shoreline, this procedure is satisfactory for censusing all species except the Ruddy Duck,

COVER: Immature Bald Eagles roosting on the shore of Mono Lake, CA 25 Nov 1999. Photo M. Cicero.

whose distribution is not so constrained and includes open-lake habitats. Accordingly, when its migration commenced in mid-September boat surveys are expanded to include transects farther offshore.

We use a standard route, starting at the LADWP boat launch and continuing counterclockwise around the lake. On occasions when all-lake censuses cannot be completed on one day, this procedure may be modified, and the census conducted to two days. Observations and counts are compiled by area (Figure 1) directly onto a standard form (see tables), which lists all species of ducks and geese that we expect to encounter, as well as a few other waterbirds (e.g., American Coot, Common Loon). For this study, all loons, grebes, geese, and ducks are considered "waterfowl." Coots are treated separately.

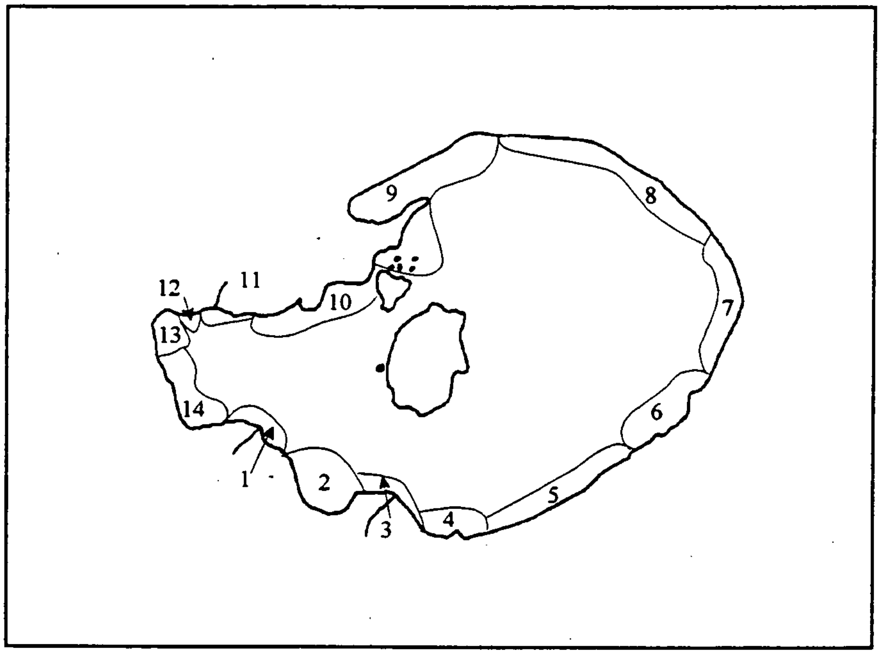


Figure 1. Observation areas used in lakewide waterfowl censuses. 1) Lee Vining Creek. 2) Ranch Cove. 3) Rush Creek. 4) South Tufa. 5) South Shore. 6) Sammann's Spring. 7) Warm Springs. 8) NE Shore. 9) Black Point E. 10) Black Point W. 11) Wilson Creek. 12) Mill Creek. 13) County Park. 14) West Shore.

As established in previous reports, boat-based surveys are the most effective way to determine the size and composition of the waterfowl population, producing results that, except for Ruddy Ducks, are probably accurate to within ± 15%. Aerial surveys follow the same route and are generally made from an elevation of 200-250 feet above lake level and at a speed of about 80 mph. These provide a general indication of waterfowl abundance and distribution. However, they are less accurate than boat surveys because ducks react more adversely to planes, breaking into small flocks and dispersing at greater distances. This renders estimates of flock size and identification to species much harder, although in most cases the two techniques agree to within ±30%.

We also make regular land-based censuses and observations at the freshwater ponds [Dechambeau Ponds (4) and County Ponds (2)] on the north shore near Black Point. Those counts are accurate to ± 10%, except perhaps in hunting season when ducks are more wary and may flee when observers are still distant. We also study the behavior of ducks in as many areas as possible, to clarify the basis for their attraction to Mono Lake and their ecological requirements. In 1999 we took special interest in numbers and behavior of waterfowl on freshwater ponds that were forming on the south shore between Navy Beach and Sammann's Springs. Because the ducks are highly mobile and easily frightened, classical time budget studies of individual birds or groups can rarely be carried out long enough to be meaningful. Thus, we adapt out techniques opportunistically to deal with the level of disturbance imposed by the general public, hunters, and biologists.

To determine the importance of Mono Lake as waterfowl habitats relative to other large, nearby lakes, we make comparative surveys of Bridgeport Reservoir and Crowley Lake in September and October. These may be done by plane, foot, or both, depending on which technique provides the best data.

RESULTS

In 1999 we conducted eight all-lake censuses of Mono Lake between mid-July and late November (Appendix I, Table 1). Most were made by boat and foot. Supplemental information was gathered by aerial surveys (3) in September, October, and November. In addition, between early May and late November we made 12 censuses by foot of the north shore ponds (Appendix I, Table 2).

Mono Lake: Breeding waterfowl

Only a handful of waterfowl occur at Mono Lake in late May. Most are late migrants or nonbreeders that pass through quickly. However, a few pairs of Gadwall are usually present and remain to nest.

Through the summer the Gadwall is virtually the only duck found on the lake itself. It is also the only species that breeds consistently. Occasionally other species nest in marshes around the lake, and in 1999 this may have included a pair of Cinnamon Teal at Sammann's Springs (D. Paul, pers. comm.), although no young were ever reported.

Gadwall breed in scattered locations in proximity to freshwater marshes.

The appearance of broods in mid-July and August indicates the size and distribution of the population (Figure 2). In 1999 22-25 pairs nested along the lake itself, with an additional 2-3 pairs at Dechambeau Ponds area. The main nesting areas are in the Wilson Creek-County Park area and Sammann's Spring. The provenance of 5-6 broods of large young at Ranch Cove in early September is hard to judge, because breeding birds were not encountered there earlier or later in the year. Perhaps these were hatched elsewhere and moving to sites with better foraging opportunities. In any case, the total lake/pond population approximates 30-35 pairs.

