PCWA-062

Placer County Water Agency

Power System: 24625 Harrison St. • Mail: P.O. Box 667 • Foresthill, California 95631
(530) 367-2291 (530) 885-6917 FAX (530) 367-4440

April 21, 2004

Mr. Takeshi Yamashita, Regional Engineer
FEDERAL ENERGY REGULATORY COMMISSION
901 Market Street, Suite 350
San Francisco, CA 94103

Re: FERC Project No. 2079-CA

Dear Mr. Yamashita:

By letter dated April 8, 2004, we sent copies of ten documents to provide you information to assist in understanding and evaluating the Middle Fork Tunnel Surge Shaft situation, particularly leakage, ground water levels and geology. These documents were sent in response to John Onderdonk's request for information that would assist in evaluating our request made by letter to you dated February 6, 2004 for a one-year extension to the schedule for installation of a steel liner in the surge shaft to mitigate leakage from the existing cracked concrete lining in order to significantly reduce water leakage through the shaft lining. The purpose of this letter is to serve as a transmittal letter for the remaining documents to assist in your evaluation.

Enclosed are one copy each of the following documents:

1. <u>Summary of Weir, Flume, And Well Monitoring Data, Middle Fork Surge Shaft,</u> (Period May, 2000 to August, 2003) prepared by Piedmont Geosciences, Inc., and PG&E Geosciences Department, dated April 13, 2000

2. <u>Middle Fork Tunnel Leak Down Test and Debris Flow Visit</u>, Memo by Jon Mattson, dated June 24, 2003

3. <u>Middle Fork Surge Shaft – Artesian Pressures in Slope</u>, Memo by Richard C. Harlan, Dated December 23, 2002

4. Graph of Hell Hole Reservoir elevation and spill on January 2, 1997, 3:00 a.m. to 10:00 p.m.

5. Five color cross-sectional diagrams showing ground water levels on 6/14/02, 7/18/02, 10/14/02 and 1/19/03

Water Conservation Is A Moral Obligation

6. Analysis of Surge For Middle Fork Tunnel Surge Tank, and Penstock – Draft, Bechtel, December, 2003

If you have any questions, please call me at (530) 885-6917.

Sincerely,

PLACER COUNTY WATER AGENCY

Stephen J. Jones

Stephen J. Jones
Power System Manager

Enclosure

cc: David Breninger
Kevin Goishi, PG&E
Richard Harlan
Edward Tiedemann

PLACER COUNTY WATER AGENCY

POWER SYSTEM

MEMO

DATE: **6/24/03**

TO: **Steve Jones**

FROM: **Jon Mattson**

SUBJECT: **Middle Fork Tunnel Leak Down Test and Debris Flow Visit June 21, 2003**

Steve

On June 21, we performed the leak down test on the Middle Fork Powerhouse tunnel. The test began at 0715 hours. Bill Emmerich ran the test from the MFPH, and Ken Hofferber closed and opened the intake wheelgate. The test was completed at 0930 hours, after the rate of decrease in water level had tapered off considerably. See the attached Excel chart and spreadsheet. In just over 2 hours, the water level dropped about 35 feet. PG&E will produce a report of actual times and elevations from the data logger.

Gregg Korbin and I also inspected the debris flow area and surge tank. We arrived on site about 0615 hours. Bob McManus, Tom Sawyer, Bill Page, and Joe ?? were at the site probably starting about 1030 hours, until early evening, though we didn't see them while we were there. There were noticeable increases at most of the weirs/flumes. These will be downloaded and charted by Todd Mihevc. Of note were a new spring in the road above flume 6, the large increase in flow from flumes 6 and 12, increase in the springs above the saddle area to about 10-15 gpm, and the overtopping of flume 2, which will have to be estimated. Substantial flow seemed to be contributed from spring 111 from the slump area to the west, though there were no large point sources visible. It was also apparent from wet areas that the surge tank leaks at the base.

Following are some photos of the site visit.

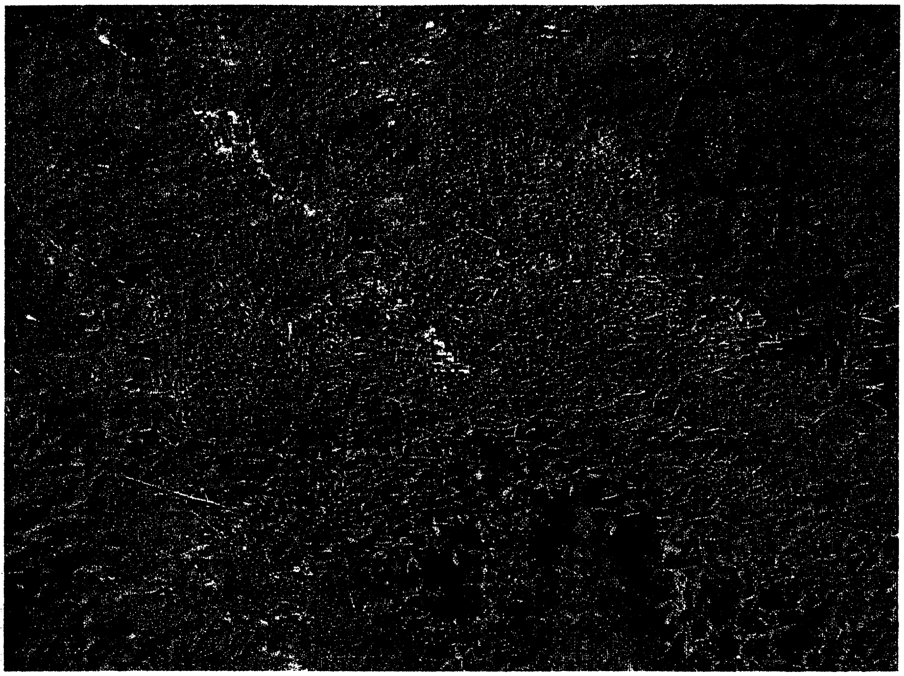
Date	Time	Pressure	HHRes	Head
6/21/03	7:15	907	4628.35	2093.1
	7:20	905		2088.5
	7:25	902		2081.5
	7:30	900		2076.9
	7:35	899		2074.6
	7:40	899		2074.6
	7:45	898		2072.3
	7:50	897		2070.0
	7:55	896	4628.36	2067.7
	8:00	896		2067.7
	8:05	895		2065.4
	8:10	895		2065.4
	8:15	895		2065.4
	8:20	894		2063.1
	8:25	894		2063.1
	8:30	894		2063.1
	8:35	894		2063.1
	8:40	893		2060.8
	8:45	893		2060.8
	8:50	893		2060.8
	8:55	893	4628.37	2060.8
	9:00	893		2060.8
	9:15	892		2058.5
	9:30	892		2058.5

Road above Flume #6 – 6/21/03, about 7:30 a.m.

Flume #6 – 6/21/03, about 7:30 a.m.

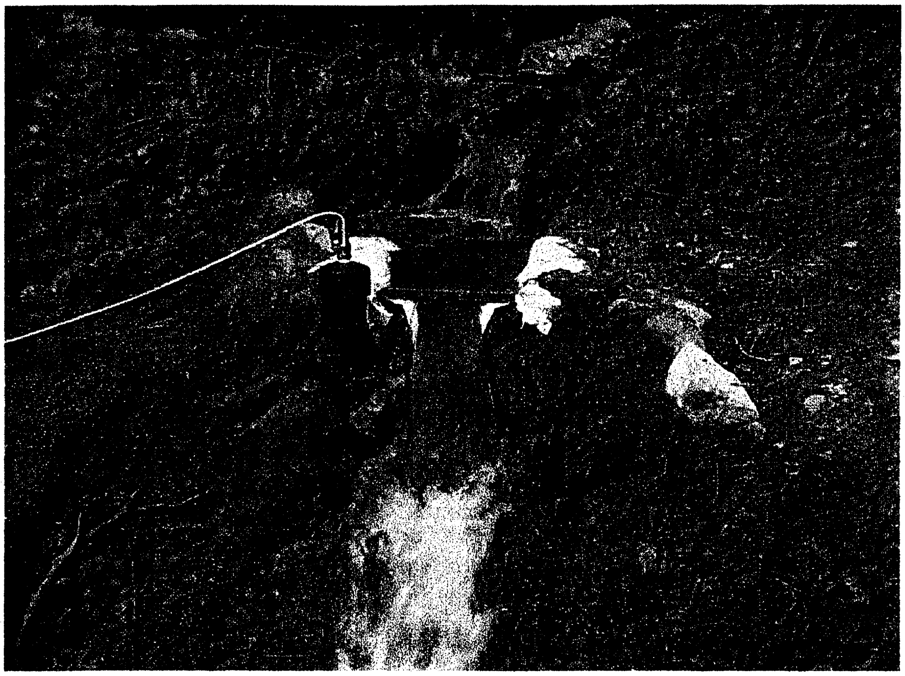
Spring 108 above Flume #6 – 6/21/03, about 7:30 a.m.

Flume #12 – 6/21/03, about 7:00 a.m.

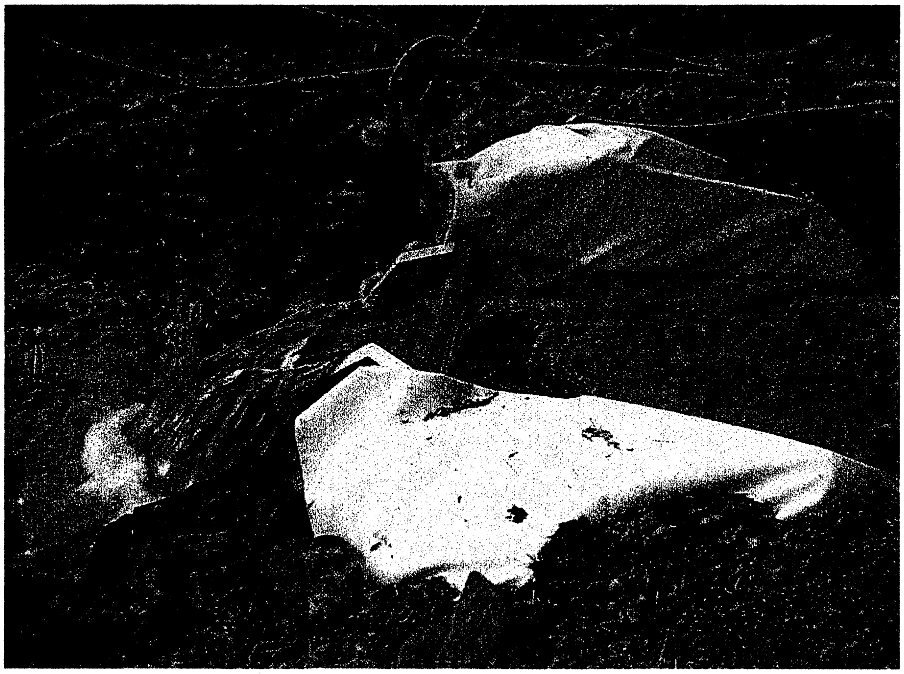


Spring 111 area below flume #12 – 6/21/03, about 8:15 a.m.

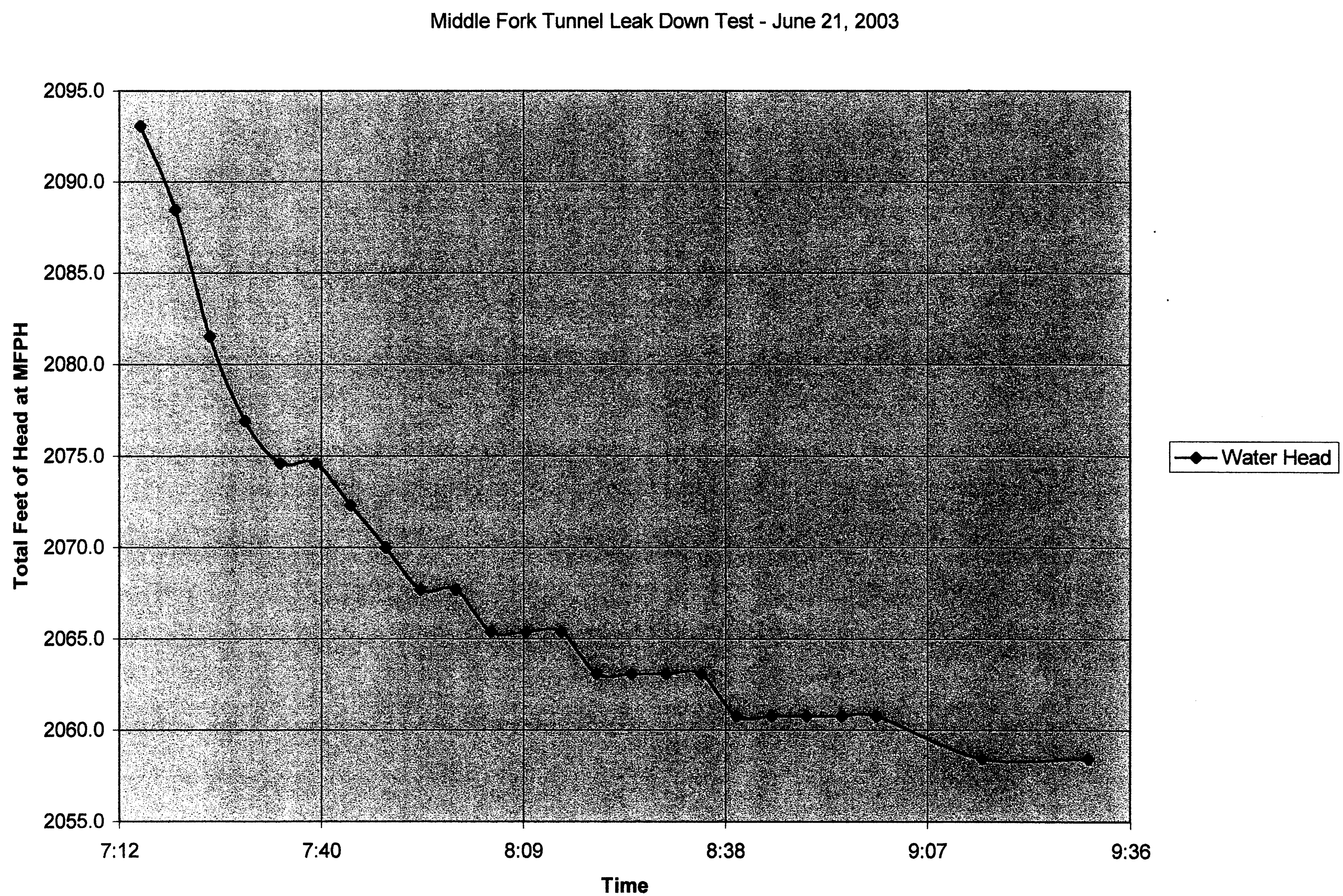
Channel area above Weir #2 – 6/21/03, about 8:30 a.m.



Flume #2 slightly overtopping – 6/21/03, about 6:45 a.m.



Flume #3 – 6/21/03, about 6:30 a.m.


Middle Fork Tunnel Leak Down Test - June 21, 2003
Total Feet of Head at MFPH
2095.0
2090.0
2085.0
2080.0
2075.0
2070.0
2065.0
2060.0
2055.0
7:12
7:40
8:09
8:38
9:07
9:36
Time
Water Head

6-21-2003 Above Flume No. 6 and Spring 108. On road due to Artesian conditions. Hell Hole Reservoir elevation = 4628.5 feet.

June 21, 2003 Weir #2

June 21, 2003 Flume #2

MEMO

RICHARD C. HARLAN
CONSULTING CIVIL AND GEOTECHNICAL ENGINEER

Date: December 23, 2002   Project No. 167

To: Stephen J. Jones, PCWA

From: Richard C. Harlan

RE: Middle Fork Surge Shaft – Artesian Pressures in Slope

As requested, I have made a brief evaluation of the effect of the artesian condition in the slopes downhill from the MF Surge Shaft on the stability of those slopes. For reference, refer to Slide No. 6 in the Hydrologic Presentation made Nov. 6, 2002, by Pohll. Please note there is an error in plotting the depth of the piezometers (transducers) in Boring B6 on that slide. They are apparently plotted by depth in feet on cross section C-C which has a scale in meters. Those piezometers are substantially higher than plotted on that slide (they are actually about 1/3 of the depth shown).

At the time of the analysis shown on Slide 6, the surge shaft water level was at Elev. 4544 ft (1385 m). There are no artesian pressures at Boring B2. However, further down the slope at B6 there is a uniform artesian head of 13 feet (4 m). That the head is uniform is questionable and there may be some error in the system (such as a leak along the hole). At B5 there is little or no artesian pressure but the piezometric head at the lower two transducers is at or slightly above the ground surface.

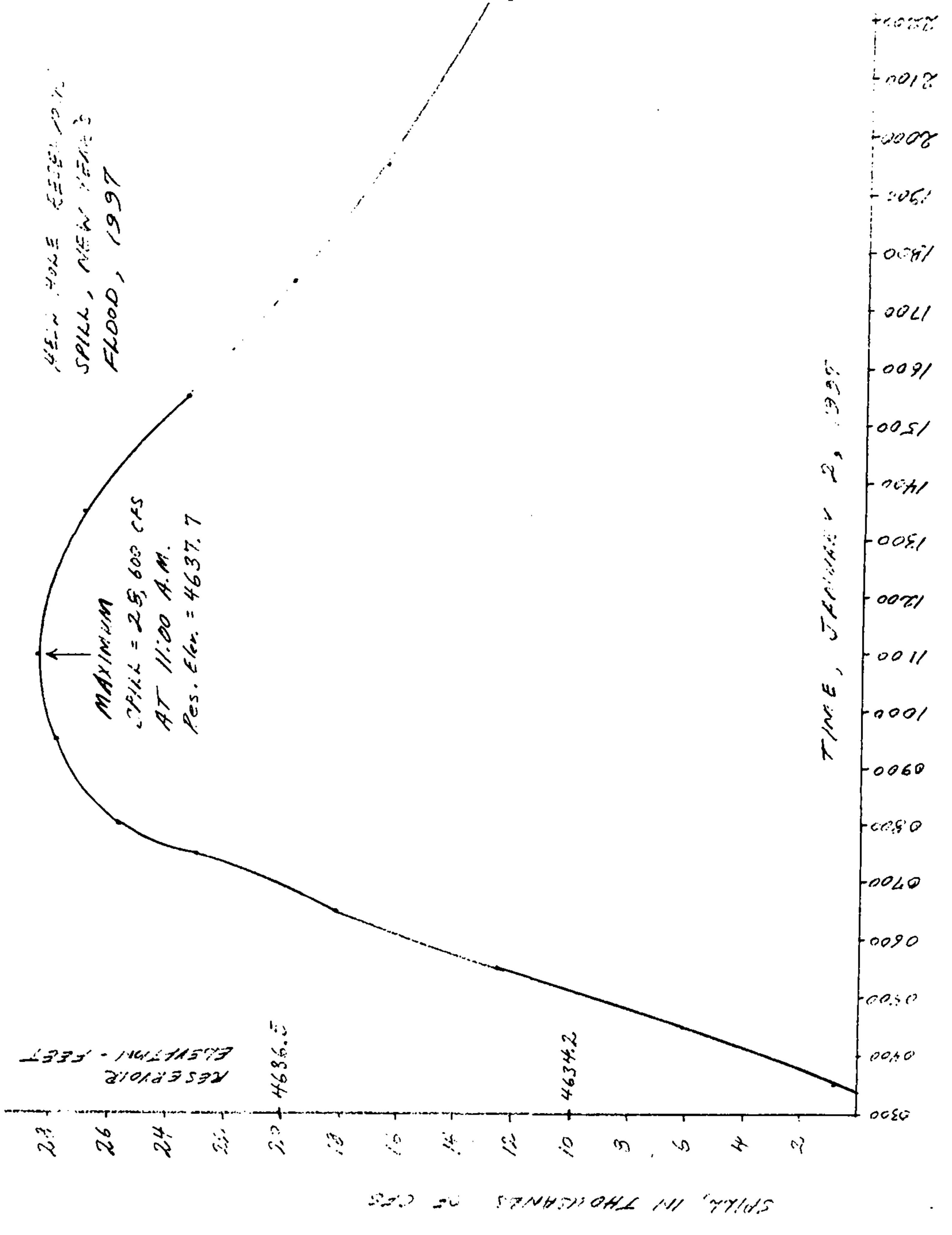
At any time that the piezometric head is at or above the surface of a soil slope, there is concern for stability, particularly when the slope is relatively steep. Below the surge shaft, slopes are in the range of 1.75:1.0 (Horiz to vert). Such a slope, if a relatively high soil strength of 46° is assumed, has a factor of safety against sliding of about 1.8 ***without seepage pressures!*** However, if the water level rises to the ground surface the factor of safety drops to 1.0. The present situation is that there is probably a very low factor of safety in the slope below the surge shaft, approaching 1.0, and stability only exists because of high strength in the colluvium and some relief of seepage pressures at the various springs.

However, now consider the situation when Hell Hole reservoir fills again and the surge shaft water level rises to 4630, some 86 feet higher than at the time of the conditions shown on Slide 6. The rise in pressures at the piezometers will not be a simple proportion of the rise at the surge shaft, but because of the artesian condition, which is caused by restriction of the exit flows on to the slope, the piezometric pressures at all of the piezometers will rise disproportionately and should be expected to be significantly artesian. The stability of the slopes under such conditions is greatly reduced and is undoubtedly what led to the debris flow failure in January 1997.

Please let me know if you need further assessment of this condition.

Richard C. Harlan

55 New Montgomery Street, No. 724 Phone 415 ♦ 541 ♦ 9445
San Francisco, CA 94105 Fax 415 ♦ 541 ♦ 9488
email rharlan@attglobal.net Cell Phone 415 ♦ 716 ♦ 1269


SPILL, NEW YEARS
FLOOD, 1997
MAXIMUM
SPILL = 28,600 CFS
AT 11:00 A.M.
Res. Elev. = 4637.7
TIME, JANUARY 2, 1997
RESERVOIR
ELEVATION - FEET
4636.5
4634.2
SPILL, IN THOUSANDS OF CFS
0300
0400
0500
0600
0700
0800
0900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
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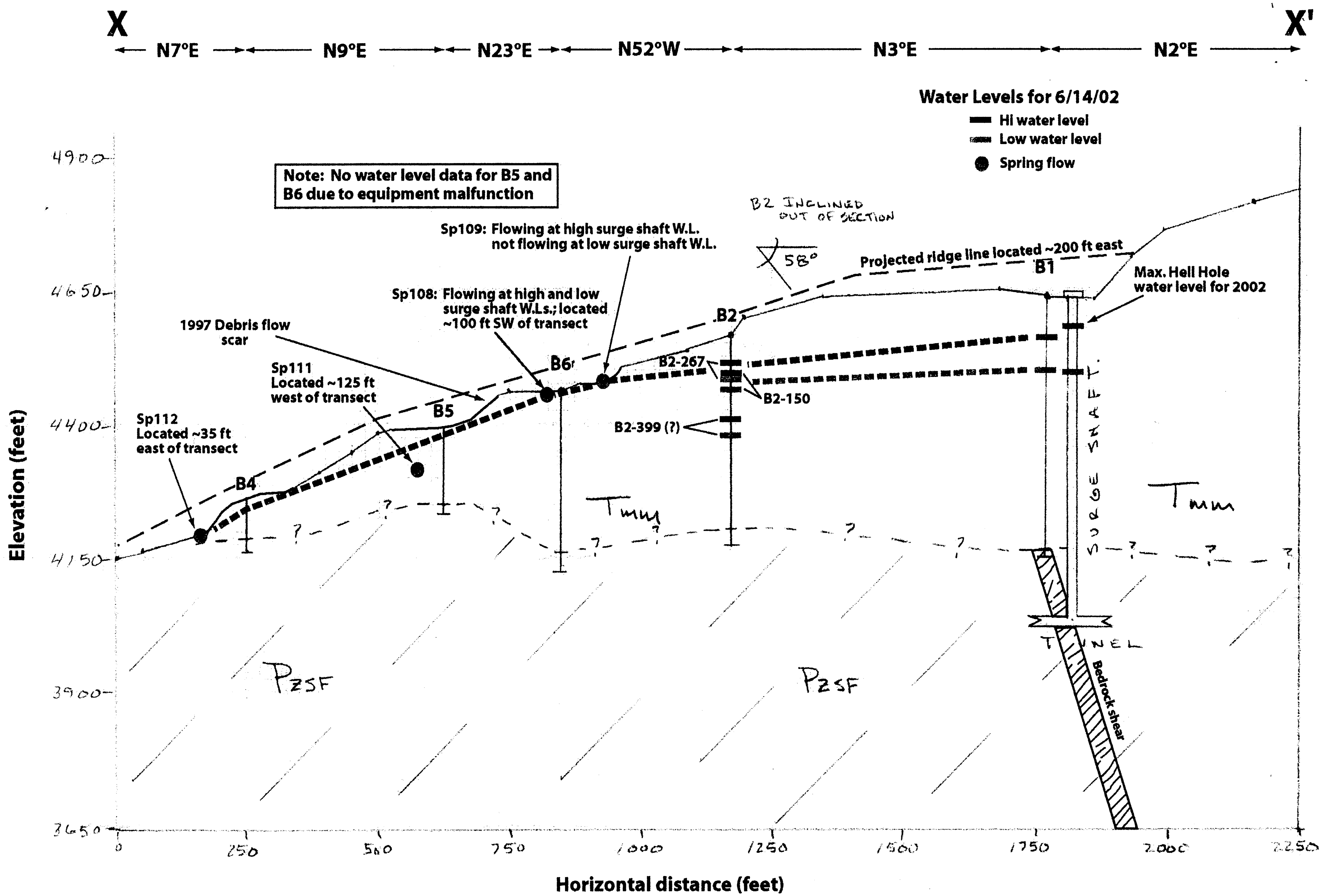
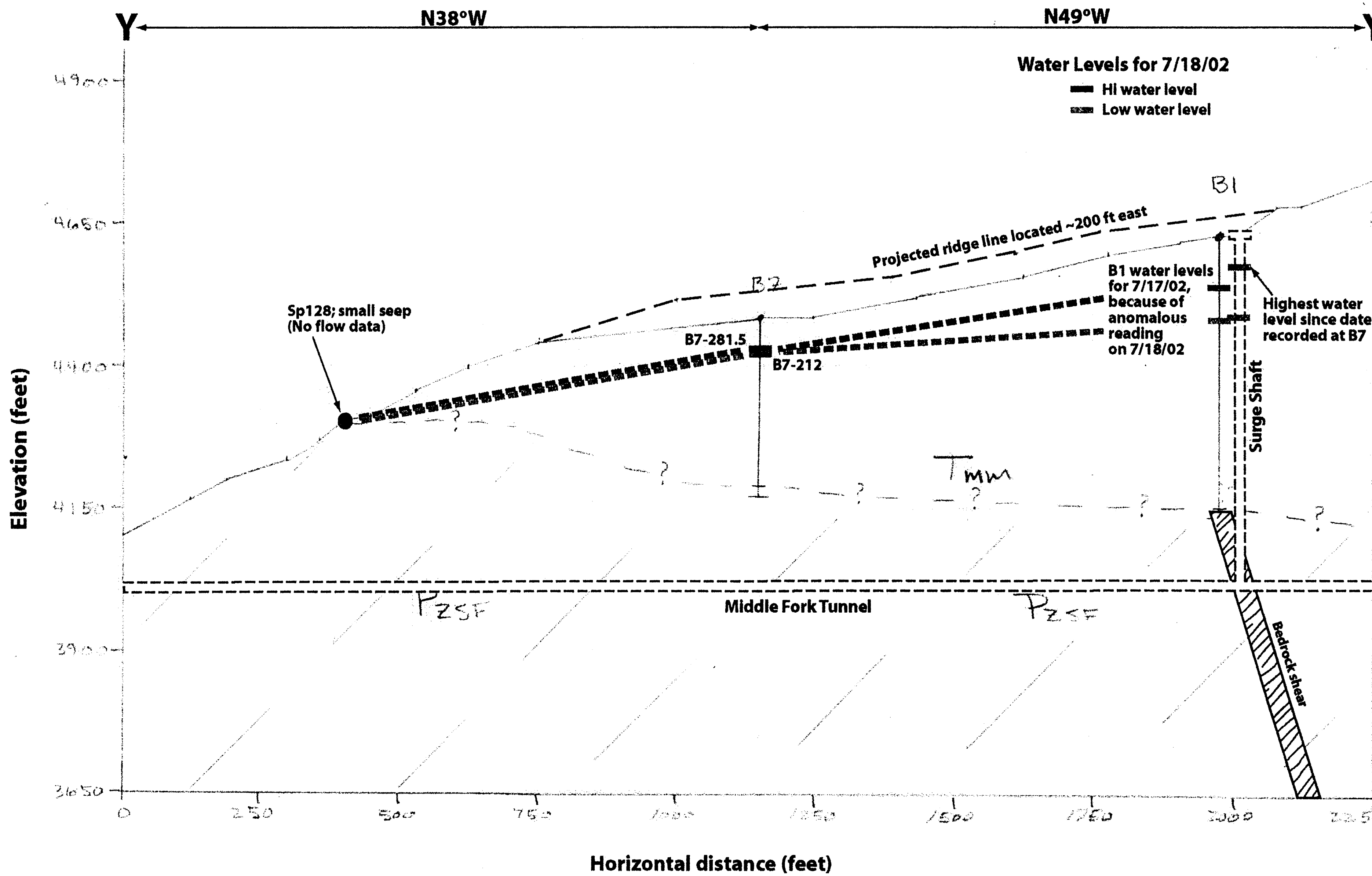
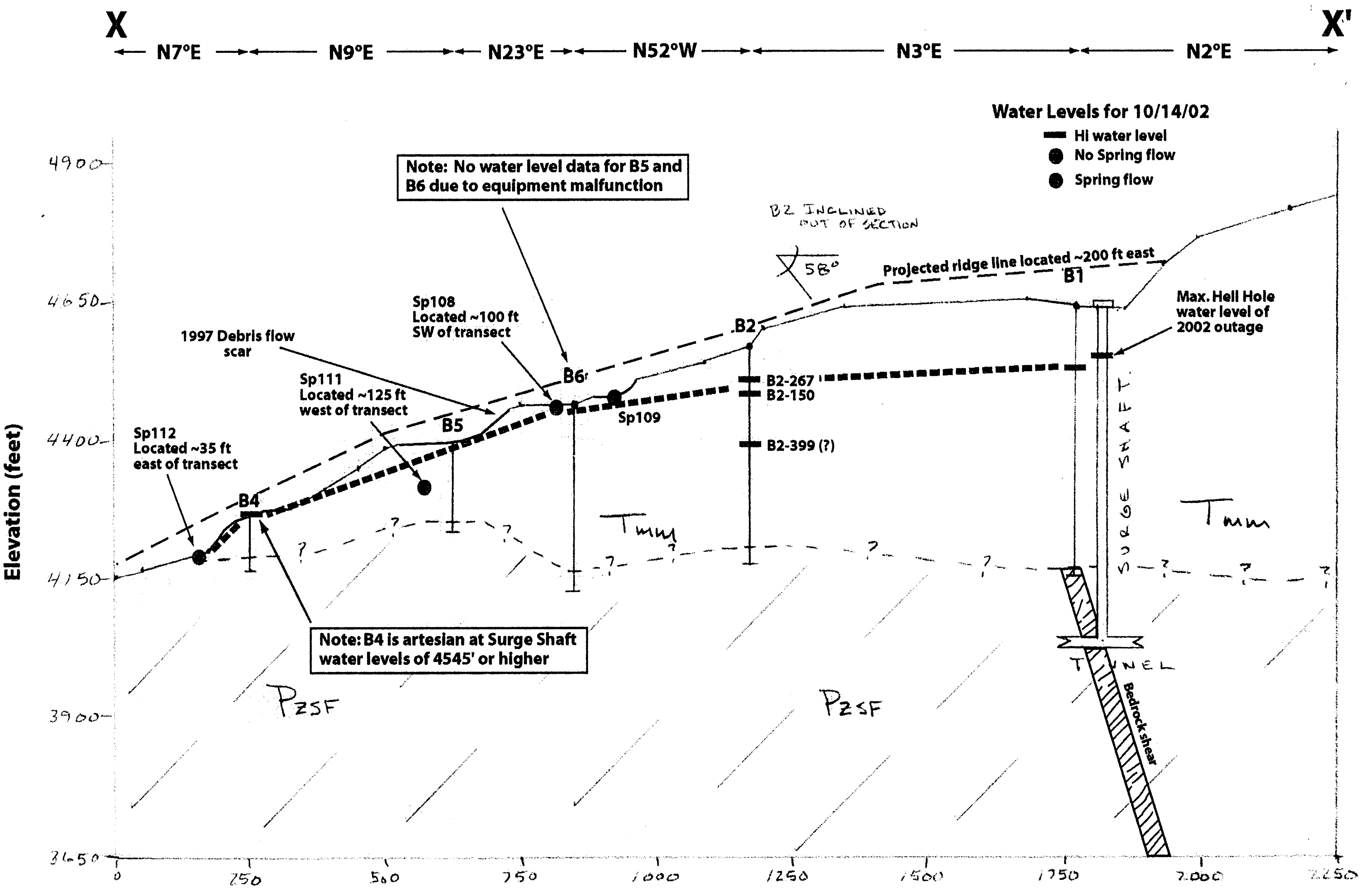


