In Response to the
State Water Resources Control Board
Order Nos. 98-05 and 98-07

Compliance Reporting

Stream Monitoring
Fish Monitoring
Waterfowl Monitoring
Runoff Forecast and Operations

May, 2004

Los Angeles Department of Water and Power

May 13, 2004

Mr. Harry Schueller, Chief Deputy Director
State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812-0100

Dear Mr. Schueller:

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

Pursuant to the State Water Resources Control Board (SWRCB) Decision 1631 and Order Nos. 98-05 and 98-07 (Orders), and in accordance with the terms and conditions of the Los Angeles Department of Water and Power's (LADWP) Mono Basin Water Right License Nos. 10191 and 10192, enclosed is a submittal entitled "Compliance Reporting", which contains the four reports required by the Orders. The reports are as follows:

- Mono Basin Operations for Runoff Year (RY) 2004-2005
- Fisheries Monitoring Report for Rush, Lee Vining, Parker, and Walker Creeks, 2003
- Mono Basin Tributaries: Lee Vining, Rush, Walker, and Parker Creeks – Monitoring Results and Analysis for Runoff Season 2003-04
- Mono Basin Waterfowl Habitat and Population Monitoring 2003-2004

In addition to the four reports, the "Compliance Reporting" also includes a report entitled "Compliance with State Water Resources Control Board Order Nos. 98-05 and 98-07". This report summarizes LADWP's restoration and monitoring activities performed during RY 2003-04 and the restoration and monitoring activities proposed for RY 2004-05.

The filing of the reports and the restoration and monitoring performed by LADWP in the Mono Basin fulfills LADWP's requirements for RY 2003-04 as set forth in Decision 1631 and Order Nos. 98-05 and 98-07. Electronic copies of the report on compact disc have been provided to the interested parties, and a bound hard copy will shortly be provided to SWRCB.

If you have any questions, please contact Dr. Mark Hanna of my staff at (213) 367-1289.

Sincerely,

Original Signed by
Thomas Erb

Thomas M. Erb
Director of Water Resources

Enclosure

c: Mr. Jim Edmondson, California Trout, Inc.
Mr. Bill Bramlette, U.S. Forest Service
Mr. James Barry, California Department of Parks and Recreation
Mr. Joe Bellomo, People for Mono Basin Preservation
Dr. William Trush, McBain & Trush
Mr. Gary Smith, Department of Fish and Game
Mr. Marshall S. Rudolph, Mono County Counsel
Mr. Jim Canaday, Division of Water Rights, State Water Resources Control Board
Ms. Paula Pennington, Department of Parks and Recreation, Grover Hot Springs State Parks
Ms. Lisa Cutting, Mono Lake Committee
Board of Supervisors, Mono County
Mr. Chris Hunter
Mr. Steve Parmenter, Department of Fish and Game
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May 2004

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Section 1

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

Compliance with State Water Resources Control Board Decision 1631 and Order Nos. 98-05 and 98-07

May, 2004

Los Angeles Department of Water and Power

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Introduction

Pursuant to State Water Resources Control Board (SWRCB) Decision 1361 and Order Nos. 98-05 and 98-07 (Orders), the Los Angeles 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) 2003-04 for compliance. This summary also provides a list of planned work/activities for RY 2004-05.

RY 2003 was the fifth full field season after the adoption of the Orders. As such, LADWP is continuing 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, scheduling field crews and other resources, coordinating with various other agencies, and preparing work plans. LADWP has completed most of the planned work/activities for compliance.

Please see **Figure 1** for an aerial image of Mono Basin, showing major streams and LADWP facilities.

Figure 1: Aerial Photograph of Mono Basin

Work Performed During Runoff Year 2003-04

Restoration Activities

Streams

In 2003, LADWP undertook and completed several measures that were outlined in the Mono Basin Stream and Stream Channel Restoration Plan (1996). These include:

- Completed designs for the Lee Vining Diversion Facility Upgrade;
- Investigated Sediment Bypass Activities for Parker and Walker Creeks;
- Completed the MGORD Closure Report
- Reassessed Side-Channel Openings on Rush Creek; and
- Continued with the grazing moratorium.

Lee Vining Diversion Facility Upgrade

LADWP plans to upgrade the Lee Vining Creek diversion facility during the fall of 2004. The facility upgrade will provide LADWP with the ability to more accurately monitor and control releases to Lower Lee Vining Creek and provide for the opportunity to bypass sediment during high flow events.

Sediment Bypass for Parker and Walker Creeks

LADWP continued investigating sediment bypass options on Walker and Parker Creeks at the points of diversion. Currently the plan is to implement a "dredge and place" operation where LADWP staff will periodically dredge the sediments trapped by the diversion facilities and place this material at strategic locations below the facilities. The timing and locations are yet to be determined. LADWP personnel are drafting a preliminary proposal that will be submitted to contracted sediment experts for their review. Once their review is complete, and their concerns addressed, the sediment bypass operations plans for both Walker and Parker Creeks will be drafted for review by interested parties.

MGORD Closure Report

The work plan for *"Habitat Conservation During Rehabilitation of MGORD"* specified that four fish habitat parameters be monitored following the conclusion of rehabilitation work. These parameters included:

a) depth of flow,
b) acreage of aquatic vegetation (elodea),
c) number of boulders with a minimum length of 2 feet on all sides in the channel, and
d) the linear extent of willows along the banks.

In August 2003, LADWP resource personnel completed a field survey of the MGORD to assess the post construction conditions within the MGORD and to determine if the criteria listed above had been met.

a) At the time of the survey, flow in the MGORD was 52 cfs, or 5 cfs greater than when the pre-project conditions were determined. This translates into a difference in stage height of 0.06 feet. Taking into account the difference in stage height, the average depth was determined to be 3.35 feet.
b) The acreage of elodea beds was determined from aerial photographs flown in June 2003. At this time the total area of elodea within the MGORD was 1.82 acres.
c) The number of boulders within the ditch was determined to be only 28 at the time the measurements were taken. Consequently, five additional boulders were added to the MGORD, bringing the number to 33.
d) During MGORD work, willows were only removed from the banks in one section of the MGORD. Willows that were removed from the bank were transplanted to where they would not create a future maintenance problem. In all other sections, the willows were mowed to provide equipment operators a view of the MGORD bottom. During the field assessment, it was determined that all of the transplanted willows had survived two growing seasons. Further all of the willows that were mowed had resprouted, and remnant roots in the willow removal area had resprouted; therefore, the linear distance of willows exceeds that measured in 2001.

Based on the above, LADWP believes that all criteria for the habitat conservation within the MGORD have been met and no further monitoring is planned.

Side-Channel Openings

The following is a summary of side channel construction sites, their condition, and current implementation status on Rush Creek:

- **Reach 3D:** Construction was completed by LADWP in 2002 based on the floodplain design developed collaboratively between LADWP and McBain and Trush (presented in RY2001 Report); manual revegetation of the floodplain may occur if necessary after five years from completion of project (2008).
- **Reach 4A:** The east side 1A channel in Reach 4A was specified to receive approximately 15 cfs of baseflow to achieve approximately 1,020 ft of rewatered channel. This channel presently is dry during summer baseflow condition, but appears influenced by groundwater during higher baseflows and spring snowmelt periods. The present primary channel appears to be recovering, and provides good habitat and geomorphic features, although the channel is somewhat straighter than the abandoned 1A. Riparian vegetation is regenerating rapidly in this reach with the higher water table producing diverse wetlands in depressional areas.
- **Reach 4B:** The channel 4bii complex was specified to receive approximately 10 cfs of baseflow to rewater approximately 3300 ft of channel. Waterfowl habitat was specified as a goal primarily due to persistence of old beaver pond structures. This channel area gets flows when main channel flows are above approximately 300 cfs, and receives a considerable amount of groundwater seepage during other times. Riparian and depressional wetland vegetation appears to be regenerating rapidly in this reach. The initial rewatering intent was to jump start riparian growth but at this point in time it does not appear to be necessary. Vehicle and equipment access is difficult. LADWP, McBain and Trush, and C. Hunter recommend deferring construction at this site.

- **Reach 4C:** The former main channel (Channel 14) was specified to be rewatered with approximately 10 cfs of baseflow to achieve 1,300 ft of channel. The excavated channel entrance site was to be selected to minimize mechanical intervention. However, local head-cutting and main channel downcutting have caused the 14-Channel to become perched considerably higher than its relative position in the recent past. Rewatering would require fairly extensive excavation that would be relatively disruptive to the main channel and surrounding area. Considerable tradeoffs would occur due to fishery and riparian habitats that have developed in the main channel that will be impacted by rewatering efforts. Riparian regeneration is occurring in this area, and appears to be on a recovery trajectory. Upstream of the 14-Channel, the 13-Channel complex receives hyporheic flows from the upstream floodplain and flow from a small side-channel exiting the right bank just downstream of the 10-Channel re-entrance to the main channel. This small channel does not appear stable and persistent in the long term. Riparian vegetation appears to be regenerating rapidly in this reach. PRBO also reports the presence of willow flycatcher in this area, benefiting from a diverse willow community with a good understory.. LADWP, McBain and Trush, and C. Hunter recommend deferring construction at this site because the tradeoffs may result in better habitat conditions as compared to existing conditions.
- **Reach 4C:** The entrance to the Channel 8 complex was to be unplugged to allow 1 to 2 cfs into the channel. Construction was completed in 2002. In contrast to rewatering for a constant flow, the final design called for flow overtopping the bank and flowing into the 8-Channel at approximately 250 cfs and above. This design was intended to avoid significant reduction of the main channel flow, and to reduce risk of channel capture by a rewatered 8-Channel. The Mono return ditch has been recently repaired. This channel will receive more surface water in the future which will encourage production of floodplain wetlands for waterfowl and other species.
- **Reach 4C:** The Channel 11 complex was to be unplugged to allow 1 to 2 cfs into the channel. This channel/plug site is located approximately 50 ft upstream of the downstream 10-Channel confluence (This an old condition and recently the channel has been aggrading even though this channel is still perched. This language sounds as if were doing something currently to perpetuate this situation.). Additionally, the riparian vegetation appears to be regenerating naturally in this area. The potential benefits of re-opening this channel are minor, whereas the mechanical intrusion would be quite disruptive. LADWP, McBain and Trush, and C. Hunter recommend deferring construction at this site.

Grazing Moratorium

There was no grazing on LADWP's land in the Mono Basin during RY 2003-04. The grazing moratorium is still in effect for all lands in the Mono Basin and will be continued for a total of at least 10 years, per the Mono Basin Stream & Stream Channel Restoration Plan (LADWP, 1996).

Waterfowl

In RY 2003-04, LADWP continued its waterfowl habitat monitoring and restoration program. The following is a summary of activities:

- Monitored Mono Lake hydrology;
- Monitored lake ornithology;
- Finalized the revised waterfowl census methodology;
- Monitored waterfowl populations; and
- Monitored lake limnology

Mono Lake Hydrology

The elevation of Mono Lake was monitored on a weekly basis. The lake elevation ranged from 6382.0 feet amsl on April 1, 2003 to 6381.8 feet amsl on March 31, 2004. The average surface area during RY 2003, based on the Pelagos Corp. 1986 bathymetric study, was approximately 70.4 square miles, or 45,026 acres.

Lake Ornithology

Ms. Deborah House, Watershed Resources Specialist with LADWP, conducted three summer waterfowl ground counts and six fall aerial surveys. The next regularly scheduled vegetation surveys are set for 2004. Aerial photography of the Mono Basin was conducted on September 17, 2003.

Waterfowl Census Methodology

A revision of the waterfowl survey protocol proposed by LADWP was negotiated with the Mono Lake Committee and peer reviewed. The new protocol is included in Section 5 of the Compliance Report.

Expert for Peer Review

Robert McKernan, director of the San Bernardino County Museum, was selected to provide peer review of the field methodologies used for monitoring waterfowl, and to review the waterfowl survey report every five years, starting with the 2003 report. His review of the field methodologies is included in section 5 of this report. His review of the 2003 report is pending.

Mono Lake Limnology

Lake limnology was monitored by UC Santa Barbara. Meromixis terminated in RY 2003. As a consequence, the lake mixed to the bottom for the first time since the winter of 1995. The resulting nutrient pulse supported annual primary production that was the highest on record. The mean annual *Artemia* biomass in 2003 was 53% higher than in 2002, though slightly less than the long-term average.

Monitoring

Stream Channel

Monitoring and Reporting

During RY 2003, McBain and Trush continued their monitoring program developed in 1997 and 1998 following the White and Blue book principles. Three monitoring reaches have been established on Rush Creek, two reaches on Lee Vining Creek, and one reach on each of Parker and Walker creeks, totaling 55 cross-sections. Detailed descriptions of McBain and Trush's monitoring of reaches, water temperature, and channel dynamics are found in their report titled "Monitoring Results and Analyses for Runoff Season 2003-04 – Mono Basin Tributaries: Lee Vining, Rush, Walker, and Parker Creeks". This report is included in Section 4 of the Compliance Report.

Fishery

Monitoring and Reporting

Mr. Hunter continued the monitoring program originally developed in RY 1997 and 1998 according to the White and Blue book principles. This plan was altered during the course of its implementation to rely more heavily on electrofishing for population estimates in place of snorkeling, as electrofishing proved to be more accurate in the beginning monitoring seasons. Pool habitats were evaluated using snorkeling surveys and pools were classified by their habitat quality rating (Class 5 being highest quality). Three planmap sections in Rush Creek (Country Road, Upper, and Lower), two planmap sections on Lee Vining Creek (Upper and Lower), and one planmap section on each of Walker and Parker creeks were studied. Mr. Hunter's detailed methods and findings are described in his report titled "Fisheries Monitoring Report for Rush, Lee Vining, Parker, and Walker creeks – 2003", located in Section 3 of Compliance Reporting.

Waterfowl

Oversight of the Monitoring Program

During RY 2003, Dr. White oversaw the Waterfowl Habitat Restoration Program in the Mono Basin. He facilitated outside review and documentation of a revised waterfowl monitoring plan and reviewed the annual reports on lake limnology and waterfowl distribution and abundance. He also made a helicopter inspection of the Mono Lake shoreline and Crowley Lake.

LADWP personnel collected hydrology data for the four streams and Mono Lake.

Informational Meetings

The LADWP sponsored two meetings during the RY 2003 for the experts and interested persons to present and discuss restoration and monitoring activities, hydrology, and other issues related to the Mono Basin. The meetings were held on April 25, 2003 and November 20, 2003.

April Meeting: This meeting, held on April 25, 2003, provided an opportunity for the stream monitoring experts to present the findings of their RY 2002 monitoring activities and discuss their proposed RY 2003 scope of work. Chris Hunter plans to move forward with a fish movement study to determine where the fish swim during their annual life cycles. He also plans to move forward with otolith sampling to determine ages of fish. The trout populations are steady and most fish are in good condition. Bill Trush stated that because flows are not expected to exceed 200 cfs, geomorphology monitoring may be suspended for the year. He also stated that aerial photos will be taken during the summer of 2003 and that they will be high resolution and cover the four tributaries from valley wall to valley wall and from LADWP facility to Mono Lake.

In addition, the preliminary RY 2003 runoff forecast and operations were discussed by LADWP. The preliminary runoff forecast indicated a "Dry Normal I" year. LADWP discussed the need to ramp flows at 25 cfs per day, to calibrate the rating section on the newly refurbished Mono Gate One Return Ditch. Attendees included those shown in **Table 1**.

Table 1
Mono Basin April Meeting Attendees

Name	Agency/Affiliation
Bill Trush	McBain & Trush
Chris Hunter	Hunter
Brad Shepard	Hunter
Lisa Cutting	MLC
Peter Vorster	MLC
Roy McDonald	MWH
Greg Reis	MLC
Janet Goldsmith	KMTG
Lissa MacVean	MWH
Sacha Heath	PRBO
Dave Martin	LADWP
Brian Tillemans	LADWP
Jim Canaday	SWRCB
Brian White	LADWP
Bob Prendergast	LADWP
Peter Kavounas	LADWP
Jim Edmondson	CalTrout

November Meeting: This meeting, held on November 20, 2003, provided an opportunity for the stream monitoring experts and waterfowl experts to present and discuss their RY 2003 activities. Darren Mierau of McBain & Trush outlined their efforts in 1) mapping of 1929 aerial photos, 2) unimpaired flow analyses, and 3) piezometer placement for groundwater monitoring. Chris Hunter reviewed his progress with the fish monitoring. He discussed the conditions of the stream (relatively high ramping rates and peaks on Lee Vining Creek) and some of the things he would like to accomplish, including determining whether the current fish sampling sites are representative of the whole system, beginning a fish movement study, and using otoliths to age fish.

An overview of the runoff recap was also presented at this meeting. Attendees included those shown in **Table 2**.

Table 2
Mono Basin November Meeting Attendees

Name	**Agency/Affiliation**
Jim Canaday	SWRCB
Bill Trush	McBain & Trush
Darren Mierau	McBain & Trush
Chris Hunter	Hunter
Ross Taylor	Hunter
Peter Vorster	MLC
Greg Reis	MLC
Lisa Cutting	MLC
Jim Edmondson	CalTrout
Janet Goldsmith	KMTG
Lissa MacVean	MWH
Peter Kavounas	LADWP
Mark Hanna	LADWP

Activities Planned for Runoff Year 2003

Restoration Activities

Streams

Sediment Bypass at Lee Vining Intake

Design and construction of the sediment bypass at the Lee Vining Intake may be completed in the fall of 2004.

MGORD Flow Test

LADWP plans to test the MGORD during peak operations on Rush Creek. During this time LADWP will take the opportunity to study the effects of increased ramping rates on the geomorphology and ecology of Rush Creek.

Peak Flows and Ramping Study

Peak flows and ramping rates for Rush and Lee Vining creeks were set forth by Order 98-05 and need to be reevaluated based on a study of data collected during the first eight to ten years of the full implementation of the Order. This study will focus on integrating the physical processes, riparian plant dynamics, and fish habitat into regulated hydrographs that address the range of water year types.

Addition to the Stream Restoration Team

Roy McDonald, of MWH, will be augmenting the current Mono Basin stream restoration effort. His expertise in the field of fluvial geomorphology will provide additional resources and perspective on this critical matter.

Waterfowl

Channel Rewatering:

There are currently no plans to rewater the channels described in the waterfowl plan (see discussion above).

Monitoring

Streams

Dr. Trush will continue the stream channel monitoring program on Rush, Lee Vining, Parker, and Walker creeks. The following specific items will be included in the RY 2004 monitoring:

Post-Transition Flows
Data collection for the determination of post-transition flows and ramping will continue if stream restoration flows are released from Grant Lake. These data support the study that will focus on integrating the physical processes, riparian plant dynamics, and fish habitat into regulated hydrographs that address the range of water year types.

Evaluate Groundwater Dynamics
Baseline groundwater elevations that did not result from high flow releases during RY2003 will now be compared to those recorded during RY 2004, so that in subsequent years' monitoring, higher groundwater elevations would be attributable to the 3D floodplain construction and side-channel re-opening.

Riparian Planting Experiments
Monitoring of plant survival at the Narrows Pilot project will continue, and conditions that favor natural riparian plant recruitment at the 3D Floodplain site and the 8-Channel site will be evaluated.

Temperature Monitoring
Temperature monitoring will be continued for the six thermographs in the system: three along Rush Creek, and one each on Parker, Walker, and Lee Vining Creek.

Fishery

Fish Monitoring
Chris Hunter and his fish monitoring team will utilize the same monitoring sites and methods for Rush, Lee Vining, Parker and Walker creeks that were used during the years 2000, 2001, 2002, and 2003. Collection of scale and otolith samples will be continued to better estimate ages of brown and rainbow trout in Rush and Lee Vining creeks.

Fish Movement Study
A fish movement study will be conducted by a graduate student and guided by Chris Hunter for the purpose of determining:

1. Whether young fish move into the MGORD from Rush Creek and remain there growing to larger sizes than they would attain in main Rush Creek;
2. Whether larger fish move out of the stream into the MGORD seeking better habitat conditions;
3. Whether mature fish from Rush Creek move into Parker and Walker creeks to spawn, or whether these streams are dependent upon resident spawners to sustain their brown trout populations;

4. Whether fish hatched in Parker and Walker usually recruit to the Rush Creek fishery.

Instream Flow Studies

The monitoring team will retain the services of an instream flow expert to determine future flow regimes that are suitable for the trout fishery.

Fish Habitat

Habitat surveys will be conducted using snorkeling and some long-term monitoring at selected pools.

Waterfowl

Dr. White will continue to oversee the waterfowl monitoring program. This program consists of the following components:

- Limnology: Dr. Jellison and Dr. Melack will continue limnological monitoring in the Mono Basin.
- Waterfowl Population Surveys: Deborah House will perform the waterfowl population surveys in the Mono Basin.
- Aerial Photography: LADWP will conduct aerial photography of the Mono Basin in a GIS-compatible format.
- Hydrology: LADWP will continue to monitor the elevation of Mono Lake and collect hydrologic data in the Mono Basin.

Informational 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 was held on April 30, 2004. The second meeting will be held in November, 2004.

Physical Projects Remaining

Streams

Intake Facilities on Walker and Parker Creeks

The control facilities on Walker and Parker creeks will be reconfigured to allow control of the amount of flow being released to the creeks. These facilities need to be designed and constructed. The designs and construction are expected to be completed within five years.

Lee Vining – Grant Lake Conduit Siphon

A retrofit of the Lee Vining – Grant Lake Conduit Siphon will be evaluated to ensure that it can operate as needed to comply with Order 98-05.

Mono Gate Control Facility

The Mono Gate Control Facility will be evaluated to determine the feasibility of a retrofit to better control the division of flows between lower Rush Creek and West Portal.

Waterfowl

Channel Rewatering on Rush Creek

No construction activities are planned for the channels on lower Rush Creek.

Section 2

Mono Basin Operations
For Runoff Year
2004-05

Mono Basin Operations for Runoff Year 2004-2005

The April 1st Mono Basin Forecast for the 2004-05 Runoff Year is 97,400 acre-feet, or 80% of normal (using the 1951-2000 average of 122,435 acre-feet). The May 1st forecast was not performed this year because no agency performed snow surveys for May. It is assumed that the May 1 forecast would be substantially the same as the April 1 forecast, and the April 29, 2004 plan titled "Preliminary Mono Basin Operations for Runoff Year 2004-05" (attached) remains essentially unchanged.

As discussed during the April 2004 Mono Basin Restoration Tracking Meeting held in Sacramento, California, on April 30th, 2004, LADWP will test the Mono Gate One Return Ditch (MGORD) during peaking operations on Lower Rush Creek. The flow test is scheduled to begin on June 1st. LADWP will ramp streamflows up by less than 40% per day to a peak flowrate of 380 cfs. This peak flowrate will be sustained for two days and is currently scheduled for June 10th and 11th. Flows will then be ramped down for three days at approximately 20% per day, until the flowrate is less than 200 cfs. Ramping down of streamflows will continue at 8% – 12%, or 10 cfs, whichever is greater, until baseflows of 47 cfs are achieved. Lower Rush Creek is expected to return to base flow levels on June 26th. Note that at anytime LADWP engineering staff believe that significant damage may occur as a direct result of the flow test, the flow test will be halted and flows will be reduced to a level deemed safe until all water required during peaking operations is expended.

April 29, 2004

Mr. Harry Schueller
Chief Deputy Director
State Water Resources Control Board
P.O. Box 100
Sacramento, California 95812-0100

Dear Mr. Schueller:

Subject: Preliminary Mono Basin Operations for Runoff Year 2004-05

The April 1, 2004 Mono Basin runoff forecast for the Runoff Year 2004-05 is 97,400 acre-feet, or 80 percent of normal (using the 1951-2000 average of 122,435 acre-feet). Thus, this year is classified as "Dry Normal II" according to the provisions of the State Water Resources Control Board (SWRCB) Order 98-05. The operations plan based on the April 1 forecast is preliminary, and will be finalized once the May 1, 2004 forecast has been developed. Unless there is substantial difference, the Los Angeles Department of Water and Power (LADWP) will not submit a revised operations plan.

To meet SWRCB requirements, LADWP intends to follow the guidelines shown in Attachment 1, with the following modifications: Mono Basin exports will be allocated over the October-to-March period, instead of the entire year, with the exception of a 10-day period in mid-July, where LADWP intends to export 30 cfs for a temperature study in the Upper Owens River. In addition, the Rush Creek hydrograph may be altered in connection with a possible flow test of the newly-refurbished Mono Gate One Return Ditch (MGORD). If and when the flow test is finalized, a supplemental letter describing the procedure will be submitted under separate cover.

Attachment 2 titled "Grant Lake Operations Model-Statistical Summaries" presents a summary of the "educated guess" of flows in the Mono Basin streams and LADWP facilities for the Runoff Year 2004-05. This simulation is based on the runoff pattern experienced in 1981, a year of similar runoff volume to the forecasted Runoff Year 2004-05. The simulated flows do not represent minimum or maximum flows, or targets of any kind. They merely provide a possible scenario of flow distribution in the basin. The scenario presented in Attachment 2 assumes that flows are controlled with precision, and is based on historical information which incorporates past temperature and precipitation patterns throughout the runoff year and reflects operational practices by Southern California Edison (SCE) in Mono Basin. The actual flows will likely be different, since facility control is not precise, weather is not likely to mimic the past, and SCE may have changed their method of operation.

Grant Lake Storage: On April 1, storage in the Grant Lake Reservoir was approximately 23,000 acre-feet, less than half of the total reservoir capacity of 47,500 acre-feet. This level and the projected fluctuation of the reservoir create some concern for the safe operation of the Grant Lake Marina for recreational purposes. As addressed below, operational decisions on diversions from Lee Vining Creek and the pattern of Mono Basin exports are influenced by this condition and are intended to assist in raising the storage in Grant Lake during the April-to-September period. Figure 1 shows the forecasted inflow, outflow, and storage for the Grant Lake Reservoir through the Runoff Year 2004-05.

Rush Creek: SWRCB Decision 1631 and Order 98-05 provide base flow and Stream Restoration Flows (SRF) requirements for Rush Creek. Order 98-05 further subdivides the "Dry Normal" classification into two categories specifically for Rush Creek. Based on this, the forecasted runoff for 2004-05 suggests that the required SRF for Rush Creek is 250 cfs for five days. As mentioned above, if and when an MGORD flow testing procedure is finalized, the Rush Creek flow schedule may be updated with another letter under separate cover. This letter would reflect the changes in Rush Creek streamflow resulting from the flow test of the MGORD.

Decision 1631 provides base flow requirements for Rush Creek, as shown in Attachment 1. LADWP intends to abide by those requirements, including the provision that "…the instream flow requirements shall be (those specified in Attachment 1) or the inflow into Grant Lake from Rush Creek, whichever is less." (Decision 1631, page 198). It is expected that on certain days instream flows may be lower than the inflow to Grant Lake. Every effort will be made to adjust flows daily to minimize this occurrence. Figure 2 shows an illustration of possible Rush Creek flows.

Lee Vining Creek: SWRCB Decision 1631 and Order 98-05 provide base flow and SRF requirements for Lee Vining Creek. LADWP intends to abide by those requirements, and operate as shown in Attachment 1. The operation includes diversion of flows in excess of the
54 cfs base flow requirement. LADWP will use its facilities to effect this diversion and will make every effort to maintain the required flow (LADWP plans to modify its Lee Vining diversion facility in the future to gain greater control of the releases into Lee Vining Creek). At this time, releases to Lee Vining Creek from the facility cannot be controlled reliably, and the diversion of water this year may result in a short-term flow of less than the required 54 cfs. LADWP will review Lee Vining Creek flow information daily and make adjustments as necessary to minimize the occasions and duration of releases below 54 cfs. The diversion from Lee Vining Creek will be undertaken to maximize the amount of stored water in Grant Lake, for reasons discussed earlier. Figure 3 shows an illustration of possible Lee Vining Creek flows.

Walker and Parker Creeks: Walker and Parker Creeks will be managed as shown in Attachment 1, in accordance with SWRCB Decision 1631 and Order 98-05.

Mono Lake Elevation: On April 1, 2004, Mono Lake's water surface elevation measured approximately 6,381.8 ft amsl (US Geological Survey datum). Given the most current forecast and the proposed operations, the elevation of Mono Lake is projected to reach a minimum of 6,380.8 amsl in December 2004 and be approximately 6,381.4 ft amsl at the end of the runoff year. This is graphically shown in Figure 4 titled "Mono Lake Elevation and Transition Period Exports". The estimate is derived from modeling and includes a number of assumptions such as normal precipitation conditions for the remainder of the year. The projected lake elevation is to be used as a general indicator only.

Mono Basin Exports: In accordance with Decision 1631, LADWP is permitted to divert up to 16,000 acre-feet during the runoff year. LADWP plans to export the allowed 16,000 acre-feet during the October-March period. In the long term, LADWP plans to divert the allowed amount in an even, year-round pattern. The operations this year reflect the Grant Lake considerations discussed earlier.

Peak Flows: The values of expected magnitude and timing of the peak flows in Lee Vining, Walker, and Parker Creeks were generated by a predictive model and are shown below:

MAGNITUDE AND TIMING OF PEAK FLOWS IN LEE VINING, WALKER, AND PARKER CREEKS

Creek	**Magnitude**	**Timing**
Lee Vining	240 cfs	June 6, 2004
Walker	34 cfs	June 13, 2004
Parker	47 cfs	June 18, 2004

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 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, 2004 forecast and assume average precipitation for the following
six months.

If you have any questions, please contact Dr. Mark Hanna at (213) 367-1289.

Sincerely,

Original signed

Thomas M. Erb
Director of Water Resources

MH:ctc

Enclosures

c: Mr. Jim Edmondson, California Trout, Inc.
Mr. Bill Bramlette, U.S. Forest Service
Mr. Burt Almond, U.S. Forest Service
Mr. James Barry, California Department of Parks and Recreation
Mr. Joe Bellomo, People for Mono Basin Preservation
Dr. William Trush, McBain & Trush
Mr. Ken Anderson, Department of Parks and Recreation
Mr. Marshall S. Rudolph, Mono County Counsel
Mr. Jim Canaday, Division of Water Rights, State Water Resources Control Board
Mr. Gary Smith, Department of Fish and Game
Ms. Lisa Cutting, Mono Lake Committee
Mr. Chris Hunter
Mr. Steve Parmenter, Department of Fish and Game
Ms. Molly Brown, U.S. Forest Service
Dr. Mark Hanna, Los Angeles Department of Water and Power

bc: Thomas M. Erb
Gene L. Coufal
Clarence Martin
Charlotte Rodrigues
Terry Williams
Steve Keef
Robert Prendergast
FileNet

ATTACHMENT 1

Mono Basin Operations, Guideline C

Year Type:……………………………..……………………………… DRY–NORMAL II
Forecasted Runoff in acre-feet..………………………………………..91,590 – 100,750

Lower Rush Creek

Base Flows:

	Apr–Sep	Oct-Mar
Flow (cfs)	47	44

Minimum base flows should equal the lesser of the inflow to Grant Lake or the minimum requirements listed above. However, if Grant Lake inflow is less than the dry year base flow requirements under Guideline A, dry year requirements apply. If Grant Lake storage drops below 11,500 acre-feet (7,089.4' elevation), base flow requirements for a dry-year under Guideline A also apply (D-1631, p 197-198).

Peak Flows: - 250 cfs for 5 days*.

Ramping:
- Begin ramping on May 15th (rule of thumb). Note that peak operations will take 34 days, so timing this with peak flows in P/W Creeks, with fish movement, and cottonwood germination is beneficial.
- 10 percent daily change during ascending and descending limbs, or 10-cfs, whichever is greater.

Augmentation: - None.

Lee Vining Creek

Base Flows:

	Apr–Sep	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.

Peak Flows*: - Allow peak flow to pass through diversion facility.

Ramping:
- 20 percent daily change during ascending and 15 percent during descending limbs, or 10-cfs, whichever is greater.
- Begin ramping on May 15th (rule of thumb).

Diversions:
- Divert flows in excess of base flows until May 15th (rule of thumb).
- Diversions may resume 7 days after peak (rule of thumb); divert flows in excess of base flow requirements.

Parker and Walker Creeks

Flow-through conditions for entire year.

Exports

4,500 acre-feet scenario – Maintain 6 cfs export throughout the year.
16,000 acre-feet scenario – Maintain 22 cfs export throughout the year.

---

*Section 1. a. (1) of Order 98-05 states that LADWP may reduce SRF's in dry/normal and normal years to maintain exports allowed under D-1631; that LADWP will seek to have between 30,000 and 35,000 acre-feet (elev. 7,113' and 7,119") in Grant Lake at the beginning and end of each runoff season; and LADWP will not be required to reduce storage in Grant Lake below 11,500 acre-feet (elev. 7089.4') to provide SRFs.

ATTACHMENT 2

Grant Lake Operations Model - Statistical Summaries
2004 Runoff Year: Dry-Normal

	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	Grant Lake Evap.	Grant Lake Misc. Losses	A-Ditch Diver.

Daily Flows

	cubic feet/second									ac-ft	cubic feet/second							
Start										23000								
Min	13	1	3	30	13	0	6	30	37	22080	40	0	0	47	62	0	-8	0
Ave	51	6	10	67	45	6	16	54	69	28183	76	0	22	61	98	3	-5	0
Max	224	34	59	155	224	99	91	380	465	33060	380	0	43	96	130	8	1	0
End										22080								

Monthly Average Flows

	cubic feet/second									1st of Month	cubic feet/second							
Apr	51	2	7	78	42	9	9	46	55	23000	46	0	0	65	80	0	-4	0
May	109	12	11	113	77	31	23	47	70	25680	47	0	0	61	76	6	-8	0
Jun	131	20	33	120	110	20	53	165	218	31800	165	0	0	71	86	8	-7	0
Jul	54	8	16	84	47	7	24	47	71	30290	57	0	10	60	85	8	1	0
Aug	35	4	8	70	35	0	12	47	59	31780	47	0	0	56	71	8	-1	0
Sep	25	3	8	48	25	0	11	42	53	32820	42	0	0	57	72	6	-1	0
Oct	30	5	5	38	29	1	10	38	48	32840	79	0	41	62	118	5	-4	0
Nov	33	8	6	43	31	2	14	41	54	30280	84	0	43	63	121	0	-5	0
Dec	32	4	5	44	32	0	9	43	52	28230	86	0	43	62	120	0	-5	0
Jan	31	3	5	47	31	0	8	42	50	25910	85	0	43	60	118	0	-6	0
Feb	38	4	6	49	38	0	10	42	53	23960	85	0	43	58	116	0	-7	0
Mar	40	2	6	74	40	0	8	44	52	22350	87	0	43	56	114	0	-7	0

Monthly Total Flows

	acre-feet									Average	acre-feet							
Apr	3029	117	396	4658	2501	528	513	2762	3275	23572	2762	0	0	3888	4781	0	-236	0
May	6675	708	705	6963	4748	1927	1413	2890	4303	29193	2890	0	0	3752	4674	357	-518	0
Jun	7766	1219	1948	7166	6562	1205	3167	9828	12995	30060	9828	0	0	4201	5094	455	-399	0
Jul	3320	466	1000	5141	2916	405	1466	2890	4356	31360	3485	0	595	3719	5236	508	48	0
Aug	2157	265	498	4333	2157	0	762	2890	3652	32315	2890	0	0	3431	4354	462	-91	0
Sep	1475	170	474	2831	1475	0	644	2492	3137	32949	2492	0	0	3378	4270	352	-74	0
Oct	1839	322	292	2361	1806	33	613	2336	2950	31660	4844	0	2507	3809	7239	289	-261	0
Nov	1988	465	354	2579	1856	132	819	2413	3232	29316	4972	0	2559	3772	7223	0	-275	0
Dec	1970	221	316	2688	1939	31	538	2635	3173	27075	5279	0	2644	3805	7372	0	-302	0
Jan	1906	208	284	2865	1906	0	492	2609	3101	24966	5253	0	2644	3707	7273	0	-378	0
Feb	2083	244	324	2718	2083	0	568	2354	2922	23123	4742	0	2388	3236	6458	0	-372	0
Mar	2472	110	368	4534	2460	12	478	2705	3183	22213	5349	0	2644	3468	7034	0	-451	0
Apr-Sep	24422	2946	5020	31092	20358	4064	7966	23752	31719		24347	0	595	22370	28409	2135	-1271	0
Oct-Mar	12258	1570	1938	17745	12050	208	3507	15053	18561		30439	0	15386	21798	42599	289	-2039	0
Annual Total	36680	4516	6958	48837	32408	4272	11474	38806	50279		54787	0	15981	44168	71008	2423	-3310	0

FIGURE 1

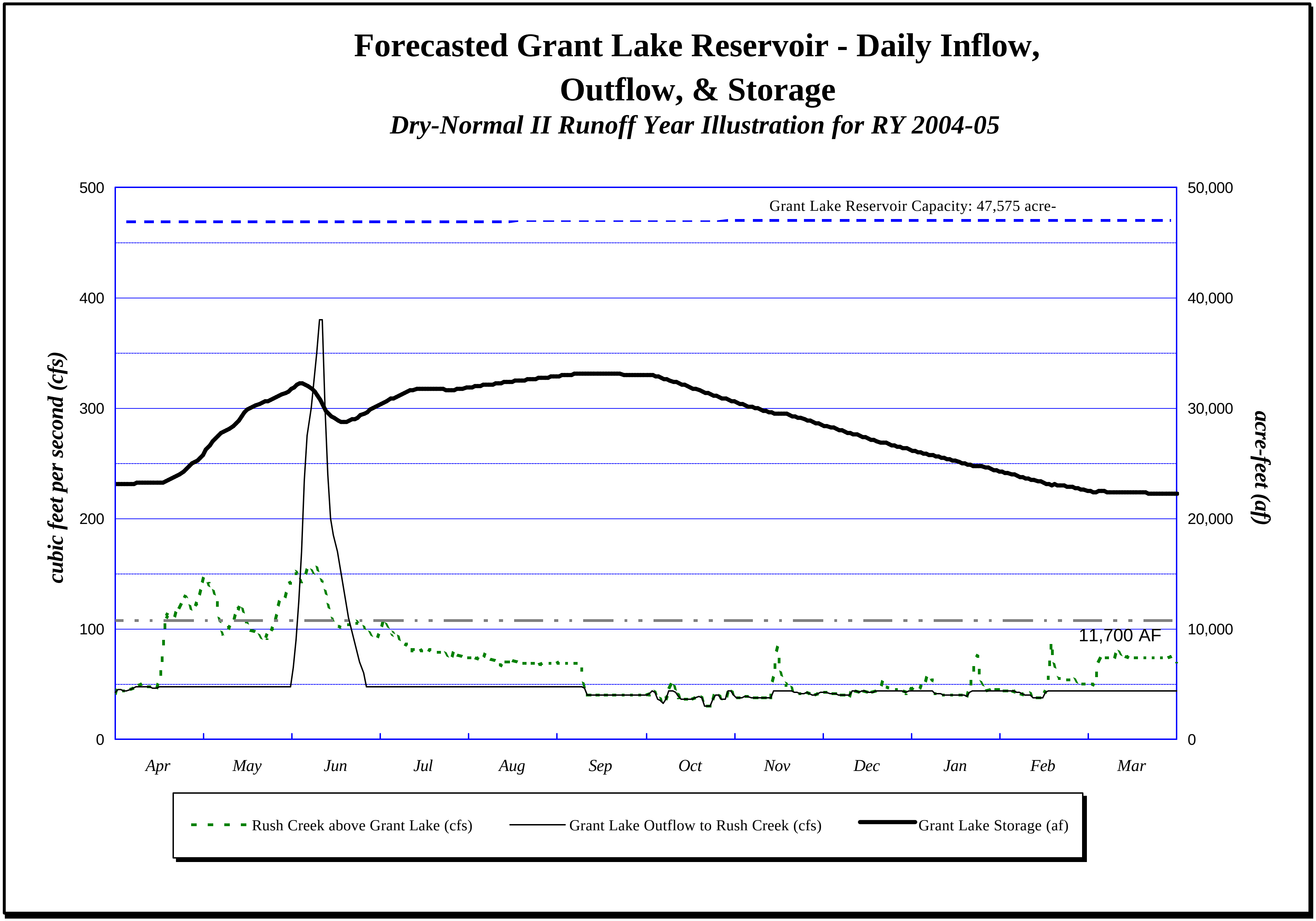
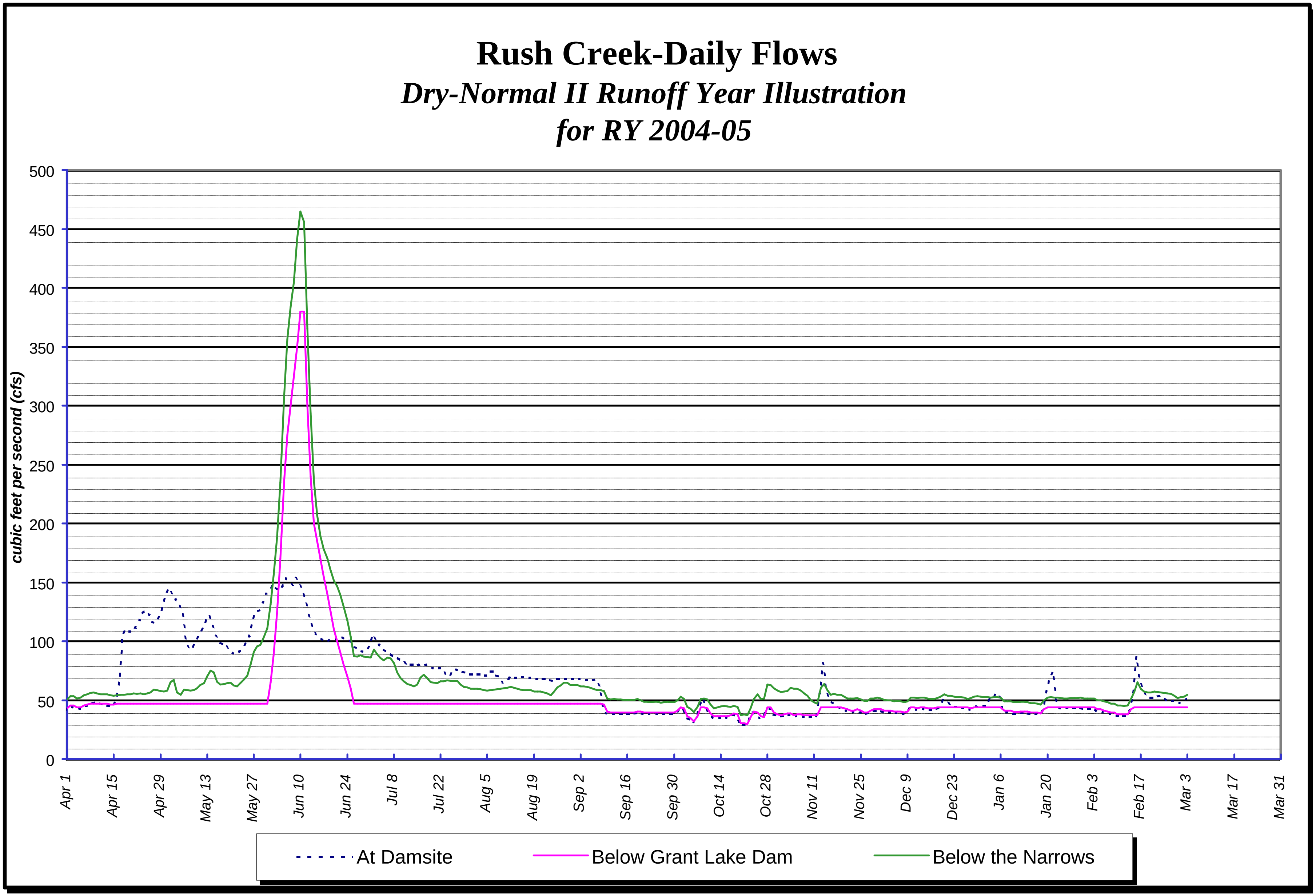

Forecasted Grant Lake Reservoir - Daily Inflow, Outflow, & Storage
Dry-Normal II Runoff Year Illustration for RY 2004-05
Grant Lake Reservoir Capacity: 47,575 acre-
11,700 AF
cubic feet per second (cfs)
acre-feet (af)
500
400
300
200
100
0
50,000
40,000
30,000
20,000
10,000
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Rush Creek above Grant Lake (cfs)
Grant Lake Outflow to Rush Creek (cfs)
Grant Lake Storage (af)

FIGURE 2



Rush Creek-Daily Flows
Dry-Normal II Runoff Year Illustration
for RY 2004-05
cubic feet per second (cfs)
500
450
400
350
300
250
200
150
100
50
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
At Damsite
Below Grant Lake Dam
Below the Narrows

FIGURE 3

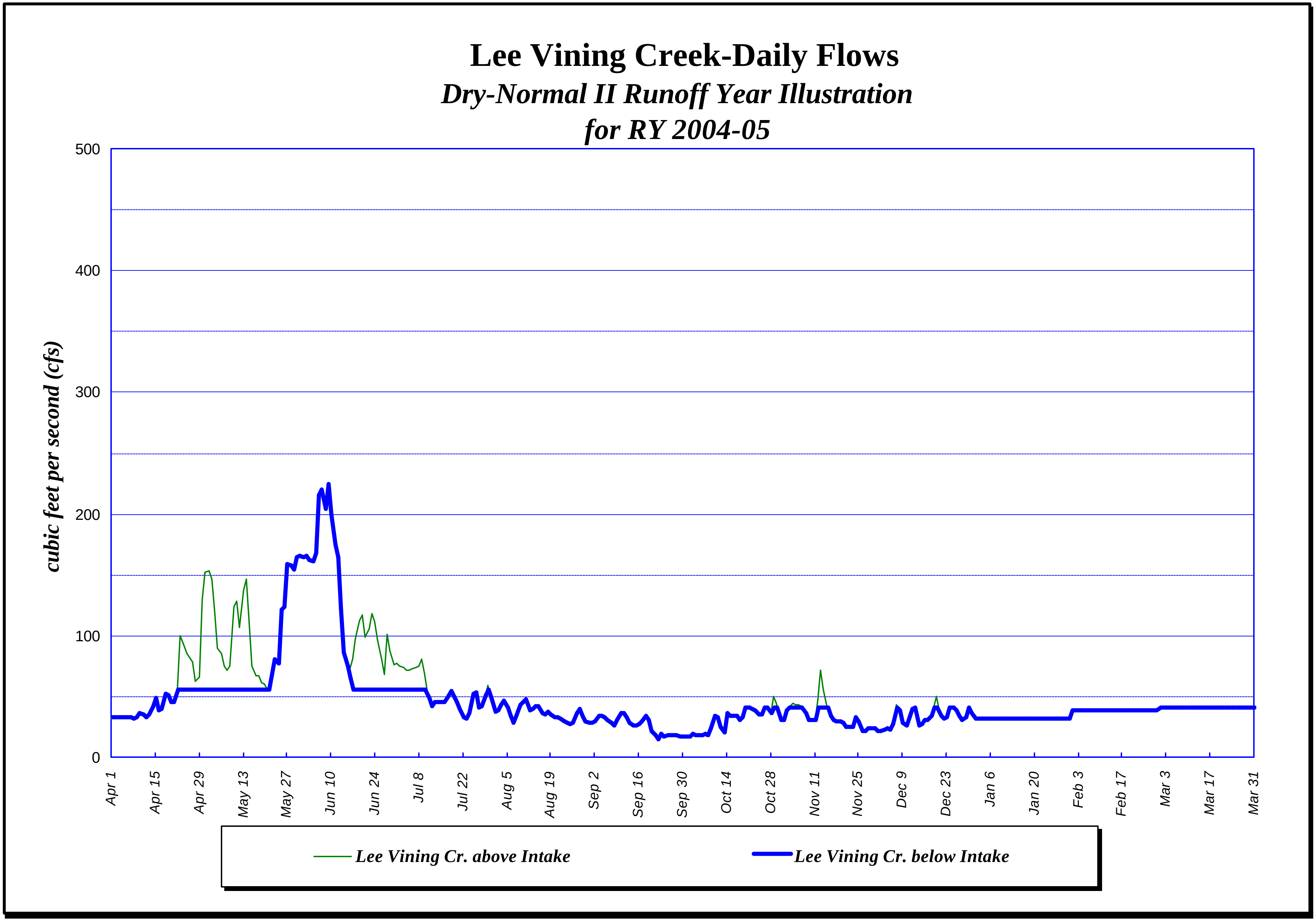
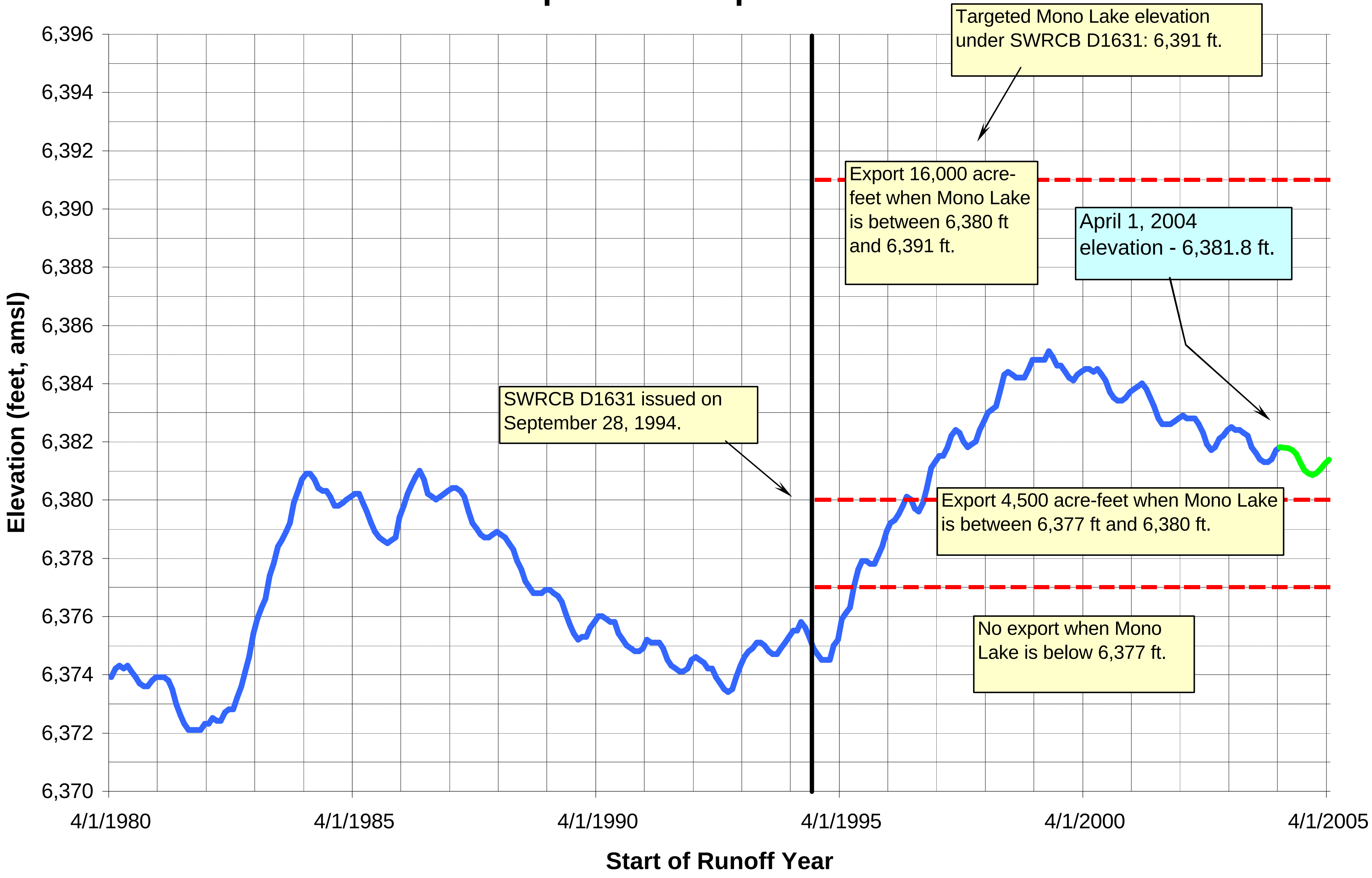

Lee Vining Creek-Daily Flows
Dry-Normal II Runoff Year Illustration
for RY 2004-05
cubic feet per second (cfs)
500
400
300
200
100
0
Apr 1
Apr 15
Apr 29
May 13
May 27
Jun 10
Jun 24
Jul 8
Jul 22
Aug 5
Aug 19
Sep 2
Sep 16
Sep 30
Oct 14
Oct 28
Nov 11
Nov 25
Dec 9
Dec 23
Jan 6
Jan 20
Feb 3
Feb 17
Mar 3
Mar 17
Mar 31
Lee Vining Cr. above Intake
Lee Vining Cr. below Intake

FIGURE 4

Mono Lake Elevation and Transition Period Exports

April 1980 - April 2005



Targeted Mono Lake elevation under SWRCB D1631: 6,391 ft.

Export 16,000 acre-feet when Mono Lake is between 6,380 ft and 6,391 ft.

April 1, 2004 elevation - 6,381.8 ft.

SWRCB D1631 issued on September 28, 1994.

Export 4,500 acre-feet when Mono Lake is between 6,377 ft and 6,380 ft.

No export when Mono Lake is below 6,377 ft.

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. USGS Datum

5/10/2004 by Paul Scantlin
Mono Lake Elev data_042804-chart

Section 3

Fisheries Monitoring Report for
Rush, Lee Vining, Parker, and Walker Creeks
2003

Fisheries Monitoring Report
For
Rush, Lee Vining, Parker and Walker creeks
2003

Prepared by:	**Chris Hunter** **Brad Shepard** **Ken Knudson** **Ross Taylor** **Matt Sloat**
Prepared for:	**Los Angeles Department of Water and Power**
Date:	**May 2004**

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Executive Summary

This report presents the results of the fifth year of fish population monitoring for Rush, Lee Vining, Parker, and Walker creeks pursuant to State Water Resources Control Board (SWRCB) WR 98-07. We used mark-recapture electrofishing techniques to estimate trout populations in three sections of Rush Creek and two main stem sections of Lee Vining Creek. Fish population estimates for two Lee Vining Creek side channels and Parker and Walker creeks were made using electrofishing depletion methods. Scale and otolith samples were collected to estimate fish ages. We provide corrected fish population estimates for the main channel portion of the Upper Lee Vining Creek and the Upper Rush Creek sections for 2002. We surveyed Rush Creek from the upper end of the County Road sample section down to its mouth at Mono Lake finishing our efforts to document the abundance and distribution of high quality pool habitats by quality class. We also day and night snorkeled most of the high quality pools found in this reach.

Densities (number per hectare) of age-1 and older brown trout declined in 2003, after reaching their highest recorded levels in 2002, in all sections of Lee Vining Creek. Estimated densities of age-1 and older brown trout increased from levels recorded in 2002 for the County Road and Lower sections in Rush Creek, but were still lower than those observed in 2001 in these two sections. Densities of age-1 and older brown trout declined slightly from 2002 to 2003 in Upper Rush Creek. Densities of age-1 and older brown trout increased dramatically (nearly four-fold) in Walker Creek during 2003, but increased only slightly in Parker Creek.

Estimated densities of age-0 brown trout were much lower than previous years in the Upper Rush Creek Section and slightly lower than 2002 for the Walker and Lower Rush Creek sections. Estimated densities of age-0 brown trout have steadily declined in the Upper Rush Creek section. Estimated densities of age-0 brown trout were higher in 2003 than in 2002, and generally higher in 2003 than all previous years sampled, in the Lee Vining Creek sections. Estimated densities of age-0 brown trout declined most dramatically from 2000 to 2003 in the Upper Section of Rush Creek. At this time we are uncertain why age-0 brown trout densities have declined each year in the Upper Rush Creek section.

Estimated densities of age-1 and older rainbow trout declined dramatically in all sections of Lee Vining Creek and held relatively steady in Rush Creek sections from 2002 to 2003. Estimated densities of age-0 rainbow trout were extremely low in 2003 in all sample sections except for the Upper Rush site. We captured no age-0 rainbow trout in Lee Vining Creek during 2003 and very low numbers during 2002. We speculated on why we have found either few or no age-0 rainbow trout fry in Lee Vining Creek in 2002 and 2003. We suggest taking a closer look at the timing of rainbow trout spawning, incubation, and emergence in Lee Vining Creek and comparing these with flow and temperature regimes to help determine if flow regimes might be adjusted to enhance early survival of rainbow trout.

Estimates of brown trout standing crops (kg/hectare) either dropped slightly from 2002 to 2003 or were similar, except in Walker Creek where standing crops increased dramatically with increased numbers of age-1 and older brown trout. The relative weights and condition factors of brown trout in Rush Creek don't appear to be varying much year-to-year. We only recaptured five brown trout that had been tagged with numbered tags in 2002 and all these fish were recaptured within the same section in which they were originally tagged.

Aging scale samples found that very few trout in Rush or Lee Vining creeks were living longer than age-3. We found generally good agreement between ages interpreted from scales and otoliths, but in the two cases where there were discrepancies ages interpreted from otoliths were higher. When average lengths of similar-aged fish were compared between Rush and Lee Vining creeks it appeared that fish in Lee Vining Creek grew at faster rates.

Pool habitat surveys located a total of 50 high quality pools (21 Class 5 and 29 Class 4 pools) in the 13.4 km (8.3 miles) of Rush Creek from the MGORD to Mono Lake. Most of these high quality pools were located in two distinct stream reaches, covering roughly one-half of Rush Creek's total length: 1) the 2.4 km reach from the MGORD down through our Upper Rush sample section; and 2) the 4.4 km reach from the Narrows to the County Road Ford. Comparisons of the frequencies of high quality pools in Rush Creek indicated that high quality pools were present within fish sample sections we have been monitoring at either higher or similar frequencies than found in most of the rest of Rush Creek. The habitat near the mouth of Rush Creek above Mono Lake was deemed marginally suitable for trout due to its shallow depths, braided channels, and lack of cover.

A total of 355 brown trout and 10 rainbow trout were observed during snorkeling surveys in thirteen of the Class 5 pools. Three brown trout longer than 350 mm were observed, with the largest being 500-550 mm in length. These large fish were all seen during night dives in deep pools with abundant hiding cover.

We compared the estimated fish population data for Rush and Lee Vining creeks to the termination criteria adopted by the SWRCB. The termination criteria are:

1. Lee Vining sustained catchable brown trout averaging 8-10 inches in length.
2. Rush Creek fairly consistently produced brown trout weighing ¾ to 2 pounds. Trout averaging 13 to 14 inches were also regularly observed.

In 2003 we estimated that Lee Vining Creek supported 16 to 25 trout per 100 m of channel length or 287 to 528 trout per hectare that were 200 mm (~8 inches) and longer in the main channel and about 10 to 13 per 100 m or 200 to 285 per hectare in side channel habitats. Most (50-90%) of these larger fish were brown trout. The numbers and densities of larger trout in Lee Vining Creek have declined from past years, thus this stream was not near termination criteria in 2003. In Rush Creek we only captured five trout (all were brown trout) that were longer than 300 mm (~12 inches) during 2003. However, only one of these fish was over 300 g (0.66 pounds), but that fish was 530 mm and 1943 g (4.2 pounds).

The SWRCB requires monitoring fish populations to determine if existing termination criteria are being met and suggested that these existing termination criteria be evaluated. The SWRCB recommended that additional quantitative termination criteria might be developed for Rush and Lee Vining creeks and that quantitative termination criteria might also be developed for Parker and Walker creeks. The lack of historical fish population data makes it very difficult to objectively evaluate the existing termination criteria with confidence. We recommend that fish population data continue to be collected for several additional years, so existing termination criteria can be scientifically and statistically evaluated. As part of these evaluations we will also consider additional or alternative termination criteria if we believe additional or alternative criteria would allow us to more objectively assess the status of these fish populations. Additional data collection will also allow us to explore relationships between trout abundance and physical parameters, such as stream flows, water temperatures, and stream channel characteristics, and to better determine the movement patterns and age-class structure of trout. We have begun to compile and analyze flow and water temperature data. These additional data will help in determining seasonal use of habitats in the system and estimate mortality rates by age and season to better assess termination criteria. We are currently evaluating termination criteria based upon standing crop (biomass per area) because we suggest estimates of this parameter would be more stable, quantifiable, and could potentially be adjusted as habitat conditions improve. We are also evaluating population size structure as possible termination criteria to be used in conjunction with standing crop estimates.

Introduction

This report presents the results of the fifth year of fish population monitoring for Rush, Lee Vining, Parker and Walker creeks pursuant to the State Water Resources Control Board Order 1631 and the subsequent Settlement Agreement negotiated among the parties. Fish population monitoring will continue until the streams have met termination criteria included in the Settlement Agreement. These termination criteria describe the believed pre-project conditions for fish population structure:

1. Lee Vining Creek sustained catchable brown trout averaging 8-10 inches in length. Some trout reached 13 to 15 inches.
2. Rush Creek fairly consistently produced brown trout weighing ¾ to 2 pounds. Trout averaging 13 to 14 inches were also regularly observed.

In addition to these criteria, Order 1631 states the monitoring team will develop and implement a means for counting or evaluating the number, weights, lengths and ages of fish present in various reaches of Rush Creek, Lee Vining Creek, Parker Creek and Walker Creek. No termination criteria were set forth for Parker and Walker creeks.

The Settlement Agreement states that the monitoring team will consider young-of-year (age-0) production, survival rates between age classes, growth rates, total fish per mile and any other quantified forms as possible termination criteria, although the Settlement Agreement does not compel the choice of any one form.

This report provides the fish population data mandated by Order 1631 and the Settlement Agreement. In addition we make recommendations for additional termination criteria. Fish length data is reported in millimeters (mm) in this report. For those not used to working in the metric system, an easy numerical reference point is 200 mm which is approximately 8 inches. An eight inch trout is often referred to as a ‘catchable’ trout.

Study Area

The same three population estimate sample sections in Rush Creek (County Road, Lower, and Upper) and two (Lower and Upper) in Lee Vining Creek sampled during previous years were again sampled from September 7 to 18, 2003 (Hunter et al. 2001 and 2002; Table 1 and Figure 1). While we expressed previous concerns (Hunter et al. 2001) about the dynamic nature of the stream channels, particularly in Rush Creek, making sample sections dynamic, it was agreed we would maintain existing sample sections after a site visit with representatives from Los Angeles Department of Water and Power (LADWP) in 2001. Sample sections experienced negligible channel changes from 2002 to 2003 with the exception of a side channel in the County Road Section of Rush Creek that captured slightly more flow in 2003; however, this did not change sample section lengths or areas (Table 1).

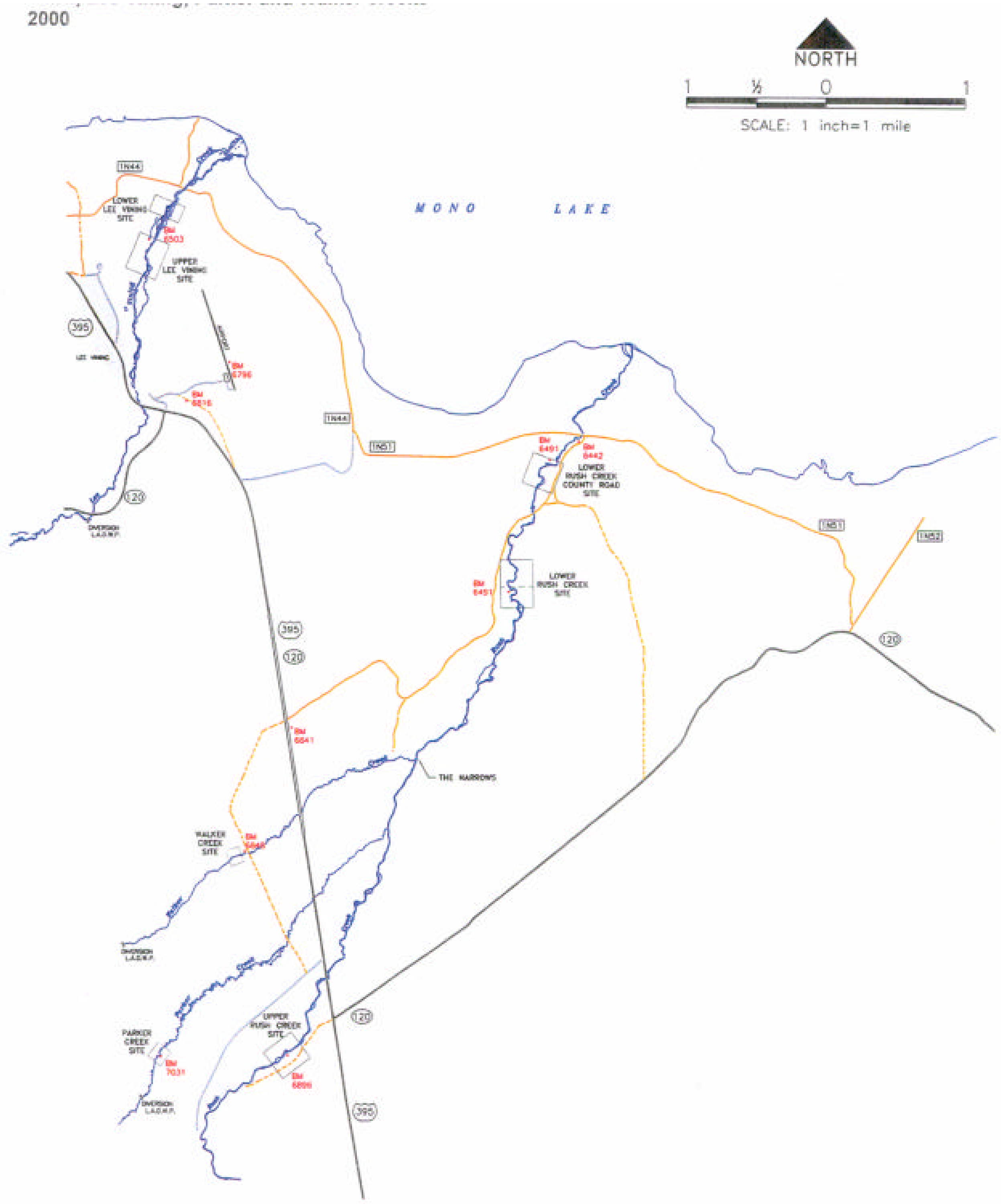

Figure 1. Map of Mono Basin study area with fish sampling sites displayed (from McBain and Trush 2000).

Table 1. Total length (m), average wetted width (m), and total surface area of sample sections in Rush, Lee Vining, Parker, and Walker creeks sampled from September 7 to September 18, 2003.

Section	Length (m)	Width (m)	Area (m^2)
Rush – County Road	813	8.4	6829
Rush - Lower	405	6.9	2794
Rush – Upper	430	7.4	3182
Lee Vining – Lower	155	4.8	744
Lee Vining - Lower-B1	195	4.8	936
Lee Vining - Upper-main	330	5.8	1914
Lee Vining - Upper-A4	201	4.4	884
Parker	98	2.2	216
Walker	100	1.8	180

We completed our counts and mapping of the distribution of pools within Rush Creek from the upper end of the County Road sample section down to its mouth at Mono Lake on September 6, 2003. All pool locations were referenced by distance (in km) downstream from the lower end of the MGORD. We used this upstream reference point because with the filling of Mono Lake, the mouth of Rush Creek at Mono Lake does not represent a stable reference point.

Stream flows in Rush Creek were similar in 2003 as in previous years of record (Figure 2). Stream flows in Lee Vining Creek were also similar, except for a very high flow event that occurred from May 29 to June 2 when flows exceeded 300 cfs (Figure 3). Flows in Rush Creek are obviously more regulated than flows in Lee Vining as evidenced by the very stable base flows between 45 to 52 cfs and very few days flows are above these base flows.

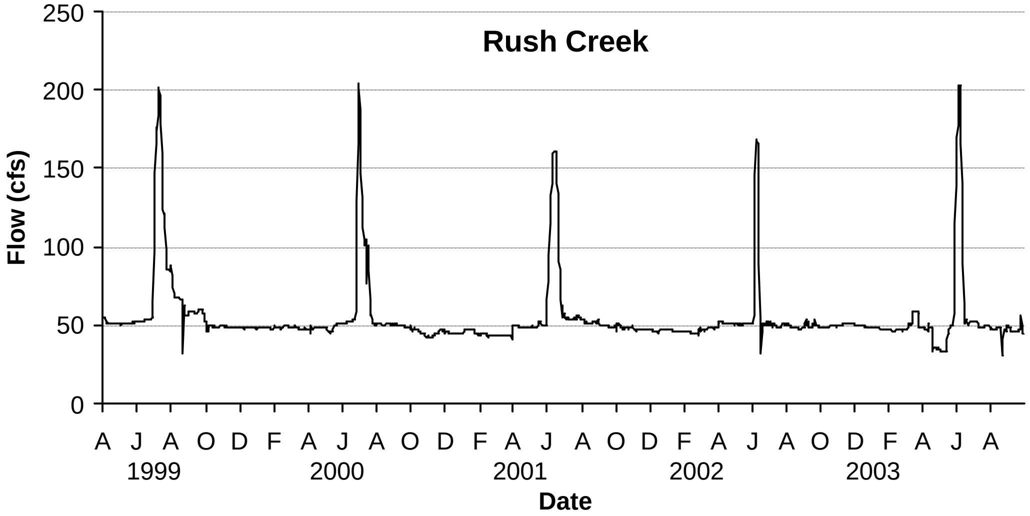

Figure 2. Daily stream flows (cubic feet per second; cfs) in Rush Creek below the MGORD from April 1999 through September 2003. Data were provided by Los Angeles Department of Water Power.

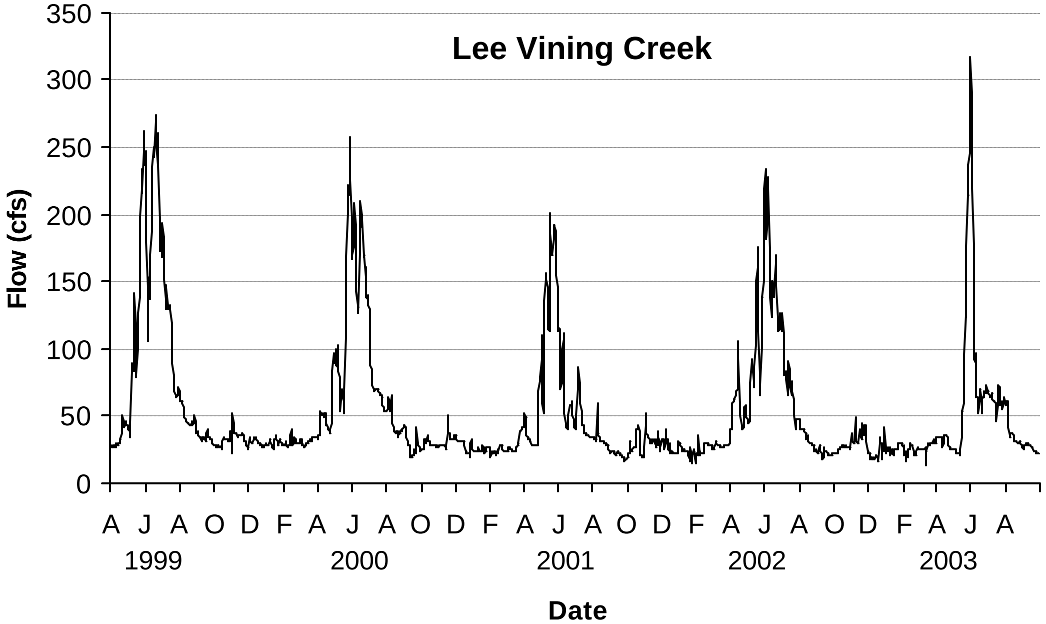

Figure 3. Daily stream flows (cubic feet per second; cfs) in lower Lee Vining Creek from April 1999 through September 2003. Data were provided by Los Angeles Department of Water Power.

We have begun to summarize stream flow and temperature data to assess potential relationships between these two variables and fish abundance, growth, survival, and condition parameters. Water temperature data from 1999 to 2003 indicated that diurnal water temperatures in Rush Creek did not vary much in the MGORD and increased in a downstream direction (Appendix A). Diurnal fluctuations and maximum daily stream temperatures increased dramatically between the Narrows and the County Road compared with temperatures between the MGORD to the Narrows.

Methods

Fish Population Estimates

During the late summer (September 7 to 18, 2003) mark-recapture estimates were made in the County Road, Lower, and Upper sections of Rush Creek, and in the main channels of the Lower and Upper sections in Lee Vining Creek. For mark-recapture estimates in Rush Creek, fish were captured using a Smith-Root® 2.5 GPP electrofishing system that consisted of a Honda® generator powering a variable voltage pulsator (VVP) that had a rated maximum output of 2,500 watts. This unit was set at 30 or less pulses per second to reduce risk of injury to fish and voltages were set to allow for capture of fish without harming fish. Obtaining this desired response in fish usually resulted in voltages ranging from 300 to 500 and amperes from 0.3 to 1.5. Mark-recapture estimates were also made in the main channel portions of Upper and Lower Lee Vining Creek. Depletion estimates were made in one sample section within each of Parker and Walker creeks and in the two side-channels of Lee Vining Creek associated with the Lower and Upper sections. For depletion estimates and the mark-recapture estimates in Lee Vining Creek, Smith-Root® BP backpack electrofishers (Models 12B and LR-24) were used to capture fish.

During mark-recapture electrofishing, the generator and VVP unit were transported downstream in a small barge. An insulated tub with two battery-powered aerators was carried in the barge to transport captured fish. A person operating a mobile anode and a dip netter fished each half of the stream in a downstream direction (total of two anode operators and two dip netters). The fifth crewmember walked the electrofishing barge downstream and monitored the generator, electrofishing unit, and condition of captured fish in the live-well, and controlled a safety shut-off switch. All netted fish were placed in the insulated tub within the barge shortly after capture.

Two backpack shockers were used when sampling the Lee Vining main-stem and side channel study sections, whereas a single backpack shocker was used in each of the Walker and Parker creek sections. At least one dip-netter per electrofisher netted fish stunned by that shocker. Another crew member served as a backup dip-netter and carried a live bucket equipped with an aerator in which all captured fish were placed immediately after capture, except in Walker Creek where one person both netted fish and transported the live bucket.

To meet the assumption of closed populations for sampling purposes, all sample sections, except the County Road Section, were blocked at both ends prior to sampling. Block fences were not placed at the boundaries of the County Road section; however, this section was long enough (813 m) that effects of movements at the ends of the sample section should have been low in proportion to the entire section. In the Upper and Lower Rush Creek sections and main channels of the Upper and Lower Lee Vining Creek sections, 12 mm mesh hardware cloth fences were installed at the upper and lower boundaries of the sections. These hardware cloth fences were installed by driving fence posts at approximately two-meter intervals through the bottom portion of the hardware cloth approximately 15 cm from its bottom edge. Rope was then strung across the top of each fence post and anchored to willows, fence posts, or trees on each bank. The hardware cloth was held vertically by wiring the top of the cloth to this rope with baling wire. These fences were installed prior to the marking run and maintained in place until after the recapture effort was completed. Fences were cleaned and checked at least once daily, and usually twice daily, to ensure they remained in place and for any possible dead fish between mark and recapture sampling.

We were able to maintain block fences much better this year as we had a single individual delegated to maintaining these fences. However, we often have difficulty maintaining lower block fences, especially in the Upper Rush Creek Section, during our sampling because we dislodge debris that clogs block fences and causes them to drop. While we kept one individual cleaning the lower block fence during our sampling, a short portion of the fence at the lower boundary of the Upper Rush Creek Section did go down for short time during our sampling. In addition, high winds immediately after our marking runs in Upper and Lower Rush Creek blew leaves and debris into the streams causing block fences at the boundaries of these sections to fail at least once. Therefore, the assumption of population closure during the estimates was not fully met. However, these fences were effective most of the time between the marking and recapture runs. We were able to keep fences blocking the two main channel sample sections in Lee Vining Creek up and effective the entire period. We discuss the implications of this assumption violation in the Discussion section. For the side channel portions of the Upper and Lower Lee Vining Creek sections and the sample sections in Parker and Walker creeks 12 mm mesh block seines were placed at sample section boundaries during depletion efforts.

All captured fish were anesthetized, measured to the nearest mm (total length), and most were weighed to the nearest gram. Data were entered onto both data sheets and into a hand-held personal computer (Compaq iPAC®) in the field. Scale samples were taken from a sub-sample of fish (see “Age-Growth Estimates” section below) for age determinations. The lower caudal fin was clipped to mark fish in the County Road section of Rush Creek and in the Upper Lee Vining Creek sections, the anal fin was clipped in the Lower Rush and Lower Lee Vining sections, and the upper portion of the caudal fin was clipped in the Upper Rush Creek section. When clipping a fin, scissors were used to make a straight vertical cut from the top, or bottom, of the fin approximately 1-3 mm deep at a location about 1-3 mm from the posterior edge of the fin. During September 2002, we tagged 101 brown trout longer than 225 mm with individually numbered Floy® anchor tags within our five sample sections in the Rush Creek drainage (Appendix B). We recorded the identification numbers for any tag-recaptures we found during 2003 sampling.

Population and biomass estimates were made for all mark-recapture estimates using an updated version of Montana Fish, Wildlife and Parks' Fisheries Plus analysis package (version 1.10). Since this program now calculates partial log-likelihood capture efficiency curves slightly differently than earlier versions of this program, we re-ran all estimates using this new program and employed the modified Peterson estimator (Chapman 1951, as cited in Ricker 1975). The updated estimates often changed slightly due to these re-calculations; however, these changes were not significant and should allow for more reliable comparisons among sections within a year and among years within sections. We have provided a summary of all updated estimates in Appendix C. During the course of updating these estimates we discovered an error in last year's report (Hunter et al. 2003) for 2002 estimates in the main channel of Upper Main Channel Section of Lee Vining Creek and in the Upper Section of Rush Creek. We provide corrected 2002 estimates in this report and caution that the population estimate portion of last year's report (Hunter et al. 2003) should be discarded and this report used in its place. We will also update the Hunter et al. (2003) report to correct these errors.

Length-Weight Regression

Length-weight regressions (Cone 1989) were calculated for brown trout in each section of Rush Creek by year to assess differences in length-weight relationships between sections and years. Log_{10} transformations were made on both length and weight prior to running regressions.

Age-Growth Estimates

Scale samples were taken from up to ten rainbow and ten brown trout within each 10 mm length group in all locations. Scales lay down annular marks making it possible to estimate a fish's age. It is important to obtain scales that develop as early as possible to ensure that the first year's annular mark is visible. Thus, scale samples were removed from each fish between the dorsal and adipose fins and about five to seven scale rows above the lateral line, since this is the area of a trout's body where scales first form. Scale samples were pressed onto soft acetate using a high-pressure scale roller. A microfiche reader set at 50X magnification was used to view the acetate impressions and annulus checks were recorded.

Otoliths, an inner ear bone, can also be used to estimate a fish's age and these structures have usually been found to be the most reliable growth structure on trout for interpreting their age (Simkiss 1974). Unfortunately, otoliths can only be obtained by sacrificing a fish. Thus, we removed both otoliths and scale samples from all incidental mortalities associated with sampling to verify scale-aging procedures. All otolith-scale pairs were assigned a unique sample number to ensure they could be matched after analysis. Otolith samples were prepared using the "cracked and burnt" methodology (Campana 1984). Otoliths were first sectioned transversely using a scalpel blade and then charred over an alcohol flame to enhance annular zonation. Charred otolith sections were then mounted in plasticine caps with their cracked surface up and immersed in oil for viewing under a dissecting microscope. Scales and otolith samples were prepared and aged by Jon Tost (North Shore Environmental Services, Thunder Bay, Ontario, Canada). A relatively high proportion of scale samples showed evidence of regeneration making aging difficult for some individuals.

All age-0 brown trout (<125 mm) had their adipose fin clipped off as a permanent mark to identify them as age-0 fish in 2003. We will track their empirical growth by subsequently recapturing these marked fish to estimate annual growth and verify our scale aging and back-calculations of annual growth.

Pool Habitat Reconnaissance in Rush Creek

Following the study plan amendment prepared for the LADWP in May 2002, the final portion of reconnaissance-level pool habitat and snorkeling surveys were completed on September 6, 2003 along the 2.7 kilometers of Rush Creek from the upper end of the County Road sample section to Mono Lake. We identified all pool habitats (Bisson et al. 1981) and classified each by quality class that ranks a pool's quality based on area, depth, and cover (Platts et al. 1983; Appendix D). All of the highest quality pools (Class 5) were referenced by distance (km) downstream from the outlet of the Mono Gate Return Ditch (MGORD), flagged with plastic flagging, and their locations were stored in a Global Positioning System receiver. We used the MGORD as our upstream reference point because, with the filling of Mono Lake, the mouth of Rush Creek is steadily changing. Stream channel length was measured with a hip chain, following the thalwag (deepest part of the channel) as closely as possible.

Since deep pools tend to be the domain of larger trout (Heggenes 2002) and since browns generally seek deeper water associated with cover as they grow (Blades and Vincent 1969; Heggenes 1988; Kocik and Taylor 1996), habitat measurements and snorkel observations were only made in the highest quality pools (Class 5). The relative abundance of fish cover by type (i.e., overhanging and submerged vegetation, woody debris, undercut banks, large rocks, root wads and bubble curtains) was estimated as the proportion of pool wetted surface area that was covered by each type. For more specific information on habitat scores at the pools, see Hunter et al. (2003). Eight to 25 depth and velocity (at depths 60% below the water surface) measurements were recorded across one or two transects per pool. Size distributions of streambed substrates were estimated using size classifications recommended by Platts et al. (1983). Vegetation along the stream adjacent to each pool was classified into general categories (grass, shrub, tree, or bare ground). Pools were typed according to procedures in Bisson et al. (1981). Maximum residual pool depth (the mean depth of the pool tail riffle subtracted from the maximum pool depth), and maximum pool diameter were recorded for all pools classified as Class 4 and 5. Snorkel surveys were made at thirteen Class 5 pools utilizing standard underwater observation techniques (Thurow 1994).

Results

Fish Population Abundance

Rush Creek

County Road Section

The majority of the brown trout captured in the County Road Section of Rush Creek were from 60 to 110 mm and the longest brown trout captured was 370 mm (Figure 2). Few rainbow trout were captured and most of these were from 140 to 160 mm with two fish over 250 mm (Figure 3). This section supported an estimated 1,928 age-0 and 621 age-1 and older brown trout in 2003 (Table 2). Estimates of brown trout were relatively precise with standard deviations ranging from 3 to 6% of the estimates. No estimate could be made for age-0 rainbow trout, but the section supported an estimated 10 age-1 and older rainbow trout; however, this estimate was likely biased due to the low number of recaptures (Table 2).

Lower Section

Length frequencies of brown trout captured in the Lower Section were similar to the distribution observed for the County Road Section (Figure 2). This section supported an estimated 1,241 age-0 and 234 age-1 older and brown trout in 2003 (Table 2). Estimates of all size classes of brown trout were relatively precise with standard deviations ranging from 3 to 7% of the estimates. No rainbow trout longer than 250 mm were captured (Figure 3). A reliable estimate could not be made for the population of rainbow trout, but when all captured fish were combined this section supported an estimated nine age-0 and older rainbow trout; however, this estimate was likely biased due to the low number of recaptures (Table 2).

Upper Section

Length frequencies of brown trout captured in the Upper Section had a slightly smoother distribution for fish over 130 mm than observed for the County Road and Lower sections. One 530 mm long brown trout was captured (Figure 4). Estimates made for the Upper Section of Rush Creek in 2002 (Hunter et al. 2003) were in error and the corrected estimates are shown in Table 3. The Upper Section of Rush Creek supported an estimated 838 age-0 and 340 age-1 and older brown trout in 2003 compared to an estimated 2,252 age-0 and 387 age-1 and older brown trout in 2002 (Table 2 versus Table 3). Many more rainbow trout were captured than in the lower two sections, and age distributions for younger rainbow could more easily be interpreted from the length frequency distribution (Figure 5). This section supported an estimated 56 age-0 and 23 age-1 and older rainbow trout in 2003 (Table 2). In 2002, this section supported an estimated 86 age-0 and 18 age-1 rainbow trout (Table 3). Rainbow trout estimates for both 2002 and 2003 were likely biased due to the low number of recaptures.

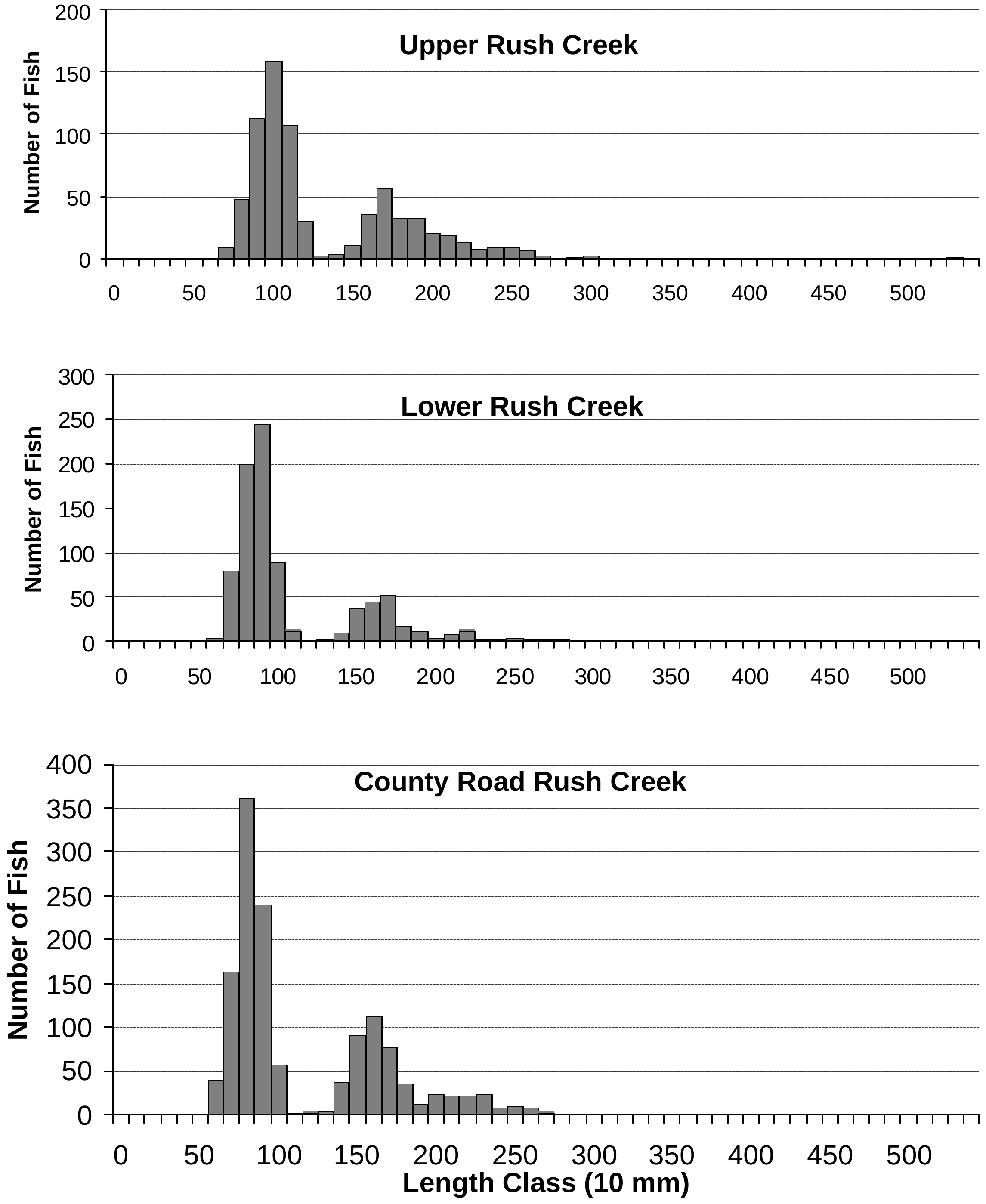

Figure 4. Length frequency histograms of brown trout captured in the Upper (top), Lower (middle) and County Road (bottom) sections of Rush Creek from September 7 to September 17, 2003. Note the different scales on both the vertical and horizontal axes between graphs.

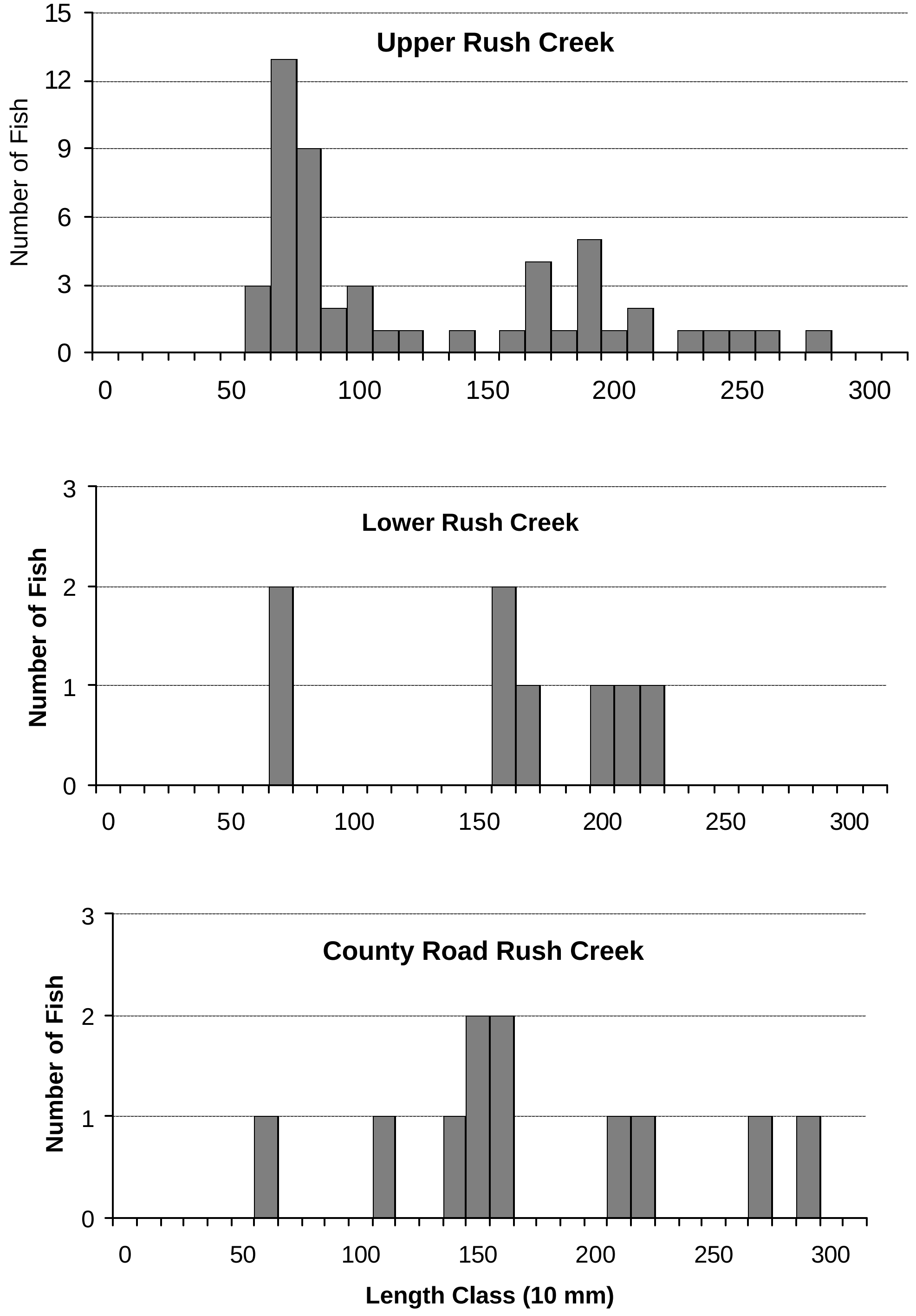

Figure 5. Length frequency histograms for rainbow trout captured in the Upper (top), Lower (middle) and County Road (bottom) sections of Rush Creek from September 7 to September 17, 2003. Note the different scales on the vertical axes between graphs.

Table 2. Mark-recapture estimates for 2003 showing total number of fish marked (M), number captured on the recapture run (C), number recaptured on the recapture run (R), and total estimated number and its associated standard error (S.E.) by stream, section, date, species, and size class. Mortalities (Morts) are those fish that were marked, but died prior to the recapture run. These mortalities were not included in the mark-recapture estimate and should be added to the estimate for an accurate total estimate.

Stream Section Date **Species**	Size Class (mm)	Mark-recapture parameter values					
		M	C	R	Morts[1/]	**Estimate**	S.E.
Rush Creek							
County Road							
9/7/2003							
Brown Trout							
	0 - 124 mm	451	498	118	34	**1894**	129.6
	125 - 199 mm	243	249	128	5	**472**	19.8
	200 - 399 mm	84	83	49	2	**142**	8.2
Rainbow Trout							
	125 - 299 mm	8	6	5	10	**10**[2/]	0.9
Lower Rush							
9/9/2003							
Brown Trout							
	0 - 124 mm	341	394	108	3	**1238**	83.0
	125 - 199 mm	150	134	107	0	**188**	4.3
	200 - 299 mm	39	37	31	0	**46**	1.5
Rainbow Trout							
	0 - 274 mm	5	7	4	4	**9**[2/]	1.0
Upper Rush							
9/8/2003							
Brown Trout							
	0 - 124 mm	264	256	88	74	**764**	53.1
	125 - 199 mm	127	112	65	8	**218**	12.0
	200 - 324 mm	68	67	41	3	**111**	6.6
Rainbow Trout							
	0 - 124 mm	20	15	5	1	**55**[2/]	14.1
	125 - 299 mm	16	15	11	1	**22**	1.7

Table 2. (Continued).

Stream Section Date		Mark-recapture parameter values					
Species	Size Class (mm)	M	C	R	Morts[1]	**Estimate**	S.E.
Lee Vining Creek							
Lower Main Channel							
9/10/2003							
Brown Trout							
	0 - 124 mm	44	39	13	0	**128**	22.2
	125 - 224 mm	17	20	13	0	**26**	1.9
	225 - 324 mm	21	16	15	0	**22**	0.7
Rainbow Trout							
	175 - 349 mm	5	6	5	0	**6**[2]	0.0
..........Upper Main Channel							
9/11/2003							
Brown Trout							
	0 - 124 mm	28	43	7	0	**158**	40.9
	125 - 199 mm	22	14	8	0	**37**	6.0
	200 - 299 mm	32	19	16	0	**38**	2.5
Rainbow Trout							
	150 - 299 mm	13	10	7	0	**18**	2.2

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[1] To arrive at a complete estimate the mortalities (“Morts”) should be added to the “Estimated number”.

[2] The number of recaptured fish for these estimates were below 7, the number recommended for an unbiased modified Peterson estimate.

Table 3. Corrected mark-recapture estimates for Upper Rush Creek and main Upper Lee Vining Creek sections in 2002 showing total number of fish marked (M), number captured on the recapture run (C), number recaptured on the recapture run (R), and total estimated number and its associated standard error (S.E.) by stream, section, date, species, and size class. Mortalities (Morts) are those fish that were marked, but died prior to the recapture run. These mortalities were not included in the mark-recapture estimate and should be added to the estimate for an accurate total estimate.

Stream Section Date **Species**	Size Class (mm)	Mark-recapture parameter values M	 C	 R	Morts[1]	**Estimate**	S.E.
Rush Creek							
Upper Rush							
9/2/2002							
Brown Trout							
	0 - 124 mm	407	556	101	25	**2227**	171.8
	125 - 199 mm	122	131	53	3	**300**	23.3
	200 - 524 mm	47	42	24	2	**82**	7.3
Rainbow Trout							
	0 - 124 mm	11	28	3	2	**86**[2]	29.5
	125 - 299 mm	12	12	8	1	**18**	1.8
Lee Vining Creek							
Upper Main Channel							
9/5/2002							
Brown Trout							
	0 - 124 mm	17	30	9	0	**55**	9.2
	125 - 224 mm	55	57	35	0	**89**	5.5
	225 - 324 mm	26	19	16	0	**31**	1.8
Rainbow Trout							
	150 - 349 mm	47	33	28	0	**55**	2.5

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[1] To arrive at a complete estimate the mortalities (“Morts”) should be added to the “Estimated number”.

[2] The number of recaptured fish for these estimates were below 7, the number recommended for an unbiased modified Peterson estimate.

Lee Vining Creek

Lower Section

Numerous age-0 brown trout were captured in both sections (Figure 6). About half of the age-0 brown trout captured in the Lower Section were captured in the main channel and half were captured in the side channel. The main channel supported an estimated 128 age-0 and 48 age-1 and older brown trout, while the side channel supported an estimated 92 age-0 and 17 age-1 and older brown trout (Tables 2 and 4). No age-0 rainbow trout (<125 mm) were captured in either sample section of Lee Vining Creek (Figure 7). Most rainbow trout were captured in the side channel portion of the Lower Section (Figure 7). The main channel supported an estimated six rainbow trout age-1 and older, while the side channel supported an estimated 13 age-1 and older rainbow trout.

Upper Section

More age-0 brown trout (< 125 mm) were captured in the side channel than in the main channel, while more age-1 and older brown trout were captured in the main channel (Figure 6). The main channel portion supported an estimated 158 age-0 and 75 age-1 and older brown trout in 2003 compared to 55 age-0 and 120 age-1 and older brown trout in 2002 (Tables 2 and 3). More age-1 and older rainbow trout were captured in the main channel than in the side channel (Figure 7). The main channel supported an estimated 18 age-1 and older rainbow trout in 2003 compared to 55 age-1 and older rainbow trout in 2002 (Table 2). Estimates made for the main channel portion of this section in 2002 (Hunter et al. 2003) were in error and the corrected estimates are shown in Table 3. We found too few age-0 rainbow trout in the main channel in either 2002 (five captured) or 2003 (none captured) to make an estimate for this size class. The side channel portion supported an estimated 127 age-0 and 51 age-1 and older brown trout, and 6 age-1 and older rainbow trout (Table 3).

Parker Creek

Only brown trout were captured in Parker Creek and most of these (63%) were less than 100 mm (Figure 8). Parker Creek supported an estimated 81 age-0 and 34 age-1 and older brown trout (Table 3).

Walker Creek

Only brown rainbow trout were captured in Walker Creek and most of these (69%) were less than 110 mm (Figure 8). Walker Creek supported an estimated 142 age-0 and 83 age-1 and older brown trout (Table 3).

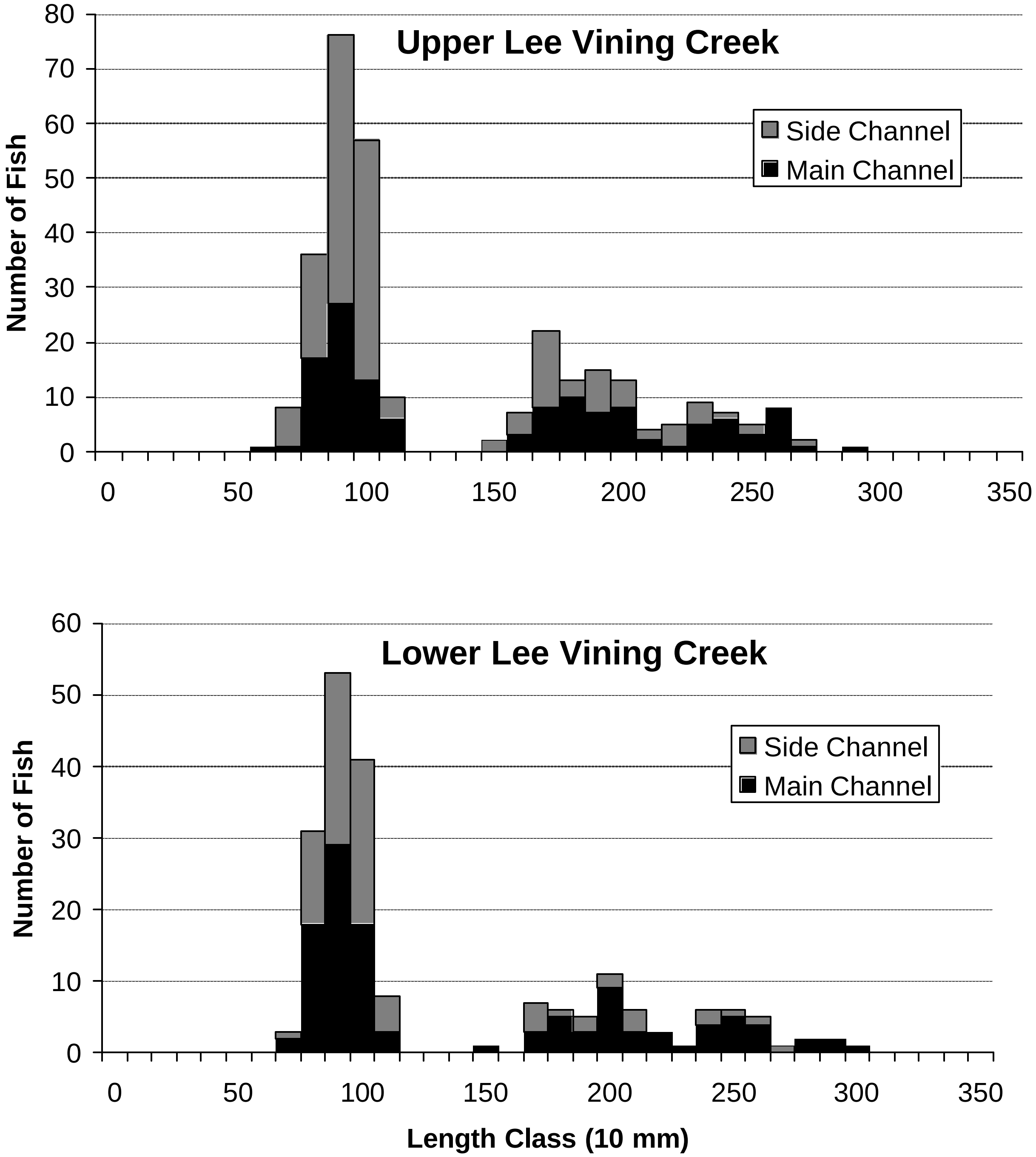


Figure 6. Length frequency histograms for brown trout captured in the Upper (top) and Lower (bottom) sections of Lee Vining Creek during September 2003 showing those fish captured in the main channel (dark bars) and side channel (cross-hatched bars) portions of each section. Note different scales on vertical axes.

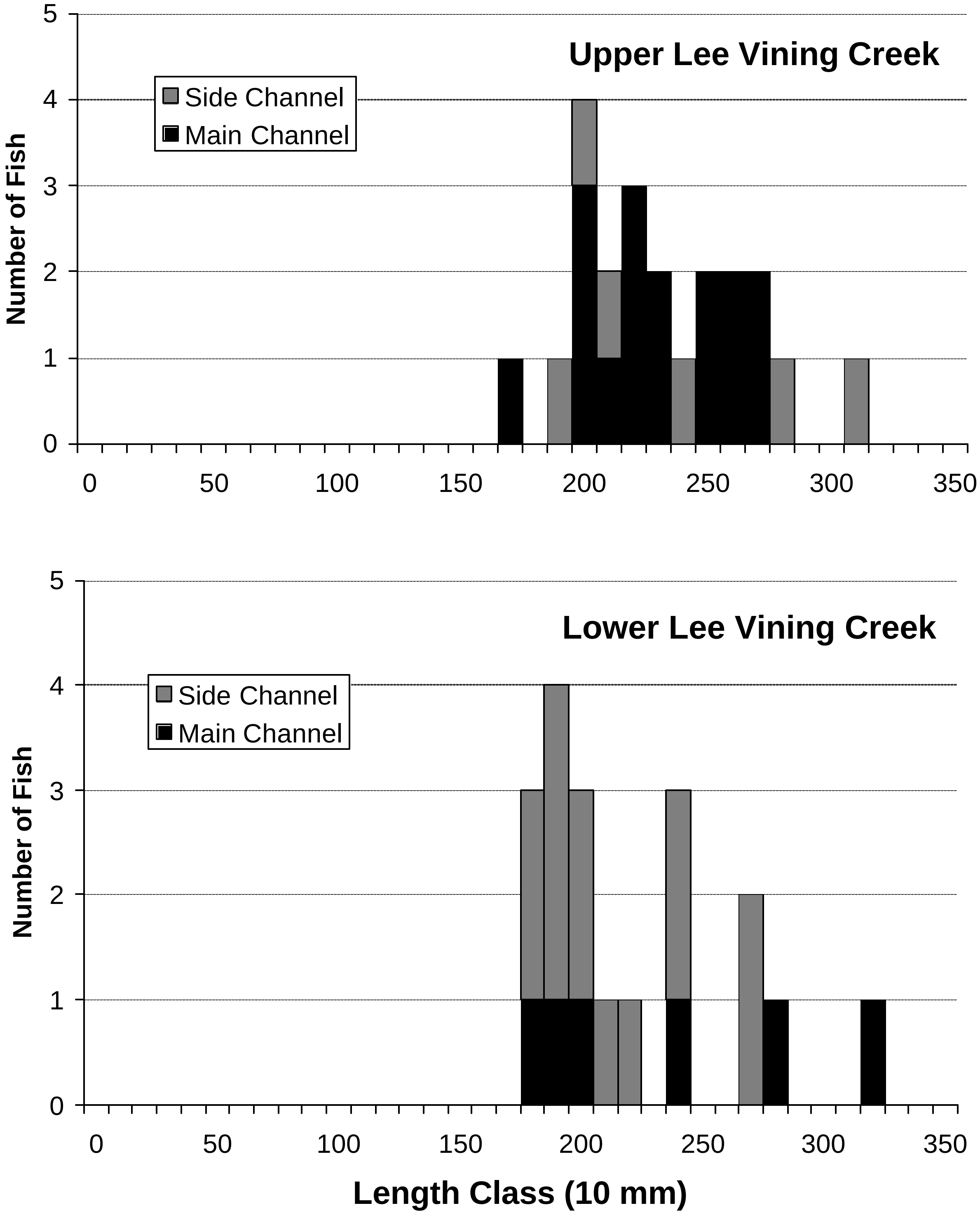


Figure 7. Length frequency histograms for rainbow trout captured in the Upper (top) and Lower (bottom) sections of Lee Vining Creek during September 2003 showing those fish captured in the main channel (dark bars) and side channel (cross-hatched bars) portions of each section.

Table 4. Depletion population estimates made in the side channel portions of the Lower and Upper sections of Lee Vining Creek and in Parker and Walker creeks during September 2003 showing number of fish captured on each pass, estimated number, and standard deviation (S.D.) by species and length group (Age-0 are young-of-the-year).

Stream (Section) Species Length Group	Number captured per pass 1	2	3	4	**Estimated number**	S.D.
Lee Vining Creek (Lower Side Channel)						
Brown Trout						
Age-0 (<125 mm)	42	24	-	-	**92**	20.1
125 + mm	17	0	-	-	**17**[1/]	-
Rainbow Trout						
Age-0 (<125 mm)	0	0	-	-	**0**[2/]	-
125 + mm	13	0	-	-	**13**[1/]	-
Lee Vining Creek (Upper Side Channel)						
Brown Trout						
Age-0 (<125 mm)	102	21	-	-	**127**	3.2
125-199 mm	25	6	-	-	**32**	1.8
200 + mm	16	3	-	-	**19**	0.8
Rainbow Trout						
Age-0 (<125 mm)	0	0	-	-	**0**[2/]	-
125 + mm	5	1	-	-	**6**	0.5
Parker Creek						
Brown Trout						
Age-0 (<125 mm)	46	23	7	-	**81**	3.8
125-199 mm	15	5	2	-	**22**	1.0
200 + mm	9	2	1	-	**12**	0.5
Walker Creek						
Brown Trout						
Age-0 (<125 mm)	109	26	-	-	**142**	4.5
125-199 mm	56	12	-	-	**70**	2.4
200 + mm	12	1	-	-	**13**	0.3

[1/] Maximum likelihood estimate not possible because all fish captured on the first pass. The estimate was considered as the first pass catch.

[2/] No fish were captured in any of the passes indicating that no fish of this size were present.

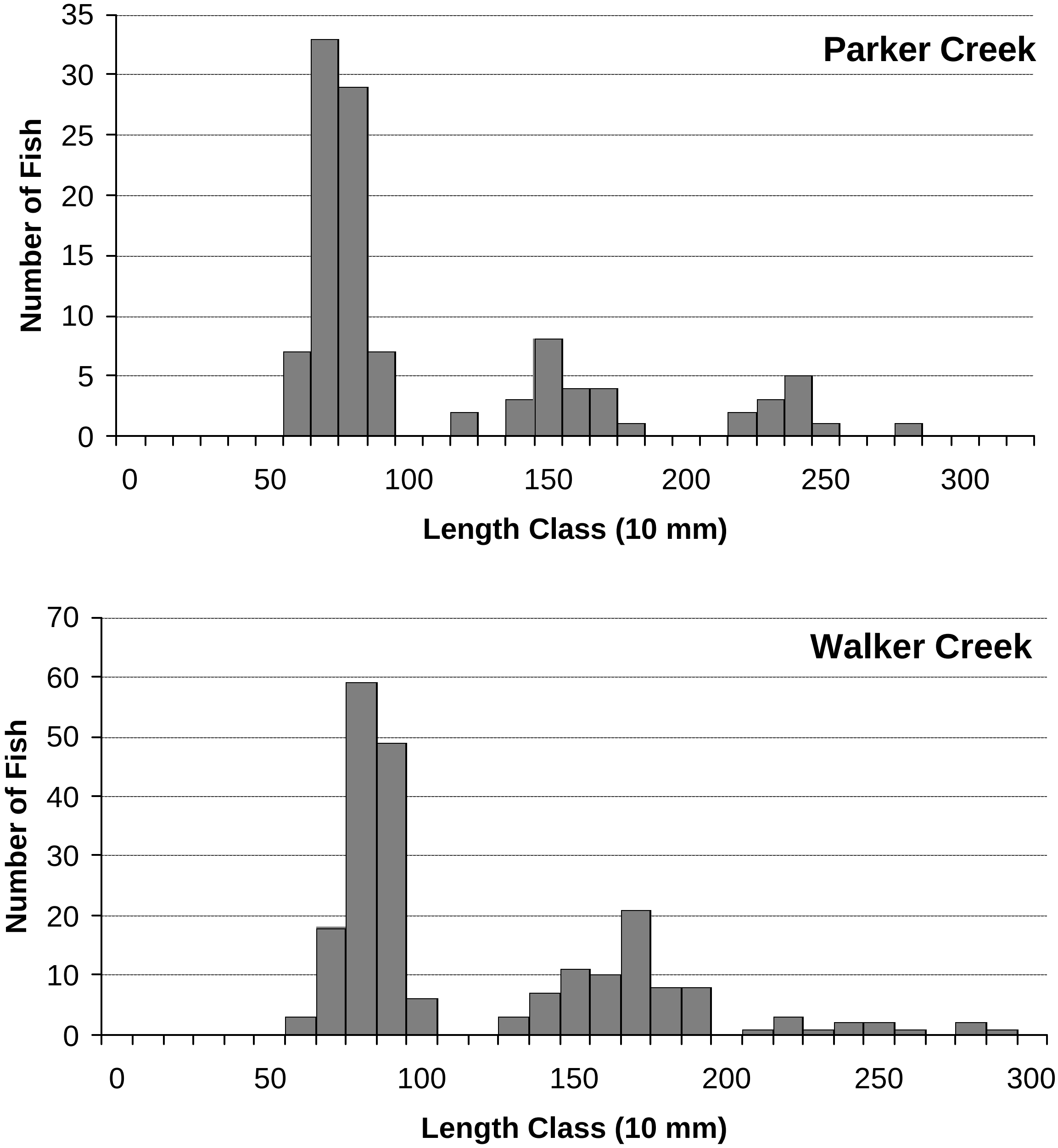


Figure 8. Length frequency histograms for brown trout captured in Parker (upper) and Walker (lower) creeks during September 2003. Note the different scales on the vertical axes.

Relative Condition of Brown Trout

Log_{10} transformed length-weight regressions for captured brown trout had R^2-values over 0.98 for almost all sample events, indicating that weight was strongly correlated to length, and the condition of brown trout captured during 2003 was about average and similar to that found in 2002 (Table 5). Regression data for 2003 indicated that condition was very similar among the three Rush Creek sample sections (Figure 9). Computation of condition factors for brown trout 150 to 250 mm showed that Upper Rush Creek brown trout in this size range were in slightly better condition than those in the lower two sections (Figure 10). Condition factors for Lee Vining Creek brown trout were slightly higher in 2003 than those for any of the other streams. Condition factors for brown trout in Lee Vining Creek were higher in 2000 and 2001 than other years. A condition factor of 1 is considered average and most computed conditions factors were close to 1 in 2003, indicating brown trout condition was about average when compared to other waters.

Age Estimates

Age estimates for rainbow trout based on scale samples found only one rainbow trout over age-3 in either Lee Vining or Rush creeks and that was an age-5 rainbow trout in Rush Creek (Figure 11; Appendix E). All similar-aged rainbow trout in Rush Creek averaged smaller than similar-aged rainbow trout in Lee Vining Creek, 174 versus 207 mm for age-1, 237 versus 261 mm for age-2, and 250 versus 324 mm for age-3 fish.

Age estimates for brown trout based on scale samples found that ten brown trout in Rush Creek were older than age-3, but none of the sampled brown trout in Lee Vining Creek were older than age-2 (Figure 12; Appendix E). Based on scale samples, it appears that brown trout age can be interpreted reasonably using length up through age-1. This was especially true when we segregated brown trout by section in Rush Creek (Figure 13). It also appeared brown trout grew at faster rates in Lee Vining Creek than in Rush Creek, 192 versus 168 mm for age-1 and 253 versus 218 for age-2.

Ages interpreted from otoliths were generally in agreement with ages interpreted from scales as 20 of 22 (91%) paired samples provided the same age estimate (Table 6). The two samples where different ages were interpreted from the different structures were a rainbow trout whose scale sample suggested it was an age-1, while its otolith showed two annuli, and a brown trout where three annuli were observed on the scales, while five annuli were seen on its otolith.

Table 5. Regression statistics for $\log_{10}$ transformed length (L) to weight (WT) for brown trout 100 mm and longer captured in Rush Creek by sample section and year. The 2003 regression equations are in bold type.

Section	Year	N	Equation	R^2	P
County Road	2000	412	$\log_{10}(WT) = 2.936*\log_{10}(L) – 4.827$	0.987	< 0.01
	2001	552	$\log_{10}(WT) = 2.912*\log_{10}(L) – 4.815$	0.979	< 0.01
	2002	476	$\log_{10}(WT) = 2.946*\log_{10}(L) – 4.884$	0.993	< 0.01
	2003	**933**	$\mathbf{\log_{10}(WT) = 3.004*\log_{10}(L) – 5.008}$	**0.988**	**<0.01**
Lower	1999	314	$\log_{10}(WT) = 3.027*\log_{10}(L) – 5.078$	0.992	< 0.01
	2000	230	$\log_{10}(WT) = 2.975*\log_{10}(L) – 4.904$	0.985	< 0.01
	2001	350	$\log_{10}(WT) = 2.975*\log_{10}(L) – 4.939$	0.986	< 0.01
	2002	250	$\log_{10}(WT) = 2.907*\log_{10}(L) – 4.784$	0.994	< 0.01
	2003	**348**	$\mathbf{\log_{10}(WT) = 3.003*\log_{10}(L) – 5.019}$	**0.991**	**<0.01**
Upper	1999	317	$\log_{10}(WT) = 2.933*\log_{10}(L) – 4.843$	0.981	< 0.01
	2000	309	$\log_{10}(WT) = 3.001*\log_{10}(L) – 4.958$	0.981	< 0.01
	2001	335	$\log_{10}(WT) = 2.987*\log_{10}(L) – 4.958$	0.992	< 0.01
	2002	373	$\log_{10}(WT) = 2.945*\log_{10}(L) – 4.859$	0.989	< 0.01
	2003	**569**	$\mathbf{\log_{10}(WT) = 2.959*\log_{10}(L) – 4.892}$	**0.992**	**<0.01**
MGORD	2001	769	$\log_{10}(WT) = 2.873*\log_{10}(L) – 4.719$	0.990	<0.01

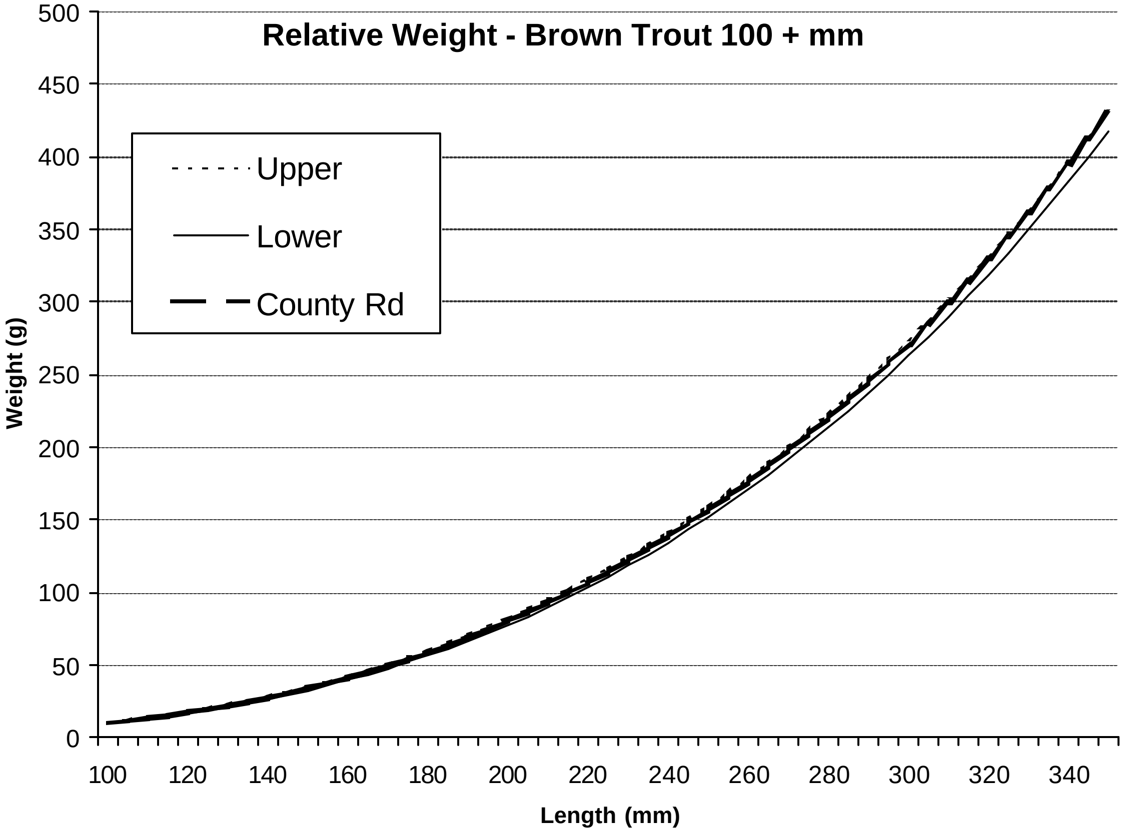


Figure 9. Length-weight regressions for brown trout captured in three sections of Rush Creek during September 2003 by section.

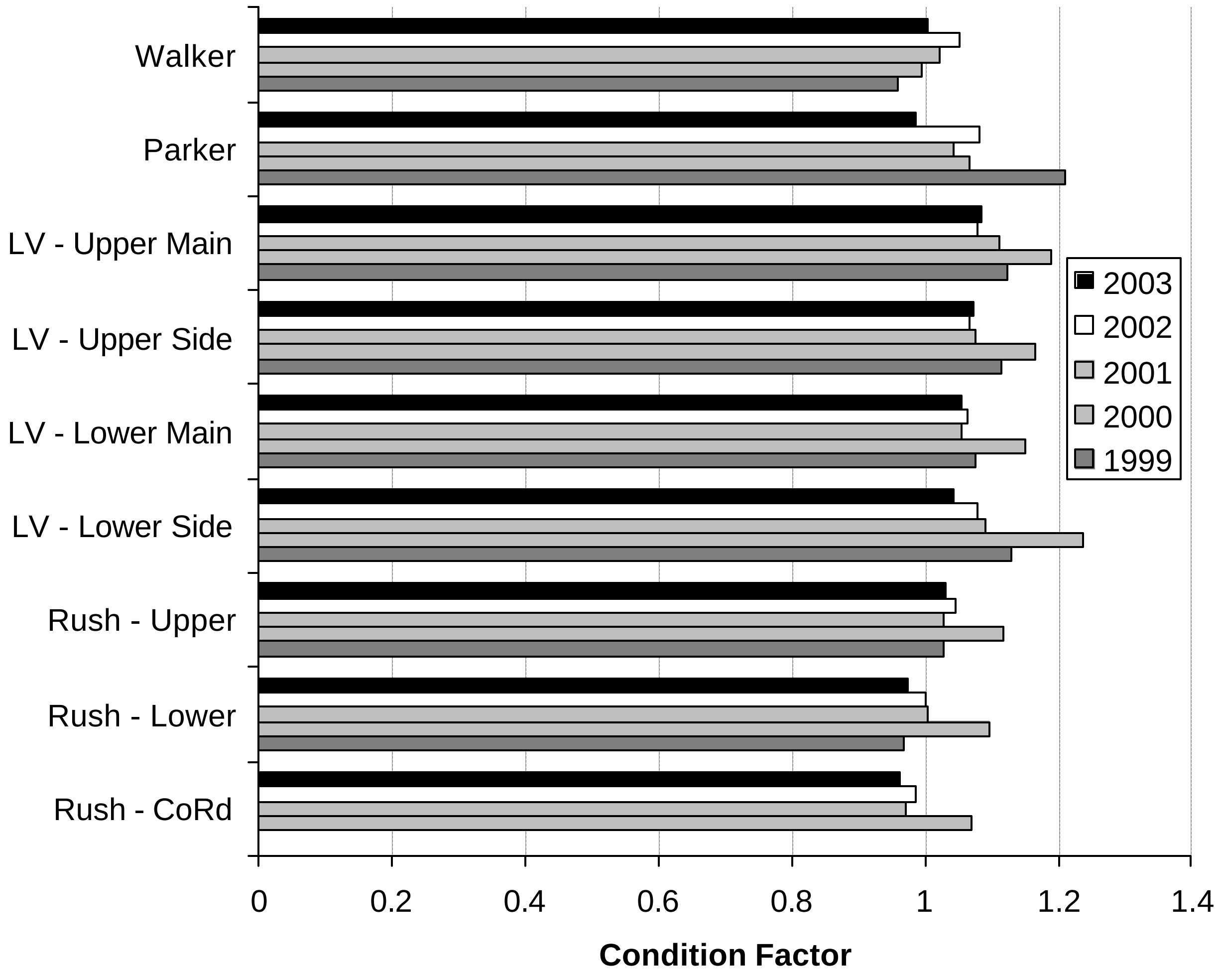
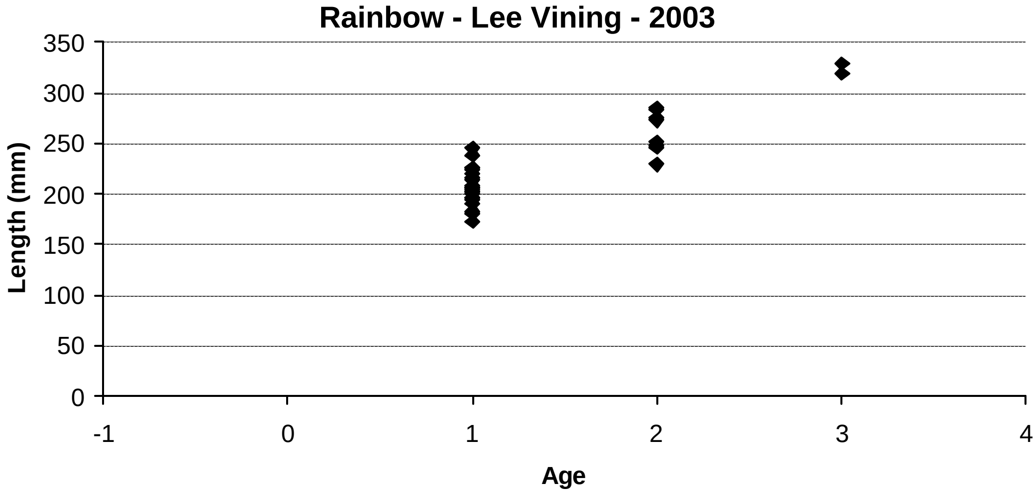


Figure 10. Condition factors for brown trout 150 to 250 mm long in Mono Lake tributaries from 1999 to 2003.



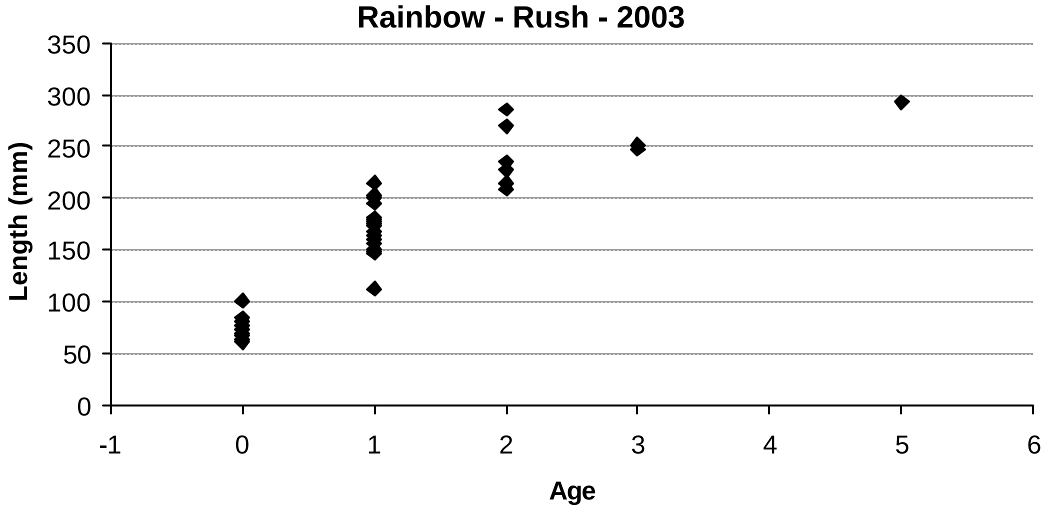


Figure 11. Distribution of lengths at age for rainbow trout in Lee Vining Creek (top) and Rush Creek (bottom) in 2003 based on ages interpreted from scale samples.

