Section 4

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

Monitoring Results and Analysis
For Runoff Season 2010-11

Mono Basin Tributaries:
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FINAL ANNUAL REPORT
Monitoring Results and Analyses for
Runoff Year 2010-2011

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1 INTRODUCTION

In April 2010 the Stream Scientists completed the *Synthesis of Instream Flow Recommendations to the State Water Resources Control Board and the Los Angeles Department of Water and Power* (Mono Basin Synthesis Report, M&T and RTA), available online at http://www.swrcb.ca.gov/waterrights/water_issues/programs/mono_lake/. During the ensuing runoff year, ongoing synoptic discharge measurement, groundwater elevation monitoring, and water temperature monitoring continued. Those data are summarized and reported in this Runoff Year (RY) 2010 Annual Report. We explored the feasibility of using the annual incremental growth of black cottonwood (*Populus balsamifera*) branches as a quantitative measure of plant vigor, and thus an indicator of riparian response to annual groundwater conditions. Recommendations for more detailed study are provided in this report. We assessed the Parker and Walker creeks sediment bypass strategy proposed by LADWP, and recommend refinements to the proposed monitoring and data collection regime. We also recommend continued maintenance of side-channel openings to provide perennial flows on Rush Creek 3D, 4bii, and 8 side-channels and Lee Vining Creek A-4 side channels.

2 HYDROLOGY

2.1 Annual Hydrographs

The Mono Basin tributaries – Rush, Lee Vining, Parker, and Walker creeks – had an atypical 2010 Runoff Year. Despite RY 2010 being the third consecutive Normal runoff year type with a forecasted 127,400 acre-feet runoff expected from the four tributaries, the snowpack was above average (104% of average), the annual snowmelt was delayed by wetter-than-usual April and May precipitation, and larger-than-normal snowmelt floods were observed in all four tributaries. LADWP implemented a May 1 forecast in RY2010, based on Ellery and Gem precipitation data and changes in the Gem Pass snow pillow data, to account for late-season precipitation. With the prior three consecutive runoff years (RYs 2007-09) of below average runoff, the wetter RY2010 snowpack allowed Grant Lake Reservoir (GLR) storage to rebound from low levels (12.9% of capacity in February 2009). Grant Lake Reservoir spilled one day shy of the entire month of July, 2010.

The Rush Creek Stream Restoration Flows (SRFs) exceeded the release requirements of SWRCB Order 98-05 of 380 cfs for 5 days. Rush Creek below the Mono Gate One Return Ditch (MGORD) had 12 consecutive days in July with streamflows above 380 cfs and a 433 cfs peak on July 11. Below the Narrows, streamflows combined with Parker and Walker creeks to peak for 14 days above 400 cfs, with a daily average peak discharge of 492 cfs on July 11th. Importantly, GLR spills coincided with the Walker Creek peak on July 7th, an important operational goal recommended in the Mono Basin Synthesis Report. In summary, the maximum daily average streamflows for Rush Creek at Damsite, below the MGORD, and below the Narrows were 478 cfs, 433 cfs, and 492 cfs, respectively.

Lee Vining Creek also had a large-magnitude snowmelt flood. The delay in onset of snowmelt runoff followed by a warm period in June resulted in an extremely rapid snowmelt ascension limb (Figure 3), with flows at Lee Vining Creek above Intake ramping from 140 cfs to a peak of 480 cfs in 5 days from June 2 to 7. No LADWP diversions occurred and the entire flood peak passed to lower Lee Vining Creek. The Lee Vining Creek at Intake peak of 511 cfs also occurred on June 7, and was slightly higher than the 'above Intake' peak estimate. The RY2010 'above Intake' peak of 480 cfs was the largest snowmelt flood since RY1995 (522 cfs) (the January 1997 winter rain-on-snow event was a comparable 524 cfs). The estimated flood peak magnitude for Lee Vining 'at Intake' (511 cfs) exceeded the January 1997 rain-on-snow flood of 422 cfs and was the largest recorded flood for Lee Vining Creek at Intake (records date back to RY1973). Secondary peaks of 275 cfs and 214 cfs occurred at Lee Vining Creek above Intake on June 30 and July 17; both peaks were completely diverted.

Parker and Walker creeks also had record snowmelt flood events (records date back to RY1973). The Parker Creek above Conduit streamflow peaked at 77 cfs on June 7. Parker Creek had two additional peaks on June 30 and July 17, reaching 59 and 56 cfs, respectively. Walker Creek had a peak event of 72 cfs on June 7, similar to the Lee Vining Creek and Parker Creek events. No diversions occurred from Parker and Walker creeks, and the 'below Conduit' peak magnitudes and dates were the same as those above the Conduit. Each RY2010 flood peak matched (Parker) or exceeded (Walker) record floods since RY1973. The snowmelt hydrographs for RY2010 extended through August and into September for each creek.

2.2 Hypothetical SEF Hydrographs

The Mono Basin Synthesis Report recommended Stream Ecosystem Flows (SEFs) replace the current Order 98-05 SRFs. Give the above average snowpack and wetter-than-usual spring conditions, RY 2010 provided a good opportunity to examine how SEF hydrographs and recommended operations would perform if implemented. Hypothetical Rush Creek and Lee Vining Creek SEF hydrographs were constructed for RY2010 (for the period April 1 through October 3) and compared to the actual RY2010 flow releases. The comparison showed an important difference between SRF and SEF hydrographs in Lee Vining Creek. While both hydrographs would require the snowmelt peak to pass downstream of the Conduit, the SRF flows captured two moderate-sized Lee Vining above Intake peaks (275 cfs on June 29 and 214 cfs on July 17), and altered the magnitude and duration of the snowmelt recession. SRF baseflows (<60 cfs) began by July 2, 2010 (Figure 5). The SEF streamflows would have provided late-June and mid-July peaks below the Conduit, and would have extended the snowmelt recession to August 1, 2010. Our comparison for the period April 1 to November 30 indicated that comparable flow volumes would be released below the Conduit: 32,719 af for SRF flows and 31,730 af for SEF flows.

A comparison of Rush Creek hydrographs is confounded by the GLR spill in RY2010 (the SRF actual flow). A spill was not recommended for Normal year SEF flow releases, and may not have occurred under SEF operations as well (Figure 6). We did not assess the SEF peak magnitude that would have resulted from a GLR spill. In addition to a slightly higher peak SRF magnitude (SRF = 433 cfs compared to SEF = 380 cfs), the SRF snowmelt peak had a longer duration and occurred later (July 9-19) than the SEF recommendation (July 4-6). The SRF flow volume released below GLR was higher than the recommended SEF release volume, due to the GLR spill.

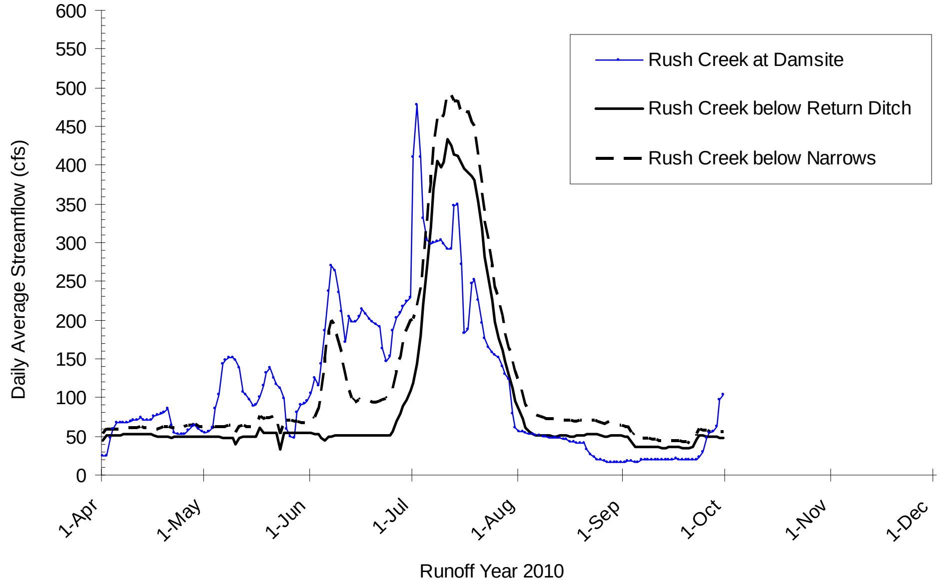

Figure 1. Rush Creek hydrographs for Runoff Year 2010.

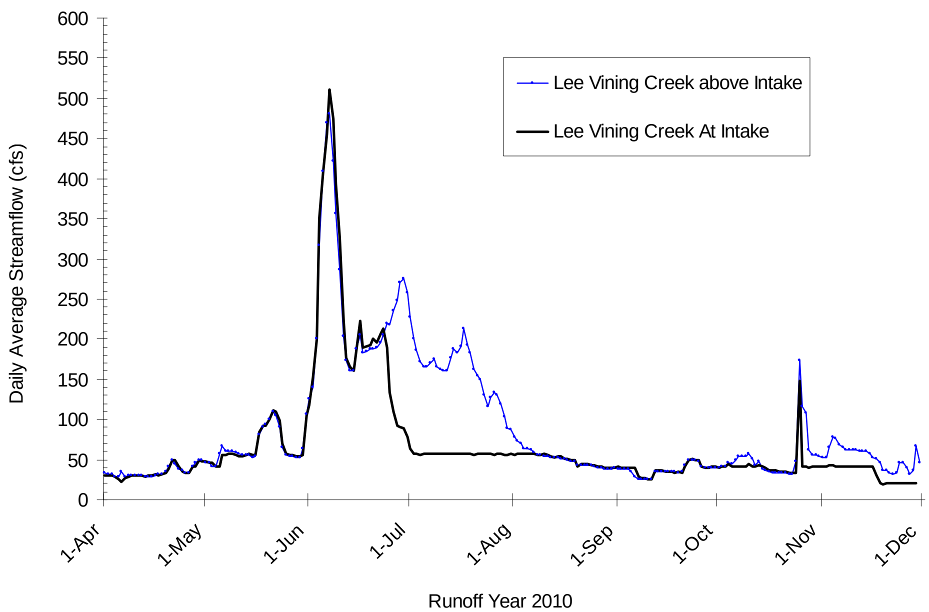

Figure 2. Lee Vining Creek hydrographs for Runoff Year 2010.

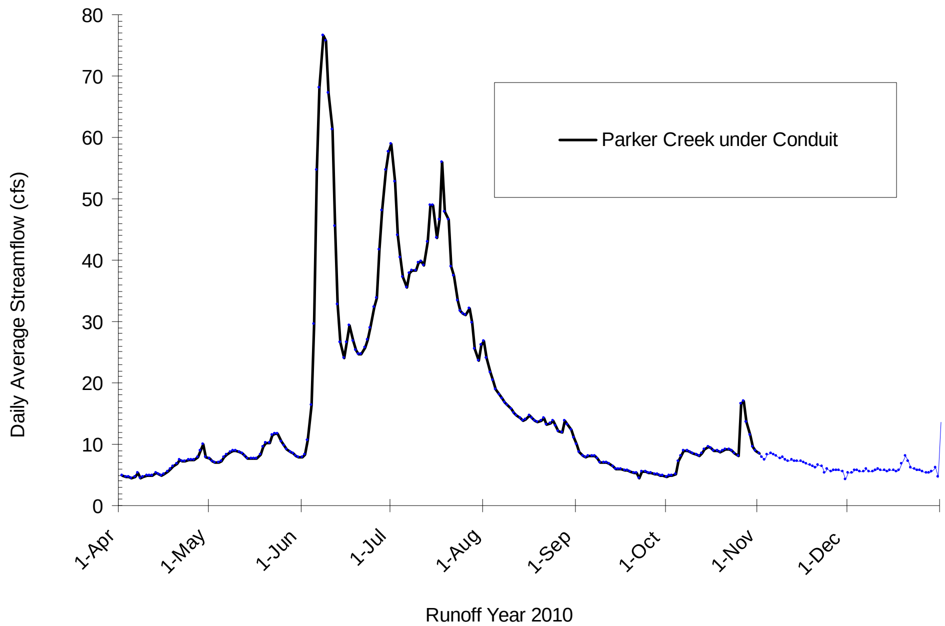

Figure 3. Parker Creek hydrograph for Runoff Year 2010.

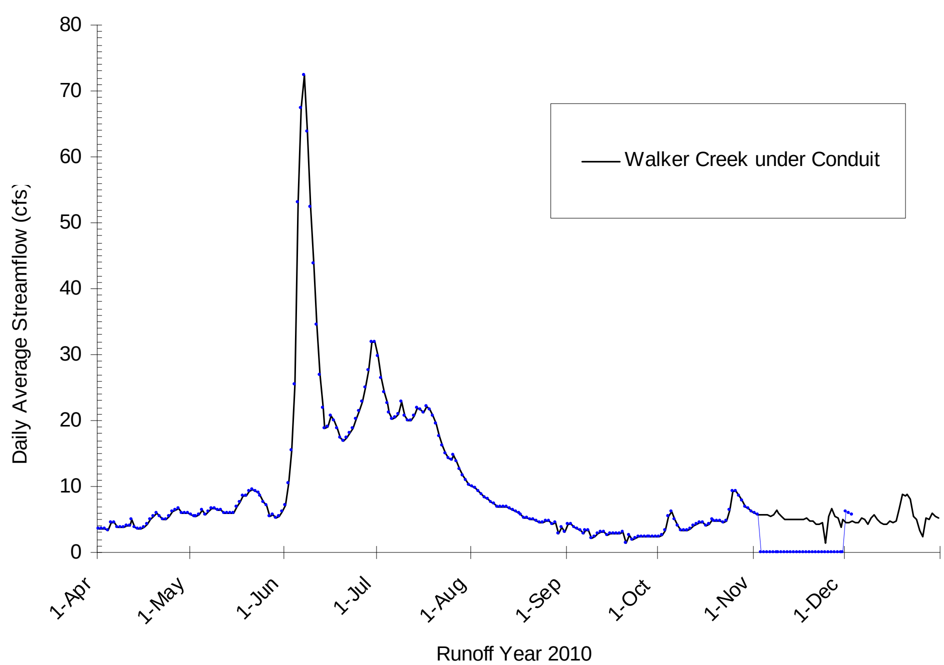

Figure 4. Walker Creek hydrograph for Runoff Year 2010.

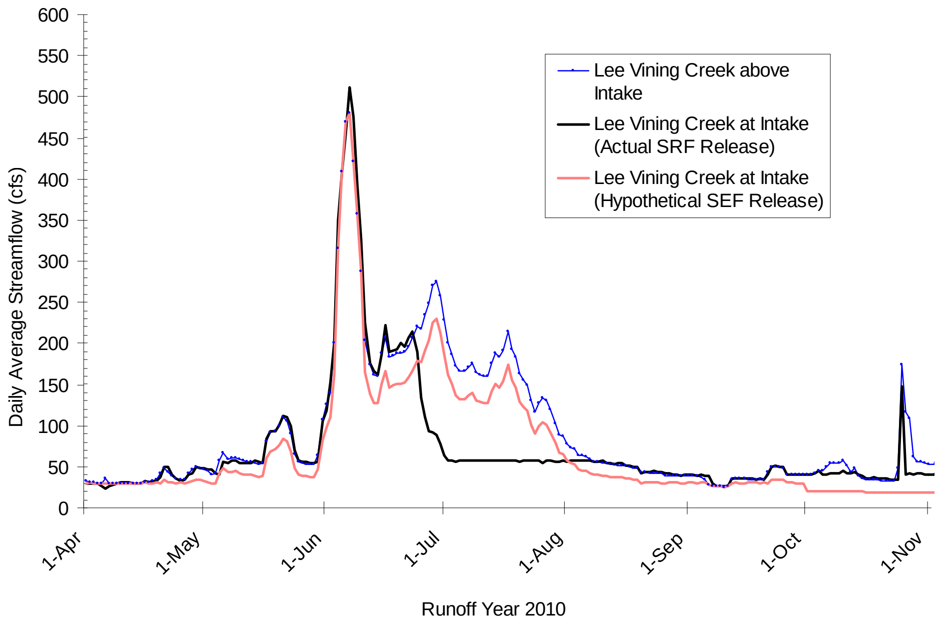

Figure 5. Comparison of RY2010 SRF and SEF hydrographs for Lee Vining Creek at Intake.

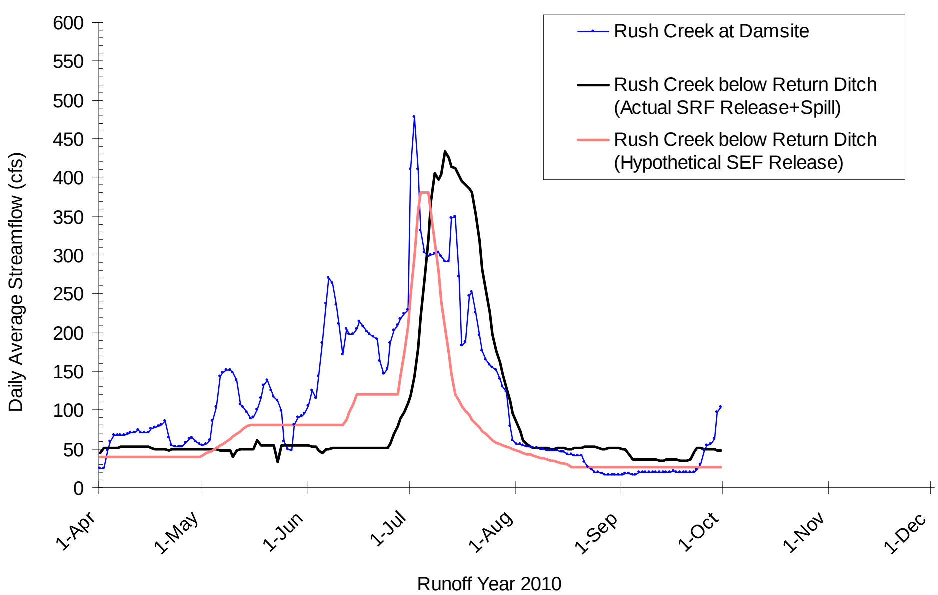

Figure 6. Comparison of RY2010 SRF and SEF hydrographs for Rush Creek below the Return Ditch.

