

Rincon Creek Monsoon Event 31 July 2006

Saguaro National Park
Tucson, Arizona



USGS gage, having stood intact for 53 years, yielded to the flow of 31 July.

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Introduction

In the early morning hours of 31 July 2006 a flood event occurred on Rincon Creek that was larger than any recorded in the past 53 years and may have qualified as a "100-year event."¹ Considerable damage was sustained by the creek and its floodplain as a result of very high flows, with attendant debris and sediment (Figure 1).



Figure 1. Considerable natural debris was washed through the watershed, including a large assortment of household and ranch items, vehicles, tools, sheds, etc.

Remarkably, all of the Saguaro Park's water level monitoring instrumentation on or near the creek survived the flow and dutifully recorded the event every 15 minutes, providing a detailed and uninterrupted chronology of water events on the creek before, during, and after the flood. Unfortunately, the only other monitoring station on the creek, the USGS/Pima County gage, was physically destroyed well before the flow was at its maximum² so there is no other recorded data of the event along the creek.

As soon as the water along the creek subsided enough for safe approach and local roads were reopened (one day later) a physical and photo survey was conducted³ to assess damage, check the instrumentation, and evaluate what needed to be surveyed before conditions changed. Five full days were then spent in the field conducting cross section and point surveys, assessing the integrity of and downloading creek instrumentation and gages, physically conducting several flow measurements, and photo-recording the area. What follows is a description and compilation of the data and surveys of this event as it affected the established study area along the creek.

Transect and Instrument Description

Water monitoring activities have been conducted in a study area of Rincon Creek since early 2003 (Figure 2). During this time eight transects were established to monitor water quantity present in selected pools along the creek, all transects being manually surveyed bi-weekly. Several staff gages

¹ Since its activation in July of 1953 the USGS gage on Rincon Creek recorded a maximum flow of 9,960 cfs on 19 August 1971.

² A last reported flow of 7,881 cfs was recorded about 30 minutes before the maximum.

³ This survey was conducted only along a study area from Transect 1 (Pool A) to the USGS gage, a distance of 0.6 mi. Time and available personnel did not permit exploration beyond this area, desirable as that may have been.

were also installed at the transects, one each at Transects 1 (Pool A), 2 (Pool B), and 4 (Pool C)⁴ to accurately monitor water elevation at those locations, and two crest gages were installed, one each at Transects 1 and 2 to record any high flows that might top the staff gages. In addition, four data loggers were installed to record water level elevations every 15 minutes. A data logger was installed at Transect 1 to monitor surface water elevation, and instruments were installed in each of three ground water monitoring wells (RC-1, RC-2, RC-3) located near Transect 1 (Figure 3).

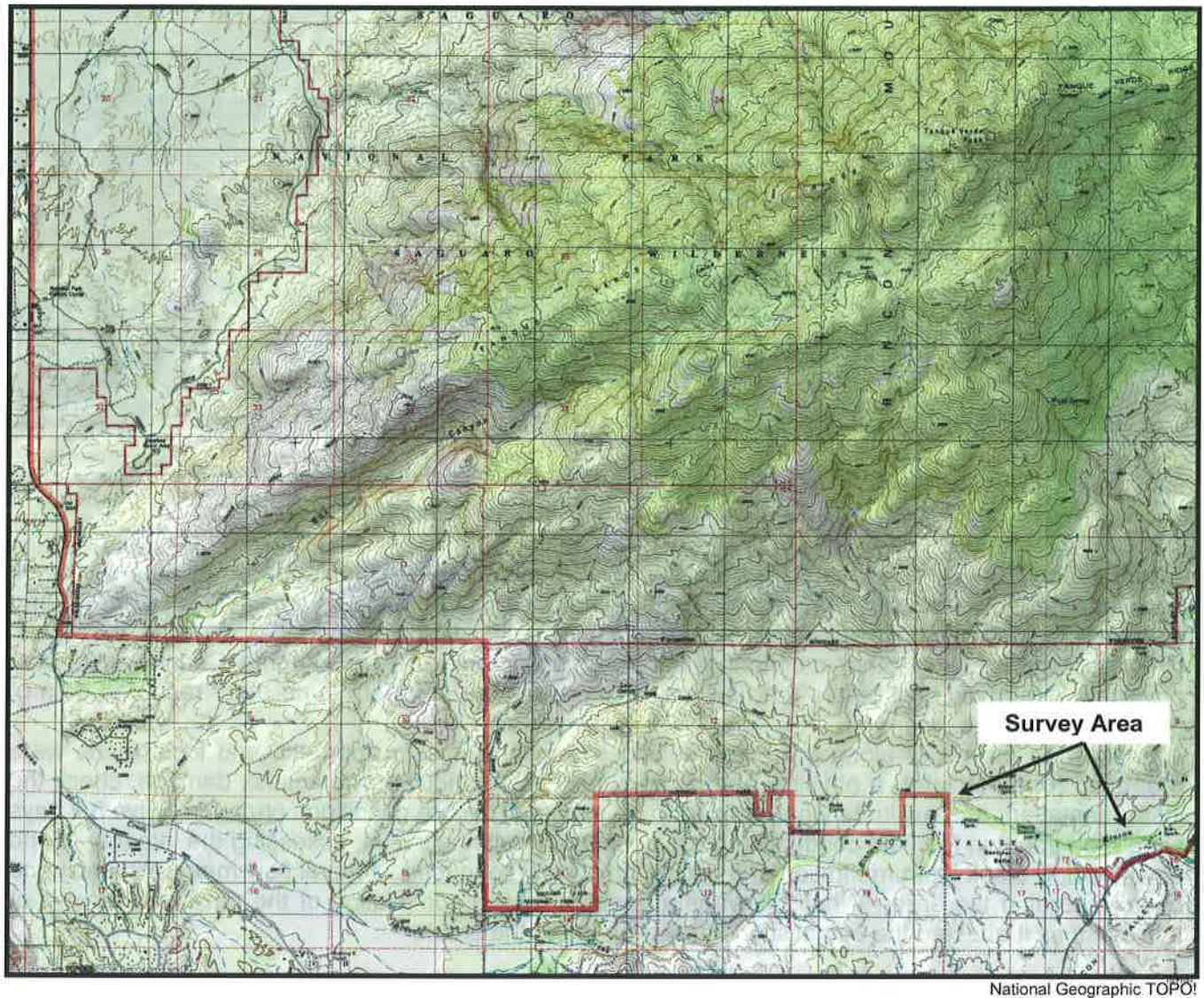


Figure 2. Rincon Creek water monitoring survey area.

⁴ A study was begun in 2003 to collect water data with the intention of applying for an Instream Water Permit from the State of Arizona. For the purposes of that study Transects 1, 2, and 4 were designated as Pools A, B, and C, respectively.

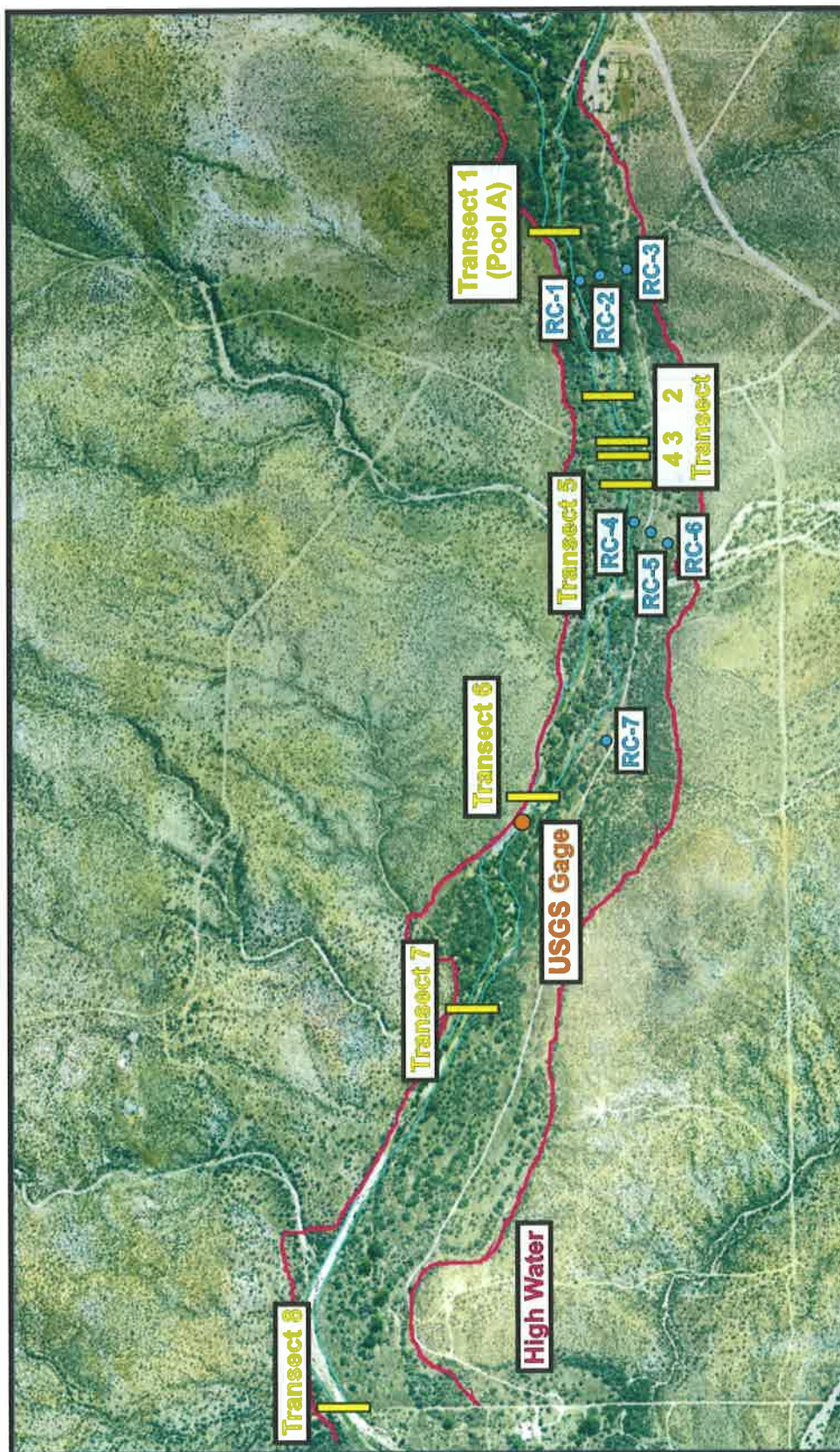


Figure 3. Transect, well, and gage locations in study area.

Impact of Flood on Transects and Instruments

The flood event dramatically altered the transect pools, normally by simply filling them nearly level with sediment and widening the channel. Transect 2, however, was physically altered with the fall of a large tree and subsequent erosion. The staff gages at Transects 1 and 4 remained intact, but the gage at Transect 2 was lost. Since all staff gages were deeply submerged in the flood water the gages were surveyed in the days following the event to ensure they had remained intact and had not moved. Fortunately, none had sustained any significant impacts by rocks and large debris carried by the flood water, although there were minor elevation changes. Both crest gages, however, were lost.

The data logger control box at Transect 1 was very nearly totally submerged by the flood water (Figure 4). The instrumentation was installed in hermetically sealed boxes so there was no water intrusion into the electronics.⁵ The data logger recorded the event at Transect 1 before, during, and after the flood and provided the best record of the event.



**Figure 4. Data logger was nearly submerged.
Water was 14.4 ft above channel bottom at this point.**

In-Situ miniTrolls[®] had been installed in three monitor wells (RC-1, RC-2, RC-3) near Transect 1 to monitor ground water levels.⁶ All three survived the flood and recorded the ground water fluctuations. RC-1 and RC-2 were topped by and submerged under several feet of flood water, RC-1 for about three hours and RC-2 for about one hour. A steel casing and cap set into a concrete base provided the well casings with protection against damage from the significant debris in the flow. RC-3 was not topped and the interior of the well casing remained dry. RC-4 and RC-5 were also topped but there were no instruments in these wells; RC-6 and RC-7 were not topped.

Weather History Leading up to Flood

For a year prior to July 2006 Tucson experienced one of the driest periods on record. Rincon Creek totally dried in late June 2005 and remained so until the last days of July 2006, slightly more than one calendar year. It is unusual in recent history that the creek should be totally dry for such an extended period of time.⁷

Monsoon rains began at the beginning of July with typical moisture flow patterns and the development of diurnal storms, although precipitation remained light until the end of the month.

⁵ Desiccant was saturated and the instrument did fail two weeks later; however, this may have been coincidental.