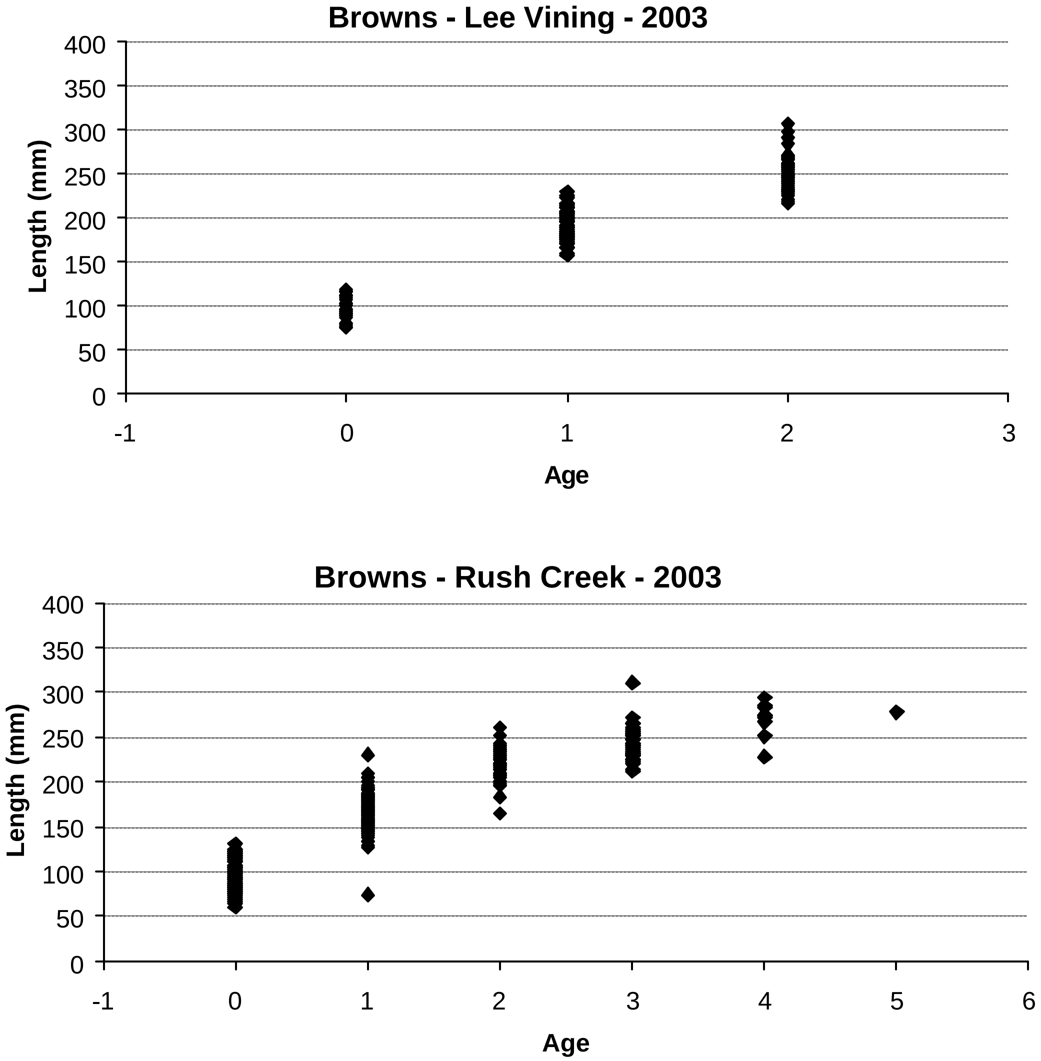
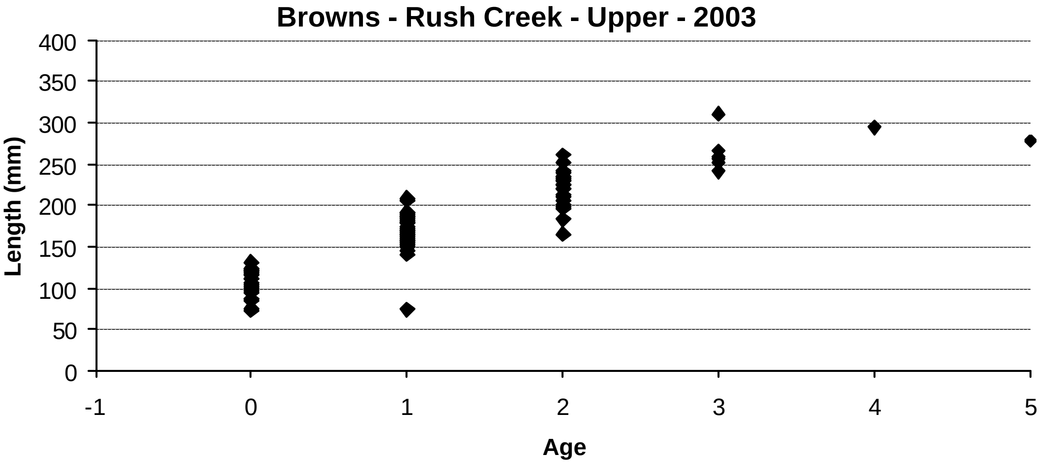
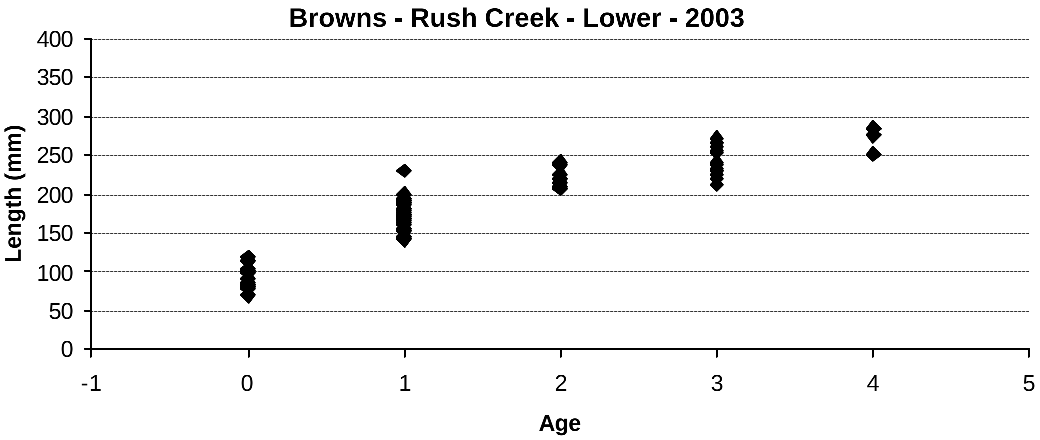


Figure 12. Distribution of lengths at age for brown trout in Lee Vining Creek (top) and Rush Creek (bottom) in 2003 based on ages interpreted from scale samples.





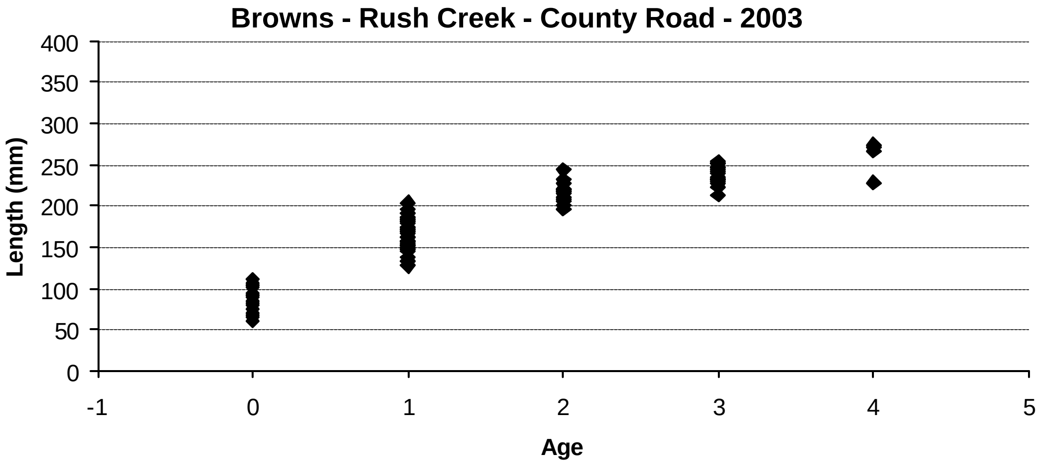


Figure 13. Distribution of lengths at age for brown trout in three sections of Rush Creek in 2003 based on ages interpreted from scale samples.

Table 6. Age interpreted from scales (Scale Age) and otoliths (Otolith Age) for brown (BRN) and rainbow (RB) trout captured in Rush and Lee Vining creeks during 2003. A few fish could not be aged using their scales because of scale regeneration and these were noted.

Stream	Section	Species	Length	Scale Age	Comments	Otolith Age
Rush Creek	County Road	BRN	152	1		1
Rush Creek	County Road	BRN	152	1		1
Rush Creek	County Road	BRN	152	1		1
Rush Creek	County Road	BRN	157	1		1
Rush Creek	County Road	BRN	158	1		1
Rush Creek	County Road	BRN	158	1		1
Rush Creek	County Road	BRN	166	1		1
Rush Creek	Upper Rush	BRN	159	1		1
Rush Creek	Upper Rush	BRN	161	1		1
Rush Creek	Upper Rush	BRN	165	1		1
Rush Creek	Upper Rush	BRN	168	1		1
Rush Creek	Upper Rush	BRN	170	1		1
Rush Creek	Upper Rush	BRN	175	1		1
Rush Creek	Upper Rush	BRN	179	1		1
Rush Creek	Upper Rush	BRN	185	1		1
Rush Creek	Upper Rush	BRN	187	1		1
Rush Creek	Upper Rush	BRN	154		Regen - Could not age	1
Rush Creek	Upper Rush	RB	147	1		2
Rush Creek	County Road	BRN	208	2		2
Rush Creek	Upper Rush	BRN	183	2		2
Rush Creek	County Road	BRN	208		Regen - Could not age	2
Rush Creek	Upper Rush	BRN	234		Regen - Could not age	2
Rush Creek	County Road	BRN	226	3		3
Rush Creek	County Road	BRN	243	3		3
Rush Creek	County Road	BRN	230	3		5

Tag Returns

We recaptured five Floy-tagged fish (one within each of sections in Rush, Walker, and Parker creeks) during September 2003, for an overall recapture rate of 5.0% (Table 7). All the recaptured browns were from their section of origin, so movement among the sections was not documented. Since we tagged fewer fish in Parker and Walker creek sample sections the recapture rates in these sections were much higher, 25 to 33%, compared to main Rush Creek, where recapture rates were 3 to 6%. These recaptured trout grew an average of 25 mm in length and 50 g in weight in one year.

Table 7. Number of trout marked and recaptured, recapture rates, lengths and weights at time of marking and time of recapture, and growth in length (mm/yr) and weight (gm/yr) for fish tagged in Rush Creek sample sections during September 2002 (9/02) and recaptured during September 2003 (9/03).

Sample Section	**Number Marked (9/02)**	**Number Recapped (9/03)**	**Recap Rate**	**Length (mm) 9/02**	**Length (mm) 9/03**	**Growth (mm/yr)**	**Weight (gr) 9/02**	**Weight (gr) 9/03**	**Growth (gm/yr)**
Upper Rush	37	1	2.7%	227	262	35	116	180	64
Lower Rush	18	1	5.5%	229	255	26	119	157	38
Rush County Road	39	1	2.6%	248	267	19	150	196	46
Walker Creek	3	1	33.3%	258	283	25	183	256	73
Parker Creek	4	1	25.0%	267	285	18	214	245	31
Totals (means)	101	5	(5.0%)			(25)			(50)

Pool Habitat Reconnaissance in Rush Creek

Twenty-one Class 5 and 29 Class 4 pools, the highest quality pools observed, were found in the 13.4 km (8.3 miles) of Rush Creek from the MGORD to Mono Lake (Appendix F). Only eight of the 21 Class 5 pools on Rush Creek had mean stream velocities of 0.3 mps or less, including four of the six pools downstream of the Lower Rush fish sampling section and two of the three pools in the Upper Rush fish sampling section (Table 8). The deepest pools were generally downstream of the Lower Rush section (pools 16-20). These lowermost pools also had the highest average cover score of 89. The lowest cover scores (50-55) were at pools within the Upper and Lower Rush fish sampling sections.

Most of the high quality pools on Rush Creek were located in two stream reaches covering about one-half the total length of the stream: Reach A, the 2.37 km of stream from the MGORD through the bottom of the Upper Rush electrofishing section; and the 4.38 km-long Reach C, extending from the Narrows to the County Road Ford (Table 9). Reach A contains 5.5 high quality pools/km ranging from boulder dominated plunge pools in the high gradient canyon section just below the MGORD to pools within the electrofishing section that are partly a result of earlier habitat enhancement efforts. Reach C contains 6.9 high quality pools/km most of which have been naturally formed by the lateral scour of streambanks, which are held in place by some of the most abundant and mature riparian vegetation on Rush Creek.

The rest of Rush Creek contains much lower numbers and densities of high quality pools. The lowest pool density (0.5 high quality pools/km) was in Reach B, extending 3.99 km from the bottom of the Upper Rush electrofishing section to the Narrows. This reach shows the effects of highway construction and, particularly, sand and gravel mining. Pools with water deeper than 0.6 m (2.0 ft.) were rare, as were any dense concentrations of riparian vegetation. In the 2.67 km-long reach D, from the County Road Ford to Mono Lake, high quality pool densities are also fairly low (1.9/km). About midway through this reach, the County Road Culvert is a barrier to upstream fish passage. Starting about 200 to 250 meters upstream of Mono Lake, Rush Creek splits into three small, very shallow (0.05 to 0.10 meter deep) channels. Hiding cover for trout is sparse in this depositional or delta area, since most riparian shrubs were dead or dying, likely due to the upstream encroachment of highly saline groundwater. The odor of hydrogen sulfide gas (H_2S), a product of the anerobic decomposition of organic matter, was prevalent when stepping on streamside sediment deposits. Aquatic macrophyte (*Elodea sp.*) beds were uncommon compared to nearby upstream segments of the stream.

The frequency of high quality (Class 4 and 5) pools per kilometer within fish sampling sections were generally higher than the mean pool frequencies in their respective reaches (i.e., there were 7.5 high quality pools per km in the Upper Rush fish sampling section compared to a mean frequency of 5.5/km in the reach from the MGORD down through the Upper Rush fish sample section (Reach A); and 1.9/km in the County Road fish sampling section compared to a mean of 1.3/km in the reach from the upper boundary of the County Road fish sample section down Rush Creek's mouth at Mono Lake (Reach D; Table 9). The frequency of high quality pools in the Lower Rush section (9.3/km) was much higher than the mean frequency of high quality pools in the reach above this section from the Upper Rush fish sample section down to the Narrows (Reach B; 0.5/km), slightly higher than the reach from the Narrows down to the top of the County Road fish sample section (Reach C; 6.9/km), but not as high as the highest density of 12.8/km we observed in a relatively short sub-reach between the Lower Rush and County Road fish sampling sections (between Class 5 pools #16 and #19; Table 9). We found an even greater difference between Class 5 pool frequencies with 8.5/km observed in the subreach between Lower Rush and County Road and 2.3/km in the Lower Rush section. The frequencies of high quality pools, as well as the depths and velocities of pools, in the Upper Rush and County Road electrofishing sections were very similar to the values found in adjoining stream reaches (Tables 8 and 9).

A total of 355 brown trout and ten rainbow trout were observed during day and night snorkel dives at thirteen of the Class 5 pools (Table 8). Three brown trout longer than 350 mm (14 inches) were observed during night dives. The largest brown (500-550 mm) was seen at pool 16, the deepest pool with the lowest mean water velocity in the study area. The two other large brown trout were observed near pool 18 (400-450 mm) and at pool 9 (350-400 mm). Additionally, three brown trout measuring 379 mm, 485 mm and 530 mm were captured in pool 7 during electrofishing at the upper Rush section in September 2002 and 2003.

Table 8. Locations of Class-5 pools, as distance below the MGORD, depths (m) and water velocities (mps) measured within these pools, their estimated cover score, and number of rainbow and brown trout observed via day and night snorkeling and the size range of the largest trout seen during 2002 and 2003.

Pool Number or Stream Landmark	Distance Below MGORD (km)	Water Depth (meters)		Water Velocity (mps)		Total Cover Score	Number Observed				Largest Length Class Observed (mm)
							Rainbow		Brown		
		Max.	Residual	Max.	Mean		Day	Night	Day	Night	
Pool 5 No. 1	0.22	1.6	1.3	1.0	0.4	90	0		5		250-300
Pool 5 No. 2	0.39	1.2	0.9	1.2	0.6	80	0		3		200-250
Pool 5 No. 3	0.63	1.2	0.9	0.8	0.4	80					
Pool 5 No. 4	0.82	1.2	1.0	0.8	0.3	90	0		5		200-250
Top Upper Rush Sec.	1.96										
Pool 5 No. 5	2.10	0.9	0.7	0.8	0.5	50	0	0	12	7	200-250
Pool 5 No. 6	2.23	1.1	0.9	0.5	0.3	50	2	2	20	10	200-250
Pool 5 No. 7	2.34	1.2	1.0	0.6	0.3	55	2	2	28	21	250-300
Bottom Upper Rush Sec.	2.37										
Ave. Values Pools 1-7		1.2	1.0	0.8	0.4	71					
Hwy 295 Bridge	3.36										
Mouth of Parker Cr.	5.45										
Mouth of Walker Cr.	6.36										
The Narrows	6.38										
Pool 5 No. 8	7.02	1.2	0.9	1.2	0.9	55					
Pool 5 No. 9	7.13	1.2	0.9	1.0	0.7	90	0	0	4	8	350-400
Pool 5 No. 10	7.33	1.4	1.0	1.0	0.7	80	0	0	9	4	150-200
Pool 5 No. 11	7.35	1.2	1.0	0.9	0.5	80	0	0	9	4	200-250
Pool 5 No. 12	7.61	1.1	0.9	1.1	0.8	85					
Pool 5 No. 13	7.95	1.4	1.0	1.0	0.3	100					
Pool 5 No. 14	8.45	1.4	1.0	1.2	1.0	95					
Top Lower Rush Sec.	8.8										
Pool 5 No. 15	9.22	1.2	0.9	0.9	0.8	50					
Bottom Lower Rush Sec.	9.23										
Ave. Values Pools 8-15		1.2	1.0	1.0	0.7	79					
Pool 5 No. 16	9.66	1.6	1.4	0.5	0.2	85	1	0	31	25	500-550
Pool 5 No. 17	9.81	1.5	1.2	0.4	0.4	90	0	0	8	38	250-300
Pool 5 No. 18	10.01	1.6	1.3	0.6	0.5	85	0	0	20	31	400-450
Pool 5 No. 19	10.13	1.2	1.0	0.5	0.3	70					
Pool 5 No. 20	10.53	1.6	1.3	0.6	0.3	115	0	1	28	25	250-300
Ave. Values Pools 16-20		1.5	1.2	0.5	0.3	89					
Co. Rd. Ford	10.70										
Top County Rd. Section	10.73										
Bottom Co. Rd. Section	11.51										
Pool No. 21	11.67	1.3	1.0	0.4	0.2	90					
Co. Rd. Culvert	11.99										
Mono Lake	13.4										

Table 9. Numbers and frequencies (number per km) of Class 4, Class 5 and total high quality (Class 4 + Class 5) pools observed in four reaches and four subreaches of Rush Creek during 2002 and 2003.

			NUMBER OF POOLS			NUMBER OF POOLS/KM		
STREAM REACH	**Stream Length (km)**	**% of Study Area**	**Class 4 Pools**	**Class 5 Pools**	**Total High Quality Pools**	**Class 4 Pools**	**Class 5 Pools**	**Total High Quality Pools**
(A) Bottom of the MGORD to the bottom of the Upper Rush electrofishing section	2.37	17.7%	6	7	13	2.5	3.0	5.5
(B) Bottom of Reach A to the mouth of Walker Creek/the Narrows	3.99	29.8%	2	0	2	0.5	0.0	0.5
(C) Bottom of Reach B to the top of the County Road electrofishing section	4.38	32.7%	17	13	30	3.9	3.0	6.9
(D) Bottom of Reach C to Mono Lake	2.67	19.9%	4	1	5	1.5	0.4	1.9
Study Area Totals or (Means)	13.40	100%	29	21	50	(2.2)	(1.6)	(3.7)
STREAM SUBREACH								
Reach A: Upper Rush electrofishing section	0.40	3.0%	0	3	3	0.0	7.5	7.5
Reach C: Lower Rush electrofishing section	0.43	3.2%	3	1	4	7.0	2.3	9.3
From Class 5 **pool 16 through pool 19**	0.47	3.5%	2	4	6	4.3	8.5	12.8
Reach D: County Road electrofishing section	0.78	5.8%	1	0	1	1.3	0.0	1.3

Discussion

Reliability of Estimates

As we explained in the Methods, our sampling activities and high winds immediately after our marking runs in 2003 the Upper and Lower Rush Creek sections caused at least one of our block fences to fail, but these fences failed over relatively short time periods and only twice in the Upper Rush Section and once in the Lower Rush Section. We do not believe these few block fence failures significantly affected population estimates in these two Rush Creek sections. Block fences did not fail in the Lee Vining sections. Having one individual dedicated to maintaining block fences dramatically improved our ability to keep these fences functional. Our inability to totally meet the population closure assumption could have resulted in over-estimates of fish populations in the two Rush Creek sections, especially if marked fish moved out of, or unmarked fish moved into, a sample section. However, we do not believe population closure assumptions were violated in 2003.

Slight changes in how mark-recapture estimates were calculated resulted in some slight changes in estimates, but standardization of the estimation technique will allow us to make more reliable comparisons among sections within a year and among years within a section. We found an error in estimates for the Upper Main Channel Section of Lee Vining Creek and Upper Section of Rush Creek for 2002. The corrected estimates did not differ too much from previous estimates for fish age-1 and older; however, estimates of age-0 fish were quite different, particularly for rainbow trout in Upper Lee Vining Creek.

Estimated Trout Density and Standing Crop Comparisons

Estimated densities (number per hectare) of age-1 and older brown trout dropped in 2003, after reaching their highest recorded levels in 2002, in all sections of Lee Vining Creek (Figure 14). Estimated densities of age-1 and older brown trout increased from levels recorded in 2002 for the County Road and Lower sections in Rush Creek, but were still lower than those observed in 2001 in these two sections. Densities of age-1 and older brown trout declined slightly from 2002 to 2003 in Upper Rush Creek. Densities of age-1 and older brown trout increased dramatically (nearly four-fold) in Walker Creek during 2003, but increased only slightly in Parker Creek.

Estimated densities of age-0 brown trout were much lower than previous years in the Upper Rush Creek Section and slightly lower than 2002 for the Walker and Lower Rush Creek sections (Figure 15). Estimated densities of age-0 brown trout have steadily declined in the Upper Rush Creek section. Estimated densities of age-0 brown trout were higher in 2003 than in 2002, and generally higher in 2003 than all previous years sampled, in the Lee Vining Creek sections (Figure 15). The relatively high densities of

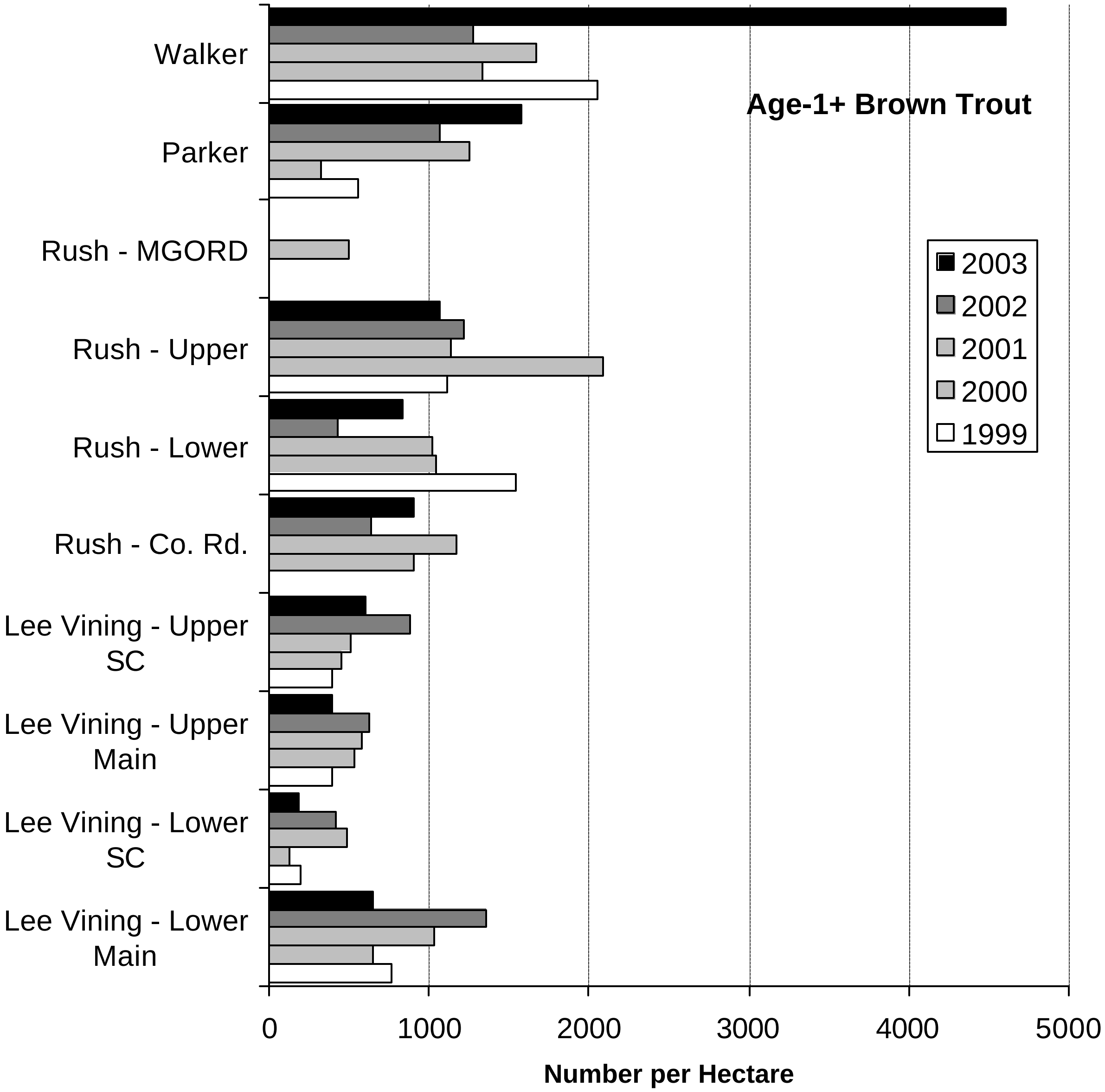


Figure 14. Estimated number of age-1 and older brown trout per hectare in sections of Walker, Parker, Rush, and Lee Vining creeks during September 2000, 2001, 2002, and 2003.

age-0 brown trout found during 2002 in Walker Creek may partly explain the high densities of age-1 and older brown trout found in this stream in 2003. Estimated densities of age-0 brown trout declined most dramatically from 2000 to 2003 in the Upper Section of Rush Creek. At this time we are uncertain why age-0 brown trout densities have declined each year in the Upper Rush Creek section. Estimates of brown trout standing crops (kg/hectare) either dropped slightly from 2002 to 2003 or were similar, except in Walker Creek where standing crops increased dramatically with the increased numbers of age-1 and older brown trout (Figures 15 and 14). Almost all standing crop estimates were 50 kg/ha or higher. McFadden and Cooper (1962) found that standing crops of brown trout in three hard-water streams and three soft-water streams in Pennsylvania ranged from 15 to 154 kg/ha (13 to 137 pounds/acre). Gard and Seegrist (1972) found that the 10-year average standing crop of brook, rainbow, and brown trout in Sagehen Creek, California was about 41.5 kg/ha (37 pounds/acre). Marshall and MacCrimmon (1970) estimated the standing crop of harvestable brown trout in the upper Sydenham River, Ontario was 63.2 kg/ha. Wiley and Dufek (1980) estimated a six-year average standing crop of 54.8 kg/ha for rainbow and brown trout in the Green River of southwestern Wyoming. Relative weights and condition factors of brown trout in Rush Creek don’t appear to be varying much year-to-year.

Estimated densities of age-1 and older rainbow trout declined dramatically in all sections of Lee Vining Creek and held relatively steady in Rush Creek sections from 2002 to 2003 (Figure 16). Estimated densities of age-0 rainbow trout were extremely low in 2003 in all sample sections except for the Upper Rush site (Figure 17). We captured no age-0 rainbow trout in Lee Vining Creek during 2003 and very low numbers during 2002. Rainbow trout spawn during the spring, thus their embryos remain within the gravel through much of the high water period and they often emerge as peak flows begin declining. Extremely high stream flows can mobilize the streambed, crushing incubating embryos. Rapidly varying flows soon after emergence occurs can either strand or flush newly emerged fry because they are relatively poor swimmers. We offer these speculative ideas on why we have found either few or no age-0 rainbow trout fry in Lee Vining Creek in 2002 and 2003. It may be worthwhile to take a closer look at the timing of rainbow trout spawning, incubation, and emergence in Lee Vining Creek and compare these with flow and temperature regimes to help determine if flow regimes might be adjusted to enhance early survival of rainbow trout.

Age

The age information collected to date has supported our original assumption that trout populations in Mono Lake tributaries generally contain relatively short-lived individuals, helping to explain the paucity of larger trout. We still need to sample ages for brown trout in the MGORD to determine if these larger fish reach older ages, or if they grow at much faster rates than trout in the rest of the system, or if is a combination of these two factors. Since there were no age-0 rainbow trout in Lee Vining Creek during 2003 and very few age-0 rainbow trout found in Rush Creek, it was difficult to determine whether

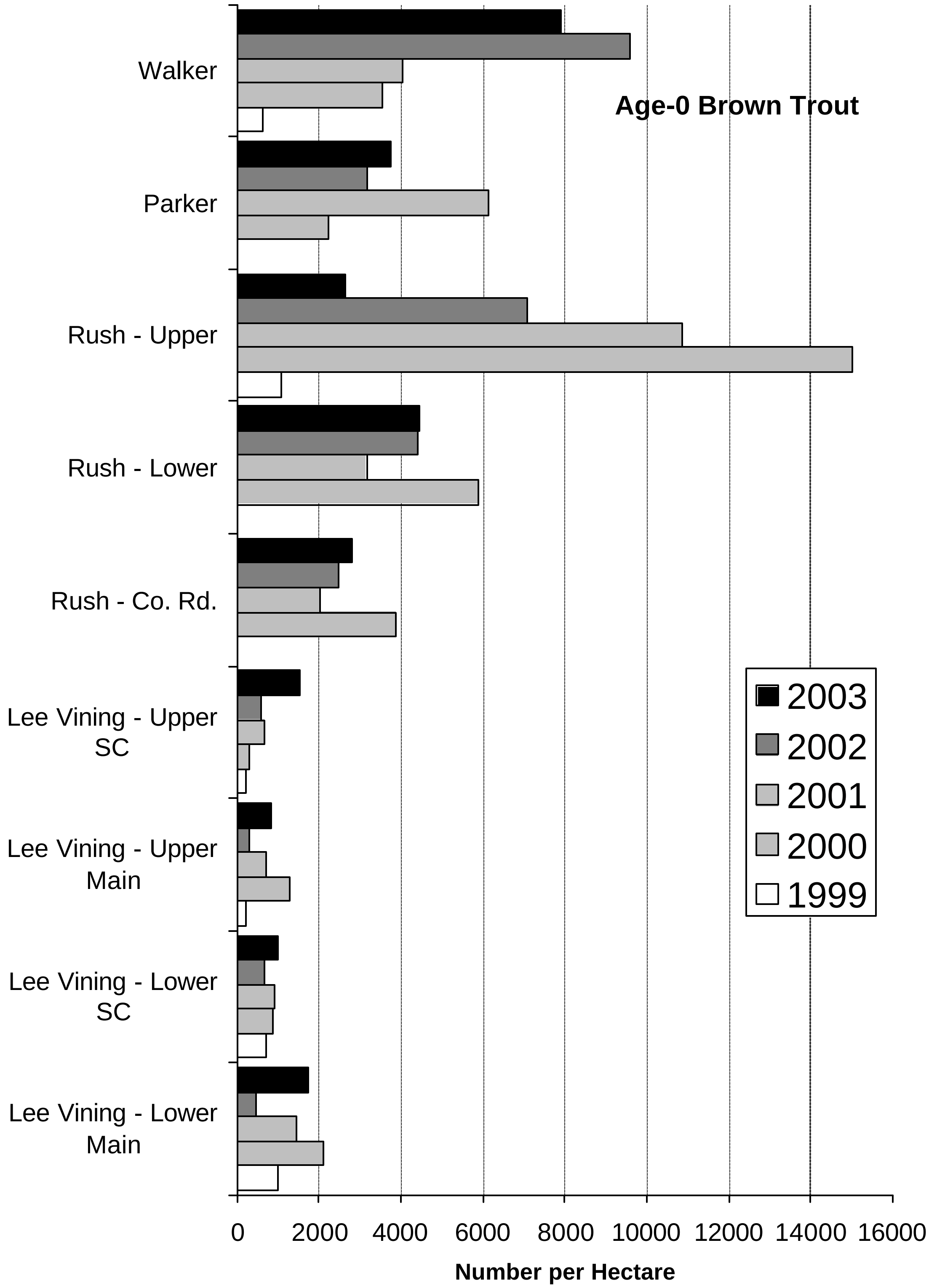


Figure 15. Estimated number of age-0 brown trout per hectare in sections of Walker, Parker, Lee Vining, and Rush creeks during September 2000, 2001, 2002, and 2003.

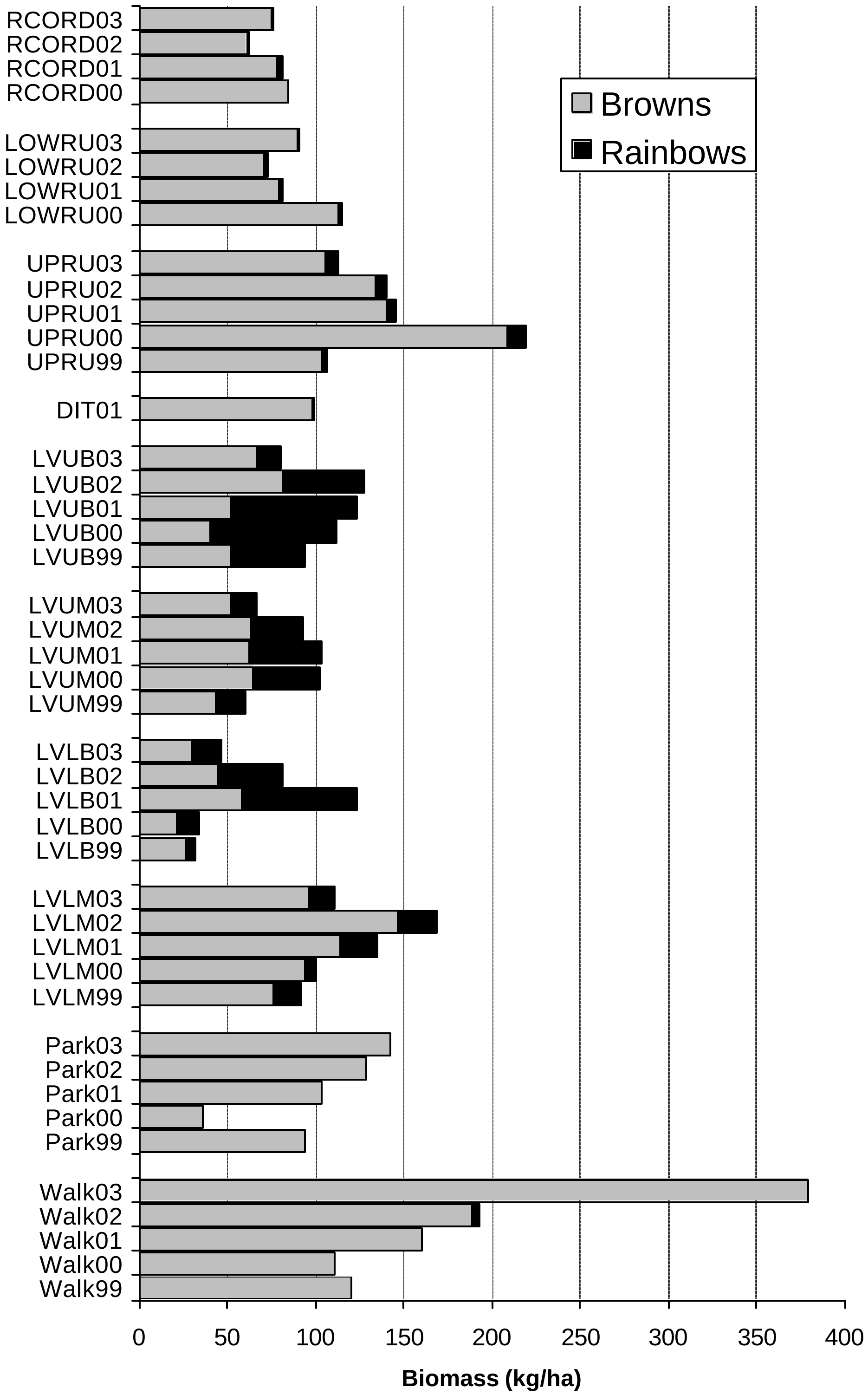


Figure 16. Standing crop (kg/hectare) of age-0 and older brown and rainbow trout in selected Mono Lake tributaries in 1999, 2000, 2001, 2002 and 2003.

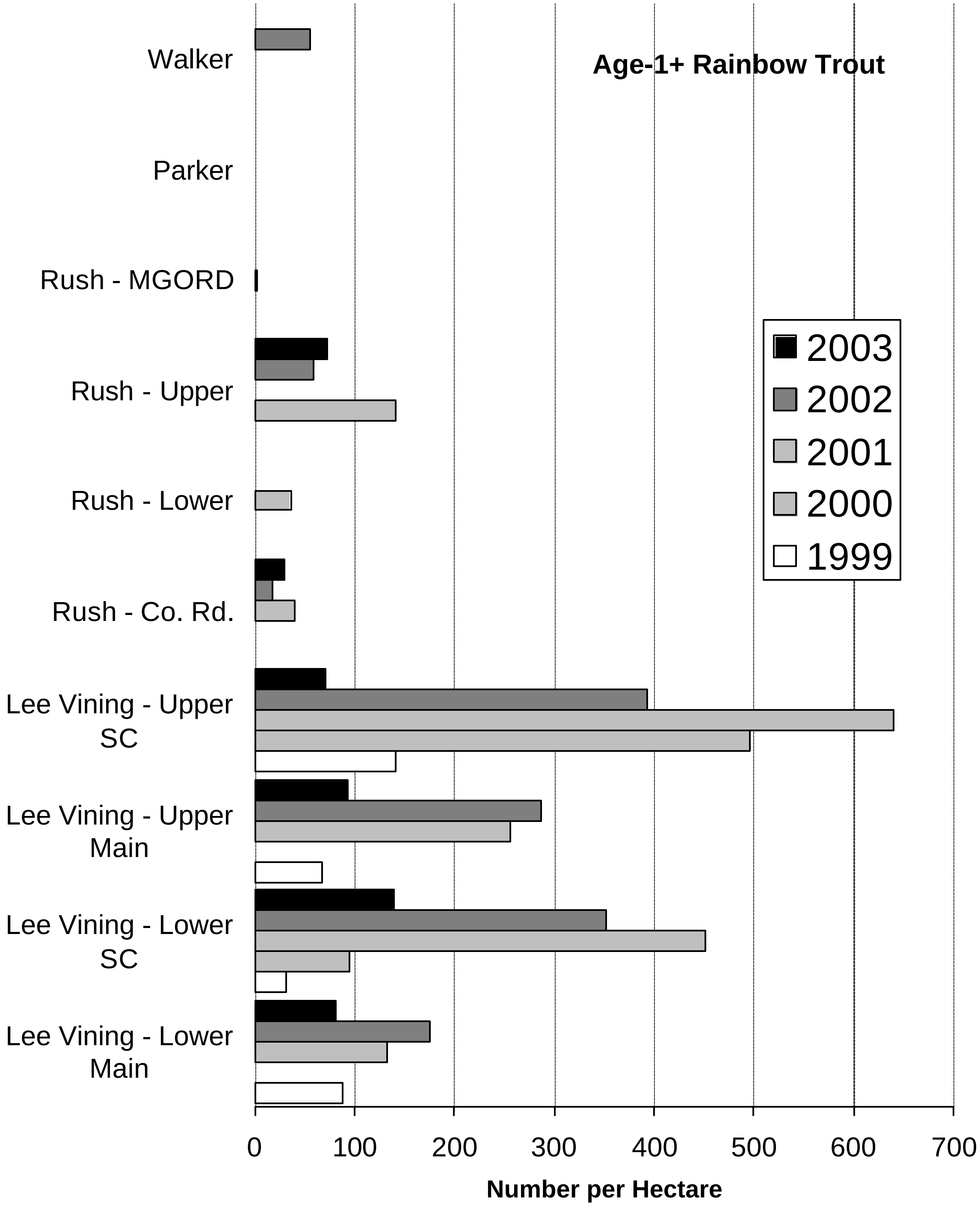


Figure 16. Estimated densities (number per hectare) of age-1 and older rainbow trout in sample sections of Lee Vining and Rush creeks.

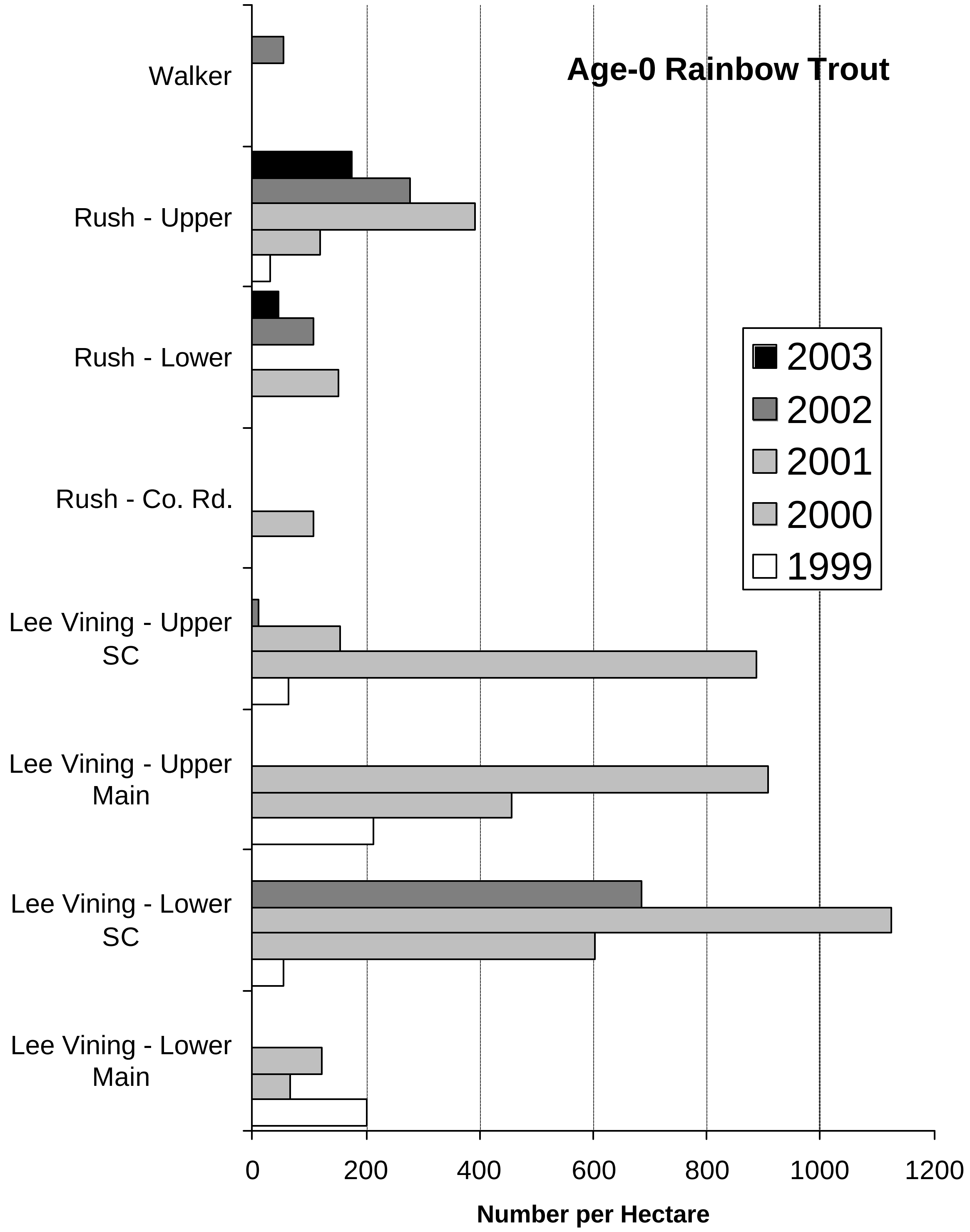


Figure 17. Estimated densities (number per hectare) of age-0 rainbow trout in sample sections of Lee Vining and Rush creeks.

the lowermost length class we used for our estimates, 0 to 124 mm, was a proper representation for age-0 rainbow trout, but from past length-frequency analyses we are confident this lower length group does represent age-0 rainbow. The minimum lengths of age-1 rainbow trout were almost always 150 mm or longer (Figure 11; Appendix E).

We plan on doing much more detailed age-growth analyses using scale and otolith data collected in 2003 and next year by back-calculating length at age using well-established scale length to fish length relationships in our next year's report.

Tag Return Information

Limited tag-return information we have collected indicates many brown trout remain within the sections they were originally tagged, at least between years when sampled at similar times of the year. Our data also suggests that tag return rates for brown trout were higher in the smaller tributaries, Parker and Walker creeks, than in main Rush Creek sections. We did not recapture any tagged rainbow trout in Rush Creek, but we had only tagged five in 2002. In 2003 we recaptured none of the 22 brown trout that we had tagged below the County Road (Oil Plant Road) in 2002. We did not sample in this area of Rush Creek in 2003, but did sample in our County Road sample section that is located just above the road.

Pool Habitat in Rush Creek

In his evaluation of a stream system with a broad range of very high to very low stream velocities, Heggenes (2002) reported that nearly two-thirds of the brown trout were found in stream velocities ranging from 0.06 to 0.25 mps. We measured stream velocities of 0.3 mps or less in only eight of the 21 Class 5 pools we found in Rush Creek. Four of these pools were located immediately downstream of the Lower Rush sample section and two of these pools were within the Upper Rush sample section (Table 8).

We observed very few pools and almost no high quality pools in the portion of Rush Creek from above Highway 395 down to the Narrows. This reach shows evidence of having been impacted by highway construction and sand and gravel mining. Pools with water depths >0.6 m (2.0 ft.) were rare, as were any dense concentrations of riparian vegetation. Significant quantities of sand and gravel have been removed from the floodplain in this reach; leaving few opportunities for lateral scour pool development along the cobble-dominated stream banks.

We observed 6.9 high quality pools/km, most of which were "lateral scour" pools, in Rush Creek from the Narrows down to our County Road fish sample section (Reach C; Table 9). These lateral scour pools form due to flows scouring the stream's bed (deepening the channel) when they encounter relatively stable stream banks at bends in the stream's channel. Much of the stream's banks in this reach of Rush Creek are stabilized by some of the most abundant and mature riparian vegetation found along Rush Creek. Based on the 7.5-minute USGS topographic map of the area (USGS

1994), Reach C was the only portion of the stream with any significant concentration of floodplain vegetation ten years ago. We suspect that Rush Creek's pools will continue to develop and their relative quality will improve for fish habitat as riparian vegetation matures to stabilize stream banks and provide recruitment of larger woody debris to the channel and if longer duration and higher peak spring flow events occur that provide the energy for scouring the stream's bed and making the channel more sinuous.

We observed that the portion of Rush Creek below the County Road is typical of an aggrading delta, likely a result of the rising level of Mono Lake. This aggradation has led to a relatively unstable channel that is often braided and has no deep, slow habitats. These habitat conditions indicate this portion of Rush Creek would not likely support large brown trout. We believe that this poor habitat in the vicinity of the Rush Creek delta would prevent, or severely limit, larger brown trout from occupying this area of Rush Creek, even to feed on the abundant supply of saline-dependent brine flies that inhabit this delta. We observed few trout and no larger trout in this delta area; however, small (25-50 mm) threespine sticklebacks (*Gasterodteus sp.*) were commonly observed in these shallow delta channels.

Methods Evaluation

Mark-recapture electrofishing appears to be providing relatively reliable estimates; however, our difficulty in maintaining block fences when weather conditions are unfavorable may be biasing estimates. Fortunately, a recent paper by Young and Schmetterling (2004) suggests that movement of trout between mark and recapture electrofishing efforts was insignificant in mountain streams of Montana. If this finding applies to streams we are monitoring in the Mono Basin, block fencing may not be necessary during our electrofishing and we could safely assume that population closure was met between our mark and recapture electrofishing efforts without the use of block fences. Our limited tagging data seems to support the hypothesis that trout are not moving too extensively, at least during the times we have been sampling, in Rush Creek. We found that having a person dedicated to maintaining block fences reduced the frequency of block net failures in 2003 compared to previous years.

We observed some channel migrations and shifts in Lee Vining Creek and the County Road Section of Rush Creek. While channel changes were minor in Lee Vining Creek, a side channel that previously had very little flow in the County Road Section of Rush Creek in 2002 conveyed about 30% of the stream's flow in 2003. We did not sample this side channel during our monitoring prior to 2003, but felt obligated to sample this channel during 2003. The changing channel configurations, particularly within our sample sections, could change the amount and, in some cases, quality of habitats we sample. While we do not believe these changes have yet been significant enough to render our annual comparisons invalid, we caution that future channel changes following a major high-flow event may be significant enough to make annual comparisons difficult. We have permanently marked the up and downstream boundaries of all sample sections. If we notice any change in the channel we re-measure channel lengths and wetted widths. We have sketched rough field maps of each sample section. We will re-map these sections if we notice any significant channel change to ensure we document significant channel changes within our sample sections.

Termination Criteria

The agreed upon termination criterion for Lee Vining Creek is to sustain a fishery for brown trout that average 8-10 inches in length with some trout reaching 13 to 15 inches. In 2003 we estimated that the main channel portions of Lee Vining Creek supported 12 to 13 trout 200 mm (~8 inches) and longer per 100 m of channel length and the side channel portions supported 10 to 24 per 100 m. Brown trout comprised from about half to over 90% of these trout. We did not capture any trout that exceeded 330 mm (~13 inches) during sampling of Lee Vining Creek during 2003 and only captured five over 300 mm (~12 inches). The density of trout over 200 mm in Lee Vining Creek was 287 to 346 per hectare in 2003 and brown trout predominated rainbow over 2:1 (Figure 18). Using the proportion of captured trout that were longer than 250 mm (~10 inches) for those length groups for which a modified Peterson mark-recapture estimates were made and multiplying the length-group estimate by those proportions provided estimates of the larger trout captured. We estimated that the two Lee Vining Creek sections supported about 90 to 130 trout > 250 mm per hectare (Figure 19). The densities of these larger trout for 2003 indicate Lee Vining Creek probably did not meet termination criteria in 2003 as it had much lower densities of larger trout than in 2002 (Hunter et al. 2003).

The agreed upon termination criterion for Rush Creek states that Rush Creek fairly consistently produced brown trout weighing 0.75 to 2 pounds. Trout averaging 13 to 14 inches (330 to 355 mm) were also allegedly observed on a regular basis prior to the dewatering of this stream. We captured only five brown trout longer than 300 mm (~12 inches) in the three Rush Creek sections during 2003 and only one of these, a 530 mm brown captured in Upper Rush exceeded 330 mm (~13 inches) in length. Four of these larger fish were captured in the Upper Rush Creek section and one in the County Road section. The estimated densities of larger trout in Rush Creek during 2002 do not indicate that this stream is close to reaching termination criteria (Figures 18 and 19).

The pool habitat reconnaissance fish surveys supported information from the annual sample sections, concluding that Rush Creek likely supports few larger brown trout. At this time we do not believe that Rush Creek is meeting the termination criteria. However, if the trout within the MGORD are included as part of Rush Creek's population, Rush Creek may also be able to meet the previously defined termination criteria (Hunter et al. 2002).

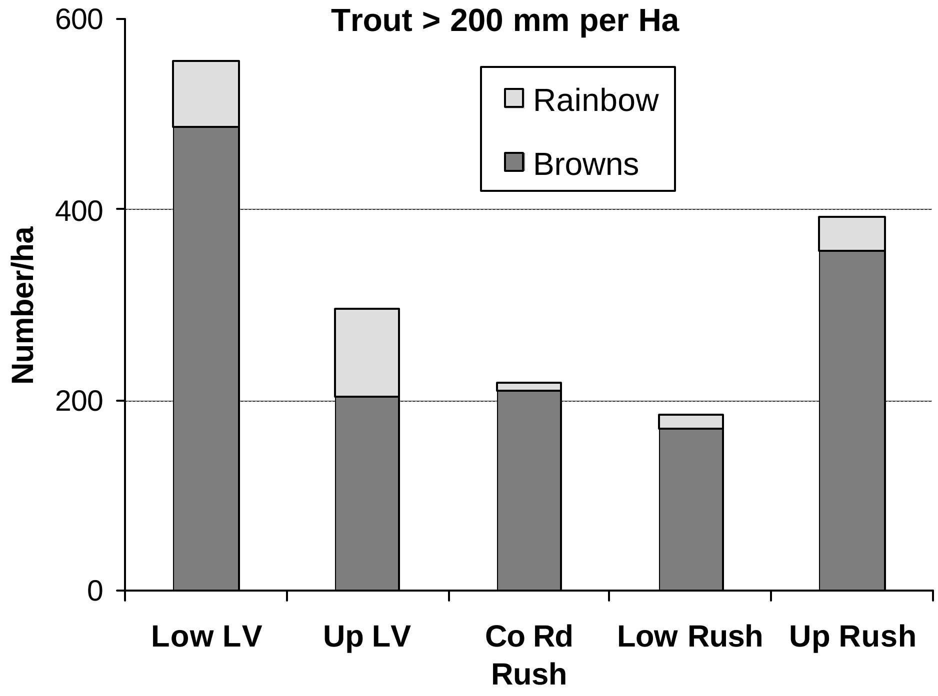


Figure 18. Density (number/ha) of rainbow and brown trout 200 mm and longer in the five sample sections in Lee Vining (LV) and Rush creeks during 2003.

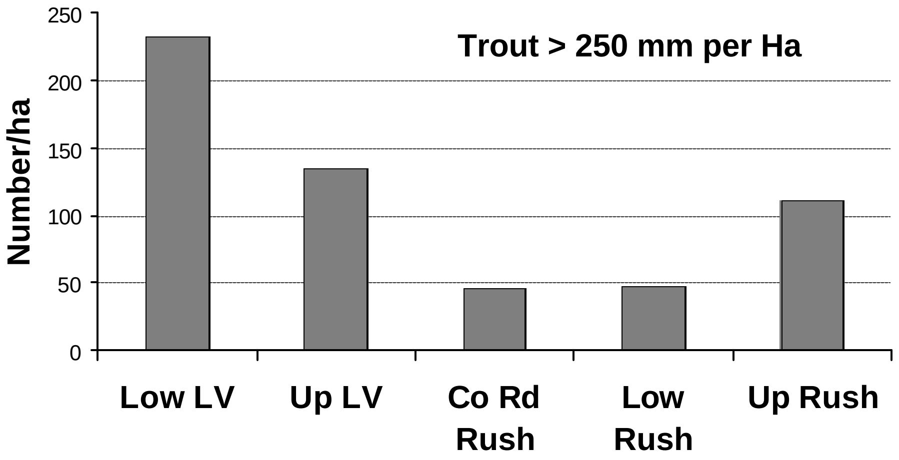


Figure 19. Density of trout longer than 250 mm in the five sample sections in Lee Vining (LV) and Rush creeks during 2003.

Recommended Termination Criteria

Our 2000 report noted that there is virtually no data available that provides an accurate picture of trout populations that these streams supported on a self-sustaining basis prior to 1941 (Hunter et al. 2000). We recommended that additional fish population data be collected from these streams for several years until we have a suitable amount of data to objectively evaluate the current termination criteria (Hunter et al. 2000 and 2001). This continues to be our recommendation. We also believe that obtaining at least six, and preferably ten, years of continuous fish abundance information will allow us to assess potential relationships between fish populations and physical habitat components, such as flows, physical habitat parameters, and water temperatures.

We are currently evaluating potential termination criteria that would be based upon standing crop estimates. We believe standing crop estimates would be more stable, more quantifiable, and would potentially relate to carrying capacities of particular stream sections. We also believe some secondary criteria related to population size structure could be developed. Both trout standing crop and size structure criteria could be related to habitat capability, thus as habitat conditions improve, as expected in Mono Basin streams, both standing crops and proportions of larger fish within the populations should increase.

Acknowledgements

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Appendix A – Water Temperature

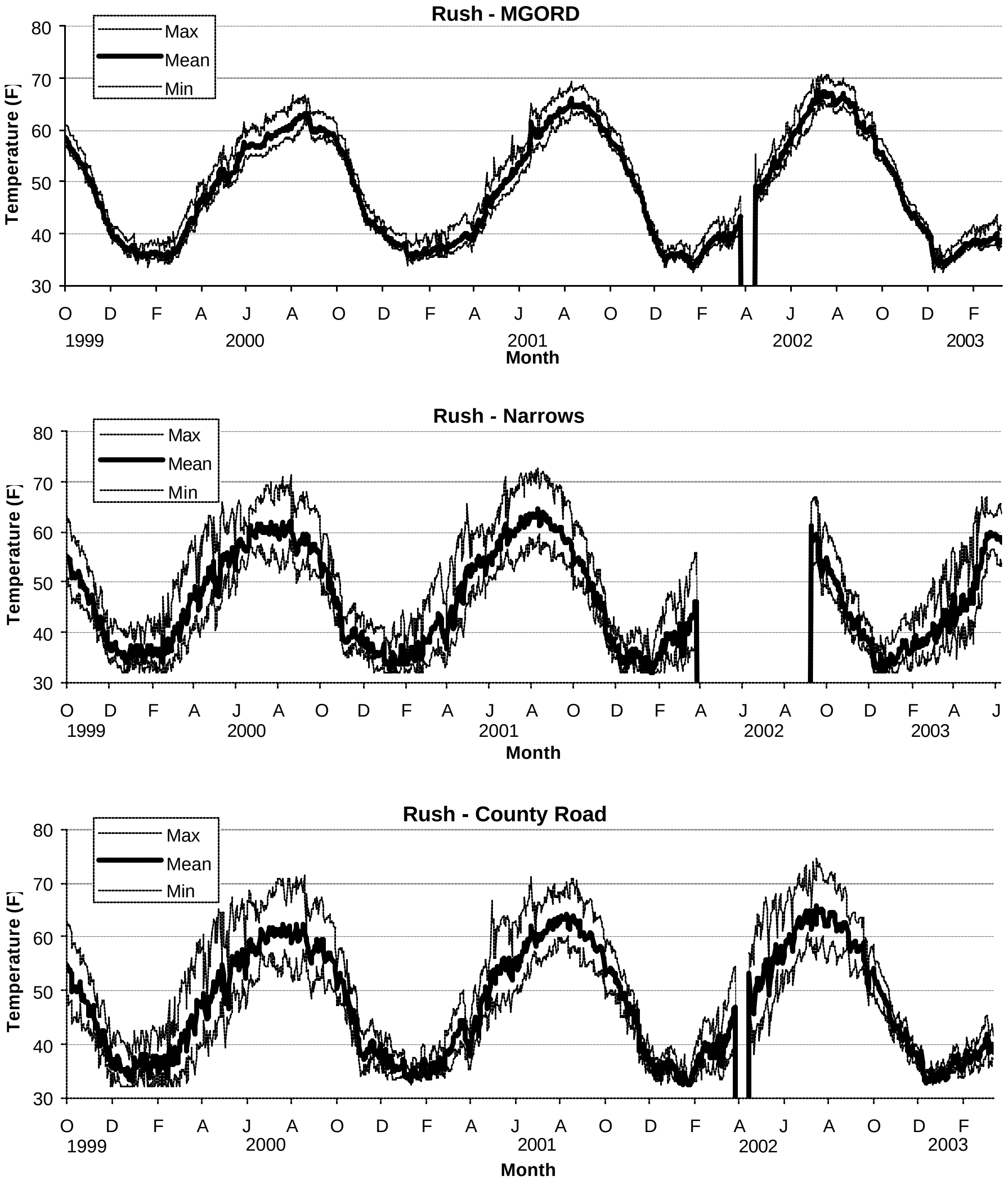


Figure A1. Mean daily (minimum and maximum) water temperatures in Rush Creek in the MGORD, just below the Narrows, and above County Road from 1999 through 2003. Data courtesy of McBain and Trush (Arcata, California).

Appendix B – Tagging Data

Table B1. Listing of all trout tagged in Mono Lake tributaries during 2002 and their recapture history. Abbreviations are BNT = brown trout; RBT = rainbow trout; WT = weight; LN = length; LN Dif = length difference; and C = condition factor.

Section	Date	Comments	Species	Tag No.	WT (gr)	LN (mm)	Recap LN	LN Dif	"C"
Upper Rush	**9/2/2002**	**Mark Run**	BNT	780	129	226			1.12
			BNT	781	139	231			1.13
			BNT	782	145	243	242	-1	1.01
			BNT	783	201	266			1.07
			BNT	784	212	273	274	+1	1.04
			BNT	785	123	231	226	-5	1.00
			BNT	786	254	275	280	+5	1.22
			BNT	787	102	224	225	0	0.89
			BNT	788	136	229	234	+5	1.13
			BNT	789	186	257			1.09
			BNT	790	116	227			0.99
			BNT	791	116	227			0.99
			BNT	792	173	252			1.08
			BNT	793	1368	485	485	0	1.20
			BNT	794	184	262	264	+2	1.02
			BNT	796	131	237	236	-1	0.98
			BNT	797	177	265	262	-3	0.95
			BNT	798	132	277	227	0	1.13
			BNT	799	120	229	230	+1	1.00
			BNT	800	135	234	241	+7	1.05
			BNT	801	126	234	234	0	0.98
			BNT	802	667	379	367	-12	1.23
			BNT	803	138	235			1.06
			BNT	804	103	230			0.84
			BNT	805	119	225	226	+1	1.04
			RBT	806	182	270	267	-3	0.92
	9/8/2002	**Recap Run**	BNT	825	122	230			1.00
			BNT	826	166	250			1.06
			BNT	827	160	250			1.03
			BNT	828	131	225			1.15
			BNT	829	168	247			1.11
			BNT	830	124	233			0.98
			BNT	831	124	237			0.93
			BNT	832	308	318			0.96
			BNT	833	131	232			1.05
			BNT	835	138	235			1.06
			BNT	836	109	231			0.89
			BNT	837	168	247			1.11

Section	Date	Comments	Species	Tag No.	WT (gr)	LN (mm)	Recap LN	LN Dif	"C"
Lower Rush	**9/3/2002**	**Mark Run**	BNT	807	202	272	270	-2	1.00
			BNT	808	124	227			1.09
			BNT	809	154	241			1.10
			BNT	810	157	249	252	+3	1.02
			BNT	811	179	253			1.10
			BNT	812	119	229	231	+2	0.99
			BNT	813	147	245	244	-1	1.00
			RBT	814	167	258			0.97
			BNT	816	154	242			1.08
			BNT	817	120	227	221	-6	1.03
			BNT	818	105	230			0.86
			BNT	819	192	268			1.00
			BNT	820	107	234	236		0.84
			BNT	821	111	226	228	+2	0.96
			BNT	822	111	230	229	-1	0.91
			BNT	823	126	232	230	-2	1.01
			BNT	824	157	248	249	+1	1.03
	9/11/2002	**Recap Run**	BNT	860	174	257			1.02
			BNT	861	112	228			0.95
Rush County Road	**9/1/2002**	**Mark Run**	RBT	751	175	264			0.95
			BNT	752	372	341			0.94
			BNT	753	114	234	232	-2	0.89
			BNT	754	117	226	226	0	1.02
			BNT	755	121	234			0.94
			BNT	756	129	230	225	-5	1.06
			BNT	757	171	263	265	+2	0.94
			BNT	758	118	227	223	-4	1.01
			BNT	759	182	263	261	-2	1.00
			BNT	760	113	230	225	-5	0.93
			BNT	761	107	230	226	-4	0.88
			BNT	762	153	252	254	+2	0.96
			BNT	763	241	290	289	-1	0.99
			BNT	764	138	227			1.18
			BNT	765	134	236	235	-1	1.02
			BNT	766	131	239	238	-1	0.96
			BNT	767	158	250	250	0	1.01
			BNT	768	110	226	225	-1	0.96
			BNT	769	135	237			1.02
			BNT	770	110	22/			0.93
			BNT	771	113	225			0.99
			BNT	772	151	259			0.87
			BNT	773	122	233			0.96
			RBT	776	196	275	279	+4	0.94

Section	Date	Comments	Species	Tag No.	WT (gr)	LN (mm)	Recap LN	LN Dif	"C"
			BNT	777	171	260	260	0	0.97
			BNT	778	104	226			0.90
			BNT	779	136	237			1.02
	9/9/2002	**Recap Run**	BNT	838	146	252			0.91
			BNT	839	136	239			1.00
			BNT	840	154	245			1.05
			BNT	841	180	259			1.03
			BNT	844	133	240			0.96
			BNT	845	141	244			0.97
			BNT	846	129	229			1.08
			BNT	847	196	271			0.98
			BNT	848	127	234			0.99
			BNT	849	115	230			0.94
			BNT	850	117	226			1.02
			BNT	851	226	284			0.99
			BNT	852	150	248			0.98
Parker Creek	**9/10/2002**	**Depl. Run**	BNT	853	134	229			1.12
			BNT	854	196	270			1.00
			BNT	855	132	237			0.99
			BNT	856	214	267			1.14
Walker Creek	**9/10/2002**	**Depl. Run**	BNT	857	183	258			1.06
			BNT	858	153	241			1.09
			BNT	859	176	256			1.05
Bl. County Road Culvert	**9/12/2002**		BNT	862	102	212			
			BNT	863	62	184			
			BNT	864	116	218			
			BNT	865	169	262			0.94
			BNT	866	100	209			
			BNT	867	85	196			
			BNT	868	116	225			1.02
			BNT	869	109	218			
			BNT	870	141	242			0.99
			BNT	871	201	279			0.93
			BNT	872	129	236			0.98
			BNT	873	87	210			
			BNT	874	117	232			0.94
			BNT	876	108	223			
			BNT	877	59	186			
			BNT	878	55	198			

Section	Date	Comments	Species	Tag No.	WT (gr)	LN (mm)	Recap LN	LN Dif	"C"
			BNT	879	86	212			
			BNT	880	93	216			
			BNT	881	114	234			0.89
			BNT	882	78	205			
			BNT	883	71	200			
			BNT	884	146	255			0.88

Appendix C – Mark-Recapture Estimates 2000 to 2003

Table C1. Mark-recapture estimates for 2000 to 2003 showing number of fish marked (M), number captured on the recapture run (C), number recaptured on the recapture run (R), and total estimated number and its associated standard error (S.E.) by stream, section, date, species, and size class. Mortalities (Morts) are those fish that were marked, but died prior to the recapture run. These mortalities were not included in the mark-recapture estimate and should be added to the estimate for an accurate total estimate.

Stream Section Date		Number of fish marked (M), captured on recapture run (C), and recaptured (R)					
Species	Size Class (mm)	M	C	R	Morts	**Estimate**	S.E.
Lee Vining Creek							
Lower Main Channel							
8/31/2000							
Brown Trout							
	0 - 124 mm	20	45	4	0	**192**	65.0
	125 - 199 mm	15	16	7	0	**33**	5.8
	200 - 349 mm	19	19	14	0	**26**	1.7
Rainbow Trout							
	0 - 324 mm	3	4	2	0	**6**	1.1
9/5/2001							
Brown Trout							
	0 - 124 mm	69	61	32	1	**131**	11.2
	125 - 224 mm	52	42	28	0	**78**	5.5
	225 - 349 mm	15	13	13	0	**15**	0.0
Rainbow Trout							
	0 - 124 mm	3	5	1	0	**11**	4.0
	125 - 374 mm	9	8	6	0	**12**	1.2
9/4/2002							
Brown Trout							
	0 - 124 mm	16	13	6	2	**33**	6.5
	125 - 199 mm	29	29	16	0	**52**	5.4
	200 - 249 mm	29	25	20	0	**36**	1.9
	250 - 349 mm	12	10	10	0	**12**	0.0
Rainbow Trout							
	150 - 349 mm	9	10	7	0	**13**	1.1
9/10/2003							
Brown Trout							
	0 - 124 mm	44	39	13	0	**128**	22.2
	125 - 224 mm	17	20	13	0	**26**	1.9
	225 - 324 mm	21	16	15	0	**22**	0.7

Stream Section Date **Species**	Size Class (mm)	Number of fish marked (M), captured on recapture run (C), and recaptured (R) M	C	R	Morts	**Estimate**	S.E.
Rainbow Trout							
	175 - 349 mm	5	6	5	0	**6**	0.0
Upper Main Channel							
8/31/2000							
Brown Trout							
	0 - 124 mm	33	86	11	1	**246**	51.1
	125 - 199 mm	13	14	2	0	**69**	27.7
	200 - 324 mm	11	24	8	0	**32**	4.2
Rainbow Trout							
	0 - 399 mm	18	50	10	0	**87**	14.6
9/4/2001							
Brown Trout							
	0 - 124 mm	37	53	14	0	**136**	22.6
	125 - 199 mm	46	41	26	0	**72**	5.4
	200 - 374 mm	29	26	20	0	**38**	2.1
Rainbow Trout							
	0 - 124 mm	41	40	9	3	**171**	39.4
	125 - 199 mm	20	10	8	0	**25**	2.6
	200 - 524 mm	21	17	15	0	**24**	1.0
9/5/2002							
Brown Trout							
	0 - 124 mm	17	30	9	0	**55**	9.2
	125 - 224 mm	55	57	35	0	**89**	5.5
	225 - 324 mm	26	19	16	0	**31**	1.8
Rainbow Trout							
	150 - 349 mm	47	33	28	0	**55**	2.5
9/11/2003							
Brown Trout							
	0 - 124 mm	28	43	7	0	**158**	40.9
	125 - 199 mm	22	14	8	0	**37**	6.0
	200 - 299 mm	32	19	16	0	**38**	2.5
Rainbow Trout							
	150 - 299 mm	13	10	7	0	**18**	2.2
Rush Creek							
County Road							
8/29/2000							
Brown Trout							
	0 - 124 mm	417	495	82	29	**2497**	222.6

Stream Section Date		Number of fish marked (M), captured on recapture run (C), and recaptured (R)					
Species	Size Class (mm)	M	C	R	Morts	**Estimate**	S.E.
	125 - 174 mm	111	148	45	2	**362**	33.8
	175 - 299 mm	118	116	61	1	**224**	13.4
Rainbow Trout							
	0 - 224 mm	24	24	8	2	**68**	14.1
9/8/2001							
Brown Trout							
	0 - 99 mm	270	263	55	14	**1277**	133.8
	100 - 124 mm	17	17	9	0	**31**	4.3
	125 - 149 mm	67	65	23	0	**186**	24.0
	150 - 174 mm	135	137	57	0	**323**	24.3
	175 - 199 mm	55	58	34	2	**93**	6.1
	200 - 224 mm	53	55	26	0	**111**	10.8
	225 - 249 mm	22	15	8	0	**40**	6.7
	250 - 374 mm	11	7	7	0	**11**	0.0
Rainbow Trout							
	125 - 274 mm	17	11	7	0	**26**	3.9
9/1/2002							
Brown Trout							
	0 - 74 mm	33	32	13	19	**79**	12.0
	75 - 124 mm	527	519	173	18	**1577**	79.7
	125 - 149 mm	18	11	8	0	**24**	2.9
	150 - 199 mm	108	135	52	1	**279**	21.3
	200 - 224 mm	50	51	32	1	**79**	4.9
	225 - 374 mm	28	28	15	0	**52**	5.7
Rainbow Trout							
	150 - 299 mm	12	5	5	0	**12**	0.0
9/7/2003							
Brown Trout							
	0 - 124 mm	451	498	118	34	**1894**	129.6
	125 - 199 mm	243	249	128	5	**472**	19.8
	200 - 399 mm	84	83	49	2	**142**	8.2
Rainbow Trout							
	125 - 299 mm	8	6	5	10	**10**	0.9
Lower Rush							
9/1/2000							
Brown Trout							
	0 - 124 mm	447	416	146	12	**1270**	68.9

Stream Section Date		Number of fish marked (M), captured on recapture run (C), and recaptured (R)					
Species	Size Class (mm)	M	C	R	Morts	**Estimate**	S.E.
	125 - 224 mm	117	123	69	1	**208**	10.4
	225 - 299 mm	18	15	14	0	**19**	0.6
Rainbow Trout							
	0 - 174 mm	16	9	4	0	**33**	8.2
9/7/2001							
Brown Trout							
	0 - 124 mm	279	305	101	41	**839**	53.9
	125 - 199 mm	152	157	100	2	**238**	8.3
	200 - 324 mm	33	40	29	0	**45**	1.5
Rainbow Trout							
	125 - 299 mm	8	10	8	0	**10**	0.0
9/3/2002							
Brown Trout							
	0 - 124 mm	450	481	179	29	**1207**	55.1
	125 - 199 mm	48	45	33	0	**65**	3.2
	200 - 299 mm	38	33	23	1	**54**	3.7
Rainbow Trout							
	0 - 99 mm	10	7	3	0	**21**	5.5
	100 - 249 mm	4	3	1	0	**9**	3.2
9/9/2003							
Brown Trout							
	0 - 124 mm	341	394	108	3	**1238**	83.0
	125 - 199 mm	150	134	107	0	**188**	4.3
	200 - 299 mm	39	37	31	0	**46**	1.5
Rainbow Trout							
	0 - 274 mm	5	7	4	4	**9**	1.0
Upper Rush							
8/30/2000							
Brown Trout							
	0 - 99 mm	492	520	63	76	**4012**	434.9
	100 - 199 mm	146	139	29	1	**685**	97.4
	200 - 399 mm	28	39	11	0	**96**	17.2
Rainbow Trout							
	0 - 124 mm	13	20	7	2	**36**	6.3
	125 - 274 mm	10	19	4	2	**43**	11.5
9/3/2001							
Brown Trout							
	0 - 74 mm	76	96	9	85	**746**	198.9

Stream Section Date		Number of fish marked (M), captured on recapture run (C), and recaptured (R)					
Species	Size Class (mm)	M	C	R	Morts	**Estimate**	S.E.
	0 - 99 mm	393	384	62	62	**2407**	252.3
	100 - 124 mm	27	68	12	5	**148**	26.2
	125 - 174 mm	59	78	22	7	**205**	27.8
	175 - 199 mm	24	25	11	6	**53**	7.9
	200 - 399 mm	51	53	30	1	**90**	6.6
Rainbow Trout							
	0 - 99 mm	17	17	2	4	**107**	45.0
	100 - 274 mm	7	6	3	1	**13**	2.9
9/2/2002							
Brown Trout							
	0 - 124 mm	407	556	101	25	**2227**	171.8
	125 - 199 mm	122	131	53	3	**300**	23.3
	200 - 524 mm	47	42	24	2	**82**	7.3
Rainbow Trout							
	0 - 124 mm	11	28	3	2	**86**	29.5
	125 - 299 mm	12	12	8	1	**18**	1.8
9/8/2003							
Brown Trout							
	0 - 124 mm	264	256	88	74	**764**	53.1
	125 - 199 mm	127	112	65	8	**218**	12.0
	200 - 324 mm	68	67	41	3	**111**	6.6
Rainbow Trout							
	0 - 124 mm	20	15	5	1	**55**	14.1
	125 - 299 mm	16	15	11	1	**22**	1.7
Rush Creek Ditch							
MGORD							
9/6/2001							
Brown Trout							
	150 - 274 mm	261	277	76	5	**945**	76.5
	275 - 424 mm	183	160	87	0	**336**	17.4
	425 - 674 mm	33	36	21	3	**56**	4.5
Rainbow Trout							
	225 - 524 mm	4	4	2	0	**7**	1.7

Morts are those fish marked on the marking run that died prior to the recapture run and these fish should be added to the estimate for the total estimate.

Appendix D – Criteria For Ranking Pool Classes (from Platts et al. (1983) Pool Quality Criteria)

Rating of pool quality; in streams of order 3 through 5

	Description	Pool Rating
1A	Maximum pool diameter is within 10 percent of the average stream width of the study site …………………...Go to 2A, 2B	
1B	Maximum pool diameter exceeds the average stream width of the study site by 10% or more………………….Go to 3A, 3B, 3C	
1C	Maximum pool diameter is less than the average stream width of the study site by 10% or more………………….Go to 4A, 4B, 4C	
2A	Maximum pool depth is less than 2 feet ………………………...Go to 5A, 5B	
2B	Maximum pool depth is greater than or equal to 2 feet…………Go to 3A, 3B, 3C	
3A	Maximum pool depth is greater than or equal to 3 feet in depth, regardless of cover conditions, or depth is greater than or equal to 2 feet with abundant fish cover (1)……………………...	Rate 5
3B	Maximum pool depth is less than 3 feet, with intermediate to abundant cover, or is between 2 and 3 feet and lacks abundant cover………………………..	Rate 4
3C	Maximum pool depth is less than 2 feet and fish cover is rated as exposed……………………………………………………………………...	Rate 3
4A	Maximum pool depth is greater than or equal to 2 feet with intermediate (2) or better cover …………………….………………………………	Rate 3
4B	Maximum pool depth is less than 2 feet, but fish cover is intermediate or better, or depth is greater than or equal to 2 feet with exposed cover conditions…………………………………………………...	Rate 2
4C	Maximum pool depth is less than 2 feet and pool is rated as exposed (3)…………………………………………………………………	Rate 1
5A	Pool with intermediate to abundant cover…………………………………………..	Rate 3
5B	Pool with exposed cover conditions………………………………………………...	Rate 2

Appendix E – Average Length by Age

Table B1. Average, minimum, and maximum lengths for rainbow and brown trout, along with sample size (n), by stream, sample section, and age interpreted from scale samples taken in 2003.

Species	Stream	Section	Age	n	Mean	Min	Max
Rainbow	**Lee Vining Creek**	**Lower - B1 Channel**	1	9	201.2	183	226
			2	2	259.5	246	273
		Lower Main Channel	1	3	210.7	181	245
			2	1	285.0	285	285
			3	1	329.0	329	329
		Upper - A4 Channel	1	3	206.3	196	216
			2	2	265.5	248	283
			3	1	319.0	319	319
		Upper Main Channel	1	8	211.5	172	238
			2	3	251.7	229	275
	Rush Creek	**County Road**	0	1	64.0	64	64
			1	6	149.2	112	167
			2	1	214.0	214	214
			5	1	293.0	293	293
		Lower Rush	0	1	73.0	73	73
			1	2	196.0	177	215
			2	2	218.0	209	227
		Upper Rush	0	10	79.1	61	101
			1	12	182.3	147	203
			2	4	251.5	215	286
			3	2	249.5	247	252
Browns	**Lee Vining Creek**	**Lower - B1 Channel**	0	4	105.0	76	116
			1	7	193.6	177	216
			2	3	262.3	249	272
		Lower Main Channel	0	12	97.1	77	115
			1	17	199.3	172	229
			2	18	261.0	227	307
		Upper - A4 Channel	0	4	85.5	75	112
			1	7	176.7	157	222
			2	7	231.4	217	256
		Upper Main Channel	0	11	98.7	87	118
			1	22	189.5	166	216
			2	21	252.1	229	291
	Rush Creek	**County Road**	0	18	88.4	61	111
			1	42	162.9	127	204
			2	15	215.2	196	243
			3	18	237.7	213	253
			4	4	260.3	228	274

Species	Stream	Section	Age	n	Mean	Min	Max
		Lower Rush	0	16	93.4	69	118
			1	30	172.9	142	230
			2	10	219.3	208	241
			3	14	242.8	212	272
			4	4	273.8	251	285
		Upper Rush	0	23	106.3	73	131
			1	32	170.3	74	209
			2	22	219.9	165	261
			3	6	264.0	241	310
			4	1	294.0	294	294
			5	1	278.0	278	278

Appendix F – Locations and Measurements of Class 4 and Class 5 Pools in Rush Creek

Pool Number or other Stream Feature	Distance Below MGORD		Lat.	Long.	Pool Depth (ft)		Pool Dimensions (ft)		Water Velocity (cfs)	
	(km)	(ft)	N37	W119	Maximum	Residual	Length	Width	Maximum	Mean
Class 5 No. 1	0.22	717	52.283	06.387	5.1	4.2	54	29	3.2	1.3
Class 4 No. 1	0.37	1200	52.354	06.388	3.6	2.5	69			
Class 5 No. 2	0.39	1284	52.367	06.396	3.8	3.0	44	24	3.8	2.1
Class 4 No. 2	0.40	1298	52.367	06.396	3.2	2.4	32			
Class 4 No. 3	0.54	1786	52.447	06.438	3.2	2.4	40			
Class 5 No. 3	0.63	2060	52.470	06.472	3.8	3.0	43	29	2.6	1.2
Class 4 No. 4	0.79	2585			3.3	2.3	25			
Class 5 No. 4	0.82	2700	52.560	06.428	4.1	3.2	44	27	2.7	1.1
Class 4 No. 5	0.85	2780	52.571	06.432	4.5	3.5	18			
Class 4 No. 6	1.74	5698	52.878	06.033	3.1	2.3	46			
Start of Up. Rush Sec.	1.96	6444	52.917	05.893						
Class 5 No. 5	2.10	6875	52.955	05.823	2.9	2.3	72	28	2.7	1.8
Class 5 No. 6	2.23	7300	52.990	05.774	3.6	2.9	52	32	1.7	1.0
Class 5 No. 7	2.34	7685	53.019	05.705	3.9	3.2	111	30	1.9	1.1
End of Up. Rush Sec.	2.37	7768	53.032	05.685						
Hwy 395 Bridge (upper)	3.36	11013								
Hwy 395 Bridge (lower)	3.45	11310								
Class 4 No. 7	4.40	14420	53.900	05.244	2.5	2.0	68			
Class 4 No. 8	5.41	17750	54.357	04.969	2.6	2.0	42			
Mouth of Parker Cr.	5.45	17870	54.379	04.975						
Class 4 No. 9	6.30	20660	54.706	04.757	3.2	2.2	38			
Mouth of Walker Cr.	6.36	20850	54.814	04.745						
Class 4 No. 10	6.38	20915	54.824	04.743	3.3	2.1	32			
Class 4 No. 11	6.93	22730	55.008	04.468	2.2	1.8	30			
Class 5 No. 8	7.02	23016	55.005	04.416	3.8	2.8	68	26	4.1	3.1
Class 4 No. 12	7.05	23135	55.022	04.403	3.5	2.8	38			
Class 5 No. 9	7.13	23375	55.049	04.373	4.1	2.9	70	22	3.3	2.3
Class 5 No. 10	7.33	24050	55.150	04.335	4.6	3.3	44	24	3.2	2.4

Table F. Continued…

Pool Number or other Stream Feature	Distance Below MGORD		Lat.	Long.	Pool Depth (ft)		Pool Dimensions (ft)		Water Velocity (cfs)	
	(km)	(ft)	N37	W119	Maximum	Residual	Length	Width	Maximum	Mean
Class 5 No. 11	7.35	24110	55.157	04.329	4.1	3.3	56	23	2.8	1.7
Class 4 No. 13	7.49	24560	55.222	04.288	3.2	2.2	52			
Class 5 No. 12	7.61	24950	55.275	04.259	3.6	2.8	72	24	3.5	2.6
Class 4 No. 14	7.65	25090	55.291	04.238	3.2	1.8	46			
Class 5 No. 13	7.95	26070	55.407	04.137	4.5	3.2	37	36	3.3	1.0
Class 4 No. 15	8.41	27600	55.604	03.973	3.6	2.1	30			
Class 5 No. 14	8.45	27725	55.621	03.972	4.5	3.2	54	14	3.8	3.2
Start of Low. Rush Sec.	8.80	28860								
Class 4 No. 16	8.98	29470	55.819	03.995	3.5	2.5	40			
Class 4 No. 17	9.06	29720	55.834	03.975	3.3	2.3	38			
Class 4 No. 18	9.13	29945	55.867	03.953	3.4	2.2	46			
Class 5 No. 15	9.22	30250	55.886	04.003	3.9	3.1	45	17	2.9	2.7
End of Low. Rush Sec.	9.23	30285	55.892	04.005						
Class 4 No. 19	9.44	30948	55.999	04.004	3.7	2.6	54			
Class 5 No. 16	9.66	31669	56.090	04.068	5.4	4.6	166	43	1.6	0.8
Class 4 No. 20	9.80	32128	56.160	04.048	4.0	2.8	38			
Class 5 No. 17	9.81	32193	56.156	04.051	4.9	4.1	68	22	1.2	1.2
Class 4 No. 21	9.87	32387	56.167	04.073	3.5	2.4	41			
Class 5 No. 18	10.01	32833	56.215	04.032	5.1	4.2	62	26	2.1	1.5
Class 5 No. 19	10.13	33235	56.218	03.981	4.1	3.3	78	18	1.8	1.0
Class 4 No. 22	10.19	33431	56.263	03.959	3.0	2.3	58			
Class 4 No. 23	10.29	33749	56.293	03.960	3.4	2.3	68			
Class 4 No. 24	10.48	34375	56.292	03.880	3.5	2.4	72			
Class 5 No. 20	10.53	34542			5.2	4.2	58	38	2.1	0.9
Class 4 No. 25	10.62	34835	56.335	03.863	3.5	2.6	38			
Start of Co. Rd. Sec.	10.73	35205	56.381	03.834						
Class 4 No. 26	10.82	35505			3.9	2.9	51			
End of Co. Rd. Sec.	11.51	37756								
Class No. 21	11.67	38278			4.2	3.1	62	36	1.3	0.7
Co. Rd. Culvert	11.99	39327								

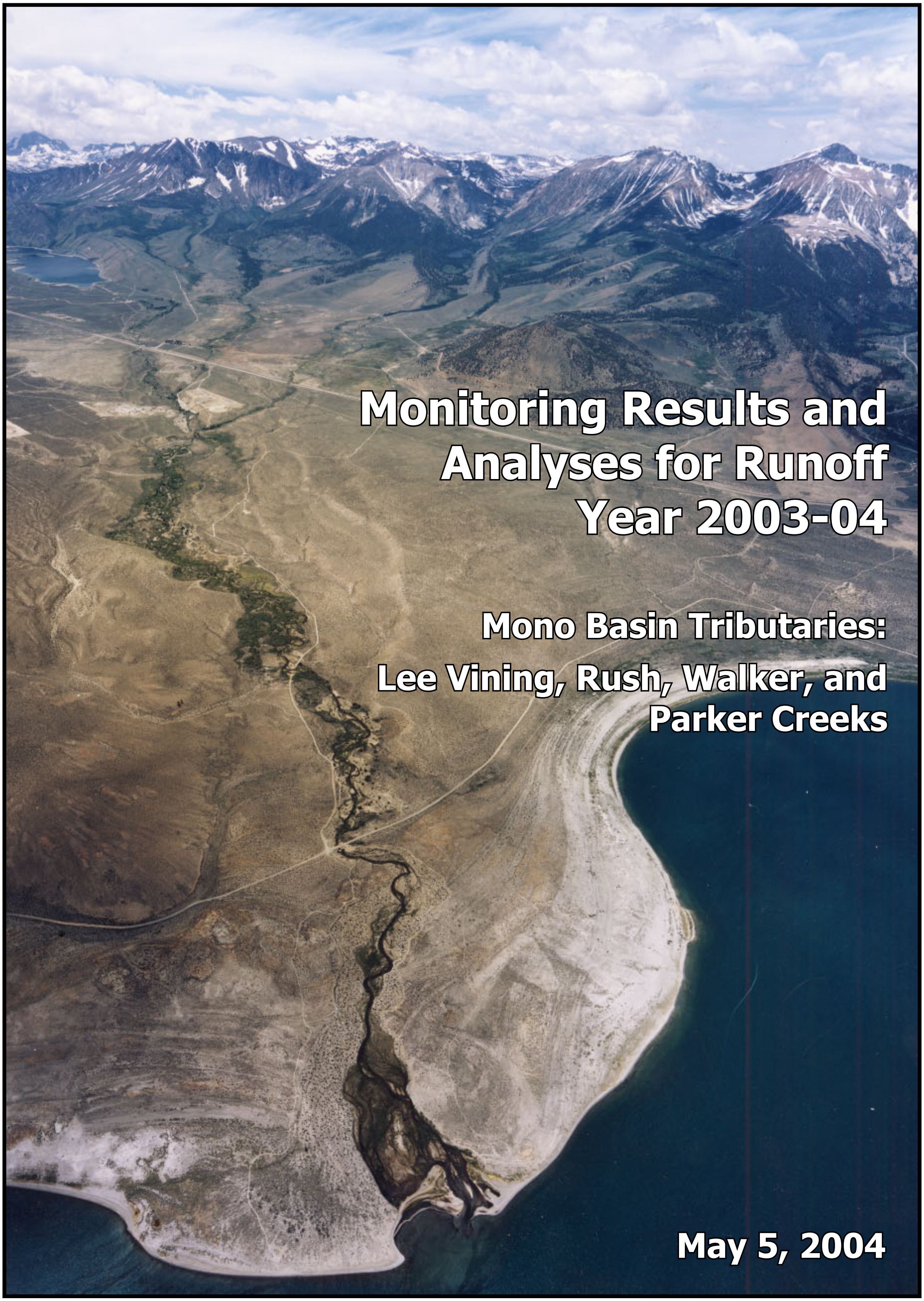
Table F. Continued…

Pool Number or other Stream Feature	Distance Below MGORD		Lat.	Long.	Pool Depth (ft)		Pool Dimensions (ft)		Water Velocity (cfs)	
	(km)	(ft)	N37	W119	Maximum	Residual	Length	Width	Maximum	Mean
Class 4 No. 27	12.00	39360			4.0	2.9				
Class 4 No. 28	12.40	40685			3.8	2.5	58			
Class 4 No. 29	12.97	42547			4.6	3.2	54			
Mono Lake	13.40	43956								

Section 4

Mono Basin Tributaries:
Lee Vining, Rush, Walker, and Parker Creeks

Monitoring Results and Analysis
For Runoff Season 2003-2004



Monitoring Results and Analyses for Runoff Year 2003-04

Mono Basin Tributaries:

Lee Vining, Rush, Walker, and Parker Creeks

May 5, 2004

Mono Basin Tributaries:
Lee Vining, Rush, Walker, and Parker Creeks

Monitoring Results and Analyses for Runoff Season 2003-04

Prepared for:

Los Angeles Department of Water and Power

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May 5, 2004

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1 INTRODUCTION

This report presents data and analyses for Runoff Year 2003-04 (beginning April 1, 2003), the fifth consecutive year of official monitoring in the Mono Basin (Figure 1) following State Water Resources Control Board (SWRCB) Decision 1631 and Order 98-05. Geomorphic and riparian monitoring activities in 2003 emphasized physical processes relative to streamflow and groundwater dynamics. This year's report is highlighted by a presentation of revised pre-1941 riparian acreages, a review of past and ongoing groundwater studies, and re-construction of unregulated annual hydrographs for Rush Creek. The rationale and strategy for evaluating the existing SWRCB stream restoration flows (SRFs) for Rush Creek also are addressed. With the prospect of significant snowmelt runoff in 2004, several ongoing investigations are described and proposed 2004 monitoring activities are summarized.

2 HYDROLOGY

The 2003 Runoff Year (RY 2003) was forecast on April 1, 2003 as a Dry-Normal I runoff year with projected runoff from the four Mono Lake tributaries (Rush, Parker, Walker, Lee Vining creeks) of 88,700 acre-feet (af), or 73% of normal using the 1941-1990 average of 122,124 acre-feet (LADWP 2003). April was an unusually wet month, increasing the projected runoff to 90,800 acre feet, or 74.3% of normal. The runoff year type remained Dry-Normal I, and operations remained with the Dry-Normal I designation.

2.1 Runoff Year 2003 Hydrographs

Rush Creek at Damsite had baseflows ranging from 30 cfs to 50 cfs from April 1 through mid-May. Baseflows ascended to an early snowmelt peak of 170 cfs on June 1, peaked at 311 cfs on June 19, and remained above 200 cfs for nine days and above 300 cfs for two days (Figure 2). SWRCB Order 98-05 requires Rush Creek Stream Restoration Flow (SRF) releases of 200 cfs for 7 days and baseflows of 44 cfs to 47 cfs (for Dry-Normal I runoff years). The 200 cfs peak flow, with a 1.3-yr recurrence (using regulated flood frequency record), was released below the Return Ditch between June 3 to June 7. With the addition of Parker and Walker creek flows, Rush Creek flows below the Narrows peaked at 283 cfs on June 3, with a total of 12 consecutive days above 200 cfs (Figure 2).

On Lee Vining Creek, SWRCB Order 98-05 requires that the peak flow be allowed past the Lee Vining intake diversion point. Prior to mid-May, baseflows for Lee Vining Creek above Intake ranged from approximately 25-35 cfs. The snowmelt flood at Lee Vining Creek above Intake had an unusually sharp ascending limb in 2003, rising from baseflows to the peak of 332 cfs in 14 days during the second half of May. The peak snowmelt flood occurred on May 30, 2003 (Figure 3). The peak flood for Lee Vining Creek Spill at Intake was 317 cfs. The recurrence interval for this peak flood (below US HWY 395) was approximately 2.8 years (regulated flood record). Diversions from Lee Vining Creek began on June 3, reducing duration of the regulated snowmelt recession by approximately 35 days: streamflows for Lee Vining Creek Spill at Intake reached 89 cfs on June 8, while flows for Lee Vining Creek above Intake remained above approximately 90 cfs until July 13.

Parker and Walker creeks had flow-through conditions at their diversion structures, and attained peak flood magnitudes of 49 cfs (May 31) and 43 cfs (May 31), respectively (Figure 4). The timing of these peaks coincides more closely with Lee Vining Creek than the Rush Creek snowmelt peak.

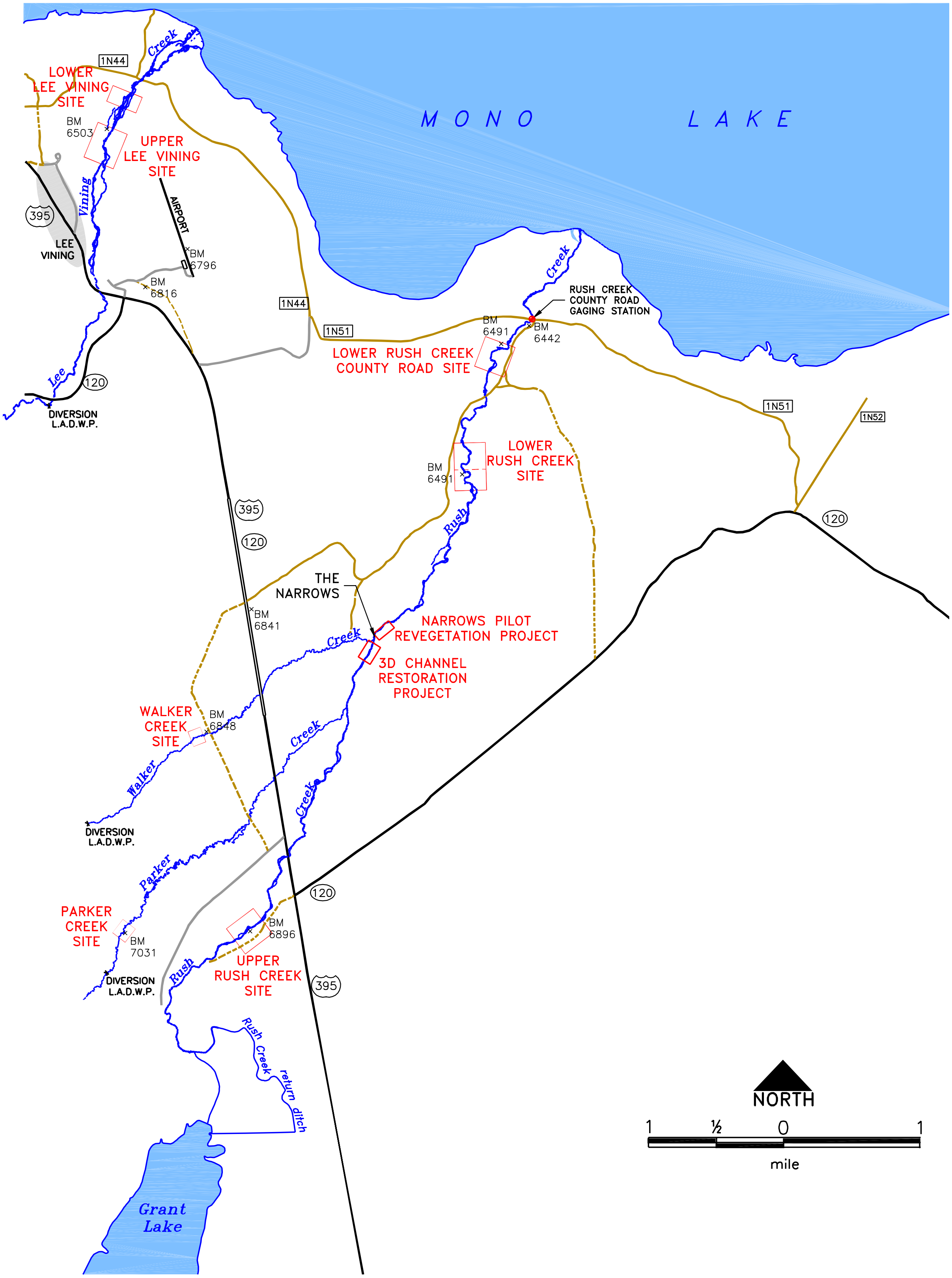


Figure 1. Location of the four Mono Basin Tributaries: Rush, Parker, Walker, and Lee Vining creeks, and the study sites on each creek.

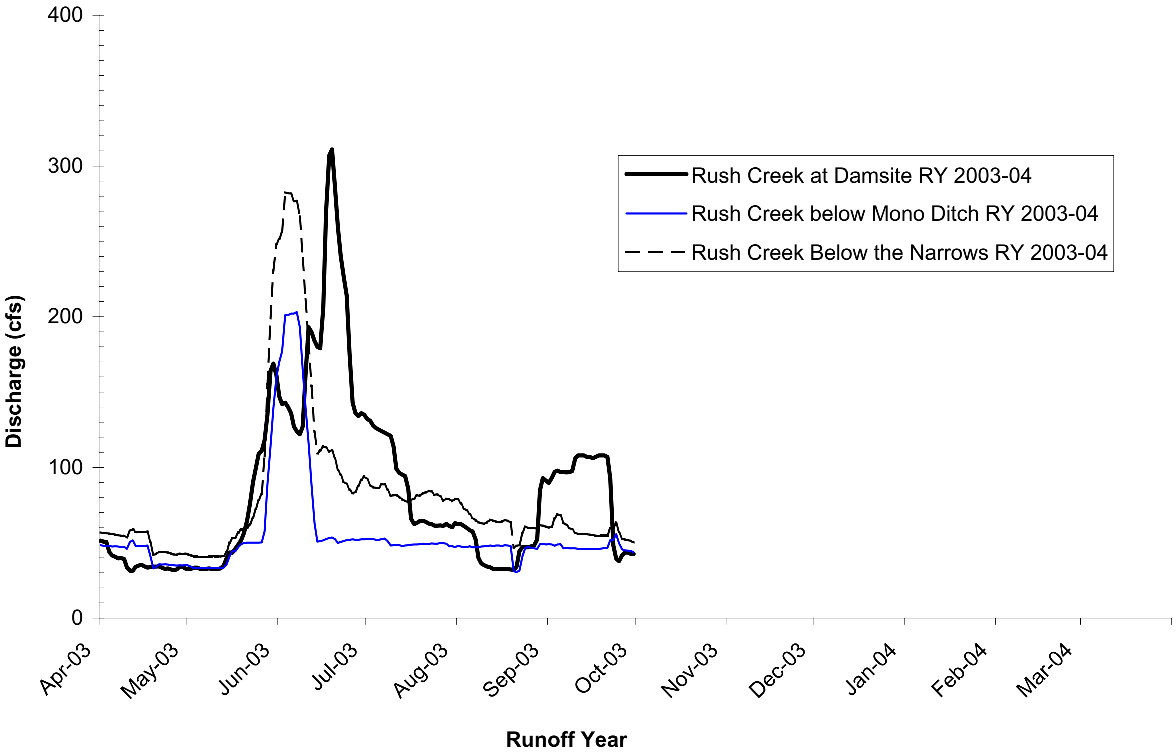


Figure 2. Annual hydrographs for Rush Creek for the first half of Runoff Year 2003-04.

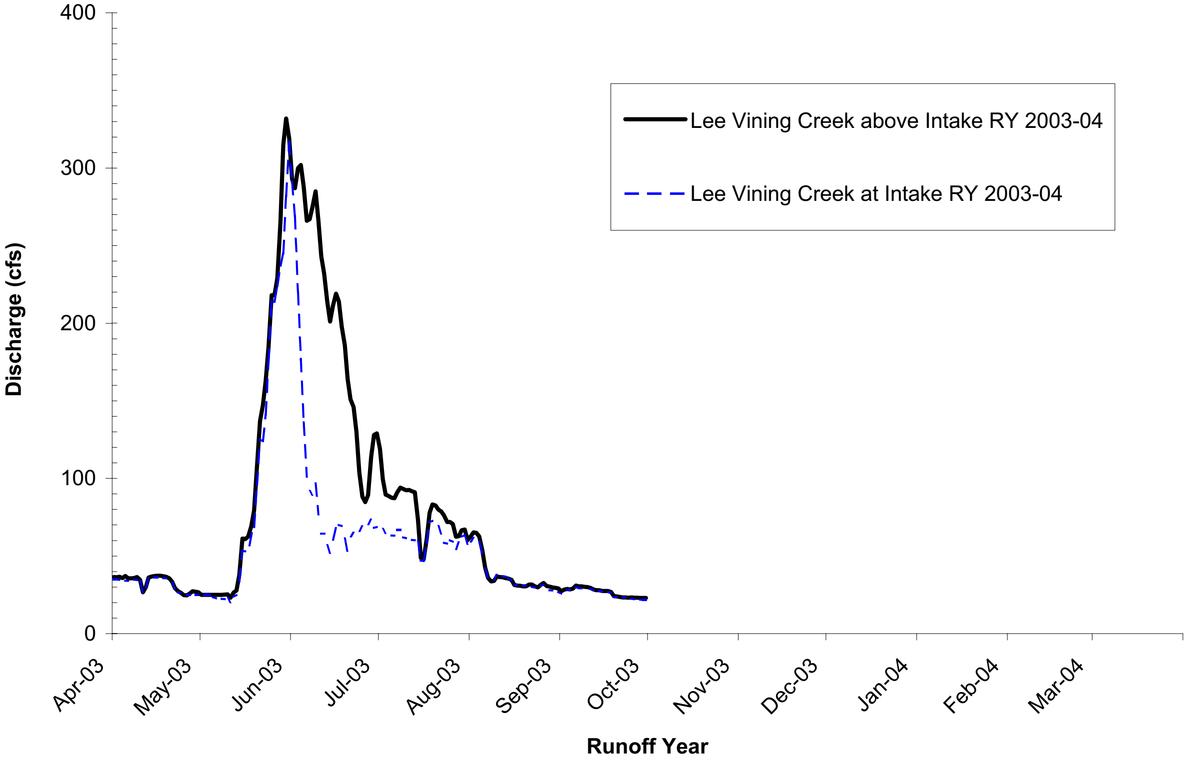


Figure 3. Annual hydrographs for Lee Vining Creek for the first half of Runoff Year 2003-04.

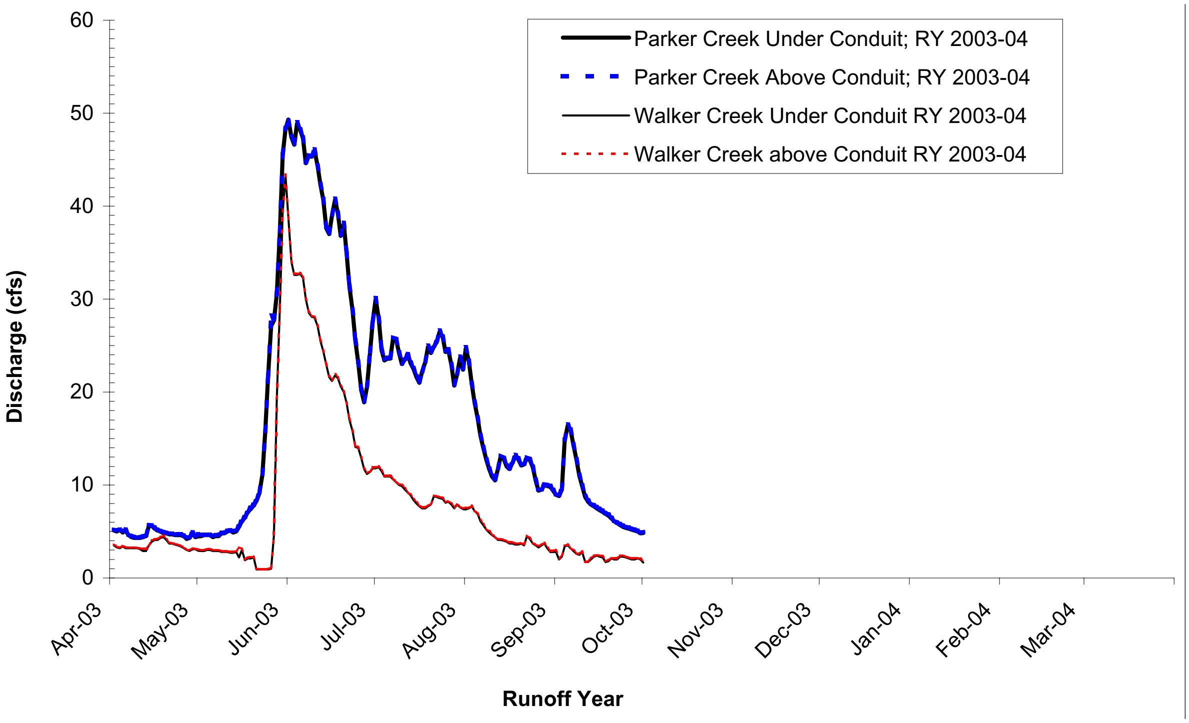


Figure 4. Annual hydrographs for Parker Creek and Walker Creek for the first half of Runoff Year 2003-04.

2.2 Synoptic Streamflow Gaging

LADPW gaging stations were not located to differentiate daily streamflows in the main channels from streamflows in numerous side-channels. During the past several years, McBain and Trush has measured discharge in study reaches to determine flow in each relevant side-channel of our study sites. These 'synoptic' streamflow measurements are typically conducted each visit to the basin and target measurements across a wide range of flows. A standard protocol for synoptic discharge measurement has been developed to keep data collection consistent.

Synoptic discharge measurements have been collected on Rush Creek and Lee Vining Creek since 1997, now comprising 20 sets of discharge measurements. On Rush Creek, our general protocol has been to measure discharge at Upper Rush Creek, the Lower Rush Creek main channel and 10–Channel, and the Rush Creek County Road gage. The two Lower Rush Creek measurements allow discharge in the planmapped reach to be calculated (total Lower Rush flow minus 10–Channel flow). We will begin to occasionally measure discharge at the 3D site to document changes in the proportion of flow down the newly constructed 3D side-channel. On Lee Vining Creek, our general protocol has been to take measurements at the upper main channel, in the B–Connector channel, and in the lower B–1 channel. These three measurements allow discharge in the A–4 and lower main channels to be calculated (A-4 = B-1 minus B-connector; lower main = upper main minus B-connector). Data for these Rush Creek and Lee Vining Creek flow measurements were presented in the RY 2002 Annual Report in Tables 2 and 3. In RY 2003, we measured 9.6 cfs at the 3D side-channel on 8/14/03, corresponding to a main channel flow (Rush Creek below Return Ditch + Parker Creek) of 60 cfs, or 16 percent of the flow into the side-channel. No other synoptic discharges were measured in RY 2003.

Empirical data for each side-channel measurement were plotted with the LADWP daily average data (Rush Creek below Narrows and Lee Vining Creek at Intake) to develop rating relationships for each side-channel site. These linear regression relationships allow discharge to be predicted at each side-channel location with a known “input” main channel flow. An example of the utility of these data is given for Lee Vining Creek where surface and groundwater stage measurements have been collected by the Mono Lake Committee (Section 2.3.4). With these synoptic rating relationships, a given ‘Lee Vining at Intake (LVI)’ flow can be converted to an A–4 or main channel flow, then used to predict stream stage and groundwater elevation for that LVI flow. Finally, the ground surface elevation can be compared to groundwater elevation to evaluate the feasibility of riparian vegetation growing on various geomorphic surfaces, or conversely explain why vegetation recruitment and/or survival has not occurred.

2.3 Monitoring Groundwater Dynamics

This section summarizes groundwater dynamics in Rush Creek and Lee Vining Creek valleys, frames hypotheses about how streamflow interacts with groundwater, and outlines our approach for linking groundwater information to riparian vegetation regeneration. The following discussion includes: (1) a general description of groundwater - surface water relationship; (2) a review of existing groundwater monitoring activities; (3) a description of groundwater monitoring at the Rush Creek 3D and 8-Channel construction sites; (4) a description of our current understanding of groundwater - surface water relationship for Rush Creek and Lee Vining Creek, and (5) groundwater monitoring activities proposed for RY 2004.

2.3.1 Terminology

Before proceeding, there are several potentially confusing terms describing groundwater systems. The following list defines these terms *as used in this report*, which are largely based on definitions by Fetter (1980) and Watson and Burnett (1993). Additional terms introduced in these definitions and not specifically defined (e.g., root zone and capillary fringe) can be found in the previous references as well as in general hydro-geologic texts.

Baseflow:	Groundwater discharge to a stream from the water table. Baseflow is a major contributor to streamflow during periods of no precipitation or surface runoff.
Gaining stream:	A stream that receives discharge from groundwater when the elevation of the water table is above the stream. Where the elevation of the water table in the land adjacent to the stream is greater than the elevation of the stream, the flow direction is from the ground to the stream.
Groundwater:	The water contained in interconnected pores located below the water table (saturated zone) in an unconfined aquifer. We assume groundwater occurrence along Rush and Lee Vining Creeks, as it relates to streamflow, soil moisture, and riparian vegetation, is unconfined.
Losing stream:	A stream that loses its water to the water table, which is located below the level of the stream. Where the elevation of the water table in the land adjacent to the stream is lower than the elevation of the stream, the flow direction is from the stream to the ground.
Piezometer:	A non-pumping well used to measure the elevation of the water table.
Saturated zone:	The zone below the water table in which rock or soil pore spaces are filled with water at pressures greater than atmospheric.

Unconfined aquifer: An aquifer in which there are no confining beds between the saturated zone and the ground surface. The depth of an unconfined aquifer extends from the top of the saturated zone (water table) to the first impermeable zone (confining bed).

Unsaturated zone: See vadose zone.

Vadose zone: The zone between the ground surface and the water table, which includes the root zone, intermediate zone, and capillary fringe. Rock or soil pore spaces in the vadose zone contain water at pressures less than atmospheric. Synonymous with *unsaturated zone*.

Water table: The water table separates the saturated zone from the unsaturated (vadose) zone. In an unconfined aquifer, the water table is the surface at which pore water pressure equals atmospheric pressure.

2.3.2 Groundwater- Surface Water Relationships in Rush and Lee Vining Creeks

From the metamorphic and granitic bedrock of the Sierra Nevada, groundwater flows northeast through glacial deposits (till) of the Tioga and Tahoe glaciations, and then through Quaternary valley fill deposits composed of alluvial sediments, lacustrine sediments, volcanic ash, and pumice (Kistler 1966; Lajoie 1968), with eventual discharge to Mono Lake (NAS 1987). At the regional scale, the generalized flow gradient in Rush Creek and Lee Vining Creek valleys is illustrated in Figure 5, which shows a conceptual diagram of groundwater and surface water flow relations for the Great Basin Region (Eakin et al. 1976) and provides the foundation for understanding surface water and groundwater hydrology for Rush and Lee Vining creeks.

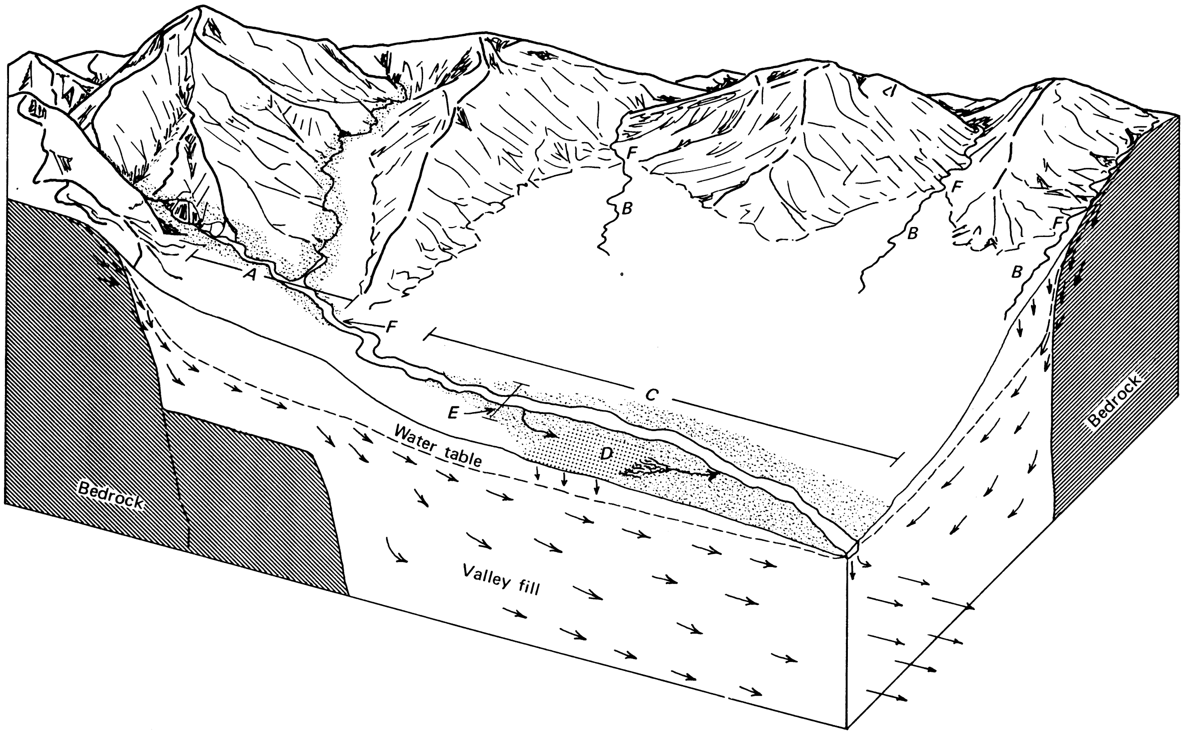
A notable feature in Figure 5 is the transition from a gaining stream to a losing stream (denoted by segments A and C, respectively). A stream may lose or gain water by seepage, depending on the water surface elevation of the stream, the elevation of the groundwater table, and permeability of the bed and banks. This transition marks an important change in groundwater – surface water relations, where the stream stops receiving groundwater discharge and starts losing water to the groundwater table (Figures 6a and 6b, respectively).

The location of groundwater recharge (losing) and discharge (gaining) areas varies seasonally and annually. In the Rush Creek and Lee Vining Creek valleys, annual hydrographs can strongly influence local groundwater elevation. As stage varies, so does the groundwater elevation adjacent to the channel. In losing reaches, the local groundwater elevation depends on streamflow; water is lost from the channel and percolates into the adjacent alluvium laterally and downward (Figure 6b). In gaining reaches, the groundwater table is usually higher than the stream elevation, yet the water table can still respond to changing stream stage (Figure 6a). Temporary reversals of this gradient are possible during rapid stage rise, during which streamflow is lost to the adjacent alluvium (Figure 7). Streamflow, therefore, is an important variable governing water table elevations.

2.3.3 Groundwater Monitoring During RY 2003

We began with the following tasks in 2003 to improve our understanding of groundwater conditions on Rush and Lee Vining creeks:

- Gather background information on past and contemporary groundwater studies and monitoring activities;



A, Gaining reach, net gain from ground-water inflow although in localized areas stream may recharge wet meadows along flood plain. Hydraulic continuity is maintained between stream and ground-water reservoir. Pumping can affect streamflow by inducing stream recharge or by diverting ground-water inflow which would have contributed to streamflow.

B, Minor tributary streams, may be perennial in the mountains but become losing ephemeral streams on the alluvial fans. Pumping will not affect the flow of these streams because hydraulic continuity is not maintained between streams and the principal ground-water reservoir. These streams are the only ones present in arid basins.

C, Losing reach, net loss in flow due to surface water diversions and seepage to ground water. Local sections may lose or gain depending on hydraulic gradient between stream and ground-water reservoir. Gradient may reverse during certain times of the year. Hydraulic continuity is maintained between stream and ground-water reservoir. Pumping can affect streamflow by inducing recharge or by diverting irrigation return flows.

D, Irrigated area, some return flow from irrigation water recharges ground water.

E, Flood plain, hydrologic regimen of this area dominated by the river. Water table fluctuates in response to changes in river stage and diversions. Area commonly covered by phreatophytes (shown by random dot pattern).

F, Approximate point of maximum stream flow.

Figure 5. Common relationships between groundwater and surface water in the Great Basin region; from U. S. Geological Survey Professional Paper 813-G (Eakin et al. 1976).

- Begin documenting groundwater hydrology at Rush Creek 3D and 8-Channel construction sites to develop site-specific surface water – groundwater relations, and to compare these results with those of nearby groundwater studies and monitoring;
- Use the available groundwater information and existing literature to develop hypotheses describing groundwater – surface water relations;
- Develop groundwater monitoring tasks to be implemented in 2004.

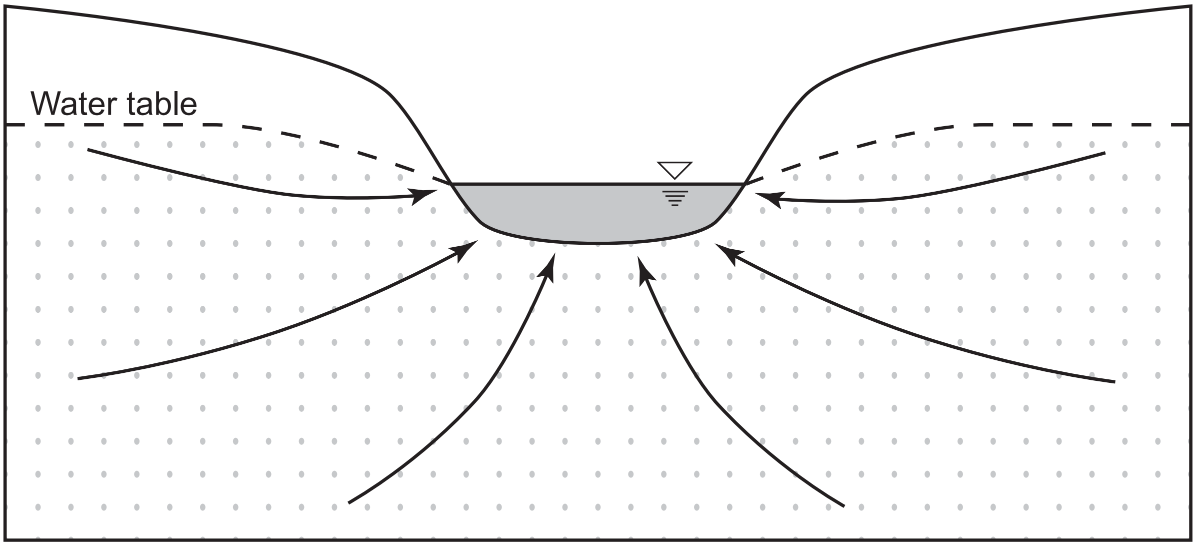


Figure 6a. Schematic cross section showing gaining stream conditions. Streamflow is gained from groundwater where the elevation of the water table is above the stream. Flow direction is from the ground to the stream.

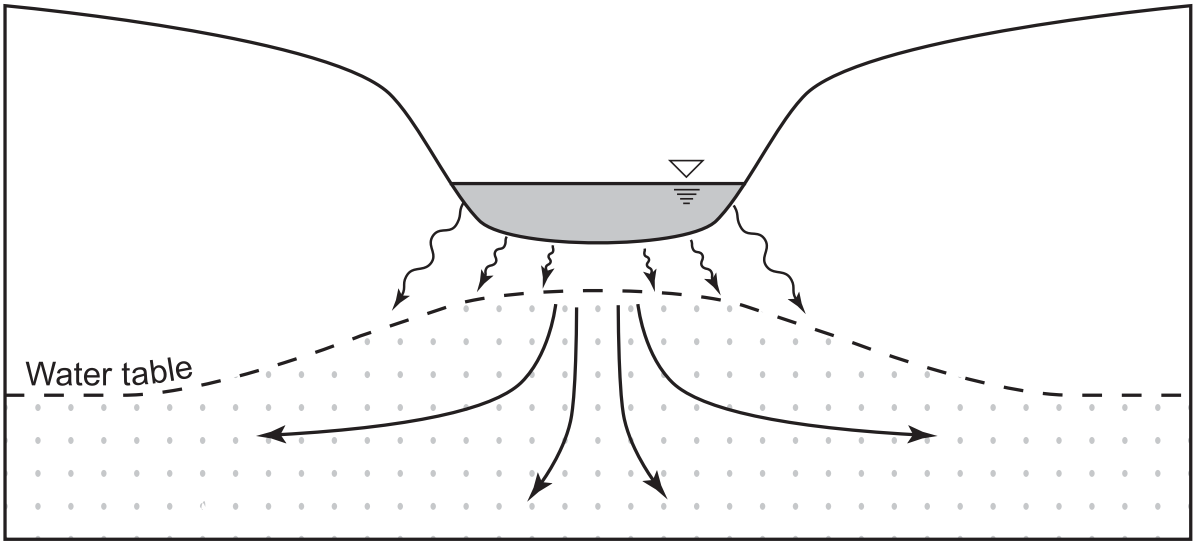


Figure 6b. Schematic cross section showing losing stream conditions. Streamflow is lost to the water table, which is located below the level of the stream. Flow direction is from the stream to the ground.

2.3.4 Existing Groundwater Studies and Monitoring Activities

There are currently numerous piezometers throughout the Rush Creek and Lee Vining Creek valleys, which can be grouped into three sets (Figure 8). The first set of piezometers, near the mouth of Lee Vining Creek, was installed by LADWP. Balance Hydrologics (1993) reports these piezometers were installed in 1980, however they may belong to a larger series of piezometers installed by LADWP in 1986 (NAS 1987). Regardless of their installation date, the piezometer set was monitored by Balance Hydrologics (1993). The second set of piezometers, installed at one site on Rush Creek and at one site on Lee Vining Creek, was installed by Northwest Biological Consulting in 1995 (Greg Reis, personal communication). The third set was installed at five study sites: three on Rush Creek, one

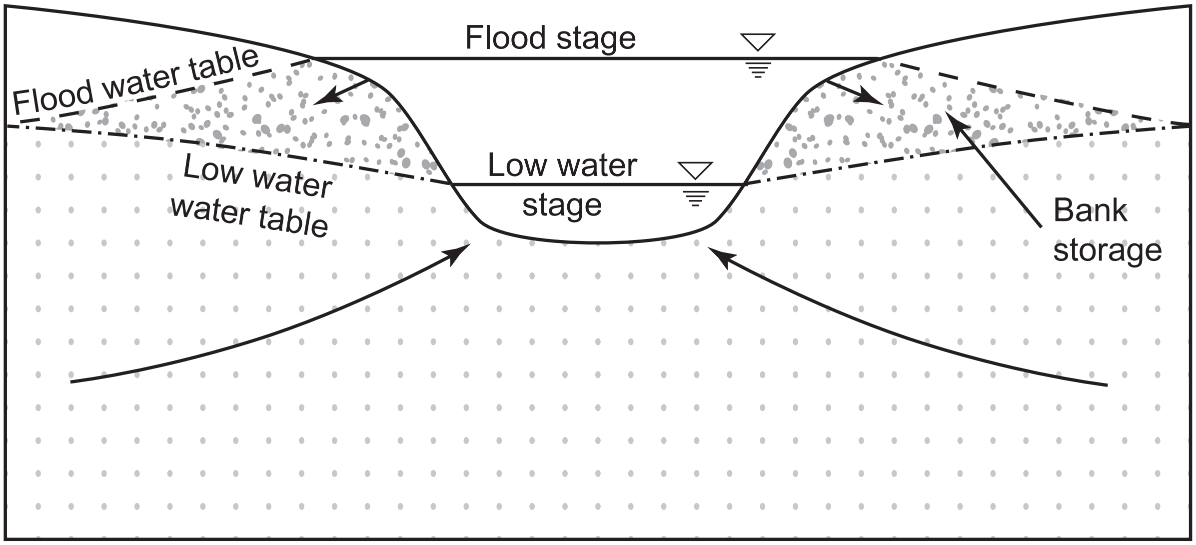


Figure 7. Schematic cross section showing reversal from gaining to losing stream caused by stream flooding. During a flood, stream stage is elevated above the water table elevation and water is lost to the adjacent alluvium. This water is taken into storage ("bank storage") where it drains to the groundwater or back into the channel. Factors affecting the magnitude and direction of groundwater flow resulting from flood events include the magnitude and duration of the flood, as well as antecedent soil moisture in the adjacent alluvium.

on Lee Vining Creek, and one each on Walker and Parker creeks. These piezometers were installed in 1991 by Balance Hydrologics. After reviewing available information associated with each set of piezometers, two data sources were found relevant to our investigation: (1) a report by Balance Hydrologics (1993) prepared for the Mono Basin Environmental Impact Report (JSA 1993), and (2) results of ongoing groundwater monitoring of the Northwest Biological Consulting piezometers by Mono Lake Committee (MLC).

2.3.4.1 Balance Hydrologics Summary Information

Balance Hydrologics conducted their study to document groundwater – surface water interactions in riparian zones of Rush, Lee Vining, Walker, and Parker creeks. Five study sites were occupied, including three sites on Rush Creek, distributed from approximately ½ mile upstream of Hwy 395 to approximately 1 mile upstream of County Road, and one site each on Walker and Parker creeks, both upstream of Hwy 395 (Figure 8). Between three and seven piezometers were installed at each study site. The Balance Hydrologics report (1993) documents groundwater – surface water relations, including groundwater elevations, gradients, and responsiveness to streamflow. However, monitoring was conducted only from May to November 1991 and for a few weeks in March 1992.

2.3.4.2 Mono Lake Committee Monitoring Data

The Mono Lake Committee (MLC) has monitored the Northwest Biological Consulting piezometers at the Rush Creek and Lee Vining Creek study sites since 1995 on a monthly to weekly basis. Greg Reis of MLC has compiled an extensive eight-year groundwater data set and has performed some analyses documenting groundwater - surface water relations. The raw data are available on the Mono Basin Clearinghouse web page (http://www.monobasinresearch.org/data/#HYDROLOGY) (Mono Lake Committee 2003), as well as their piezometer monitoring protocol (http://www.monobasinresearch.org/images/piezoprotocol.pdf) (Mono Lake Committee 2002). Results of their monitoring provide a useful long-term record of groundwater dynamics.

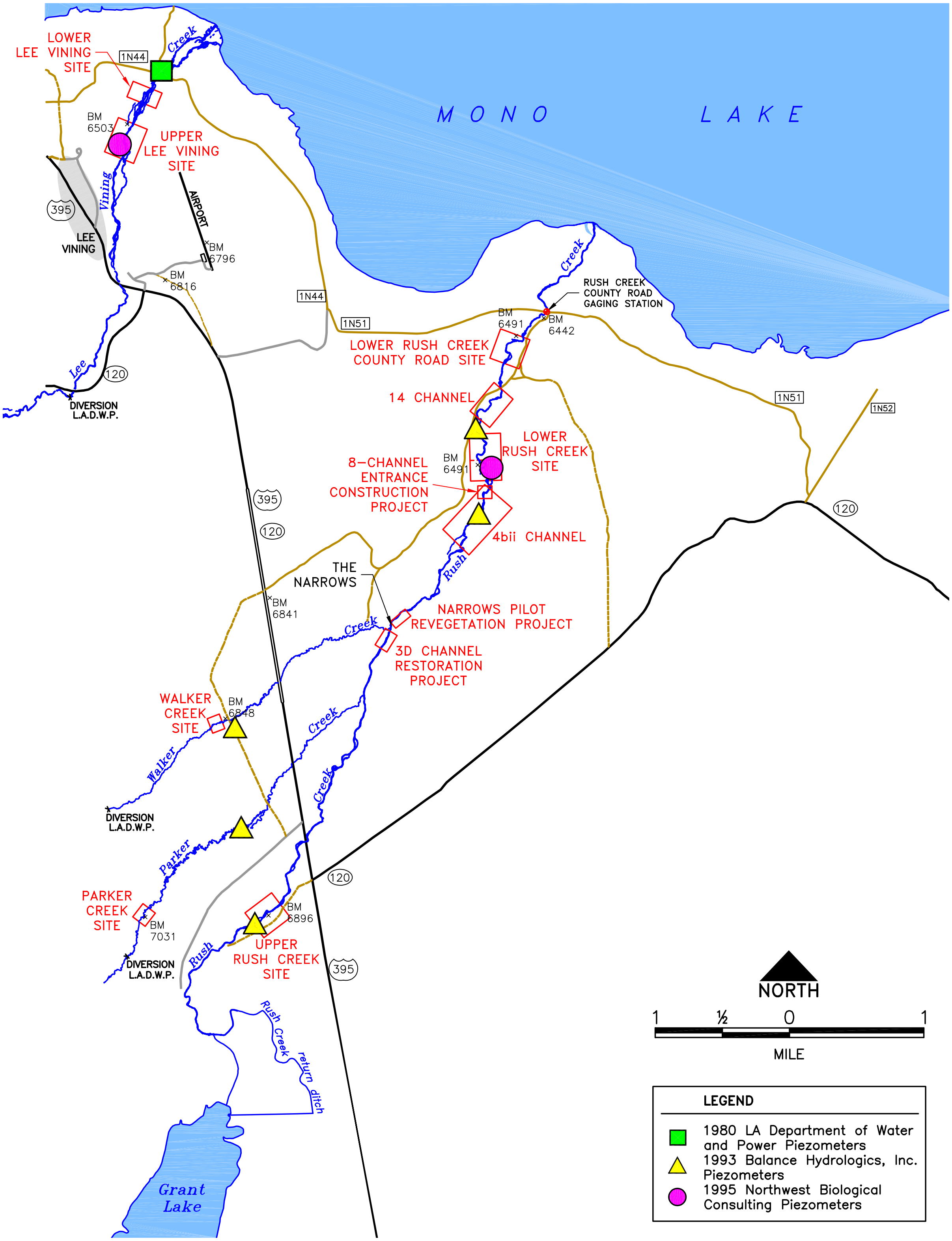


Figure 8. Map of Rush and Lee Vining Creeks showing the location of piezometers installed for previous groundwater monitoring (i.e., LADWP, Northwest Biological Consulting, Balance Hydrologics), the location of current groundwater monitoring sites (McBain and Trush 3D and 8-Channel sites), and the location of the Rush Creek 4bii and 14-Channel areas.