2.3 Synoptic Streamflow Gaging

Instantaneous measurements of streamflow along the Rush and Lee Vining creek corridors (referred to as synoptic measurements) are being collected by LADWP monthly except during snowmelt runoff when streamflows are too high for accurate measurement and/or conditions are unsafe. The purpose of this data collection is to better understand the magnitude of flow losses along the stream corridors during different seasons and runoff year types (except the snowmelt season), and within sub-reaches of Rush Creek, so that bypass flows and flow releases can more accurately achieve the recommended flow magnitudes in specific stream reaches. Routine monthly measurements at consistent sites began in May 2009 on Rush Creek and in April 2010 on Lee Vining Creek. The December 2009 data were omitted because a flow release change occurred during data collection. Data collected during the past two runoff years from November 2009 to December 2010 by LADWP hydrographers were evaluated here. Measurement locations and flow estimation methods are summarized in Table 1. The following discussion highlights the summary data presented in Table 2.

Table 1. Location and method for synoptic discharge measurements collected in RY2009 and 2010 by LADWP.

Location	Distance from Mono Gate One or Conduit (mi)	Discharge Method
MGORD Current Meter Bridge	1.4	Rating Table 3
Rush Creek at Old Highway 395 Bridge	3.4	Current Meter
Rush Creek above Parker Creek	4.9	Current Meter
Parker Creek at Conduit	0.0	Parshall Flume
Parker Creek at Mouth	3.0	4 ft Cip Weir
Walker Creek at Conduit	0.0	Parshall Flume
Walker Creek at Mouth	2.9	2 ft Cip Weir
Rush Creek below the Narrows	5.6	Sum of Flows
Rush Creek Below 10 Channel Confluence	7.6	Current Meter
Rush Creek at County Road	9.1	Current Meter
Lee Vining Creek at Langemann Gate	0.0	Adjustable Weir
Lee Vining Creek Below County Road	3.6	Current Meter

Upper Rush Creek. Upper Rush Creek from the MGORD to the Narrows had two sub-reaches for which flow losses were computed: from the MGORD footbridge to Old Hwy 395 and Old Hwy 395 to the Narrows. The upper sub-reach (MGORD footbridge to Old Hwy 395) had overall streamflow losses averaging 1.6 cfs/mi during the sampling period reported (11/2009 to 12/2010), and had consistent rates of flow losses in terms of cfs/mi during the non-summer season. Measurements reported since November 10, 2009 were collected at baseflow releases ranging from 29.4 cfs to 51.6 cfs. Flow losses in this period during non-summer months ranged from 0.8 to 1.8 cfs/mi. Flow losses increased during the summer months to 2.1 to 3.6 cfs/mi. Flow losses from the lower sub-reach (Hwy 395 to Parker Creek) were slightly lower, particularly the September to December 2010 measurements (0.5 to 1.8 cfs/mi), but overall had a similar range as the upper sub-reach, ranging from 0.5 to 3.2 cfs/mi, compared to 0.8 to 3.6 cfs/mi for the MGORD to Hwy 395 sub-reach.

Lower Rush Creek. Lower Rush Creek from the Narrows to the County Road also had two sub-reaches in which flow losses were computed, with intermediate boundary defined by the lower Rush Creek gage located at XS-9+82 below the 10-Channel confluence. The upper sub-reach in the Rush Creek bottomlands (Narrows to Lower Rush) had nearly identical rates of streamflow losses as the lower sub-reach (Lower Rush to County Road), averaging 1.1 cfs/mi during the sampling period from November

2009 to December 2010, compared to 1.0 cfs/mi for the lower bottomlands sub-reach. However, this comparison is slightly skewed by the November 2009 measurement in which the flow measurements indicate a flow gain of 2.3 cfs in the upper bottomlands sub-reach, compared with a more typical flow loss of 2.9 cfs in the lower sub-reach. The upper bottomlands sub-reach also had slightly higher flow losses in the dry season months (August through October), ranging from 1.0 to 2.9 cfs/mi compared to 1.1 to 1.3 cfs/mi in the lower sub-reach. Overall, streamflow losses in upper Rush Creek (MGORD to Parker Creek) and in the Rush Creek bottomlands (Narrows to County Road) were consistent and within expected discharge measurement error (Table 3), with exception of the summer growing season, when higher rates of flow loss occurred.

Parker and Walker Creeks. LADWP installed Cipolletti weirs at the mouth of Parker and Walker creeks in October 2009 to accurately estimate streamflow. These flow estimates were compared to flow release estimates below the Conduit on each tributary, to determine flow losses along the two tributary corridors. Estimates of streamflow releases below the conduit were equally accurate because they were derived from Parshall Flumes with long-term rating data. Estimates of streamflow losses for the sampling period November 2009 to December 2010 were comparable to losses observed on Rush Creek, ranging from 0.0 to 0.8 cfs/mi on Parker Creek, and -0.2 to 0.6 cfs/mi (negative number indicates streamflow gain) on Walker Creek. On Walker Creek, several estimates during RY2009 and one estimate in RY2010 had a flow gain between the conduit and Rush Creek. This may be explained by measurement error given that flow gains were not observed in other tributaries and were typically very small values in Walker Creek (Table 2). However, gaining streamflow on Walker Creek is plausible given the known existence of historic and contemporary Vestal Springs that enter Rush Creek below the Narrows. The September 20, 2010 measurement on Walker Creek showed a loss of 66% of the total flow between the conduit and Rush Creek. Again, sampling error or flow loss could account for the measurement difference. Flow loss rates (cfs/mi) observed in Parker and Walker creeks were slightly higher during the April to October measurements during higher streamflows.

Lee Vining Creek. LADWP field crew began collecting synoptic flow measurements on Lee Vining Creek at the County Road in RY2010. These measurements were compared to the ‘Lee Vining Creek at Conduit’ gaged flow estimates to compute flow gains/losses in Lee Vining Creek. As was observed in Rush, Parker, and Walker creeks, Lee Vining Creek had the highest rates of flow loss during the summer low-flow season, with losses of up to 25% of the total flow between the Lee Vining Creek conduit and the County Road. Flow loss MAGNITUDES of 12 and 10 cfs at baseflow releases of 50 and 40 cfs were estimated for August and September 2010 (both estimates were 25% of the Lee Vining below Intake release) were substantial. The estimated rate of flow loss of 3.4 cfs/mi during the August 2011 measurement was exceeded by only the Rush Creek Hwy 395 to MGORD section in October 2010 in which 3.6 cfs/mi flow losses were estimated.

Table 2. Summary of synoptic streamflow measurements collected by LADWP during the past two runoff years (expressed in cfs), with computations of streamflow gains and losses for sub-reaches of Rush, Lee Vining, Parker, and Walker creeks.

		Runoff Year 2009				Runoff Year 2010						
Measurement Location	Stream Mile	10-Nov	11-Jan	16-Feb	16-Mar	19-Apr	18-May	17-Aug	20-Sep	19-Oct	18-Nov	13-Dec
Measured by:		DWP	DWP	DWP	DWP	DWP	DWP	DWP	DWP	DWP	DWP	DWP
Mono Gate One Return Ditch	1.4	30.7	34.1	34.1	33.1	48.3	51.6	50.5	35.1	48.6	29.9	29.4
Rush Creek at Old Hwy 395	3.4	27.1	31.6	32.0	31.2	46.7	49.9	46.3	30.4	41.4	27.0	26.3
Rush Creek above Parker Creek	4.9	22.3	28.8	29.9	28.1	43.5	46.8	44.2	29.3	38.7	26.3	25.2
Parker Creek below Conduit	0.0	4.0	2.7	3.2	3.3	6.8	9.6	13.9	5.2	8.9	6.5	5.6
Parker Creek below Hwy 395	3.0	3.3	1.7	1.8	2.3	4.9	7.7	12.4	2.8	6.9	5.2	5.5
Walker Creek below Conduit	0.0	2.5	2.2	2.1	2.4	5.6	8.5	5.8	1.5	4.8	5.1	4.3
Walker Creek at confluence	2.9	2.7	1.6	2.8	2.5	4.8	7.4	4.1	0.5	4.0	5.1	4.3
Rush Creek below the Narrows (Sum of Gaged Flows)	5.6	37.2	39.0	39.4	38.8	60.7	69.7	70.2	41.9	62.3	41.5	39.3
Rush below Narrows (Sum of Measured Flows)	5.6	28.3	32.1	34.4	32.9	53.2	62.0	60.7	32.5	49.6	36.5	35.0
Lower Rush Creek Mainstem blw 10 Falls	7.6	30.6	31.0	31.9	30.8	51.5	60.3	54.8	29.2	47.6	34.0	31.9
Rush Creek at County Road	9.1	27.7	29.8	30.3	30.3	50.7	60.0	52.9	27.5	45.9	32.0	29.7
Lee Vining Creek at Langmann Gate	0.0					33.8	92.7	49.6	41.9	34.6	40.9	19.6
Lee Vining Creek at County Road	3.6					27.9	90.4	37.3	31.4	27.3	33.0	14.5
Streamflow Gain/Loss: MGORD to Hwy 395		3.6	2.5	2.1	1.9	1.6	1.7	4.3	4.8	7.2	2.9	3.1
Rate of Flow Loss (cfs/mi)		1.8	1.2	1.1	0.9	0.8	0.9	2.1	2.4	3.6	1.5	1.5
Percent Loss (%)		11.9%	7.3%	6.3%	5.7%	3.3%	3.4%	8.4%	13.5%	14.8%	9.8%	10.4%
Streamflow Gain/Loss: Hwy 395 to Parker		4.7	2.8	2.1	3.1	3.2	3.1	2.0	1.1	2.7	0.7	1.2
Rate of Flow Loss (cfs/mi)		3.2	1.9	1.4	2.1	2.1	2.0	1.4	0.7	1.8	0.5	0.8
Percent Loss (%)		17.5%	8.8%	6.4%	10.0%	6.8%	6.1%	4.4%	3.6%	6.5%	2.6%	4.5%
Streamflow Gain/Loss: MGORD to Parker		8.4	5.3	4.2	5.0	4.8	4.8	6.3	5.8	9.9	3.6	4.2
Rate of Flow Loss (cfs/mi)		1.7	1.1	0.9	1.0	1.4	1.4	1.8	1.7	2.8	1.0	1.2
Percent Loss (%)		27.3%	15.5%	12.3%	15.1%	9.9%	9.3%	12.4%	16.6%	20.4%	12.2%	14.4%
Streamflow Gain/Loss: MGORD/Conduit to Narrows (measured flows)		8.9	6.9	5.0	5.9	7.5	7.7	9.5	9.3	12.7	5.0	4.3
Rate of Flow Loss (cfs/mi)		1.6	1.2	0.9	1.1	1.8	1.8	2.3	2.2	3.0	1.2	1.0
Percent Loss (%)		24.0%	17.7%	12.6%	15.2%	12.3%	11.0%	13.5%	22.3%	20.4%	12.0%	10.9%
Streamflow Gain/Loss: Narrows to Lower Rush		-2.3	1.1	2.5	2.0	1.7	1.7	5.9	3.3	2.0	2.5	3.1
Rate of Flow Loss (cfs/mi)		-1.2	0.5	1.3	1.0	0.9	0.8	2.9	1.7	1.0	1.3	1.5
Percent Loss (%)		-8.1%	3.4%	7.4%	6.2%	3.2%	2.7%	9.7%	10.1%	4.1%	6.8%	8.8%
Streamflow Gain/Loss: Lower Rush to County Road		2.9	1.2	1.6	0.6	0.9	0.3	1.9	1.7	1.6	2.0	2.2
Rate of Flow Loss (cfs/mi)		2.0	0.8	1.1	0.4	0.6	0.2	1.3	1.1	1.1	1.3	1.5
Percent Loss (%)		9.6%	3.8%	5.0%	1.9%	1.7%	0.5%	3.5%	5.8%	3.4%	5.9%	6.9%
Streamflow Gain/Loss: Narrows to County Road		0.6	2.3	4.2	2.6	2.6	2.0	7.8	5.0	3.7	4.5	5.3
Rate of Flow Loss (cfs/mi)		0.2	0.6	1.2	0.7	0.7	0.6	2.2	1.4	1.0	1.3	1.5
Percent Loss (%)		2.3%	7.1%	12.1%	7.9%	4.8%	3.2%	12.8%	15.4%	7.4%	12.4%	15.0%
Streamflow Gain/Loss: MGORD to County Road		0.6	2.3	4.2	2.6	2.6	2.0	7.8	5.0	3.7	4.5	5.3
Rate of Flow Loss (cfs/mi)		0.2	0.6	1.2	0.7	0.7	0.6	2.2	1.4	1.0	1.3	1.5
Percent Loss (%)		2%	7%	12%	8%	5%	3%	13%	15%	7%	12%	15%
Streamflow Gain/Loss: Parker Conduit to Rush Creek		0.7	1.0	1.4	1.0	1.9	1.9	1.5	2.5	2.0	1.3	0.1
Rate of Flow Loss (cfs/mi)		0.2	0.3	0.5	0.3	0.6	0.6	0.5	0.8	0.7	0.4	0.0
Percent Loss (%)		18%	38%	44%	29%	28%	19%	11%	47%	23%	20%	2%
Streamflow Gain/Loss: Walker Conduit to Rush Creek		-0.2	0.6	-0.7	-0.1	0.8	1.0	1.7	1.0	0.8	0.1	-0.1
Rate of Flow Loss (cfs/mi)		-0.1	0.2	-0.2	0.0	0.3	0.4	0.6	0.3	0.3	0.0	0.0
Percent Loss (%)		-7%	28%	-31%	-2%	14%	12%	29%	66%	17%	1%	-2%
Streamflow Gain/Loss: Lee Vining Conduit to Rush Creek						5.9	2.3	12.3	10.6	7.3	7.9	5.1
Rate of Flow Loss (cfs/mi)						1.6	0.6	3.4	2.9	2.0	2.2	1.4
Percent Loss (%)						18%	3%	25%	25%	21%	19%	26%

Table 3. Summary of streamflow loss rates (cfs/mile) for Upper and Lower Rush Creek measured by LADWP during the past two runoff years.

	RY 2009				RY 2010						
	10-Nov	11-Jan	16-Feb	16-Mar	19-Apr	18-May	17-Aug	20-Sep	19-Oct	18-Nov	13-Dec
	(cfs/mile)										
Upper Rush Creek (MGORD to Parker Creek)	1.7	1.1	0.9	1.0	1.4	1.4	1.8	1.7	2.8	1.0	1.2
Lower Rush Creek (Narrows to County Road)	0.2	0.6	1.2	0.7	0.7	0.6	2.2	1.4	1.0	1.3	1.5

2.4 Groundwater Monitoring

Groundwater monitoring continued in RY2010. Data are currently being collected by M&T and DWP at six piezometers surrounding the Lower Rush Creek 8-Channel, and by the Mono Lake Committee at six piezometers in lower Rush Creek and at ten piezometers in upper Lee Vining Creek. Data from each of these sites were compiled for RY2010; data from the 8-Floodplain piezometers are presented in this report.

The 8-Floodplain groundwater monitoring began with six piezometers (numbered 8C-1 through 6) installed in RY2004 and 8C-7 and 8C-8 installed in RY2005. Piezometer 8C-8 has had a datalogger recording groundwater during the snowmelt season since RY2005; five other piezometers (8C-2, 4, 5, 6, and 7) have been continuously recording groundwater elevation since RY2008. Daily average groundwater elevation data for these six sites are presented in Appendix A. Piezometers 8C-2, 4, and 5 are located within approximately 20 ft of the left bank of Rush Creek. Piezometers 8C-6, 7, and 8 are approximately 400 to 500 ft away from Rush Creek, associated more closely with the seasonally fluctuating 8-Channel. Each group of piezometers exhibited different groundwater patterns.

As a reminder, the 8-Channel was mechanically opened in 2004 and modified in 2005 to allow seasonal flows, then re-opened in March 2007 to allow perennial flow into the 8-Channel. The past three years have each been Normal runoff year types (Table 4), with 2008 and 2009 at the lower end of the Normal year-type range of annual yield (at 86.1% and 88.4% of average); RY2010 was near the upper end of the Normal yield range (May 1 forecast at 104% of average). Each Normal runoff years has provided unique patterns of flow timing and rates of flow into the 8-Channel from which general patterns of groundwater responses can be observed. Piezometer 8C-6 is provided as an example to illustrate these streamflow-groundwater response patterns (Figure 7).

Groundwater Peaks in RYs 2008 to 2010. Previous annual reports have discussed the importance of the proximity of groundwater elevation relative to the ground surface in promoting or sustaining riparian seedling germination, initiation, and vegetation growth. Peak groundwater elevation is an important variable determining the extent of ground surface saturation, and combined with capillarity, determining the extent to which shallow groundwater can promote riparian germination and sustain growth during subsequent summer and fall seasons. Groundwater elevation measured at the 8-Floodplain piezometers is influenced by mainstem discharge rate (discharge), water surface stage height (elevation), and by the 8 side-channel discharge/elevation. Using piezometer 8C-6 to represent groundwater conditions influenced by the 8 side-channel, peak groundwater elevations were compared to the Rush Creek below the Narrows snowmelt peak. Runoff years 2008 and 2010 had similar peak magnitudes of 423 cfs and 492 cfs below the Narrows (RY2010 had a longer duration snowmelt flood). Those snowmelt floods promoted groundwater peak elevations within 0.13 ft of one another at piezometer 8C-6 and within 2.1 ft of the ground surface (Table 5). RY2009 groundwater peak resulting from a 111 cfs peak discharge was 2 ft lower than RYs 2008 and 2010 (Figure 7). RY2005 and 2006 peak groundwater elevations were measured by field crew, not recorded by datalogger. During these Wet-Normal and Wet runoff years (Table 5), groundwater elevations were nearly 1 ft higher than the peak elevations from subsequent Normal runoff years. RY2004 (Dry-Normal II) had a modest snowmelt peak of 372 cfs, and the lowest recorded peak groundwater elevation; the RY2007 8C-6 peak groundwater elevation was also likely low, but was not measured in the field.

