Pacific Gas and Electric Company®

Power Generation

245 Market Street
San Francisco, CA 94105

Mailing Address
Mail Code N11C
P. O. Box 770000
San Francisco, CA 94177

January 31, 2013

Via Electronic Submittal (E-File)

Ms. Barbara Evoy
Deputy Director, Division of Water Rights
State Water Resources Control Board
1001 I Street, 14th Floor
Sacramento, CA 95814

The Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE. Room I-A
Washington, D.C. 20426

RE: Pit 1 Hydroelectric Project, FERC No. 2687
Shasta Crayfish Study Report

Dear Ms. Evoy and Secretary Bose:

Enclosed please find the Pit 1 Shasta Crayfish Study Report (Attachment A), which presents the results of the Shasta Crayfish Study Plan (Study Plan) for Pacific Gas and Electric Company's (PG&E's) Pit 1 Hydroelectric Project (FERC No. 2687). PG&E submitted the Study Plan on June 29, 2010 in compliance with Paragraph 3 of the *Order Approving Temporary Suspension of Flushing Flows Requirements* issued July 6, 2010 by the State Water Resources Control Board (SWRCB) and Paragraph A of the *Order Temporarily Amending License and Incorporating Temporary Amendment to Water Quality Certification* issued August 10, 2010 by the Federal Energy Regulatory Commission (FERC). Following State Water Board approval of a PG&E time extension request, FERC issued an order on September 28, 2012 extending the deadline to file the Shasta Crayfish Study Report to January 31, 2013.

A draft of this report was transmitted to the SWRCB, California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), and members of the Shasta Crayfish Technical Review Group (TRG) for their review on October 31, 2012 (Attachment B). Comments were received via email from the USFWS and SWRCB on December 11 and December 13, 2012 respectively. PG&E received comments from CDFW by letter dated December 21, 2012. The emails and letter transmitting comments are included in Attachment B. A follow-up call was held on December 18, 2012 with PG&E and SWRCB staff to discuss and clarify their comments. In response to the comments received, the report was restructured and text was expanded or clarified accordingly.

If you have any questions regarding this submittal, please contact me at (415) 973-5747, or by email at J3AD@pge.com.

Sincerely,

Jessica Albietz, License Coordinator
Hydro Licensing

Attachment A: *Pit 1 Shasta Crayfish Study Report, Pursuant to California State Water Resources Control Board Order WQ 2010-0009-Exec*

Attachment B: Consultation History

- Email from PG&E to Shasta Crayfish TRC and Agencies dated October 31, 2012 asking for review of the Draft Shasta Crayfish Study Report
- Letter from CDFG to PG&E dated December 21, 2012 with comments
- Email from USFWS to PG&E dated December 11, 2012 transmitting comments
- Email from SWRCB to PG&E dated December 13, 2012 transmitting comments

cc: Electronically via email

Peter Barnes
State Water Resources Control Board
Division of Water Rights
P.O. Box 2000
Sacramento, CA 95812-2000
PBarnes@waterboards.ca.gov

Kim Squires
U.S. Fish and Wildlife Service
2800 Cottage Way, Room W-2605
Sacramento, CA 95825
kim_squires@fws.gov

Ryan Olah
U.S. Fish and Wildlife Service
2800 Cottage Way, Room W-2605
Sacramento, CA 95825
Ryan_olah@fws.gov

Josh Hull
Recovery Branch Chief
U.S. Fish and Wildlife Service
2800 Cottage Way, Room W-2605
Sacramento, CA 95825
Josh_Hull@fws.gov

Matthew Myers
California Department of Fish and Wildlife
601 Locust St.
Redding, CA 96001
Mmyers@dfg.ca.gov

Steve Baumgartner
Region 1 Fishery Biologist
California Department of Fish and Wildlife
601 Locust Street
Redding, CA 96001
sbaumgartner@dfg.ca.gov

Glenn Yoshioka
Native Nongame Fishes Coordinator
California Department of Fish and Game
1416 Ninth Street, 12th Floor, Suite 1280
Sacramento, CA 95814
gyoshioka@dfg.ca.gov

Maria Ellis
Spring Rivers Ecological Sciences LLC
P.O. Box 153
21451 Cassel Road
Cassel, CA 96016
maria@springrivers.com

Theo Light
Department of Biology
Shippensburg University
1871 Old Main Drive
Shippensburg, PA 17257
tsligh@ship.edu

Jessica Petersen
Post-doctoral Associate
University of Minnesota
St Paul, MN 55108
jlpetersen@ucdavis.edu

PIT 1 SHASTA CRAYFISH STUDY REPORT

PURSUANT TO

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD ORDER WQ 2010-0009-EXEC

Pit 1 Hydroelectric Project
FERC Project No. 2687

January 2013

Prepared By:

Pacific Gas and Electric Company™

TABLE OF CONTENTS

Page

APPENDICES

LIST OF FIGURES

Page

LIST OF TABLES

1.0 INTRODUCTION

This document presents the results of the Shasta Crayfish Study Plan (PG&E 2012a) developed for the Pit 1 Hydroelectric Project, Federal Energy Regulatory Commission (FERC) Project No. 2687 (Pit 1 Project), operated by Pacific Gas and Electric Company (PG&E). FERC issued PG&E a new license for the continued operation of the Pit 1 Project on March 19, 2003.[1] The 2003 license incorporates the California State Water Resources Control Board (State Water Board) Clean Water Act Section 401 Water Quality Certificate (401 Certification). Condition 13 of the 401 Certification requires PG&E to release a continuous minimum fish/aquatic habitat release and flushing flows through Fall River Pond to control growth of aquatic vegetation and mosquito production in the Fall River Pond. The flushing flows are to be released for two consecutive days (Saturday and Sunday) three times per year in May or June, in July, and at the end of August. PG&E developed the Shasta Crayfish Study Plan in compliance with the State Water Board 2010 Order[2], which temporarily suspended flushing flow requirements.

The Shasta crayfish (*Pacifastacus fortis*), which is listed as endangered under the Federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA), is found in the Pit 1 Bypass Reach. On May 26, 2009, the United States Fish and Wildlife Service (USFWS) sent a letter to the State Water Board expressing concern regarding a decline in Shasta crayfish in the Pit 1 Bypass Reach and requesting suspension of the 2009 flushing flows. The letter stated that flushing flows are reducing/eliminating coldwater habitat for Shasta crayfish and providing beneficial habitat for the competitor/predator non-native crayfish species.

On April 15, 2010, FERC sent a letter to the State Water Board requesting a temporary suspension of flushing flows for 2010. The State Water Board issued orders in 2010 and 2012[3] that temporarily suspended these flushing flows in 2010, 2011, and 2012, while a California

---

1 102 FERC ¶ 61,309. Order Issuing New License (issued March 19, 2003).

2 State of California State Water Resources Control Board Order WQ 2010-0009-EXEC. Order Approving Temporary Suspension of Flushing Flow Requirements (State Water Board 2010 Order, issued July 6, 2010).

3 State of California State Water Resources Control Board Order WQ 2012-0008-EXEC. Order Approving Extension of the Temporary Suspension of Flushing Flow Requirements (State Water Board 2012 Order, issued June 14, 2012).

Environmental Quality Act (CEQA) process is implemented to analyze the effects of permanently suspending the flushing flow requirements (Appendix A). FERC, in turn, issued orders in 2010[4] and 2012[5] temporarily amending the Pit 1 license to suspend flushing flows.

PG&E developed the Shasta Crayfish Study Plan in consultation with appropriate resource agencies, including extensive involvement of the USFWS, California Department of Fish and Wildlife (CDFW, California Department of Fish and Game [CDFG] prior to January 1, 2013), and other members of the Shasta Crayfish Technical Review Committee (TRC). At the September 14, 2010 meeting, the TRC determined that sufficient information was already available to evaluate the goals of the study plan as outlined in the State Water Board 2010 Order and that authorization of incidental take related to additional studies or monitoring would depend on whether they provided any benefit to the species. The consensus of the TRC was that additional monitoring would not be beneficial to the species or necessary to address the SWRCB study plan goals. Furthermore, the USFWS stated that any disturbance related to additional monitoring or studies would have to be justified as "wholly beneficial for the recovery of the species" (Spring Rivers 2011).

The State Water Board approved the Shasta Crayfish Study Plan on June 21, 2012, with a request that the plan be updated to reflect the current schedule. PG&E filed the Shasta Crayfish Study Plan (PG&E 2012a) for FERC approval on June 26, 2012, in compliance with ordering paragraph (C) of the 2010 FERC order. FERC issued an order modifying and approving the plan on September 28, 2012.

The goal of the Shasta Crayfish Study Plan is to develop information on the potential impacts of current Pit 1 Project operations on Shasta crayfish in the Pit 1 Bypass Reach and downstream of Pit 1 Powerhouse (Pit 1 Peaking Reach), including: (1) the impact of non-native crayfish on Shasta crayfish; (2) the effects of flushing flows on Shasta crayfish habitat in the Pit 1 Bypass Reach; and (3) the effect of daily peaking operations at the Pit 1 Powerhouse on potential Shasta

---

[4] 132 FERC ¶ 62.101. Order Temporarily Amending License and Incorporating Temporary Amendment to Water Quality Certification (issued August 10, 2010).

[5] 140 FERC ¶ 62.080. Order Temporarily Amending License and Incorporating Temporary Amendment to Water Quality Certification (issued July 26, 2012).

crayfish habitat in the Pit 1 Peaking Reach. In compliance with the Shasta Crayfish Study Plan, this Pit 1 Shasta Crayfish Study Report compiles, reviews, and analyzes existing literature and data on Shasta crayfish, stream flow, and water temperature to evaluate the potential effects of Pit 1 Project operations on Shasta crayfish in the Pit 1 Bypass Reach and Pit 1 Peaking Reach. In addition, this document presents the results of a 2012 field study including the number, location, and temperature of all visibly identifiable springs in the Pit 1 Bypass Reach and an estimate of the amount of potential coldwater refugia habitat created by the Pit 1 Bypass Reach springs at the current summer minimum instream flow of 150 cfs.

1.1 LICENSE-REQUIRED MONITORING

1.1.1 Water Flow and Quality Monitoring

Pursuant to License Article 401 and SWRCB 401 Certification Condition 13 (Appendix B), PG&E implemented three summer flushing flows each year for seven years between 2003 and 2009. Pursuant to License Article 401 and SWRCB 401 Certification Condition 14 (Appendix B), PG&E monitored surface aquatic vegetation on Fall River Pond from 2005 through 2012, and continues annual monitoring. Monitoring data since 2005 showed that the continuous minimum base flows have been controlling the nuisance aquatic vegetation in Fall River Pond, and that flushing flows have not been needed (PG&E 2010a, 2011a, 2012b).

Pursuant to License Article 401 and SWRCB 401 Certification Condition 8 (Appendix B), PG&E has implemented minimum instream flows from the Pit 1 Forebay into the Lower Fall River and thence the Pit River beginning in 2003. As measured at the Fall River Weir, instantaneous flows downstream of the Fall River Pond are 150 cfs in the summer and early fall (June 1 to October 31); 75 cfs transitioning from and to the winter-spring flow (May 16 to May 31, November 1 to November 15); and 50 cfs in the winter and spring (November 16 to May 15).