2.3.4.3 McBain and Trush Groundwater Field Mapping

Groundwater conditions at two additional sites have been monitored. The Rush Creek 4bii and 14-Channel areas (Figure 8) were identified as potential side-channel restoration sites in SWRCB Order 98-05. Side-channel re-opening has been deferred at these sites to give natural recovery an opportunity before considering remedial actions (McBain and Trush 2001). Because of the cost and the potential site disturbance associated with piezometer installation, we have identified two locations (there may be other sites) where natural depressions in the ground topography allow groundwater to be observed above the ground surface. We will survey groundwater elevations at these sites during the Runoff Year 2004 field season.

2.3.4.4 Groundwater Monitoring at Rush Creek 3D and 8-Channel Construction Sites

Construction at the 3D and 8-Channel study sites was recommended based, in part, on surface water – groundwater relations. At the 3D project site, the right bank floodplain was graded to allow inundation at approximately 250 cfs. The floodplain surface was lowered, thereby reducing the depth to the groundwater table. At the 8-Channel, the previously blocked side-channel entrance was excavated and the side-channel contoured to improve flow access (reducing the side-channel entrance flow threshold from greater than 2,000 cfs to approximately 250 cfs). Each of these projects potentially increases groundwater availability for riparian vegetation.

On August 12 and 13, 2003, McBain and Trush installed nine piezometers at the Rush Creek 3D site and five piezometers at the 8-Channel sites (Figures 9 and 10). Monitoring objectives at both sites are to: (1) observe seasonal groundwater elevations and soil moisture conditions, and their response to streamflows, and (2) observe natural recruitment of riparian vegetation and relate this to groundwater and soil moisture conditions. Of particular interest is the duration of elevated groundwater and soil moisture conditions (the groundwater “signature”) caused by overbank flows, floodplain inundation, and increased side-channel flow during the snowmelt flood

Piezometers were installed by excavating a test pit with a backhoe, setting the piezometer vertically into the pit, and then backfilling the pit with the excavated material. Each test pit was described using the conventions of the Unified Soil Classification System (USCS) (ASTM 2000), which includes descriptions of stratigraphy and general particle size information. Test pits at the 3D site were excavated between 4.5 and 6.0 ft below ground surface (BGS), and 8-Channel test pits were excavated to between 7.5 and 11.5 ft BGS. In general, each pit contained well-graded sandy gravels and gravelly sands. Groundwater was encountered in every test pit except 8C-5, ranging from 2.5 to 6.0 ft BGS at the 3D site and from 5.5 to 7.5 ft BGS at the 8-Channel site. Test pit 8C-5 was dry to 11.5 ft BGS.

Piezometers were installed after excavating each test pit. Each piezometer was constructed of 2-inch diameter PVC pipe that has its lower portion perforated to allow water to flow freely but reduce sediment from entering. The piezometers were capped at their base and have a threaded cap at their top. The pit was then carefully backfilled by the backhoe to the approximate original ground surface elevation, leaving one to two feet exposed above ground level (Figures 11 and 12). After a piezometer was set, we installed a threaded cap that could be removed to record groundwater depth. A small notch was cut on top of the pipe under each cap, on its north side to serve as a reference point for all measurements. The top of the pipe next to the notch on each piezometer was then surveyed to establish its elevation in real coordinates.

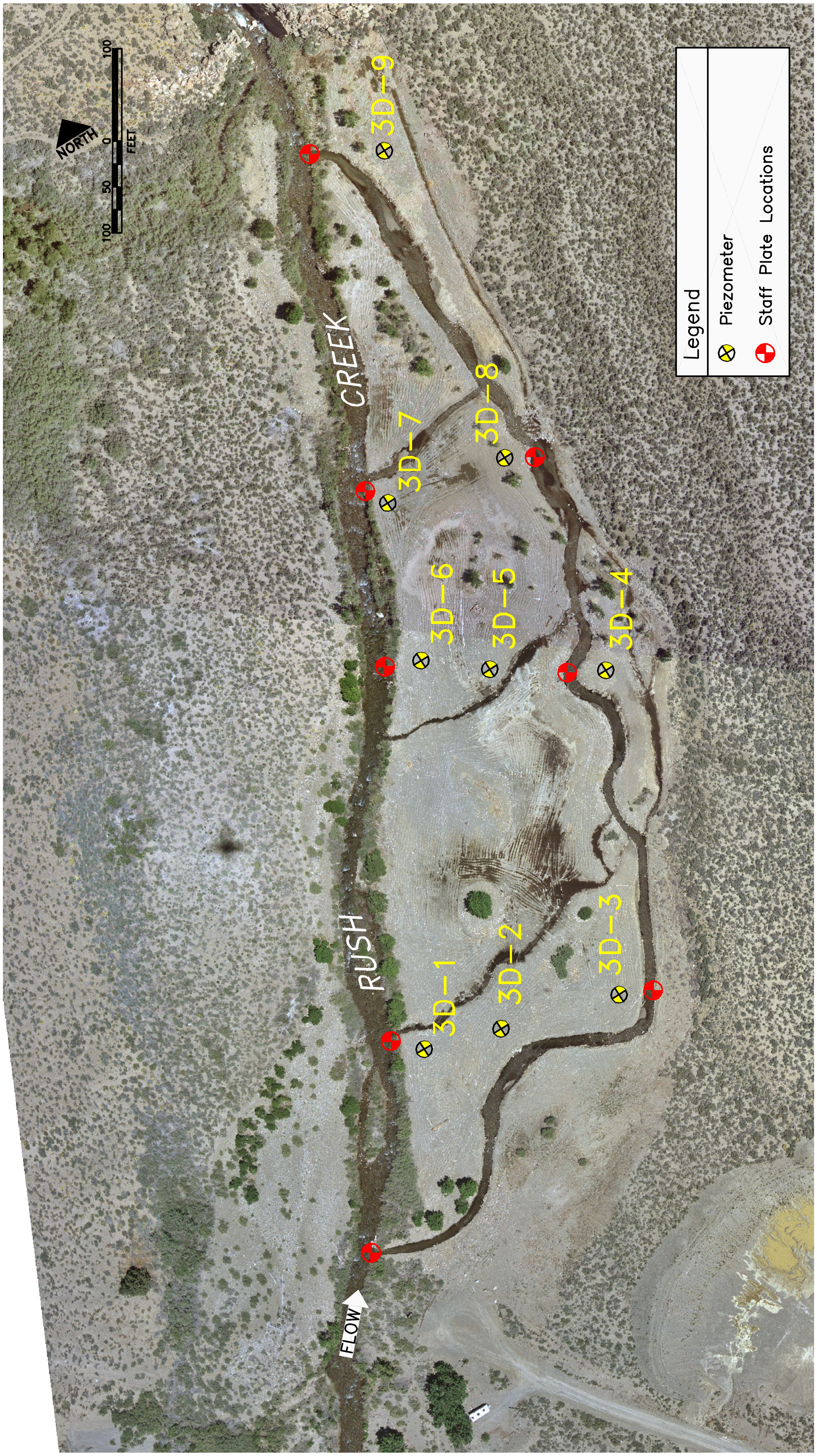


Figure 9. Aerial photograph of the Rush Creek 3D floodplain site, showing the location of piezometers and staff plates.

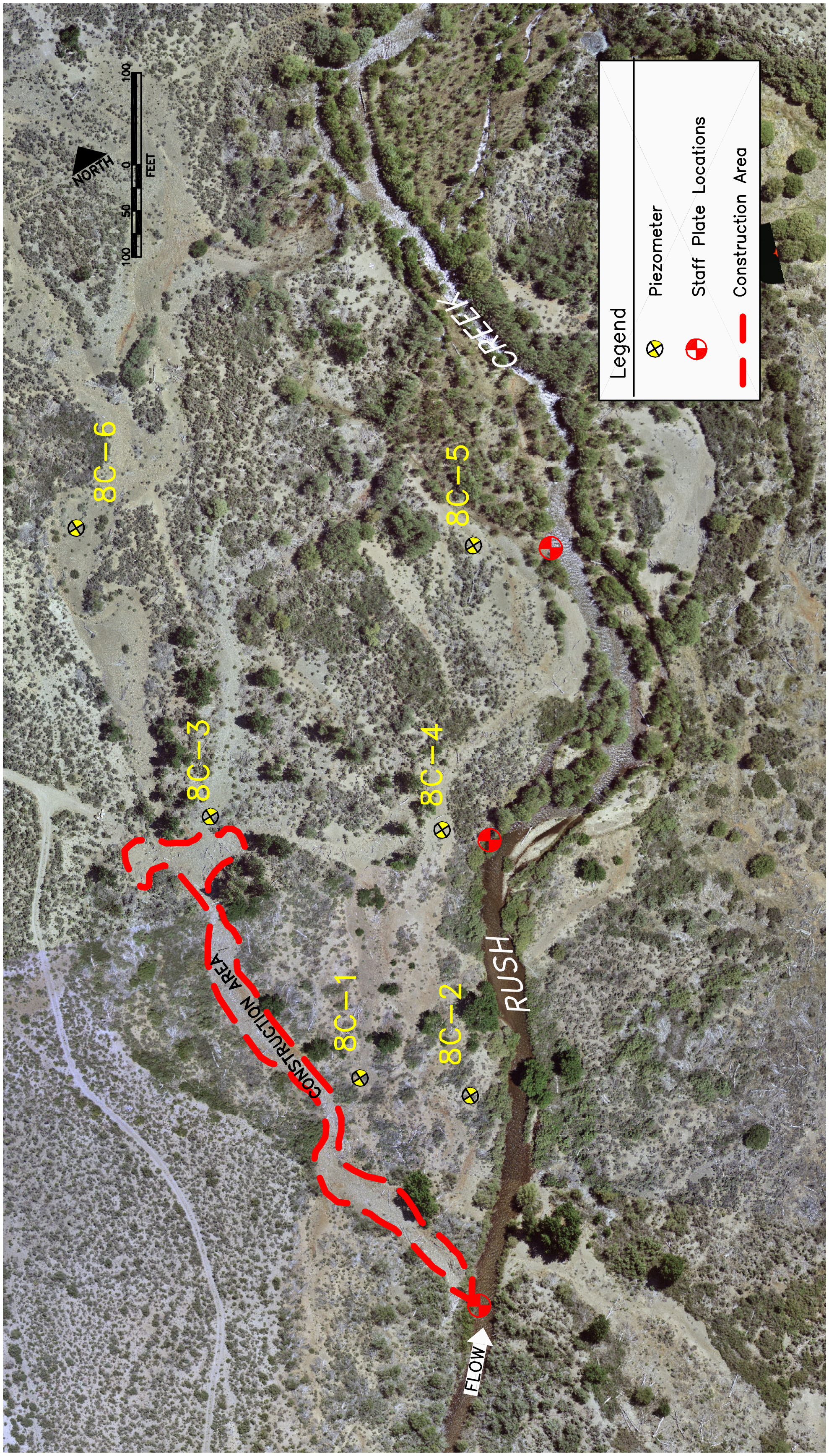


Figure 10. Aerial photograph of the Rush Creek 8-Channel site, showing the location of piezometers and staff plates.

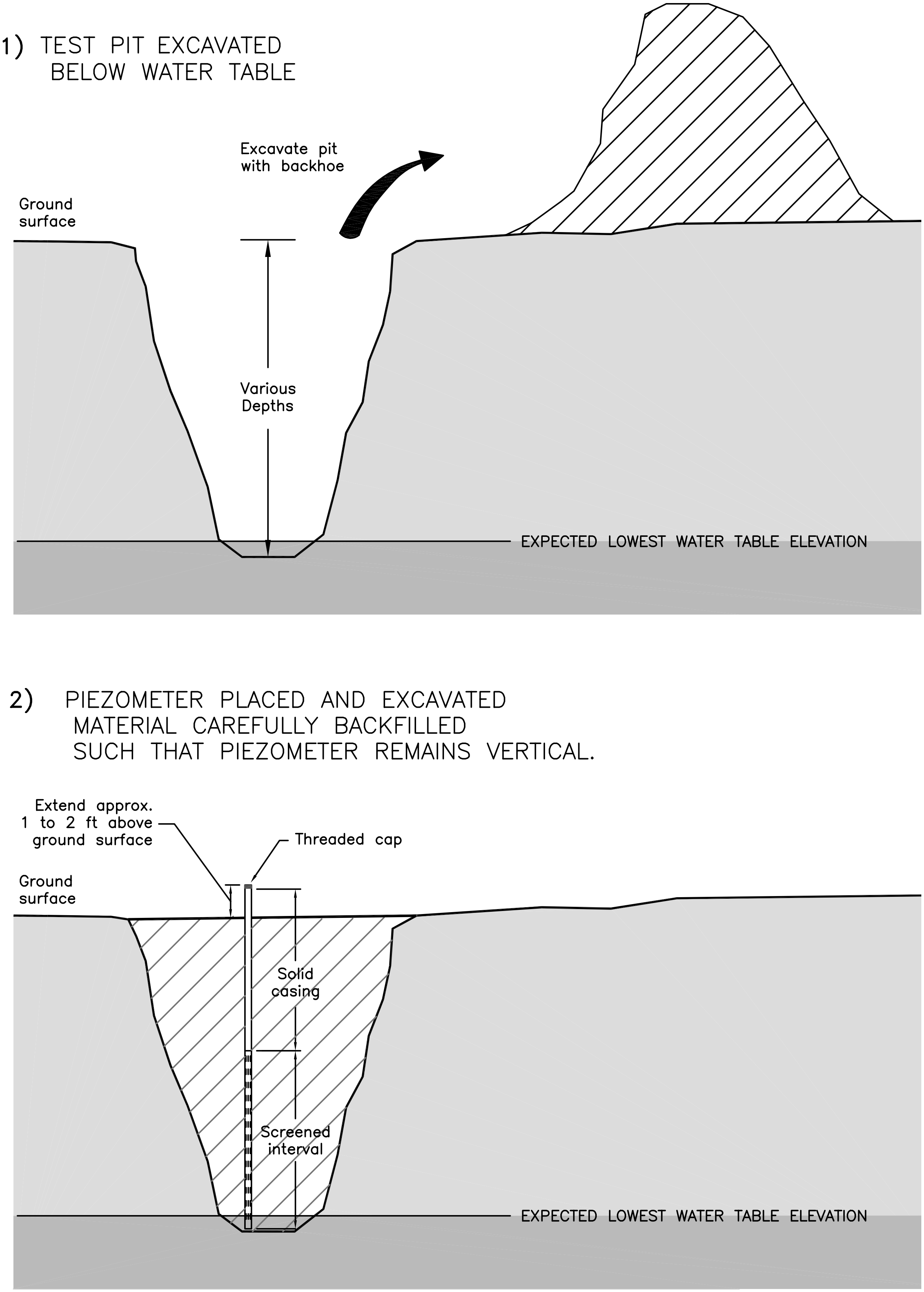


Figure 11. Schematic drawing of test pit excavation and piezometer installation methods.

Figure 12. Photograph of a piezometer at the 8-Channel construction site immediately following installation.

2.3.5 Groundwater Behavior at Rush and Lee Vining Creek Study Sites

Based on the concepts described in Section 2.3.2 and data evaluated in Section 2.3.4, hypotheses of groundwater and surface water are presented, accompanied by current groundwater findings and initial analyses.

Hypothesis 1: **Streamflow at Rush Creek and Lee Vining Creek study sites is generally losing, however short-term reversals (gaining) are possible.** Losing streamflow conditions have been documented during synoptic stream gaging on Rush Creek and Lee Vining Creek (Kondolf 1989; McBain and Trush 2003). Monitoring results reported by Balance Hydrologics (1993) also document losing conditions. Their report noted that "water was generally infiltrating from the creeks into the alluvial sediments and that stream stage controlled the depth to ground water in the alluvial corridors and bounding terraces."

Our analysis of two selected years of data collected by MLC on Lee Vining Creek show both losing and gaining conditions. Limited analyses were performed for this report because we only recently received aerial photographs and a digital terrain model (DTM) which allowed us to plot topography in relation to measured groundwater elevations at MLC piezometer monitoring sites. In addition, piezometer casing elevations have been surveyed only at the Lee Vining Creek B- and C-arrays (Figure 13), so our analysis was limited to these specific locations where topography and groundwater elevations were referenced to the same datum. Because the MLC data set is extensive, we selected a subset of groundwater measurements at the B- and C-array piezometers based on runoff year type and season. Using comparatively wet and dry runoff years (RY 1998: Wet-Normal, and RY 2002: Dry-

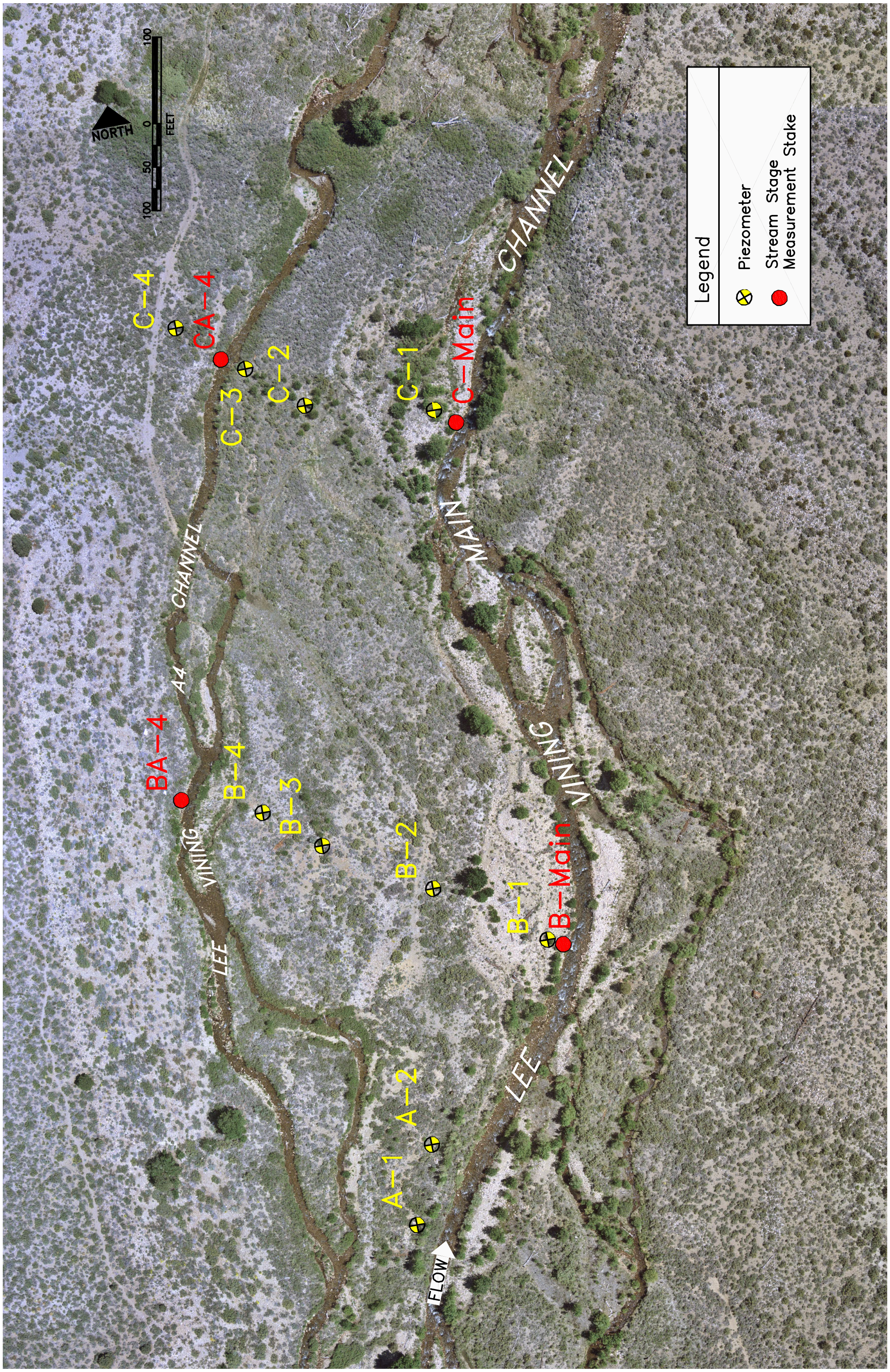


Figure 13. Aerial photograph of Lee Vining Creek A-, B-, and C- piezometer arrays, and metal fence posts used as staff gages to determine stream water surface elevations.

Normal I), we selected data from four months (October, May, June, and August) to provide a seasonal range of groundwater table elevations at these arrays. Plots of these elevations for the B- and C-arrays are in Figures 14 and 15, respectively.

Groundwater table elevations at the B-array (Figure 14) show consistent losing streamflow conditions at the Lee Vining main channel, but a combination of losing and gaining at the A-4 channel. This condition is expected as groundwater flows from high to low elevations. Groundwater table elevations at the C-array, however, show a different relation to streamflow. Streamflow at the C-array appears mostly gaining, driven by a pronounced mound in the groundwater table at piezometer C-2 (Figure 15). At this time we do not know exactly what is causing the mounding. Several explanations are possible, but are premature without additional analysis (e.g., additional months from 1998 and 2002 and/or additional years). In addition to cross sectional groundwater table gradients, we reviewed the groundwater elevations across different runoff years. The 1998 groundwater elevations (Wet / Normal runoff year type) are all higher than the 2002 groundwater elevations (Dry / Normal I runoff year type), suggesting that the groundwater table may be higher in wetter runoff years. This is supported by groundwater elevations during similar magnitude daily average flows in each runoff year. For example, daily average streamflow on October 8, 1997 (27 cfs) is much higher than the groundwater table elevation recorded on August 30, 2002 (for a streamflow of 24 cfs).

<u>**Hypothesis 2**</u>: **Groundwater elevation responds to variations in streamflow and the responsiveness of the water table decreases with increasing distance from the channel.** Analysis of streamflow and groundwater data by Balance Hydrologics and MLC shows that groundwater rises and falls with even subtle changes in stream stage. Based on their monitoring at all sites (Lee Vining, Rush, Walker, and Parker creeks), Balance Hydrologics concluded that “groundwater levels generally rose and fell with stream levels, even several hundred feet from the creeks and extending under the terraces that bound the alluvial corridors”. Monitoring by MLC also supports this conclusion: groundwater data from the B- and C-arrays on Lee Vining Creek showed that these piezometers respond quite rapidly to changes in streamflow. The response of each piezometer to changes in streamflow differs slightly, but overall changes in streamflow are translated directly to groundwater elevations.

The relationship between streamflow and groundwater elevation can be illustrated using the complete MLC monitoring record for the B- and C-array piezometers (Figures 16 and 17; Appendix A). A hydrograph was generated for the Lee Vining Creek mainstem above the B-connector channel based on daily average discharge for each groundwater monitoring date (beginning June 1995 and continuing through December 2003). Corresponding groundwater hydrographs for the piezometers (B1 through B4, and C1 through C4) are plotted with the streamflow hydrograph to illustrate similar hydrograph shapes and response times. Note that the plotted hydrograph represents *daily average* streamflow, which may not necessarily reflect actual flow conditions when the groundwater measurements were made, particularly for measurements during rapidly changing stage. Future work to relate streamflow magnitude to groundwater elevation should not use daily average data; rather, this relation should use recorded streamflow as close as possible to the time groundwater was measured (e.g., 15-minute data). In addition, we are in the process of receiving the raw field measurement forms from MLC, which may contain additional information to help qualify individual measurements.

Rapid groundwater response to changes in stream stage has been documented by MLC on Rush and Lee Vining creeks (Figures 16 and 17). Similar rapid response was documented by Balance Hydrologics (1993); however, many Balance Hydrologics piezometers are located farther from the wetted channel than those monitored by MLC (up to several hundred feet farther). Balance Hydrologics’ recorded fluctuations in stream stage and groundwater elevation show that the magnitude of groundwater change decreases with increasing distance from the channel, and that the

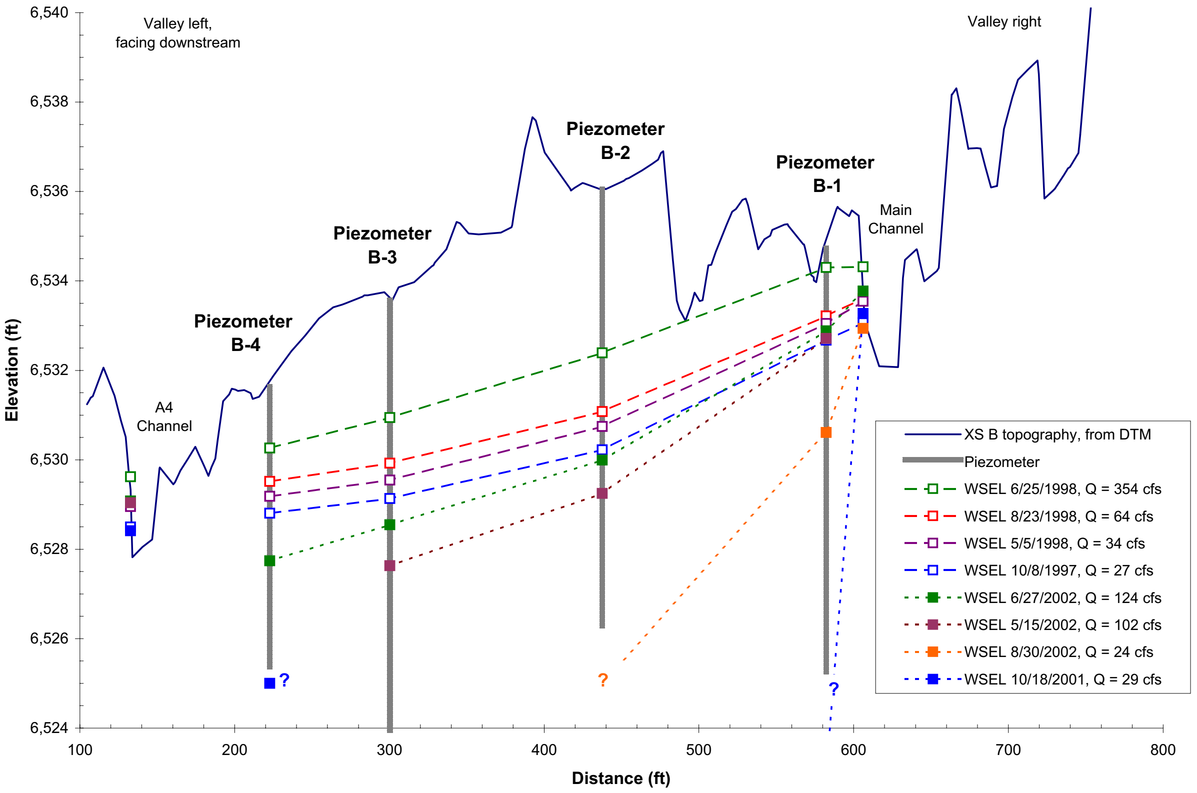


Figure 14. Cross section of Lee Vining Creek B piezometers showing ground topography and selected groundwater elevations from 1998 and 2002. Note that the water table surface in these figures is portrayed as a straight line, created by connecting data points. The actual water table surface is irregular and may mimic the ground topography (Watson and Burnett 1993).

timing (lag) increases with increasing distance from the channel. Although in general, piezometers closest to the channel responded faster with greater magnitudes, responsiveness varied between monitoring sites. This has potentially significant implications for using streamflows to distribute groundwater across the stream valley, as streamflows that may be sufficient to generate suitable groundwater (and soil moisture) conditions at certain sites may be insufficient at others. Moreover, factors other than streamflow play a large role in groundwater distribution (e.g., topographic gradient and variations in soils types). These factors strongly influence the slope at which groundwater interacts with the wetted channel and likely varies from site to site. Without subsurface investigations, these dynamics only can be inferred.

2.3.6 Groundwater Monitoring for RY 2004

A portion of our work outlined for 2004 and 2005 focuses on improving our understanding of the local groundwater – surface water relations, and how these relations affect soil moisture and groundwater availability for woody riparian vegetation. Individual tasks are as follows:

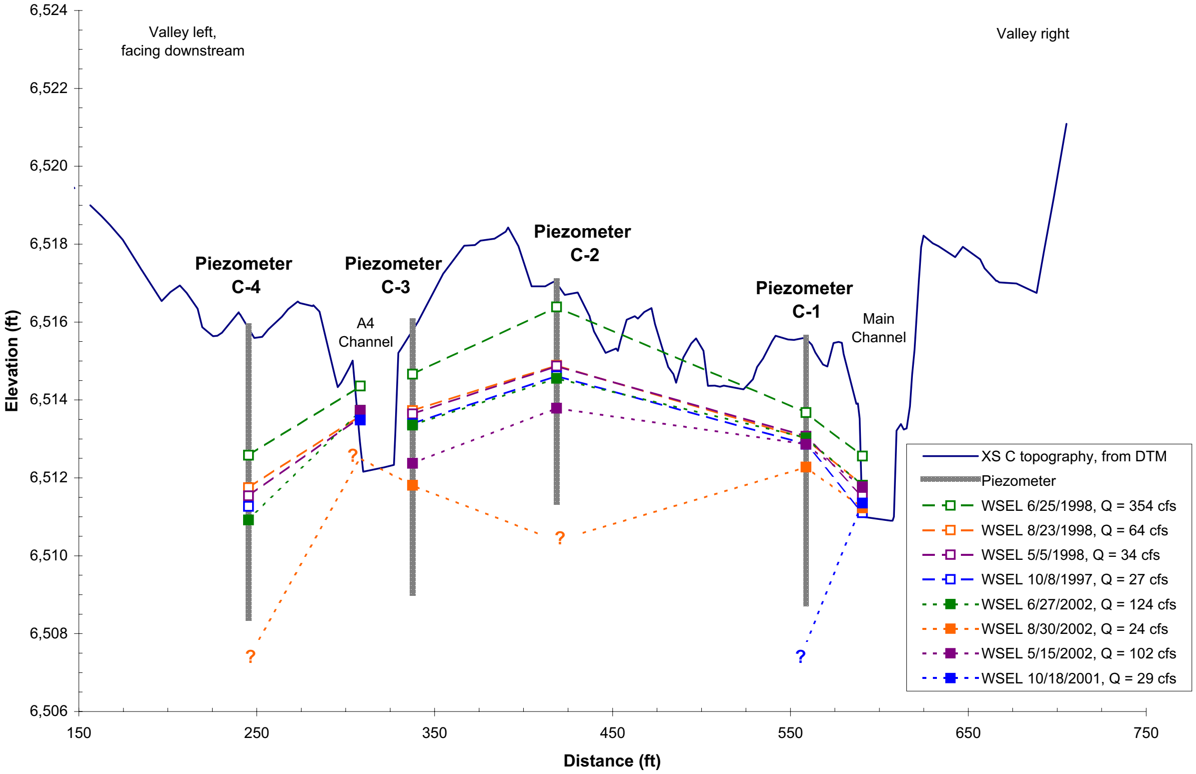


Figure 15. Cross section profile of Lee Vining Creek C piezometers showing ground topography and selected groundwater elevations from 1998 and 2002. Note that the water table surface in these figures is portrayed as a straight line, created by connecting data points. The actual water table surface is irregular and may mimic the ground topography (Watson and Burnett 1993).

Continue analyzing groundwater data collected by the MLC at Rush and Lee Vining creeks. Before additional analysis of the available monitoring data can begin, certain tasks must first be completed, including survey casing elevations for Lee Vining Creek A-array and Rush Creek piezometers and creating topographic profiles from the DTM through Lee Vining Creek A-array and Rush Creek piezometer arrays. After these tasks are completed, we will analyze the groundwater elevation and streamflow data over longer periods to quantify groundwater – surface water relations (e.g., stratify data by runoff year type, season, flow magnitude, mapped vegetation type, and mapped geomorphology). Monitoring to investigate groundwater gradients and their relation to the riparian zone is planned for RY 2004. Based on the extensive MLC groundwater record, we will relate streamflow to groundwater elevation at each piezometer (and possibly for the Balance Hydrologics piezometers), which will prove useful if groundwater responsiveness to streamflow at the monitoring sites can be extrapolated to other areas (e.g., floodplains and low terraces). Assuming future monitoring by the MLC continues at approximately the same schedule, we will incorporate their results with ours. At this juncture, their monitoring frequency appears sufficient for our needs. We also plan to review the MLC piezometer field measurement forms for specific monitoring data that appear anomalous and for any supporting anecdotal information.

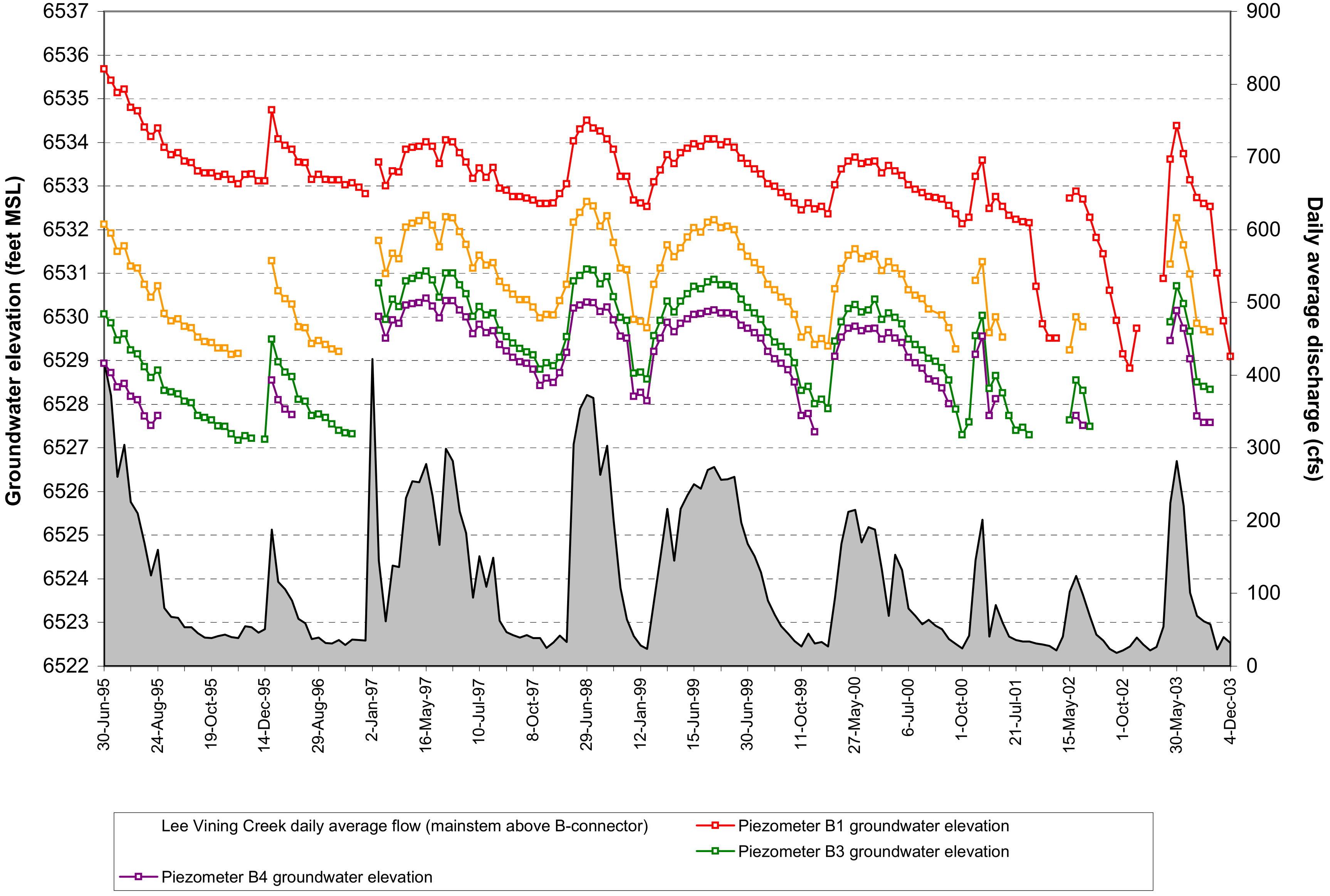


Figure 16. Groundwater and stream hydrographs for the Lee Vining Creek B piezometers, showing groundwater fluctuations and responsiveness to streamflow. Groundwater elevations and flow data are from June 1995 through December 2003.

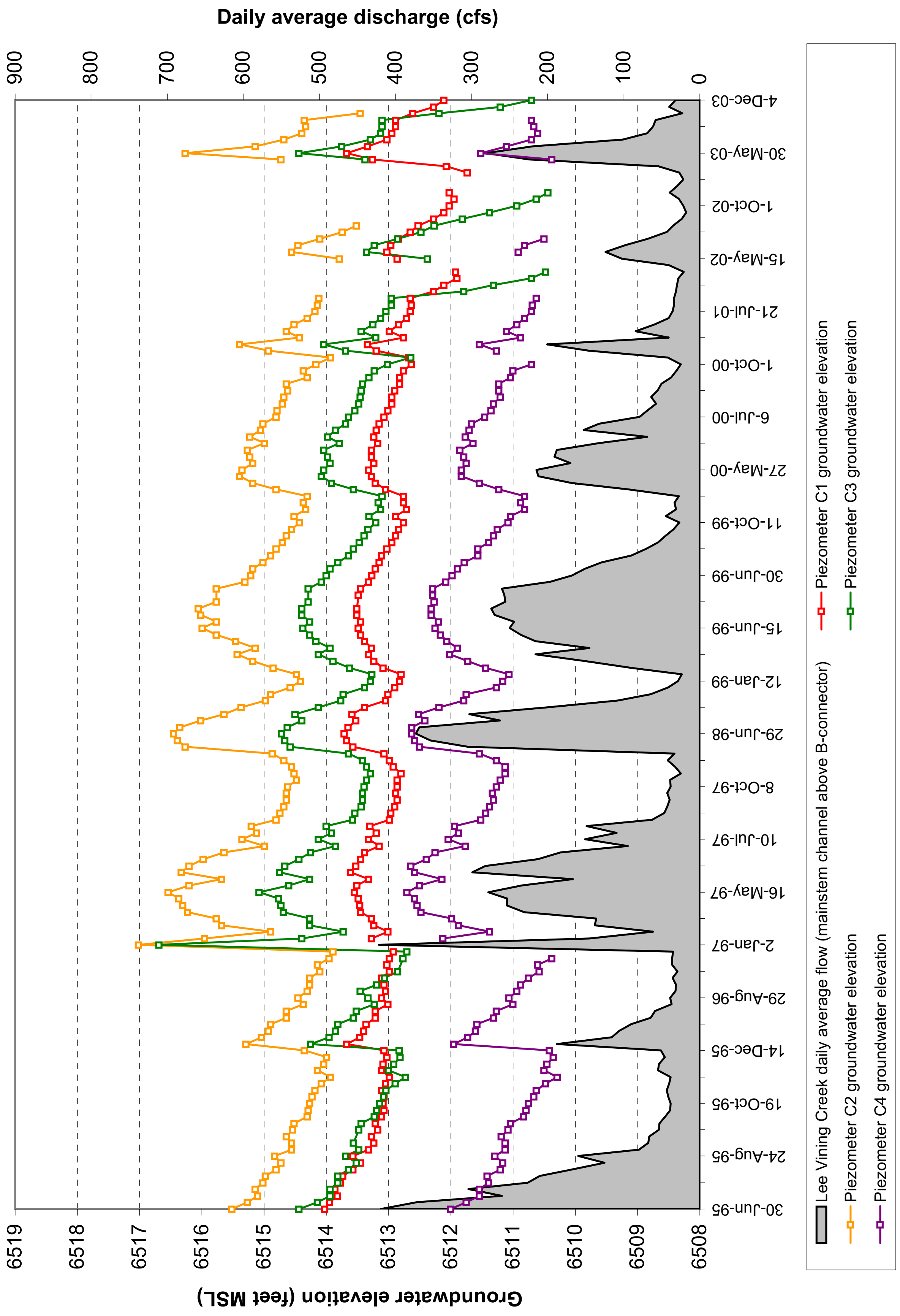


Figure 17. Groundwater and stream hydrographs for the Lee Vining Creek C piezometers, showing groundwater fluctuations and responsiveness to streamflow. Groundwater elevations and flow data are from June 1995 through December 2003.

Piezometer monitoring at 3D construction site and at the 8-Channel floodplain/terrace. Since their installation, piezometers at the 3D floodplain construction site have been monitored twice. Groundwater monitoring will be conducted monthly with more frequent monitoring (e.g., weekly to daily) during the snowmelt runoff. We will install pressure transducers and dataloggers in one piezometer at the 3D site and one at the 8-Channel site to continuously record groundwater elevations, and will use this record to correlate spot elevation measurements from routine monitoring of all other piezometers.

The complex of floodplain and terraces accessed by peak streamflows entering the newly excavated 8-Channel entrance on lower Rush Creek will be closely monitored. The RY 2003 piezometers were installed in six locations spanning contemporary floodplain surfaces to middle terraces. Of particular interest will be whether flood flows temporarily accessing the valley bottom via the 8-Channel will leave its signature on the groundwater table through the summer. We will also be qualitatively examining whether a zone of high soil moisture remains constant but tracks the rise and fall of the groundwater table, or whether it stretches and/or shrinks with changing season and groundwater elevation.

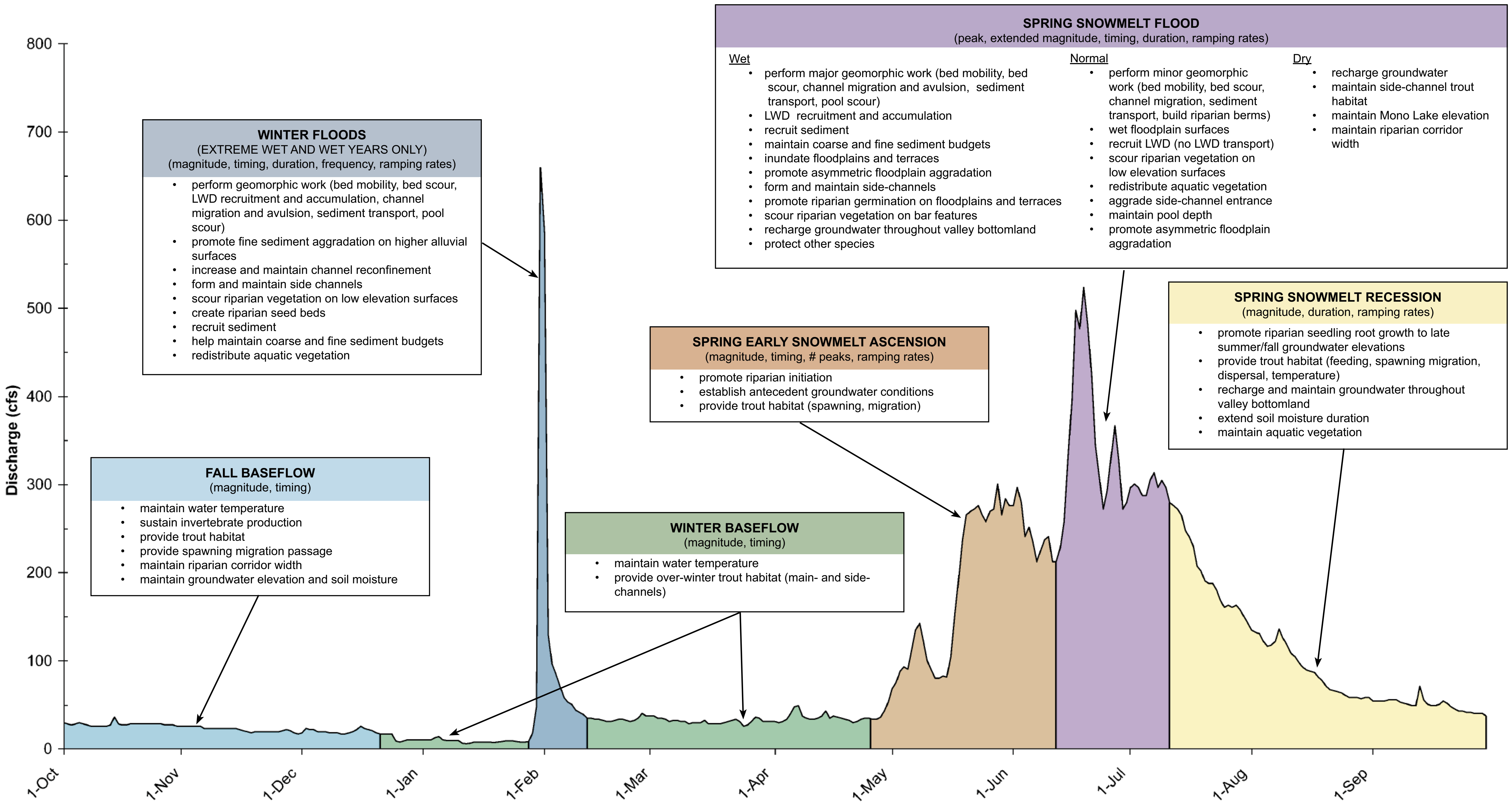
2.4 Unregulated Annual Hydrographs as a Tool for Evaluating SWRCB Stream Restoration Flows

One primary purpose of the Mono Basin monitoring program is to evaluate, and eventually to recommend changing if necessary, the stream restoration flows (SRFs) prescribed in SWRCB Order 98-05. The SRF's are intended to restore Rush and Lee Vining creek ecosystems by *providing proper flow management in a pattern that allows natural stream processes to develop functional, dynamic, and self-sustaining stream systems* (SWRCB Order 98-05 Section 5.1 Paragraph 2). This evaluation has been ongoing, documented in Annual Reports since Runoff Year 1999 (McBain and Trush 2000, 2001, 2002, 2003).

The SRFs are set forth in Order 98-05 for the "Transition" period (before Mono Lake attains 6392 ft) and "Post-Transition" period (once Mono Lake attains 6392 ft). The transition SRF flow schedules are presented in Appendix B. Annual hydrographs for these regulated transition flows are discussed in Section 2.4.1.6.

Flow evaluation requires more than simply monitoring; field data must be compared to quantifiable norms or standards. Development of these norms can be, and usually is, as important as the actual monitoring results. Natural stream processes have been designated as the norm necessary to meet SWRCB Order 98-05.

Magnitude, duration, frequency, and timing of natural stream processes can be quantified by dissecting unregulated annual hydrographs into discrete components, then attributing specific stream processes to each hydrograph component (Figure 18). For example, we have been monitoring gravel and cobble movements on alluvial features (e.g., marked rock movements on point bar surfaces and riffle beds) since 1999 to determine a flow threshold for channelbed mobility. As a natural stream process, channelbed mobility has a magnitude, frequency, duration, and timing. The magnitude is the critical bed shear stress (i.e., in units of lbs/ft^2) produced by the threshold peak flow mobilizing the channelbed. Frequency and timing are related to peak snowmelt runoff, a discrete component of the annual hydrograph. Usually wetter runoff years are necessary to generate threshold peak flows or greater. Therefore the frequency and timing of wetter years set the frequency and timing of channelbed mobility. Duration of channelbed mobility is the most difficult to grasp and quantify. Presumably the longer the threshold flow (or greater flow) continues, a greater percentage of the channelbed surface mobilizes.



SPRING SNOWMELT FLOOD
(peak, extended magnitude, timing, duration, ramping rates)

Wet
- perform major geomorphic work (bed mobility, bed scour, channel migration and avulsion, sediment transport, pool scour)
- LWD recruitment and accumulation
- recruit sediment
- maintain coarse and fine sediment budgets
- inundate floodplains and terraces
- promote asymmetric floodplain aggradation
- form and maintain side-channels
- promote riparian germination on floodplains and terraces
- scour riparian vegetation on bar features
- recharge groundwater throughout valley bottomland
- protect other species

Normal
- perform minor geomorphic work (bed mobility, bed scour, channel migration, sediment transport, build riparian berms)
- wet floodplain surfaces
- recruit LWD (no LWD transport)
- scour riparian vegetation on low elevation surfaces
- redistribute aquatic vegetation
- aggrade side-channel entrance
- maintain pool depth
- promote asymmetric floodplain aggradation

Dry
- recharge groundwater
- maintain side-channel trout habitat
- maintain Mono Lake elevation
- maintain riparian corridor width

WINTER FLOODS
(EXTREME WET AND WET YEARS ONLY)
(magnitude, timing, duration, frequency, ramping rates)
- perform geomorphic work (bed mobility, bed scour, LWD recruitment and accumulation, channel migration and avulsion, sediment transport, pool scour)
- promote fine sediment aggradation on higher alluvial surfaces
- increase and maintain channel reconfinement
- form and maintain side channels
- scour riparian vegetation on low elevation surfaces
- create riparian seed beds
- recruit sediment
- help maintain coarse and fine sediment budgets
- redistribute aquatic vegetation

SPRING SNOWMELT RECESSION
(magnitude, duration, ramping rates)
- promote riparian seedling root growth to late summer/fall groundwater elevations
- provide trout habitat (feeding, spawning migration, dispersal, temperature)
- recharge and maintain groundwater throughout valley bottomland
- extend soil moisture duration
- maintain aquatic vegetation

SPRING EARLY SNOWMELT ASCENSION
(magnitude, timing, # peaks, ramping rates)
- promote riparian initiation
- establish antecedent groundwater conditions
- provide trout habitat (spawning, migration)

FALL BASEFLOW
(magnitude, timing)
- maintain water temperature
- sustain invertebrate production
- provide trout habitat
- provide spawning migration passage
- maintain riparian corridor width
- maintain groundwater elevation and soil moisture

WINTER BASEFLOW
(magnitude, timing)
- maintain water temperature
- provide over-winter trout habitat (main- and side-channels)

Figure 18. Example of a modeled unimpaired hydrograph for Rush Creek (Runoff Year 1963) used to illustrate the important hydrograph components identified for unimpaired Rush Creek flows, and the important ecological functions associated with each component.

Establishing the natural frequency, timing, and duration of channelbed mobility, to define a norm for this natural stream process, requires analysis of unregulated annual hydrographs. Rush and Lee Vining creek daily flows recorded at gaging stations upstream of LADWP's operations have been regulated by SCE's operations. An important task completed in 2003 was development of unregulated annual hydrographs for Rush Creek.

The importance of reconstructing unregulated annual hydrographs can be appreciated from the following steps outlining how the existing SRF's are being evaluated:

STEP 1: Reconstruct unregulated annual hydrographs for all runoff year types, identify annual hydrograph components, then compute the magnitude, duration, frequency, timing, and ramping rates of unregulated flows in each annual hydrograph component.

STEP 2: Identify natural stream processes associated with each annual hydrograph component.

STEP 3: Quantify relationships and thresholds between these natural stream processes and the annual hydrograph components, i.e., the magnitude, duration, frequency, and timing of each natural process.

STEP 4: Prioritize which natural stream processes are necessary to *develop functional, dynamic, and self-sustaining stream systems* and evaluate whether the SRFs provide the magnitude, duration, frequency, and/or timing to restore *functional, dynamic, and self-sustaining stream systems.*

Step 4 would be extremely difficult and less efficient without Step 1.

Steps 1 and 2 are detailed in Section 2.4.1 and 2.4.2 for Rush Creek. Step 3, presented in Section 2.4.3, summarizes monitoring activities and analyses of natural stream processes that are underway, completed in RY 2003, and anticipated in RY 2004. Step 4 is being addressed but is not reported in this Annual Report because field monitoring is ongoing.

2.4.1 STEP 1: Constructing Rush Creek Unimpaired Hydrographs

Describing unregulated hydrology is confounded by SCE hydropower operations at Waugh Lake, Gem Lake, and Agnew Lake (Hasencamp 1994), which modify the daily average flows and flood peaks entering Grant Lake at the "Rush Creek at Damsite" gage (Table 1). Additionally, hydrologic data prior to and during much of the history of diversion by LADWP have largely been compiled as mean monthly records (Trihey and Associates 1993, M. Hanna, personal communication 2004). Because SCE reservoirs were operational prior to 1937 on Rush Creek, all flow data measured on Rush Creek include effects of upstream flow regulation by hydro-generation operations (Appendix C).

Unimpaired daily average flows on Rush Creek at the Damsite were estimated three ways:

COMPUTED UNIMPAIRED: measured impaired flows at the Rush Creek at Damsite are adjusted by storage changes in upstream SCE reservoirs (computed by Hasencamp 1994).

MODELED UNIMPAIRED: Adjusting unregulated flows at Buckeye Creek and Little Walker River based on computed unimpaired water yields at these streams and Rush Creek at Damsite.

COMBINED COMPUTED AND MODELED UNIMPAIRED: Spring snowmelt hydrograph used from the computed unimpaired predictions, and the remainder of the runoff year estimated by modeled unimpaired predictions. This combined method was ultimately used in the hydrograph component analysis.

Table 1. Summary of local gaging stations and measurement locations used in estimating Rush Creek unimpaired hydrographs.

Location	Upstream regulation	Type of data reported	Drainage area (mi^2)	Operator	Station ID	Period of Record used
Rush Creek above Grant Lake	SCE reservoirs	Daily average flow	51.3	USGS	10-287400	1937-1979
Rush Creek at Damsite	SCE reservoirs	Monthly average flow	51.3	LADWP	unknown	1980-1990
Rush Creek at Damsite	SCE reservoirs	Daily average flow	51.3	LADWP	unknown	1990-2003
Waugh, Gem, and Agnew lakes	SCE reservoirs	Daily storage change	unknown	SCE	unknown	1941-2003
Lee Vining Creek near Lee Vining	SCE reservoirs	Daily average flow	34.9	USGS	10-287900	1935-1979
Lee Vining Creek near Lee Vining	SCE reservoirs	Monthly average flow	34.9	LADWP	unknown	1980-1990
Lee Vining Creek near Lee Vining	SCE reservoirs	Daily average flow	34.9	LADWP	unknown	1990-2003
Buckeye Creek near Bridgeport	None	Daily average flow	44.1	USGS	10-291500	1954-1979, 1997-2001
Little Walker River near Bridgeport	None	Daily average flow	63.1	USGS	10-295500	1945-1986, 1996-2001

2.4.1.1 Method 1. Computed Unimpaired Hydrographs

Unimpaired flows are computed by estimating the inflow to SCE reservoirs from the daily reservoir storage change and adding this flow to measured flows at LADWP gaging station data. These computed unimpaired discharge values are synthetic (i.e., they are not measured flows), and are useful to evaluate changes in the magnitude, duration, and timing of unimpaired flows resulting from operations upstream of the gaging stations. The archived records for daily reservoir storage change from SCE are not readily available, but the computed unimpaired annual hydrographs between May 1 and August 31 were produced for Runoff Years 1941 to 1994 by Hasencamp (1994). Only mean monthly SCE reservoir storage changes were available for Runoff Years 1995 to 2003, therefore we excluded these years from our computations. Annual hydrographs of computed unimpaired data from

1941-1994 are presented in Appendix C. While these hydrographs are missing many components (due to reservoir storage), they most accurately predict the spring snowmelt hydrograph, including the annual maximum daily flood peak during the snowmelt runoff, the timing and duration of snowmelt peaks, and the snowmelt recession period (discussed below).

As an example of the utility of the unimpaired flow data, we compared RY 2003 unimpaired flows to the measured flows on Rush and Lee Vining creeks. The Rush Creek computed unimpaired flow (Rush Creek Runoff) peaked at 460 cfs on June 19, 2003 (Figure 19), with a flood recurrence interval of 1.7 years, using the unimpaired flood record. The computed unimpaired flow remained above 300 cfs for 21 non-consecutive days between May 27 and June 21. The unimpaired peak flow below the Narrows peaked at 518 cfs on June 19, remained above 300 cfs for 38 days (all of June) and above 400 cfs for 14 days. This unimpaired flood also had a recurrence interval of 1.7 years. SCE reservoir operations therefore reduced the snowmelt peak for Rush Creek from approximately 460 cfs to the actual Rush Creek at Damsite flow of 311 cfs, reduced the peak duration by approximately 54 days, and likely altered the flood peak timing, although this cannot be determined with the existing computed unimpaired flow data which uses the mean monthly storage change instead of the mean daily storage change.

The computed unimpaired peak for Lee Vining Runoff was 376 cfs on May 30, which was slightly larger than the measured flow for Lee Vining Creek above Intake (Figure 20). This unimpaired peak flow had a recurrence interval of approximately 4.3 years using the unimpaired peak flood record. The unimpaired peak flows remained above 300 cfs for 14 consecutive days, from late May into June.

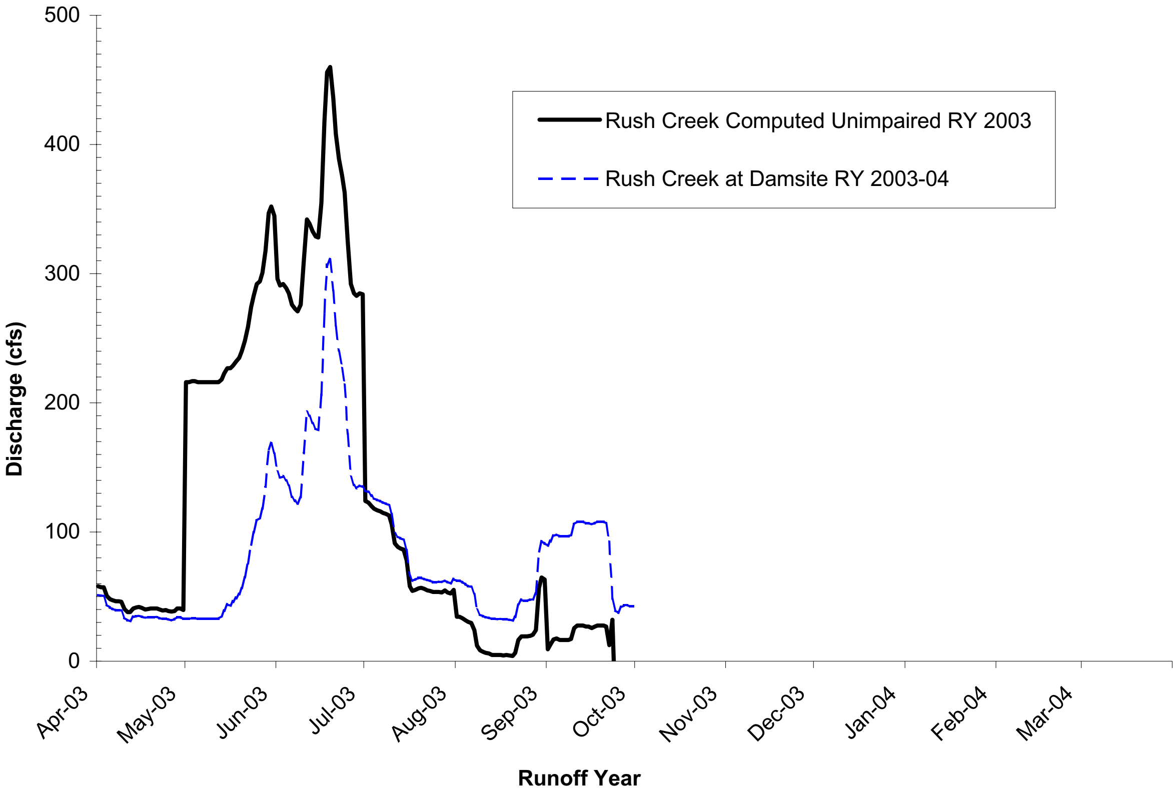


Figure 19. Computed unimpaired hydrographs for Rush Creek, representing unimpaired flows entering Grant Lake, and below the Narrows.

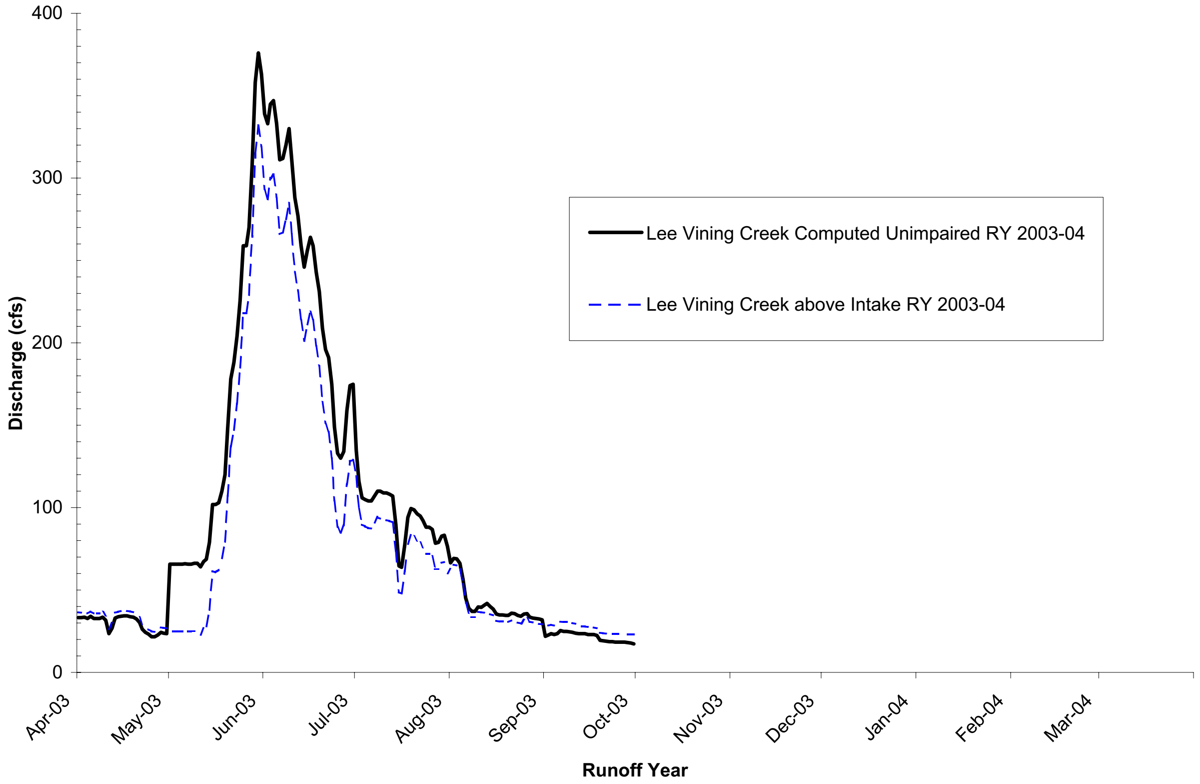


Figure 20. Computed unimpaired hydrographs for Lee Vining Creek, representing unimpaired flows at the Lee Vining Creek intake structure.

2.4.1.2 Method 2. Modeled Unimpaired Hydrographs

Because this Rush Creek computed unimpaired data set does not contain all hydrograph components needed to complete Step 1, we developed "modeled unimpaired" hydrographs for the Rush Creek at Damsite location by correlating nearby unregulated streams. Buckeye Creek near Bridgeport (USGS 10-291500) and Little Walker River (USGS 10-295500) were identified as candidates for correlating with Rush Creek. Daily average flows for a given runoff year were estimated using the following ratios of annual water yield:

$Ybuckeye_i$=Annual water yield for Buckeye Creek for a given year "i"

$Yrush_i$=Unimpaired annual water yield for Rush Creek for a given year "i" as measured at the Rush Creek at Damsite gaging station

$Qrush = (Yrush_i/Ybuckeye_i)Qbuckeye$

$Ywalker_i$=Annual water yield for Little Walker River for a given year "i"

$Yrush_i$=Unimpaired annual water yield for Rush Creek for a given year "i" as measured at the Rush Creek at Damsite gaging station

$Qrush = (Yrush_i/Ywalker_i)Qwalker$

The main assumption of this approach is that Buckeye Creek and Little Walker River watersheds experience storm and snowmelt runoff patterns (winter floods, spring snowmelt timing, etc.) similar to Rush Creek. This modeling procedure essentially fits an unimpaired hydrograph *shape* to the known Rush Creek runoff *volume* using the ratio of annual yields.

Following conversion of the data, Little Walker River and Buckeye Creek data were plotted as annual hydrographs superimposed onto the Rush Creek data to examine the "fit." The magnitude and timing of runoff events for the modeled Buckeye and Little Walker River data were similar, supporting the assumption that watersheds in the region experience similar precipitation and runoff patterns. Modeled Rush Creek unimpaired snowmelt hydrographs from the Little Walker River data did not fit the Rush Creek computed unimpaired data for the same snowmelt runoff period as well as the Buckeye Creek data. Little Walker River drainage area was larger than Rush Creek and Buckeye Creek, yet the unit runoff was less than both creeks. Additionally, the USGS records state "small diversions above the station." For these reasons, only the Buckeye Creek data were analyzed further.

The Rush Creek computed unimpaired data are likely the most accurate at representing snowmelt runoff because they are computed from daily values of actual runoff and upstream reservoir storage changes. These computed unimpaired hydrographs have higher snowmelt peaks than the modeled unimpaired data; for example, the first three years of Wet/Normal and Normal runoff years (1973-75) had computed unimpaired peaks from 100 cfs to 240 cfs higher than the modeled unimpaired peaks. During dry runoff year types (1976-77), snowmelt peaks were more similar in magnitude, although the computed unimpaired snowmelt hydrographs were still slightly higher. The timing and duration of high flow events are similar for the computed and modeled data.

The non-snowmelt period is probably best represented by the modeled unimpaired data because the daily average computed unimpaired flows from SCE reservoir storage change do not exist for the non-snowmelt period, and because the modeled unimpaired data do not predict negative flow values. Therefore, for analyzing hydrograph components we synthesized the two predictions of unimpaired Rush Creek hydrographs as follows (Method 3):

- March to August: Computed unimpaired data from Method 1.
- September to April: Modeled unimpaired data from Method 2.

Modeled unimpaired hydrographs and computed unimpaired hydrographs for Rush Creek were plotted with the regulated Rush Creek at Damsite data hydrographs for Runoff Years 1973 to 1979 in which all three methods overlapped (Figure 21). The regulated data at Rush Creek at Damsite show the effects of SCE operations on Rush Creek annual hydrographs (hydrographs in Appendix C also provide this comparison). The spring snowmelt hydrograph is reduced in magnitude in all runoff year types, whereas baseflow magnitudes throughout the late-summer and fall are elevated relative to unimpaired flows. Peak flows entering Grant Lake also occur later in the season than the unimpaired peak flows. These changes in streamflow were also documented in Hasencamp (1994). Winter peaks apparent in the modeled unimpaired data do not occur at the Grant Lake gaging station because the near-empty SCE reservoirs capture these peaks. While not apparent in the daily average unimpaired data, diurnal fluctuations in flow are common to snowmelt dominated streams. These daily fluctuations are also masked by SCE operations for the streamflows recorded at the Damsite gage.

2.4.1.3 Methods for Hydrograph Component Analysis

Hydrographs from Method 3 were used to compute summary statistics describing the magnitude, duration, frequency, timing, and ramping rates for individual hydrograph components for different runoff year types. The resulting hydrographs from Method 3 are named "unimpaired hydrographs" for the remainder of this section.

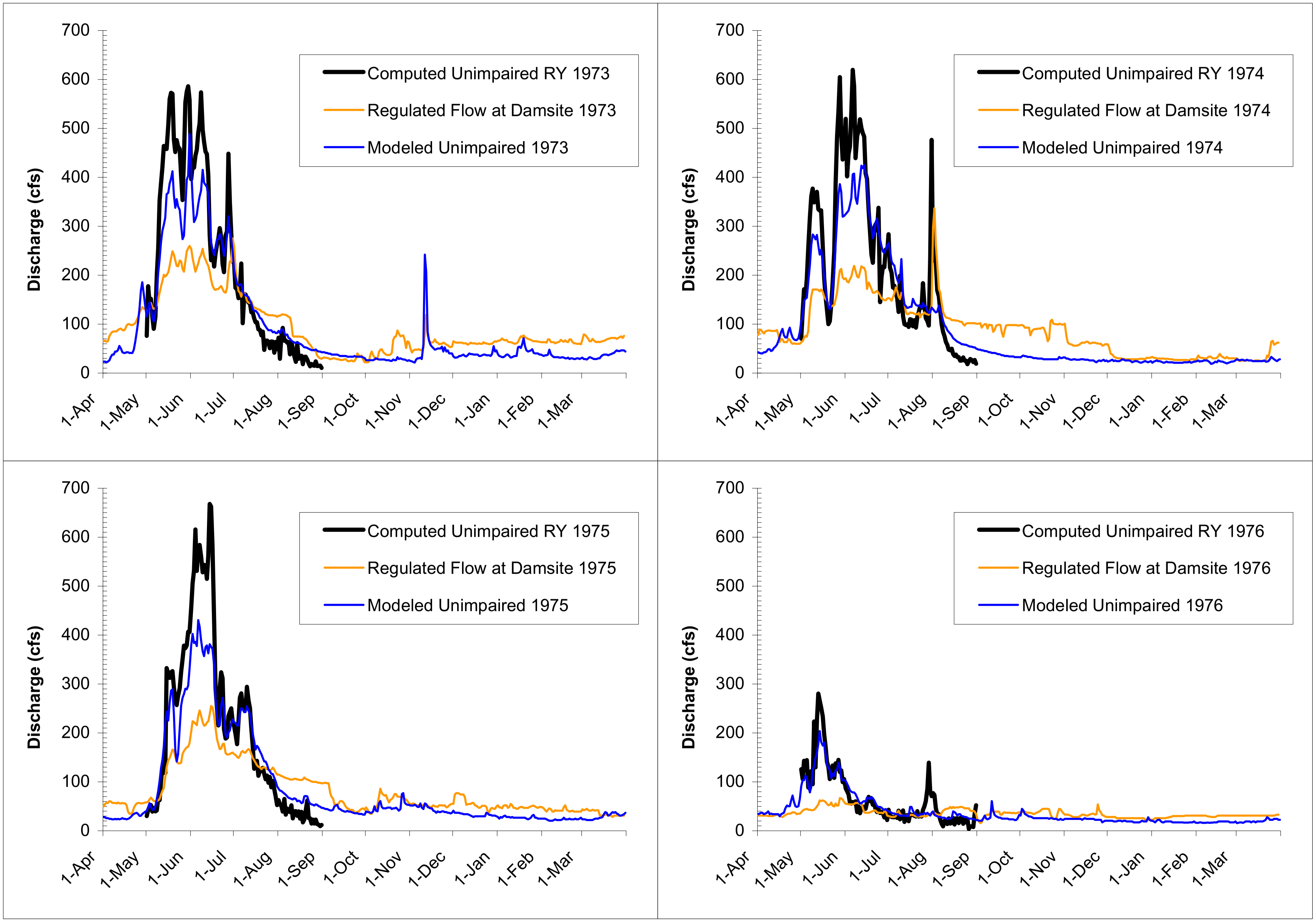


Figure 21. Comparison of Rush Creek computed and modeled unimpaired hydrographs, and the regulated flows from Rush Creek at Damsite for Runoff Years 1973-79 (the only years where all three data sets overlapped). The computed unimpaired data are available for only the snowmelt runoff period (May 1-August 31).

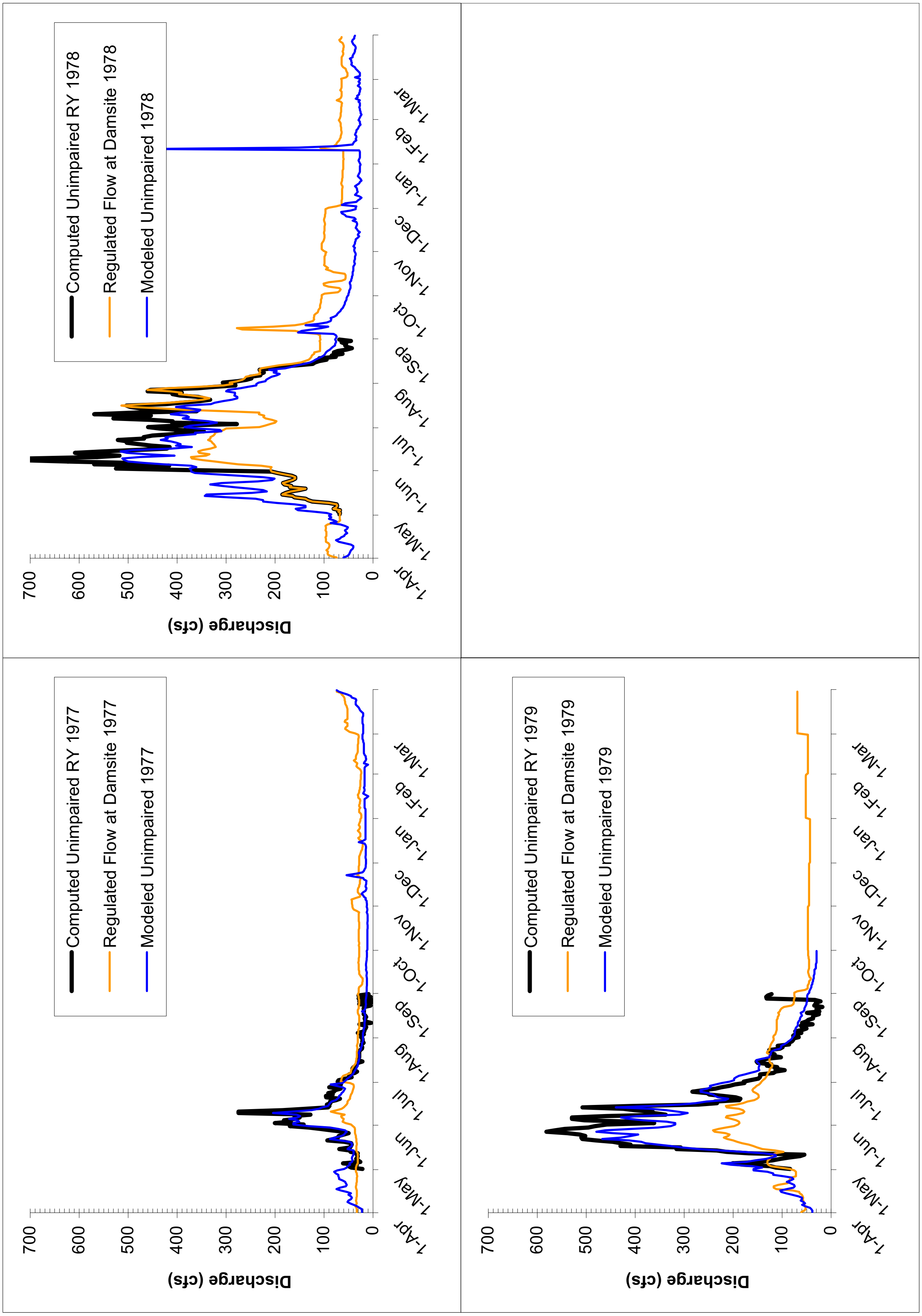


Figure 21. Continued..

The analytical process of describing magnitude, duration, frequency, timing, and ramping rates is called a "hydrograph component analysis," and begins by examining annual unimpaired hydrographs to identify discrete seasonal patterns in flow (each called a "hydrograph component"). Most unimpaired annual hydrographs for Rush Creek at Damsite exhibited distinct snowmelt runoff and low flow periods. Examined closely, however, the hydrographs differed in seasonal baseflow magnitude, occasional winter flood peaks resulting from rain-on-snow events, and distinct phases to the snowmelt runoff. Important hydrograph components identified on Rush Creek were:

- fall baseflow (magnitude and timing)
- winter baseflow (magnitude and timing)
- winter floods (magnitude, timing, duration, frequency, ramping rates)
- spring snowmelt ascension and secondary peaks (magnitude, timing, # peaks, ramping rates)
- annual snowmelt peak (peak magnitude, timing, and duration; extended snowmelt magnitude and duration)
- snowmelt recession (recession rates, extended recession magnitude and duration)

We next used the annual yield to assign each runoff year to one of seven runoff year types identified by Order 98-05 (Table 2). Total annual yields were ranked from wettest to driest years, the percent of average yield was computed, and the appropriate year type designation was assigned (Figure 22). Annual yield for the four Mono Lake tributaries combined (Rush, Parker, Walker, and Lee Vining) were used to compute the year type designations for the period of record 1941 to 2003 (Table 3).

Once each runoff year was assigned a year type, runoff years of each year type were grouped and statistics computed for magnitude, duration, frequency, timing, and ramping rates for each hydrograph component. For example, the fall baseflow statistic for each runoff year was the *median* daily average flow from October 1 to December 20. Fall baseflow for each runoff year type was computed as the median of the medians from the individual runoff years.

Hydrograph component analysis reduces variability within each hydrograph component for a given runoff year type, but preserves inter-annual variability in the same component among all runoff year types. Inter-annual patterns in flow magnitude, duration, and timing do not always meet our expectations. For example, Extreme Wet years do not *always* have the largest flow magnitude and duration, nor do Dry years always have the smallest.

2.4.1.4 Results of Hydrograph Component Analysis

In the following sections we describe the magnitude, duration, frequency, timing, and rates of change for each unregulated hydrograph component. We do not quantify Rush Creek annual hydrographs and components below the Narrows in this Annual Report. Higher streamflows below the Narrows are due to inflow of Parker and Walker creeks. Results from the hydrograph component analysis are summarized in Table 4.

Fall baseflow: Occurring between October 1 and December 20, this hydrograph component often included the single lowest daily average flow of a runoff year. In wetter runoff years, fall baseflows steadily decreased through the fall. Thus fall baseflows were strongly influenced by the magnitude and timing of the snowmelt peak and recession; the magnitude generally descended slowly into winter, ranging from 18 to 42 cfs, punctuated only by infrequent late-fall thunderstorms or early-winter floods (e.g., RYs 1964, 1967, and 1974). Variability within each runoff year type was minimal. The maximum computed baseflow in the fall for any runoff year was 50 cfs in RY 1956.

Table 2. Runoff year types and the range of annual yields used to determine the Stream Restoration Flows for the Mono Basin tributaries.

Runoff Year Type	Runoff Range (acre-feet)	Percent of Average Runoff	Exceedence Probability
Extreme Wet	>195,400	>160%	8%
Wet	166,700 - 195,400	136.5% - 160%	20%
Wet-Normal	130,670 - 166,700	107% - 136.5%	40%
Normal	100,750 - 130,670	82.5% - 107%	60%
Dry-Normal II	92,207 - 100,750	75.5% - 82.5%	70%
Dry-Normal I	83,655 - 92,207	68.5% - 75.5%	80%
Dry	<83,000	<68.5%	100%

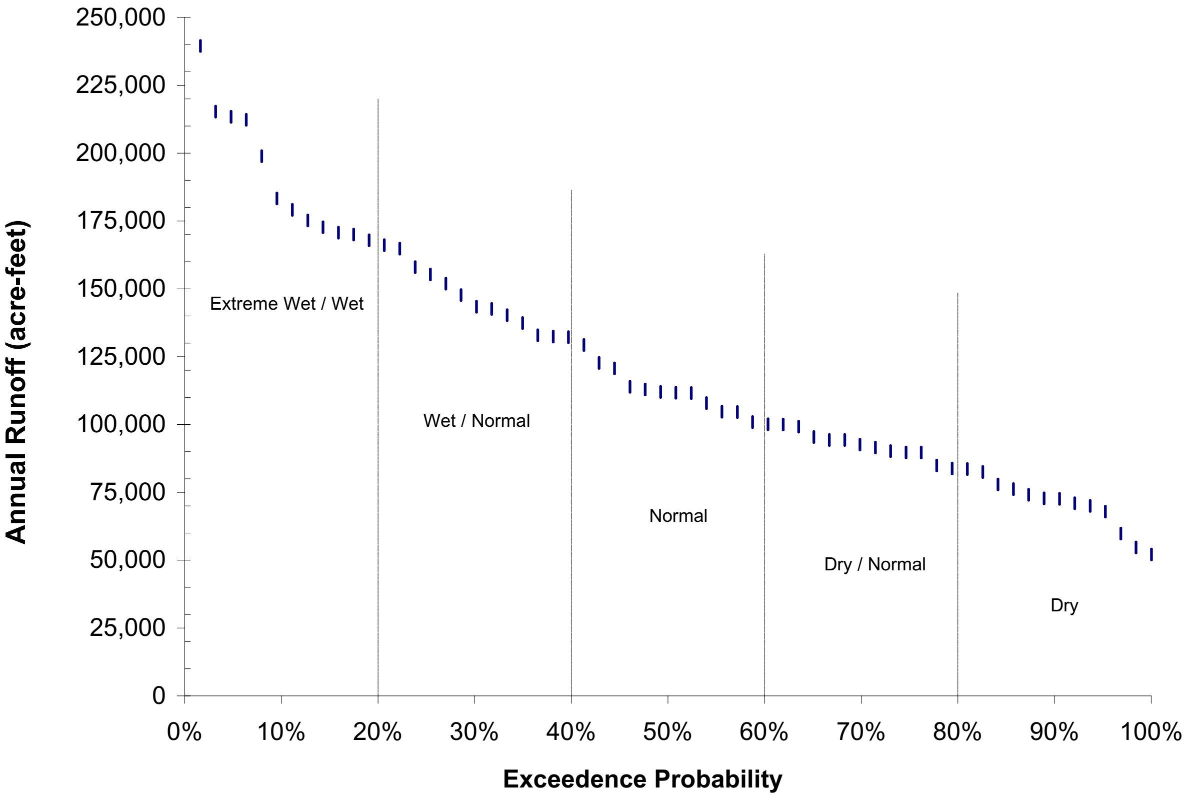


Figure 22. Distribution of annual runoff (acre feet) for the combined Mono Basin tributaries (Rush, Parker, Walker, and Lee Vining creeks) for the available period of record. The runoff year types were based on five classes of equally weighted exceedence probabilities (20% for each class), with two classes further subdivided into Extreme Wet and Wet, and Dry-Normal I and II.

Table 3. Summary of annual runoff for the Mono Basin tributaries for the available period of record (1941-2003). The 1941-1994 average yield of 122,124 acre feet serves as the base period for average yield for runoff year designations.

Runoff Year	Runoff for Mono Basin Tributaries (Rush, Parker, Walker, Lee Vining)	Percent of Average Runoff	Runoff Year Type	Rank	Exceedence Probability
1941	183,298	150.1%	WET	6	10%
1942	166,120	136.0%	WET/NORMAL	13	21%
1943	151,895	124.4%	WET/NORMAL	17	27%
1944	100,903	82.6%	NORMAL	37	59%
1945	155,308	127.2%	WET/NORMAL	16	25%
1946	129,306	105.9%	NORMAL	26	41%
1947	83,586	68.4%	DRY	51	81%
1948	94,295	77.2%	DRY/NORMAL II	42	67%
1949	89,708	73.5%	DRY/NORMAL I	48	76%
1950	111,973	91.7%	NORMAL	31	49%
1951	111,651	91.4%	NORMAL	32	51%
1952	175,249	143.5%	WET	8	13%
1953	95,382	78.1%	DRY/NORMAL II	41	65%
1954	83,776	68.6%	DRY/NORMAL I	50	79%
1955	99,234	81.3%	DRY/NORMAL II	40	63%
1956	167,862	137.5%	WET	12	19%
1957	104,570	85.6%	NORMAL	36	57%
1958	158,038	129.4%	WET/NORMAL	15	24%
1959	74,091	60.7%	DRY	55	87%
1960	71,000	58.1%	DRY	58	92%
1961	72,644	59.5%	DRY	57	90%
1962	132,382	108.4%	WET/NORMAL	24	38%
1963	137,370	112.5%	WET/NORMAL	22	35%
1964	84,864	69.5%	DRY/NORMAL I	49	78%
1965	142,599	116.8%	WET/NORMAL	20	32%
1966	94,271	77.2%	DRY/NORMAL II	43	68%
1967	198,927	162.9%	EXTREME WET	5	8%
1968	82,467	67.5%	DRY	52	83%
1969	213,384	174.7%	EXTREME WET	3	5%
1970	104,683	85.7%	NORMAL	35	56%
1971	113,861	93.2%	NORMAL	29	46%
1972	91,468	74.9%	DRY/NORMAL I	45	71%
1973	132,914	108.8%	WET/NORMAL	23	37%
1974	132,217	108.3%	WET/NORMAL	25	40%
1975	120,726	98.9%	NORMAL	28	44%
1976	54,719	44.8%	DRY	62	98%
1977	52,093	42.7%	DRY	63	100%
1978	179,090	146.6%	WET	7	11%
1979	122,670	100.4%	NORMAL	27	43%
1980	170,001	139.2%	WET	11	17%
1981	100,062	81.9%	DRY/NORMAL II	38	60%
1982	212,296	173.8%	EXTREME WET	4	6%
1983	239,529	196.1%	EXTREME WET	1	2%
1984	147,719	121.0%	WET/NORMAL	18	29%
1985	107,892	88.3%	NORMAL	34	54%
1986	170,669	139.8%	WET	10	16%
1987	67,911	55.6%	DRY	60	95%
1988	70,036	57.3%	DRY	59	94%
1989	89,725	73.5%	DRY/NORMAL I	47	75%
1990	59,782	49.0%	DRY	61	97%
1991	77,935	63.8%	DRY	53	84%
1992	72,766	59.6%	DRY	56	89%
1993	140,291	114.9%	WET/NORMAL	21	33%
1994	76,218	62.4%	DRY	54	86%
1995	215,252	176.3%	EXTREME WET	2	3%
1996	164,817	135.0%	WET/NORMAL	14	22%
1997	143,433	117.4%	WET/NORMAL	19	30%
1998	172,744	141.4%	WET	9	14%
1999	112,946	92.5%	NORMAL	30	48%
2000	111,621	91.4%	NORMAL	33	52%
2001	92,630	75.8%	DRY/NORMAL II	44	70%
2002	90,227	73.9%	DRY/NORMAL I	46	73%
2003	100,000	81.9%	DRY/NORMAL II	39	62%
	121,859	**1941-2003 Average Runoff**			
	122,124	**1941-1990 Average Runoff**			

Winter baseflow: The winter baseflow hydrograph component usually had the lowest computed baseflow for a runoff year. Modeled unimpaired data show these baseflows are remarkably consistent within each runoff year type, ranging from 35 cfs in Extreme Wet years to less than 20 cfs in Dry years. Winter baseflows were occasionally of two distinct magnitudes, coming either before or after an infrequent winter flood. For example, RY 1963 had low-magnitude winter baseflows descending from 28 cfs to 18 cfs through January, then higher magnitude baseflows of 32 cfs following the winter flood that occurred on January 3, 1963. In RY 1997, the maximum winter baseflow of 56 cfs resulted from the sustained high baseflows following the January 2, 1997 flood. Water years with no winter floods had more consistent winter baseflow magnitudes.

Winter floods: Winter floods were infrequent and extreme magnitude floods of short duration typically generated by rain-on-snow events from late-December through January and more likely to occur in wetter runoff years. Seven of 33 runoff years (21% probability of occurrence) from the modeled unimpaired data had winter floods, and all occurred in Normal, Wet/Normal, or Wet years. Winter flood magnitude also generally increased with wetter runoff years. The single winter flood from RY 1970 (Normal year type) peaked at 169 cfs, but 5 of the 7 winter flood peaks exceeded 450 cfs daily average discharge. The instantaneous peak was likely higher. The largest recorded winter flood for Rush Creek at Damsite (from the actual gaged data) was the January 1997 flood of 250 cfs. In contrast, the maximum daily average discharge for Lee Vining Creek above Intake on January 3, 1997 was 524 cfs, and Buckeye Creek peaked at 1,050 on January 2, 1997. The 1997 flood on Rush Creek thus appears to have been attenuated by upstream SCE reservoirs. Other winter floods have also likely been eliminated because of SCE reservoirs. Winter flood durations typically lasted 1 to 3 days and had extremely sharp ramping rates frequently exceeding a 1000% daily rate of change (e.g., 48 cfs/day to 660 cfs/day).

Spring snowmelt ascension and secondary peaks: The annual hydrographs showed three distinct phases during the spring snowmelt period – the snowmelt ascension, snowmelt peak, and snowmelt recession – with each phase lasting several weeks or longer. In nearly all runoff years, the early snowmelt ascension period had one or more moderate peaks. These early snowmelt peaks were a prelude to the annual maximum peak, effectively extending overall duration of the snowmelt period an entire month or longer. During this early snowmelt ascension period, discharge remained well above winter baseflow even though the flood peak was weeks away. The magnitude of these secondary peaks ranged between 200 cfs and 500 cfs, with higher peaks occurring in wetter runoff years. The snowmelt ascension period generally began in early May and peaked during mid- to late May, often with several secondary peaks during this period. The onset of spring snowmelt was also generally later in wetter years. Roughly 10% to 17% of the annual runoff volume was associated with this early peak phase. Changes in daily average flows during snowmelt peak ascension consistently ranged from 12% to 15% (cfs/day), but occasionally reached as high as 30% to 40% though usually for no more than two consecutive days.

Spring snowmelt peak: The snowmelt peak is the most obvious, and perhaps most important, hydrograph component on Rush Creek. The snowmelt peak normally began in late May or early June, then lasted several weeks. The peak normally occurred June or early July, with a general trend of peaking later in wetter runoff years. Peak flow magnitudes ranged from 300 cfs in Dry runoff years to 700 cfs to 800 cfs in Wet and Extreme Wet runoff years. Some Dry/Normal and Normal runoff years had snowmelt peaks exceeding 400 cfs.

Snowmelt peak duration was computed two ways: first by the duration from the onset of snowmelt runoff to the snowmelt peak (ascension duration in Table 4) and then by the duration in which the discharge remained at 85% of the annual maximum peak (flood duration in Table 4). The ascension duration lasted one to several weeks, while the snowmelt peak duration lasted 3 to 10 days, i.e. flows

Table 4. Estimates of unimpaired flows (magnitude, duration, and timing) for each hydrograph component identified for Rush Creek.

Hydrograph Component	RUNOFF YEAR TYPE					
	Extreme Wet	Wet	Wet-Normal	Normal	Dry-Normal	Dry
Number of Runoff Years for Modeled Unimpaired	1	4	9	8	6	5
Daily Average Annual Discharge (cfs)	139	117	94	76	61	44
Average Annual Yield (af)	100,411	84,666	68,160	54,902	44,340	31,549
Maximum Annual Yield (af)	100,411	91,617	76,709	58,487	47,173	39,016
Minimum Annual Yield (af)	100,411	80,151	63,078	49,000	41,855	24,397
Fall Baseflow (Oct 1 - Dec 20)						
Median	39	42	32	25	18	18
Minimum	39	32	23	18	14	14
Maximum	39	50	44	41	28	24
Winter Baseflow (Dec 21 - Mar 21)						
Median	35	30	29	26	23	17
Minimum	35	24	23	20	15	17
Maximum	35	36	56	35	35	21
Winter Floods (Dec 21 - Mar 30)						
Flood Magnitude (maximum)		491	1,048	169		
Flood Magnitude (average)		301	499	169		
Flood Duration (median number of days)		1	3	1		
Flood Frequency (number of winter storms)		2	6	1		
Earliest Flood Date		23-Dec	11-Nov	16-Jan		
Latest Flood Date		23-Mar	5-Feb	16-Jan		
Average Flood Volume (AF)		1,308	1,673	456		
Number of Runoff Years for Computed Unimpaired	5	7	13	12	13	11
Spring Early Snowmelt Peaks (Mar 21- May 31)						
Secondary Peak Magnitude (median)	507	411	377	262	306	203
Secondary Peak Duration (median)	21	22	24	17	14	19
Start of Snowmelt Ascension (median)	15-May	6-May	2-May	1-May	3-May	4-May
Secondary Snowmelt Peak Date (median)	30-May	20-May	16-May	16-May	15-May	7-May
End of Snowmelt Ascension (median)	8-Jun	29-May	29-May	22-May	22-May	25-May
Snowmelt Ascension Runoff Volume	16,908	8,544	9,477	5,580	5,106	4,356
Daily Ramping Rates (maximum)	33%	40%	33%	35%	33%	39%
Daily Ramping Rates (average)	12%	13%	12%	12%	13%	13%
Spring Snowmelt Flood (May 1 - July 15)						
Magnitude used to Compute Duration	686	591	498	400	356	254
Snowmelt Flood Magnitude (median)	807	695	586	470	419	299
Snowmelt Ascension Duration (median)	22	13	13	16	11	8
Snowmelt Flood Duration (median)	3	4	9	6	10	4
Start of Snowmelt Flood (median)	8-Jun	29-May	29-May	22-May	22-May	25-May
End of Snowmelt Flood (median)	17-Jul	30-Jul	17-Jul	1-Jul	26-Jun	12-Jun
Date of Flood Peak (median)	1-Jul	11-Jun	21-Jun	7-Jun	8-Jun	5-Jun
Snowmelt Runoff Volume (median)	49,941	51,675	32,021	27,248	19,319	9,042
Snowmelt Recession (July 15 - Sep 30)						
Start of Snowmelt Recession (median date)	17-Jul	30-Jul	17-Jul	1-Jul	26-Jun	12-Jun
End of Snowmelt Recession (median date)	31-Aug	28-Aug	20-Aug	27-Jul	15-Jul	10-Jul
Duration of Recession (median number of days)	45	31	31	31	25	25
Daily Ramping Rates (maximum)	10%	18%	12%	9%	10%	17%
Daily Ramping Rates (average)	5%	5%	5%	4%	5%	6%
Snowmelt Recession Runoff Volume (median)	18,924	7,503	7,192	4,606	3,238	2,614
Summer Baseflow						
Minimum (median)	77	72	42	28	23	14
Maximum (median)	77	103	70	50	31	25

steadily rose over several weeks, then sustained a maximum peak lasting several days. This snowmelt peak hydrograph was distinct from winter peak flows, which were extremely brief. Winter peaks are caused by rainfall and rain-on-snow events, while snowmelt peaks are a function primarily of the snowpack and ambient air temperatures (Vorster 1985). The spring snowmelt hydrograph component comprised the largest proportion of the total annual runoff volume, as well as the annual maximum discharge in most years. Approximately 29% (Dry Year) to 61% (Wet Year) of the total annual runoff volume was associated with the snowmelt peak hydrograph component.

Snowmelt recession: The snowmelt recession had an extended duration period connecting the snowmelt peak to the summer or fall baseflows (when recession occurred throughout the summer). The critical aspect of the snowmelt recession was the rate of the recession, or the percentage change in flow, which in turn determined the duration of the snowmelt recession and affected the rate of change in stage height of the stream. Maximum daily ramping rates, computed as the percent daily change in flow, ranged from 9% to 18%; these maximum rates usually lasted only one or two consecutive days. The average daily ramping rates consistently ranged from 4% to 6% across all runoff year types. Snowmelt recession extended a minimum of four weeks, though often up to six weeks. Consequently, snowmelt recession frequently extended through August. The median date for the end of snowmelt recession for the wetter 40% of runoff year types (Extreme Wet, Wet, Wet/Normal) was the end of August. Normal years (the next 20% of runoff year types) included most of July in the snowmelt recession period. The snowmelt recession component comprised the smallest proportion (7% to 11%) of the total annual runoff volume.

2.4.1.5 Flood Frequency Analyses

The annual peak flow was one of the most important hydrograph components, providing the impetus for most physical processes associated with channel maintenance, maintaining coarse and fine sediment budgets, uprooting trees and recruiting large woody debris, and promoting riparian regeneration on higher elevation surfaces. Snowmelt runoff peak magnitudes are usually lower than winter flood peaks, but their frequency is greater and duration longer with the snowmelt runoff period occasionally lasting months. The annual peak flood may be considered the instantaneous peak in a runoff year (typically applied in flood frequency analyses) or the highest daily average flow in the runoff year (if instantaneous values are unavailable). Peak flood frequencies were analyzed for several these data sets:

- Rush Creek Computed Unimpaired (maximum daily average flows);
- Rush Creek at Damsite (impaired, annual maximum instantaneous peak flows);
- Rush Creek below Return Ditch (SRF flows, maximum daily average flows);
- Rush Creek below Narrows (unimpaired, maximum daily average flows);
- Rush Creek below Narrows (impaired, maximum daily average flows);
- Regional Regression Analyses for Rush Creek Unimpaired.

Each analysis is described below. Results for all analyses are presented in Table 5 and annual maximum flood frequency curves are presented in Appendix D.

Rush Creek Computed Unimpaired. This analysis was presented in Hasencamp (1994; Figure 7) for 1941 to 1990. Our analysis extended the period of record through 2003. Data from 1995 to 2003 are based on LADWP Rush Creek Runoff data, which currently add the SCE mean monthly storage change to Rush Creek at Damsite, and thus underestimate the annual peak magnitude. Additionally, the data in Hasencamp (1994) and in our analysis are the daily average maxima, not the instantaneous peaks. This application underestimates the actual flood peaks. Using three years in

Table 5. Summary of flood magnitudes for different recurrence intervals estimated for several sites along Rush Creek.

	Q1.5		Q2.0		Q2.33		Q5		Q10		Q25		Q50	
(all data in cfs)	Raw Data	Pearson III Fit	Raw Data	Pearson III Fit	Raw Data	Pearson III Fit	Raw Data	Pearson III Fit	Raw Data	Pearson III Fit	Raw Data	Pearson III Fit	Raw Data	Pearson III Fit
Rush Creek Runoff Unimpaired (1)	411	435	484	502	507	532	683	666	780	776	908	915	1,046	1,019
Rush Creek at Damsite (2)	182	172			250	244	381	363	489	475	655	639	896	777
Rush Creek below Return Ditch (3)	250				380		400		450		500		500	
Rush Creek below Narrows (1937-2003) (4)	346				457		491		523		624		624	
Rush Creek below Narrows (1980-2003) (5)	346				469		522		568		652		772	
Rush Creek below Narrows Unimpaired (6)	497	495			587	605	775	755	882	874	1,011	1,023	1,168	1,133
Rush Creek (Waananen and Crippen-Buckeye) (7)			320				483		602		765		908	
Rush Creek (Waananen and Crippen-Lee Vining) (8)			440				617		730		867		915	
Lee Vining Creek Runoff (9)	287	283	375	339	387	364	492	473	596	561	635	670		
Lee Vining Creek below Intake (10)	221	199	271	250	294	272	363	367	408	446	502	522	512	578

(1) Data Source: LADWP Rush Creek Computed Unimpaired or 'Rush Creek Runoff' (Rush Creek at Damsite + SCE Storage Change)
(2) Data Source: Data for 1937-1979 from USGS archives for 'Rush Creek abv Grant Lake nr June Lake, CA (USGS 10287400); 'Data for 1980-2003 from LADWP 'Rush Creek at Damsite'
(3) Data Source: Uses 'Rush Creek at Damsite' for 1937-2003, assigns water year class based on SWRCB Order 98-05, then assigns Stream Restoration Flow for each water year
(4) Data Source: Uses 'Rush Creek below Return Ditch' for 1937-2003 and adds Parker and Walker average peak flow determined for each water year class
(5) Data Source: Uses 'Rush Creek below Return Ditch' for 1980-2003 and adds Parker and Walker actual peak data for each water year
(6) Data Source: Uses 'Rush Creek Computed Unimpaired' for 1941-2003 and adds Parker and Walker Creek average peak flow for each water year class
(7) Data Source: Applies Waananen and Crippen Regional Flood Regressions, using Buckeye Creek gaged data
(8) Data Source: Applies Waananen and Crippen Regional Flood Regressions, using Lee Vining Creek gaged data

Table 6. Comparison of 'maximum daily average discharge' and 'maximum instantaneous discharge' for Rush Creek at Damsite.

Runoff Year	Max Daily Average Discharge (cfs)	Max Instantaneous Discharge (cds)	Difference	Percent Difference
1998	495	519	24	5%
1999	222	266	44	20%
2000	372	381	9	2%

which the annual instantaneous peak is available (1998 to 2000), we compared these data to the daily average maximum (Table 6). The instantaneous peak was as much as 20% higher, and averaged 9% higher than the maximum daily average discharge for the runoff year. The unimpaired maximum daily average 1.5-yr flood was 411 cfs; the 5-yr flood was 666 cfs. The Rush Creek computed unimpaired flood of record was 1,078 cfs on June 1, 1986, with approximately 75-yr recurrence interval. This flood is not significantly greater than the measured flood of record for Rush Creek at Damsite of 1,070 cfs (July 14, 1967). Note these highest floods occurred during early summer snowmelt and not as winter storms

Rush Creek at Damsite. The flood frequency analysis for Rush Creek at Damsite shows the effects of SCE regulation on streamflows entering Grant Lake. Data from Runoff Years 1937 to 1979 are available from USGS archives for Rush Creek above Grant Lake nr June Lake, CA (USGS Stn 10-287400) and are instantaneous annual maximum flood data; data for the period 1980 to 2003 were obtained from LADWP for Rush Creek at Damsite and are maximum daily average flows. These data are appropriately compared to the computed unimpaired data to show the effects of SCE operations on flood peaks. The 1.5-yr flood was reduced from 435 cfs to 172 cfs; the 5-yr flood was reduced from 683 cfs to 381 cfs. Comparison between the computed unimpaired and the Damsite flood frequency data shows that SCE reservoir operations impair large floods less than small floods; the larger floods appear to cause the reservoirs to spill and more closely resemble unimpaired peaks. The predicted 1.5-yr flood from Hasencamp (1994) was 165 cfs; our updated 1.5-yr flood is 172 cfs. The flood of record for this site is the July 1967 flood of 1,070 cfs.

Rush Creek below Return Ditch. SWRCB Order 98-05 established SRFs to be released according to the runoff year designation (Appendix B). We used the Rush Creek at Damsite annual yield to predict runoff year types for the period of record (1937 to 2003), determined the runoff year designation, then assigned a SRF peak flow for each runoff year. This analysis thus simulates a flood frequency curve for the future, though it underestimates flood magnitudes by not including spill events. According to Hasencamp (1994) there were 11 spill events between 1950 and 1994. Because of the unusual distribution of flood peaks derived from the SRF flows, the Log-Pearson III fit is poor and therefore not presented on the flood frequency curve. Comparing Rush Creek at Damsite with Rush Creek below Return Ditch flood frequencies shows the difference between existing regulated conditions for flows entering Grant Lake and flow releases from Grant Lake required by SWRCB Order 98-05. Dryer year types require smaller magnitude SRF flow releases. The Return Ditch releases are larger than the existing SCE regulated peaks at Damsite. At larger and less frequent floods, the SWRCB releases are somewhat comparable or are smaller than the peaks at Damsite. The Rush Creek below Return Ditch Q1.5-yr is 250 cfs, slightly higher than the 172 cfs for Rush Creek at Damsite, but still smaller than the computed unimpaired Q1.5-yr of 411 cfs.

Rush Creek below Narrows-Unimpaired. This analysis uses the Rush Creek computed unimpaired data for 1941 to 2003, then adds Parker Creek and Walker Creek daily average peak discharges for each runoff year type. As with the Rush Creek computed unimpaired analysis, this analysis may underestimate the flood peak magnitudes by using the peak daily average discharge for the unimpaired data, instead of the annual instantaneous maximum discharge. However, this factor may be offset by assuming that the Parker and Walker annual peaks occurred on the same day, which was usually not the case. The unimpaired floods below the Narrows ranged from nearly 500 cfs for Q1.5-yr to 775 cfs for the 5-yr flood.

Rush Creek below Narrows-Impaired. This analysis adds flood peaks for Parker and Walker creeks to the peak SRF flows in the "below Return Ditch analysis." Because the period of record for Parker and Walker creek gaging stations above the intakes only goes back to RY 1980, flood peaks were generated for each SWRCB runoff year type using the 1980 to 2003 period of record and calculating the average flood peak for each year type. Using these Parker and Walker flood magnitudes may slightly inflate the Rush Creek flood magnitudes because it assumes the Parker and Walker peaks occur simultaneously, which isn't always true. This may be offset, however, by using maximum daily average discharge as Parker and Walker peak floods rather than their instantaneous peaks. Additionally, a portion of the Parker and Walker record for flows above the conduit (1981 to 1990) is provided as monthly averages, which further underestimates the actual peak discharge. Because of the unusual distribution of flood peaks derived from the SRF flows, the Log-Pearson III distribution is a poor fit to the data and is not used. We repeated the analysis using only the period of record 1980 to 2003 from which data for Parker and Walker creeks are available. This analysis still assumes, however, that Parker and Walker annual peaks always occur on the same day, which is not necessarily always true. These two analyses are presented separately in Table 5, but the flood frequency values differ slightly. The predicted regulated Q1.5-yr below the Narrows is approximately 346 cfs; the 5-yr flood is approximately 523 cfs to 568 cfs.

Regional Regression Equations. An evaluation of regional flood frequency regression equations can provide approximate information on flood frequency in cases where little or no stream gaging data exist. Given the difficulty of predicting flood frequency from the historic gaging records with upstream regulation, we used the regression equations as another tool to estimate unimpaired flood frequency. This analysis predicts flood magnitudes of selected frequency for ungaged (or regulated) watersheds by using multiple regression analysis to correlate flood discharge magnitude for a given recurrence with selected basin characteristics (drainage area, precipitation, and altitude). Regression analyses and associated regional relationships are provided by Waananen and Crippen (1977). Two applications of the equations were used: (1) applying the equation with drainage area, precipitation data, and altitude for Rush Creek at a given locations, and (2) applying the equation, but normalizing drainage area, precipitation data, and altitude with a nearby unregulated gaging station. Equation 1 illustrates the basic Waananen and Crippen equation; Equation 2 illustrates the modified equation to normalize with a nearby unregulated reference stream with adequate gaging period of record.

$$\begin{aligned} Q_{2Rush} &= 0.24A^{0.88} P^{1.58} H^{-0.80} \\ Q_{5Rush} &= 1.20A^{0.82} P^{1.37} H^{-0.64} \\ Q_{10Rush} &= 2.63A^{0.80} P^{1.25} H^{-0.58} \\ Q_{25Rush} &= 6.55A^{0.79} P^{1.12} H^{-0.52} \end{aligned} \qquad (1)$$

Where A=drainage area (mi^2), P=mean annual precipitation (in), and H=altitude index (ft/1000).

$$\begin{aligned}
Q_{2Rush} &= Q_{2ref}(A_{Rush}/A_{ref})^{0.88}\,(P_{Rush}/P_{ref})^{1.58}\,(H_{Rush}/H_{ref})^{-0.80}\\
Q_{5Rush} &= Q_{5ref}(A_{Rush}/A_{ref})^{0.82}\,(P_{Rush}/P_{ref})^{1.37}\,(H_{Rush}/H_{ref})^{-0.64}\\
Q_{10Rush} &= Q_{10ref}(A_{Rush}/A_{ref})^{0.80}\,(P_{Rush}/P_{ref})^{1.25}\,(H_{Rush}/H_{ref})^{-0.58}\\
Q_{25Rush} &= Q_{25ref}(A_{Rush}/A_{ref})^{0.79}\,(P_{Rush}/P_{ref})^{1.12}\,(H_{Rush}/H_{ref})^{-0.52}
\end{aligned} \tag{2}$$

Where A_{Rush}= Rush Creek drainage area (mi^2), P_{Rush}=Rush Creek mean annual precipitation (in), H_{Rush}=Rush Creek altitude index (ft/1000), A_{ref}= drainage area (mi^2) for unregulated reference stream, P_{ref}=mean annual precipitation (in) for unregulated reference stream, H_{ref}= altitude index (ft/1000) for unregulated reference stream, and Q_{ref}=flood magnitude for a given recurrence interval on an unregulated reference stream.

Our analysis showed Lee Vining Creek is a better predictor of flood magnitudes (closer fit to our own analyses) than Buckeye Creek, but with slightly lower magnitudes than flood estimates from the Rush Creek Runoff (computed unimpaired) analysis.

2.4.1.6 Existing Stream Restoration Flows (SRFs)

Existing SRF flows required by SWRCB Order 98-5 were plotted for each runoff year type as an annual hydrograph (Figures 23). We compared the annual runoff volumes for Rush Creek at Damsite to the annual runoff volumes required by the SRF flow releases (Table 7). The average annual yield for Rush Creek (for 1937 to 2003) was 59,581 acre feet. Given the exceedence probability for each runoff year designation and the required SRF release for each runoff year type, the average annual runoff necessary for the SRF streamflows was 45,000 acre feet, or 75.5% of the average unimpaired annual runoff.

Table 7. Comparison of average runoff for each year type to the annual runoff computed for the SWRCB "Transition" Stream Restoration Flows. The average runoff for each category is the weighted average based on the frequency of each runoff year type. Current regulated flows require a minimum release of approximately 75.4% of the unimpaired flow volume; actual releases occasionally exceed the minimum requirements.

Runoff Year Type	Rush Creek at Damsite Average Runoff (af)	Order 98-05 SRF Runoff (af)	Exceedence Probability	No. Years in Class
Extreme Wet	106,409	63,730	8%	4
Wet	85,374	62,389	12%	6
Wet/Normal	71,710	50,946	20%	17
Normal	54,689	47,600	20%	16
Dry/Normal II	47,035	39,389	10%	8
Dry/Normal I	43,111	38,122	10%	4
Dry	34,402	24,248	20%	12
Average Runoff	59,581	44,895		67
Percent of Unimpaired Average Runoff:		**75.4%**		

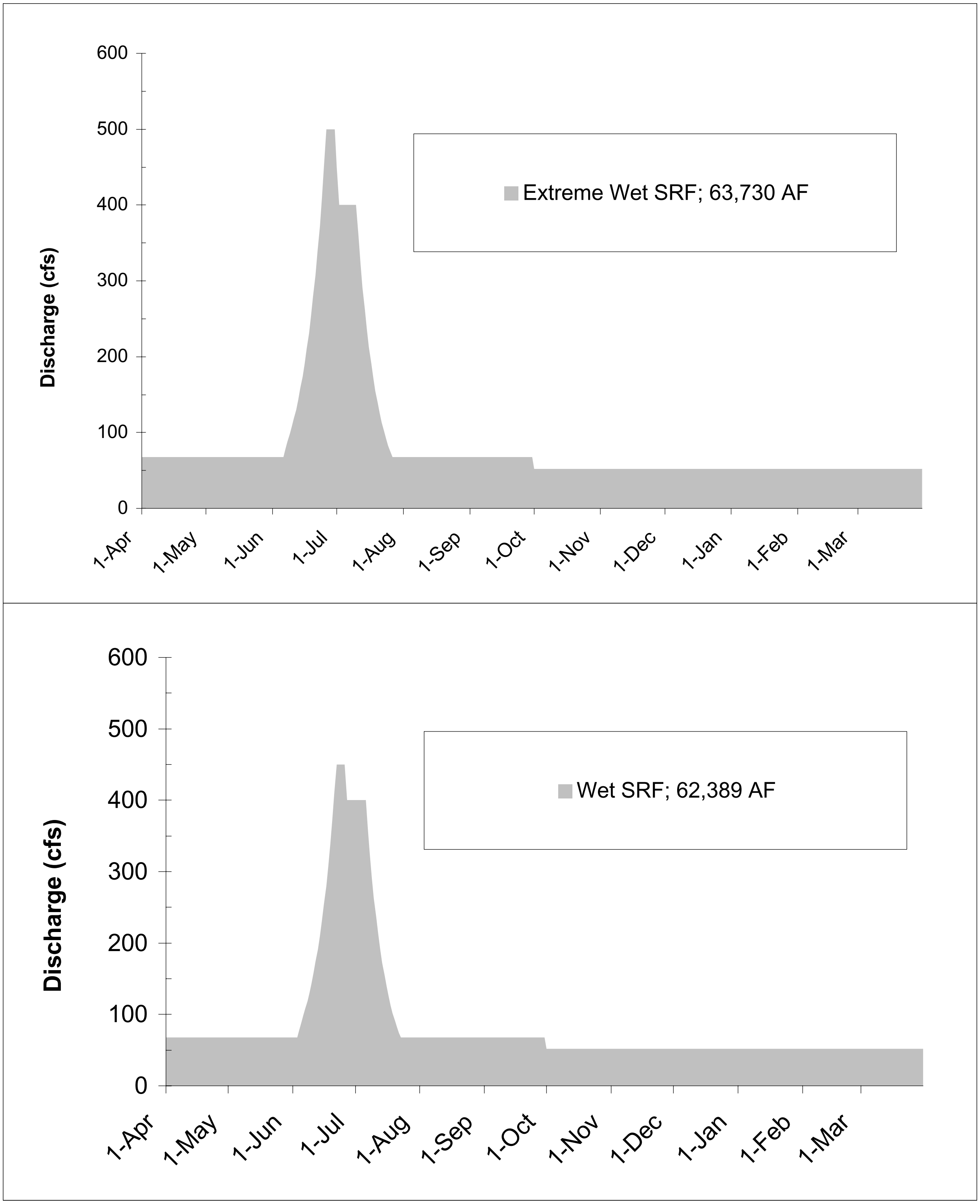


Figure 23. SWRCB Order 98-05 "Transition" Stream Restoration Flows for Rush Creek for seven different runoff year types.

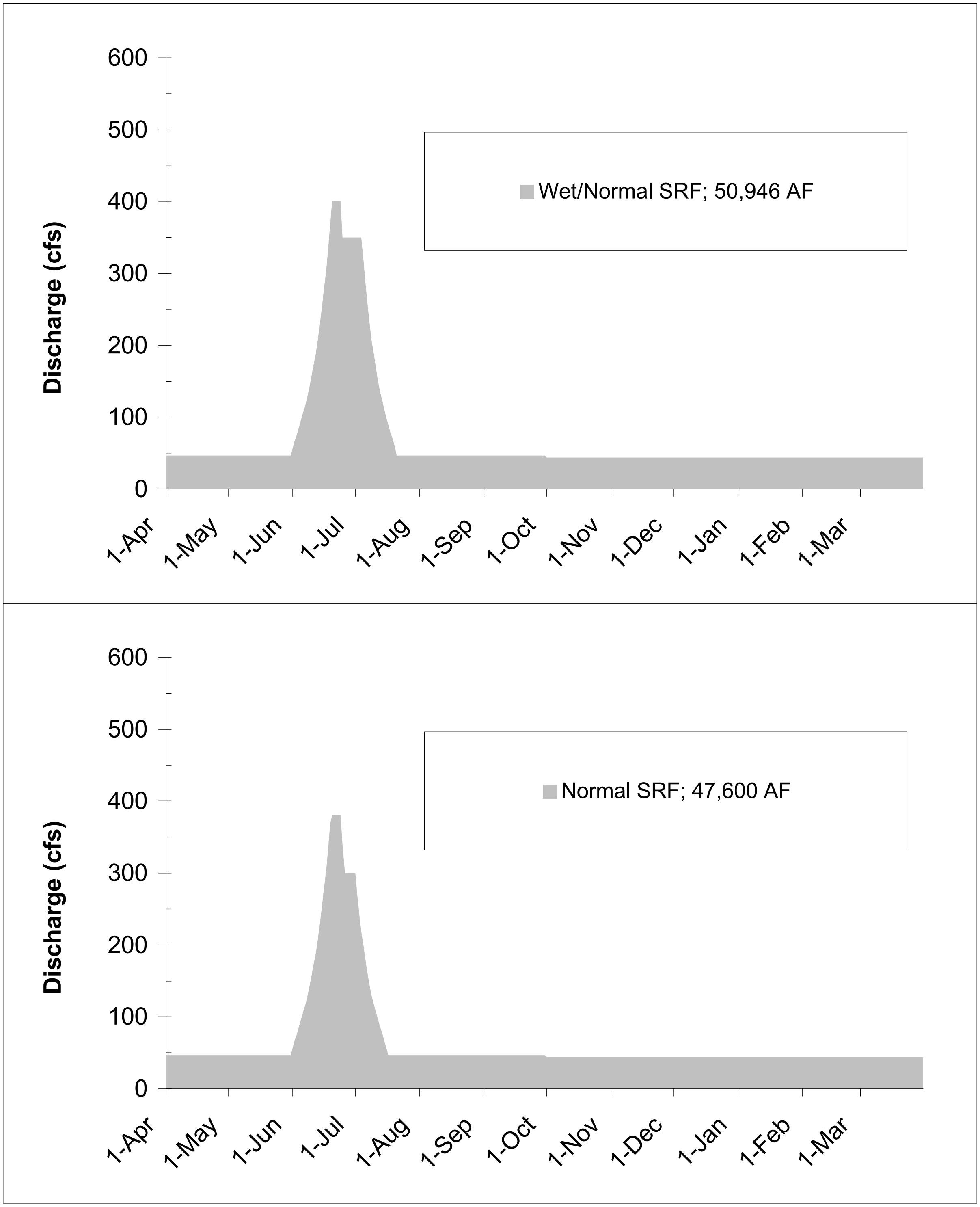
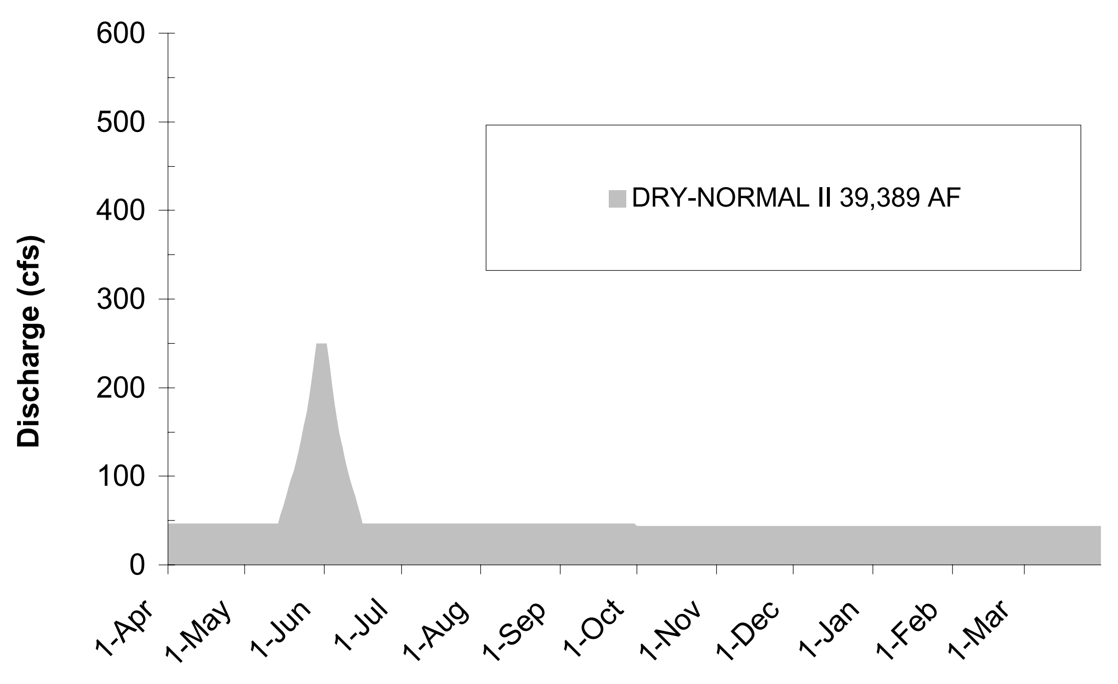


Figure 23. Continued.



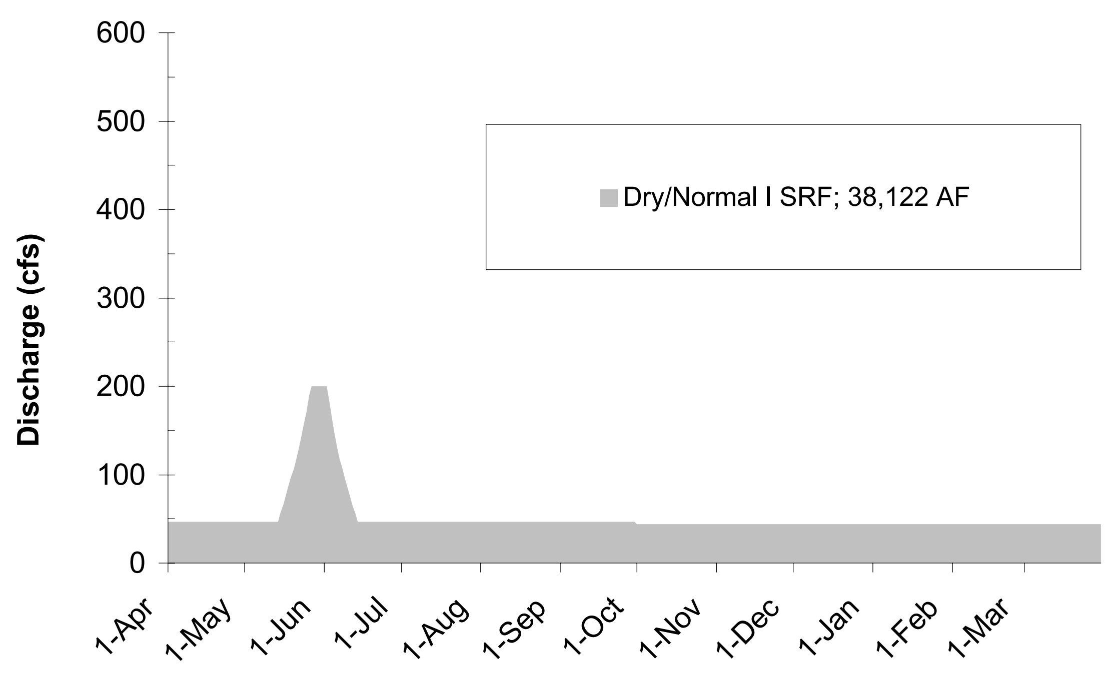


Figure 23. Continued.

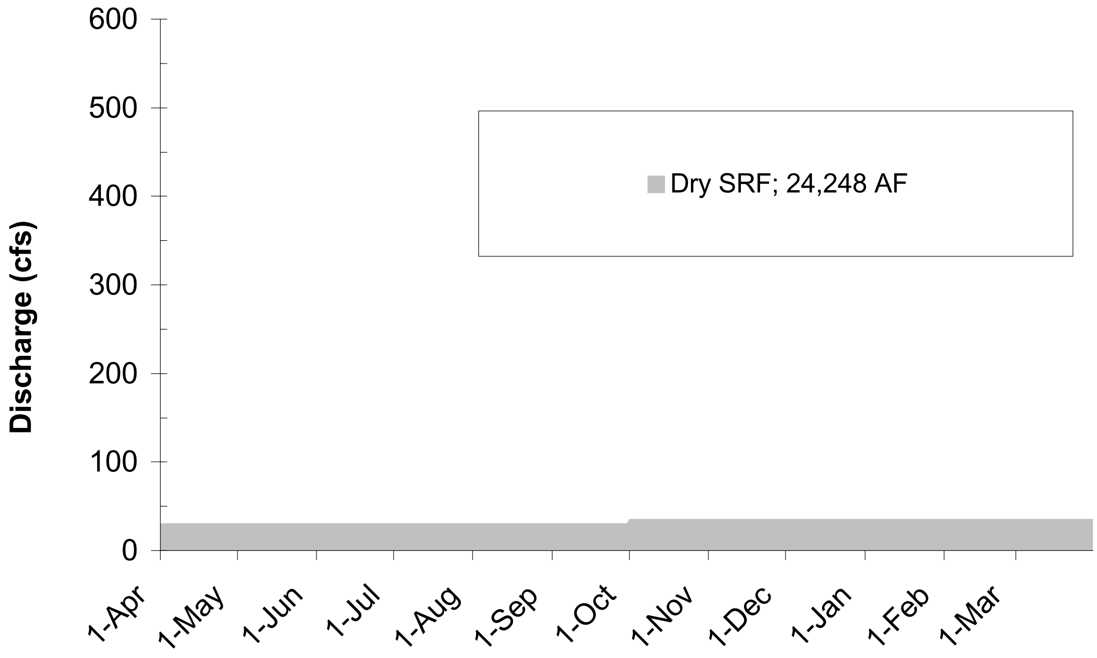


Figure 23. Continued

2.4.1.7 Future Data Analyses

With a hydrograph component analysis completed for Rush Creek, we will perform a similar hydrograph component analysis of unimpaired annual hydrographs on Lee Vining Creek in 2004. We will also evaluate annual maximum flood frequencies for Lee Vining Creek.

2.4.2 STEP 2: Identifying Likely Ecological Functions for Each Annual Hydrograph Component

The classification of runoff year types and the analysis of hydrograph components only become restoration tools when ecological processes have been explicitly and quantitatively attributed to specific hydrologic events. This necessity was acknowledged in the RTC Scientists' Restoration Plan (Ridenhour et al. 1995). Since the Restoration Plan's completion and SWRCB Orders, monitoring of channel morphology and fluvial processes, riparian vegetation dynamics, and trout population changes has provide limited opportunity for linking key ecological processes to streamflow. Some linkages have been quantified (e.g., establishing flow thresholds for channelbed mobilization) while others are still mostly conceptual (e.g., groundwater recharge of low terraces below the Narrows). Following the 'golden years' of high snowmelt runoff in RY 1996 and RY 1997, floods have been highly subdued due to low annual snowpacks and modified by re-construction of Mono Ditch. This period limited opportunities to observe many fluvial processes in the mainstem channels, in the side-channels, and on the floodplain. A healthy Mono Ditch and the prospect of at least a Normal 2004 runoff year make this coming snowmelt hydrograph potentially significant geomorphically and ecologically for Rush Creek and Lee Vining Creek, providing an ideal opportunity to increase our understanding of the linkages between key ecological processes and streamflow.

This section summarizes geomorphic and biological processes linked to each annual hydrograph component, including those processes likely to occur this snowmelt runoff season. Figure 18 highlights these ecological processes for each annual hydrograph component in an example wet runoff year for Rush Creek.

2.4.2.1 Hydrograph Component: Fall Baseflows

Fall baseflows influence habitat quality and quantity for aquatic benthic macroinvertebrates and trout while also sustaining groundwater recharge in the riparian corridor. Under contemporary and possibly brief pre-1941 conditions, trout and invertebrates were stressed by higher than preferred temperatures and shrinking physical habitat availability. On Rush Creek, daily temperature fluctuations at the Return Ditch are presently less pronounced than farther downstream, demonstrating the effect of steady flow releases from Grant Lake (Figure 24). Temperatures at the Narrows and the lower Rush Creek Ford have nearly identical daily fluctuations that exhibit different patterns from the Ditch temperatures (Figure 25), indicating temperatures at these lower two stations are less dependent on baseflow releases from Grant Lake and are driven more by ambient conditions. The success of migrating brown trout seeking favorable spawning sites upstream may be influenced by the magnitude of fall baseflows. Fall baseflows had no unique historic function geomorphically or with respect to woody riparian germination or seedling establishment.

2.4.2.2 Hydrograph Component: Winter Baseflows

Winter baseflows provide potentially limiting over-wintering habitat for adult brown and rainbow trout, most importantly deep pools with ample cover. With water temperatures well below the preferred range for aquatic macroinvertebrate production and fish growth, the extent of exposed riffle habitat may not have been, or is, an important wintertime environmental factor.

2.4.2.3 Hydrograph Component: Winter Floods

Winter floods are intense but brief events that have the stream power to deeply scour and mobilize the channelbed and gravel bars, open and close side-channels, avulse the main channels, and deposit fine sediment onto the highest alluvial surfaces (i.e., natural levees along terraces and floodplains). Winter flood peaks often exceeded the subsequent snowmelt flood peak in wetter runoff years. These may have functioned as infrequent “re-setting” floods that dramatically altered the channel network meanwhile maintaining multiple channels. Many large woody debris jams likely owe their existence to the recruitment and transport capacities of these unusually large peak floods. Snowmelt peaks in wet runoff years also perform these functions, though probably not as completely or as efficiently when peak magnitude rather than duration is required to accomplish a particular task.

2.4.2.4 Hydrograph Component: Spring Snowmelt Ascension

Ecological functions specific to spring snowmelt ascension range from those typically provided by baseflows to those requiring peak flows. We hypothesize that this period of early snowmelt runoff may contribute to recharging groundwater (while soil moisture is also receiving a boost from melting snow) throughout the riparian corridor by meeting antecedent conditions and thus promoting a stronger groundwater signature by the ensuing peak snowmelt flood. Biologically, this is a period of renewed growth stimulated by rising air temperatures and more sunlight. Several riparian plant species disperse seeds in April and May, while seed germination may be triggered or aided by higher flows. Stream temperatures enter a range preferred by trout and macroinvertebrates for optimal growth and productivity. The gradually rising baseflows punctuated by numerous secondary peak events increase the amount of trout habitat and highly productive riffle area for macroinvertebrates. Preferred temperatures and abundant habitat produce a highly productive period that may ultimately determine how well fish survive stressful times to come. Depending on the timing of snowmelt, rainbow trout spawning and amphibian egg laying along the channel margins and in off-channel ponded areas (warmed by the spring sun) also are happening. Secondary channels begin to fill, either from groundwater seepage or rising main channel flows.