Variables Influencing Peak Groundwater Elevation. With available data, we evaluated the relationships between peak groundwater elevations (dependent variable) and three independent variables: (1) Rush Creek annual yield below the Narrows (in acre-feet), (2) the Runoff Year final forecast (in percent of average annual yield) (independent variables), and (3) Rush Creek peak discharge below the Narrows. Those three variables were moderately correlated to one another but may affect the peak groundwater elevations differently. For example, the final forecast represents each year's snowpack conditions in the Sierra's relative to other years. Those conditions may or may not be reflected in the magnitude, duration, and annual streamflow yield in the lower stream corridors due to regulation in the upper basin. The annual water yield in Rush Creek below the Narrows was generally a poor predictor of peak groundwater elevation at the 8-Floodplain (Figure 8); r^2 values were below 0.5. Piezometer 8C-5 best correlated to the annual water volume in Rush Creek. The final runoff forecast was also a poor predictor of peak groundwater elevation (Figure 9), with only piezometers 8C-6 and 8C-7 moderately correlated with forecasted runoff. The best predictor of peak groundwater elevation was the annual peak discharge below the Narrows (Figure 10). Several piezometers were strongly correlated between peak discharge and peak groundwater elevation, including 8C-2, 4, 7 and 8 (r^2= 0.84, 0.84, 0.95, and 0.56, respectively). Piezometer 8C-5 had the lowest correlation, likely a result of channel changes (migration, aggradation in the mainstem Rush Creek) adjacent to this piezometer which have caused higher relative groundwater elevations in the past three Normal runoff years, than was observed during the preceding wetter runoff years (2004 and 2005). Piezometer 8C-6 had a low r^2 value (0.40); however, when RY2004 was excluded from the analysis the correlation was much higher (0.86). We suspect that, despite the moderately high peak discharge in RY2004 (372 cfs), piezometer 8C-6 groundwater elevation remained low because the 8 side-channel had not yet been re-opened.

Table 4. Summary of runoff year types and peak discharge for Rush Creek below the Narrows during the past seven years with Rush Creek 8-Floodplain groundwater monitoring.

Runoff Year	Final Runoff Forecast	Runoff Year Type	Rush Creek Peak Daily Average Discharge Below the Narrows (cfs)
2004	79.8%	Dry-Normal II	372
2005	132.2%	Wet-Normal	467
2006	136.7%	Wet	584
2007	52.3%	Dry	64
2008	86.1%	Normal	423
2009	88.4%	Normal	111
2010	104.0%	Normal	492

Table 5. Groundwater peak elevations at 8-Floodplain piezometers.

	Peak Groundwater Elevation (ft)					
	8C-2	8C-4	8C-5	8C-6	8C-7	8C-8
RY2004	6516.4	6512.3	6506.2	6504.4		
RY2005	6517.0	6513.3	6506.7	6509.1	6505.3	6503.8
RY2006	6516.7	6513.6	6507.2	6508.9	6505.5	6504.7
RY2007						6503.7
RY2008	6516.6	6513.4	6507.2	6508.2	6504.9	6505.0
RY2009	6515.4	6511.6	6506.4	6506.1	6503.2	6503.3
RY2010	6516.9	6513.8	6507.8	6508.1	6505.0	6505.1
Ground Surface at Piezometer	6518.4	6514.7	6508.4	6510.2	6510.2	6506.8

Seasonal Groundwater Fluctuations. In RY2008 during the August 12 to 22 instream flow habitat mapping study on Rush Creek, experimental flow releases (Rush Creek below the Narrows) peaked at 94 cfs on August 17 and dropped to 22 cfs on August 21. The August 17 streamflow "peak" caused a sudden 2 ft spike in groundwater elevation. Then, at the lowest Rush Creek flow releases of 22 cfs below the Narrows, mainstem flows receded below the 8-Channel entrance threshold and flow into the 8-Channel ceased. This event precipitated a near-immediate drop in groundwater elevation of up to 3 feet at several piezometers in the Rush Creek 8-Floodplain, and followed by another 2 ft increase in groundwater elevation when flows were increased and sediment was manually excavated from the 8-Channel entrance to allow flow to resume down the 8-Channel. As described above, the 8C-6, 8C-7, and 8C-8 were strongly affected by side-channel flow magnitude.

A similar perturbation in groundwater elevation occurred in RY2010, recorded in field observations from Greg Reis of the Mono Lake Committee and in groundwater response data (Figure 7).

- 8/4 - 84 cfs bottomlands; Channel 8 presumed dry after this point;
- 8/11 - 75 cfs bottomlands; Channel 8 dry; in evening reopened entrance a small amount;
- 8/12 - 73 cfs bottomlands; Channel 8 flow reaching first bend; 11 am reopened enough for flow to reach past parking area by 1 pm (and still advancing);
- 9/7 - 50 cfs bottomlands; Channel 8 flow drying up just before parking area; 9am work on entrance got flow to parking area by 10 am.

Between August 3 and August 12, streamflows dropped from 105.6 cfs to 84.5 cfs. Groundwater elevation at piezometer 8C-6 dropped approximately 1.7 ft, then rose approximately 3 ft in the six days following the August 11 and 12 manipulations at the 8-Channel entrance. Groundwater elevation again dropped nearly 2 ft in mid-September in response to low fall streamflows dropping to 45 cfs below the Narrows, but rebounded with an immediate 3 ft response to a September 21-24 increase in streamflows from 45 to 60 cfs below the Narrows. These data indicate that hand manipulation of 8-Channel entrance can successfully maintain groundwater elevations across the 8-Floodplain, as the 8-Channel re-opening was intended. With hand labor of approximately 2 to 3 hours cumulative time by G. Reis in RY2010, Rush Creek streamflows above 56 cfs have enabled 8-Channel streamflow to sustain relatively high groundwater elevations at 8C-6 and other 8-Floodplain piezometers. Groundwater elevations in the fall of 2010 have remained approximately 1 to 2 ft higher than previous years.

The ground surface elevation at a particular piezometer location varied according to topography across the 8-Floodplain, so we examined the annual range or fluctuation in groundwater elevation (annual max – annual min) at each piezometer to assess the intra-annual fluctuation in groundwater elevation. For the 8-Floodplain piezometers, a 3 to 6 ft range of annual groundwater fluctuation was observed for RYs 2008-10 (Table 6), although RY2010 is not yet complete.

December Groundwater Spikes. The 8-Floodplain piezometers have also occasionally exhibited a rapid increase of approximately 1 to 2 ft in groundwater elevation. This occurred in December 2008 and 2009. Data are not yet available for December 2010. These sudden increases in groundwater elevation do not appear related to precipitation events.

Table 6. Annual groundwater fluctuations (annual maximum – annual minimum) for each 8-Floodplain piezometer with continuously recording dataloggers.

	Annual Groundwater Fluctuation (ft)		
	RY2008	RY2009	RY2010
8C-2	4.6	3.4	4.3
8C-4	4.9	4.8	5.8
8C-5	4.3	4.1	3.6
8C-6		5.2	6.0
8C-7	5.6	4.0	5.1
8C-8	4.6	3.3	4.3

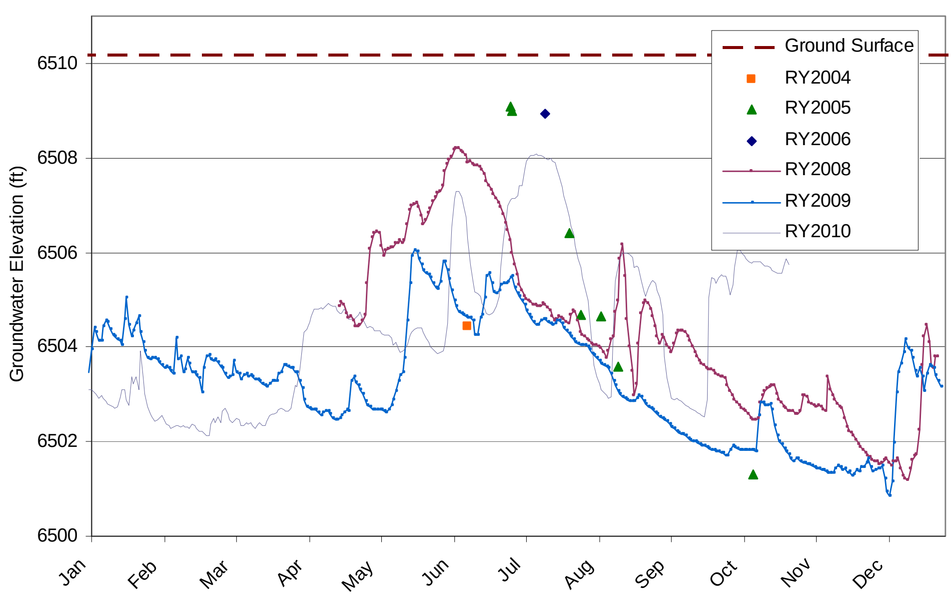

Figure 7. Daily average groundwater data at Piezometer 8C-6 in the 8-Floodplain, located 460 ft from the Rush Creek mainstem, close to the 8-Channel.

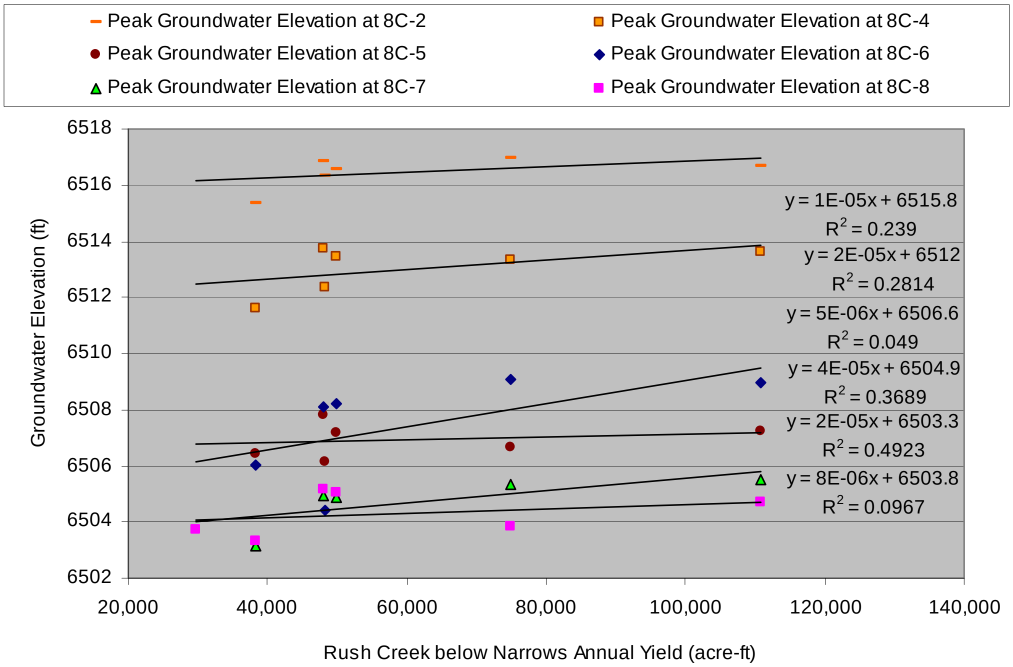

Figure 8. Comparison of peak groundwater elevations at Rush Creek 8-Floodplain with total annual yield (acre-feet) below the Narrows for RYs 2004 to 2010.

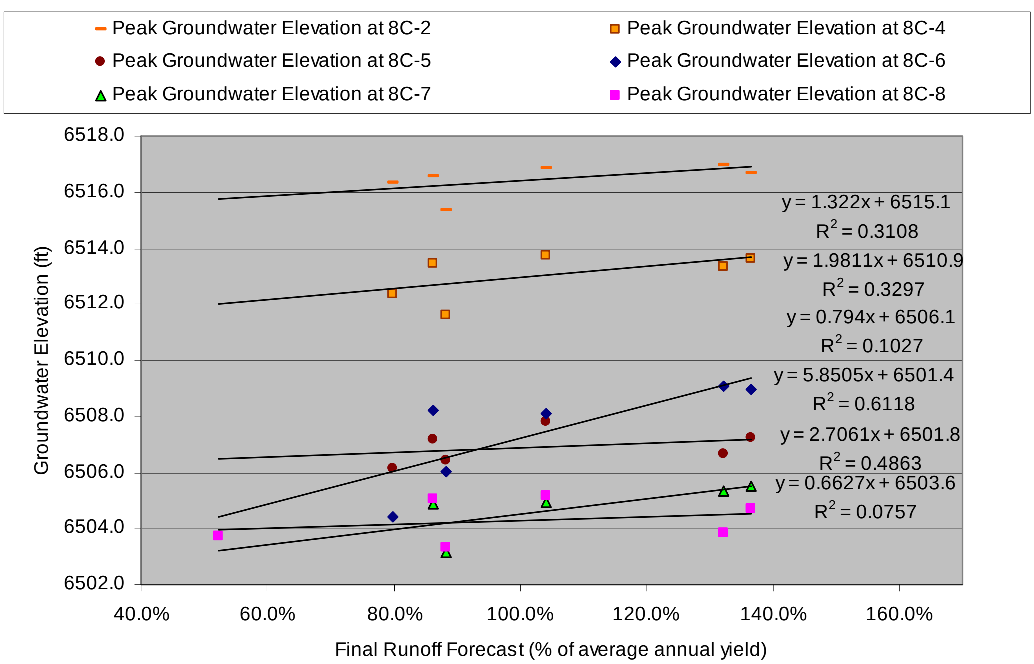

Figure 9. Comparison of peak groundwater elevations at Rush Creek 8-Floodplain with the Mono Basin final runoff forecast (% of average) for RYs 2004 to 2010.

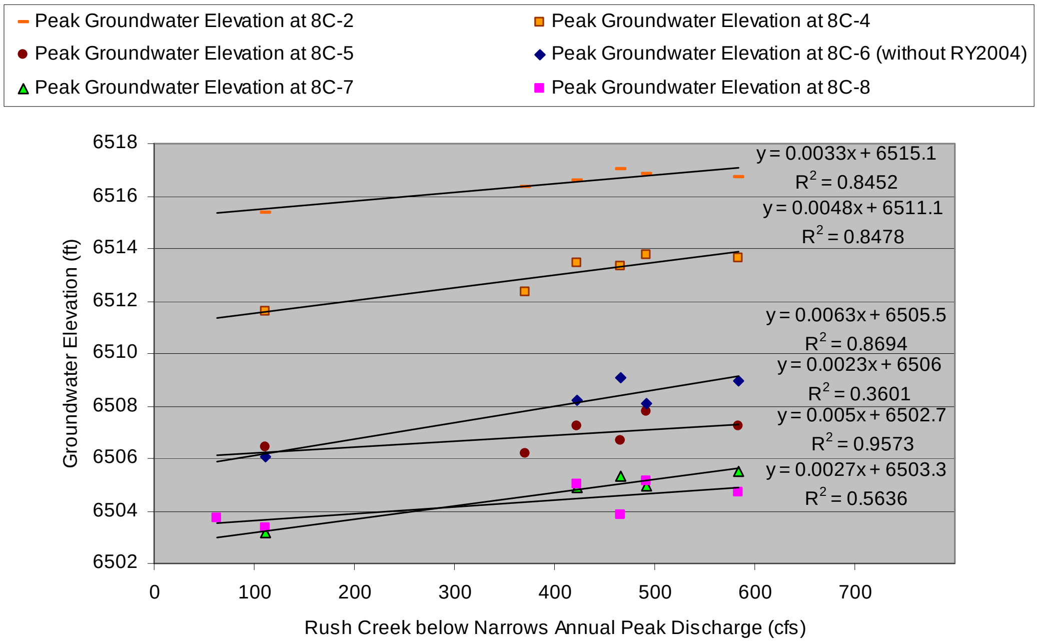

Figure 10. Comparison of peak groundwater elevations at Rush Creek 8-Floodplain with annual peak discharge (cfs) below the Narrows for RYs 2004 to 2010.

2.5 Water Temperature Monitoring

Water temperature monitoring continued in RY2010 at fourteen sites on Rush, Lee Vining, Parker, and Walker creeks (Table 7). Water temperature data for RYs 2000 to 2010 are in Appendix B. Given the wetter runoff conditions in RY2010, a full Grant Lake Reservoir and wetter spring conditions, water temperature conditions were generally good in Rush Creek during the summer, compared to several previous years with lower reservoir elevations and drier conditions. For example, the Rush Creek at MGORD bottom RY2010 annual maximum temperature was 67.7 ^{o}F, compared to 78.1 ^{o}F and 79.5 ^{o}F in RY2007 and RY2008, respectively. Cooler upstream Rush Creek temperatures resulting from a full GLR, resulted in cooler downstream temperatures. The Rush Creek at County Road annual maximum temperature of 71.6 ^{o}F was the lowest annual maximum water temperature at that site since RY2006. In contrast, the annual maximum temperature for Parker creeks at its confluences with Rush Creek was unusually high in RY2010, which had an annual maximum temperature of 74.1 ^{o}F; the next closest annual maximum was 70.8 ^{o}F.

Table 7. Location of water temperature dataloggers deployed along the four Mono Lake tributaries, and their data collection status the past two runoff years.