Pursuant to License Article 401 and SWRCB 401 Certification Condition 16 (Appendix B), PG&E developed and implemented a five-year water quality and water temperature monitoring program (PG&E 2003). PG&E conducted annual water quality (*in situ*) and water temperature monitoring at nine stations (four in the Fall River and five in the Pit River) from 2004 through 2009. Temperature, dissolved oxygen, pH, turbidity, and conductivity were sampled twice monthly from May 16 through October 31 and flow was monitored with pressure transducers at the lower end of Big Eddy and at the footbridge upstream of the Pit 1 Powerhouse. Annual reports of the Pit 1 water quality monitoring results have been filed with the State Water Board and FERC (PG&E 2004a, 2005, 2006a, 2007, 2008, 2009a, 2010b, 2011b, 2012c).

Pursuant to SWRCB 401 Certification Condition 17 (Appendix B), PG&E submitted a five-year summary report (PG&E 2009a) recommending several modifications of the water quality monitoring program. Based on the monitoring results, PG&E also recommended that minimum instream flow not be increased over the current 150-cfs release. FERC approved an amendment to the water quality monitoring plan (PG&E 2010b) on May 4, 2010, following SWRCB's January 29, 2010 letter approving the proposed amendment (filed with FERC on February 12, 2010). In May of 2010, PG&E began implementing the amended program (PG&E 2010c) of monthly water quality monitoring at six stations (two in Fall River and four in Pit River) that adequately represent water conditions in the Fall and Pit rivers.

1.1.2 Shasta Crayfish Monitoring

Pursuant to Article 410 of the Pit 1 Project license (Appendix B), the TRC was established to assist PG&E in the design and implementation of the terms and conditions of its license (primarily focused on Shasta crayfish protection and recovery in the Pit 1 Project area). Pursuant to License Articles 409 and 412 (Appendix B), PG&E developed a Shasta Crayfish Management Plan in consultation with the TRC (PG&E 2004b). FERC issued an order approving the plan on July 7, 2004. The TRC has met twice a year (more in some years) and has been one of the primary forums for PG&E to consult with resource agencies, including USFWS and CDFW to address species protection measures. PG&E conducted extensive monitoring, implemented license conditions for the protection of the Shasta crayfish, engineered and constructed non-native crayfish barriers to protect native crayfish habitat, and funded recovery actions (such as the Sucker Springs Creek Restoration Project) throughout the species range based on guidance from the TRC.

As part of the Pit 1 Shasta Crayfish Management Plan (PG&E 2004b), Shasta crayfish monitoring surveys and non-native crayfish removal surveys have been implemented within the Pit 1 Project boundary and other locations throughout the range of the species. Survey results are discussed in biannual TRC meetings. Annual reports filed with the TRC and FERC in the spring of each year present monitoring results and updates on recovery and management actions, and summarize discussions with the TRC.

License Articles 411 and 412 (Appendix B) include requirements for PG&E to establish funds, adjusted annually for inflation, for Shasta crayfish monitoring and non-native crayfish removal, respectively. In consultation with the TRC, these surveys have been implemented not only within the Pit 1 Project area, but throughout the range of the species. The data collected during the term of the license have increased the information available to USFWS and CDFW, and have been crucial to informing management decisions with the TRC for the management, protection, and recovery of the species. During years in which monitoring surveys are not scheduled (e.g., 2011–2012, years 8 and 9 of the Pit 1 license) or when the annual management funds are not completely spent, the remaining funds are allocated as recovery funds to be used for TRC-approved Shasta crayfish projects, such as the Sucker Springs Creek Restoration Project.

Pursuant to License Article 413, PG&E developed and implemented a Crayfish Barrier Plan (PG&E 2006b) to construct and maintain two exclusion barriers to protect Shasta crayfish and their habitat from invasion by signal crayfish (*Pacifastacus leniusculus*) and other non-native crayfish species (i.e., *Orconectes virilis*). FERC issued an order modifying and approving the Crayfish Barrier Plan on March 8, 2007. In consultation with the TRC, potential barrier locations were selected to provide the greatest benefit to Shasta crayfish not only within the Pit 1 Project area, but throughout the range of the species. The upper Fall River and Spring Creek were rated the two highest priority potential barrier locations due to the size of the Shasta crayfish populations, the size and quality of Shasta crayfish habitat, and the relatively few signal crayfish found in the vicinity or upstream of the potential barrier locations during the 2006 surveys. PG&E completed both Crayfish Barrier Plan projects in 2007 (Spring Rivers 2007). As part of the plan, PG&E also provides annual funding for non-native crayfish removal surveys upstream of the two barriers; this funding is in addition to the non-native crayfish removal funding required by License Article 412. As required by the Crayfish Barrier Plan (PG&E 2006b) and the USFWS Biological Opinion and Incidental Take Statement (1-1-07-F-0333) for the Upper Fall River Crayfish Barrier Project, PG&E continues annual monitoring and reporting for the long-term evaluation of barrier effectiveness in the TRC annual reports (Spring Rivers 2008, 2009, 2010, 2011, 2012).

1.2 PROJECT DESCRIPTION

The Pit 1 Project encompasses approximately 3,500 acres of land and water, with almost 3,000 acres in the upper Pit 1 Project, which is defined as the area upstream of the Fall River Diversion Dam. The upper Pit 1 Project consists of approximately 22 miles of the Fall River, 5 miles of the Tule and Little Tule rivers, and Ja She Creek, Horr Pond, and Big Lake, which form the headwaters of the Tule River.

Immediately downstream of the Fall River Diversion Dam is the Pit 1 Forebay. The Fall River Diversion Dam and Pit 1 Forebay comprise the Fall River Diversion complex, which diverts water to Pit 1 Powerhouse. Diversion flows are passed directly to Pit 1 Powerhouse or stored in the Pit 1 Forebay for later diversion to the powerhouse during peaking operations. Powerhouse flows are released into the Pit River from the powerhouse tailrace, bypassing 0.9 miles of the Fall River and 7.6 miles of the Pit River.

Immediately downstream of Pit 1 Forebay is the 0.7-mile-long Fall River Pond, formed by the Fall River Pond Weir. Water is diverted from the pond via Knoch's Diversion to a user with riparian rights superior to PG&E's. Downstream of the Fall River Pond Weir is a 0.2-mile-long reach of Fall River ending at its confluence with the Pit River. The Pit 1 Project boundary includes the Pit River Weir, which is a concrete weir that was constructed to maintain minimum water levels in the Pit River to satisfy upstream water rights for agricultural uses between Pittville and Fall River Mills. Pit 1 Project stream reaches and their relationship to Project facilities are shown in Figure 1-1.

The Pit 1 Project diverts water from the lower Fall River at the Pit 1 Intake to the Pit 1 Powerhouse located on the Pit River between the Fall River confluence and Lake Britton, subsequently reducing flows in segments of both the Fall and Pit rivers. The bypass reach of the Fall River is defined as the reach extending from the Pit 1 Forebay Dam to the confluence with the Pit River. This reach, which includes Fall River Pond and the cascade section between the Fall River Pond Weir and the Pit River confluence, is identified as the Lower Fall River Reach.

The Pit 1 Bypass Reach is defined as the river section extending from the confluence with the Fall River downstream to the Pit 1 Powerhouse tailrace. The Pit 1 Peaking Reach is defined as the river section extending from the Pit 1 Powerhouse tailrace downstream to Lake Britton. The Pit 1 Bypass and Pit 1 Peaking reaches, including the location of known spring resources, are detailed in Figure 1-2.

1.2.1 Pit River Reaches

The Pit River in the Pit 1 Project area is composed of three segments that are characterized by distinctly different morphologies and hydrologies. The first section extends from Pittville (located 8.8 miles upstream of the Fall River confluence) to the downstream end of the Big Eddy pool section (Figure 1-2). This segment, which includes the upper Pit 1 Bypass Reach, is characterized by a very low gradient (0.05%) with correspondingly wide, low-velocity, deep-pool channel morphology. The Fall River enters the Pit River immediately upstream of the Pit River Weir. Prior to the diversion of the majority of Fall River to the Pit 1 Powerhouse, the inflow of Fall River into the Pit River created a backwater effect in the Pit River upstream to Pittville. The Pit River Weir was constructed by PG&E after the Pit 1 Powerhouse went on line to create a similar backwater effect to maintain water surface elevation for the pump intakes in order to satisfy upstream water rights for agricultural uses between Pittville and Fall River Mills. The Pit River Weir creates a long (8.9 miles) impoundment that receives seasonally significant inflow from agricultural returns along its length. Downstream of the weir, the low-gradient, deep-pool morphology continues for approximately 1.9 miles of the upper Pit 1 Bypass Reach. This 1.9-mile portion of the low gradient segment of the upper Pit 1 Bypass Reach is referred to as Big Eddy (Figure 1-2).

The lower Pit 1 Bypass Reach, which extends from the downstream end of Big Eddy to the Pit 1 Powerhouse tailrace (Figure 1-2), is distinctly different than the Big Eddy segment. Confined by the Pit 1 Canyon, the lower Pit 1 Bypass Reach has a much higher gradient than Big Eddy and is the location of the Pit River Falls. This segment is characterized by much shallower depths, narrower channel widths, and a uniformly higher gradient (1.7%) with resultant higher velocities. In addition, flow in the lower Pit 1 Bypass Reach is substantially augmented by approximately 100 cfs of spring accretion flow, which changes the nature of the instream conditions and ecology.

The third segment is the Pit 1 Peaking Reach, which extends downstream from the Pit 1 Powerhouse tailrace to the head of Lake Britton (Figure 1-2). After the Pit River exits the Pit 1 Canyon near the confluence with the Pit 1 Powerhouse tailrace, the gradient (0.8%) is less than half that of the lower Pit 1 Bypass Reach. This high-flow section of the Pit River captures all flows from both the Pit and Fall Rivers and is augmented by Sucker Springs Creek and numerous smaller springs.

Historically, the Pit 1 Project was a run-of-river operation without the capacity for water storage (1922–1945). After PG&E finished construction of the Pit 1 Forebay in 1945, the Pit 1 Project has operated with peaking flows in the reach downstream of the Pit 1 Powerhouse. Prior to the current FERC license (between 1945 and 2003), base flows in the Pit 1 Peaking Reach during the summer were more variable. Under the 2003 license, PG&E maintains at least 700 cfs in the Pit River downstream of the tailrace, and uses the generator-loading and generator-unloading rates specified in SWRCB 401 Certification 12. As a result, summer base flows in the Pit 1 Peaking Reach are relatively stable in the range of 900 to 1,100 cfs. During periods of peak energy demand, peaking events temporarily increase flows to near 2,000 cfs. The 2003 license conditions have substantially decreased the amount of dewatered shoreline compared to pre-license conditions.

1.3 Document Organization

The document is organized into six main sections: (1) Introduction; (2) Shasta Crayfish—a review of Shasta crayfish management goals, status, habitat and temperature preferences, and the effects of non-native crayfish; (3) Methods; (4) Results; (5) Discussion; and (6) Summary and Conclusions.