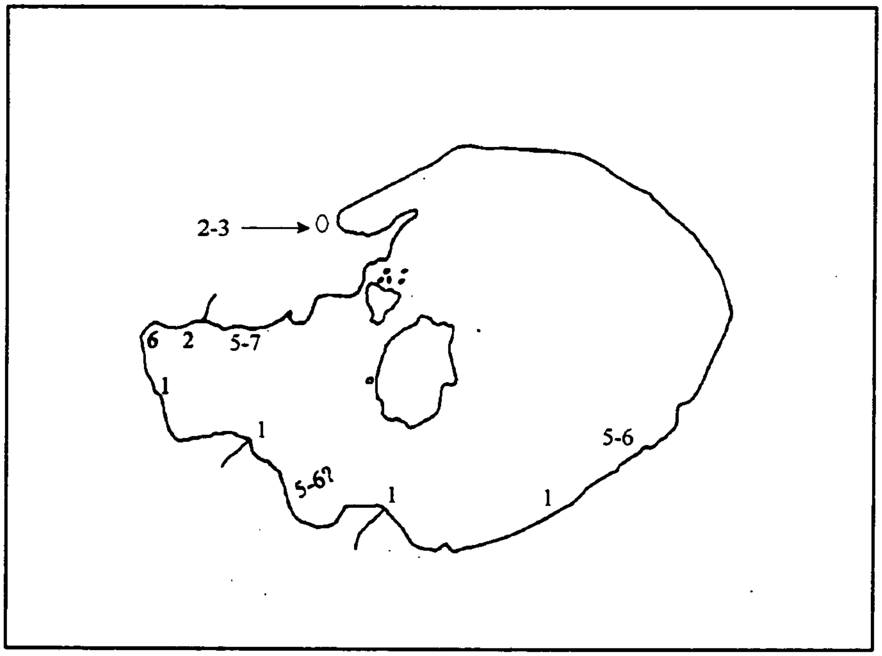


Figure 2. Distribution and size of the nesting population of Gadwall at Mono Lake, CA, 1999.

The main hatching period was 10-15 July. Most broods were large (8-10), as is typical of this species. Production was good. On 15 August I estimated that there were 205 local juveniles present; the exact figure could not be determined because large juveniles could not be distinguished at a distance from attending adults. Juveniles become capable of flight in September and local breeders leave by the end of the month or the first days of October.

In most years, a few adults male Gadwall attempt to molt at Mono Lake. In 1999 they numbered < 20. These seem to be restricted to the Wilson Creek area. Molting males tend to be in extremely worn plumage because they have missed at least one wing molt. Some remain flightless into early October.

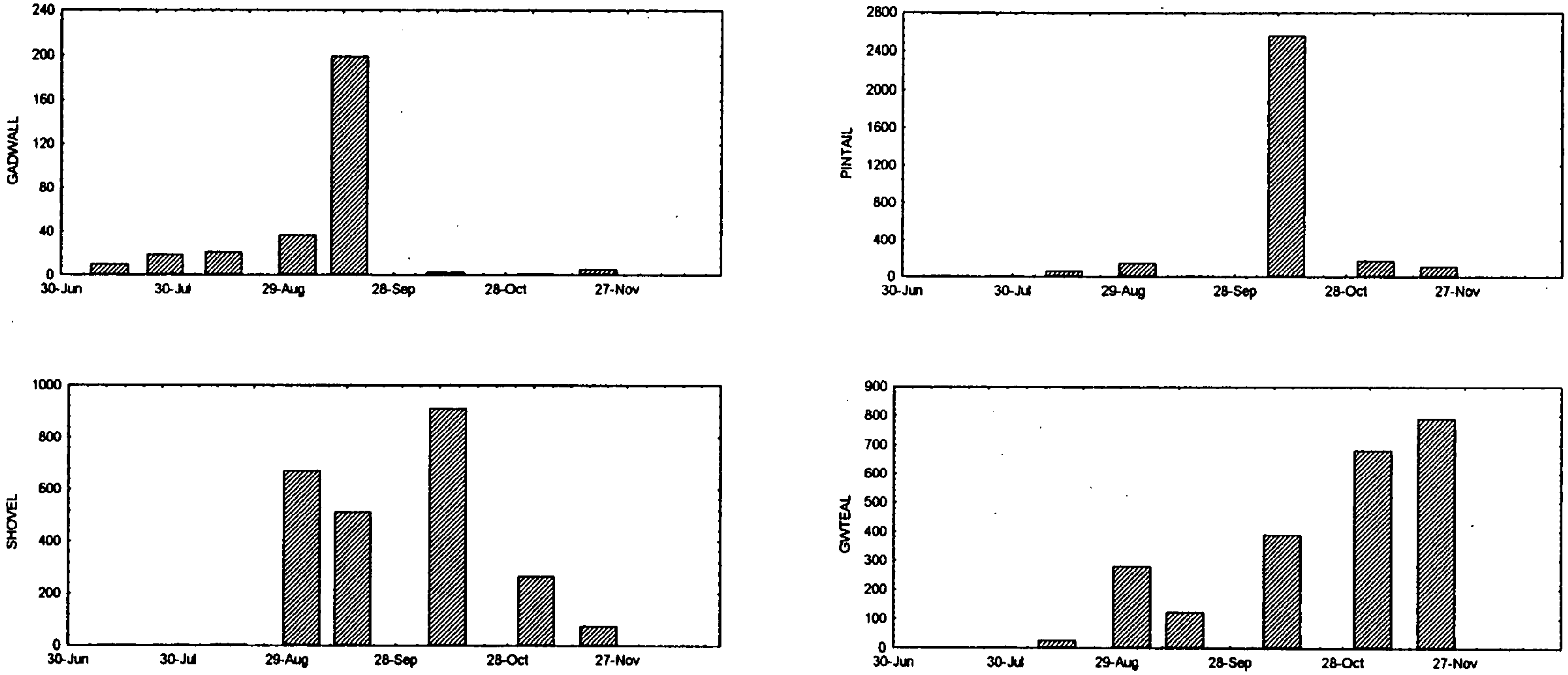
For studies of food habits, growth, and migration, we captured and banded 10 adult and 43 juvenile Gadwall in 1999. A detailed report on Gadwall biology at Mono Lake is in preparation.

Mono Lake: Migrating waterfowl

In 1999, 20 species of ducks and geese (plus Cackling Goose) were recorded at lake or adjacent ponds. Four species-- Mallards, Shovelers, Green-winged Teal, and Pintail-- comprised over 98% of the dabbling ducks; this included 92% of the birds identified to species, and almost all of the "unknowns". The fall migration begins in mid-August with the arrival of small numbers of several species. The most common is the Northern Shoveler, which by early September made up 25-46% of the total population. Mallards and Pintail tend to arrive in late September and peak in mid-October. Green-winged Teal occur through the fall but are commonest from October onward, and are the dominant dabbler in late fall and early winter (Figure 3).