Thermograph Site Name	Location	Serial No.	WY2009 Status	WY2010 Status
RUSH CREEK AT DAMSITE	One logger installed inside the clockhouse (gauge house) by LADWP 15 ft concrete Parshall Flume.	2443023		
RUSH CREEK at MGORD TOP	Two loggers attached to rebar pin along LEFT BANK, approximately 200-300 ft downstream of the Gate-House.	2306353	data gap 10/20/2008 to 5/3/2009	complete year
RUSH CREEK at MGORD BOTTOM	Two dataloggers located at the downstream end of the MGORD on a staff plate near RIGHT BANK at entrance to the "A" Ditch.	1037792	complete year	complete year
RUSH CREEK at OLD HWY 395	Two datalogger, one at ~100 ft downstream of old Hwy395 Bridge on RIGHT BANK rebar pin downstream of a 1.5 ft diamater boulder, adjacent where the RB floodplain narrows.Secondary datalogger is 20ft upstream, under RB willows.	2443104	complete year	complete year
RUSH CREEK above PARKER CREEI	One datalogger located in P4-5 on LEFT BANK attached to a willow tree, downstream of an old rock wing dam or weir structure.	2443103		data gap 6/25/10 to 10//12/10
RUSH CREEK blw NARROWS	Two dataloggers located approximately 100 ft downstream of the Narrows, on LEFT BANK in an eddy behind large, square, flat-topped boulder.	1177230	complete year	complete year
RUSH CREEK below 10-Falls	One datalogger located at XS -9+82 gage site, attached to staff plate on LEFT BANK.	1121121	complete year	data gap 7/23/10 to 9/30/10; note discrepancy in data from WL16
RUSH CREEK at COUNTY RD	One datalogger located at the County Rd below the culvert, attached to the staff plate in the culvert outfall pool on the RIGHT BANK.	2443101	gap in data 7/10 to 9/30	gap in data 10/1 to 12/1 and 5/13 to 5/14
PARKER CREEK below CONDUIT	Two dataloggers located ~100 feet downstream of the conduit road crossing, one attached to rebar pin on left bank, just before channel enters overgrown, impenetrable willow brush; second is attached to rebar pin on LEFT BANK ~10 ft upstream.	1037787	data gap 7/10/2009 to 9/30/2009	data gap 10/1/2009 to 5/14/2010
PARKER CREEK at CONFLUENCE	One datalogger located ~100 ft upstream of the confluence with Rush Creek, in a braided reach with two channels, attached to rebar on RIGHT BANK of the right split channel.	1273222	complete year	complete year
WALKER CREEK below CONDUIT	One datalogger located approximately 50 ft downstream from LADWP flume below Conduit on LEFT BANK attached to a willow tree.	2306355	data gap 7/10/2008 to 9/30/2009	data gap 10/1/2009 to 5/15/2010;
WALKER CREEK at CONFLUENCE	Two dataloggers, one located approximately 25 ft upstream of the confluence with Rush Creek above the Narrows, on LEFT BANK tucked under willows and large boulder. Second datalogger is 25 ft further upstream where the foot trail crosses the creek, on RIG	2306360	data gap 10/1/2008 to 5/4/2009	complete year
LEE VINING CREEK below CONDUIT	One datalogger located approximately 150 ft downstream from LADWP Intake on RIGHT BANK attached to a t-post.	12373223	complete year	complete year
LEE VINING CREEK at COUNTY RD	One datalogger located ~50 below the County Road Crossing on LEFT BANK under large Alder, attached to rebar under alder roots.	2443099	data gap 10/1/2008 to 10/22/2008	data gap 5/13 (one day)

**All instruments are now Onset ProV2 temp loggers

3 GEOMORPHOLOGY

3.1 Side Channel Maintenance

During the past several runoff seasons, the Stream Scientists, LADWP, and MLC field crews have documented aggradation of side-channel entrances from coarse and fine bedload deposited by snowmelt peaks. Channel entrances have required routine sediment removal to maintain artificial perennial flows into side-channels. In August 2008, during Rush Creek experimental flow releases for habitat mapping, stranding and mortality of brown trout was documented in the 8-Channel when perennial side-channel flows were interrupted. Section 2.4 of this Annual Report demonstrated the immediate effect on groundwater elevation when the 8-Channel entrance became plugged by fine sediment deposition and then was subsequently reopened (Figure 7). The Synthesis Report recommends continued side-channel maintenance for Rush Creek 4bii, 8, and 3D channels, and Lee Vining Creek A3 and A4 channels, and suggests a 2 ft difference between riffle crest thalweg (RCT) elevation and side-channel invert elevation as a threshold for ceasing side-channel maintenance.

To ensure the desired conditions are attained, i.e., perennial streamflow in side-channels and sustained groundwater elevations in proximity to floodplain surfaces, the following steps are recommended:

(1) During the upcoming 2011 field season, M&T field crew should survey thalweg profiles at channel entrances to establish riffle crest thalweg elevations as a baseline for determining when side-channel maintenance can cease.

(2) During the RY2011 as the snowmelt recession limb approaches baseflow, M&T or LADWP field crew should routinely examine side-channel entrance conditions to ensure continued perennial flow.

(3) The past several years, hand labor has been adequate to restore side-channel flow; more detailed side-channel entrance manipulation is also feasible.

(4) A simple guideline for an adequate side-channel flow rate should be when at least a portion of side-channel flow returns to the main channel.

(5) Observations and maintenance activities should be recorded in field notes so these actions can be related back to groundwater data or other field observations such as riparian seedling desiccation.

3.2 Parker and Walker Creeks Sediment Bypass Strategy

During the past two years (2009 and 2010), LADWP has implemented a pilot plan for passing sediment downstream of the Parker and Walker creek diversion structures. LADWP is proposing to adopt the pilot operations plan as a long-term solution to sediment bypass requirements. The Stream Scientists and other Interested Parties were asked to review the proposed Sediment Bypass Operations Plan (Operations Plan) to determine its efficacy in meeting sediment bypass objectives. The following comments are provided for SWRCB and LADWP consideration.

In summary, at least three approaches have been considered for sediment bypass operations: (1) continue to allow sediment to be trapped by the Parker and Walker creek forebays, then excavate and dispose of this material. This has been the routine operation the past several decades. This option would rely on sediment recruitment from the channelbed and banks downstream of the diversion structures compensating for blocked sediment and maintaining sufficient sediment supply. This option did not meet the SWRCB requirement to pass sediment downstream of diversion structures; (2) continue to allow sediment to be trapped by the Parker and Walker creek forebays, then excavate and re-introduce this material downstream of the diversion structures. A gravel hopper was proposed as one re-introduction mechanism. A delay in material entrapment (in the forebay) and subsequent placement (into the downstream reach) was acceptable; (3) utilize existing sluice pipes already integrated into the diversion structures to pass the sediment load capable of being transported through the forebay pools to the sluice pipes. This option was evaluated by LADWP in 2009 and 2010.

Before determining if the sediment sluicing operation is performing adequately, additional information and monitoring refinements will be required.

(1) There needs to be a distinction between coarse and fine sediment. Of the total sediment load delivered to the forebays, we assume some fraction of bedload is not transported to the sluice pipe, and thus remains in the forebay as a prograding delta deposit. The operations and monitoring evaluation should initially quantify the sediment composition and volume of any coarse material not being transported to the sluice pipe before a final Operations Plan is feasible. If coarse material is still accumulating in the forebay, the Operations Plan needs to specify how this material will be treated. Once relative volumes of coarse (trapped) sediment and fine (bypassed) sediment are known, the Stream Scientists can determine if this is an acceptable long-term condition.

(2) The estimation of sediment bypass volume relies on before-and-after bathymetric surveys at the confluence of the stream channel and forebay. Survey extents must include a large enough area of the forebay to capture all sediment deposition, as well as one riffle crest upstream of the forebay in the free-flowing stream channel. The evaluation of long-term coarse sediment accumulation in the forebay should consider whether continued progradation will eventually allow coarse sediment to route through the pool and to the sluice pipe, and/or whether a modification of the pool could facilitate this process.

(3) Depending on the outcome of the ongoing sluice pipe Operations Plan, the Stream Scientists may request assessing the composition of sediment being passed through the sluice pipe, either as suspended sediment or as bedload. Currently the Stream Scientists think this effort is not warranted.

4 WOODY RIPARIAN PLANT VIGOR AND BASEFLOWS

4.1 Introduction

An important outcome of the Synthesis Report was the 80 cfs minimum baseflow recommendation to maintain favorable shallow groundwater conditions for woody riparian vigor below the Rush Creek Narrows. Because the duration of an 80 cfs baseflow typically extends well into the growing season, a substantial volume of water must be released annually. The Synthesis Report predicts drought stress (visible as shoot dieback) and seedling mortality when this 80 cfs baseflow occurs less than 77 days (50%) of the growing season. Similarly, the Synthesis Report identifies a 30 cfs baseflow for Lee Vining Creek. Therefore, two baseflow characteristics required quantification relative to shallow groundwater dynamics: magnitude and duration. The Synthesis Report notes (p.143) that "This threshold [the 80 cfs threshold for Lower Rush Creek] lacks a sharply defined inflection, but rather displays a gradient in groundwater decline with declining discharge spanning from approximately 90 cfs down to 66 cfs." Groundwater monitoring results can be variable. More data, as being monitored by LADWP (Section 2.4 of this report), will help refine this sharp inflection in shallow groundwater elevation (Refer to Figure 9-1, p.144 in the Synthesis Report). However, continued groundwater monitoring must be consequential, otherwise monitoring would simply be for monitoring's sake.

Future monitoring must possess an established pathway for modifying the Synthesis Report if the science warrants modification. To accomplish this, monitoring must be devised to quantify relationships between a management prescription (the independent variable) and a desired ecological outcome (the dependent variable). With shallow groundwater monitoring the independent variable, what would be the dependent variable(s)? Given the importance of both baseflow recommendations, we performed a brief pilot study in Summer 2010 to evaluate whether annual incremental growth of cottonwoods could be used to establish a quantitative relationship between plant vigor and baseflows. Data collection was not intensive nor was it intended to be statistically rigorous. Rather, the insight gained from this pilot effort would help in designing a comprehensive investigation for Summer 2011.

4.2 Quantifying Cottonwood Vigor

Plant vigor is often identified as a desirable monitoring variable because it should directly measures a plant's response to change(s) in its environment. Plant vigor is often described as the measure of an individual plant's health typically relying on leaf color, overall appearance, presence of disease, and/or other indicators of plant stress. Often several indicators are combined into an index. Unfortunately most health criteria are subjective; if recommended for future monitoring, measurement consistency would be a major concern.

Trees with an ample groundwater supply through many growing seasons will exhibit uniform increments in total annual growth (e.g., along the mainstem channel the roots typically have ready and consistent access to water). Where groundwater supply is inconsistently available year to year, as on aggraded floodplains without side-channels or on emergent floodplains, variable increments in total annual growth will reflect that availability.

The annual incremental increase in canopy area and/or tree height can be used to quantify vigor. The annual incremental ring in wood is a measure of vigor: the more wood made in a year, the more vigorous the growth and the greater the tree's biomass at the end of the growing season. Stromberg and Patten (1991) show on Rush Creek that increasing water availability during the year meant wider growth rings, and presumably more biomass and vigorously growing trees. Coring trees would be the best direct measure of vigor. However heart-rot and the potential of causing disease precluded us from recommending incremental tree coring as the preferred monitoring tool.

Multiple bud scales that cover emerging leaves fall away when the growing season begins (May 1), leaving several linear scars (Figure 11). Multiple bud scale scars at the branch tip define the terminal bud scars (Figure 11). The shoot elongates as the leaves enlarge while new leaves grow from the terminal apical meristem as the growing season advances. Shoot length and leaf number are directly related to physical, hydrologic, and biologic conditions during the growing season. A new terminal bud consisting of multiple bud scales and dormant leaves then develops as the growing season ends. The total annual growth increment is the distance between two sets of terminal bud scars. This annual increment in branch length is a quantifiable measure and acceptable surrogate for tree coring.

4.3 2010 Pilot Study

Four cottonwood trees were selected from locations along the mainstem and within interfluves between the 8-Channel and Rush Creek mainstem channel in the fall 2010. Lower branches were sampled all standing within arms-reach from the ground. Annual increments in branch length were measured back to the trunk. Panoramic photos were taken of two tree branches to determine whether annual increments in branch length measured in the field could be reliably estimated from the photos, i.e., whether the two sets of terminal bud scars for each year's growth could be reliably identified.

A cottonwood branch is comprised of spurs and long shoots (Figure 12). Spurs are short branches having minor variation in length and leaf number between years.

Figure 11. Example of cottonwood branch showing bud scales and linear bud scars.

Long shoots have long sections and short sections. Some branches were mostly short sections with one or two long sections (Figure 13). Other branches have long sections with a few short sections interspersed (Figure 14). Occasionally a spur branch will change its growth mode and begin making long shoots. Generally branches comprised mostly of shorter sections occurred along the mainstem and had been growing since re-watering in the late 1980's (Figure 13). Branches with longer sections occurred in the interfluve area on aggraded floodplains and had been vigorously growing since the 8-Channel reopened (Figure 14).

The length of shoot sections varied year-to-year (Figure 15). All sampled branches showed accelerated growth in RY2006 (a wet runoff year) and revealed some growth in RY2007 (a dry runoff year) when flows did not exceed 80 cfs below the Narrows. Measurements in the field were better at estimating annual branch increments than measurements from the panoramic photographs. The stitched photos had some distortion from being unable to consistently photograph at 90º to the entire branch; some annual growth increments were slightly shorter than had been measured from the same branch in the field.

Growth was compared to the number of days above 60 cfs and 80 cfs within a runoff year. Regardless of the streamflow threshold used, the length of a branch section generally increased as the number of good days increased (Figures 16 and 17). This limited analysis suggested that 80 cfs was a better predictor of growth than 60 cfs for the few branches measured. The same increments of growth within a RY were associated with longer streamflow durations at 60 cfs than 80 cfs. The point where the regression line intercepted 0% growth was 87 days for 60 cfs and 47 days for 80 cfs, suggesting that to grow similar lengths of shoots using 60 cfs requires a longer duration streamflow.

The relationship between annual shoot length and the number of days above 80 cfs was correlated (r^2=0.54, Figure 18), however when a standardized time period between 2001 and 2010 was considered, shoot length was more strongly correlated with the total number of days above 80 cfs (r^2=0.77, (Figure 19). Future analyses should use data standardized to a similar time period regardless of the year the branch started growing.

Individual shoot growth began to exceed 10% of the total lengths after 47 days of streamflows greater than 80 cfs (Figure 17). When the data were standardized to the 2001 to 2010 period the regression intersects 0% growth at 58 days. When an envelope curve was drawn above the data the point where grow increases rapidly, the duration of flows above 80 cfs was 82 days (Figure 19). The results of the pilot study suggested that 82 days of 80 cfs would be the minimum duration required to grow long shoots based only on the few branches measured. However, the pilot study accomplished its purpose by demonstrating that a quantitative assessment of vigor was feasible and could be related to the annual hydrograph.

Figure 12. Example of cottonwood branch showing short and long shoots.

4.4 2011 Cottonwood Vigor Assessment

An assessment of cottonwood vigor will rely on annual increments in branch length as its dependent variable. The 2011 Assessment will require two phases: (1) develop a defensible protocol of estimating vigor in one cottonwood and (2) compare spatial differences in vigor (i.e., different floodplain and side-channel locations) and temporal differences in vigor with/among each location being assessed. The overall goal of this assessment is (1) to develop a statistically relevant and biologically meaningful relationship between cottonwood vigor and the number of good days.

Phase 1 will be implemented late-spring through early-summer. Sampling the branches from one tree can introduce significant bias to the overall sampling design, and depending on the number of sampled branches needed per tree, will affect how many trees/locations can be sampled in Phase 2. Several trees will be intentionally over-sampled (a sample being measured annual branch increments back to the trunk) to explore how much aspect, age, and tree height affects annual growth. At this point, the necessary number of sampled branches, and how they would be sampled, is unknown. Variation in growth between branches for the same RY's growth increment and the variation in growth between RY's on the same branch will be evaluated. This analysis must be completed before implementing Phase 2. While sampling to achieve Phase 1 objectives, study locations for Phase 2 will be identified. A technical memo will be prepared presenting preliminary results from the Phase 1 effort (primarily a methodology for sampling a tree's vigor to implement Phase 2) and identifying Phase 2 study site locations (including trees proposed for sampling per site).

Phase 2 will be implemented late-summer. Four geomorphic settings will be sampled along Rush Creek between the MGORD and the County Road: mainstem bank, emergent floodplain, aggraded floodplain with a side-channel, and an aggraded floodplain without a side-channel. Three geomorphic settings will be sampled along Lee Vining Creek between HWY395 and the County Road: mainstem bank, emergent floodplain, and aggraded floodplain with a side-channel. The basic data set resulting from Phase 2 sampling will be a distribution of annual growth increments (i.e., among the trees sampled within one location) by location by RY for both creeks. These data will be plotted similarly to the pilot analysis, to identify thresholds in annual growth increment as a function of streamflow magnitude and duration, then compared to the outcome anticipated from the Synthesis Report.