⁶ Seven monitoring wells had been established but only three are instrumented; the others (RC-4 through RC-7) are manually surveyed bi-weekly.

⁷ USGS gage records, available back to 1953 (1974 - 1987 excluded), indicate dry periods of typically half or less of this duration.

During the last week of July, however, there was a significant change in the weather pattern which resulted in exceptionally heavy and frequent nocturnal rains in southeastern Arizona.⁸ Moisture from Tropical Storm Emilia entered the state from the southwest while at the same time a stationary upper level low pressure system developed in New Mexico. This resulted in typical storm development in northern Arizona along the Mogollon Rim during the afternoon hours. The low pressure, however, now pushed these storms to the southwest, arriving in the Tucson area in the very early morning hours. The rains were at times very heavy and arrived daily for five consecutive days as the weather system remained stationary, thoroughly saturating the area.⁹ Table 1 lists daily total precipitation and daily maximum flow for the last week of July, as recorded by the weather stations along the creek and in the watershed. Rincon Peak data for this period was lost due to equipment failure.

Table 1. July Precipitation and Flow

Date	USGS (in.)	Madrona (in.)	Manning Camp (in.)	Happy Valley Saddle (in.)	Flow at USGS (cfs)
1 – 25*	2.45	2.53	5.01	-	0
26	0	0	0	0	0
27	0.87	1.39	2.20	1.82	40
28	0.28	0.21	0.47	0.28	22
29	1.18	1.10	1.93	1.86	470
30	0.83	0.72	0.63	1.44	1,192
31	1.85**	2.89	1.28	4.46	7,781**
Total	7.46	8.84	11.52	9.86***	

* For daily rainfall accumulations see Appendix F.

** Last recorded 31 July at 0314

*** This number does not reflect accumulations of 1 – 25 July (data not available).

Chronology of Flood Event

First flow on Rincon Creek in 2006 was recorded on 27 July, with a surge of about 2 feet at Transect 1 and a flow of 40 cfs at the USGS gage (Figure 5). The water quickly receded but then began rising slowly over the next two days until it had reached a depth equal to the first surge height. Flow, however, decreased by half. Midday 29 July a second surge of about 3.5 feet (470 cfs) was recorded. Levels decreased slowly again until the following day when another surge of 4 feet (1,192 cfs) was recorded. Total depth during this surge was now about 8 feet, within one foot of topping well RC-1.¹⁰

In the early hours of 31 July (beginning about 0230) a third large flood surge was recorded, surely the result of very heavy rains in the first hour or two after midnight both on the creek and in the watershed. Surge height was 10 ft, for a maximum depth at 0345 of 14.4 ft at Transect 1. The USGS gage recorded a flow of 7,881 cfs at 0314 at which time the gage was lost. The surge had yet to increase another 3-4 ft so this last recorded flow was considerably below the maximum. Both RC-1 and RC-2 recorded abrupt flooding as the wells were topped at about 0300.

It now takes more than two full days for the water levels to return to pre-flood surge levels (Transect 1 depth of 3 ft). A very small surge (~1 ft) is recorded late on 2 August, this being the result of an observed rain shower in the watershed only a mile or two distant. In each case the peak surge in the creek occurs within several hours or less of a rain event in the watershed (Figure 6).

⁸ Twice as much rain fell in the last week of July than is normal for the entire month.

⁹ Detailed meteorological history and descriptions of this weather pattern can be found at NOAA National Weather Service Forecast Office Storm Reviews, Tucson, AZ.

¹⁰ Well casings with caps extend approximately 3 feet above ground level.

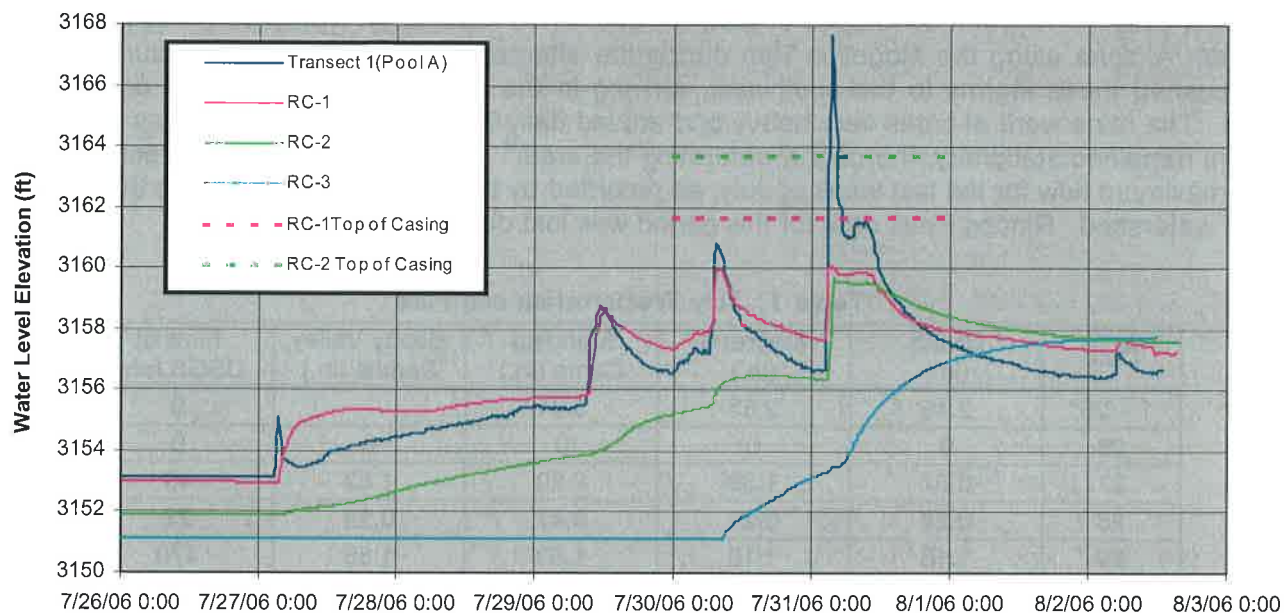


Figure 5. Flood water elevations at Transect 1 and wells.

Accumulation, normally over an hour or two, as recorded by the weather stations at the USGS gage on the creek, at Madrona Ranger Station, at Happy Valley Saddle (HVS), and at Manning Camp, all automated gages. These numbers may vary slightly from those in Table 1 since very light showers were recorded at other times on some days.

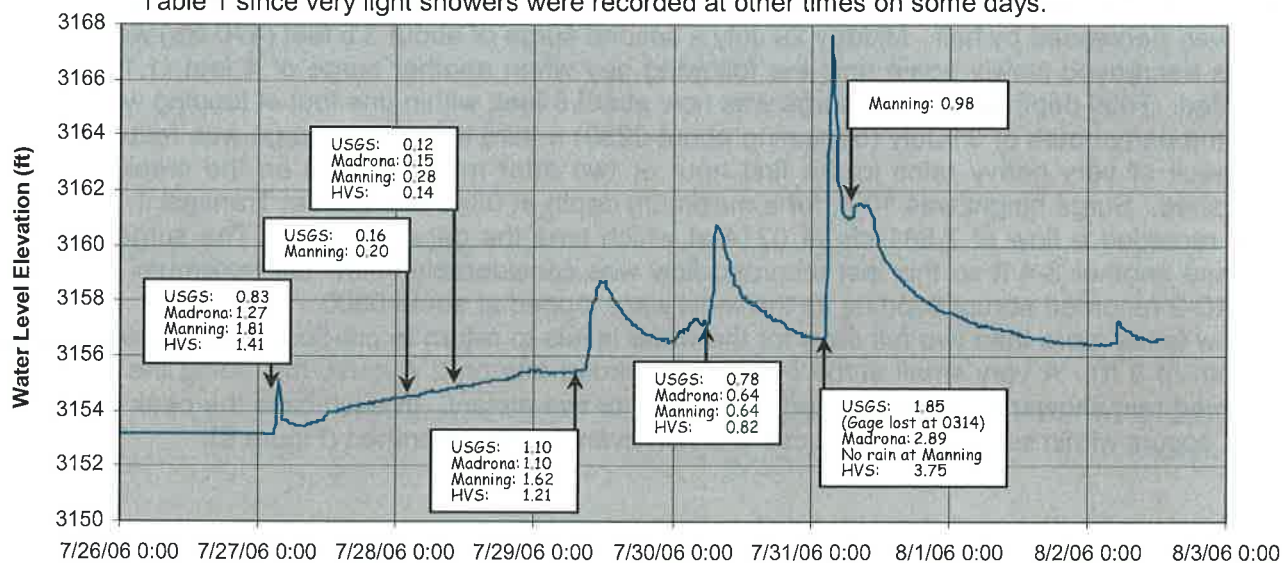


Figure 6. Influence of rainfall accumulations (in.) on flood elevations at Transect 1.

Approach to the creek was not possible until 1 August due to access road closures and safety in the immediate area of the creek. A walking survey of the area was promptly conducted followed by several days of surveying, maintaining instruments, and measuring flow. Several manual flow measurements were performed at Transect 1 at different gage heights.¹¹

Rincon Creek may have been the first to experience the large flows of 31 July and it did have the fourth largest flow of the instrumented drainages around the valley. Sabino Canyon recorded a flow of 16,000 cfs at 0815, Rillito River 26,100 cfs at 0915, and the Santa Cruz River 17,000 cfs at 1045. Flow in other drainages were considerably less: Pantano River at 2,300 cfs, Ventana Canyon at 3,000 cfs, and Tanque Verde Wash at 1,700 cfs.¹²

Cross Section Survey, Flow Calculation

A cross section survey at Transect 1 (Figure 7) was conducted on 3 and 4 August after the flood to calculate the peak flow. Flood width at the cross section, as determined by the high water marks, was 525 feet. Two additional field checks of the high water at two other locations along the study area confirmed the high water line as shown on Figure 3.

Maximum flow at Transect 1 is calculated to have been 14,000 cfs on 31 July.¹³ Flow at the USGS gage is estimated to have been 15,000 cfs, this higher flow due to locally heavy rains entering the creek via one small and two larger tributaries upstream of the USGS gage and downstream from Transect 1.

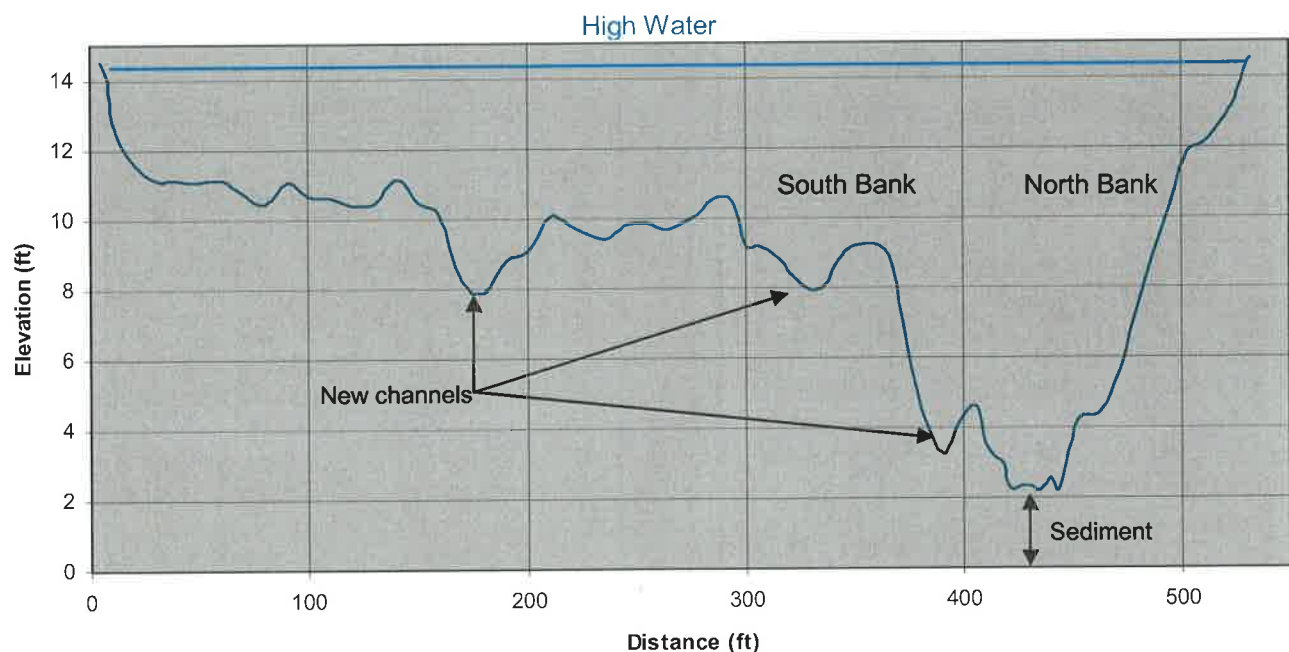


Figure 7. Transect 1 cross section after flood.