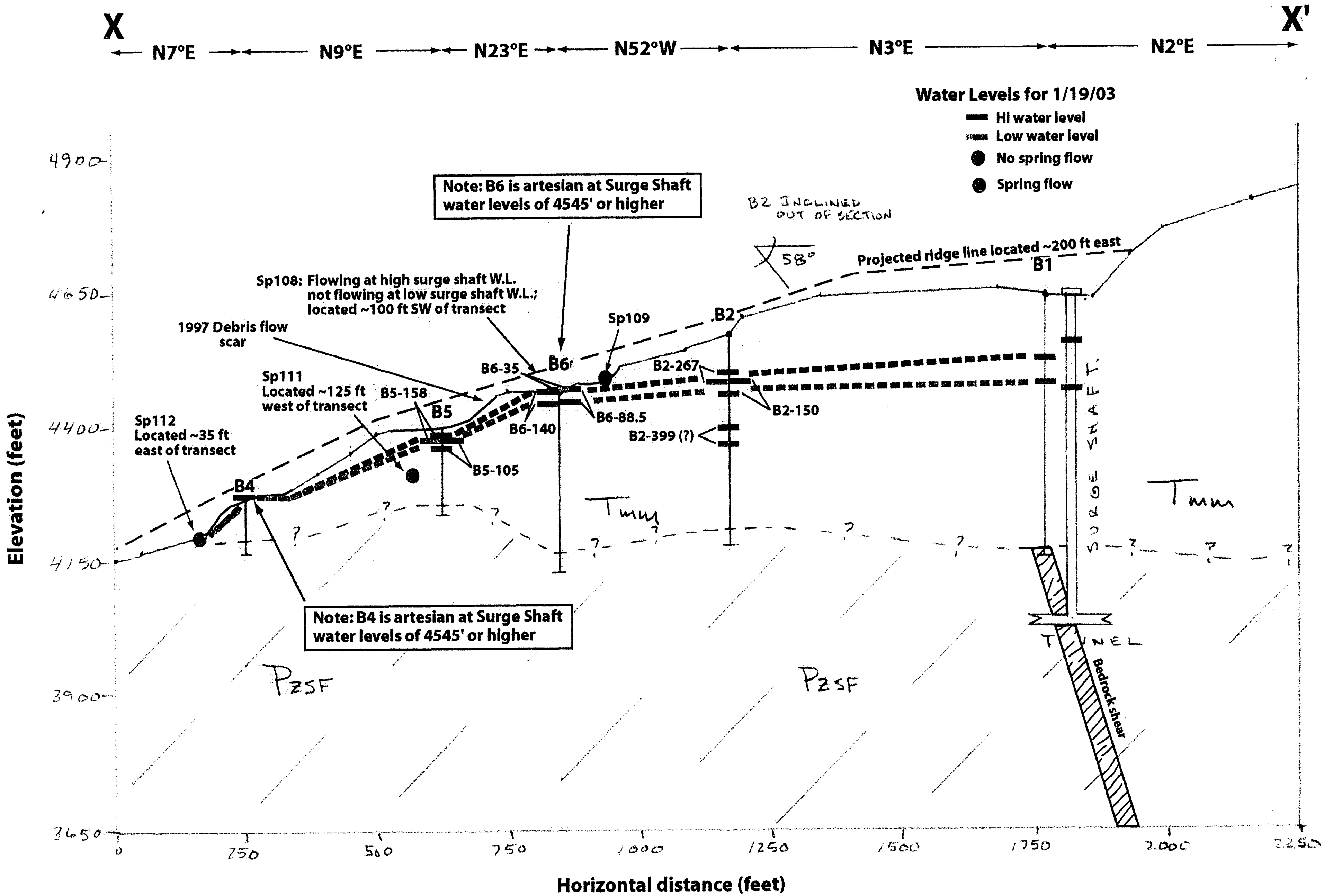
Ground water levels at maximum water in Hell Hole
Section X-X'



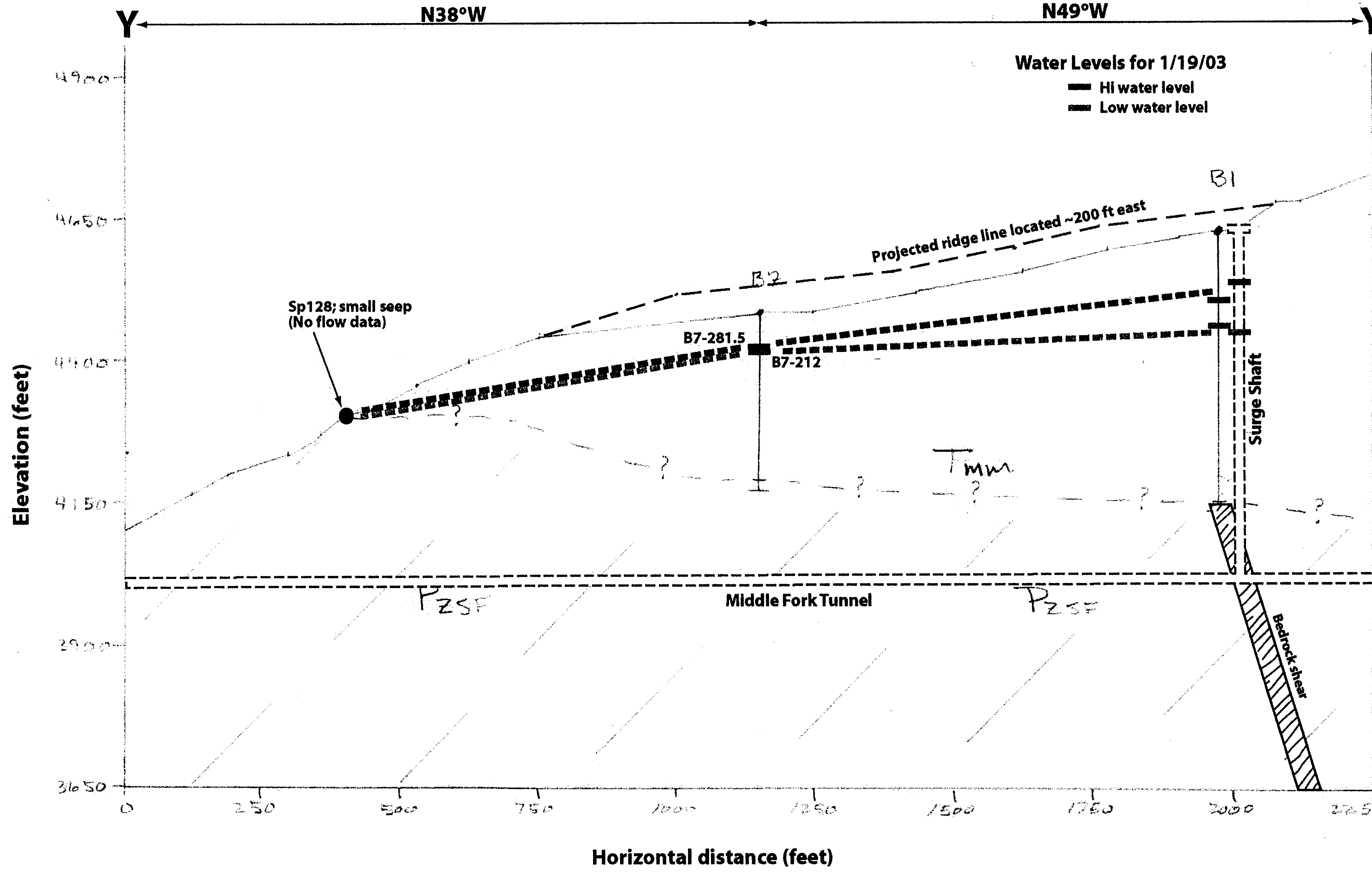
Ground water levels, July 2003
Section Y-Y'



Ground water levels during 2002 outage
Section X-X'



Ground water levels, January 2003
Section X-X'



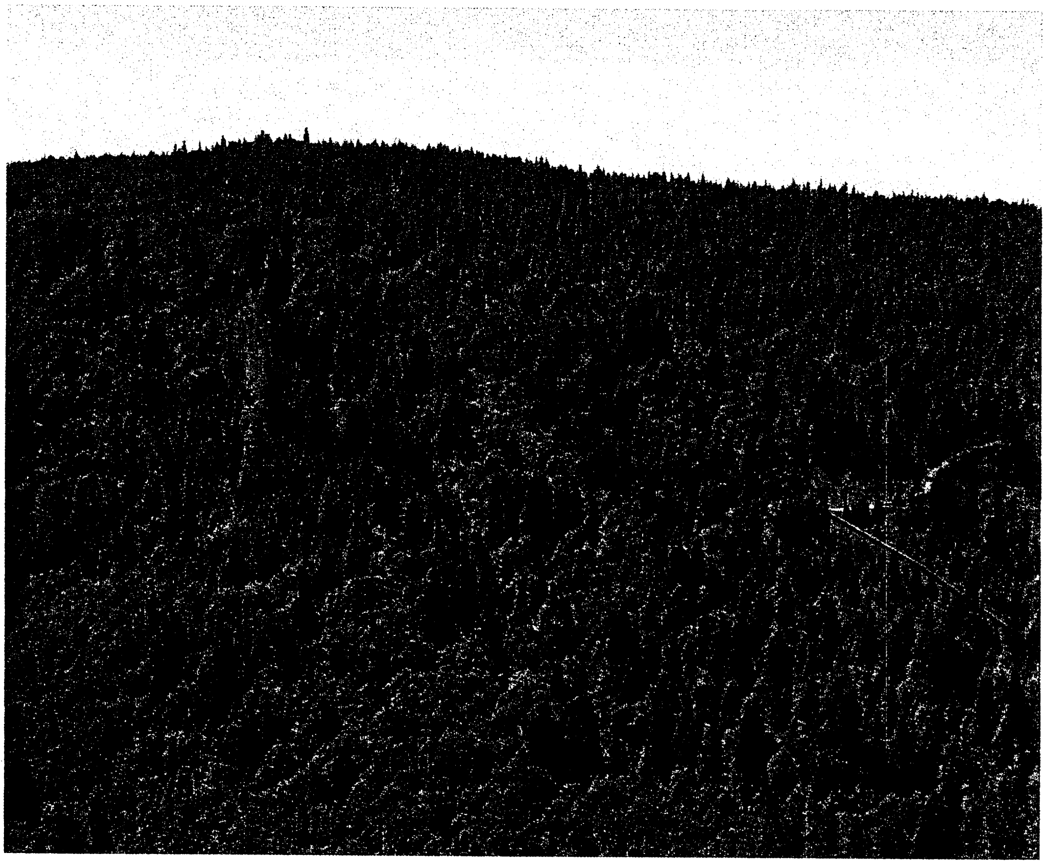
Ground water levels, January 2003
Section Y-Y'

SUMMARY OF WEIR, FLUME, AND WELL MONITORING DATA

MIDDLE FORK SURGE SHAFT

Period of Record May 2000 to August 2003

Placer County, California



Prepared by:

T.M. Mihevc, S.N. Bacon, and T.L. Sawyer

Piedmont GeoSciences, Inc.

and

W.D. Page and R.A. McManus

Geosciences Department, Pacific Gas and Electric Company

Prepared for:

Hydro Generation Department, Pacific Gas and Electric Company

April 13, 2004

PIEDMONT GEOSCIENCES, Inc.

10235 Blackhawk Dr. • Reno, Nevada 89506 • 775-972-3234

SUMMARY OF WEIR, FLUME, AND WELL MONITORING DATA

MIDDLE FORK SURGE SHAFT

Period of Record May 2000 to August 2003

Placer County, California

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1.0 INTRODUCTION

This report presents a summary of all weir and well monitoring data for the period of record, May 2000 to August 2003, to help with the hydrogeologic evaluation of the Middle Fork Surge Shaft. The monitoring data were collected and complied by Piedmont GeoSciences, Inc. under the technical direction of PG&E Geosciences Department for the PG&E Hydro Generation Department. Additional data for the Surge Shaft water levels were provided by Mr. John Hollfelder, PG&E Geosciences Department. These data are part of the on-going monitoring of several weirs and observation wells, or piezometers, in the project area (Figures 1-1 and 1-2). Various relationships between surge shaft water levels, calculated from head measurements taken at the Middle Fork Valvehouse, and weir discharge or hydraulic head measured in the observation wells are illustrated in this report. The processed monitoring data for the weirs and wells are enclosed on the CD-ROM included with this report (see pocket).

1.1 CHANGES MADE TO MONITORING EQUIPMENT

Several changes were made during the period of record:

1) Installation of a new automated weir monitoring station, weir 10 to capture flows from spring 205 in June 2002.
2) In January 2003, automated monitoring equipment at weirs 2, 7, 8 and 9 was removed because after more than 2 years of data collection at these sites no new information contributing to understanding the hydrogeologic conditions in the Mehrten Formation was being collected.
3) In January 2003, V-notch weirs 1, 3, 6, and 11 were replaced with H-flumes 1, 3, 6, and 11, respectively, to improve the accuracy at higher flows and to increase the reliability of the monitoring.
4) Installation of H-flumes F7 and F2 in January 2003 to collect data from springs 109 and 108, and from springs 111, 108 and 109, respectively.
5) Completion of borings B4 and B5, and drain borings D1, D2, D3, D4, and D5 in September, 2002 (for more information on these borings, see report entitled "Data from Middle Fork Borings B4, B5, and Drains, Middle Fork Tunnel and

Surge Shaft, Placer County, California", dated January 30, 2003)(Appendix A).

The H-flumes were installed in an effort to more accurately measure discharge. Bucket-stopwatch measurements indicated that the V-notch weirs underestimate flows, particularly those above about 35 to 45 gpm. A comparison of the V-notch weir and H-flume discharge measurements indicate that on average the flume measured flows exceed weir measured flows by approximately 11 percent.

In the subsequent sections we provide a description of the hydrogeologic conditions and monitoring data at the Middle Fork Surge Shaft area and present these data. The weir data are presented along with the H-flume data for those weirs that were replaced with flumes (i.e., 1, 3, 6, and 11). Data from new monitoring stations, H-flumes F2 and F7, are presented separately in addition to piezometers.

2.0 HYDROGEOLOGY

This section of the report discusses the groundwater conditions in the hillslope around the surge shaft. First the conditions prior to the construction of the Middle Fork hydroelectric project as best we can reconstruct, and second, the conditions after the tunnel and surge shaft were in operation. Most information is from the detailed measurements of spring flows and piezometer readings that started in May 2000 and is summarized herein. These data are also included as digital files in Appendix B.

2.1 PRE-PROJECT (NATURAL) CONDITIONS

Little is known of the groundwater conditions prior to building the Middle Fork tunnel and penstock and construction notes are few and in some cases incomplete. One spring, Sp121, issuing from the metamorphic rock is a natural spring that was used as a source of water during construction of the penstock.

Construction notes and logs of the Middle Fork surge shaft document that numerous springs and seeps were encountered in the Mehrten Formation during its excavation, but that the underlying metamorphic rock was relatively "tight" (Figure 2-1). Although these records are incomplete, we know that excavation began August 5, 1964 and proceeded from top to bottom with generally two shifts working per day. Water entering the shaft overnight had to be pumped out prior to each workday. When the excavation reached a depth of 500 feet, the shaft would fill with as much as 35 to 50 feet of water overnight. However, with the onset of the intense December 1964 storm/flood event all construction activities abruptly ended on December 17. At that time the surge shaft excavation extended to a depth of 512 feet, completely through the Mehrten Formation and 10 to 15 feet into the underlying Shoo Fly metamorphic rock. When construction resumed two months later, on February 19, 1965, the excavation had filled with 200 feet with water. In addition to pumping, drain borings were drilled through the bottom of the surge shaft excavation and into the Middle Fork tunnel to control the seepage.

Thus the construction records are interpreted to indicate that the static water level in the Mehrten Formation at the Ralston spur ridge, prior to filling and pressurizing the Middle Fork tunnel, was at an approximate elevation of 4318 feet during the winter of 1965.

2.2 POST-PROJECT CONTIONS

2.2.1 Springs Near the Surge Shaft

More than 40 springs and several additional seeps (moist areas generally with no free water) occur within a 2.3 mile (3.7 kilometer) radius of the Middle Fork surge shaft, with the majority located within 0.7 miles (1.1 kilometers) (Figures 1-2 and 2-2). Most of the springs and seeps discharge from the lower 100 to 120 feet of the Mehrten Formation or at the Mehrten/Shoo Fly contact. The springs along the contact account for the greatest total discharge (Figure 2-2; Table 2-1). The common occurrence of springs along the contact indicates perched groundwater conditions within the Mehrten Formation, that likely extend 100 to 120 feet above the contact under natural groundwater conditions, based on the geomorphology of the spring areas. Specifically some of these springs, for example Sp112 and Sp400, are in well-defined sapping bowls (i.e., where spring flow has eroded fine-grained materials producing a bowl-shaped topographic depression) suggesting that these springs pre-date the project. Only a few minor springs and several seeps have been found in Shoo Fly bedrock, the most significant in terms of discharge is spring Sp121, the natural spring used as a water source during construction.

The greatest density of springs and the highest-discharging springs occur north of the surge shaft, in the area of the 1997 debris flow (Figure 2-2). These springs are generally coincident with a paleo-valley or trough in the top of the impermeable Shoo Fly bedrock, where the trough intersects the south wall of the Middle Fork America River canyon (see inset, Figure 2-3). Discharge from the various individual springs in this area varies considerably from less than 1 to greater than 300 gpm (Table 2-1). In addition to the present report, information on springs in the project area is provided in the October 31, 2000 report by Cotton Shires & Associates and others (2000)(Appendix A).

We found the remains of one 90° V-notch wooden weir north of the surge shaft at spring Sp112 (Figure 2-2) and a record of flow measurements that we believe are from this weir, although the actual location remains uncertain. Regardless, the record provides strong evidence that spring flow near the surge shaft has been influenced by head in the tunnel/surge shaft system for nearly three decades and likely from the onset of facility operations as has been inferred by the PG&E Board of Consultants. Mr. Victor Wright, consultant to PCWA, was the first to recognize and report this relationship based on this weir record (Wright, 1976). The record provides flow measurements of 56 gpm prior to unwatering the Middle Fork tunnel for repairs in October 1975, when the water in the surge shaft was at an elevation of 4407 feet, and reduced spring flow of 5 gpm during the time the tunnel was unwatered (Cotton Shires & Associates and others, 2000)(Appendix A). For comparison, flow at spring Sp112 was 93 gpm in July 2001 at the same surge shaft water level (Appendix B). Apparently under current conditions flow at Sp112 has increased by approximately 66 percent (or these measurements are from two different springs). If spring flow has significantly increased, then the increase likely results from erosion/piping of fractures along the groundwater flow paths in the Mehrten and weathered Mehrten Formation. Also possibly consistent with increased flows is the location of the old weir remnants. Rather then being in a position to capture the entire Sp112 discharge, the weir remnants lie below only one of two main discharge points. We infer that the southern discharge point did not exist at the time the old weir was installed.

3.0 MONITORING DATA

After monitoring the weirs manually for several months in 2000, we established a system to monitor the spring discharges with automated equipment at more than a dozen weirs or flumes installed in the project area from October 2000 to January 2003 (Figures 2-2 and 3-1). Discharge measurements were made at intervals of 10 to 20 minutes, or less throughout the period of record. Initially 90° V-notch weirs were installed, but at three of the lower flowing weirs (W6, W7, W9) the V-notch was changed to 60° (Figure 3-2) to increase the range (i.e., resolution) of stage level readings. Subsequent "bucket-and-stopwatch" flow measurements indicate that the weir measurements underestimate flows above about 35 to 45 gpm, by an average of approximately 11 percent. Therefore at six locations H-flumes (Figure 3-3) were installed to more accurately measure flows at the higher discharging springs.

The data collected at each of the monitoring stations is briefly discussed in the following sections and has been included as computer files in Appendix B. Changes in weir/flume (i.e. spring) flows with changes in surge shaft water levels are discussed in Section 3.3 (below). Several earlier project reports contain additional information on the monitoring equipment, data and analyses, see for example the reports entitled: "*Middle Fork Tunnel and Surge Shaft Geologic and Hydrologic Data Report (Period September, 2000 to June, 2001) Placer County, California*" dated August, 2001 (Piedmont GeoSciences and PG&E Geosciences Department, 2001) and the "*Hydrogeologic Analysis, Middle Fork surge shaft and Tunnel, Placer County, California*" (Piedmont GeoSciences and PG&E Geosciences Department, 2002)(Appendix A).

The significance of flows during annual outages is discussed in Section 3.3.1.

3.1 MONITORING DATA DISCUSSION

Weir/Flume 1—Weir/flume 1 is within the margins of the 1997 debris flow scar and passes discharge from spring Sp114, which has several discharge points distributed along the contact between the Mehrten Formation and Shoo Fly Complex (Figure 2-2). Weir 1 was replaced with an H-flume in January 2003. The 3-year period of record for weir/flume 1 is continuous and presented in Figure 3-4 along with surge shaft water levels and precipitation. During the period of record, weir/flume 1 had daily average discharges that ranged between 0 and 110 gpm with a mean flow of 50 gpm (Table 2-1). In addition to groundwater discharge, precipitation events contribute to flows at weir/flume 1. Rain events on the hydrograph are characterized by a very rapid increase on the rising limb and a slower decrease on the recession limb. The influence of significant rain events on weir/flume 1 discharge is reflected in the higher flows (spikes) during the 2002 and 2003 rainy season (Figure 3-4). The weir 1 pool had a tendency to partly fill with sediment, which was removed each time the monitoring data was downloaded. The weir was replaced on January 4, 2003 with an H-flume because they allow sediment to pass and improve reliability.

The weir/flume 1 hydrograph shows two significant stepped increases in flows in the early The first is recorded in the early Spring of 2001 and 2002 that coincide with a surge shaft water elevation of approximately 4450 feet (Figure 3-4). The second, lesser stepped increase is evident in May, 2001, 2002 and 2003 when the surge shaft water elevation ranged from 4515 to 4560 feet. As discussed in a following section, these step functions in spring discharge may be related to a change from unconfined to confined aquifer conditions.

Weir 2—Weir 2 is located below the contact between the Mehrten Formation and Shoo Fly Complex within the 1997 debris flow chute. The weir is situated within the main watercourse that flows down the axis of the 1997 debris flow scar and measures flow from springs Sp108 and Sp109 (combined flow of flume 7), Sp401, Sp111 and Sp114, and drains D1-D5 (Figure 2-2). Automated monitoring equipment was removed from weir 2 on January 4, 2003 to be installed upstream at the site of flume 2 (Figure 2-2). The period of record for weir 2 is continuous from October 2000 to January 2003 and is presented in Figure 3-5. During the period of record, weir 2 had daily average discharges that ranged from 0 to 200 gpm with a mean flow of 30 gpm (Table 2-1). The weir 2 pool receives considerable sediment from the 1997 debris flow scar, which was removed each time the monitoring data was downloaded. Currently manual readings are made during each data-download visits.

Flow at weir 2 commences when the surge shaft water level reached an approximate elevation of 4500 ft (Figure 3-5). Like weir 1, weir 2 also shows a significant stepped increase in flow when the surge shaft water level reached an approximate elevation of 4550 feet.

Flume 2—Flume 2 is near the Mehrten/Shoo Fly contact and within the 1997 debris flow scar. The flume passes flow from the main watercourse flowing down the axis of the 1997 debris flow chute, specifically flow from springs Sp108 and Sp109 (combined flow of flume 7), Sp401, and Sp114 (Figure 2-2). On 4 January 2003 this H-flume and associated automated monitoring equipment were installed. The period of record for flume 2 is presented in Figure 3-6. During the period of record, January 2003 to September 2003, flume 2 had daily average discharges that ranged from 5 to 175 gpm with a mean flow of 90 gpm (Table 2-1). Like weir 2, flume 2 receives considerable sediment from the 1997 debris flow scar, which passes without obstructing flow. In June 2003, when Hell Hole Reservoir was spilling, flow exceeded the capacity of the flume resulting in water overtopping the rim of the flume pool and then flowing through adjacent flume 11. Like weirs 1 and 2, flume 2 also shows a stepped increase in flow when the surge shaft water level reached an approximate elevation of 4550 feet.

Weir/Flume 3—Weir/flume 3 is nearly 150 feet downslope and about 300 feet north of the Mehrten/ Shoo Fly contact, east of the 1997 debris chute. The weir/flume measures flow from spring Sp112 (Figure 2-2), the largest discharging spring in the surge shaft area. On 5 January 2003 the V-notch weir was replaced with an H-flume to better measure the flows. The period of record for weir/flume 3 is continuous and presented in Figure 3-7. During this period, weir/flume 3 daily average discharges ranged between 40 and 370 gpm with a mean flow of 155 gpm (Table 2-1). Weir/flume 3 is installed on coarse alluvial materials that allow some minor underflow.