5 LITERATURE CITED

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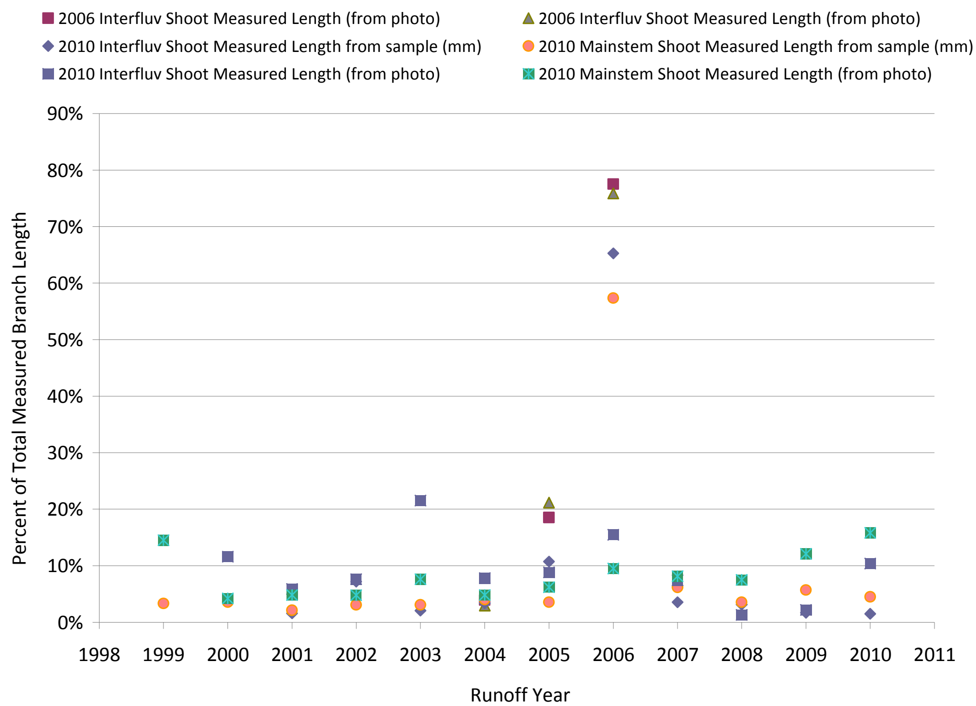


Figure 15. Percent of total cottonwood branch annual shoot growth for each runoff year.

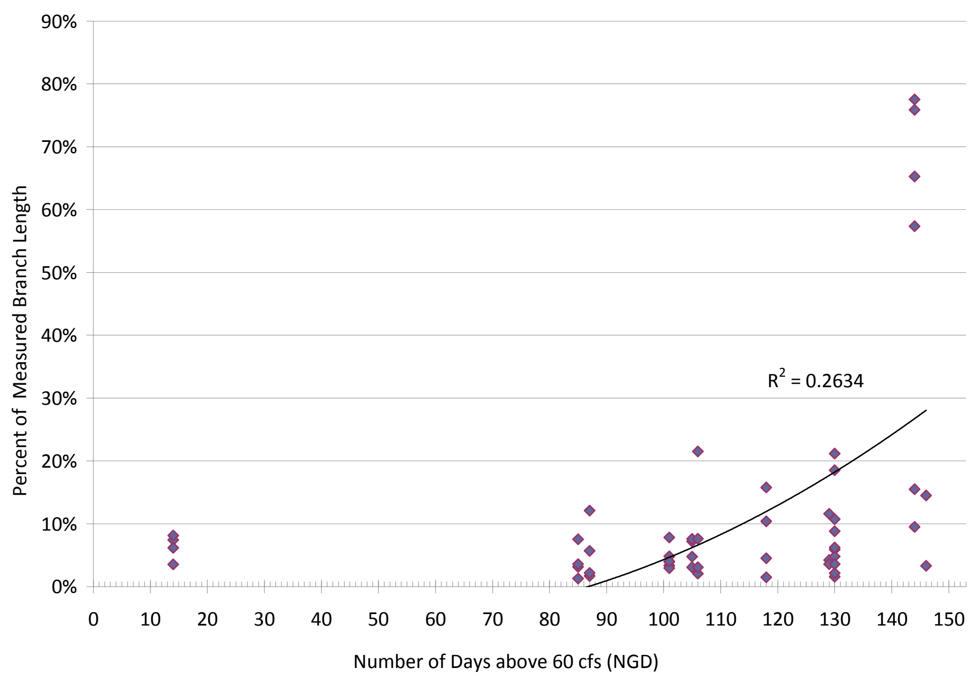


Figure 16. Comparison of cottonwood shoot growth to the number of days Rush Creek below the Narrows streamflows exceeded 60 cfs during the riparian growing season (May 1 to September 30).

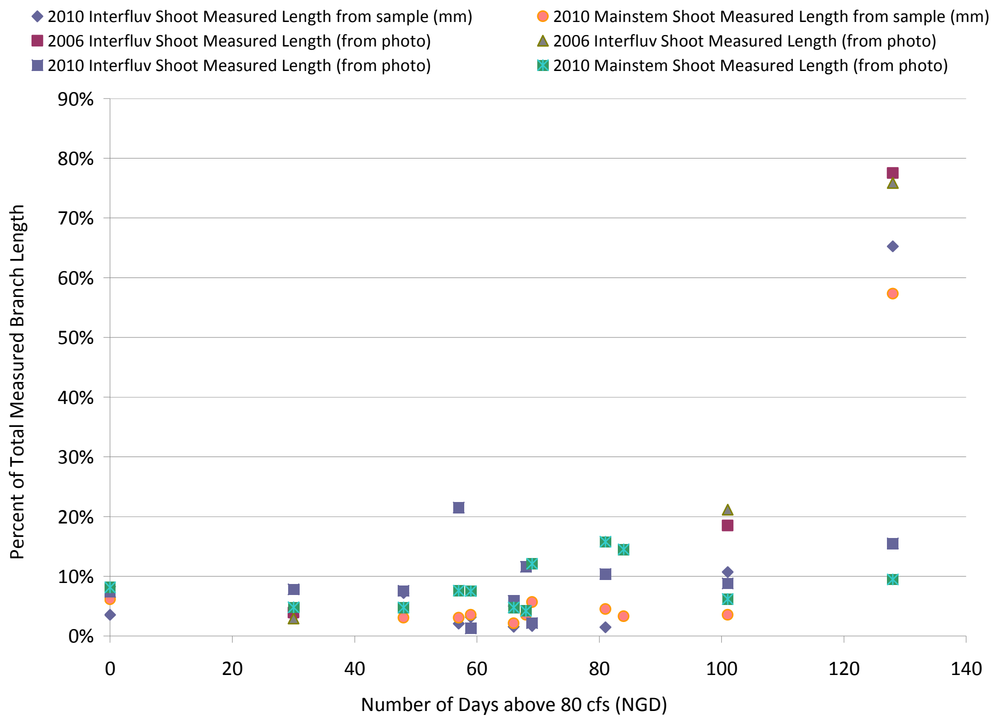


Figure 17. Comparison of cottonwood shoot growth to the number of days Rush Creek below the Narrows streamflows exceeded 80 cfs (the Synthesis Report recommendation) during the riparian growing season (May 1 to September 30).

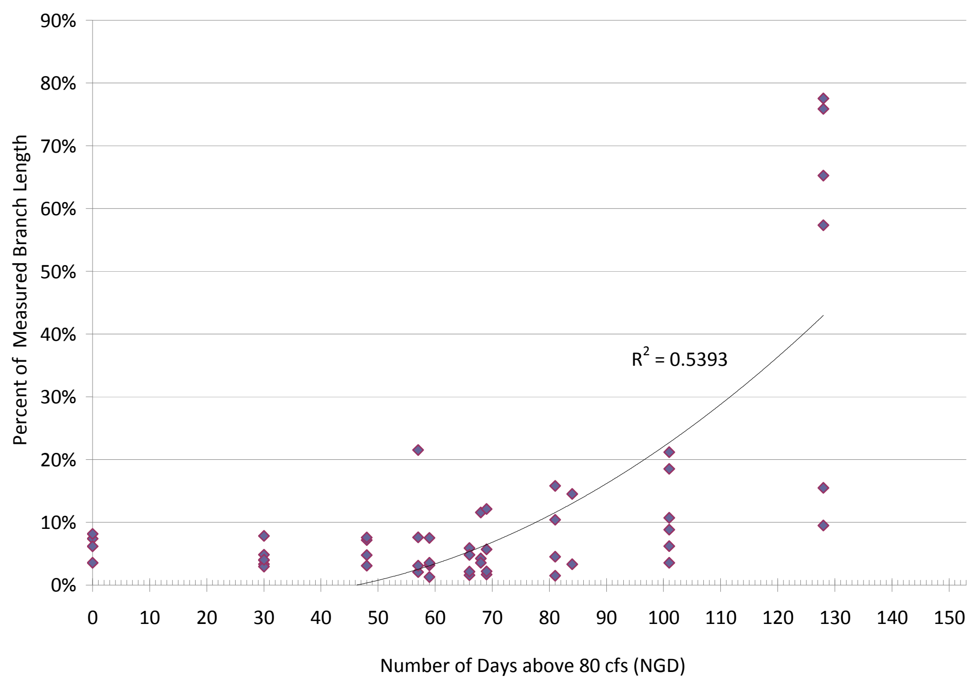


Figure 18. Relationship between annual shoot length and the number of days above 80 cfs.

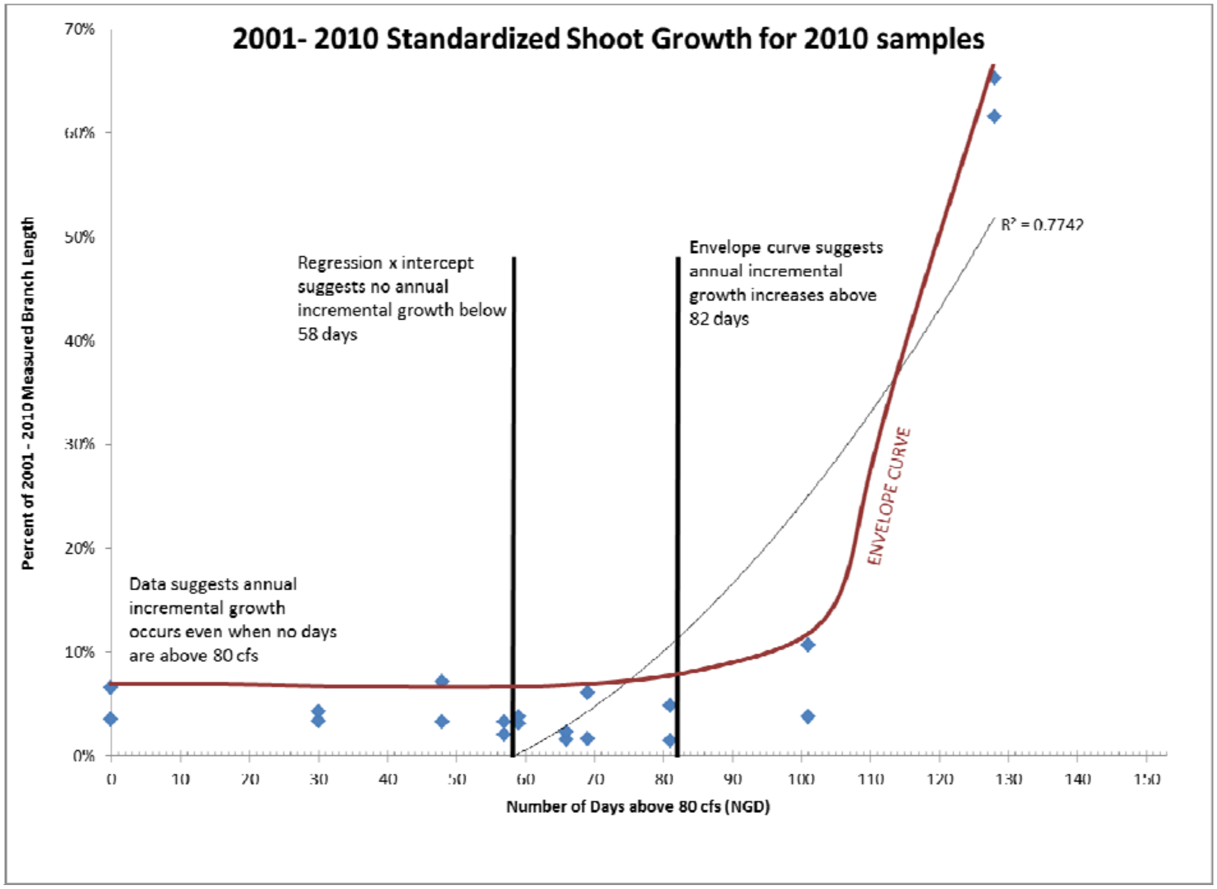
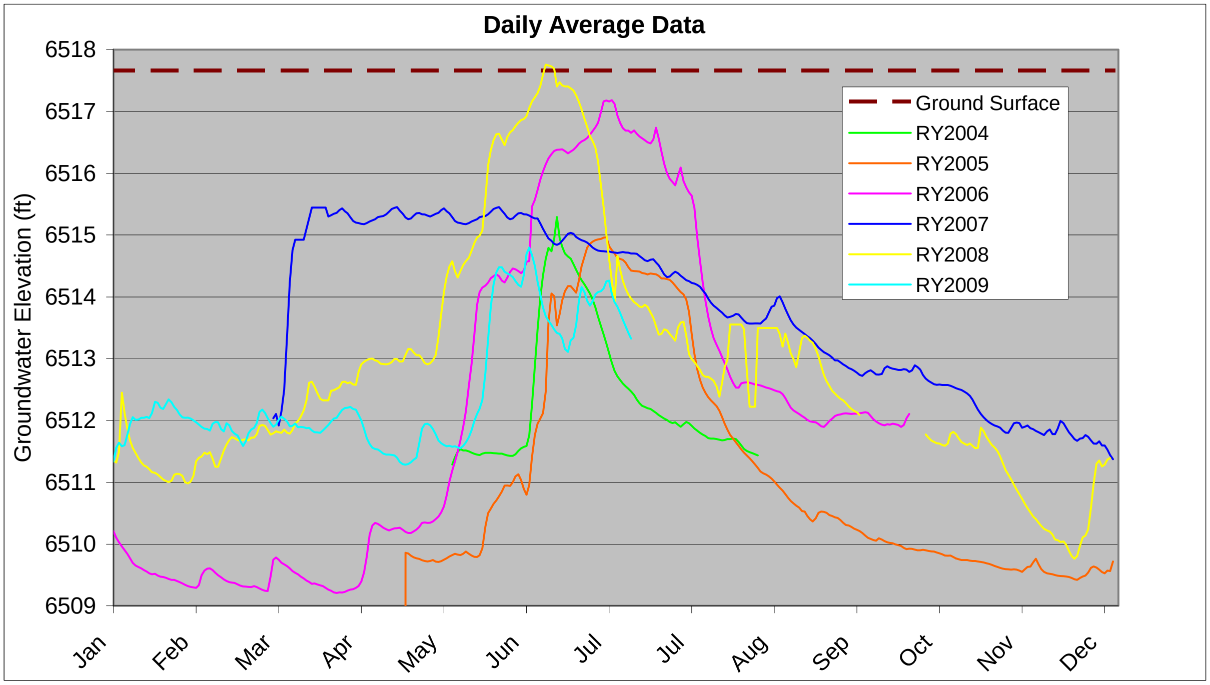
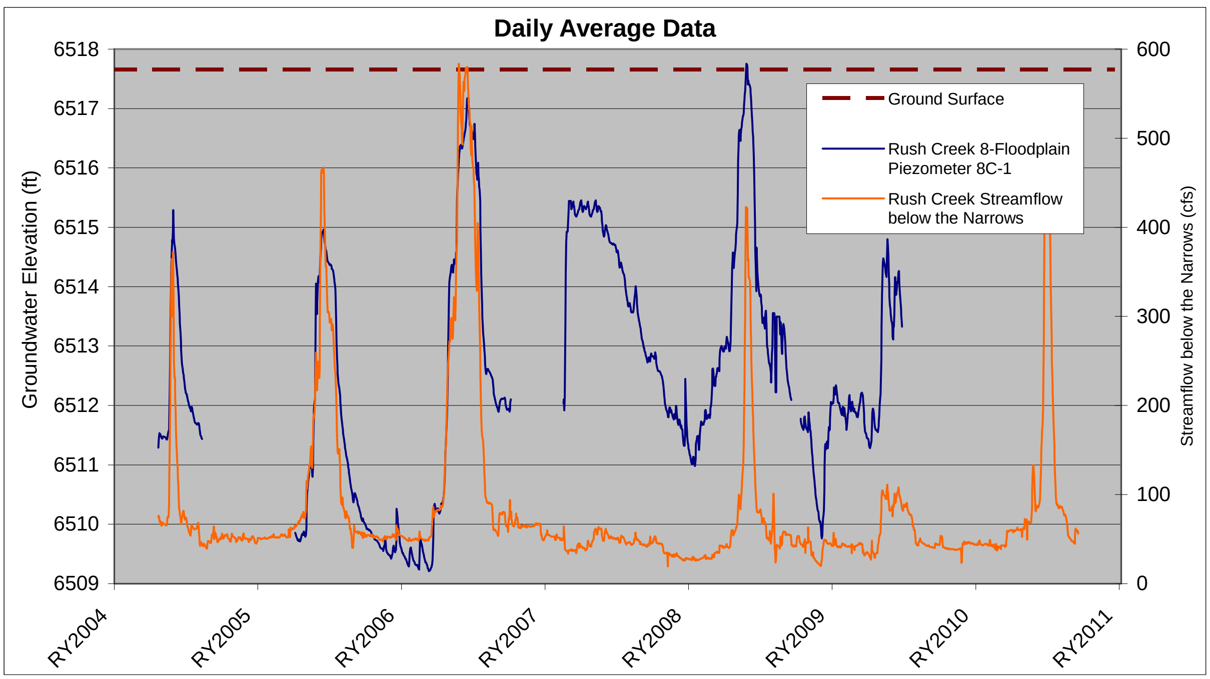


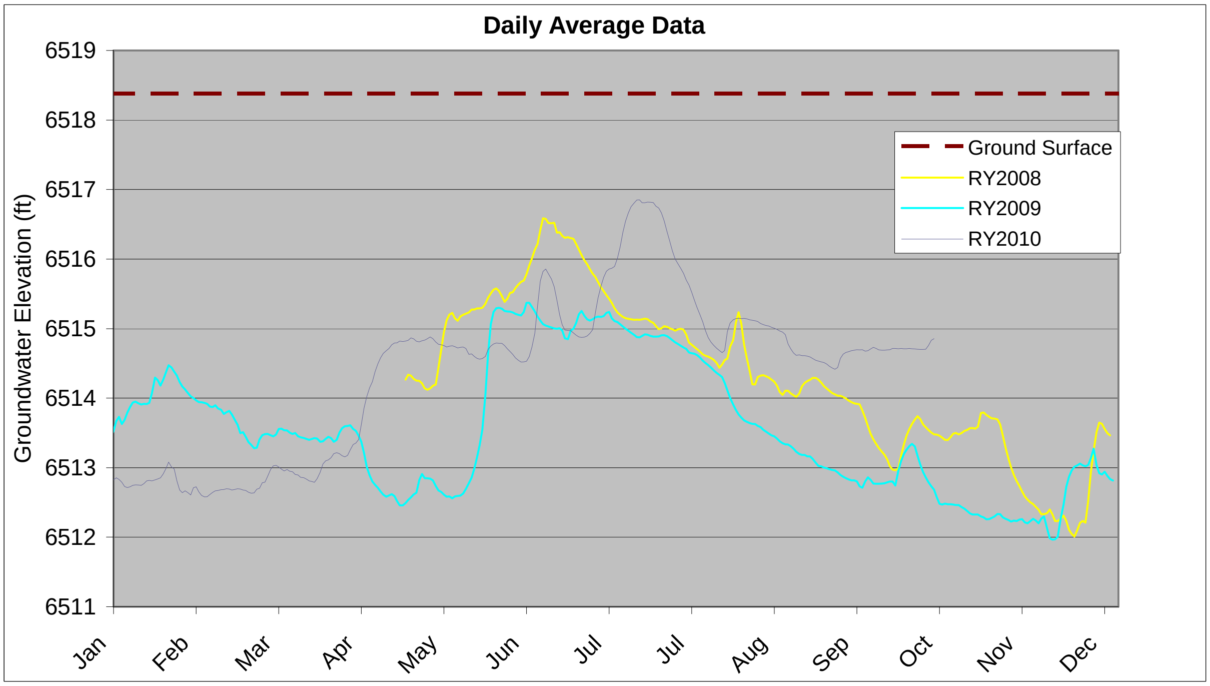
Figure 19. Relationship between annual shoot length and the number of days above 80 cfs standardized for the same span of runoff years (RYs 2001 to 2010). The brown line is a best-fit curve drawn by hand.