¹¹ Flows of 110 cfs at water depths of 3.5 ft (now on top of 1-2 ft of deposited sediment) at Transect 1 were measured. This was also determined to be the maximum safe wading condition at this location.

¹² Pima County Flood Control District sensor data

¹³ National Park Service Water Resources Division, Water Rights Branch, Ft. Collins, CO

Photo Survey

Many photos were taken of the creek as soon as access was possible and before conditions could change much. A selection of these photos appears in Appendix E. Many others are available but this selection provides a comprehensive view of the creek "before" and "after" without being repetitive.

Flow at Madrona Ranger Station on Chimenea Creek

Since Chimenea Creek, one of the largest drainages of the Rincon Creek watershed (Figure 8), lies within the Park, is easily accessible, and the confined channel lends itself relatively well to survey and flow calculations, the flow along Chimenea was calculated to offer an idea of the flow distribution in the watershed during the flood event. Two cross sections were established on Chimenea Creek at Madrona Ranger Station while high water indicators were still present. Surveys were conducted and the maximum flow of 31 July was calculated. Survey methods and calculation details can be found in Appenix G. The maximum flow along Chimenea Creek during the flood event was nearly 11,000 cfs, contributing the majority of the 14,000 cfs flow at Transect 1 on Rincon Creek. The balance of the flow was surely contributed by Madrona Creek and the upper reaches of Rincon Creek, which drains the Rincon Peak area.

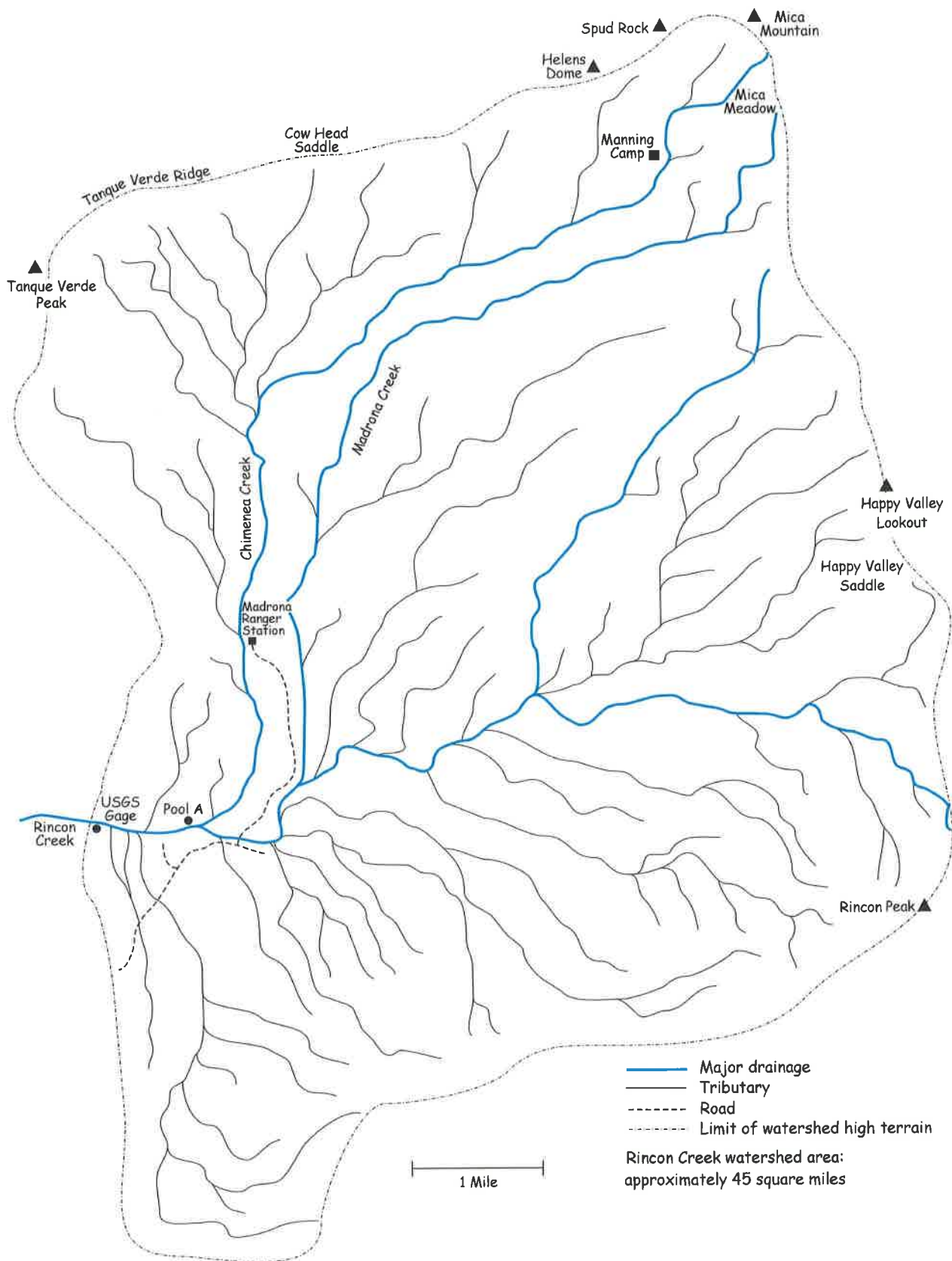


Figure 8. Rincon Creek watershed.

APPENDIX A

Transect 1 (Pool A) Data Logger Elevations

Elevation at 0.00 at staff gage:
3155.51

<u>Date/Time</u>	<u>Stage (ft)</u>	<u>Water Level Elevation</u>							
7/27/06 0:00	-0.04	3153.17	7/27/06 10:30	0.44	3153.65	7/27/06 22:30	1.20	3154.41	
7/27/06 0:15	-0.04	3153.17	7/27/06 10:45	0.45	3153.66	7/27/06 22:45	1.19	3154.40	
7/27/06 0:30	-0.04	3153.17	7/27/06 11:00	0.47	3153.68	7/27/06 23:00	1.21	3154.42	
7/27/06 0:45	-0.04	3153.17	7/27/06 11:15	0.51	3153.72	7/27/06 23:15	1.23	3154.44	
7/27/06 1:00	-0.04	3153.17	7/27/06 11:30	0.56	3153.77	7/27/06 23:30	1.26	3154.47	
7/27/06 1:15	-0.04	3153.17	7/27/06 11:45	0.62	3153.83	7/27/06 23:45	1.29	3154.50	
7/27/06 1:30	-0.04	3153.17	7/27/06 12:00	0.66	3153.87	7/28/06 0:00	1.27	3154.48	
7/27/06 1:45	-0.04	3153.17	7/27/06 12:15	0.70	3153.91	7/28/06 0:15	1.26	3154.47	
7/27/06 2:00	-0.04	3153.17	7/27/06 12:30	0.73	3153.94	7/28/06 0:30	1.27	3154.48	
7/27/06 2:15	-0.04	3153.17	7/27/06 12:45	0.75	3153.96	7/28/06 0:45	1.27	3154.48	
7/27/06 2:30	-0.04	3153.17	7/27/06 13:00	0.75	3153.96	7/28/06 1:00	1.27	3154.48	
7/27/06 2:45	-0.04	3153.17	7/27/06 13:15	0.79	3154.00	7/28/06 1:15	1.30	3154.51	
7/27/06 3:00	0.60	3153.81	7/27/06 13:30	0.80	3154.01	7/28/06 1:30	1.33	3154.54	
7/27/06 3:15	0.53	3153.74	7/27/06 13:45	0.80	3154.01	7/28/06 1:45	1.32	3154.53	
7/27/06 3:30	1.92	3155.13	7/27/06 14:00	0.82	3154.03	7/28/06 2:00	1.32	3154.53	
7/27/06 3:45	1.31	3154.52	7/27/06 14:15	0.84	3154.05	7/28/06 2:15	1.33	3154.54	
7/27/06 4:00	0.83	3154.04	7/27/06 14:30	0.86	3154.07	7/28/06 2:30	1.33	3154.54	
7/27/06 4:15	0.57	3153.78	7/27/06 14:45	0.86	3154.07	7/28/06 2:45	1.35	3154.56	
7/27/06 4:30	0.50	3153.71	7/27/06 15:00	0.88	3154.09	7/28/06 3:00	1.34	3154.55	
7/27/06 4:45	0.46	3153.67	7/27/06 15:15	0.88	3154.09	7/28/06 3:15	1.37	3154.58	
7/27/06 5:00	0.43	3153.64	7/27/06 15:30	0.89	3154.10	7/28/06 3:30	1.37	3154.58	
7/27/06 5:15	0.39	3153.60	7/27/06 15:45	0.93	3154.14	7/28/06 3:45	1.38	3154.59	
7/27/06 5:30	0.36	3153.57	7/27/06 16:00	0.92	3154.13	7/28/06 4:00	1.37	3154.58	
7/27/06 5:45	0.33	3153.54	7/27/06 16:15	0.95	3154.16	7/28/06 4:15	1.38	3154.59	
7/27/06 6:00	0.32	3153.53	7/27/06 16:30	0.97	3154.18	7/28/06 4:30	1.40	3154.61	
7/27/06 6:15	0.31	3153.52	7/27/06 16:45	0.96	3154.17	7/28/06 4:45	1.39	3154.60	
7/27/06 6:30	0.28	3153.49	7/27/06 17:00	0.99	3154.20	7/28/06 5:00	1.45	3154.66	
7/27/06 6:45	0.28	3153.49	7/27/06 17:15	0.99	3154.20	7/28/06 5:15	1.46	3154.67	
7/27/06 7:00	0.26	3153.47	7/27/06 17:30	0.99	3154.20	7/28/06 5:30	1.50	3154.71	
7/27/06 7:15	0.25	3153.46	7/27/06 17:45	1.00	3154.21	7/28/06 5:45	1.52	3154.73	
7/27/06 7:30	0.24	3153.45	7/27/06 18:00	1.03	3154.24	7/28/06 6:00	1.52	3154.73	
7/27/06 7:45	0.24	3153.45	7/27/06 18:15	1.04	3154.25	7/28/06 6:15	1.54	3154.75	
7/27/06 8:00	0.26	3153.47	7/27/06 18:30	1.04	3154.25	7/28/06 6:30	1.52	3154.73	
7/27/06 8:15	0.25	3153.46	7/27/06 18:45	1.04	3154.25	7/28/06 6:45	1.52	3154.73	
7/27/06 8:30	0.30	3153.51	7/27/06 19:00	1.08	3154.29	7/28/06 7:00	1.51	3154.72	
7/27/06 8:45	0.31	3153.52	7/27/06 19:15	1.08	3154.29	7/28/06 7:15	1.52	3154.73	
7/27/06 9:00	0.32	3153.53	7/27/06 19:30	1.10	3154.31	7/28/06 7:30	1.52	3154.73	
7/27/06 9:15	0.34	3153.55	7/27/06 19:45	1.09	3154.30	7/28/06 7:45	1.55	3154.76	
7/27/06 9:30	0.35	3153.56	7/27/06 20:00	1.10	3154.31	7/28/06 8:00	1.54	3154.75	
7/27/06 9:45	0.38	3153.59	7/27/06 20:15	1.09	3154.30	7/28/06 8:15	1.56	3154.77	
7/27/06 10:00	0.40	3153.61	7/27/06 20:30	1.12	3154.33	7/28/06 8:30	1.55	3154.76	
7/27/06 10:15	0.40	3153.61	7/27/06 20:45	1.15	3154.36	7/28/06 8:45	1.57	3154.78	
			7/27/06 21:00	1.15	3154.36	7/28/06 9:00	1.58	3154.79	
			7/27/06 21:15	1.14	3154.35	7/28/06 9:15	1.61	3154.82	
			7/27/06 21:30	1.14	3154.35	7/28/06 9:30	1.62	3154.83	
			7/27/06 21:45	1.17	3154.38	7/28/06 9:45	1.61	3154.82	
			7/27/06 22:00	1.18	3154.39	7/28/06 10:00	1.62	3154.83	
			7/27/06 22:15	1.18	3154.39	7/28/06 10:15	1.63	3154.84	