The Ruddy Duck is usually the commonest duck at Mono Lake through most of the fall. The main influx starts in mid-September and birds are present into early winter. The highest count in 1999 was ca. 4,000 in mid-October. However, this species is impossible to census accurately because of its more offshore distribution, where birds become undetectable among the hundreds of thousands of grebes, and counts unavoidably underestimate the size of the actual population, which is probably on the order of 5,000 birds.

Censuses totals for Mono Lake in 1999 are shown in Figure 4. Numbers from July-August do not include flightless Gadwall ducklings. After these birds fledge, they become indistinguishable from other Gadwalls, so that counts in September may include locally-produced birds in addition to migrants (see above). The peak waterfowl count was 10,657 in mid-October. Over 19,000 individual ducks were recorded on the censuses. How closely this matches the total size of the population visiting Mono Lake cannot be determined without information on length of stay (turnover times). Teal may have a relatively long stay as they are consistently found in good numbers along the extreme west end of the lake, between the Shrimp Plant and County Park. The residence time of individual Ruddy Ducks , like that of Eared Grebes, is evidently measured in weeks or even months (Jehl in prep.). Most of the rarer species probably pass through in a day or so, because they are usually encountered only once and have limited, if any, foraging opportunities.



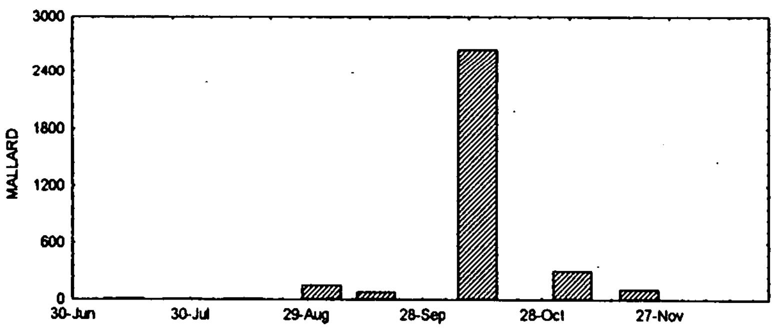


Figure 3. Phenology of migration of common dabbling ducks at Mono Lake. Note that vertical scales vary.

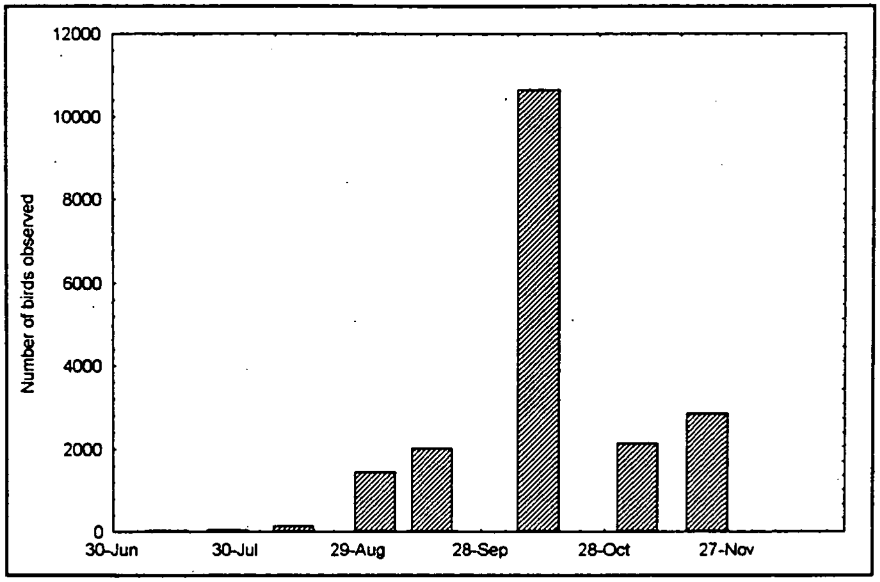


Figure 4. Censuses total of waterfowl for Mono Lake, CA, 1999.

*Pond Surveys (*Appendix I, Table 2)

Three pairs of Gadwall nested on Dechambeau Ponds, evidently one pair on each of Ponds 1-3. Some or all of these evidently shifted to Pond 2, as that was the only pond with ducklings after mid-August. Coots also nested on Ponds 1 and 2 (total 3 pairs), but young were seen most consistently on Ponds 2 and 3. There was no evidence of nesting on Pond 4.

The timing of fall migration through these ponds parallels that on the main lake, but the freshwater habitat attracts a different array of species. Ruddy Ducks and Shovelers, which are abundant on Mono Lake, rarely appear on the ponds, whereas Cinnamon Teal are disproportionately common. Coots are the commonest and most consistent visitors. The highest waterfowl count was 152 on 13 October.

As noted in earlier reports, the condition and attractiveness of the ponds varies through the year. In 1999 County Pond consistently held the largest number of migrants ducks (and other migrating waterbird species), whereas County Pond 2 was dry and barren. Dechambeau 1, which historically had held the major duck populations, was little used. Ponds 2 and 3 usually attracted a few birds but their surface area (especially Pond 3) was often greatly decreased by the overgrowth of algae. Pond 4 occasionally hold a duck or two in early spring and in late fall. For most of the year, however, its major use was as a bathing place for hundreds of California Gulls.

Because waterfowl are wary, and because these ponds attract many human visitors including hunters, the fall counts may slightly underestimate their usage. Even so, it is clear that the number of waterfowl there comprises only a trivial fraction of that found on the main lake.

Aerial Censuses

Comparative censuses were made at Bridgeport Reservoir, Mono Lake, and Crowley Lake on 17 September and 14 October 1999 (Tables 3, 4). In September, as in past years, numbers at ML were far smaller than elsewhere, but in October they were more than twice as great, owing to exceptionally large numbers of Mallards and Pintail. It is impossible to make much of these data because they are complicated by several unmeasurable factors that vary from year to year. These include foraging conditions at each lake (particularly variable at Bridgeport Reservoir, where there have been major changes in water level into Walker Lake), annual differences in the time of migration or in weather that promotes or impairs flights, levels of human disturbance (visitors, hunters, fishing tubes on Crowley Lake), the ability to detect Ruddy Ducks on Mono Lake, and differences in population estimates made from a plane vs from a boat or on foot. Thus, while numbers at Mono Lake have usually been smaller than elsewhere (Table 5), additional data will be needed to test whether there are any trends in the waterfowl populations in the region or at any particular lake.

As in previous years, lakes in the June Lake Loop held very few (< 200) waterfowl in October and November, and observations on species composition indicated that turnover was extremely rapid (1-2 days). The major value of these lakes to waterfowl is as a brief resting location away from hypersaline water. The only waterbirds that occur in significant numbers are coots, which occur by the hundreds at Grant Lake.