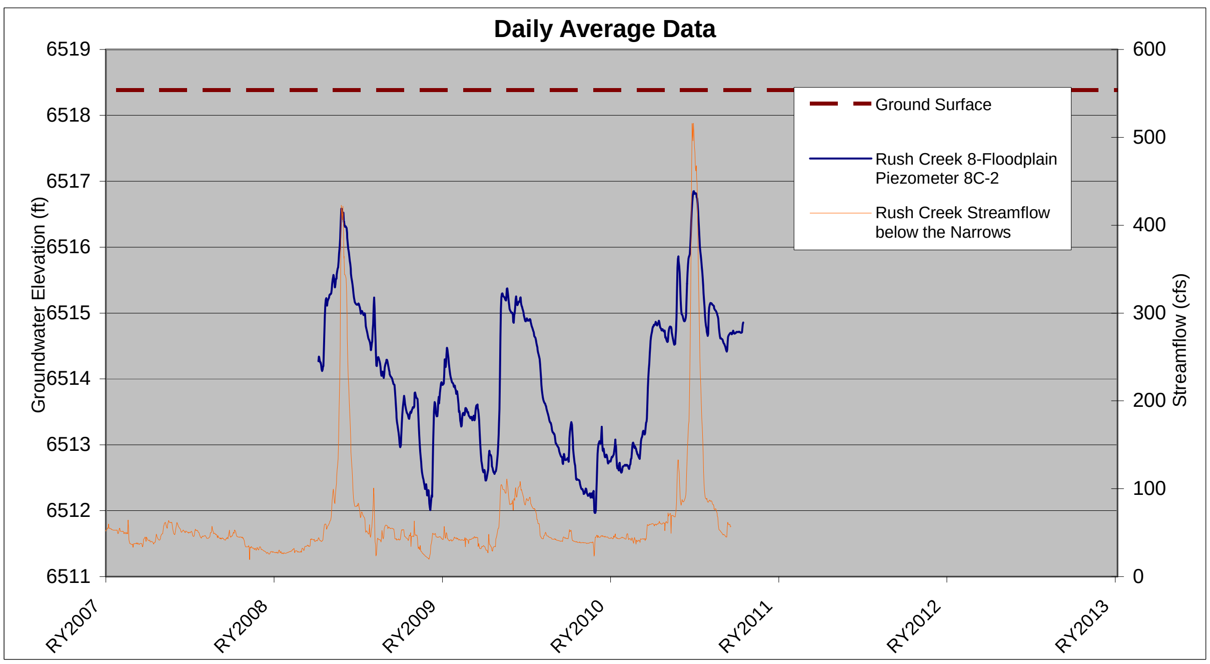
Appendix A. Groundwater data collected at piezometers installed in the 8 Floodplain.