7/28/06 10:30	6.19	3155.47	7/28/06 23:15	5.93	3155.73	7/29/06 12:00	3.07	3158.59
7/28/06 10:45	6.18	3155.48	7/28/06 23:30	5.93	3155.73	7/29/06 12:15	3.06	3158.60
7/28/06 11:00	6.17	3155.49	7/28/06 23:45	5.93	3155.73	7/29/06 12:30	3.10	3158.56
7/28/06 11:15	6.17	3155.50	7/29/06 0:00	5.93	3155.73	7/29/06 12:45	3.16	3158.50
7/28/06 11:30	6.16	3155.50	7/29/06 0:15	5.93	3155.73	7/29/06 13:00	3.19	3158.47
7/28/06 11:45	6.15	3155.51	7/29/06 0:30	5.93	3155.73	7/29/06 13:15	3.25	3158.41
7/28/06 12:00	6.14	3155.52	7/29/06 0:45	5.93	3155.73	7/29/06 13:30	3.32	3158.35
7/28/06 12:15	6.13	3155.53	7/29/06 1:00	5.93	3155.73	7/29/06 13:45	3.37	3158.29
7/28/06 12:30	6.13	3155.53	7/29/06 1:15	5.93	3155.73	7/29/06 14:00	3.41	3158.25
7/28/06 12:45	6.12	3155.54	7/29/06 1:30	5.93	3155.73	7/29/06 14:15	3.45	3158.21
7/28/06 13:00	6.11	3155.55	7/29/06 1:45	5.93	3155.73	7/29/06 14:30	3.49	3158.17
7/28/06 13:15	6.11	3155.55	7/29/06 2:00	5.93	3155.73	7/29/06 14:45	3.52	3158.14
7/28/06 13:30	6.10	3155.56	7/29/06 2:15	5.93	3155.73	7/29/06 15:00	3.55	3158.11
7/28/06 13:45	6.09	3155.57	7/29/06 2:30	5.93	3155.73	7/29/06 15:15	3.59	3158.08
7/28/06 14:00	6.09	3155.57	7/29/06 2:45	5.93	3155.73	7/29/06 15:30	3.62	3158.04
7/28/06 14:15	6.08	3155.58	7/29/06 3:00	5.93	3155.73	7/29/06 15:45	3.66	3158.00
7/28/06 14:30	6.08	3155.59	7/29/06 3:15	5.93	3155.73	7/29/06 16:00	3.69	3157.97
7/28/06 14:45	6.07	3155.59	7/29/06 3:30	5.93	3155.73	7/29/06 16:15	3.73	3157.93
7/28/06 15:00	6.07	3155.60	7/29/06 3:45	5.93	3155.73	7/29/06 16:30	3.76	3157.90
7/28/06 15:15	6.06	3155.60	7/29/06 4:00	5.93	3155.73	7/29/06 16:45	3.80	3157.86
7/28/06 15:30	6.06	3155.61	7/29/06 4:15	5.93	3155.73	7/29/06 17:00	3.83	3157.83
7/28/06 15:45	6.05	3155.61	7/29/06 4:30	5.93	3155.73	7/29/06 17:15	3.86	3157.80
7/28/06 16:00	6.04	3155.62	7/29/06 4:45	5.92	3155.74	7/29/06 17:30	3.89	3157.77
7/28/06 16:15	6.04	3155.62	7/29/06 5:00	5.92	3155.74	7/29/06 17:45	3.92	3157.75
7/28/06 16:30	6.03	3155.63	7/29/06 5:15	5.92	3155.74	7/29/06 18:00	3.94	3157.72
7/28/06 16:45	6.03	3155.63	7/29/06 5:30	5.92	3155.74	7/29/06 18:15	3.96	3157.70
7/28/06 17:00	6.02	3155.64	7/29/06 5:45	5.92	3155.74	7/29/06 18:30	3.98	3157.68
7/28/06 17:15	6.02	3155.64	7/29/06 6:00	5.92	3155.74	7/29/06 18:45	4.01	3157.66
7/28/06 17:30	6.01	3155.65	7/29/06 6:15	5.92	3155.75	7/29/06 19:00	4.02	3157.64
7/28/06 17:45	6.00	3155.66	7/29/06 6:30	5.91	3155.75	7/29/06 19:15	4.04	3157.62
7/28/06 18:00	6.00	3155.66	7/29/06 6:45	5.91	3155.75	7/29/06 19:30	4.06	3157.60
7/28/06 18:15	5.99	3155.67	7/29/06 7:00	5.90	3155.76	7/29/06 19:45	4.08	3157.58
7/28/06 18:30	5.99	3155.67	7/29/06 7:15	5.90	3155.76	7/29/06 20:00	4.10	3157.56
7/28/06 18:45	5.98	3155.68	7/29/06 7:30	5.89	3155.77	7/29/06 20:15	4.12	3157.55
7/28/06 19:00	5.98	3155.69	7/29/06 7:45	5.88	3155.78	7/29/06 20:30	4.13	3157.53
7/28/06 19:15	5.97	3155.69	7/29/06 8:00	5.87	3155.79	7/29/06 20:45	4.15	3157.51
7/28/06 19:30	5.97	3155.69	7/29/06 8:15	5.86	3155.81	7/29/06 21:00	4.16	3157.50
7/28/06 19:45	5.96	3155.70	7/29/06 8:30	5.84	3155.82	7/29/06 21:15	4.18	3157.48
7/28/06 20:00	5.96	3155.70	7/29/06 8:45	5.83	3155.83	7/29/06 21:30	4.19	3157.47
7/28/06 20:15	5.95	3155.71	7/29/06 9:00	5.81	3155.85	7/29/06 21:45	4.21	3157.45
7/28/06 20:30	5.95	3155.71	7/29/06 9:15	5.80	3155.87	7/29/06 22:00	4.22	3157.44
7/28/06 20:45	5.95	3155.71	7/29/06 9:30	5.75	3155.91	7/29/06 22:15	4.24	3157.43
7/28/06 21:00	5.95	3155.71	7/29/06 9:45	5.63	3156.03	7/29/06 22:30	4.25	3157.41
7/28/06 21:15	5.95	3155.71	7/29/06 10:00	5.26	3156.40	7/29/06 22:45	4.26	3157.40
7/28/06 21:30	5.94	3155.72	7/29/06 10:15	4.68	3156.98	7/29/06 23:00	4.27	3157.39
7/28/06 21:45	5.94	3155.72	7/29/06 10:30	4.28	3157.38	7/29/06 23:15	4.28	3157.38
7/28/06 22:00	5.94	3155.72	7/29/06 10:45	3.99	3157.67	7/29/06 23:30	4.29	3157.37
7/28/06 22:15	5.94	3155.72	7/29/06 11:00	3.71	3157.95	7/29/06 23:45	4.30	3157.36
7/28/06 22:30	5.94	3155.72	7/29/06 11:15	3.44	3158.22	7/30/06 0:00	4.31	3157.35
7/28/06 22:45	5.94	3155.72	7/29/06 11:30	3.24	3158.42	7/30/06 0:15	4.30	3157.36
7/28/06 23:00	5.93	3155.73	7/29/06 11:45	3.12	3158.54	7/30/06 0:30	4.27	3157.39

7/30/06 0:45	4.24	3157.42	7/30/06 13:30	3.15	3158.52	7/31/06 2:15	3.99	3157.67
7/30/06 1:00	4.20	3157.46	7/30/06 13:45	3.15	3158.52	7/31/06 2:30	3.98	3157.68
7/30/06 1:15	4.15	3157.51	7/30/06 14:00	3.14	3158.52	7/31/06 2:45	2.78	3158.88
7/30/06 1:30	4.12	3157.54	7/30/06 14:15	3.14	3158.52	7/31/06 3:00	1.64	3160.02
7/30/06 1:45	4.09	3157.57	7/30/06 14:30	3.20	3158.46	7/31/06 3:15	1.57	3160.09
7/30/06 2:00	4.06	3157.60	7/30/06 14:45	3.28	3158.38	7/31/06 3:30	1.57	3160.09
7/30/06 2:15	4.04	3157.63	7/30/06 15:00	3.27	3158.39	7/31/06 3:45	1.57	3160.09
7/30/06 2:30	4.02	3157.64	7/30/06 15:15	3.28	3158.38	7/31/06 4:00	1.65	3160.01
7/30/06 2:45	4.02	3157.64	7/30/06 15:30	3.31	3158.35	7/31/06 4:15	1.73	3159.93
7/30/06 3:00	3.99	3157.67	7/30/06 15:45	3.33	3158.33	7/31/06 4:30	1.80	3159.86
7/30/06 3:15	3.93	3157.73	7/30/06 16:00	3.37	3158.29	7/31/06 4:45	1.82	3159.84
7/30/06 3:30	3.88	3157.78	7/30/06 16:15	3.38	3158.28	7/31/06 5:00	1.81	3159.85
7/30/06 3:45	3.83	3157.83	7/30/06 16:30	3.41	3158.25	7/31/06 5:15	1.82	3159.84
7/30/06 4:00	3.79	3157.87	7/30/06 16:45	3.41	3158.25	7/31/06 5:30	1.85	3159.81
7/30/06 4:15	3.77	3157.89	7/30/06 17:00	3.44	3158.22	7/31/06 5:45	1.85	3159.81
7/30/06 4:30	3.78	3157.88	7/30/06 17:15	3.47	3158.19	7/31/06 6:00	1.85	3159.81
7/30/06 4:45	3.80	3157.86	7/30/06 17:30	3.50	3158.16	7/31/06 6:15	1.85	3159.81
7/30/06 5:00	3.82	3157.84	7/30/06 17:45	3.53	3158.13	7/31/06 6:30	1.83	3159.84
7/30/06 5:15	3.81	3157.85	7/30/06 18:00	3.55	3158.11	7/31/06 6:45	1.86	3159.80
7/30/06 5:30	3.76	3157.90	7/30/06 18:15	3.56	3158.10	7/31/06 7:00	1.85	3159.82
7/30/06 5:45	3.76	3157.91	7/30/06 18:30	3.53	3158.13	7/31/06 7:15	1.82	3159.84
7/30/06 6:00	3.77	3157.89	7/30/06 18:45	3.50	3158.16	7/31/06 7:30	1.81	3159.85
7/30/06 6:15	3.76	3157.91	7/30/06 19:00	3.60	3158.06	7/31/06 7:45	1.80	3159.86
7/30/06 6:30	3.68	3157.98	7/30/06 19:15	3.62	3158.04	7/31/06 8:00	1.79	3159.87
7/30/06 6:45	3.57	3158.09	7/30/06 19:30	3.64	3158.02	7/31/06 8:15	1.79	3159.87
7/30/06 7:00	3.25	3158.42	7/30/06 19:45	3.66	3158.00	7/31/06 8:30	1.80	3159.86
7/30/06 7:15	2.56	3159.10	7/30/06 20:00	3.68	3157.98	7/31/06 8:45	1.80	3159.86
7/30/06 7:30	1.73	3159.93	7/30/06 20:15	3.70	3157.96	7/31/06 9:00	1.79	3159.87
7/30/06 7:45	1.72	3159.95	7/30/06 20:30	3.72	3157.94	7/31/06 9:15	1.79	3159.88
7/30/06 8:00	1.70	3159.96	7/30/06 20:45	3.74	3157.93	7/31/06 9:30	1.79	3159.87
7/30/06 8:15	1.70	3159.97	7/30/06 21:00	3.75	3157.91	7/31/06 9:45	1.80	3159.86
7/30/06 8:30	1.74	3159.92	7/30/06 21:15	3.77	3157.89	7/31/06 10:00	1.82	3159.84
7/30/06 8:45	1.83	3159.83	7/30/06 21:30	3.79	3157.87	7/31/06 10:15	1.83	3159.83
7/30/06 9:00	1.90	3159.76	7/30/06 21:45	3.80	3157.86	7/31/06 10:30	1.84	3159.82
7/30/06 9:15	2.04	3159.62	7/30/06 22:00	3.82	3157.84	7/31/06 10:45	1.95	3159.71
7/30/06 9:30	2.20	3159.46	7/30/06 22:15	3.83	3157.83	7/31/06 11:00	2.09	3159.57
7/30/06 9:45	2.33	3159.33	7/30/06 22:30	3.85	3157.81	7/31/06 11:15	2.17	3159.49
7/30/06 10:00	2.47	3159.19	7/30/06 22:45	3.86	3157.80	7/31/06 11:30	2.27	3159.39
7/30/06 10:15	2.60	3159.06	7/30/06 23:00	3.87	3157.79	7/31/06 11:45	2.37	3159.29
7/30/06 10:30	2.66	3159.00	7/30/06 23:15	3.89	3157.77	7/31/06 12:00	2.45	3159.21
7/30/06 10:45	2.74	3158.92	7/30/06 23:30	3.90	3157.76	7/31/06 12:15	2.40	3159.26
7/30/06 11:00	2.80	3158.86	7/30/06 23:45	3.91	3157.75	7/31/06 12:30	2.45	3159.21
7/30/06 11:15	2.86	3158.80	7/31/06 0:00	3.93	3157.74	7/31/06 12:45	2.50	3159.16
7/30/06 11:30	2.90	3158.76	7/31/06 0:15	3.94	3157.72	7/31/06 13:00	2.57	3159.09
7/30/06 11:45	2.93	3158.73	7/31/06 0:30	3.95	3157.71	7/31/06 13:15	2.63	3159.03
7/30/06 12:00	2.95	3158.71	7/31/06 0:45	3.96	3157.70	7/31/06 13:30	2.72	3158.95
7/30/06 12:15	2.97	3158.69	7/31/06 1:00	3.97	3157.69	7/31/06 13:45	2.77	3158.89
7/30/06 12:30	2.99	3158.67	7/31/06 1:15	3.98	3157.68	7/31/06 14:00	2.81	3158.85
7/30/06 12:45	3.04	3158.62	7/31/06 1:30	4.00	3157.67	7/31/06 14:15	2.84	3158.82
7/30/06 13:00	3.10	3158.57	7/31/06 1:45	4.00	3157.66	7/31/06 14:30	2.89	3158.77
7/30/06 13:15	3.12	3158.54	7/31/06 2:00	4.00	3157.66	7/31/06 14:45	2.94	3158.72