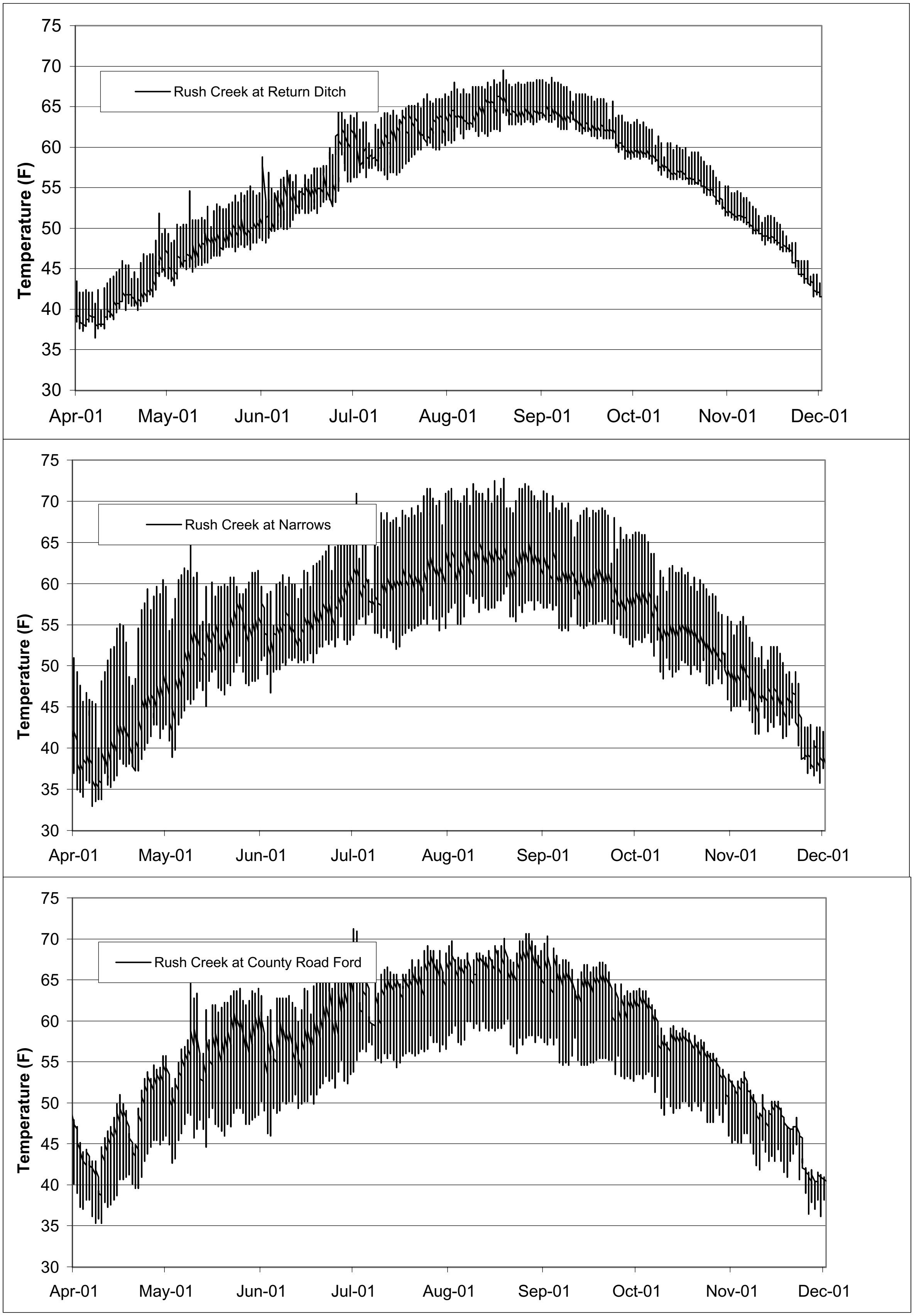


Figure 24. Hourly water temperatures for Rush Creek at three locations where thermographs are arrayed: below the Return Ditch, above the Narrows, and above the Ford, for a single runoff season (2001).

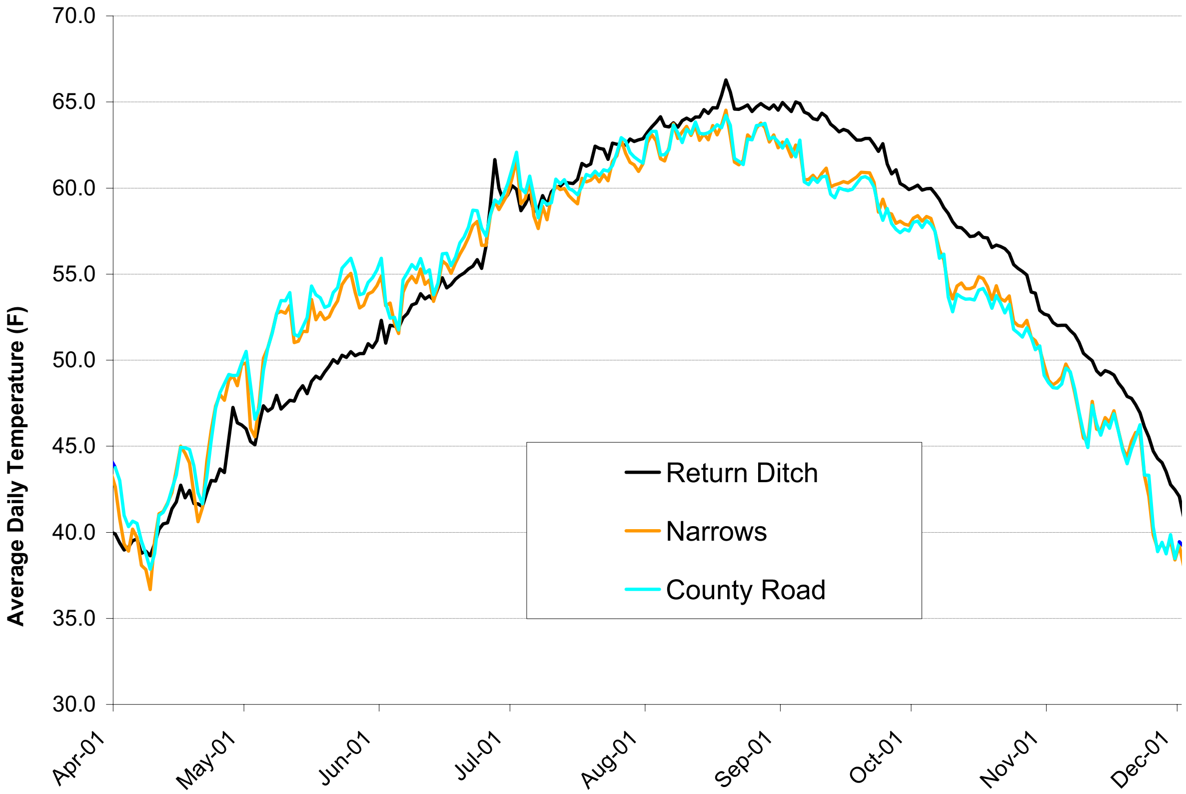


Figure 25. Mean daily temperatures for Rush Creek thermographs, showing the effect of Grant Lake warming on release temperatures. The similarity of the data from the two lower thermographs indicates that ambient conditions have superceded the influence of Grant Lake release temperatures in controlling daily fluctuations in water temperatures.

2.4.2.5 Hydrograph Component: Snowmelt Flood

The most prominent and highly predictable annual hydrological event is high and sustained runoff beginning late-spring through mid-summer. Ecological functions attributed to this hydrograph component include: (A) recharge of soil moisture and groundwater in the existing floodplain and terraces, (B) disseminate viable seeds and improve germination success, (C) aggrade the floodplain and terraces to sustain a confined channel, (D) open/close existing side-channel entrances, (E) induce channel avulsions, (F) generate LWD through channel migration, (G) redistribute LWD into effective logjams, (H) supply coarse sediment from bank erosion, (I) scour seedlings from specific alluvial features, (J) periodically mobilize diverse alluvial deposits and the general channelbed, (K) establish a dynamic equilibrium for coarse and fine sediment budgets, (L) promote channel sinuosity, and (M) create a new floodplain following periodic channel downcutting or aggradation in response to fluctuations in Mono Lake water levels.

2.4.2.6 Hydrograph Component: Spring Snowmelt Recession

The spring snowmelt recession limb of the snowmelt hydrograph ranges from a very high flow magnitude to a very low one, similar to the snowmelt ascension limb but in reverse. Though a mirror image, the recession limb is less punctuated with bursts of peak flows and experiences much warmer air temperatures. Young trout and amphibians newly hatched during the snowmelt peak or early in the snowmelt recession limb must contend with rapidly dropping flows. Cottonwood and willow seedlings also must maintain root growth rates comparable to receding water levels or desiccate.

2.4.3 STEP 3: Linking Ecological Processes, Hydrograph Components, and Runoff Year Types

An important prescription for restoring healthy stream ecosystems will be the release of annual flow regimes capable of providing the required physical and biological functions for recovery. The unimpaired hydrograph accomplishes many functions at once, but not all functions performed by a given annual hydrograph component are accomplished in all runoff year types. For example, the unregulated peak snowmelt hydrograph component mobilized the tops of point bars in Wet years, but not in Dry years. A prescription under regulated flows should strive to accomplish the same function at the same frequency: mobilizing the tops of point bars with the snowmelt peak hydrograph component when Wet years naturally occur but not mobilizing the top of point bars in a naturally occurring Dry runoff year (i.e., releasing a lesser snowmelt peak).

Because each function depends on a specific range in the magnitude, duration, frequency, timing, and rate of streamflow, inter-annual variation in the snowmelt-dominated annul hydrograph favors some functions over others in any particular RY type. Collectively the Rush Creek and Lee Vining stream ecosystems are in a state of year-to-year disequilibrium but longer term equilibrium, with each possible sequence of runoff years producing a unique stream ecosystem response.

This section links geomorphic and biological processes accomplished by annual hydrograph components to different types of runoff year, including those processes likely to occur this snowmelt runoff season. The list of functions for each RY type is not exhaustive. Probably many functions exist that we may never acknowledge. Not all those we do acknowledge can be quantified. Only those functions considered the most fundamental to a healthy stream ecosystem and those relevant to the SWRCB Order's termination criteria are being quantified (i.e., Step 4 in the evaluation).

The following categorization of each expected process among different runoff year types definitely is a work in progress. Many expectations are based on our understanding of how unregulated alluvial streams work in general, as well as based on field observations for Rush or Lee Vining creeks. With re-construction of the unregulated Rush Creek annual hydrographs in 2003 and future construction of Lee Vining unregulated annual hydrographs in 2004, we will be able to field test the prioritized stream processes. The RY types are abbreviated as: All RY's (ALL), Extreme Wet (EW), Wet (W), Wet-Normal (WN), Normal (N), Dry-Normal II (DNII), Dry-Normal I (DNI), and Dry (D).

Table 8. List of some important stream processes hypothesized to maintain a 'functional, dynamic, and self-sustaining stream system', and the different runoff years during which these processes typically occur.

Natural Stream Process	*Runoff Year Types*
Deposit Fine Sediment onto Natural Levees, Floodplain, and Terraces	N, WN, W, EW
Open/Close/Maintain Existing Side-Channel Entrances	WN, W, EW
Prevent Encroachment of Active Side-Channels	WN, W, EW
Create/Retire Side-Channels (Avulsions)	W, EW
Scour Alternate Bar Surfaces	N, WN, W, EW
Scour Gravel Deposits	DNII, N, WN, W, EW
Scour Riffles/Cascades	N, WN, W, EW
Point Bar Movement/Floodplain Creation	N, WN, W. EW
Baseflow Over-wintering Trout Rearing Habitat	ALL
Baseflow Summer/Fall Trout Rearing Habitat	ALL
Baseflow Brown Trout Spawning Habitat	ALL
Baseflow Rainbow Trout Spawning Habitat	ALL
Access to Tributaries During Spawning Migration	DNI, DNII, N, WN, W, EW
Baseflow Aquatic Macroinvertebrate Productivity Window	ALL
Maintain Groundwater to Prevent/Minimize Contracting the Riparian Corridor	ALL
Promote Snowmelt Signature on Groundwater Table in Floodplain and Terraces	N, WN, W, EW
Create Riparian Germination Surfaces	W, EW
Provide Soil Moisture for Riparian Recruitment Box	N, WN, W, EW
Create Log/Debris Jams at Pools (requires mobilizing and routing logs)	N, WN, W, EW
Achieve Favorable Annual Thermographs for Trout and Macroinvertebrate Productivity (note: historically this may not have been achieved throughout the year in all RY types)	ALL
Sustain Alcove and Secondary Channel Aquatic Environments	DNII, N, WN, W, EW

Note that a given stream process will be accomplished to a varying degree depending on RY type. For example, fine sediment deposition onto the floodplain and terraces should be greater in a Wet runoff year compared to a Normal runoff year (that may barely register a net accumulation only in recently formed floodplain surfaces). Therefore, an important ongoing task has been refining and prioritizing each expected stream process relative to RY type. Each process requires individual consideration.

3 GEOMORPHOLOGY

3.1 Channel Dynamics

3.1.1 Cross Section and Longitudinal Profile Surveys

Cross sections established in our planmapped study sites were not re-surveyed in RY 2003-04. We established four new cross sections at the Rush Creek 3D site that correspond to the piezometer cross sections installed at the site. These new cross sections were monumented with rebar pins at each cross section endpoint and traversed the entire floodway from valley toe to toe. At the 8-Channel site, three new cross sections that correspond to newly installed piezometer arrays were also established and monumented with rebar pins at cross section endpoints. No additional longitudinal profiles were surveyed in RY 2002.

3.1.2 Bed Mobility Experiments

The April 1 forecast initially predicted a Dry-Normal I runoff year type with maximum SRFs for Rush Creek set at 200 cfs. The previous four years had provided similar runoff conditions, and we therefore determined that setting up tracer rock and scour core experiments for the RY 2003-04 would not provide substantial additional data, so these experiments were not conducted. The Runoff Year 2002-03 Annual Report summarizes all our bed mobility data.

3.1.3 Planmapping

Planmapping did not occur in RY 2002. The SWRCB Orders require planmapping every five years. Planmaps were prepared in 1999 and will be repeated in the RY 2004-05 field season.

3.2 Termination Criteria

Runoff Year 2003-04 was a Dry-Normal I runoff year with relatively low spring snowmelt runoff. These conditions combined with the Dry-Normal and Normal runoff year conditions during the previous four years have not appreciably altered the stream channel networks along the Rush Creek and Lee Vining Creek valleys. Therefore, no updates to the geomorphic termination criteria were made in 2003. The riparian acreage termination criteria are addressed in Section 4.2 below. Chris Hunter reports separately on the trout population termination criteria.

The new set of aerial photographs flown in June of 2003 were completed in February 2004 by Aerial Photomapping Services. The orthorectification for this photo set included development of a digital terrain model with contour accuracy of ±1 ft. This photo set will now allow us to digitize a channel centerline and accurately determine the main channel length, channel gradient, and channel sinuosity. This procedure will be done in the spring of 2004. The analysis will replicate the original termination criteria for each reach of Rush Creek and Lee Vining Creek.

Two additional quantitative measures have been discussed in the past as potential new termination criteria – channel confinement using shear stress, and variation in longitudinal thalweg elevation. Our planned 2004 fieldwork will include planmapping and re-survey of the thalweg profiles, and surveys of historic channel geometry, and will provide data with which to continue to assess these measures.

4 RIPARIAN VEGETATION MONITORING

4.1 Origin of the Riparian Vegetation Termination Criteria

Vegetation along Rush, Parker, Walker, and Lee Vining creeks is either desert or riparian, with riparian vegetation further distinguished as woody riparian vegetation, grassland, or wet meadows[1] (Stine 1991; JSA 1993; McBain and Trush 2000). While ambient conditions surrounding these four streams are arid, they sustain local groundwater conditions across their valley bottoms sufficiently in excess of local precipitation to sustain riparian vegetation. Strictly speaking, accessibility of groundwater to riparian vegetation across the valley bottoms defines the riparian corridor.

Where topography provides valley wall confinement, the riparian corridor exists within a "stream migration corridor", though the stream and riparian corridor may shift within this migration corridor over time. The stream migration corridor for Rush and Lee Vining creeks above the county road was defined as the area from valley toeslope to toeslope. Along Lee Vining and Rush creeks near the county road, where valley wall confinement is lacking, a topographic break between the 1929 floodplain/low terraces and adjacent high terrace surfaces was used to define the migration corridor. Due to lake level lowering, Rush and Lee Vining creeks are currently incised where there is no valley wall confinement, especially below the county road. For Parker and Walker creeks, with no valley confinement, the riparian corridor was defined as the zone where vegetation influences the aquatic system, set at 150 ft from each creek's centerline. The blue and white books (LADWP 1997) also propose a 150 ft setback for these unconfined reaches. Changes in woody riparian vegetation cover are quantified within the stream migration corridors or 150 ft setback for each creek.

The extent of riparian vegetation is a focal point of stream ecosystem recovery. SWRCB D-1631 and subsequent orders required LADWP to restore "pre-diversion" riparian vegetation conditions and established termination criteria. The 1929 aerial photographs have been used to quantify vegetated areas under pre-diversion conditions (Stine 1991, 1992; McBain and Trush 2002). Jones and Stokes Associates (JSA) used a combination of 1929 and 1940 aerial photographs to estimate the pre-diversion riparian vegetation in the Mono Basin Environmental Impact Report (JSA 1993). Because of the importance of riparian vegetation termination criteria, and because our ability to compare these original estimates to contemporary estimates has improved with recent technology, we evaluated the termination criteria by re-mapping riparian vegetation on the 1929 aerial photos. For this evaluation we obtained the highest quality digital images of the 1929 aerial photos, orthorectified them, then re-mapped the 1929 riparian vegetation using patch-type definitions from the 1999 vegetation surveys, while still allowing comparisons to the original JSA 1929 mapping. Our objectives were to:

- establish consistent assessment boundaries applicable to all vegetation surveys;
- establish accurate and repeatable methods for estimating the 1929 acreages (e.g., excluding vegetated areas supported by irrigation);
- compare our estimates of 1929 riparian vegetation acreage to the original JSA pre- diversion estimates, to the SWRCB Order 98-05 termination criteria and to our 1999 acreage estimates.

In the following sections we describe the original methods JSA used to estimate 1929 acreages and our updated methods used in 2003, then summarize the status of the riparian vegetation termination criteria.

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[1] Vegetation is "all the plant species in a region, and the way they are arranged" and appears as a mosaic of several definable plant stand types (Sawyer and Keeler-Wolf 1995) that rely on the elevated groundwater conditions found along streams within the riparian corridor.

4.1.1 Jones and Stokes Riparian Vegetation Estimates

Jones and Stokes Associates (JSA) quantified riparian vegetation (both woody riparian and wet meadows) along the four tributaries by mapping the vegetation on 1929/1940 and 1989 aerial photographs (JSA 1993). Mapping was hand drawn on topographic maps derived from the 1991 photogrammetry by translating air photo observations from air photos onto the topo maps (i.e., a technician examined the 1929, 1940, or 1989 air photos and then drew vegetation boundaries on topographic maps side-by-side with the air photos). These hand drawn maps were then electronically planimetered to estimate vegetation acreages. Patch types mapped by JSA included: conifer-broadleaf, cottonwood willow aspen, willow scrub mixed riparian (i.e., woody riparian vegetation) and wet meadow (JSA 1993).

Pre-diversion (1929/1940) and 1989 riparian acreage estimates were presented in the Mono Basin EIR (JSA 1993). JSA compared 1989 vegetated areas to pre-diversion vegetated areas to evaluate impacts of diversion and establish a baseline for assessing riparian vegetation recovery. Pre-diversion acreages were first proposed as a recovery goal in the Mono Basin EIR.

To develop a consistent recovery baseline, the Restoration Plan (Ridenhour et al. 1995) used the pre-diversion acreage estimates for the riparian vegetation termination criteria. Only woody vegetation acreage along Lee Vining and Rush creeks was included; wet meadow acreage was not included in the termination criteria because the relationship of wet meadows to human activities or stream influence was ambiguous. During the development of the restoration plan, the final woody riparian vegetation acreage values used in the termination criteria were reduced in many stream reaches compared to those estimated by JSA (Table 9). Parker and Walker creeks had no termination criteria.

4.1.2 McBain and Trush 1929 Vegetation Acreage Estimates

We obtained film diapositives of the original 1929 aerial photo negatives, scanned them at high resolution (1200 dpi), and color corrected them in Adobe Photoshop to improve contrast and interpretability. Using AutoCAD Map, the photos were rubbersheeted using 1996 USGS Digital Orthorectified Quarter Quadrangles (DOQQs) to locate coincident ground control points (typically road intersections). The photos were then printed at 1:1800 scale (1 inch = 150 feet) and laminated for vegetation mapping. This “spatially accurate” map was used to estimate acreages of the 1929 vegetation for Rush, Lee Vining, Parker, and Walker creeks using vegetation classes consistent with vegetation mapped in 1999 by McBain and Trush (McBain and Trush 2000), and was comparable to the vegetation classes mapped by JSA (JSA 1993). We viewed the original film diapositives concurrently through an enlarging “photo loop” on a light table for additional accuracy of patch determination (McBain and Trush 2003). Patch types were named using the patch type classification developed in 1999 mapping. An example of the plant stands mapped on the 1929 photos is shown in Figure 26.

After delineating the patches on the laminated photo set, we orthorectified the 1929 aerial photos using ERDAS Imagine software with OrthoBASE module. The images were rectified using horizontal control points located on the 1996 USGS DOQQs, automatic tie points using the spectral characteristics of the overlapping imagery, and Digital Elevation Models (DEMs) to correct for topographic relief distortion produced from the relations between the topography and the flat photographic film. Also, since there was no camera calibration report available for the 1929 photos, we estimated the interior parameters of the camera using the flight scale and measurements of the fiducial marks in the photos. The root mean square error (the degree of correspondence between the control points on the resulting 1929 orthophotos and the 1996 DOQQ basephotos) was less than one meter for the Lee Vining Creek block and less than 3 meters for the Rush/Walker/Parker creek block.

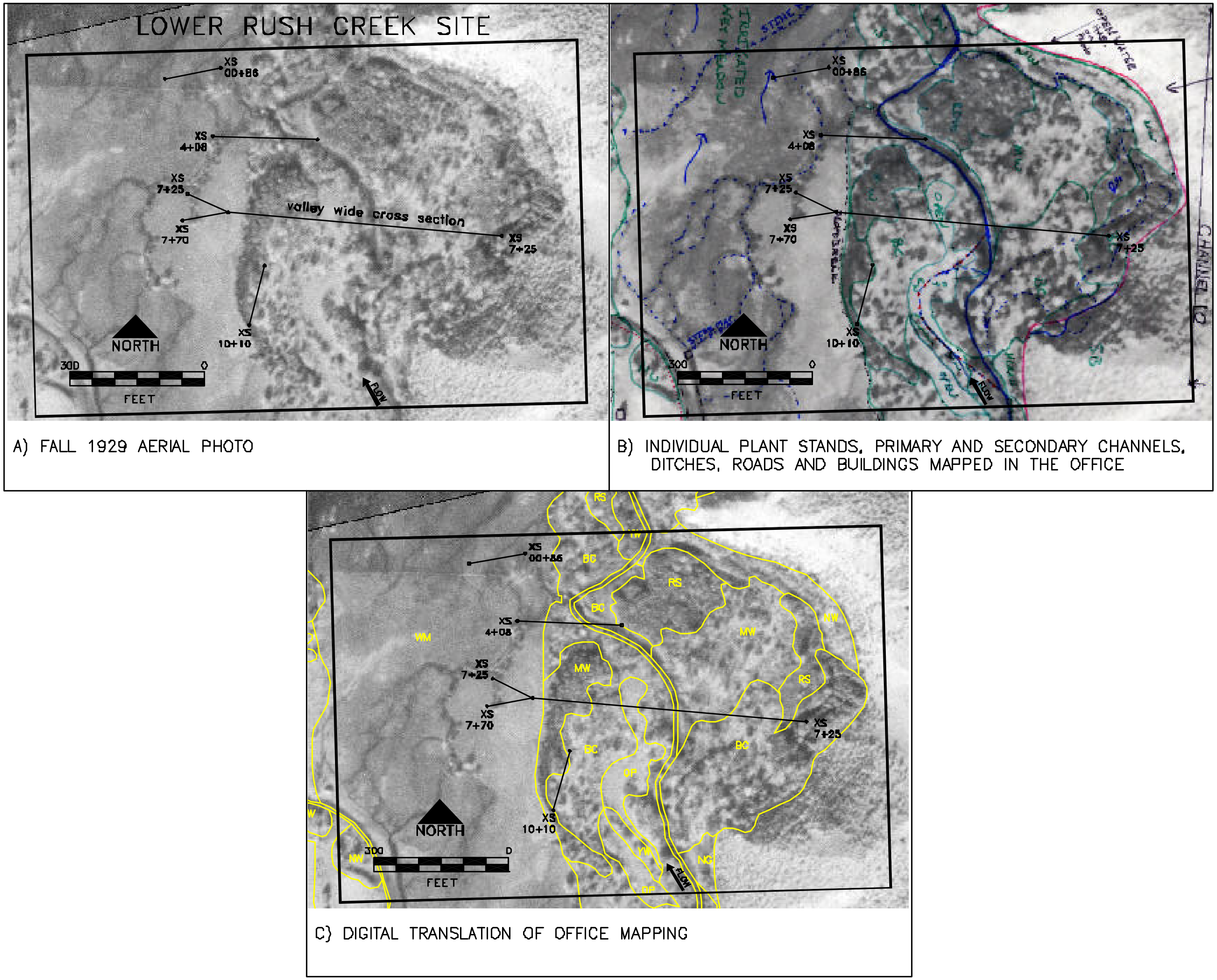
Table 9. Summary of pre-diversion riparian vegetation acreages quantified by JSA, the termination criteria and work completed by McBain and Trush.

RUSH CREEK					
Stream Segment	**Woody Riparian Vegetation (Acres)**				
	Termination Criteria (SWRCB D1631)		**Pre-diversion (JSA 1993)**	**Pre-diversion (McBain and Trush 2004)**	
1	6.2		7.4	N/A	
2	5.0		8.1	5.6	
3a	21.5		24.8	25.5	
3b	2.9		1.5	3.5	
3c	11.2		10.8	17.3	
3d	10.0		22.1	10.3	
4a	26.0	144.7	149.6	37.4	138.6
4b	80.0			73.0	
4c	38.7			28.2	
5a	37.8		37.8	33.0	
5b	N/A		N/A	N/A	

LEE VINING CREEK			
Stream Segment	**Woody Riparian Vegetation (Acres)**		
	Termination Criteria (SWRCB D1631)	**Pre-diversion (JSA 1993)**	**Pre-diversion (McBain and Trush 2004)**
1	20.0	20.3	N/A
2a	30.0	15.0	N/A
2b	Combined with 2a	14.9	9.8
3a	22.2	23.2	18.5
3b	32.9	34.7	36.8
3c	4.0	4.3	4.5
3d	N/A	0.0	0.0

PARKER CREEK			
Stream Segment	**Woody Riparian Vegetation (Acres)**		
	Termination Criteria (SWRCB D1631)	**Pre-diversion (JSA 1993)**	**Pre-diversion (McBain and Trush 2004)**
1	N/A	14.5	6.0
2	N/A	35.4	36.4
3	N/A	2.5	2.8
4	N/A	5.9	4.3

WALKER CREEK			
Stream Segment	**Woody Riparian Vegetation (Acres)**		
	Termination Criteria (SWRCB D1631)	**Pre-diversion (JSA 1993)**	**Pre-diversion (McBain and Trush 2004)**
1 combined with 4	N/A	16.2	22.5
2 combined with 5	N/A	3.5	6.9
3	N/A	2.9	9.3



A) FALL 1929 AERIAL PHOTO

B) INDIVIDUAL PLANT STANDS, PRIMARY AND SECONDARY CHANNELS, DITCHES, ROADS AND BUILDINGS MAPPED IN THE OFFICE

C) DIGITAL TRANSLATION OF OFFICE MAPPING

Figure 26. Example of 1929 aerial photograph of lower Rush Creek showing riparian vegetation mapping conducted in Rush, Parker, Walker, and Lee Vining creeks.

By spatially correcting the 1929 aerial photos and mapping the vegetation patches directly onto those photos, we produced a more accurate and reproducible inventory of the 1929 riparian vegetation than was possible for JSA. For our evaluation, the 1940 aerial photos were not used because they were of poorer quality than the 1929 photos. An example of the plant stands mapped on the 1929 photos is shown in Figure 26.

4.1.3 McBain and Trush 1999 Vegetation Acreage Estimates

SWRCB Order 98-05 requires riparian vegetation mapping and new estimates of riparian acreages every five years or after Extreme Wet runoff year types. The first "official" vegetation mapping occurred in 1999 (riparian corridor vegetation mapping) and was reported (McBain and Trush 2000). Vegetation was described in 2001 (plant stand structure and composition monitoring). Methods and results of this assessment are described in annual reports for Runoff Years 2002 and 2003, and summarized here.

Plant stands and geomorphic units within the migration corridors of the four tributaries were mapped *in the field* directly onto laminated air photos. Individual plant stands were defined by the dominant plant species in the canopy (McBain and Trush 2000). Geomorphic units were defined by distinct changes in ground surface elevations. Geomorphic units were numbered sequentially from lowest to highest elevation relative to the stream channel, starting with the wetted channel as unit-0 and continuing to a high terrace as unit-5. Plant stands and geomorphic units were no smaller than 9 m^2 (3x3 meters). After field mapping, geomorphic units and plant stands were digitized and entered into GIS-compatible software. An example of the sequence of plant stand and geomorphic unit mapping on the 1999 photos is shown in Figure 27. The complete set of plates produced from the 1999 maps is compiled as a photo atlas appended to this report (McBain and Trush, 2004).

In 2003 we re-assessed the migration corridor boundary delineated in 1999 to establish a long-term, fixed corridor boundary. In 1999, the migration corridor was defined using a hand drawn line on the 1999 air photos along the valley toe-slope. The 1929 corridor boundary was hand drawn on the laminated aerial photos, but was not based on topography. When the 1929 and the 1999 corridor boundaries were compared, several errors and exclusions were apparent. Neither of these two corridor boundaries was adequate to define the extent of riparian vegetation. We therefore modified and renamed the previously defined riparian corridor boundary (McBain and Trush 2000) as the 'migration corridor boundary' (described in Section 4.1). The riparian vegetation acreage estimates for 1929 used this boundary, the 1999 woody riparian vegetation acreages were updated using this boundary, and riparian acreages in future years will be quantified using this migration corridor boundary.

4.2 Riparian Acreage Estimates

Using our re-defined migration corridor boundaries and the stream reach delineations adopted by Ridenhour et al. (1995) (Figure 28), we quantified pre-diversion (1929) and contemporary (1999) riparian vegetation acreages for the four tributaries. All vegetation patches within the migration corridors were quantified, but only plant stands consisting of woody riparian vegetation were compared to the termination criteria. This included all woody transition patch types (e.g., Wood's rose and buffalo berry stands). If a plant stand extended beyond the migration corridor boundary, the area outside the boundary was excluded. To maintain consistency with previous estimates (JSA 1993), grasslands and wet meadows were excluded. Woody riparian vegetation acreages are summarized in Tables 9 to 11 for 1929, 1989, and 1999 conditions; the 1929 and 1999 vegetation maps are presented in Appendix E. Given that professional interpretation is required to delineate vegetation patch types on the 1929 photos, all riparian vegetation acreage estimates provided in this report are considered preliminary, and are subject to review of the methodologies used.

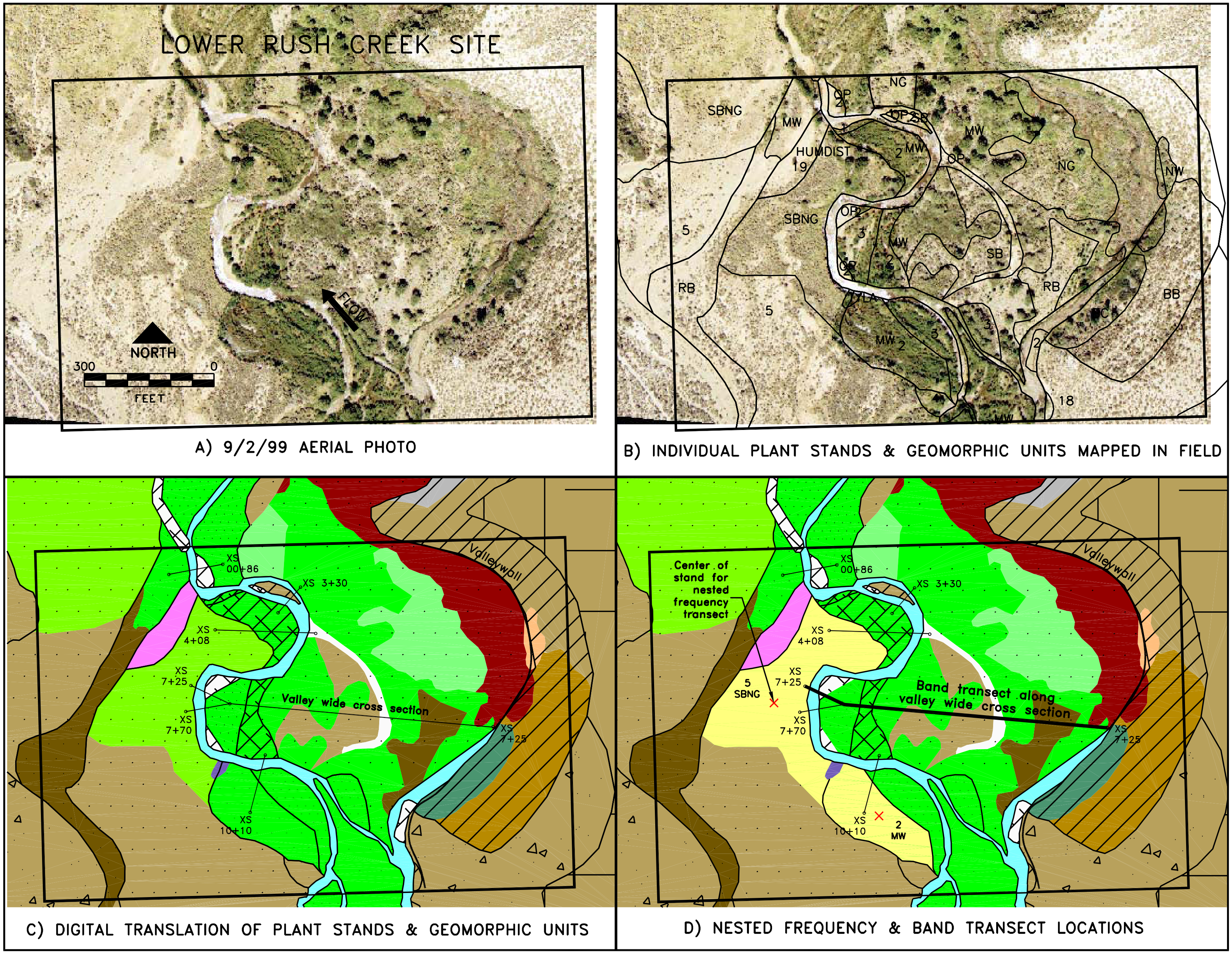


Figure 27. Example of 1999 aerial photograph of lower Rush Creek showing riparian vegetation and geomorphic unit mapping conducted in Rush, Parker, Walker, and Lee Vining creeks.

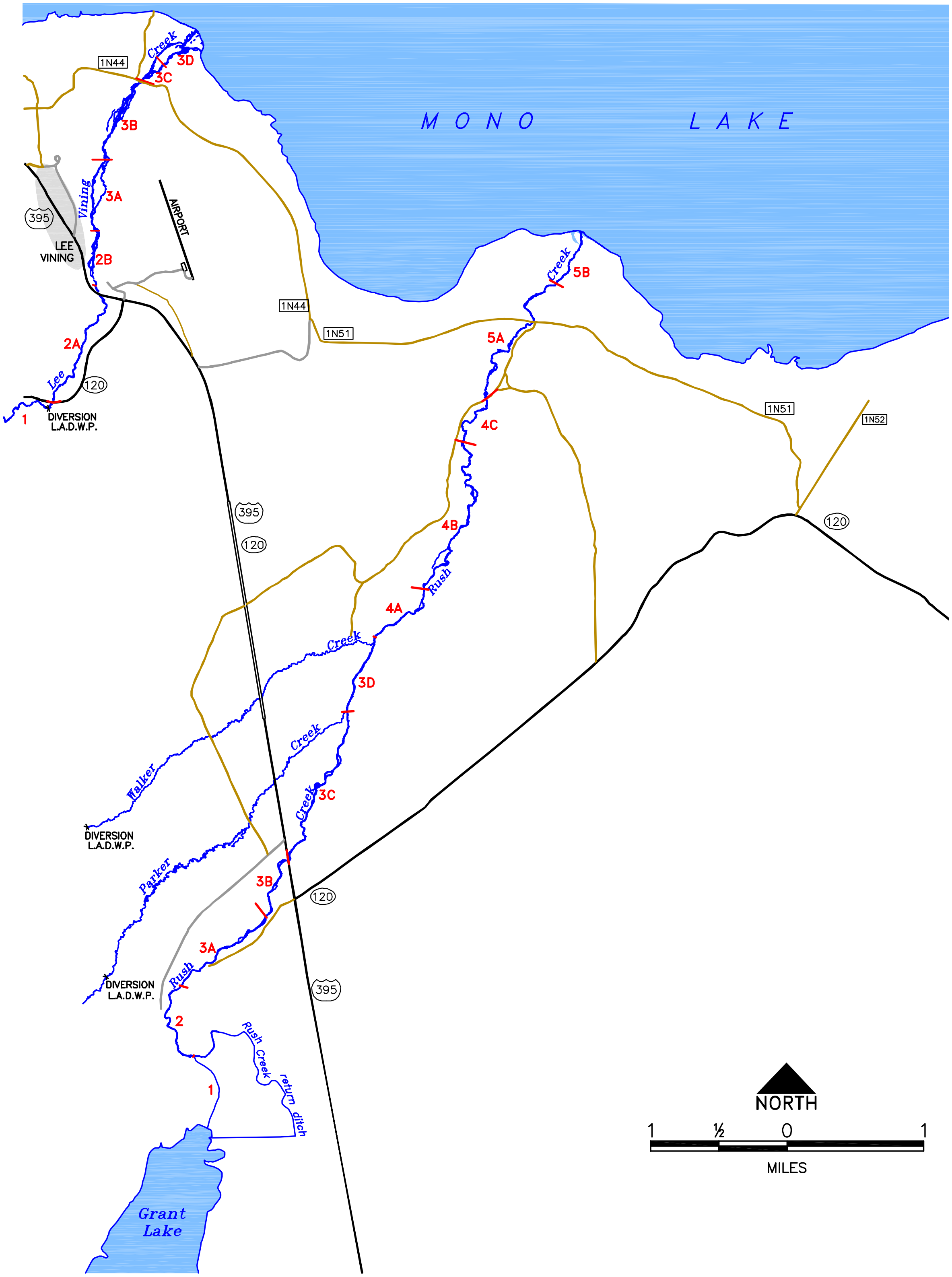


Figure 28. Map of the Mono Basin showing reach boundaries adapted from Ridenhour et al. (1995) used to develop termination criteria for discrete reaches of Rush and Lee Vining creeks.

Table 10. Comparison of the woody riparian vegetation coverage established in the termination criteria, to the 1989 acreages quantified by JSA, and the 1999 acreages quantified by McBain and Trush.

RUSH CREEK							
Stream Segment	**Woody Riparian Vegetation (Acres)**						
	Termination Criteria (SWRCB D1631)		**1989 Vegetation (JSA 1993)**	**1999 Vegetation (McBain & Trush)**		**Difference Between Termination Criteria and 1999 Estimates**	
1	6.2		1.7	N/A		N/A	
2	5.0		5.9	5.4		0.4 acres	
3a	21.5		12.7	12.2		-9.3 acres	
3b	2.9		0.1	1.4		-1.5 acres	
3c	11.2		4.1	10.4		-0.8 acres	
3d	10.0		4.0	10.0		0.0 acres	
4a	26.0	144.7	90.0	22.0	114.2	-4.0 acres	-30.5
4b	80.0			60.3		-19.7 acres	
4c	38.7			31.9		-6.8 acres	
5a	37.8		11.0	27.9		-9.9 acres	
5b	N/A		*combined with 5a*	6.2		N/A	

LEE VINING CREEK				
Stream Segment	**Woody Riparian Vegetation (Acres)**			
	Termination Criteria (SWRCB D1631)	**1989 Vegetation (JSA 1993)**	**1999 Vegetation (McBain & Trush)**	**Difference Between Termination Criteria and 1999 Estimates**
1	20.0	19.8	N/A	N/A
2a	30.0	13.4	N/A	N/A
2b	*Combined with 2a*	10.9	10.6	-6.0 acres
3a	22.2	6.9	12.5	-9.7 acres
3b	32.9	7.5	20.8	-12.1 acres
3c	4.0	3.3	4.9	0.9 acres
3d	N/A	8.6	12.7	N/A

Table 11. Comparison of the 1929 woody riparian vegetation coverage quantified by McBain and Trush, to the 1989 acreages quantified by JSA, and the 1999 acreages quantified by McBain and Trush.

PARKER CREEK			
Stream Segment	**Woody Riparian Vegetation (Acres)**		
	Pre-Diversion Vegetation (McBain & Trush)	**1989 Vegetation (Jones & Stokes 1993)**	**1999 Vegetation (McBain & Trush)**
1	6.0	15.2	14.0
2	36.4	31.3	38.8
3	2.8	0.5	0.8
4	4.3	2.2	1.5

WALKER CREEK			
Stream Segment	**Woody Riparian Vegetation (Acres)**		
	Pre-Diversion Vegetation (McBain & Trush)	**1989 Vegetation (Jones & Stokes 1993)**	**1999 Vegetation (McBain & Trush)**
1 combined with 4	22.5	13.1	13.5
2 combined with 5	6.9	1.3	0.35
3	9.3	2.8	7.3

4.2.1 1929 Riparian Vegetation

We compared the acreage of woody riparian vegetation from our mapping of the 1929 photos to 1929 acreages quantified by JSA (1993), and to the termination criteria (Table 9). Our 1929 acreage estimates were closest to the termination criteria, mostly falling between the JSA estimates and the termination criteria. The updated migration corridor and stream reach designations were minor sources of differences (mostly decreases) in woody riparian acres between the different estimates. The greatest source of acreage differences between the estimates was created because our assessment of the 1929 photos re-classified stands as either riparian or desert. In some reaches we identified more desert patches within the migration corridor than were identified by JSA, but in some reaches we identified more riparian patches than were identified by JSA. Our 1929 woody riparian acreage estimates were different from the termination criteria acreages and from the JSA pre-diversion acreage estimates when evaluated on a reach-by-reach basis. But the similarity of the overall corridor-wide estimates (within approximately 6% for Lee Vining Creek; 0% for Rush Creek) suggests all the estimates are reasonable (Table 9).

Comparing the 1929 and 1999 maps revealed interesting trends. In the 1929 photos, tree size, height and canopy diameter could not be quantified, but the number of patch types that included trees, compared to those that did not, were apparent. The relative proportion of vegetation composed of trees versus shrubs is a useful measure of *riparian vegetation quality*. As may be expected, a larger percentage of the 1929 riparian stands was composed of trees compared to the contemporary riparian corridor. Patch sizes in 1929 were also generally larger and more contiguous.

The 1929 riparian corridor was already disturbed by human activities. Irrigation, grazing, vegetation clearing, and canal building are all apparent in the aerial photos. Irrigation had created a much wider riparian corridor in many locations by distributing water on low lying terraces that would not otherwise have had access to groundwater. These terraces converted to grassy meadows. In other locations, side-channels appear to have either fed canals or drained them (e.g., the Indian Ditch area of Rush Creek). These side-channels also sustained riparian vegetation.

4.2.2 Summary of Woody Riparian Vegetation Termination Criteria and Vegetation Structure

Riparian woody vegetation cover for 1989 and 1999 was compared to the termination criteria (Table 10). We estimated the 1999 riparian woody cover acreages based on our maps; the 1989 acreages were from the JSA (1993). Woody riparian acreage was insufficient in 1999 to meet the termination criteria in most reaches of Lee Vining and Rush creeks, but exceeded the termination criteria acreages in Rush Creek reach 2 and 3D, and in Lee Vining Creek reach 3C (Table 10, Figures 29 and 30).

In 2003, we reported that a greater percentage of patches along Lee Vining Creek currently have species growing into the tree layer (>15 ft), while Rush Creek has three times fewer such patches (McBain and Trush 2003). We defined stand *quality* as the number of patches that have trees compared to the number of patches composed only of shrubs. The number of patches dominated by trees in 1929 can be quantified and used as a measure of riparian structural quality. Future vegetation mapping and possible revegetation projects should therefore not only evaluate area, but should also consider the species composition, and how these species will influence the structure of riparian woody vegetation.

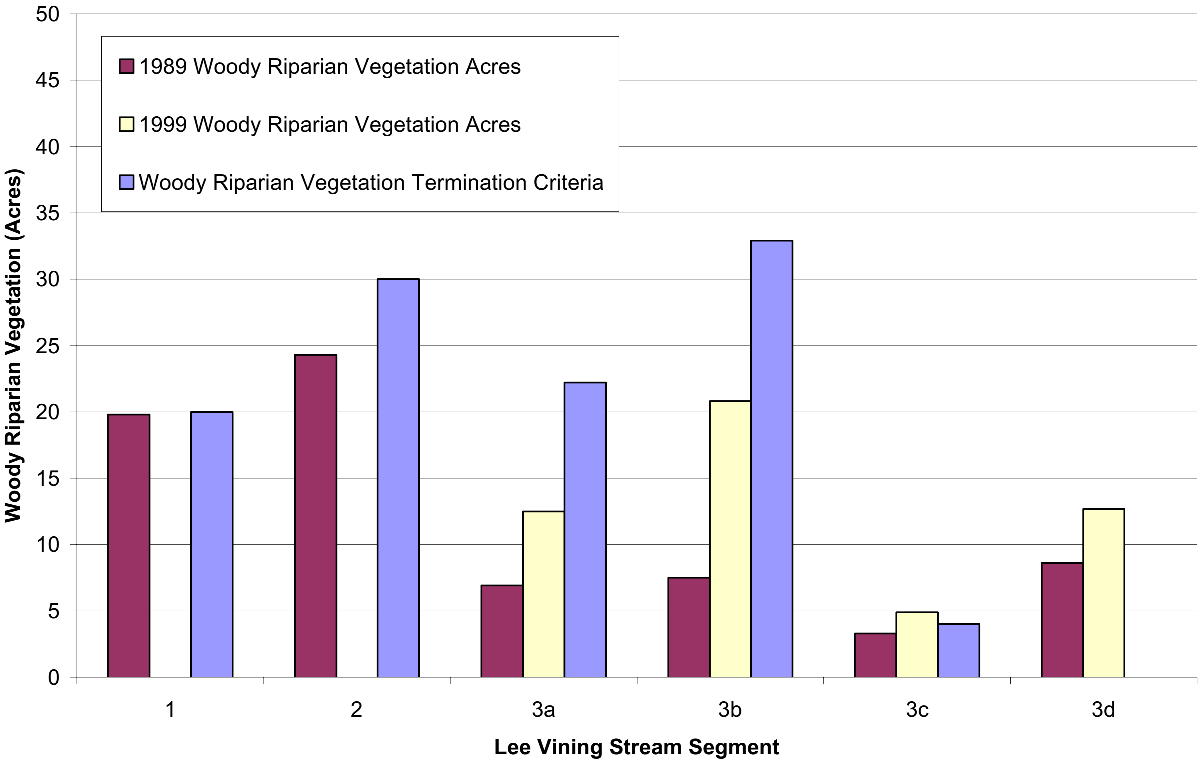


Figure 29. Comparison of 1989 and 1999 Lee Vining Creek woody riparian vegetation acreage estimates to the termination criteria. Reaches 1 and 2 upstream of Hwy 395 were not mapped in 1999.

4.3 Initiation of Riparian Vegetation at 3D and 8-Channel Sites

Construction of the 3D floodplain and the reopening of the 8-Channel entrance occurred in the fall 2002. Their freshly disturbed surfaces were exposed to seeds dispersed by woody riparian plants during the spring and summer 2003 growing season. Peak flows in 2003 were insufficient for entering the newly opened 8-Channel. As a result, no 2003 cohort seedlings (only clonal re-sprouts of narrowleaf willow) were observed anywhere along the length of the reopened channel. Woody riparian initiation at the 3D channel, where peak flows in 2003 did inundate the site, was abundant.

The species composition and patchy mosaic of seedlings that initiated in 2003 at the 3D channel were encouraging. Black cottonwood, yellow willow, and shiny willow seedlings were observed in great abundance (> 100 seedlings/sq ft) along the constructed channel and in shallow depressions throughout the site. Patches of seedlings tended to be either a combination of yellow willow and shiny willow, or exclusively black cottonwood, reflecting the difference in seed dispersal timing and the exposed areas that supported seed germination during seed dispersal.

In the summer 2004 we will continue quantifying the woody riparian vegetation response to the construction of the 3D channels and reopening of the 8-Channel. Permanent monuments will be established where 3.3 sq ft (1m) quadrats are placed and woody seedlings sampled.

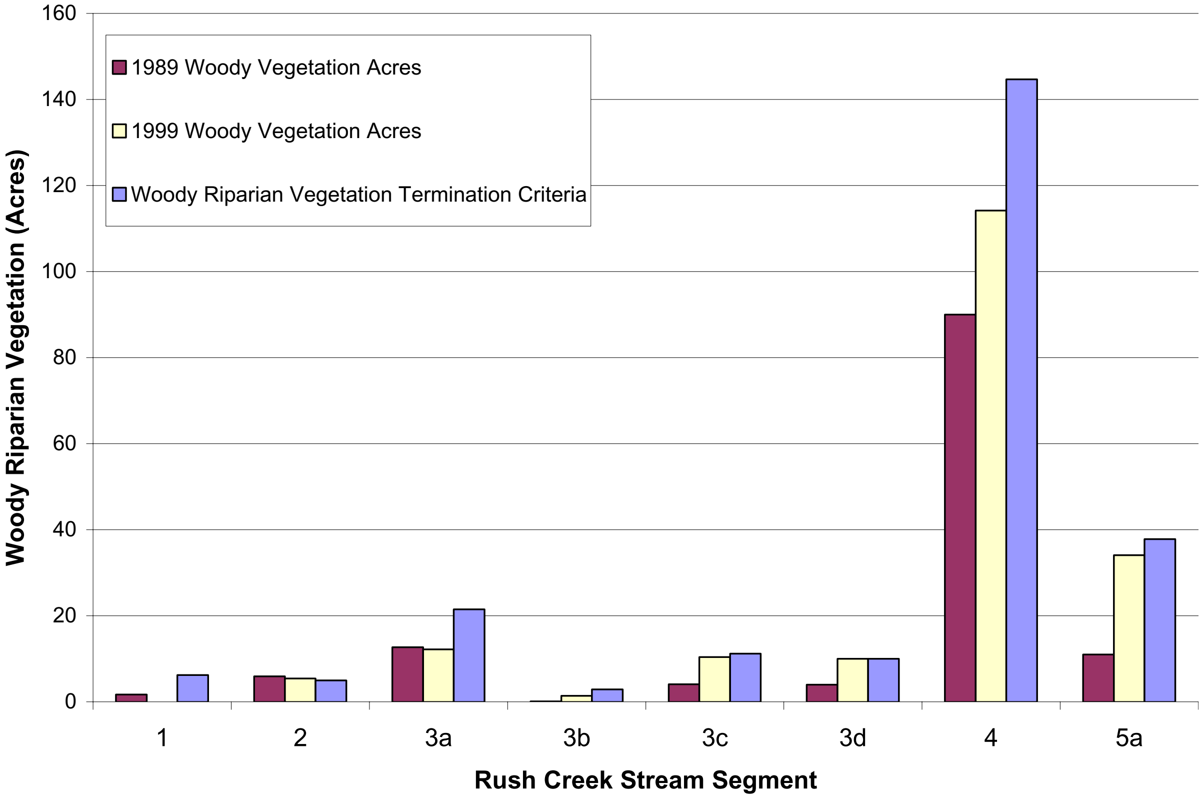


Figure 30. Comparison of 1989 and 1999 Rush Creek woody riparian vegetation acreage estimates to the termination criteria. Reach 1 between Grant Lake and the Return Ditch was not mapped in 1999.

5 2004 MONITORING SEASON

With completion of the Rush Creek Return Ditch, and the anticipation of a flow test of 380 cfs in the Return Ditch, Rush Creek is likely to have a Stream Restoration Flow of approximately 380 cfs below the Return Ditch. If timed to correspond to Parker and Walker creek peak flows, the Rush Creek peak discharge below the Narrows could exceed 420-450 cfs. This flow provides a much needed opportunity for field data collection for many of our monitoring components. The 2004 field season is thus expected to be busy. The following summarizes our anticipated 2004 monitoring activities

Measure streamflow in the mainstem and adjoining side-channels to document changing flow proportions using methods established in the last few years;

Monitor the 3D and 8-Channel piezometers in Lower Rush Creek and quantify relationships between streamflow and shallow groundwater elevation to document the high flow signature on shallow groundwater dynamics;.

Monitor stage height at the entrance to the 4Bii-Channel of Lower Rush Creek and surface water ponding in the floodplain hydraulically connected to the 4Bii-Channel;

Reset all tracer rock and scour core experiments and monitor their movement resulting from the snowmelt runoff. Re-survey cross sections and longitudinal profiles, and planmap study sites to document changes in channel morphology;

Monitor aggradation on floodplain surfaces, relate aggradation to depth of inundation, turbidity, roughness, duration of the hydrograph, and floodplain elevation;

Quantify geomorphic termination criteria for main channel lengths, sinuosity, channel gradient, and variation in longitudinal profile on Rush and Lee Vining Creeks.

Estimate bed-averaged shear stresses along a pair of channel segments in the Upper Lee Vining Creek planmap site, and at a pair of sites on Rush Creek below the Narrows to evaluate contemporary and pre-1941 channel morphologies;

Planmap study sites on Rush, Parker, Walker, and Lee Vining creeks using a combination of aerial photographs and total station surveys. Planmapping will document the wetted channel, active channel, and bankfull channel boundaries, habitat unit boundaries, physical conditions contributing to channel complexity (large woody debris and debris jams, boulders, off-channel alcoves, undercut and sloughing banks).

Map geomorphic surfaces and riparian plant stand types in Fall 2004

Monitor the 3D Floodplain, 8-Channel, and Narrows Pilot Plantings;

Miscellaneous Activities:

- Continue collecting temperature data at existing thermograph locations and install six new thermographs in Rush and Lee Vining creeks.
- Complete the installation of cross sections and staff plates at the 3D and 8-Channel sites.
- Document flood peak effects on LWD mobilization and logjam formation (possibly including a few “marked” log experiments).
- Investigate 13-channel hydraulic connection to the ‘10 Falls.’
- Back-calculate empirically derived ‘n’ values in complex, confined mainstem reaches in lower Rush Creek and (possibly) confined B-1 reach on lower Lee Vining Creek.

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APPENDIX A

Lee Vining Creek Groundwater Monitoring at the B and C Piezometers for Runoff Years 1996 to 2002.

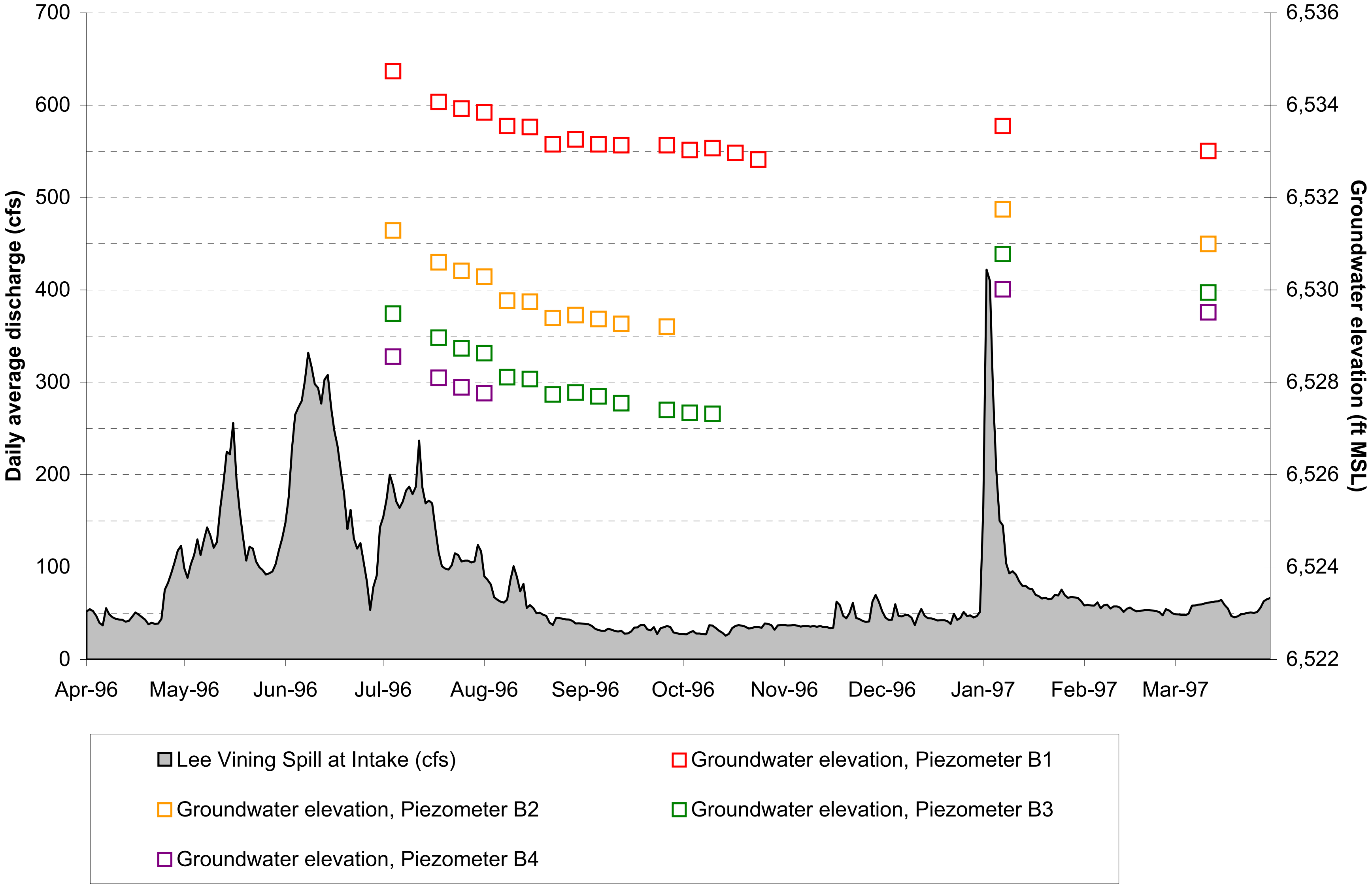


Figure A-1. Runoff Year 1996 streamflow hydrograph and groundwater elevations for the Lee Vining Creek B-array piezometers. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

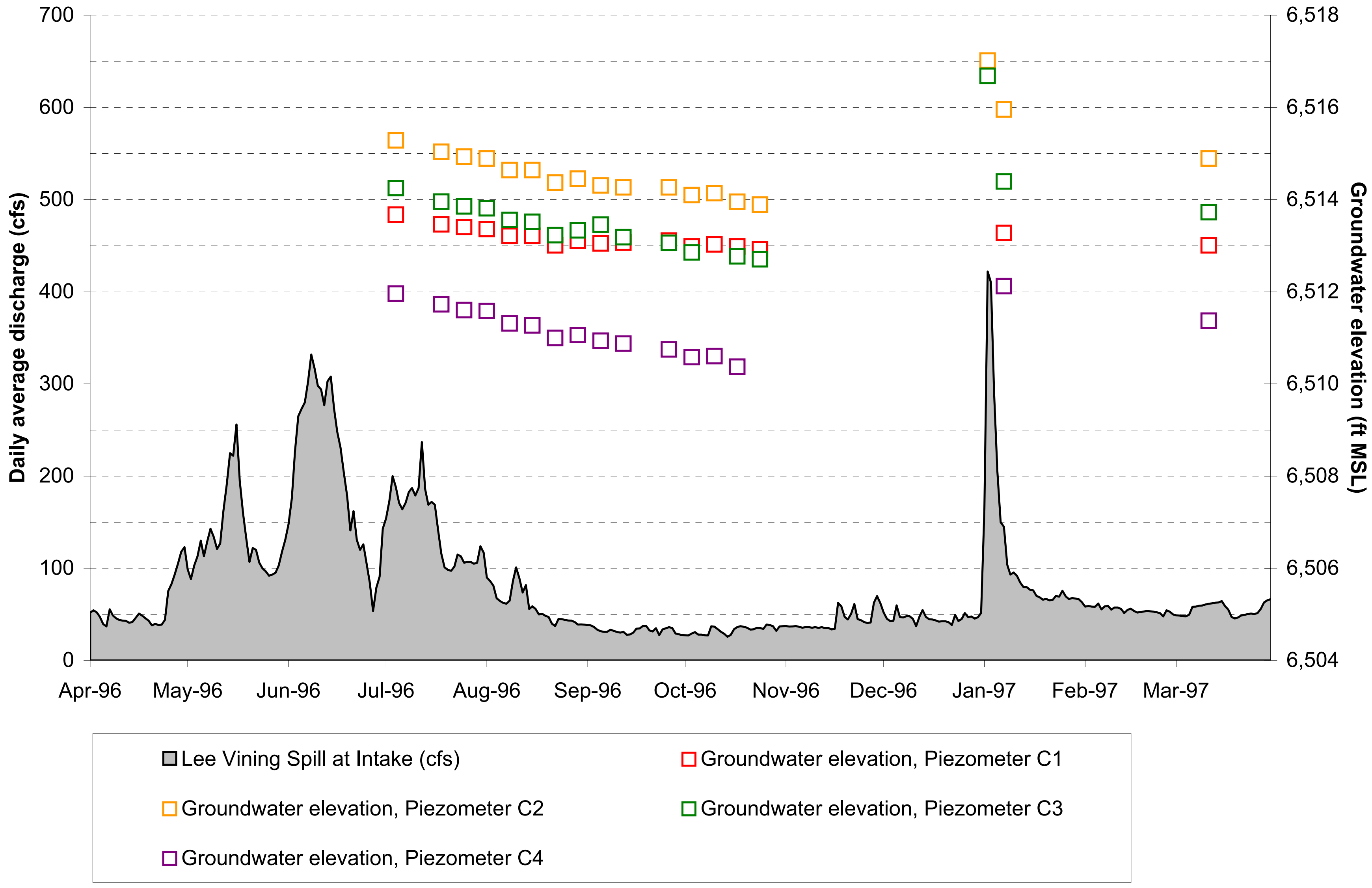


Figure A-2. Runoff Year 1996 streamflow hydrograph and groundwater elevations for the Lee Vining Creek C-array piezometers. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

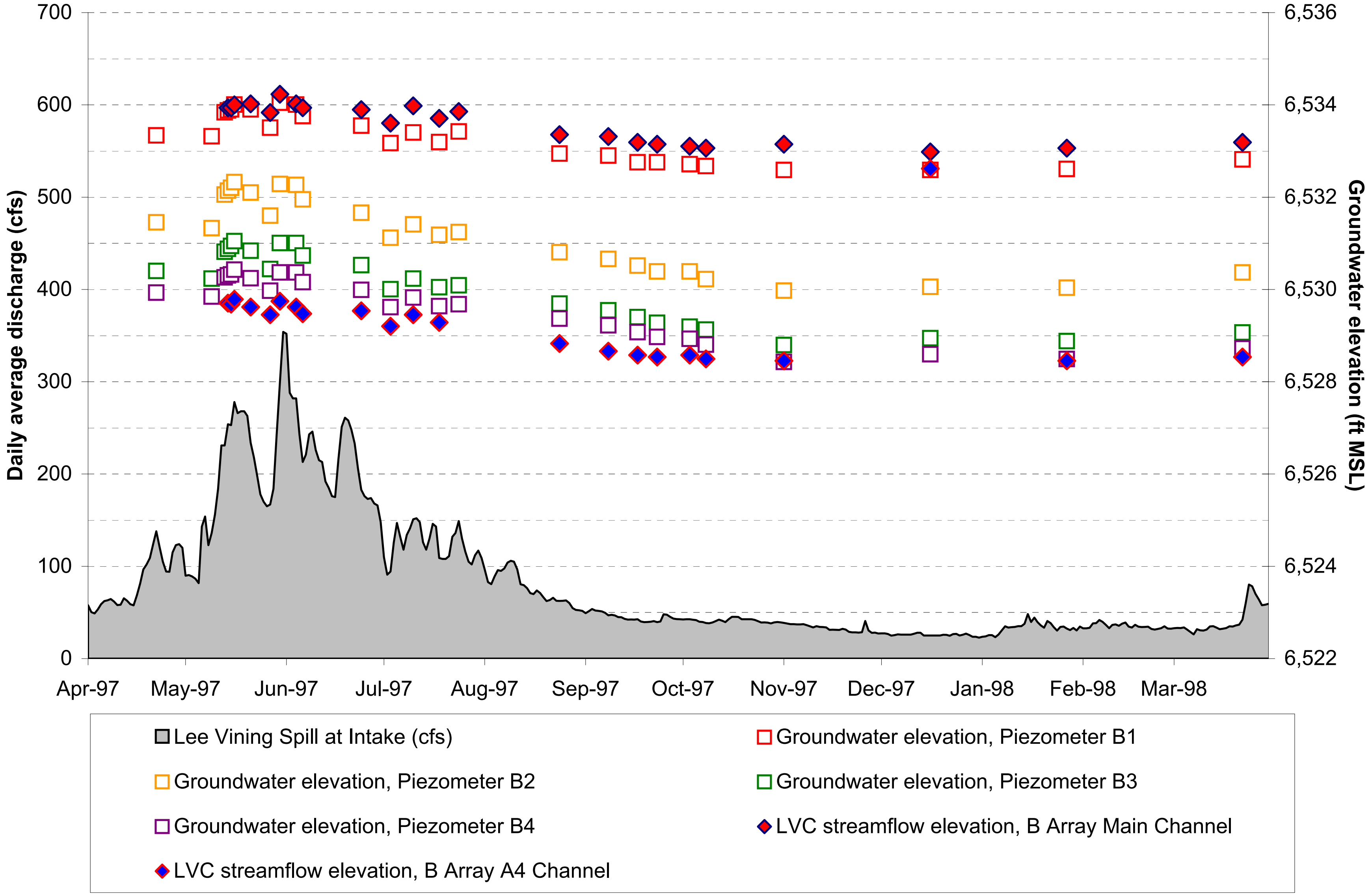


Figure A-3. Runoff Year 1997 streamflow hydrograph, groundwater elevations for the Lee Vining Creek B-array piezometers, and streamflow elevations for the main channel and A-4 channel. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths and streamflow elevations were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

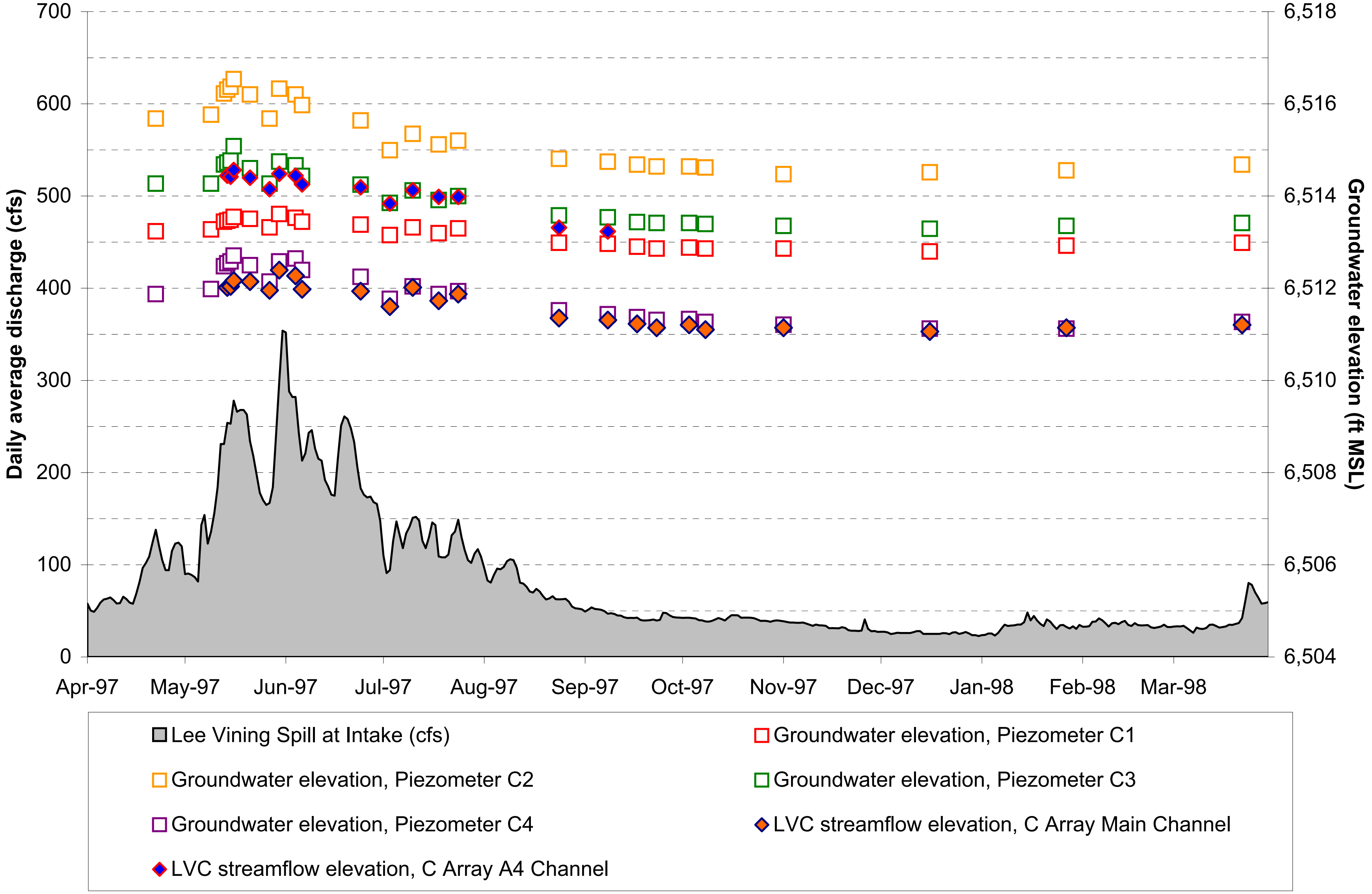


Figure A-4. Runoff Year 1997 streamflow hydrograph, groundwater elevations for the Lee Vining Creek C-array piezometers, and streamflow elevations for the main channel and A-4 channel. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths and streamflow elevations were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

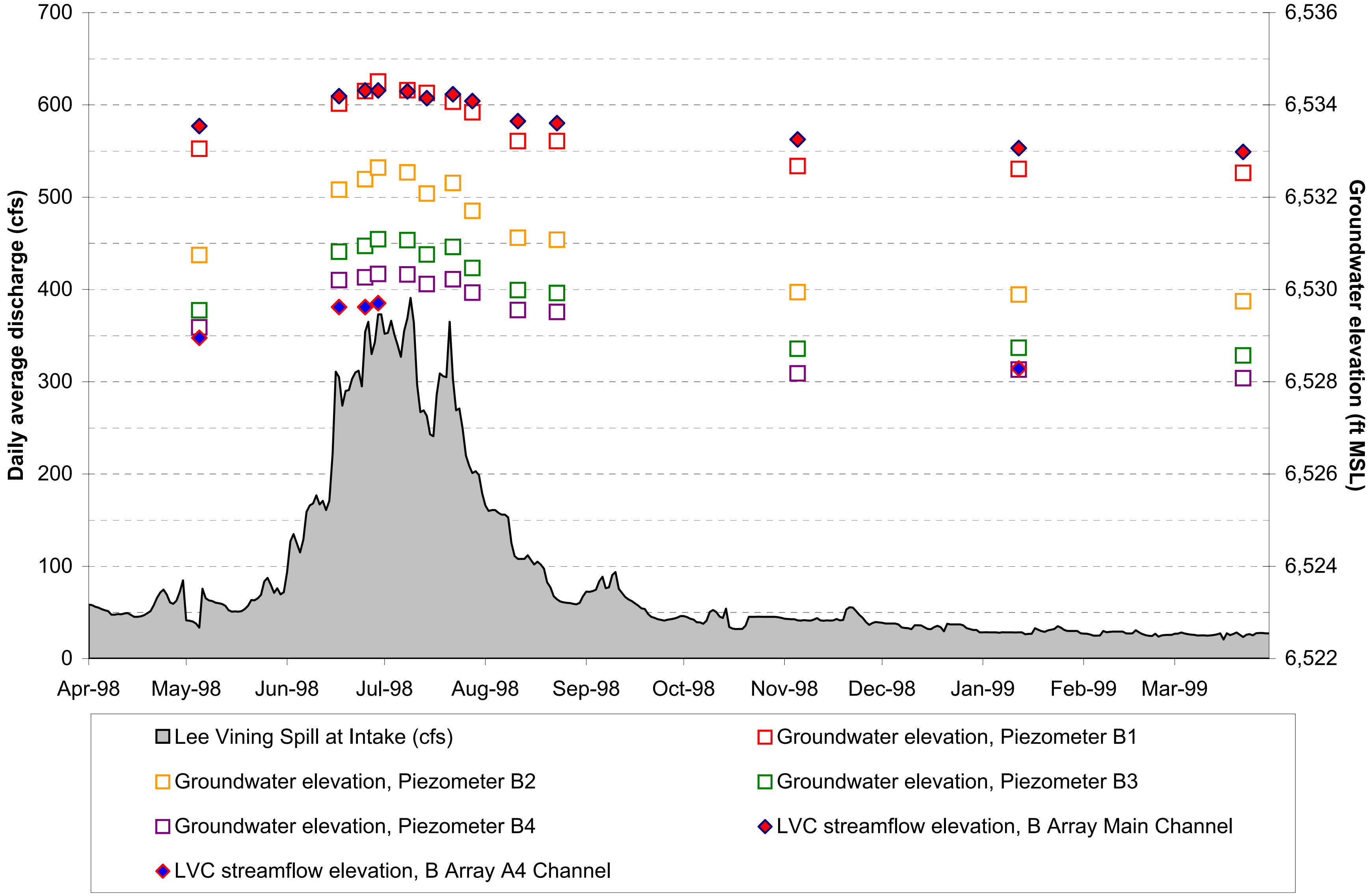


Figure A-5. Runoff Year 1998 streamflow hydrograph, groundwater elevations for the Lee Vining Creek B-array piezometers, and streamflow elevations for the main channel and A-4 channel. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths and streamflow elevations were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

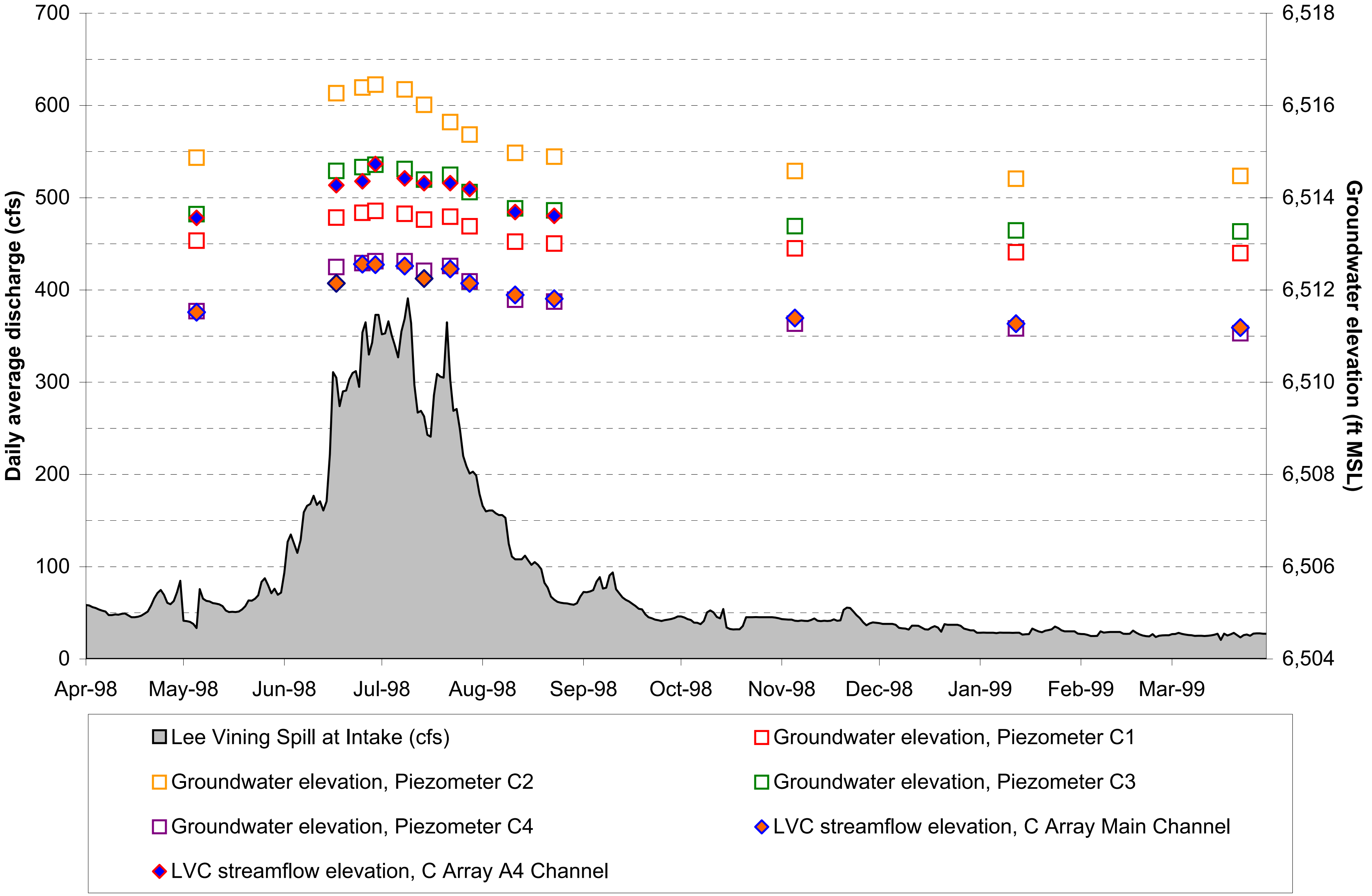


Figure A-6. Runoff Year 1998 streamflow hydrograph, groundwater elevations for the Lee Vining Creek C-array piezometers, and streamflow elevations for the main channel and A-4 channel. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths and streamflow elevations were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

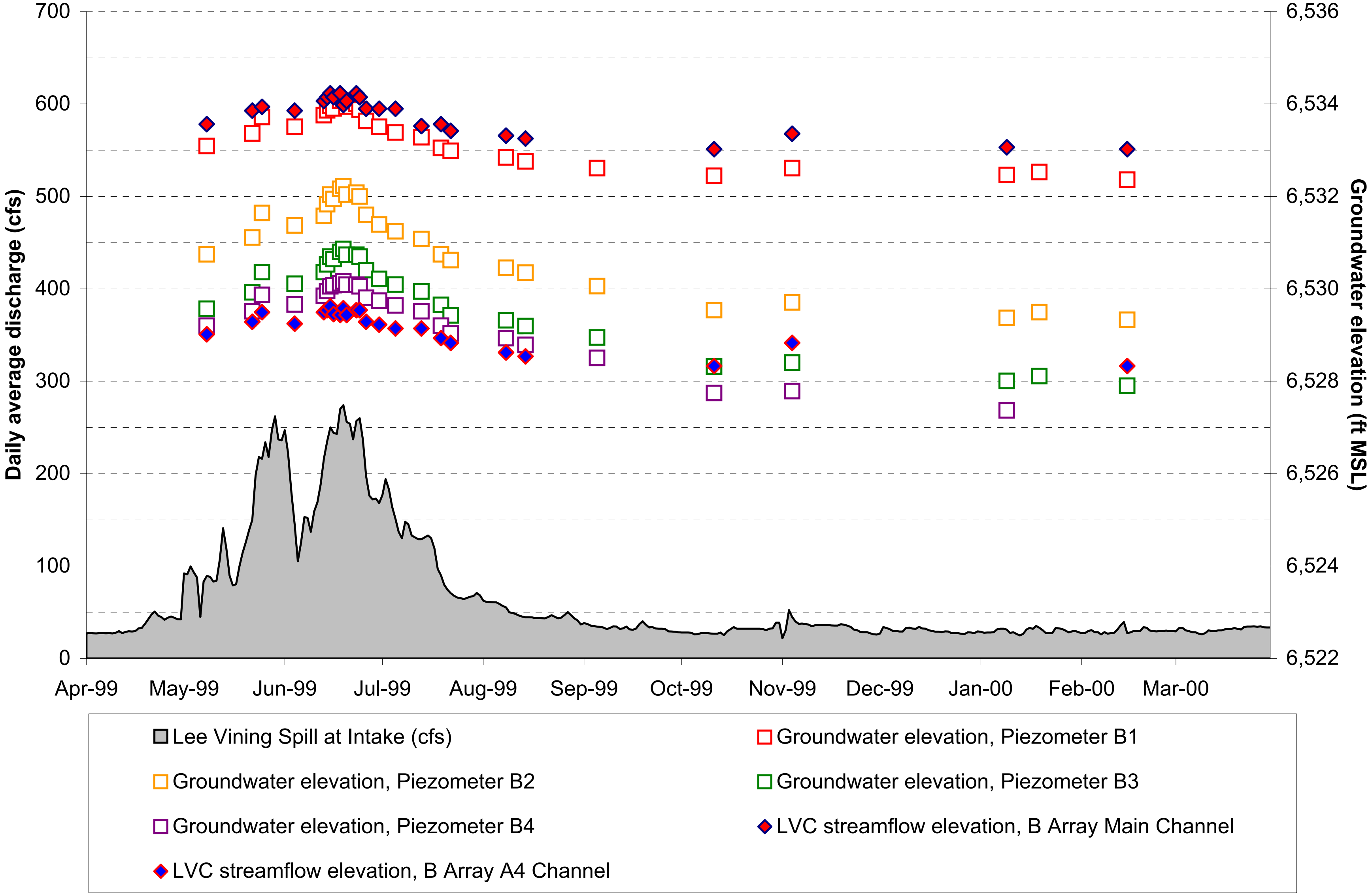


Figure A-7. Runoff Year 1999 streamflow hydrograph, groundwater elevations for the Lee Vining Creek B-array piezometers, and streamflow elevations for the main channel and A-4 channel. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths and streamflow elevations were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

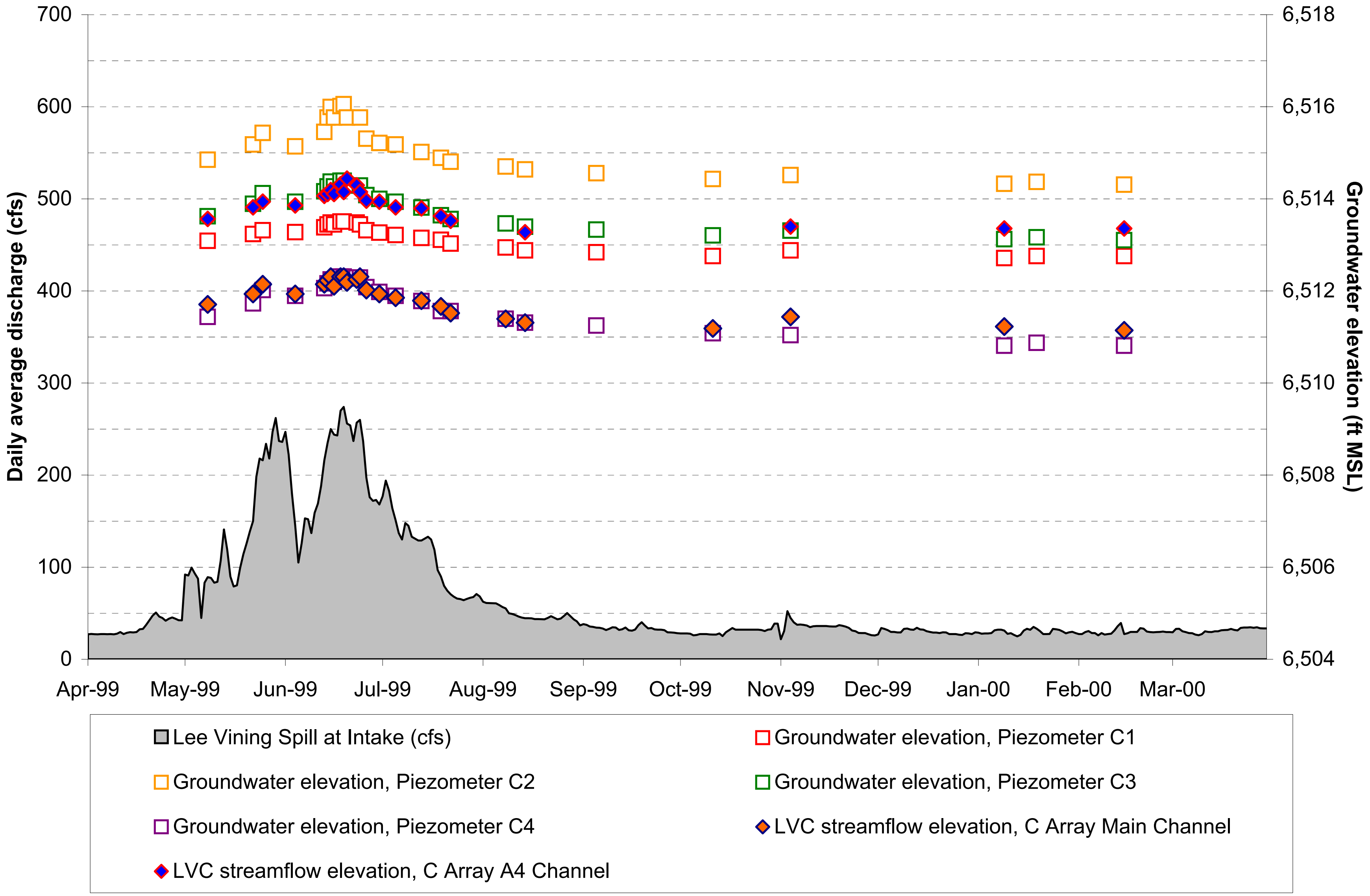


Figure A-8. Runoff Year 1999 streamflow hydrograph, groundwater elevations for the Lee Vining Creek C-array piezometers, and streamflow elevations for the main channel and A-4 channel. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths and streamflow elevations were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

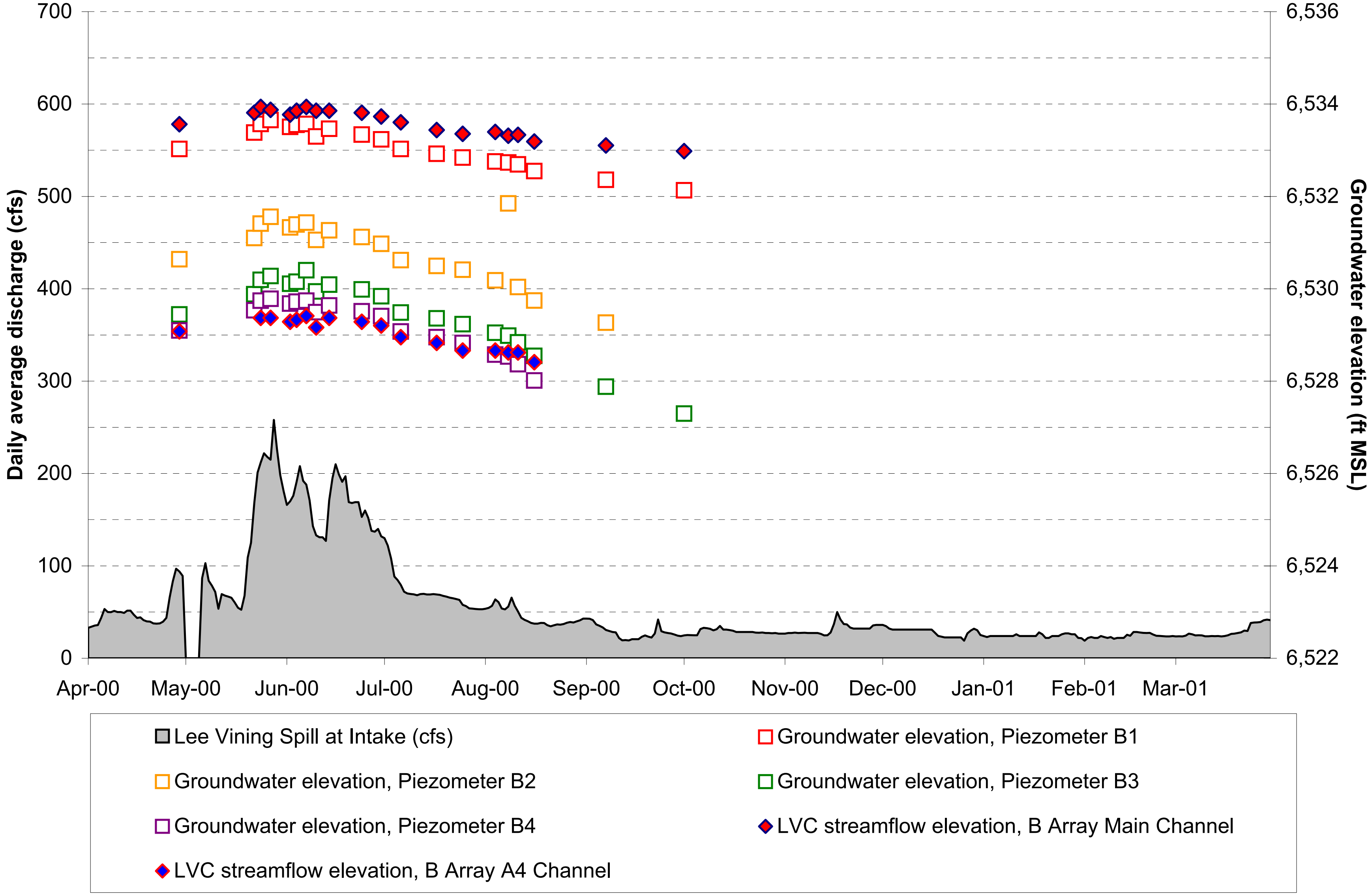


Figure A-9. Runoff Year 2000 streamflow hydrograph, groundwater elevations for the Lee Vining Creek B-array piezometers, and streamflow elevations for the main channel and A-4 channel. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths and streamflow elevations were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

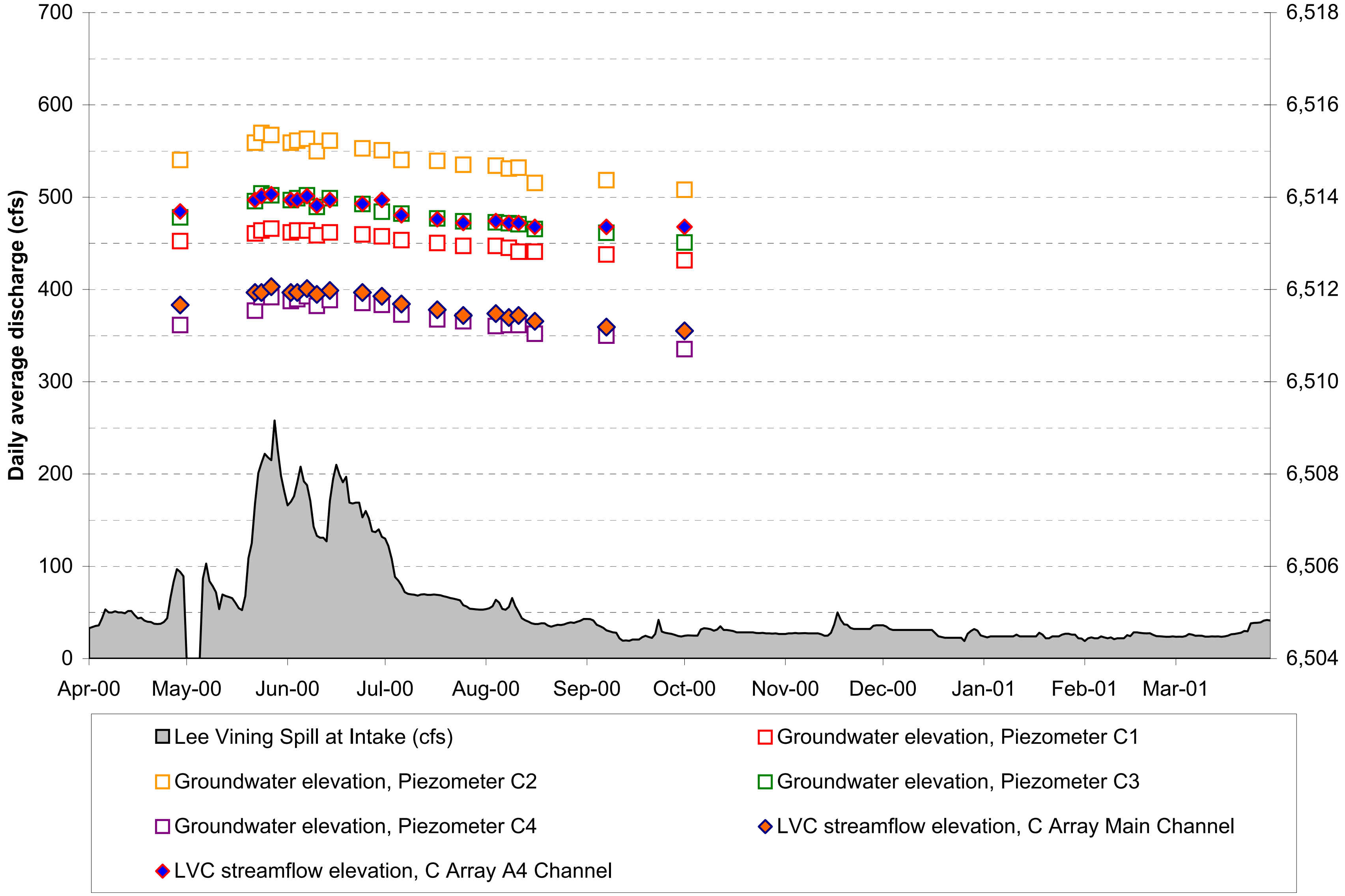


Figure A-10. Runoff Year 2000 streamflow hydrograph, groundwater elevations for the Lee Vining Creek C-array piezometers, and streamflow elevations for the main channel and A-4 channel. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths and streamflow elevations were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

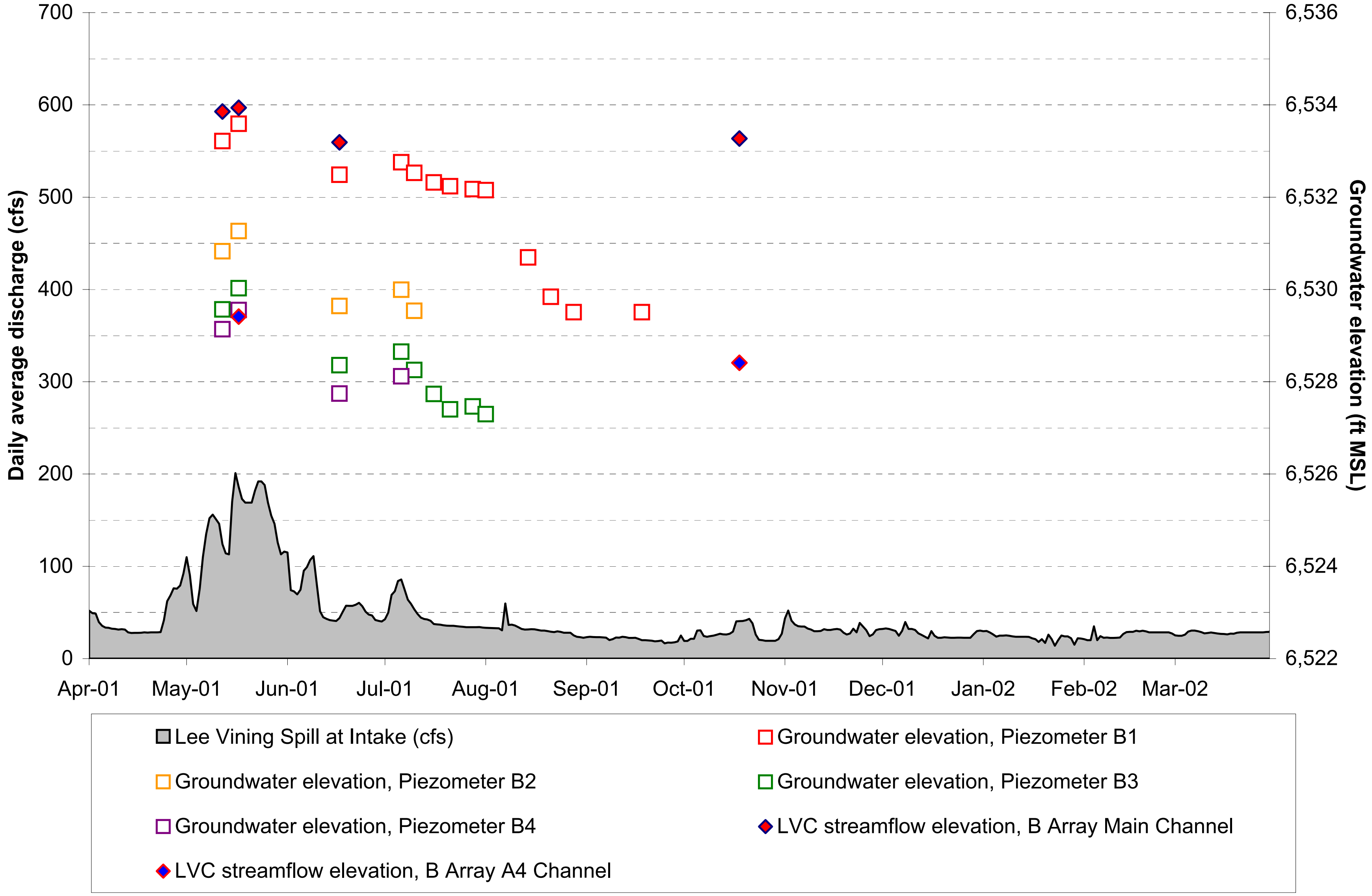


Figure A-11. Runoff Year 2001 streamflow hydrograph, groundwater elevations for the Lee Vining Creek B-array piezometers, and streamflow elevations for the main channel and A-4 channel. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths and streamflow elevations were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

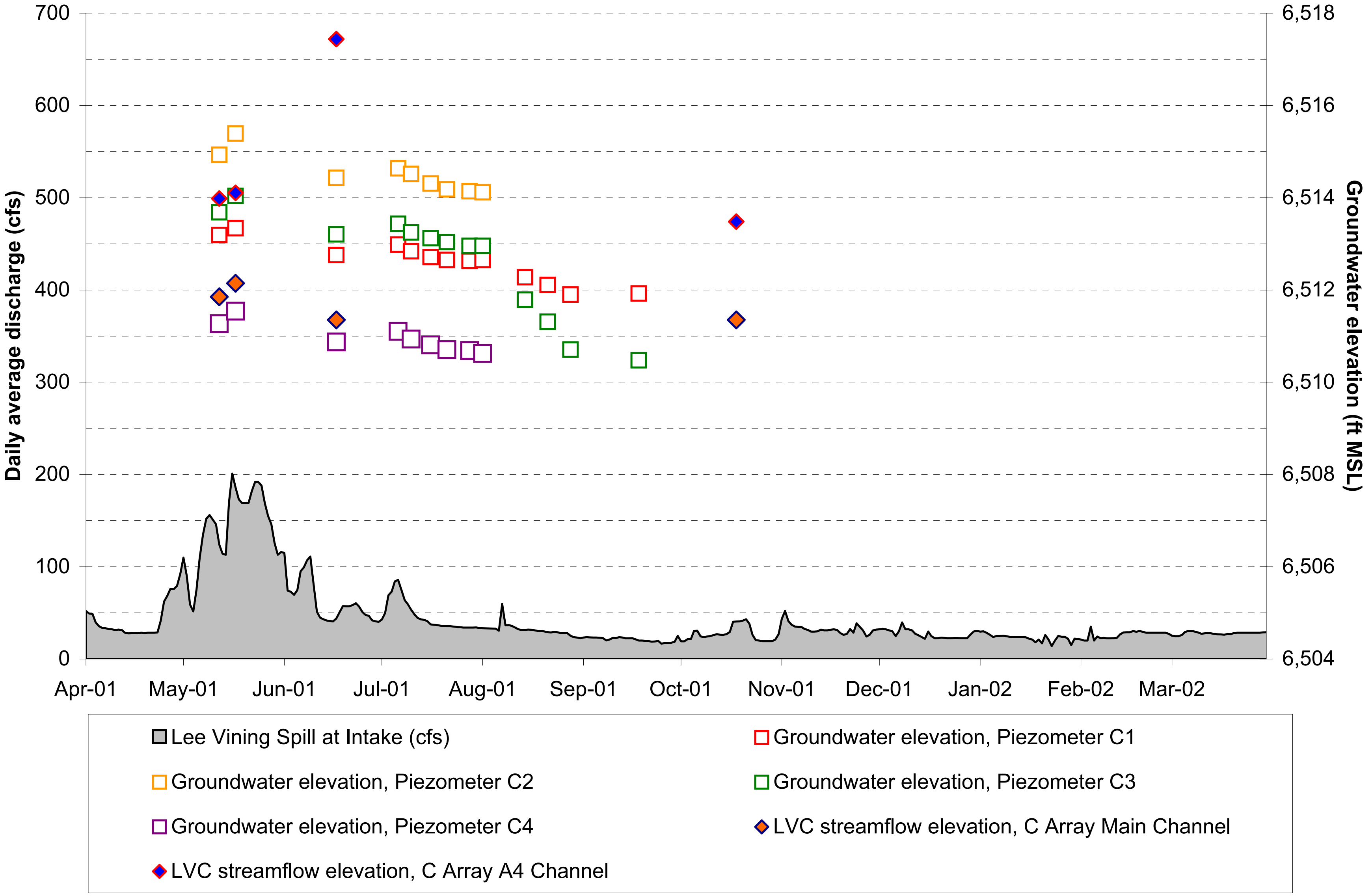


Figure A-12. Runoff Year 2001 streamflow hydrograph, groundwater elevations for the Lee Vining Creek C-array piezometers, and streamflow elevations for the main channel and A-4 channel. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths and streamflow elevations were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

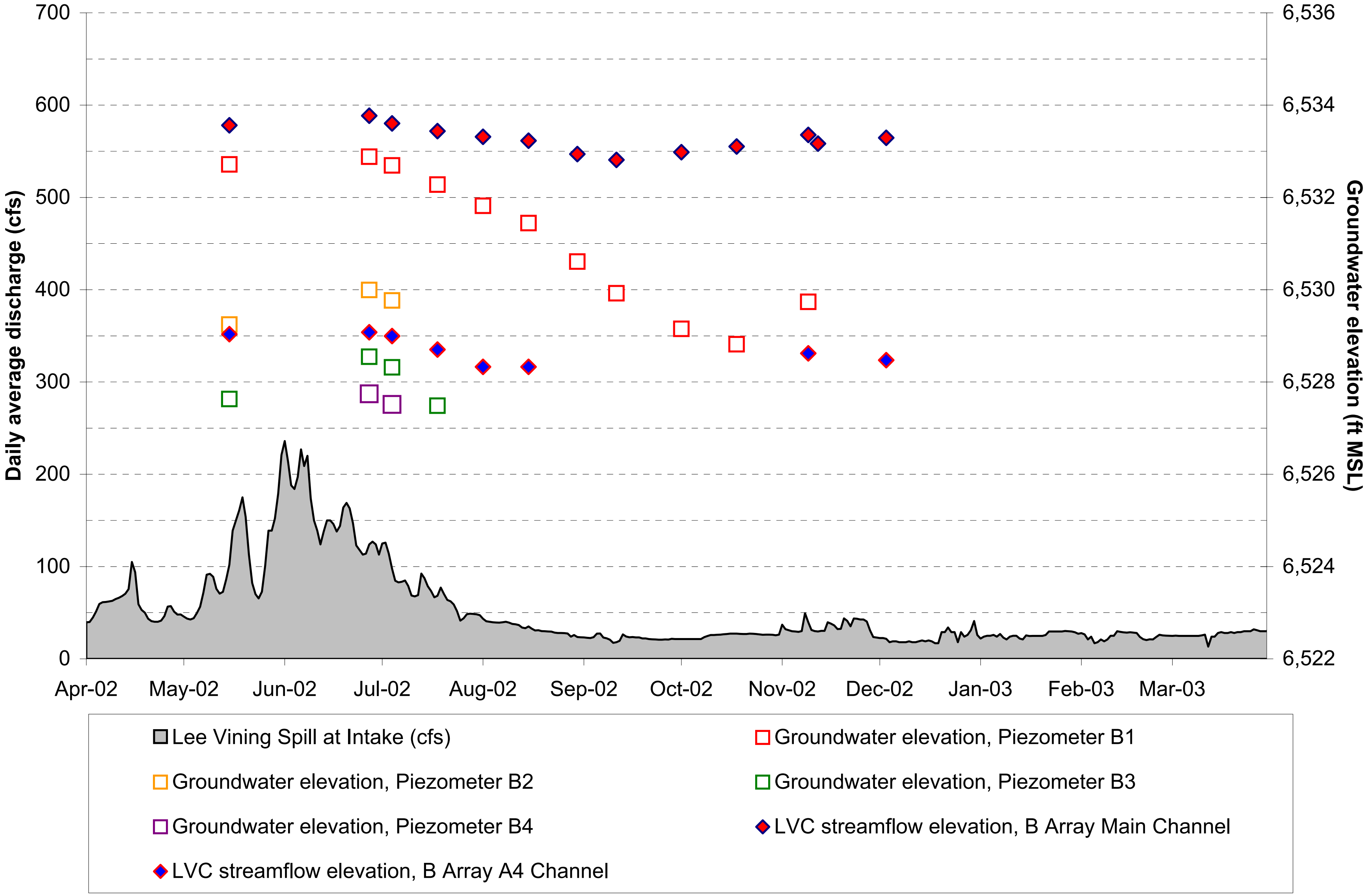


Figure A-13. Runoff Year 2002 streamflow hydrograph, groundwater elevations for the Lee Vining Creek B-array piezometers, and streamflow elevations for the main channel and A-4 channel. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths and streamflow elevations were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

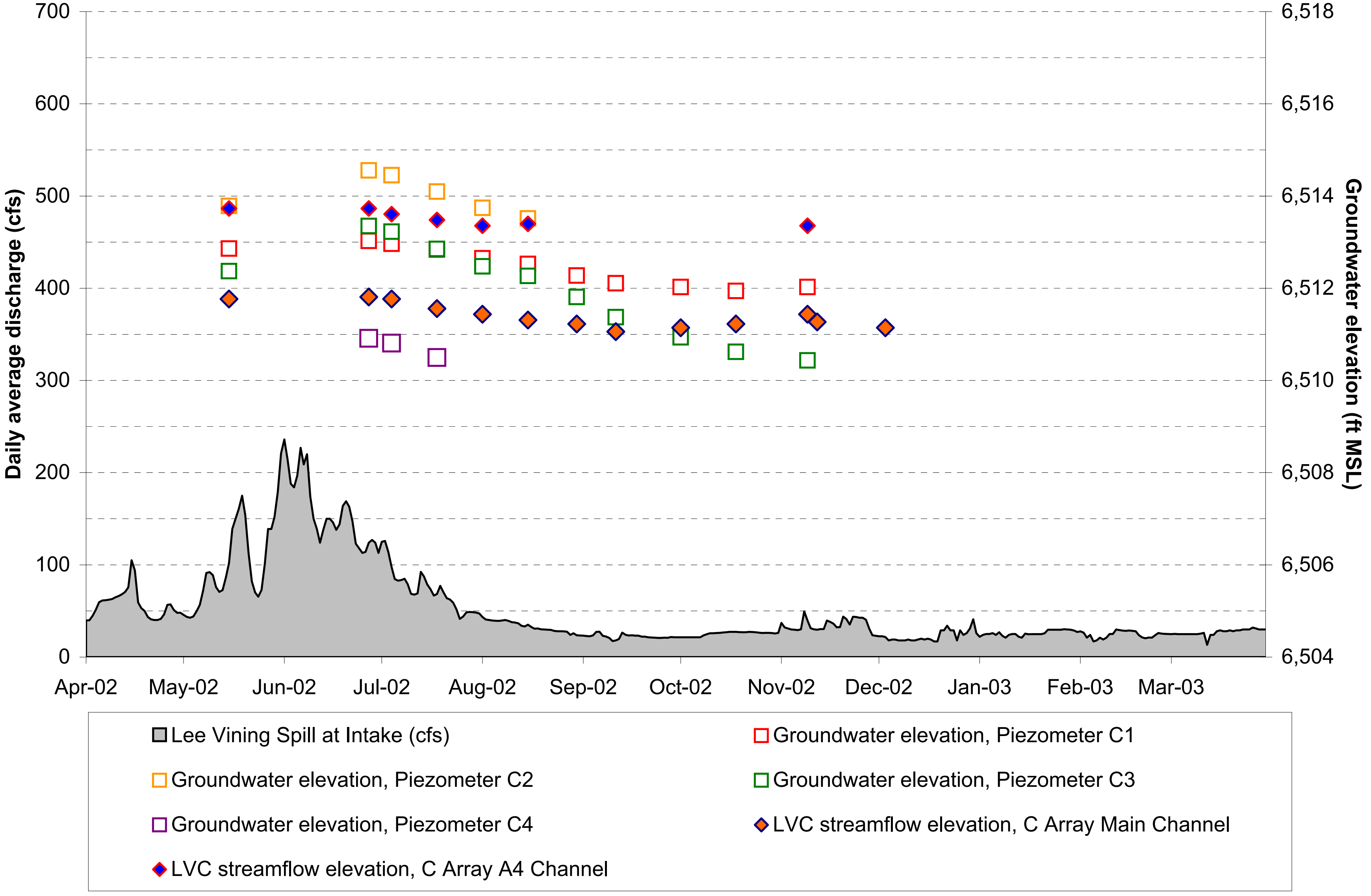


Figure A-14. Runoff Year 2002 streamflow hydrograph, groundwater elevations for the Lee Vining Creek C-array piezometers, and streamflow elevations for the main channel and A-4 channel. Streamflow hydrograph is Lee Vining Creek Spill at Intake daily average flow. Groundwater depths and streamflow elevations were collected by the Mono Lake Committee and converted to real elevations by McBain and Trush.

APPENDIX B

Stream Restoration Flows During the Transition Period for Mono Basin Tributaries

TABLE 1. STREAM RESTORATION FLOWS DURING TRANSITION PERIOD

CREEK	YEAR TYPE[1]	STREAM RESTORATION FLOW REQUIREMENT (Based on Flows Proposed in Settlement Agreement)[2]
RUSH	Extreme Wet	500 cfs (5 days) followed by 400 cfs (10 days)[3]
	Wet	450 cfs (5 days) followed by 400 cfs (10 days)[3]
	Wet/Normal	400 cfs (5 days) followed by 350 cfs (10 days)[3]
	Normal	380 cfs (5 days) followed by 300 cfs (7 days)
	Dry/Normal I II	250 cfs (5 days) when anticipated runoff is 75-82.5% of normal 200 cfs (7 days) when anticipated runoff is 68.5-75% of normal
	Dry	None
LEE VINING	Extreme Wet	Flow through conditions[3]
	Wet	Allow peak to pass[3]
	Dry/Normal, Normal, & Wet/Normal	Allow peak to pass[3]
	Dry	None
PARKER	Dry/Normal through Extreme Wet	Flow through conditions[4]
	Dry	None
WALKER	Dry/Normal through Extreme Wet	Flow through conditions[4]
	Dry	None

[1] "Year Types" are based on 1941-1990 average runoff of 122,124 acre-feet. (See Grant Lake Operations and Management Plan, Table T.) The Year Types are established based on the LADWP April 1 preliminary runoff forecast and may be adjusted after the final May 1 forecast is issued. The Year Types are defined as follows:

Dry -------------------less than 68.5% of average runoff
Dry/Normal ---------between 68.5% and 82.5% of average runoff
Normal --------------between 82.5% and 107% of average runoff
Wet/Normal---------between 107% and 136.5% of average runoff
Wet-------------------between 136.5% and 160% of average runoff
Extreme Wet--------greater than 160% of average runoff

[2] The Settlement Agreement identifies the above flows as "Channel Maintenance Flows." This order refers to the flows above as "Stream Restoration Flows" (SRFs) in order to distinguish between the flows required for stream restoration under this order and the Channel Maintenance Flows required by Decision 1631. The SRFs specified above are required during the transition period until Mono Lake reaches 6.392 feet. After Mono Lake reaches 6.392 feet, the SRFs in all four streams are as set out in Table 2. In Dry/Normal and Normal years, SRFs may be reduced to the extent necessary to maintain the quantity of water exports allowed under the provisions of Decision 1631. In Dry/Normal and Normal years, Licensee will attempt to hold 30,000 to 35,000 acre-feet in storage in Grant Lake at the beginning and end of the runoff year and will not be required to release water for SRFs that would reduce Grant Lake storage to below 11,500 acre-feet.

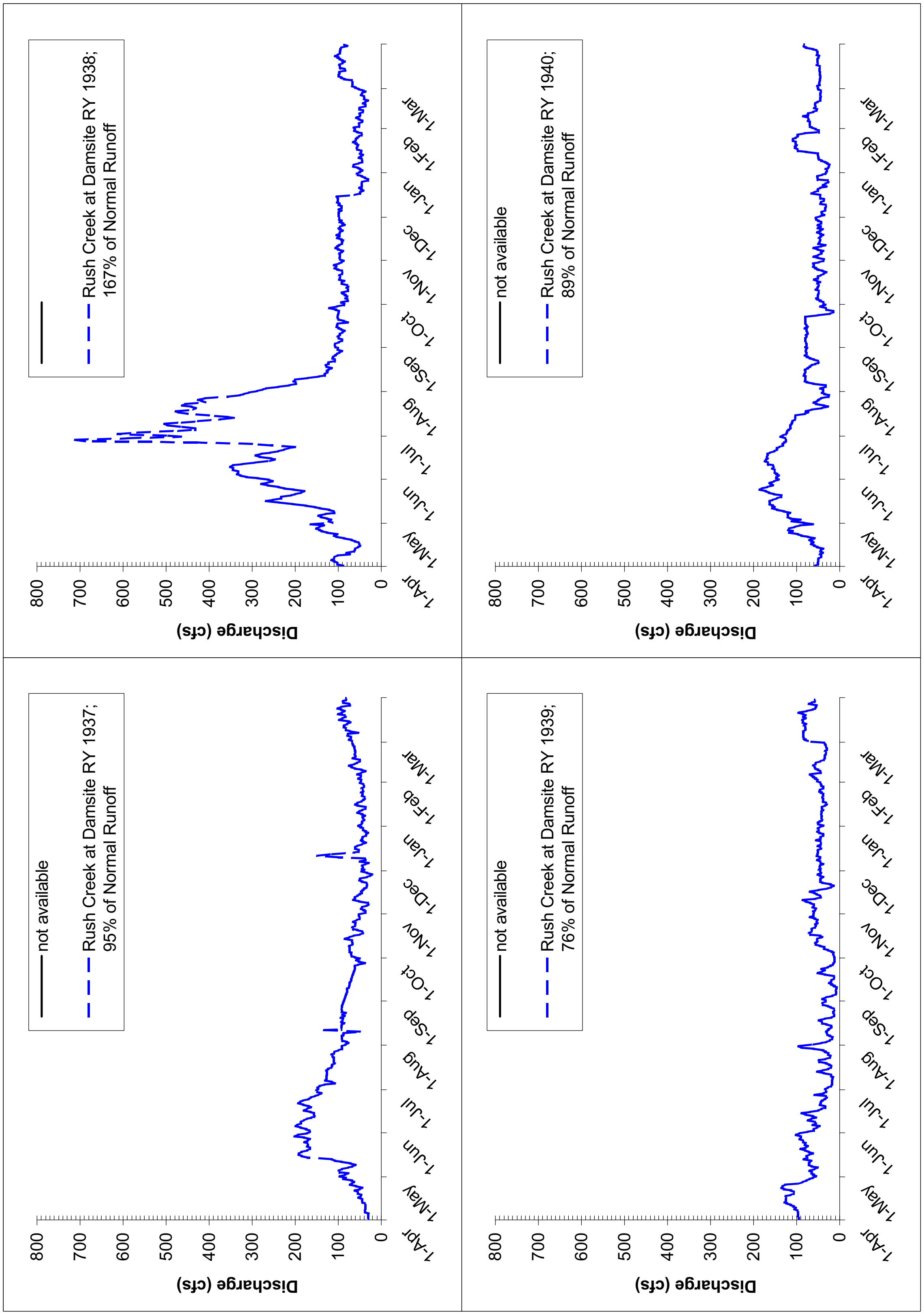
[3] Rush Creek SRFs may be augmented with Lee Vining Creek diversions (up to 50 cfs) in Wet-Normal, (up to 100 cfs) in Wet, and (up to 150 cfs) Extreme Wet years. If water is diverted from Lee Vining Creek to augment Rush Creek SRFs, the diversions should not start less than 7 days after the peak flow in Lee Vining Creek has been attained and the diversions should continue, exclusive of ramping, for a maximum of 15 days in Extreme Wet and Wet runoff years, and a maximum of 5 days in Wet/Normal runoff years. There shall be no diversion of Lee Vining Creek water to augment Rush Creek SRFs during Normal, Dry/Normal and Dry runoff years.

[4] Walker and Parker Creeks shall be allowed to flow without any diversions, either for irrigation from above or below the Lee Vining conduit or into the Lee Vining conduit during the period when Rush Creek SRFs are being made.