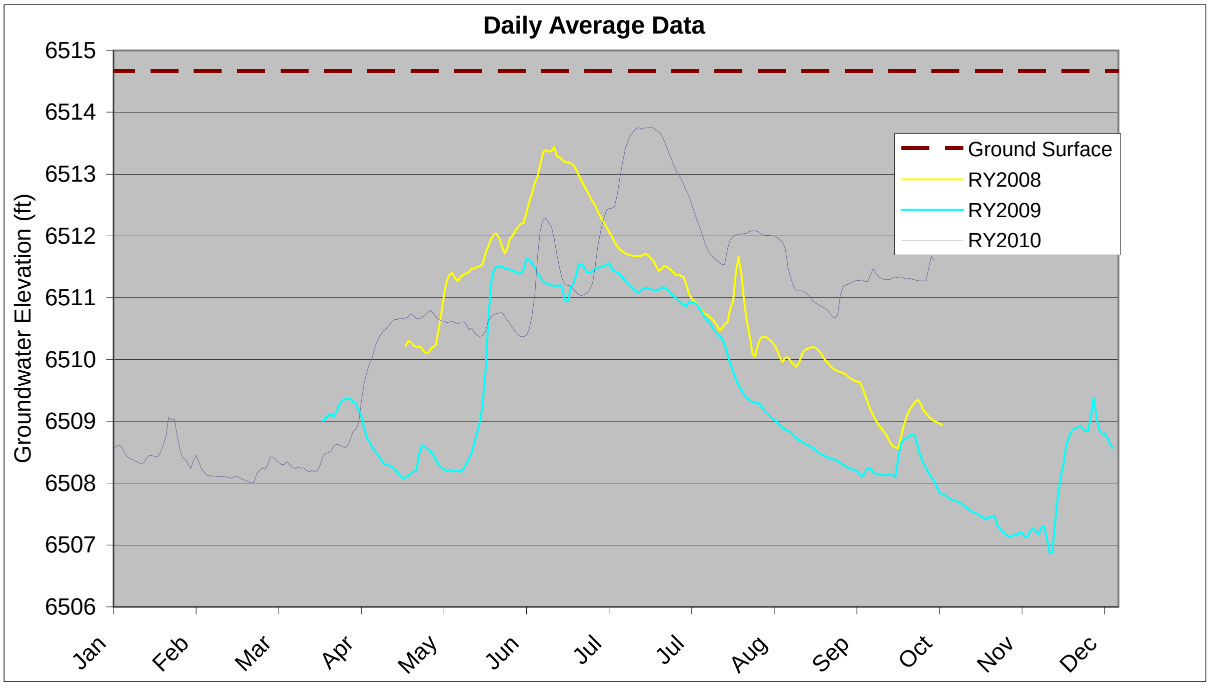


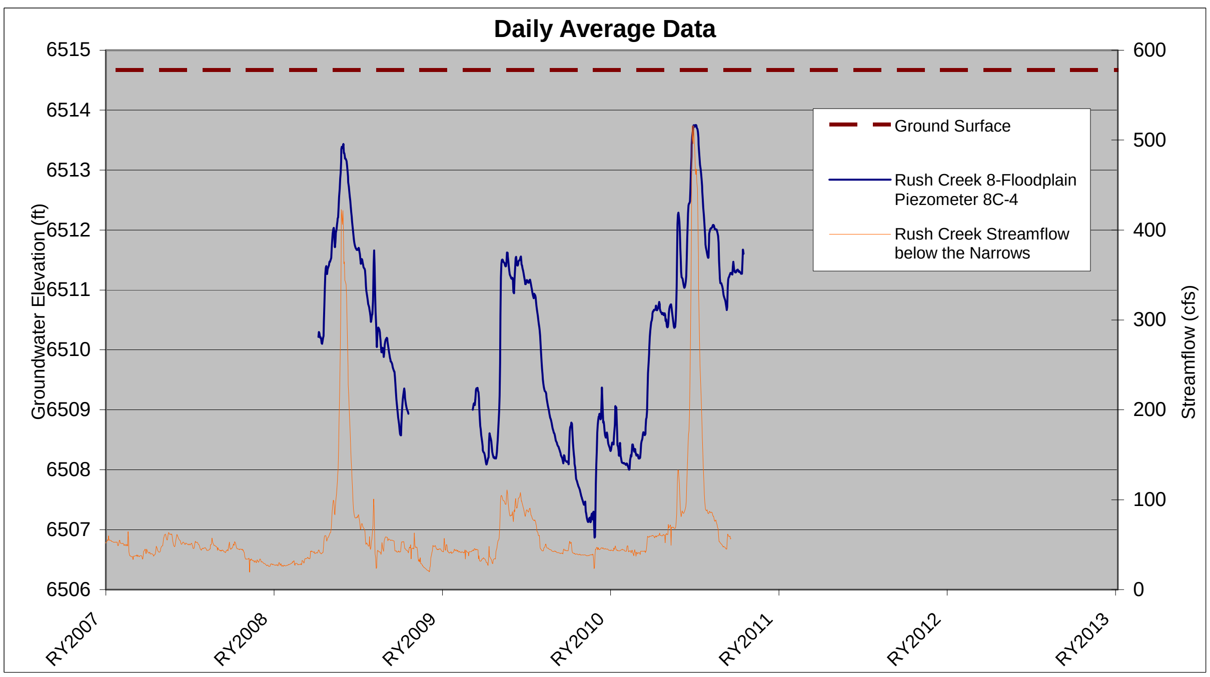
Rush Creek 8-Floodplain Piezometer 8C-1



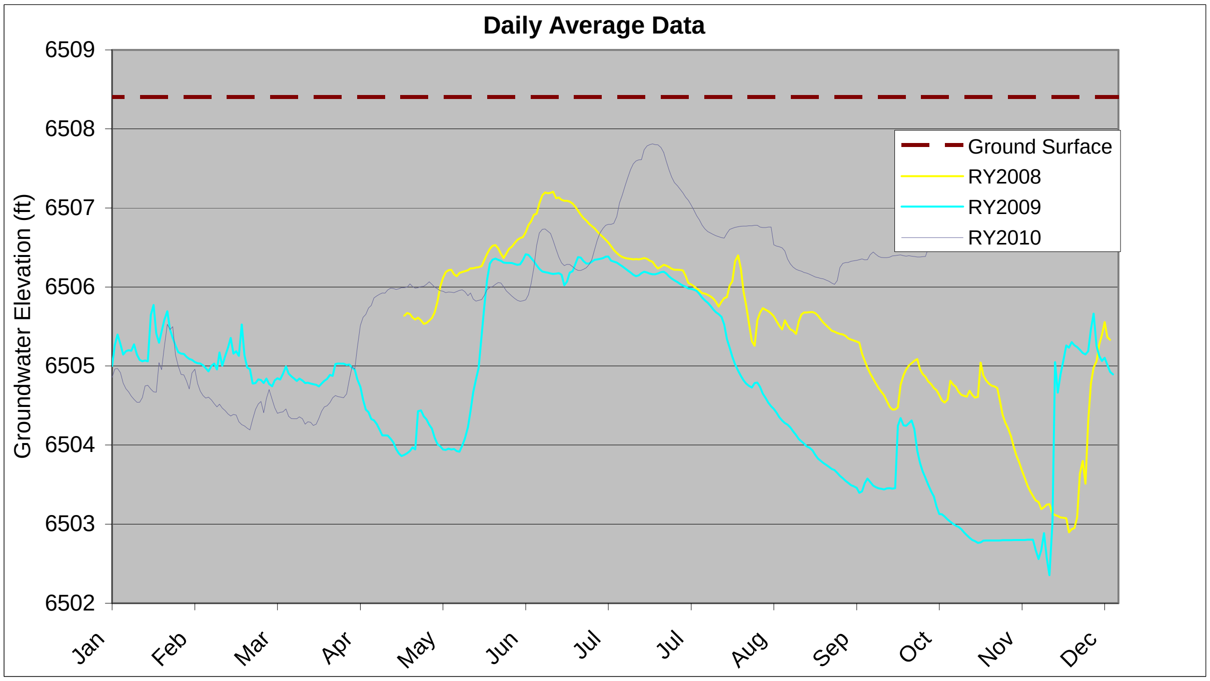


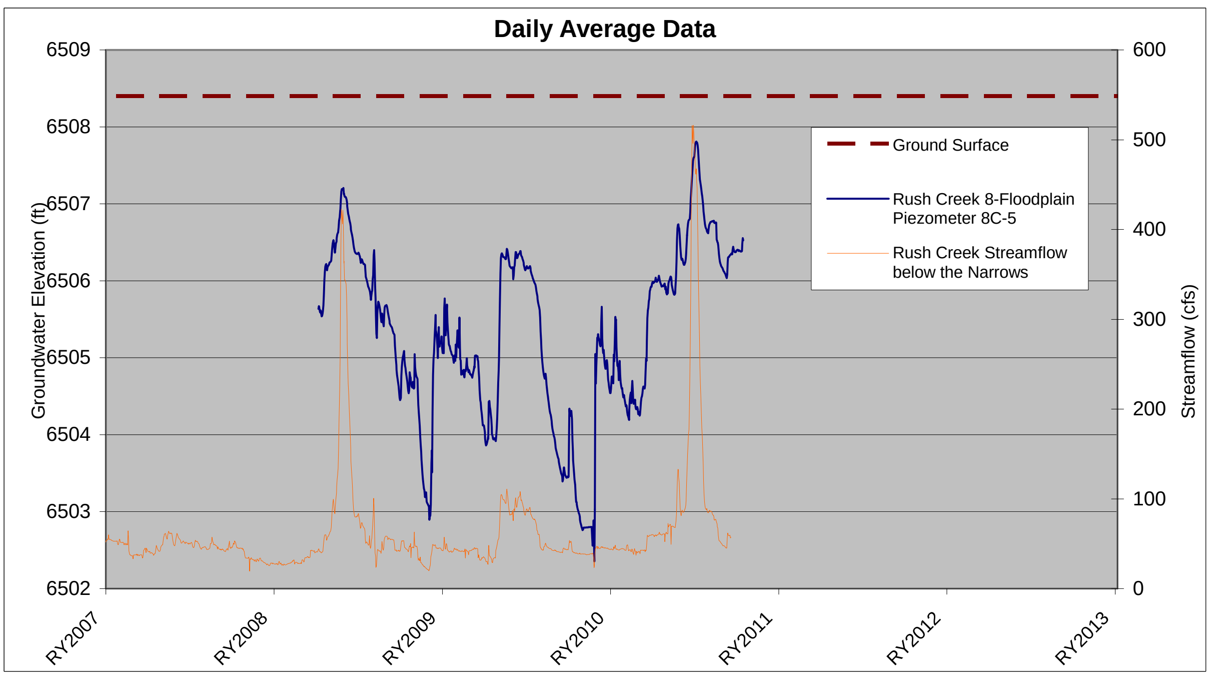
Rush Creek 8-Floodplain Piezometer 8C-2



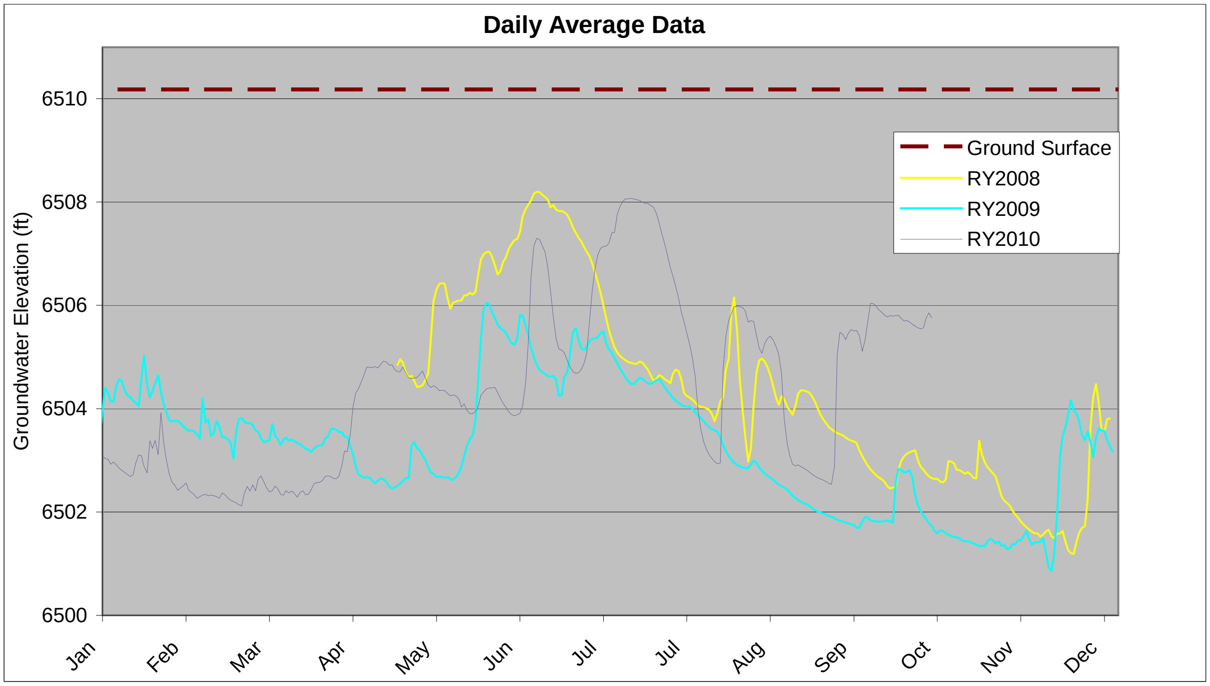


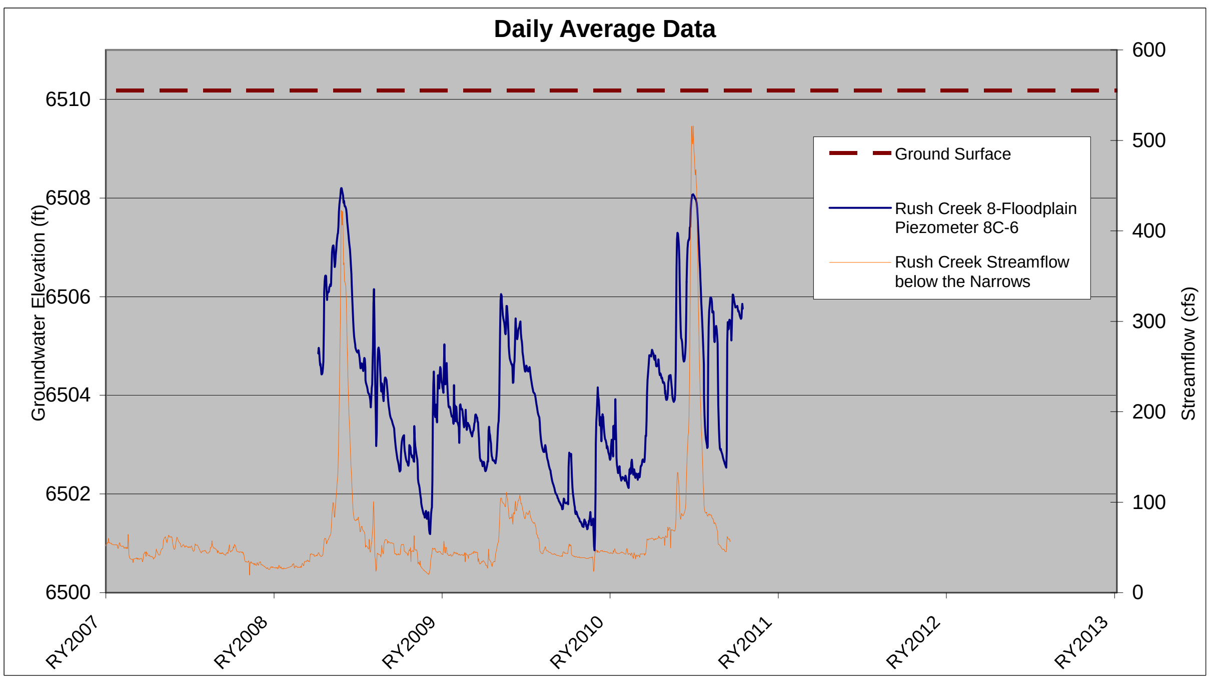
Rush Creek 8-Floodplain Piezometer 8C-4



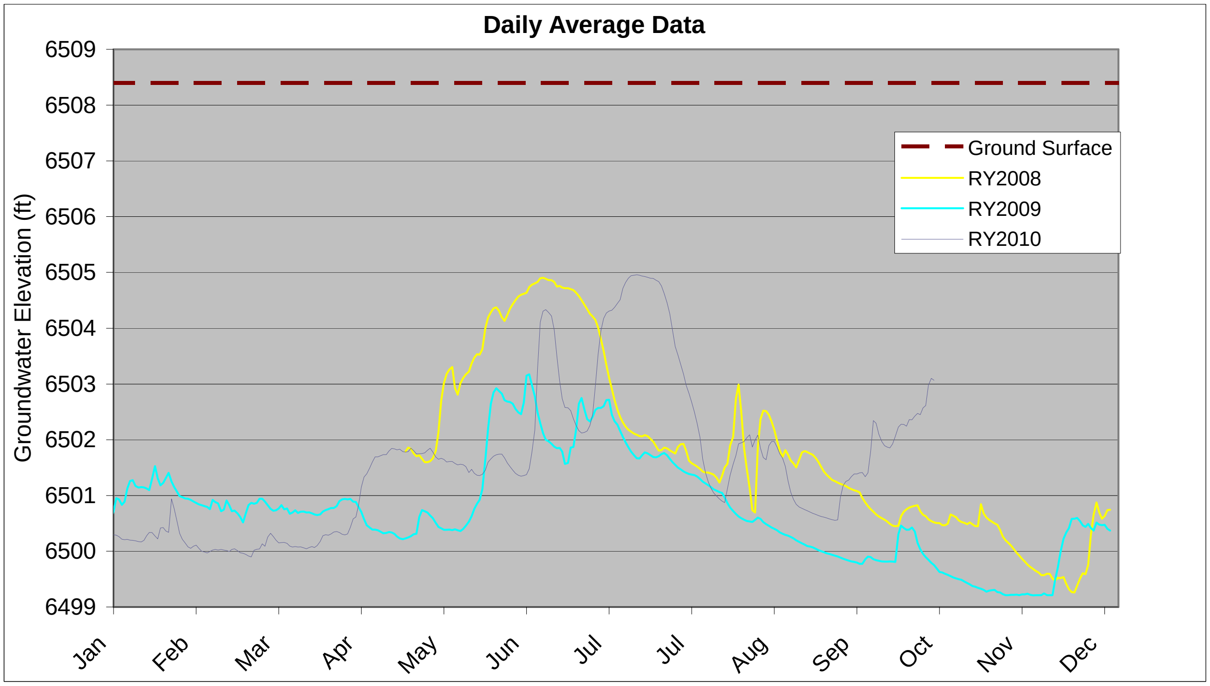


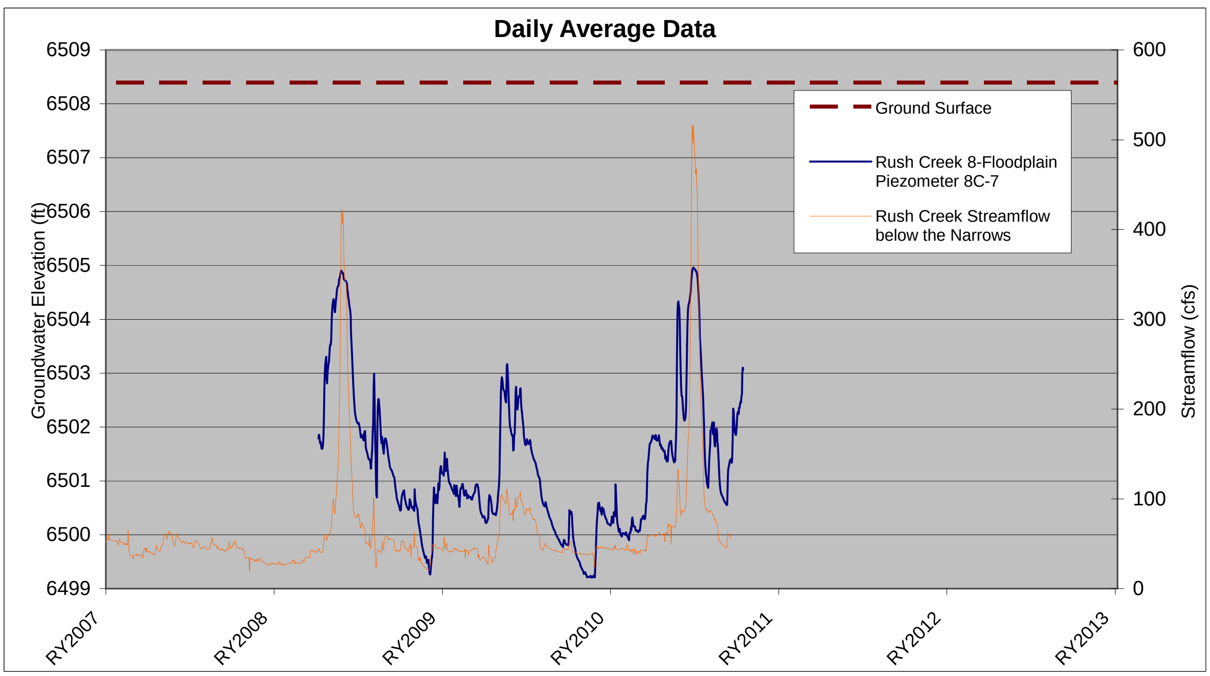
Rush Creek 8-Floodplain Piezometer 8C-5



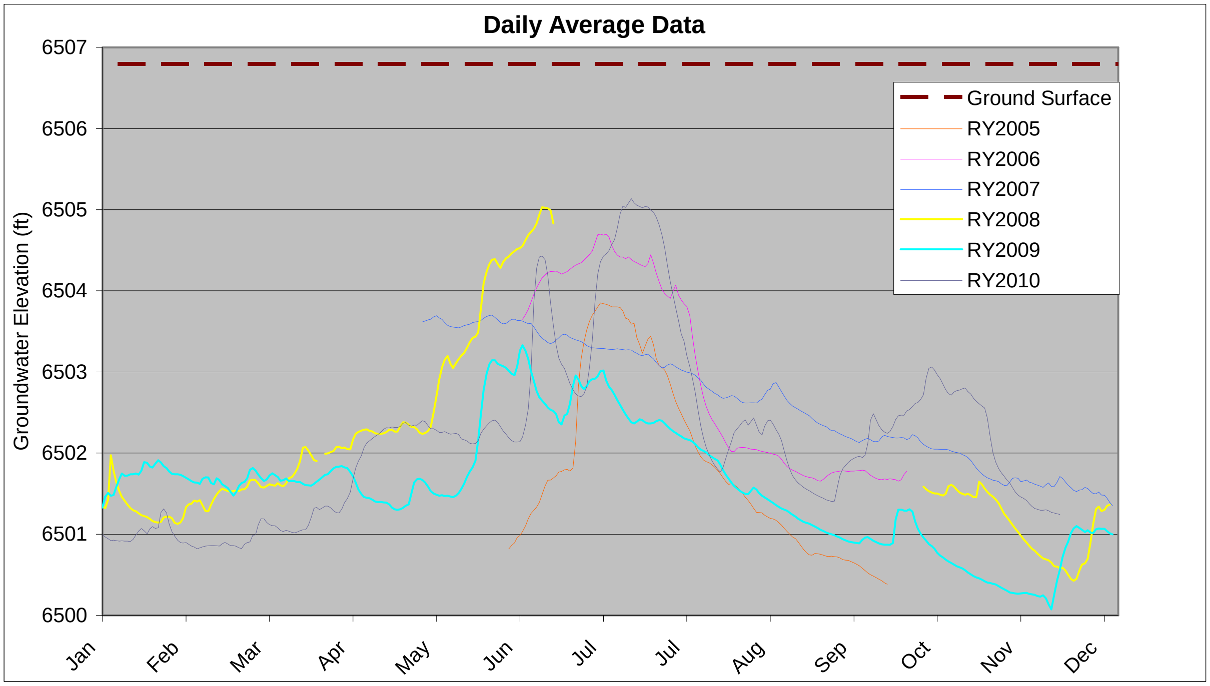


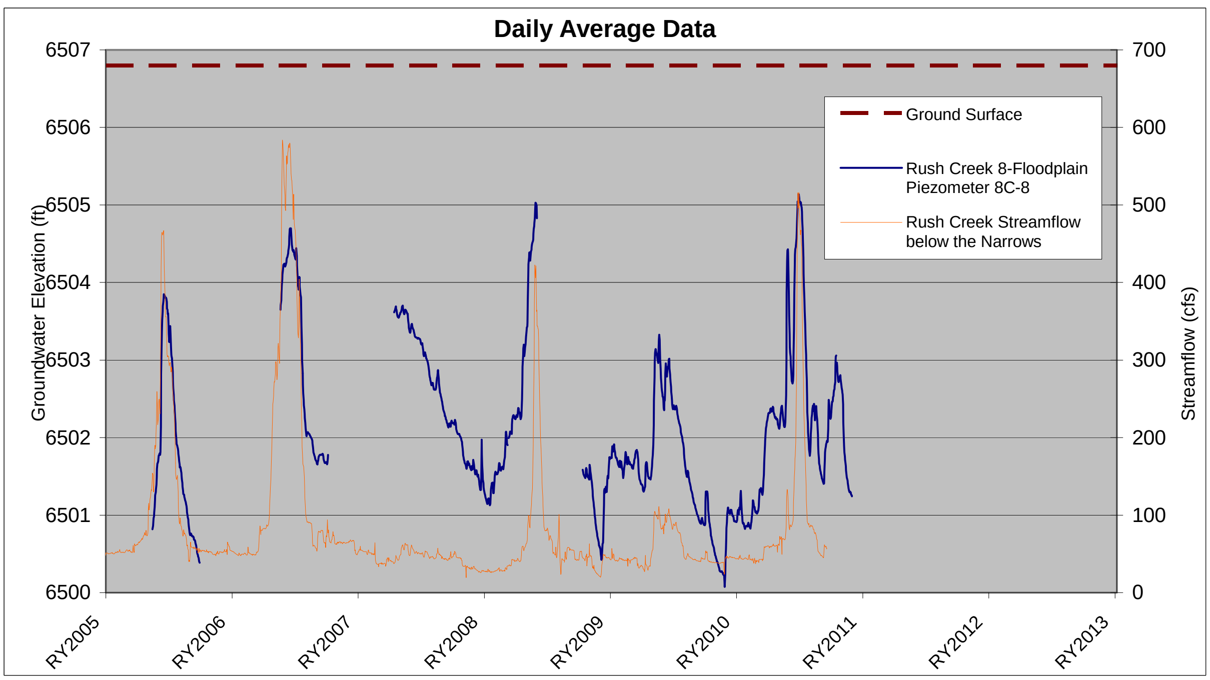
Rush Creek 8-Floodplain Piezometer 8C-6





Rush Creek 8-Floodplain Piezometer 8C-7





Rush Creek 8-Floodplain Piezometer 8C-8

Appendix B. Water temperature data for Rush, Lee Vining, Parker, and Walker creeks.

Rush Creek at Damsite											
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)											44.1
ANNUAL MAX (°F)											61.7
ANNUAL MIN (°F)											32.4
MAX DAILY FLUX (°F)											3.5
WINTER MAX (°F)											36.6
WINTER MIN (°F)											32.4
WINTER AVERAGE (°F)											34.4
MAX WINTER FLUX (°F)											1.8
SUMMER MAX (°F)											61.7
SUMMER MIN (°F)											49.4
SUMMER AVERAGE (°F)											57.0
MAX SUMMER FLUX (°F)											3.5
MWAT											60.0
MWMT											60.8
DATE OF ANNUAL MAX											8/27/2010
Start Date											11/9/2009
End Date											9/30/2010
Number of Days Sampled											325

Rush Creek at MGORD Top											
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)									NA	58.8	47.3
ANNUAL MAX (°F)									69.9	66.1	65.1
ANNUAL MIN (°F)									NA		36.0
MAX DAILY FLUX (°F)									4.6		7.5
WINTER MAX (°F)									NA		39.2
WINTER MIN (°F)									NA		36.1
WINTER AVERAGE (°F)									NA		38.2
MAX WINTER FLUX (°F)									NA		1.1
SUMMER MAX (°F)									69.9	66.1	65.1
SUMMER MIN (°F)									60.3	55.6	53.5
SUMMER AVERAGE (°F)									66.0	61.0	57.9
MAX SUMMER FLUX (°F)									4.6	6.4	7.5
MWAT									68.4	63.8	62.4
MWMT									69.3	64.9	63.5
DATE OF ANNUAL MAX									7/29/2008	8/5/2009	8/21/2010
Start Date									1/0/1900	5/4/2009	10/1/2009
End Date									9/30/2008	9/30/2009	9/30/2010
Number of Days Sampled									39721	150	365

Rush Creek MGORD Bottom											
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)	49	49	51	47	43	45	46.3	50.4	49.1	45.6	47.3
ANNUAL MAX (°F)	67	69	71	69	64	65	64.5	78.1	79.5	68.8	67.7
ANNUAL MIN (°F)	34	34	32	32	32	32	32	33.2	29.6	31.8	32.9
MAX DAILY FLUX (°F)	9	10	9	6	9	9	11.1	18.4	22.2	16.1	11.2
WINTER MAX (°F)	43	42	43	43	44	40	42	51.3	51.3	43.5	43.9
WINTER MIN (°F)	34	34	32	32	32	32	32	33.2	29.6	31.8	34.1
WINTER AVERAGE (°F)	37	37	37	37	37	34	37	37.8	34.8	33.2	37.9
MAX WINTER FLUX (°F)	5	5	5	5	5	5	7	12.3	16.4	8.2	7.5
SUMMER MAX (°F)	67	69	71	69		65	65	78.1	79.5	68.8	67.7
SUMMER MIN (°F)	55	53	57	60		53	50	54.6	54.2	45.8	52.9
SUMMER AVERAGE (°F)	60	62	64	64		57	55	64.1	65.7	60.1	58.3
MAX SUMMER FLUX (°F)	9	10	8	6		9	8	18.4	16.9	16.1	11.2
MWAT							59.4	66.8	68.6	63.8	62.5
MWMT							63.2	76.8	76.8	68.0	66.2
DATE OF ANNUAL MAX	8/27/2000	8/19/2001	7/30/2002	8/20/2003	10/1/2003	9/10/2005	9/12/2006	8/3/2007	7/30/2008	8/19/2009	8/21/2010
Start Date	10/10/1999	10/1/2000	10/1/2001	10/1/2002	10/1/2003	12/1/2004	10/1/2005	10/1/2006	10/1/2007	10/1/2008	10/1/2009
End Date	9/30/2000	9/30/2001	9/30/2002	9/30/2003	5/6/2004	9/30/2005	9/30/2006	9/30/2007	9/30/2008	9/30/2009	9/30/2010
Number of Days Sampled	357	365	365	365	218	303	365	365	366	365	365