From March 18 to April 7, 2003 a "Drain Test" was conducted to evaluate if a hydrologic connection exists between Sp112 and the nearby drains D1-D5 (Figure 2-2). The test was prompted by the observation that Sp112 discharge became turbid and dramatically decreased during drilling of drain D3, which exhibited a seemingly corresponding increase in discharge.

During the test, which consisted of closing flow valves at each of the five drains, flume 3 discharge increased approximately 160 gpm (Figure 3-7). This dramatic response confirms that a hydrologic connection exists through the Mehrten Formation between the drains and the spring and, further, that drains provide an effective means to help control spring discharge.

During a 2 month period in the Spring of 2002, weir 3 flows increased from 115 gpm to 285 gpm. Despite a continuously increasing surge shaft water level, flows subsequently decreased to 220 gpm in May 2002. The overall increase in weir 3 discharge followed the 2001-2002 precipitation season (Figure 3-7) and, therefore, may reflect a contribution of natural groundwater consistent with results from isotopic analysis of spring waters (discussed in Section 3.2).

Weir 3 also shows a stepped increase in flow in the Spring of 2002 when the water in the surge shaft is at elevation about 4480 feet.

Weir 4—Weir 4 is located adjacent to the valvehouse access road (USFS 14N22) and measures flow from spring Sp106, which discharges at the base of road fill that appears to cover a discharge point/area along the Mehrten/Shoo Fly contact (Figure 2-2). The period of record for weir 4, October 2000 through July 2003, is continuous and presented in Figure 3-8. Weir 4 daily average discharge for the period of record ranges from 5 to 65 gpm with a mean flow of 25 gpm (Table 2-1). As a consequence of the very small drainage area, weir 4 discharge exhibited only relatively minor changes during significant precipitation events of the rainy seasons of 2000 through 2003 (Figure 3-8). Changes in weir 4 discharge follows seasonal water levels in the surge shaft, but not the daily or weekly changes (discussed in Section 3.3).

Weir 5—Weir 5 is adjacent to weir 4 along the valvehouse access road and is in a prominent drainage channel that heads at the Middle Fork surge tank (Figure 2-2). Weir 5 measures discharge from several springs along the Mehrten/Shoo Fly contact, Sp103, Sp104, Sp105, and Sp107, and from two springs, Sp204 and Sp205, that discharging higher in the drainage basin (Figure 2-2). The period of record for weir 5 is continuous and presented in Figure 3-9.

Weir 5 daily average discharges ranged from 20 to 235 gpm with a mean flow of 60 gpm during this period (Table 2-1). The record is significantly influenced by rain events and snowmelt that have a large and long lasting effect on discharge measured at the weir, as reflected by the occurrence of significant precipitation events between January and May 2002 and 2003 and snow melt between April and May 2003. Like weir 4, weir 5 flows correspond to long-term surge shaft water levels, rather than to short-term levels (discussed in Section 3.3).

Weir/Flume 6—Weir/flume 6 is nearly 100 feet west of the 1997 debris flow, adjacent to boring B6 and to the project access road destroyed in two places by this event. The weir/flume passes flow from spring Sp108 (Figure 2-2). This spring, which is the highest in the project area, discharges from fractures in Mehrten mudflow deposits exposed in a small, geomorphically fresh appearing, spring-sapping bowl. The period of record for weir/flume 6 is continuous and presented in Figure 3-10. The V-notch weir was replaced with an H-flume on 5 January 2003. The daily average discharge at weir/flume 6 ranged from 0 to 85 gpm with a mean discharge of 15 gpm (Table 2-1).

Weir/flume 6 flow ceased in November 2000 when the surge shaft water elevation dropped below 4465 feet and resumed in April 2002 when the water elevation reached 4525 feet (Figure 3-10). In detail, weir 6 discharge 'peaks' are notably asymmetric, having a steeper declining limb as illustrated by the shape of the flow curve during the 2002 outage (see also Figure 26 in Sawyer and others, 2002). We refer to this as the "garden-hose" effect, meaning that when the hydraulic head of the system increases it gradually initiates flow and subsequently discharge at the spring. However, discharge abruptly ceases when the applied head is removed.

Weir 7—Weir 7 is within the 1997 debris flow scar, near the head of this prominent feature. The weir passes discharge from spring Sp109 (Figure 2-2), which at the head of the 1997 debris flow scar. The period of record for weir 7, which is discontinuous because equipment malfunctions, is presented in Figure 3-11. The record for weir 7 indicates that the daily average discharge ranged from 0 to 8 gpm with a mean discharge of 1 gpm during times when it was flowing (Table 2-1). On 5 January 2003 automated equipment was removed from weir 7, which currently is manually monitored during each data-download visit. The weir 7 pool commonly fills to the nap of the weir with sediment, which is removed each time the monitoring data is downloaded or recorded.

Flume 7—Flume 7 is in the upper part of the 1997 debris flow scar approximately where the access road was destroyed by this landslide. This flume passes flow from flume 6 (Sp108), weir 7 (Sp109), and at times passes artesian flow leaking from piezometer B6 (Figure 2-2). Flume 7 was installed on 4 January 2003. The period of record for flume 7 is complete and presented in Figure 3-12. The record indicates that the daily average discharge ranged from 0 to 96 gpm with a mean discharge of 31 gpm (Table 2-1). Like weir 7, flume 7 receives sediment from the unvegetated scar, which passes through the flume.

Weir 8—Weir 8 is located along a fairly significant drainage that flows in a concrete canal through the upper switchyard at the Middle Fork Powerhouse and that heads near the surge tank (Figure 1-2). This weir measures the combined discharge of weirs 4 and 5 and several small springs that discharge into the drainage below these weirs. The period of record for weir 8 begins in October 2000 and ends on 19 May 2002 (Figure 3-13), when the automated monitoring equipment was removed. Weir 8 daily average discharge ranged from 10 to 285 gpm, with a mean of 100 gpm (Table 2-1). The record is significantly influenced by precipitation and snowmelt that have a large and long lasting effect on measured discharge. The actual maximum flow at weir 8 is unknown because at rare high flows the weir was overtopped. Because it provided no additional information and was strongly affected by evapotranspiration and precipitation (e.g., Piedmont GeoSciences and PG&E Geosciences Department, 2001), the automated monitoring equipment was removed.

Weir 9—Weir 9 was along the "powerhouse-valvehouse" access road and measured discharge from spring Sp121 (Figure 1-2), a natural spring in the Shoo Fly metamorphic rock that was used as a source of water during construction of the penstock. Weir 9 discharge ranged from 0 to 20 gpm, with a mean discharge of 2 gpm (Table 2-1). The period of record is continuous up to 5 January 2003, when the monitoring equipment was removed. The equipment was removed because after more than 2 years of data collection, no relationship between weir 9 discharge and surge shaft water levels had been identified (Figure 3-14).

Weir 10—Weir 10 is in the same prominent valley as weir 5 but about 500 feet further upstream. In June 2002 the weir was installed to measure flow from spring Sp205 which issues from within the lower part of the Mehrten Formation (Figure 2-2). The period of record for weir 10, which is continuous from that date until it was removed in January 2003, is presented in Figure 3-15. Weir 10 daily average discharge ranged from 5 to 35 gpm, with a mean discharge of 5 gpm, during this period (Table 2-1). The record is significantly influenced by precipitation and snowmelt that have a large and long lasting effect on discharge measured at weir 10, as reflected by the occurrence of significant precipitation events between January and May 2003 and snow melt between April and May 2003 (Figure 3-15).

Weir/Flume 11—Weir/flume 11 is within the 1997 debris flow scar near flume 2 and receives the combined flow of drains D1, D2, D3, D4 and D5 (Figure 2-2). Weir 11 was installed with automated monitoring equipment in October 2002 and was replaced with an H-flume on 4 January 2003. The period of record for weir/flume 11 is continuous and presented in Figure 3-16. Weir/flume 11 daily average discharge ranged from 70 to 180 gpm, with a mean of 110 gpm (Table 2-1); these values exclude data collected during a hydrologic test of the drains (see weir/flume 3 discussion above). During the Drain Test, discharge of less than 3 gpm was measured at weir/flume 11.

3.2 WATER CHEMISTRY

Chemical Composition—Water that flows through different geologic materials will dissolve minerals of different chemical make up. Therefore water will be tagged or fingerprinted with ions from the minerals that are dissolved along the waters flow path. Water samples were collected from the Middle Fork Penstock, several of the weirs, and Brushy Spring at various times/seasons from November 2000 to July 2001. Brushy Spring is a natural spring that discharges 3,300 feet southeast of the surge shaft (Figure 1-2) but at an elevation higher than Hell Hole Reservoir. Brushy Spring represents groundwater locally derived from the Mehrten

Formation while the penstock water is derived from the granitic mountains near the crest of the Sierra Nevada. It was anticipated that because of the different geologic materials in the source areas of these two end members, that the chemical composition would be different and provide natural tracers to help differentiate the source of the water that feeds the weirs.

The chemical composition of the waters turned out to be indistinct from each as illustrated in the stiff diagrams (Figure 3-17) that show little difference in the ionic chemistry of the two end members, the penstock water and Brushy Spring (SP100) water. Therefore ionic chemistry could not be used as a finger print of the different waters (for additional discussion see "Middle Fork tunnel and surge shaft Geologic and Hydrologic Data Report (Period September, 2000 to June, 2001) Placer County, California" (Piedmont GeoSciences, and PG&E Geosciences Department, 2001)(Appendix A).

Isotopic Composition—Another tool used to finger print waters is comparison of the stable isotopes of oxygen and hydrogen. Isotopic differences exist for many reasons. In the study area, the two most important causes of isotopic fractionation are rainout and elevation of recharge. Rainout occurs when an air mass cools and droplets form. While this is occurring, equilibrium fractionation between the vapor and the condensing phase preferentially put deuterium (^{2}H) and ^{18}O in the rain or snow and leaves the air mass depleted with respect to those isotopes. As the process continues, precipitation along the trajectory of the air mass becomes lighter or more depleted with respect to the heavier isotopes. This process is independent of altitude. Both of these factors will tend to deplete precipitation of the heavier isotopes in the drainage basin upstream of Hell Hole Reservoir, relative to the surge shaft project area. Consequently, the isotopic composition along a storm path will become progressively lighter. The temperature at which droplets form also plays a role in the rate of fractionation. Precipitation at higher elevation will tend to be more depleted or more negative. These factors will make the penstock water, derived higher in the Sierra Nevada, more negative than those derive on the lower Ralston Ridge in the project area.

Even though these waters are ionically indistinct, they show distinct isotopic differences in the oxygen and hydrogen. Figure 3-18 is a plot of the stable isotopes from samples collected in the study area between November, 2000 and July, 2001. As can be seen in this figure, a distinct difference exists between penstock water and Brushy Spring water, making this a useful tool in evaluating the sources of water in the springs that feed the weirs/flumes. The analysis is complex because the isotopic values from both the source waters and springs change over time. This is important since travel time through the hydrologic system may be much slower than the observed hydraulic response (discussed below).

The isotopic values of water from weir 9 (Sp121) and spring Sp206 are grouped near those of Brushy Spring (Sp100). This is expected since both the spring that feeds weir 9 and Brushy Spring are natural springs, and Sp206 is suspected to be a natural spring because it is located near Big Crater at the base on the Mehrten Formation about 1.6 miles (2.6 km) west of the surge tank (Figure 1-2). Spring Sp200, which also issues from the base of the Mehrten Formation about 1,200 feet east of the surge tank (Figure 1-2), also is isotopically similar to Brushy Spring suggesting little or no contribution of penstock water. Whereas, water from weirs 1 and 3, and to a lesser extent from weirs 4 and 5, group more closely with water from the penstock (Figure 3-18). This suggests that weir 1 and 3 discharge is almost completely derived from penstock water, and that there is a lag time associated with discharge that is a minimum of weeks and probably of months (i.e., considerably slower than the "response time" of the springs feeding those weirs [discussed in the following section]).

The isotopic values show substantial variation, but follow understandable trends. For example, samples from weir 1 show enrichment in the heavier isotopes from November to January, which is similar to the change observed in the penstock water (Figure 3-18). The samples from weirs 3 and 5 show a depletion of the heavier isotopes between November and January, such that their isotopic signatures became similar to the penstock water. These isotopic trends indicate that in January a greater portion of the discharge from weirs 1, 3 and 5 was derived from the penstock water.

Because of their close proximity, the isotopic signature of weir 4 water is very similar to that of weir 5, as expected. The similar isotopic signatures of water from weirs 4 and 5 and the penstock in the January 2001 sampling could be interpreted to mean that the waters from weirs 4 and 5 are almost completely derived from the penstock. However, if the travel time of water along the travel path between the surge shaft and weirs 4 and 5, is on the order of several months, a larger portion of their discharge would be derived locally, as suggested when comparing the isotopic signatures from weirs 4 and 5 to that of the penstock for the November 2000 sampling (Figure 3-18).

3.3 HYDROLOGIC RESPONSE TO SURGE SHAFT WATER LEVELS

If spring discharge, as measured as flow at the weirs and flumes, is directly influenced by leakage from the surge shaft, then the head and the duration of head in the tunnel/surge shaft system are two parameters that would control spring discharge. Additionally, precipitation events and discharge of naturally occurring groundwater could also influence flow through the weirs and flumes, especially seasonally.

In general, as discussed in Section 3.1, flow through the weirs and flumes increases or decreases subsequent to corresponding changes in the head in the tunnel/surge shaft system, and to precipitation events. The general relationship between weir/flume flow (i.e., spring discharge) and hydraulic head is evident in the average daily discharge hydrographs for weirs/flumes 1, 3 , 6 and 11, weirs 2 and 7, and flumes 2 and 7 (Figures 3-4, 3-5, 3-6, 3-16, 3-7, 3-10, 3-11, and 3-12), which also show surge shaft water elevations (i.e., proxy for head in the system). These hydrographs show that discharge trends closely mimic changes in surge shaft water levels and, thus, respond to changes in the system head. The relationship is less apparent in the hydrographs for weirs 4, 5, 8, and 10 (Figures 3-8, 3-9, 3-13, 3-15), and no relationship is evident in the hydrographs for weir 9 (Figure 3-14). Thus head changes in the tunnel/surge shaft system show the greatest response in spring discharge for those springs in the Mehrten Formation located north of the surge shaft and least for those to the west.

In the surge shaft area the relationship between weir/flume flow and hydraulic head is further illustrated in Figure 3-19, which plots the combined discharge from weirs 1, 2, 3, 4, 5 and 6 against surge shaft water elevations. These weirs were selected because their flows have been shown to systematically and proportionally vary with changes in system head (discussed above). Although the relationship can be expressed by a linear or an exponential expression, as shown by similar coefficient of correlation (R^2-values of 0.70 vs. 0.72, respectively), the exponential expression has a slightly better fit, particularly at high flows/heads. Similar plots are provided for flows at individual weirs in the report "*Hydrogeologic Analysis, Middle Fork surge shaft and Tunnel, Placer County, California*", dated September 5, 2002 (Piedmont GeoSciences and PG&E Geosciences Department, 2002)(Appendix A).

Springs north of the surge shaft also respond to head changes relatively rapidly, whereas the response of those to the west is significantly slower. The elapsed time between the occurrence of a significant water level (i.e., head) change in the surge shaft and the corresponding change in weir discharge, or the "response time", is listed in Table 3-1 for weirs 1 through 9. The response times for weirs 1, 2, 3 and 4 are shown graphically in Figures 3-20, 3-21, 3-22 and 3-23. As these data show weirs 1, 2, 3 and 6 have response times ranging from 0.2 to 15 hours; all are located north of the surge shaft. To the west the response at weir 4 to the west appears to lag the preceding head change by 20 to 32 days (Table 3-1; Figure 3-23). Considering the distance from the surge shaft to the spring(s) feeding the weirs, "response rates" were determined that range from as little as approximately 2 feet per hour, in the case of weir 4, to as fast as of 1,600 to 6,300 feet per hour, in the case of weir 6. Conceptually the response rate is the rate at which a *pressure wave* propagates through the aquifer system and, therefore, differs from the unknown actual flow rate. The high response rates are consistent with fracture flow, rather than porous media flow. The trend of response times decreasing and response rates correspondingly increasing with increases in surge shaft water levels, shows that higher heads provide greater available driving force to overcome friction along flow paths within the Mehrten aquifer system.

In addition, the response is more rapid and has a higher amplitude and greater periodicity at relatively high surge shaft water levels. For example, flows at weir/flume 1, weir 2, flume 2, weir/flumes 3 and 6, and weir 7 show greater periodicity at surge shaft water elevations above about 4450 to 4500 feet (Figures 3-4, 3-5, 3-6, 3-7, 3-10, 3-11). This change in response probably reflects a change from unconfined to confined aquifer conditions, although unlikely it could reflect a zone of higher conductivity within the upper Mehrten Formation.

Thus, the magnitude and rate of response of springs north of the surge shaft is much greater than it is for those springs to the west, indicating strong horizontal anisotropy within the Mehrten aquifer in the surge shaft area.

In addition to system head, spring discharge is also controlled by the duration that a given head condition is maintained, until an equilibrium condition is reached. For example, the flows through weirs 1, 3 and 4 were greater in May, 2001 than in November, 2000 despite the maximum system head being 40 feet lower (Figures 3-4, 3-7, 3-8). This anomaly is explained when it is realized that the daily *average* surge shaft water elevation was higher in May then in November, which resulted in higher weir flows in May. The increased flows in May could also be explained, at least in part, by a higher natural groundwater table during this time of year. The dependence of spring discharge on the time-weighted average of system head is illustrated in Figure 3-19, which shows regression lines fitted to the daily average surge shaft water elevations and daily average discharge from weirs 1, 2, 3, 4, 5 and 6. The relatively low coefficient of correlation, 0.70 to 0.72, indicates that system head and the duration of system head are only two of the parameters controlling spring flows, with discharge of natural groundwater and precipitation being two additional parameters.

In addition to weir flows, piezometric levels measured by pressure transducers in multi- and single-staged piezometers also are controlled in part by the head in the system and to the duration of that head condition is maintained.

The piezometer data show the significant between surge shaft and piezometer water levels. The full range of measured piezometer water levels, in addition to statically determined levels, are shown in Table 3-2. Hydrographs for individual piezometers B1, B2, B4, B5, B6, and B7, which include surge shaft water levels, are shown in Figures 3-24 through 3-29; piezometer B3 is not included because this shallow piezometer has been dry throughout the monitoring period. These data show that piezometer water level increases or decreases with corresponding changes in surge shaft water levels. This relationship demonstrates that surge shaft water levels dramatically affect the elevation of groundwater in the vicinity of the surge shaft. The strong correlation of fluctuations in the surge shaft to levels in piezometer B1, which is next to the surge shaft, and B-2, which is to the north, apparently reflect that the two are connected by a zone of intersecting open fractures.

Transducers in three of the piezometers, B4, B5 and B6, have all recorded artesian conditions when the surge shaft water elevation is above about 4500 feet (Table 3-2; Figures 3-26, 3-27, 3-28). Thus confined aquifer conditions occur at surge shaft water elevation of 4500 feet or somewhat less, supporting the inference that the change in spring response (discussed above) at this approximate water elevation reflects a change from unconfined to confined aquifer conditions.

3.3.1 Hydrologic Response To Annual Outages

Because spring discharge is controlled by the duration of head in the system and the system head remains relatively constant during annual outages of the Middle Fork hydroelectric system, flows measured at several weirs fed by springs in the Mehrten Formation were evaluated for the four outages: September 23 to November 23, 2000 (only partly recorded; see Cotton Shires & Associates and others, 2000 for details); September 30 to November 30, 2001; September 13 to October 20, 2002; and November 6 to November 26, 2003. Hydrographs for weir/flume discharge during the 2001, 2002 and 2003 outages are shown in Figures 3-30, 3-31 and 3-32, respectively. As expected, weir flows increased during the outages, 24 percent on average during 2000, from 15 to 35 percent on average during 2001, from 18 to 48 percent on average in 2002, and from 21 to 27 percent on average in 2003 (Table 3-3). The range in percentages reported for the 2001, 2002, and 2003 outages reflects that maximum flows often occurred during the outage rather than at the end; no flow measurements are available during the 2000 outage. The greater increase in 2002 appears to reflect both higher flows at higher heads and the exponential relationship between these parameters (Figure 3-19), particularly at relative high head conditions. During the 2001 outage the surge shaft was at elevation about 4430 feet, and the weir flows were variable. However, when the surge shaft water was higher, at 4450 to 4460 feet, during the 2002 and 2003 outages, the flows at weirs 1, 2, 3 and 6 were more uniform and reached or closely approached a steady state condition (Table 3-3), indicating that the flows had equilibrated to the relatively constant head conditions.

The 2002 and 2003 outages had only a minor effect on the piezometer water levels. During the 2002 outage piezometer water levels increased from 0.5 to 8.3 feet, except piezometer B5-158 (i.e., level recorded by the pressure transducer at a depth of 158 ft in piezometer B5), *which decreased 2.0 feet (Table 3-2; Figures 3-24 through 3-29); due to equipment failures,* data was not recorded at piezometers B4, B6 and B7. During the 2003 outage piezometer water levels increased from 3.5 to 13.8 feet (Table 3-2). Thus the maximum increase is comparable to the approximate 5 to 10-foot increase in the surge shaft water levels during the outages.

4.0 TABLES

TABLE 2-1
WEIR/FLUME DISCHARGE FOR PERIOD OF RECORD
(October, 2000 to August, 2003)

Weir / Flume (Spring)	Daily Average Discharge (gpm)	
	Range	Mean Flow[1]
W1/F1 (Sp114)	0.0 - 111.2	49.7
W2 (Sp109;108; 111;401; D1-D5)	0.0 - 198.2	32.0
F2 (Sp109;108; 111;401)	3.0 - 175.8	89.9
W3/F3 (Sp112)	38.6 - 372.2	157.3
W4 (Sp106)	5.5 - 65.2	27.0
W5 (Sp103;105; 205)	20.9 - 234.7	62.0
W6/F6 (Sp108)	0.0 - 85.9	13.7
W7 (Sp109)[2]	0.0 - 7.8	1.2
F7 (Sp108;109)[2]	0.0 - 96.1	30.7
W8 (Sp103;105; 106;205)[2]	10.1 - 287.5	100.3
W9 (Sp121)[2]	0.0 - 22.1	2.0
W10 (Sp205)[2]	2.9 - 37.2	7.1
W11/F11 (D1-D5)[2]	72.4 - 182.4[3]	112.2[3]

[1] Mean flow represents arithmetic mean of daily average discharge data recorded during the period of record.
[2] Weir or flume was not monitored during entire period of record.
[3] Discharge data does not include measurements during Drain Test.

TABLE 3-1
SUMMARY OF WEIR DISCHARGE AND RESPONSE CHARACTERISTICS[1]
(Selected Monitoring Period: 21 October, 2000 to 10 June, 2002)

Weir	Spring/ Elevation/ Bearing from Shaft (ft)	Discharge Min. (gpm)	Discharge Max. (gpm)	Discharge Mean (gpm)	Distance to Surge Shaft (ft)	Date	Approx. Shaft Water Elevation (ft)	Response Times Falling Head (hrs)	Response Times Rising Head (hrs)	Response Rate (ft/hr)	Remarks
1	Sp114 4421 North	1.0	87.4	31.6	1800	Nov 00 May 01 June 02	4532 4525 4591	11-12 12-13 9	11-12 11-14 9-14	150-164 130-150 130-200	W1 discharge clearly and quickly responses to changes in surge shaft water level
2	Sp111 ± Sp109 4299- 4470 North	0	159.4	3.5	1800	Oct 00 May 01 June 02	4540 4579 4578	8 5 5	10 8-10 7	180-225 180-360 360	W2 discharge clearly and quickly responses to changes in surge shaft water level
3	Sp112 4204	38.0	284.9	100.9	1850	Nov 00 May 01 June 02	4532 4524 4579	16 21 12	14 15 11	116-132 88-123 154-168	W3 discharge clearly and moderately quickly responses to changes in surge shaft water level
4	Sp106 4245 Northwest	5	38.3	15.8	1450	Oct-Dec 01 May 01 Mar 02	4419 to 4430 4465 4458	– – ~20 days?	~31-32 days? ~29 days? ~27 days?	~2 ~2 ~2-3	Difficult to identify changes in W4 discharge related to changes in surge shaft water levels; long response times and low response rates are apparent from available data
5	several 4238-4381 Northwest	20.6	131.7	46.9	1450	– – –	– – –	– – –	– – –	– – –	Not able to determined response time and rates with available data; Precipitation obscures relationship between water levels and W5 discharge (see text)

TABLE 3-1 (CONTINUED)
SUMMARY OF WEIR DISCHARGE AND RESPONSE CHARACTERISTICS[1]
(Selected Monitoring Period: 21 October, 2000 to 10 June, 2002)

Weir	Spring/ Elevation/ Bearing From Shaft (ft)	Discharge			Approx. Distance to Surge Shaft (ft)	Date	Shaft Water Elevation (ft)	Response Times			Remarks
		Min. (gpm)	Max. (gpm)	Mean (gpm)				Falling Head (hrs)	Rising Head (hrs)	Response Rate (ft/hr)	
6	Sp108 4470 North	0	26.1	4.7	1050	Nov 00 May 01	No Weir 6 Flow				
						May-June 02	4566 to 4580	0.2-0.4	0.25-0.7	1600-6300	W6 discharge clearly and rapidly responses to changes in surge shaft water level
7	Sp109 4465 North	0*	19*	–	1150	Nov 00	–	–	–	–	Data only collect for a brief period at onset of period of record
						May 01	No Weir 7 Flow				
						May-June 02	No data recorded				
8	Several 4238-4381 Northwest	6.47	287.5	90.6	–	–	–	–	–	–	Receives the combined flow from Weirs 4 and 5, but relationship is obscured by probable evapotranspiration; See Weirs 4 and 5
9	Sp121 3130 North-northwest	0	22.5	2.5	–	–	–	No relationship between discharge and surge shaft water levels			

[1] Based on monitoring data for period 21 October 2000 to 10 June 2002 (Piedmont GeoSciences and PG&E, [Sept. 5] 2002), thus discharge values differ from those presented in Table 3-1 which covers the entire period of record.

[2] Data reported in Cotton Shires & Associates and others (2000).

TABLE 3-2
PIEZOMETER WATER ELEVATION RANGES FOR PERIOD OF RECORD[1]

Piezo. # (~Surf. Elev.)	Daily Average Elevations (ft)				Water Level Elevation Changes During 2002 Annual Outage			Water Level Elevation Changes During 2003 Annual Outage		
	Date	Min *(95% Min.)*	Max (95% Max.)	Mean	Initial (ft)	Final (ft)	Diff. (ft)	Initial (ft)	Final (ft)	Diff. (ft)
B1	9/1/2002	4464.0			4515.2	4522.9	7.7	4520.3	4526.7	6.4
(4631 ft)	6/28/2003		4567.8							
		4472.1	*4553.1*	*4509.9*						
B2-150	3/31/2002	4438.4			4477.7	4486.0	8.3	4481.4	4484.9	3.5
(4564 ft)	10/19/2002		4535.9							
		4447.2	*4500.8*	*4471.9*						
B2-267	2/1/2002	4396.0			4495.5	4500.5	5.0	4496.5	4504.4	7.9
	6/28/2003		4532.3							
		4400.3	*4519.9*	*4480.5*						
B2-399	2/15/2002	4287.1			4387.4	4392.1	4.6	4389.8	4395.1	5.3
	6/28/2003		4424.5							
		4292.8	*4411.7*	*4372.3*						
B3[3] (4565 ft)	No water in piezometer				No water			No water		
B4	9/8/2002	4259.7			No Data[2]	No Data[2]	N/A	4267.8	4272.5	4.7
(4267 ft)	4/8/2003		4276.4							
		4262.9	*4274.1*	*4270.4*						
B5-30	9/14/2002	4355.8			No Data[2]	No Data[2]	N/A	4381.1	4388.4	7.3
(4373 ft)	6/29/2003		4398.7							
		4356.6	*4396.8*	*4375.4*						
B5-105	12/6/2002	4351.0			4369.4	4369.9	0.5	4371.9	4377.6	5.7
	6/21/2003		4388.2							
		4355.0	*4385.6*	*4369.9*						
B5-158	12/6/2002	4354.8			4380.3	4378.3	-2.0	4368.6	4380.3	11.7
	5/4/2003		4387.1							
		4360.5	*4388.1*	*4375.0*						

TABLE 3-2 (continued)
PIEZOMETER WATER ELEVATION RANGES FOR PERIOD OF RECORD[1]

Piezo. # (~Surf. Elev.)	Daily Average Elevations (ft)				Water Level Elevation Changes During 2002 Annual Outage			Water Level Elevation Changes During 2003 Annual Outage		
	Date	Min (95% Min.)	Max (95% Max.)	Mean	Initial (ft)	Final (ft)	Diff. (ft)	Initial (ft)	Final (ft)	Diff. (ft)
B6-35 (4460 ft)	12/6/2002	4455.5			No Data[2]	No Data[2]	N/A	No Data[2]	No Data[2]	N/A
	7/20/2002		4481.4							
		4456.8	4473.4	4463.9						
B6-88.5	12/5/2002	4448.1			No Data[2]	No Data[2]	N/A	No Data[2]	No Data[2]	N/A
	7/20/2002		4482.0							
		4453.8	4473.3	4463.6						
B6-140.5	12/5/2002	4447.3			No Data[2]	No Data[2]	N/A	No Data[2]	No Data[2]	N/A
	7/20/2002		4482.1							
		4452.9	4472.6	4462.5						
B7-212 (4481 ft)	12/6/2002	4404.6			No Data[2]	No Data[2]	N/A	4410.5	4423.9	13.4
	7/7/2003		4432.5							
		4408.9	4431.2	4419.7						
B7-281.5	12/6/2002	4410.6			No Data[2]	No Data[2]	N/A	4415.6	4429.4	13.8
	7/7/2003		4439.6							
		4415.4	4438.7	4426.4						

[1] Values in bold font indicate artesian conditions.