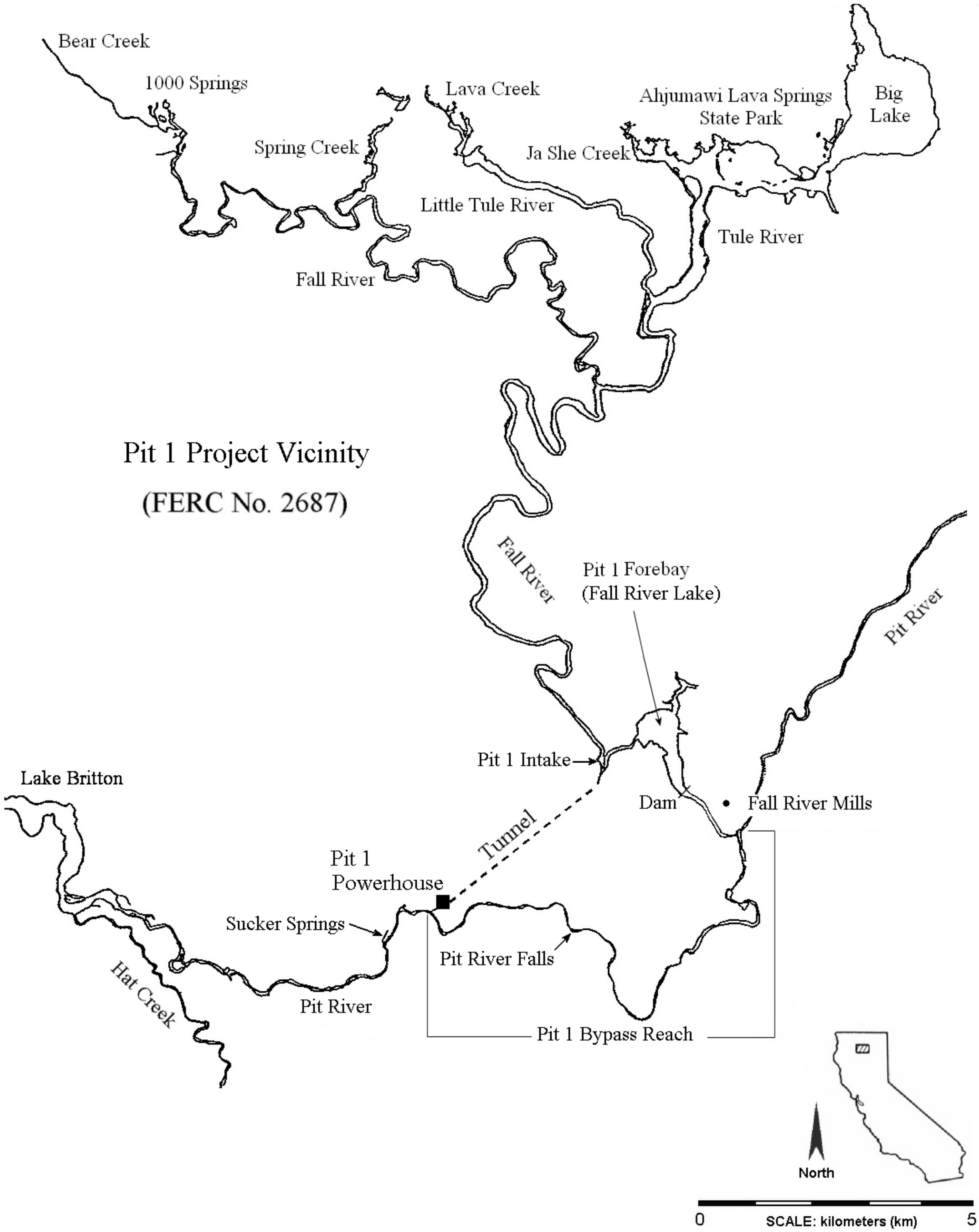


Figure 1-1. Pit 1 Project Vicinity

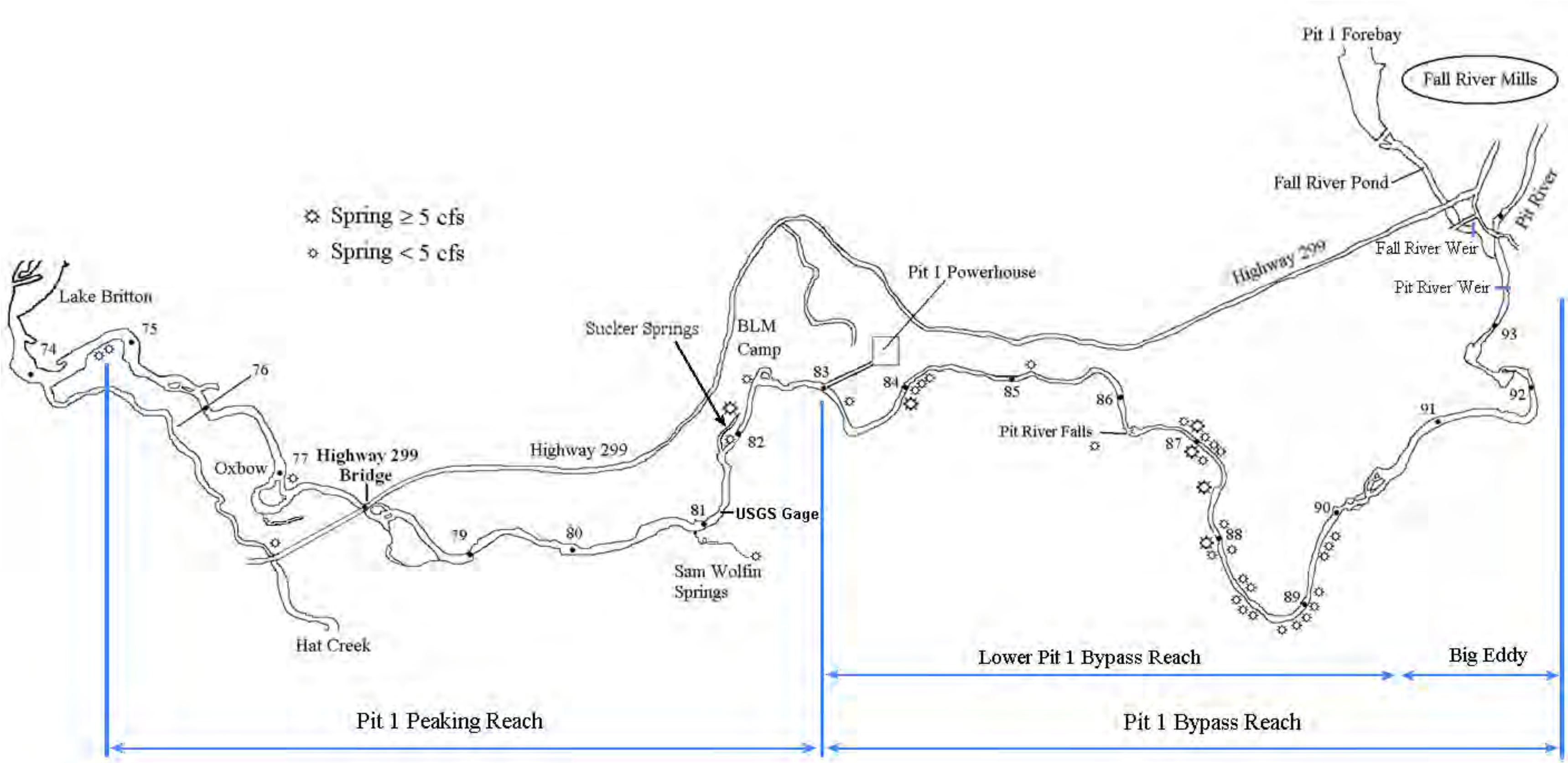


Figure 1-2. Pit River showing location of springs in the Pit 1 Bypass and Pit 1 Peaking reaches.

2.0 SHASTA CRAYFISH

The Shasta crayfish was listed as endangered under the Federal ESA on September 30, 1988 (53 FR38460-38465) and as endangered under the CESA on February 26, 1988. Critical habitat has not been designated for this species. Figure 2-1 shows the known distribution, range, and population status of Shasta crayfish.

2.1 POTENTIAL PIT 1 PROJECT EFFECTS ON SHASTA CRAYFISH

The hydroelectric operations of the Pit 1 Project directly affect the flows in the Lower Fall River Reach, Pit 1 Bypass Reach, and Pit 1 Peaking Reach. The diversion of Fall River water at the Pit 1 Intake to the Pit 1 Powerhouse reduces flows in both the Lower Fall River Reach and the Pit 1 Bypass Reach. Pit 1 Project operations, including new license-required flow regimes implemented in 2003, affect the Lower Fall River Reach and Pit 1 Bypass Reach through flushing flows, minimum instream flow releases, and unplanned outages during the warmer months and the Pit 1 Peaking Reach through peaking flows.

Historically, Shasta crayfish have been documented in all three Pit 1 Project reaches affected by hydroelectric operations, including one location in the Lower Fall River Reach, three locations in the Pit 1 Bypass Reach, and one location in the Pit 1 Peaking Reach (USFWS 1998, Ellis 1999, Spring Rivers 2009). Populations outside of these three reaches (i.e., Lower Fall River Reach, Pit 1 Bypass Reach, and Pit 1 Peaking Reach) are not affected by the hydroelectric operations of the Pit 1 Project.

Other activities related to the Pit 1 Project license have the potential to affect Shasta crayfish populations throughout the Pit 1 Project vicinity, although beneficial effects are expected. These activities include the Shasta crayfish monitoring surveys and non-native crayfish removal surveys implemented as part of the Pit 1 Shasta Crayfish Management Plan (PG&E 2004b), the crayfish barriers and non-native crayfish removal surveys implemented as part of the Crayfish Barrier Plan (PG&E 2006b), and TRC-recommended recovery and restoration activities.

PG&E implements Shasta crayfish monitoring surveys and non-native crayfish removal surveys within the Pit 1 Project boundary and other locations throughout the range of the species as part of the Pit 1 Shasta Crayfish Management Plan (PG&E 2004b). Information gathered during these surveys are crucial to help inform management decision. These surveys, however, also have the potential to result in modification and degradation of Shasta crayfish habitat, as well as, Shasta crayfish mortality, and therefore require an incidental take statement from USFWS.

PG&E continues to monitor and maintain the Crayfish Barrier Plan projects completed in 2007 (Spring Rivers 2007), including annual funding for non-native crayfish removal surveys upstream of the two barriers. These actions help control the non-native signal crayfish populations, which benefits the Shasta crayfish populations in these areas (Spring Rivers 2008, 2009, 2010, 2011, 2012).

2.2 SHASTA CRAYFISH MANAGEMENT GOALS

Shasta crayfish management is directed by both the Shasta Crayfish TRC (for PG&E activities related to the Pit 1 Project [FERC Project No. 2687] and the Hat Creek Hydroelectric Project [FERC Project No. 2661]) and USFWS' Shasta Crayfish Recovery Team (for actions not required by a PG&E license). Given its critically endangered status, small population size, and the dramatic range-wide decline of Shasta crayfish in the last few decades, species management is focused on protecting Shasta crayfish within each of the three genetically distinct clusters: (1) Crystal Lake, (2) Sucker Springs/Spring Creek/Ja She Creek, and (3) Rainbow Spring/Thousand Springs (Petersen and May 2008, 2011, 2012a, 2012b, Spring Rivers 2012). Shasta crayfish management objectives target two primary goals: (1) the protection and enhancement of existing Shasta crayfish populations in the wild; and (2) the creation of Shasta crayfish refugia that are protected from invasion by non-native crayfish (Spring Rivers 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012). Given that the estimated total population size may be less than 1,000 Shasta crayfish, the sacrifice of any individuals is considered to be extremely costly for the species. As such, the relative benefits of any activity affecting Shasta crayfish needs to be considered against the costs of potential increased stress or higher mortality.