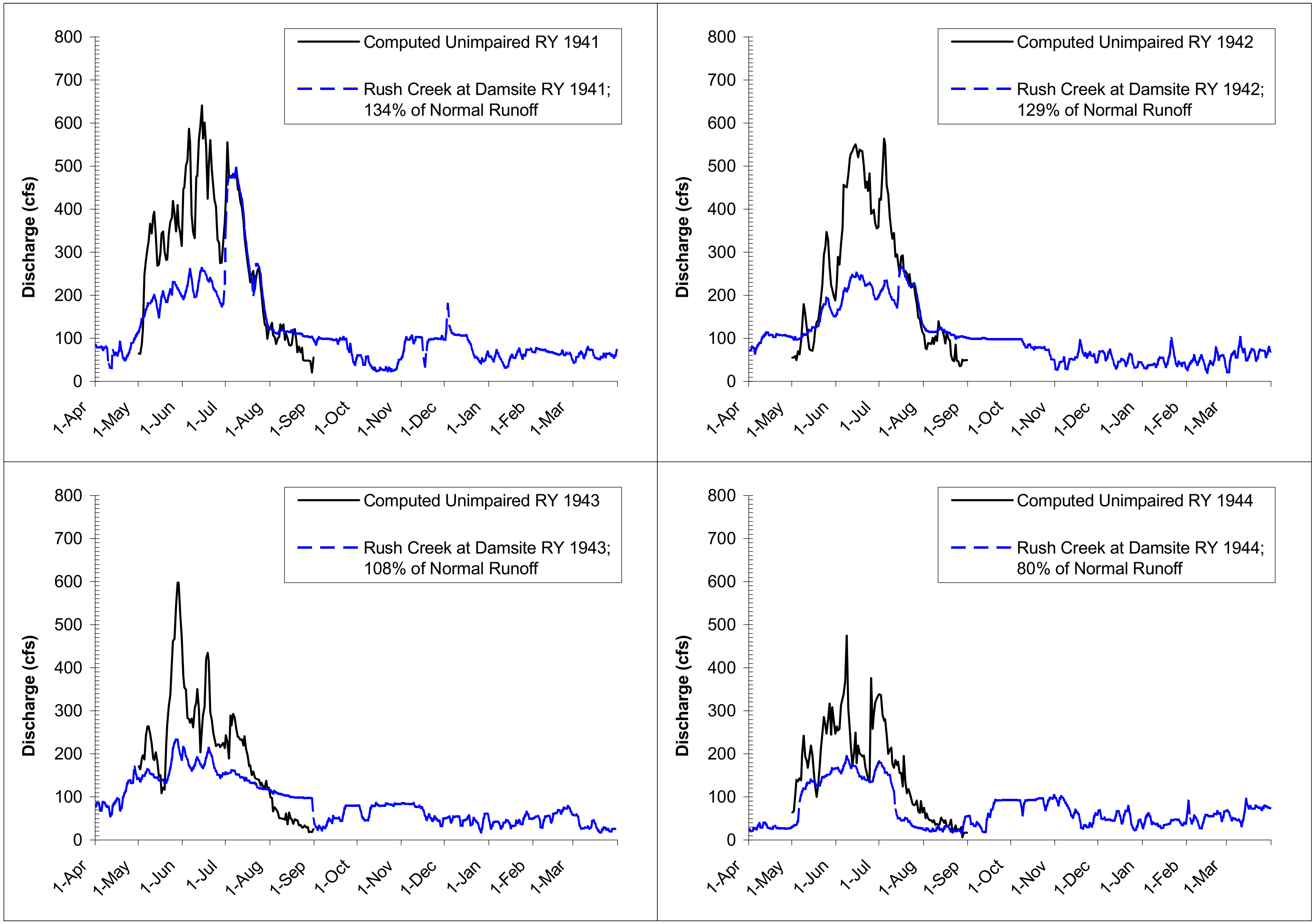
Attachment 1

APPENDIX C

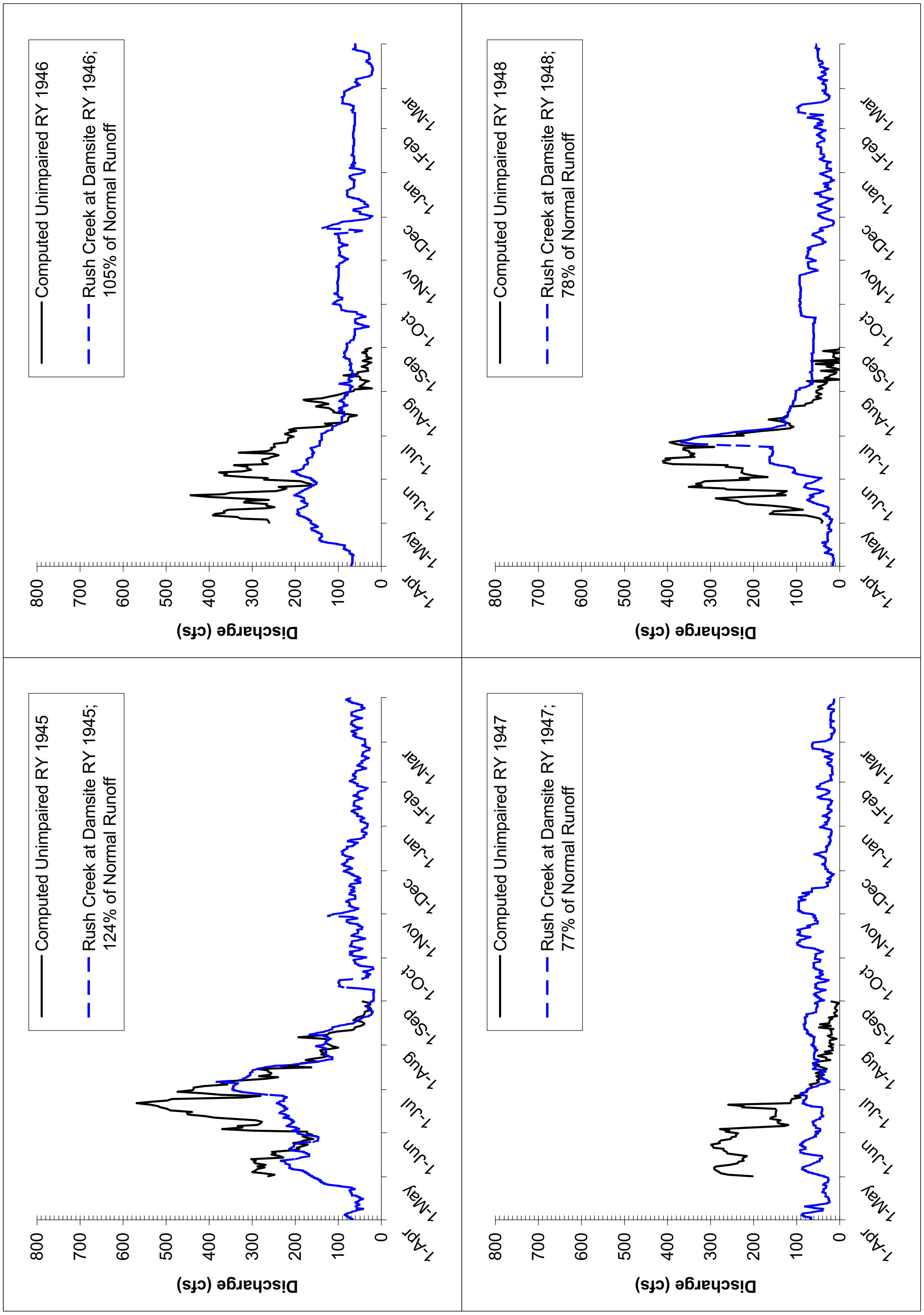
Annual Hydrographs for Rush Creek Computed Unimpaired Flows and Rush Creek at Damsite Flows for the Available Periods of Record



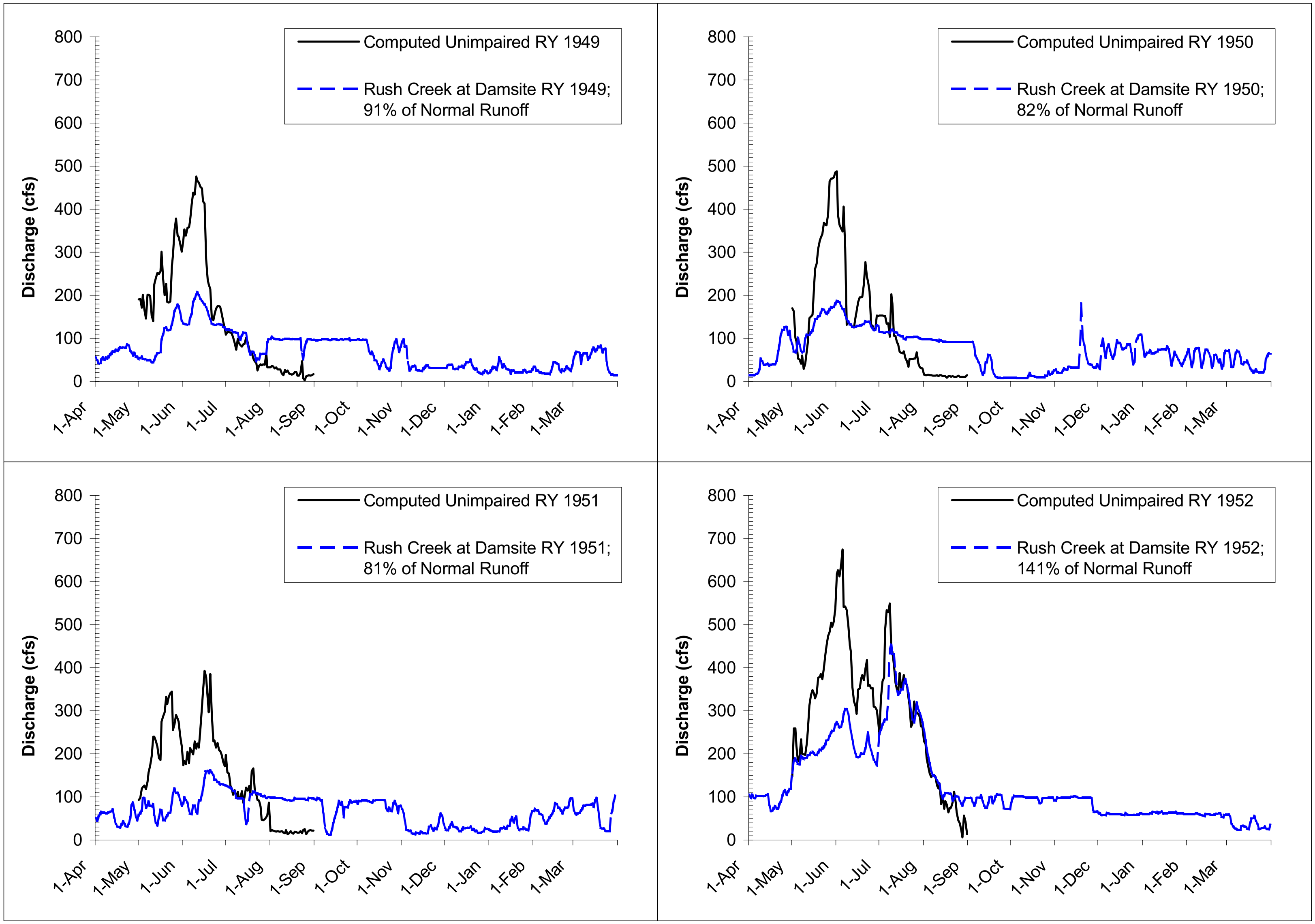
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



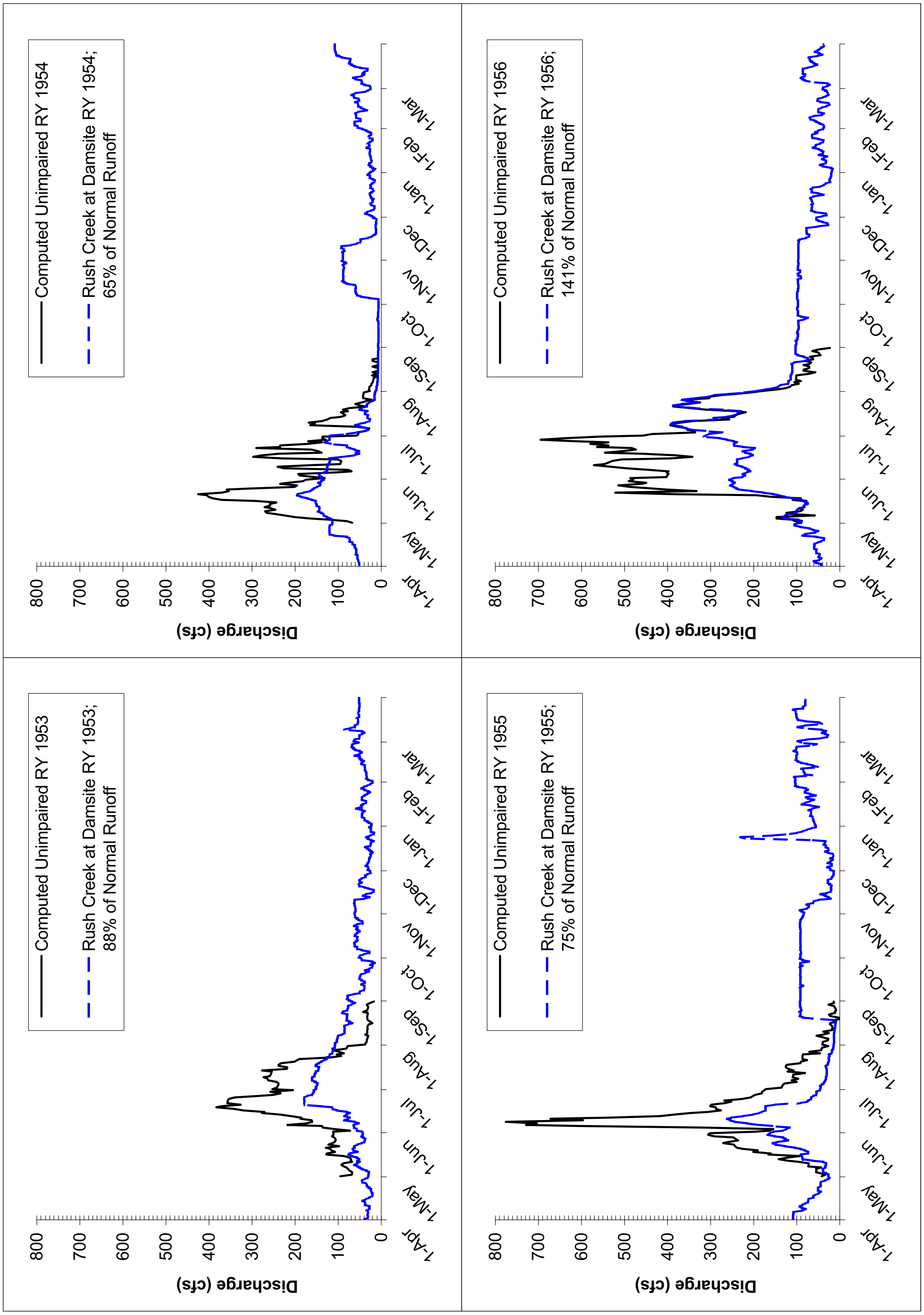
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



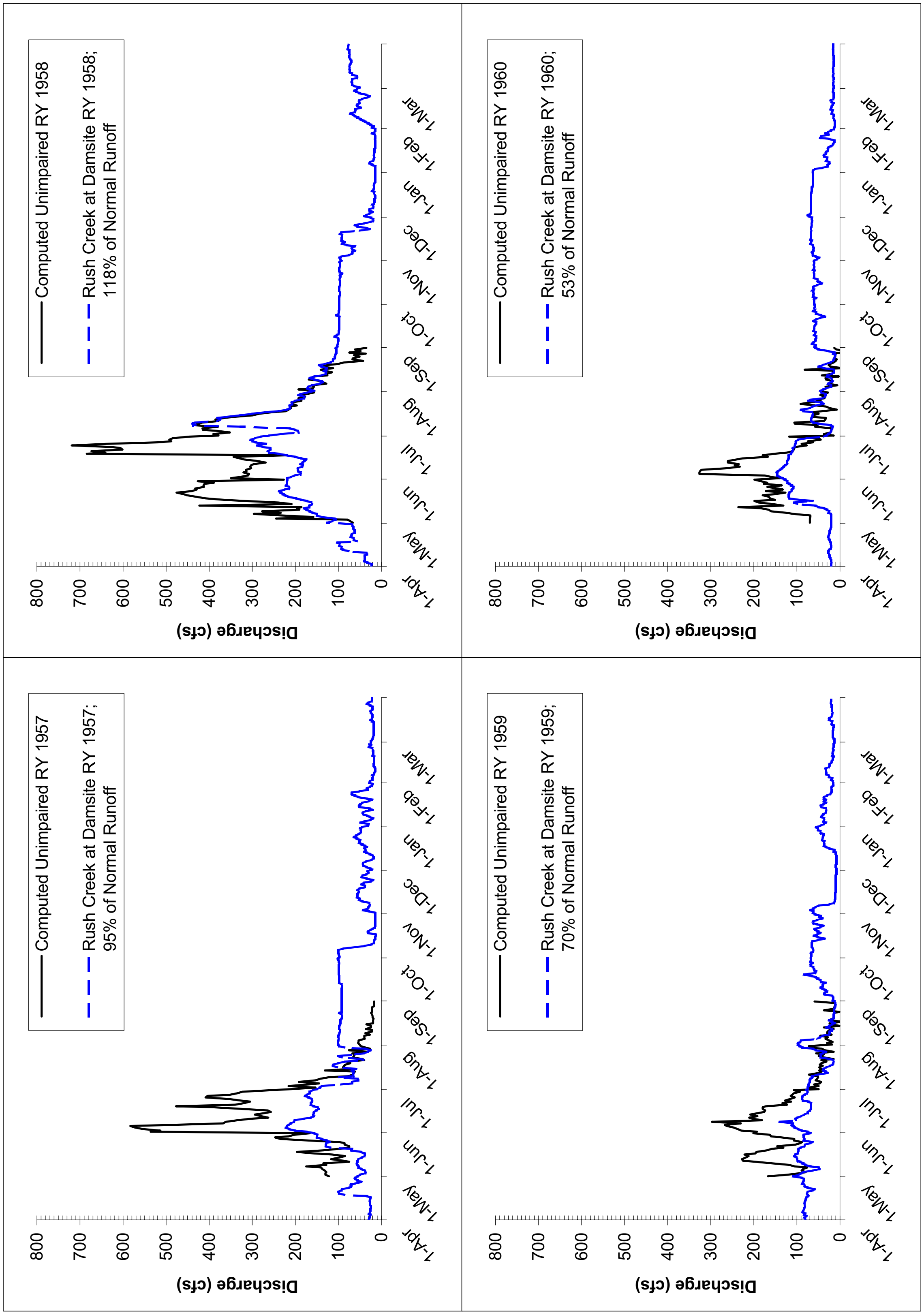
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



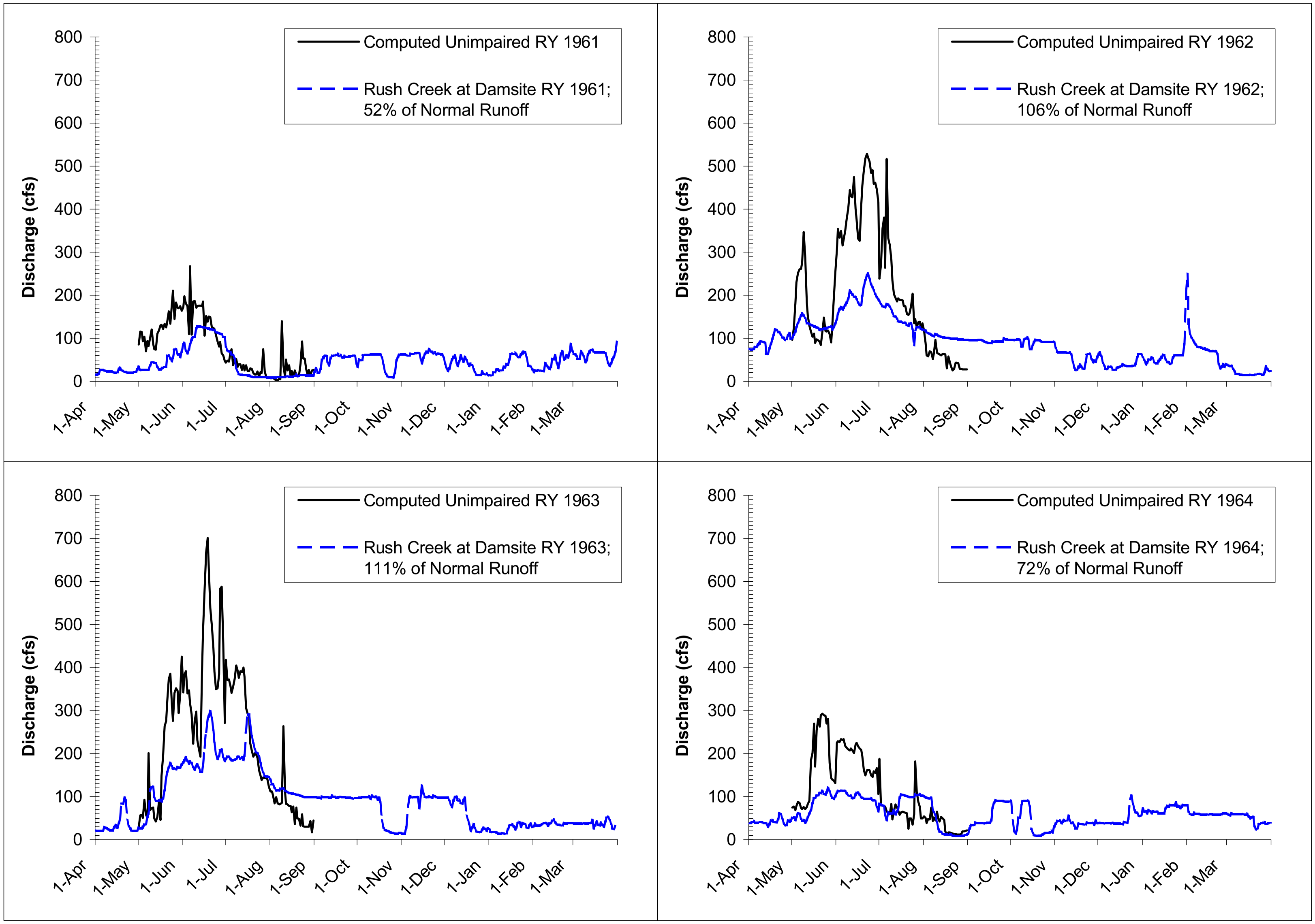
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



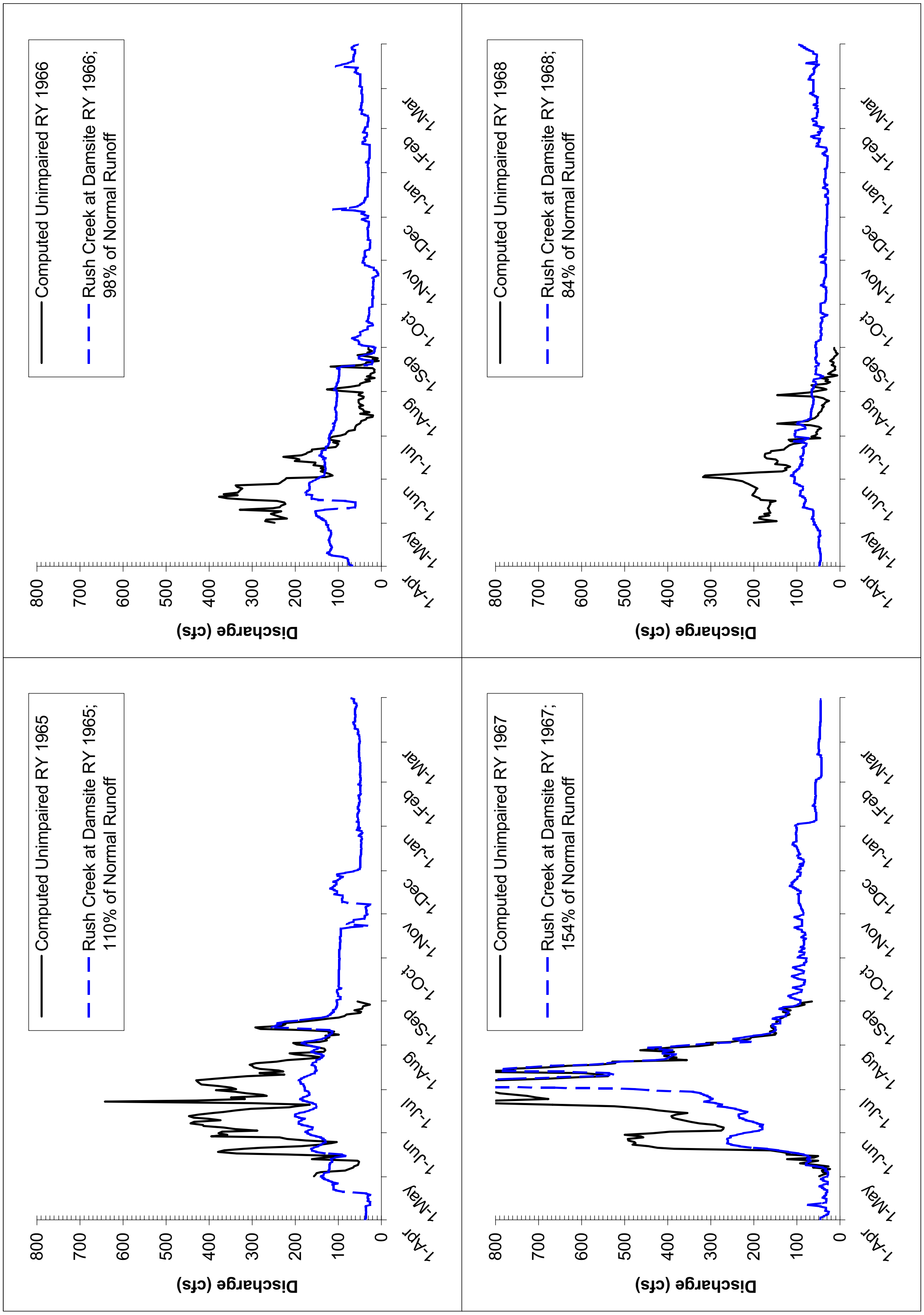
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



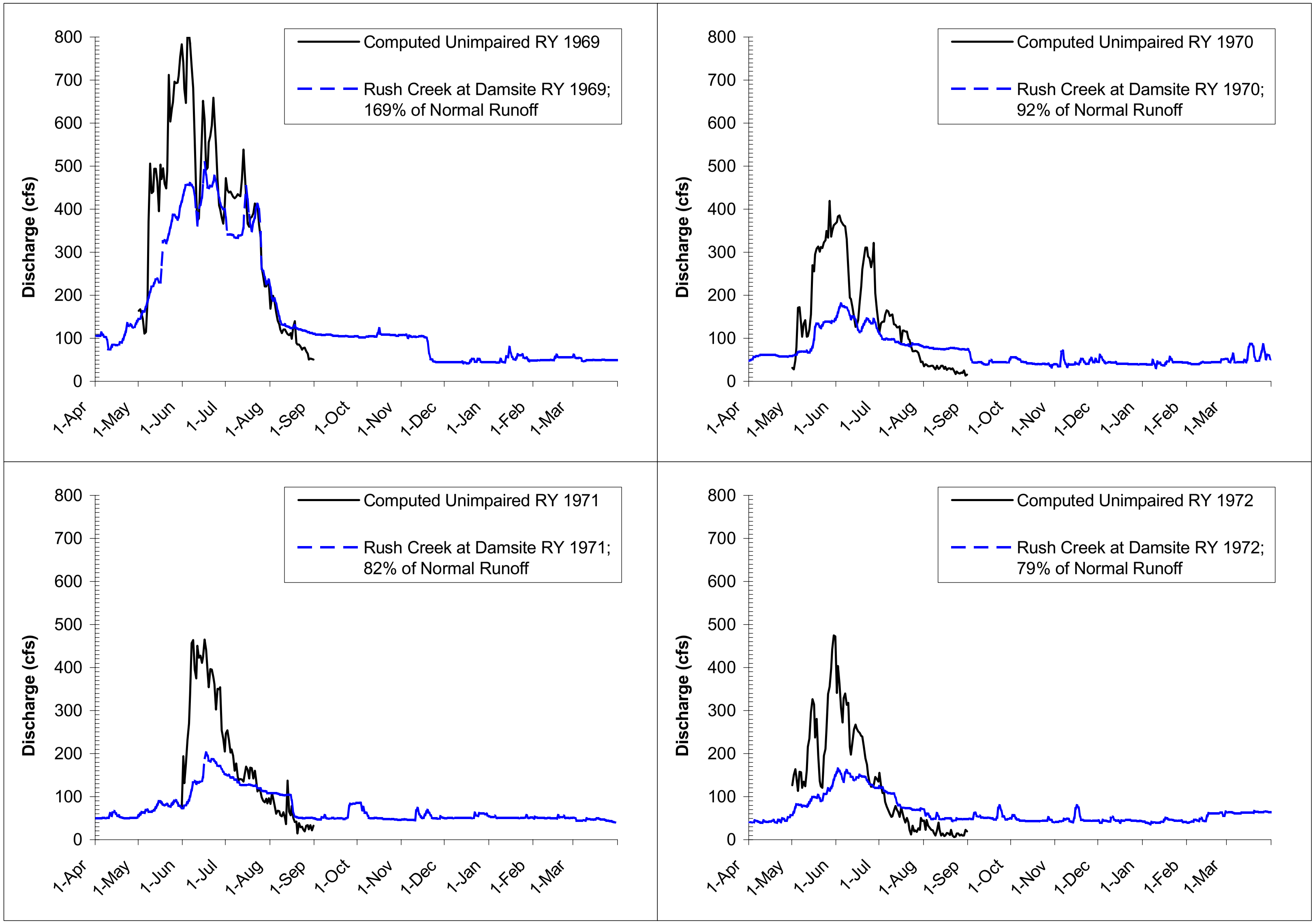
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



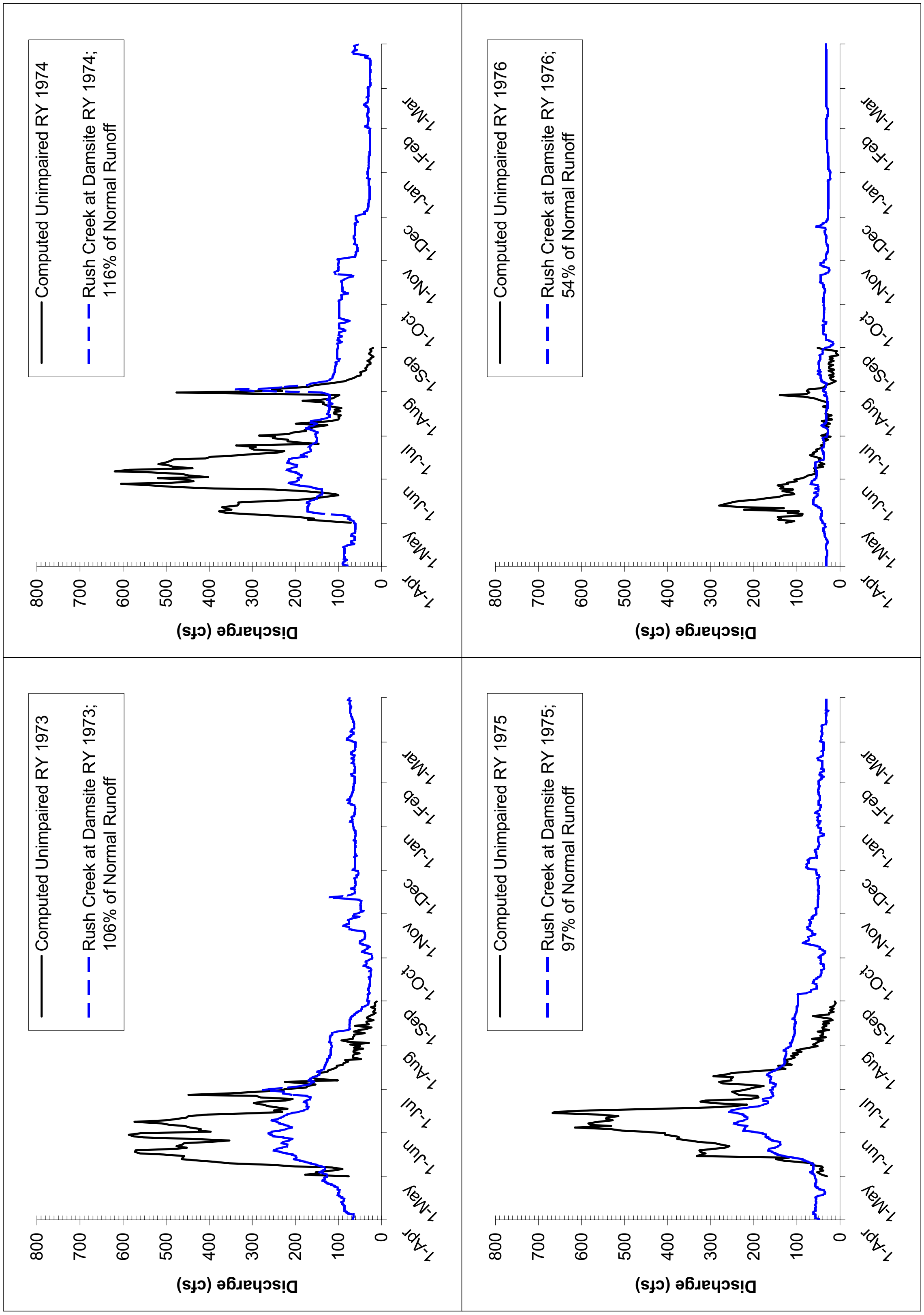
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



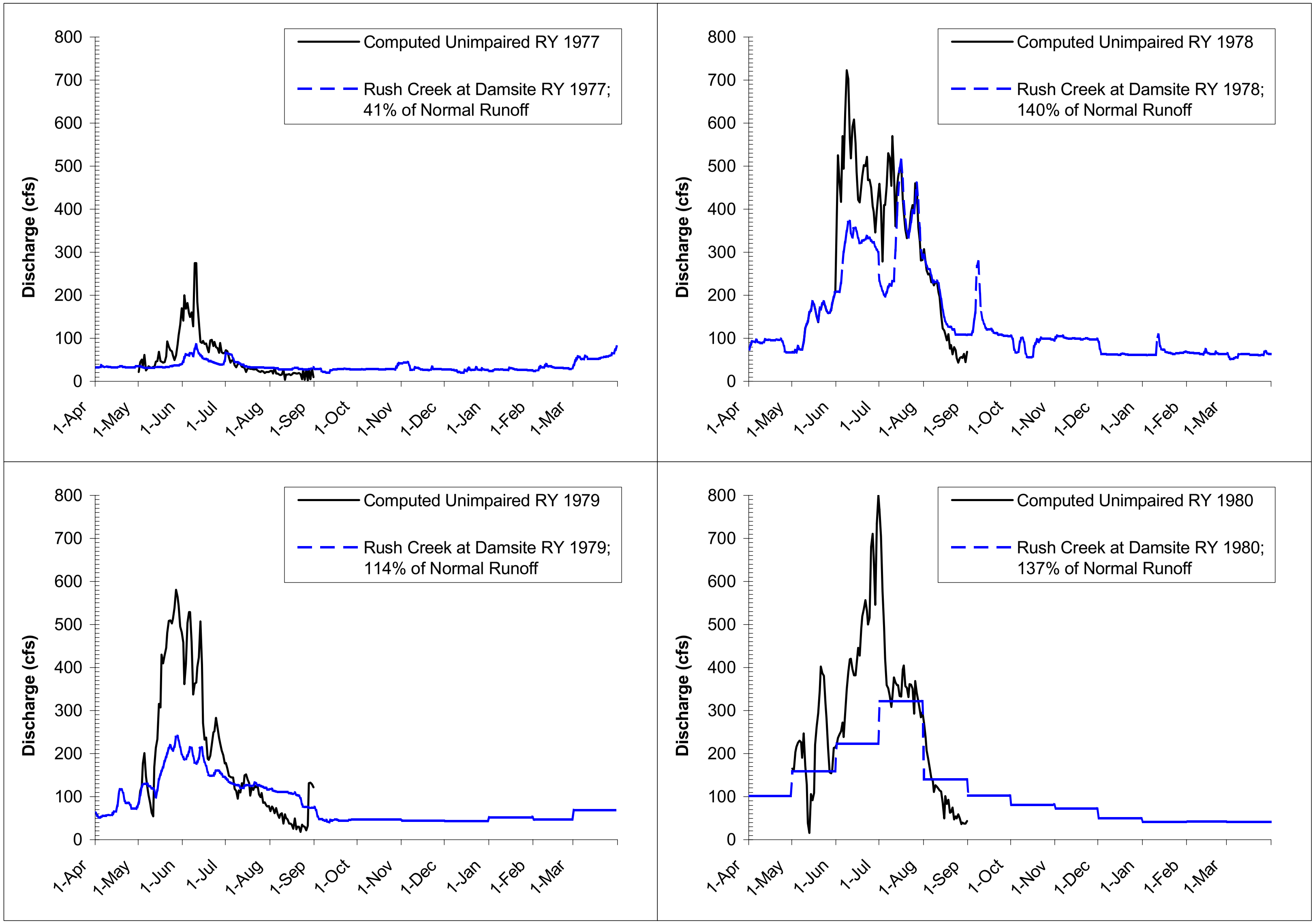
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



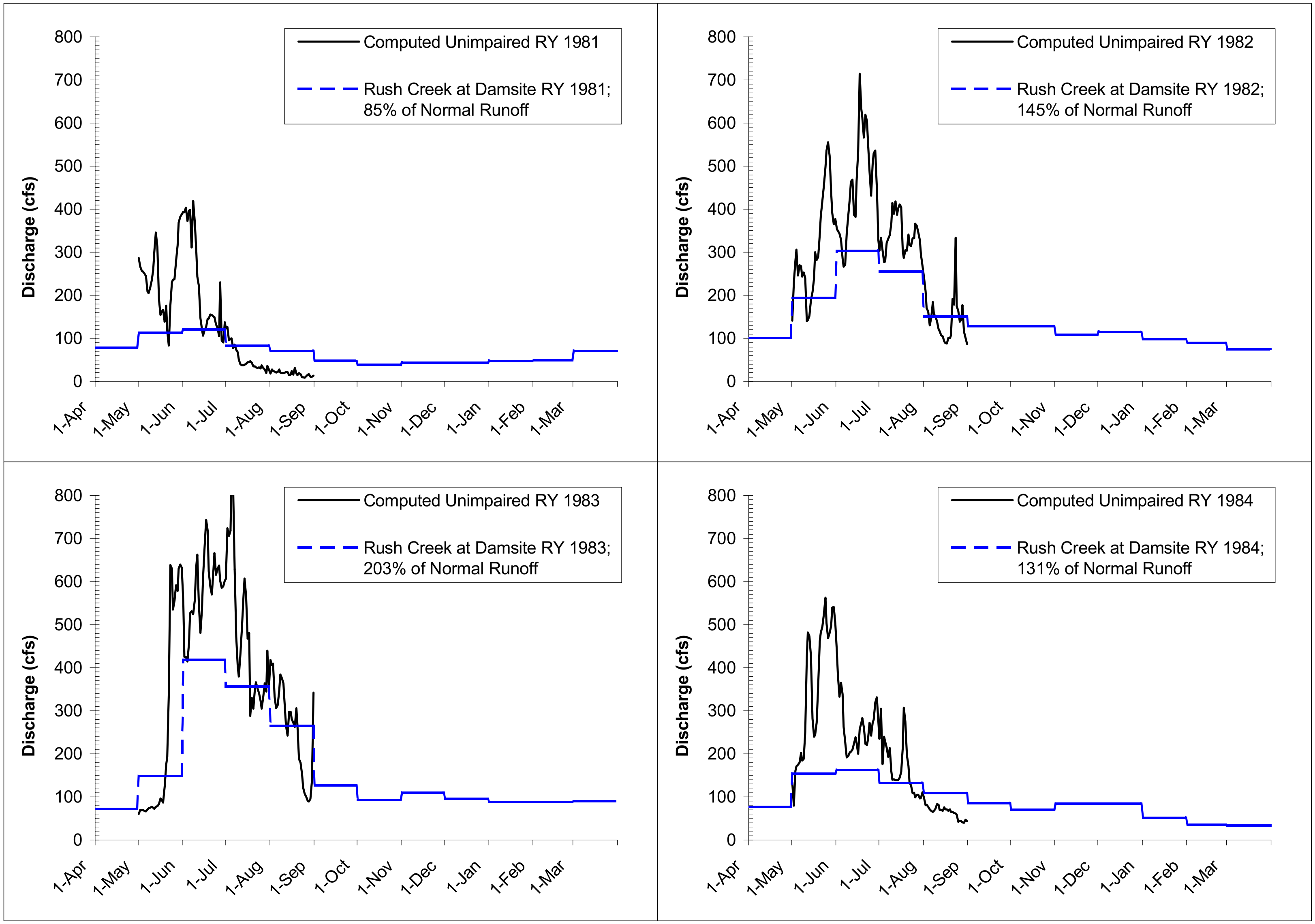
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



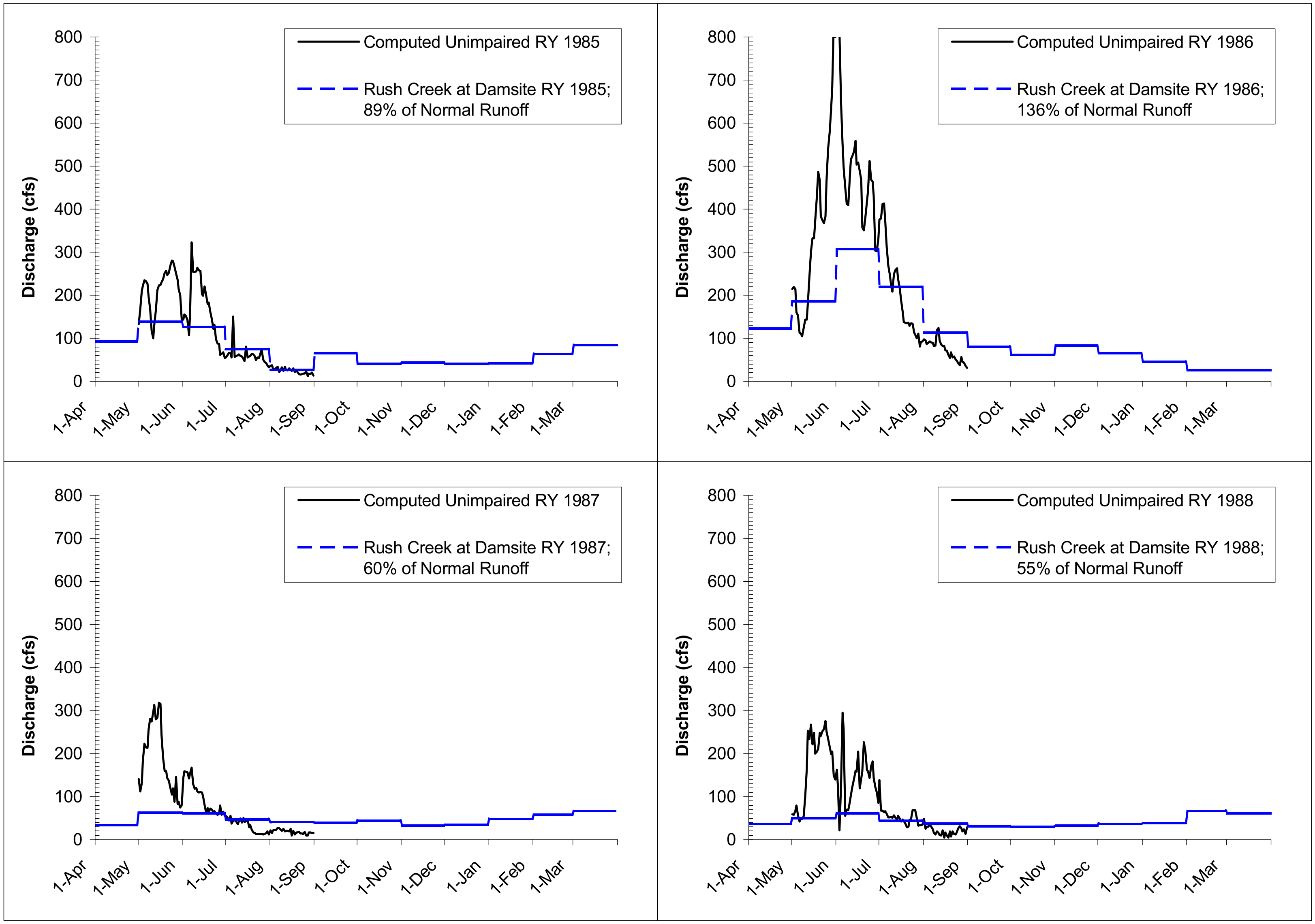
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



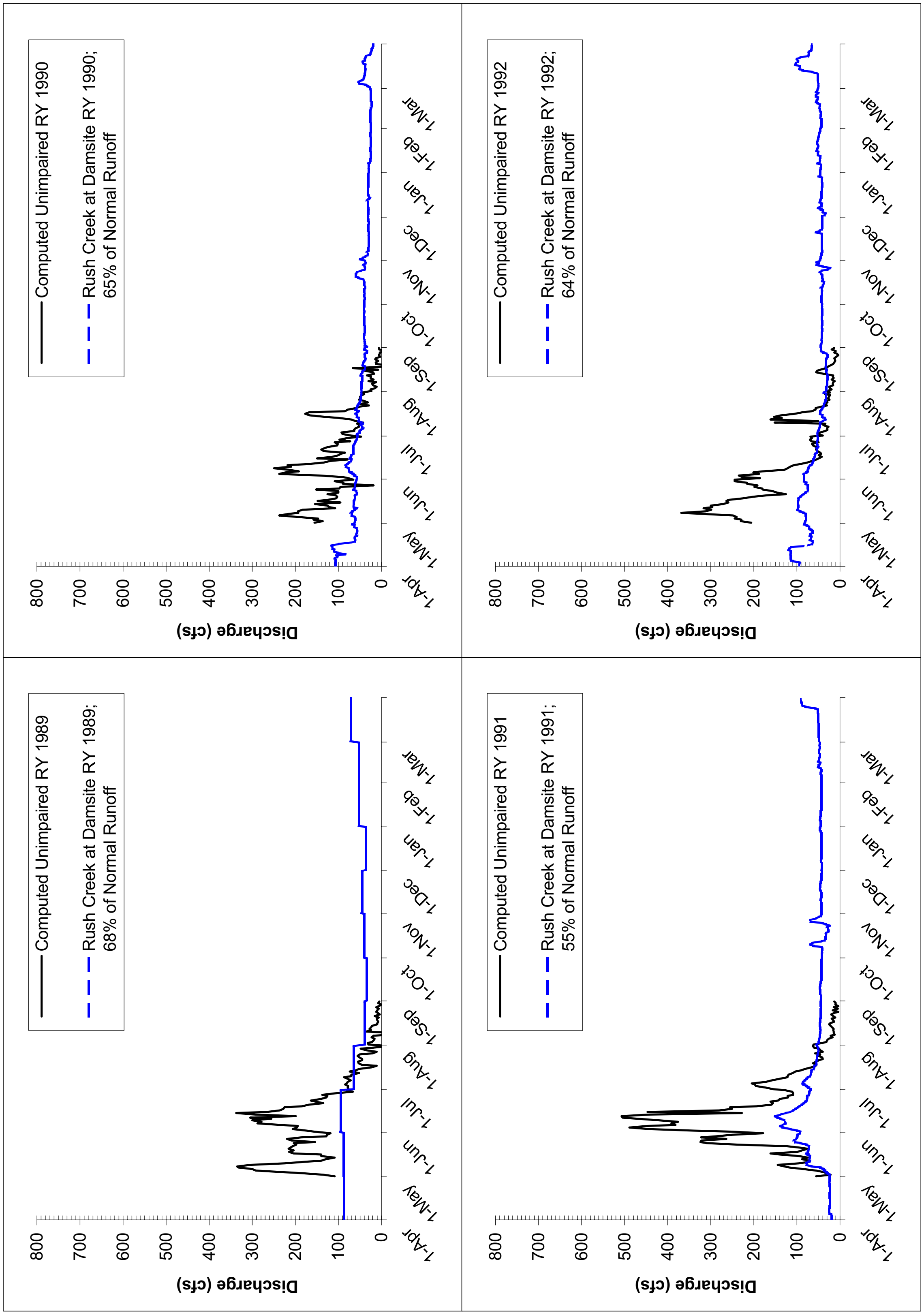
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



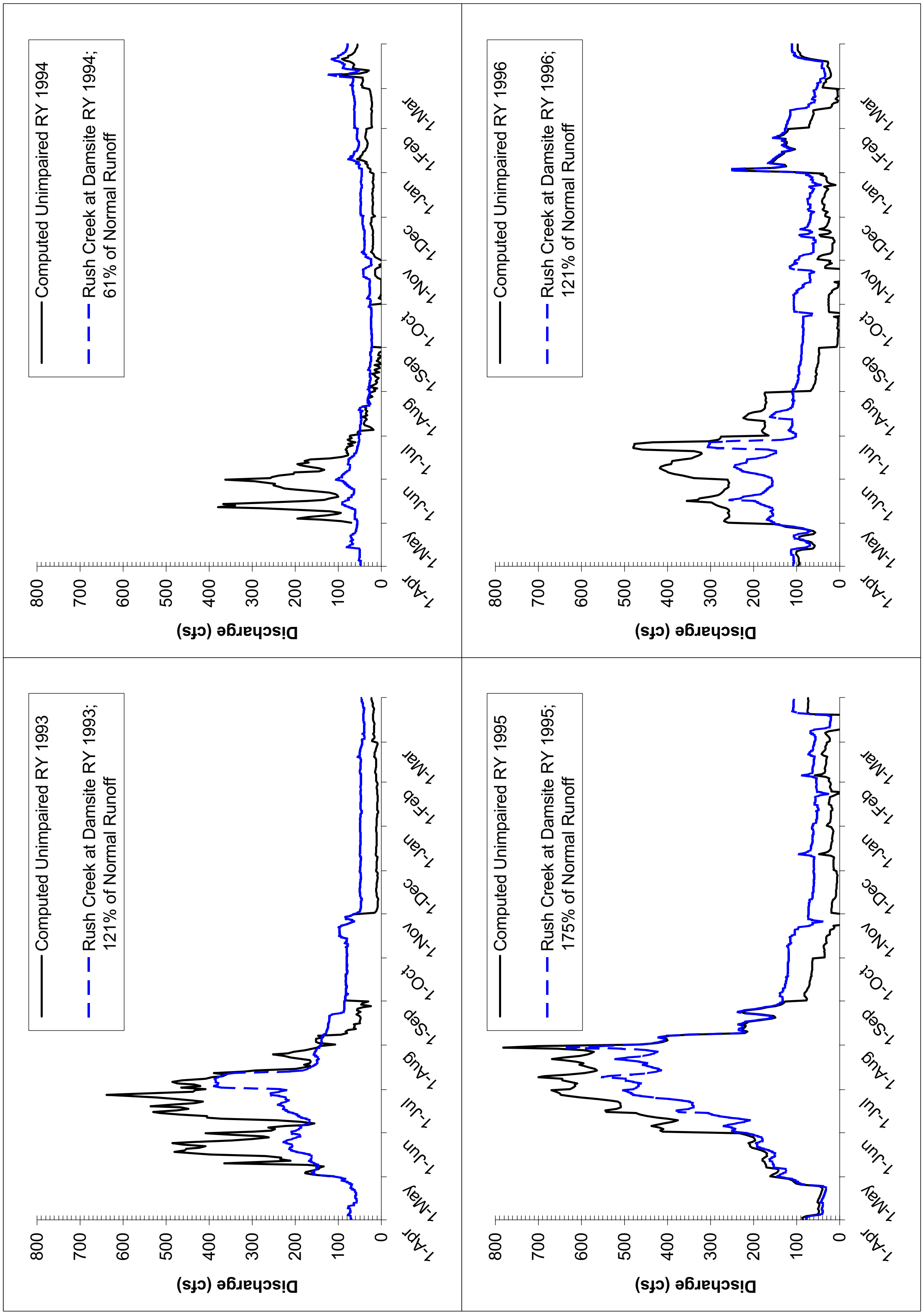
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



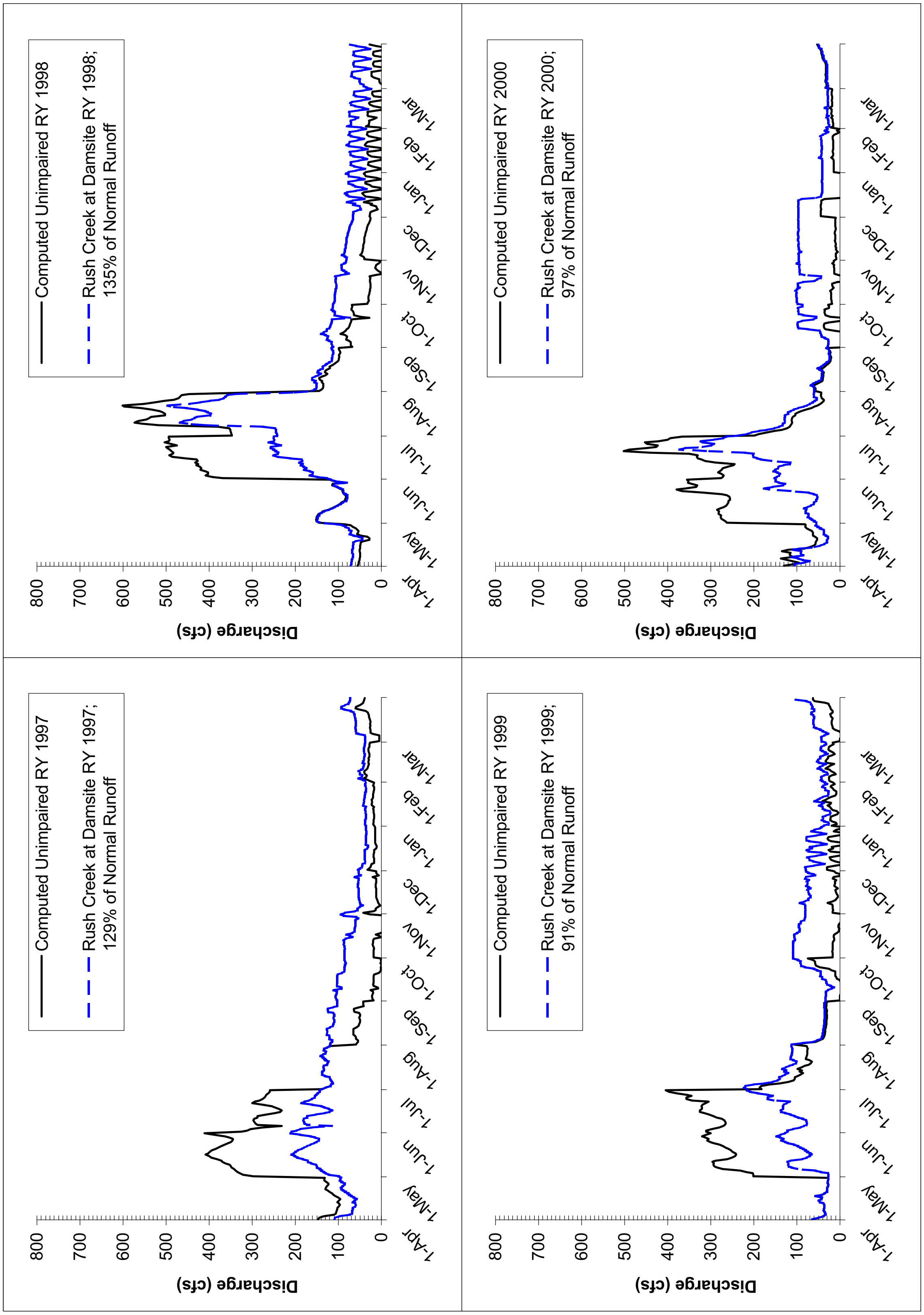
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



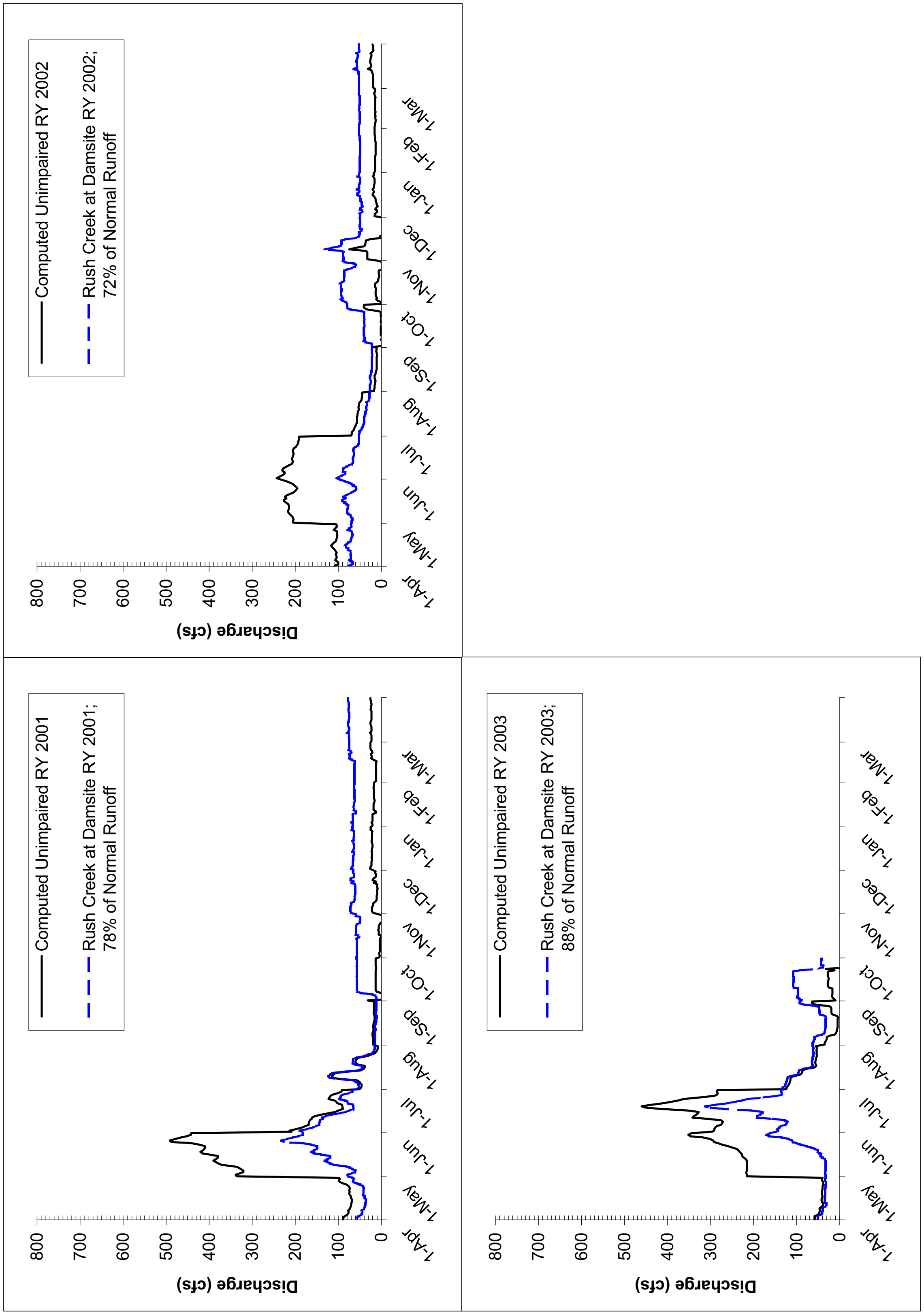
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]



Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]

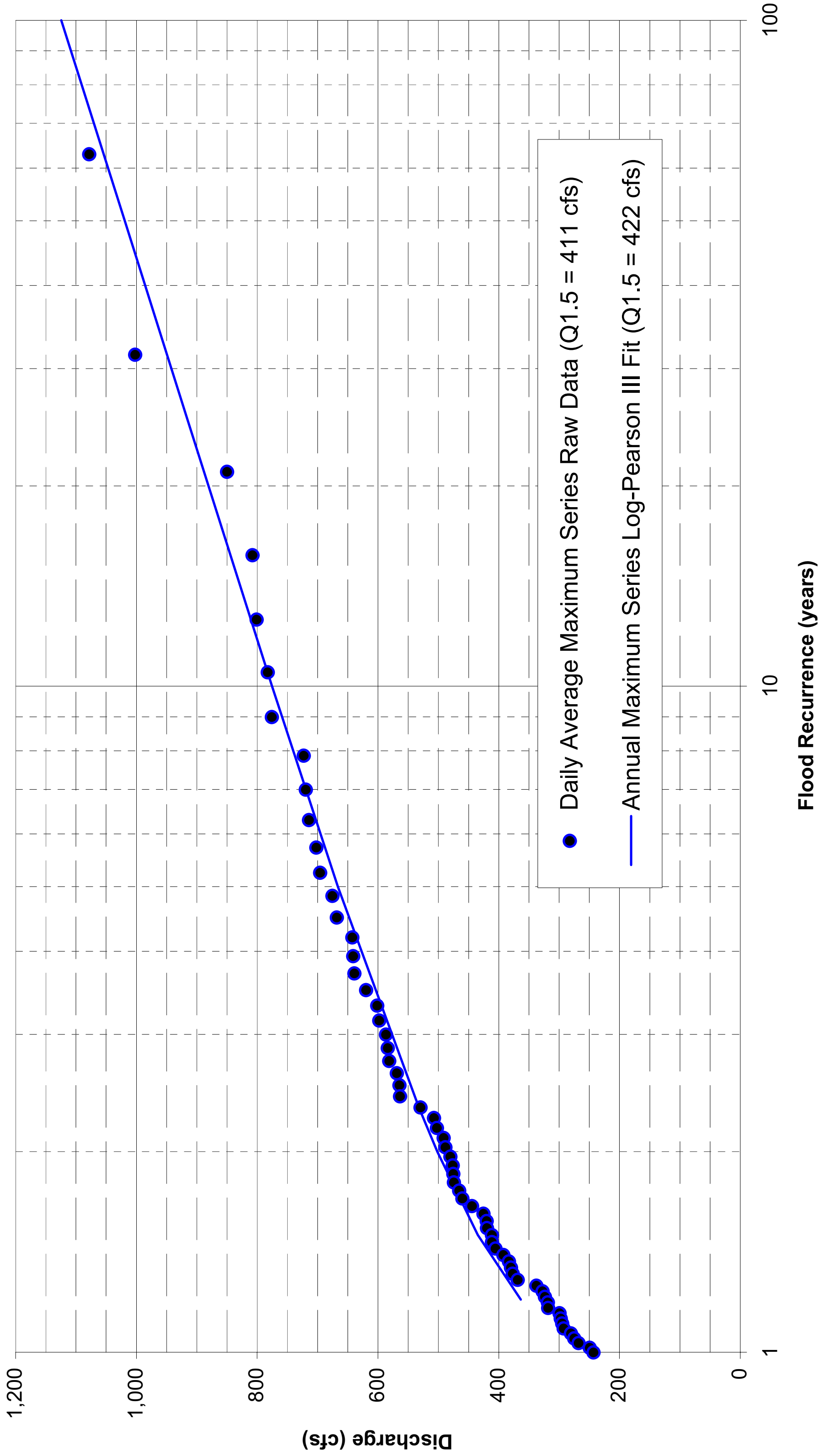


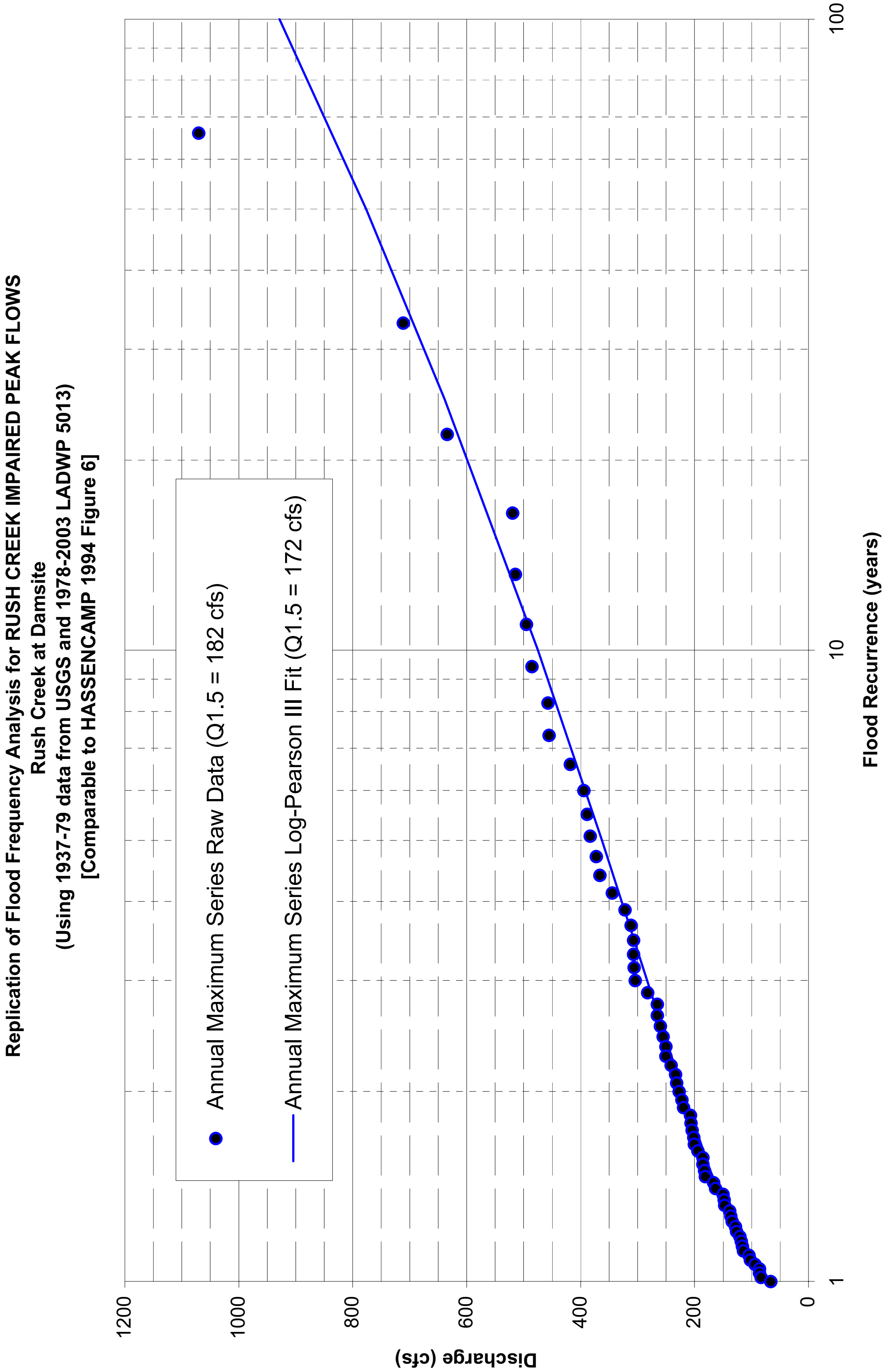
Rush Creek Computed Unimpaired and Regulated Flows [at Damsite]

APPENDIX D

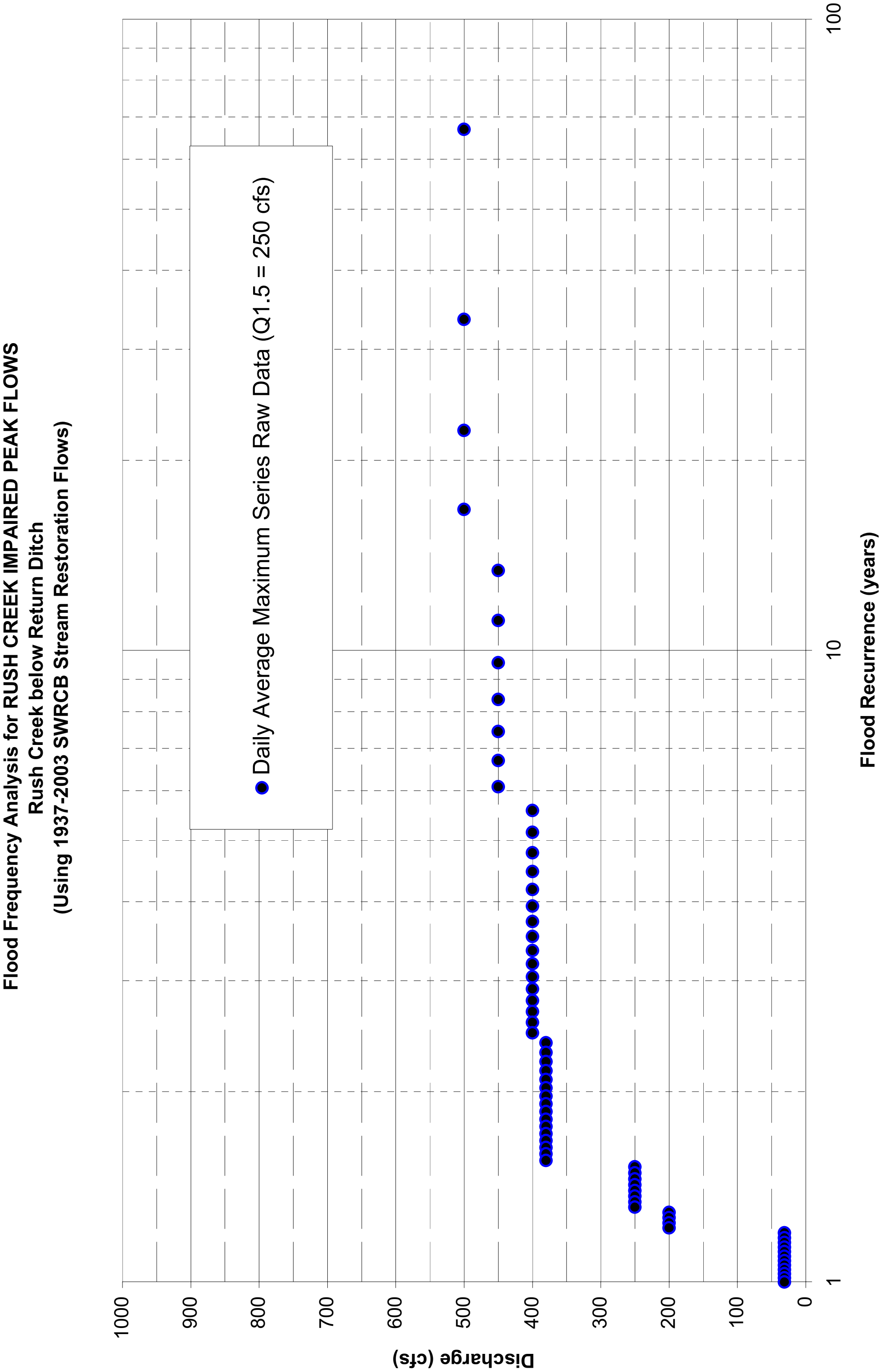
Flood Frequency Curves for Rush Creek

Replication of Flood Frequency Analysis for RUSH CREEK UNIMPAIRED PEAK FLOWS
Rush Creek at Damsite + SCE Storage Change
(Using 1941-1990 data from Hassencamp (1994) and 1991-2003 RCR)
[Comparable to HASSENCAMP 1994 Figure 5.]



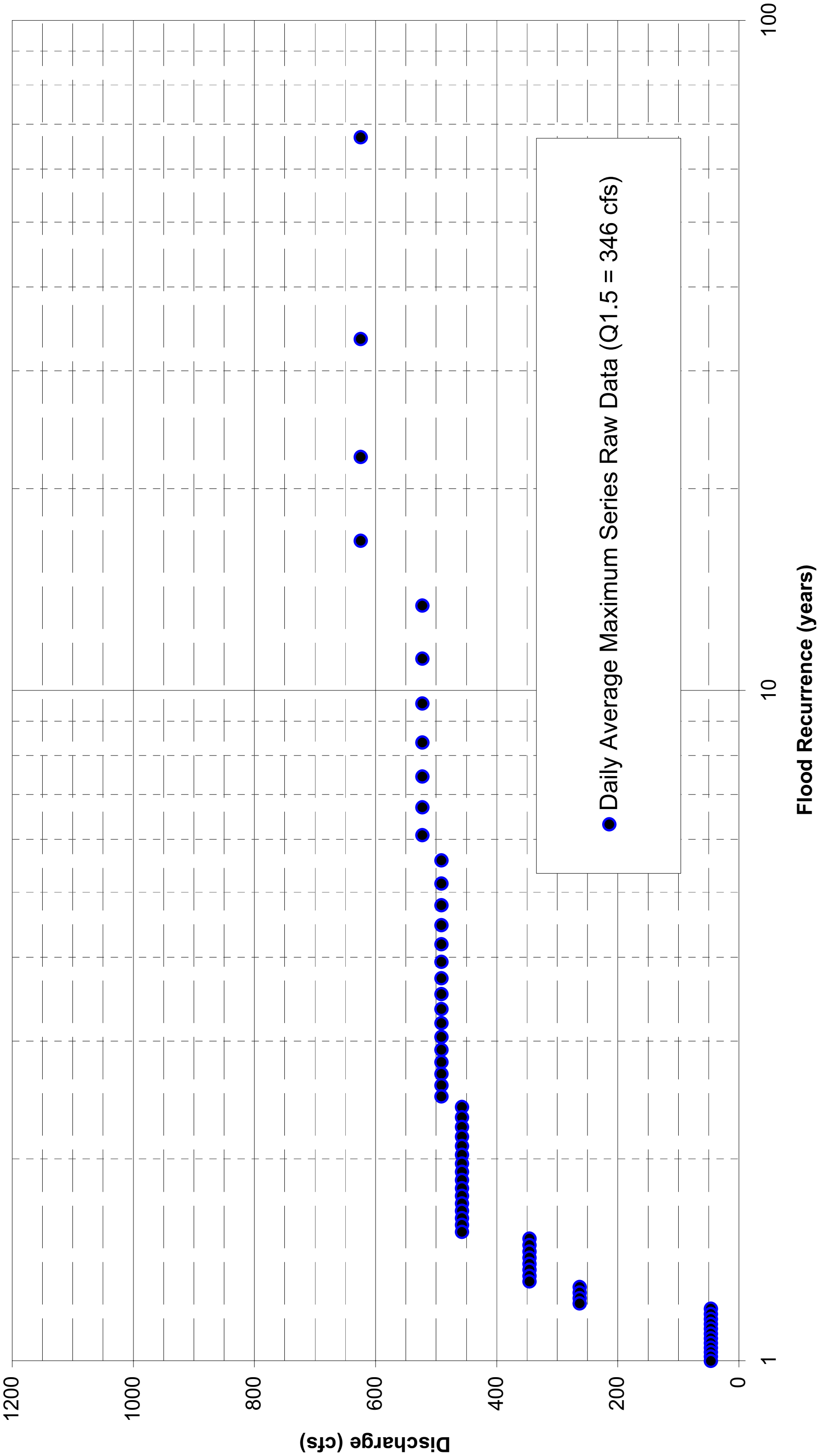


Replication of Flood Frequency Analysis for RUSH CREEK IMPAIRED PEAK FLOWS
Rush Creek at Damsite
(Using 1937-79 data from USGS and 1978-2003 LADWP 5013)
[Comparable to HASSENCAMP 1994 Figure 6]

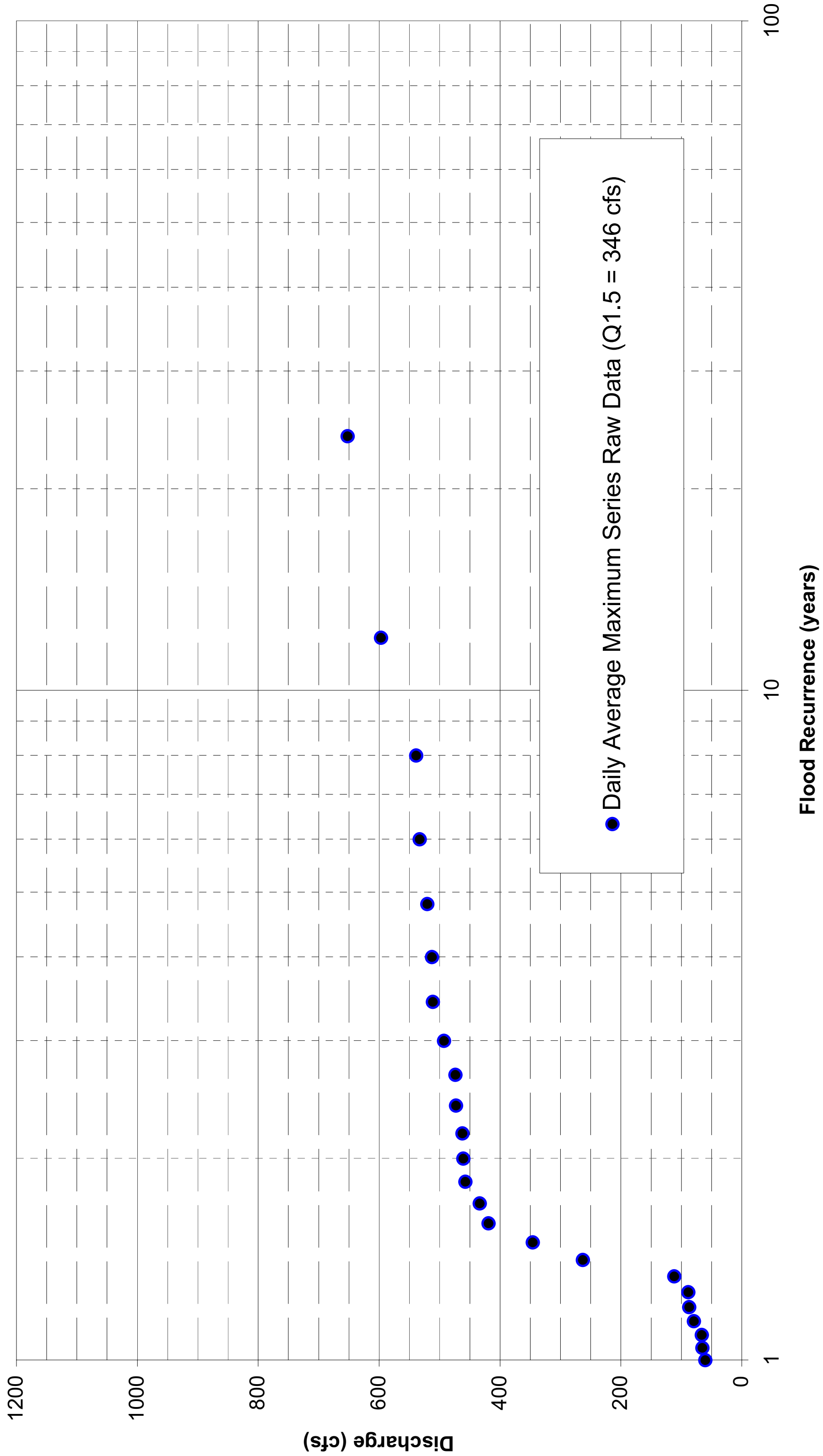


Flood Frequency Analysis for RUSH CREEK IMPAIRED PEAK FLOWS
Rush Creek below Return Ditch
(Using 1937-2003 SWRCB Stream Restoration Flows)

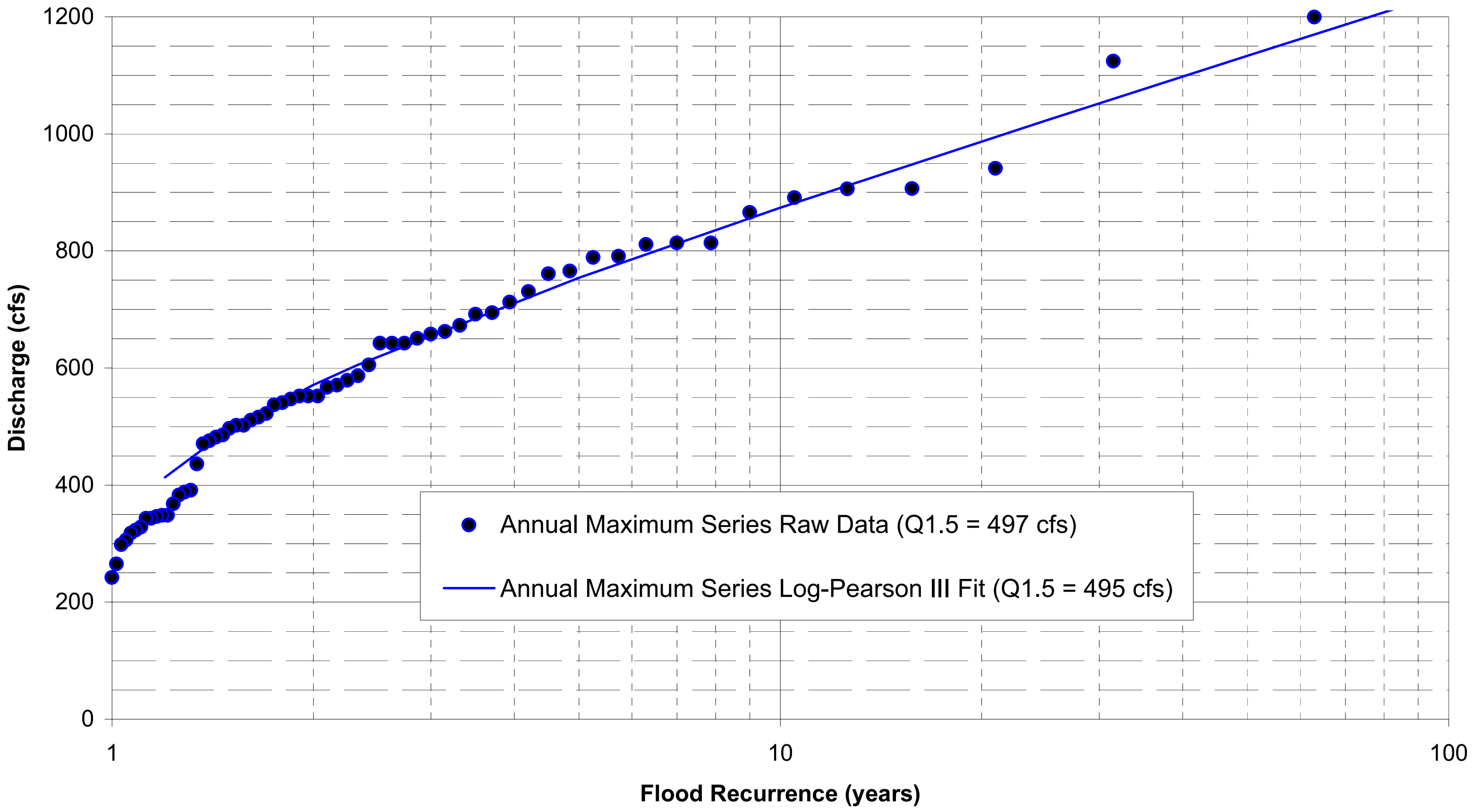
Flood Frequency Analysis for RUSH CREEK IMPAIRED PEAK FLOWS
Rush Creek below Narrows
(Using 1937-2003 SWRCB Stream Restoration Flows)



Flood Frequency Analysis for RUSH CREEK IMPAIRED PEAK FLOWS
Rush Creek below Narrows
(Using 1980-2003 SWRCB Stream Restoration Flows)



Flood Frequency Analysis for RUSH CREEK UNIMPAIRED below Narrows
Rush Creek Runoff + Parker and Walker Average Peaks
(Using 1941-1990 data from Hassencamp (1994) and 1991-2003 RCR)



APPENDIX E

Riparian Vegetation Atlas – DRAFT

The draft riparian vegetation atlas was not included in this year's (RY200304) annual report. Please contact Mark Hanna of the Los Angeles Department of Water & Power if you are interested in reviewing the atlas before it is finalized for next year's (RY200405) report.

Section 5

Mono Basin Waterfowl
Habitat and Population Monitoring
2003-2004

Waterfowl Habitat Restoration Project
Annual Report
2003

Mono Basin Hydrology

Mono Basin water exports are reported in Appendix 1.

The elevation of Mono Lake was measured on forty occasions during Runoff Year 2003-2004. The reads are reported in Appendix 1.

Lake Limnology

Dr. Robert Jellison of the University of California Santa Barbara conducted eleven limnological surveys on Mono Lake. The results are reported in Appendix 2.

Waterfowl Surveys

Ms. Debbie House, Watershed Resources Specialist with the Los Angeles Department of Water and Power, conducted three summer ground counts and six fall aerial surveys. The results are reported in Appendix 3.

Ms. House took aerial photographs of waterfowl habitat at Mono Lake, Crowley Lake and Bridgeport reservoirs. The photographs are shown in Appendix 3.

On September 11, 2003, Mr. Robert McKernan accompanied Ms. House and Dr. Brian White, the Waterfowl Director under Order 98-05, on a fall aerial survey to review the field program and assess the ability of Ms. House to differentiate and count waterfowl from the air. Mr. McKernan’s review is presented in Appendix 4.

Vegetation

The next regularly scheduled vegetation surveys are set for 2005.

Mono Lake Waterfowl Restoration Project
Compliance Checklist
2003

Hydrology	**Appendix 1**
Mono Lake Elevation	☑
Walker Creek Flows	☑
Parker Creek Flows	☑
Lee Vining Creek Flows	☑
Rush Creek Flows	☑
Mono Basin Exports	☑

Limnology	**Appendix 2**
Meteorology	☑
Physicochemical Variables	☑
Primary Producers	☑
Secondary Producers	☑

Ornithology	**Appendix 3**
Population Surveys	☑
Aerial Photography	☑
Time Activity Budget	**Required at Stabilization**

Vegetation	**Required 2005**

Brian White

Brian White
Waterfowl Coordinator

APPENDIX 1

Hydrology

May 5, 2004

Mr. Harry Schueller, Chief Deputy Director
State Water Resources Control Board
P.O. Box 100
Sacramento, California 95812-0100

Dear Mr. Schueller:

Subject: Update on Mono Basin Operations During 2003-04 Runoff Year

The runoff for Mono Basin Runoff Year 2003-2004 was a bit "atypical" with peak flows occurring quite a bit earlier and much higher than predicted. The following is a summary of the Los Angeles Department of Water and Power's (LADWP) operations in the Mono Basin for the 2003-04 runoff year:

- <u>Mono Basin Exports</u>: Exports were completed in March 2003. LADWP exported a total of 15,818 acre-feet, less than the maximum allowed under Decision 1631 of 16,000 acre-feet.

- <u>Rush Creek</u>: Grant Lake's elevation on April 1, 2003 was approximately 7,099.5 ft amsl, 30.5 ft below the lip of the spillway. The low elevation of the reservoir provided no opportunity to spill. A peak inflow into Grant Lake (Rush Creek at Damsite) of 148 cfs was forecasted to occur on May 31. Rush Creek at Damsite experienced its peak on June 19 with a magnitude of 342 cfs (average daily). Rush Creek below the confluence of the Return Ditch experienced a flow of approximately 200 cfs (average daily) for seven days, from June 2 to June 8. The 200 cfs was achieved by ramping the outflow to the return ditch up to its peak and back down again by 25 cfs per day. This ramping rate was altered by agreement with the parties from the normal 10 percent or 10 cfs per day to the 25 cfs per day to accommodate rating of the newly refurbished Return Ditch.

Rush Creek below the narrows experienced a flow magnitude of approximately 280 cfs (average daily) on June 3.

- Parker Creek: There were no diversions for export during the year. The creek experienced its peak of a magnitude of 51 cfs (average daily) on May 31. The peak exceeded the forecasted magnitude of 42 cfs by 9 cfs, and it occurred 18 days earlier than the forecasted date of June 18.

- Walker Creek: There were no diversions for export during the year. The creek experienced its peak of a magnitude of 43 cfs (average daily) on May 30. The peak exceeded the forecasted magnitude of 26 cfs by 17 cfs, and it occurred 15 days earlier than the forecasted date of June 14.

- Lee Vining Creek: Diversions were made from Lee Vining Creek to Grant Lake totaling approximately 8,000 acre-feet. The creek experienced its peak magnitude of 362 cfs (average daily) on May 30. The peak exceeded the forecasted peak of 178 cfs by more than double, and occurred four days earlier than the forecasted date of June 3. There was no augmentation from Lee Vining Creek made to Rush Creek flows.

- Runoff - Actual vs. Forecasted: The forecasted runoff for the period April 1 through March 31 was 88,410 acre-feet while the actual runoff was measured at 106,730 acre-feet; a difference of nearly 18,000 acre-feet. Three main factors included in this discrepancy are 1) a wetter than average April 2003, adding a significant amount of precipitation to the Mono Basin, 2) a warmer than average May 2003, sending more water, more quickly, down the streams instead of into groundwater storage, and 3) a warmer than average March 2004, sending approximately 5,000 acre-feet more water down the streams from the 2004-05 runoff year's storage.

  Peak runoff timing occurred one to three weeks earlier than forecasted for Lee Vining, Parker, and Walker Creeks. For Rush Creek the peak occurred three weeks later than forecasted. Rush and Lee Vining Creeks experienced peak flow magnitudes more than twice what was forecasted. Parker and Walker Creeks also experienced flow magnitudes higher than those forecasted. The table below compares May 1 forecasted values to those actually measured.

	Forecasted		Measured	
	Magnitude	Timing	Magnitude	Timing
Rush Creek @ Damsite	148 cfs	May 31	313 cfs	June 19
Parker Creek	40 cfs	June 18	51 cfs	May 31
Walker Creek	26 cfs	June 14	43 cfs	May 30
Lee Vining Creek	178 cfs	June 3	362 cfs	May 30
Runoff (acre-feet)	88,410	N/A	106,730*	N/A

*an additional 5,000 af came down in March 2004, presumably from the 2004-05 runoff period

- Grant Lake Reservoir: Flow releases from the reservoir to Rush Creek were maintained slightly above the minimum and exports were suspended until late September to help reduce impacts to recreation at Grant Lake reservoir.

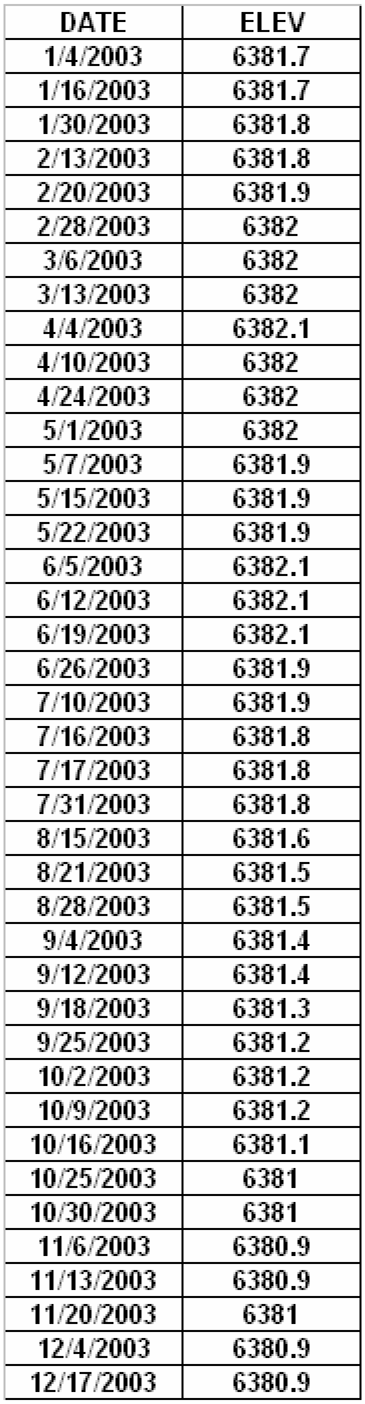
If you have any questions or need additional information, please contact Dr. Mark Hanna at (213) 367-1289.

Sincerely,

Gene L. Coufal
Manager
Aqueduct Business Group

c: Mr. Jim Edmondson, California Trout, Inc.
Mr. Bill Bramlette, U.S. Forest Service
Mr. Burt Almond, U.S. Forest Service
Mr. James Barry, California Department of Parks and Recreation
Mr. Joe Bellomo, People for Mono Basin Preservation
Dr. William Trush, McBain & Trush
Mr. Ken Anderson, Department of Parks and Recreation
Mono County Board of Supervisors
Mr. Marshall S. Rudolph, Mono County Counsel
Mr. Dan Lyster, Mono County
Ms. Paula Pennington, Department of Parks and Recreation
Mr. Jim Canaday, Division of Water Rights, State Water Resources Control Board
Mr. Gary Smith, California Department of Fish and Game
Ms. Lisa Cutting, Mono Lake Committee
Mr. Chris Hunter
Mr. Steve Parmenter, California Department of Fish and Game
Ms. Molly Brown, U. S. Forest Service
Dr. Mark Hanna

Mono Lake Elevations - 2003



DATE	ELEV
1/4/2003	6381.7
1/16/2003	6381.7
1/30/2003	6381.8
2/13/2003	6381.8
2/20/2003	6381.9
2/28/2003	6382
3/6/2003	6382
3/13/2003	6382
4/4/2003	6382.1
4/10/2003	6382
4/24/2003	6382
5/1/2003	6382
5/7/2003	6381.9
5/15/2003	6381.9
5/22/2003	6381.9
6/5/2003	6382.1
6/12/2003	6382.1
6/19/2003	6382.1
6/26/2003	6381.9
7/10/2003	6381.9
7/16/2003	6381.8
7/17/2003	6381.8
7/31/2003	6381.8
8/15/2003	6381.6
8/21/2003	6381.5
8/28/2003	6381.5
9/4/2003	6381.4
9/12/2003	6381.4
9/18/2003	6381.3
9/25/2003	6381.2
10/2/2003	6381.2
10/9/2003	6381.2
10/16/2003	6381.1
10/25/2003	6381
10/30/2003	6381
11/6/2003	6380.9
11/13/2003	6380.9
11/20/2003	6381
12/4/2003	6380.9
12/17/2003	6380.9

APPENDIX 2

Limnology

2003 ANNUAL REPORT

MIXING AND PLANKTON DYNAMICS IN MONO LAKE, CALIFORNIA

Robert Jellison, Ph.D.

Marine Science Institute

University of California

Santa Barbara, CA 93106

Submitted: 12 April 2004

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EXECUTIVE SUMMARY

Limnological monitoring of the plankton dynamics in Mono Lake continued during 2003 and witnessed the breakdown of an extended period of persistent chemical stratification (meromixis) initiated in 1995. Chapter 1 describes previous results of limnological studies of the seasonal plankton dynamics observed from 1979 through 2002, a period which encompassed a wide range of varying hydrologic and annual vertical mixing regimes including two periods of persistent chemical stratification or meromixis (1983–88 and 1995–2003). In brief, long-term monitoring has shown that Mono Lake is highly productive compared to other temperate salt lakes, that this productivity is nitrogen-limited, and that year-to-year variation in the plankton dynamics has largely been determined by the complex interplay between varying climate and hydrologic regimes and the resultant seasonal patterns of thermal and chemical stratification which modify internal recycling of nitrogen. The importance of internal nutrient cycling to productivity is highlighted in the years immediately following the onset of persistent chemical stratification (meromixis) when upward fluxes of ammonium are attenuated. These seasonal variations in the physical and nutrient environments have obscured any real or potential impacts due to the effects of changing salinity over the range observed during the period of regular limnological monitoring (1982-present).

Chapter 2 provides a detailed description of the laboratory and field methods employed.

Chapter 3 describes the results of our limnological monitoring program during 2003. Persistent chemical stratification (meromixis) nearly broke down early in the year (February-March) prior to the onset of seasonal thermal stratification. This resulted in an upward pulse of nutrients (ammonia) into the upper mixed layer early in the year. Following a small rise in surface elevation and slight freshening of the mixed layer due to snowmelt runoff, decreased inflow and evaporative concentration led to an inverse chemical gradient with slightly more saline mixolimnetic water overlying the monimolimnion (region beneath the chemocline). Thus autumn cooling led to complete mixing of the lake in mid-November and the end of an 8-yr period of meromixis (1995-2003).

Algal biomass, as characterized by chlorophyll *a* concentration, was high throughout the winter and spring (50-96 μg chl *a* l^{-1}, January through May) and autumn (50-62 μg chl *a* l^{-1}, October through November). Throughout the summer *Artemia* grazing and nutrient availability limit algal biomass and values are typically less than 3 μg chl *a* l^{-1}. In summer 2003, algal biomass never fell below 3 μg chl *a* l^{-1} despite near average *Artemia* abundance. The annual estimate of lakewide primary production was 1,645 g C m^{-2} y^{-1}, more than twice the revised (see section "Planktonic Primary Production") estimate of 763 g C m^{-2} y^{-1} for 2002 and the highest of any year from 1982-2003.

In 2003, the mean annual *Artemia* biomass increased 53% from 4.9 g m^{-2} in 2002 to 7.5 g m^{-2} in 2003, although it is still slightly below the long-term (1983-2003) average of 9.2 g m^{-2}. Recruitment of ovoviviparous (live-bearing) reproduction into the 2nd generation was low and accounts for below average mean annual biomass. Recent analysis of seasonal *Artemia* dynamics indicates small changes in algal biomass immediately following maturation of the 1st generation dramatically affects recruitment into the summer generation. A detailed cohort analysis of 2003 stage-specific *Artemia* data is being conducted. Total annual cyst production also increased over 2002 and was 4.2 x 10^6 m^{-2}, close to the long-term (1983-2003) mean of 4.5 x 10^6 m^{-2}.

In summary, the breakdown of a second episode of meromixis has resulted in increased vertical fluxes of nutrients into the euphotic zone and high levels of primary productivity. *Artemia* biomass and reproduction increased compared to 2003 but remain slightly below the long-term mean. Changes in physical and chemical factors due to variation in the annual mixing regime continue to dominate the plankton dynamics of Mono Lake. Based on the years immediately following breakdown of the 1980s episode of meromixis, we expect next year to exhibit above average levels of primary productivity. The response of the *Artemia* population to variation in primary production is muted and their dynamics appear to be highly dependent on the details of stratification and food availability during critical periods making predictions difficult. Given near average cyst production in 2003 and a monomictic mixing regime, we would expect the *Artemia* population in 2004 to be similar to those observed during 1990-1994.

ACKNOWLEDGEMENTS

Laboratory work was performed at the Sierra Nevada Aquatic Research Lab and University of California, Santa Barbara. Sandra Roll and Kimberly Rose assisted with field sampling and laboratory analyses. K. Rose also assisted with presenting data and reviewing text of this report. This work was supported by a grant from the Los Angeles Department of Water and Power to R. Jellison and J. M. Melack at the Marine Science Institute, University of California, Santa Barbara.

LIMNOLOGICAL MONITORING COMPLIANCE

This report fulfills the Mono Lake limnological monitoring requirements set forth in compliance with State Water Resources Control Board Order Nos. 98-05 and 98-07. The limnological monitoring program consists of four components: meteorological, physical/chemical, phytoplankton, and brine shimp population data. Meteorological data are collected continuously at a station on Paoha Island, while the other three components are assessed on eleven monthly surveys (every month except January). A summary of previous monitoring is included in Chapter 1, the methodology employed is detailed in Chapter 2, and results and discussion of the monitoring during 2003 presented in Chapter 3. The relevant pages of text, tables, and figures for the specific elements of each of the four required components are given below.

	Text	Tables	Figures
Meteorological			
Wind Speed	30		79
Wind Direction	30		
Air Temperature	31		80
Incident Radiation	31		81
Humidity	31		82
Precipitation	31-32		83
Physical/Chemical			
Water Temperature	32-33	57	85
Transparency	35-36	61	89-90
Underwater light	36		91
Dissolved Oxygen	36-37	62	92
Conductivity	34	58	86, 87
Nutrients (ammonia and phosphate)	37-38	63	93
Plankton			
Chlorophyll *a*	39-41	64	94
Primary production	47-51	75	101-106
Artemia Abundance	41-47	65	96-97
Artemia Instar distribution	41-47	68	
Artemia Fecundity/Length	41-47	72	
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CHAPTER 1
INTRODUCTION

Background

Saline lakes are widely recognized as highly productive aquatic habitats, which in addition to harboring unique assemblages of species, often support large populations of migratory birds. Saline lake ecosystems throughout the world are threatened by decreasing size and increasing salinity due to diversions of freshwater inflows for irrigation and other human uses (Williams 1993, 2002); notable examples in the Great Basin of North America include Mono Lake (Patten et al. 1987), Walker Lake (Cooper and Koch 1984), and Pyramid Lake (Galat et al. 1981). At Mono Lake, California, diversions of freshwater streams out of the basin beginning in 1941 led to a 14 m decline in surface elevation and an approximate doubling of the lake's salinity.

In 1994, following two decades of scientific research, litigation, and environmental controversy, the State Water Resources Control Board (SWRCB) of California issued a decision to amend Los Angeles' water rights to "establish fishery protection flows in streams tributary to Mono Lake and to protect public trust resources at Mono Lake and in the Mono Lake Basin" (Decision 1631). The decision restricts water diversions until the surface elevation of the lake reaches 1,948 m and requires long-term limnological monitoring of the plankton dynamics.

Long-term monitoring of the plankton and their physical, chemical, and biological environment is essential to understanding the effects of changing lake levels. 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 25-yr period, 1979–2003, and have yielded a standardized data set from which to analyze seasonal and year-to-year changes in the plankton. The limnological monitoring program for Mono Lake specifies eleven monthly surveys from February through December.

Seasonal Mixing Regime and Plankton Dynamics

Limnological monitoring at Mono Lake can be divided into several periods corresponding to two different annual circulation patterns, meromixis and monomixis, and the transition between them.

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). During this period Mono Lake was characterized by declining lake levels, increasing salinity, and a monomictic thermal regime. No further limnological research was conducted until summer 1976 when a broad survey of the entire Mono Basin ecosystem was conducted (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, 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. Detailed descriptions 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, 1995a, 1996a, 1997, 1998a, 1999, 2001, 2002; Jellison and Melack 2000) 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 600 to 700 μM. Under previous monomictic conditions, summer ammonium accumulation beneath the thermocline was 80–100 μM, and 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 (~30,000 individuals m^{-2}) and within the range seen from 1984–88, but decreased by late spring to ~4,000 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 that 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 µg 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.* 1995b) 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 was returning to that observed before the onset of meromixis.

Spring and summer peak abundances 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 (~27,000 m^{-2}). Summer abundance of adults increased slightly (~29,000 m^{-2}) in 1994 when runoff was lower and lake levels were declining.

Meromictic conditions with rising (1995-1999) and falling (1999-2002) lake levels

1995

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*. 1996a). 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 slightly lower to that observed in 1993 (~27,000 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 continued, a shallower mixed layer, lower mixed-layer ammonium and chlorophyll *a* concentrations, slightly smaller *Artemia,* and smaller brood sizes compared to 1994 were all observed. The full effects of the onset of meromixis in 1995 were not evident until 1996.

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}.

A single mid-July peak in adults characterized *Artemia* population dynamics in 1996 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 (~35,000 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}).

1997

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}). Concomitant increases in transparency and the depth of the euphotic zone were also observed. As in 1996, a single mid-July peak in adults characterized the *Artemia* population dynamics in 1997 with little evidence of recruitment of second generation *Artemia* into adults. The peak midsummer adult abundance (~27,000 m^{-2}) was slightly lower than 1996 but similar to 1995 (~24,000 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.

1998

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, a single mid-July peak in adults characterized the Artemia population dynamics in 1998 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 (~27,000 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 was significantly smaller than has been observed in any other previous year 1987–94 (81–156 eggs $brood^{-1}$).

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 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 similar to those observed in 1998 but slightly 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 of 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 (~35,000 m^{-2}), 1997 (~27,000 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).

2000

In 2000, persistent chemical stratification (meromixis) continued but weakened due to evaporative concentration of the upper mixed layer accompanying a net 0.7 ft annual decline in surface elevation and slight freshening of water beneath the chemocline. The midsummer difference in density between 2 and 28 m attributable to chemical stratification declined from 12.2 kg m^{-3} in 1999 to 10.5 kg m^{-3} in 2000. Most likely of greater significance to the overall plankton dynamics is the marked midwinter deepening (ca. 2 m) of the chemocline. Not only were significant amounts of ammonium-rich monimolimnetic water entrained, but less of the lake is now effectively meromictic; only 38% of the lake's area and 16% of the volume were beneath the chemocline.

Algal biomass, as characterized by the concentration of chlorophyll *a*, was higher in 2000 compared to 1999 and varied in the mixolimnion from a midsummer low of 1.4 µg chl *a* l^{-1} to the December high of 54.2 µg chl *a* l^{-1}. The December value is the highest observed during the entire 21 years of study. Although adult *Artemia* abundance (peak of ~22,000 m^{-2}) was anomalously low (50% of the long-term mean), *Artemia* biomass and total annual cyst production were only slightly below the long-term mean, 12 and 16%, respectively. Thus, while meromixis persisted in 2000, the combined effects of declining lake levels, the reduced proportion of the lake beneath the chemocline, and increased upward fluxes of ammonium due to the large buildup of monimolimnetic ammonium offset, to some degree, the effect of the absence of winter holomixis.

2001

Persistent chemical stratification (meromixis) continued but weakened in 2001 due to evaporative concentration of the upper mixed layer accompanying a net 0.8 ft decline in surface elevation and slight freshening of water beneath the chemocline. Colder than average mixolimnetic temperatures (1.5–2.2ºC) observed in February 2001 enhanced deep mixing. The midsummer difference in density between 2 and 28 m attributable to chemical stratification has declined from 10.5 kg m^{-3} in 2000 to 8.9 kg m^{-3} in 2001. Most likely of greater significance to the overall plankton dynamics was the marked midwinter deepening (ca. 2 m) of the chemocline. Not only were significant amounts of ammonium-rich monimolimnetic water entrained, but less of the lake was effectively meromictic. At the end of 2001, only 33% of the lake's area and 12% of the volume were beneath the chemocline. Ammonium concentrations in the monimolimnion continued their 6-year increase with concentrations at 28 and 35 m generally 900–1200 μM.

Algal biomass, as characterized by chlorophyll *a* concentration, was similar to that observed during 2000 except that the autumn bloom was somewhat later as adult *Artemia* were more abundant in September and October compared to 2000.

As in 2000, the 2001 *Artemia* population was characterized by fairly rapid development of the 1st generation, a pulse of ovoviviparous reproduction in June, peak of adult abundance in July at ~38,000 m^{-2}, followed by a decline to very low numbers by November. In 2000, the autumn decline was very rapid and resulted in the lowest seasonal mean abundance of any year studied. In 2001 the autumn decline was less rapid and resulted in a seasonal mean abundance identical to the long-term mean of ~20,000 m^{-2}. The 2001 mean annual *Artemia* biomass was 8.8 g m^{-2} or 9 % below the long-term mean of 9.7 g m^{-2} and slightly higher than calculated in 2000 (8.2 g m^{-2}).

In Mono Lake, oviparous (cyst) reproduction is always much higher than ovoviviparous (live-bearing) reproduction. Although adult *Artemia* were more abundant in 2001 compared to 2000, total annual cyst production was lower, 3.02×10^6 m^{-2} compared to 4.03×10^6 m^{-2} in 2000. While this is 37% below the long-term mean of 4.77

x 10^6 m^{-2}, it is not expected to have a significant impact on 2002 abundance as food availability is a much stronger determinant of the spring generation of *Artemia.*

2002

Meromixis continued but weakened due to evaporative concentration of the upper mixed layer accompanying a net 0.8 ft decline in surface elevation and slight freshening of water beneath the chemocline. The peak difference in density between 2 and 28 m attributable to chemical stratification declined from 10.5 kg m^{-3} in 2000 to 8.9 kg m^{-3} in 2001 to 5.5 kg m^{-3} in 2002. More importantly the chemical stratification between 2 and 32 m decreased to ~1 kg m^{-3} and the chemocline was eroded downward several meters to ~30 m. Not only were significant amounts of ammonium-rich monimolimnetic water entrained, but only 14% by area and 3% by volume of the lake is below the chemocline.

Algal biomass, as characterized by chlorophyll *a* concentration, was high during both spring (60-78 μg chl *a* l^{-1}, February and March) and autumn (60-80 μg chl *a* l^{-1}, November). Annual estimates of lakewide primary production were 723 g C m^{-2} y^{-1} and continued the consistent upward trend from the lowest value of 149 g C m^{-2} y^{-1} in 1997.

As in 2000 and 2001, the *Artemia* population was characterized by fairly rapid development of the 1st generation, a pulse of ovoviviparous reproduction in June, adult abundance peak in August at ~26,000 m^{-2}, followed by a decline to very low numbers by November. In 2002, the mean annual *Artemia* biomass was 4.9 g m^{-2} almost 50% below the long-term mean of 9.7 g m^{-2}. Recent analysis of seasonal *Artemia* dynamics indicates small changes in algal biomass immediately following maturation of the 1st generation, dramatically affects recruitment into the summer generation. In 2002, a larger spring hatch and spring adult generation lowered algal biomass and led to decreased recruitment into the summer adult population. This inter-generational compensatory interaction is a dominant feature of the seasonal and annual variation of adult abundance observed in the long-term monitoring (1982-present).

Total annual cyst production (2.5×10^6 m^{-2}), along with abundance of ovigerous females, was less than in the previous three years (3.0-4.2×10^6 m^{-2}), though the size of ovigerous females was larger than in these years. Annual cyst production was the same as in 1997, and was 53% below the long term mean of 4.77×10^6 m^{-2}.

Long-term integrative measures: annual primary productivity, mean annual *Artemia* biomass and egg production

The availability of dissolved inorganic nitrogen or phosphorus has 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 indicates inorganic nitrogen limits the standing biomass of algae (Jellison 1992, Jellison and Melack 2001). 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 showed 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

1993a). Also, a gradual increase in photosynthetic production occurred even before meromixis was terminated because of increased vertical flux of ammonium due to deeper mixing into ammonium-rich monimolimnetic water. 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 after 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 were made during 1993-2001. 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 continually increasing estimates of annual primary production through the breakdown of meromixis in 2003.

The mean annual biomass of *Artemia* was estimated from instar-specific abundance and length-weight relationships for the period 1983–99 and by direct weighing from 2000 to the present. The mean annual biomass has varied from 5.3 to 17.6 g m^{-2} with a 22-yr (1982-2003) mean of 9.3 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 increased in 1998-2001 to 8-9 g m^{-2} and decreased markedly in 2002 to 4.9 g m^{-2}, before increasing to near average levels during 2003.

Scientific publications

In addition to the long-term limnological monitoring, the City of Los Angeles has partially or wholly funded a number of laboratory experiments, analyses, and analytical modeling studies resulting in the following peer-reviewed research publications by University of California, Santa Barbara (UCSB) researchers.

Dana, G. L. and P.H. Lenz. 1986. Effects of increasing salinity on an *Artemia* population from Mono Lake, California. Oecologia 68:428-436.

Dana, G.L., C. Foley, G. Starrett, W. Perry and J.M. Melack. 1988. In situ hatching of *Artemia monica* cysts in hypersaline Mono Lake, Pages 183-190. In: J.M. Melack, ed., Saline Lakes. Developments in Hydrobiology. Dr. W. Junk Publ., The Hague (also appeared in Hydrobiologia 158: 183-190.)

Dana, G. L., R. Jellison, and J. M. Melack. 1990. *Artemia monica* egg production and recruitment in Mono Lake, California, USA. Hydrobiologia 197:233-243.

Dana, G. L., R. Jellison, J. M. Melack, and G. Starrett. 1993. Relationships between *Artemia monica* life history characteristics and salinity. Hydrobiologia 263:129-143.

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Jellison, R. 1987. Study and modeling of plankton dynamics in Mono Lake, California. Report to Community and Organization Research Institute, Santa Barbara.

Jellison, R., G. L. Dana, and J. M. Melack. 1992. Ecosystem responses to changes in freshwater inflow to Mono Lake, California, p. 107–118. In C. A. Hall, Jr., V. Doyle-Jones, and B. Widawski [eds.] The history of water: Eastern Sierra Nevada, Owens Valley, White-Inyo Mountains. White Mountain Research Station Symposium 4. Univ. of Calif., Los Angeles.

Jellison, R., J. Romero, and J. M. Melack. 1998a. The onset of meromixis during restoration of Mono Lake, California: Unintended consequences of reducing water diversions. Limnol. Oceanogr. 43:706-711.

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Jellison, R. and J. M. Melack. 2001. Nitrogen limitation and particulate elemental ratios of seston in hypersaline Mono lake, California, USA. Hydrobiol. 466:1-12.

Jellison, R., L. G. Miller, J. M. Melack, and G. L. Dana. 1993. Meromixis in hypersaline Mono Lake, California II. Nitrogen fluxes. Limnol. Oceanogr. 38:1020–1039.

Jellison, R., G. L. Dana, and J. M. Melack. 1995. Zooplankton cohort analysis using systems identification techniques. J. Plankton Res. 17:2093–2115.

Jellison, R., R. Anderson, J. M. Melack, and D. Heil. 1996. Organic matter accumulation in Mono Lake sediments during the past 170 years. Limnol. Oceanogr. 41:1539–1544.

Melack, J.M. and R. Jellison. 1998. Limnological conditions in Mono Lake: Contrasting monomixis and meromixis in the 1990s. Hydrobiologia 384:21-39.

Miller, L. G., R. Jellison, R. S. Oremland, and C. W. Culbertson. 1993. Meromixis in hypersaline Mono Lake, California III. Breakdown of stratification and biogeochemical response to overturn. Limnol. Oceanogr. 38:1040–1051.

Romero, J.R., J.C. Patterson, and J. M. Melack. 1996. Simulation of the effect of methane bubble plumes on vertical mixing in Mono Lake. Aquat. Sci. 58:210–223.

Romero, J.R. and J.M. Melack. 1996. Sensitivity of vertical mixing to variations in runoff. Limnol. Oceanogr. 41:955–965.

Romero, J. R., R. Jellison, J. M. Melack. 1998. Stratification, vertical mixing, and upward ammonium flux in hypersaline Mono Lake, California. Archiv fuer Hydrobiol. 142: 283-315.

Other related current research

A wide array of research is being conducted at Mono Lake and Dr. Jellison is actively collaborating with various researchers on several other projects. These include an NSF-funded microbial observatory at Mono Lake (J. Hollibaugh and S. Joye, Univ. Georgia; J. Zehr, UCSC), and NSF-funded study of viral dynamics (S. Jiang, UCI and G. Steward, U. Hawaii) and analysis of the effects of *Artemia* abundance on feeding and reproductive success of California Gulls (D. Winkler, Cornell; J. Jehl, Hubbs Sea-World Institute).

CHAPTER 2
METHODS

Meteorology

Continuous meteorological data is collected at the Paoha station located on the southern tip of Paoha Island. The station is approximately 30 m from the shoreline of the lake with the base located at 1948 m asl, several meters above the current surface elevation of the lake. Sensor readings are made every second and stored as either ten minute or hourly values. A Campbell Scientific CR10 datalogger records up to 3 weeks of measurements and radio frequency telemetry is used to download the data weekly.

Wind speed and direction (RM Young wind monitor) are measured at a height of 3 m above the surface of the island and are averaged over a 10-minute interval. The maximum wind speed during the ten-minute interval is also recorded. The 10-minute wind vector magnitude, wind vector direction, and the standard deviation of the wind vector direction are computed from the measurements of wind speed and wind direction and stored. Hourly measurements of average photosynthetically available radiation (PAR, 400 to 700 nm, Li-Cor 192-S) and total rainfall (Qualimetrics 601 I-B tipping bucket), and ten minute averages of relative humidity (Vaisalia HMP35C) and air temperature (Vaisalia HNV35C and Omnidata ES-060) are also made and stored.

The Cain Ranch meteorological station is located approximately 7 km southwest of the lake at an elevation of 2088 m. Throughout the 1980s, LADWP measured wind and temperature at this station. Currently UCSB maintains and records hourly averages of incoming shortwave (280 to 2800 nm; Eppley pyranometer), longwave radiation (3000 to 50000 nm; Eppley pyrgeometer) and PAR (400 to 700 nm; Li-Cor 192-S) at this site.

Sampling Regime

The limnological monitoring program for Mono Lake specifies eleven monthly surveys from February through December. In 2003, the lake was surveyed on 6 January 2003 (as weather did not permit a December 2002 sampling) and approximately mid-month February through December. The November sampling was added due to the interest in the interaction between grebe migration and autumn *Artemia* abundance. *Artemia*, temperature, conductivity, oxygen, ammonium, chlorophyll *a*, and Secchi depth were sampled on every survey.

Field Procedures

In situ profiles

Water temperature and conductivity were measured at eight buoyed, pelagic stations (2, 3, 4, 5, 6, 7, 8, and 12) (Fig. 1). Profiles were taken with a high-precision, conductivity-temperature-depth profiler (CTD) (Seabird Electronics model Seacat 19) (on loan from the University of Georgia) equipped with sensors to additionally measure photosynthetically available radiation (PAR) (LiCor 191S), fluorescence (695 nm) (WETLabs WETStar miniature fluorometer), and transmissivity (660 nm) (WETlabs C-Star Transmissometer). The CTD was deployed by lowering it at a rate of ~0.25 m s^{-1}. An analysis of salinity spiking from the mismatch in the time response of the conductivity and temperature sensors indicated a 1.7 s displacement of the temperature data provided the best fit. The pumped fluorometer data required a 3.7 s shift, and other sensors (pressure, PAR, transmissivity) required a distance offset based on their relative placement. As density variations in Mono Lake can be substantial due to chemical stratification, pressure readings were converted to depth by integrating the mass of the water column above each depth.

Conductivity readings at in situ temperatures (C_t) were 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. 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 6 and the following density equation:

$$\begin{aligned}\rho(t, C_{25}) = 1.0034 + 1.335 \times 10^{-5} t - 6.20 \times 10^{-6} t^2 + 4.897 \times 10^{-4} C_{25} \\ + 4.23 \times 10^{-6} C_{25}^2 - 1.35 \times 10^{-6} t C_{25}\end{aligned}.$$

The relationship between total dissolved solids and conductivity for Mono Lake water was given by:

$$TDS(g\ kg^{-1}) = 3.386 + 0.564 \times C_{25} + 0.00427 \times C_{25}^2.$$

To obtain TDS in grams per liter, the above expression was multiplied 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.

Dissolved oxygen was measured at one centrally located station (Station 6). Dissolved oxygen concentration was measured with a Yellow Springs Instruments temperature-oxygen meter (YSI, model 58) and probe (YSI, model 5739). The oxygen electrode is calibrated at least once each year against Miller titrations of Mono Lake water (Walker *et al.* 1970).

Water samples

Chlorophyll and nutrient samples were collected from seven to eleven depths at one centrally located station (Station 6). In addition, 9-m integrated samples for chlorophyll *a* determination and nutrient analyses were collected with a 2.5 cm diameter tube at seven stations (Station 1, 2, 5, 6, 7, 8, and 11) (Fig. 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.

Artemia samples

The *Artemia* population was sampled by one net tow from each of twelve, buoyed stations (Fig. 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. Two additional samples were collected at Stations 1, 6, and 8, to analyze for presence of rotifers, and to archive a representative of the population.

Laboratory Procedures

Water samples

Upon return to the laboratory samples were immediately processed for ammonium and chlorophyll determinations. Ammonium concentrations were measured immediately, while chlorophyll samples were filtered onto 47 mm Whatman GF/F filters and kept frozen until the pigments were analyzed within two weeks of collection.

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 fresh lettuce.

Ammonium concentrations were measured using the indophenol blue method (Strickland and Parsons 1972). In addition to regular standards, internal standards were analyzed because the molar extinction coefficient is less in Mono Lake water than in distilled water. Oxygen gas was bubbled into Mono Lake water and used for standards and sample dilutions. Oxygenating saline water may help reduce matrix effects that can occur in the spectrophotometer (S. Joye, pers. comm.) When calculating concentration, the proportion of ammonium in the Mono Lake dilution water in diluted (deep) samples was subtracted from the total concentration.

Artemia samples

Artemia abundances were 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 >100 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 seven stations (Stations 1, 2, 5, 6, 7, 8, and 11) were further classified as to instars 1–7.

Live females were collected for brood size and length analysis from seven buoyed stations (Stations 1, 2, 5, 6, 7, 8, and 11) 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 include).

Long-term integrative measures of productivity

Primary Production

Photosynthetically available radiation (PAR, 400-700 nm) was recorded continuously at Cain Ranch, seven kilometers southwest of the lake, from 1982 to 1994 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 with a conductivity-temperature-depth profiler (Seabird, SB19) (see Methods, Chapter 2). Phytoplankton samples were filtered onto glass fiber filters and extracted in acetone (see above).

Photosynthetic activity was measured using the radiocarbon method. Carbon uptake rates were measured in laboratory incubations within five hours of sample collection. Samples were kept near lake temperatures and in the dark during transport.

Samples were incubated in a "photosynthetron", a temperature-controlled incubator in which 28 20-ml samples are exposed to a range of light intensities from 0 to 1500 μE m^{-2} s^{-1}. After a 4-h incubation, samples were filtered through a Whatman GF/F filter at a pressure not exceeding 125 mm of Hg and rinsed three times with filtered Mono Lake water. Filters were then soaked for 12 h in 1 ml of 2.0 N HCl, after which 9 ml of scintillation cocktail were added and activity measured on a liquid scintillation counter. Chlorophyll-normalized light-limited (α^B) and saturated (P_m^B) parameters were determined via non-linear least-squared fitting to a hyperbolic tangent equation: $P^B = P_m{}^B \tanh\left(\frac{\alpha^B I}{P_m{}^B}\right)$ where I is the light intensity and P^B is the measured chlorophyll-specific uptake of carbon.

Estimates of daily integral production were made using a numerical interpolative model (Jellison and Melack 1993a). 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 Paoha meteorological station, 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. Prior to 2000, *Artemia* biomass was estimated from stage specific abundance and adult length data, and weight-length relationship determined in the laboratory simulating in situ conditions of food and temperature (see Jellison and Melack 2000 for details). Beginning in 2000, biomass was determined directly by drying and weighing of *Artemia* collected in vertical net tows.

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 were used to further refine the biomass estimates. The adult female weight was 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 from seven stations on each sampling date.

CHAPTER 3

RESULTS AND DISCUSSION

Holomixis (complete mixing) occurred in mid-November and thus ended an 8-yr period of persistent chemical stratification initiated in 1995. Evaporative concentration of the mixolimnion during declining lake levels of the past 5 years, less saline subsurface inputs (Clark and Hudson 2001), enhanced boundary-layer turbulent fluxes (MacIntyre et al. 1999, MacIntyre and Jellison 2001), and possibly double diffusive mixing processes all contributed to the breakdown of meromixis. Limnological changes accompanying the breakdown of this episode of meromixis were generally similar to those observed during the breakdown of the 1980s (1983-1988) episode of meromixis.

Meteorological Data

Wind Speed and Direction

Mean daily wind speed varied from 0.8 – 10.9 m s^{-1} over the year, and averaged 3.2 m s^{-1} (Fig. 2). The daily maximum 10-min averaged wind speeds averaged 3.5 times mean daily wind speeds and the maximum recorded wind speed was 27.9 m s^{-1} on 10 October. Unlike during 2002 when the mean monthly wind speed varied only from 2.2 to 3.5 m s^{-1}, it was much more variable in 2003. Mean monthly wind speed in 2003 varied from a low of 1.4 m s^{-1} in January to 5.1 m s^{-1} in April (coefficient of variation, 66%). As observed in the past, winds were predominately from the southwest and the monthly vector-averaged wind direction was 239 degrees, ranging from 90 – 264 degrees over the year. Although the mean monthly wind speeds were more variable in 2003, the yearly mean wind speed was identical during 2002 and 2003 at 3.2 m s^{-1}.

Air Temperature

Mean daily air temperatures ranged from a minimum of –7°C on 9 February to a maximum of 25°C on 21 July (Fig. 3). Air temperatures ranged from 5°C to 34°C during the summer (June through August) with a mean daily range of 11°C to 25°C and from –11°C to 12°C during the winter (December through February) with a mean daily range of -7°C to 8°C.

Incident Photosynthetically Available Radiation

Photosynthetically available radiation (400-700 nm) exhibits a regular sinusoidal curve dictated by the temperature latitude (38°N) of Mono Lake. Maximum daily values typically range from about ~15 Einsteins m^{-2} day^{-1} at the winter solstice to ~65 Einsteins m^{-2} day^{-1} in mid-June (Fig. 4). Daily values that diverge from the curve indicate overcast or stormy days. During 2003, the annual mean was 35.0 Einsteins m^{-2} day^{-1}, with daily values ranging from 1.1 Einsteins m^{-2} day^{-1} on 20 April to 65.0 Einsteins m^{-2} day^{-1} on 2 July. This annual mean was slightly lower than observed in 2002 (39.9 Einsteins m^{-2} day^{-1}), presumably indicating more cloudy days in 2003.

Relative Humidity and Precipitation

Mean daily relative humidity followed a general pattern of high values in January, decreasing to lows in May through August, and increasing through December. The lake experienced several brief periods of increased humidity over the year, particularly from 24 July to 3 August, 23-27 August and from 31 October to 19 November (Fig. 5). The yearly mean was 54.0%, with a maximum of 99.1% occurring on 9 January, and a minimum of 27.0% on 1 July (Fig. 5).

During 2003, annual precipitation, collected at Paoha meteorological station was 101.1 mm (Fig. 6). Total precipitation was higher than in 2001 and 2002 (87.9 mm and

69.1 mm, respectively). The most rainy days occurred in December (9 days totaling 11.6 mm) and November (7 days totaling 18.4 mm), while the most precipitation fell in January (47.2 mm), owing to the two largest precipitation events of the year, on January 6 and 17 (23.5 mm and 15.4 mm, respectively). April, May and July also had a fair amount of rainfall (4.3 mm, 10.8 mm and 5.5 mm, respectively), while no precipitation occurred during February, March and October. This seasonal pattern is differs from that observed in 2002 in that we see no precipitation during February and March and substantially more in May. The detection limit for the tipping bucket gage is 1 mm of water. As the tipping bucket is not heated, the instrument is less accurate during periods of freezing due to sublimation or other losses of falling snow.

Surface Elevation

In 2003, the surface elevation of Mono Lake rose ~0.7 ft from the winter low of 6381.8 ft asl (USGS datum) in November 2002 to 6382.5 ft asl in early April (Fig. 7). The surface elevation steadily declined from the April high to 1.2 ft lower by the end of the year. Thus, a net annual decline of 0.7 ft in surface elevation occurred in 2003, similar to previous declines of 0.7, 0.8, and 0.8 ft observed in 2000, 2001, and 2002, 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 arising from the timing and magnitude of freshwater inputs. The annual pattern of seasonal thermal stratification observed during 1990–94 is typical of large temperate lakes, with the lake being vertically isothermal during holomixis in the late autumn through early winter. This pattern was altered during a previous episode of meromixis (1982-88) and similarly in the current episode of meromixis 1995–03; (Fig. 8, Table 1) due to vertical salinity gradients associated with the lack of holomixis.

Apart from the absence of a winter period of holomixis, the most notable difference in the thermal regime during 1996–02 compared to monomictic years is the presence of significant inverse thermal stratification at mid and lower depths (20–26 m). While there was still slight inverse thermal stratification in early 2003, it was much less pronounced than that observed earlier in the meromictic episode. In early January 2003, the upper water column was well-mixed with a temperature of 3.6-3.7 °C, while below the weak chemocline at 30 m the temperature increased to 4.0-4.1 °C. This weak inverse thermal stratification disappeared by April. Deep mixing as evidenced by slight cooling of the monimolimnion during March and April virtually ending meromixis early in 2003.

In February 2003, the temperature in the mixolimnion (3.6-3.7 °C) was significantly warmer than both February 2001 (1.5 °C) and 2002 (2.2 °C), and similar to February 2000 (3.3 °C). A seasonal thermocline had formed by 19 March and became more pronounced at a depth of 13 m by mid-April. Epilimnetic temperatures were 7.0 - 7.5 °C in mid-April increasing to over 20 °C in June and July. The July thermocline was very pronounced with a 5.7 °C difference between 9 and 10 m. The seasonal thermocline deepened to ca. 15 m by mid-October and was absent on the 14 November sampling. On the 14 November sampling, epilimnetic temperatures were slightly cooler than mid-depth waters and near bottom water temperatures had increased by over 3°C since the October survey. Thus, the lake was actively mixing prior to and during the November survey. The water column was isothermal at 5.6 °C during the mid-December survey.

Conductivity and Salinity

Salinity, expressed as total dissolved solids, can be calculated from conductivity measurements corrected to a reference temperature (25 °C, 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.

In 2003, conductivity of the mixolimnion decreased slightly from 82.4 mS cm^{-1} in January to 81.5 – 81.7 mS cm^{-1} in June due to spring runoff (Fig. 9, Table 2). Evaporative concentration through the second half of the year resulted in mixolimnetic conductivities increasing to 83.3-83.4 mS cm^{-1} by October at which time it was greater than the deeper water (82.6-82.7 mS cm^{-1}). The mixolimnetic salinity (TDS) ranged from 77.7 to 80.1 g kg^{-1} (82.8-85.5 g l^{-1} at 25°C).

Monimolimnetic conductivities and salinities decreased slightly from 84.2-84.4 mS cm^{-1} in January to 83.2 mS cm^{-1} (79.7 g kg^{-1}) during December holomixis following the breakdown of meromixis in November.

Density Stratification: Thermal and Chemical

The large seasonal variation in freshwater inflows associated with a temperate climate and year-to-year climatic variation lead to complex patterns of seasonal density stratification. Much of the year-to-year variation in the plankton dynamics observed during the past two decades at Mono Lake can be attributed to marked differences in chemical stratification resulting from variation in freshwater inflows.

Density stratification was much less in 2003 (Table 3) compared to previous years (1995-2002) of the current meromictic episode due to weak chemical stratification. Density of water below 28 m ranged from 1.072–1.074 g cm^{-3}, while minimum densities of 1.067 g cm^{-3} were recorded near the surface (< 4 m). This minimum density occurred in June and July.

A comparison of the density differences between 2 and 32 m due to thermal versus chemical stratification indicates that chemical density stratification made a minimal contribution to overall stratification during 2003 and a slight inverse chemical gradient occurred in September and October similar to monomictic years (Fig. 10, Table 4). Annual peaks in chemical stratification increased each year from 1995 to 1998 (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 subsequently decreased and disappeared altogether in 2003 due to evaporative concentration as the lake level declined.

Summer thermal stratification regularly contributes 3.5 to 4.5 kg m^{-3} of density stratification between 2 and 32 m. In 2003, the peak thermal stratification was nearly three times as large as the chemical stratification observed early in the year.

December conductivity profiles from 1994–2003 (Fig. 11) clearly show the progression of the 8-yr episode of meromixis. The December profile during holomixis in 2003 was 83.2 mS cm^{-1} (79.9 g kg^{-1}) compared to 91.3 mS cm^{-1} (90.5 g kg^{-1}) in 1994. Thus a 12% decrease in salinity has occurred between late 1994 and the present.

Transparency and Light Attenuation

In 2003, average lakewide transparencies as determined by Secchi depth were between 0.63-5.7 m (Fig. 12, Table 5). The Secchi depths were the lowest observed during the past decade during every monthly survey. Lower Secchi depths in 2003 are due to increased phytoplankton biomass associated with the weakening of meromixis and increased upward fluxes of nutrients. The maximum transparency occurred in August and was later than in previous years. With the exception of 1995 (also in August), all other maxima have occurred in June or July.

In Mono Lake, variation in Secchi depth is predominately due to changes in algal biomass. Standing algal biomass reflects the balance between all growth and loss processes. Thus, variation in Secchi depth often reflects the detailed development of the *Artemia* population as much as changes in nutrient availability.

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. The annual pattern of Secchi depths during 2003 was within the range observed during the past 25 years (Fig. 13).

The attenuation of PAR within the water column varies seasonally, primarily as a function of changes in algal biomass. In 2003, the depth of the euphotic zone, operationally defined as the depth at which only 1% of the surface insolation is present, varied from a low of 4.5 m in November to a high of 14 m in August (Fig. 14). While generally similar to previous years, the depth of the midsummer euphotic zone was reduced compared to other years due to high phytoplankton abundance.

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 and chemical processes deplete the oxygen once the lake stratifies. During meromictic periods, the monimolimnion (the region beneath the persistent chemocline) remains anoxic throughout the year.

In February 2003, dissolved oxygen concentrations in the upper water column ranged from 5.8-7.3 mg l^{-1} (Fig. 15, Table 6). The values are similar to those observed in February 2002 (5.5 to 7.5 mg l^{-1}). The depth of the oxycline associated with persistent chemical stratification was 27-35 m, having deepened from 25-27 m a year earlier. The annual maximum concentrations of mixolimnetic oxygen occurred in May (8.8-9.4 mg l^{-1}). The annual maximum concentrations were higher than 2002 (6.6-7.5 mg l^{-1}) and 2000 (7.7-8.0 mg l^{-1}) but lower than 2001 (9–10 mg l^{-1}). Mixolimnetic dissolved oxygen remained relatively high during midsummer with values ranging between of 3.5-8.3 mg l^{-1}. Dissolved oxygen increased slightly in September (4.7-5.8 mg l^{-1}), started to decline in October (3.8-4.8 mg l^{-1}) and by November, the entire lake was anoxic (<0.5 mg l^{-1}).

The anoxic zone (depth below which dissolved oxygen concentrations are <0.5 mg l^{-1}) went from 29-30 m in January to 18 m in February and 13 m in March. Between March and October it varied between 12-16 m. In November the lake became entirely anoxic indicating a breakdown of all chemical stratification and upward flux of reduced chemical species and sources of biological oxygen demand.

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.* 1993b). 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 2003, mixolimnetic ammonium concentration was higher in February (1.4 µM) than in any year since 1995 (1.3 µM) (Fig.16, Table7). Concentrations decreased slightly to 0.8-1.1 µM during March to May. At 2 m, the highest values were reported in June (2.0 µM) and August (2.3 µM), much lower than the single spike observed in June, 2002 (10.7 µM). In November 2003, ammonium concentrations were high through the entire water column at ca. 23.1-34.1 µM.

Higher euphotic zone ammonium concentrations during June through August result from *Artemia* ammonium excretion and decreased algal uptake accompanying *Artemia* grazing and lower standing algal biomass. While this seasonal feature is observed during both meromictic and monomictic conditions, it is generally larger during monomictic periods. During meromictic conditions it is often reduced in magnitude and often only observed during one monthly sampling. During 2003, elevated epilimnetic ammonium concentrations due to *Artemia* grazing and excretion were reduced.

Ammonium concentrations in the monimolimnion decreased dramatically in the early months of 2003 indicating active mixing and near breakdown of meromixis prior to the onset of seasonal thermal stratification. Ammonium concentration at 35 m decreased from 973 µM in January to 139 µM in April. By mid-November holomixis had begun and ammonium concentrations near the bottom (35 m) decreased to 33 µM. The monimolimnetic increase in ammonium during this 8-yr episode of meromixis to concentrations of ~1100 μM was greater than observed during the 1980s 5-yr (1983–88) episode of meromixis when ammonium concentrations had increased to ~600 μM (Jellison *et al*. 1989).

Soluble reactive phosphate concentrations remain several orders of magnitude above those that are saturating for phosphate uptake by phytoplankton. Thus, seasonal variation is not expected to significantly affect the plankton dynamics.

Phytoplankton (algal biomass and fluorescence)

The phytoplankton community, as characterized by chlorophyll *a* concentration, shows pronounced seasonal variation. During 2003, mixolimnetic concentrations varied from 60-76 μg chl *a* l^{-1} during January and February, increased to 70-93 μg chl *a* l^{-1} during the spring bloom in May, before decreasing to midsummer minimum values of ca. 4 μg chl *a* l^{-1}. As *Artemia* grazing declined and entrainment of nutrients occurred due to deepening of the mixed-layer an autumn bloom occurred during which chlorophyll concentrations increased to ca. 50-62 μg chl *a* l^{-1} during October to December (Fig. 17, Table 8). Spring and early summer concentrations were higher than any year during this period of meromixis (1995-2002). In June, a sample from the mid-depth chlorophyll maximum (14 m) was 150 μg chl *a* l^{-1}. Values in April and May ranged from 70 – 93 μg l^{-1}. The high spring values of chlorophyll coincide with the decrease in monimolimnion ammonium concentrations and are certainly the result of high upward fluxes of ammonium, the limiting nutrient in Mono Lake.

Monimolimnetic (28 m) concentrations of chlorophyll *a* varied from 30 to 63 μg chl *a* l^{-1}, with higher concentrations occurring during the early and late season algal blooms. Because 28 m is well below the euphotic zone (Fig. 14), increased chlorophyll *a* at this depth is most likely due to sinking of algal cells from the euphotic zone, rather than an indication of a viable population.

Prominent mid-depth maxima in chlorophyll were observed throughout much of the period. However, chlorophyll *a* determinations are only made on a limited number of samples collected at discrete depths. *In situ* fluorescence profiles determined at 5–10 cm scales indicate strong vertical variation in biotic conditions.

A Seabird Seacat profiler equipped with a transmissometer, PAR sensor, and fluorometer was acquired and deployed on routine surveys beginning in July 2000. This has enabled a much better characterization of the vertical distribution of fluorescing and light absorbing particles than sampling with a Van Dorn bottle. Regressions of chlorophyll *a* determinations versus in situ fluorescence taken throughout the water column from yield a strong correlation and indicate the usefulness of fluorescence to characterize chlorophyll *a* distributions. However, there is a fair amount of scatter about the regression on any given day, and thus an accurate estimate of chlorophyll *a* requires depth and date specific comparisons to laboratory chlorophyll *a* extractions. Also, there is a known depression in fluorescence in near-surface waters exposed to high light.

Fluorescence profiles at station 6 give a detailed image of variation in the vertical structure of the phytoplankton community (Fig. 18). The development of the seasonal deep chlorophyll maximum was similar in timing to that observed in 2002 but shorter in duration. Prominent mid-depth peaks appeared in the oxycline/nutricline regions in June through August as opposed to May through September in 2002. Further, while the observed fluorescence was higher in 2003 than 2002, the regions below the chlorophyll maximum remained relatively high, resulting in a large initial spike which declined only slightly with depth. Fluorescence at 35 m increased steadily from January to December while the mid-depth peaks largely disappeared with autumn mixing during September. The complex interplay between biogeochemical processing by micro-organisms and in situ light, oxygen, density, and nutrient gradients is a major focus of the NSF-funded Microbial Observatory at Mono Lake.

***Artemia* Population Dynamics**

Population Overview

The *Artemia* population in 2003 was similar in timing to 2002, with fairly rapid development of the 1st generation in May and rapid decline of the adult population after mid-August (Table 9a, Fig. 19). Two peaks in naupliar abundance occurred, the first in April (15,307 ± 6430 m^{-2}; uncertainty in estimate is indicated as 1 standard error throughout this chapter), and the second in June (115,383 ± 15687 m^{-2}). The April naupliar peak reflects hatching, growth, and survival of over-wintering cysts and was somewhat smaller than that observed in April 2002 (~37,000 m^{-2}). The June peak represents reproductive output of the first generation of adults and was larger than the peaks observed in 2002 (~66,000 m^{-2}), 2001 (~36,000 m^{-2}) and 2000 (~93,000 m^{-2}). Higher reproductive output of the 1st generation despite lower numbers of individuals highlights the role of food limitation. Juvenile abundance was significantly lower throughout 2003, than in preceding years, and most likely represents the rapid maturation of naupliar instars under abundant food conditions as indicated by unusually high mixed-layer chlorophyll concentrations throughout summer 2003. Ovoviviparous reproduction was highest in June (11% of females had ovoviviparous eggs) and was higher than occurred in either 2001 or 2000 but slightly lower than 2002. Two peaks in adult abundances were also observed, occurring in June and August, with abundances of

24,686 ± 5643 and 29,142 ± 2977 m^{-2} respectively. The abundance of adults rapidly declined to 7864 ± 955 m^{-2} in September and decreased to 0 m^{-2} by November when the lake became anoxic.

Nauplii (Instars 1-7)

Hatching of over-wintering cysts typically becomes significant by late-February, as water temperatures warm after a cold dormancy period (Dana 1981), and continues through May. The presence of significant numbers (2,023 ± 594 m^{-2}) of instar 1 nauplii on 21 February 2003 (Fig. 19) indicates hatching of over-wintering cysts had begun in February. This has been observed in all previous years 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. The naupliar abundance on this sampling date was higher than February abundance in 2002, probably owing to the fact that sampling occurred 9 days earlier in 2002. February abundances were lower in 2003 than both 2000 and 2001. Naupliar abundances increased to 15,307 ± 6430 m^{-2} in April, decreased to 6,088 ± 1965 m^{-2} in May, and increased to the annual peak in mean lakewide abundance of 115,383 ± 15,687 m^{-2} in June (Table 9a). The peak in naupliar abundance was higher than any since before 1991 (range, 13,000 m^{-2} to 93,000 m^{-2}, no data available for 1995). After June 2003, naupliar abundances decreased steadily to 1,777 ± 248 m^{-2} by September and to 0 m^{-2} by November due to anoxia throughout the water column at autumn overturn.