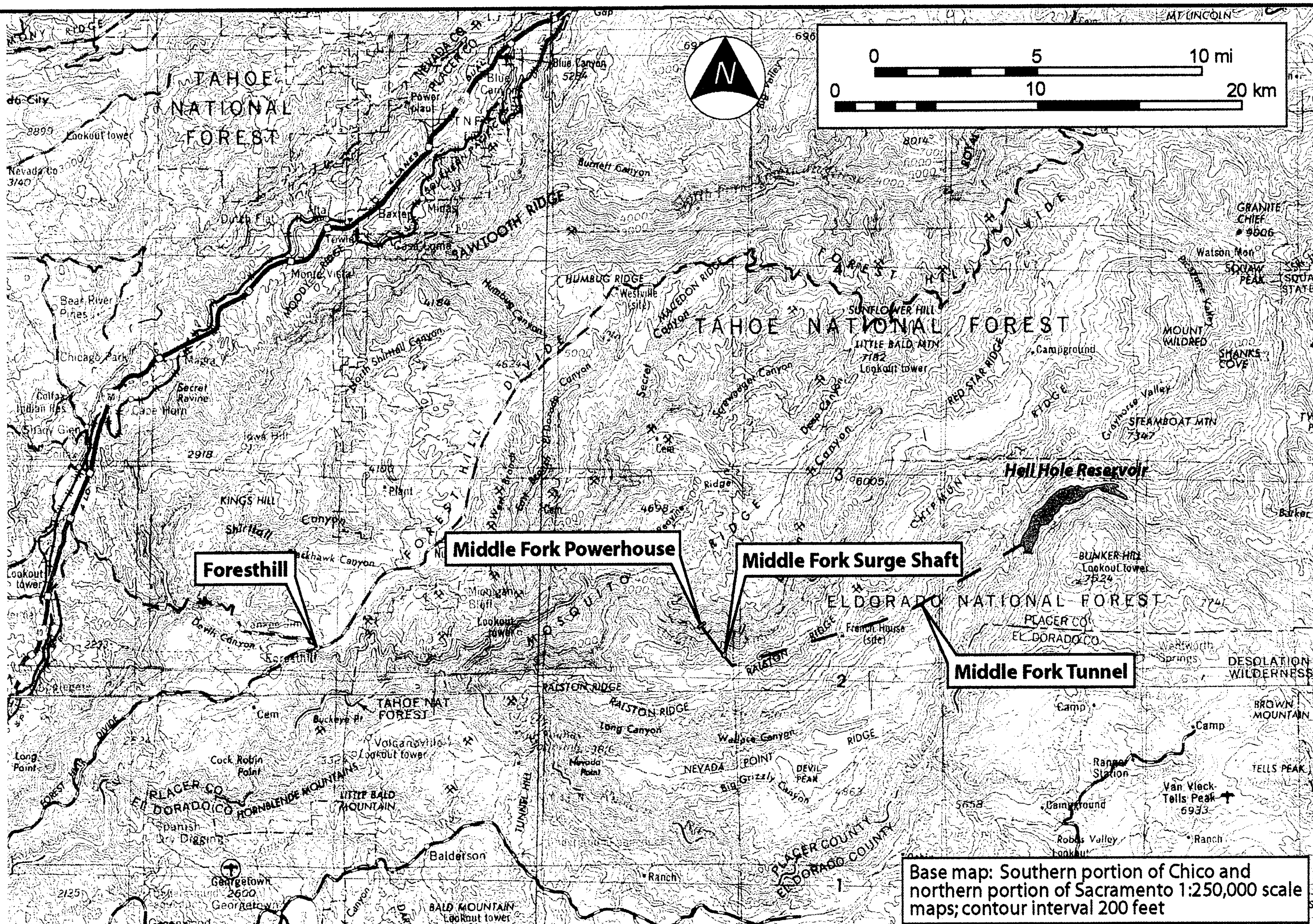
[2] No data due to equipment failure.

[3] The single transducer in this shallow piezometer has never recorded any water (ie., dry piezometer).

TABLE 3-3
WEIR AND FLUME DISCHARGE DURING ANNUAL OUTAGES 2000, 2001, 2002 AND 2003

Weir/ Flume	2000 Surge Shaft Water Level (ft)	2000 Outage Change in Discharge* (gpm, %)	2001 Surge Shaft Water Level (ft)	2001 Outage Change in Discharge* (gpm, %)	2002 Surge Shaft Water Level (ft)	2002 Outage Change in Discharge* (gpm, %)	2003 Surge Shaft Water Level (ft)	2003 Outage Change in Discharge* (gpm, %)	Remarks
1	4547[1] (start) to 4543 (end)	No Data	4428 (start) to 4423 (end)	3.4-6.5 309%-590%	4543 (start) to ~4553 (end)	17.1-20.5 29%-35%	4553 (start) to 4557 (end)	12.8-16.8 18%-23%	Steady state condition reached or approached during 2002 & 2003 outages; [1]Hell Hole Reservoir level
2		12.8 23%		No Flow		130.2-165.8[2] 216%-275[2]		9.3-18.2 10%-20%	Steady state condition reached or approached during 2002 & 2003 outages; [2]Discharge from drains (weir 11) not removed
3		40.3 26%		11.8-26.1 22%-49%		10.2-94.1 5%-46%		56.7-63.4 26%-29%	Steady state condition reached or approached during 2002 & 2003 outages
4		12.0 50%		-1.28 -13%		12.3-12.4 47%		10.0 36% -	—
5		23.4 52%		-0.1 ~0%		24.2-24.6 43%-44%		25.1-26.8 50%-53%	
6		-5.6 -30%		No Flow		7.9-8.9 144%-162%		0.3-2.9 1%-11%	Steady state condition reached or approached during 2002 & 2003 outages
7		-8.1 -8%		No Flow		No Flow		-3.3-2.1 -10%-6%	
Total		75 gpm 24%		14-33 gpm 15%-35%		202-326 (72-196[3]) 50%-80% (18%-48[3]%)		111-140 gpm 21%-27%	[3]Discharge from drains (weir 11) removed

5.0 FIGURES



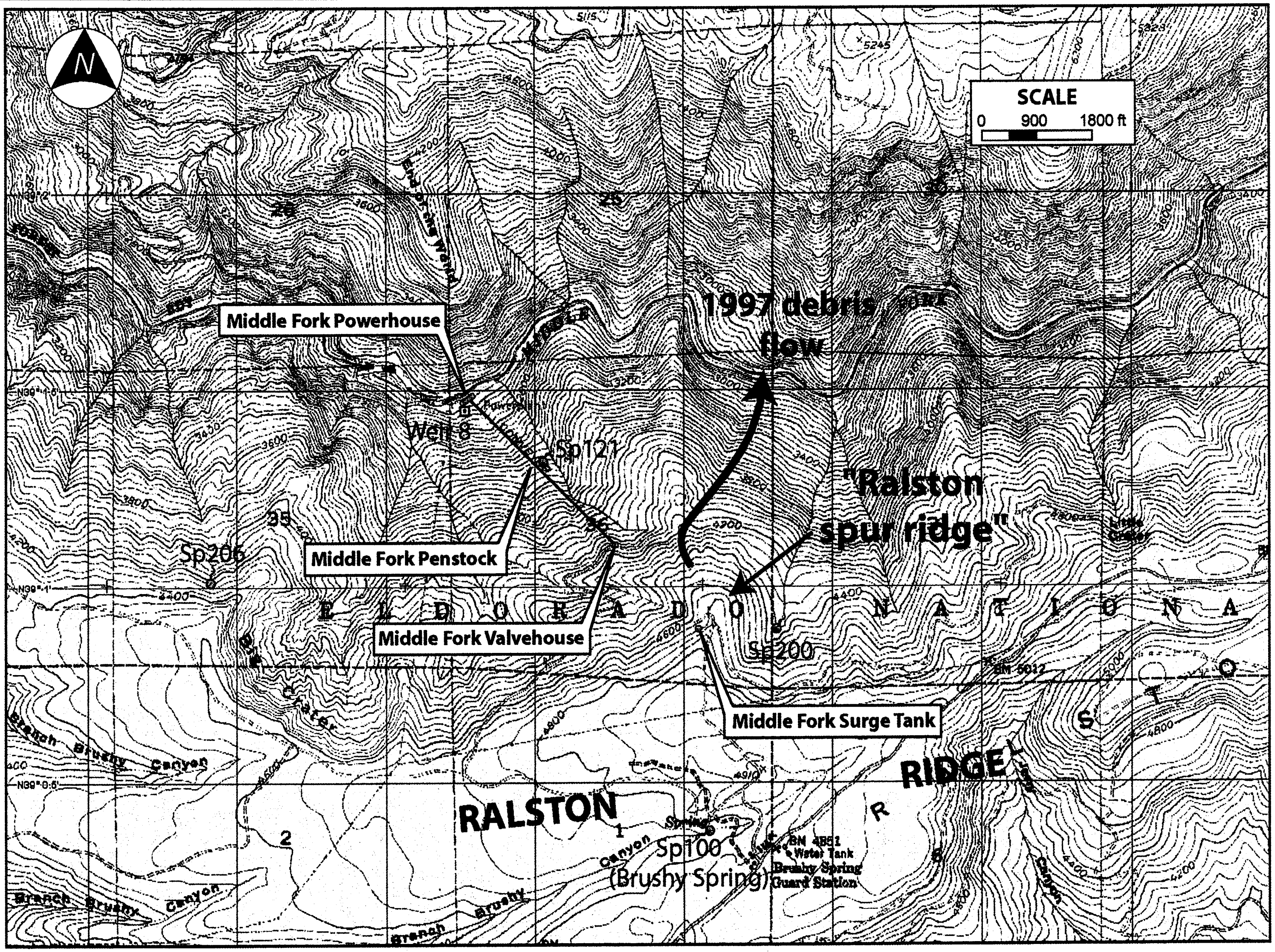
PGS PG&E

REGIONAL LOCATION MAP OF SURGE SHAFT REGION

Geology and Hydrogeology at the Middle Fork Surge Shaft
Placer County, California

FIGURE 1-1

1062-107

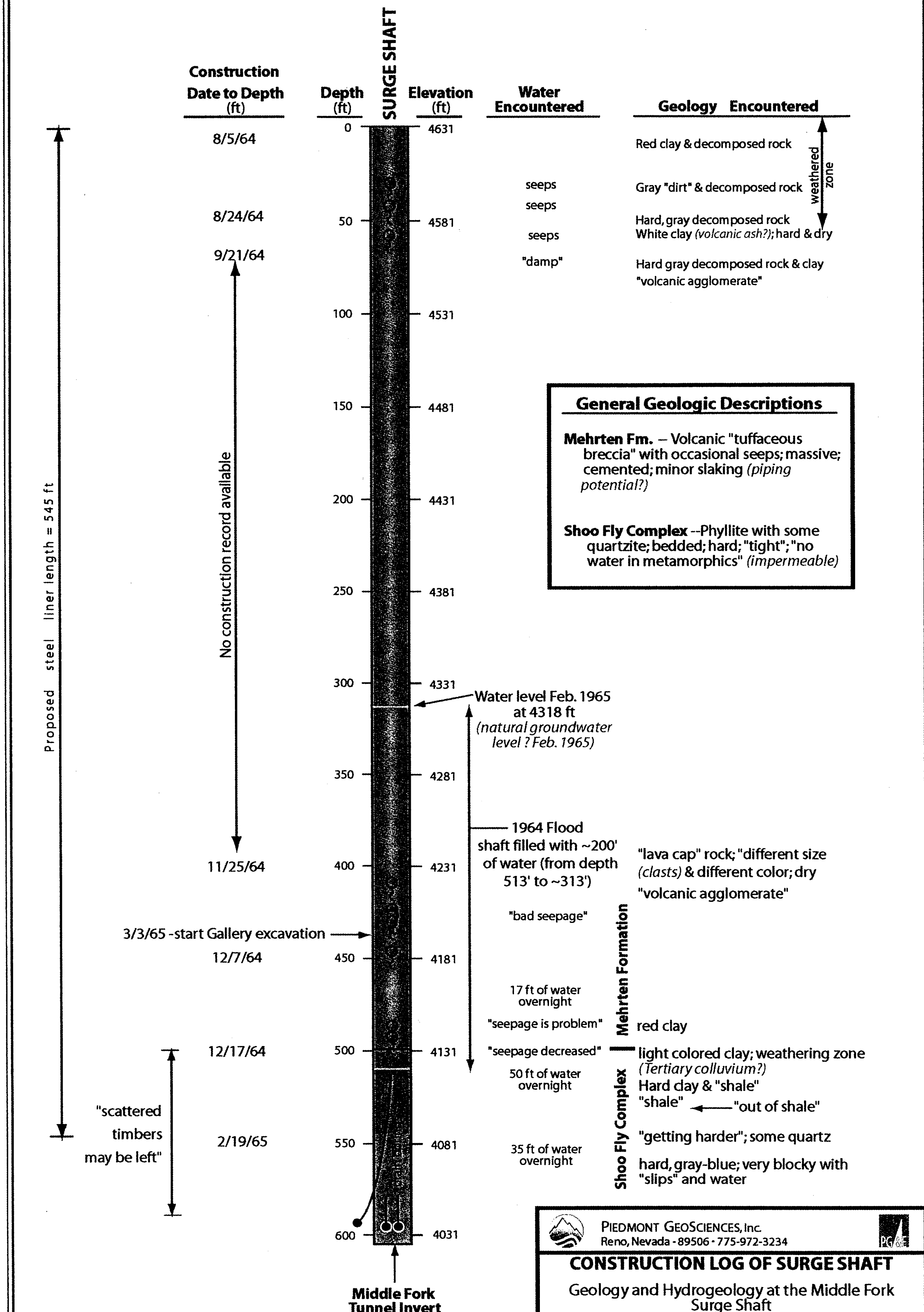


MAP OF SURGE SHAFT AREA

Geology and Hydrogeology at the Middle Fork Surge Shaft
Placer County, California

FIGURE 1-2

1062-107



Sources: Attachments D-1 and D-2 of Jon Mattson's (PCWA) memo dated 1/7/02

Notes shown in italized blue font are compiler's interpretations.

PIEDMONT GEOSCIENCES, Inc.
Reno, Nevada - 89506 - 775-972-3234

CONSTRUCTION LOG OF SURGE SHAFT

Geology and Hydrogeology at the Middle Fork Surge Shaft

COMPILED BY	VERTICAL SCALE	PROJECT NO.
TS	1" = 50'	1062-107
APPROVED BY	DATE	FIGURE NO.
WP	2/24/2004	2-1

LARGE-FORMAT IMAGES

One or more large-format images (over 8 ½" X 11") go here. These images are available in FERRIS at:

For Large-Format(s):
Accession No.: 20040430-0172

Security/Availability:

- [x] PUBLIC
- [ ] NIP
- [ ] CEII
- [ ] NON-PUBLIC/PRIVILEGED

File Date: 4-26-04 **Docket No.:** P 2079

Parent Accession No.: 20040430-0171

Set No.: 1 **of** 1

Number of page(s) in set: 1

TRP-G REV.- 4/2003 (yellow)

EXPLANATION

Qc Quaternary colluvial deposit; shown infilling swales and forming thin surface veener near surge tank

Qls Quaternary landslide deposit
- 1997 debris flow scar and chute

Tmm Tertiary (Miocene) Mehrten Formation; volcaniclastic sediment; commonly mantled with Quaternary colluvium (not shown)
- Mehrten outcrop

Pzsf Paleozoic Shoo Fly Complex; chiefly quartzite and phyllite; locally mantled with relatively thin Quaternary colluvium (not shown)
- Shoo Fly outcrop
- Shoo Fly rocks in surficial colluvium

Spring; discharge in gpm on 6/21/03 when Hell Hole Reservoir was spilling
- <1 (seep)
- 1-10
- 10-100
- >100

Automated V-notch weir monitoring station

Manual V-notch weir monitoring station

Automated H-flume monitoring station

Automated piezometer-monitoring station
- Angled piezometer-boring B2
  approx. terminous of boring

Sub-horizontal drain boring;
approx. terminous of boring

Culvert or pipes

B B' Geologic cross section

Landslide/compaction(?) scarp at Middle Fork Tunnel muck pile

Potential debris-flow chute

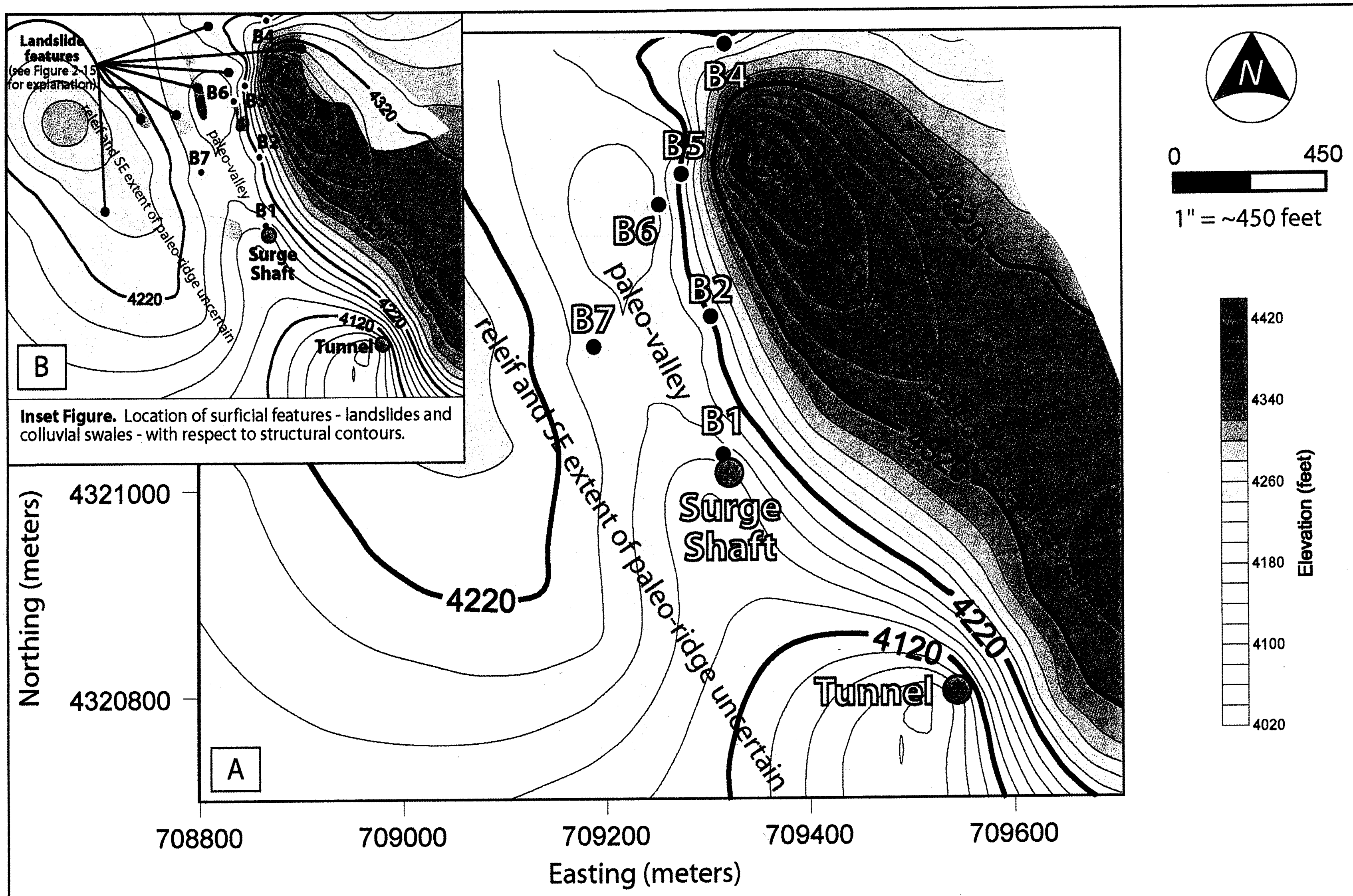
75°-85° Orientation of joint, including downhole geophysical data

65°-89° Orientation of foliation

GEOLOGIC MAP OF SURGE SHAFT AREA
Geology and Hydrogeology at the Middle Fork Surge Shaft
Placer County, California

Figure 2-2b

1062-107

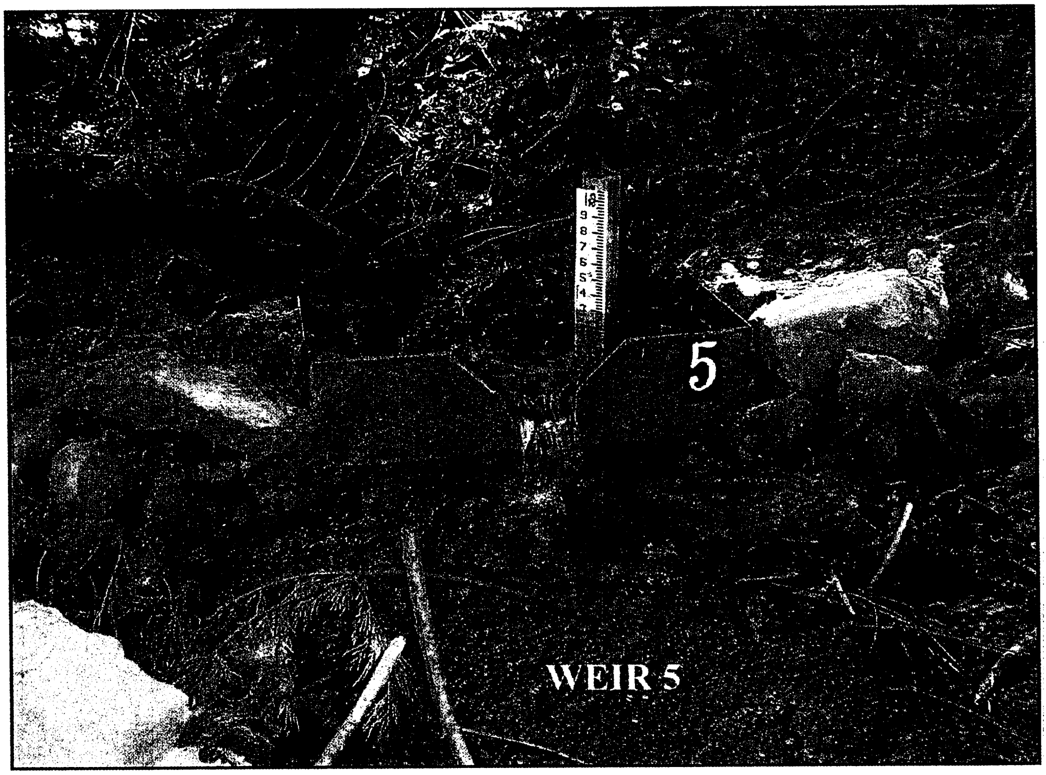


STRUCTURAL CONTOUR MAP ON TOP OF SHOO FLY COMPLEX

Geology and Hydrogeology at the Middle Fork Surge Shaft

Figure 2-3

1062-107



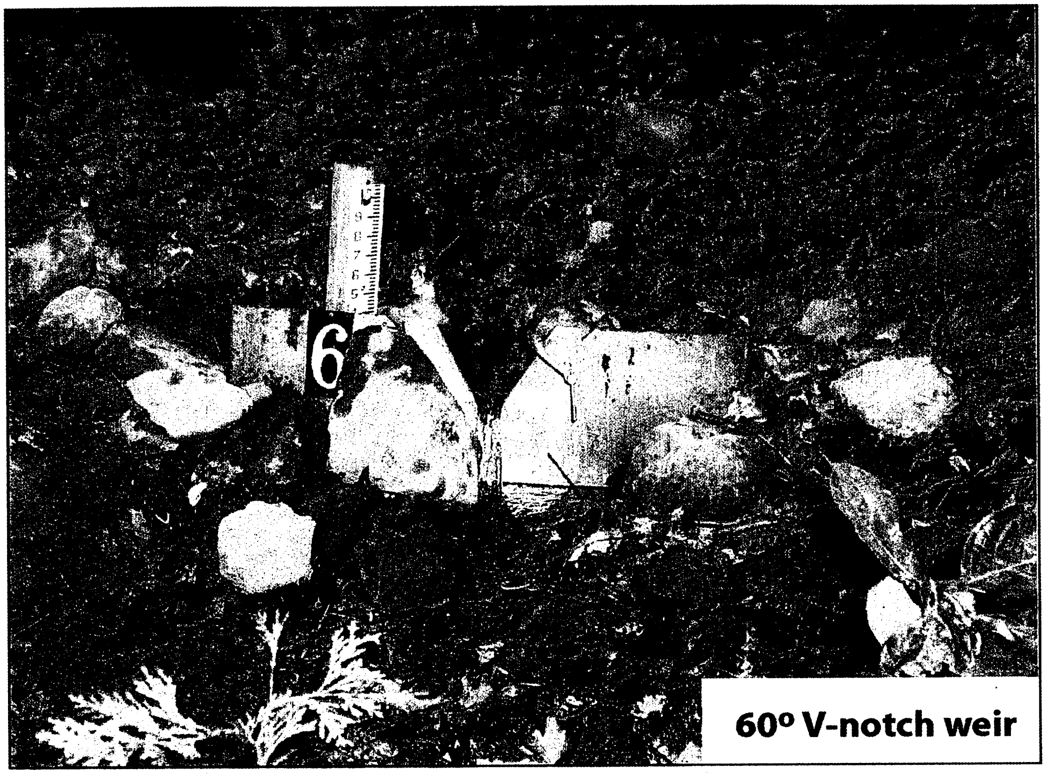
PGS PG&E

PHOTOGRAPHS OF TYPICAL WEIRS

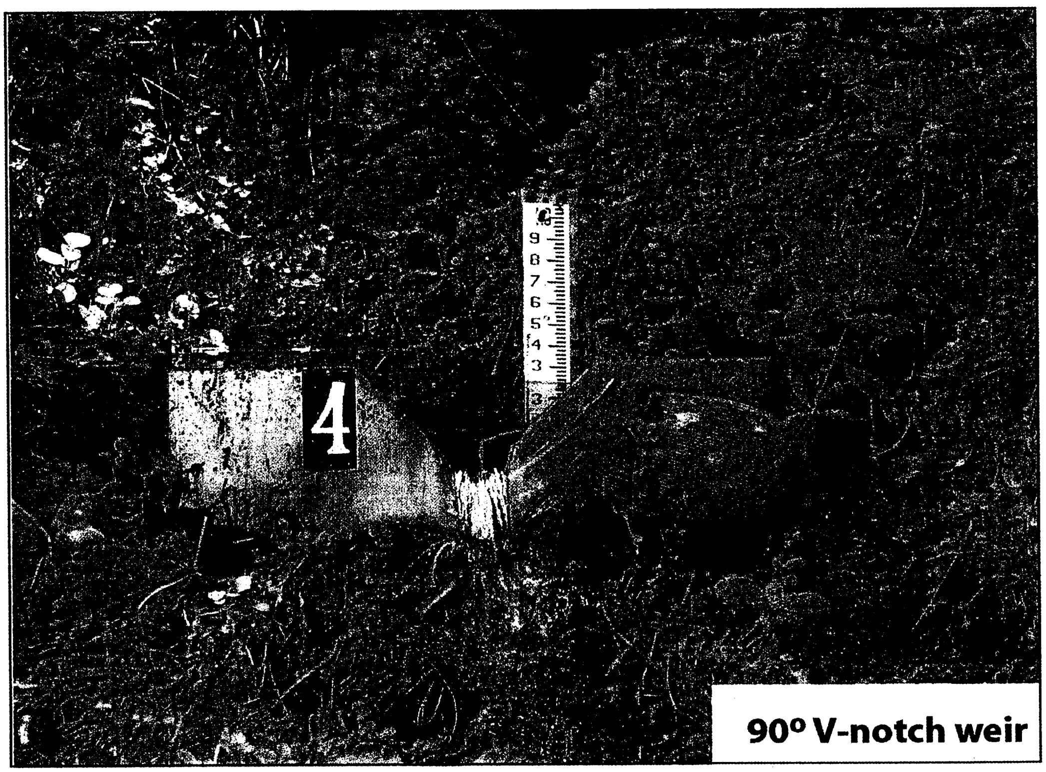
Geology and Hydrogeology at the Middle Fork Surge Shaft
Placer County, California