7/31/06 15:00	4.57	3159.08	8/1/06 3:45	5.41	3158.24	8/1/06 16:30	5.79	3157.86
7/31/06 15:15	4.59	3159.06	8/1/06 4:00	5.42	3158.23	8/1/06 16:45	5.80	3157.85
7/31/06 15:30	4.62	3159.03	8/1/06 4:15	5.43	3158.22	8/1/06 17:00	5.80	3157.85
7/31/06 15:45	4.64	3159.01	8/1/06 4:30	5.44	3158.21	8/1/06 17:15	5.81	3157.84
7/31/06 16:00	4.66	3158.99	8/1/06 4:45	5.45	3158.20	8/1/06 17:30	5.82	3157.84
7/31/06 16:15	4.69	3158.96	8/1/06 5:00	5.46	3158.19	8/1/06 17:45	5.82	3157.83
7/31/06 16:30	4.71	3158.94	8/1/06 5:15	5.47	3158.18	8/1/06 18:00	5.83	3157.82
7/31/06 16:45	4.73	3158.92	8/1/06 5:30	5.48	3158.17	8/1/06 18:15	5.83	3157.82
7/31/06 17:00	4.75	3158.90	8/1/06 5:45	5.49	3158.16	8/1/06 18:30	5.84	3157.81
7/31/06 17:15	4.77	3158.88	8/1/06 6:00	5.50	3158.15	8/1/06 18:45	5.84	3157.81
7/31/06 17:30	4.79	3158.86	8/1/06 6:15	5.51	3158.14	8/1/06 19:00	5.85	3157.80
7/31/06 17:45	4.82	3158.84	8/1/06 6:30	5.52	3158.13	8/1/06 19:15	5.85	3157.80
7/31/06 18:00	4.84	3158.81	8/1/06 6:45	5.53	3158.12	8/1/06 19:30	5.86	3157.79
7/31/06 18:15	4.86	3158.79	8/1/06 7:00	5.54	3158.11	8/1/06 19:45	5.86	3157.79
7/31/06 18:30	4.88	3158.77	8/1/06 7:15	5.55	3158.10	8/1/06 20:00	5.87	3157.78
7/31/06 18:45	4.90	3158.76	8/1/06 7:30	5.56	3158.10	8/1/06 20:15	5.87	3157.78
7/31/06 19:00	4.91	3158.74	8/1/06 7:45	5.56	3158.09	8/1/06 20:30	5.88	3157.77
7/31/06 19:15	4.93	3158.72	8/1/06 8:00	5.57	3158.08	8/1/06 20:45	5.88	3157.77
7/31/06 19:30	4.95	3158.70	8/1/06 8:15	5.58	3158.07	8/1/06 21:00	5.89	3157.76
7/31/06 19:45	4.97	3158.68	8/1/06 8:30	5.59	3158.06	8/1/06 21:15	5.89	3157.76
7/31/06 20:00	4.99	3158.66	8/1/06 8:45	5.60	3158.05	8/1/06 21:30	5.90	3157.75
7/31/06 20:15	5.01	3158.64	8/1/06 9:00	5.60	3158.05	8/1/06 21:45	5.90	3157.75
7/31/06 20:30	5.02	3158.63	8/1/06 9:15	5.61	3158.04	8/1/06 22:00	5.91	3157.74
7/31/06 20:45	5.04	3158.61	8/1/06 9:30	5.62	3158.03	8/1/06 22:15	5.91	3157.74
7/31/06 21:00	5.06	3158.59	8/1/06 9:45	5.63	3158.02	8/1/06 22:30	5.92	3157.73
7/31/06 21:15	5.08	3158.58	8/1/06 10:00	5.63	3158.02	8/1/06 22:45	5.92	3157.73
7/31/06 21:30	5.09	3158.56	8/1/06 10:15	5.64	3158.01	8/1/06 23:00	5.93	3157.72
7/31/06 21:45	5.11	3158.54	8/1/06 10:30	5.65	3158.00	8/1/06 23:15	5.93	3157.72
7/31/06 22:00	5.12	3158.53	8/1/06 10:45	5.66	3158.00	8/1/06 23:30	5.93	3157.72
7/31/06 22:15	5.14	3158.52	8/1/06 11:00	5.66	3157.99	8/1/06 23:45	5.94	3157.71
7/31/06 22:30	5.15	3158.50	8/1/06 11:15	5.67	3157.98	8/2/06 0:00	5.94	3157.71
7/31/06 22:45	5.17	3158.49	8/1/06 11:30	5.68	3157.98	8/2/06 0:15	5.95	3157.70
7/31/06 23:00	5.18	3158.47	8/1/06 11:45	5.68	3157.97	8/2/06 0:30	5.95	3157.70
7/31/06 23:15	5.19	3158.46	8/1/06 12:00	5.69	3157.96	8/2/06 0:45	5.96	3157.70
7/31/06 23:30	5.21	3158.44	8/1/06 12:15	5.69	3157.96	8/2/06 1:00	5.96	3157.69
7/31/06 23:45	5.22	3158.43	8/1/06 12:30	5.70	3157.95	8/2/06 1:15	5.96	3157.69
8/1/06 0:00	5.23	3158.42	8/1/06 12:45	5.71	3157.94	8/2/06 1:30	5.97	3157.68
8/1/06 0:15	5.25	3158.40	8/1/06 13:00	5.71	3157.94	8/2/06 1:45	5.97	3157.68
8/1/06 0:30	5.26	3158.39	8/1/06 13:15	5.72	3157.93	8/2/06 2:00	5.98	3157.67
8/1/06 0:45	5.27	3158.38	8/1/06 13:30	5.73	3157.93	8/2/06 2:15	5.98	3157.67
8/1/06 1:00	5.29	3158.36	8/1/06 13:45	5.73	3157.92	8/2/06 2:30	5.98	3157.67
8/1/06 1:15	5.30	3158.35	8/1/06 14:00	5.74	3157.91	8/2/06 2:45	5.99	3157.66
8/1/06 1:30	5.31	3158.34	8/1/06 14:15	5.74	3157.91	8/2/06 3:00	5.99	3157.66
8/1/06 1:45	5.32	3158.33	8/1/06 14:30	5.75	3157.90	8/2/06 3:15	6.00	3157.66
8/1/06 2:00	5.33	3158.32	8/1/06 14:45	5.75	3157.90	8/2/06 3:30	6.00	3157.65
8/1/06 2:15	5.35	3158.31	8/1/06 15:00	5.76	3157.89	8/2/06 3:45	6.00	3157.65
8/1/06 2:30	5.36	3158.29	8/1/06 15:15	5.77	3157.89	8/2/06 4:00	6.00	3157.65
8/1/06 2:45	5.37	3158.28	8/1/06 15:30	5.77	3157.88	8/2/06 4:15	6.01	3157.64
8/1/06 3:00	5.38	3158.27	8/1/06 15:45	5.78	3157.87	8/2/06 4:30	6.01	3157.64
8/1/06 3:15	5.39	3158.26	8/1/06 16:00	5.78	3157.87	8/2/06 4:45	6.01	3157.64
8/1/06 3:30	5.40	3158.25	8/1/06 16:15	5.79	3157.86	8/2/06 5:00	6.02	3157.63

8/2/06 5:15	6.02	3157.63
8/2/06 5:30	6.02	3157.63
8/2/06 5:45	6.02	3157.63
8/2/06 6:00	6.02	3157.63
8/2/06 6:15	6.02	3157.63
8/2/06 6:30	6.02	3157.63
8/2/06 6:45	6.02	3157.63
8/2/06 7:00	6.01	3157.64
8/2/06 7:15	6.01	3157.64
8/2/06 7:30	6.01	3157.64
8/2/06 7:45	6.01	3157.64
8/2/06 8:00	6.02	3157.64
8/2/06 8:15	6.02	3157.63
8/2/06 8:30	6.02	3157.63
8/2/06 8:45	6.02	3157.63
8/2/06 9:00	6.02	3157.63
8/2/06 9:15	6.02	3157.63
8/2/06 9:30	6.02	3157.63
8/2/06 9:45	6.03	3157.63
8/2/06 10:00	6.03	3157.62
8/2/06 10:15	6.03	3157.62
8/2/06 10:30	6.03	3157.62
8/2/06 10:45	6.03	3157.62
8/2/06 11:00	6.03	3157.62
8/2/06 11:15	6.03	3157.62
8/2/06 11:30	6.03	3157.62
8/2/06 11:45	6.04	3157.62
8/2/06 12:00	6.04	3157.61
8/2/06 12:15	6.04	3157.61
8/2/06 12:30	6.04	3157.61
8/2/06 12:45	6.04	3157.61
8/2/06 13:00	6.04	3157.61
8/2/06 13:15	6.04	3157.61
8/2/06 13:30	6.04	3157.61
8/2/06 13:45	6.04	3157.61
8/2/06 14:00	6.05	3157.61
8/2/06 14:15	6.05	3157.60
8/2/06 14:30	6.05	3157.60
8/2/06 14:45	6.05	3157.60
8/2/06 15:00	6.05	3157.60
8/2/06 15:15	6.05	3157.60
8/2/06 15:30	6.05	3157.60

APPENDIX E

Photo Survey



Transect 1 (Pool A) looking upstream before ...



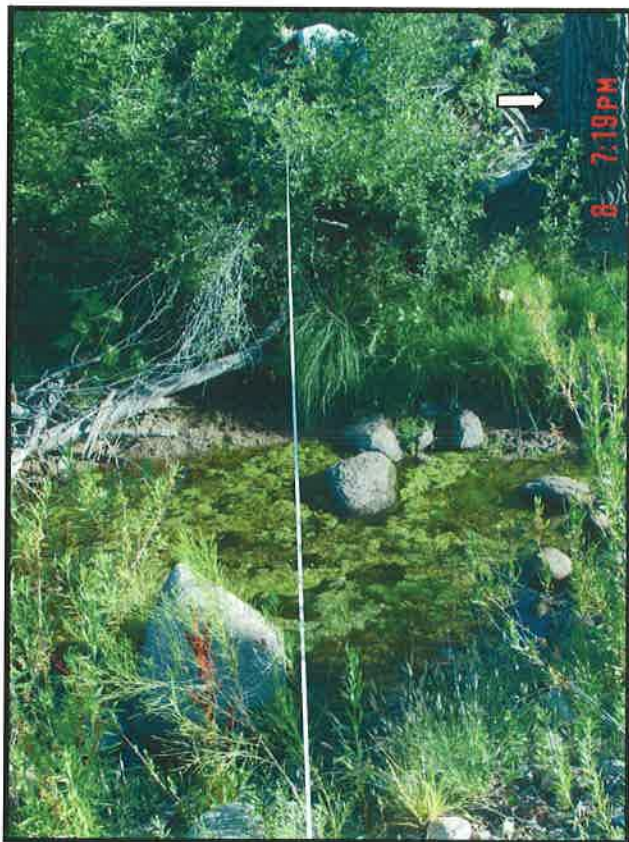
and after flood. Channel width changed little at this point but much vegetation was swept away and there was considerable erosion and sediment deposition on the south bank. Flow is estimated to be about 130 cfs at this time.



Transect 3 before ...



and after. Sediment in foreground is 2-3 ft deep, and road on far bank is no longer passable due to severe erosion and debris accumulation.