Ovoviviparous second generation nauplii hatched from June through October of 2003 (Table 11a). Peak ovoviviparous hatching occurred in June, when ovoviviparously reproducing females comprised 11.0 percent of fecund females (Table 11c). The peak percent of ovoviviparous females was higher than that observed in 2002 (7%), 2001

(5.8%), 2000 (5%), and 1999 (8%) but slightly lower than in 1998 (12%). This year the very large second peak in nauplii suggests that ovoviviparous reproduction resulted in recruitment into a large second generation of nauplii.

Nauplii were present in decreasing numbers in samples until November 2003. A lack of naupliar recruitment from July to September has been evident in past years, with naupliar instar stages (3-7) absent in *Artemia* samples (1984, 1987, 1989, 1990–91, 1996–98). This pattern, indicative of the lack of recruitment of third and fourth generations, was less pronounced in 1999, and has not occurred in the last four years. In 2003, all size classes were represented from May through November (Table 10). Naupliar abundances declined rapidly in the autumn. In 2000 and 2001, abundances of ~2,000-3,000 m^{-2} continued through October, while in 2002 and 2003, naupliar abundances declined to ~150 and 1,063 ± 108 m^{-2}, respectively, by October.

Juveniles (Instars 8-11)

In 2003 the annual juvenile maximum occurred in August (1,610 ± 253 m^{-2}, Table 9a, Fig. 19) and was lower than the peak abundances during 1991-2002 (~5,000 m^{-2} – 32,000 m^{-2}). The timing of maximum abundance was later to that observed in May, 2000, 2001, 1993-1994 and 1996-1997, and June in 1998 and 1999. An initial peak of 1,269 ± 388 m^{-2} juveniles in May with a decrease in June to 205 ± 79 m^{-2} indicates the 2nd peak in July may have been due to recruitment of a second generation of juveniles. After August, the abundance of juveniles decreased rapidly to 0 m^{-2} in November.

Adults

In 2003, adult abundance increased to a peak of 24,686 ± 5,643 m^{-2} in June (Fig. 19, Table 9a). This peak was a month earlier than in 2002, 2001, 2000, and 1999. Abundance then decreased to 19,007 ± 4,181 m^{-2} in July and increased to a second peak of similar abundance (29,142 ± 2,977 m^{-2}) in August. Both peaks were higher than the maximum in 2002 and 2000, lower than 2001, and at the low end of the range observed 1982 – 2003 (Fig. 20). The peak in June was earlier than most peak abundances during the period 1982 – 2003, except 1986, 1988, and 1993. The maximum abundance of *Artemia* in the eastern sector of the lake (27,163 ± 4,372 m^{-2}) occurred in August, after the maximum in the western sector (34,769 ± 11,077 m^{-2} in June) (Table 9a). From June through August, adult abundances in the western sector were greater than abundances in the eastern sector.

Similar to 2002, abundance decreased more rapidly than observed during most previous years. This is somewhat unexpected given the abundant food available throughout the summer of 2003 and may reflect the increased mortality associated with higher reproductive output. A detailed cohort modeling analysis of this year's *Artemia* abundance data is being planned.

Analysis of long-term monitoring data of plankton dynamics reveals a 4-fold variation in summer peak abundance of adult brine shrimp. The summer population consists of overlapping generations of individuals, those hatched in spring from over-wintering cysts and those produced ovoviviparously during June-July. A persistent feature of the seasonal pattern of *Artemia* abundance is that during years with smaller or delayed spring generations much larger summer populations develop. This occurs despite relatively small year-to-year differences in ovoviviparous reproduction. Detailed stage-specific analysis indicates near cessation of development in early instars and increased mortality when algal biomass declines to below 1 μg chlorophyll a l^{-1}. During years with smaller or delayed first generations, algal biomass declines more slowly to these critical concentrations and adult recruitment is markedly enhanced.

The seasonal dynamics in 2003 exemplify this pattern. Chlorophyll a concentrations were very high in the spring (50 µg l^{-1} in March) and 1st generation naupliar development was early, with a peak of 15,307 ± 6,430 m^{-2} in mid-April. Adult abundances increased to 24,686 ± 5,643 m^{-2} in June, ovoviviparous reproduction was relatively high (11%), indicating that food quality or quantity was good, and the second generation (and annual maximum) naupliar peak was very high (see *Nauplii* discussion). However, by mid-June, during the development of 1st and 2nd instars of the 2nd generation, phytoplankton remained relatively high (3.3 µg l^{-1} in August). This suggests other factors may be contributing to low recruitment during this period.

Ovigerous females increased rapidly from zero on 15 May 2003 to a maximum of 9,205 ± 1,431 m^{-2} on June 18 (Fig. 21, Table 11a). The maximum abundance occurred a month later than most years (except 1998 and 1999), and was higher than in the four previous years (~5,300 m^{-2}, ~6,500 m^{-2}, ~6,300 m^{-2}, ~10,400 m^{-2} in 2002, 2001, 2000, and 1999, respectively). Ovigerous females decreased to 4,199 ± 891 m^{-2} in July, increased to 6,325 ± 1,045 m^{-2} in August and then decreased rapidly to 1,076 ± 194 m^{-2} in September, 4396 ± 82 m^{-2} in October and to zero by November. The percent ovigerity was 84% in June, and increased to 98% by September. The period of ovigerity was slightly longer in 2003 than in 2002 but shorter than in 2000 and 2001, as ovigerous females appeared one month later.

Ovoviviparity of adult females reached a peak of 11 % on 18 June, higher than 2001 (5.1 %), 2000 (4.2 %), 2002 (7 %) and within the range observed during 1990–99

(8-70 %). The percent of ovoviviparous females decreased to 5.0 %, 2.7 %, 2.9%, 2.1% and 0 % in July through November respectively (Fig. 21, Table 11c).

Mean female length ranged from 10.7 to 12.1 mm in 2003 (Table 12). The maximum length was higher than the range of maxima from 1996–01 (10.3 to 12 mm), and within the range of maxima during the period 1987–95 (11.6 to 13.7 mm). Mean female length increased to the annual maximum in October. Shorter lengths of fecund females during the summers of 1996–99 reflect lower ambient algal concentrations. The large females observed in September 2002 and October 2001 and 2003 most likely reflect increased chlorophyll *a* concentrations (9/2003: 18 µg l^{-1}, 9/2002: 5.1µg l^{-1}, 10/2001: 7.2 µg l^{-1}) compared to recent years (1.4 µg l^{-1} in 1999, 1.2 µg l^{-1} in 1998).

Mean brood size of ovigerous females in June 2003, when the first generation of *Artemia* matured, was 75 eggs brood^{-1}, higher than the brood size at maturation in 2002 (54 eggs brood^{-1} in June), 2001 (35 eggs brood^{-1} in July) and in 2000 (68 eggs brood^{-1} in June). Maximum brood size (109 eggs brood^{-1}) occurred in October (Table 12). Maximum brood sizes in previous years were 114, 89, 110, 48, and 50 eggs brood^{-1} in 2002, 2001, 2000, 1999, and 1998, respectively.

Artemia Population Statistics, 1979-2003

Year to year variation in climate, hydrological conditions, vertical stratification, food availability, and possibly salinity have led to large differences in *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 (Table 13, Fig. 22). Seasonal peak abundances were also significantly higher (1.5–2 times the mean) in 1987 and 1988 as the 1980s episode of meromixis weakened and nutrients that had accumulated beneath the chemocline were transported upward. However, in most years the seasonal peaks of adult abundance were similar (30–40,000 m^{-2}) and the seasonal (1 May to November 30) mean of adult abundance is remarkably constant (14–20,000 m^{-2}). The overall mean seasonal abundance of adult *Artemia* from 1979 to 2003 was ~19,400 m^{-2}. During this 25-yr record, mean seasonal abundance was lowest in 2000 (~10,500 m^{-2}) and 2002 (~11,600 m^{-2}). In 2003, mean seasonal abundance increased slightly to ~13,800 m^{-2}.

During most years, the seasonal distribution of adult abundance was roughly normal or lognormal. However, in several years the seasonal abundance was not described well by either of these distributions. Therefore, the abundance-weighted centroid of temporal occurrence was calculated to compare overall seasonal shifts in the timing of adult abundance. The center of the temporal distribution of adults varied from day 190 (9 July) to 252 (9 September) in the 25-yr record from 1979 to 2003 (Table 13, Fig. 23). During five years when there was a small spring hatch (1980–83, and 1989) the overall temporal distribution of adults was much later (24 August – 9 September) and during 1986 an unusually large 1st generation shifted the seasonal temporal distribution much earlier to 9 July. During 2003, the overall temporal distribution of adults (22 July) was just 3 days later than in 2002 and among the earliest of the long-term record.

Long term integrative measures of productivity

Planktonic primary production

Photosynthetic rates were determined by laboratory radiocarbon uptake measurements from 1982-1992 (Jellison and Melack 1988, 1993b) and combined with an interpolative model of chlorophyll, temperature, and in situ photosynthetically-available light (PAR) to estimate annual productivity. While radiocarbon uptake measurements were not conducted from 1993-2001, a significant fraction of the chlorophyll-specific variance in maximum (P_m^B) and light-limited uptake rates (α^B) is explained by temperature (Jellison and Melack (1988, 1993b) and estimates of primary production in subsequent years was made employing measurements of light, chlorophyll, temperature and estimates of P_m^B and $\alpha^{B.}$ As 1989 and 1990 had elevated ammonia concentrations due to the breakdown of meromixis, regressions were performed on just 1991 and 1992 for use in subsequent years. The exponential equation:

$$P_m^B = 0.237 \text{ x } 1.183^T \qquad n=42, r^2=0.86$$

where T is temperature (°C) explained 86% of the overall variation. As found in previous analyses (Jellison and Melack 1993b), 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 reported here are within the range reported in other studies (Jellison and Melack 1993b).

In 1995, rising lake levels and greater salinity stratification reduced the vertical flux of nutrients and may have affected the photosynthetic rates, but previous regression analyses (Jellison and Melack 1993b) using an extensive data set collected during periods of different nutrient supply regimes indicated little of the observed variance in photosynthetic rates can be explained by simple estimates of nutrient supply. 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. Thus, we suggested the above regressions might explain most of the variance in photosynthetic rates and provide a reasonable alternative to frequent, costly field and laboratory measurements using radioactive tracers.

In 2001, new “photosynthetrons” (see Methods, Chapter 2) were constructed and direct measurements of carbon uptake were resumed to determine photosynthetic parameters. The new “photosynthetrons” provide more light levels and better control and measurement of the incubator’s light and temperature. Thus, more accurate measurements of P_m^B and α^B are possible and carbon uptake experiments are now routinely conducted with a sample from the upper mixed layer (2 m) and a sample from a depth near the bottom of the epilimnion (10-16 m). These measurements enable annual productivity changes associated with varying nutrient regimes or changing phytoplankton composition to be estimated more accurately than during 1993 to 2001 when P_m^B and α^B were estimated from previously derived regressions.

The reported results of carbon uptake measurements performed during 2002 (see 2002 Annual Report) are in error due to unusual time-dependent behavior of samples taken to determine the initial activity of the radioactive carbon inocula. Although initial methodological experiments indicated consistent performance with the scintillation fluor, subsequent analysis has revealed that during warmer months strong non-photochemical quenching occurred over the course of 2-4 days during which samples were counted. This problem does not occur with the samples containing the phytoplankton collected on filters and thus all experiments were re-analyzed using the known volume and radioactivity of the inocula. For this reason, we report the results of measurements for both 2002 and 2003 here.

During 2002 and 2003, thirty-six carbon uptake experiments were conducted with natural phytoplankton assemblages from either the mixed-layer or near the bottom of the epilimnion (Table 14). Chlorophyll-specific maximum carbon uptakes (P_m^B) rates and light-limited rates (α^B) were determined for each sample by fitting a hyperbolic tangent curve to the data using least-squares nonlinear estimation. A typical experiment (May 2003) and one with more scatter (September) along with the fitted curve are shown in Fig. 24. Chlorophyll-specific maximum carbon uptakes (P_m^B) rates ranged from 0.44 to 11.9 g C g Chl a^{-1} h^{-1}, while light-limited rates (α^B) ranged from 1.3 to 16.7 g C g Chl a^{-1} $Einst^{-1}$ m^2 (Table 14).

Using the interpolative model to integrate the photosynthetic parameters with in situ temperature, chlorophyll, and light resulted in annual productivity estimates of 763 g C m^{-2} and 1645 g C m^{-2} for 2002 (Fig. 25) and 2003 (Fig. 26), respectively. Daily production rates ranged from 0.4 to 5.3 g C m^{-2} in 2002 and from 1.4 to 10.8 g C m^{-2} in 2003. Daily photosynthetic rates were higher during 2003 compared to 2002 throughout January through September. Given the two-fold increase in estimated productivity during 2003 compared to 2002, it is informative to examine what accounts for this difference. Year-to-year variations in water temperature and insolation are minor when averaged over the whole year. While the maximum uptake rates were somewhat (27%) higher in 2003 (Fig. 27A), the major difference was the much higher chlorophyll concentrations throughout April to October during 2003 (Fig. 27B). The higher algal biomass accounts for the much higher estimated daily photosynthetic rates in 2003. The fact that the difference in algal biomass between 2002 and 2003 accounted for most the difference in estimated productivity is consistent with earlier findings that the variation in algal biomass was the primary determinant of year-to-year differences in productivity as opposed to variation in chlorophyll-specific growth rates (Jellison and Melack 1988, 1993b). While daily rates of primary production were higher in 2003 through most of the year, autumn (October – December) rates when ammonia-rich monimolimnetic was entrained during both years are roughly similar (Fig. 28).

Annual primary production in 2003 was the highest observed during the period from 1982 to present (Table 15, Fig. 29). Estimates from previous years ranged from 149 g C m^{-2} in 1997 to 1107 g C m^{-2} in 1982 with a long-term average of 481 g C m^{-2} for 1982 – 2002. In 1988, a 5-yr episode of meromixis was breaking down and nutrients which had accumulated beneath the thermocline were mixed into the euphotic zone leading to higher algal biomass and estimated annual production of 1064 g C m^{-2}. During 2003, an 8-yr period of chemical stratification broke down and significant amounts of ammonia were entrained into the mixed layer. Estimates of planktonic photosynthesis at Mono Lake 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 egg production

Artemia biomass was estimated from instar-specific population data and previously derived weight-length relationships for the period 1982–99. Variation in weight-length relationships among sampling dates was assessed from 1996–99 and found to lead to errors of up to 20% in the annual estimates. Thus, in 2000 we implemented direct drying and weighing of vertical net tow samples collected explicitly for biomass determinations.

In 2003, *Artemia* biomass increased from 0.0 during January to 31.3 g dry weight m^{-2} in mid-June before declining to near zero following holomixis in mid-November. The 2003 mean annual biomass of 7.5 g m^{-2} is 53% higher than that observed in 2002 and 19% below the long-term mean of 9.3 g m-2 for 1982-2003 (Fig. 30, Table 15)

The highest estimated mean annual *Artemia* 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 lower values in 2002 and in 1997, *Artemia* biomass has remained relatively constant since 1993 and was only slightly higher during 1990–92.

In Mono Lake, oviparous (cyst) reproduction is always much higher than ovoviviparous (live-bearing) reproduction (Fig. 31, Table 15). In 2003, total annual naupliar production (0.6 x 10^6 m^{-2}) was among the highest observed with that observed in 1990 (1.0 x 10^6 m^{-2}) and 1991 (0.7 x 10^6 m^{-2}) being higher. The overall mean of naupliar production for the period 1983-2003 is 0.25 x 10^6 m^{-2}. Despite naupliar production being 6-fold higher than that observed in 2002, low recruitment into the summer generation of adults led to less of an increase in cyst production. Total annual cyst production in 2003 increased 68% over 2002 to 4.2 x 10^6 m^{-2} cysts and was nearly equal to the long-term (1983-2003) annual mean production of 4.5 x 10^6 m^{-2}. Thus, the 3-yr trend of declining cyst production was reversed in 2003**.**

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Table 1. Temperature (ºC) at Station 6, January – December 2003.

	Dates											
Depth (m)	1-6	2-21	3-19	4-19	5-12	6-16	7-16	8-14	9-15	10-17	11-14	12-16
1	-	3.73	-	7.77	10.86	-	-	19.56	18.89	15.20	8.22	5.56
2	3.56	3.58	6.01	7.54	10.84	20.58	20.95	19.54	18.89	15.18	8.36	5.56
3	3.67	3.46	5.87	7.47	10.53	20.54	20.97	19.55	18.90	15.19	8.62	5.57
4	3.74	3.39	5.82	7.40	10.03	20.54	20.98	19.55	18.91	15.23	8.74	5.57
5	3.74	3.49	5.79	7.34	9.02	20.57	21.01	19.44	18.92	15.28	8.74	5.57
6	3.72	3.45	5.82	7.20	8.94	20.41	21.04	19.29	18.92	15.31	8.77	5.58
7	3.73	3.41	5.80	7.23	8.73	15.59	21.03	18.99	18.92	15.34	8.76	5.58
8	3.74	3.38	5.75	7.16	8.70	13.62	20.67	18.87	18.92	15.38	8.75	5.58
9	3.75	3.31	5.55	7.21	8.69	11.79	20.13	18.85	18.91	15.41	8.76	5.58
10	3.76	3.29	5.24	7.17	8.39	10.13	14.43	18.81	18.90	15.41	8.77	5.58
11	3.64	3.23	4.62	7.36	8.07	9.13	11.20	17.15	18.90	15.01	8.79	5.59
12	3.58	3.18	4.23	7.38	7.64	8.70	9.65	11.32	18.67	14.86	8.80	5.58
13	3.58	3.17	3.71	7.04	7.16	8.27	8.47	8.78	15.79	14.81	8.84	5.58
14	3.57	3.16	3.66	6.07	7.07	7.55	7.67	7.62	11.98	14.29	8.86	5.59
15	3.58	3.16	3.55	5.30	6.91	7.08	7.14	7.01	7.61	12.31	9.01	5.59
16	3.61	3.16	3.43	5.01	6.67	6.70	6.97	6.79	7.20	8.72	9.19	5.59
17	3.58	3.17	3.41	4.80	6.56	6.41	6.57	6.51	7.03	8.40	9.25	5.59
18	3.59	3.17	3.39	4.45	6.21	6.12	6.30	6.29	6.61	8.37	9.30	5.59
19	3.56	3.18	3.38	4.29	5.86	6.02	6.15	6.13	6.20	7.19	9.39	5.59
20	3.58	3.21	3.38	4.14	5.46	5.77	5.86	5.94	5.96	7.16	9.46	5.59
21	3.60	3.23	3.35	3.89	4.89	5.66	5.61	5.93	5.78	6.64	9.55	5.59
22	3.65	3.26	3.32	3.70	4.67	5.31	5.52	5.78	5.76	6.50	9.61	5.60
23	3.67	3.29	3.36	3.65	4.57	5.06	5.44	5.70	5.67	6.39	9.64	5.60
24	3.68	3.30	3.35	3.62	4.31	4.97	5.36	5.56	5.60	6.28	9.64	5.61
25	3.69	3.31	3.39	3.59	4.22	4.88	5.30	5.48	5.59	6.27	9.63	5.61
26	3.66	3.34	3.41	3.58	4.05	4.73	5.22	5.36	5.47	6.22	9.62	5.62
27	3.67	3.46	3.43	3.56	3.97	4.63	5.13	5.25	5.38	6.10	9.60	5.62
28	3.70	3.44	3.43	3.57	3.93	4.61	5.03	5.04	5.33	6.00	9.53	5.62
29	3.97	3.46	3.44	3.56	3.89	4.52	4.95	5.01	5.28	5.99	9.53	5.61
30	4.04	3.48	3.48	3.55	3.86	4.45	4.78	5.00	5.24	5.57	9.49	5.59
31	4.12	3.52	3.53	3.55	3.83	4.35	4.71	4.98	5.15	5.51	9.31	5.58
32	4.15	3.67	3.60	3.54	3.81	4.28	4.64	4.95	5.11	5.49	8.97	5.58
33	4.09	3.83	3.65	3.54	3.79	4.21	4.60	4.91	5.06	5.39	8.90	5.57
34	4.04	3.97	3.67	3.54	3.77	82.57	4.54	4.88	5.05	5.39	8.87	5.57
35	4.01	4.06	3.72	3.54	3.76	4.10	4.49	4.85	5.01	5.43	8.78	5.57
36	4.00	4.10	3.75	3.54	-	4.09	4.48	4.79	5.01	5.38	8.77	5.57
37	3.98	4.11	3.76	3.54	-	-	4.47	-	-	5.25	8.80	5.56

Table 2. Conductivity (mS cm^{-1} at 25ºC) at Station 6, January – December 2003.

	Dates											
Depth (m)	1-6	2-21	3-19	4-19	5-12	6-16	7-16	8-14	9-15	10-17	11-14	12-16
1	-	82.23	-	81.76	81.80	-	-	82.67	82.96	83.24	81.59	81.45
2	82.35	82.10	81.76	81.78	81.81	81.55	82.20	82.67	82.96	83.24	81.85	82.34
3	82.39	82.03	81.76	81.79	81.99	81.61	82.21	82.67	82.98	83.25	82.21	82.80
4	82.40	82.08	81.82	81.79	81.80	81.65	82.21	82.67	83.01	83.29	82.43	82.92
5	82.40	82.09	81.85	81.78	81.98	81.71	82.23	82.62	83.02	83.29	82.57	83.04
6	82.40	82.11	81.87	81.81	82.09	81.72	82.24	82.58	83.03	83.31	82.68	83.06
7	82.41	82.12	81.87	81.86	82.05	81.45	82.24	82.51	83.03	83.31	82.56	83.13
8	82.43	82.13	81.87	81.86	82.10	81.57	82.14	82.54	83.04	83.36	82.74	83.14
9	82.43	82.16	81.83	81.93	82.12	81.52	82.05	82.53	83.04	83.39	82.83	83.15
10	82.44	82.23	81.84	81.84	81.99	81.69	81.57	82.51	83.04	83.44	82.88	83.16
11	82.44	82.23	81.84	81.98	81.91	81.68	81.85	81.71	83.05	83.36	82.89	83.20
12	82.44	82.24	81.98	81.96	81.88	81.64	81.54	80.95	82.79	83.34	82.88	83.21
13	82.44	82.26	82.00	81.65	81.94	81.85	81.87	81.69	82.36	83.26	82.64	83.21
14	82.44	82.27	82.13	81.86	81.97	81.93	82.14	81.96	80.93	83.14	82.83	83.21
15	82.44	82.28	82.09	82.06	81.94	81.88	82.14	82.04	82.34	82.99	82.73	83.21
16	82.46	82.29	82.17	82.11	81.94	82.02	82.11	82.18	82.29	82.96	82.74	83.21
17	82.45	82.29	82.20	82.04	81.92	81.98	82.16	82.20	82.36	82.91	82.80	83.21
18	82.47	82.30	82.21	82.22	81.83	-	82.24	82.23	82.15	82.97	82.86	83.21
19	82.46	82.32	82.21	82.29	81.87	82.18	82.26	82.32	82.24	82.80	82.89	83.21
20	82.47	82.35	82.25	82.35	81.91	82.23	82.22	82.35	82.19	82.89	82.90	83.21
21	82.48	82.39	82.29	82.39	81.98	82.22	82.36	82.42	82.36	82.72	82.79	83.21
22	82.50	82.42	82.30	82.48	82.05	82.22	82.35	82.44	82.34	82.82	82.88	83.21
23	82.50	82.44	82.39	82.52	82.09	82.40	82.41	82.45	82.40	82.70	83.02	83.21
24	82.52	82.47	82.43	82.58	82.09	82.35	82.40	82.43	82.48	82.72	83.10	83.22
25	82.52	82.50	82.48	82.60	82.12	82.40	82.42	82.46	82.42	82.75	83.16	83.22
26	82.54	82.55	82.52	82.60	82.19	82.43	82.46	82.49	82.48	82.70	83.19	83.22
27	82.58	82.70	82.59	82.61	82.22	82.47	82.46	82.50	82.48	82.63	83.24	83.22
28	82.58	82.75	82.59	82.62	82.24	82.48	82.51	82.55	82.51	82.68	83.31	83.22
29	82.90	82.84	82.64	82.61	82.24	82.50	82.51	82.57	82.51	82.64	83.26	83.22
30	83.07	82.92	82.71	82.60	82.27	82.52	82.54	82.56	82.47	82.52	83.34	83.23
31	83.65	83.01	82.81	82.60	82.27	82.50	82.51	82.54	82.49	82.58	83.57	83.23
32	84.11	83.26	82.93	82.59	82.29	82.55	82.52	82.55	82.50	82.58	83.98	83.23
33	84.14	83.42	82.97	82.59	82.29	82.57	82.54	82.52	82.51	82.56	83.63	83.23
34	84.19	83.46	83.01	82.58	82.30	-	82.56	82.51	82.51	82.56	83.52	83.24
35	84.24	83.26	83.06	82.57	82.31	82.59	82.59	82.51	82.52	82.57	83.48	83.24
36	84.31	83.11	83.06	82.57	-	82.59	82.57	82.51	82.53	82.55	83.39	83.24
37	84.38	83.03	83.07	82.57	-	-	82.58	-	-	82.53	83.53	83.24

Table 3. Density (g cm^{-3}) at Station 6, January – December 2003.

	Dates											
Depth (m)	1-6	2-21	3-19	4-19	5-12	6-16	7-16	8-14	9-15	10-17	11-14	12-16
1	-	1.0718	-	1.0706	1.0700	-	-	1.0685	1.0691	1.0705	1.0703	1.0706
2	1.0720	1.0717	1.0709	1.0707	1.0700	1.0669	1.0675	1.0685	1.0691	1.0705	1.0706	1.0717
3	1.0720	1.0716	1.0709	1.0707	1.0703	1.0669	1.0675	1.0685	1.0691	1.0706	1.0709	1.0722
4	1.0720	1.0717	1.0710	1.0707	1.0702	1.0670	1.0675	1.0685	1.0691	1.0706	1.0712	1.0723
5	1.0720	1.0717	1.0710	1.0707	1.0706	1.0670	1.0675	1.0685	1.0691	1.0706	1.0713	1.0725
6	1.0720	1.0717	1.0711	1.0708	1.0707	1.0671	1.0675	1.0685	1.0691	1.0706	1.0715	1.0725
7	1.0720	1.0717	1.0711	1.0708	1.0707	1.0683	1.0675	1.0685	1.0691	1.0706	1.0713	1.0726
8	1.0721	1.0718	1.0711	1.0708	1.0708	1.0690	1.0675	1.0686	1.0691	1.0706	1.0715	1.0726
9	1.0721	1.0718	1.0711	1.0709	1.0708	1.0694	1.0676	1.0686	1.0691	1.0706	1.0716	1.0726
10	1.0721	1.0719	1.0711	1.0708	1.0707	1.0700	1.0688	1.0686	1.0692	1.0707	1.0717	1.0726
11	1.0721	1.0719	1.0712	1.0709	1.0707	1.0702	1.0700	1.0682	1.0692	1.0707	1.0717	1.0727
12	1.0721	1.0719	1.0715	1.0709	1.0708	1.0703	1.0699	1.0689	1.0689	1.0708	1.0717	1.0727
13	1.0721	1.0719	1.0716	1.0706	1.0709	1.0706	1.0706	1.0703	1.0693	1.0707	1.0714	1.0727
14	1.0721	1.0719	1.0717	1.0710	1.0710	1.0708	1.0710	1.0709	1.0687	1.0707	1.0716	1.0727
15	1.0721	1.0720	1.0717	1.0714	1.0710	1.0709	1.0712	1.0711	1.0713	1.0710	1.0715	1.0727
16	1.0721	1.0720	1.0718	1.0715	1.0710	1.0711	1.0711	1.0713	1.0713	1.0718	1.0715	1.0727
17	1.0721	1.0720	1.0718	1.0714	1.0710	1.0711	1.0713	1.0713	1.0714	1.0718	1.0715	1.0727
18	1.0721	1.0720	1.0718	1.0717	1.0710	1.0713	1.0714	1.0714	1.0713	1.0719	1.0716	1.0727
19	1.0721	1.0720	1.0718	1.0718	1.0711	1.0714	1.0715	1.0715	1.0714	1.0719	1.0716	1.0727
20	1.0721	1.0720	1.0719	1.0719	1.0712	1.0715	1.0715	1.0716	1.0714	1.0720	1.0716	1.0727
21	1.0721	1.0721	1.0719	1.0720	1.0713	1.0715	1.0717	1.0717	1.0716	1.0719	1.0714	1.0727
22	1.0721	1.0721	1.0720	1.0721	1.0715	1.0716	1.0717	1.0718	1.0716	1.0721	1.0715	1.0727
23	1.0721	1.0721	1.0721	1.0722	1.0715	1.0718	1.0718	1.0718	1.0717	1.0719	1.0717	1.0727
24	1.0722	1.0722	1.0721	1.0722	1.0716	1.0718	1.0718	1.0718	1.0718	1.0720	1.0718	1.0727
25	1.0722	1.0722	1.0722	1.0723	1.0716	1.0718	1.0718	1.0718	1.0718	1.0720	1.0718	1.0727
26	1.0722	1.0723	1.0722	1.0723	1.0717	1.0719	1.0719	1.0719	1.0718	1.0720	1.0719	1.0727
27	1.0722	1.0724	1.0723	1.0723	1.0718	1.0720	1.0719	1.0719	1.0719	1.0719	1.0720	1.0727
28	1.0722	1.0725	1.0723	1.0723	1.0718	1.0720	1.0720	1.0720	1.0719	1.0720	1.0720	1.0727
29	1.0726	1.0726	1.0723	1.0723	1.0718	1.0720	1.0720	1.0720	1.0719	1.0719	1.0720	1.0727
30	1.0728	1.0727	1.0724	1.0723	1.0718	1.0721	1.0720	1.0720	1.0719	1.0719	1.0721	1.0727
31	1.0734	1.0728	1.0725	1.0723	1.0719	1.0721	1.0720	1.0720	1.0719	1.0720	1.0724	1.0727
32	1.0740	1.0731	1.0727	1.0723	1.0719	1.0721	1.0720	1.0720	1.0719	1.0720	1.0730	1.0727
33	1.0740	1.0732	1.0727	1.0723	1.0719	1.0722	1.0721	1.0720	1.0720	1.0720	1.0726	1.0727
34	1.0741	1.0732	1.0728	1.0723	1.0719	1.0722	1.0721	1.0720	1.0719	1.0719	1.0724	1.0727
35	1.0742	1.0730	1.0728	1.0722	1.0719	1.0722	1.0721	1.0720	1.0720	1.0720	1.0724	1.0727
36	1.0743	1.0728	1.0728	1.0722	-	1.0722	1.0721	1.0720	1.0720	1.0719	1.0723	1.0727
37	1.0743	1.0727	1.0728	1.0722	-	-	1.0721	-	-	1.0719	1.0725	1.0727

Table 4. Temperature, conductivity, and density stratification (x 0.0001 g cm^{-3}) at Station 6, January – December 2003.

Date	Temperature		Conductivity		Density Difference due to		
	2 m	32 m	2 m	32 m	Temperature	Conductivity	Both
1-6	3.56	4.15	82.35	84.11	-0.87	20.92	20.05
2-21	3.58	3.67	82.10	83.26	-0.13	13.74	13.61
3-19	6.01	3.60	81.76	82.93	3.79	13.80	17.60
4-19	7.54	3.54	81.78	82.59	6.65	9.54	16.19
5-12	10.84	3.81	81.81	82.29	13.23	5.64	18.87
6-16	20.58	4.28	81.55	82.55	41.00	11.67	52.67
7-16	20.95	4.64	82.20	82.52	41.83	3.74	45.58
8-14	19.54	4.95	82.67	82.55	36.48	-1.41	35.07
9-15	18.89	5.11	82.96	82.50	34.06	-5.40	28.66
10-17	15.18	5.49	83.24	82.58	21.97	-7.77	14.20
11-14	8.36	8.97	81.85	83.98	-1.26	25.12	23.87
12-16	5.56	5.58	82.34	83.23	-0.03	10.52	10.49

Table 5. Secchi Depths (m), January – December 2003

	Dates											
Station	1-6	2-21	3-19	4-19	5-15	6-12	7-17	8-13	9-18	10-17	11-14	12-16
Western Sector												
1	-	1.20	0.80	0.60	0.60	4.75	6.80	6.30	2.50	1.00	0.60	-
2	-	0.90	0.80	0.90	0.70	4.70	6.30	5.50	2.20	1.10	0.60	0.85
3	0.80	0.95	0.90	1.00	0.65	4.00	5.00	5.50	2.60	1.00	0.70	1.00
4	0.80	0.90	1.00	1.00	0.62	3.95	4.70	5.00	1.70	0.90	0.70	-
5	0.85	0.90	1.00	0.60	0.65	3.25	4.20	6.00	1.80	0.95	0.70	-
6	0.90	0.90	1.10	0.90	0.65	3.20	3.25	5.75	1.90	0.90	0.70	0.95
Avg.	0.84	0.96	0.93	0.83	0.65	3.98	5.04	5.68	2.12	0.98	0.67	0.93
S.E.	0.02	0.05	0.05	0.08	0.01	0.27	0.54	0.18	0.15	0.03	0.02	0.04
n	4	6	6	6	6	6	6	6	6	6	6	3
Eastern Sector												
7	-	1.00	1.00	0.80	0.62	3.00	3.00	5.25	2.10	0.90	0.70	0.90
8	-	0.90	1.00	1.00	0.60	3.25	2.90	5.20	1.60	0.80	0.60	0.85
9	-	1.00	0.90	0.95	0.60	2.70	3.00	5.75	1.90	0.90	0.55	-
10	-	0.80	1.10	0.80	0.65	3.00	3.50	6.20	1.50	0.90	0.60	-
11	-	0.90	0.95	0.80	0.65	3.60	4.00	5.50	2.00	0.80	0.60	-
12	-	0.90	0.90	0.70	0.60	3.25	3.60	6.00	1.80	0.95	0.60	-
Avg.	-	0.92	0.98	0.84	0.62	3.13	3.33	5.65	1.82	0.88	0.61	0.88
S.E.	-	0.03	0.03	0.05	0.01	0.12	0.18	0.17	0.09	0.03	0.02	0.02
n	0	6	6	6	6	6	6	6	6	6	6	2
Total Lakewide												
Avg.	0.84	0.94	0.95	0.84	0.63	3.55	4.19	5.66	1.97	0.93	0.64	0.91
S.E.	0.02	0.03	0.03	0.04	0.01	0.19	0.37	0.12	0.10	0.02	0.02	0.03
n	4	12	12	12	12	12	12	12	12	12	12	5

Table 6: Dissolved Oxygen (mg l^{-1}) at Station 6, January – December 2003

	Dates											
Depth (m)	1-6	2-21	3-19	4-19	5-12	6-16	7-16	8-14	9-15	10-18	11-14	12-16
0	2.2	5.8	6.1	5.5	8.5	3.5	4.7	4.0	5.7	4.8	0.8	2.8
1	1.7	6.6	6.6	6.1	9.3	3.5	5.6	3.9	5.8	4.8	0.7	1.9
2	0.8	6.9	6.6	6.2	9.4	4.2	5.6	3.9	5.8	4.8	0.5	1.8
3	0.7	7.3	6.5	6.0	8.8	4.3	5.7	3.9	5.7	4.6	<0.5	1.8
4	0.6	5.8	6.3	5.9	8.9	4.3	5.7	3.9	5.6	4.4	<0.5	1.8
5	0.4	5.5	5.9	5.8	7.4	4.4	5.7	3.8	5.5	4.2	<0.5	1.8
6	0.4	5.5	5.7	4.8	6.0	4.4	5.6	3.8	5.3	3.8	<0.5	1.8
7	0.4	4.0	5.5	4.4	5.7	8.3	5.4	3.7	5.2	4.2	<0.5	1.7
8	0.4	3.9	5.5	3.9	5.6	7.7	5.2	3.5	5.2	4.5	<0.5	1.7
9	0.3	3.2	5.3	3.3	5.6	5.7	7.9	3.5	5.1	4.4	<0.5	1.7
10	0.3	3.0	5.0	2.9	5.5	3.9	7.8	3.5	5.1	4.1	<0.5	1.7
11	0.8	1.9	2.5	2.0	4.2	2.7	6.7	2.0	4.9	4.2	-	1.7
12	1.2	1.6	2.0	1.7	3.2	1.5	2.7	<0.5	4.7	3.3	-	1.7
13	1.2	1.4	<0.5	<0.5	2.2	<0.5	0.7	<0.5	<0.5	2.8	-	1.7
14	1.2	1.2	<0.5	<0.5	0.9	<0.5	<0.5	<0.5	<0.5	0.8	-	1.7
15	1.2	1.1	<0.5	<0.5	0.7	<0.5	-	<0.5	<0.5	<0.5	-	1.7
16	1.1	1.0	<0.5	<0.5	<0.5	<0.5	-	<0.5	<0.5	<0.5	-	1.7
17	1.1	0.9	-	<0.5	<0.5	<0.5	-	-	-	<0.5	-	1.7
18	1.2	<0.5	-	<0.5	-	-	-	-	-	-	-	1.7
19	1.3	<0.5	-	-	-	-	-	-	-	-	-	-
20	1.5	<0.5	-	-	-	-	-	-	-	-	-	1.7
21	1.5	<0.5	-	-	-	-	-	-	-	-	-	-
22	1.1	<0.5	-	-	-	-	-	-	-	-	-	1.7
23	1.1	<0.5	-	-	-	-	-	-	-	-	-	-
24	1.1	<0.5	-	-	-	-	-	-	-	-	-	1.7
25	0.6	<0.5	-	-	-	-	-	-	-	-	-	-
26	0.6	<0.5	-	-	-	-	-	-	-	-	-	1.7
27	0.6	<0.5	-	-	-	-	-	-	-	-	-	-
28	<0.5	<0.5	-	-	-	-	-	-	-	-	-	1.7
29	<0.5	<0.5	-	-	-	-	-	-	-	-	-	-
30	-	<0.5	-	-	-	-	-	-	-	-	-	1.7
31	-	<0.5	-	-	-	-	-	-	-	-	-	-
32	-	<0.5	-	-	-	-	-	-	-	-	-	1.8
33	-	<0.5	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-	-	1.8
35	-	-	-	-	-	-	-	-	-	-	-	-
36	-	-	-	-	-	-	-	-	-	-	-	1.8

Table 7. Ammonia (µM) at Station 6, January – December 2003.

	Dates											
Depth (m)	1-6	2-21	3-19	4-18	5-12	6-16	7-16	8-14	9-15	10-18	11-14	12-15
1												
2	9.7	1.4	0.9	0.8	1.1	2.0	0.3	2.3	0.9	0.5	34.1	25.0
3	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-
8	13.4	2.1	1.1	-	1.0	0.4	0.3	3.9	0.1	0.5	26.1	23.5
9	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	1.3	2.9	-	-	-	-	-	0.6	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-
12	9.0	8.0	7.5	11.0	1.3	0.4	0.5	12.8	1.1	1.1	31.3	25.2
13	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	8.7	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-
16	9.3	12.1	29.5	27.6	13.9	24.6	35.0	49.6	33.5	45.9	25.2	25.8
17	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	--	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-
20	-	13.8	23.3	50.4	32.6	72.5	76.6	87.7	112.9	93.9	25.9	25.4
21	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-
24	-	21.6	59.7	64.2	98.1	113.6	101.4	91.9	116.4	91.1	23.1	25.0
25	-	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-
28	-	66.7	101.7	66.2	113.1	132.2	126.7	124.7	149.2	108.3	23.8	23.6
29	-	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-	-	-
35	973.1	888.6	395.3	139.2	124.6	156.6	153.5	146.3	190.6	143.5	32.6	22.6

Table 8. Chlorophyll *a* (mg/m^3) at Station 6, January – December 2003.

	Dates											
Depth (m)	1-6	2-21	3-19	4-18	5-12	6-16	7-16	8-14	9-15	10-18	11-14	12-16
1	-	-	-	-	-	-	-	-	-	-	-	-
2	63.4	76.1	49.1	74.7	71.3	4.1	7.3	3.8	18.4	58.5	54.4	62.2
3	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	75.6	-	-	-	-	-	-	-
5	-	-	-	-	73.7	-	-	-	-	-	-	-
6	-	-	-	-	92.8	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-
8	60.8	70.4	49.7	73.2	88.4	14.4	7.4	3.3	17.1	59.5	57.5	52.1
9	-	-	-	-	85.4	-	-	-	-	-	-	-
10	-	-	47.0	60.0	84.7	-	-	-	-	58.48	-	-
11	-	-	-	-	86.0	-	-	-	-	-	-	-
12	62.2	63.0	41.2	47.7	91.0	47.6	41.0	44.4	19.8	54.0	56.8	49.6
13	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	151.9	-	55.0	33.6	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-
16	62.6	52.2	39.7	44.9	66	68.7	47.9	46.5	38.9	36.8	60.4	50.4
17	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-
20	65.8	54.0	41.2	40.0	53.3	59.0	42.8	46.4	38.5	29.0	65.1	48.8
21	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-
24	64.5	44.3	37.9	35.2	44.1	46.5	43.3	41.3	36.3	29.7	59.0	45.8
25	-	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-
28	63.2	39.7	48.2	35.7	38.3	40.0	39.6	42.9	39.2	30.8	61.7	49.2

Table 9a. *Artemia* lake and sector means, 2003.

	Instars		adult	adult	adult	adult	adult	adult	adult	
	1-7	8-11	male	fem ?	fem e	fem c	fem n	fem tot	total	total
Lakewide Mean:										
1/6	0	0	0	0	0	0	0	0	0	0
2/21	3167	0	2	0	0	0	0	0	2	3169
3/19	4398	0	0	0	0	0	0	0	0	4398
4/19	15307	13	0	0	0	0	0	0	0	15320
5/15	6088	1269	771	0	944	0	0	944	1715	9073
6/18	115383	205	13711	864	1771	7404	937	10975	24686	140274
7/17	40074	725	14212	302	597	3702	195	4795	19007	59806
8/13	7525	1610	19839	1342	2978	4849	134	9302	29142	38276
9/18	1777	30	6761	54	27	993	30	1103	7864	9671
10/17	1063	67	1923	18	77	369	8	473	2396	3526
11/14	0	0	0	0	0	0	0	0	0	0
12/16	13	0	0	0	0	0	0	0	0	13
Western Sector Mean:										
1/6	0	0	0	0	0	0	0	0	0	0
2/21	1006	0	3	0	0	0	0	0	3	1009
3/19	2807	0	0	0	0	0	0	0	0	2807
4/19	4034	7	0	0	0	0	0	0	0	4041
5/15	2361	352	376	0	443	0	0	443	818	3531
6/18	110165	193	21183	902	2704	8757	1223	13586	34769	145127
7/17	39115	751	23447	483	751	5366	322	6922	30369	70235
8/13	7485	1047	23126	1395	2227	4266	107	7995	31120	39651
9/18	1979	27	6399	40	27	1033	33	1134	7532	9537
10/17	647	33	1576	17	60	242	0	319	1895	2575
11/14	0	0	0	0	0	0	0	0	0	0
12/16	13	0	0	0	0	0	0	0	0	13
Eastern Sector Mean:										
1/6										
2/21	5329	0	0	0	0	0	0	0	0	5329
3/19	5989	0	0	0	0	0	0	0	0	5989
4/19	26579	20	0	0	0	0	0	0	0	26600
5/15	9816	2186	1167	0	1445	0	0	1445	2612	14614
6/18	119732	215	7485	832	993	6278	698	8800	16284	136231
7/17	41033	698	4977	121	443	2039	67	2669	7646	49376
8/13	7565	2173	16553	1288	3729	5433	161	10610	27163	36902
9/18	1576	33	7123	67	27	952	27	1073	8196	9806
10/17	1479	100	2271	20	94	497	17	627	2897	4477
11/14	0	0	0	0	0	0	0	0	0	0
12/16	13	0	0	0	0	0	0	0	0	13

(?): undifferentiated egg mass (e): empty ovisac

(c): cysts (n): nauplii

*Due to severe weather, on 1/6 only stations 3, 4, 5, 6 were sampled and on 12/16 only stations 2, 3, 6, 7, 8, 11

Table 9b. Standard errors of *Artemia* sector means (Table 9a), 2003.

	Instars		adult	adult	adult	adult	adult	adult	adult	
	1-7	8-11	male	fem ?	fem e	fem c	fem n	fem tot	total	total
SE of Lakewide Mean:										
1/6	0	0	0	0	0	0	0	0	0	0
2/21	880	0	2	0	0	0	0	0	2	879
3/19	1276	0	0	0	0	0	0	0	0	1276
4/19	6430	8	0	0	0	0	0	0	0	6429
5/15	1965	388	216	0	248	0	0	248	451	2556
6/18	15687	79	3867	192	486	1139	317	1863	5643	15828
7/17	6369	131	3367	112	111	798	80	939	4181	6739
8/13	1827	253	2600	338	519	733	59	1452	2977	3903
9/18	248	10	850	19	10	186	11	198	955	976
10/17	108	13	608	26	17	126	33	158	728	746
11/14	162	15	306	5	15	78	6	95	388	520
12/16	0	0	0	0	0	0	0	0	0	0
SE of Western Sector Mean:										
1/6	0	0	0	0	0	0	0	0	0	0
2/21	277	0	3	0	0	0	0	0	3	275
3/19	779	0	0	0	0	0	0	0	0	779
4/19	1081	7	0	0	0	0	0	0	0	1086
5/15	939	175	270	0	242	0	0	242	506	1537
6/18	18241	129	7455	277	867	2182	693	3643	11077	16186
7/17	9604	136	3790	199	136	1251	144	1368	4761	8128
8/13	3457	293	4334	592	471	1255	68	2238	4280	5690
9/18	432	13	988	27	17	269	16	272	1113	1203
10/17	179	10	455	8	13	70	0	85	533	695
11/14	0	0	0	0	0	0	0	0	0	0
12/16	7	0	0	0	0	0	0	0	0	7
SE of Eastern Sector Mean:										
1/6										
2/21	1209	0	0	0	0	0	0	0	0	1209
3/19	2354	0	0	0	0	0	0	0	0	2354
4/19	11397	14	0	0	0	0	0	0	0	11393
5/15	3249	542	266	0	334	0	0	334	564	3754
6/18	25926	107	843	289	312	1011	154	1341	1973	27143
7/17	9269	238	1191	50	163	357	32	451	1615	9500
8/13	1651	262	2578	390	858	806	102	1894	4372	5823
9/18	262	16	1466	27	13	282	17	313	1652	1653
10/17	121	21	396	7	27	124	11	152	527	587
11/14	0	0	0	0	0	0	0	0	0	0
12/16	13	0	0	0	0	0	0	0	0	13

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii
*Due to severe weather, on 1/6 only stations 3, 4, 5, 6 were sampled and on 12/16 only stations 2, 3, 6, 7, 8, 11

Table 9c. Percentage in different classes for Artemia sector means (Table 9a), 2003.

	Instars		adult	adult	adult	adult	adult	adult	adult	
	1-7	8-11	male	fem ?	fem e	fem c	fem n	fem tot	total	total
Lakewide (%):										
1/6	0	0	0	0	0	0	0	0	0	0
2/21	99.9	0	0.1	0	0	0	0	0	0.1	100
3/19	100	0	0	0	0	0	0	0	0	100
4/19	99.9	0.1	0	0	0	0	0	0	0	100
5/15	67.1	14	8.5	0	100	0	0	10.4	18.9	100
6/18	82.3	0.1	9.8	7.9	16.1	67.5	8.5	7.8	17.6	100
7/17	67	1.2	23.8	6.3	12.5	77.2	4.1	8	31.8	100
8/13	19.7	4.2	51.8	14.4	32	52.1	1.4	24.3	76.1	100
9/18	18.4	0.3	69.9	4.9	2.4	90	2.7	11.4	81.3	100
10/17	30.1	1.9	54.5	3.8	16.3	78	1.7	13.4	68	100
11/14	0	0	0	0	0	0	0	0	0	0
12/16	100	0	0	0	0	0	0	0	0	100
Western Sector (%):										
1/6	0	0	0	0	0	0	0	0	0	0
2/21	99.7	0	0.3	0	0	0	0	0	0.3	100
3/19	100	0	0	0	0	0	0	0	0	100
4/19	99.8	0.2	0	0	0	0	0	0	0	100
5/15	66.9	10	10.6	0	100	0	0	12.5	23.2	100
6/18	75.9	0.1	14.6	6.6	19.9	64.5	9	9.4	24	100
7/17	55.7	1.1	33.4	7	10.8	77.5	4.7	9.9	43.2	100
8/13	18.9	2.6	58.3	17.4	27.9	53.4	1.3	20.2	78.5	100
9/18	20.8	0.3	67.1	3.5	2.4	91.1	2.9	11.9	79	100
10/17	25.1	1.3	61.2	5.3	18.8	75.9	0	12.4	73.6	100
11/14	0	0	0	0	0	0	0	0	0	0
12/16	100	0	0	0	0	0	0	0	0	100
Eastern Sector (%):										
1/6										
2/21	100	0	0	0	0	0	0	0	0	100
3/19	100	0	0	0	0	0	0	0	0	100
4/19	99.9	0.1	0	0	0	0	0	0	0	100
5/15	67.2	15	8	0	100	0	0	9.9	17.9	100
6/18	87.9	0.2	5.5	9.5	11.3	71.3	7.9	6.5	12	100
7/17	83.1	1.4	10.1	4.5	16.6	76.4	2.5	5.4	15.5	100
8/13	20.5	5.9	44.9	12.1	35.1	51.2	1.5	28.8	73.6	100
9/18	16.1	0.3	72.6	6.2	2.5	88.7	2.5	10.9	83.6	100
10/17	33	2.2	50.7	3.2	15	79.3	2.7	14	64.7	100
11/14	0	0	0	0	0	0	0	0	0	0
12/16	100	0	0	0	0	0	0	0	0	100

(?): undifferentiated egg mass (e): empty ovisac

(c): cysts (n): nauplii

The fem-?, e, c, n, percentages are of the total females

*Due to severe weather, on 1/6 only stations 3, 4, 5, 6 were sampled and on 12/16 only stations 2, 3, 6, 7, 8, 11

Table 10. Lakewide *Artemia* instar analysis, 2003.

	Instars									
	1	2	3	4	5	6	7	8-11	adults	total
Mean:										
1/6	0	0	0	0	0	0	0	0	0	0
2/21	2023	0	0	0	0	0	0	0	3	2026
3/19	4191	445	0	0	0	0	0	0	0	4636
4/19	4384	3075	3605	3944	2814	546	198	11	0	18577
5/15	402	1029	1018	914	673	511	417	750	1305	7019
6/18	29595	47186	23961	4277	782	230	92	276	24789	131187
7/17	2610	4403	12026	10290	3990	2162	931	736	21443	58592
8/13	770	1000	943	1391	1966	1046	770	1564	27330	36781
9/18	253	241	270	425	282	75	80	34	7289	8951
10/17	149	92	161	195	178	92	54	46	2027	2995
11/14	0	0	0	0	0	0	0	0	0	0
12/16	12	0	0	0	0	0	0	0	0	12
Standard error of mean:										
1/6	0	0	0	0	0	0	0	0	0	0
2/21	594	0	0	0	0	0	0	0	3	593
3/19	1715	265	0	0	0	0	0	0	0	1967
4/19	1866	1829	2422	2575	1887	358	182	11	0	11045
5/15	49	275	309	258	147	125	111	230	408	1632
6/18	4677	11260	6706	1367	336	116	59	110	7995	21541
7/17	1056	1693	3400	2662	1048	460	181	179	6493	10922
8/13	324	704	514	512	780	327	236	274	4659	5939
9/18	78	59	60	120	80	26	36	14	1273	1278
10/17	44	24	45	50	38	22	17	14	493	633
11/14	0	0	0	0	0	0	0	0	0	0
12/16	8	0	0	0	0	0	0	0	0	8
Percentage in different age classes:										
1/6	0	0	0	0	0	0	0	0	0	0
2/21	99.9	0	0	0	0	0	0	0	0.1	100
3/19	90.4	9.6	0	0	0	0	0	0	0	100
4/19	23.6	16.6	19.4	21.2	15.1	2.9	1.1	0.1	0	100
5/15	5.7	14.7	14.5	13	9.6	7.3	5.9	10.7	18.6	100
6/18	22.6	36	18.3	3.3	0.6	0.2	0.1	0.2	18.9	100
7/17	4.5	7.5	20.5	17.6	6.8	3.7	1.6	1.3	36.6	100
8/13	2.1	2.7	2.6	3.8	5.3	2.8	2.1	4.3	74.3	100
9/18	2.8	2.7	3	4.7	3.2	0.8	0.9	0.4	81.4	100
10/17	5	3.1	5.4	6.5	5.9	3.1	1.8	1.5	67.7	100
11/14	0	0	0	0	0	0	0	0	0	0
12/16	100	0	0	0	0	0	0	0	0	100

*Due to severe weather, on 1/6 only stations 3, 4, 5, 6 were sampled and on 12/16 only stations 2, 3, 6, 7, 8, 11

Table 11a. *Artemia* reproductive summary, lake and sector means, 2003.

	Adult Females Total	Ovigery	e	?	c	n
Lakewide Mean:						
1/6	0	0	0	0	0	0
2/21	0	0	0	0	0	0
3/19	0	0	0	0	0	0
4/19	0	0	0	0	0	0
5/15	944	0	944	0	0	0
6/18	10975	9205	1771	864	7404	937
7/17	4795	4199	597	302	3702	195
8/13	9302	6325	2978	1342	4849	134
9/18	1103	1076	27	54	993	30
10/17	473	396	77	18	369	8
11/14	0	0	0	0	0	0
12/16	0	0	0	0	0	0
Western Sector Mean:						
1/6	0	0	0	0	0	0
2/21	0	0	0	0	0	0
3/19	0	0	0	0	0	0
4/19	0	0	0	0	0	0
5/15	443	0	443	0	0	0
6/18	13586	10882	2704	902	8757	1223
7/17	6922	6171	751	483	5366	322
8/13	7995	5768	2227	1395	4266	107
9/18	1134	1106	27	40	1033	33
10/17	319	258	60	17	242	0
11/14	0	0	0	0	0	0
12/16	0	0	0	0	0	0
Eastern Sector Mean:						
1/6	0	0	0	0	0	0
2/21	0	0	0	0	0	0
3/19	0	0	0	0	0	0
4/19	1445	0	1445	0	0	0
5/15	8800	7807	993	832	6278	698
6/18	2669	2227	443	121	2039	67
7/17	10610	6882	3729	1288	5433	161
8/13	1073	1046	27	67	952	27
9/18	627	533	94	20	497	17
10/17	0	0	0	0	0	0
11/14	0	0	0	0	0	0
12/16	0	0	0	0	0	0

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii
*Due to severe weather, on 1/6 only stations 3, 4, 5, 6 were sampled and on 12/16 only stations 2, 3, 6, 7, 8, 11

Table 11b. Standard errors of *Artemia* reproductive summary (Table 11a), 2003

			Adult Females			
	Total	Ovigery	e	?	c	n
Standard Error of Lakewide Mean:						
1/6	0	0	0	0	0	0
2/21	0	0	0	0	0	0
3/19	0	0	0	0	0	0
4/19	0	0	0	0	0	0
5/15	248	0	248	0	0	0
6/18	1863	1431	486	192	1139	317
7/17	939	891	111	112	798	80
8/13	1452	1045	519	338	733	59
9/18	198	194	10	19	186	11
10/17	95	82	15	5	78	6
11/14	0	0	0	0	0	0
12/16	0	0	0	0	0	0
Standard Error of Western Sector Mean:						
1/6	0	0	0	0	0	0
2/21	0	0	0	0	0	0
3/19	0	0	0	0	0	0
4/19	0	0	0	0	0	0
5/15	242	0	242	0	0	0
6/18	3643	2833	867	277	2182	693
7/17	1368	1352	136	199	1251	144
8/13	2238	1855	471	592	1255	68
9/18	272	270	17	27	269	16
10/17	85	75	13	8	70	0
11/14	0	0	0	0	0	0
12/16	0	0	0	0	0	0
Standard Error of Eastern Sector Mean:						
1/6	0	0	0	0	0	0
2/21	0	0	0	0	0	0
3/19	0	0	0	0	0	0
4/19	334	0	334	0	0	0
5/15	1341	1141	312	289	1011	154
6/18	451	336	163	50	357	32
7/17	1894	1113	858	390	806	102
8/13	313	303	13	27	282	17
9/18	152	128	27	7	124	11
10/17	0	0	0	0	0	0
11/14	0	0	0	0	0	0
12/16	0	0	0	0	0	0

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii
*Due to severe weather, on 1/6 only stations 3, 4, 5, 6 were sampled and on 12/16 only stations 2, 3, 6, 7, 8, 11

Table 11c. *Artemia* percentages in different reproductive categories (Table 11a), 2003.

	Adult Females					
	Total	Ovig	e	?	c	n
Lakewide Mean (%):						
1/6	0	0	0	0	0	0
2/21	0	0	0	0	0	0
3/19	0	0	0	0	0	0
4/19	0	0	0	0	0	0
5/15	100	0	100	0	0	0
6/18	100	83.9	16.1	9.4	88.8	11.2
7/17	100	87.6	12.5	7.2	95	5
8/13	100	68	32	21.2	97.3	2.7
9/18	100	97.6	2.4	5	97.1	2.9
10/17	100	83.7	16.3	4.5	97.9	2.1
11/14	0	0	0	0	0	0
12/16	0	0	0	0	0	0
Western Sector Mean (%):						
1/6	0	0	0	0	0	0
2/21	0	0	0	0	0	0
3/19	0	0	0	0	0	0
4/19	0	0	0	0	0	0
5/15	100	0	100	0	0	0
6/18	100	80.1	19.9	8.3	87.7	12.3
7/17	100	89.2	10.8	7.8	94.3	5.7
8/13	100	72.1	27.9	24.2	97.6	2.4
9/18	100	97.5	2.4	3.6	96.9	3.1
10/17	100	80.9	18.8	6.6	100	0
11/14	0	0	0	0	0	0
12/16	0	0	0	0	0	0
Eastern Sector Mean (%):						
1/6						
2/21	0	0	0	0	0	0
3/19	0	0	0	0	0	0
4/19	0	0	0	0	0	0
5/15	100	0	100	0	0	0
6/18	100	88.7	11.3	10.7	90	10
7/17	100	83.4	16.6	5.4	96.8	3.2
8/13	100	64.9	35.1	18.7	97.1	2.9
9/18	100	97.5	2.5	6.4	97.2	2.8
10/17	100	85	15	3.8	96.7	3.3
11/14	0	0	0	0	0	0
12/16	0	0	0	0	0	0

(?): undifferentiated egg mass (e): empty ovisac
(c): cysts (n): nauplii
Total, ovigery, and e given as percentages of total number of females.
? given as percentage of ovigerous females.
Cyst and naup given as percentages of individuals with differentiated egg masses.
*Due to severe weather, on 1/6 only stations 3, 4, 5, 6 were sampled and on 12/16 only stations 2, 3, 6, 7, 8, 11

Table 12. *Artemia* fecundity summary, 2003.

	#eggs/brood				female length		
	mean	SE	%cyst	%intended	mean	SE	n
Lakewide Mean:							
6/18	75.5	3.6	0.9	0.6	11.7	0.1	7
7/17	44.4	2.9	1.0	0.6	11.3	0.1	7
8/13	32.2	1.6	0.9	0.6	10.7	0.2	7
9/18	72.2	5.3	0.9	0.7	11.2	0.2	7
10/17	108.8	9.9	0.9	0.5	12.1	0.1	6
Western Sector Mean:							
6/18	74.6	4.2	0.9	0.6	11.7	0.1	4
7/17	42.1	2.7	1.0	0.6	11.2	0.2	4
8/13	31.5	2.8	0.9	0.5	10.4	0.3	4
9/18	66.2	6.4	0.9	0.7	10.9	0.1	4
10/17	94.3	7.3	1.0	0.6	12.0	0.2	3
Eastern Sector Mean:							
6/18	76.8	7.4	0.9	0.5	11.6	0.2	3
7/17	47.5	5.8	0.9	0.6	11.4	0.2	3
8/13	33.2	1.4	1.0	0.7	11.0	0.2	3
9/18	80.3	7.7	1.0	0.6	11.7	0.0	3
10/17	123.3	15.0	0.8	0.4	12.3	0.1	3

‘n’ in last column refers to number of stations averaged.
Ten females were collected and measured from each station.

Table 13. Summary Statistics of Adult *Artemia* Abundance from 1 May through 30 November, 1979–2003.

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
2000	10550	9080	22384	210
2001	20031	20037	38035	209
2002	11569	9955	25533	200
2003	13778	12313	29142	203

*Centroid calculated as the abundance-weighted mean day of occurrence.

Table 14. Photosynthetic parameters for 2002 and 2003

Date	Depth (m)	α^B	P_m^B
2/21/2002	2	1.34	0.52
2/21/2002	10	1.84	0.63
3/19/2002	2	2.26	0.68
3/19/2002	10	2.56	0.68
4/16/2002	2	3.92	1.60
4/16/2002	10	2.24	0.65
5/16/2002	2	6.98	4.75
5/16/2002	11	5.79	1.56
8/15/2002	2	6.39	5.53
8/15/2002	16.5	1.61	0.44
9/13/2002	2	16.74	6.50
9/13/2002	20.5	2.77	0.87
10/14/2002	2	6.31	2.69
10/14/2002	16	10.96	2.93
11/19/2002	2	6.43	2.45
11/19/2002	20	7.41	2.39
1/6/2003	2	4.48	1.09
2/21/2003	2	4.85	1.46
3/19/2003	2	5.27	1.74
3/19/2003	10	5.06	1.43
4/18/2003	2	5.89	1.56
4/18/2003	10	11.45	3.01
5/15/2003	2	7.04	2.84
5/15/2003	10	7.20	1.97
6/16/2003	2	10.48	8.90
6/16/2003	13.5	4.36	1.34
7/16/2003	2	9.29	6.85
7/16/2003	11.5	7.96	1.26
8/14/2003	2	15.40	11.90
8/14/2003	14.5	4.52	0.84
9/15/2003	2	11.43	5.11
9/15/2003	14.5	4.17	0.80
10/18/2003	2	7.91	2.53
10/18/2003	10	9.13	2.73
11/14/2003	2	6.72	1.60
12/16/2003	2	6.55	1.70

P_m^B: Chlorophyll-specific maximum carbon uptakes rates (g C g Chl a^{-1} h^{-1})

α^B: Chlorophyll-specific light-limited uptake rates (g C g Chl a^{-1} $Einst^{-1}$ m^2)

Table 15. Long term Integrative Measures of Productivity: Annual Primary Production, *Artemia* biomass and egg production (see Chapter 2 for methods), 1982-2003.

Year	**Planktonic Primary Production** (g C m^{-2} y^{-1})	***Artemia*** **Biomass** (g dry weight m^{-2})	***Artemia*** **Naupliar Production** (10^6 m^{-2})	***Artemia*** **Cyst Production** (10^6 m^{-2})
1982	1107	9.3	0.2	4.8
1983	523	9.3	0.2	4.8
1984	269	7.8	0.1	3.7
1985	399	7.8	0.2	4.6
1986	462	7.7	0.4	3.0
1987	371	12.5	0.2	6.4
1988	1064	15.2	0.2	4.7
1989	499	17.6	0.1	6.7
1990	641	11.0	1.0	6.1
1991	418	9.7	0.7	5.5
1992	435	10.2	0.3	5.8
1993	602	8.9	0.3	6.3
1994	446	8.7	0.2	5.6
1995	227	8.4	0.4	4.9
1996	221	8.2	0.0	3.6
1997	149	5.3	0.0	2.5
1998	228	8.0	0.0	2.8
1999	297	8.9	0.0	4.2
2000	484	8.2	0.1	4.0
2001	532	8.8	0.1	3.0
2002	763	4.9	0.1	2.5
2003	1645	7.5	0.6	4.2

*Carbon uptake measurements not conducted during 1982, 1993-2001. Estimates in these years are based on temperature, chlorophyll, light, and regressions of photosynthetic rates (P_m^B) and (α^B) versus temperature (see methods).

FIGURE CAPTIONS

Fig. 1. UCSB sampling stations at Mono Lake. Solid circles represent permanently moored buoys. Open circles represent old intermediate stations.

Fig. 2. Wind speed; daily mean and 10-min. maximum, 2003.

Fig. 3. Daily air temperature; mean, maximum, and minimum, 2003.

Fig. 4. Daily photosynthetically available radiation, 2003.

Fig. 5. Mean daily relative humidity, 2003.

Fig. 6. Daily precipitation, 2003.

Fig. 7. Mono Lake surface elevation (ft asl), 1979–03, USGS datum.

Fig. 8. Temperature (°C) at station 6, 2003.

Fig. 9. Conductivity (mS cm^{-1} corrected to 25°C) at station 6, 2003.

Fig.10. Density difference (10^{-4} g cm^{-3}) between 2 and 32 m at station 6 due to temperature and chemical stratification from 1991–2003.

Fig. 11. December salinity stratification, 1994–03.

Fig. 12. Mean lakewide Secchi depth (m), 1994–03. Error bars show standard errors of the lakewide estimate based on 12-20 stations.

Fig. 13. Mean lakewide Secchi depth ($\log_{10}$ m) 1979–03.

Fig. 14. Light attenuation (% of surface) at station 6, 2003. Dots denote the dates and depths of samples.

Fig. 15. Dissolved oxygen concentration (mg O_2 l^{-1}) at station 6, 2003.

Fig. 16. Ammonium concentration (µM) at station 6, 2006. Dots denote the dates and depths of samples.

Fig. 17. Concentration of chlorophyll *a* (µg chl *a* l^{-1}) at station 6, 2007. Dots denote the dates and depths of samples.

Fig. 18. Seasonal fluorescence profiles at station 6, 2003.

Fig. 19. Lakewide *Artemia* abundance during 2003: nauplii (instars 1-7), juveniles (instars 8-11), and adults (instars 12+).

Fig. 20. Reproductive characteristics of *Artemia* during 2003: 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.

Fig. 21. Lakewide estimates of adult *Artemia* based on 3-20 stations, 1982–03 (see Methods). The mean relative error of the lakewide estimates is 20-25%.

Fig. 22. Summary statistics of the seasonal (1 May through 30 November) lakewide abundance of adult *Artemia*, 1979–03. Values are based on interpolated daily abundances.

Fig. 23. Temporal center of abundance-weighted centroid of the seasonal (1 May through 30 November) distribution of adult *Artemia*, 1979–03. Centroid is based on interpolated daily abundances of adult *Artemia*.

Fig. 24. Chlorophyll-specific uptake rates for May and September 2003 for samples collected from the surface mixed layer and the deep chlorophyll maximum.

Fig. 25. Chlorophyll-specific light saturated carbon uptake rate (g C g Chl^{-1} h^{1}), algal biomass (mg m^{-3}), and daily primary production (g C m^{-2}), 2002 (revision of data contained in 2002 Annual Report).

Fig. 26. Chlorophyll-specific light saturated carbon uptake rate (g C g Chl^{-1} h^{1}), algal biomass (mg m^{-3}), and daily primary production (g C m^{-2}), 2003.

Fig. 27. Comparison of 2002 versus 2003 A) Chlorophyll-specific specific light saturated carbon uptake rate (g C g Chl^{-1} h^{1}) B) Mixed-layer (2 m depth) chlorophyll *a* concentrations µg Chl l^{-1}.

Fig. 28. Comparison of 2002 versus 2003 calculated daily primary production (g C m^{-2} y^{-1}) calculated with a numerical interpolative model of chlorophyll, temperature, insolation, attenuation, and photosynthetic parameters.

Fig. 29. Annual phytoplankton production estimates (g C m^{-2}), 1982–03.

Fig. 30. Mean annual *Artemia* biomass, 1983–03. Data for the period 1982–99 estimated from instar-specific population data and previously derived weight-length relationships. In 2000–03, *Artemia* biomass was measured directly by determining dry weights of plankton tows.

Fig. 31. Annual *Artemia* reproduction, ovoviviparous (live-bearing) and oviparous (cyst-bearing), 1983–03.

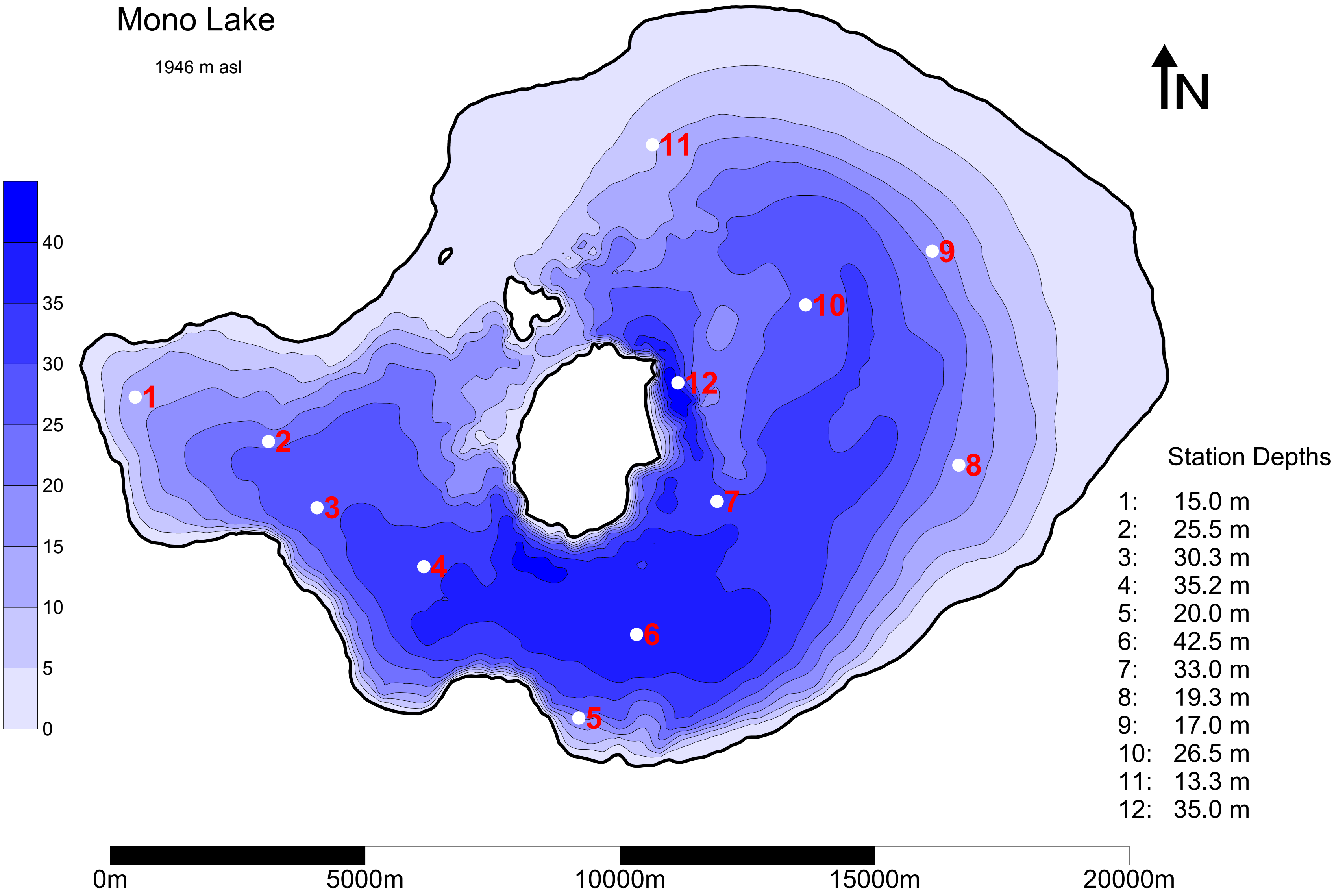

Mono Lake
1946 m asl
40
35
30
25
20
15
10
5
0
N
1
2
3
4
5
6
7
8
9
10
11
12
Station Depths
1: 15.0 m
2: 25.5 m
3: 30.3 m
4: 35.2 m
5: 20.0 m
6: 42.5 m
7: 33.0 m
8: 19.3 m
9: 17.0 m
10: 26.5 m
11: 13.3 m
12: 35.0 m
0m
5000m
10000m
15000m
20000m

Figure 1

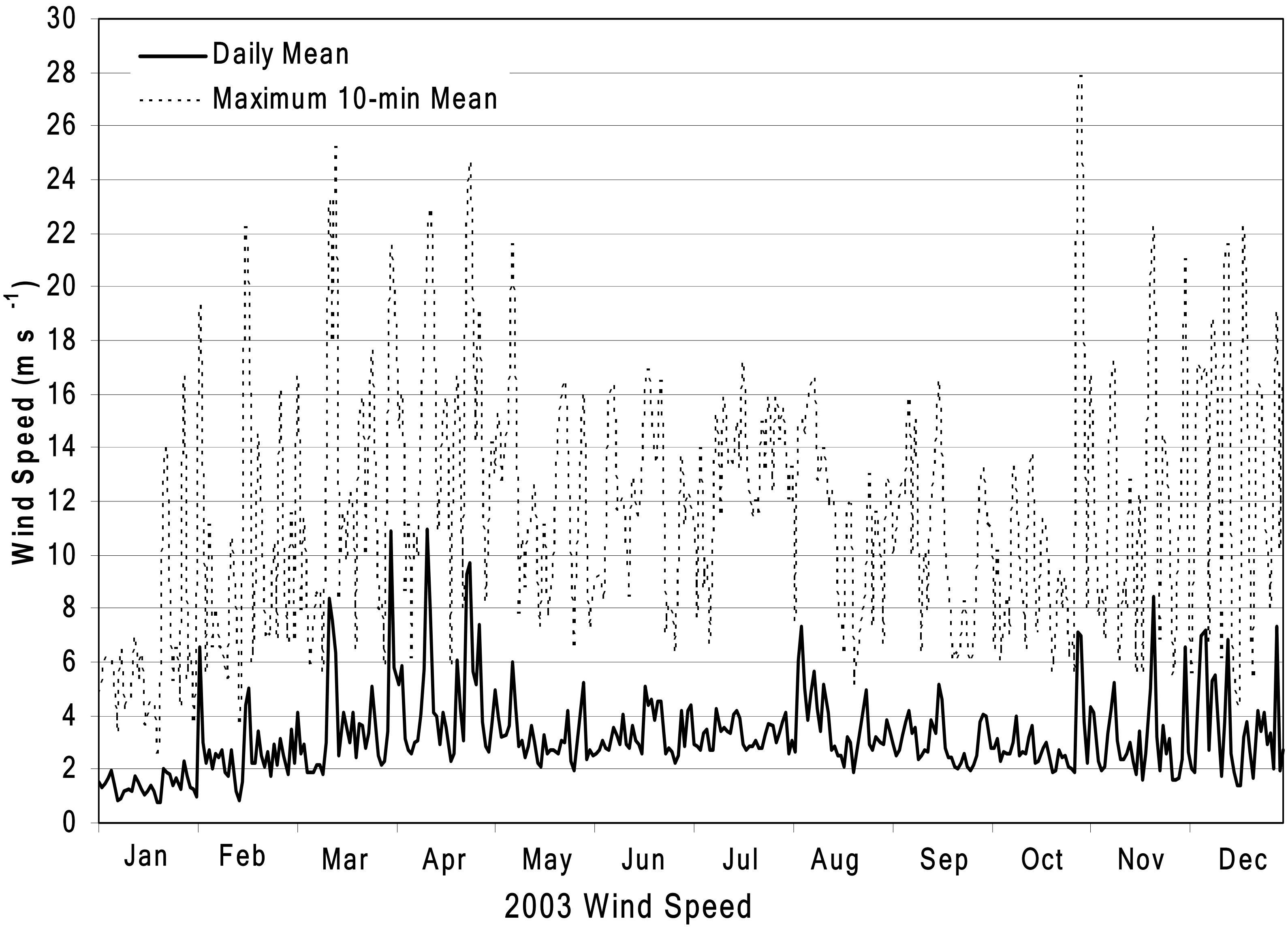
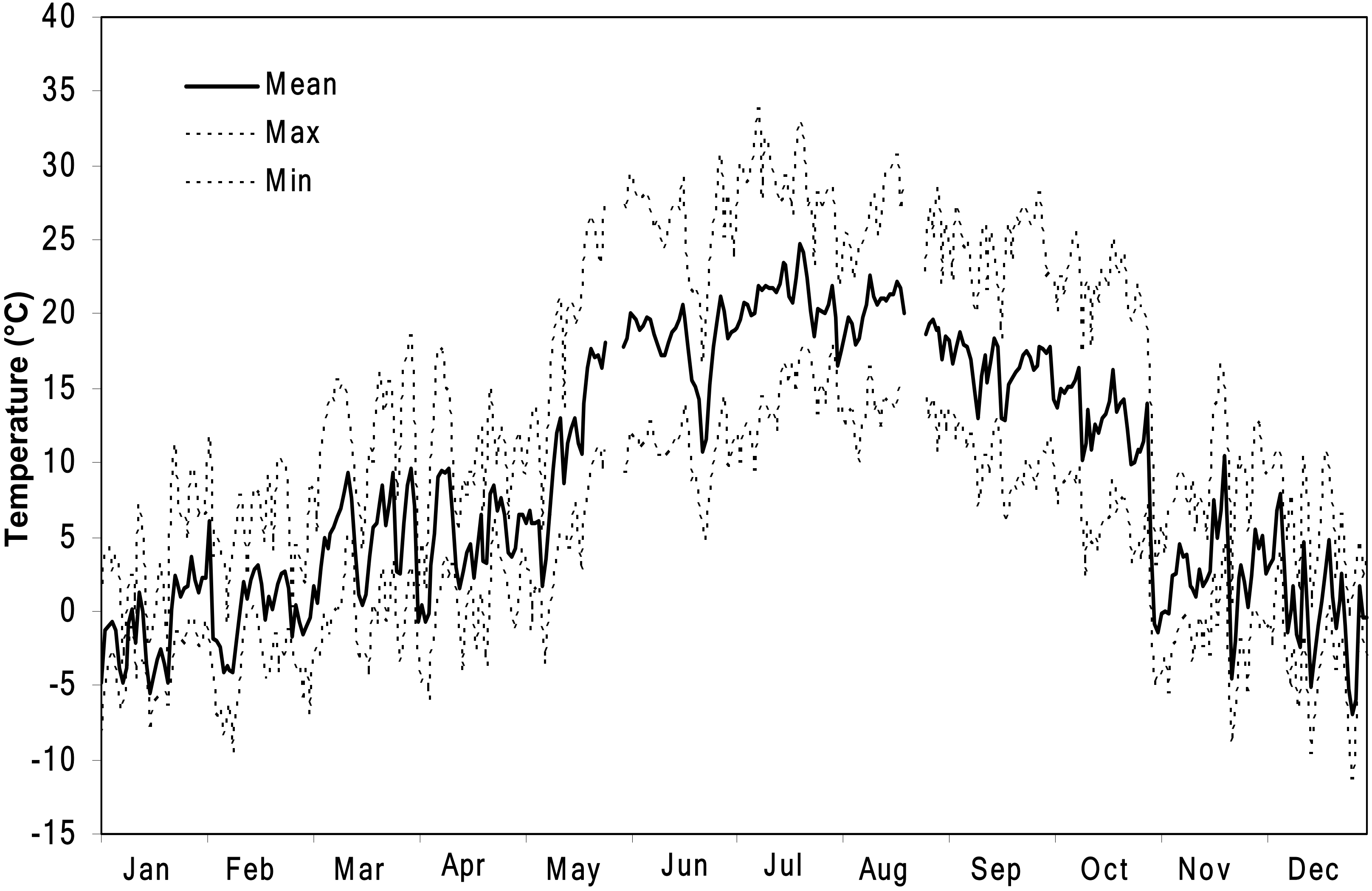

Daily Mean
Maximum 10-min Mean
Wind Speed (m s -1)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2003 Wind Speed

Figure 2



2003 Daily Air Temperature

Figure 3

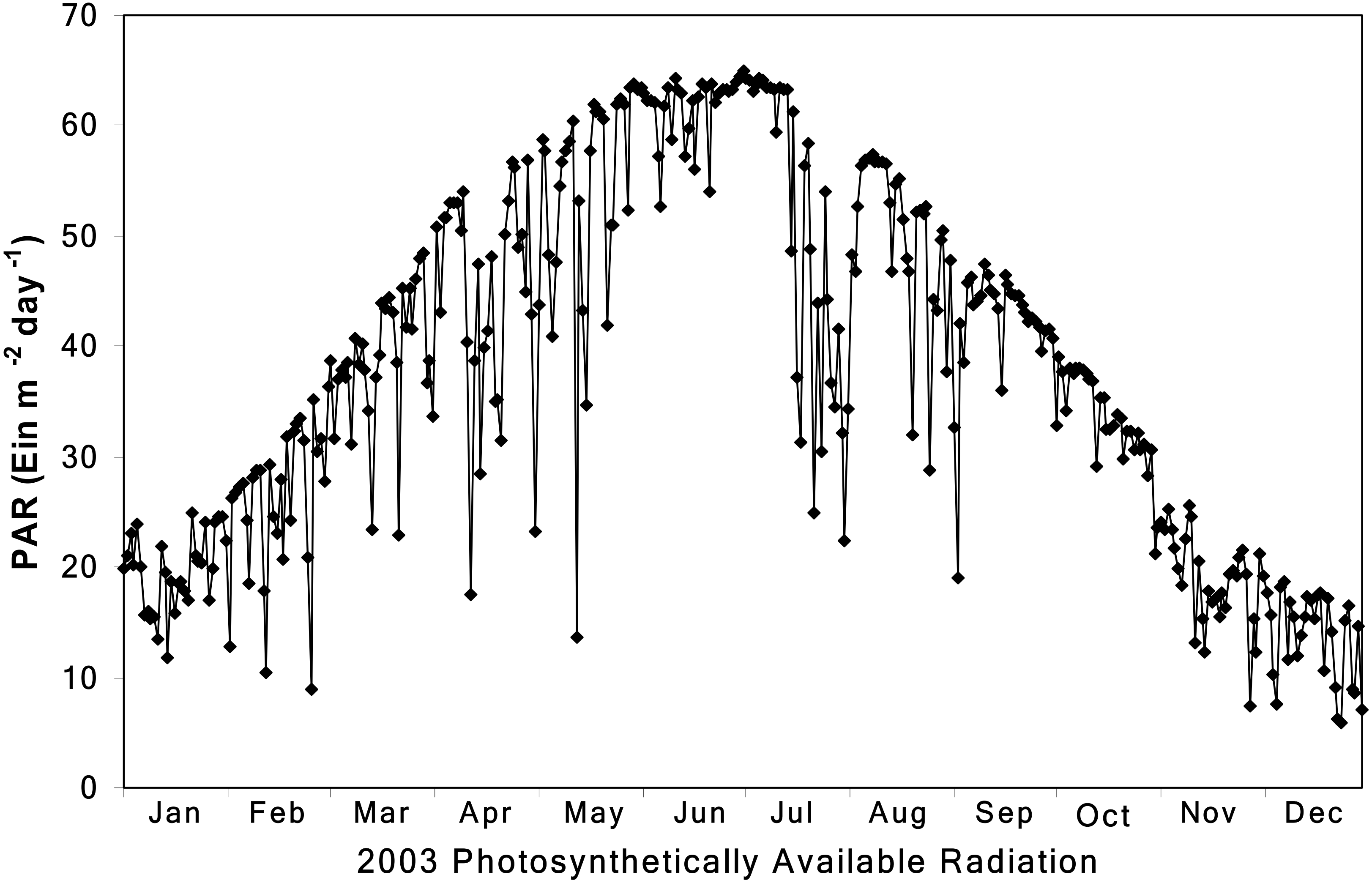
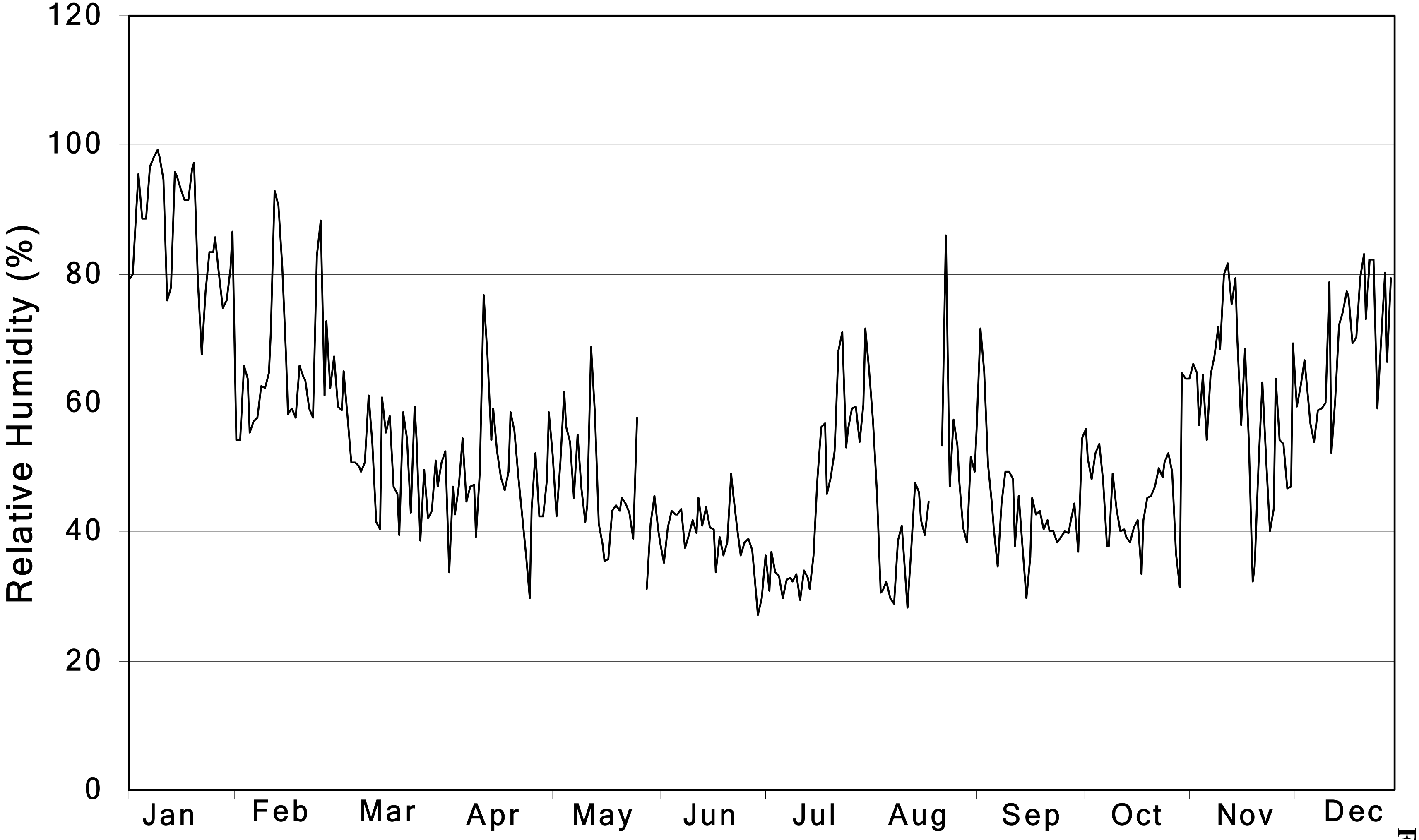

PAR (Ein m -2 day -1)
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2003 Photosynthetically Available Radiation

Figure 4



2003 Mean Daily Relative Humidity

Figure 5

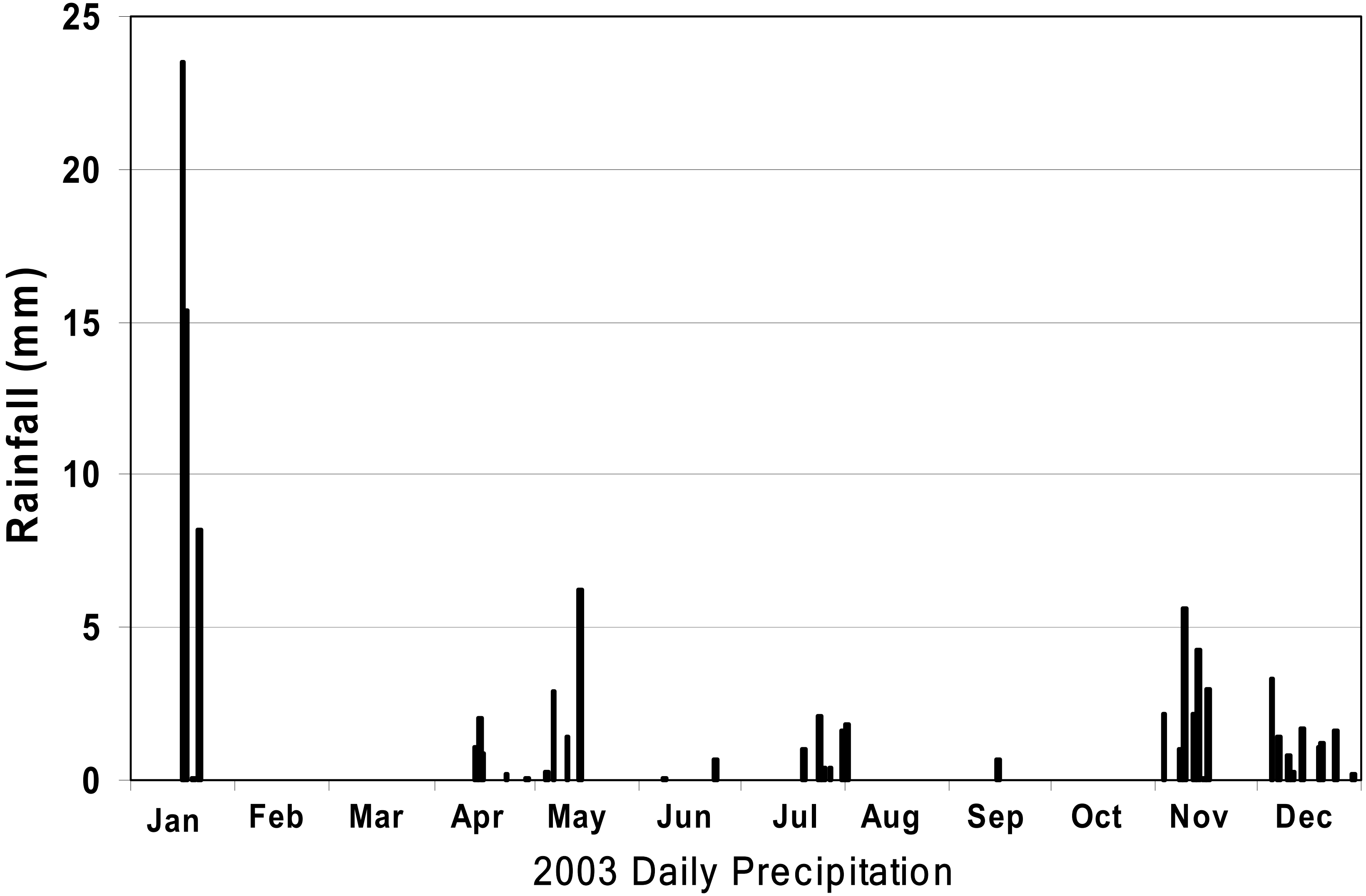

25
20
15
10
5
0
Rainfall (mm)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2003 Daily Precipitation

Figure 6

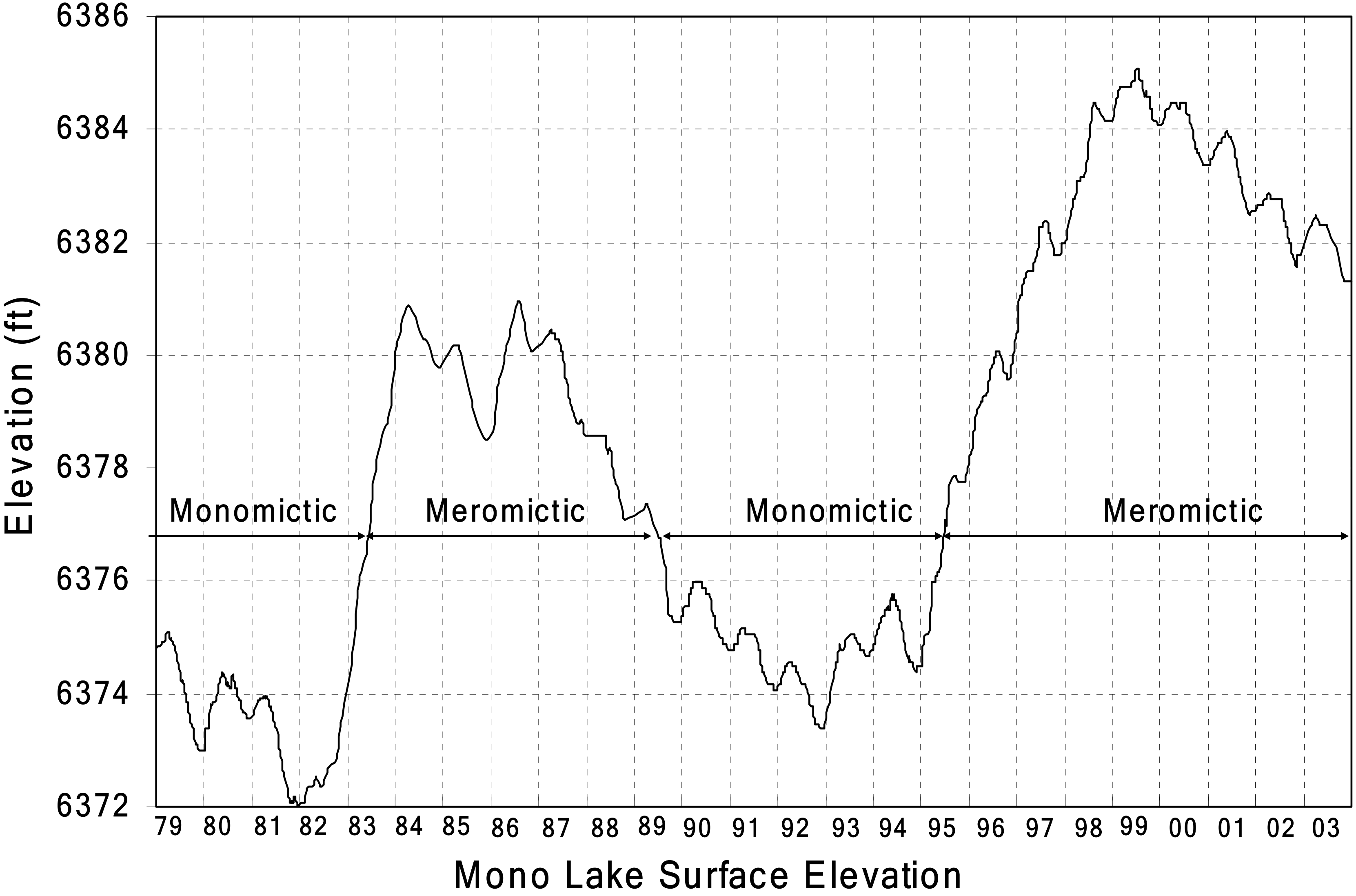
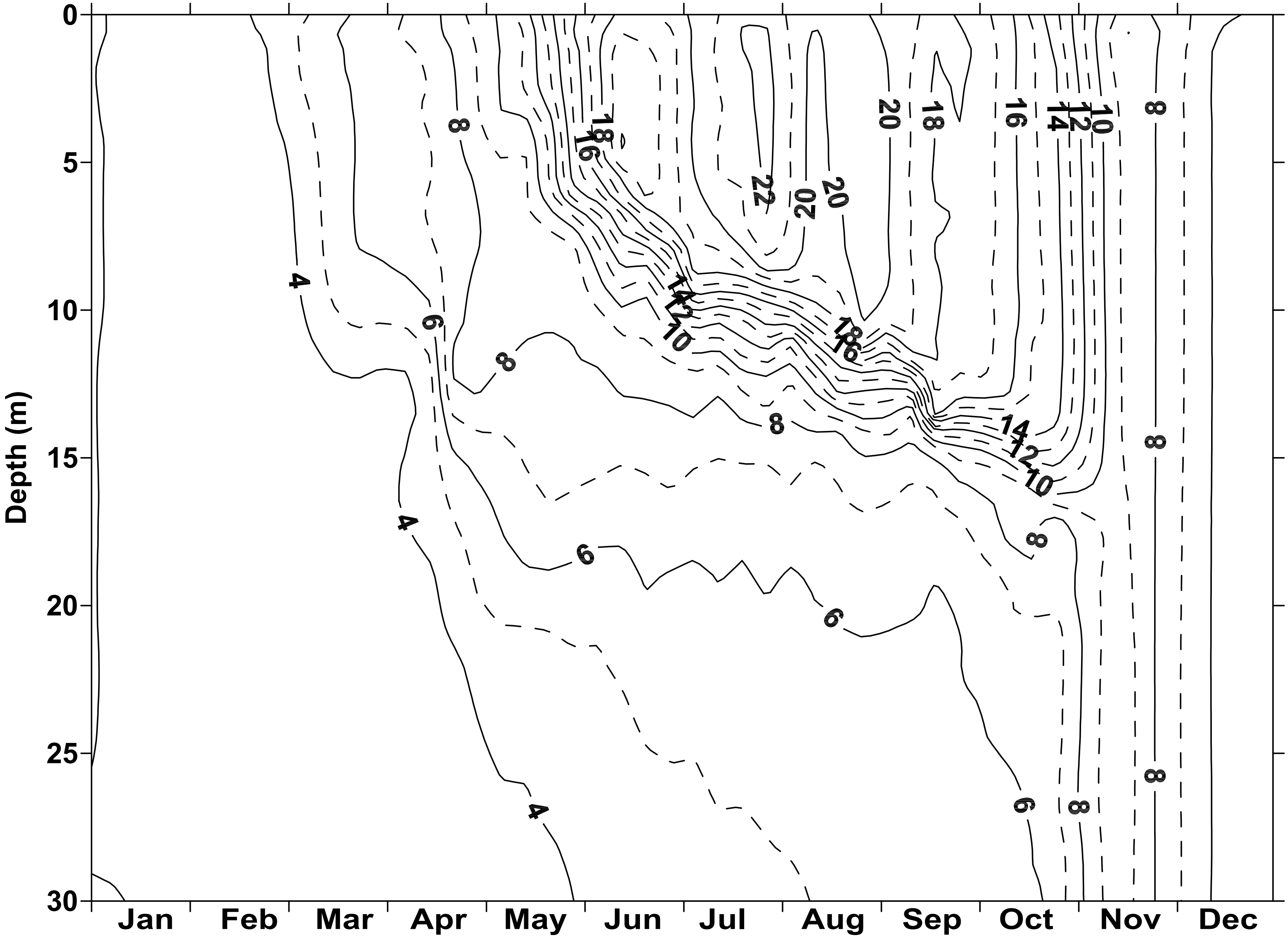
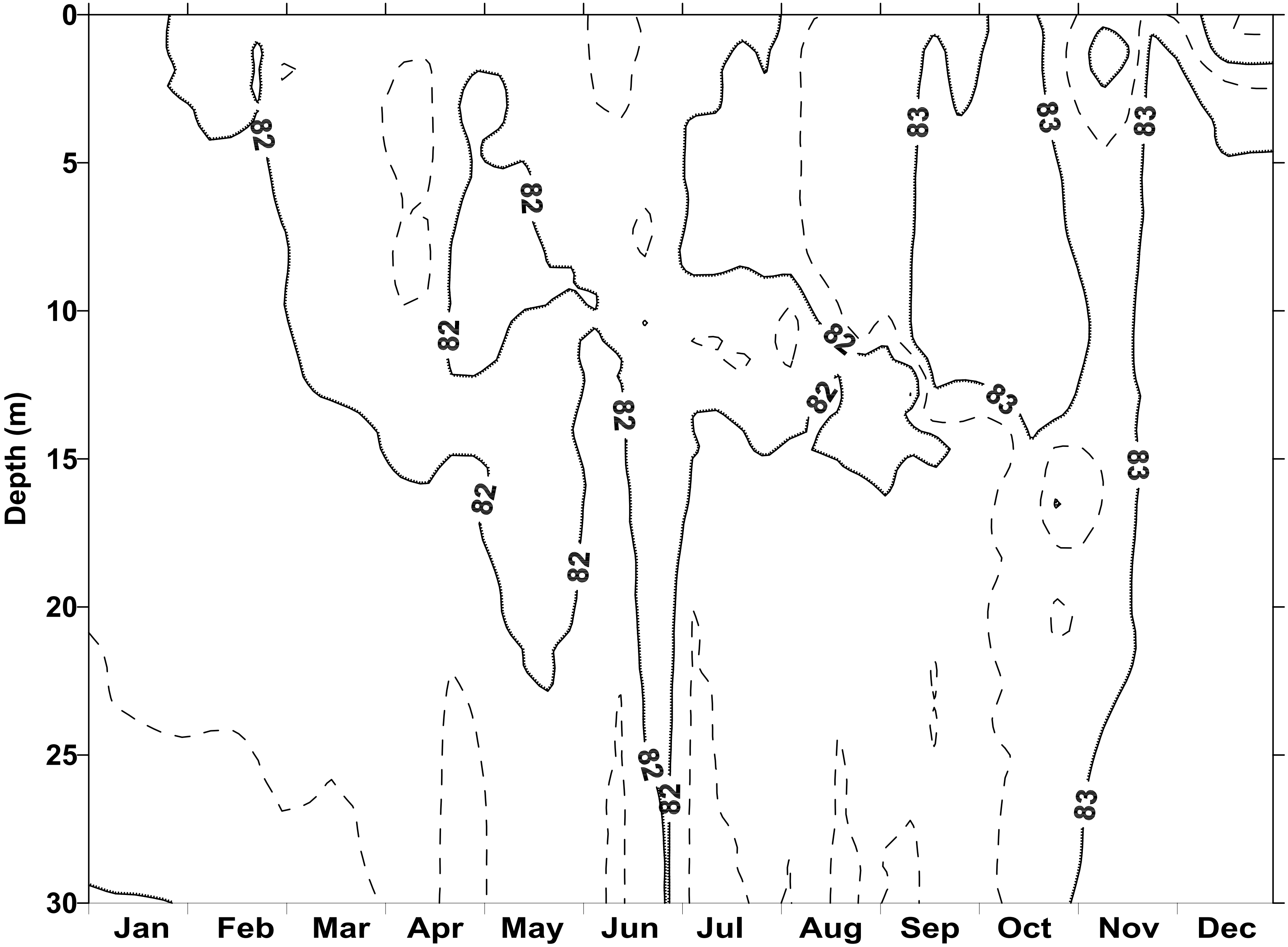

6386
6384
6382
6380
6378
6376
6374
6372
Elevation (ft)
Monomictic
Meromictic
Monomictic
Meromictic
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
Mono Lake Surface Elevation

Figure 7



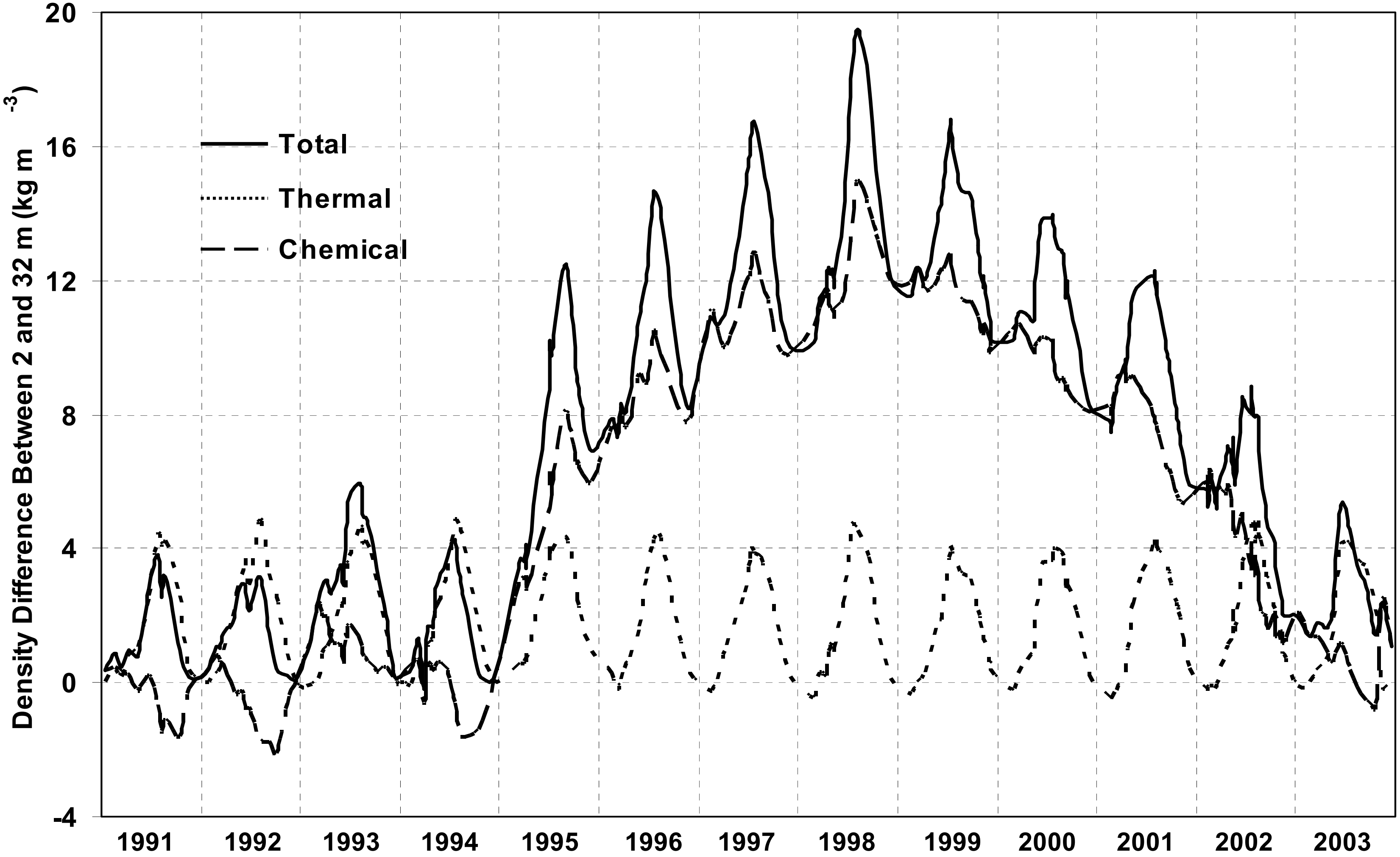
Temperature (C) at Station 6, 2003

Figure 8



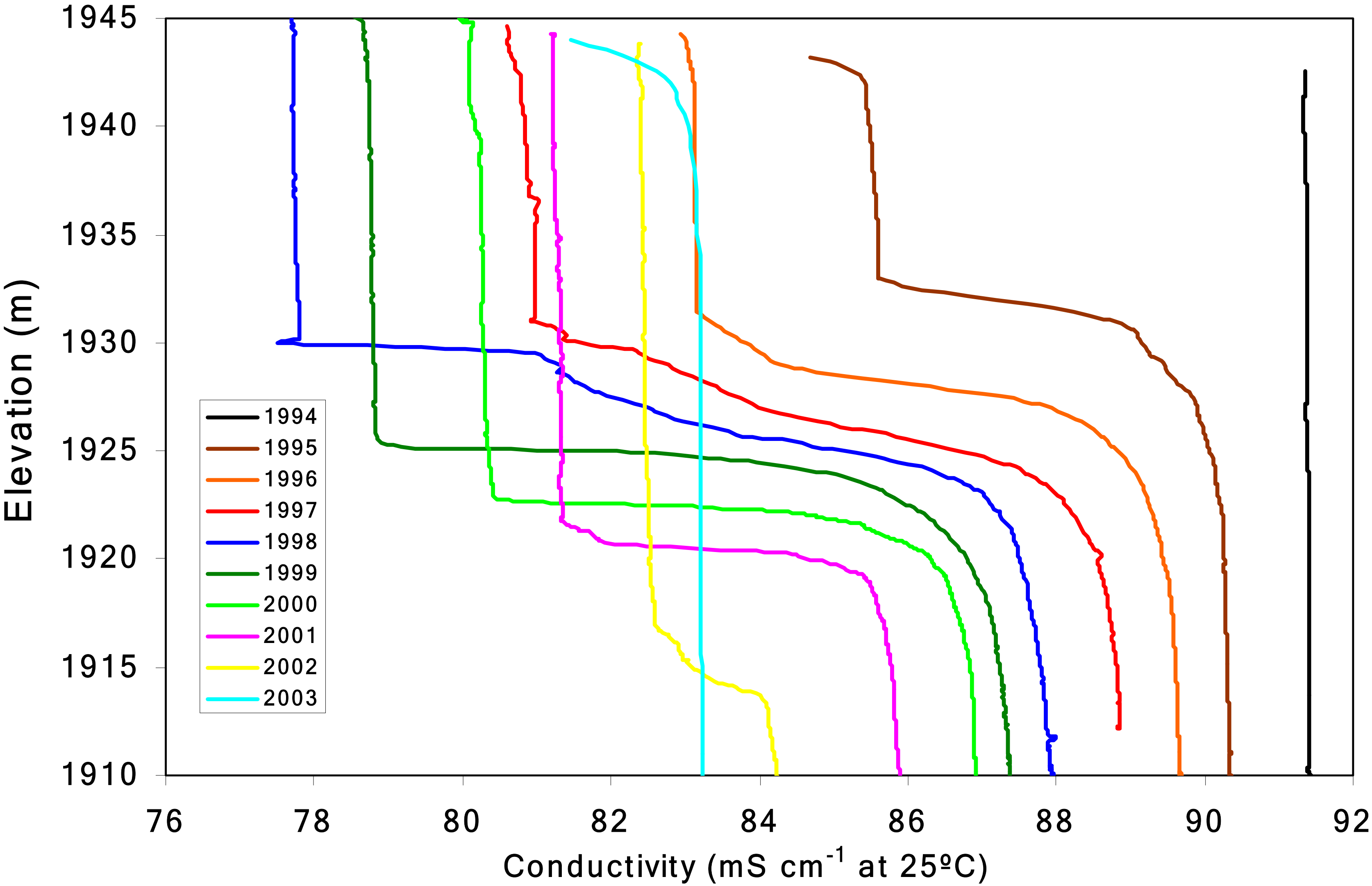
Conductivity (mS/cm) at Station 6, 2003

Figure 9



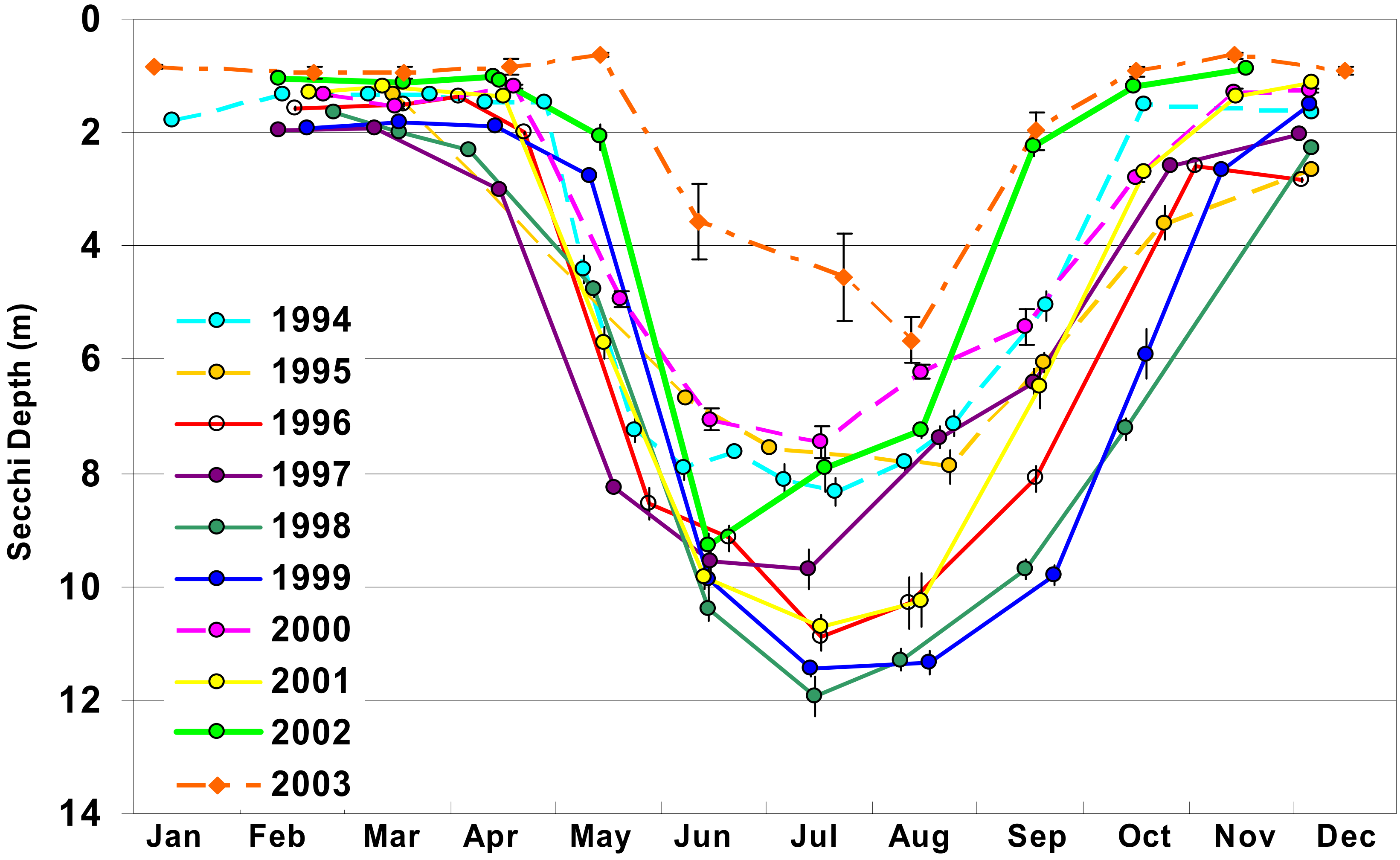
Density Stratification (2-32 m) 1991 - 2003

Figure 10



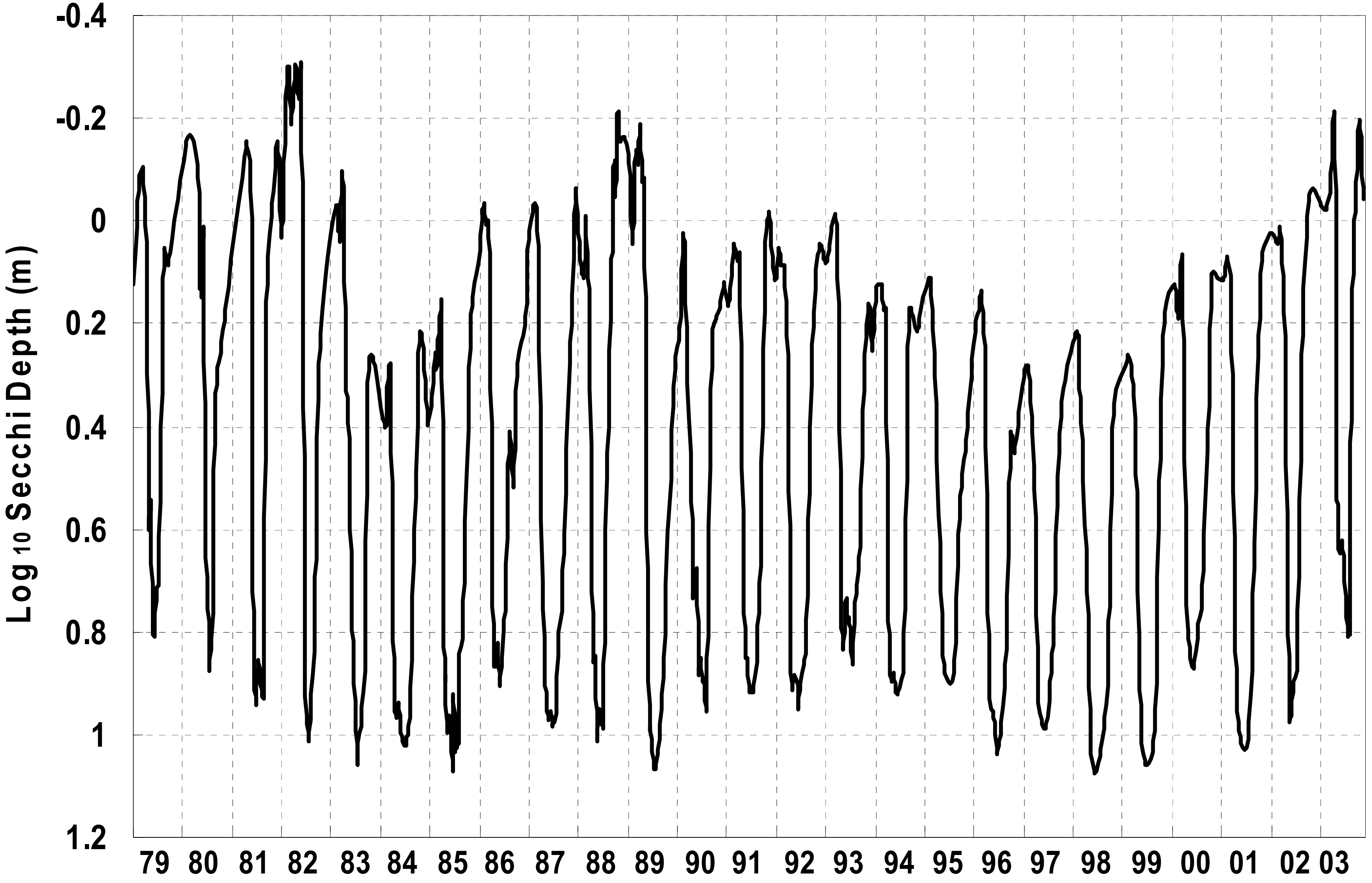
December Salinity Stratification at Mono Lake

Figure 11



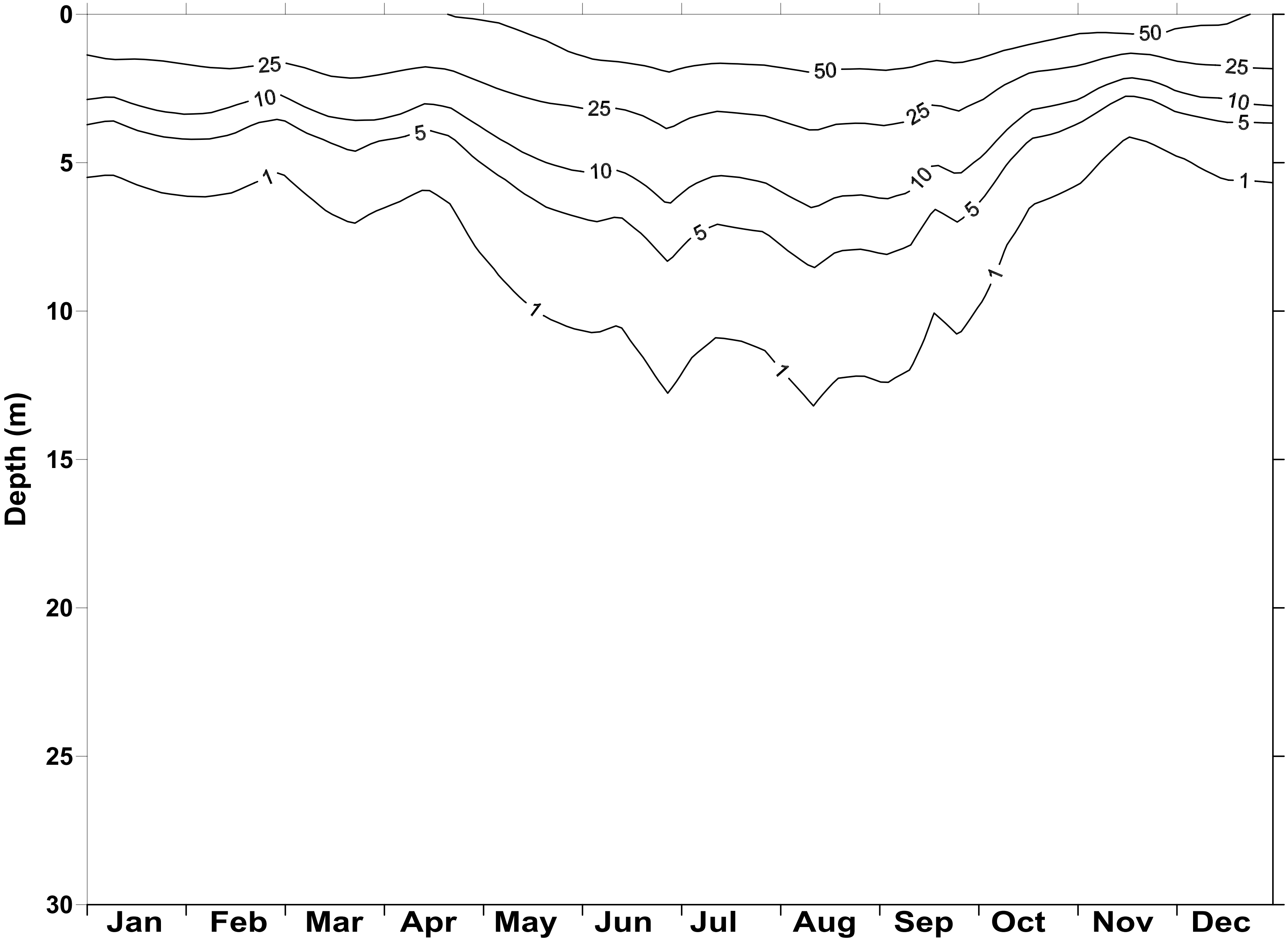
Mono Lake Transparency

Figure 12



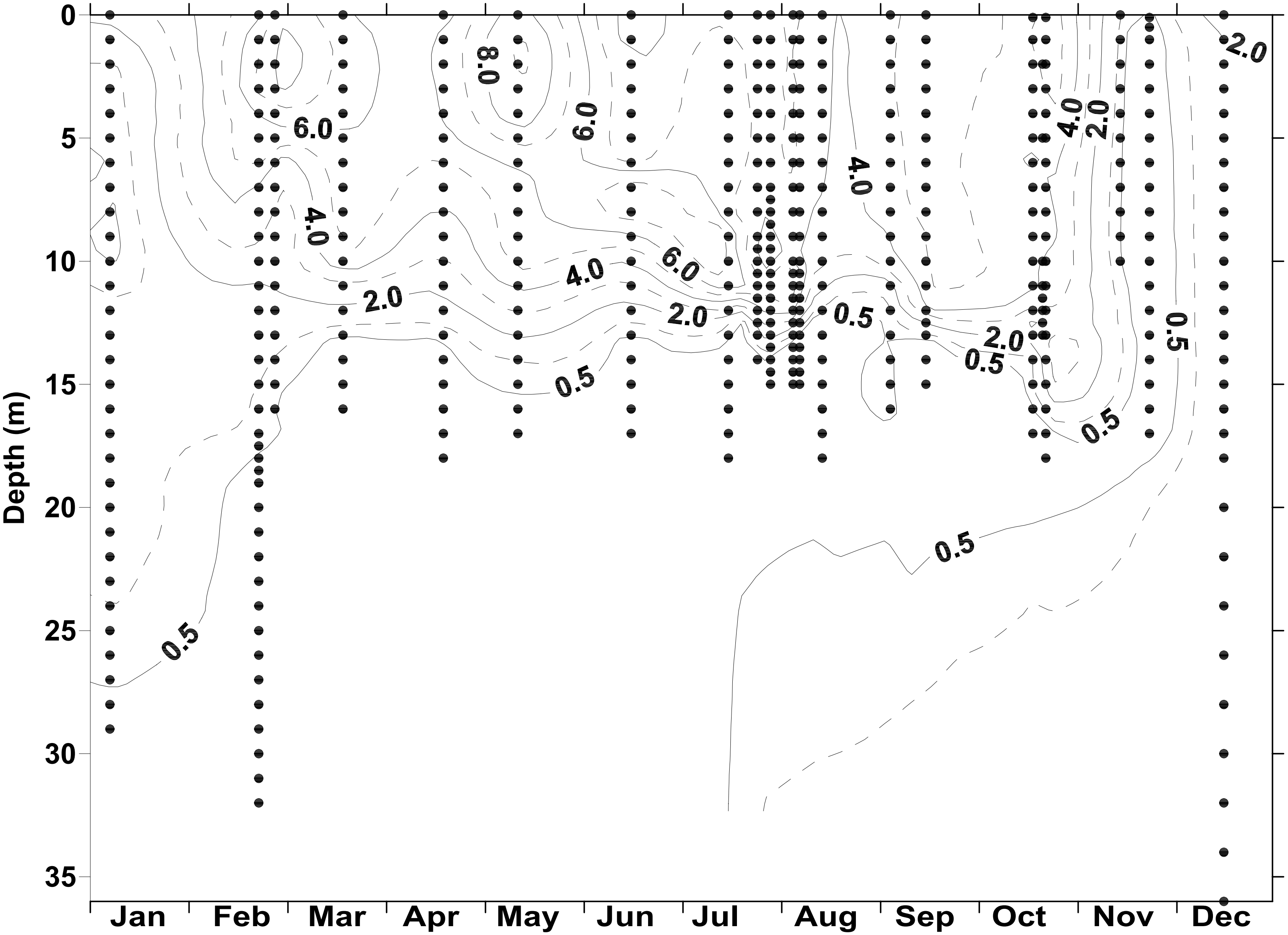
Transparency in Mono Lake

Figure 13



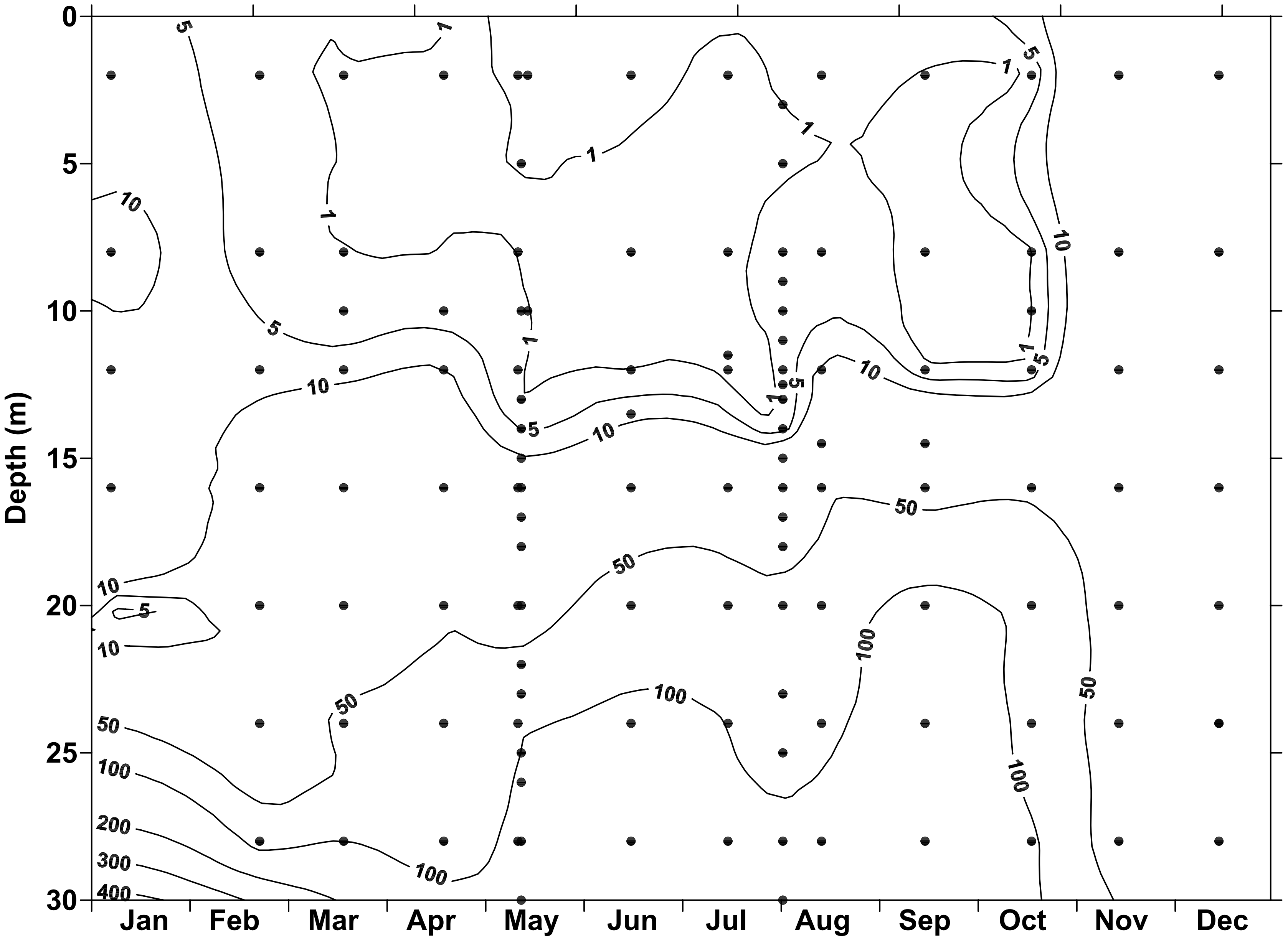
Light Attenuation (Percent of Surface) at Station 6, 2003