The first Shasta crayfish management objective is to protect and enhance existing Shasta crayfish populations in the wild. Shasta crayfish monitoring survey data are used to assess status and trends in existing Shasta crayfish populations in the wild so that steps can be taken to protect and enhance populations when possible. The frequency of the TRC-prescribed Shasta crayfish monitoring surveys, which is every five years, is balanced to be able to detect populations changes early on, but to minimize the inherent disturbance, degradation, and modification from the surveys themselves. Surveys are particularly disruptive in areas where the lava substrate has the multi-layered, jigsaw-puzzle-like structure found along the margins of the Pit 1 Bypass Reach and elsewhere. Although every effort is made to place all substrate back into its original position, monitoring surveys have the potential to negatively affect the habitat. This, in turn, can affect the Shasta crayfish population and the results of future surveys. In an effort to help control non-native crayfish populations, all non-native crayfish encountered during Shasta crayfish monitoring surveys and any other Shasta crayfish activity are removed. If discretionary anthropogenic activities that are potentially harmful to Shasta crayfish or Shasta crayfish habitat are identified, steps are taken to stop the potentially harmful activities. Where feasible, crayfish barriers are installed and maintained to help control non-native crayfish populations at Shasta crayfish locations. In addition to non-native crayfish removal during monitoring surveys, non-native crayfish removal surveys focusing solely on removal of non-native crayfish are conducted in areas that meet the following criteria: (1) limited areal extent, (2) relatively simple substrate (e.g., not complex, layered, "bottomless" substrate; no deep burrows in banks; no cracks in cement, etc.), (3) can be physically separated into smaller areas, and (4) limited immigration of non-native crayfish. Removal surveys target reproductive adults prior to release of free-living young-of-year between January to March in an effort to minimize reproduction of non-native crayfish.

The second Shasta crayfish management objective is to create Shasta crayfish refugia that are protected from invasion by non-native crayfish. Creation of Shasta crayfish refugia may include the following measures, as needed: (1) installation of crayfish barriers to prevent immigration of non-native crayfish; (2) eradication of existing non-native crayfish population; (3) habitat restoration and enhancement; (4) development of Safe Harbor Agreements to protect landowners; and (5) reintroduction of Shasta crayfish. In order for a location to be considered for a Shasta crayfish refugia site it must meet the following criteria: (1) natural or anthropogenic barriers that prevent immigration of non-native crayfish; (2) no non-native crayfish or area suitable for eradication of non-native crayfish (see criteria for non-native crayfish removal); (3) protection from other anthropogenic disturbances. Most areas suitable for potential Shasta crayfish refugia sites are located in and around the headwater spring areas. There are three

Shasta crayfish refugia projects currently underway. The USFWS, Shasta Crayfish TRC, and PG&E are developing a Rock Creek Restoration and Reintroduction Plan to restore habitat and reintroduce Shasta crayfish into Rock Creek, which is a spring-fed tributary to Baum Lake in the Hat Creek drainage. If a feasible plan can be developed and approved, Shasta crayfish from Crystal Lake would be used for the introduction, which would protect the Crystal Lake genome. The Sucker Springs Creek Restoration Project will create a protected refuge for the Sucker Springs Shasta crayfish. The Kerns Pond Refugia Project has created and enhanced habitat at the spring outflow area in a small isolated pond. Shasta crayfish from small dwindling satellite populations around Big Lake will be relocated into Kerns Pond.

2.3 SPECIES STATUS

Recent monitoring results for Shasta crayfish have indicated a substantial, range-wide decline in Shasta crayfish distribution and abundance, including a decline in the abundance of Shasta crayfish in the lower Pit 1 Bypass Reach upstream of the Pit River Falls since 2005 (PG&E 2009b, Spring Rivers 2009). Table 2-1 summarizes Shasta crayfish populations in the Pit 1 Project vicinity, including population characteristics (number, density, estimated population size, and percent composition) as derived from all previous and current surveys; habitat area; current population estimates; and potential Pit 1 Project effects. Table 2-2 summarizes Shasta crayfish populations in the Hat Creek Project vicinity, including population characteristics (number, density, estimated population size, and percent composition) as derived from all previous and current surveys; habitat area; current population estimates; and potential Hat Creek Project effects. The total population size throughout the species range is estimated to consist of between 785 to 2,250 Shasta crayfish at present (Tables 2-1 and 2-2). The current total population size is less than a quarter and potentially less than a tenth of the estimated 8,000 Shasta crayfish present in the early 1990s (Tables 2-1 and 2-2, USFWS 1998, Ellis 1999).

The Lower Fall River Reach is the likely vicinity of the type locality (i.e., Fall River at Fall City Mills) where Shasta crayfish were first collected in 1898 (USFWS 1998). In addition, one live Shasta crayfish was electroshocked and collected from Fall River Pond at the State Highway 299 Bridge in 1974 (USFWS 1998). In 1978, one dead Shasta crayfish was collected in the Fall River Pond at the State Highway 299 Bridge (USFWS 1998). Largemouth bass, a predator of crayfish, were apparently introduced into Fall River Pond sometime between the 1974 and 1978 surveys. During numerous surveys in 1990, 1992, 1994, 1995, 2004, and 2005, no Shasta crayfish were found in Fall River Pond, however, both non-native signal crayfish and non-native northern crayfish were common (USFWS 1998, Spring Rivers 2005). Shasta crayfish have not been found in the Lower Fall River Reach since 1978 and are presumed to have been extirpated from Fall River Pond.

Two Pit 1 Bypass Reach locations are upstream of the approximately 9-meter-high Pit River Falls, which is considered a barrier to the passage of non-salmonid fish. In 1995, Shasta crayfish were first found in the Pit 1 Bypass Reach during a freshwater mussel survey of a limited area of the mainstem river upstream of the falls (lower Pit River location). In October 2005, a total of 21 Shasta crayfish (6 adults, 7 juveniles, and 8 young-of-year) were found in an approximately 600-meter-long reach of the Pit River above the Pit River Falls (upper and lower Pit River locations). The presence of all age classes of Shasta crayfish, including young-of-year, indicated a healthy reproducing population in the mainstem Pit River in 2005. Neither the 1995 freshwater mussel survey, nor the 2005 crayfish survey upstream of the falls were exhaustive in terms of substrate surveyed. Shasta crayfish were, however, fairly common and the most abundant crayfish species found in both 1995 and 2005. During the 2005 survey, 21 Shasta crayfish were found, compared to 10 signal crayfish and 12 northern crayfish. During a more exhaustive survey of the substrate in same area in September 2008, only one adult male Shasta crayfish was found, but 29 signal crayfish and 23 northern crayfish were found, indicating that both non-native crayfish species were much more abundant than Shasta crayfish. Between 2005 and 2008, the number of signal crayfish almost tripled (10 to 29), and the number of northern crayfish almost doubled (12 to 23) in this reach, while Shasta crayfish numbers plummeted (21 to 1, 95% decrease).

The third Pit 1 Bypass Reach location (Pit 1 Footbridge) is associated with a spring located 1.4 miles (2.3 km) downstream of the falls and 0.7 miles (1.1 km) upstream of the Pit 1 Powerhouse tailrace. Only two individuals, both dead, juvenile, male Shasta crayfish, have been found at this location fifteen years apart. One was found in 1980, and the other was found under a cobble near the spring outflow during an exhaustive survey of the substrate in the area in 1995 (USFWS 1998). In order to find a freshly dead crayfish under a cobble, there must have been living crayfish in this area, at least during the 1980 to 1995 period. This indicates that the substrate being used by Shasta crayfish was not being adequately sampled, as is the case with the very large mid-channel boulder substrate.

The fourth Pit River location (Pit 1 Sand Pits) is the only record of Shasta crayfish downstream of the Pit 1 Powerhouse (Pit 1 Peaking Reach). In 1978, a total of eight Shasta crayfish were found sympatric with non-native northern crayfish in the mainstem Pit River at the Oxbow near the sand pit springs downstream of the Highway 299 Bridge. During subsequent surveys in 1991, 1995, 2004, and 2005, no Shasta crayfish were found in this location. By 1992, non-native signal crayfish had also replaced non-native northern crayfish throughout the Pit 1 Peaking Reach (Ellis 1999, Spring Rivers 2009).

Although the Lower Fall River Reach, Pit 1 Bypass Reach, and Pit 1 Peaking Reach have all historically contained populations of Shasta crayfish, Shasta crayfish have only been found in the Pit 1 Bypass Reach during recent monitoring (monitoring conducted as required by the 2003 Project license). Within the Pit River, potential Shasta crayfish habitat in the lower portion of the Pit 1 Bypass Reach is the primary focus of this evaluation. The Pit 1 Project peaking operations under the 2003 license would not directly affect the species since the species has not been found in the Pit 1 Peaking Reach since 1978.

The decline in the Shasta crayfish distribution and abundance has often coincided with the invasion of signal crayfish; this trend was observed in the 1990s (USFWS 1998, Ellis 1999) and during the recent monitoring since the 2003 Pit 1 Project license was issued (Spring Rivers 2009). Although signal crayfish were first found in the drainage in the late 1970s, the dramatic expansion of this non-native species occurred between 1990 and 2007. The result is that no allopatric Shasta crayfish populations have been found since 2006[6], all populations are now sympatric with signal crayfish (USFWS 1998, Ellis 1999, Spring Rivers 2009). During this period of rapid signal crayfish expansion the Shasta crayfish populations in upper Fall River at Sand Springs, Fall River at Fletcher's Bend, Fall River at Lennihan's Footbridge, Lava Creek,

---

6 The Shasta crayfish population in Rising River was still allopatric in 1995, but has not been surveyed since that period due to lack of landowner permission. Rising River will be surveyed as soon as permission is given.

Ja She Creek, and Big Lake Springs all suffered dramatic declines within a few years following the invasion of signal crayfish (Spring Rivers 2009, 2011).

The Crystal Lake Shasta crayfish population has also been significantly reduced following the invasion of signal crayfish, including the likely extirpation of Shasta crayfish at the Crystal Lake Outflow (Spring Rivers 2009, 2012). The decline of the Crystal Lake Shasta crayfish population, however, occurred at a much slower rate over a two-decade period. The persistence of the Shasta crayfish population in Crystal Lake following the invasion of signal crayfish may be due to the Crystal Lake genome, which was found to have the highest level of genetic variation in both the nuclear and mitochondrial DNA of any Shasta crayfish population (Petersen and May 2008, 2011, 2012a, 2012b, Spring Rivers 2012).

The two largest Shasta crayfish populations, which are in Thousand Springs and upper Spring Creek in the upper Fall River drainage, have not suffered the dramatic declines observed in other Shasta crayfish populations sympatric with signal crayfish (Spring Rivers 2009, 2011). The Shasta crayfish populations at Thousand Springs and upper Spring Creek have benefited from the crayfish barriers and signal crayfish removal surveys implemented as part of the Crayfish Barrier Plan (PG&E 2006b) developed for License Article 413. PG&E completed these two crayfish barrier projects, which were considered by the TRC to provide the greatest benefit to Shasta crayfish not only within the Pit 1 Project area, but throughout the range of the species. PG&E began annual funding and implementation of non-native crayfish removal surveys upstream of the barriers in 2007. The upper Fall River crayfish barrier, which is located outside the Pit 1 Project area, was installed just downstream of the large Shasta crayfish population at Thousand Springs. Non-native crayfish removal surveys have been conducted annually, generally two times per year, in Thousand Springs upstream of the barrier to control the signal crayfish population since 2007. The second barrier project was the improvement of the Spring Creek Road crossing, where culverts create velocity barriers to signal crayfish that occur downstream in lower Spring Creek and Fall River. The crossing was improved by filling in crevices and gaps surrounding the culverts thereby eliminating habitat used by signal crayfish. Surveys to remove signal crayfish have also been conducted annually, generally two times per year, in Spring Creek upstream of the culverts since 2007.