Figure 3-1

1062-107



60° V-notch weir



90° V-notch weir

PHOTOGRAPHS OF TYPICAL WEIRS

Geology and Hydrogeology at the Middle Fork Surge Shaft
Placer County, California

Figure 3-2

1062-107

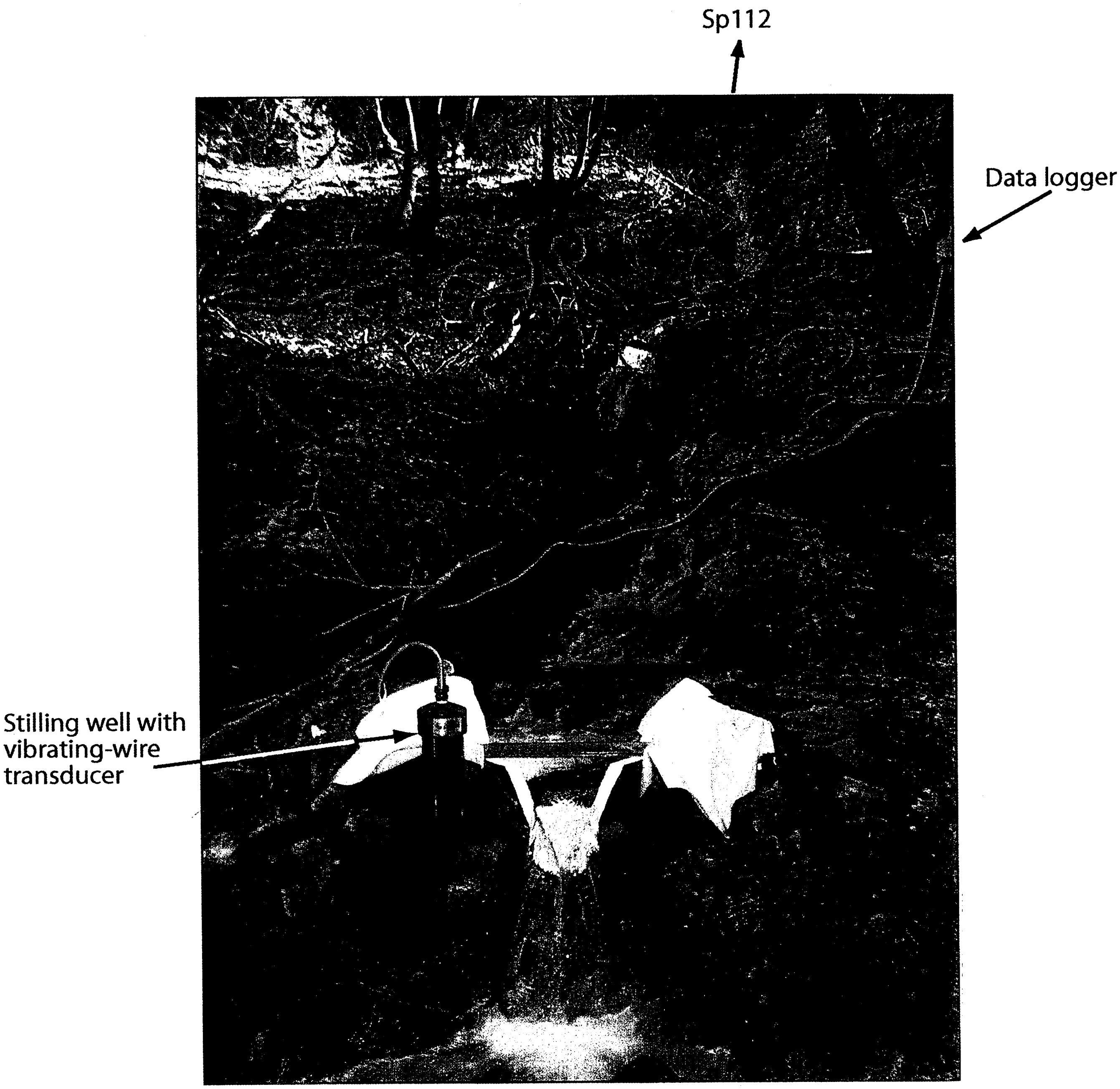


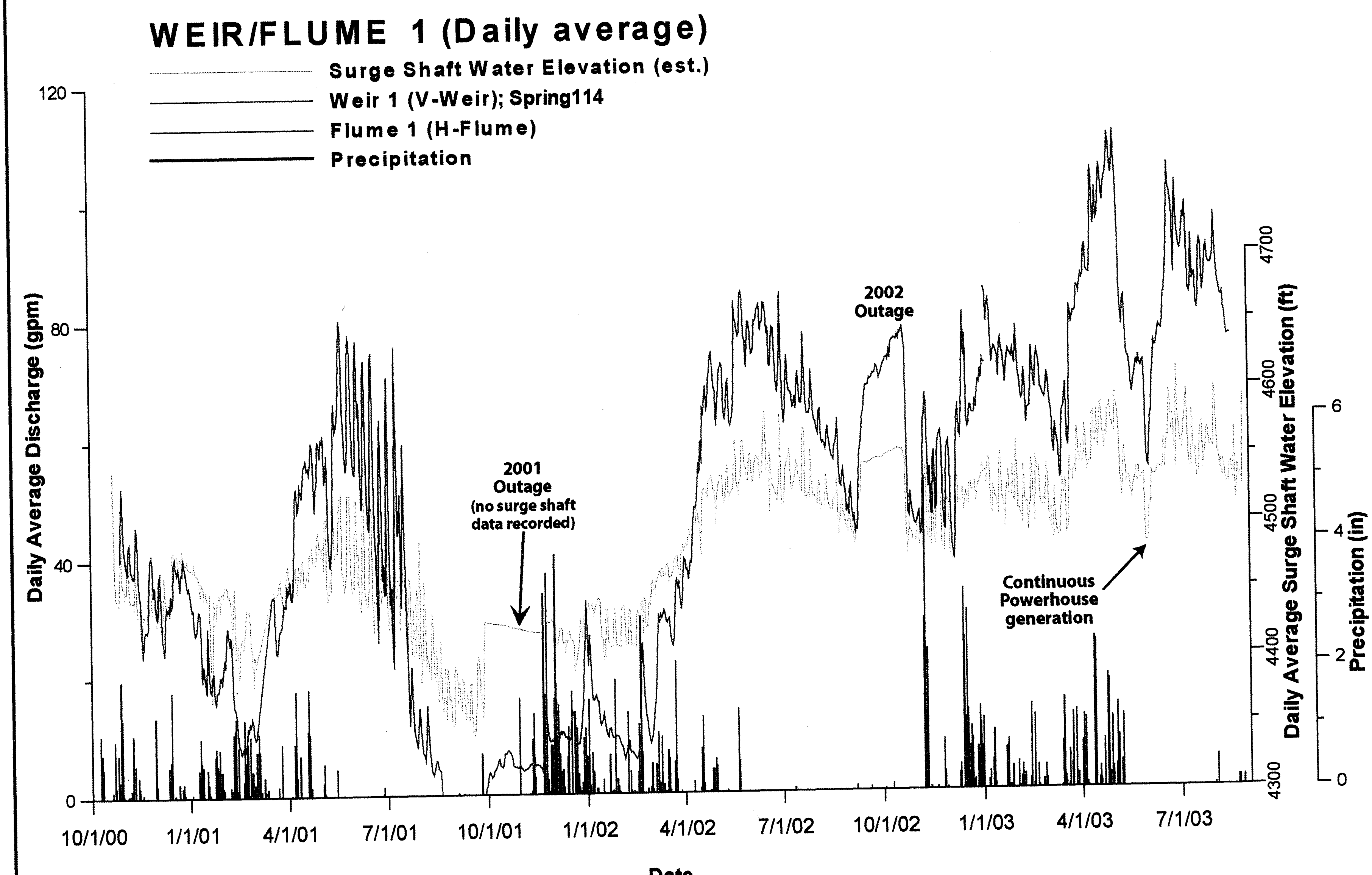
Photo of H-flume 3

PHOTOGRAPH OF TYPICAL H-FLUME

Geology and Hydrogeology at the Middle Fork Surge Shaft
Placer County, California

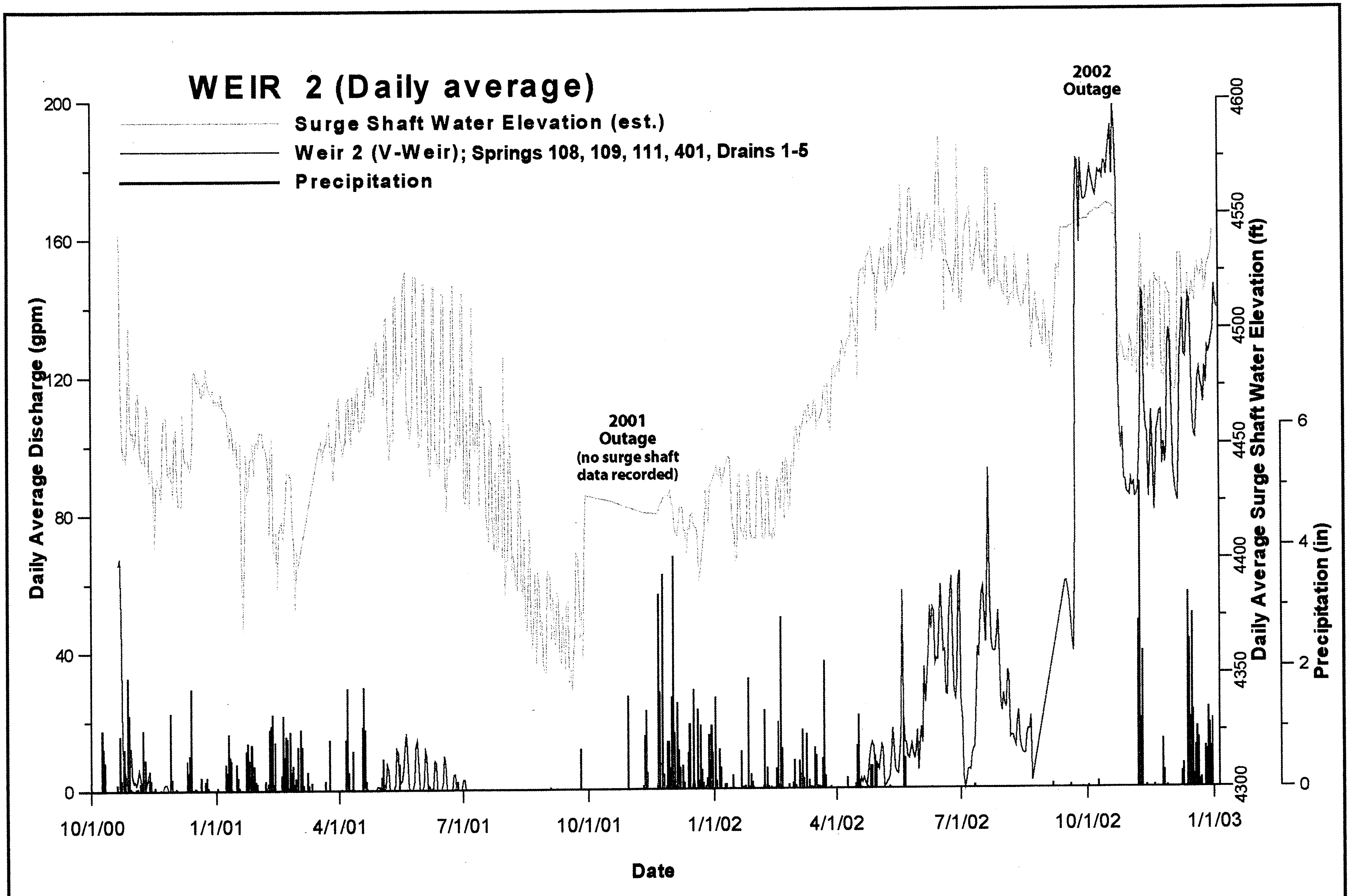
Figure 3-3

1062-107

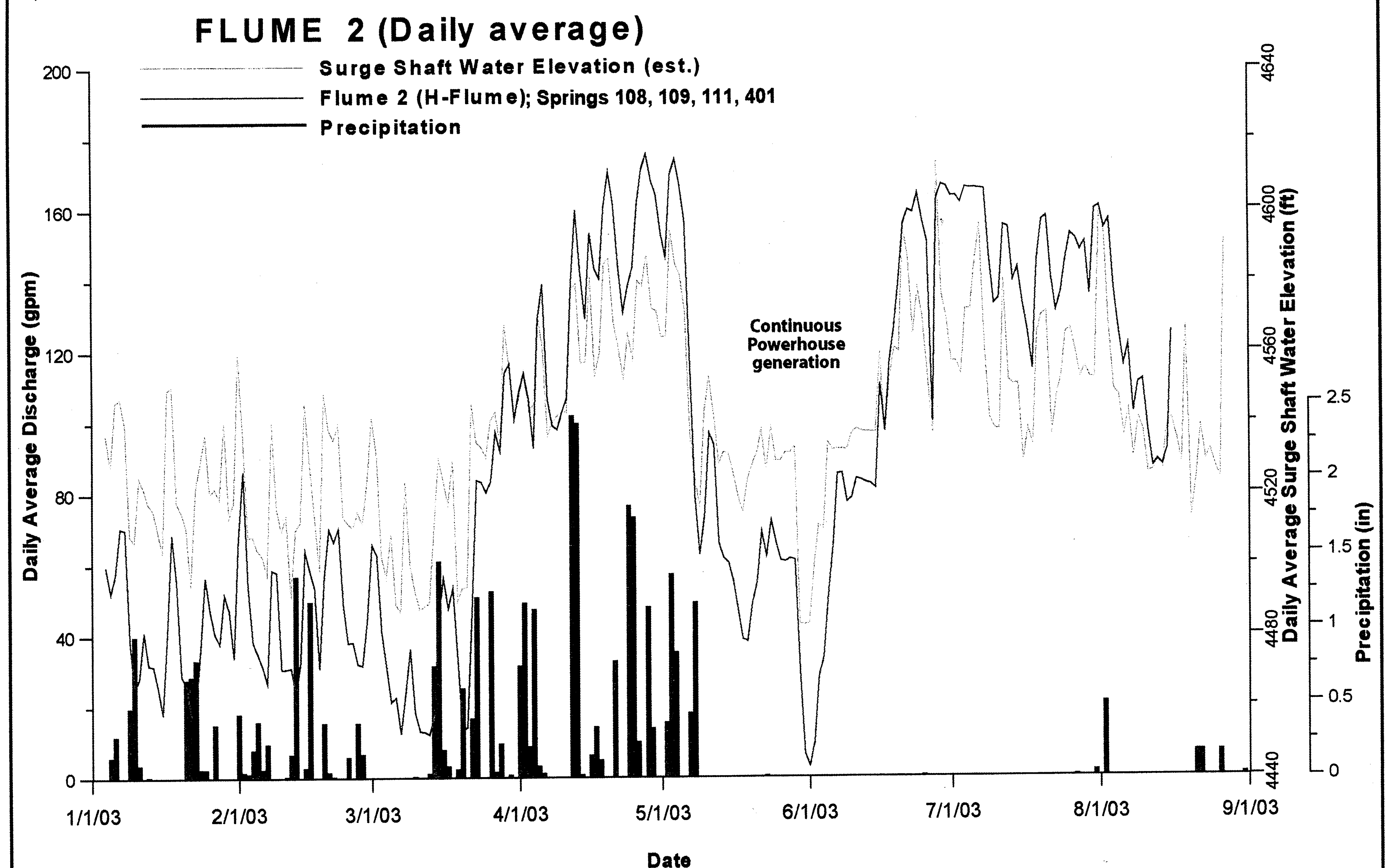


WEIR/FLUME 1 DISCHARGE FOR PERIOD OF RECORD
Geology and Hydrogeology at the Middle Fork Surge Shaft

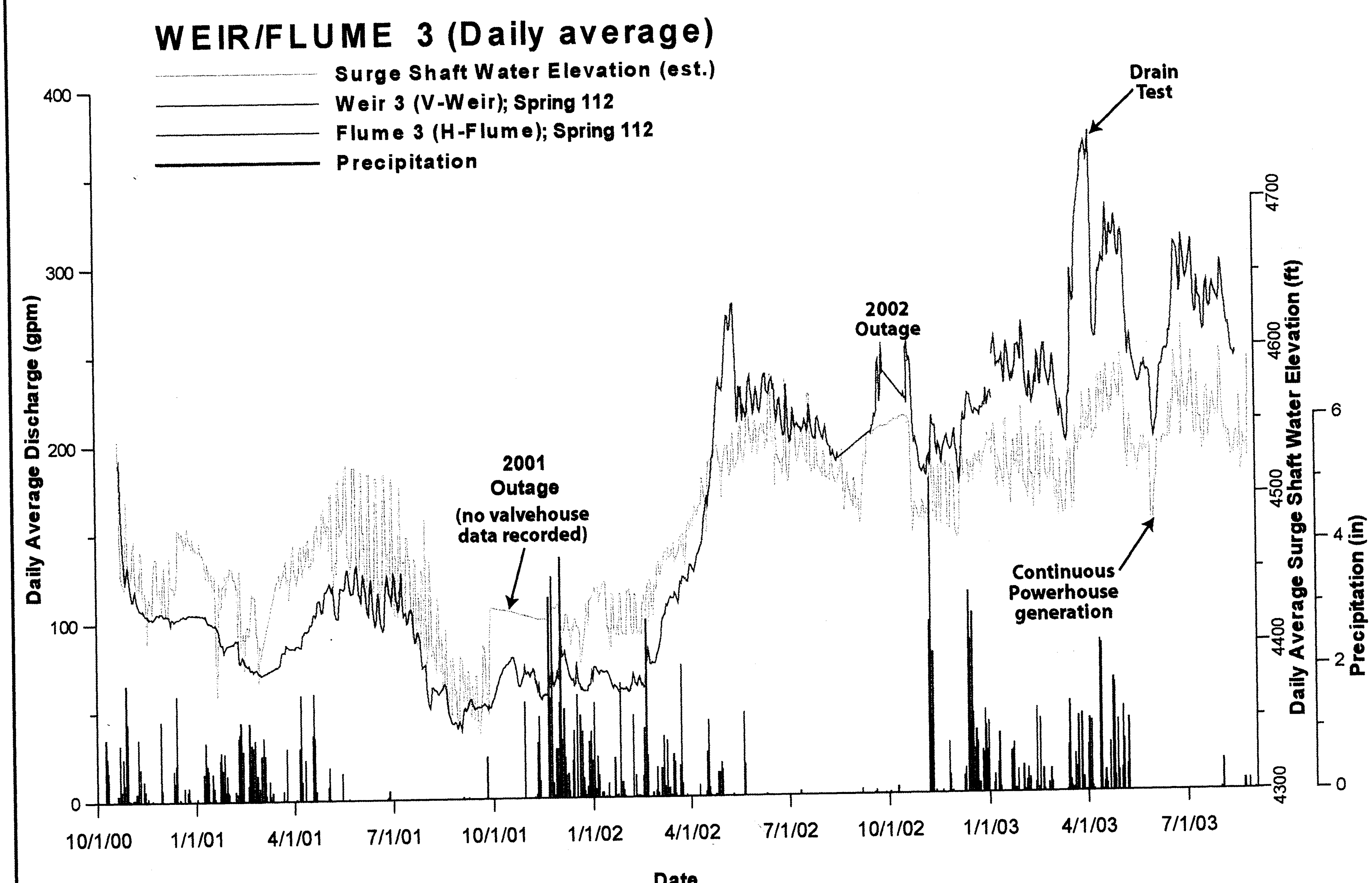
BY	APPROVED BY	PROJECT NO.	SCALE	FIGURE 3-4
TM, SB	WP	1062-107	As reported	Date 2/24/04



WEIR 2 DISCHARGE FOR PERIOD OF RECORD Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-5
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As reported	Date 2/24/04

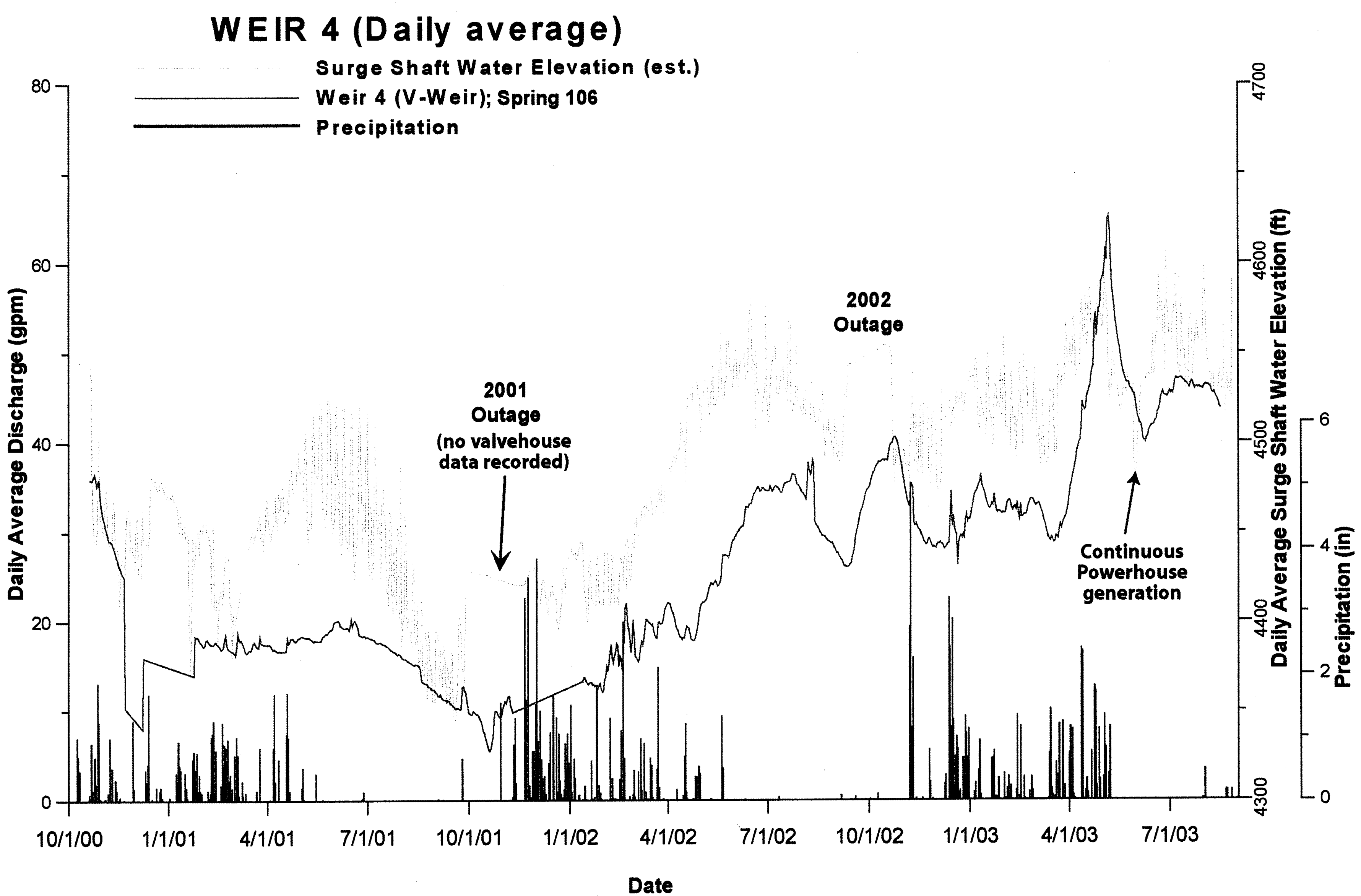


FLUME 2 DISCHARGE FOR PERIOD OF RECORD Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-6
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As reported	Date 2/24/04

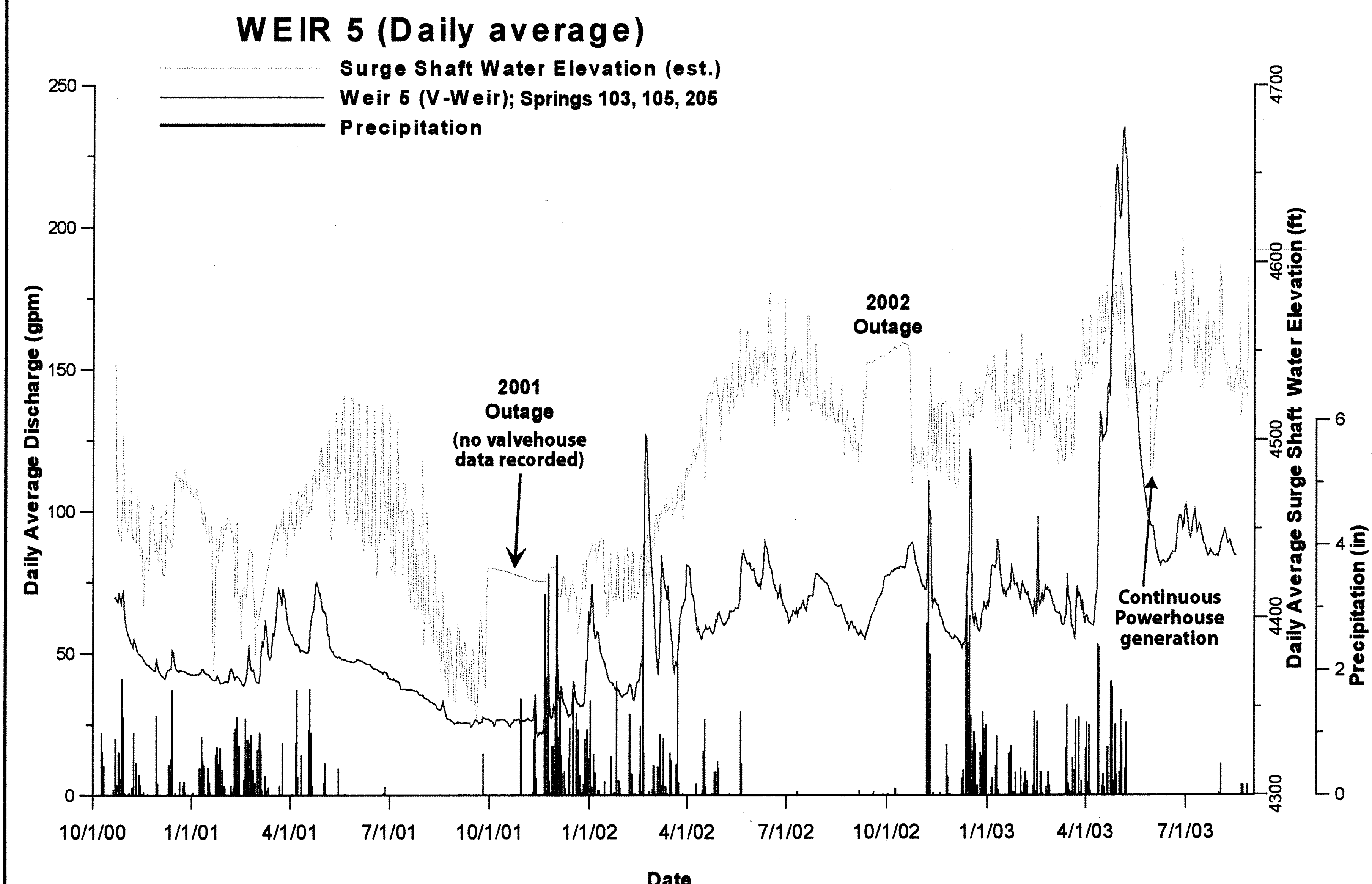


WEIR/FLUME 3 DISCHARGE FOR PERIOD OF RECORD
Geology and Hydrogeology at the Middle Fork Surge Shaft