Transect 2 before ...



and after. Topography of this pool was the most seriously altered. When the large tree fell a second channel was eroded behind it, more than doubling the channel width



USGS gage before ...



and after. This portion of the survey area showed the most pronounced erosion and vegetation loss.



View upstream from Transect 6 before ...



and after. A new, larger channel can be seen upstream on the left.



RC-5 looking West along access road. Well was topped (note high water mark on vegetation).



View looking West along access road.



RC-4 was also topped (note high water mark on vegetation).



View looking upstream at large tributary showing erosion and channel widening.



View upstream from Transect 3. Channel has more than doubled in width and vegetation has been swept away, allowing Transect 2 to be clearly seen.



Transect 2. Only remnants of the staff gage and crest gage support structures remain.

APPENDIX F
Daily Rainfall Accumulations

<u>Date, July</u>	<u>USGS</u>	<u>Madrona</u>	<u>Manning</u>
1	0	0	0.43
2	0.39	0.07	0.20
3	0	0	0
4	0.79	0.48	0.99
5	0.24	0.53	1.45
6	0	0	0.16
7	0.16	0.29	1.30
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	0.51	0.86	0.08
14	0	0	0
15	0	0	0
16	0	0	0
17	0	0	0
18	0.12	0.04	0
19	0.04	0.01	0.08
20	0	0	0
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0
25	0.20	0.25	0.32

APPENDIX G

Calculation of Flow on Chimenea Creek

In order to estimate the discharge (flow) along Chimenea Creek during the flood event of 31 July 2006 two cross sections were established, one at Pool 1K and one at Pool 2A. Locations were selected based on ease of locating the high water marks on both banks, finding suitable reaches that were relatively flat and/or uniform for at least short distances upstream, and finding relatively wide cross sections.¹

Cross section surveys were conducted using the rod and level technique to determine the cross section areas. Elevations were measured to the bedrock which forms the channel bottom in this drainage. The depth of what little sediment that was present in the cross sections was probed where it occurred.² A Nikon Total station was used for the survey of the longitudinal profile of the drainage in the area of the two cross sections. The slope between the high water marks of the cross sections was measured as was the slope (water's edge) of the thalweg.



Cross section (high water line) at Pool 1K. View downstream. Note figure in center for scale. Large cobbles/boulders and thick vegetation are present on both banks outside the channel, and were submerged in the high flow.



View upstream at Pool 1K.

¹ Chimenea Creek is a typical mountain drainage, characterized by steep banks, a steep thalweg slope, a channel bottom of bedrock and large boulders, and some fine and coarse sediments in some of the pools.

² Sediment cross section area must be considered as part of the total channel cross section since sediment surely was not present at maximum flow, being deposited as water levels and velocity of flow decreased.



View from right bank across cross section at Pool 1K.



Cross section (high water line) at Pool 2A. View downstream. Note figures for scale. As with Pool 1K, boulders and thick vegetation are present outside the channel and were submerged in the high flow.



Right bank at Pool 2A.



View from right bank across cross section at Pool 2A.

Discharge was calculated using WinXSPRO.³ Thalweg slope was measured directly, and Manning's roughness coefficients were estimated using a table of coefficients for similar, representative conditions. Sediment transport and loads were ignored since little if any sediment was being deposited during the peak discharge, the period of interest of this study.

Manning's roughness coefficient, n : Both cross sections were divided into segments to accommodate the dramatic changes in roughness at high water. The coefficient n for the channel can be easily estimated from similar conditions cited in the literature but once the flood water extended beyond the channel, roughness increased dramatically with large cobbles, rough topography, boulders as large as six feet, and dense vegetation (trees and brush). Manning's coefficient has to be adjusted for these factors to reflect the extreme roughness (relative to typical channels cited in the literature), yielding roughness coefficients in excess of 0.1. Using the only readily available documentation for high-slope, very rough mountain drainages,⁴ n was adjusted to reflect the unique characteristics of each cross section: $n = n_b$ (a 'base' roughness value) + n_1 (correction for surface irregularities) + n_2 (correction for cross section variations) + n_3 (correction for obstructions) + n_4 (correction for vegetation). In those segments where water depth was sufficient to begin attenuating the effects of submerged obstructions, n was reduced at high water to reflect the reduced 'roughness' with increasing depth. This, however, was found to make little difference in the total discharge under the conditions of these cross sections.

Thalweg slope: The slope of the high water marks (i.e., slope of the water surface between the two cross sections) was measured to be 7.3% (36 ft elevation difference over 490 ft). The channel was relatively straight at both cross sections and the elevations of each pair of high water marks were in good agreement, suggesting that at the selected high water marks there was no large local turbulence at water's edge or 'piling up' of water due to a local obstruction. The average slope of the thalweg was measured to be 6.9% (59 ft elevation difference over 850 ft).⁵ However, using 7.3% as the high water slope and 6.9% as the low water slope made no appreciable difference in the total calculated discharge over using 7.3% for both high and low flows, under the conditions of these cross sections. This is to be expected: much lower flows would be more influenced by the local thalweg slope.

Total discharge, Q : Total discharge at cross section 1K was calculated to be 10,816 cfs, and 10,888 cfs at cross section 2A. Since nothing was entering or leaving the system in the short distance between the cross sections, Q must be the same for both, and indeed there is an agreement within <1%. This, however, must be recognized as rather fortuitous given the subjective nature of selecting n values! Rating curves for both cross sections were also well-behaved, not surprising given there are no overhangs, perched channels, or other structures that would negatively influence the curves.

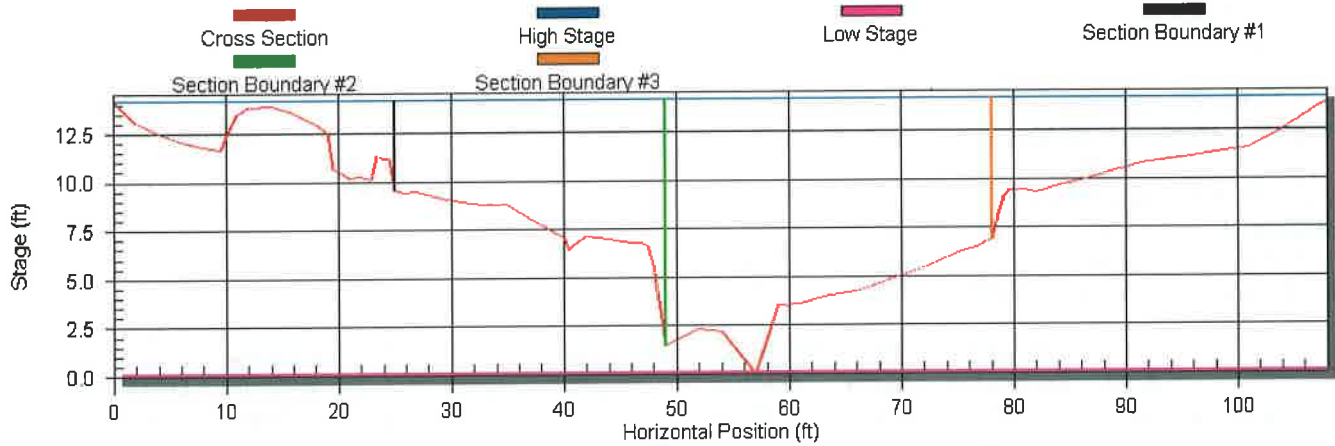
The following are the graphs, calculations, and reports for the cross sections, presented in detail so they may be reproduced or modified as needed.

³ WinXSPRO, A Channel Cross Section Analyzer, User's Manual, Version 3.0. USDA Forest Service. General Technical Report RMRS-GTR-147. January 2005.

⁴ Arcement, G.J., Jr. and Schneider, V.R. Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains, United States Geological Survey Water-Supply Paper 2339.

⁵ Elevations were surveyed upstream and downstream from the cross sections, as far as possible, in order to average any local variations.

Cross Section 1K Profile



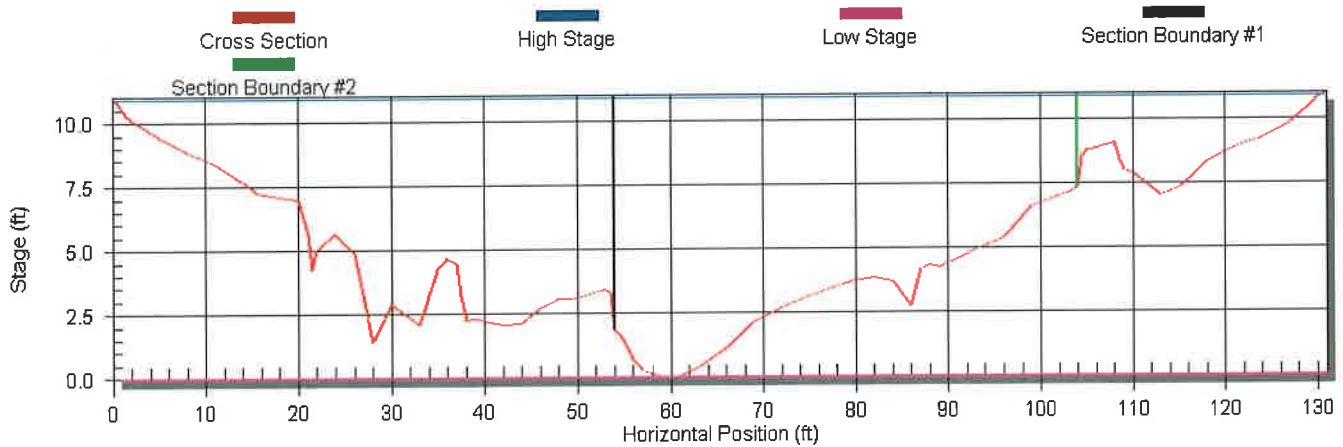
$n_b = 0.070$
 $n_1 = 0.020$
 $n_2 = 0.003$
 $n_3 = 0.030$
 $n_4 = \underline{0.000}$
 $n = 0.123$

$n_b = 0.070$
 $n_1 = 0.020$
 $n_2 = 0.003$
 $n_3 = 0.020$
 $n_4 = \underline{0.000}$
 $n = 0.113$

$n_b = 0.070$
 $n_1 = 0.000$
 $n_2 = 0.003$
 $n_3 = 0.004$
 $n_4 = \underline{0.000}$
 $n = 0.077$

$n_b = 0.070$
 $n_1 = 0.010$
 $n_2 = 0.003$
 $n_3 = 0.028$
 $n_4 = \underline{0.002}$
 $n = 0.113$

Cross Section 2A Profile



$n_b = 0.070$
 $n_1 = 0.020$
 $n_2 = 0.003$
 $n_3 = 0.030$
 $n_4 = \underline{0.000}$
 $n = 0.123$

$n_b = 0.070$
 $n_1 = 0.010$
 $n_2 = 0.003$
 $n_3 = 0.004$
 $n_4 = \underline{0.000}$
 $n = 0.087$

$n_b = 0.070$
 $n_1 = 0.020$
 $n_2 = 0.003$
 $n_3 = 0.028$
 $n_4 = \underline{0.002}$
 $n = 0.123$

Analysis Procedure: Hydraulics & Regression
 Cross Section Number: 1K
 Survey Date: 05/24/07

Subsections/Dividing positions
 D / 25.00/ B / 49.00/ A / 78.00/

Resistance Method: Manning's *n*

SECTION	D	B	A	C
Low Stage <i>n</i>	0.123	0.113	0.077	0.113
High Stage <i>n</i>	0.123	0.103	0.067	0.103