The Shasta crayfish population in Sucker Springs Creek, a tributary to the Pit River between the Pit 1 Powerhouse and the Hat Creek confluence (Figure 1-1 and 2-1), was significantly reduced in size following CDFG hatchery-related habitat dewatering and the invasion of signal crayfish in 1996 (USFWS 1998, Spring Rivers 2009). The Sucker Springs Creek Restoration Project includes signal crayfish eradication measures, crayfish barriers, and habitat improvements that will ultimately create refugia for the Shasta crayfish in Sucker Springs Creek. In consultation with the TRC, PG&E has provided expertise, labor, materials, heavy machinery, and funding[7] for the Sucker Springs Creek Restoration Project.

2.4 SHASTA CRAYFISH HABITAT

Most Shasta crayfish populations are found in headwater spring areas, which are characterized by constant and cold water temperature, constant flow, and high water clarity. Shasta crayfish are found, almost without exception, under lava boulders (greater than 300 mm diameter) or lava cobbles (75-300 mm diameter) on either clean or sandy lava gravel (2-75 mm diameter) (USFWS 1998, Ellis 1999). Substrate composed of basalt boulders and cobbles is present at all but one of the 38 locations within the range where Shasta crayfish have been recorded. The lava substrate is often complex with lava boulders and cobbles on either lava gravel or on top of more lava boulders and cobbles. In 1992 along the levees of McArthur Swamp on the south shore of the upper Tule River, one Shasta crayfish was found in a burrow and another under a board on organic substrate. This was the only location at which Shasta crayfish have been found without boulders and cobbles (lava substrate at this location had been buried by dredged fill used to bolster the levees prior to 1992). Shasta crayfish have not been found at this location during numerous subsequent surveys in 1992, 1997, 2007.

Most Shasta crayfish are found in areas with little to no velocity, such as pools, runs, or in the lower velocity microhabitats such as river margins and in areas protected by large substrate or underneath layers of substrate. Shasta crayfish have not been found in higher velocity riffles or cascades. In the Pit 1 Bypass Reach, most Shasta crayfish have been found in lower velocity

---

7 During years in which monitoring surveys are not scheduled or when the license-required annual management funds are not completely spent, the remaining funds are allocated as recovery funds to be used for TRC-approved Shasta crayfish projects, such as the USFWS' Sucker Springs Restoration Project.

marginal areas protected from the main river current. Large bed substrate in the Pit River also creates lower velocity microhabitat areas. Shasta crayfish are generally found in areas with water that is at least one-foot deep. Young-of-year Shasta crayfish are occasionally found in shallower water. Most Shasta crayfish were found under rocks that had a longest dimension (i.e., A-diameter) greater than 10 cm (Ellis 1999). Shasta crayfish were found together in groups of two or three under one rock at most sites. There is a tendency for more than one Shasta crayfish to be found together under larger rocks and in one population (Thousand Springs Fish Trap Cove) as many as five to nine individuals were commonly found together. Underneath certain larger rocks (A-diameters of 60 to 109 cm) in Thousand Springs Fish Trap Cove, between 10 and 25 individuals were consistently found together.

Shasta crayfish have generally been found in colder habitats that are lower in alkalinity, hardness, pH, and specific conductance than locations with other species (PG&E unpublished data 1991, 1992). Shasta crayfish are found in areas with alkalinity between 50 and 100 milligrams per liter (mg/L), total hardness between 20 and 63 mg/L, pH between 7.2 and 9.4, specific conductivity between 110 and 190 mg/L, total dissolved solids between 65 and 170 mg/L, and dissolved oxygen content between 4.5 and 13.7 mg/L (PG&E unpublished data 1991, 1992). The range in pH values found in the springs of the midreaches of the Pit River drainage is large, driven by the nature of volcanic water sources being more basic than non-volcanic sources.

2.5 Crayfish Temperature Physiology

Habitat temperature is a critically important environmental factor for crayfish and other ectotherms, because temperature affects all biological processes (Stillman 2004). In response to changes in temperature, ectotherms go through an acclimation process that enhances their ability to function and survive when the environment changes. Temperature acclimation develops gradually over time at the molecular, physiological, and behavioral level (Stillman 2004). Molecular and physiological changes can occur in response to ambient temperature fluctuations; these changes include remodeling of the muscle membrane lipid composition (Cossins and Bowler 1976) and adjustment of oxygen binding characteristics within haemolymph (McMahon 2002). This acclimation ability enables some crayfish species to modulate their temperature tolerance in response to natural environmental changes (Layne et al. 1985, Mundahl 1989). To adapt to more sudden or extreme changes in temperature, however, crayfish may seek out and move into more suitable thermal habitat (Mundahl 1989, Payette and McGaw 2003). This can minimize physiological stress, but potentially increase competitive interactions with other crayfish species as well as exposure to predators.

Crayfish that have not had sufficient time to acclimate to their changing environment or cannot find suitable refugia may experience physiological and/or behavioral stress. The relative amount of stress will depend on the magnitude, frequency, and seasonality of the changes, as well as an individual species' ability to tolerate the change (Thorp and Wineriter 1981). White (1983) found that *Procambarus clarkii* that were acclimated to 10 °C reached 50% lethality two to three times sooner when exposed to extreme high temperatures (35–40 °C) than *Procambarus clarkii* that were acclimated to 20 °C. The cold-acclimated crayfish reached heat-induced neuromuscular shock at 32.8 °C. Other researchers have also shown that crayfish acclimated to colder temperatures cannot adapt to sudden or extreme increases in temperature as well as crayfish acclimated to warmer temperatures (Cossins and Bowler 1976, Layne et. al 1985, Chung et al. 2012). Thermal acclimation also has significant effects on behavioral contests and competitive success. Crayfish acclimated to the temperature of their environment had more fighting success and greater dominance and competitive ability than crayfish acclimated to a colder or warmer temperature (Seebacher and Wilson 2006).

In a natural environment, crayfish can be exposed to daily and seasonal temperature fluctuations. Thorp and Wineriter (1981) found that growth of *Procambarus acutus* under a variable temperature regime (minimum = 10 °C, maximum = 25 °C, mean = 17.5 °C) was similar to growth under a constant 17.5 °C regime. Mortality under the variable regime, however, was higher than mortality under a constant 10 °C or constant 17.5 °C and approximated mortality under a constant 25 °C. In other words, growth was more related to mean temperature during a variable regime, while mortality was more related to maximum temperature during a variable regime.

The results of the aforementioned studies indicate that the effects of temperature change on a given crayfish species will depend on the magnitude, frequency, and seasonality of the changes, as well as the thermal environment to which the species is acclimated. In addition, temperature tolerances are not consistent among species (Chung et al. 2012) and have not been investigated for habitat-specialist species such as the Shasta crayfish, which evolved in relatively cold and thermally stable spring habitats.

2.5.1 Shasta Crayfish Temperature Criteria

There have not been any experimental studies to determine temperature tolerances or preferences of Shasta crayfish, and such studies likely would not be granted resource agency authorization given the current small population size and status of the species. Temperature criteria for Shasta crayfish were developed for this document using (1) temperature data collected in the 1990s and since the 2003 license from known Shasta crayfish locations (see Section 4.4); (2) the 2004 Coldwater Refugia Study (PG&E 2009b, see Section 4.3); and (3) the 2012 Pit 1 Bypass Reach Spring inflow study (see Section 4.5). This information was used to define the range of mean daily water temperatures that create Cold (<15–17 ºC), Marginally Cold (17.1–18 ºC), and Cool (18.1–19 ºC) refugia habitat for Shasta crayfish in the lower Pit 1 Bypass. The rationale for these criteria is presented in Section 5.3.2 *Temperature Criteria for the Lower Pit 1 Bypass Reach.*

2.6 NON-NATIVE CRAYFISH

The biggest known threat to the continued existence of the Shasta crayfish is non-native crayfish, which are predators, competitors, and potential sources of new diseases and pathogens. Two species of non-native crayfish, northern crayfish and signal crayfish, were introduced to the drainage in the 1960s and 1970s, respectively. Multiple introductions of both species are thought to have been solely the result of the use of these species as bait by anglers (Eng and Daniels 1982). Signal crayfish, which are now found throughout most of the range of the Shasta crayfish, have a significantly negative impact on Shasta crayfish through some combination of competition and predation, as well as the potential introduction of foreign diseases, pathogens, and epifauna (Ellis 1999). Northern crayfish are also potential competitors and predators and are sympatric with Shasta crayfish in the upper Tule River drainage and in lower Pit 1 Bypass Reach.

The introduction of non-native signal crayfish into the Pit River drainage in northeastern California has led to invasions into previously allopatric populations of Shasta crayfish. The distribution of Shasta crayfish within its range is extremely fragmented, whereas signal crayfish are now found throughout most of the area. Although these species exhibit very different behavior, they overlap along several important niche dimensions (Ellis 1999). Differences in size, activity, aggression, reproduction, diet, and environmental tolerances support the hypothesis that signal crayfish will ultimately replace Shasta crayfish unless protected refugia are developed.

Signal crayfish are highly aggressive and possess a relatively large body size, both of which are characteristics generally common to invasive species. Signal crayfish young-of-year become free-living at a slightly smaller size (approximately 5 mm total carapace length [TCL] from the tip of the rostrum to the posterior edge of the carapace) than Shasta crayfish young-of-year (approximately 6 mm TCL). They quickly achieve a size advantage over Shasta crayfish, however, because they are faster growing and become free-living weeks to months before Shasta crayfish. Based on age-class estimations from size-frequency distributions of both species (Macdonald and Pitcher 1979), signal crayfish are faster growing and generally have a two-fold length advantage over Shasta crayfish at each age class beyond young-of-year (Ellis 1999). The largest Shasta crayfish found to date was a 58.7-mm TCL male at Big Lake Springs; that individual was probably 10 years old. To date, the largest signal crayfish found in the midreaches of the Pit River drainage was an 83.3-mm TCL male in Baum Lake; that individual was probably 5 years old.

Although signal crayfish reach reproductive maturity at lengths greater than 30 mm TCL, which is similar to the size at maturity for Shasta crayfish (TCL > 27 mm), signal crayfish generally obtain reproductive size in their second year, compared to the fourth year for Shasta crayfish. Fecundity of both species is positively correlated with size. A comparison of the number and size of eggs carried by gravid females of the two species at Crystal Lake outflow (Crystal Lake is a tributary to Hat Creek) showed that Shasta crayfish had significantly fewer, larger eggs than signal crayfish. Shasta crayfish had an average of about 30 eggs, whereas signal crayfish averaged over 100 eggs and have been found with more than 240 eggs.

The growth rate of Shasta crayfish during a field enclosure experiment was significantly reduced in treatments with signal crayfish, particularly large signal crayfish (Ellis 1999). A laboratory experiment showed that Shasta crayfish initiated fewer non-aggressive contacts and spent significantly more time being passive and burrowing when signal crayfish were present. Signal crayfish were more aggressive and initiated agonistic behavior more frequently. Predation of Shasta crayfish by large signal crayfish was also observed in the laboratory. Interspecific interactions were strongly asymmetric and size dependent. Signal crayfish, in particular large signal crayfish, had a much greater effect on Shasta crayfish than vice versa. Shasta crayfish sympatric with signal crayfish displayed reduced activity and feeding, which would result in a lower growth rate and fecundity of females. The signal crayfish invasion has resulted in rapid, drastic declines in the abundance of the native crayfish. The invasions of non-native signal crayfish into this native crayfish community are highly successful and appear likely to result in the replacement and extinction of the Shasta crayfish if measures are not taken to develop and protect refuge populations (Ellis 1999, Spring Rivers 2009).