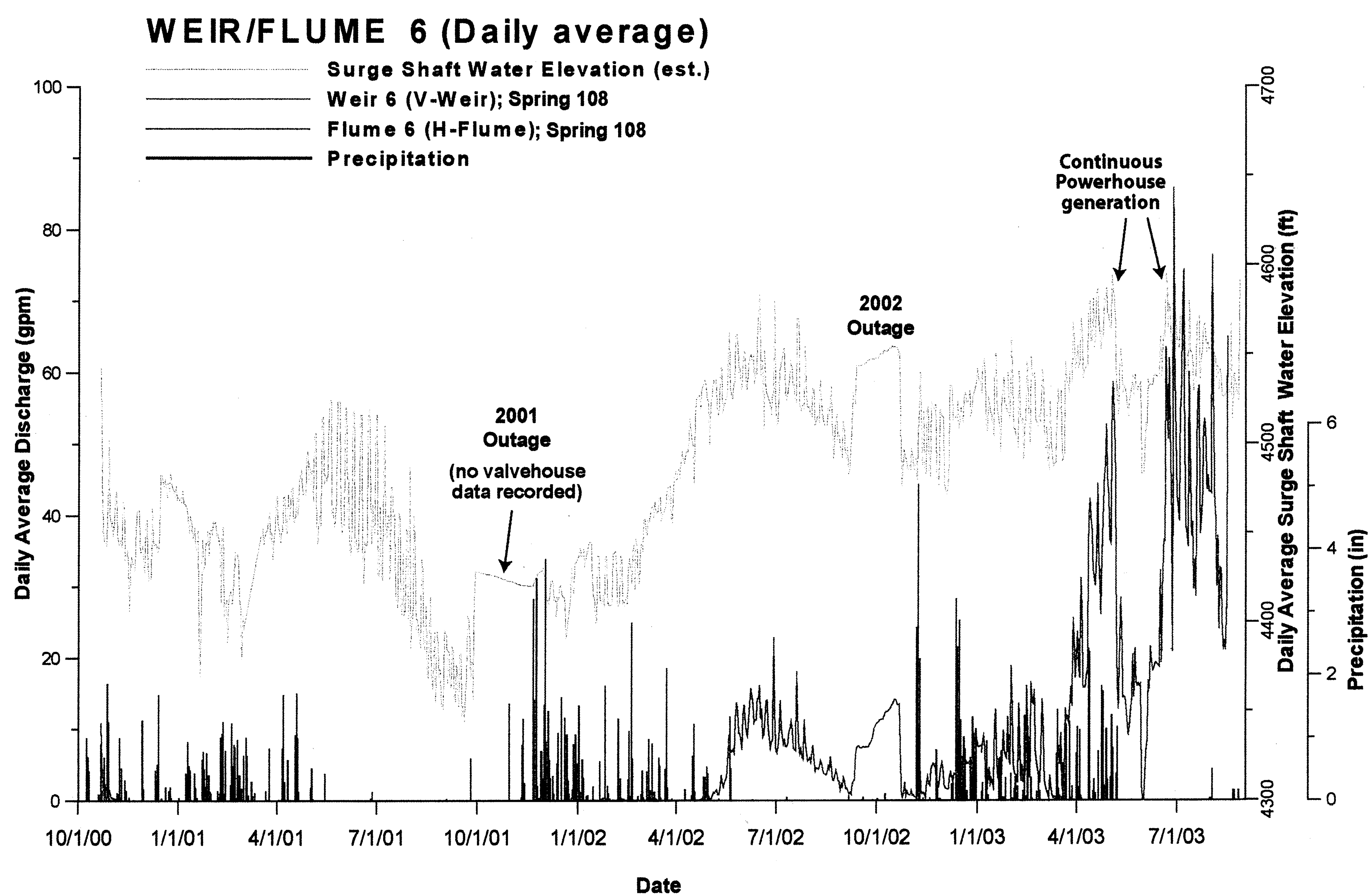
BY	APPROVED BY	PROJECT NO.	SCALE	FIGURE 3-7
TM, SB	WP	1062-107	As reported	Date 2/24/04



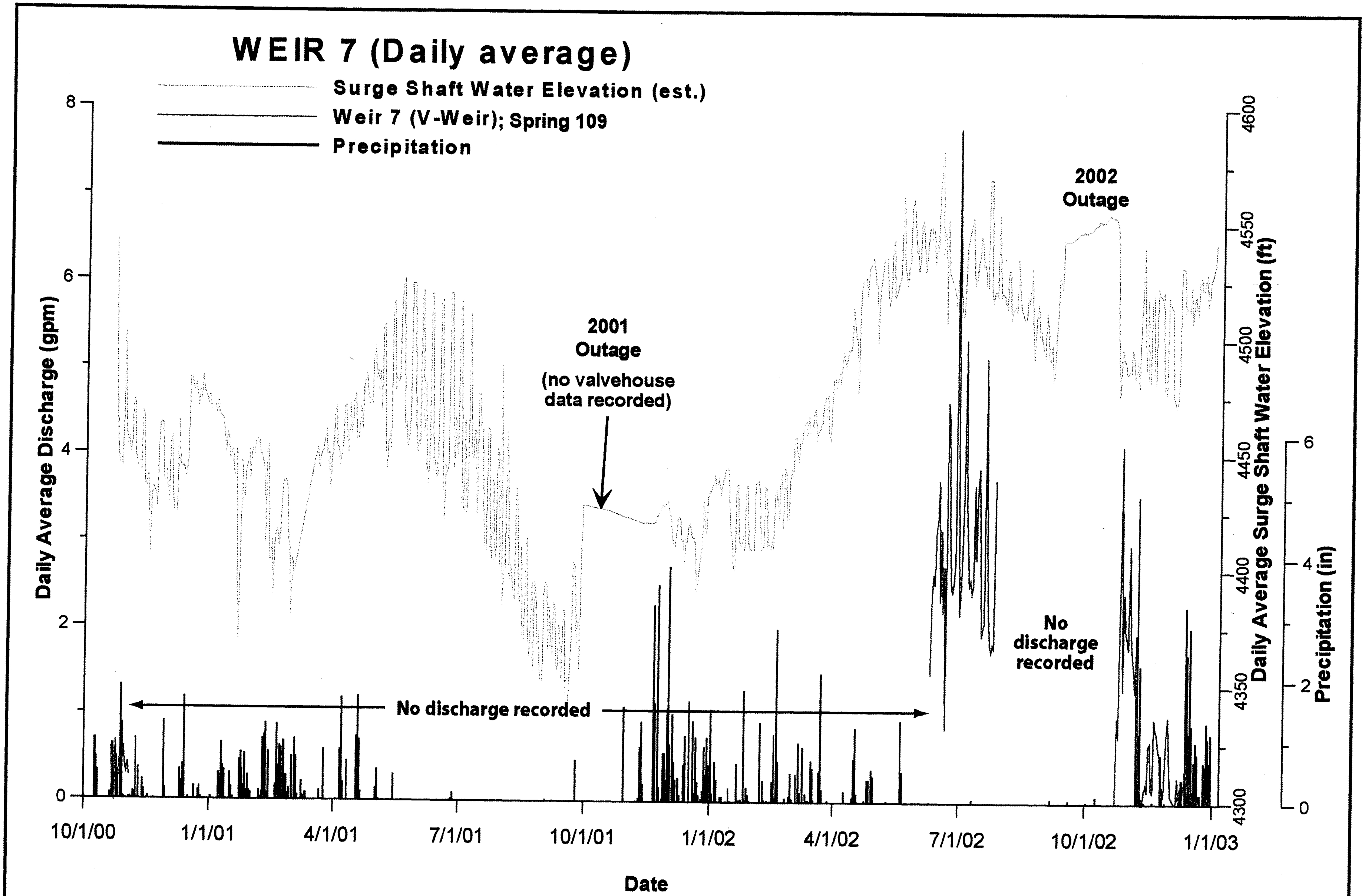
	WEIR 4 DISCHARGE FOR PERIOD OF RECORD Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-8
	BY TM,SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As reported	Date 2/24/04



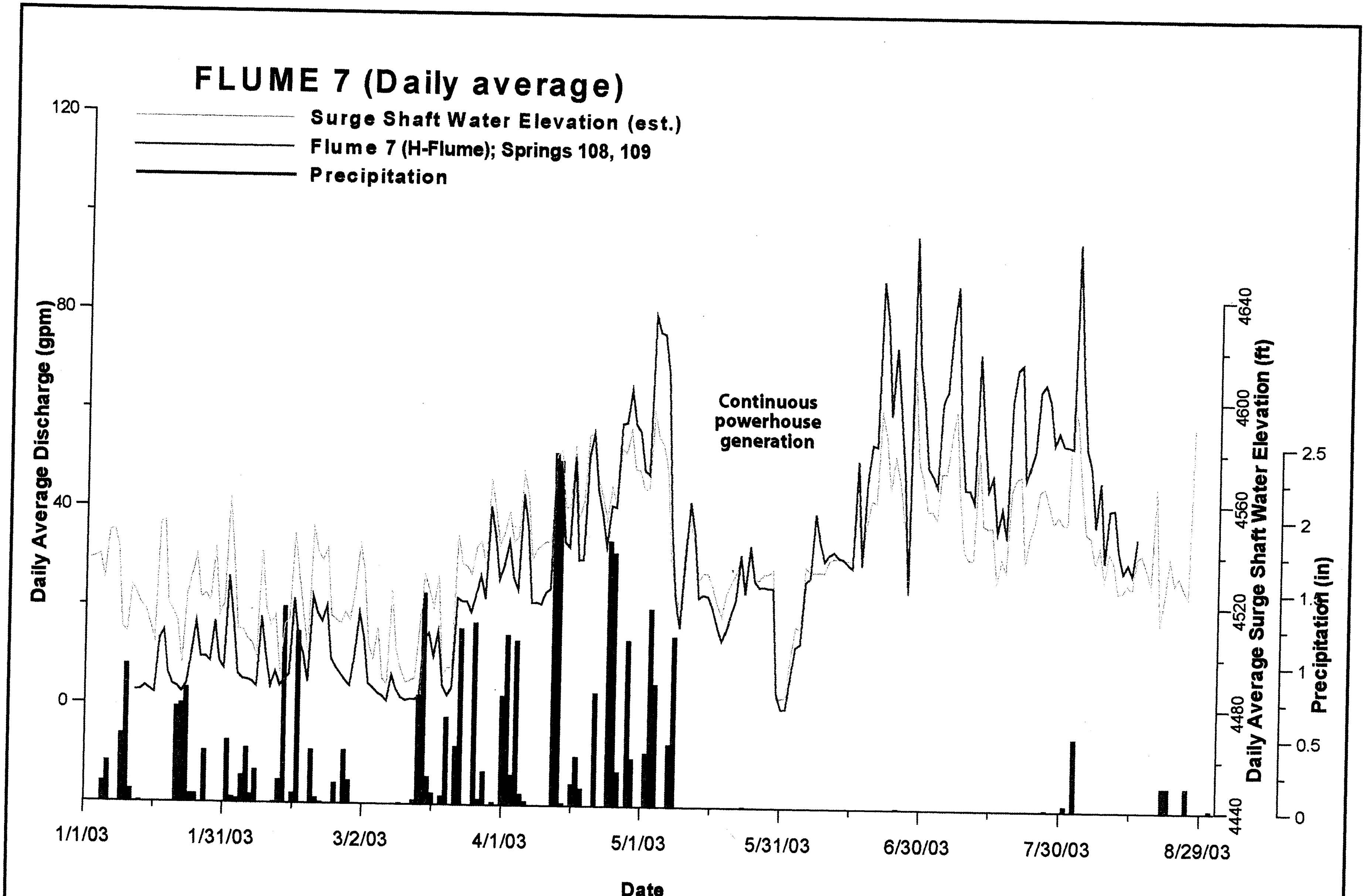
WEIR 5 DISCHARGE FOR PERIOD OF RECORD Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-9
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As reported	Date 2/24/04



WEIR/FLUME 6 DISCHARGE FOR PERIOD OF RECORD Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-10
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As reported	Date 2/24/04



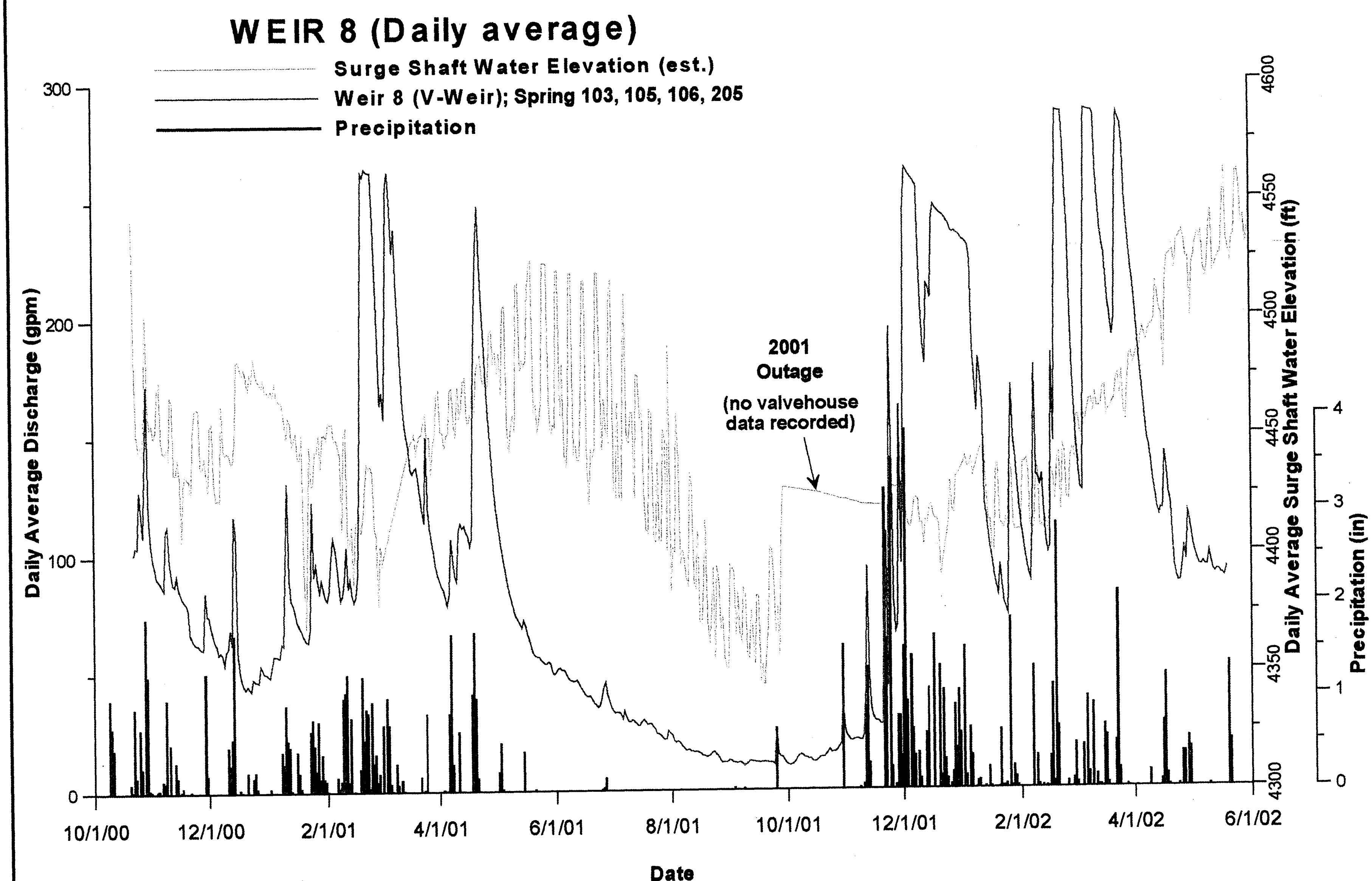
	WEIR 7 DISCHARGE FOR PERIOD OF RECORD Geology and Hydrogeology at the Middle Fork Surge Shaft	FIGURE 3-11
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107
SCALE As reported	Date 2/24/04	



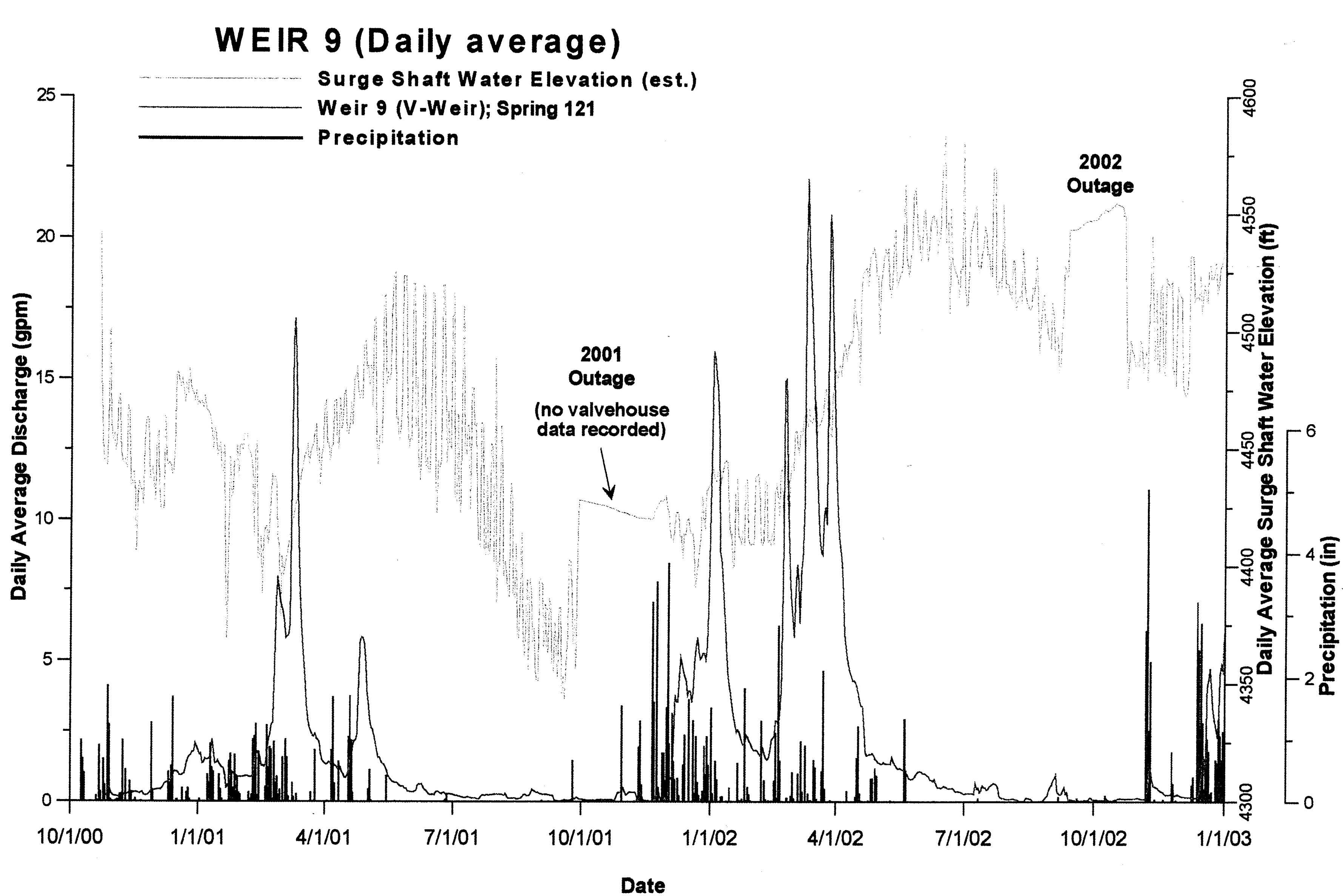
FLUME 7 DISCHARGE FOR PERIOD OF RECORD

Geology and Hydrogeology at the Middle Fork Surge Shaft

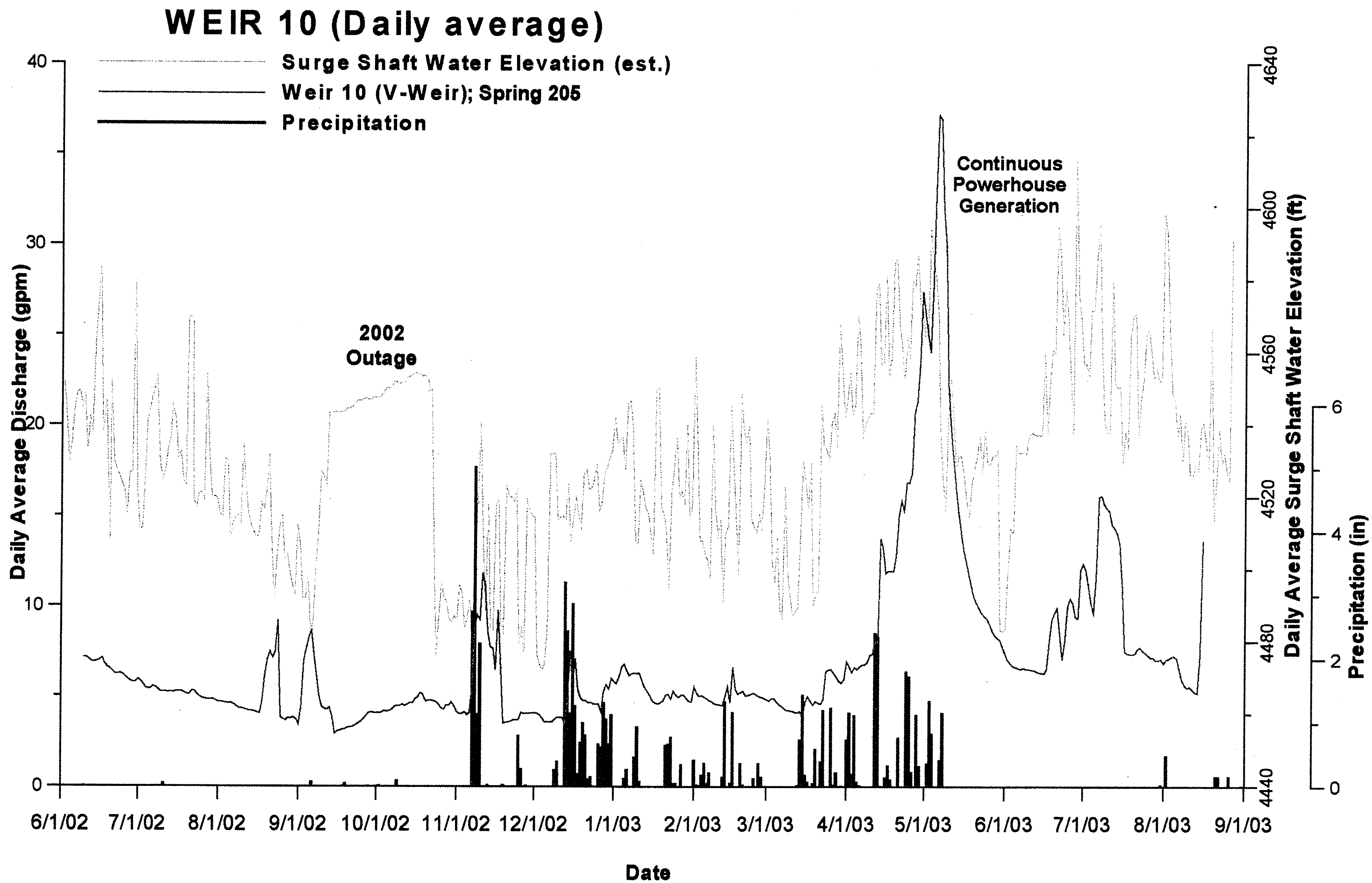
BY	APPROVED BY	PROJECT NO.	SCALE	FIGURE 3-12
TM,SB	WP	1062-107	As reported	Date 2/24/04



WEIR 8 DISCHARGE FOR PERIOD OF RECORD Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-13
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As Reported	Date 2/24/04



WEIR 9 DISCHARGE FOR PERIOD OF RECORD Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-14
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As Reported	Date 2/24/04

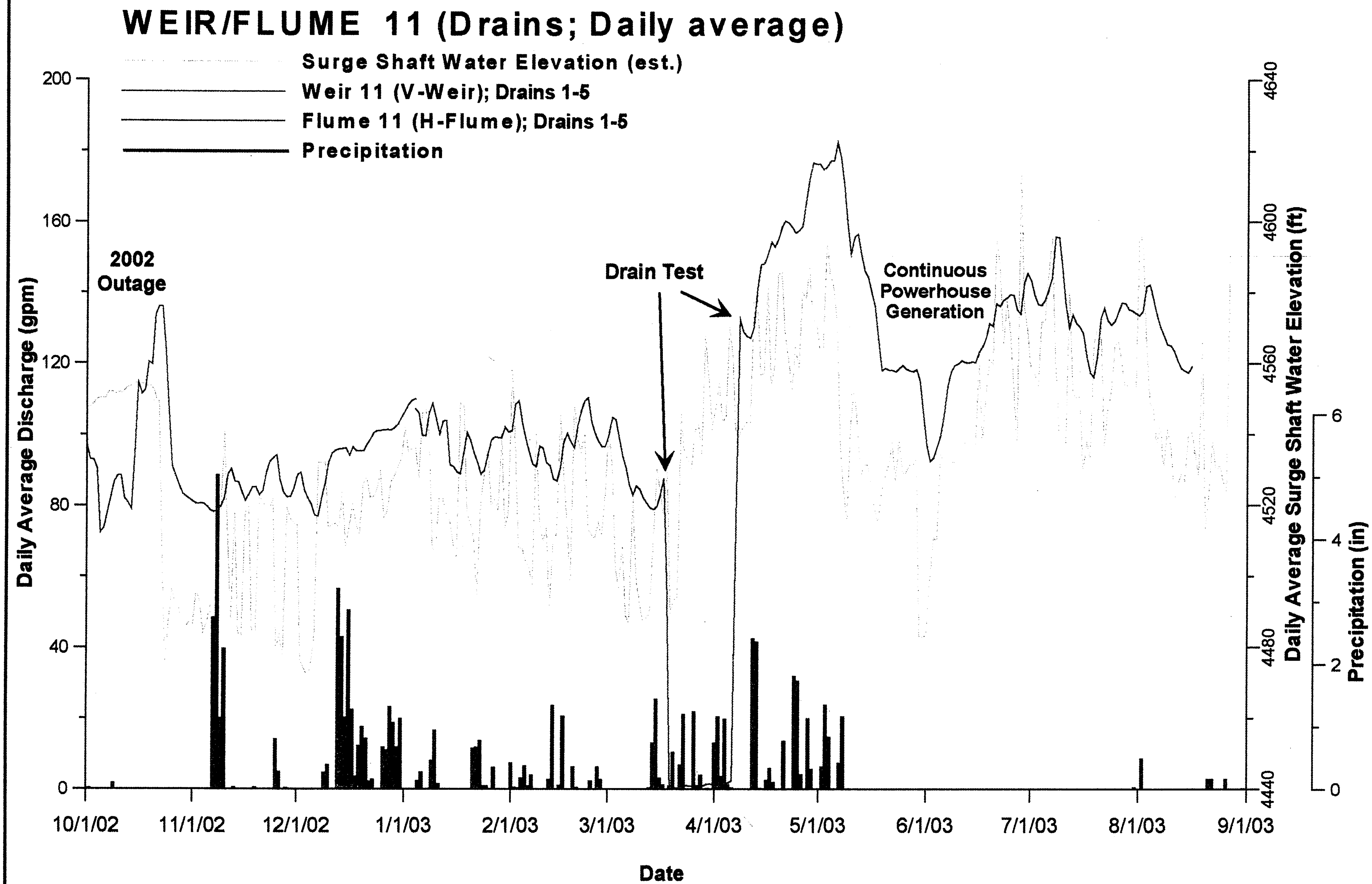


WEIR 10 DISCHARGE FOR PERIOD OF RECORD

Geology and Hydrogeology at the Middle Fork Surge Shaft

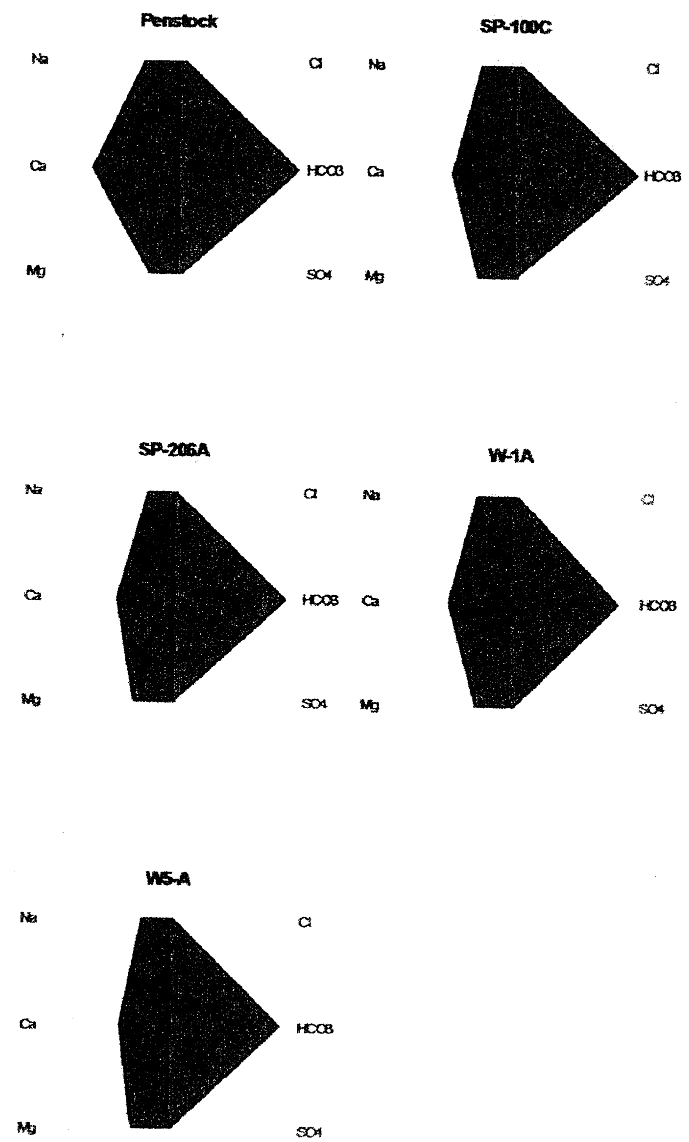
BY	APPROVED BY	PROJECT NO.	SCALE	Date
TM, SB	WP	1062-107	As Reported	2/24/04