On aerial surveys on 17 September we took photographs of habitat conditions around Mono Lake, including the areas of most importance to waterfowl. A representative series of photos is included in Appendix II. Original slides are on file at Hubbs Sea-World Research Institute.

Annual comparisons

Census totals for Mono Lake from 1995-1999 are shown in Figure 5. Numbers, diversity, and migration phenology were similar in all years, except that mid-October numbers in1999 were slightly higher, as discussed above.

TABLE 3. Comparisons of waterfowl population at Bridgeport Reservoir, Mono Lake, and Crowley Lake. Date: 17 September 1999.

	Bridgeport Reservoir	Mono Lake	Crowley Lake
Method	Air	Air	Air
Species			
Western Grebe	200	0	150
Canada Goose	25	10	0
American Wigeon	0	0	475
Gadwall	1125	76	950
Green-winged Teal	2500	400	3800
Mallard	3375	140	3800
Northern Pintail	375	60	475
Cinnamon Teal	0	0	5
Northern Shoveler	375	1900	90
Redhead	0	7	21
Common Merganser	+		-
Ruddy Duck	100	627	750
Unknown	275	356	200
TOTAL WATERFOWL	**8350**	**3576**	**10716**
American Coot	10,000-13,000	250	3500
White Pelican	50	0	>50
Cormorant	50	0	>50
Great Blue Heron	-	1	50
American Avocet	+ few	2500	-
Red-necked Phalarope	0	0*	0

* None from the air, >5000 on the lake.

TABLE 4. Comparisons of waterfowl populations at Bridgeport Reservoir, Mono Lake, and Crowley Lake. Date: 14 October 1999.

	Bridgeport Res.	Mono Lake	Crowley Lake
Method	air	air/boat	land
Species			
Eared Grebe	5	ND	4a
Pied-billed Grebe	2		
Western Grebe	450	3	30
Canada Goose	180		71
Gadwall	1	2	
Green-winged Teal	1200	390	1100
Mallard	1200	2657	+++
Northern Pintail	1000	2563	+++
Northern Shoveler	200	910	++
Canvasback		3	7
Bufflehead	3		
Common Merganser	7		
Ruddy Duck	400	3998	1300
Unknown	300	131	2050 (mostly Mallard + Pintail)
TOTAL Waterfowl	**4948**	**10657**	**4562**
American Coot	1120	997	755
White Pelican	80	4	40
Cormorant	80	-	55
Great Blue Heron	3	3	10
Bald Eagle	1	-	-

a One adult was still attending young (not included)

TABLE 5. Comparative counts of waterfowl at Bridgeport, Mono, and Crowley lakes. Numbers of Ruddy Ducks are given in parentheses.

Year	Date	Bridgeport	Mono	Crowley
1996	9 Sep	2871 (0)	1225 (40)	-
1997	17 Sep	27,050 (0)	2338 (6)	12,035 (600)
1999	17 Sep	8350 (106)	3576 (627)	10,716 (750)
1996	16 Oct	6860 (0)	2153 (360)	8516 (3840)
1997	14-15 Oct	3908 (2845)	1662 (500)	2000 (500)
1998	17 Oct	-	6230 (4250)	-
1999	14 Oct	4948 (400)	10,657 (3998)	4562 (1300)

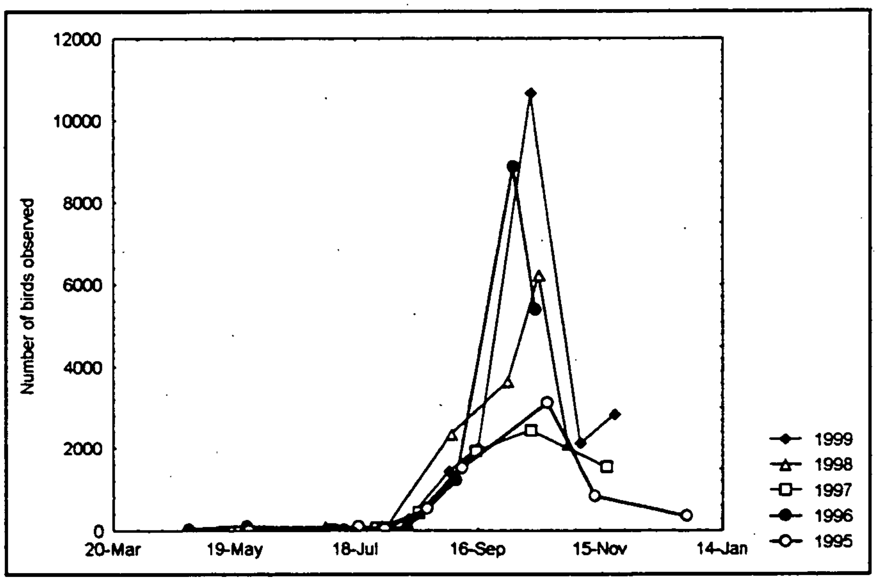


Figure 5. Census totals for Mono Lake from 1995-1999.

Controlled Burning

One project of the Recovery Plan called for burning of marsh vegetation in the vicinity of Sammann's Spring to create additional waterfowl habitat. A 50-acre plot was burned January 1998, as was a 5-acre plot that had been burned three years earlier (D. Carle, Flames on ice. Mono Lake Newsletter 21(4): 4, 1999). My observations, both from a plane and boat, revealed no evidence that waterfowl used these areas, indicating that the program was ineffectual.

Hypopycnal zones

We mapped the size of the hypopycnal zone at the mouth of Lee Vining Creek on five occasions between April and November, and made observations of waterfowl use and distribution there and at other areas where streams or seeps enter the lake. With one exception, there was no indication that any of these areas were used for anything but place to rest in proximity freshwater marsh feeding areas. Data from several years will be summarized elsewhere.

Behavioral studies

S. I . Bond studied the distribution and behavior of ducks at Mono Lake from 28 September-3 October. The major goal was to obtain data on activity budgets, habitat use, and daily movements of as many species as possible. The observations extend data collected in recent years and will be incorporated in further reports.

DISCUSSION

Data gathered in 1999 supplemented those gathered in earlier survey years (1995-1998), as well as historical records, and help provide a more thorough understanding of waterfowl populations at Mono Lake. Overall numbers were little changed from past years. The major concentration points (for all but Ruddy Ducks) remain at Sammann's Springs and the Wilson Creek delta, with much smaller numbers occurring along the extreme western end of the lake between the Shrimp Plant and County Park, and in the mouth of Rush Creek.