Table 2-1 Summary of Shasta crayfish populations in the Pit 1 Project vicinity, including population characteristics (number, density, estimated population size, and percent composition) from previous and current surveys, potential license effects, habitat area [a], current population estimate, and means of potential take related to the Pit 1 Project license (FERC Project No. 2687).

	Region and Location	1978 [b]	1990, 1991, 1992 [c]	1993 [d] 1997 [e]	2001 [f]	2004–2007 [a, g]	2007–2009 [a, h]	2009–2010 [a, i]	Potential Pit 1 Project Effects	Habitat Area [a] (m^2)	Current Population Estimate	Potential Take
Upper Fall River	Thousand Springs above barrier	**5–20 Shasta** (100%) 0.23–0.75 Shasta/m^2	**230 Shasta** (100%)			**280 Shasta** (92%) 0.212 Shasta/m^2 24 signal (8%) 0.018 signal/m^2	**250 Shasta** (71%) 0.189 Shasta/m^2 102 signal (29%) 0.077 signal/m^2	**113 Shasta** (26%)-'09 0.085 Shasta/m^2 **169 Shasta** (41%) '10 0.128 Shasta/m^2 325 signal (74%) -'09 0.246 signal/$m^2$247 signal (59%) -'10 0.187 signal/m^2	PG&E is funding non-native crayfish removal efforts. PG&E installed a crayfish barrier to prevent upstream migration of signal crayfish	High Quality 1322 Marginal 0 Total 1322	300–600	Survey
	Thousand Springs below barrier (Sand Springs)		**24 Shasta** (100%)			**2 Shasta** (<1%) 0.011 Shasta/m^2 1518 signal (>99%) 7.989 signal/m^2	**0 Shasta** 38 signal (100%) 0.200 signal/m^2		None	High Quality 190 Marginal 0 Total 190	0–20	Survey
	Rainbow Spring	**8 Shasta** (100%) **9 Shasta** (1985)	**45 Shasta** (88%) 6 signal (12%)			**19 Shasta** (45%) 0.044 Shasta/m^2 (*2003 survey*) 23 signal (55%) 0.053 signal/m^2	**8 Shasta** (5%) 0.018 Shasta/m^2 153 signal (95%) 0.352 signal/m^2		Non-native crayfish removal during monitoring surveys	High Quality 434 Marginal 0 Total 434	10–50	Survey
	Fletcher's Bend		**4–11 Shasta** (65%) 0–6 signal (35%)	**4 Shasta** (29%) 0 Shasta (1995) 10 signal (71%)		**0 Shasta** 450 signal (100%) 1.705 signal/m^2	**0 Shasta** 90 signal (100%) 0.341 signal/m^2	**PRESUMED EXTIRPATED**	None	High Quality 264 Marginal 0 Total 264	0	
	Lennihan's Footbridge		**11–13 Shasta** (68%) 0–6 signal (32%)	**1 Shasta** (17%) 5 signal (83%)		**0 Shasta** 112 signal (100%) 0.519 signal/m^2	**0 Shasta** 122 signal (100%) 0.565 signal/m^2	**PRESUMED EXTIRPATED**	None	High Quality 216 Marginal 0 Total 216	0	
Spring Creek	Upper coves	**50 Shasta** (100%) Pop. Size: 600–1000 0.79 Shasta/m^2	**466 Shasta** (100%) Population size: 4640 ± 627 0.83 Shasta/m^2			**316 Shasta** (70%) 0.033 Shasta/m^2 76 signal (30%) 0.008 signal/m^2	**94 Shasta** (23%) 0.010 Shasta/m^2 310 signal (77%) 0.032 signal/m^2	**265 Shasta** (44%) 0.028 Shasta/m^2 331 signal (56%) 0.035 signal/m^2	PG&E is funding non-native crayfish removal efforts. PG&E removed potential refugia for signal crayfish helping to facilitate non-native crayfish removal.	High Quality 9553 Marginal 37 Total 9590	300–600	Survey
	Lower Coves	**8 Shasta** (100%) Pop. Size: 10–50 0.50 Shasta/m^2	**17 Shasta** (100%)			**26 Shasta** (30%) 0.015 Shasta/m^2 61 signal (70%) 0.034 signal/m^2	**13 Shasta** (3%) 0.007 Shasta/m^2 435 signal (97%) 0.244 signal/m^2	**2 Shasta** (<1%) 0.001 Shasta/m^2 246 signal (>99%) 0.138 signal/m^2		High Quality 1780 Marginal 0 Total 1780	5–20	Survey
Lava Creek	Lava Creek	**47 Shasta** (100%) 2.85 Shasta/m^2	**118 Shasta** (98%) 2 signal (1990) (2%)	**12–73 Shasta** (1993–1995) many signal			**45 Shasta** (9%) 468 signal (91%)		Non-native crayfish removal during monitoring surveys	ND	50–200	Survey
	Horr's Northern Pond	**12 Shasta** (100%) Pop. Size: 50–100 0.12 Shasta/m^2		**0 Shasta** 0 signal				**PRESUMED EXTIRPATED**	None	ND	0	

	Region and Location	1978 [b]	1990, 1991, 1992 [c]	1993 [d] 1997 [e]	2001 [f]	2004–2007 [a, g]	2007–2009 [a, h]	2009–2010 [a, i]	Potential Pit 1 Project Effects	Habitat Area [a] (m^2)	Current Population Estimate	Potential Take
Ja She Creek	Ja She Creek headwaters	**0 Shasta** (at bridge)	**33 Shasta** 1 signal (at bridge)		**62 Shasta** (15%) 0.007 Shasta/m^2 364 signal (85%) 0.043 signal/m^2	**54 Shasta** (4%) 0.006 Shasta/m^2 1386 signal (96%) 0.163 signal/m^2	**82 Shasta** (4%) 0.010 Shasta/m^2 1783 signal (96%) 0.210 signal/m^2	**33 Shasta** (2%) 0.004 Shasta/m^2 1945 signal (98%) 0.229 signal/m^2	Non-native crayfish removal during monitoring surveys	High Quality 8507 Marginal 463 Total 8970	50–100	Survey
	Crystal Springs Cove	**1 Shasta** molt 0.04 Shasta/m^2	**11 Shasta** (100%)		**17 Shasta** (5%) 0.005 Shasta/m^2 315 signal (95%) 0.085 signal/m^2	**4 Shasta** (<1%) 0.001 Shasta/m^2 1791 signal (>99%) 0.485 signal/m^2	**4 Shasta** (<1%) 0.001 Shasta/m^2 1748 signal (>99%) 0.473 signal/m^2	**0 Shasta** 4124 signal (>99%) 1.117 signal/m^2 4 northern (<1%) 0.001 northern/m^2	Non-native crayfish removal during monitoring surveys	High Quality 3693 Marginal 89 Total 3782	0–20	Survey
	Tule Coves		**16 Shasta** (67%) 8 signal (33%)		**13 Shasta** (25%) 0.062 Shasta/m^2 39 signal (75%) 0.185 signal/m^2	**8 Shasta** (13%) 0.038 Shasta/m^2 52 signal (87%) 0.246 signal/m^2	**2 Shasta** (2%) 0.009 Shasta/m^2 103 signal (97%) 0.488 signal/m^2 1 northern (1%) 0.005 northern/m^2	**0 Shasta** 26 signal (96%) 0.123 signal/m^2 1 northern (4%) 0.005 northern/m^2	Non-native crayfish removal during monitoring surveys	High Quality 211 Marginal 20 Total 231	0–20	Survey
Upper Big Lake	Big Lake Springs	**12 Shasta** (100%) 1.00 Shasta/m^2	**39 Shasta** (100%)		**61 Shasta** (100%) 0.345 Shasta/m^2	**36 Shasta** (92%) 0.203 Shasta/m^2 3 signal (8%) 0.017 signal/m^2	**41 Shasta** (27%) 0.232 Shasta/m^2 109 signal (73%) 0.616 signal/m^2	**2 Shasta** (1%) 0.011 Shasta/m^2 142 signal (99%) 0.802 signal/m^2	Non-native crayfish removal during monitoring surveys	High Quality 177 Marginal 0 Total 177	5–50	Survey
	North Big Lake		**32 Shasta** (100%)		**49 Shasta** (83%) 0.0375 Shasta/m^2 10 signal (17%) 0.008 signal/m^2	**9 Shasta** (2%) 0.007 Shasta/m^2 355 signal (98%) 0.269 signal/m^2	**8 Shasta** (1%) 0.006 Shasta/m^2 590 signal (99%) 0.448 signal/m^2	**6 Shasta** (<1%) 0.005 Shasta/m^2 768 signal (>99%) 0.583 signal/m^2	Non-native crayfish removal during monitoring surveys	High Quality 1318 Marginal 8 Total 1326	5–50	Survey
	Northeast Big Lake	**10 Shasta** (100%) 1.11 Shasta/m^2	**32 Shasta** (100%)		**0 Shasta** 6 signal (100%) 0.022 Shasta/m^2	**1 Shasta** (25%) 0.004 Shasta/m^2 3 signal (75%) 0.011 signal/m^2	**0 Shasta** 0 signal	**0 Shasta** 47 signal (100%) 0.170 signal/m^2	Non-native crayfish removal during monitoring surveys	High Quality 276 Marginal 0 Total 276	0–20	Survey
	Northwest Big Lake		**7 Shasta** (100%)		**3 Shasta** (20%) 0.273 Shasta/m^2 12 signal (80%) 1.091 Shasta/m^2	**1 Shasta** (33%) 0.091 Shasta/m^2 2 signal (67%) 0.182 signal/m^2	**2 Shasta** (20%) 0.182 Shasta/m^2 8 signal (80%) 0.727 signal/m^2	**0 Shasta** 1 signal (100%) 0.091 signal/m^2	Non-native crayfish removal during monitoring surveys	High Quality 11 Marginal 0 Total 11	0–20	Survey

	Region and Location	1978 [b]	1990, 1991, 1992 [c]	1993 [d] 1997 [e]	2001 [f]	2004–2007 [a, g]	2007–2009 [a, h]	2009–2010 [a, i]	Potential Pit 1 Project Effects	Habitat Area [a] (m^2)	Current Population Estimate	Potential Take
Tule River Levee System	South Big Lake (only South Big Lake Levee Cove in 2004–2007)	**30 Shasta** (100%) 3.56 Shasta/m^2	**0–9 Shasta** (100%)	**2 Shasta** (66%) 1 northern (33%)		**9 Shasta** (43%) 0.007 Shasta/m^2 3 signal (14%) 0.002 signal/m^2 9 northern (43%) 0.007 northern/m^2	**0 Shasta** 3 signal (5%) 0.002 signal/m^2 59 northern (95%) 0.047 northern/m^2	**0 Shasta** 0 signal 0 northern (poor visibility)	PG&E's maintenance of the levees minimizes in-water activities and disturbances that could be harmful to Shasta crayfish.	High Quality 0 Marginal 1265 Total 1265	0–20	Survey
Tule River Levee System	Northeast upper Tule River	**30 Shasta** (100%) 1.20 Shasta/m^2	**5 Shasta** (83%) 1 signal (17%)		**0 Shasta**	**0 Shasta** 0 signal 5 northern (100%) No habitat identified	**0 Shasta** 2 signal (13%) 14 northern (87%)	PRESUMED EXTIRPATED	None	High Quality 0 Marginal 0 Total 0	0	
Tule River Levee System	South shore upper Tule River		**4 Shasta** (29%) 10 signal (71%)	**0 Shasta** 1 signal YOY		**0 Shasta** 18 signal (23%) 0.857 signal/m^2 60 northern (77%) 2.857 northern/m^2	PRESUMED EXTIRPATED		None	High Quality 0 Marginal 21 Total 21	0	
Tule River Levee System	East shore upper Tule River		**Shasta** molts 11 signal			**0 Shasta** 1 signal (100%) No habitat identified	PRESUMED EXTIRPATED		None	High Quality 0 Marginal 0 Total 0	0	
Tule River Levee System	Horr Pond levee		**7 Shasta** (100%)		**0 Shasta** 26 signal (84%) 0.347 signal/m^2 5 northern (16%) 0.067 northern/m^2	**0 Shasta** 7 signal (18%) 0.093 signal/m^2 33 northern (82%) 0.440 northern/m^2	**0 Shasta** 4 signal (17%) 0.053 signal/m^2 20 northern (83%) 0.267 northern/m^2	PRESUMED EXTIRPATED	None	High Quality 75 Marginal 0 Total 75	0	
Fall River Pond	Fall River Pond	**1 Shasta** (dead) 0.15 Shasta/m^2	**0 Shasta** 0 to many signal 0 to most northern			**0 Shasta** 8 signal (3%) 0.002 signal/m^2 230 northern (97%) 0.047 northern/m^2	PRESUMED EXTIRPATED		None	High Quality 4852 Marginal 64 Total 4916	0	