FIGURE 3-15



	WEIR/FLUME 11 DISCHARGE FOR PERIOD OF RECORD Geology and Hydrogeology at the Middle Fork Surge Shaft			FIGURE 3-16
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As Reported	Date 2/24/04

Stiff Diagrams



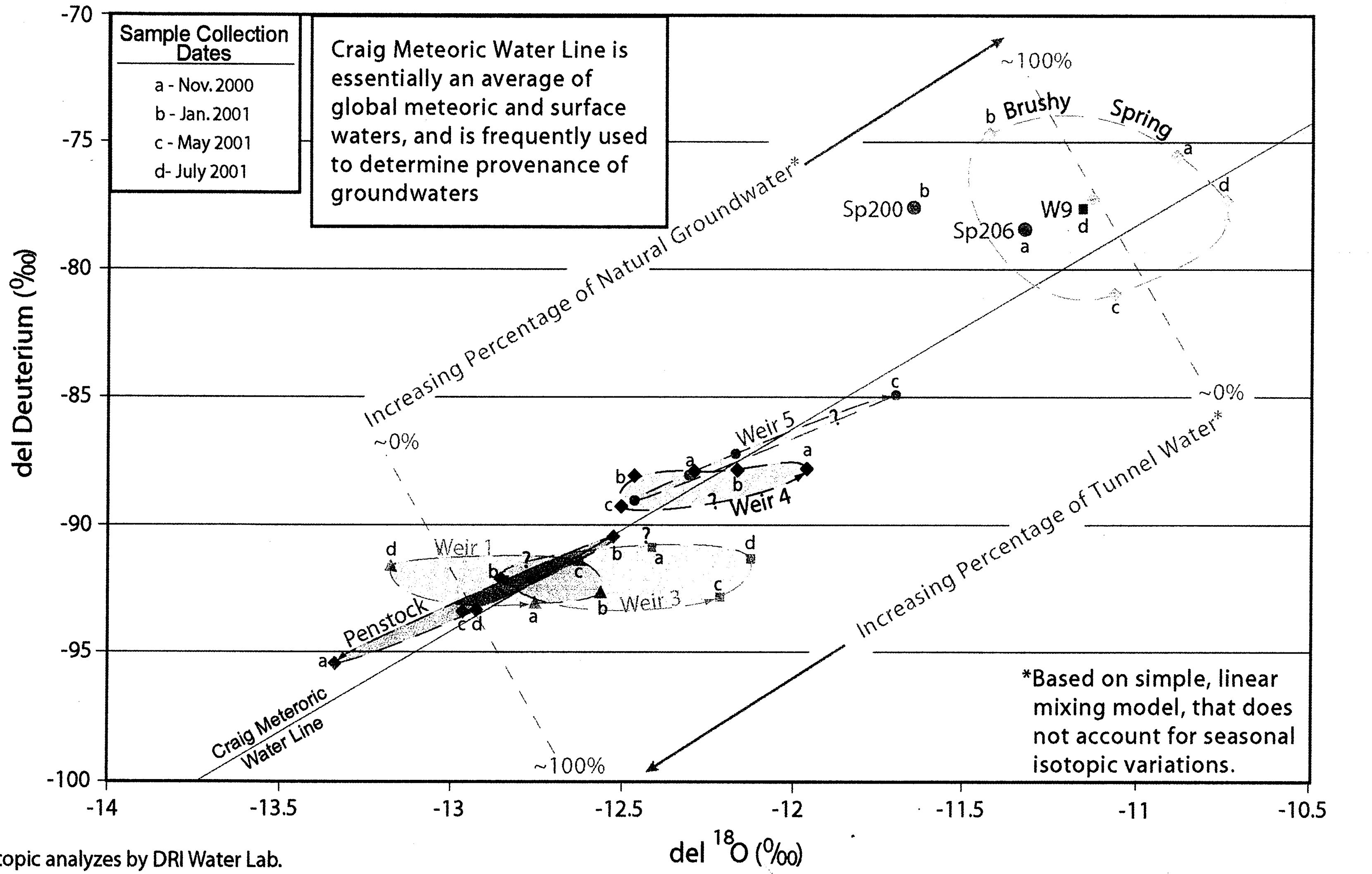
Samples collected November, 2000

STIFF DIAGRAMS OF MAJOR IONIC WATER CHEMISTRY

Geology and Hydrogeology at the Middle Fork Surge Shaft
Placer County, California

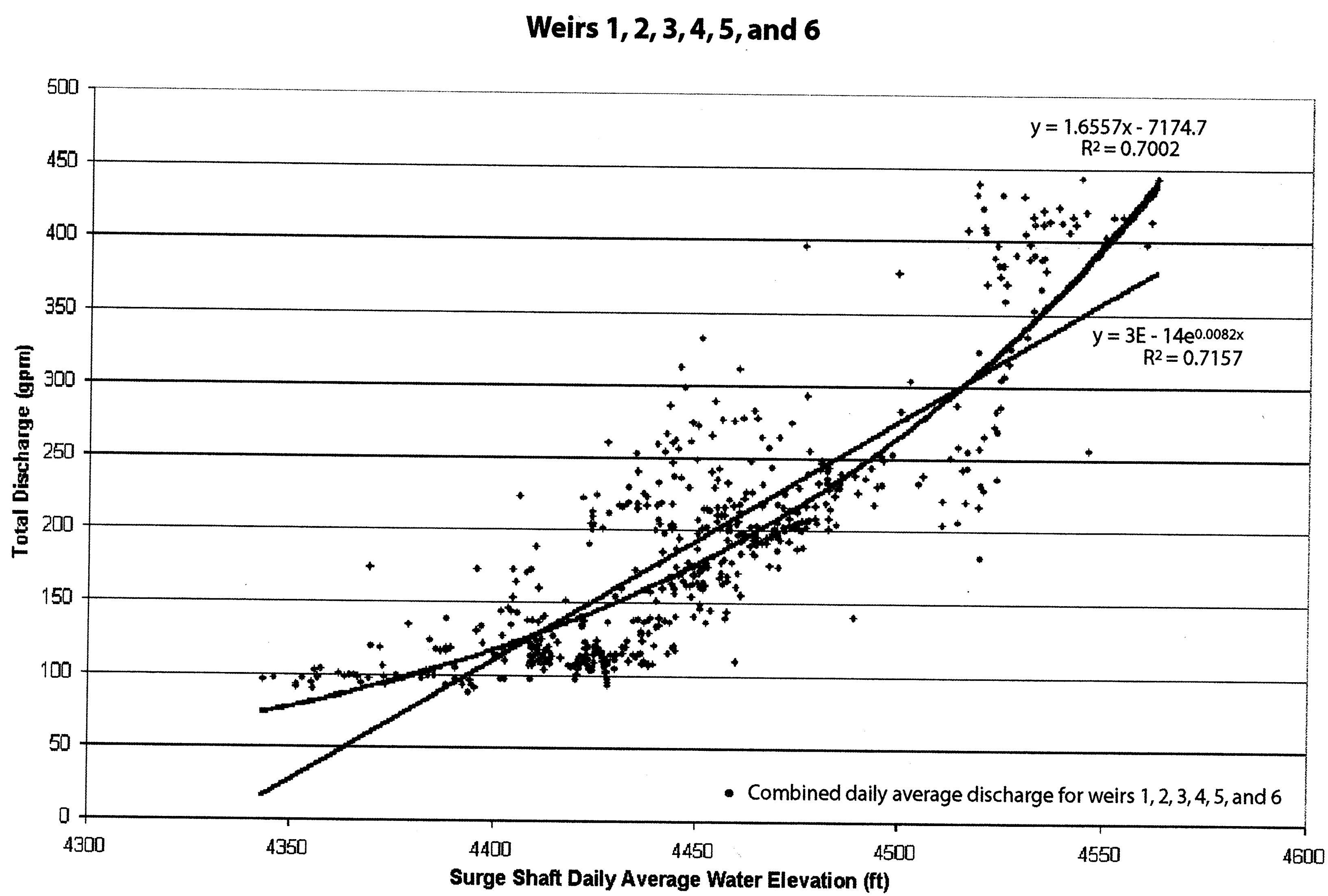
Figure 3-17

1062-107

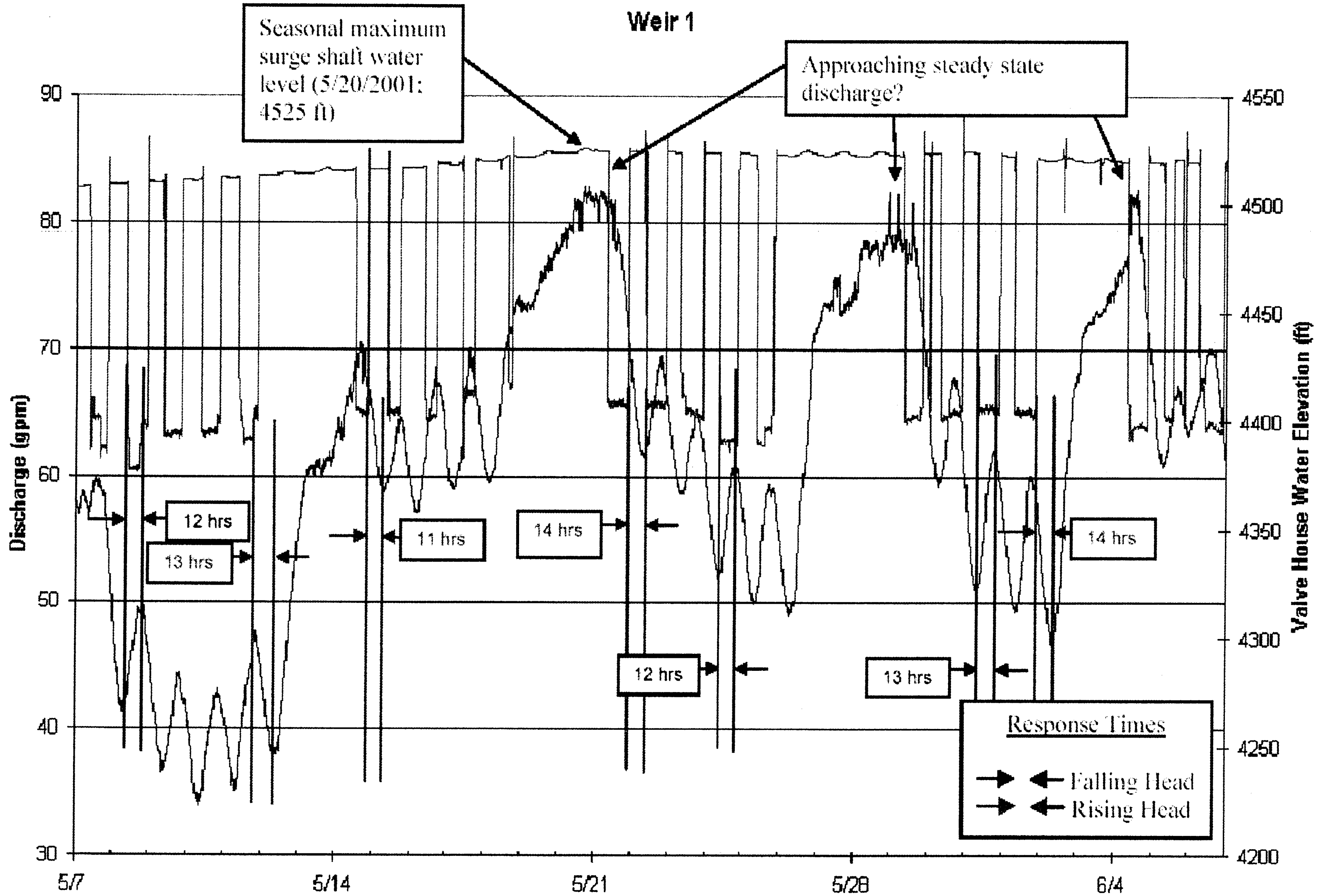


Isotopic analyzes by DRI Water Lab.

ISOTOPIC COMPOSITION OF GROUNDWATER AND TUNNEL WATER Geology and hydrogeology at Middle Fork Surge Shaft				FIGURE 3-18
MIXING MODEL BY TM	APPROVED BY WP	PROJECT NO. 1062-107	SCALE N/A	Date 2/24/04



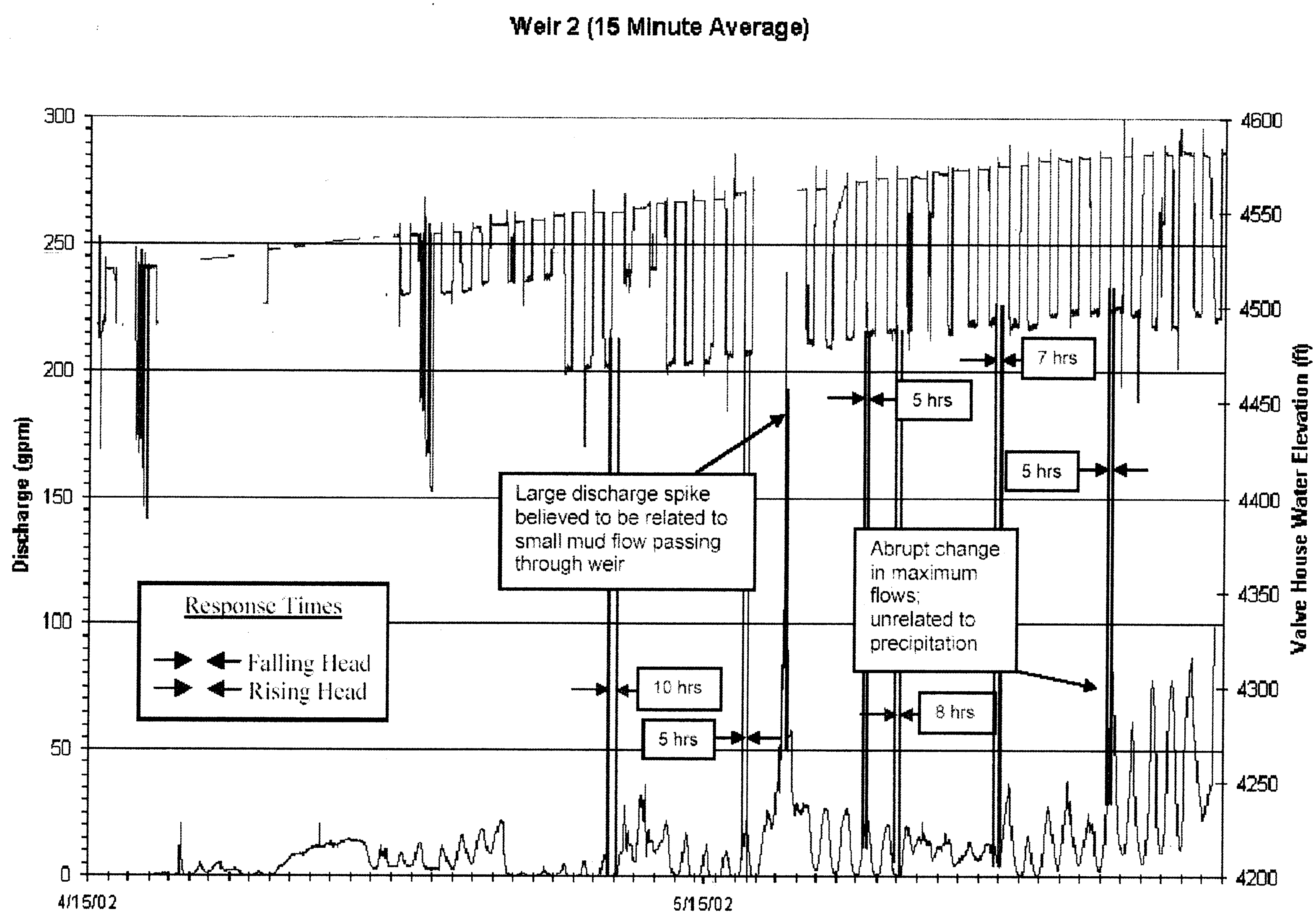
RELATIONSHIP BETWEEN SURGE SHAFT WATER ELEVATION AND DAILY AVERAGE DISCHARGE BETWEEN OCTOBER, 2000 AND JUNE, 2002 Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-19
BY TS	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As reported	Date 2/24/03



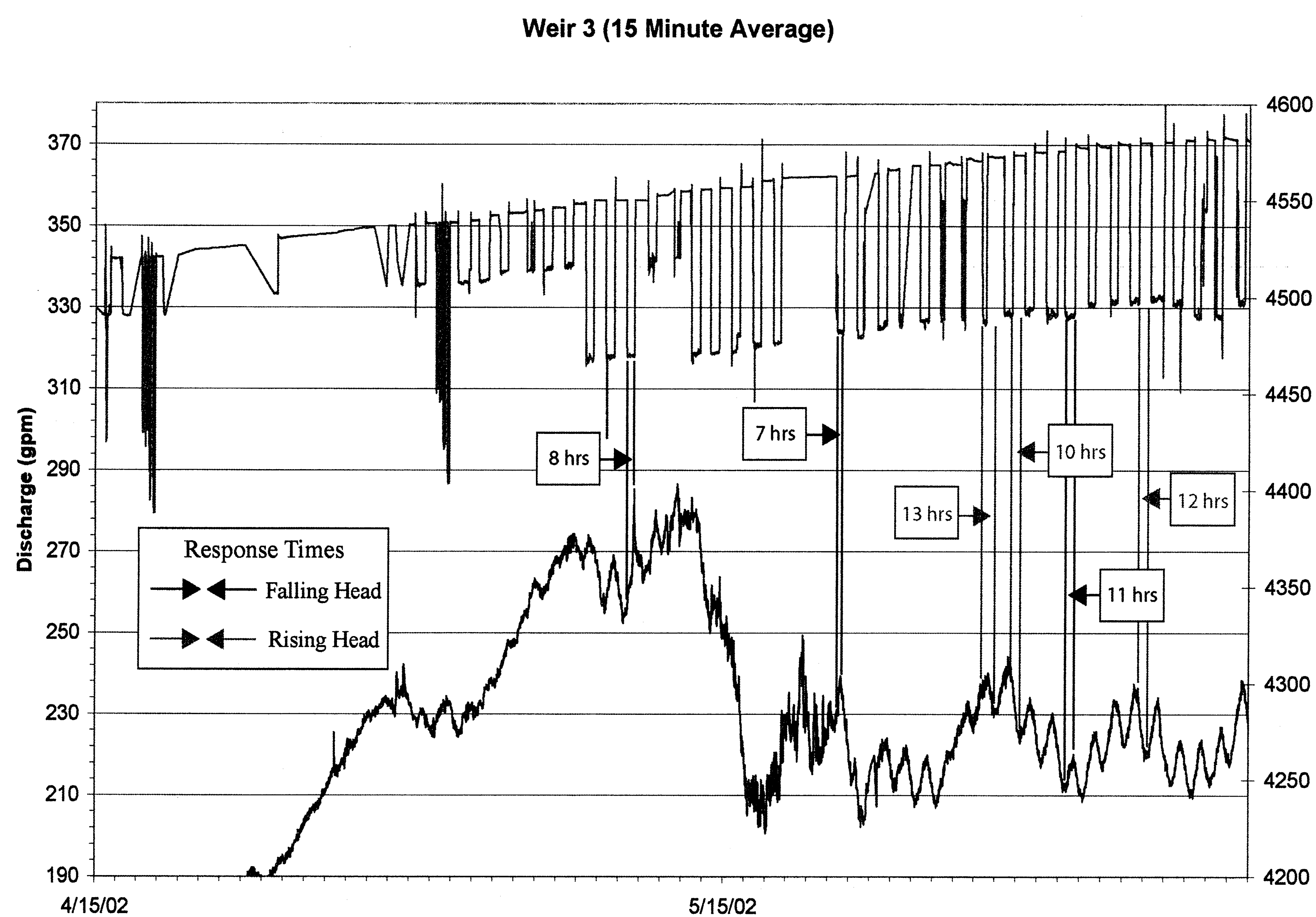
RESPONSE TIME OF WEIR 1 TO VALVEHOUSE WATER LEVELS

Geology and Hydrogeology at the Middle Fork Surge Shaft

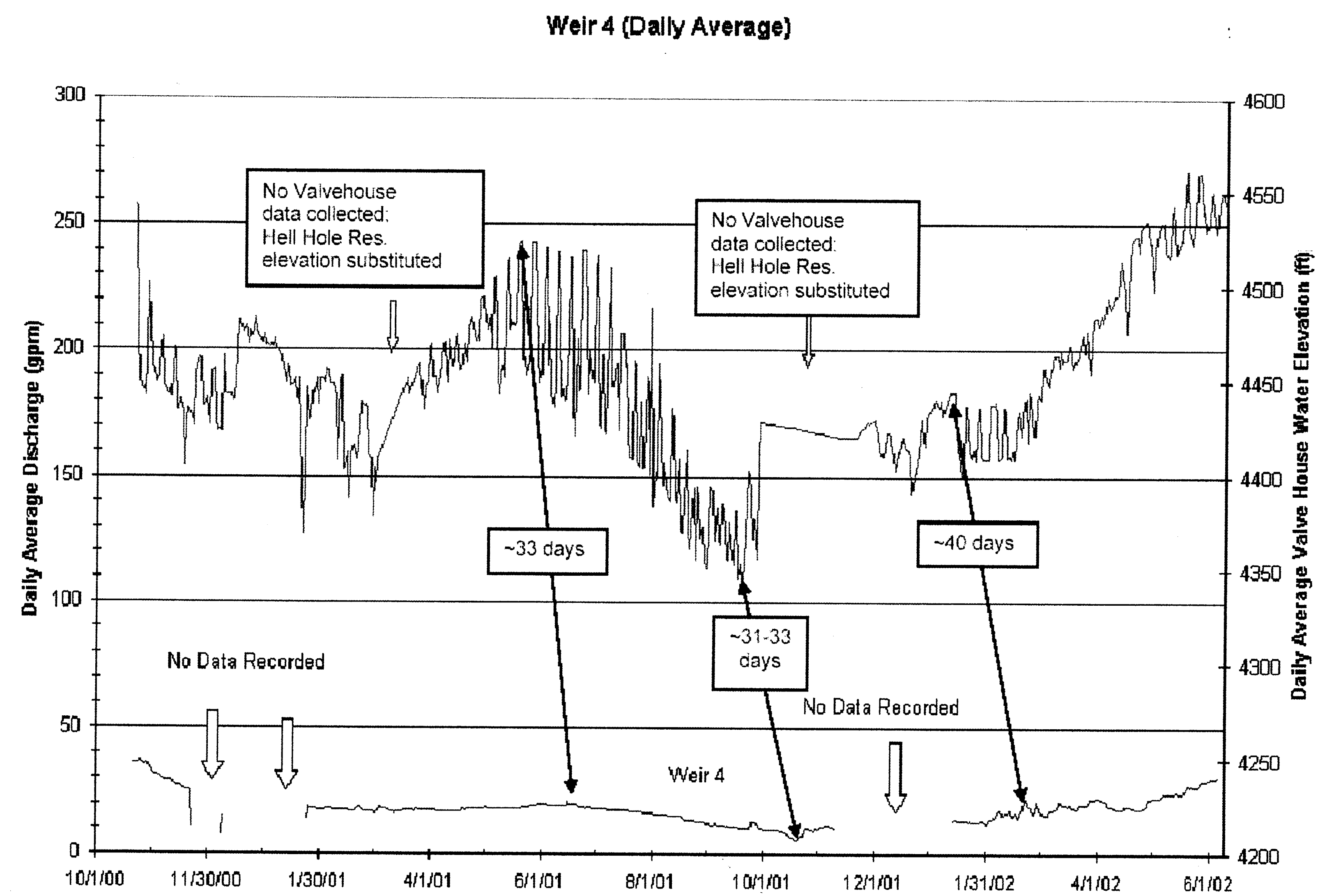
BY	APPROVED BY	PROJECT NO.	SCALE	FIGURE	Date
TS	WP	1062-107	As reported	3-20	2/24/04



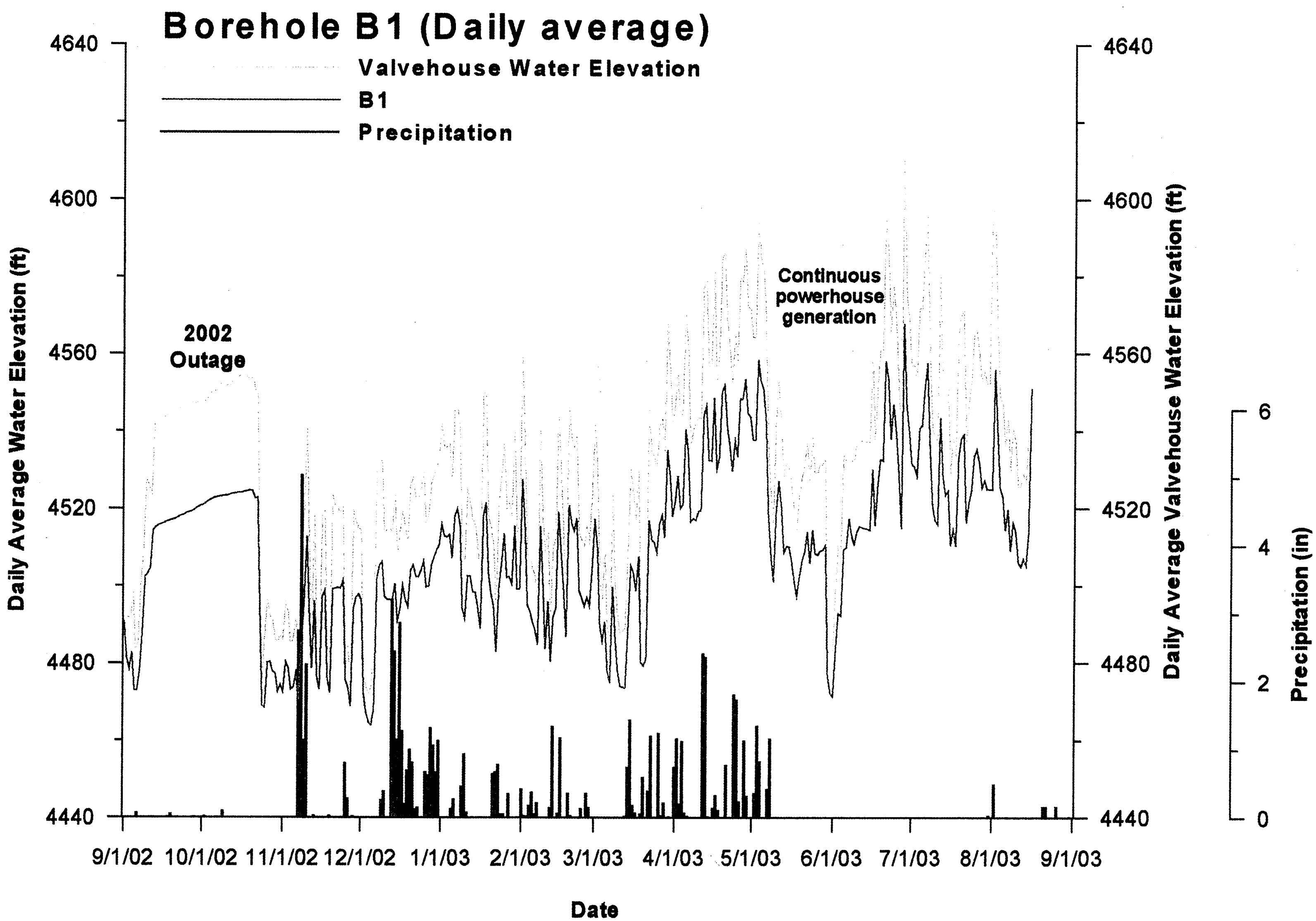
	RESPONSE TIME OF WEIR 2 TO VALVEHOUSE WATER LEVELS Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-21
	BY TS	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As reported	Date 2/24/04



RESPONSE TIME OF WEIR 3 TO VALVEHOUSE WATER LEVELS Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-22
BY TS	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As reported	Date 2/24/04