Stage (ft)	Section	Area (ft ²)	Wetted Perimeter (ft)	Top Width (ft)	Hydraulic Radius (ft)	Hydraulic Depth (ft)	Slope (ft/ft)	<i>n</i>	Average Velocity (ft/s)	Discharge Q (cfs)
0.01	T	0.00	0.03	0.02	0.00	0.00	0.0690	0.077	0.12	0.00
1.01	T	1.00	2.89	1.97	0.35	0.51	0.0693	0.076	2.53	2.52
2.01	A	4.46	7.75	5.85	0.58	0.76	0.0696	0.076	3.60	16.07
2.01	B	0.04	0.56	0.13	0.06	0.27	0.0696	0.113	0.56	0.02
2.01	T	4.50	8.30	5.98	0.54	0.75	0.0696		3.58	16.09
3.01	A	13.26	12.29	9.72	1.08	1.36	0.0698	0.075	5.53	73.33
3.01	B	0.29	1.58	0.37	0.18	0.77	0.0698	0.112	1.13	0.33
3.01	T	13.54	13.87	10.09	0.98	1.34	0.0698		5.44	73.65
4.01	A	24.72	17.90	15.00	1.38	1.65	0.0701	0.074	6.60	163.02
4.01	B	0.78	2.61	0.62	0.30	1.27	0.0701	0.111	1.59	1.25
4.01	T	25.50	20.51	15.62	1.24	1.63	0.0701		6.44	164.27
5.01	A	42.98	23.81	20.82	1.80	2.06	0.0704	0.073	7.98	342.86
5.01	B	1.52	3.64	0.86	0.42	1.77	0.0704	0.110	2.00	3.05
5.01	T	44.50	27.46	21.68	1.62	2.05	0.0704		7.77	345.91
6.01	A	66.31	28.41	25.30	2.33	2.62	0.0707	0.073	9.58	635.09
6.01	B	2.52	4.71	1.21	0.54	2.09	0.0707	0.109	2.39	6.03
6.01	T	68.83	33.12	26.51	2.08	2.60	0.0707		9.31	641.12
7.01	A	93.80	32.23	29.00	2.91	3.23	0.0710	0.072	11.23	1053.21
7.01	B	5.19	12.04	7.70	0.43	0.67	0.0710	0.109	2.08	10.82
7.01	D	0.00	0.13	0.05	0.02	0.06	0.0710	0.123	0.25	0.00
7.01	T	98.99	44.40	36.75	2.23	2.69	0.0710		10.75	1064.02
8.01	A	122.80	32.23	29.00	3.81	4.23	0.0713	0.071	13.60	1669.69
8.01	B	15.52	16.37	11.83	0.95	1.31	0.0713	0.108	3.56	55.23
8.01	D	0.25	1.20	0.44	0.20	0.56	0.0713	0.123	1.12	0.27
8.01	T	138.57	49.80	41.27	2.78	3.36	0.0713		12.45	1725.19
9.01	A	151.80	32.23	29.00	4.71	5.23	0.0715	0.071	15.85	2405.79
9.01	B	29.40	23.69	19.00	1.24	1.55	0.0715	0.107	4.30	126.39
9.01	D	0.95	2.35	0.99	0.40	0.96	0.0715	0.123	1.77	1.67
9.01	T	182.15	58.27	48.99	3.13	3.72	0.0715		13.91	2533.85
10.01	A	180.80	32.23	29.00	5.61	6.23	0.0718	0.070	18.02	3258.44
10.01	B	51.90	28.73	24.00	1.81	2.16	0.0718	0.106	5.57	289.22
10.01	D	5.65	10.16	8.59	0.56	0.66	0.0718	0.123	2.20	12.41
10.01	C	0.03	0.48	0.14	0.07	0.23	0.0718	0.109	0.62	0.02
10.01	T	238.39	71.60	61.73	3.33	3.86	0.0718		14.93	3560.09
11.01	A	209.80	32.23	29.00	6.51	7.23	0.0721	0.069	20.14	4226.07
11.01	B	75.90	28.73	24.00	2.64	3.16	0.0721	0.106	7.25	550.05
11.01	D	17.74	18.75	17.11	0.95	1.04	0.0721	0.123	3.13	55.60
11.01	C	2.98	6.44	4.43	0.46	0.67	0.0721	0.107	2.23	6.66
11.01	T	306.42	86.14	74.54	3.56	4.11	0.0721		15.79	4838.37
12.01	A	238.80	32.23	29.00	7.41	8.23	0.0724	0.069	22.23	5308.12
12.01	B	99.90	28.73	24.00	3.48	4.16	0.0724	0.105	8.79	877.72
12.01	D	39.37	26.16	24.43	1.51	1.61	0.0724	0.123	4.28	168.51
12.01	C	9.18	12.44	9.18	0.74	1.00	0.0724	0.106	3.09	28.35

12.01	T	387.26	99.57	86.61	3.89	4.47	0.0724		16.48	6382.70
13.01	A	267.80	32.23	29.00	8.31	9.23	0.0727	0.068	24.29	6504.80
13.01	B	123.90	28.73	24.00	4.31	5.16	0.0727	0.104	10.24	1268.54
13.01	D	65.42	29.39	27.50	2.23	2.38	0.0727	0.123	5.57	364.16
13.01	C	21.55	19.99	15.66	1.08	1.38	0.0727	0.105	4.04	86.98
13.01	T	478.67	110.34	96.16	4.34	4.98	0.0727		17.18	8224.48
14.01	A	296.80	32.23	29.00	9.21	10.23	0.0729	0.067	26.34	7816.85
14.01	B	147.90	28.73	24.00	5.15	6.16	0.0729	0.103	11.63	1720.27
14.01	D	94.30	32.32	30.25	2.92	3.12	0.0729	0.123	6.68	629.97
14.01	C	40.98	29.64	24.66	1.38	1.66	0.0729	0.103	4.84	198.18
14.01	T	579.98	122.92	107.92	4.72	5.37	0.0729		17.87	365.27
14.20	A	302.31	32.23	29.00	9.38	10.42	0.0730	0.067	26.73	8079.28
14.20	B	152.46	28.73	24.00	5.31	6.35	0.0730	0.103	11.89	1812.86
14.20	D	100.10	32.87	30.77	3.05	3.25	0.0730	0.123	6.88	688.28
14.20	C	45.70	30.02	24.98	1.52	1.83	0.0730	0.103	5.17	236.34
14.20	T	600.57	123.85	108.76	4.85	5.52	0.0730		18.01	10,816.76

STAGE	ALPHA	FROUDE
0.01	1.000000	0.287366
1.01	1.000000	0.627128
2.01	1.012220	0.726850
3.01	1.030321	0.827080
4.01	1.040789	0.888506
5.01	1.044519	0.956090
6.01	1.048069	1.018730
7.01	1.080531	1.154068
8.01	1.156882	1.197360
9.01	1.237155	1.271324
10.01	1.344367	1.339224
11.01	1.445918	1.372423
12.01	1.553660	1.373585
13.01	1.640615	1.357129
14.01	1.717962	1.358541
14.20	1.728654	1.350685

Q = aR^b a=99.418671 b=2.876250 r^2=0.997755 n=16

Q = aZ^b a=0.002350 b=6.061 r^2=0.863413 n=16

Analysis Procedure: Hydraulics & Regression
 Cross Section Number: 2A
 Survey Date: 05/24/07

Subsections/Dividing positions
 B / 54.00/ A / 104.00/

Resistance Method: Manning's *n*

SECTION	B	A	C
Low Stage <i>n</i>	0.123	0.087	0.123
High Stage <i>n</i>	0.113	0.077	0.123

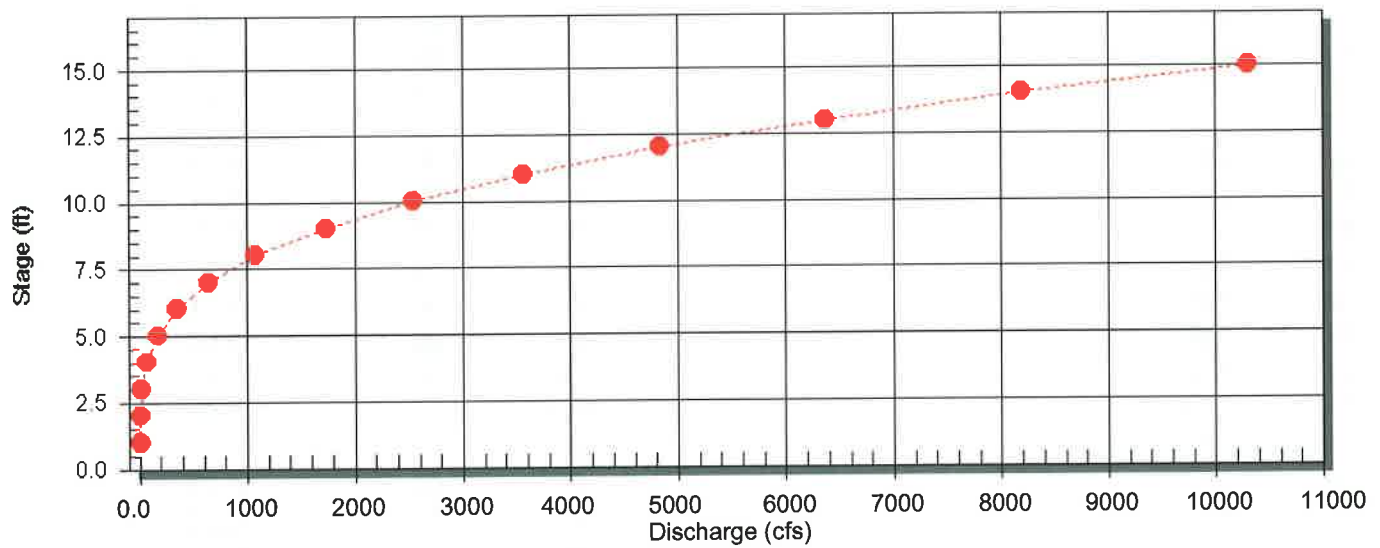
Stage (ft)	Section	Area (ft ²)	Wetted Perimeter (ft)	Top Width (ft)	Hydraulic Radius (ft)	Hydraulic Depth (ft)	Slope (ft/ft)	<i>n</i>	Average Velocity (ft/s)	Discharge Q (cfs)
0.01	T	0.00	0.74	0.74	0.00	0.00	0.0690	0.087	0.13	0.00
1.01	T	6.81	10.34	10.02	0.66	0.68	0.0694	0.086	3.45	23.48
2.01	A	19.19	15.33	14.62	1.25	1.31	0.0697	0.085	5.37	102.96
2.01	B	0.31	1.76	1.15	0.18	0.27	0.0697	0.122	1.01	0.32
2.01	T	19.50	17.09	15.77	1.14	1.24	0.0697		5.30	103.28
3.01	A	36.21	21.71	20.71	1.67	1.75	0.0701	0.084	6.59	238.45
3.01	B	11.03	20.23	16.94	0.55	0.65	0.0701	0.121	2.17	23.92
3.01	T	47.23	41.93	37.66	1.13	1.25	0.0701		5.55	262.38
4.01	A	62.58	34.62	32.86	1.81	1.90	0.0705	0.083	7.04	440.87
4.01	B	33.91	30.31	25.06	1.12	1.35	0.0705	0.120	3.54	120.19
4.01	T	96.50	64.92	57.92	1.49	1.67	0.0705		5.81	561.06
5.01	A	98.61	41.30	39.36	2.39	2.51	0.0708	0.082	8.60	847.63
5.01	B	60.86	36.22	29.00	1.68	2.10	0.0708	0.119	4.70	286.11
5.01	T	159.47	77.52	68.36	2.06	2.33	0.0708		7.11	1133.74
6.01	A	140.60	45.63	43.54	3.08	3.23	0.0712	0.081	10.33	1452.59
6.01	B	92.65	41.31	33.26	2.24	2.79	0.0712	0.118	5.76	534.02
6.01	T	233.25	86.95	76.79	2.68	3.04	0.0712		8.52	1986.61
7.01	A	185.73	50.10	47.86	3.71	3.88	0.0716	0.081	11.85	2201.13
7.01	B	126.29	42.90	34.35	2.94	3.68	0.0716	0.117	6.99	882.90
7.01	T	312.02	92.99	82.21	3.36	3.80	0.0716		9.88	3084.03
8.01	A	235.42	52.27	50.00	4.50	4.71	0.0719	0.080	13.68	3221.37
8.01	B	165.25	49.93	41.28	3.31	4.00	0.0719	0.116	7.65	1263.72
8.01	C	4.15	8.82	8.12	0.47	0.51	0.0719	0.123	1.97	8.17
8.01	T	404.83	111.02	99.40	3.65	4.07	0.0719		11.10	4493.26
9.01	A	285.42	52.27	50.00	5.46	5.71	0.0723	0.079	15.78	4503.84
9.01	B	209.19	55.69	46.95	3.76	4.46	0.0723	0.115	8.42	1761.06
9.01	C	15.58	18.57	16.88	0.84	0.92	0.0723	0.123	2.90	45.16
9.01	T	510.19	126.53	13.82	4.03	4.48	0.0723		12.37	6310.06
10.01	A	335.42	52.27	50.00	6.42	6.71	0.0727	0.078	17.82	5978.86
10.01	B	258.56	60.40	51.54	4.28	5.02	0.0727	0.114	9.29	2403.25
10.01	C	36.61	25.29	23.44	1.45	1.56	0.0727	0.123	4.18	152.99
10.01	T	630.60	137.96	124.98	4.57	5.05	0.0727		13.53	8535.10
10.90	A	379.92	52.27	50.00	7.27	7.60	0.0730	0.077	19.62	7453.31
10.90	B	305.54	62.88	53.86	4.86	5.67	0.0730	0.113	10.22	3122.79
10.90	C	58.72	28.42	26.43	2.07	2.22	0.0730	0.123	5.31	311.74
10.90	T	744.18	143.57	130.29	5.18	5.71	0.0730		14.63	10,887.84