Region	Region and Location	1978 [b]	1990, 1991, 1992 [c]	1993 [d] 1997 [e]	2001 [f]	2004–2007 [a, g]	2007–2009 [a, h]	2009–2010 [a, i]	Potential Pit 1 Project Effects	Habitat Area [a] (m^2)	Current Population Estimate	Potential Take
Mainstem Pit River	Upper and lower Pit River (Pit 1 Bypass)		**4 Shasta** (1995) many northern			**21 Shasta** (49%) 0.028 Shasta/m^2 10 signal (23%) 0.013 signal/m^2 12 northern (28%) 0.016 northern/m^2	**1 Shasta** (dead, 2%) 0.001 Shasta/m^2 29 signal (55%) 0.039 signal/m^2 23 northern (43%) 0.031 northern/m^2		Minimum instream flow releases and summer pulsed flows (i.e., flushing, recreational, outage spill flows) through the Pit 1 Bypass Reach increase mean daily water temperatures, reduce the size of coldwater habitat created by coldwater springs, and eliminate diel temperature fluctuations and cooler nighttime water temperatures	High Quality 750 Marginal 0 Total 750	5–50	Minimum Instream Flow Releases, Summer Pulsed Flows, Survey
	Pit 1 Footbridge (Pit 1 Bypass)	**1 Shasta** (dead)	**1 Shasta** (dead) signal present 0 northern			**0 Shasta** 3 signal (1%) 0.040 signal/m^2 198 northern (99%)[2] 2.640 northern/m^2				High Quality 75 Marginal 0 Total 75	0–20	
	Pit 1 Sand Pits (below Pit 1 Powerhouse and 299 Bridge)	**8 Shasta** (3%) 0.44 Shasta/m^2 297 northern (97%) 3.11 northern/m^2	**0 Shasta** abundant signal 0 northern			**0 Shasta** many signal 1 northern	PRESUMED EXTIRPATED		Project peaking results in fluctuations in flow	ND	0	
Sucker Springs	Sucker Springs Creek (all ponds)	**10 Shasta** (100%) 0.2 Shasta/m^2	**4 Shasta** (<<1%) Pond 5 47 signal (>>99%) Pond 5	**27 Shasta** Pond 3	**53 Shasta** Pond 1	**3 Shasta** (<<1%) 2066 signal (>>99%)	**7 Shasta** (1%) 750 signal (99%)		Non-native crayfish removal during monitoring surveys	High Quality 1400 Marginal 0 Total 1400	5–50	Survey

[a] ND=habitat area not determined. Habitat and crayfish data were verified and updated in 2009. Crayfish densities were calculated using the total area of high quality habitat except at South Big Lake and South shore upper Tule River where the area of marginal habitat, which was the only habitat present, was used.
[b] Daniels, June – October 1978 (unpublished data in letter dated 7/13/95, Daniels 1978, Daniels 1980, Eng and Daniels 1982)
[c] Light 1990 unpublished notes, Hesseldenz and Ellis 1991, Light et al. 1991, 1995, Erman et al. 1993, Ellis 1996
[d] Ellis 1993 data (Ellis 1994,1999)
[e] PG&E Shasta crayfish monitoring along the South shore Tule River levee on 6 March, 12 August, 31 October 1997 (Spring Rivers unpublished data)
[f] Ahjumawi Lava Springs State Park Survey (Spring Rivers 2001)
[g] PG&E Shasta crayfish monitoring March 2004 – February 2007 (Spring Rivers 2007)
[h] PG&E Shasta crayfish monitoring March 2007 – March 2009
[i] PG&E Shasta crayfish monitoring April 2009 – December 2010

Table 2-2 Summary of Shasta crayfish populations in the Hat Creek Project vicinity, including population characteristics (number, density, estimated population size, and percent composition) from previous and current surveys, potential license effects, habitat area [a], current population estimate, and means of potential take related to the Hat Creek Project license (FERC Project No. 2661).

	Region and Location	1978 [b]	1990 [c]–1991 [d]	1993 [e]	2003 [a, f]	2004 [a, g]	2007 [a, h]	2010 [a, i]	Potential License Effects	Habitat Area [a] (m^2)	Current Population Estimate	Potential Take
Crystal Lake	Southwest Cove	**12 Shasta** (100%) 0.12 Shasta/m^2	signal (no scuba)	**31 Shasta** (50%) 31 signal (50%)	**137 Shasta** (55%) 0.147 Shasta/m^2 113 signal (45%) 0.122 signal/m^2	**263 Shasta** (55%) 0.283 Shasta/m^2 216 signal (45%) 0.232 signal/m^2	**130 Shasta** (43%) 0.140 Shasta/m^2 174 signal (57%) 0.187 signal/m^2	**43 Shasta** (25%) 0.046 Shasta/m^2 130 signal (75%) 0.140 signal/m^2	Non-native crayfish removal during monitoring surveys	High Quality 930 Marginal 2069 Total 2999	50–300	Survey
	Middle Cove		**~2 Shasta** (33%) 4 signal (67%)	**5 Shasta** (33%) 10 signal (67%)	**2 Shasta** (2%) 0.003 Shasta/m^2 123 signal (98%) 0.202 signal/m^2	**2 Shasta** (1%) 0.003 Shasta/m^2 217 signal (99%) 0.356 signal/m^2	**0 Shasta** 154 signal (100%) 0.252 signal/m^2	**0 Shasta** 207 signal (100%) 0.339 signal/m^2	Non-native crayfish removal during monitoring surveys	High Quality 610 Marginal 1226 Total 1836	0–20	Survey
	Outflow	**658 Shasta** (100%) 6.89 Shasta/m^2 Pop. Size: 2000–3000 Shasta	**98 Shasta** (13%) population size: 369 ± 135 Shasta 646 signal (87%)	**50 Shasta** (13%) 90 signal (87%)	**23 Shasta** (2%) 0.097 Shasta/m^2 1220 signal (98%) 5.126 signal/m^2	**7 Shasta** (<1%) 0.029 Shasta/m^2 1327 signal (>99%) 5.576 signal/m^2	**2 Shasta** (<1%) 0.008 Shasta/m^2 457 signal (>99%) 1.920 signal/m^2	**0 Shasta** 496 signal (100%) 2.084 signal/m^2	Non-native crayfish removal during monitoring surveys	High Quality 238 Marginal 613 Total 851	0–20	Survey
Baum Lake	Baum Lake at Crystal Inflow	**3 Shasta** (1%) 0.09 Shasta/m^2 230 signal (99%) 3.81 signal/m^2	**0 Shasta** 19 signal (100%)	**1 Shasta** (10%) 9 signal (90%)	**0 Shasta** 172 signal (100%) 0.831 signal/m^2	**0 Shasta** 283 signal (100%) 1.367 signal/m^2	**0 Shasta** 193 signal (100%) 0.932 signal/m^2	PRESUMED EXTIRPATED	None	High Quality 207 Marginal 225 Total 432	0	
	Rock Creek				**0 Shasta** 0 signal				Restoration/ Reintroduction Plan	Potential Habitat High Quality 1259	0	
Rising River	Rising River Road Bridge			**7 Shasta** (100%)					None	ND	ND	Survey
	Rising River footbridge			**7 Shasta** (100%)					None	ND	ND	Survey
	Rising River Lake outflow	**25 Shasta** (100%) 2 Shasta/m^2 Pop. Size: 100 Shasta	**18 Shasta** (100%)	**18 Shasta** (100%)					None	ND	ND	Survey
	Rising River Lake			**5 Shasta** (100%)					None	ND	ND	Survey

[a] ND=habitat area not determined. Habitat and crayfish data were verified and updated in 2009. Crayfish densities were calculated using the total area of high quality habitat.
[b] Daniels, 12 June – 7 November 1978 (unpublished data in letter dated 7/13/95, Daniels 1978, Daniels 1980, Eng and Daniels 1982)
[c] Clarke and Light, 19, 22, 27 June & 3 July 1990 (Light 1990 unpublished notes, Light 1991, Light et al. 1991, 1995, Erman et al. 1993)
[d] Light and Myrick—Summer 1991 (Light 1991 unpublished data, Erman et al. 1993)
[e] Ellis and Cook, 6 August and 21 & 27 October 1993 (Ellis 1994, Ellis 1999)
[f] PG&E Shasta crayfish monitoring September 2003 – February 2004 (Spring Rivers 2004)
[g] PG&E Shasta crayfish monitoring November 2004 – February 2005 (Spring Rivers 2005
[h] PG&E Shasta crayfish monitoring January– April 2007 (Spring Rivers 2008)
[i] PG&E Shasta crayfish monitoring January–April 2011 (Spring Rivers unpublished data)