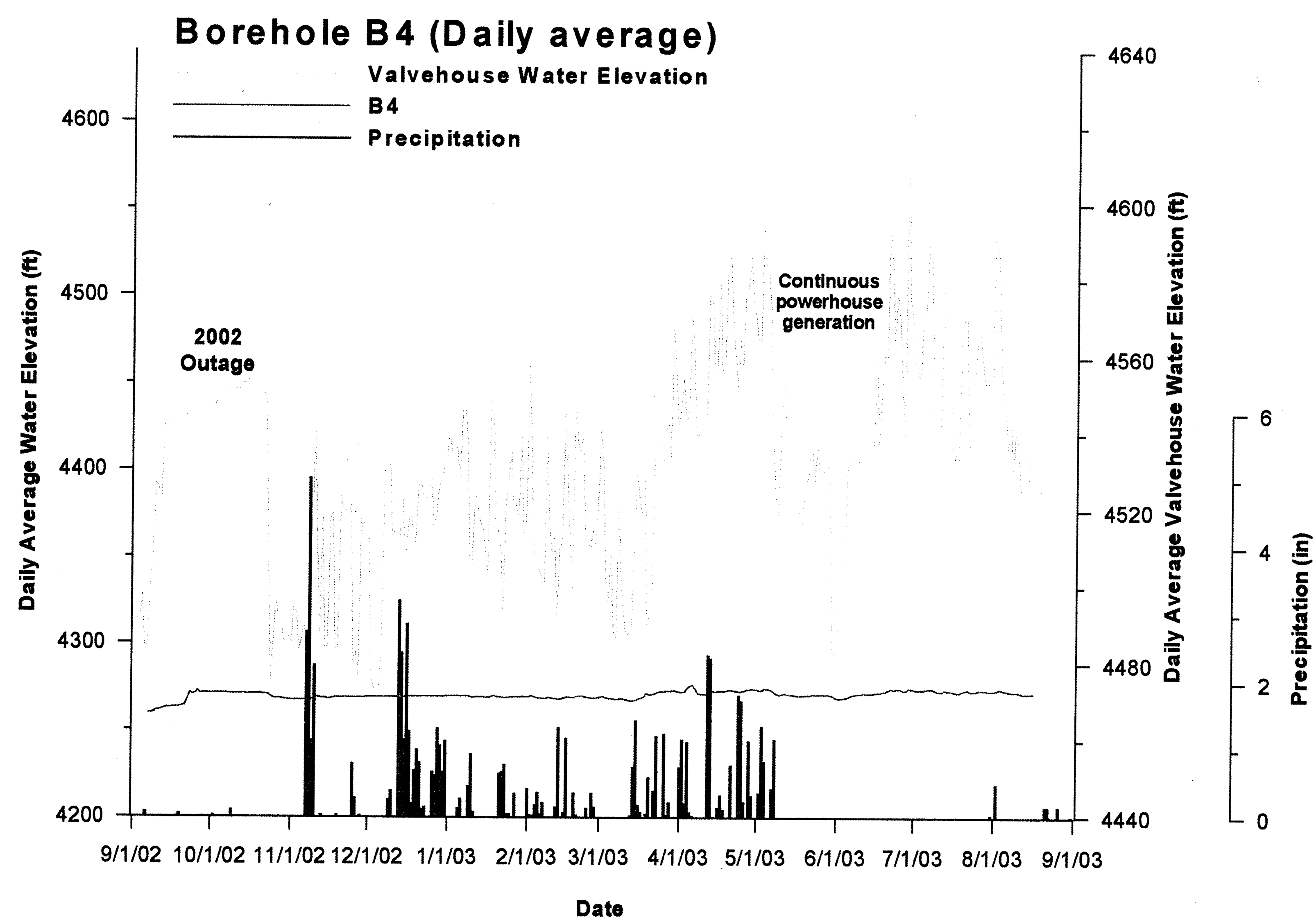
RESPONSE TIME OF WEIR 4 TO VALVEHOUSE WATER LEVELS Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-23
BY TS	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As reported	Date 2/24/04



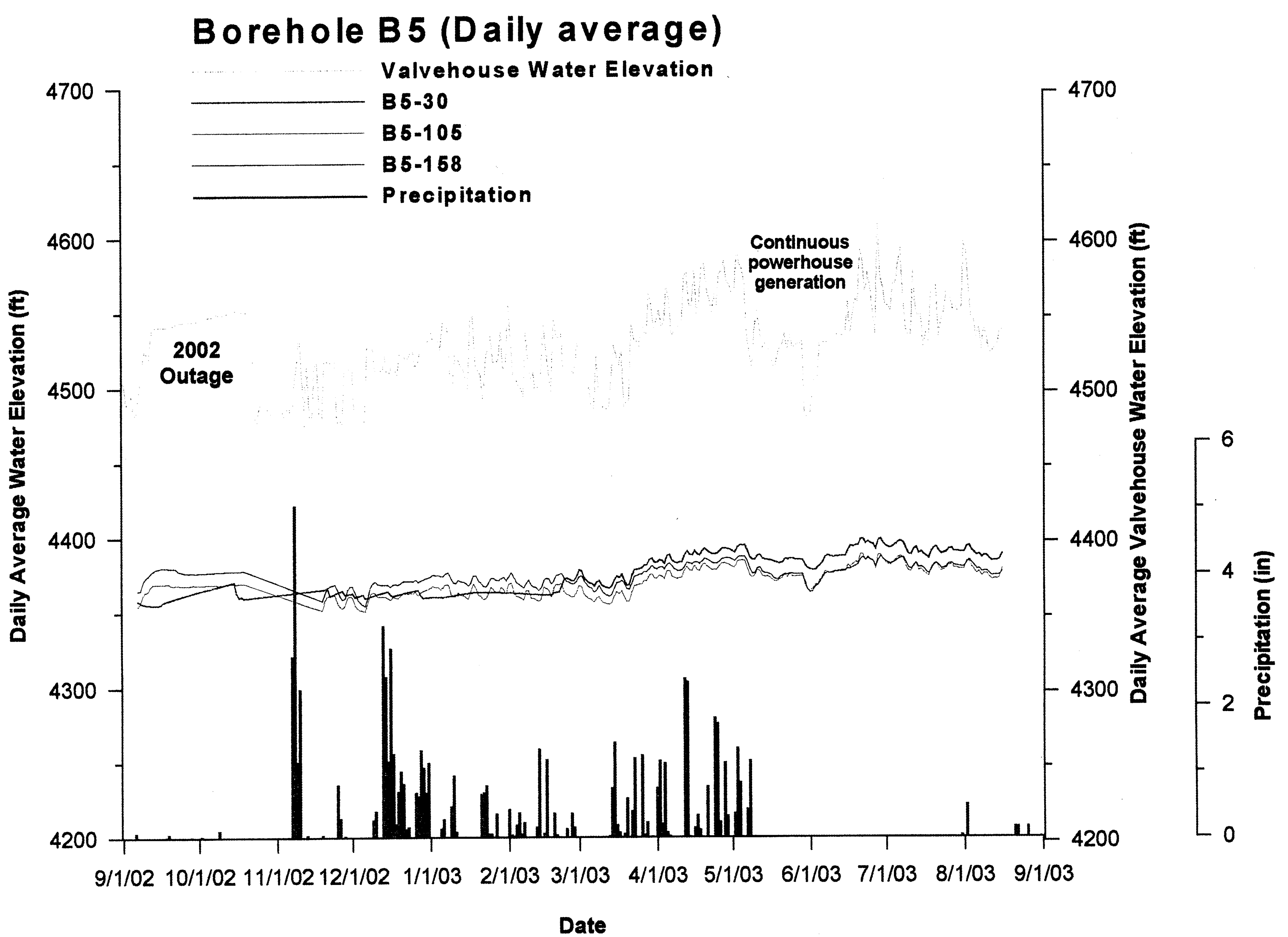
B1 WATER ELEVATIONS FOR PERIOD OF RECORD

Geology and Hydrogeology at the Middle Fork Surge Shaft

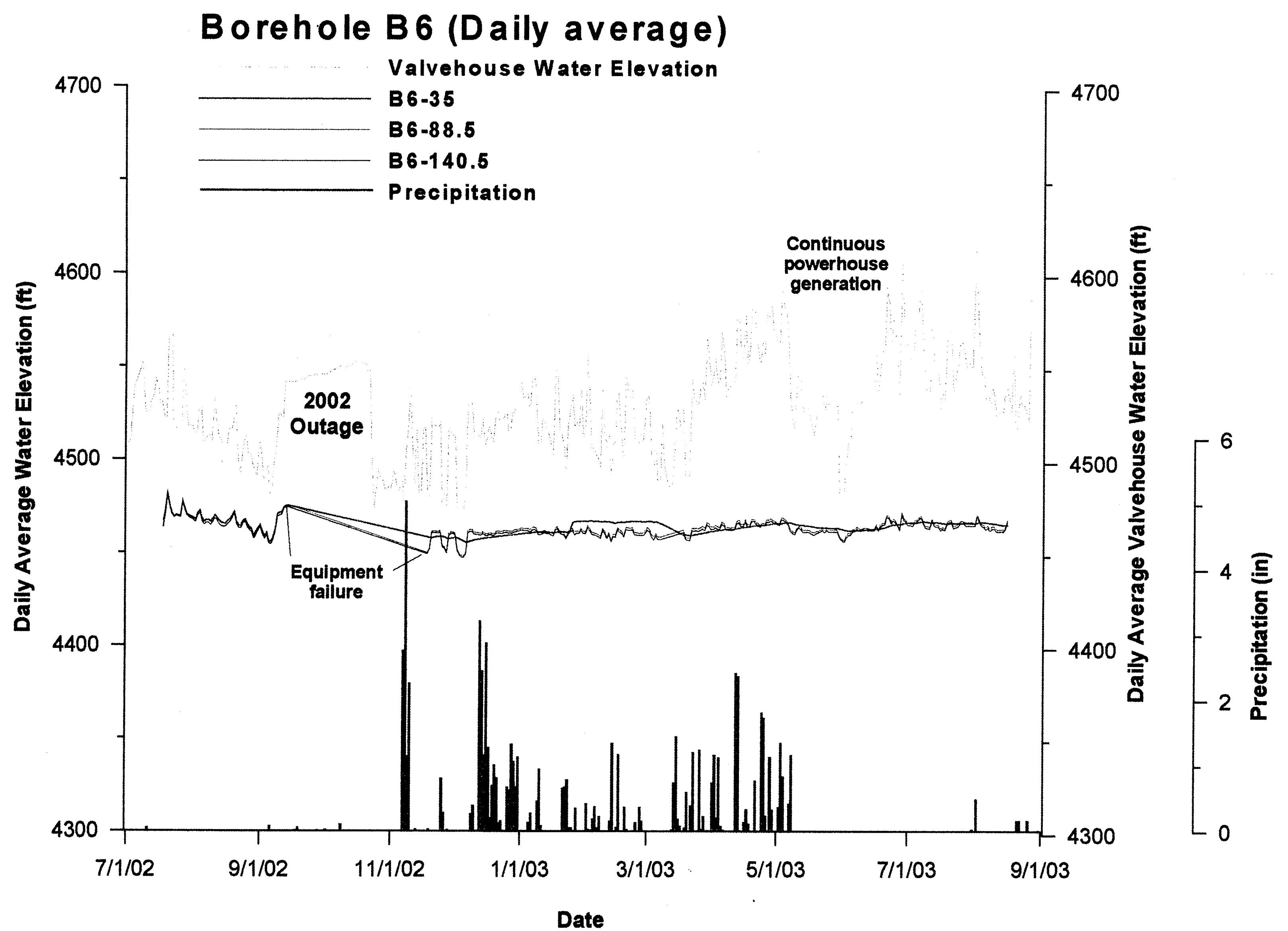
BY	APPROVED BY	PROJECT NO.	SCALE	FIGURE 3-24
TM, SB	WP	1062-107	AS REPORTED	Date 2/24/04



B4 WATER ELEVATIONS FOR PERIOD OF RECORD Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-26
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE AS REPORTED	Date 2/24/04



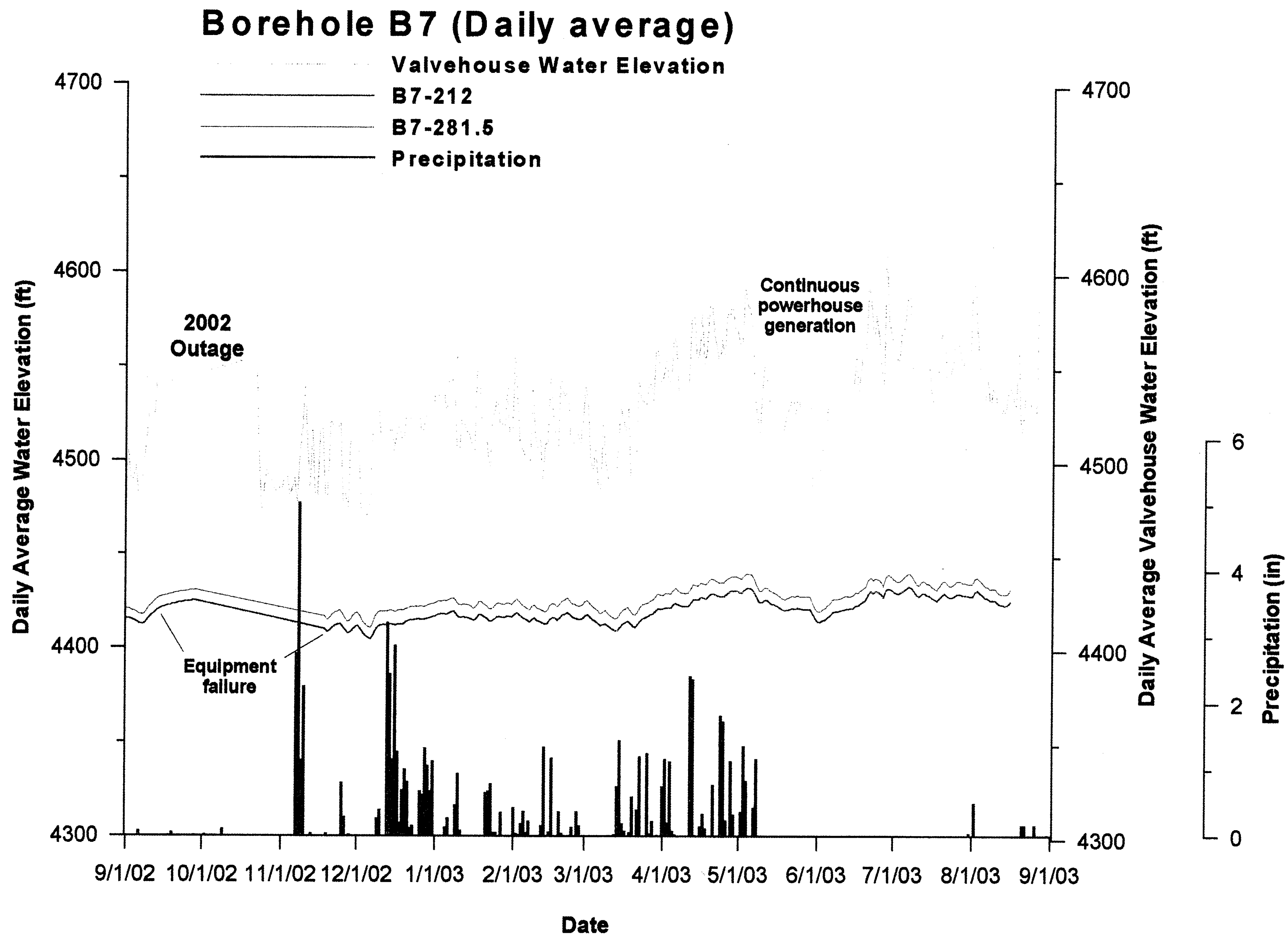
B5 WATER ELEVATIONS FOR PERIOD OF RECORD Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-27
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE AS REPORTED	Date 2/24/04



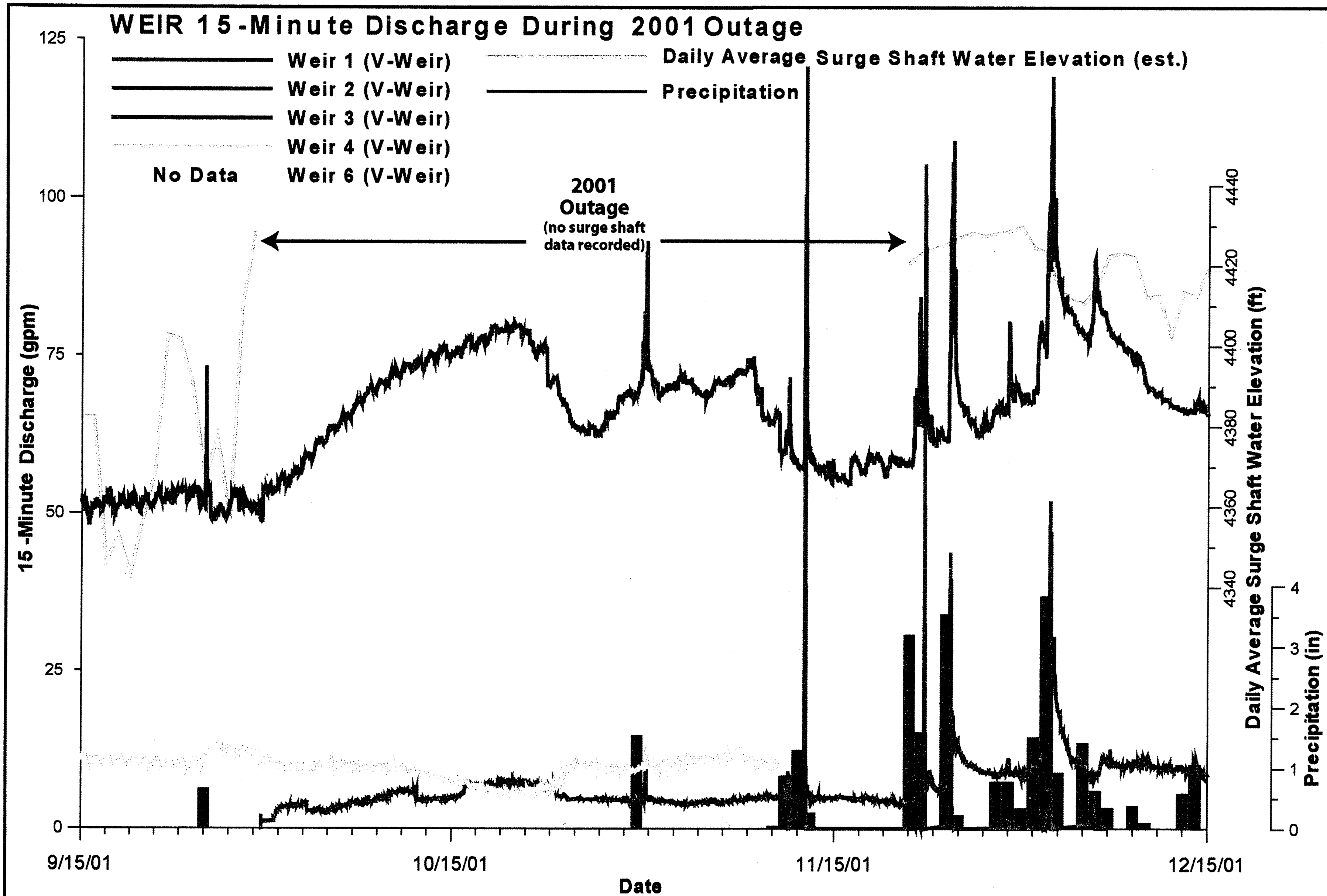
B6 WATER ELEVATIONS FOR PERIOD OF RECORD

Geology and Hydrogeology at the Middle Fork Surge Shaft

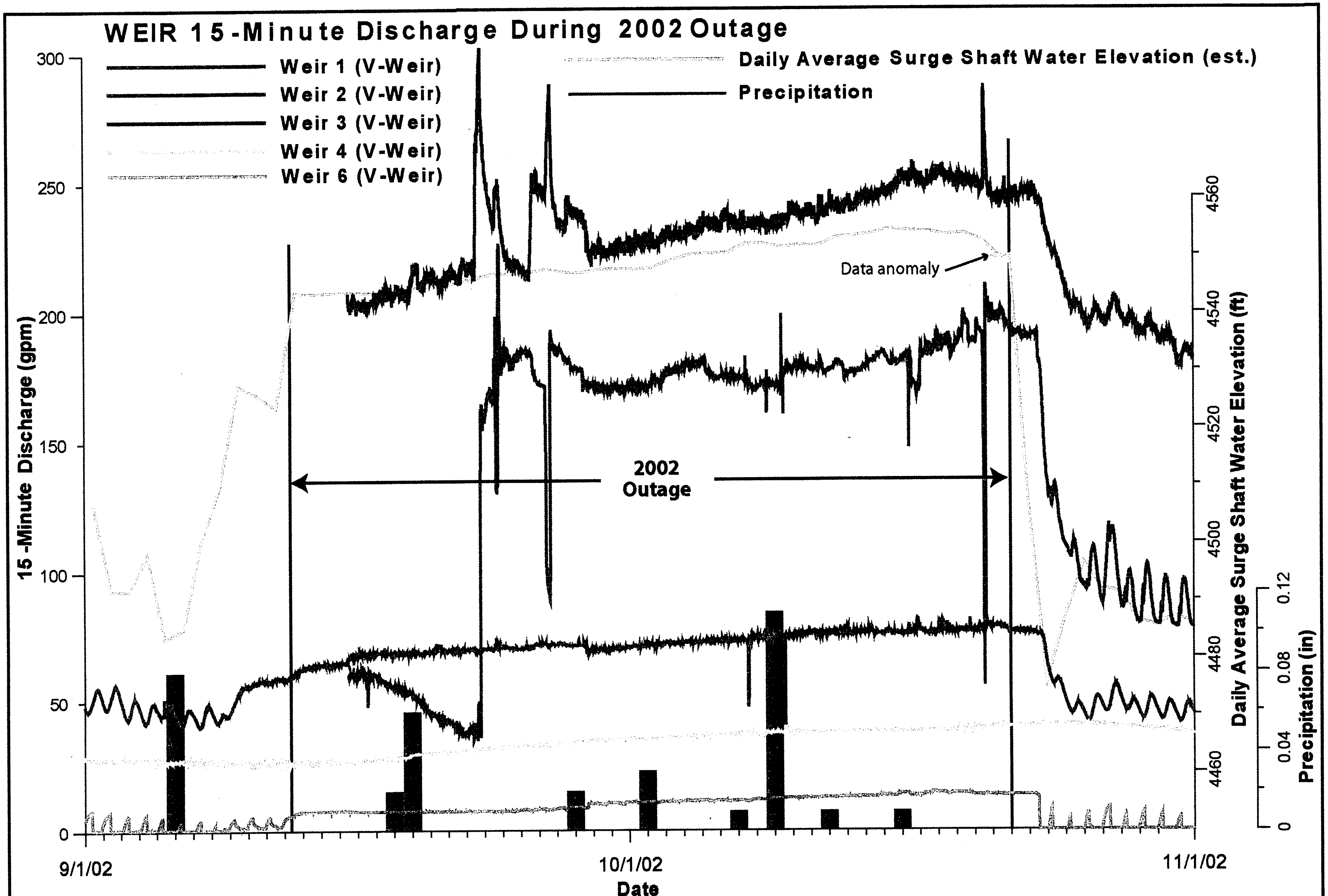
BY	APPROVED BY	PROJECT NO.	SCALE	FIGURE
TM, SB	WP	1062-107	AS REPORTED	3-28
				Date 2/24/04



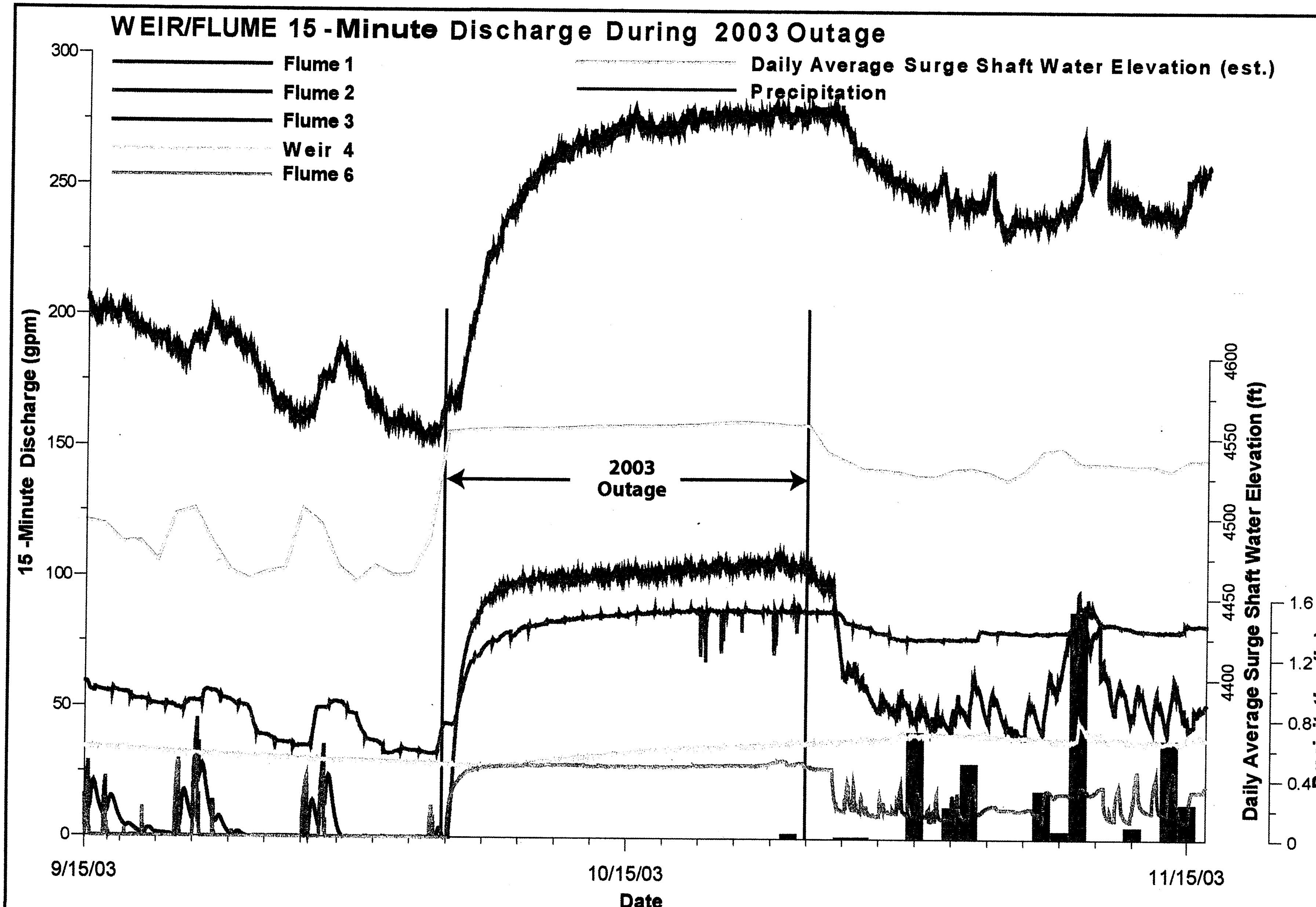
B7 WATER ELEVATIONS FOR PERIOD OF RECORD Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-29
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE AS REPORTED	Date 2/24/04



WEIR DISCHARGE DURING 2001 OUTAGE Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-30
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As reported	Date 2/24/04



	WEIR DISCHARGE DURING 2002 OUTAGE Geology and Hydrogeology at the Middle Fork Surge Shaft			FIGURE 3-31
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As reported	Date 2/24/04



WEIR/FLUME DISCHARGE DURING 2003 OUTAGE Geology and Hydrogeology at the Middle Fork Surge Shaft				FIGURE 3-32
BY TM, SB	APPROVED BY WP	PROJECT NO. 1062-107	SCALE As reported	Date 2/24/04

6.0 APPENDICES

APPENDIX A

PREVIOUS TECHNICAL DOCUMENTS

Cotton-Shires & Associates, Piedmont GeoSciences, and PG&E Geosciences Department, 2000, Middle Fork Tunnel, Surge Shaft and Penstock, engineering geologic and geotechnical report, Placer County, California: Report for PG&E Hydro-Generation Department, October 31, 2000, 72p., plus tables, figures, plates and appendices.

Geosciences Department, 2000, PCWA Middle Fork Tunnel, historic documents: compilation of documents concerning planning and construction of the Middle Fork Tunnel; report for PG&E Hydro Generation Department; 79 documents listed with copies included.

McManus, R., 2002, Notes on Middle Fork Surge Shaft Construction records: report for Middle Fork Technical Subcommittee, January 30, 2002, 4 p.

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APPENDIX B

WELL, WEIR, AND FLUME MONITORING DIGITAL DATA FILES, CD-R

(see back pocket)