STAGE	ALPHA	FROUDE
0.01	1.000000	0.327626
1.01	1.000000	0.737835
2.01	1.023443	0.839472
3.01	1.291392	0.874075
4.01	1.233059	0.793842

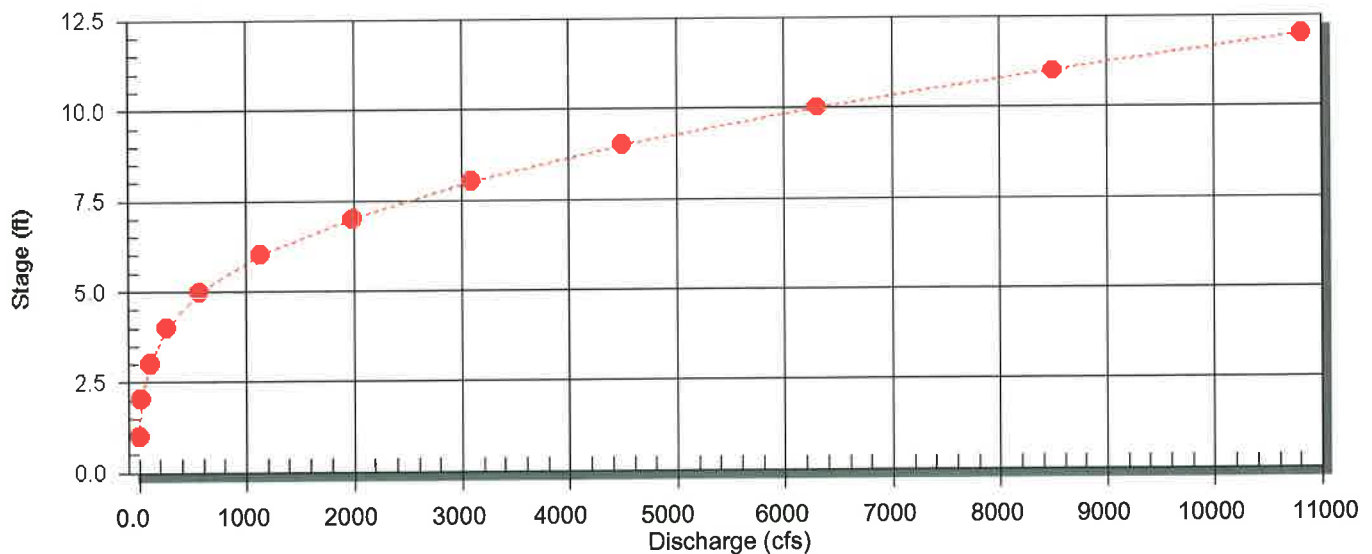
5.01	1.203341	0.820299
6.01	1.198948	0.861238
7.01	1.169269	0.894086
8.01	1.223214	0.969204
9.01	1.291521	1.029486
10.01	1.349407	1.061874
10.90	1.374535	1.078821

$Q = aR^b$ $a=163.184128$ $b=2.458240$ $r^2=0.992338$ $n=12$
 $Q = aZ^b$ $a=0.025866$ $b=5.700$ $r^2=0.856251$ $n=12$

Cross Section 1K Rating Curve



Cross Section 2A Rating Curve



Chimenea Pool 1K Cross Section Survey

24 May 2007

Surveyors: D. Swann, M. Daniels,
J. Balmat, C. Perger

Datum: Pool 1L bolt @ elevation 4.47 (this survey)

All measurements in feet

Right bank high water stake: 536910 / 3557678

Left bank high water stake: 536945 / 3557664

WinXSPRO Data Set

Elevations subtracted from maximum depth
(15.17 ft at position 57) for WinXSPRO contour

<u>Position</u>	<u>Elevation</u>	<u>Sediment</u>
-----------------	------------------	-----------------

0	0.96	
2	2.14	
4	2.68	
6	3.09	
8	3.39	
9.5	3.52	
10	2.85	
11	1.70	
12	1.32	
14	1.30	
16	1.60	
18	2.20	
19	2.70	
19.5	4.52	
20	4.62	
21	4.97	
22	4.94	
23	5.04	
23.5	3.88	
24	4.00	
24.5	4.02	
25	5.62	
26	5.74	
27	5.72	
29	6.06	
31	6.26	
33	6.36	
35	6.36	
37	7.10	
39	7.80	
40	8.09	
40.5	8.77	
41	8.48	
42	8.10	
44	8.21	
46	8.40	
47	8.45	
47.5	8.56	
48	9.58	
49	10.20	3.5

<u>Position</u>	<u>Elevation</u>	<u>WinXSPRO Contour</u>
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0	0.96	14.21
2	2.14	13.03
4	2.68	12.49
6	3.09	12.08
8	3.39	11.78
9.5	3.52	11.65
10	2.85	12.32
11	1.70	13.47
12	1.32	13.85
14	1.30	13.87
16	1.60	13.57
18	2.20	12.97
19	2.70	12.47
19.5	4.52	10.65
20	4.62	10.55
21	4.97	10.20
22	4.94	10.23
23	5.04	10.13
23.5	3.88	11.29
24	4.00	11.17
24.5	4.02	11.15
25	5.62	9.55
26	5.74	9.43
27	5.72	9.45
29	6.06	9.11
31	6.26	8.91
33	6.36	8.81
35	6.36	8.81
37	7.10	8.07
39	7.80	7.37
40	8.09	7.08
40.5	8.77	6.40
41	8.48	6.69
42	8.10	7.07
44	8.21	6.96
46	8.40	6.77
47	8.45	6.72
47.5	8.56	6.61
48	9.58	5.59
49*	13.70	1.47

52	9.86	3.0
54	9.99	3.1
57	11.07	4.1
59	11.66	
61	11.60	
63	11.26	
66	10.96	
69	10.30	
72	9.79	
75	8.97	
77	8.64	
77.5	8.40	
78	8.28	
78.5	7.00	
79	6.14	
79.5	5.76	
80	5.78	
81	5.76	
82	5.92	
84	5.58	
86	5.25	
89	4.79	
92	4.35	
95	4.17	
98	3.89	
101	3.58	
104	2.70	
107	1.62	
110	0.68	
112	0.16	
114	-.020	

52*	12.86	2.31
54*	13.00	2.17
57*	15.17	0.00
59	11.66	3.51
61	11.60	3.57
63	11.26	3.91
66	10.96	4.21
69	10.30	4.87
72	9.79	5.38
75	8.97	6.20
77	8.64	6.53
77.5	8.40	6.77
78	8.28	6.89
78.5	7.00	8.17
79	6.14	9.03
79.5	5.76	9.41
80	5.78	9.39
81	5.76	9.41
82	5.92	9.25
84	5.58	9.59
86	5.25	9.92
89	4.79	10.38
92	4.35	10.82
95	4.17	11.00
98	3.89	11.28
101	3.58	11.59
104	2.70	12.47
107	1.62	13.55
108.8**	0.96	14.21

* Sediment 'removed' for elevation to bedrock

** Position interpolated for same elevation
as right bank

Chimenea Pool 2A Cross Section Survey

24 May 2007

Surveyors: D. Swann, M. Daniels,
J. Balmat, C. Perger

No datum

All measurements in feet

Sediment difficult to probe;

depths are likely underestimates

Right bank high water stake: 537008 / 3557778

Left bank high water stake: 537031 / 3557748

WinXSPRO Data Set

Elevations subtracted from maximum depth
(14.04 ft at position 59) for WinXSPRO contour

<u>Position</u>	<u>Elevation</u>	<u>Sediment</u>
0	3.08	
2	3.92	
5	4.64	
8	5.21	
11	5.64	
14	6.32	
15.5	6.78	
17	6.88	
20	7.05	
21	7.17	1.2
21.5	8.26	1.5
22	8.31	0.7
24	8.41	
26	8.52	0.6
28	9.49	3.1
30	10.15	1.0
33	10.64	1.3
35	9.79	
36	9.36	
37	9.56	
37.5	10.80	
38	11.80	
39	11.77	
42	11.94	
44	11.90	
46	11.30	
48	10.92	
50	10.96	
53	10.57	
53.5	10.71	
54	12.18	
54.5	12.33	
55	12.63	
56	13.32	
57	13.78	
59	14.04	
61	14.01	

<u>Position</u>	<u>Elevation</u>	<u>WinXSPRO Contour</u>
0	3.08	10.96
2	3.92	10.12
5	4.64	9.40
8	5.21	8.83
11	5.64	8.40
14	6.32	7.72
15.5	6.78	7.26
17	6.88	7.16
20	7.05	6.99
21*	8.37	5.67
21.5*	9.76	4.28
22*	9.01	5.03
24	8.41	5.63
26*	9.12	4.92
28*	12.59	1.45
30*	11.15	2.89
33*	11.94	2.10
35	9.79	4.25
36	9.36	4.68
37	9.56	4.48
37.5	10.80	3.24
38	11.80	2.24
39	11.77	2.27
42	11.94	2.10
44	11.90	2.14
46	11.30	2.74
48	10.92	3.12
50	10.96	3.08
53	10.57	3.47
53.5	10.71	3.33
54	12.18	1.86
54.5	12.33	1.71
55	12.63	1.41
56	13.32	0.72
57	13.78	0.26
59	14.04	0.00
61	14.01	0.03

63	13.68
66	12.93
69	11.90
72	11.29
75	10.90
79	10.38
82	10.12
84	10.29
85	10.82
86	11.28
87	9.82
88	9.68
89	9.76
90	9.62
93	9.08
96	8.66
99	7.43
102	7.01
103	6.90
104	6.69
104.5	5.50
105	5.20
105.5	5.20
106	5.13
108	4.92
108.5	5.64
109	6.00
110	6.16
113	7.00
115	6.72
118	5.70
121	5.16
124	4.77
127	4.17
130.0	3.21
133.5	2.37

63	13.68	0.36
66	12.93	1.11
69	11.90	2.14
72	11.29	2.75
75	10.90	3.14
79	10.38	3.66
82	10.12	3.92
84	10.29	3.75
85	10.82	3.22
86	11.28	2.76
87	9.82	4.22
88	9.68	4.36
89	9.76	4.28
90	9.62	4.42
93	9.08	4.96
96	8.66	5.38
99	7.43	6.61
102	7.01	7.03
103	6.90	7.14
104	6.69	7.35
104.5	5.50	8.54
105	5.20	8.84
105.5	5.20	8.84
106	5.13	8.91
108	4.92	9.12
108.5	5.64	8.40
109	6.00	8.04
110	6.16	7.88
113	7.00	7.04
115	6.72	7.32
118	5.70	8.34
121	5.16	8.88
124	4.77	9.27
127	4.17	9.87
130.0	3.21	10.83
130.8**	3.08	10.96

* Sediment 'removed' for elevation to bedrock
 **Position interpolated for same elevation
 as right bank

Chimenea Longitudinal Survey

<u>Easting</u>	<u>Northing</u>	<u>Elevation</u>	<u>Description</u>
537032	3557763	3474	Start
537035	3557747	3478	Left 2A rebar
537007	3557777	3477	Right 2A rebar
537036	3557804	3486	Bankfull
537034	3557803	3485	Edge of water
537023	3557768	3467	Edge of water Pool 2A
537009	3557750	3466	Thalweg
536989	3557738	3459	Thalweg
536939	3557740	3453	Traverse point
536976	3557742	3457	Thalweg
536949	3557743	3450	Edge of water
536927	3557713	3441	Edge of water
536926	3557699	3441	Traverse point
536912	3557675	3443	Right 1K rebar
536944	3557668	3439	Left 1K rebar
536922	3557681	3431	Edge of water
536928	3557692	3434	Pool 1L datum
536921	3557662	3434	Edge of water
536925	3557668	3434	Edge of water Pool 1K
536918	3557632	3430	Edge of water
536920	3557597	3430	Edge of water
536920	3557579	3426	Edge of water
536916	3557528	3429	Pool 1D benchmark

Δ Elevation (high water) cross section 1K to 2A: $3477 - 3441 = 36$ ft

Δ Elevation (thalweg) along surveyed reach: $3485 - 3426 = 59$ ft

Distance between cross section 1K and 2A: $(536912 / 3557675) - (537007 / 3557777) \cong 150$ m = 490 ft

Distance of survey reach: $(537034 / 3557803) - (536920 / 3557579) \cong 260$ m = 850 ft

High water slope between 1K and 2A: $36/490 = 7.3\%$

Thalweg slope of entire reach: $59/850 = 6.9\%$