Changing habitat conditions around the lake have, as yet, has little effect on numbers or distribution. Along the south shore to the east of Navy Beach, a series of ponds has formed just inshore of the beach. One, open to the lake, has salinities of 0- 40 o/oo. The others are fed by freshwater springs and are potable (salinity 0-5 o/oo). All offer conditions that may be suitable for some duck foraging (marsh vegetation, brine fly pupae), and one was used to raise a brood of Gadwall. Repeated observations, however, indicated that they were used by only a handful (< 20) of migratory ducks. Moreover, all the that open to the lake began to freeze over by early November, and were therefore unavailable.

In my experience, the Warm Springs area has never held any significant number of migrating ducks, except when those disturbed at Sammann's Springs seek temporary refuge there. The area's unattractiveness has been due to the lack of marsh habitat for feeding and the hypersaline (and foodless) condition of the lagoons that form along the shore. In mid-October 1999, however, there were 5300 ducks in the area, mostly in lagoons. Because only a few birds were seen there later in the year, it may be that mid-October concentration was a response to hunting pressure near Sammann's Springs. On the other hand, the amount of marsh feeding habitat may be increasing because of renewed spring activity associated with the rising lake. This water drains into the lake and can lower salinity in the shoreline lagoons, which can promote the creation of foraging habitats for some species.

In 1999 a flying service was established at the Lee Vining Airport. The convenience of this service will help us to gather additional data for late fall, when boat surveys of the far reaches of the lake are often precluded by unstable weather.

APPENDIX I

Table 1. Results of all-lake boat censuses of waterfowl at Mono Lake, CA 14 July through 23 November 1999.

Table 2. Results of waterfowl censuses at freshwater ponds on the north shore of Mono Lake, CA 9 May through 24 November 1999

TABLE 1. Results of all-lake boat censuses of waterfowl at Mono Lake, CA. 14 July 1999. Observer: J. Jehl

Species	LV Ck.	Ranch Cove	Rush Ck	So Tufa	So Shore	Sammann's	Warm Sp	NE Shore	Blk PT E	Blk Pt W	Wilson Ck	Mill Ck	Co Park	W Shore	Other	Σ	Percent
Common Loon																	
Eared Grebe																	
Pied-billed Grebe																	
Western Grebe																	
Canada Goose										5						5	15.15
American Wigeon																	
Gadwall											10[a]					10	30.30
Green-winged Teal																	
Mallard										6	8					14	42.42
Northern Pintail						2										2	6.06
Cinnamon Teal										1						1	3.03
Northern Shoveler																	
Canvasback																	
Redhead																	
Lesser Scaup											1[b]					1	3.03
Bufflehead																	
Ruddy Duck																	
unknown ???																	
TOTAL Waterfowl	0	0	0	0	0	2	0	0	0	12	19	0	0	0		**33**	
American Coot																	

[a] three females with 40 chicks

[b] flightless

TABLE 1. Results of all-lake boat censuses of waterfowl at Mono Lake, CA. 20-30 July 1999. Observer: J. Jehl

Species	LV Ck.	Ranch Cove	Rush Ck	So Tufa	So Shore	Sammann's	Warm Sp	NE Shore	Blk PT E	Blk Pt W	Wilson Ck	Mill Ck	Co Park	W Shore	Other	Σ	Percent
Common Loon																	
Eared Grebe																	
Pied-billed Grebe																	
Western Grebe																	
Canada Goose										4						4	9.76
American Wigeon																	
Gadwall	1+B/4										18[a]					19[b]	46.34
Green-winged Teal																	
Mallard											6					6	14.63
Northern Pintail											2					2	4.88
Cinnamon Teal											4					4	9.76
Northern Shoveler																	
Canvasback																	
Redhead											2					2	4.88
Lesser Scaup																	
Bufflehead																	
Ruddy Duck											2					2	4.88
unknown ???					1										1	2	4.88
TOTAL Waterfowl	1 juv	0	0	0	1	0	0	0	0	4	34 + 8b	0	0	0	1	**41**	
American Coot																	

[a] '8br + 8-10 Ad in molt

[b] For all Gadwall only adults are shown in totals.

TABLE 1. Results of all-lake boat censuses of waterfowl at Mono Lake, CA. 14 August1999. Observer: J. Jehl

Species	LV Ck.	Ranch Cove	Rush Ck	So Tufa	So Shore	Sammann's	Warm Sp	NE Shore	Blk PT E	Blk Pt W	Wilson Ck	Mill Ck	Co Park	W Shore	Other	Σ	Percent
Common Loon																	
Eared Grebe																	
Pied-billed Grebe																	
Western Grebe																	
Canada Goose																	
American Wigeon																	
Gadwall					1 + 8y	5 + 37y					5 + 59y (est)	2 + 10y (est)	6 + 89y	2 +2y		21[a]	14.69
Green-winged Teal			10								4		10			24	16.78
Mallard					6	7							1			14	9.79
Northern Pintail				9	2	50										61	42.66
Cinnamon Teal				8												8	5.59
Northern Shoveler					5											5	3.50
Canvasback																	
Redhead																	
Lesser Scaup																	
Bufflehead																	
Ruddy Duck													4 no fly			4	2.80
unknown ???						6										6	4.20
TOTAL Waterfowl	0	0	10	17	14 +8y	68 +37y	0	ND	ND	0	9 + 59y (est)	2 + 10y (est)	21 + 89y	2		**143**	
American Coot															3		

a For all Gadwall only adults are shown in total.

TABLE 1. Results of all-lake boat censuses of waterfowl at Mono Lake, CA. 3-4 September 1999. Observer: J. Jehl

Species	LV Ck.	Ranch Cove	Rush Ck	So Tufa	So Shore	Sammann's	Warm Sp	NE Shore	Blk PT E	Blk Pt W	Wilson Ck	Mill Ck	Co Park	W Shore	Other	Σ	Percent
Common Loon																	
Eared Grebe																	
Pied-billed Grebe																	
Western Grebe																	
Canada Goose					14											14	0.97
American Wigeon																	
Gadwall		6A + 45Y			6	5 (no broods)					20A + 50Y					37[a]	2.56
Green-winged Teal			200			30					50					280	19.36
Mallard			10		15	100					30					155	10.72
Northern Pintail			10			100					40					150	10.37
Cinnamon Teal						50										50	3.46
Northern Shoveler					21	500					150					671	46.40
Canvasback																	
Redhead											10					10	0.69
Lesser Scaup																	
Bufflehead																	
Ruddy Duck		2							8					1	2	13	0.90
unknown ???			10		6								50	0	0	66	4.56
TOTAL Waterfowl		8 + 45y	230		62	785	0	0	8	0	300 + 5oy		50	1	2	**1446**	
Ibis			2													2	
American Coot			3													3	

a For all Gadwall only adults are shown in total.