Rush Creek at Old Highway 395											
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)						NA	47.2	49.5	48.3	49.0	47.2
ANNUAL MAX (°F)						66	66.7	72.2	75.7	71.3	68.4
ANNUAL MIN (°F)						NA	32	31.5	28.3	31.9	31.9
MAX DAILY FLUX (°F)						NA	11.3	15.4	19.8	18.0	13.5
WINTER MAX (°F)						NA	45	51.0	48.0	51.8	47.4
WINTER MIN (°F)						NA	32	31.5	28.3	31.9	32.1
WINTER AVERAGE (°F)						NA	34	37.1	33.5	36.2	37.3
MAX WINTER FLUX (°F)						NA	11	12.6	15.2	11.4	12.3
SUMMER MAX (°F)						66	67	72.2	75.7	71.3	68.4
SUMMER MIN (°F)						52.78	53	52.9	56.9	52.6	51.6
SUMMER AVERAGE (°F)						57.2901	57	62.7	65.2	61.3	59.1
MAX SUMMER FLUX (°F)						12.22	11	15.1	13.9	13.5	12.4
MWAT							59.2	65.0	67.7	62.9	62.1
MWMT							64.7	71.0	74.8	70.3	67.8
DATE OF ANNUAL MAX						NA	9/12/2006	8/8/2007	7/30/2008	8/19/2009	8/25/2010
Start Date						6/1/2005	10/1/2005	10/1/2006	10/1/2007	10/1/2008	10/1/2009
End Date						9/30/2005	9/30/2006	9/30/2007	9/30/2008	9/30/2009	9/30/2010
Number of Days Sampled						122	365	365	366	365	365

Rush Creek at the Narrows											
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)	48	48	42	45	48	NA	44.3	49.3	48.2	47.8	46.3
ANNUAL MAX (°F)	71	73	67	67	72	NA	67.2	73.2	74.9	71.9	70.3
ANNUAL MIN (°F)	32	32	32	32	31	NA	0	32.0	32.0	31.9	31.9
MAX DAILY FLUX (°F)	20	20	18	21	16	NA	14.5	19.9	20.7	21.1	17.4
WINTER MAX (°F)	52	50	50	51	49	NA	46	54.3	49.4	53.9	48.0
WINTER MIN (°F)	32	32	32	32	31	NA	32	32.0	32.0	31.9	31.9
WINTER AVERAGE (°F)	37	36	36	37	35	NA	33	37.1	34.1	35.6	36.2
MAX WINTER FLUX (°F)	16	15	15	14	16	NA	13	17.2	16.3	15.8	14.6
SUMMER MAX (°F)	71	73	67	67		NA	67	73.2	74.9	71.9	70.3
SUMMER MIN (°F)	50	52	53	52		NA	48	50.2	52.3	49.7	48.9
SUMMER AVERAGE (°F)	59	61	58	58		NA	57	62.1	63.4	60.0	58.7
MAX SUMMER FLUX (°F)	17	16	14	14		NA	14	17.7	18.0	16.6	14.9
MWAT							58.5	64.8	66.5	61.6	61.1
MWMT							64.9	71.2	73.4	70.0	68.5
DATE OF ANNUAL MAX	8/27/2000	8/19/2001	9/21/2002	5/27/2003	7/23/2004	NA	9/5/2006	7/22/2007	8/21/2008	8/21/2009	8/25/2010
Start Date	########	10/1/2000	10/1/2001	10/1/2002	10/1/2003	10/1/2004	########	10/1/2006	10/1/2007	10/1/2008	10/1/2009
End Date	9/30/2000	9/30/2001	9/30/2002	9/30/2003	9/30/2004	########	9/30/2006	9/30/2007	9/30/2008	9/30/2009	9/30/2010
Number of Days Sampled	357	365	365	365	366	19	313	365	366	365	365

Rush Creek below 10-Falls											
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)									63.9	48.5	46.4
ANNUAL MAX (°F)									71.0	72.7	67.3
ANNUAL MIN (°F)									0.0	32.0	0.0
MAX DAILY FLUX (°F)									13.8	19.8	25.2
WINTER MAX (°F)									0.0	55.0	49.2
WINTER MIN (°F)									0.0	32.0	32.0
WINTER AVERAGE (°F)										36.3	36.1
MAX WINTER FLUX (°F)									0.0	17.0	16.2
SUMMER MAX (°F)									71.0	72.7	67.0
SUMMER MIN (°F)									55.4	49.4	0.0
SUMMER AVERAGE (°F)									64.3	60.0	63.5
MAX SUMMER FLUX (°F)									13.8	17.3	8.8
MWAT									65.6	62.0	64.5
MWMT									70.3	70.3	66.6
DATE OF ANNUAL MAX									7/21/2008	8/21/2009	6/5/2010
Start Date									6/10/2008	10/1/2008	10/1/2009
End Date									9/30/2008	9/30/2009	9/30/2010
Number of Days Sampled									112	365	365

Rush Creek at County Road											
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)	48	48	49	45	49	NA	NA	49	47.9	44.2	46.6
ANNUAL MAX (°F)	72	71	75	74	75	NA	70	75	75.6		71.6
ANNUAL MIN (°F)	32	32	32	32	32	33	NA	32	31.9	32.0	31.9
MAX DAILY FLUX (°F)	22	18	21	18	24	NA	16	22	22.9	22.0	21.8
WINTER MAX (°F)	53	47	48	45	56	52	NA	55	50.4	54.4	50.1
WINTER MIN (°F)	32	32	32	32	32	34	NA	32	32.0	32.0	31.9
WINTER AVERAGE (°F)	37	36	36	37	36	36	NA	37	34.1	35.5	35.9
MAX WINTER FLUX (°F)	19	9	12	8	20	17	NA	17	16.7	17.4	17.9
SUMMER MAX (°F)	72	71	75	NA	.	NA	70	75	75.6	68.4	71.6
SUMMER MIN (°F)	48	52	51	NA	.	NA	48	48	49.4	49.1	48.2
SUMMER AVERAGE (°F)	60	61	62	NA	.	NA	61	62	62.9	58.1	59.3
MAX SUMMER FLUX (°F)	18	17	16	NA	.	NA	16	20	19.4	17.2	17.6
MWAT							62	65	65.5	58.7	61.4
MWMT							69	73	74.4	67.3	69.6
DATE OF ANNUAL MAX	8/27/2000	7/1/2001	7/25/2002	8/16/2003	7/22/2004	NA	9/6/2006	7/22/2007	8/15/2008		8/26/2010
Start Date	########	10/1/2000	10/1/2001	2003 to 3/21/	10/1/2003	10/1/2004	5/31/2006	10/1/2006	10/1/2007	10/1/2008	12/1/2009
End Date	9/30/2000	9/30/2001	9/30/2002	/2003 to 9/30/2	9/30/2004	6/30/2005	9/30/2006	9/30/2007	9/30/2008	7/10/2009	9/30/2010
Number of Days Sampled	357	365	365	224	366	273	122	365	366	283	303

Lee Vining Creek below Conduit											
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)						not available	not available	not available	42.0	42.2	41.0
ANNUAL MAX (°F)						53	not available	64.7	63.1	60.8	60.4
ANNUAL MIN (°F)						not available	31	30.9	31.5	31.9	31.9
MAX DAILY FLUX (°F)						12	not available	16.4	14.9	14.6	14.3
WINTER MAX (°F)						not available	41	not available	43.7	45.9	41.7
WINTER MIN (°F)						not available	31	not available	31.5	31.9	31.9
WINTER AVERAGE (°F)						not available	34	not available	33.7	34.5	34.5
MAX WINTER FLUX (°F)						not available	8	not available	9.9	11.2	8.5
SUMMER MAX (°F)						51	not available	64.7	63.1	60.8	60.4
SUMMER MIN (°F)						43	not available	40.9	42.6	43.8	42.2
SUMMER AVERAGE (°F)						47	not available	53.1	53.3	52.3	50.8
MAX SUMMER FLUX (°F)						4	not available	14.5	13.8	10.6	11.6
MWAT									55.3	46.5	53.6
MWMT									62.2	50.7	58.9
DATE OF ANNUAL MAX						8/14/2005	not available	7/30/2007	8/15/2008	8/20/2009	8/26/2010
Start Date						4/17/2005	11/21/2005	4/24/2007	10/1/2007	10/1/2008	10/1/2009
End Date						8/15/2005	4/30/2006	9/30/2007	9/30/2008	9/30/2009	9/30/2010
Number of Days Sampled						120	160	159	366	365	365

Lee Vining at County Road											
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)							41.9	44.4		41.4	42.1
ANNUAL MAX (°F)					66		60.4	67.0		64.2	63.0
ANNUAL MIN (°F)						32	32	31.9	31.9	31.9	31.9
MAX DAILY FLUX (°F)							13.8	14.0		17.8	14.5
WINTER MAX (°F)						47	42	47.0	45.1	47.5	46.5
WINTER MIN (°F)						32	32	31.9	31.9	31.9	31.9
WINTER AVERAGE (°F)						35	34	34.8	33.7	34.4	34.1
MAX WINTER FLUX (°F)						12	10	10.8	10.5	11.8	13.2
SUMMER MAX (°F)							60	67.0		64.2	63.0
SUMMER MIN (°F)							41	43.4		31.9	43.2
SUMMER AVERAGE (°F)							52	56.2	51.7	51.0	53.8
MAX SUMMER FLUX (°F)							11	13.9		12.4	11.7
MWAT							55.0	49.2	50.8	57.8	56.7
MWMT							58.8	58.5	55.5	63.3	62.1
DATE OF ANNUAL MAX					8/9/2004		7/28/2006	7/30/2007	not available	7/20/2009	7/23/2010
Start Date					5/5/2004	10/1/2004	########	10/1/2006	10/1/2007	########	10/1/2009
End Date					9/30/2004	4/17/2005	9/30/2006	9/30/2007	6/25/2008	9/30/2009	9/30/2010
Number of Days Sampled					148	198	352	365	269	344	365

Parker Creek below Conduit										missing data from July(	
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)	43	43	NA	43	NA	41	42.4	44.2	43.2	41.3	50.8
ANNUAL MAX (°F)	62	64	NA	69	NA	57	58.2	64.2	62.8	68.6	61.9
ANNUAL MIN (°F)	26	32	32	32	0	32	32	31.8	31.8	0.0	38.2
MAX DAILY FLUX (°F)	18	18	14	13	13	12	13.4	12.3	22.7	22.0	13.2
WINTER MAX (°F)	48	39	43	43	46	40	39	46.2	56.2	43.5	
WINTER MIN (°F)	39	32	32	32	31	36	32	31.8	31.8	31.8	
WINTER AVERAGE (°F)	41	33	33	33	33	38	32	34.2	33.0	33.2	
MAX WINTER FLUX (°F)	18	3	9	8	10	5	5	8.7	22.7	8.2	
SUMMER MAX (°F)	59	63	NA	69		57	58	64.2	62.8		61.9
SUMMER MIN (°F)	52	47	NA	45		37	40	43.7	45.1		43.0
SUMMER AVERAGE (°F)	54	55	NA	55		49	51	55.9	55.3		52.6
MAX SUMMER FLUX (°F)	18	10	NA	11		12	9	10.9	9.8		9.5
MWAT							39355.0	56.5	57.7	48.2	55.7
MWMT							64.2	62.8	62.1	51.2	59.8
DATE OF ANNUAL MAX	7/30/2000	6/5/2001	NA	8/14/2003	NA	8/12/2005	7/28/2006	7/16/2007	8/24/2008	5/17/2009	8/26/2010
Start Date	11/7/1999	10/1/2000	10/1/2001	10/1/2002	10/1/2003	10/1/2004	10/1/2005	10/1/2006	10/1/2007	10/1/2008	5/14/2010
End Date	9/30/2000	9/30/2001	5/2/2002	9/30/2003	5/6/2004	8/16/2005	9/30/2006	9/30/2007	9/30/2008	7/10/2009	9/30/2010
Number of Days Sampled	329	365	214	365	218	320	365	365	366	283	139

Parker Creek at Confluence											
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)					NA		43.1	44.9	43.8	43.6	42.0
ANNUAL MAX (°F)					72		62.2	68.1	70.8	62.5	74.1
ANNUAL MIN (°F)					NA		32	21.6	29.7	31.1	31.7
MAX DAILY FLUX (°F)					16		15.8	23.3	23.7	22.4	31.4
WINTER MAX (°F)					NA		47	54.8	37.4	52.8	37.8
WINTER MIN (°F)					NA		32	21.6	31.9	31.1	31.8
WINTER AVERAGE (°F)					NA		33	33.8	32.2	32.7	32.4
MAX WINTER FLUX (°F)					NA		14	19.4	3.8	19.5	5.9
SUMMER MAX (°F)							62	68.1	70.8	61.9	74.1
SUMMER MIN (°F)							39	40.6	43.5	46.3	34.2
SUMMER AVERAGE (°F)							53	57.4	56.9	55.4	54.0
MAX SUMMER FLUX (°F)							13	16.6	19.1	10.9	31.4
MWAT							55.7	60.9	60.2	48.7	57.2
MWMT							60.2	66.8	69.4	55.9	69.6
DATE OF ANNUAL MAX					8/11/2004		9/5/2006	8/22/2007	8/15/2008	8/26/2009	8/25/2010
Start Date					5/6/2004		10/10/2005	10/1/2006	10/1/2007	10/1/2008	10/1/2009
End Date					9/30/2004		9/30/2006	9/30/2007	9/30/2008	9/30/2009	9/30/2010
Number of Days Sampled					148		355	365	366	365	365

Walker Creek below Conduit											
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)	46	45	NA	45	45	44	44.5	41.5	44.3		56.1
ANNUAL MAX (°F)	69	70	NA	77	76	69	68.6	66.3	74.5	60.8	68.6
ANNUAL MIN (°F)	29	32	32	32	29	31	32	31.8	31.8		
MAX DAILY FLUX (°F)	NA	23	16	32	34	16	9.3	9.2	23.5	9.6	12.3
WINTER MAX (°F)	55	38	45	42	47	37	38	43.8	36.4	38.9	
WINTER MIN (°F)	41	32	32	32	32	34	32	31.8	31.8	32.2	
WINTER AVERAGE (°F)	43	33	33	33	33	35	33	33.5	32.5	33.1	
MAX WINTER FLUX (°F)	24	6	12	9	12	4	4	6.2	3.2	3.6	
SUMMER MAX (°F)	68	70	NA	71	.	69	69	66.3	68.1	60.8	68.6
SUMMER MIN (°F)	58	46	NA	43	.	35	41	42.6	44.7	0.0	45.6
SUMMER AVERAGE (°F)	61	59	NA	59	.	56	58	57.1	59.2	58.4	59.5
MAX SUMMER FLUX (°F)	32	19	NA	16	.	11	9	7.0	9.3		10.4
MWAT							63.7	62.4	63.0		64.4
MWMT							66.7	64.7	66.5		68.2
DATE OF ANNUAL MAX	7/30/2000	8/16/2001	NA	5/22/2003	9/14/2004	7/19/2005	7/28/2006	7/28/2007	6/12/2008	7/5/2009	7/20/2010
Start Date	11/7/1999	10/1/2000	10/1/2001	10/1/2002	10/1/2003	10/1/2004	10/1/2005	10/1/2006	10/1/2007	10/1/2008	5/15/2010
End Date	9/30/2000	9/30/2001	4/4/2002	9/30/2003	9/30/2004	8/16/2005	9/30/2006	9/30/2007	9/30/2008	7/10/2009	9/30/2010
Number of Days Sampled	329	365	186	365	366	320	365	279	366	282	139

Walker Creek at Confluence											
WATER YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DAILY AVERAGE (°F)					NA	45	46.1	45.8	39.7		43.6
ANNUAL MAX (°F)					76	71	71.9	72.0	66.1	70.4	70.2
ANNUAL MIN (°F)					NA	27	33	31.8	20.7	40.3	31.8
MAX DAILY FLUX (°F)					NA	17	30.7	20.6	23.8	19.1	21.8
WINTER MAX (°F)					NA	46	44	52.9	43.7		38.2
WINTER MIN (°F)					NA	34	33	31.8	29.6		31.8
WINTER AVERAGE (°F)					NA	36	35	34.8	33.0		32.8
MAX WINTER FLUX (°F)					NA	13	11	16.7	11.8		6.3
SUMMER MAX (°F)					.	71	72	72.0	66.0	70.4	70.2
SUMMER MIN (°F)					.	43	37	41.8	59.0	50.5	43.0
SUMMER AVERAGE (°F)					.	60	58	57.8	63.6	58.7	59.4
MAX SUMMER FLUX (°F)					.	13	31	20.6	7.0	14.9	16.6
MWAT							63.9	61.8	44.6		64.3
MWMT							69.0	69.0	50.5		69.6
DATE OF ANNUAL MAX					9/14/2004	7/17/2005	9/5/2006	7/12/2007	6/16/2008	7/18/2009	7/18/2010
Start Date					5/6/2004	10/1/2004	10/1/2005	10/1/2006	10/1/2007	5/4/2009	10/1/2009
End Date					9/30/2004	9/30/2005	9/30/2006	9/30/2007	6/20/2008	9/30/2009	9/30/2010
Number of Days Sampled					147	365	365	365	264	150	365

Figure 13. Cottonwood branch from a mature cottonwood rooted along the right bank of the 8-Channel, showing annual (long) shoot growth from RY1986 to 2010.

Figure 14. Cottonwood branch from a younger mature cottonwood tree rooted on the 8-Floodplain interfluve, showing annual (long) shoot growth from RY2000 to 2010.