Figure 14



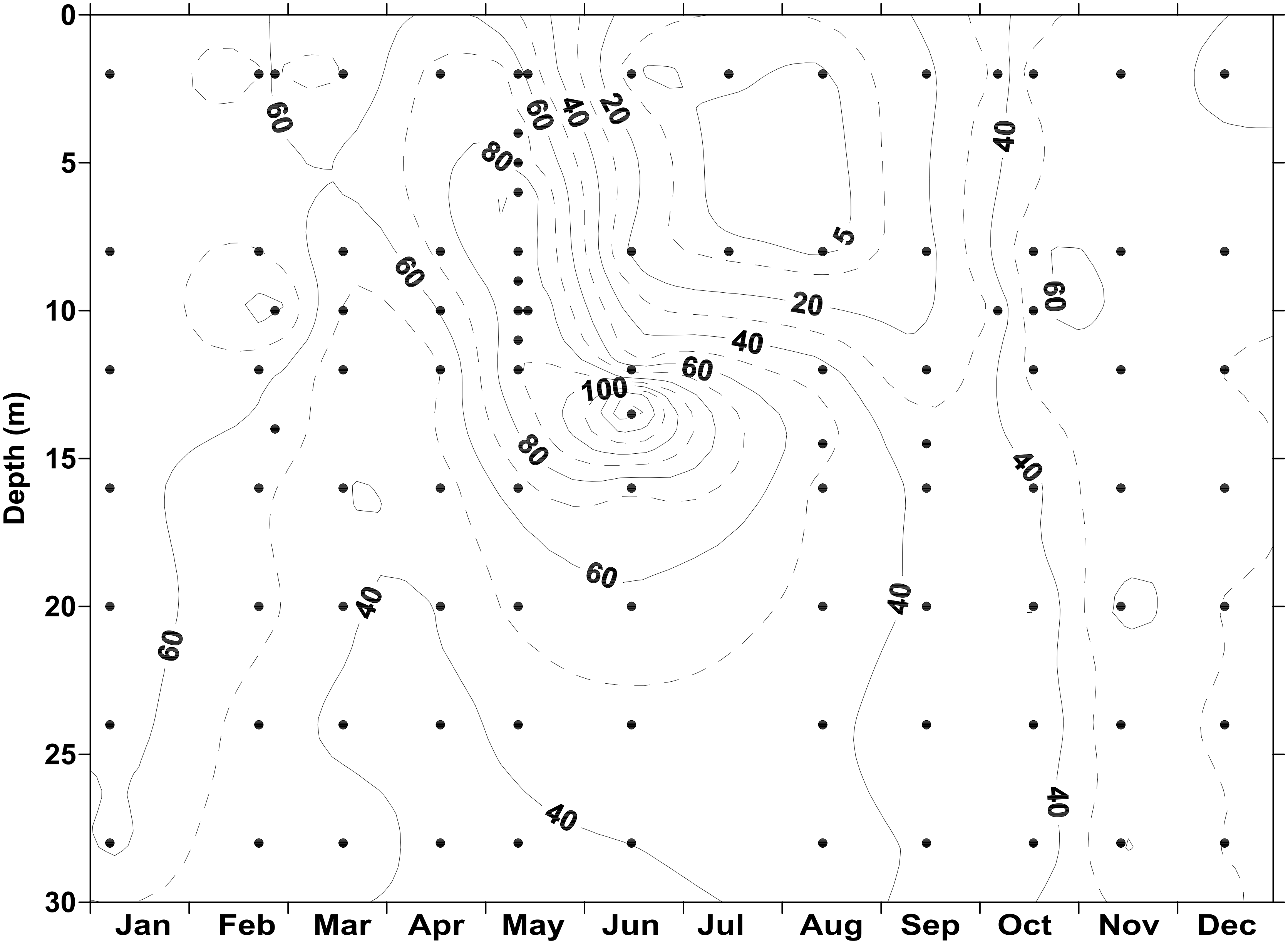
Dissolved Oxygen (mg/l) at Station 6, 2003

Figure 15



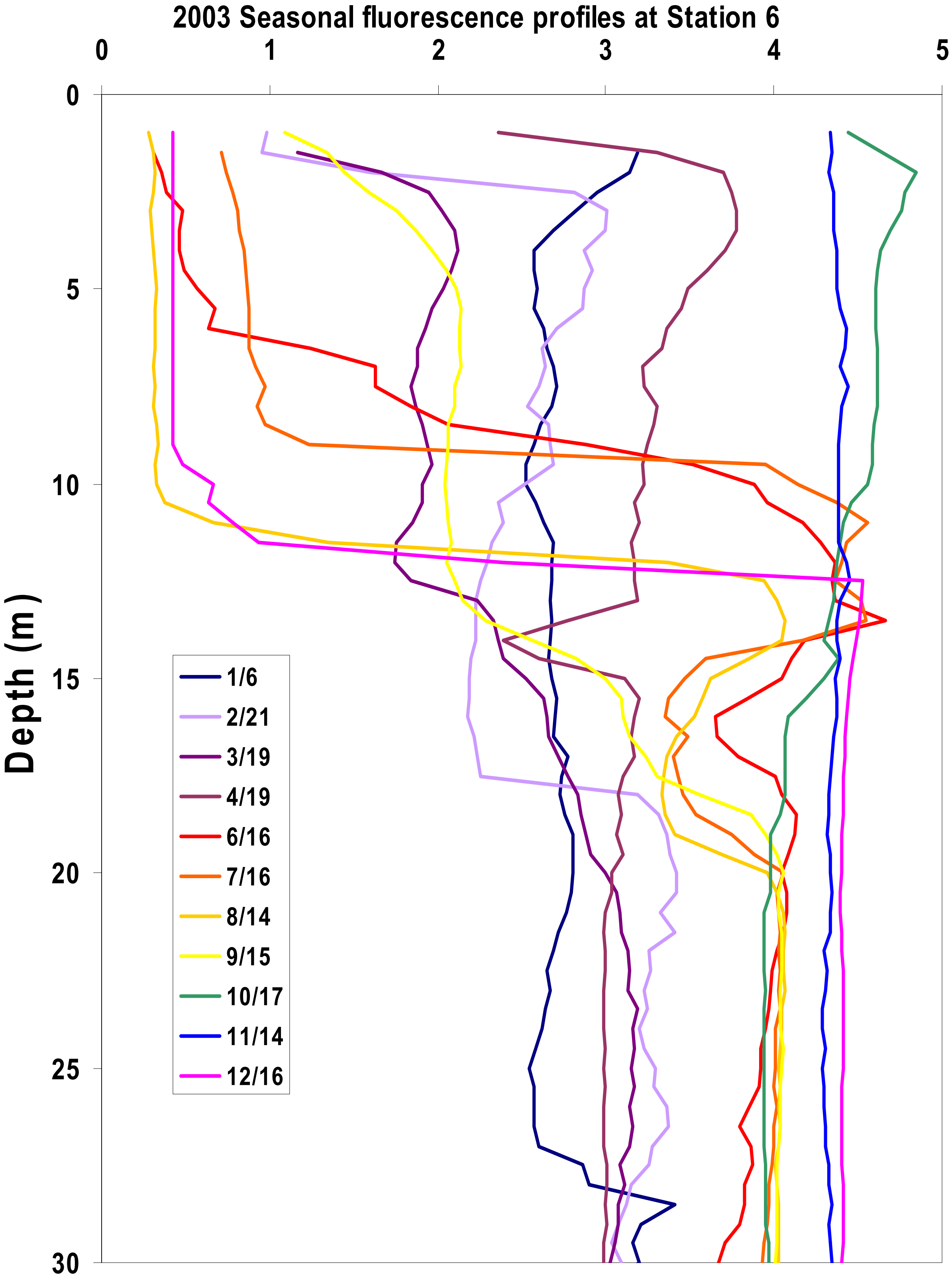
Ammonia (µM) at Station 6, 2003

Figure 16



Chlorophyll a (µ g/l) at Station 6, 2003

Figure 17


2003 Seasonal fluorescence profiles at Station 6
0
1
2
3
4
5
0
5
10
15
20
25
30
Depth (m)
1/6
2/21
3/19
4/19
6/16
7/16
8/14
9/15
10/17
11/14
12/16

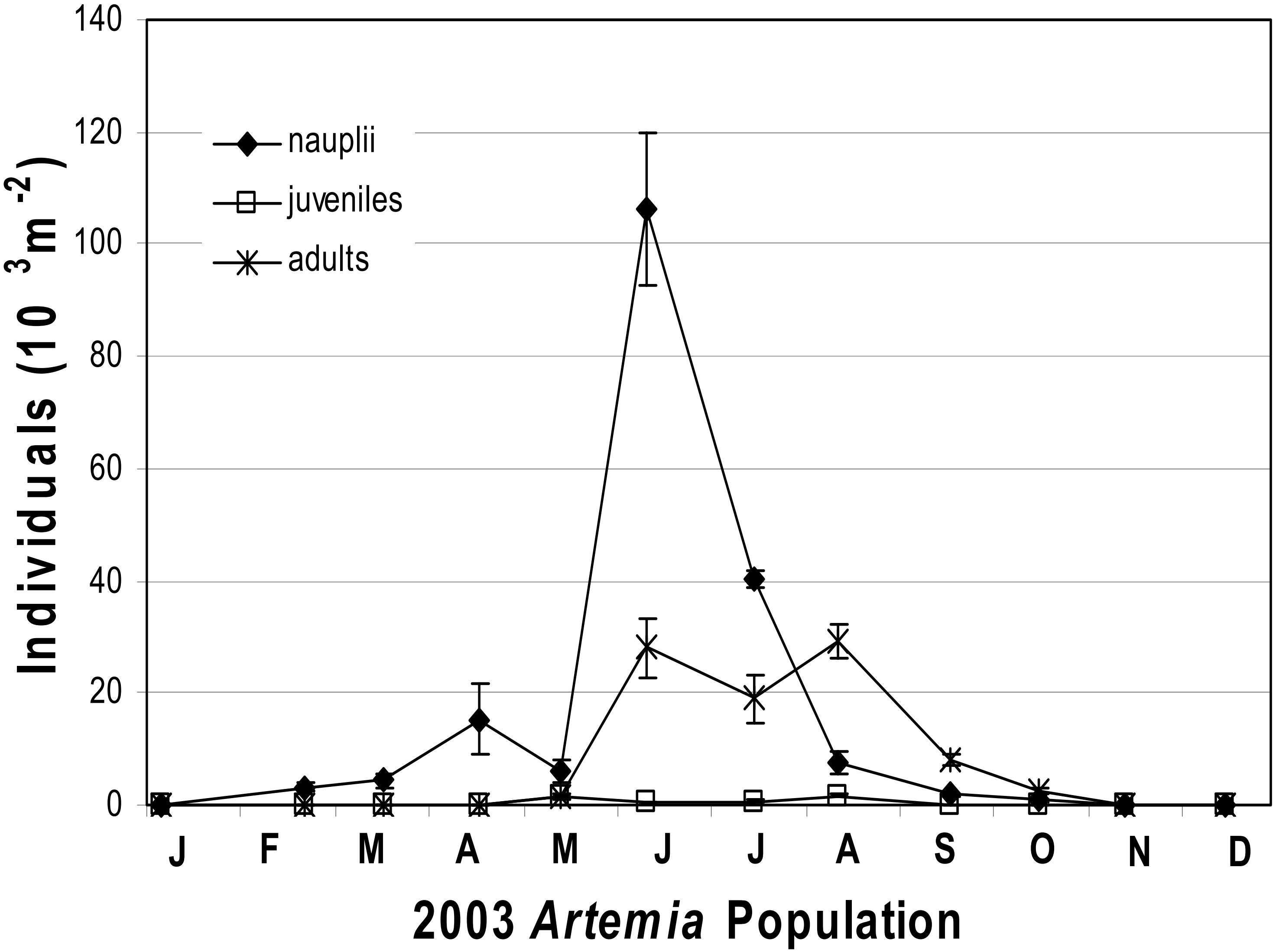

Individuals (10 3m -2)
0
20
40
60
80
100
120
140
nauplii
juveniles
adults
J
F
M
A
M
J
J
A
S
O
N
D
2003 *Artemia* Population

Figure 19

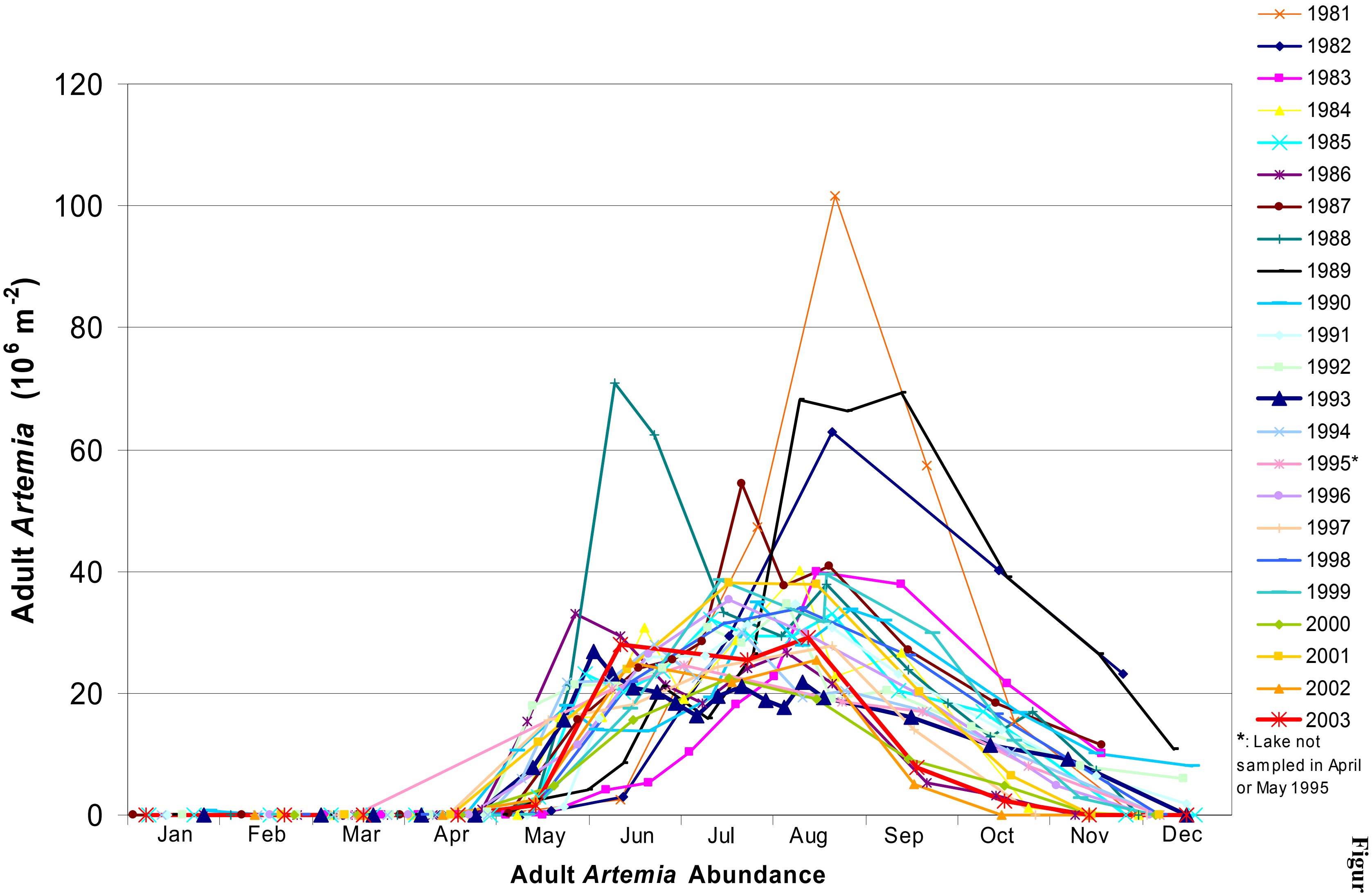
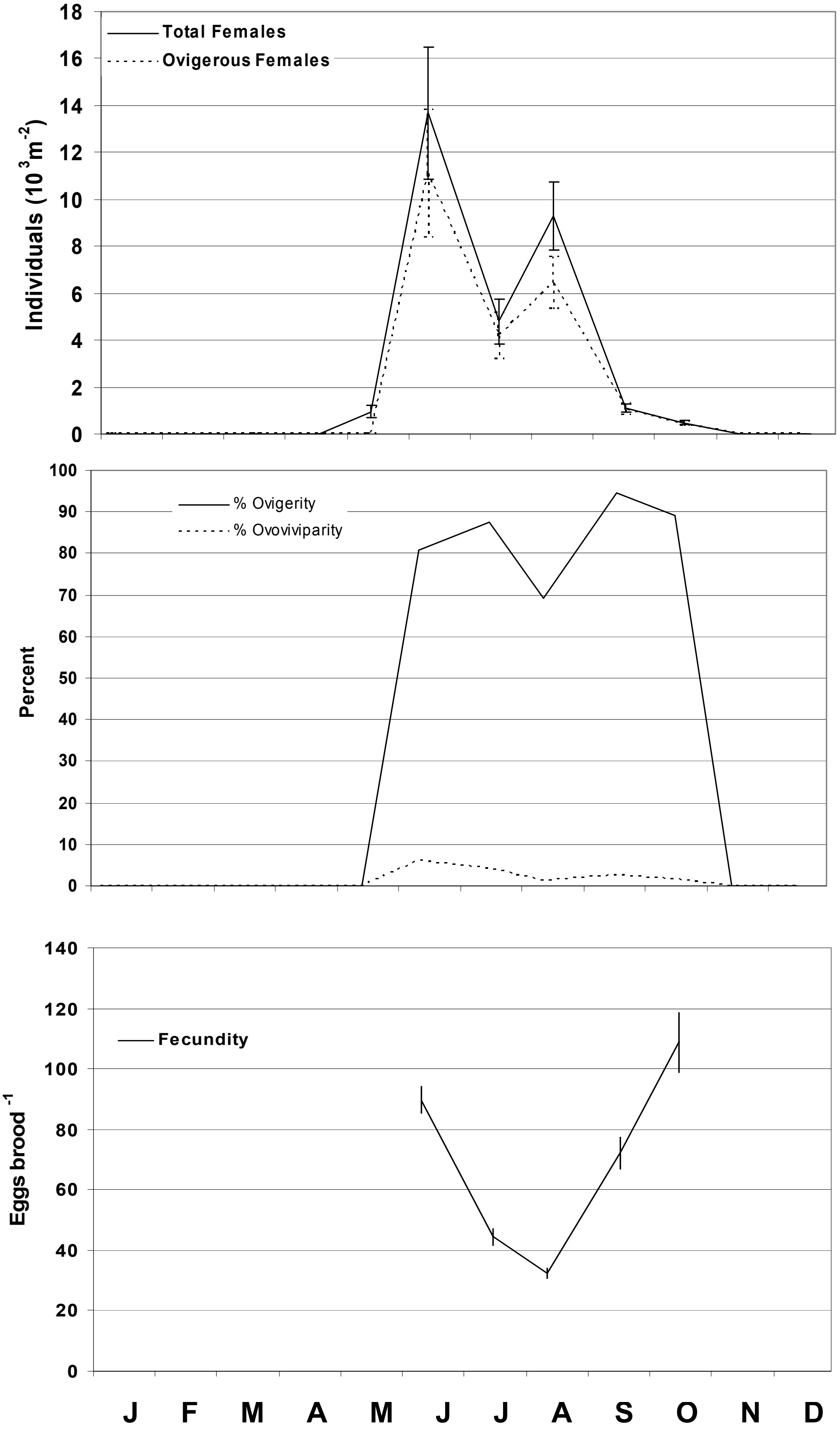
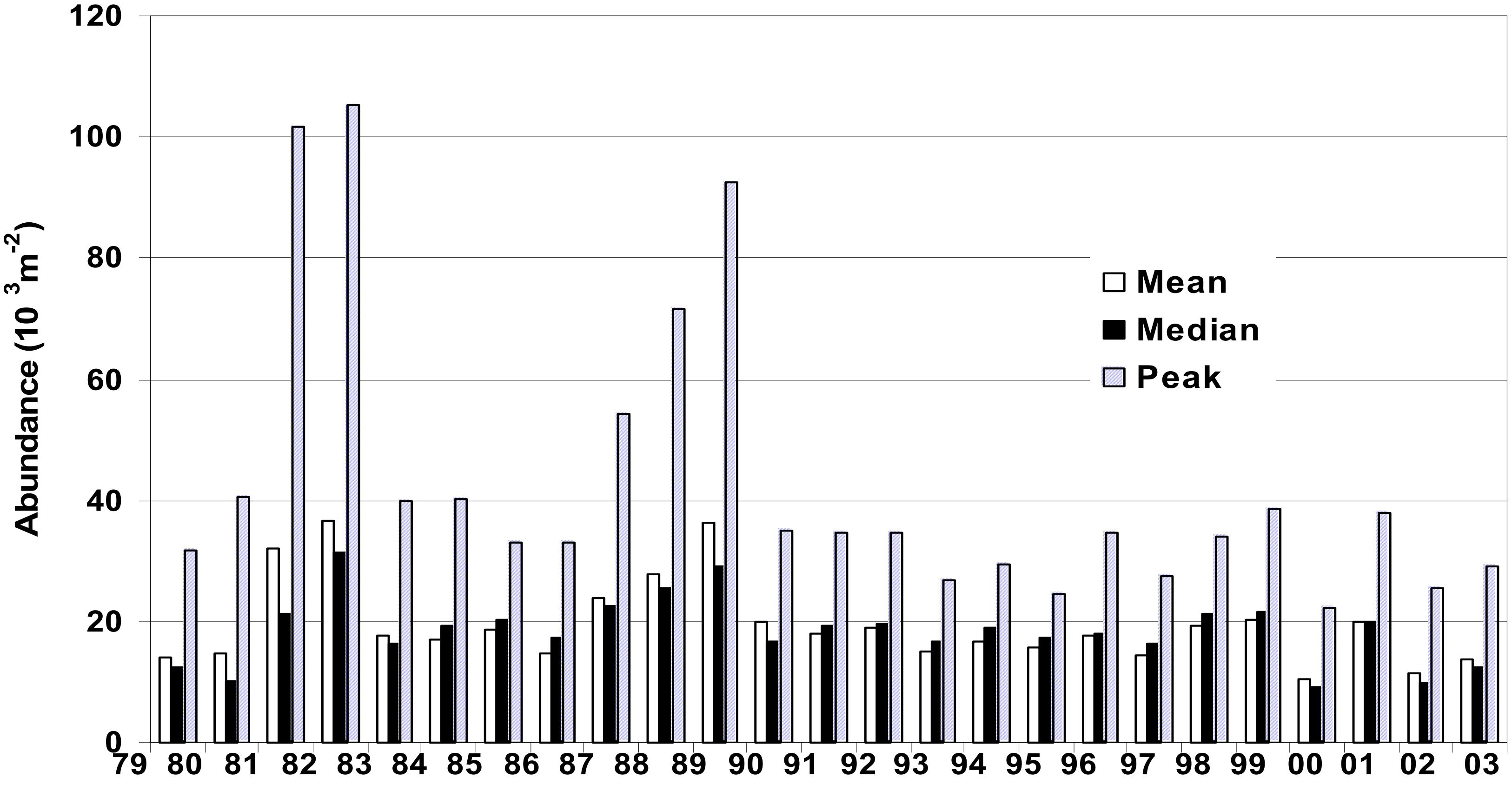

120
100
80
60
40
20
0
Adult *Artemia* (10^6 m^{-2})
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Adult *Artemia* Abundance
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995*
1996
1997
1998
1999
2000
2001
2002
2003
*: Lake not sampled in April or May 1995

Figure 20

Figure 21

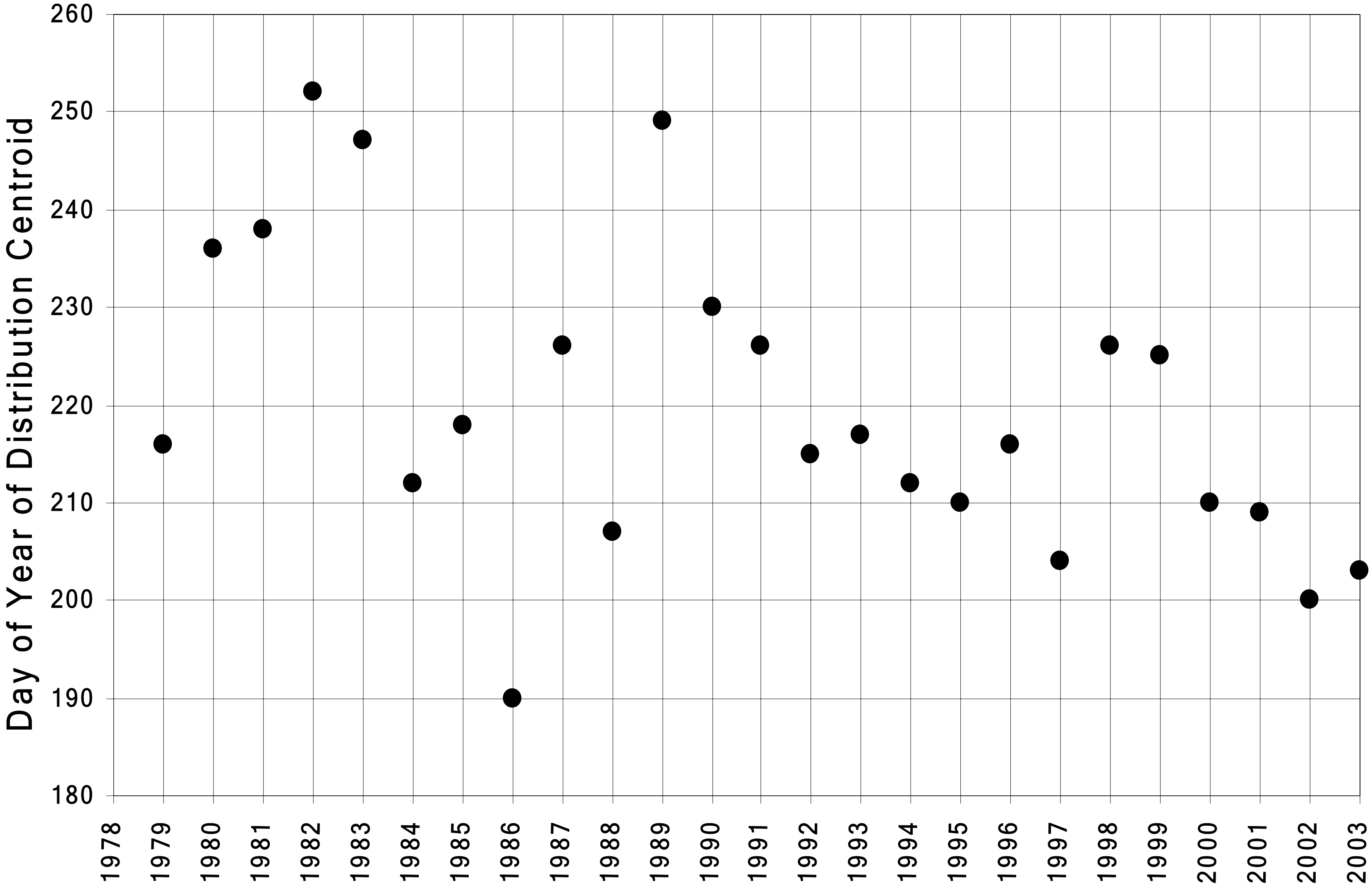
2003 *Artemia* Population





Adult *Artemia* Summary Statistics

Figure 22

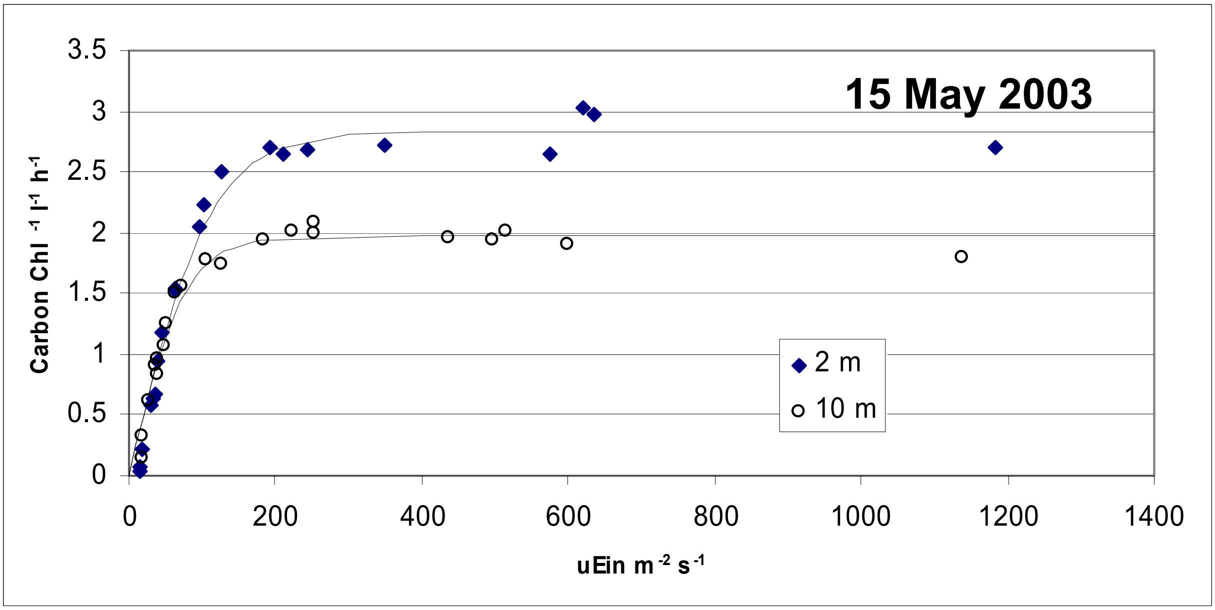


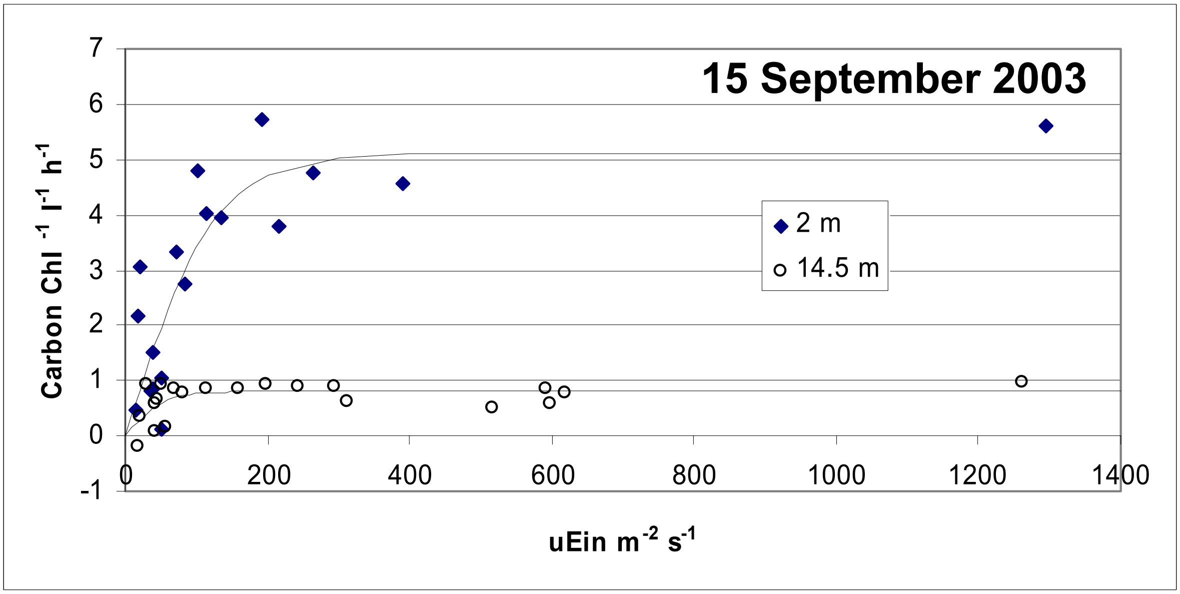
Adult *Artemia* Temporal Distribution

Figure 23

Figure 24

2003 Carbon uptake measurements (examples from May and September)





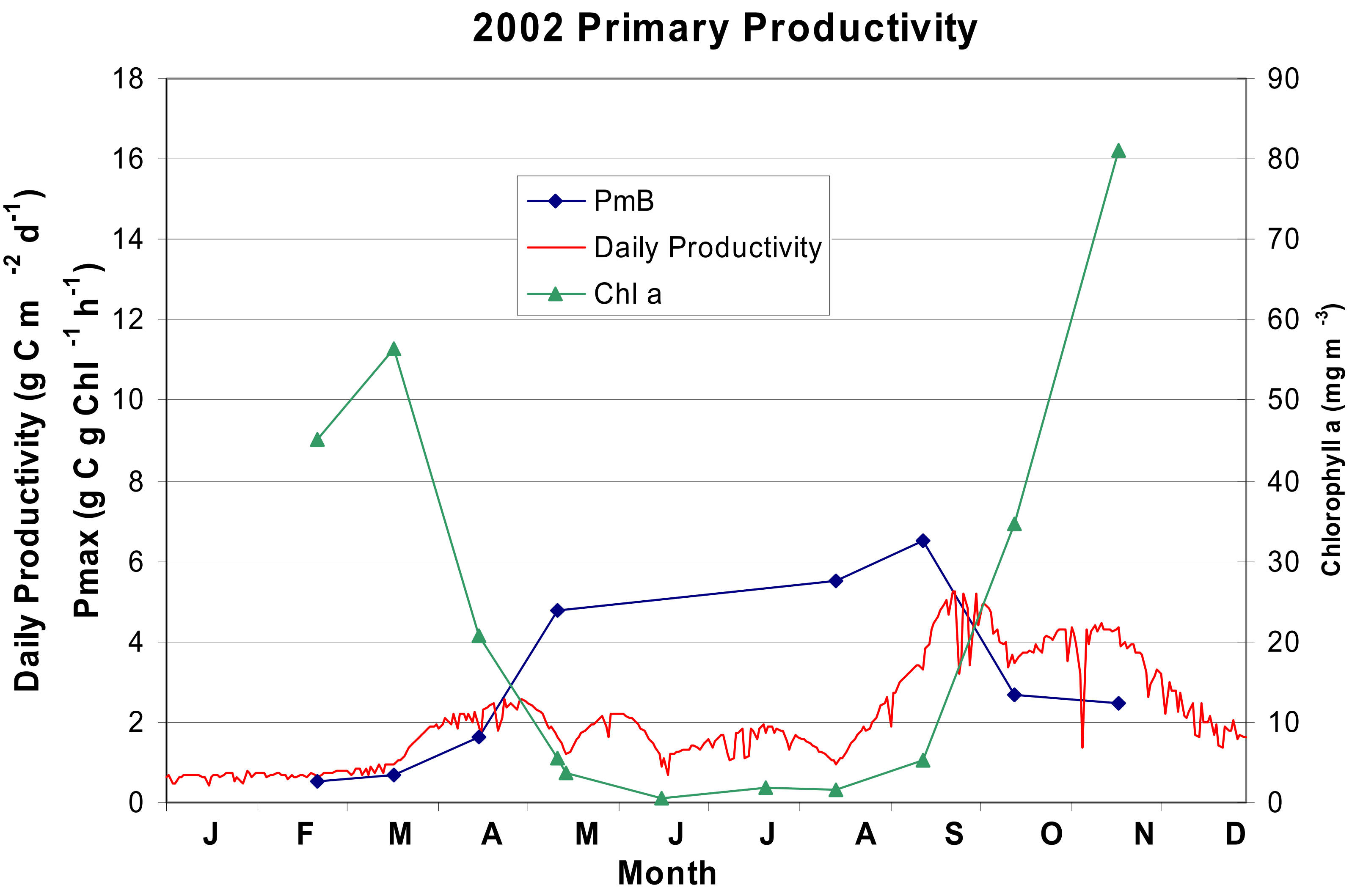

2002 Primary Productivity
PmB
Daily Productivity
Chl a
18
16
14
12
10
8
6
4
2
0
90
80
70
60
50
40
30
20
10
0
Daily Productivity (g C m -2 d-1)
Pmax (g C g Chl -1 h-1)
Chlorophyll a (mg m -3)
J
F
M
A
M
J
J
A
S
O
N
D
Month

Figure 25

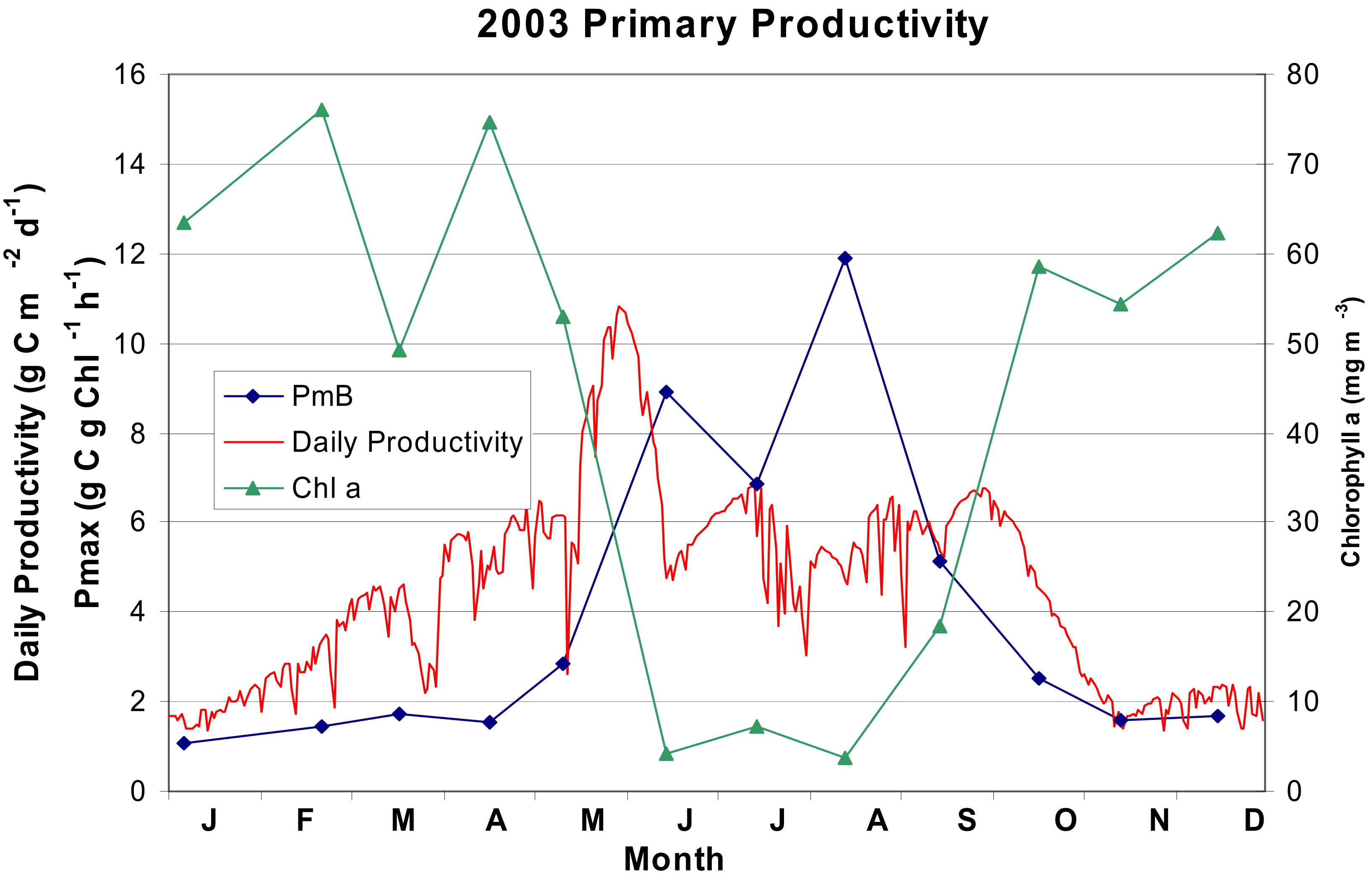
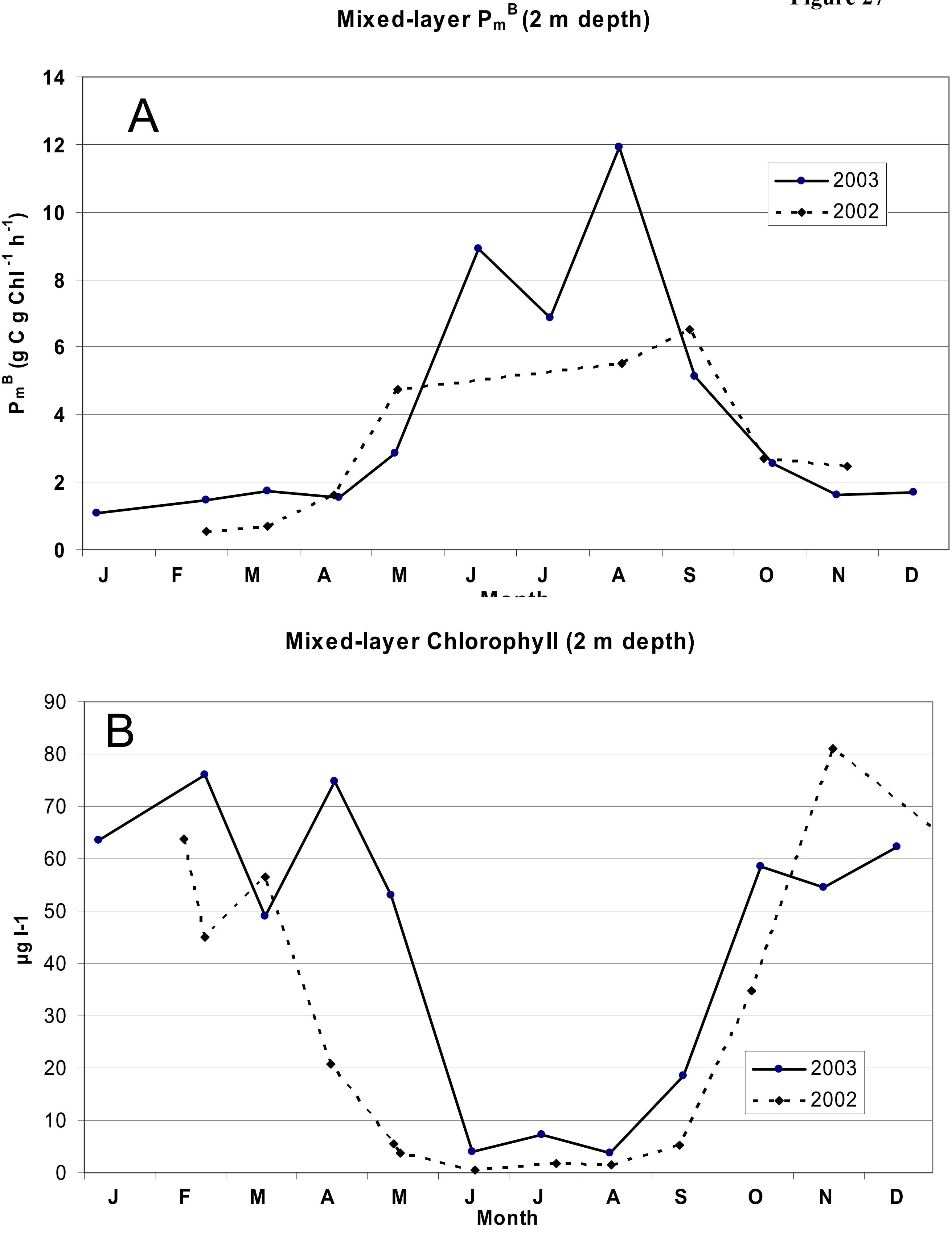

2003 Primary Productivity
Daily Productivity (g C m -2 d-1)
Pmax (g C g Chl -1 h-1)
Chlorophyll a (mg m -3)
Month
PmB
Daily Productivity
Chl a
16
14
12
10
8
6
4
2
0
80
70
60
50
40
30
20
10
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 26

Figure 27



Mixed-layer P_m^B (2 m depth)

Mixed-layer Chlorophyll (2 m depth)

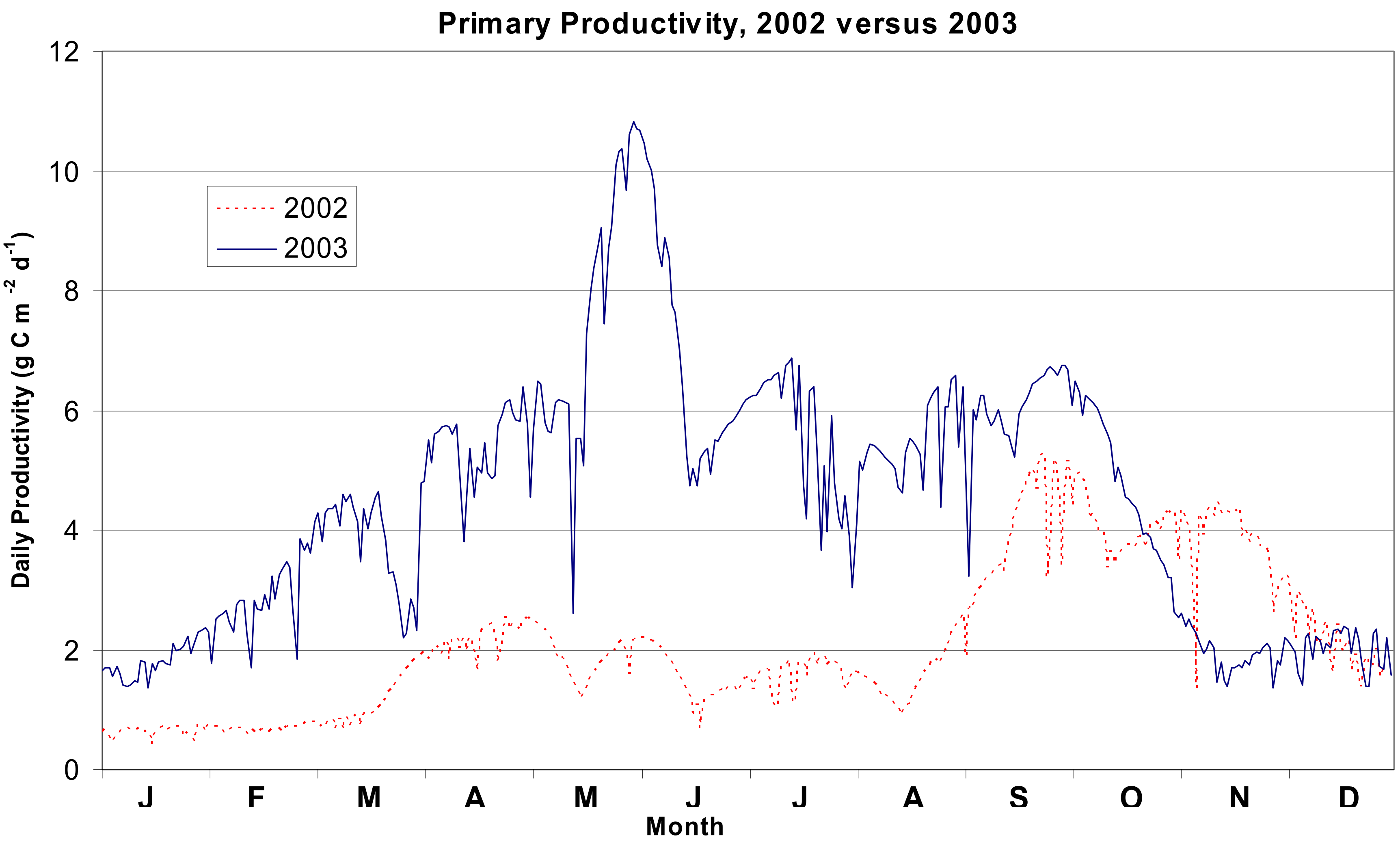

Primary Productivity, 2002 versus 2003
2002
2003
Daily Productivity (g C m $^{-2}$ d $^{-1}$)
0
2
4
6
8
10
12
J
F
M
A
M
J
J
A
S
O
N
D
Month

Figure 28

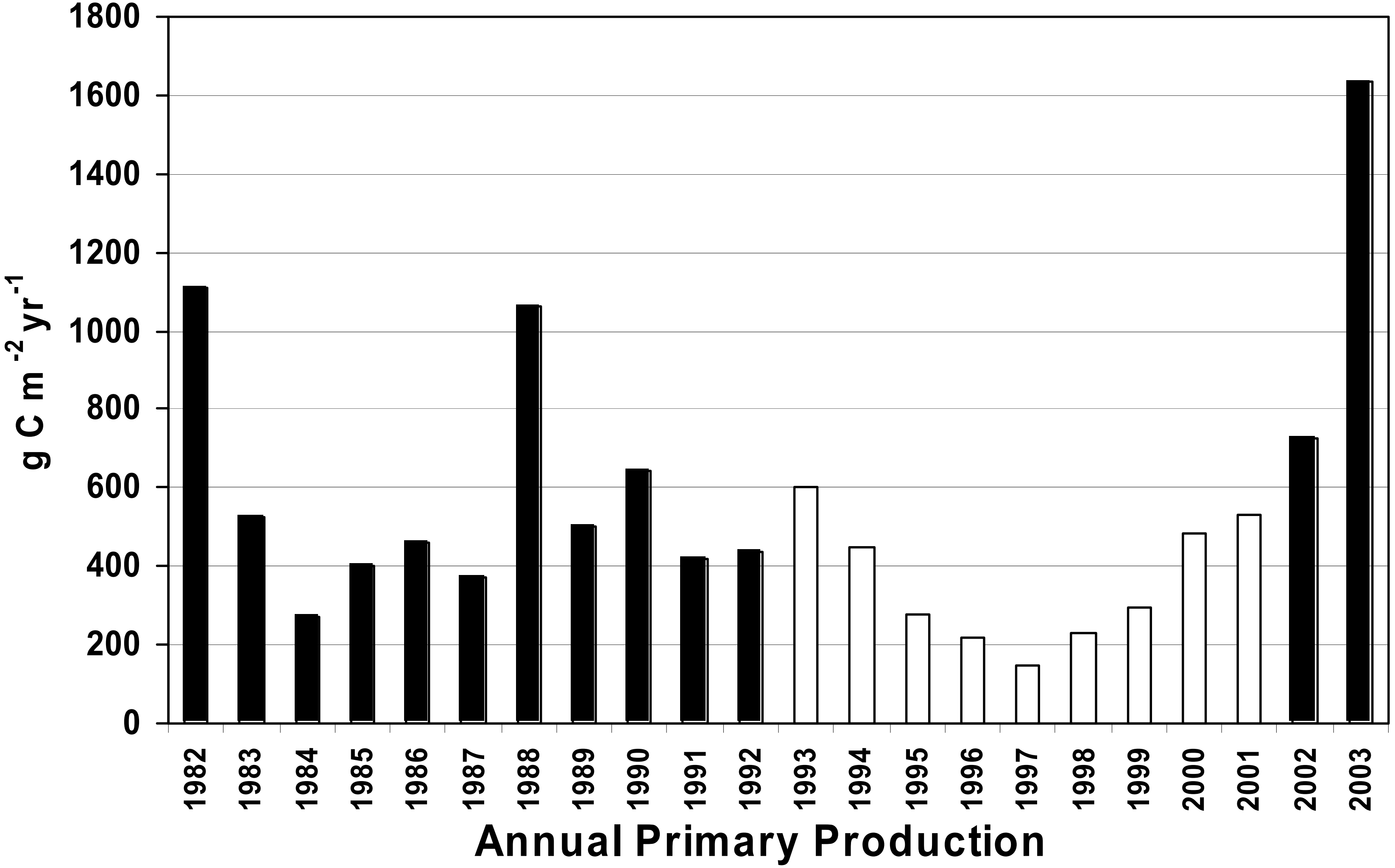

1800
1600
1400
1200
1000
800
600
400
200
0
g C m -2 yr -1
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Annual Primary Production

Figure 29

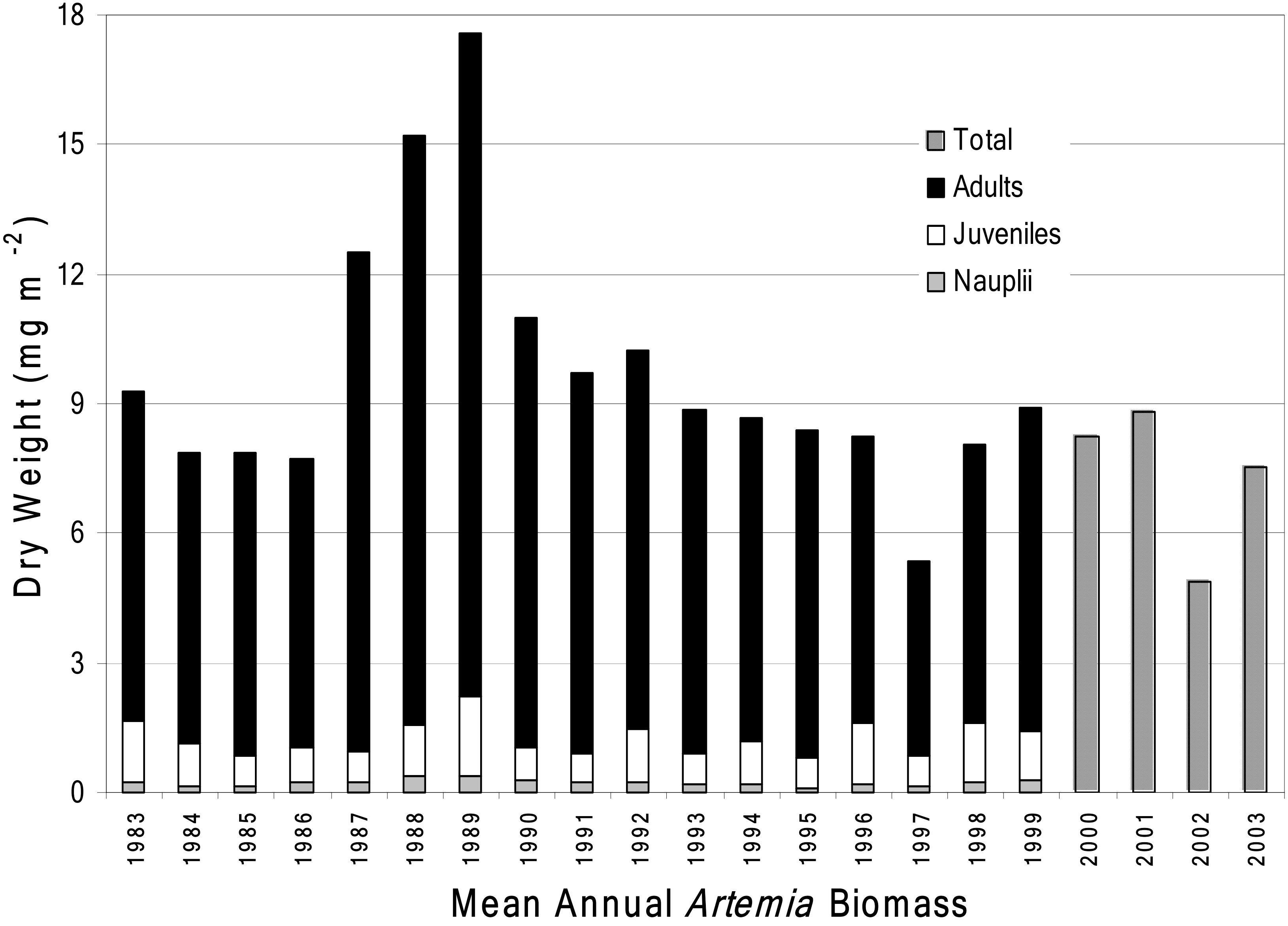

Dry Weight (mg m -2)
18
15
12
9
6
3
0
▨ Total
■ Adults
☐ Juveniles
▨ Nauplii
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Mean Annual *Artemia* Biomass

Figure 30

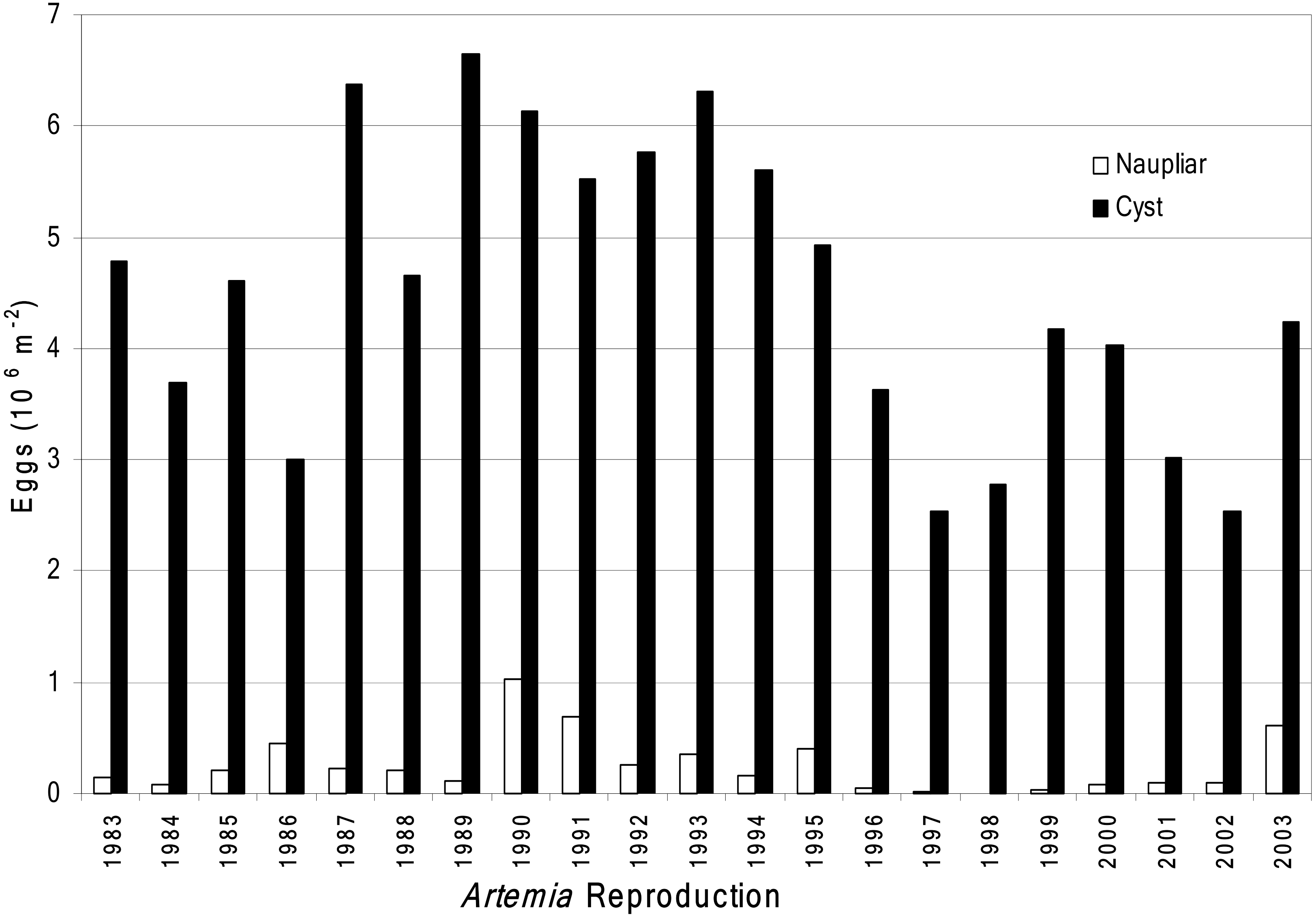

7
6
5
4
3
2
1
0
Eggs (10^6 m^{-2})
☐ Naupliar
■ Cyst
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Artemia Reproduction

Figure 31

APPENDIX 3

Ornithology

MONO LAKE WATERFOWL POPULATION MONITORING

2003 ANNUAL REPORT

LOS ANGELES DEPARTMENT OF WATER AND POWER
PREPARED BY DEBBIE HOUSE
WATERSHED RESOURCES SPECIALIST
BISHOP, CA 93514
April 2004

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Data summary

Executive Summary

Waterfowl populations were monitored in 2003 at Mono Lake, Bridgeport Reservoir and Crowley Reservoir in compliance with State Water Resources Control Board Order 98-05. At Mono Lake, three summer ground counts and six fall aerial surveys for waterfowl were conducted. Six fall aerial surveys were conducted at Bridgeport and Crowley Reservoirs in order to provide data to evaluate whether long-term trends observed at Mono Lake are mirrored at other Eastern Sierra water bodies, or are specific to changes occurring at Mono Lake.

A total of nine waterfowl species were encountered at Mono Lake during summer surveys, while six species used Mono Lake wetlands for brooding. Gadwall was the most abundant and widespread waterfowl species breeding at Mono Lake.

A total of 81 broods were detected during summer surveys. A minimum of 65 broods, including 46 Gadwall, seven Mallard, and five Northern Pintail, two Green-winged Teal, one Cinnamon Teal, and four Canada Goose broods were detected during surveys. As was the case in 2002, Mill Creek, Wilson Creek and the South Shore Lagoon areas supported the greatest number of waterfowl broods.

A total of 19 shorebird species were encountered during the summer surveys. Of the shorebird species that were detected throughout the summer, the most abundant breeding species was American Avocet. Other shorebird species for which evidence of breeding was detected include Wilson's Phalarope, Killdeer, Spotted Sandpiper, and Snowy Plover. The Warm Springs and Sammann's Springs areas attracted the greatest number of shorebird species throughout the season.

A total of thirteen waterfowl species were recorded at Mono Lake during fall aerial surveys. In terms of total detections, 43,242 waterfowl individuals were detected on the lake throughout the fall season, while 432 were detected at the Restoration Ponds. The peak

number of waterfowl detected at Mono Lake was 9,920 and occurred on the September 18 survey.

The primary areas of waterfowl use during fall 2003 were the south shore (including Sammann's Spring and South Shore Lagoons), Wilson and Mill Creek deltas, and the northwest shore sites (Lee Vining Creek and DeChambeau Creek). The distribution of Ruddy Ducks varied throughout the fall migratory period with early-season detections primarily in areas offshore of DeChambeau Embayment and Bridgeport Creek, while late-season detections were primarily along the west shore.

A total of 17 waterfowl species were recorded at Bridgeport Reservoir during fall aerial surveys. The peak number of waterfowl detected at Bridgeport Reservoir was 20,941 individuals. In terms of total detections, 58,821 waterfowl individuals were detected at Bridgeport Reservoir throughout the fall season. The most abundant species, in terms of total detections were Northern Shoveler, Gadwall, Green-winged Teal and Mallard. The West Bay area was the primary area of waterfowl concentration.

A total of 19 waterfowl species were recorded at Crowley Reservoir during fall aerial surveys. The peak number of waterfowl detected at Crowley Reservoir was 15,555 individuals. In terms of total detections, 74,215 waterfowl individuals were detected at Crowley Reservoir throughout the fall season. The most abundant species, in terms of total detections were Mallard, Green-winged Teal, Northern Pintail and Northern Shoveler. The west shore of Crowley Reservoir (McGee Bay and Hilton Bay) held large numbers of waterfowl all season.

Comparison counts of Bridgeport and Crowley Reservoirs indicate a large disparity among the three bodies of water with regard to total detections of the dominant species. The data indicate that there is a higher proportional use of Mono Lake by Ruddy Ducks, and lower proportional use of Mono by Green-winged Teal, Mallard, Gadwall, and Northern Pintail as compared to Bridgeport and Crowley Reservoirs.

An analysis of the trend in peak waterfowl numbers indicates a significant, positive trend in the peak number of waterfowl, (exclusive of Ruddy Ducks) detected at Mono Lake since 1996.

Waterfowl Monitoring Compliance

This report fulfills the Mono Lake waterfowl population surveys and studies requirement set forth in compliance with the State Water Resources Control Board Order No. 98-05. The waterfowl monitoring program consists of summer ground counts at Mono Lake, fall migration counts at Mono Lake, fall comparative counts at Bridgeport and Crowley Reservoirs, and photos of waterfowl habitats taken from the air. Three summer grounds counts and six fall aerial surveys were conducted at Mono Lake in 2003. Six comparative fall aerial counts were completed at Bridgeport and Crowley Reservoirs. Photos of shoreline habitats and the restoration ponds were taken from a helicopter on September 29, 2003.

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2003 Mono Lake Waterfowl Population Monitoring

Los Angeles Department of Water and Power
Prepared by Debbie House
Watershed Resources Specialist
Bishop, CA

INTRODUCTION

Waterfowl population monitoring is being conducted on an annual basis at Mono Lake in order to evaluate the response of waterfowl populations to restoration efforts in the Mono Basin watershed [State Water Resources Control Board Order Numbers 98-05 and 98-07 (Orders)]. The monitoring of waterfowl populations in the Mono Basin is expected to continue until at least the year 2014, or until the target lake level (6392 foot elevation) is reached and the lake cycles through a complete wet/dry cycle (LADWP 2000a). Restoration activities in the Mono Basin that are expected to influence waterfowl use include the rewatering of Mono Lake tributaries, an increase in the lake level, leading to increased surface area of open-water habitats, a subsequent decrease in the salinity of the lake, and changes to lake-fringing wetlands, and the creation of freshwater pond habitat. With the exception of the creation and maintenance of freshwater pond habitat at the DeChambeau and County Pond complexes, the majority of the changes in waterfowl habitats will come through passive restoration – proper flow management in the tributaries to achieve healthy, functional riparian systems, and decreased water diversions from the watershed that will result in increases in level of the lake.

Since waterfowl are migratory, their populations are influenced by factors on their wintering grounds, summering grounds, and along their migration route. In order to evaluate whether long-term trends observed at Mono Lake are mirrored at other Eastern Sierra water bodies, or are specific to changes occurring at Mono Lake, fall waterfowl surveys are also conducted at Bridgeport and Crowley Reservoirs.

All summer surveys were conducted by the author. Fall surveys were conducted by the author with assistance from Annette Henry, LADWP Watershed Resources Specialist.

METHODS

Summer Ground Counts

Summer ground counts were conducted in order to document summer use by waterfowl and shorebird species of the Mono Lake shoreline, selected tributaries, and the freshwater restoration ponds. These ground surveys were conducted as area searches. Area searches were conducted as either transect surveys, or by making observations from a stationary point.

Three ground counts surveys were conducted at three-week intervals beginning in early June. Three days were required to complete a survey of all areas. The ground count survey dates for 2003 are provided as Appendix 1. As a note, the summer surveys dates reported in the 2002 Annual Report (LADWP 2003) were incorrect. The actual surveys dates are reported in Appendix 1 also.

The locations surveyed were those identified in the Waterfowl Restoration Plan as current or historic waterfowl concentration areas, namely, South Tufa (SOTU), South Shore Lagoons (SSLA), Sammann's Spring (SASP), Warm Springs (WASP), Wilson Creek (WICR), Mill Creek (MICR), DeChambeau Creek delta (DECR), Rush Creek bottomlands and delta (RUCR), Lee Vining Creek bottomlands and delta (LVCR), DeChambeau Restoration Ponds (DEPO), and County Ponds (COPO). Areas surveyed during summer grounds counts are shown in Figure 1.

Transect surveys along the shoreline were conducted at South Tufa, South Shore Lagoons, Sammann's Spring, Warm Springs, DeChambeau Creek, Wilson Creek and Mill

Creek sites. Transects surveys were conducted by walking at an average rate of approximately 2 km/hr. Due to the fact that waterfowl are easily flushed, and females with broods are especially wary, the shoreline was scanned well ahead of the observer in order to increase the probability of detecting broods.

Transect surveys were also conducted in lower Rush and Lee Vining Creeks, from the County Road down to the deltas. Surveys along lower Rush Creek were conducted by walking along the southern bluff above the creek. This route offered a good view of the creek while limiting wildlife disturbance or the flushing of waterfowl far ahead of the observer. In Lee Vining Creek, surveys of the creek channel were conducted by walking north of the main channel, which offered the best view of the channel. At the mouth of the creek, the main channel splits in two and forms two delta areas separated by a tall berm-like formation. In order to obtain good views of both delta areas, it was necessary to cross the main channel and walk on top of this berm. In both areas, birds within 100 meters either side of the deltas were also recorded.

At the DeChambeau Pond complex, observations were taken from a stationary point at each of the five ponds. Observation points were selected as to provide a full view of each pond. At the County Ponds, observations were taken from a single location that allowed full viewing of both ponds. At the stationary observation points at the ponds, a minimum of 5 minutes was spent at each point.

All summer ground surveys were started within one hour of sunrise and were completed within approximately six hours. The order in which the various sites were visited was varied in order to minimize the effect of time of day on survey results. The total time spent surveying each area was recorded.

For every waterfowl and shorebird species encountered, the following were recorded based upon initial detection: the time of the observation, the habitat type the individual was using, and an activity code indicating how the bird, or birds, were using the habitat. The activity codes used were resting, foraging, flying over, nesting, brooding, sleeping, swimming, and other.

If a waterfowl brood was detected, the size of the brood was recorded, a GPS reading was taken (UTM, NAD 27, Zone 11, CONUS), and the location of each brood was marked on an air photo while in the field. Each brood was also assigned to an age class based on plumage and body size (Gollop and Marshall 1954). Since the summer surveys were conducted at three-week intervals, any brood assigned to class I (which would include subclasses Ia, Ib, and Ic) using the Gollop and Marshall age classification scheme, would be a brood that hatched since a previous visit. Assigning broods to an age class will allow for the determination of the minimum number of “unique broods” using Mono Lake wetland and shoreline habitats.

The habitat categories used follows the classification system found in the report entitled “1999 Mono Basin Vegetation and Habitat Mapping” (LADWP 2000b). The habitat classification system defined in that report is being used for the mapping of lakeshore vegetation and the identification of changes in lake-fringing wetlands associated with changes in lake level. The specific habitat categories used in that mapping effort, and in this project, include: marsh, wet meadow, alkaline wet meadow, dry meadow/forb, riparian scrub, great basin scrub, riparian forest, freshwater stream, ria, freshwater pond, brackish lagoon, hypersaline lagoon, and unvegetated. For reference, the definition of each of these habitat types is provided as Appendix 2. Representative photos of these habitats can be found in the report entitled *Mono Lake Waterfowl Population Monitoring 2002 Annual Report* (LADWP 2003). Two additional habitat types, open water (within 50 meters off-shore) and open water (>50 meters offshore), were used in order to more completely represent areas used by waterfowl and shorebirds. Although a “>50 meter” category was used, these observations will not be included in final calculations unless the presence of waterfowl offshore is likely due to observer influence (e. g. the observer sees a that a female duck is leading her brood offshore and is continuing to swim away from shore).

Fall Surveys

Overview of methodology

Aerial surveys were conducted in the fall at Mono Lake, Bridgeport Reservoir and Crowley Reservoir. Six surveys were conducted at two-week intervals beginning the first week of September and ending the middle of November. Surveys at all three bodies of water were conducted on the same day. A summary of the fall survey schedule is provided as Appendix 3.

Surveys of Mono Lake were started at approximately 0900 hrs and completed in approximately one and one-half hours. Bridgeport Reservoir was surveyed second, followed by Crowley. All three surveys were completed by 1200 hrs. Poor weather forced the rescheduling of the fourth fall survey, and a resultant 5-day delay of the flight. During the November 14, 2003 survey, Mono Lake was surveyed last due to the presence of a thick layer of fog early in the morning.

Observations were recorded onto a handheld digital recorder, and then later transcribed. Unlike the 2002 surveys, a second observer was available for all flights. At Mono Lake, this second observer sat on the same side of the plane as the author during the perimeter flights, and counted shorebirds and waterbirds. During the cross-lake transect counts, the second observer sat on the opposite side of the plane and censused Ruddy Ducks. At Bridgeport and Crowley, the second observer sat on the opposite side of the plane during the entire survey, and counted waterfowl. Since the second observer was only counting shorebirds at Mono Lake during perimeter flights, and the majority of ducks (with the exception of Ruddy Ducks) are detected along the shoreline, the 2003 counts, are comparable to 2002. Thus, the addition of a second observer in 2002 will not affect trend analysis which excludes Ruddy Duck numbers (see *Trend Analysis* section below).

Mono Lake Aerial Surveys

Aerial surveys of Mono Lake consisted of a perimeter flight of the shoreline and fixed cross-lake transects. The shoreline was divided into 15 lakeshore segments (Figure 2) in order to document spatial use patterns of waterfowl. Coordinates forming the beginning of each segment were generated from the 2002 aerial photo of Mono Lake (2002 aerial image taken by A. K. Curtis, and processed by Air Photo, USA) and can be found as Appendix 4, along with the four-letter code for each lakeshore segment. The segment boundaries are the same as those used by Jehl (2001) except for minor adjustments made in order to provide the observer with obvious landmarks that are seen easily from the air.

Eight parallel cross-lake transects are conducted over the open water at Mono Lake. The eight transects used for surveys are spaced at one-minute intervals and correspond to those used by Boyd and Jehl (1998) for conducting monitoring of Eared Grebes during fall migration. The latitudinal alignment of each transect is provided as Appendix 5.

Each of the eight transects is further divided into two to four subsegments of approximate equal length (see Figure 2). The total length of each cross-lake transect was first determined from the 2001 aerial photo. These lengths were then divided into the appropriate number of subsections for a total of twenty-five subsegments of approximately 2-km each. This approach creates a grid-like sampling system that will allow for the evaluation of the spatial distribution of waterfowl on the open water. Since the airspeed and approximate length of each subsection was known, it was possible to use a stopwatch to determine the starting and stopping locations of each subsection when over open water.

Aerial surveys were conducted in a Cessna 172 XP at a speed of approximately 130 kilometers per hour, and at a height of approximately 60 meters above ground. Perimeter surveys were conducted at approximately 250 meters from the shoreline. When conducting aerial surveys, the perimeter of the lake was flown first in a counterclockwise direction, starting in the Ranch Cove area. Cross-lake transects were flown immediately afterward, starting from the southernmost transect and proceeding north. In order to reduce the possibility of double-counting, only birds seen from or originating from the observer's side of the aircraft were recorded.

Ground verification counts were conducted when flight conditions did not allow the identification of a large percentage of waterfowl encountered, or to confirm the species or numbers present. During a ground validation count, the total waterfowl present in an area was recorded first, followed by a count the number of individuals of each species present.

Bridgeport Reservoir Aerial Surveys

The shoreline of Bridgeport was divided into three segments (Figure 3). Appendix 4 contains the four-letter code for each lakeshore segment. UTM Coordinates will be collected during a 2004 flight. Flights started at the dam at the north end of the reservoir and proceeded counterclockwise. The distance from shore, flight speed, and height above ground were the same as at Mono Lake. When flying over fisherman on the water, the pilot temporarily increased the height above ground. The reservoir was circumnavigated twice during each survey due to the small size of the reservoir and the presence of large concentrations of waterfowl. The second flight allowed for the confirmation of both numbers of birds and species composition.

Crowley Reservoir Aerial Surveys

The shoreline of Crowley Reservoir was divided into seven segments (Figure 4). Coordinates forming the beginning of each segment were generated from the 2000 aerial photo of Crowley Reservoir (2000 aerial image taken by A. K. Curtis, and processed by Air

Photo, USA) and can be found as Appendix 4, as well as the four-letter code used for each segment. Each survey began at the mouth of the Owens River (UPOW) and proceeded counterclockwise. The distance from shore, flight speed, and height aboveground were the same as at Mono Lake during most of each flight. On occasion, there were large numbers of fishermen on the water. This required the pilot to temporarily increase the height above ground during the flight in some areas of the lake. The reservoir was circumnavigated twice during each survey due to presence of large concentrations of waterfowl. The second flight allowed for the confirmation of both numbers of birds and species composition.

Trend analysis

Simple linear regression analysis was used to evaluate the trend in peak waterfowl numbers detected at Mono Lake since 1996. This analysis was done only on waterfowl counts excluding Ruddy Duck numbers due to the difference in survey methods employed for this species from 1996-2001 versus 2002 and 2003. The regression equation was then tested using ANOVA to determine the significance of the regression, e.g. is the slope significantly different from zero (Zar 1996).

Photo documentation

As required by the Orders, photo documentation of lake-fringing waterfowl habitats was completed in 2003. Photos were taken from a helicopter at all bodies of water.

Photos at Mono Lake were taken on September 29, 2003 and are provided as Figure 5. The photos of Mono Lake were georeferenced using the 2002 digital aerial photos of Mono Lake. The extent of the shoreline included in each digital photo taken from the helicopter was determined using the aerial photos. The coordinates for the shoreline area depicted in each photo were then generated from the 2002 aerial photos. The coordinates are shown on each photo. The general shoreline area depicted in each photo is also indicated on an outline of lake provided with each set of photos.

Photos of Crowley Reservoir were taken on September 29, 2003 and are provided as Figure 6. The general shoreline area depicted in each photo is indicated on an outline of the reservoir.

Photos of Bridgeport Reservoir were taken on September 22, 2003 and are provided as Figure 7. The general shoreline area depicted in each photo is indicated on an outline of the reservoir.

Data Summary

Summer ground counts

Summer transect surveys - waterfowl

A total of nine waterfowl species were encountered during summer surveys. The number of waterfowl detected in each survey area during each visit can be found in Tables 1-3, while Table 4 provides a summary of the number of detections for each species during each survey. Gadwall was the most widespread species, and was encountered in all areas. Mallard and Cinnamon Teal were also widespread and were encountered at ten of eleven of the summer survey areas.

Brood summary

A total of 81 broods were detected during summer counts, with 65 of those categorized as “unique”. The number of unique broods represents the minimum number of broods using the lake. The number of unique broods was determined by eliminating Class II broods or broods known to have not been detected during a previous survey. Thus, the minimum number of broods included 46 Gadwall, seven Mallard, five Northern Pintail, two Green-winged Teal, one Cinnamon Teal, and four Canada Goose broods. Table 5 shows the age class and size of all broods detected. Figures 8-10 show the location of unique broods detected during each of the surveys (Class II broods excluded). The greatest number of unique broods per area (15), was detected in the Mill Creek area, followed by Wilson Creek (13) and South Shore Lagoons (11) (Table 6a). In terms of the total number of broods observed in each area, the Mill Creek, Wilson Creek, and South Shore Lagoon areas were also the most heavily used (Table 6b). No broods were detected in the South Tufa area.

The greatest number of unique broods (37) was detected on the last visit (July 21-23) (Table 6a). Based on my observations, I believe that the majority of broods raised at Mono Lake were detected by the completion of the third survey. At all summer survey sites except Mill Creek, there were no male/female pairs remaining, and no indication of territorial behavior or distraction behavior by females. Also by this third survey, the number of waterfowl detected had dropped from 430 to 271, possibly due to the departure of male ducks following breeding. A similar drop in numbers was seen in 2002 between the first of July survey (414 waterfowl) and the survey the third week of July (117 total waterfowl).

During the last visit at Mill Creek, however, one female Green-winged Teal and four Gadwall were behaving as if they either were still nesting or had a brood on shore. These females were calling frequently yet remaining close to shore while all other ducks (most with broods) were leading their broods well offshore.

Summer transect surveys – shorebirds

A total of 19 shorebird species were encountered during the summer surveys. The number of shorebirds detected in each survey area during each visit can be found in Tables 1-3, while Table 4 provides a summary of the number of detections for each species during each survey. Definitive southbound migrants were detected during the second survey, and the highest number of shorebird species detected per survey was on the last survey during the third week of July. Numerically, the most shorebird species detected throughout the season were at Warm Springs (15) and Sammann's Springs (14).

The shorebird species for which evidence of breeding was detected include American Avocet, Killdeer, Wilson's Phalarope, Spotted Sandpiper, and Snowy Plover. Of the breeding shorebird species, American Avocet was most abundant with the main concentration of birds in the Sammann's Spring and Warm Spring areas. The most widespread shorebird species was Killdeer which was detected at all survey areas, followed by Wilson's Phalaropes and American Avocet.

Phalaropes, (including Wilson's Phalarope, Red-necked Phalarope, and a single Red Phalarope), were the most abundant migrant shorebirds. The number of phalaropes reported in Tables 1-3 represent only individuals seen within 50 meters of shore, although large rafts could be seen offshore in some areas. Large numbers of Wilson's Phalaropes were detected by the second survey (30 June to 2 July), while Red-necked Phalaropes were not detected from shore until the third survey (third week of July). In 2002, large numbers of staging Wilson's Phalaropes were detected in the DeChambeau Creek area, near the County Park boardwalk. In 2003, however, large numbers of phalaropes (both Wilson's and Red-necked) staged in on- or near-shore areas along the south shore (South Shore Lagoon and Sammann's Spring areas), and the Wilson Creek delta area.

Restoration Ponds

All five DeChambeau Ponds contained water all season, although the water level in Pond 5 appeared lower than in 2002. The water level in County Pond 1 also appeared low, and this pond was covered by a thick layer of surface algae on all three visits. County Pond 2, unlike last year, was full of water and had a dense growth of wetland vegetation.

Three Gadwall broods were detected at DeChambeau Ponds (Ponds 1 and 2) and an additional unidentified *Anas* brood was detected at the DeChambeau Pond 5 (Table 6).

At least six American Coot broods were raised at the DeChambeau Pond complex. Three Gadwall broods were also detected at County Ponds (both ponds combined).

Habitat Use by Waterbirds

Figure 11 shows the relative percent habitat use by the most abundant waterfowl and shorebird species. The total number of observations for each species in 2003 is indicated below the species code on Figure 11. Due to the ephemeral nature of some of the habitat categories, namely the lagoons, it is not possible to determine "use versus availability" for each habitat. Some general patterns of habitat use appear, however. Gadwall and Mallard used a variety of habitats. American Avocets were observed primarily in the nearshore areas of the lake, unvegetated habitats, and hypersaline lagoons. Killdeer were observed primarily in unvegetated areas, while Spotted Sandpipers were primarily using freshwater stream areas and unvegetated habitats.

Fall Aerial Surveys

Mono Lake

A total of thirteen waterfowl species and 43,242 individuals were recorded at Mono Lake during fall aerial surveys (Table 7). The peak number of waterfowl detected at Mono Lake on any single count was 9,920 and occurred on the September 18 survey (Table 7, Figure 12). In terms of total detections, Ruddy Ducks and Northern Shovelers were the dominant species during fall migration (Figure 13) with Ruddy Ducks accounting for 63.27% (27,357) of all detections, and Northern Shovelers accounting for 25.10% (10,853) of all detections (Table 7). Northern Shoveler was the dominant species through September with the peak number of this species (6,008 individuals) recorded on the second survey (18 September). Ruddy Ducks were dominant throughout the remainder of the fall survey season. Unlike last year, Ruddy Duck numbers showed two peaks. The initial peak of 6,406 occurred on the October 2 flight, followed by a decline in numbers on the following survey. Numbers then increased again, with the second peak of 6,432 individuals detected on November 14.

Tables 8 – 13 provide the results of each of the six fall surveys in terms of number of each species detected in each lakeshore segment. Figure 14 shows the relative percent use of each lakeshore segment by waterfowl during each fall survey. The primary areas of waterfowl use during fall 2003 were the south shore (including Sammann's Spring and South Shore Lagoon area), Wilson and Mill Creek deltas, and the northwest shore sites (Lee Vining Creek and DeChambeau Creek). During the September 4 survey, the majority of Northern Shovelers using the lake (a flock of 3,000) were in the South Shore Lagoon area, while on the next two subsequent surveys, Northern Shovelers concentrated in the Wilson and Mill Creek deltas. From the middle of October on, the majority of waterfowl were detected along the northwest shore at Lee Vining Creek delta and DeChambeau Creek delta, while few birds were at Wilson or Mill Creek.

A total of five waterfowl species and 432 individuals were detected at the DeChambeau and County Pond complexes during fall surveys (Table 14). County Pond 1 continued to have a thick layer of algae into the fall, and no waterfowl were detected using this pond during the fall surveys.

The most abundant shorebirds at Mono Lake during fall were phalaropes and American Avocets (Table 15). During fall, the main concentration of American Avocets was the north shoreline areas including Bridgeport Creek, DeChambeau Embayment, and Black Point (see Tables 8-13). Concentrations of phalaropes were detected in the Sammann's Spring area, north shore areas, and off-shore.

Ruddy Duck Distribution

The distribution of Ruddy Ducks varied throughout the fall migratory period (Figure 15). The relative width of the lines represents the percent of total detections on that survey, while Table 16 provides the counts of Ruddy Ducks for the cross-lake segments and summarizes the lakeshore segment counts for this species. Initially, Ruddy Ducks staged in areas offshore of DeChambeau Embayment and Bridgeport Creek area and most of the individuals (range 71 – 99.4%) were detected on cross-lake transects. This pattern held through the end of October. During the last two fall surveys (November 4 and 14), the majority of Ruddy Ducks were detected close to the shore along the west shore of the lake and in the DeChambeau Embayment and Black Point areas, and thus were recorded during the perimeter flight. A similar pattern was observed in 2002, although movement toward shoreline areas appeared to occur earlier in the year in 2002 (by October 3) (LADWP 2002).

Fall Aerial Surveys

Bridgeport Reservoir

A total of 17 waterfowl species and 58,821 individuals were recorded at Bridgeport Reservoir during fall aerial surveys (Table 17). The peak number of waterfowl detected on any single count at Bridgeport Reservoir was 20,941 individuals and occurred on October 2 (Table 17, Figure 12). Following the October 2 count, a ground visit confirmed this estimate from the air.

Figure 16 shows the number of each species detected per survey at Bridgeport Reservoir for all species that comprised at least 1% of the total detections for fall. The most abundant species, in terms of total detections were Northern Shoveler followed by Gadwall, Green-winged Teal and Mallard. The majority of Northern Shovelers and Gadwall were detected on the first three surveys (September 4 to October 2). Green-winged Teal numbers indicated two “waves” of migration. Numbers first increased with each successive survey from September 4 through October 2, showed a drop on the mid-October count, then increased over the next two surveys. The peak number of Mallards was detected during the October 2 survey, with substantially fewer detected on subsequent surveys.

Tables 18-23 provide the results of each of the six fall surveys in terms of number of each species detected by lakeshore segment. The West Bay area was the primary area of waterfowl concentration throughout the fall season (Figure 17).

Fall Aerial Surveys

Crowley Reservoir

A total of 19 waterfowl species and 74,215 individuals were detected at Crowley Reservoir during fall aerial surveys (Table 24). The peak number of waterfowl detected on any single count at Crowley Reservoir was 15,555 individuals and occurred on October 2 (Table 24, Figure 12).

The most abundant species, in terms of total detections were Mallard followed by Green-winged Teal, Northern Pintail and Northern Shoveler. Figure 18 shows the number of each species detected per survey at Crowley for all species that comprised at least 1% of the total detections for fall. The majority of Mallards were detected on the last two surveys in the month of November. Although there was a slight increase in the number of detections through the fall survey period, there was no noticeable peak to the number of Green-winged Teal detected at Crowley. The majority of Northern Pintail were detected during the two October flights, while the majority of Northern Shovelers were detected between September 18 and October 2.

Tables 25-30 provide the results of each of the six fall surveys in terms of number of each species detected by lakeshore segment. Through the beginning of November, the majority of waterfowl detections at Crowley were in McGee Bay (MCBA) (Figure 19). The relative use of the Chalk Cliffs area (CHCL) increased in November due a large flock of Mallards present along this east shore area of the reservoir. The majority of the flock was offshore. A similar situation was observed in 2002, when a large raft of Mallards was detected offshore along the east shore during the mid-November flight.

Comparison of Mono Lake with Bridgeport and Crowley Reservoirs

The peak number of waterfowl detections at Bridgeport and Crowley Reservoirs occurred on the October 2 survey, while the peak at Mono Lake occurred on the September 18 survey (refer to Figure 12). All three locations showed an increase in total detections from early September to October, followed by a decline in numbers, and a second pulse of migrants from mid-October to mid-November.

The relative and absolute abundance of waterfowl species differed greatly between Mono Lake and the two reservoirs. For comparison, Figure 20 shows the relative abundance of the three most abundant species at Mono Lake and the five most abundant species at Bridgeport and Crowley on each survey. Two species dominated fall migration at Mono - Northern Shoveler early in the season, and Ruddy Ducks throughout the remainder of the fall. In contrast, the dominant species at the reservoirs varied through the fall migration period.

Figure 21 is a bar graph showing the absolute abundance of the three most abundant species at Mono, and the five most abundant species at Bridgeport and Crowley on each survey, while the side graphs show the total detections over the entire fall survey period. The side graphs show a noticeable disparity between the two reservoirs and Mono Lake in terms of total detections for several species. The total detections of Ruddy Ducks over the season was much higher at Mono Lake than Bridgeport or Crowley. The total detections of the other dominant species at Mono, Northern Shoveler, does not appear to be significantly different the total detections at either Bridgeport or Crowley. In contrast, the total detections of species dominant at the reservoirs, namely Green-winged Teal, Mallard, Gadwall, and Northern Pintail, were noticeably lower at Mono.

Analysis of trend in waterfowl numbers

The 1996 to 2003 data indicates a significant positive trend in peak waterfowl numbers, excluding Ruddy Ducks ($p = 0.018$, $df = 1,6$). Figure 22 is a graph of the regression line that illustrates the relationship of the peak number of waterfowl detected at Mono Lake over time (1996-2003).

DISCUSSION

Six waterfowl species (Gadwall, Mallard, Northern Pintail, Green-winged Teal, Cinnamon Teal and Canada Goose) were found to use the Mono Lake wetlands for brooding. Although Cinnamon Teal are often present throughout the summer at Mono, this was the first year in which a brood was detected using Mono Lake wetlands since state-mandated monitoring began in 1996. The total number of waterfowl broods detected in 2003 (65) is slightly higher, although comparable to that reported in 2002 (56). As was the case in the previous year, the Mill Creek, Wilson Creek, and South Shore Lagoon areas supported the greatest number of waterfowl broods.

Fall migration at Mono Lake was dominated by the presence of Northern Shovelers and Ruddy Ducks. The primary areas of waterfowl use during fall were the south shore (including Sammann’s Spring and South Shore Lagoon area), Wilson Creek, and sites on the west shore including DeChambeau Creek and Lee Vining Creek. While the Wilson Creek area appears attractive to Northern Shovelers, after the departure of the majority of Northern Shovelers, few waterfowl were detected in this area. Instead, the main areas of use by waterfowl later in the season were west shore and south shore sites. A similar pattern was observed in 2002, and possibly in previous years surveys. It is unknown whether this seasonal shift in waterfowl use is due to a difference in prey availability or foraging conditions for Northern Shoveler versus species dominant later in the fall, namely Mallards, Green-winged Teal and Canada Goose, human disturbance, or some other factor.

Ruddy Ducks exhibited a shift in distribution throughout the fall, occurring primarily off-shore early in fall, and close to the shoreline later in the fall. Johnson and Jehl (2002) report that Ruddy Ducks eat primarily brine fly larvae at Mono Lake and forage in shallow areas of the lake in the vicinity of hard substrates. The areas where Ruddy Ducks concentrate coincide well with shallow-water areas of the lake with the exception of the eastern shore, where generally few are detected. This exception is likely due to the fact that the eastern end of the lake, while shallow, has very limited submerged, hard substrates with which the brine fly are associated. With the information available, it is difficult to interpret completely the seasonal pattern of Ruddy Duck distribution. Some questions that remain unanswered include whether the time budgets of the birds in the off-shore areas early in fall are significantly different than those occurring in the near-shore areas later in the fall, how long individuals remain at the lake, and whether individuals exhibit seasonal movement while at the lake due to body condition, molt stage, or prey availability.

This was the first year that comparison counts were conducted at all three bodies through the entire fall survey period. This data provided insight regarding the relative use of Mono Lake, Bridgeport Reservoir, and Crowley Reservoir by waterfowl during fall migration. On any single count throughout the fall, the number of Ruddy Ducks at Mono Lake was greater than at either Bridgeport or Crowley, and there were significantly more total detections of Ruddy Ducks at Mono Lake. While it is not known how long individual Ruddy Ducks stay at Mono Lake, the fact that there were always more Ruddy Ducks at Mono Lake indicates a higher proportional use of Mono Lake than Bridgeport or Crowley Reservoirs by this species. The large disparity in total detections of Green-winged Teal, Mallard, Gadwall, and Northern Pintail between Mono Lake and the two reservoirs indicates that either a comparable number of individuals of these species are not stopping at Mono Lake, or that the turnover rate of individuals at Mono Lake is high, or both.

The analysis of the trend in peak waterfowl numbers indicates a significant, positive trend in the peak number of waterfowl, (exclusive of Ruddy Ducks) detected at Mono Lake since 1996. The variable nature of population data necessitates caution in the interpretation of this relative short-term trend.

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Table 1. Summer ground data, Survey 1 – June 9-11, 2003

Waterfowl	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Blue-winged Teal				2			2					**4**
Canada Goose			2				4			2		**8**
Cinnamon Teal	14	3		1	3	1	12		2		5	**41**
Gadwall	1	4	22	9	2		20	60	5	19	48	**190**
Green-winged Teal	1	5	4	1	1				1	1	1	**15**
Mallard		1	11	4	3	3	3	14		2	9	**50**
Northern Pintail		1				2	6	2	1		2	**14**
Total waterfowl by area	**16**	**14**	**39**	**17**	**9**	**6**	**47**	**76**	**9**	**24**	**65**	**322**

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet			29			166	155	93	26	2	26	**497**
Black-necked Stilt				3		5	3				4	**15**
Dowitcher sp.											2	**2**
Killdeer	2		5	4		4	11	3	8	2	7	**46**
Snowy Plover						21	13					**34**
Spotted Sandpiper	5	7	1							3	3	**19**
Willet						1						**1**
Wilson's Phalarope		1	6		2	33	363	14			6	**425**
Total shorebirds by area	**7**	**8**	**41**	**7**	**2**	**230**	**545**	**110**	**34**	**7**	**48**	**1039**

Table 2. Summer ground data, Survey 2 – June 30- July 2, 2003

Waterfowl	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Brandt							1					**1**
Canada Goose			20					5			1	**26**
Cinnamon Teal				7		1	2	1		3		**14**
Gadwall	4	8	8	4	1	5	1	14	2	218	43	**308**
Green-winged Teal	1									2		**3**
Mallard		2	9			2	18	11		12	10	**64**
Northern Pintail						2		3		3	2	**10**
Ruddy Duck				1						2		**3**
Unidentified *Anas* sp.				1								**1**
Total waterfowl by area	**5**	**10**	**37**	**13**	**1**	**10**	**22**	**34**	**2**	**240**	**56**	**430**

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet		5	7			82	257	67	4	5	11	**438**
Black-necked Stilt		2				6						**8**
Killdeer	5	5	7	1	1	2	13	2	4	6	18	**64**
Least Sandpiper							18					**18**
Long-billed Curlew						2		1		2	2	**7**
Long-billed Dowitcher						4						**4**
Snowy Plover						26	31		3			**60**
Spotted Sandpiper	7	4	1							6		**18**
Western Sandpiper						7						**7**
White-faced Ibis						1	9					**10**
Willet						7	3					**10**
Wilson's Phalarope	250	2480				11	4158	1		362	5861	**13123**
Total shorebirds by area	**262**	**2496**	**15**	**1**	**1**	**148**	**4489**	**71**	**11**	**381**	**5892**	**13767**

Table 3. Summer ground data, Survey 3 – July 21-23, 2003

Waterfowl	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Blue-winged Teal								1				**1**
Canada Goose			35				5				3	**43**
Cinnamon Teal				2		2					6	**10**
Gadwall		9	5	3	2	1		9		96	41	**166**
Green-winged Teal										1	4	**5**
Mallard	1	3				3	10	4		1	15	**37**
Northern Pintail								2		2	2	**6**
Ruddy Duck										3		**3**
Total waterfowl by area	**1**	**12**	**40**	**5**	**2**	**6**	**15**	**16**	**0**	**103**	**71**	**271**

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet			17			134	226	21	24	7	139	**568**
Greater Yellowlegs						1	3					**4**
Killdeer	2	8	15	1	4	12	4		13	4	23	**86**
Least Sandpiper		12					13	7	9			**41**
Long-billed Curlew								1	1			**2**
Long-billed Dowitcher						9	10					**19**
Marbled Godwit						1	1					**2**
Red Phalarope											1	**1**
Red-necked Phalarope	125					115	1268	2331		25	12160	**16024**
Ruddy Turnstone						2						**2**
Semi-palmated Plover						3						**3**
Snowy Plover						11	13					**24**
Spotted Sandpiper	4	8	13				1	4		7	3	**40**
Western Sandpiper						32	73					**105**
Whimbrel									1			**1**
White-faced Ibis							12	4	1			**17**
Willet							1		8			**9**
Wilson's Phalarope	10	4				7	3620	24	1		1043	**4709**
Total shorebirds by area	**141**	**32**	**45**	**1**	**4**	**327**	**5245**	**2392**	**58**	**43**	**13369**	**21657**

Table 4. Summary of ground count data for Mono Lake, 2003

Waterfowl	Survey 1	Survey 2	Survey 3	Total Detections
Blue-winged Teal	4		1	5
Brandt		1		1
Canada Goose	8	26	43	77
Cinnamon Teal	41	14	10	65
Gadwall	190	308	166	664
Green-winged Teal	15	3	5	23
Mallard	50	64	37	151
Northern Pintail	14	10	6	30
Ruddy Duck		3	3	6
Unidentified *Anas* sp.		1		1
Total Waterfowl	322	430	271	1023

Shorebirds	Survey 1	Survey 2	Survey 3	Total Detections
American Avocet	497	438	568	1503
Black-necked Stilt	15	8		23
Greater Yellowlegs			4	4
Killdeer	46	64	86	196
Least Sandpiper		18	41	59
Long-billed Curlew		7	2	9
Long-billed Dowitcher		4	19	23
Marbled Godwit			2	2
Red Phalarope			1	1
Red-necked Phalarope			16024	16024
Ruddy Turnstone			2	2
Semi-palmated Plover			3	3
Snowy Plover	34	60	24	118
Spotted Sandpiper	19	18	40	77
Western Sandpiper		7	105	112
White-faced Ibis		10	17	27
Whimbrel			1	1
Willet	1	10	9	20
Wilson's Phalarope	425	13123	4709	18257
Total Shorebirds	1037	13767	21657	36461

Table 5. 2003 Brood data

Date	Species	Brood ID	Location	Easting	Northing	Age Class	Brood size
9-Jun-03	Mallard	MALL 1	South Shore Lagoons	327121	4202880	II	2
10-Jun-03	Cinnamon Teal	CITE 1	Wilson Creek	314091	4209731	Ia	8
11-Jun-03	Canada Goose	CAGO1	Samman's Spring	330234	4205004	(1/2 adult)	2
30-Jun-03	Gadwall	GADW1	South Shore Lagoons	326195	4202401	Ia	3
30-Jun-03	Gadwall	GADW2	South Shore Lagoons	326443	4202660	Ia	3
30-Jun-03	Gadwall	GADW3	South Shore Lagoons	326443	4202660	Ia	5
30-Jun-03	Gadwall	GADW4	South Shore Lagoons	326467	4202677	Ia	4
30-Jun-03	Northern Pintail	NOPI1	South Shore Lagoons	328457	4204030	Ic	13
1-Jul-03	Canada Goose	CAGO2	DeChambeau Creek	311721	4209309	(3/4adult)	8
1-Jul-03	Canada Goose	CAGO3	DeChambeau Creek	311726	4209311	(downy)	3
1-Jul-03	Canada Goose	CAGO4	DeChambeau Creek	311725	4209313	(downy)	6
1-Jul-03	Gadwall	GADW5	Mill Creek	313537	4209590	Ia	2
1-Jul-03	Gadwall	GADW6	Mill Creek	313538	4209590	Ic	6
1-Jul-03	Gadwall	GADW7	Mill Creek	313549	4209602	Ia	2
1-Jul-03	Gadwall	GADW9	Mill Creek	313664	4209611	Ia	2
1-Jul-03	Gadwall	GADW8	Mill Creek	313664	4209612	Ia	6
1-Jul-03	Gadwall	GADW10	Mill Creek	313669	4209608	Ia	2
1-Jul-03	Gadwall	GADW11	Mill Creek	313670	4209608	Ia	8
1-Jul-03	Gadwall	GADW12	Mill Creek	313716	4209576	Ia	5
1-Jul-03	Gadwall	GADW13	Wilson Creek	313941	4209666	Ia	5
1-Jul-03	Gadwall	GADW14	Wilson Creek	313944	4209665	Ib	2
1-Jul-03	Gadwall	GADW15	Lee Vining Creek	315320	4205234	Ib	5
1-Jul-03	Green-winged Teal	GWTE1	Lee Vining Creek	315320	4205234	Ia	4
1-Jul-03	Gadwall	GADW16	County Pond 2	317748	4212503	Ib	1
1-Jul-03	*Anas* sp.	*Anas* sp.	DeChambeau Pond 5	317331	4213027	IIb or IIc	3
1-Jul-03	Northern Pintail	NOPI2	Mill Creek	313353	4209442	Ia	8
2-Jul-03	Gadwall	GADW17	Sammann’s Spring	329625	4204545	Ia	8
2-Jul-03	Mallard	MALL2	Sammann’s Spring	330159	4204864	Ia	3
2-Jul-03	Mallard	MALL3	Sammann’s Spring	330158	4204863	II	7
21-Jul-03	Gadwall	GADW18	Rush Creek	319873	4202645	Ib	10
21-Jul-03	Gadwall	GADW19	Rush Creek	319874	4202646	Ib	1
21-Jul-03	Gadwall	GADW20	South Shore Lagoons	326255	4202439	I	14
21-Jul-03	Gadwall	GADW21	South Shore Lagoons	326255	4202449	I	14
21-Jul-03	Gadwall	GADW22	South Shore Lagoons	326495	4202693	II	6
21-Jul-03	Gadwall	GADW23	South Shore Lagoons	326511	4202707	II	7
21-Jul-03	Gadwall	GADW24	South Shore Lagoons	327092	4202958	IIa	4
21-Jul-03	Gadwall	GADW25	South Shore Lagoons	327973	4203661	Ib	6
21-Jul-03	Mallard	MALL4	Rush Creek	319873	4202646	Ic	5
21-Jul-03	Mallard	MALL5	South Shore Lagoons	328400	4203957	IIc	6
21-Jul-03	Northern Pintail	NOPI3	South Shore Lagoons	328376	4204011	Ia	5
21-Jul-03	Northern Pintail	NOPI4	South Shore Lagoons	328378	4204013	Ia	5
22-Jul-03	Gadwall	GADW26	DeChambeau Creek	311809	4209385	Ib	10
22-Jul-03	Gadwall	GADW27	DeChambeau Creek	311810	4209388	Ic	5
22-Jul-03	Gadwall	GADW28	DeChambeau Creek	311810	4209392	Ic	2
22-Jul-03	Gadwall	GADW29	DeChambeau Creek	311810	4209393	Ic	3
22-Jul-03	Gadwall	GADW30	DeChambeau Creek	311811	4209393	Ib	10

Table 5. Continued

22-Jul-03	Gadwall	GADW31	Mill Creek	313551	4209602	II	7
22-Jul-03	Gadwall	GADW32	Mill Creek	313551	4209602	IIb	4
22-Jul-03	Gadwall	GADW33	Mill Creek	313553	4209604	I	10
22-Jul-03	Gadwall	GADW34	Mill Creek	313553	4209604	I	5
22-Jul-03	Gadwall	GADW35	Mill Creek	313565	4209610	II	4
22-Jul-03	Gadwall	GADW36	Mill Creek	313568	4209611	IIb	2
22-Jul-03	Gadwall	GADW37	Mill Creek	313571	4209612	IIa	7
22-Jul-03	Gadwall	GADW38	Mill Creek	313576	4209614	I	2
22-Jul-03	Gadwall	GADW39	Mill Creek	313584	4209615	Ib or Ic	7
22-Jul-03	Gadwall	GADW40	Mill Creek	313610	4209617	I	6
22-Jul-03	Gadwall	GADW41	Mill Creek	313675	4209606	Ib	8
22-Jul-03	Gadwall	GADW42	Wilson Creek	313931	4209656	Ib	7
22-Jul-03	Gadwall	GADW43	Wilson Creek	314018	4209708	Ia	5
22-Jul-03	Gadwall	GADW44	Wilson Creek	314020	4209708	II	5
22-Jul-03	Green-winged Teal	GWTE2	Wilson Creek	314020	4209708	I	5
22-Jul-03	Gadwall	GADW45	Wilson Creek	314020	4209708	Ia	8
22-Jul-03	Gadwall	GADW46	Wilson Creek	314030	4209716	II	6
22-Jul-03	Gadwall	GADW47	Wilson Creek	314034	4209716	I	6
22-Jul-03	Gadwall	GADW48	Wilson Creek	314039	4209719	Ib	4
22-Jul-03	Gadwall	GADW49	Wilson Creek	314047	4209720	I	11
22-Jul-03	Gadwall	GADW50	Wilson Creek	314096	4209721	II	8
22-Jul-03	Gadwall	GADW51	Wilson Creek	314095	4209717	IIb	2
22-Jul-03	Gadwall	GADW52	Wilson Creek	314154	4209721	I	10
22-Jul-03	Gadwall	GADW53	Wilson Creek	314154	4209721	IIa	3
22-Jul-03	Gadwall	GADW54	Wilson Creek	314257	4209689	I	8
22-Jul-03	Gadwall	GADW55	Wilson Creek	314264	4209687	II	10
22-Jul-03	Gadwall	GADW56	DeChambeau Pond 1	317234	4213432	Ic	9
22-Jul-03	Gadwall	GADW57	DeChambeau Pond 1	317233	4213433	Ic	8
22-Jul-03	Gadwall	GADW58	County Pond 1	317837	4212540	Ib	8
22-Jul-03	Gadwall	GADW59	County Pond 1	317839	4212543	Ic	7
22-Jul-03	Gadwall	GADW60	DeChambeau Pond 2	317240	4213377	Ic	2
22-Jul-03	Mallard	MALL6	Lee Vining Creek	315353	4205247	Ic	10
22-Jul-03	Northern Pintail	NOPI5	Wilson Creek	313849	4209533	Ib	13
23-Jul-03	Mallard	MALL7	Warm Springs	331874	4211550	Ib	2
23-Jul-03	Mallard	MALL8	Sammann’s Spring	329685	4204630	Ib	8

Table 6a. Number of unique broods detected per visit

Shoreline segment	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	Total unique broods
Survey 1	0	0	0	0	0	0	1	1	0	0	1	3
Survey 2	2	0	3	0	1	0	3	5	0	9	2	25
Survey 3	1	3	5	3	2	1	1	5	0	6	10	37
Total unique broods	3	3	8	3	3	1	5	11	0	15	13	65

Table 6b. Total number of broods detected per visit

Shoreline segment	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	Total broods
Survey 1							1	1			1	3
Survey 2	2		3	1	1		3	5		9	2	26
Survey 3	1	3	5	3	2	1	1	9		11	16	52
Total broods detected	3	3	8	4	3	1	5	15	0	20	19	81

Table 7. Summary of fall aerial survey counts – Mono Lake

Species	4-Sept	18-Sept	2-Oct	14-Oct	4-Nov	14-Nov	**Total Detections**	%Total Detections
American Wigeon		3	5	2		32	42	0.09
Bufflehead		1				1	2	0.00
Canada Goose		5		8	46	212	271	0.63
Cinnamon Teal		3	4				7	0.02
Gadwall	249	45	40	20	5		359	0.83
Green-winged Teal	40	157	212	210	268	682	1569	3.63
Lesser Scaup			2		1	8	11	0.03
Mallard	90	1	29	37	399	407	963	2.23
Northern Pintail		1	10		14	46	71	0.16
Northern Shoveler	3287	6008	1318	180	30	30	10853	25.10
Redhead		1			4		5	0.01
Ring-necked Duck		1				2	3	0.01
Ruddy Duck	1436	2909	6406	4304	5870	6432	27357	63.27
Unidentified *Anas*		785	282	155	494	10	1726	3.99
Unidentified diving ducks					3		3	0.01
Total waterfowl	5102	9920	8308	4916	7134	7862	43242	

Table 8. Mono Lake - fall aerial survey, 4 September, 2003

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Gadwall										240				5	4	249	249
Green-winged Teal			20									20				40	40
Mallard			3	83							4					90	90
Northern Shoveler			3000	60				8	5	60	150	4				3287	3287
Ruddy Duck								4			32					36	1436
Total Waterfowl	0	0	3023	143	0	0	0	12	5	300	186	24	0	5	4	3702	5102

	Lakeshore segment							Shoreline Total	Lakewide Total
Species	West shore	South Shore	SASP	WASP	North Shore	West shore	RACO		
American Avocet			50	2	3724			3776	3776
Black-necked Stilt			10	20	40			70	70
Phalaropus sp.			3400		1300			4700	11750
Unidentified shorebirds		61	6		1921		150	1988	1988
Wading birds			8		18			26	26
White-faced Ibis					20			20	20
Forster's Tern			20					20	20
Total Waterbirds	0	61	3494	22	7023	0	150	10600	17650

Table 9. Mono Lake - fall aerial survey, 18 September, 2003

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Wigeon	3															3	3
Bufflehead															1	1	1
Canada Goose												5				5	5
Cinnamon Teal	3															3	3
Gadwall	2			1								30				33	45
Green-winged Teal	60								2		65	30				157	157
Mallard				1												1	1
Northern Shoveler	15			65			115	3	25	5200	520	60		5		6008	6008
Northern Pintail	1															1	1
Redhead	1															1	1
Ring-necked Duck	1															1	1
Ruddy Duck		2				45					4				77	128	2909
Unidentified	265									150	65	305				785	785
Total Waterfowl	351	2	0	67	0	45	115	3	27	5350	654	430	0	5	78	**7127**	**9920**

	Lakeshore segment															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Avocet	40			235	475	305	1375	1077	477							3984	3984
American Coot	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	18
Black-necked Stilt				26	2											28	28
White-faced Ibis				20												20	20
Large wading bird									17						1	18	18
Western/Least Sandpiper		7		20	18									89		134	134
Phalaropus sp.												95	350	50		495	8315
Marbled Godwit					2				6							8	8
Killdeer					4											4	4
Long-billed Curlew									8	1						9	9
Total waterbirds	43	7	0	301	501	305	1375	1077	508	1	0	95	350	139	1	4703	12538

Table 10. Mono Lake - fall aerial survey, 2 October, 2003

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Wigeon														5		5	5
Cinnamon Teal	2													2		4	4
Gadwall											25			15		40	40
Green-winged Teal	60			8				4				30		110		212	212
Lesser Scaup														2		2	2
Mallard					8								1	20		29	29
Northern Pintail														10		10	10
Northern Shoveler				18						1075	225					1318	1318
Ruddy Duck	2	40	9	6			400	250		200	475	200	61		153	1796	6406
Unidentified	23				20							170		69		282	282
Total Waterfowl	87	40	9	32	28	0	400	254	0	1275	725	400	62	233	153	3698	8308

	Lakeshore segment															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Avocet				40	34	20	3217	700	600	115						4726	4726
American Coot			3	225										20		248	254
Black-necked Stilt					1											1	1
Great Blue Heron													1	1	1	3	3
Great Egret			3													3	3
Medium wading bird						15	2									17	17
Phalaropus sp.									5500							5500	18000
Western/Least Sandpiper	10											35				45	45
Willet										2						2	2
Total Waterbirds	10	0	6	265	35	35	3219	700	6100	117	0	35	1	21	1	10545	23051

Table 11. Mono Lake - fall aerial survey, 14 October, 2003

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Wigeon																0	0
Canada Goose										8						8	8
Gadwall											20					20	20
Green-winged Teal				80						40				90		210	210
Mallard											12			25		37	37
Northern Shoveler														180		180	180
Ruddy Duck												25				25	4304
Unidentified														155		155	155
Total Waterfowl	0	0	0	80	0	0	0	0	0	48	32	25	0	450	0	635	4914

	Lakeshore segment															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Avocet				75					21			15				111	111
American Coot																0	0
American White Pelican				550												550	552
Common Loon																0	1
Phalaropus sp.																0	725
Western Grebe																0	1
Chalidris sp.			3						83							86	86
Total Waterbird	0	0	3	625	0	0	0	0	104	0	0	15	0	0	0	747	1476

Table 12. Mono Lake - fall aerial survey, 4 November, 2003

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Canada Goose			4	10			10					22				46	46
Gadwall										5						5	5
Green-winged Teal			39	38	12						55			120	4	268	268
Lesser Scaup																0	1
Mallard	18		35	50	18						66	120	54	30	8	399	399
Northern Pintail				2									12			14	14
Northern Shoveler										30						30	30
Redhead														4		4	4
Ruddy Duck	265	451		12				55	802	93	192	120	1443	450	448	4331	5870
Unidentified Anas				5								140	49	300		494	494
Unidentified diving ducks										3						3	3
Total Waterfowl	283	451	78	117	30	0	10	55	802	131	313	402	1558	904	460	5594	7134

	Lakeshore segment															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Coot											1					1	3
American Avocet					15			30		8		6				59	59
American White Pelican				3												3	3
Great Egret								1								1	1
Killdeer						2			1							3	3
Western Grebe		1														1	1
Medium Wading bird	50			4												54	54
Calidris sp.					25	5			15							45	45
Total Waterbirds	50	1	0	7	40	7	0	31	16	8	1	6	0	0	0	167	169

Table 13. Mono Lake - fall aerial survey, 14 November, 2003

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Wigeon										12		20				32	32
Bufflehead												1				1	1
Canada Goose				200			11								1	212	212
Green-winged Teal			20	220							12	430				682	682
Lesser Scaup								2						6		8	8
Mallard		3	147	14	2			22	65			150	2	2		407	407
Northern Pintail			2	2					30				12			46	46
Northern Shoveler			4					3	18			5				30	30
Ring-necked Duck														2		2	2
Ruddy Duck	105	8	17	11				3232	256	11		1	1485	358	73	5557	6432
Unidentified Anas				4				6								10	10
Total Waterfowl	105	11	190	451	2	0	11	3265	369	23	12	607	1499	368	74	6987	7862

Waterbird Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Coot	1							2				12	122	10	1	148	148
American White Pelican				3				1								4	4
American Avocet								8								8	8
Killdeer		6				2										8	8
Unidentified shorebirds						5		3		22						30	30
Great Blue Heron										1	1				1	3	3
Great Egret								1								1	1
Willet												4				4	4
Least Sandpiper			8	20	3											31	31
Total Waterbirds	1	6	8	23	3	7	0	15	0	23	1	16	122	10	2	237	237

Table 14. Mono Lake Restoration ponds – Aerial waterfowl counts - 2003

Sept 4	CAGO	GADW	MALL	NOSH	RUDU	*Anas*	AMCO
COPO_1							
COPO_2		3					
DEPO_1						15	10
DEPO_2						10	
DEPO_3						7	
DEPO_4						5	20
DEPO_5				1			
Total		3		1		37	30

Sept 18	CAGO	GADW	MALL	NOSH	RUDU	*Anas*	AMCO
COPO_1							
COPO_2							2
DEPO_1						40	5
DEPO_2						30	
DEPO_3			15				
DEPO_4							35
DEPO_5							
Total		0	15			70	42

Oct 2	CAGO	GADW	MALL	NOSH	RUDU	*Anas*	AMCO
COPO_1							
COPO_2							3
DEPO_1		20				5	26
DEPO_2							8
DEPO_3			2			3	15
DEPO_4						20	30
DEPO_5							
Total		20	2			28	82

Oct 18	CAGO	GADW	MALL	NOSH	RUDU	*Anas*	AMCO
COPO_1							
COPO_2							22
DEPO_1						120	
DEPO_2					2		
DEPO_3							12
DEPO_4			5		5	15	25
DEPO_5							1
Total			5		7	135	60

Nov 4	CAGO	GADW	MALL	NOSH	RUDU	*Anas*	AMCO
COPO_1							
COPO_2			4				25
DEPO_1							60
DEPO_2							2
DEPO_3	20		25			40	
DEPO_4							
DEPO_5							
Total			29			40	87

Nov 14	CAGO	GADW	MALL	NOSH	RUDU	*Anas*	AMCO
COPO_1							
COPO_2							27
DEPO_1							70
DEPO_2							
DEPO_3							2
DEPO_4			10			10	65
DEPO_5							
Total			10			10	164

Total Detections	CAGO	GADW	MALL	NOSH	RUDU	*Anas*	Total Waterfowl
	20	23	61	1	7	320	432

Table 15. Summary of shorebird/waterbird counts at Mono Lake during fall aerial counts

Survey Date	4-Sep	18-Sep	2-Oct	18-Oct	4-Nov	14-Nov	Total Detections
American Avocet	3776	3984	4726	111	59	8	12664
American Coot		18	254		3	148	423
American White Pelican				552	3	4	559
Black-necked Stilt	70	28	1				99
Common Loon				1			1
Double-crested cormorant			3				3
Forster's Tern	20						20
Great Blue Heron			3			3	6
Great Egret			3		1	1	5
Killdeer		4			3	8	15
Least Sandpiper	31						31
Long-billed Curlew		9					9
Marbled Godwit		8					8
Western Grebe				1	1		2
White-faced Ibis	20	20					40
Willet				2		4	6
Chalidris spp.	1988	134	45	86	45	30	2328
Phalaropus spp.	11750	8315	18000	725			38790
Unidentified Wading birds	26	18	17		54		115

Table 16. Seasonal distribution of Ruddy Ducks. Total Ruddy Ducks and % of total Ruddy Ducks detected along each cross-lake transect or lakeshore segment during fall surveys.