TABLE 1. Results of all-lake boat censuses of waterfowl at Mono Lake, CA. 17-18 September 1999. Observer: J. Jehl and D. Paul.

Species	LV Ck.	Ranch Cove	Rush Ck	So Tufa	So Shore	Sammann's	Warm Sp	NE Shore	Blk PT E	Blk Pt W	Wilson Ck	Mill Ck	Co Park	W Shore	Other	Σ	Percent
												17 Sep	17 Sep				
Common Loon																	
Eared Grebe																	
Pied-billed Grebe																	
Western Grebe															1	1	0.05
Canada Goose																	
American Wigeon						9										9	0.45
Gadwall		2[a]			34	140[b]			13		10					199	9.88
Green-winged Teal			20			50					50			2		122	6.05
Mallard					5	26					30		20	3		84	4.17
Northern Pintail					2	3					5					10	0.50
Cinnamon Teal					40											40	1.99
Northern Shoveler			5			400			7		100					512	25.41
Canvasback																	
Redhead											5					5	0.25
Lesser Scaup																	
Bufflehead																	
Ruddy Duck[c]						107			621				20	100		848	42.08
unknown ???			5						10	80	40		50			185	9.18
TOTAL Waterfowl	0	2	30	0	81	735	ND	ND	651	80	240	0	90	105		**2015**	
American Coot						14					30		-	-	23	67	

[a] Non Flying juveniles

[b] All flying (D. Paul)

[c] Ruddy Duck numbers are minimum.

TABLE 1. Results of all-lake boat censuses of waterfowl at Mono Lake, CA. 13-14 October 1999. Observer: J. Jehl

Species	LV Ck.	Ranch Cove	Rush Ck	So Tufa	So Shore	Sammann's	Warm Sp	NE Shore	Blk PT E	Blk Pt W	Wilson Ck	Mill Ck	Co Park	W Shore	Other	Σ	Percent
							air 14Oct	air 14Oct	air 14Oct								
Common Loon																	
Eared Grebe																	
Pied-billed Grebe																	
Western Grebe															3	3	0.03
Canada Goose																	
American Wigeon																	
Gadwall						1 (air 14Oct)								1		2	0.02
Green-winged Teal			300						10					80		390	3.66
Mallard	2		25			30	2500		70					30		2657	24.93
Northern Pintail	8				5	10	2500		40					-		2563	24.05
Cinnamon Teal														-			0.00
Northern Shoveler						240	300		20					350		910	8.54
Canvasback					3											3	
Redhead														-			
Lesser Scaup														-			
Bufflehead																	
Ruddy Duck[a]	10	370	1000	50	500	400		118		150	200	200	500	300	200	3998	37.52
unknown ???					40	50			40				1	-		131	1.23
TOTAL Waterfowl	20	370	1325	50	548	731	5300	118	180	150	200	200	501	761	203	**10657**	
American Coot	12		5	0	17	300 (375 air 14Oct)	300		260		50	20	-	-		947	

[a] Ruddy Duck numbers are minimum.

TABLE 1. Results of all-lake boat censuses of waterfowl at Mono Lake, CA. 6 November 1999. Observer: J. Jehl

Species	LV Ck.	Ranch Cove	Rush Ck	So Tufa	So Shore	Sammann's	Warm Sp	NE Shore	Blk PT E	Blk Pt W	Wilson Ck	Mill Ck	Co Park	W Shore	Other	Σ	Percent
		ND		ND				ND	Inc								
Common Loon																	
Eared Grebe																	
Pied-billed Grebe																	
Western Grebe																	
Canada Goose						Cackling-2	33			30						65	3.06
American Wigeon							2									2	0.09
Gadwall																	
Green-winged Teal						250					100		30	300		680	31.97
Mallard					22	180				33	50			20		305	14.34
Northern Pintail					1		70				100					171	8.04
Cinnamon Teal																	
Northern Shoveler	6				20	0	2			35	200			2		265	12.46
Canvasback																	
Redhead																	
Lesser Scaup					1											1	0.05
Bufflehead					2											2	0.09
Ruddy Duck[a]				?	75				50	80		20		100	50	375	17.63
unknown ???						100	40						20	100		260	12.22
Red-breasted Merg					1											1	0.05
TOTAL Waterfowl	6	ND	-	ND	122	532	147	ND	50	178	450	20	50	522	50	**2127**	
American Coot						5	0				25			50		80	

[a] Ruddy Duck numbers are minimum.

TABLE 1. Results of all-lake boat censuses of waterfowl at Mono Lake, CA. 23 November 1999. Boat (west end) and air (all lake).

Observer: J. Jehl

Species	LV Ck.	Ranch Cove	Rush Ck	So Tufa	So Shore	Sammann's	Warm Sp	NE Shore	Blk PT E	Blk Pt W	Wilson Ck	Mill Ck	Co Park	W Shore	Other	Σ	Percent
Common Loon																	
Eared Grebe																	
Pied-billed Grebe																	
Western Grebe																	
Canada Goose						20	3	10		21				2		56	1.97
American Wigeon			2											1		3	0.11
Gadwall			5													5	0.18
Green-winged Teal		80	280[a]		20	10	70		180		50			100		790	27.78
Mallard		10			42	20	2	10						30		114	4.01
Northern Pintail							10		100							110	3.87
Cinnamon Teal																	
Northern Shoveler		40	30									2		2		74	2.60
Canvasback																	
Redhead																	
Lesser Scaup																	
Bufflehead																	
Ruddy Duck	2	90	10		300		3	480^{+}					30	400		1315^{+}	46.24
unknown ???	15					250	7		100							372	13.08
Goldeneye (sp)					3											3	0.11
Hooded Merganser													2 F			2	0.07
TOTAL Waterfowl	17	220	327	0	365	300	95	500^{+}	380	21	50	2	32	535		**2844^{+}**	
American Coot	58	13	40										5			116	

[a] These birds flew to Wilson Creek, then Mill Creek. Counted only once.

TABLE 2. Results of waterfowl censuses at freshwater ponds adjacent to Mono Lake, CA. 9 May 1999.
Observer: J. Jehl

Dechambeau Ponds					Co Ponds		Other	Σ	
Species	1	2	3	4	1	2			Comments
Common Loon					DRY				
Eared Grebe		2		5				7	
Pied-billed Grebe									
Western Grebe									
Canada Goose									
American Wigeon									
Gadwall				2				2	
Green-winged Teal				6				6	
B-W Teal				2				2	
Mallard	2							2	
Northern Pintail									
Cinnamon Teal	10	4	2					16	
Northern Shoveler									
Canvasback									
Redhead		1						1	
Lesser Scaup									
Bufflehead									
Ruddy Duck									
unknown ???									
TOTAL Waterfowl	12	7	2	15				36	
Calif Gull				800				800	
American Coot		15	12	10				37	

Pond 1 & 2 getting wet. Yellow-headed Blackbird

TABLE 2. Results of waterfowl censuses at freshwater ponds adjacent to Mono Lake, CA. 2 June 1999.
Observer: J. Jehl

	Dechambeau Ponds				Co Ponds		Other	Σ	Comments
Species	1	2	3	4	1	2			
						DRY			
Common Loon									
Eared Grebe									
Pied-billed Grebe									
Western Grebe									
Canada Goose									
American Wigeon									
Gadwall		4	2	2	1*			9	
Green-winged Teal									
Mallard		1		2				3	
Northern Pintail									
Cinnamon Teal	4		2	2				8	
Northern Shoveler									
Canvasback									
Redhead									
Lesser Scaup									
Bufflehead									
Ruddy Duck									
unknown ???									
TOTAL Waterfowl	4	5	4	6	1			**20**	
American Coot		3	3	10				16	

* May have been flushed from Dechambeau.

All ducks in pairs. No evidence of nesting yet.

TABLE 2. Results of waterfowl censuses at freshwater ponds adjacent to Mono Lake, CA. 15 July 1999.
Observer: J. Jehl

	Dechambeau Ponds				Co Ponds		Other	Σ	Comments
Species	1	2	3	4	1	2			
Common Loon									
Eared Grebe									
Pied-billed Grebe									
Western Grebe									
Canada Goose									
American Wigeon									
Gadwall			1 +b9*					1	
Green-winged Teal									
Mallard									
Northern Pintail									
Cinnamon Teal									
Northern Shoveler									
Canvasback									
Redhead									
Lesser Scaup									
Bufflehead									
Ruddy Duck									
unknown ???									
TOTAL Waterfowl			1					1	
American Coot	3 (1 chick)	1	2	0	0	0		6	

* about three days old

TABLE 2. Results of waterfowl censuses at freshwater ponds adjacent to Mono Lake, CA. 29 July 1999.
Observer: J. Jehl

Dechambeau Ponds					Co Ponds		Other	Σ	
Species	1	2	3	4	1	2			Comments
						DRY			
Common Loon									
Eared Grebe									
Pied-billed Grebe									
Western Grebe									
Canada Goose									
American Wigeon									
Gadwall	2 + B	1 + B8						3	
Green-winged Teal									
Mallard									
Northern Pintail									
Cinnamon Teal	1		10		4			15	
Northern Shoveler									
Canvasback									
Redhead									
Lesser Scaup									
Bufflehead									
Ruddy Duck									
unknown ???									
TOTAL Waterfowl	3	1	10		4			**18**	
California Gull				*					
American Coot		3 + 3B						3	

* Pond 4 continues to be only a gull bath. 150 at one time, hundreds in and out.

TABLE 2. Results of waterfowl censuses at freshwater ponds adjacent to Mono Lake, CA. 12 August 1999.
Observer: J. Jehl

	Dechambeau Ponds				Co Ponds		Other	Σ	Comments
Species	1	2	3[a]	4	1	2			
						DRY			
Common Loon									
Eared Grebe									
Pied-billed Grebe		1						1	
Western Grebe									
Canada Goose									
American Wigeon									
Gadwall		2A, 7Y						2	
Green-winged Teal					2			2	
Mallard					2			2	
Northern Pintail					50			50	
Cinnamon Teal					35			35	
Northern Shoveler					1			1	
Canvasback									
Redhead									
Lesser Scaup									
Bufflehead									
Ruddy Duck									
unknown ???					3			3	
TOTAL Waterfowl		3		0	93			**96**	
Cgull					50			50	
Solitary Sp					1			1	
Lesser Yellow-legs					1			1	
American Coot	2A, 4Y	1A, 4Y						3	

a Pond 3. Choked with algae

TABLE 2. Results of waterfowl censuses at freshwater ponds adjacent to Mono Lake, CA. 3 September 1999.
Observer: J. Jehl

	Dechambeau Ponds				Co Ponds		Other	Σ	Comments
Species	1[a]	2	3[a]	4	1	2			
						DRY			
Common Loon									
Eared Grebe									
Pied-billed Grebe			1					1	
Western Grebe									
Canada Goose									
American Wigeon									
Gadwall		1 +6b			6			7	
Green-winged Teal									
Mallard					4			4	
Northern Pintail					3			3	
Cinnamon Teal									
Northern Shoveler		6						6	
Canvasback									
Redhead									
Lesser Scaup									
Bufflehead									
Ruddy Duck									
unknown ???					2			2	
TOTAL Waterfowl	0	7	1	0	15			**23**	
American Coot		3	2(+1b)		1				

a Pond 3 clogged with algae, Pond 1 getting clogged.

TABLE 2. Results of waterfowl censuses at freshwater ponds adjacent to Mono Lake, CA. 20 September 1999. Observer: J. Jehl

Dechambeau Ponds					Co Ponds		Other	Σ	Comments
Species	1	2	3	4	1	2			
						DRY			
Common Loon									
Eared Grebe									
Pied-billed Grebe									
Western Grebe									
Canada Goose									
American Wigeon									
Gadwall		2 (1yg)			9			11	
Green-winged Teal					3			3	
Mallard									
Northern Pintail					3			3	
Cinnamon Teal			3					3	
Northern Shoveler									
Canvasback									
Redhead									
Lesser Scaup									
Bufflehead									
Ruddy Duck									
unknown ???									
TOTAL Waterfowl		2	3		15			**20**	
American Coot		23	2		2			27	

TABLE 2. Results of waterfowl censuses at freshwater ponds adjacent to Mono Lake, CA. 29 September 1999. Time: 1000-1100. Observer: S. Bond.