Segment	4-Sep	***%Det***	18-Sep	***%Det***	2-Oct	***%Det***	14-Oct	***%Det***	4-Nov	***%Det***	14-Nov	***%Det***
1a									62	***1.06***	22	***0.34***
1b			11	***0.38***	1	***0.02***	2	***0.05***	328	***5.59***		
2a			7	***0.24***							28	***0.44***
2b			2	***0.07***	2	***0.03***			13	***0.22***		
2c	13	***0.91***	10	***0.34***	52	***0.81***	18	***0.42***			2	***0.03***
3a			5	***0.17***	110	***1.72***	55	***1.28***			16	***0.25***
3b			2	***0.07***							2	***0.03***
3c			53	***1.82***	4	***0.06***	12	***0.28***				
3d			60	***2.06***	327	***5.10***	250	***5.81***	59	***1.01***	78	***1.21***
4a	5	***0.35***			3	***0.05***	21	***0.49***	89	***1.52***	25	***0.39***
4b	8	***0.56***	80	***2.75***			14	***0.33***	6	***0.10***		
4c	4	***0.28***	11	***0.38***			30	***0.70***				
4d	1	***0.07***	8	***0.28***	14	***0.22***	116	***2.70***	6	***0.10***	7	***0.11***
5a	10	***0.70***	153	***5.26***	466	***7.27***	68	***1.58***	138	***2.35***	79	***1.23***
5b			46	***1.58***	7	***0.11***	1	***0.02***			60	***0.93***
5c			20	***0.69***	1	***0.02***						
5d					2	***0.03***	123	***2.86***	10	***0.17***	116	***1.80***
6a	109	***7.59***	8	***0.28***	5	***0.08***	477	***11.08***	556	***9.47***	310	***4.82***
6b	29	***2.02***			8	***0.12***	3	***0.07***				
6c	38	***2.65***	39	***1.35***	13	***0.20***	16	***0.37***			10	***0.16***
7a	665	***46.31***	708	***24.34***	46	***0.72***	875	***20.33***	97	***1.65***	65	***1.01***
7b	88	***6.13***	585	***20.11***	60	***0.94***	156	***3.62***				
7c	20	***1.39***	315	***10.83***	9	***0.14***	527	***12.24***	148	***2.52***	10	***0.16***
8a	230	***16.02***	330	***11.68***	2365	***36.92***	1260	***29.28***	6	***0.10***	43	***0.67***
8b	180	***12.53***	318	***10.93***	1115	***17.41***	255	***5.92***	21	***0.36***	2	***0.03***
RUCR					2	***0.03***			265	***4.51***	105	***1.63***
SOTU			2	***0.07***	40	***0.62***			451	***7.68***	8	***0.12***
SSLA					9	***0.14***					17	***0.26***
SASP					6	***0.09***			12	***0.20***	11	***0.17***
WASP												
NESH			45	***1.55***								
BRCR					400	***6.24***						
DEEM	4	***0.28***			250	***3.90***			55	***0.94***	3232	***50.25***
BLPO						***0.00***			802	***13.66***	256	***3.98***
WICR					200	***3.12***			93	***1.58***	11	***0.17***
MICR	32	***2.23***	4	***0.14***	475	***7.41***			192	***3.27***		
DECR					200	***3.12***	25	***0.58***	120	***2.04***	1	***0.02***
WESH					61	***0.95***			1443	***24.58***	1485	***23.09***
LVCR									450	***7.67***	358	***5.57***
RACO			77	***2.65***	153	***2.39***			448	***7.63***	73	***1.13***
Total	**1436**		**2909**		**6406**		**4304**		**5870**		**6432**	

Table 17. Summary of fall aerial survey counts – Bridgeport Reservoir

Species	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Survey 6	Total Detections	%Total Detections
American Wigeon		175	220		11		406	0.69
Bufflehead		4	45	60	111	74	294	0.50
Canada Goose	195	260	250	380		502	1587	2.70
Canvasback					10	15	25	0.04
Cinnamon Teal		451					451	0.77
Common Goldeneye						3	3	0.01
Common Mergenser	7		3		13	29	52	0.09
Gadwall	2337	3717	4569	435	25	5	11088	18.85
Green-winged Teal	470	2200	2390	756	1462	3089	10367	17.62
Lesser Scaup				70	6	6	82	0.14
Mallard	597	154	6605	884	874	612	9726	16.53
Northern Pintail		457	2200	2457	12	60	5186	8.82
Northern Shoveler	3540	2700	3738	2327	188	15	12508	21.26
Redhead	13	92	55	58	26		244	0.41
Ring-necked Duck		2	20			10	32	0.05
Ruddy Duck	200		285	427	42	3	957	1.63
Tundra Swan						85	85	0.14
Unidentified *Anas*	130	3502	561	722	280	533	5728	9.74
Total Waterfowl	7489	13714	20941	8576	3060	5041	58821	

Table 18. Bridgeport Reservoir - fall aerial survey, 4 September, 2003

Waterfowl Count	Lakeshore segment			Total
Species	NOAR	WEBA	EASH	
Canada Goose	0	195	0	195
Common Mergenser	7	0	0	7
Gadwall	7	2300	30	2337
Green-winged Teal	0	470	0	470
Mallard	14	580	3	597
Northern Shoveler	0	3500	40	3540
Redhead	13	0	0	13
Ruddy Duck	0	200	0	200
Unidentified	30	100	0	130
Total waterfowl	71	7345	73	7489

Table 19. Bridgeport Reservoir - fall aerial survey, 18 September, 2003

Waterfowl Count	Lakeshore segment			Total
Species	NOAR	WEBA	EASH	
American Wigeon	0	175	0	175
Bufflehead	0	4	0	4
Canada Goose	0	260	0	260
Cinnamon Teal	0	450	1	451
Gadwall	32	3600	85	3717
Green-winged Teal	0	2200	0	2200
Mallard	0	150	4	154
Northern Pintail	2	450	5	457
Northern Shoveler	0	2700	0	2700
Redhead	2	90	0	92
Ring-necked Duck	0	2	0	2
Unidentified	55	3425	22	3502
Total waterfowl	91	13506	117	13714

Table 20. Bridgeport Reservoir - fall aerial survey, 2 October, 2003

Waterfowl Count	Lakeshore segment			Total
Species	NOAR	WEBA	EASH	
American Wigeon	0	200	20	220
Bufflehead	0	25	20	45
Canada Goose	0	250	0	250
Common Mergenser	0	0	3	3
Gadwall	32	3750	787	4569
Green-winged Teal	140	2000	250	2390
Mallard	926	5000	679	6605
Northern Pintail	0	1700	500	2200
Northern Shoveler	358	3000	380	3738
Redhead	5	50	0	55
Ring-necked Duck	0	20	0	20
Ruddy Duck	0	285	0	285
Unidentified	26	125	410	561
Total waterfowl	1487	16405	3049	20941

Table 21. Bridgeport Reservoir - fall aerial survey, 14 October, 2003

Waterfowl Count	Lakeshore segment			Total
Species	NOAR	WEBA	EASH	
Bufflehead	2	52	6	60
Canada Goose	0	380	0	380
Gadwall	5	420	10	435
Green-winged Teal	6	750	0	756
Lesser Scaup	0	70	0	70
Mallard	7	830	47	884
Northern Pintail	12	2415	30	2457
Northern Shoveler	25	2252	50	2327
Redhead	0	50	8	58
Ruddy Duck	27	400	0	427
Unidentified	0	650	72	722
Total waterfowl	84	8269	223	8576

Table 22. Bridgeport Reservoir - fall aerial survey, 4 November, 2003

Waterfowl Count	Lakeshore segment			Total
Species	NOAR	WEBA	EASH	
American Wigeon	0	11	0	11
Bufflehead	22	40	49	111
Canvasback	0	10	0	10
Common Mergenser	5	0	8	13
Gadwall	20	0	5	25
Green-winged Teal	200	920	342	1462
Lesser Scaup	0	6	0	6
Mallard	24	650	200	874
Northern Pintail	0	0	12	12
Northern Shoveler	120	30	38	188
Redhead	2	16	8	26
Ruddy Duck	0	0	42	42
Unidentified	0	200	80	280
Total waterfowl	393	1883	784	3060

Table 23. Bridgeport Reservoir - fall aerial survey, 14 November, 2003

Waterfowl Count	Lakeshore segment			Total
Species	NOAR	WEBA	EASH	
Bufflehead	18	40	16	74
Canada Goose	0	500	2	502
Canvasback	0	15	0	15
Common Goldeneye	0	0	3	3
Common Mergenser	26	0	3	29
Gadwall	0	0	5	5
Green-winged Teal	680	2320	89	3089
Lesser Scaup	2	4	0	6
Mallard	0	587	25	612
Northern Pintail	0	60	0	60
Northern Shoveler	2	13	0	15
Ring-necked Duck	8	0	2	10
Ruddy Duck	0	0	3	3
Tundra Swan	0	85	0	85
Unidentified	0	480	53	533
Total waterfowl	736	4104	201	5041

Table 24. Summary of fall aerial survey counts – Crowley Reservoir

Species	4-Sept	18-Sept	2-Oct	14-Oct	4-Nov	14-Nov	Total Detections	%Total Detections
American Wigeon		20		12	345	950	1327	1.79
Bufflehead				38	765	421	1224	1.65
Canada Goose	208	282	520	135	474	600	2219	2.99
Canvasback					26	1	27	0.04
Cinnamon Teal	1146	669	110				1925	2.59
Common Goldeneye						2	2	0.00
Common Mergenser					2	11	13	0.02
Gadwall	912	3986	862	536	121	456	6873	9.26
Greater White-fronted Goose	1	1	5				7	0.01
Green-winged Teal	1600	2070	2186	2496	2541	2589	13482	18.17
Lesser Scaup		27		25	132	240	424	0.57
Mallard	560	704	1735	881	5951	6232	16063	21.64
Northern Pintail	100	1250	2872	2762	792	503	8279	11.16
Northern Shoveler	1662	2803	2612	1084	4	30	8195	11.04
Redhead		100	110	116	12		338	0.46
Ring-necked Duck					66	31	97	0.13
Ruddy Duck	80	137	120	522	466	125	1450	1.95
Snow Goose					6		6	0.01
Tundra Swan					14	31	45	0.06
Unidentified *Anas*	735	2209	4423	1908	1022	1922	12219	16.46
Total Waterfowl	7004	14258	15555	10515	12739	14144	74215	

Table 25. Crowley Reservoir - fall aerial survey, 4 September, 2003

Waterfowl Count	Lakeshore segment							Total detections
Species	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
Canada Goose	0	15	0	10	18	80	85	208
Cinnamon Teal	0	6	27	1109	0	0	4	1146
Gadwall	140	0	70	700	0	0	2	912
Greater White-fronted Goose	0	0	0	0	1	0	0	1
Green-winged Teal	100	0	0	1500	0	0	0	1600
Mallard	0	0	0	550	0	0	10	560
Northern Pintail	0	0	0	100	0	0	0	100
Northern Shoveler	115	22	0	1275	0	0	250	1662
Ruddy Duck	0	0	0	80	0	0	0	80
Unidentified	45	0	50	565	0	0	75	735
Total waterfowl	400	43	147	5889	19	80	426	7004

Table 26. Crowley Reservoir - fall aerial survey, 18 September, 2003

Waterfowl Count	Lakeshore segment							Total Detections
Species	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	0	0	0	20	0	0	0	20
Canada Goose	0	0	0	282	0	0	0	282
Cinnamon Teal	0	0	12	610	35	0	12	669
Gadwall	200	0	3	3620	163	0	0	3986
Greater White-fronted Goose	0	0	1	0	0	0	0	1
Green-winged Teal	0	0	0	2000	0	0	70	2070
Lesser Scaup	0	0	2	25	0	0	0	27
Mallard	0	35	4	600	65	0	0	704
Northern Pintail	50	0	0	1200	0	0	0	1250
Northern Shoveler	250	0	0	2418	65	0	70	2803
Redhead	0	0	0	100	0	0	0	100
Ruddy Duck	0	0	25	112	0	0	0	137
Unidentified Anas	450	0	4	1098	322	0	335	2209
Total waterfowl	950	35	51	12085	650	0	487	14258

Table 27. Crowley Reservoir - fall aerial survey, 2 October, 2003

Waterfowl Count	Lakeshore segment							Total Detections
Species	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
Canada Goose	0	0	0	400	60	0	60	520
Cinnamon Teal	50	0	0	0	60	0	0	110
Gadwall	100	0	2	550	60	0	150	862
Greater White-fronted Goose	0	0	0	5	0	0	0	5
Green-winged Teal	50	0	1	575	710	0	850	2186
Mallard	330	0	0	1160	0	0	245	1735
Northern Pintail	50	0	0	2760	12	0	50	2872
Northern Shoveler	100	0	12	2200	0	0	300	2612
Redhead	0	0	0	110	0	0	0	110
Ruddy Duck	0	0	2	110	0	0	8	120
Unidentified	370	0	53	3570	0	0	430	4423
Total waterfowl	1050	0	70	11440	902	0	2093	15555

Table 28. Crowley Reservoir - fall aerial survey, 14 October, 2003

Waterfowl Count	Lakeshore segment							Total Detections
Species	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	0	0	0	0	0	0	12	12
Bufflehead	4	0	1	28	0	5	0	38
Canada Goose	0	0	0	60	75	0	0	135
Gadwall	250	1	21	200	4	0	60	536
Green-winged Teal	100	0	3	2200	85	0	108	2496
Lesser Scaup	0	0	0	25	0	0	0	25
Mallard	0	0	14	450	0	337	80	881
Northern Pintail	0	0	5	2680	30	7	40	2762
Northern Shoveler	1	0	8	895	0	0	180	1084
Redhead	2	0	12	100	0	2	0	116
Ruddy Duck	0	0	10	512	0	0	0	522
Unidentified	0	4	5	1877	0	2	20	1908
Total waterfowl	357	5	79	9027	194	353	500	10515

Table 29. Crowley Reservoir - fall aerial survey, 4 November, 2003

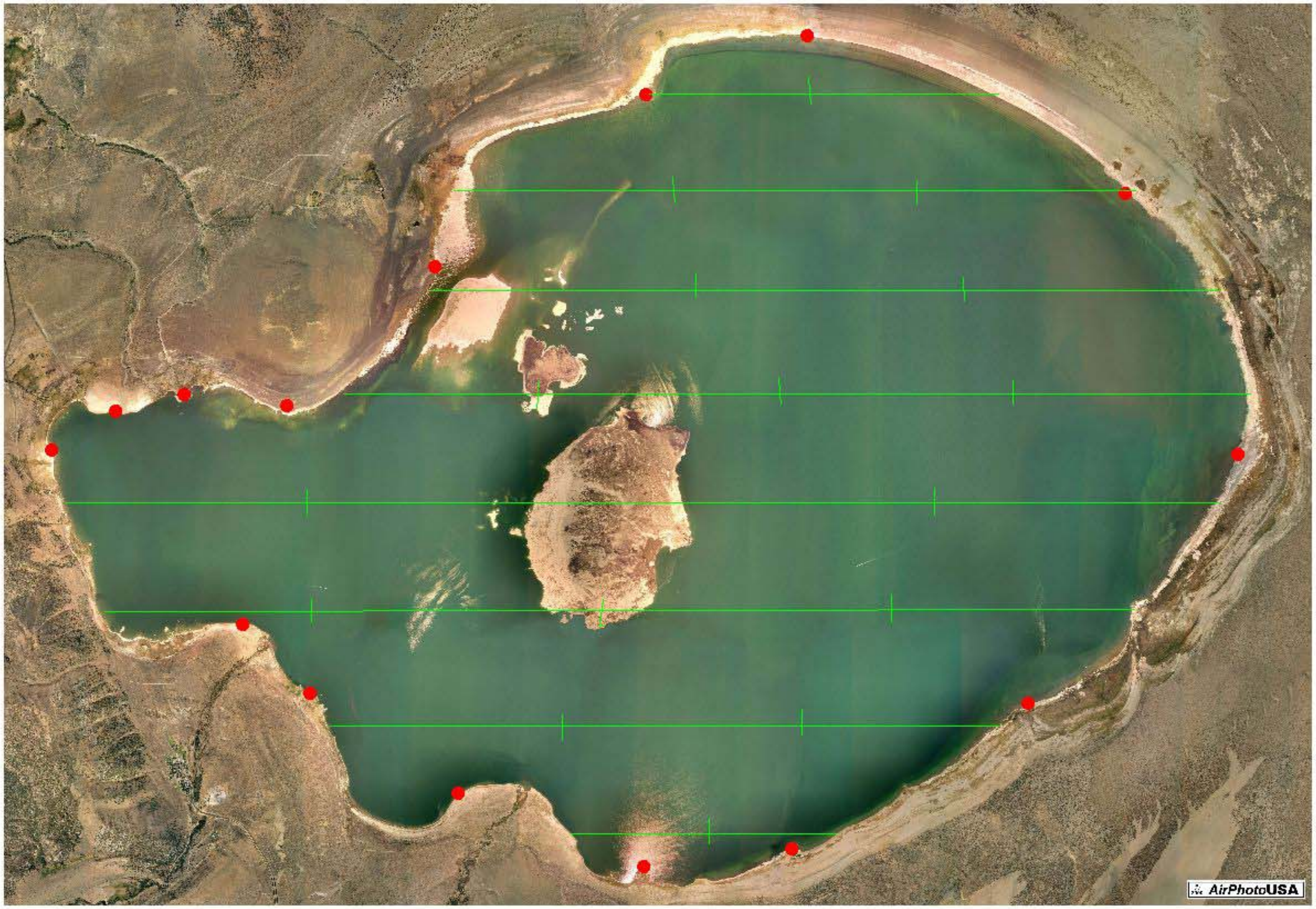
Waterfowl Count	Lakeshore segment							Total Detections
Species	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	75	20	0	250	0	0	0	345
Bufflehead	17	49	0	176	74	249	200	765
Canada Goose	42	0	9	185	0	88	150	474
Canvasback	0	0	0	0	20	0	6	26
Common Mergenser	0	0	2	0	0	0	0	2
Gadwall	17	4	0	30	20	0	50	121
Green-winged Teal	60	2	0	2264	60	135	20	2541
Lesser Scaup	30	8	0	0	20	0	74	132
Mallard	420	27	21	1500	18	3915	50	5951
Northern Pintail	250	0	12	500	0	0	30	792
Northern Shoveler	0	4	0	0	0	0	0	4
Redhead	0	0	0	12	0	0	0	12
Ring-necked Duck	2	0	0	12	0	50	2	66
Ruddy Duck	60	0	0	200	100	1	105	466
Snow Goose	0	0	0	6	0	0	0	6
Tundra Swan	0	0	8	6	0	0	0	14
Unidentified	450	0	20	450	15	45	42	1022
Total waterfowl	1423	114	72	5591	327	4483	729	12739

Table 30. Crowley Reservoir - fall aerial survey, 14 November, 2003

Waterfowl Count	Lakeshore segment							Total Detections
Species	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	300	0	0	0	0	400	250	950
Bufflehead	0	15	16	54	43	8	285	421
Canada Goose	10	0	0	360	0	150	80	600
Canvasback	1	0	0	0	0	0	0	1
Common Goldeneye	0	0	0	0	0	0	2	2
Common Mergenser	0	2	0	6	0	3	0	11
Gadwall	100	6	0	0	0	150	200	456
Green-winged Teal	514	0	6	1567	2	300	200	2589
Lesser Scaup	0	5	0	5	0	150	80	240
Mallard	15	80	43	150	50	5694	200	6232
Northern Pintail	100	0	0	0	0	400	3	503
Northern Shoveler	0	0	0	30	0	0	0	30
Ring-necked Duck	0	0	30	0	0	1	0	31
Ruddy Duck	0	0	0	0	0	125	0	125
Tundra Swan	0	6	0	15	0	0	10	31
Unidentified *Anas*	1000	12	0	600	150	0	160	1922
Total waterfowl	2040	126	95	2787	245	7381	1470	14144

Figure 1. Summer ground survey areas

Figure 2. Lakeshore segments, segment boundaries, and cross-lake transects used for fall aerial surveys of Mono Lake



ASP

Figure 3. Lakeshore segments and segment boundaries used for fall aerial surveys of Bridgeport Reservoir

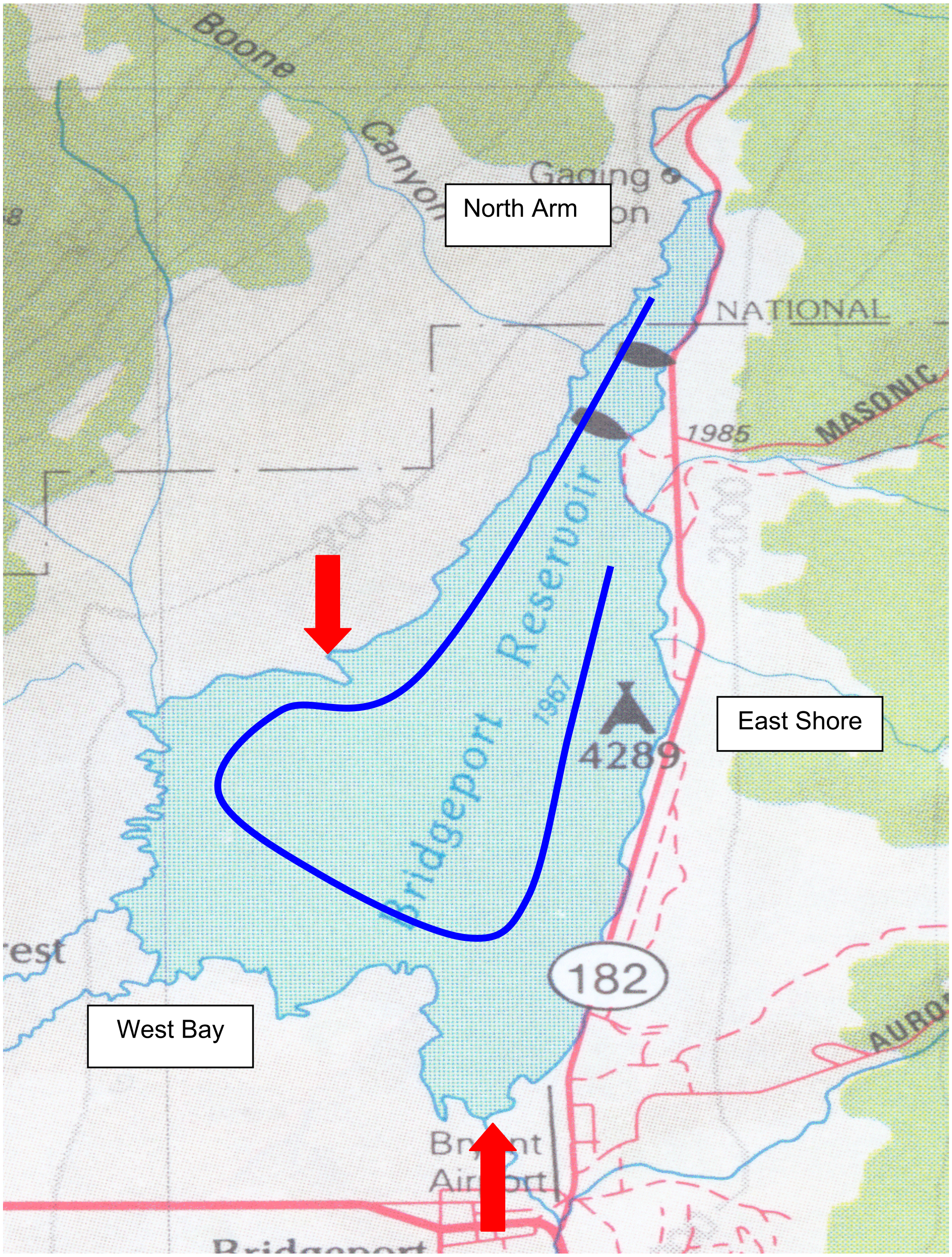


Figure 4. Lakeshore segments and segment boundaries used for fall aerial surveys of Crowley Reservoir

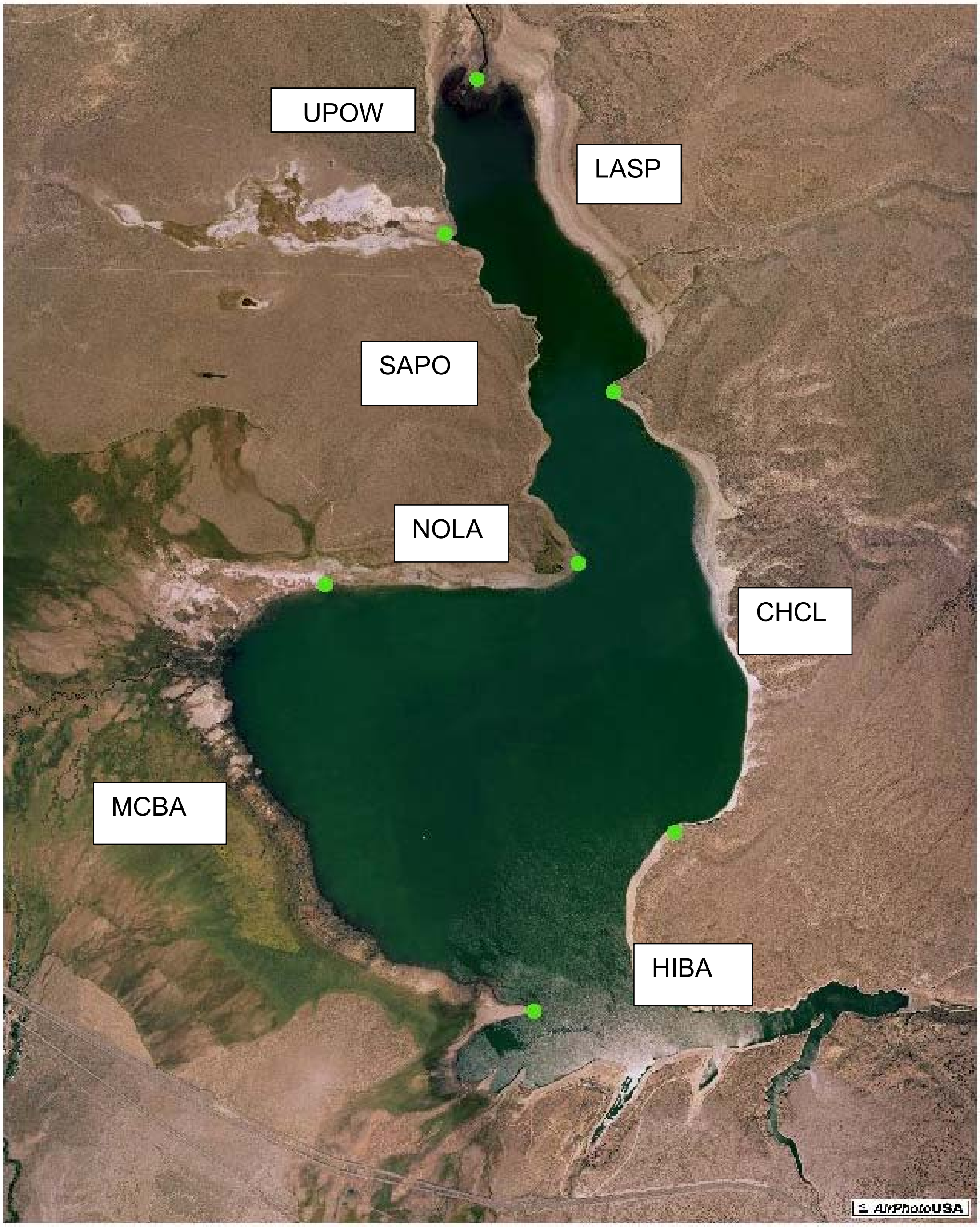
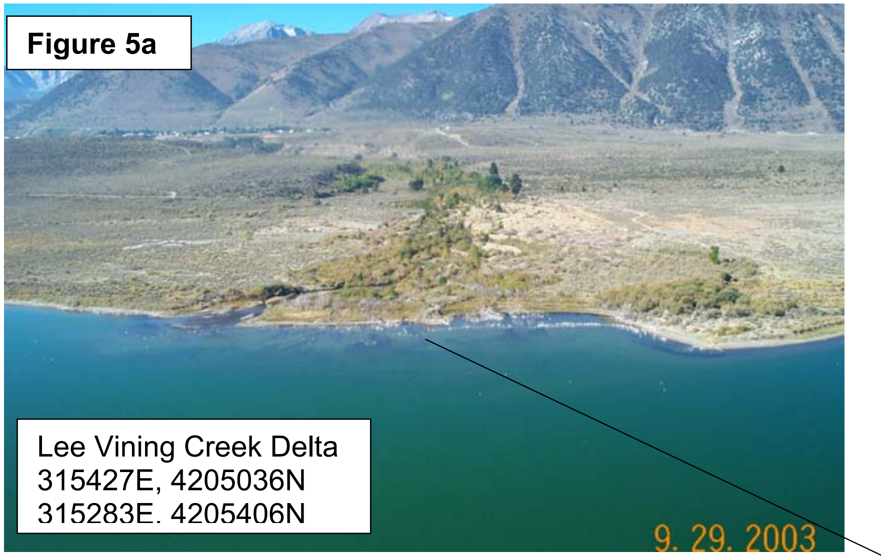


Figure 5. Photos of shoreline habitats at Mono Lake. Taken from a helicopter on September 29, 2003. The coordinates on each photo indicate the shoreline area depicted in the photo (NAD 27, Zone 11).

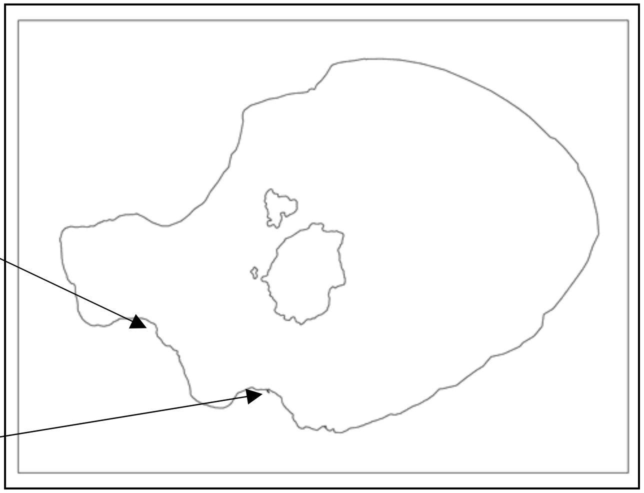
Figure 5a



Lee Vining Creek Delta
315427E, 4205036N
315283E. 4205406N

Figure 5b

Rush Creek Delta
319984E, 4202685N
319607E, 4202773N



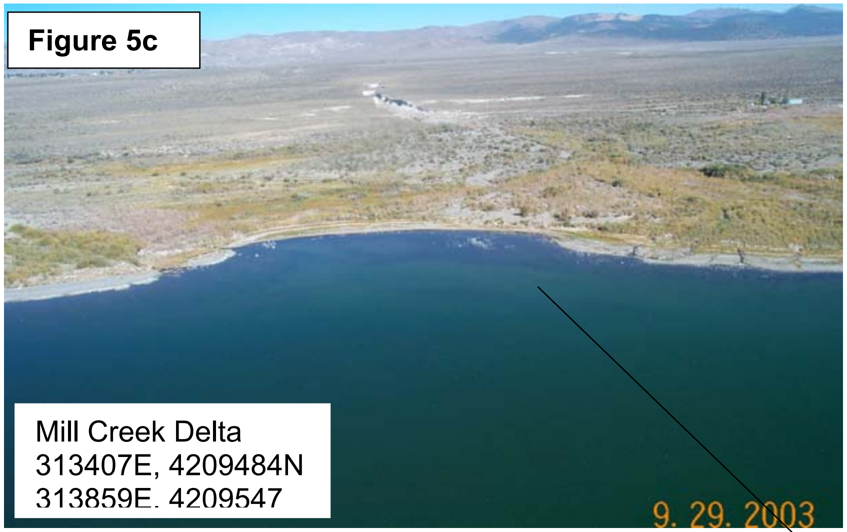


Figure 5c

Mill Creek Delta
313407E, 4209484N
313859E, 4209547

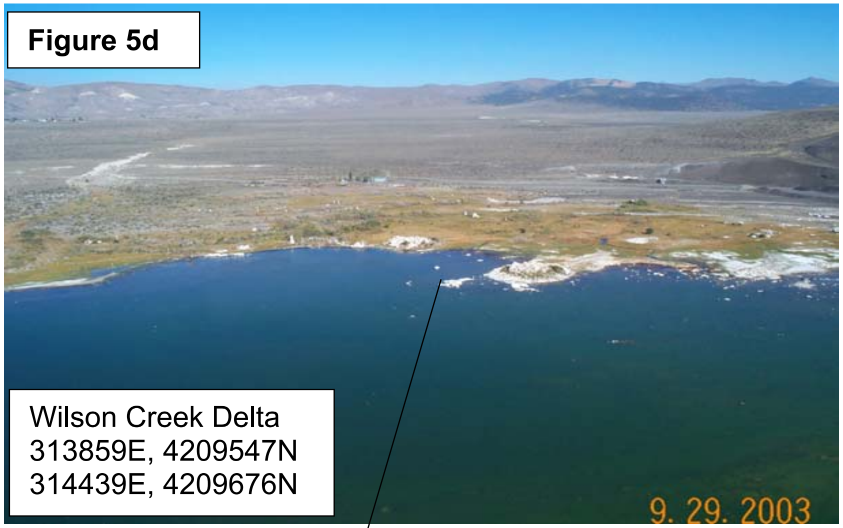


Figure 5d

Wilson Creek Delta
313859E, 4209547N
314439E, 4209676N

Figure 5e

DeChambeau Creek Delta
311658E, 4209237N
312150E, 4209338N

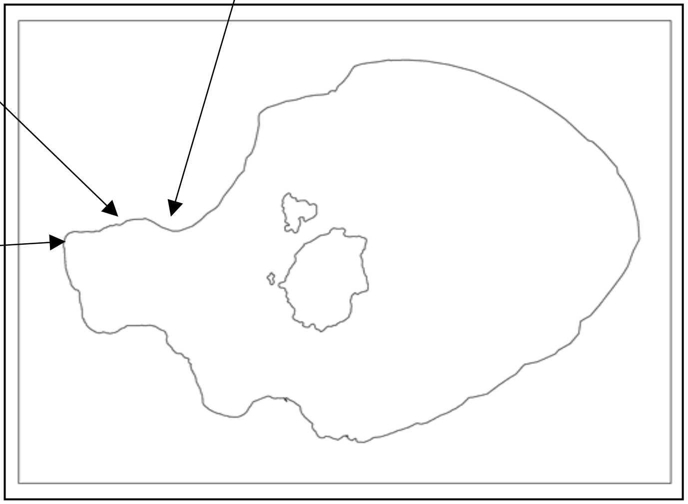
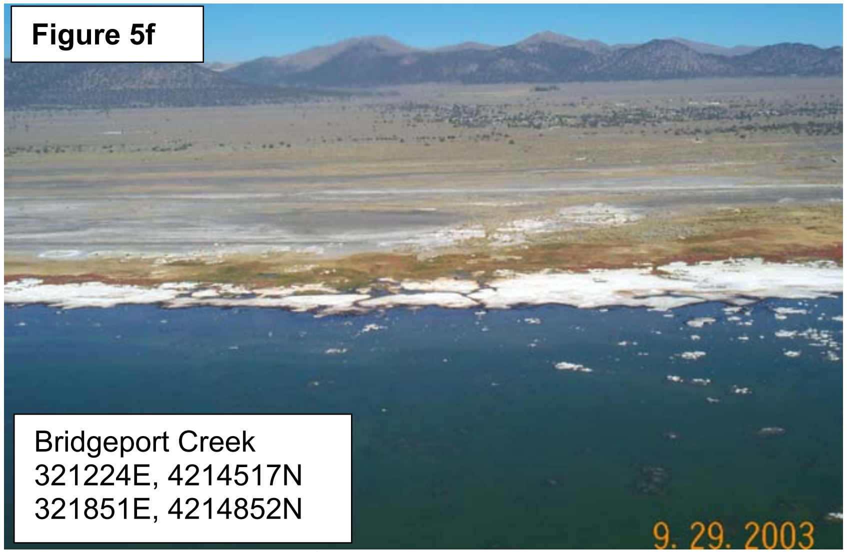


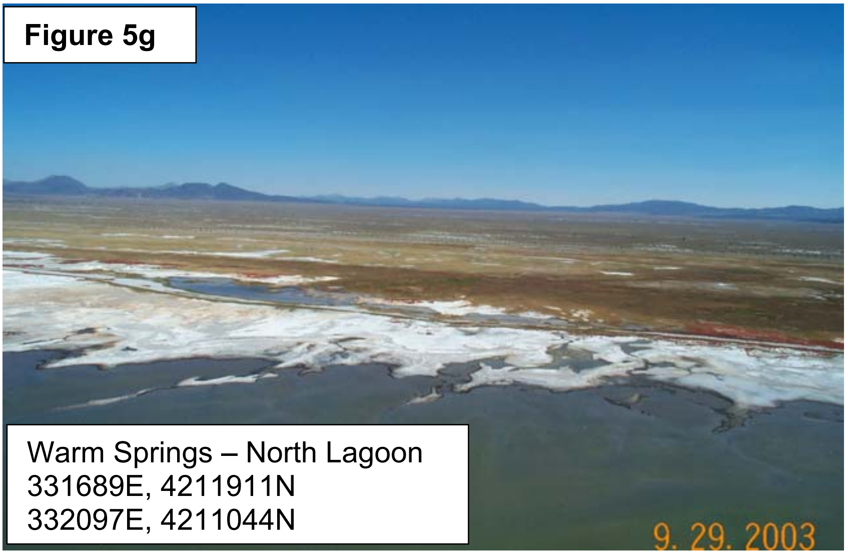
Figure 5f



Bridgeport Creek
321224E, 4214517N
321851E, 4214852N

9. 29. 2003

Figure 5g



Warm Springs – North Lagoon
331689E, 4211911N
332097E, 4211044N

9. 29. 2003

Figure 5h

Warm Springs – South Lagoon
332294E, 4210726N
332461E, 4210139N

9. 29. 2003

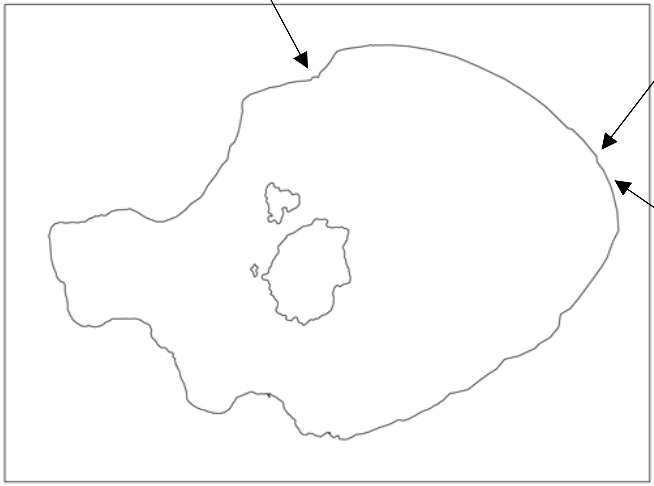


Figure 5i

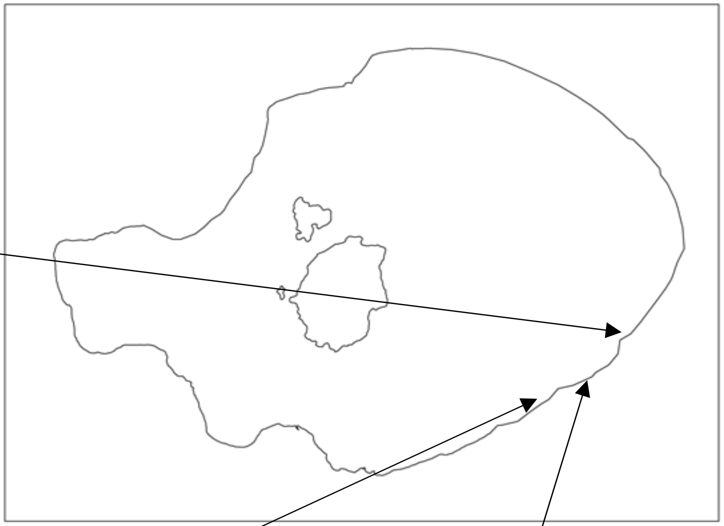
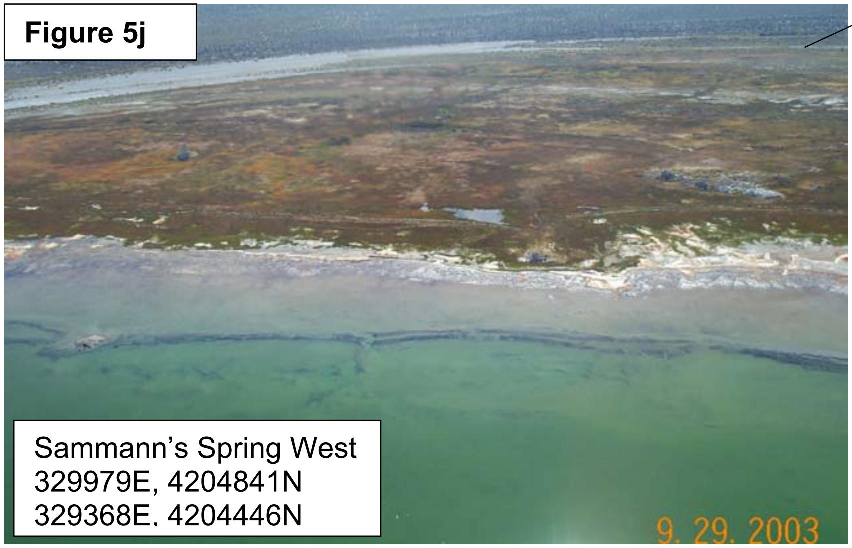
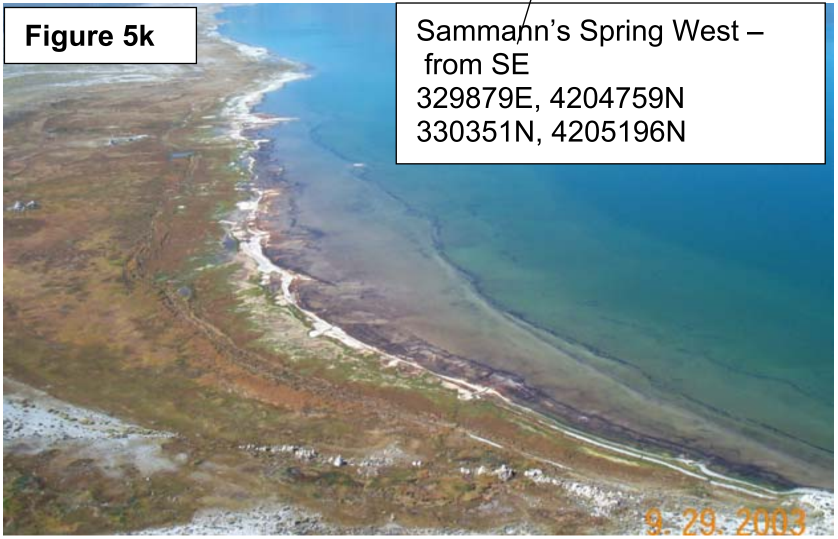


Figure 5j

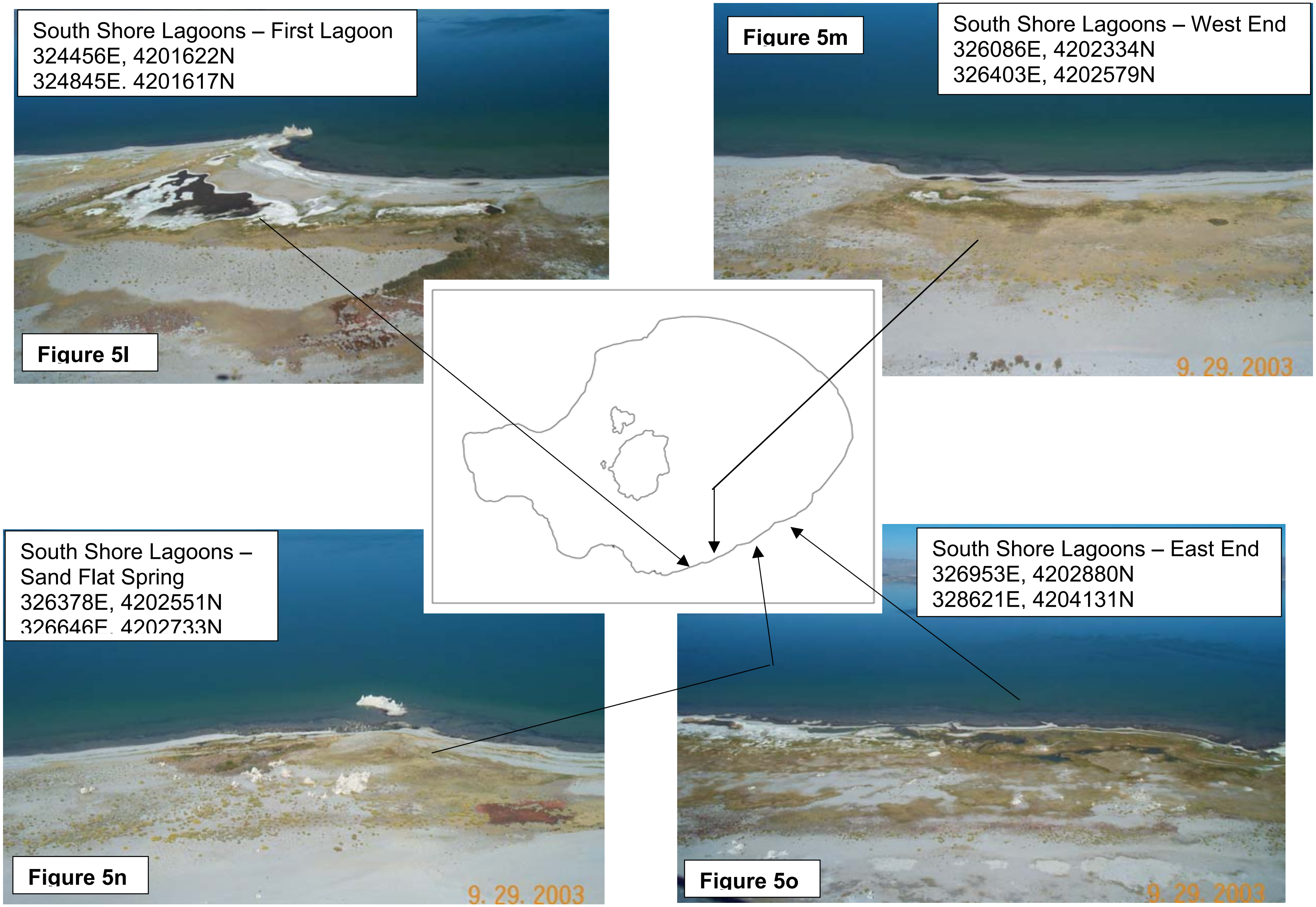


Sammann's Spring West
329979E, 4204841N
329368E, 4204446N

Figure 5k



Sammann's Spring West – from SE
329879E, 4204759N
330351N, 4205196N



South Shore Lagoons – First Lagoon
324456E, 4201622N
324845E, 4201617N

Figure 5l

Figure 5m

South Shore Lagoons – West End
326086E, 4202334N
326403E, 4202579N

9. 29. 2003

South Shore Lagoons –
Sand Flat Spring
326378E, 4202551N
326646E, 4202733N

Figure 5n

9. 29. 2003

South Shore Lagoons – East End
326953E, 4202880N
328621E, 4204131N

Figure 5o

9. 29. 2003

Figure 6. Photos of shoreline habitats at Crowley Reservoir. Taken from a helicopter on September 29, 2003

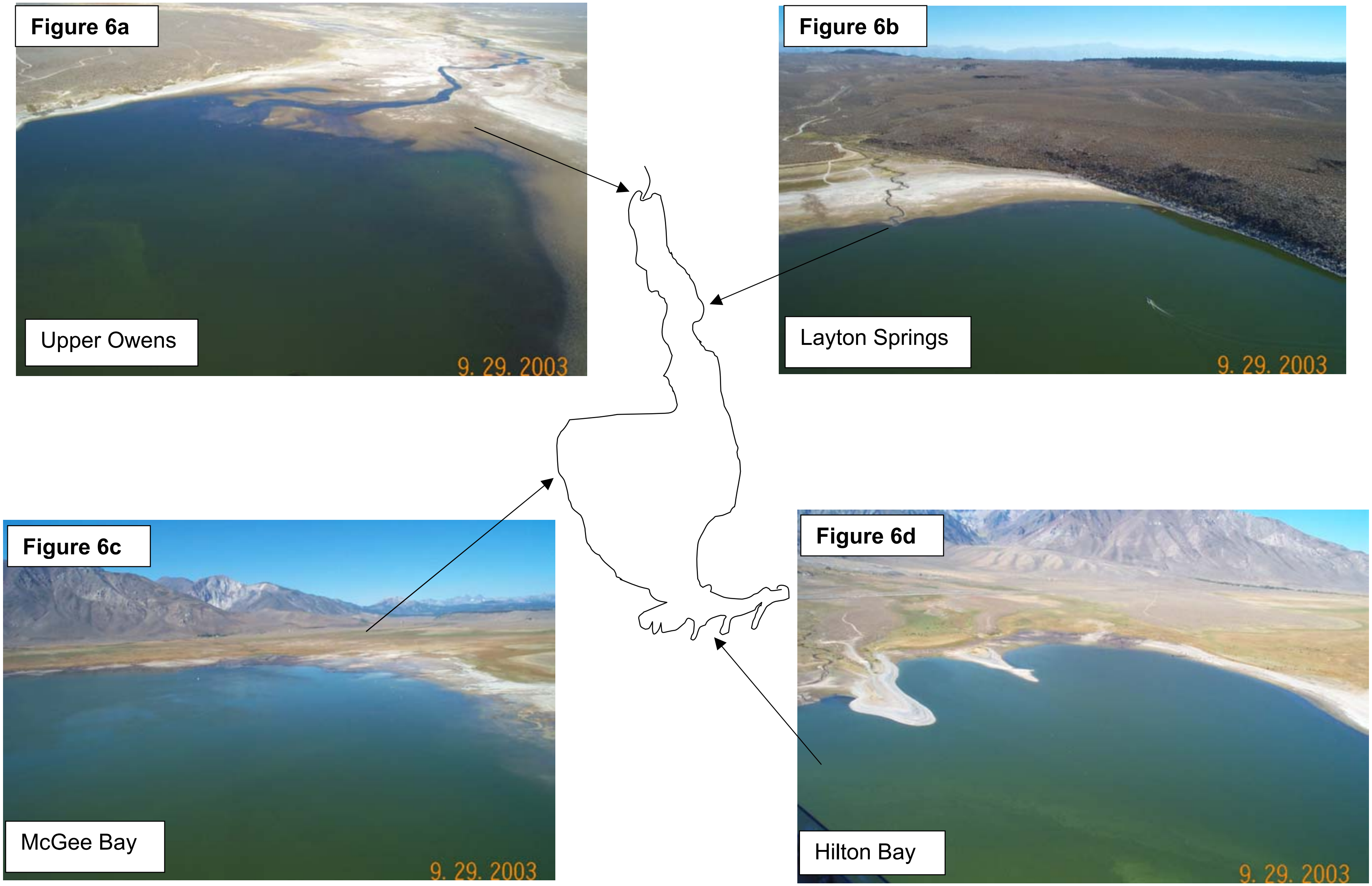


Figure 7. Photos of shoreline habitats at Bridgeport Reservoir.
Taken from a helicopter on September 22, 2003

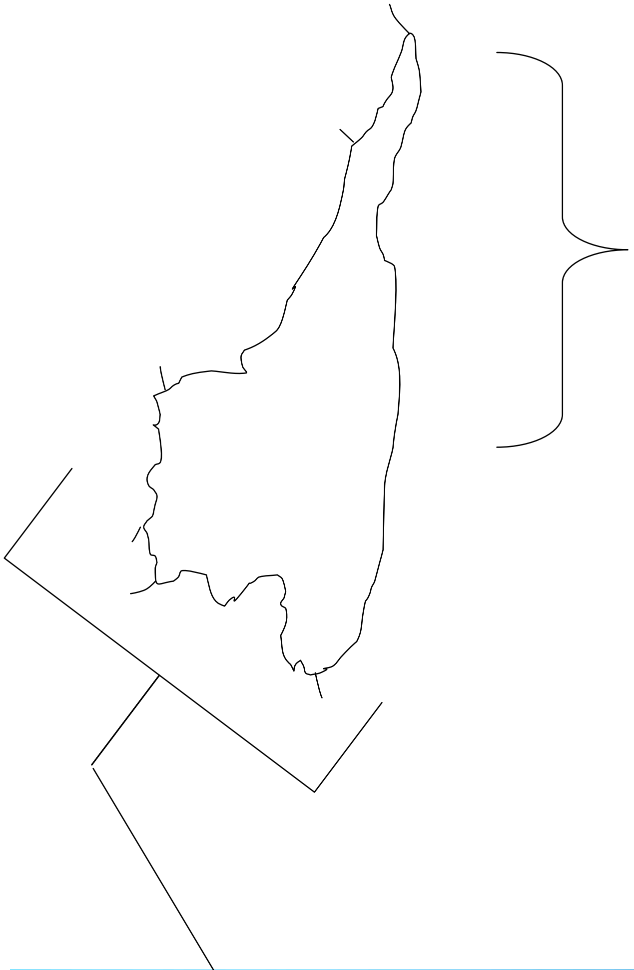


Figure 7a

North Arm and north part of East Shore

Figure 7b

West Bay and south end of East Shore

Figure 8. Broods detected during first ground count, 2003 (June 9- 11). Only unique broods are depicted.

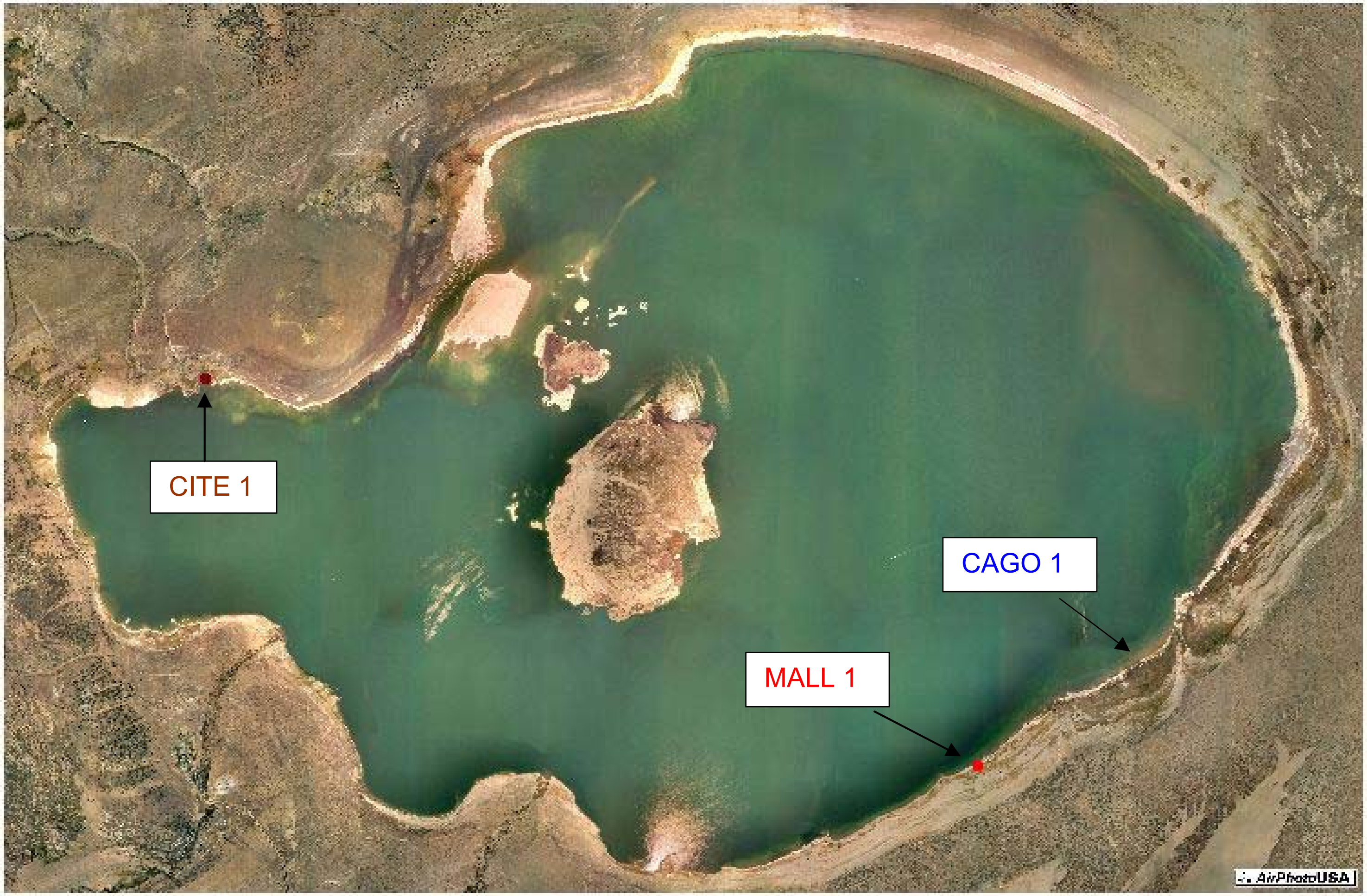


Figure 9. Broods detected during second ground count, 2003 (June 30- July 2). Only unique broods are depicted.

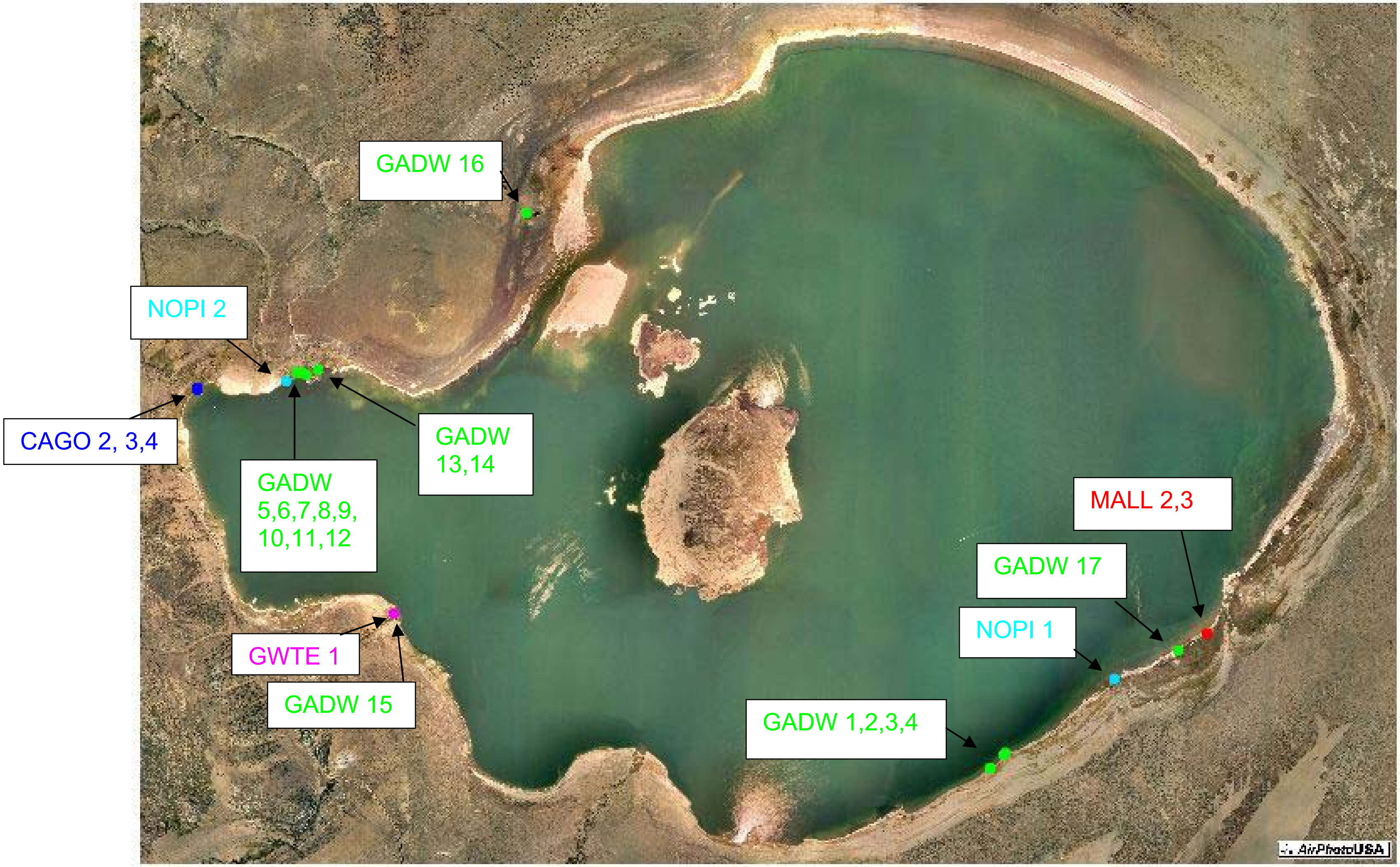


Figure 10. Broods detected during third ground count, 2003 (July 21- 23). Only unique broods are depicted.

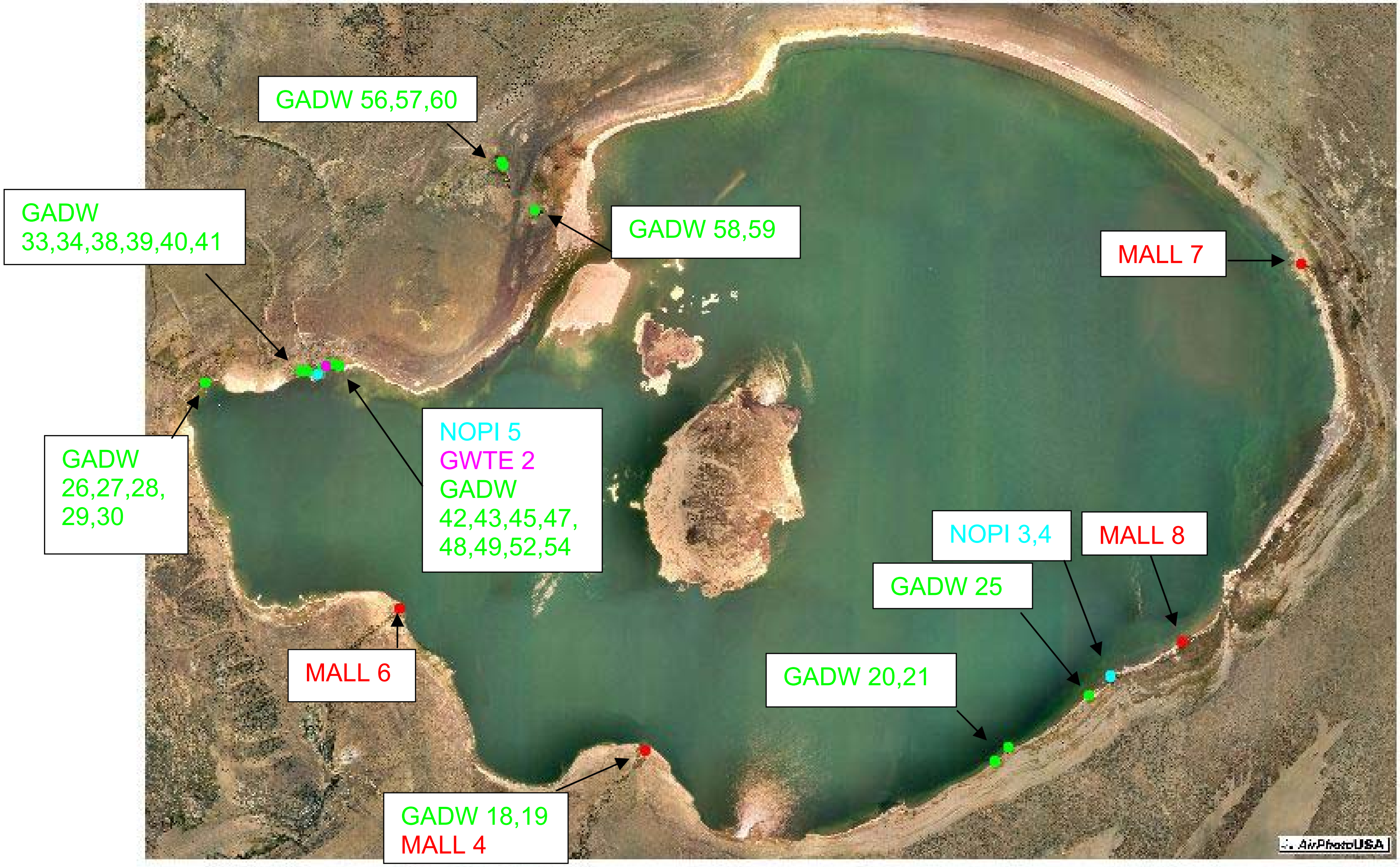


Figure 11. Summer habitat use by the dominant species. Values represent the percent of all observations for that species in 2003.

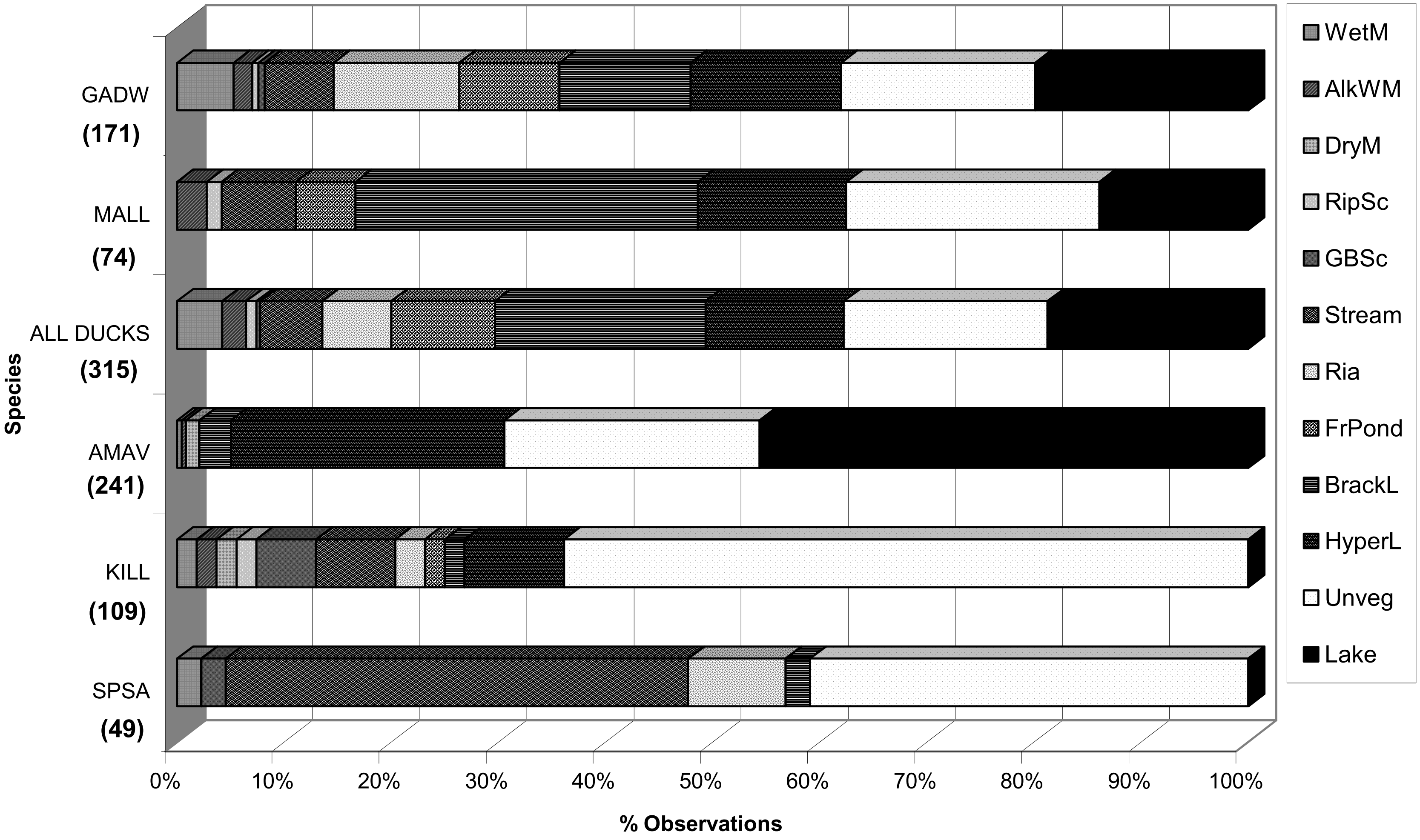


Figure 12. Total waterfowl detected at each waterbody during fall aerial surveys, 2003.

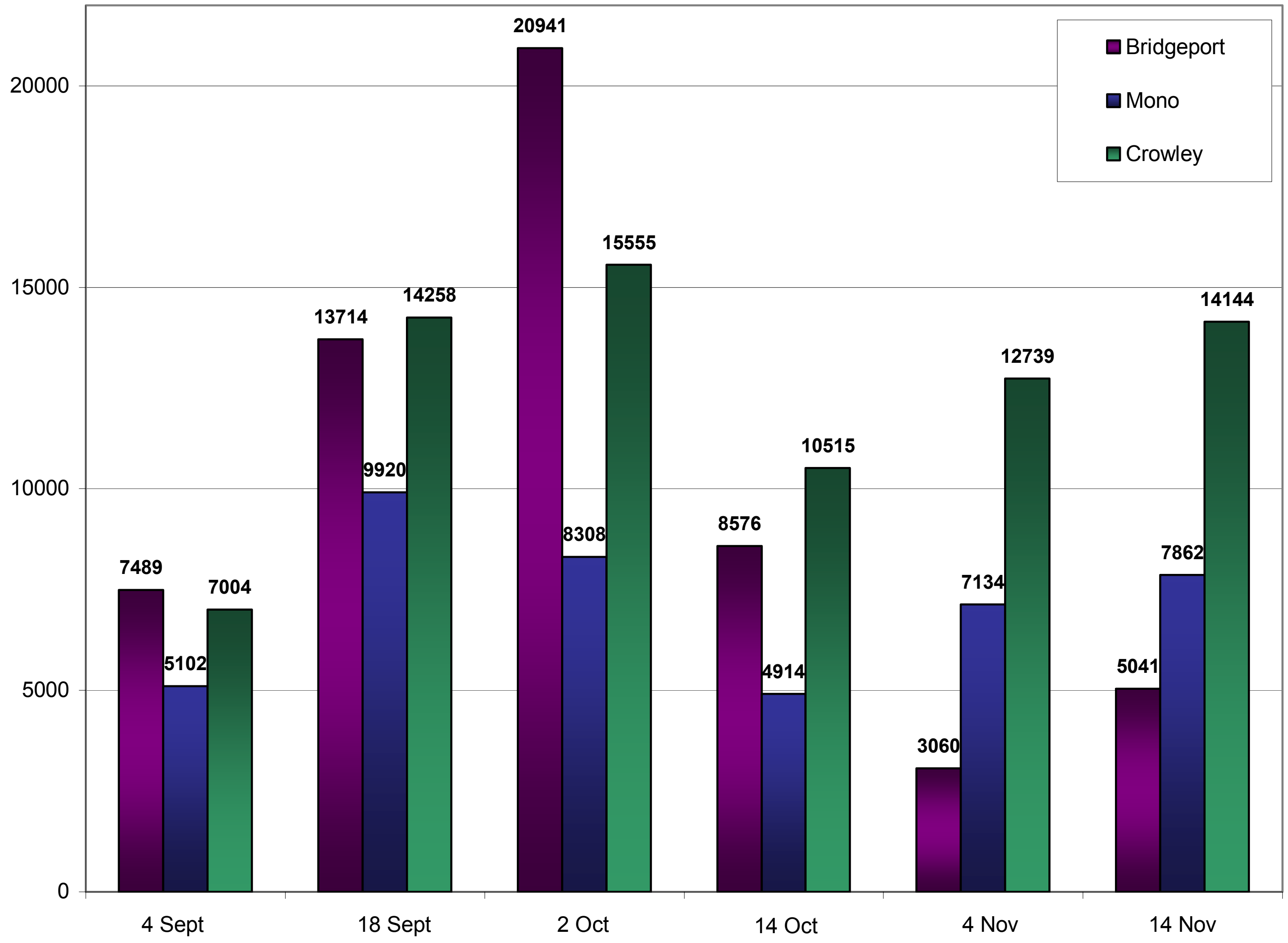


Figure 13. Total detections of dominant species at Mono Lake during fall aerial surveys

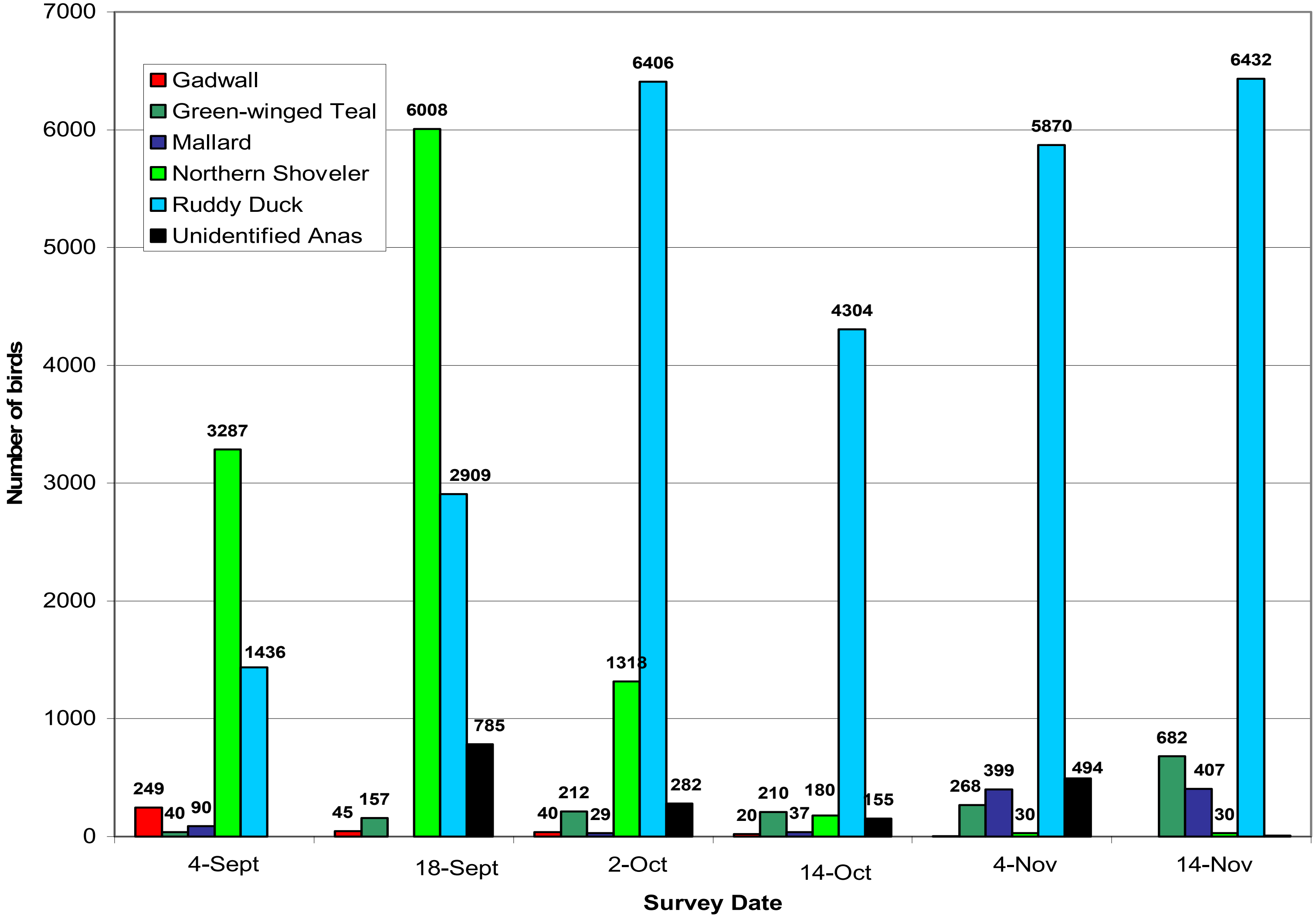


Figure 14. The proportion of waterfowl detected offshore (on crosslake transects) and in each of the lakeshore segments at Mono Lake during each fall aerial survey.

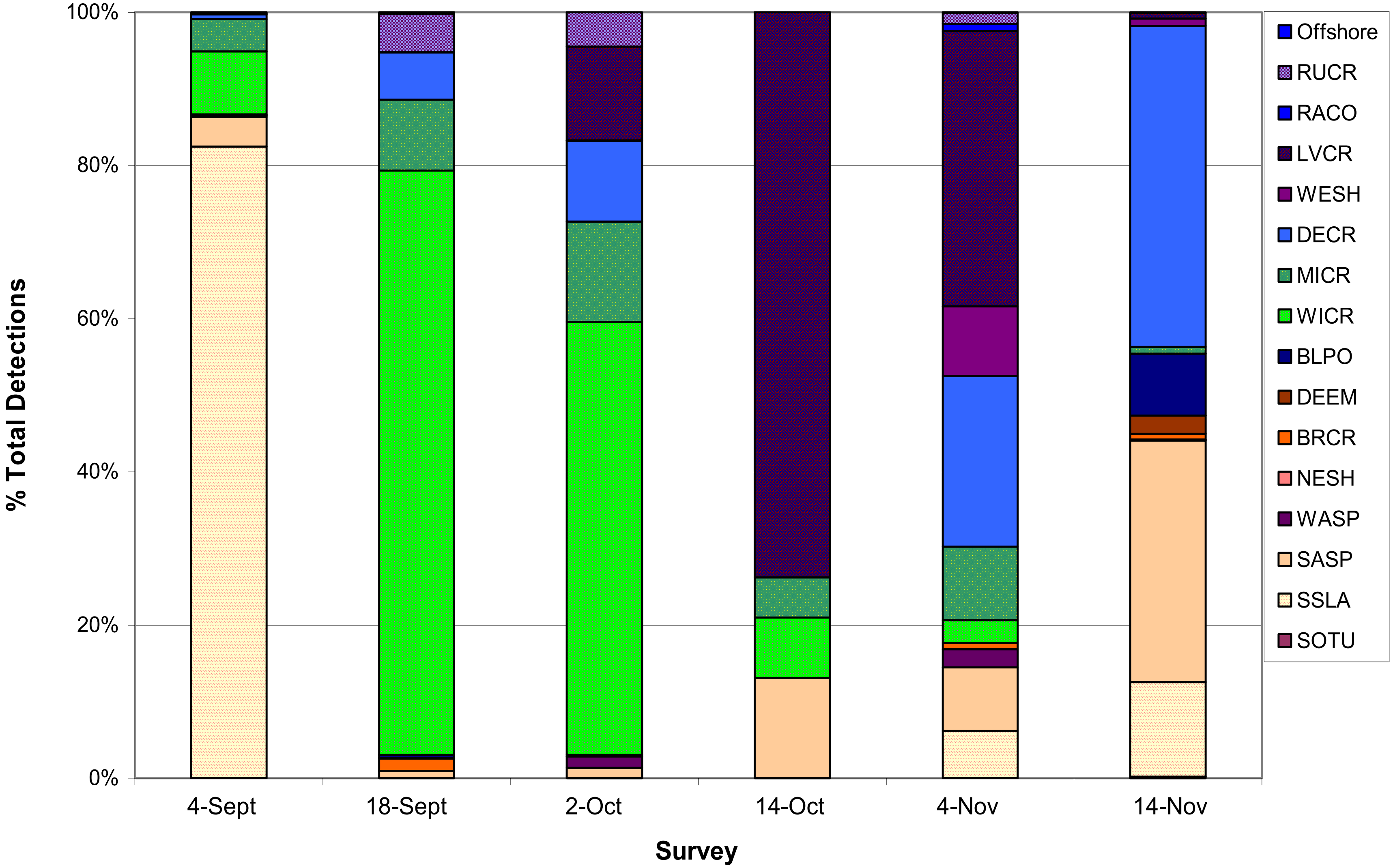
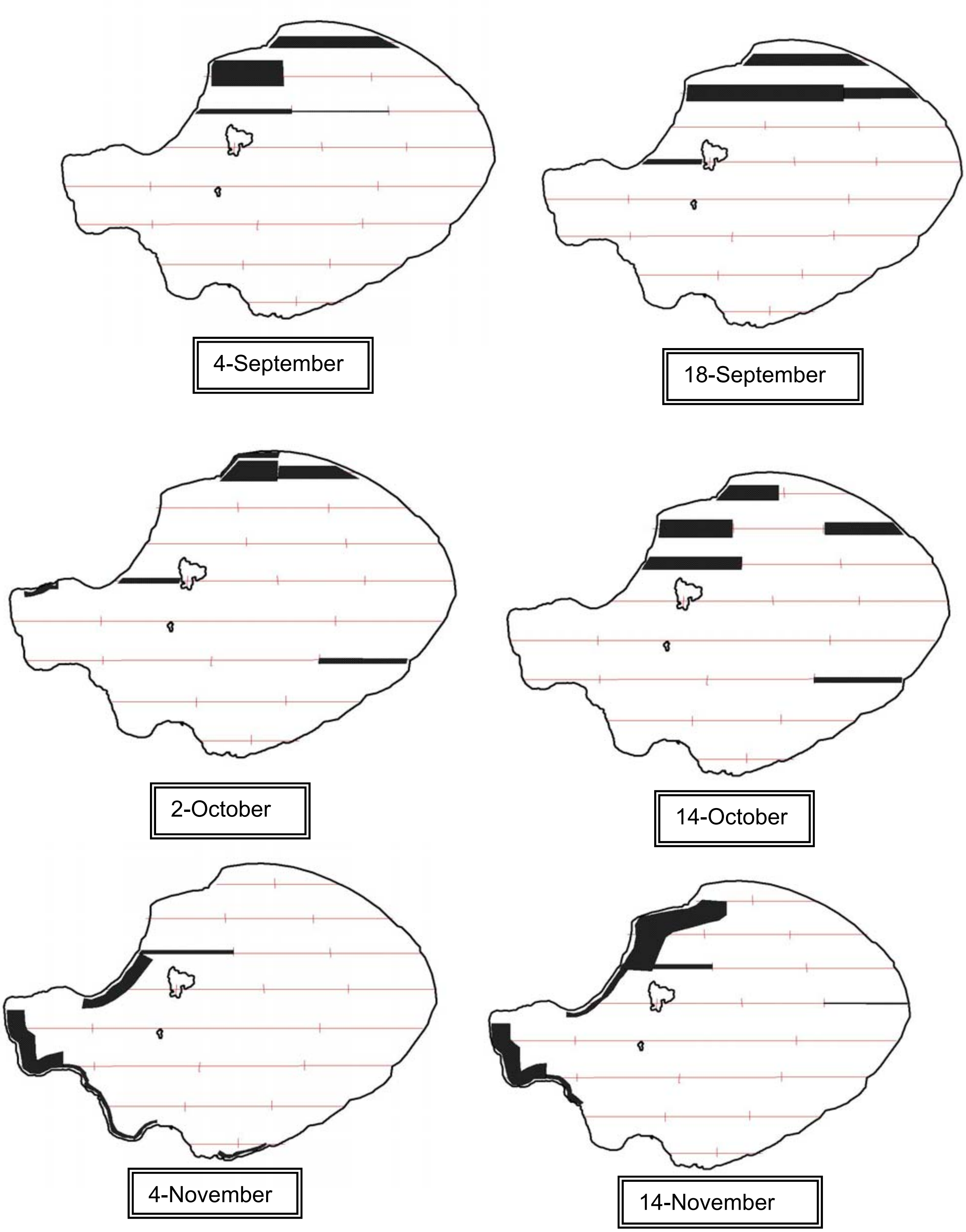


Figure 15. Relative distribution of Ruddy Ducks at Mono Lake during each fall survey, 2003.



4-September

18-September

2-October

14-October

4-November

14-November

Figure 16. Total detections of dominant species at Bridgeport Reservoir during fall aerial surveys

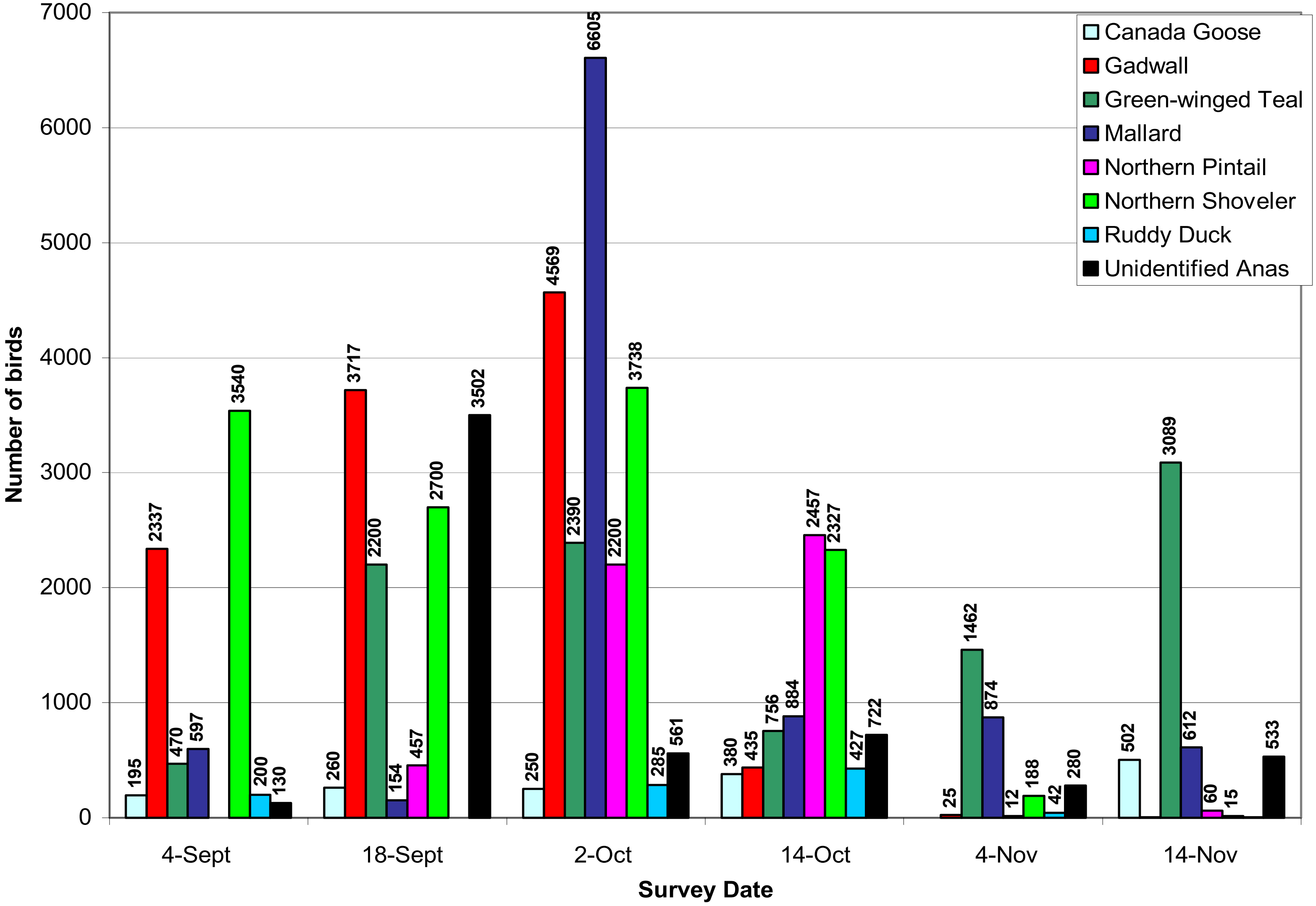


Figure 17. The proportion of waterfowl detected in each of the lakeshore segments at Bridgeport Reservoir during each fall aerial survey.

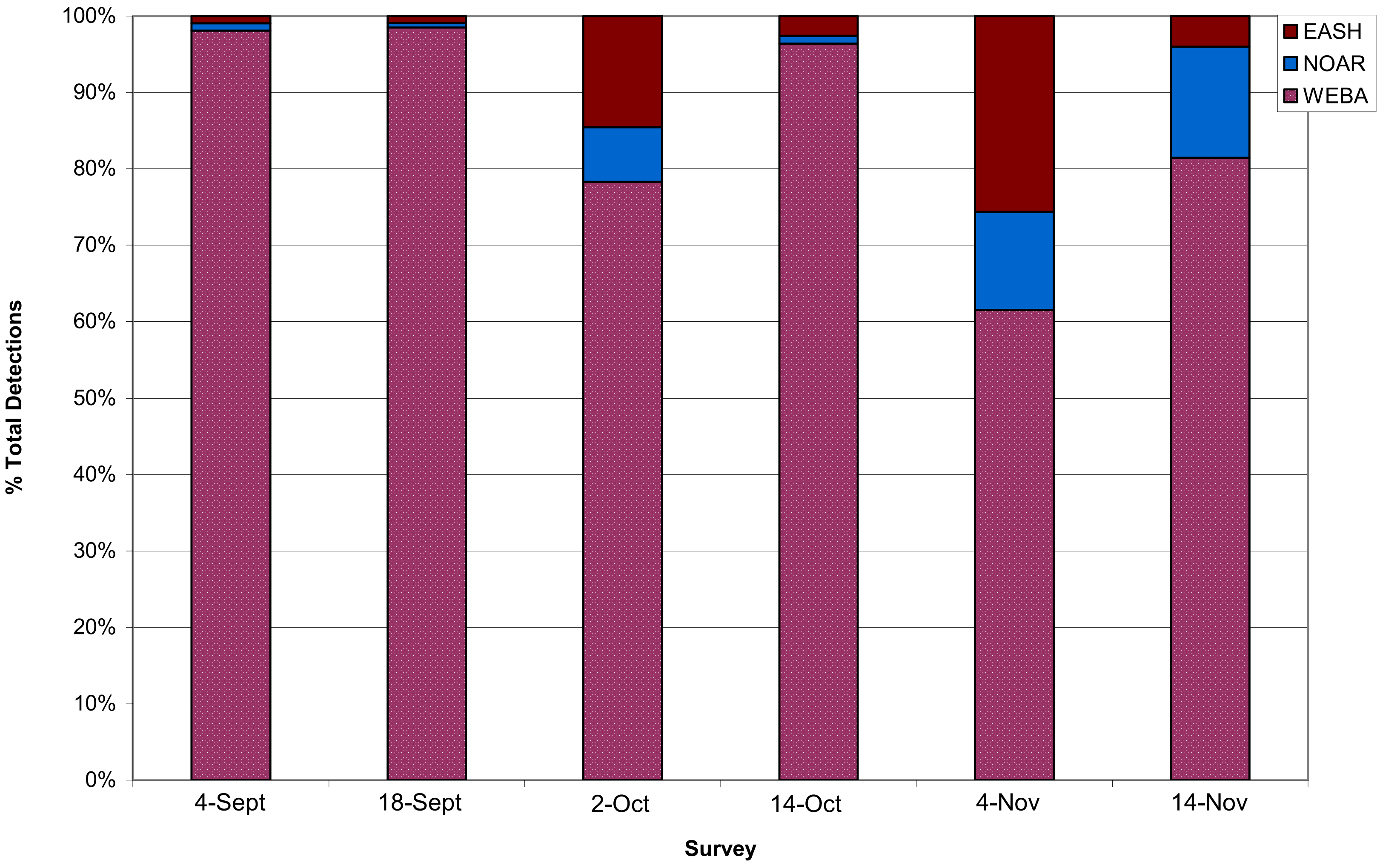


Figure 18. Total detections of dominant species at Crowley Reservoir during fall aerial surveys

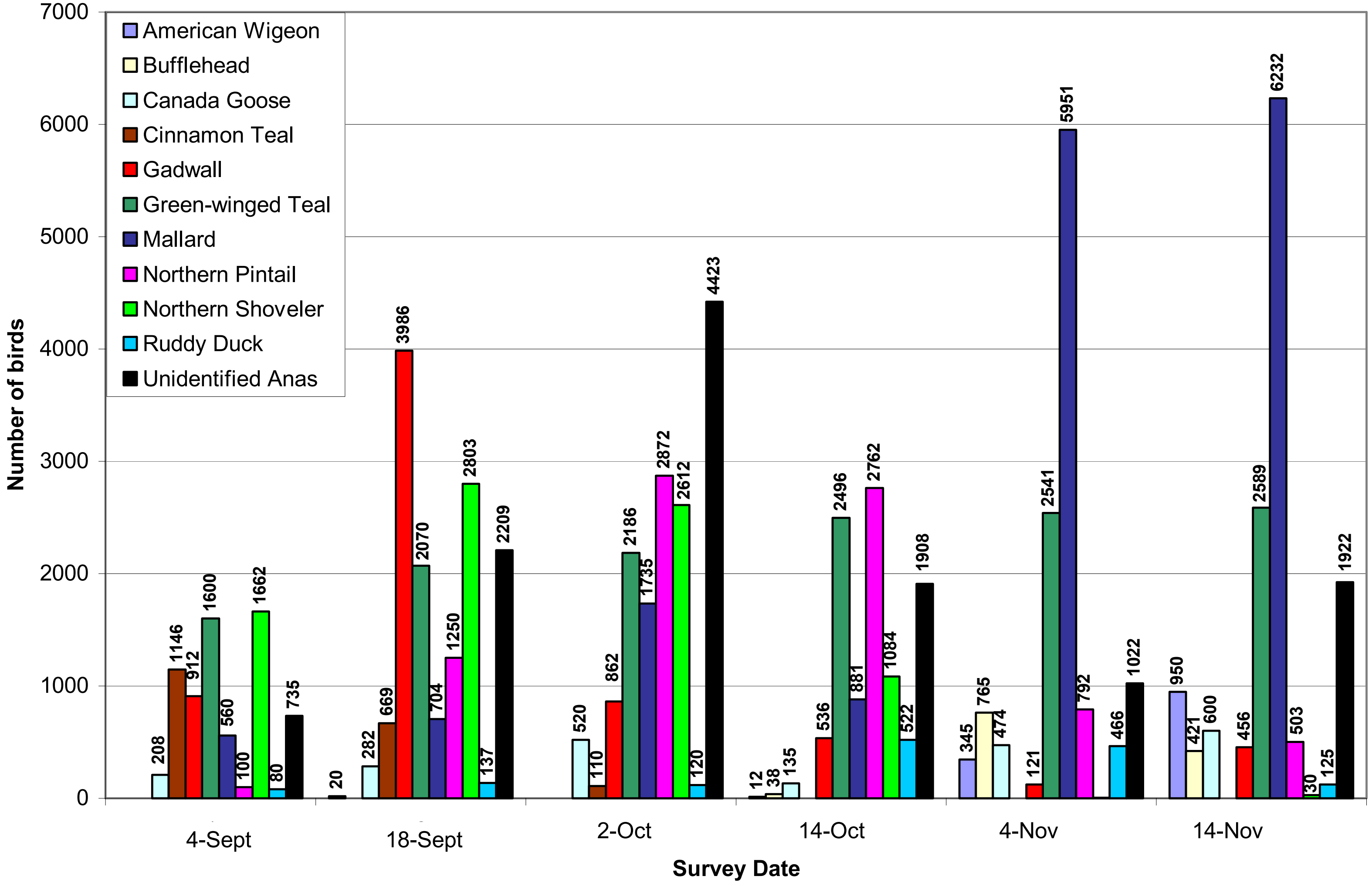


Figure 19. The proportion of waterfowl detected in each of the lakeshore segments at Crowley Reservoir during each fall aerial survey.

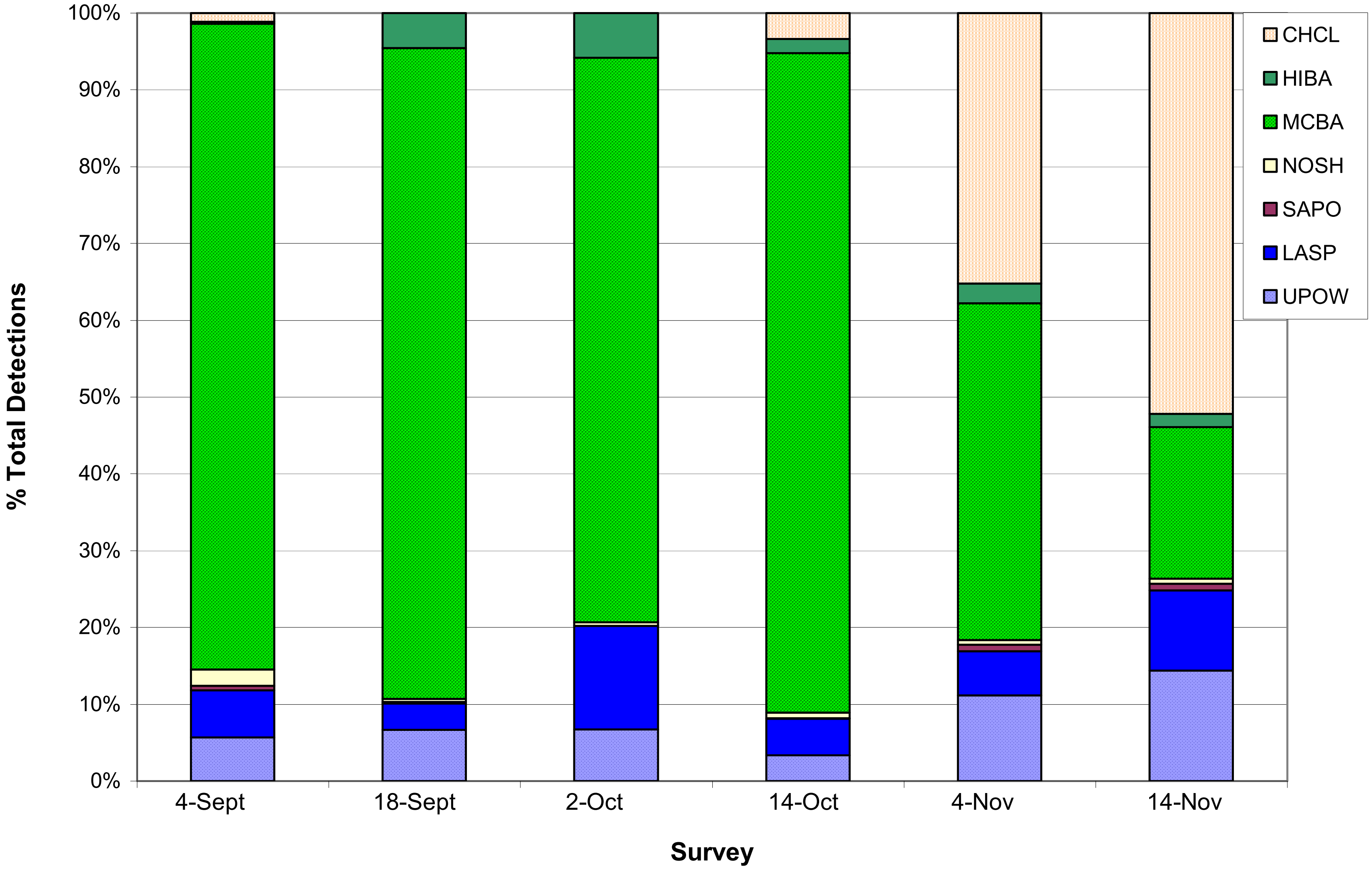


Figure 20. The proportional abundance of the three most abundant species at Mono and five most abundant species at Crowley and Bridgeport Reservoirs.

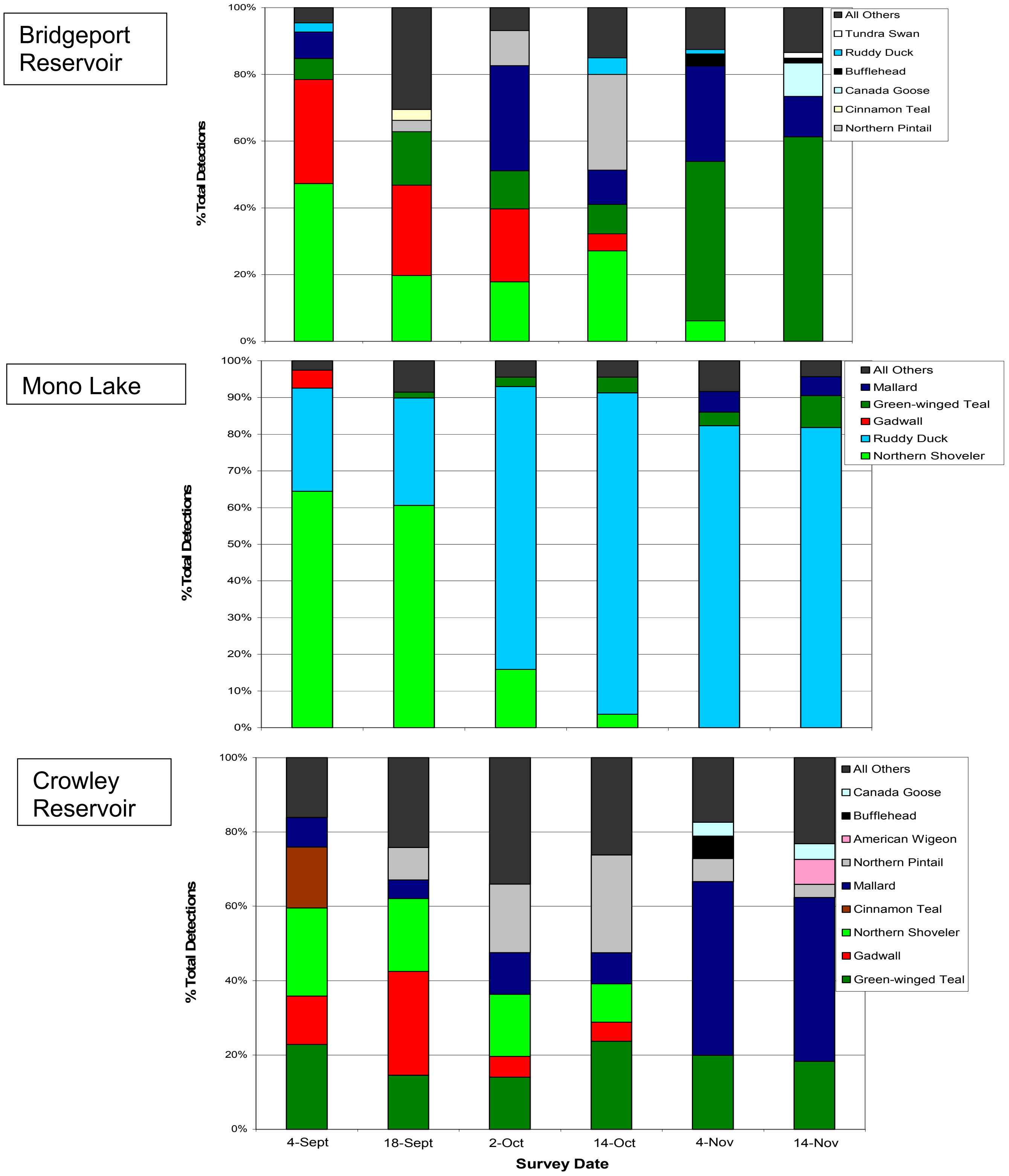


Figure 21. Total detections of the dominant species at all three bodies of water. The graphs on the right represent detections summed over all six fall surveys.

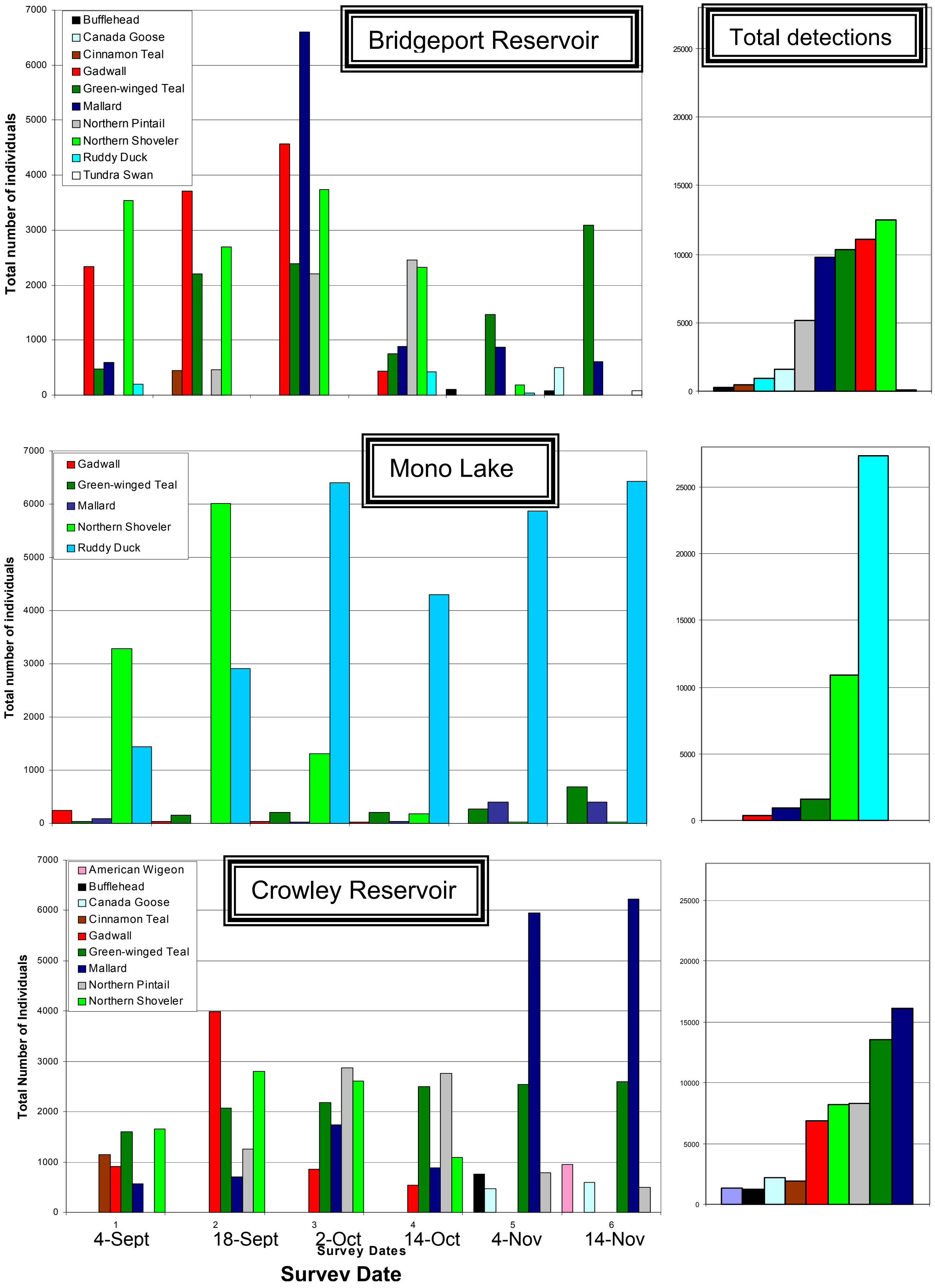
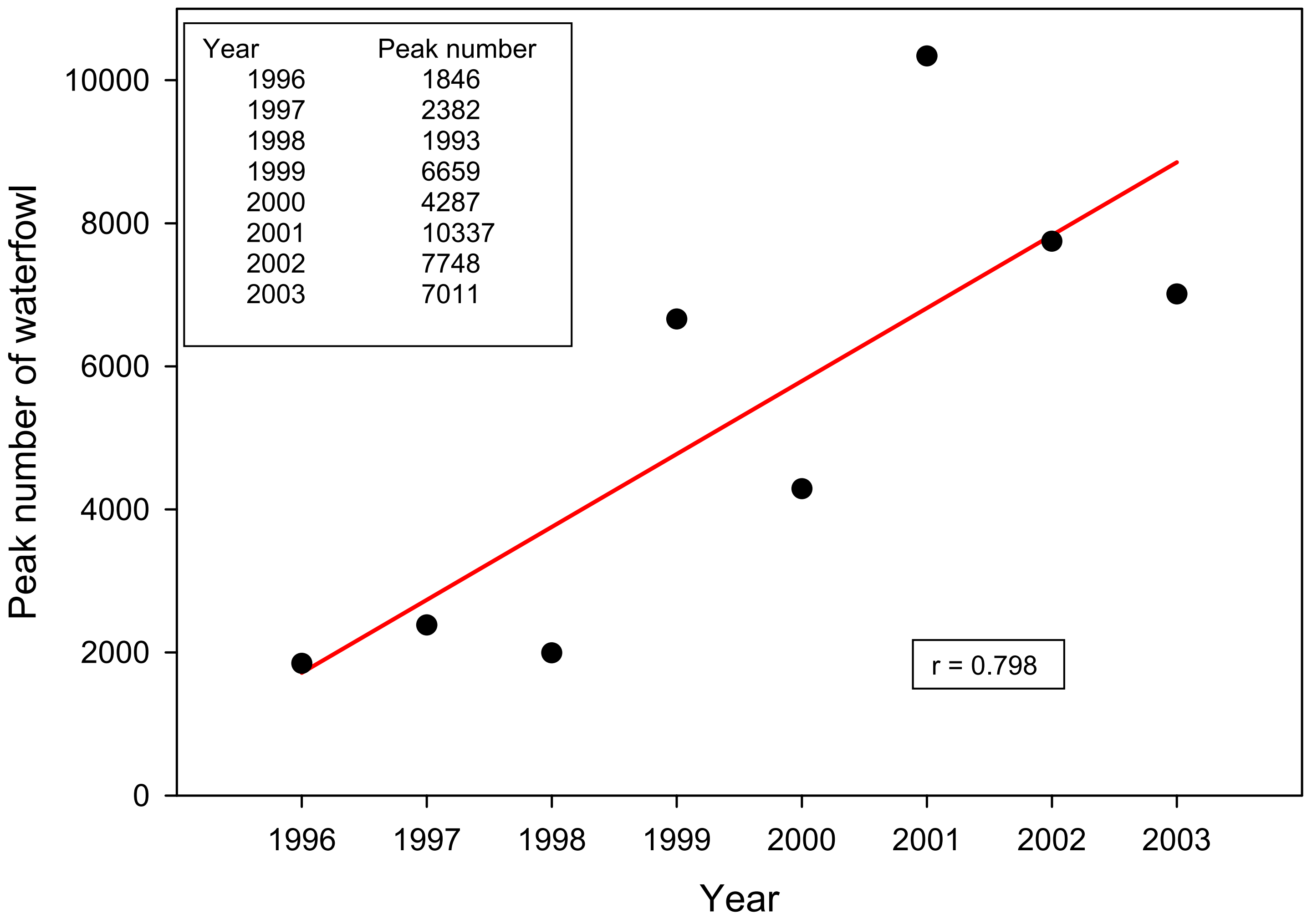


Figure 22. Trend in peak waterfowl numbers (not including Ruddy Ducks) at Mono Lake, 1996-2003



Year	Peak number
1996	1846
1997	2382
1998	1993
1999	6659
2000	4287
2001	10337
2002	7748
2003	7011

Appendix 1. Summer ground count survey dates (Mono Lake)

Survey number	1	2	3
***2002 Survey Dates**	June 5-7	July 1-3	July 22-24
2003 Survey Dates	June 9-11	June 30- July 2	July 21-23

*The survey dates that appeared in the 2002 Annual Report were incorrect. The actual 2002 survey dates are supplied here.

Appendix 2. Habitat categories used for documenting use by waterfowl and shorebird species (from *1999 Mono Basin Habitat and Vegetation Mapping, Los Angeles Department of Water and Power 2000*).

Marsh

Areas with surface water usually present all year and dominated by tall emergent species such as hard-stem bulrush (*Scirpus acutus*), cattail (*Typhus 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.

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 (*Artemisia 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

Freshwater-stream habitats are watered, freshwater channels such as exist in Rush Creek and Lee Vining Creeks.

Freshwater-ria

Freshwater-ria areas were surface water areas at the mouths of streams that likely have some salt/freshwater stratification.

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

Lagoons along the shoreline created by the formation of littoral bars with an extensive area of marsh or wet meadow indicating the presence of springs was present landward, were identified 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

Lagoons along the shoreline created by the formation of littoral bars, but without an extensive area of marsh or wet meadow present landward, were identified as ephemeral hypersaline lagoons. These were presumed to contain concentrated brine due to evaporation.

Unvegetated

Unvegetated areas were defined as those that were barren to sparsely vegetated (<15 percent cover). This class included sandy areas, alkaline flats, tufa, and delta outwash deposits.

Appendix 3. Fall aerial survey dates

Survey Number	**1**	**2**	**3**	**4**	**5**	**6**
Mono Lake	4 Sept	18 Sept	4 Oct	18 Oct	4 Nov	14 Nov
Bridgeport Reservoir	4 Sept	18 Sept	4 Oct	18 Oct	4 Nov	14 Nov
Crowley Reservoir	4 Sept	18 Sept	4 Oct	18 Oct	4 Nov	14 Nov

Appendix 4. Lakeshore segment boundaries (UTM, Zone 11, NAD 27, CONUS)

Mono Lake	**Lakeshore Segment**	**Code**	**Easting**	**Northing**
	South Tufa	SOTU	321920	4201319
	South Shore Lagoons	SSLA	324499	4201644
	Sammann’s Spring	SASP	328636	4204167
	Warm Springs	WASP	332313	4208498
	Northeast Shore	NESH	330338	4213051
	Bridgeport Creek	BRCR	324773	4215794
	DeChambeau Embayment	DEEM	321956	4214761
	Black Point	BLPT	318252	4211772
	Wilson Creek	WICR	315680	4209358
	Mill Creek	MICR	313873	4209544
	DeChambeau Creek	DECR	312681	4209246
	West Shore	WESH	315547	4208581
	Lee Vining Creek	LVCR	314901	4205535
	Ranch Cove	RACO	316077	4204337
	Rush Creek	RUCR	318664	4202603
Crowley Reservoir				
	Upper Owens	UPOW	346150	4168245
	Sandy Point	SAPO	345916	4167064
	North Landing	NOLA	346911	4164577
	McGee Bay	MCBA	345016	4164414
	Hilton Bay	HIBA	346580	4161189
	Chalk Cliff	CHCL	347632	4162545
	Layton Springs	LASP	347177	4165868
Bridgeport Reservoir				
	North Arm	NOAR	To be collected in 2004	
	West Bay	WEBA		
	East Shore	EASH		

Appendix 5. Cross-lake transect positions for Mono Lake

Cross-lake transect number	Latitude
1	37º 57’00”
2	37º 58’00”
3	37º 59’00”
4	38º 00’00”
5	38º 01’00”
6	38º 02’00”
7	38º 03’00”
8	38º 04’00”

APPENDIX 4

Waterfowl Protocol Review, Robert McKernan

Mono Lake Waterfowl Monitoring Program - Peer Review

Prepared by: Robert L. McKernan, San Bernardino County Museum

Prepared for: Los Angeles Department of Water and Power

Date: March 2004

Background

Aerial visual surveys using fix-winged aircraft are a common methodology used by biologists to determine temporal and spatial patterns of waterbird populations on lakes, bays, wetlands, estuaries, oceanic areas, etc. Similar to surveys by boat, aerial visual surveys provide an indices through estimation of waterbird numbers. Aerial visual surveys provide an excellent method for coverage of large geographic areas in relatively short time periods, and offer a consistent measure of waterbird numbers. Aerial visual surveys have been used to establish a long-term population trend for wintering Eared Grebe (*Podiceps nigricollis*) at the Salton Sea, California (Jehl & McKernan 2002).

Aerial visual techniques are quite efficient for monitoring bird populations over large geographic areas (Buckley and Buckley 2000). Estimates of accuracy of this technique have been mixed when aerial visual techniques are used in bodies of water when dense vegetation occurs. McCrimmon (1982) found that aerial estimates by observers were quite comparable to ground counts for nesting Great Blue Herons (*Ardea albus*), while Gibbs et al. (1988) and Dodd and Murphy (1995) found that aerial visual estimates averaged 87% and 80% of ground counts, respectively. Aerial estimates were acceptable for detection of a 15% annual change in numbers for statewide surveys (Dodd and Murphy 1995).

Questions surrounding estimating large numbers of flocks that may comprise thousands of birds has been assumed to be a major problem (Jehl, 1999). These concerns center on the ability of an observer to differentiate between certain species, usually in large flocks. However, studies comparing aerial and ground techniques found that census numbers for Ciconiiformes were similar for aerial versus ground (boat) surveys (Frederick al. 1996). Using aerial census techniques during long-term waterbird census studies conducted at the Salton Sea over two decades established three critical aspects of aerial censusing:
1) Maintaining the same observer(s) through the duration of the study, 2) Standardizing aerial census routes, and 3) Having the ability to periodically double-check estimates of large rafting flocks >200,000 immediately after the completion of the aerial census.

Combining these three elements in aerial visual surveys will markedly reduce error of aerial estimates (McKernan, unpubl.).

Review of LADWP field protocol at Mono Lake

I accompanied Debbie House (DH), LADWP Biologist, on one field day, 11 September 2003, where I assessed DH standard aerial methods for Mono Lake, Bridgeport Reservoir, and Crowley Lake (Appendix 1). During the 11 September review, all methods were evaluated, which included aircraft type, survey routes, speed of the aircraft, and altitude of the aircraft (Appendix 2). In addition, DH was evaluated on species recognition, and her ability to estimate waterbird numbers in various conditions (flying, rafting, diving, etc.), which also entailed multiple questions on species identification. Furthermore, detailed evaluations were completed regarding field recognition of Eared Grebes (*Podceps nigricollis*), Ruddy Duck (*Oxyura jamaicensis*), dabbling ducks Genus *Anas*, and diving ducks, Genus *Aythya*, and *Mergus*.

Results of field protocol evaluation

During the 11 September 2003 review, a detailed evaluation was made of Debbie House's ability and experience at identifying waterbirds, and estimating waterbirds numbers. Also evaluated was the established protocol/methodology developed and used for Mono Lake, Bridgeport Reservoir, and Crowley Lake (Appendix 1). Specific evaluation was made of the physical placement of near shore and offshore transects at the three study sites (Appendix 2).

Observer's ability with waterbird identification

Through random questioning during in-flight observations, Ms. House's recognition of waterbird species was first-rate. She was extremely detailed in her accounts of what waterbirds represented which species and why. With any aerial visual survey, the key factor is experience with actual flight time to develop knowledge for counting and identifying birds rafting on the water. It was apparent, through my examination, that Debbie House had gained satisfactory experience in identification of waterbirds from an aircraft. In fact, based on more than sixty identification questions posed to Ms. House, she correctly answered all questions regarding waterbird identification, and multiple questions they included separation of RUDU and EAGR. I believe Ms. House's ability to separate RUDU and EAGR during aerial visual surveys at Mono Lake, Bridgeport Reservoir, and Crowley Lake are very accurate. In addition, during this protocol field review, her ability and confidence in separation of RUDU versus EAGR in all aerial survey conditions was excellent.

Observer's ability with waterbird population estimates

Similar to species identifications, I evaluated Debbie House on her ability to estimate rafting numbers of waterbirds during the protocol review of 11 September. During the protocol review at Mono Lake, Bridgeport Reservoir, and Crowley Lake, we had an excellent variety of birds and diverse numbers to estimate. My method for evaluating Ms. House was to quiz her on estimates of loafing waterbird group size at various vantage points right angle to the aircraft. Through multiple comparisons, ± 105 different group size flocks (25 – 3500), Ms. House was within 2% to 5% of my estimates. The accuracy of waterbird estimation displayed by Ms. House was outstanding.

Species recognition

Most species of waterbird can be clearly identified during aerial visual surveys assuming that all protocol parameters are maintained (Appendix 2). However, certain species, such as Eared Grebe (EAGR) and Ruddy Duck (RUDU) have proposed identification problems for some biologists during aerial visual surveys. These problems occur because both species, EAGR and RUDU are of similar size from the dorsal view and can exhibit similar plumage coloration. The general morphology for Eared Grebe is length 28-34 cm, and wingspan 56-60 cm. Eared Grebe plumage dorsally is usually dark dusky wash on sides that is contrasted with a white breast. The general morphology of Ruddy Duck is, length 35-43 cm, and wingspan 53-62 cm. Ruddy Duck plumage dorsally during eclipse plumage phase (winter) appears dusky-brown.

Although these two species, EAGR and RUDU are similar in size, as with identification through ground observations, specific traits can be discerned during aerial visual surveys (Appendix 3). Eared Grebe has a faint but detectable contrast between the back and flanks that can be seen dorsally from the air which aids in separation of RUDU. Another identification trait for EAGR, which help in separation between EAGR and RUDU, is the rounded body shape that EAGR reveal when loafing on water (Appendix 3). Obviously, these traits are subtle, however they have been a proven key to identification during aerial visual surveys to establish a long-term population trend for wintering Eared Grebe at the Salton Sea, California (Jehl & McKernan 2002).

As with EAGR, there are reliable plumage and body traits that allow clear separation of RUDU during aerial visual surveys (Appendix 3 and 4). The body of RUDU appears more elongated dorsally than EAGR from the air. Moreover the head/bill of the RUDU makes body size proportionally larger than EAGR dorsally from the air. Furthermore, the RUDU tail also adds to the elongated appearance, which aids in separation of EAGR dorsally from the air. These body shape and color techniques have been used with success during aerial visual surveys to establish a long-term population trend for wintering Ruddy Duck at the Salton Sea, California (McKernan in prep. 2004).

Assessment of aerial survey routes

The evaluation of the survey route methodology was developed and used for Mono Lake, Bridgeport Reservoir, and Crowley Lake (Appendix 1). Specific evaluation was made of the physical placement of near shore and offshore transects at the three study sites.

Mono Lake

Flight routes at Mono Lake included eight transects which bisected the lake from east to west. These eight transects accomplishes complete coverage of the lake surface of Mono Lake. The spacing/distance between each transect is good to eliminate double counting of waterbirds. However each transect placement is at an excellent proximity to the adjacent transect so large concentrations of rafting waterbirds can be detected.

Bridgeport Reservoir

With the smaller water surface at Bridgeport Reservoir, multiple transects could not be used. Instead, Ms. House deployed a complete coverage transect which begins at the North Arm of the reservoir and proceeds south to the West Bay and loops back along the East Shore, terminating near the North Arm. This transect provides adequate coverage of this site, and will allow complete coverage of the reservoir.

Crowley Lake

Similar to Bridgeport Reservoir, the Crowley Lake small surface area is not conducive to a series of transects which bisect the lake surface. As an alternative, Ms. House established a transect that circumnavigates the lake surface of Crowley. This is an effective method to view all areas of the lake, both near shore and open water areas.

SUMMARY

I, Robert L. McKernan, accompanied Debbie House, LADWP Biologist, on one field day, 11 September 2003. I assessed Ms. House's standard aerial methods for Mono Lake, Bridgeport Reservoir, and Crowley Lake. During the 11 September review, all methods were evaluated, which included aircraft type, survey routes, speed of the aircraft, and altitude of the aircraft. Furthermore, Debbie House was evaluated on species recognition, and her ability to estimate waterbird numbers in various conditions (flying, rafting, diving, etc.), which also entailed multiple questions on species identification. Additionally, detailed evaluations were completed regarding field recognition of Eared Grebes (*Podceps nigricollis*), Ruddy Duck (*Oxyura jamaicensis*), dabbling ducks Genus *Anas*, and diving ducks, Genus *Aythya*, and *Mergus*.

In my conclusion, which is based on twenty-five years of experience conducting ornithological aerial visual surveys, and development of multiple protocols for bird species detect ability, Ms. House's aptitude to estimate and identify waterbird species through aerial visual surveys is superb. Debbie has excellent training with estimates and species recognition. I believe Ms. House's protocol and methodology is more than adequate for detecting annual changes in waterbird populations at Mono Lake, Bridgeport Reservoir, and Crowley Lake.

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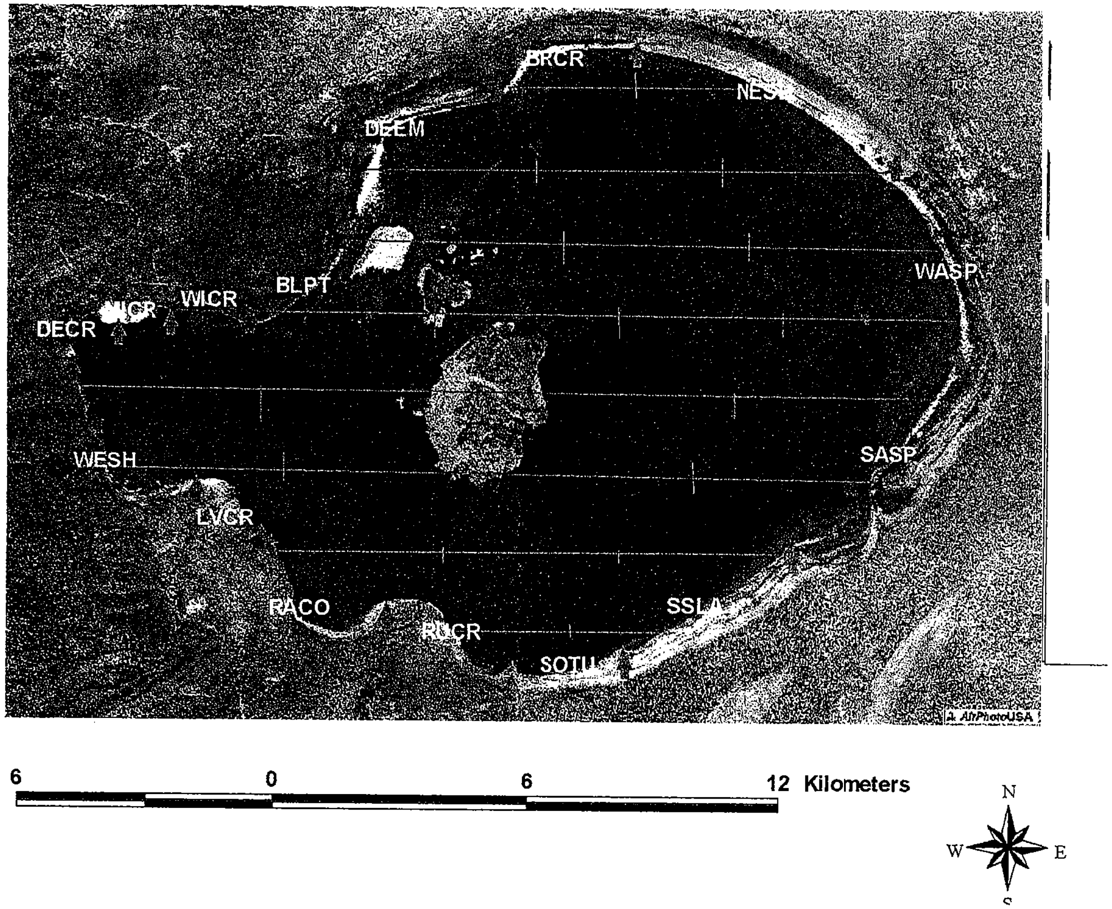
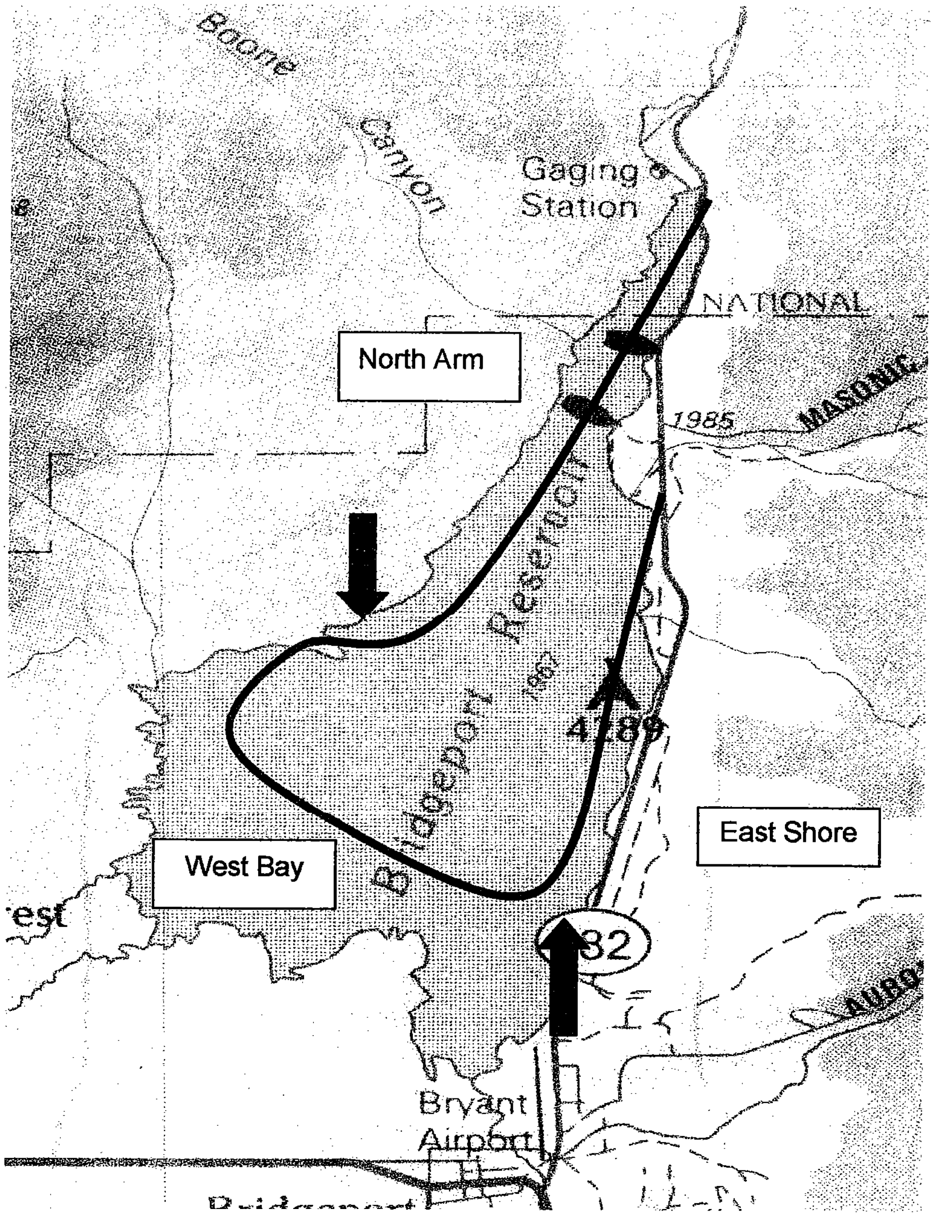
APPENDIX

Figure 3. Lakeshore segments, segment boundaries, and cross-lake transects used for fall aerial surveys of Mono Lake



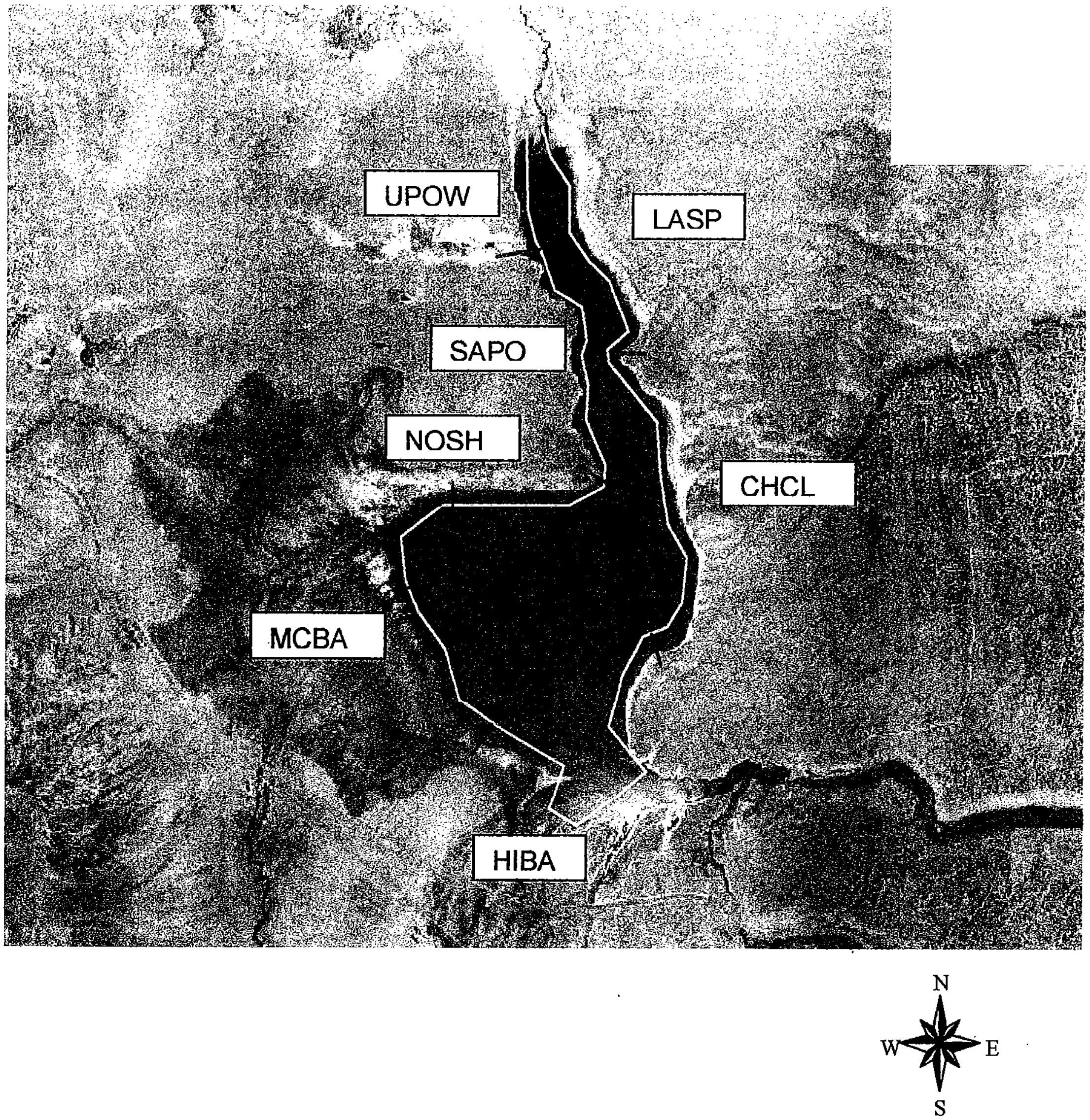
APPENDIX 1.

Figure 5. Lakeshore segments and segment boundaries used for fall aerial surveys of Bridgeport Reservoir

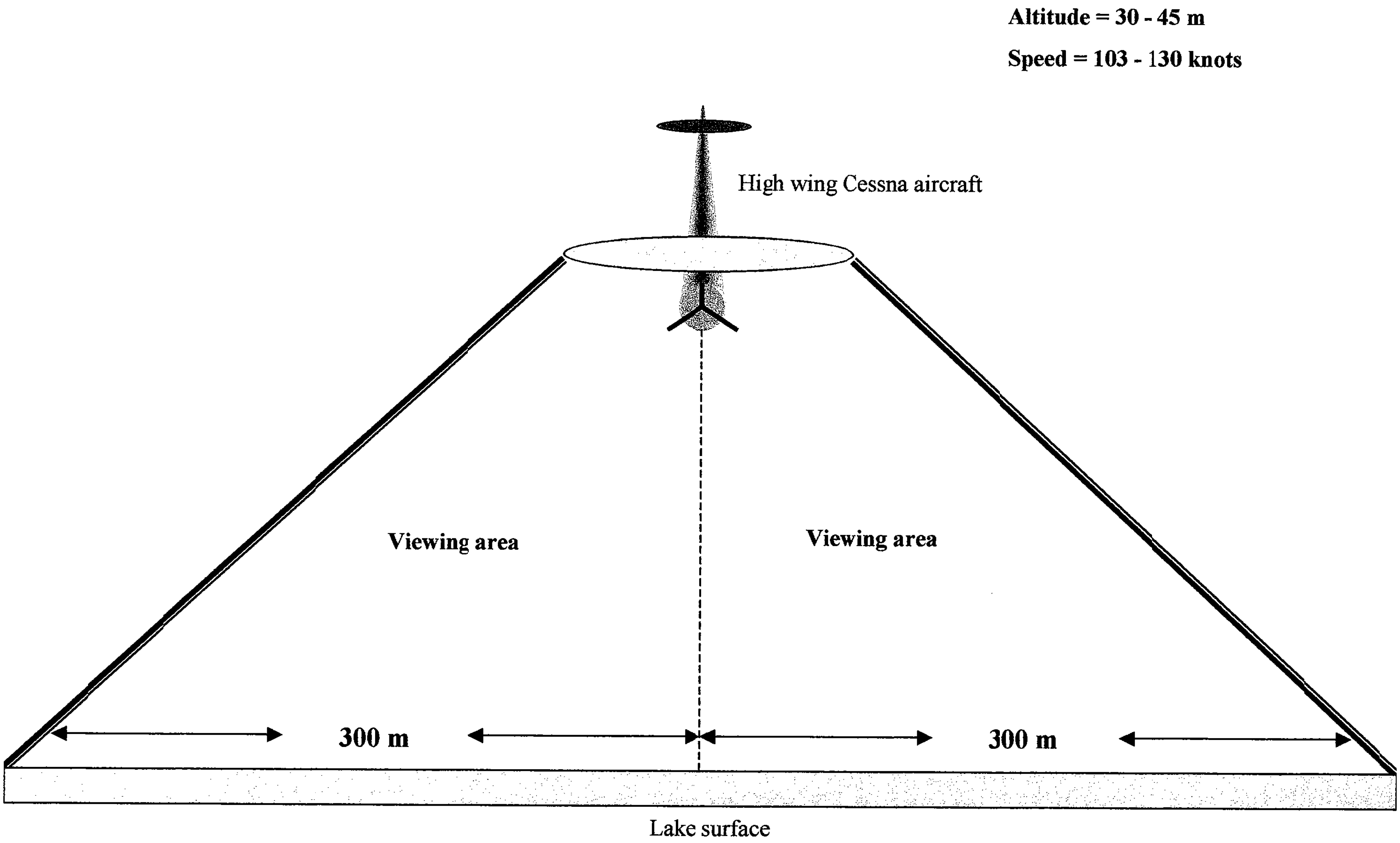


APPENDIX 1.

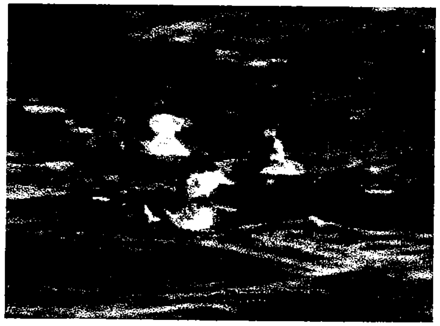
Figure 4. Lakeshore segments and segment boundaries used for fall aerial surveys of Crowley Reservoir

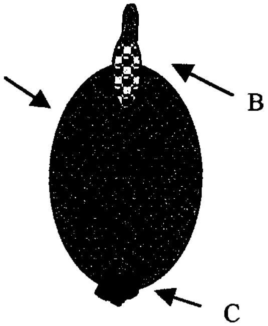


Appendix 2. Standard estimating method for aerial bird surveys



Appendix 3. Aerial view of Ruddy Duck versus Eared Grebe





Ruddy Duck

A = RUDU body appears more elongated than EAGR dorsally from the air
B = RUDU head/bill makes body size proportionally larger than EAGR dorsally from the air
C = RUDU tail also adds to the elongated appearance which aids in separation of EAGR dorsally from the air

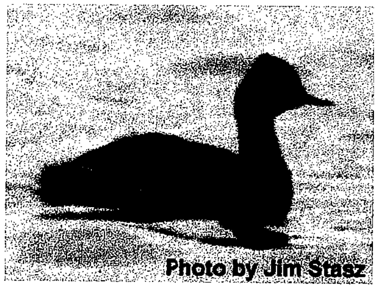
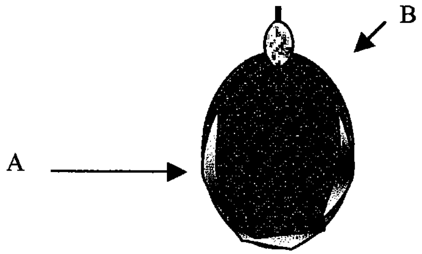


Photo by Jim Stasz

Photo by Jim Stasz



Eared Grebe

A = EAGR has faint but detectable contrast between the back and flanks that can be seen dorsally from the air which aids in separation of RUDU
B = EAGR appearance dorsally from the air suggest a more rounded body than RUDU

Appendix 4. Mix group separation of RUDU versus EAGR