	Dechambeau Ponds				Co Ponds		Other	Σ	
Species	1	2	3	4	1	2			Comments
						DRY			
Common Loon									
Eared Grebe					2			2	
Pied-billed Grebe					1			1	
Western Grebe									
Canada Goose									
American Wigeon					2			2	
Gadwall									
Green-winged Teal									
Mallard									
Northern Pintail					2			2	
Cinnamon Teal									
Northern Shoveler									
Canvasback									
Redhead									
Lesser Scaup									
Bufflehead									
Ruddy Duck									
Unknown ???					42			42	
TOTAL Waterfowl					49			**49**	
American Coot			32[a]		7				

[a] including seven young

TABLE 2. Results of waterfowl censuses at freshwater ponds adjacent to Mono Lake, CA. 2 October 1999.
Time: 1645-1730. Observer: S. Bond.

	Dechambeau Ponds				Co Ponds		Other	Σ	
Species	1	2	3	4	1	2			Comments
						DRY			
Common Loon									
Eared Grebe									
Pied-billed Grebe									
Western Grebe									
Canada Goose					19			19	
American Wigeon									
Gadwall			1					1	
Green-winged Teal									
Mallard									
Northern Pintail					5			5	
Cinnamon Teal									
Northern Shoveler					2			2	
Canvasback									
Redhead									
Lesser Scaup									
Bufflehead									
Ruddy Duck									
unknown ???					12			12	
TOTAL Waterfowl			1		38			**39**	
American Coot		1	38		7				

Two tourists and two wet Labrador Retrievers were at Dechambeau Ponds when I arrived. The dogs had already hit Pond 1.

TABLE 2. Results of waterfowl censuses at freshwater ponds adjacent to Mono Lake, CA. 13 October 1999.
Time: 1630-1800. Observer: J. Jehl

	Dechambeau Ponds				Co Ponds		Other	Σ	
Species	1	2	3	4	a	2			Comments
						Dry			
Common Loon									
Eared Grebe									
Pied-billed Grebe									
Western Grebe									
Canada Goose					1			1	
American Wigeon									
Gadwall									
Green-winged Teal									
Mallard					120			120	
Northern Pintail					30			30	
Cinnamon Teal									
Northern Shoveler									
Canvasback									
Redhead									
Lesser Scaup									
Bufflehead									
Ruddy Duck		1						1	
unknown ???									
TOTAL Waterfowl	0	1	0	0	151	Dry		**152**	
Common Egret					1			1	
Peep					150			150	
American Coot		75	3					78	

a County Pond 1 was drying. Had peeps, Dunlin-1, Long-billed Dow-3, Killdeer-5.

Ducks very wary - hunting season has started.

TABLE 2. Results of waterfowl censuses at freshwater ponds adjacent to Mono Lake, CA. 7 November 1999.
Time: 0630-0730. Observer: J. Jehl

	Dechambeau Ponds				Co Ponds		Other	Σ	
Species	1	2	3[a]	4	1	2			Comments
						Dry			
Common Loon									
Eared Grebe									
Pied-billed Grebe									
Western Grebe									
Canada Goose									
American Wigeon									
Gadwall									
Green-winged Teal	1							1	
Mallard									
Northern Pintail									
Cinnamon Teal									
Northern Shoveler									
Canvasback									
Redhead									
Lesser Scaup									
Bufflehead									
Ruddy Duck			1	3				4	
unknown ???									
TOTAL Waterfowl	1	0	1	3	0	Dry		5	
American Coot		60	10	7				77	

a Pond 3 now clear - cold killed algae

TABLE 2. Results of waterfowl censuses at freshwater ponds adjacent to Mono Lake, CA. 24 November 1999. Time: 1000-1130. Observer: J. Jehl

	Dechambeau Ponds				Co Ponds		Other	Σ	
Species	1	2	3	4	1	2			Comments
Common Loon									
Eared Grebe		5	2					7	
Pied-billed Grebe									
Western Grebe									
Canada Goose									
American Wigeon		1						1	
Gadwall				1				1	
Green-winged Teal									
Mallard									
Northern Pintail									
Cinnamon Teal									
Northern Shoveler									
Canvasback									
Redhead									
Lesser Scaup									
Bufflehead									
Ruddy Duck			8					8	
unknown ???									
TOTAL Waterfowl	0	6	10	1	0	DRY		**17**	
American Coot	0	30	15	30				75	

Pond 1 3/4 frozen: Pond 2 and 3 open (hot water): Pond 4 3/4 frozen.

Co. Pond 1 frozen. New water line to Pond 1. Road now clear. More water in Pond than two weeks ago - full. No overflow to Pond 2.

APPENDIX II

PHOTOGRAPHS OF MAJOR WATERFOWL CONCENTRATION POINTS ALONG THE PERIPHERY OF MONO LAKE, 17 SEPTEMBER 1999.

Photos taken consecutively from Rush Creek counterclockwise to Wilson Creek and County Park

1.The mouth of Rush Creek

2. Lagoons and freshwater ponds forming about 1 mile east of Navy Beach.

3. Freshwater pond with cattail, about 1.5 mi E of Navy Beach

4. Lagoon about 2 mi E of Navy Beach.

5. Freshwater lagoon forming just west of Sammann's Spring Tufa field.

6. Tufa grove area at Sammann's Springs. This area and that just to the southwest is the major concentration area for waterfowl at Mono Lake

7. Sandbars and lagoons along east shore between Sammann's Springs and Warm Springs.

8. Lagoon with ducks in vicinity of Warm Springs, east shore Mono Lake.

9. Fringing lagoons border nearly the entire eastern and northeastern shore of the lake. These are hypersaline and do not attract waterfowl.

10. Lagoonal situations associated with tufa shoals east of Black Point. Ruddy Ducks are often common in this region.

11. Marsh at the mouth of Wilson Creek. This is one of the two major concentration points for migrating waterfowl.

Figure 1. The mouth of Rush Creek.

Figure 2. Lagoons and freshwater ponds forming about 1 mile east of Navy Beach.

Figure 3. Freshwater pond with cattail, about 1.5 mi E of Navy Beach.

Figure 4. Lagoon about 2 mi E of Navy Beach.

Figure 5. Freshwater lagoon forming just west of Sammann's Spring Tufa field.

Figure 6. Tufa grove area at Sammann's Springs. This area and that just to the southwest is the major concentration area for waterfowl at Mono Lake.

Figure 7. Sandbars and lagoons along east shore between Sammann's Springs and Warm Springs.

Figure 8. Lagoon with ducks in vicinity of Warm Springs, east shore Mono Lake.

Figure 9. Fringing lagoons border nearly the entire eastern and northeastern shore of the lake. These are hypersaline and do not attract waterfowl.

Figure 10. Lagoonal situations associated with tufa shoals east of Black Point. Ruddy Ducks are often common in this region.

Figure 11. Marsh at the mouth of Wilson Creek. This is one of the two major concentration points for migrating waterfowl.