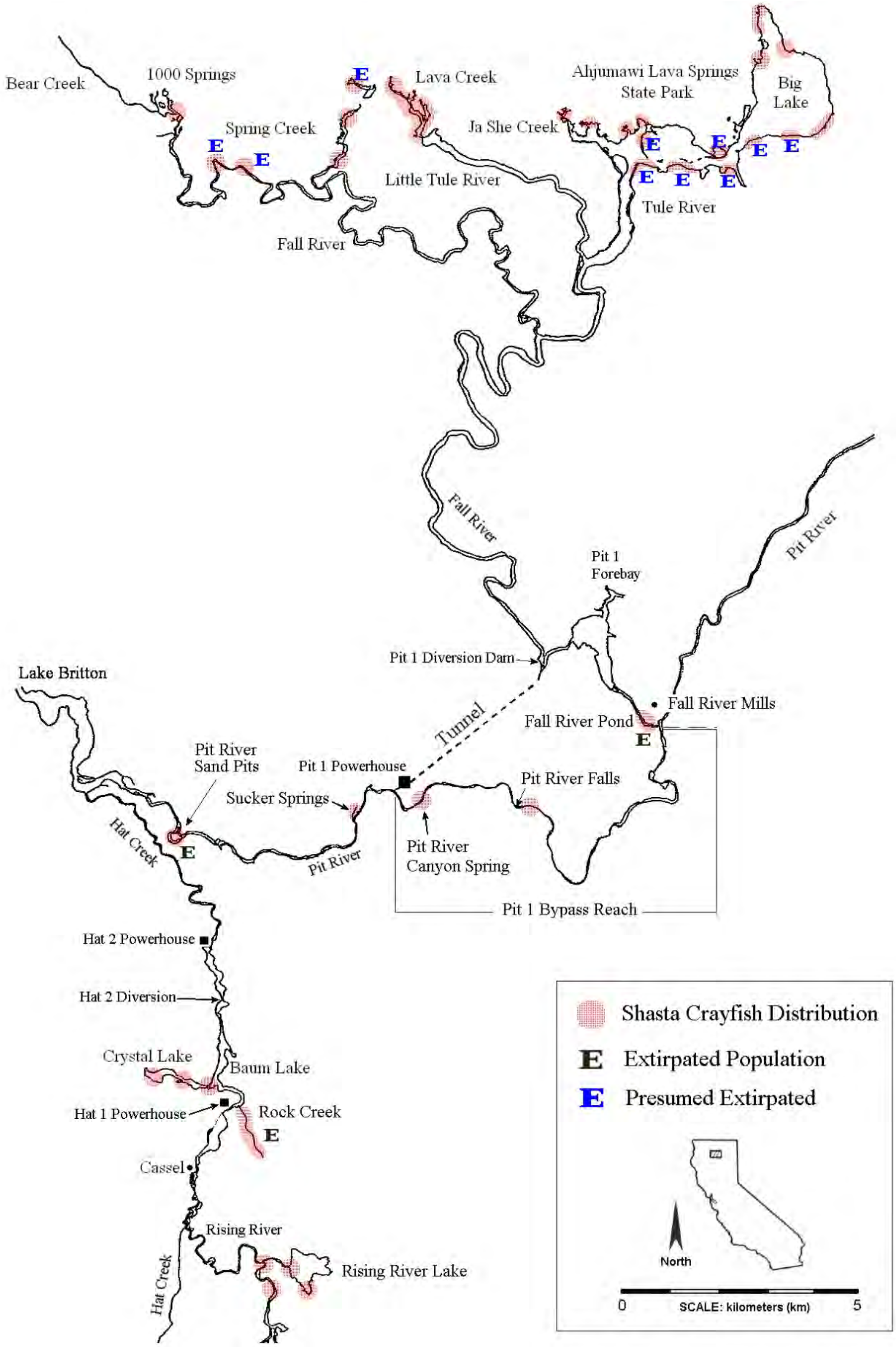


Figure 2-1. Known distribution, range, and population status of the Shasta crayfish (*Pacifastacus fortis*).

3.0 METHODS

This section provides an analysis of regional and local water resource data from a number of different sources. The data sources and rationales for utilization of different data in regard to the impact assessment are defined in this section.

3.1 REGIONAL CONDITIONS

In order to properly compare available water resource data, each monitoring period was evaluated with regard to its monitoring setting. The monitoring setting is defined as the combined influence of regional meteorology and hydrology on water resource conditions during the specific period being evaluated.

3.1.1 Meteorology

Regional meteorological conditions were defined using data from the permanent station located at the Hat Creek Powerhouse No. 1 (CDEC Station ID HTC [CDEC 2012a]). Data from the Hat Creek Powerhouse No. 1 meteorological station were used to define the monthly air temperature exceedance characteristics for the June-through-September period compared with the long term data record. This station was also used to define annual precipitation and rank each monitoring year (i.e., percent of normal rainfall) for the period of record.

3.1.2 Hydrology

Regional runoff in the Pit 1 Project area was defined using data from the United States Geological Survey (USGS) stream gage on the Pit River downstream of Pit 1 Powerhouse (USGS Gage 11355010). Data from the USGS Gage (e.g., USGS 2012) were used to rank each monitoring year (i.e., percent of normal runoff) through the Pit 1 Project for the period of record. This station measures all stream flow leaving the Project area, and since the Project is not capable of storing large volumes of water for long periods (maximum active storage 364 acre-feet), nor does the project transfer waters outside the watershed, it is therefore the best source to define long term runoff in the watershed. The data from this stations is used to rank water years (annual totals), and monthly average data for each applicable monitoring period.

3.2 Pit 1 Project Relicensing-Compliance Monitoring Programs

Water resource data, including hydrological and climatological data, were obtained from PG&E's existing database of monitoring results from the relicensing and compliance monitoring programs associated with the Pit 1 Project. For this document, three flow regime periods are defined, the Pre-1993, Pre-2003, and Post-2003 regimes.

Water resource data from June through September (Summer) collected during the 1990–1992 relicensing effort define conditions in the Pit River before operations of the Muck Valley Hydroelectric Project[8] (in 1993) and implementation of the license-required flow regime consisting of both minimum instream flows and flushing flows in 2003. This period is identified as the Pre-1993 regime throughout this document. Data collected during the 1990–1992 effort were presented in the Exhibit E of the PG&E Pit 1 License Application (PG&E 1993a). The hydrologic regime for the summer months during this period was influenced primarily by natural runoff conditions and agricultural influences (input and withdrawals) under critically dry conditions during the entire period (DWR Water Year Indices [CDEC 2012b]). Table 3-1 identifies the monitoring period associated with each of the hydrologic regimes, as well as the water year type.

Summer water resource data from a 1995 unpublished monitoring effort were used to highlight the impact Muck Valley operations have had on the hydrologic regime in the Pit 1 Bypass Reach. During the period from October 1993 through June 2003 (prior to implementation of the Fall River minimum instream flows and flushing flows), no releases were made from the Pit 1 Project to the Pit River through the Lower Fall River reach, and as a result, Muck Valley operations and agricultural influences (input and withdrawals) were the primary non-natural, variable influences on the hydrologic conditions in the Pit 1 Bypass Reach. This period is identified as the Pre-2003 Regime throughout this document. The 1995 data were collected as part of PG&E's voluntary effort to define how flow conditions in the Big Eddy section

---

8 Beginning in 1993, the flow regime in the Pit River upstream of the Pit 1 Project was altered by the operations of the Muck Valley Hydroelectric Project (FERC License No. 8296-CA), owned by Malacha Hydro Limited Partnership.

influenced thermal stratification and dissolved oxygen levels. The hydrologic regime during 1995 was defined as "wet" using the DWR index (CDEC 2012b).

Summer water resource data collected during the 2004–2011 compliance monitoring efforts were used to define current conditions in the Pit 1 Bypass Reach following implementation of the Fall River minimum instream flows (2003–present) and Fall River Pond flushing flows (2003–2009). This period is identified as the Post-2003 Regime throughout this document. Data from these monitoring efforts are contained in each of the eight annual reports completed as part of the compliance monitoring requirement of the existing Pit 1 FERC license (PG&E 2004a, 2005, 2006a, 2007, 2008, 2009a, 2010b, 2011b, 2012c). The hydrologic regime for the summer months during this period is influenced by natural runoff conditions, the required minimum instream flows (MIF) from the Pit 1 Project (Fall River as the source), flushing flow events (2003–2009), Muck Valley operations, and agricultural influences (input and withdrawals).

It should be noted that the data sets used to define the three flow-regime periods differ significantly with regard to monitoring settings and monitoring duration. The Pre-1993 data set (1990–1992) was collected during consecutive dry-year conditions at the end of the 1987–1992 drought. As a result, this data set represents what could be considered as worst-case-scenario conditions before either Muck Valley or the Fall River minimum instream flows affected the flow regime in the Pit 1 Bypass Reach. The Pre-2003 regime, which was collected in 1995 under wet-year conditions, is defined using a single data year from a single station (Big Eddy Station PR2). This data set is included primarily to illustrate the effect of Muck Valley operations on conditions in the Pit 1 Bypass Reach. The Post-2003 regime as defined by the data set (2004–2011) is the most robust, covering a number of different water-year types and air-temperature conditions.

3.2.1 Monitoring Locations

This section will discuss key stations from the relicensing and compliance monitoring programs in support of this investigation. Table 3-2 identifies all stations used for this investigation and their associated monitoring history, and monitoring activities.

A total of four water resource monitoring stations in the Pit 1 Bypass Reach were utilized for this investigation (Figure 3-1). The first of these stations, which was instrumented only during the 1990–1992 period, was located immediately downstream of the Pit River Weir (Station P7).

A second station (Station PR2) was located at the downstream end of Big Eddy, 1.9 miles downstream of the Pit River Weir. This location, which was first instrumented in August 1991, has been used for all subsequent monitoring efforts.[9] This location defines terminal conditions in the low-gradient, Big Eddy section of the bypass reach as well as initial conditions in the lower Pit 1 Bypass Reach entering the canyon.

The Pit River Falls (Station PR3), which is the third station in the Pit 1 Bypass Reach, was located immediately downstream of the Pit River Falls (4.6 miles downstream of the Pit River Weir, and 0.3 miles downstream of spring habitat with documented occurrences of Shasta crayfish). This location, which was first instrumented in May 1990, has been used for all subsequent monitoring efforts through 2009. This location defines intermediate conditions in the lower Pit 1 Bypass Reach.

The final station in the Pit 1 Bypass Reach (Station PR4) was located 0.6 miles upstream of the Pit 1 Powerhouse tailrace at the Pit 1 Footbridge (5.9 miles downstream of the Pit River Weir). This location was first instrumented in May 1990, and the same location was used for all subsequent monitoring efforts through 2011. This location defines conditions at the downstream end of the lower Pit 1 Bypass Reach.

Two water resource monitoring stations were used to define conditions in the Pit 1 Peaking Reach (Table 3-2). The first station (P10) was monitored during the 1990–1992 Relicensing effort; this station was located approximately 300 feet downstream of the Pit 1 Powerhouse tailrace confluence. The second station (PR5) has been monitored since 2004 as part of the ongoing FERC required compliance monitoring program (PG&E 2010c); and is located

---

9 As specified in the Water Quality Monitoring Plan Amendment (PG&E 2010c) water quality monitoring continues at six locations, including PR2, PR4, and PR5. Station PR1 was moved to a new location upstream of the bypass reach. Two stations are located in the Fall River, one upstream and one downstream of the Pit 1 Forebay.

approximately 1,000 feet downstream of the tailrace confluence. Both of these stations are located in the same general area and measure similar conditions in the Pit 1 Peaking Reach (Figure 3-1).

3.3 2004 COLDWATER REFUGIA STUDY

The 2004 Coldwater Refugia Study was conducted in the Pit 1 Bypass Reach in August 2004, and the results were presented as part of PG&E's 2009 report "*A Biological Evaluation of Thermal Effects from Summer Flushing/Whitewater Flows on Spring-influenced Aquatic Habitat in the Pit 1 Bypass Reach*" (PG&E 2009b). During the 2004 monitoring effort, temperature arrays were installed in the outflow of an approximately 5 cfs spring downstream of the Pit 1 Footbridge (i.e., PG&E Spring) to quantify the area of coldwater habitat during a 900-cfs flushing flow event (977 cfs at the Pit 1 Footbridge PR4 gage station) on August 28 and a base flow of 277 cfs (150-cfs Fall River minimum instream flow release plus Pit River flow plus 100 cfs spring accretion) on August 30 (PG&E 2009b). The mean daily water temperature in the mainstem river (outside the coldwater refugia habitat) was 21.5 ºC during the flushing flow and 19.8 ºC at the base flow.

3.3.1 Jet Plume Model

The data from the 2004 Coldwater Refugia Study were used to verify predictions made by the application of jet/plume theoretical formulae (Fisher et al. 1979). A Jet-Plume model, which utilized the formulae developed for a jet/plume injecting into a moving cross stream, was used as a conceptual tool to characterize changes in the physical habitats associated with cool spring inflows under different flow regimes (PG&E 2009b). The Jet-Plume model was used to predict changes to coldwater habitat in spring-influenced areas of the Pit 1 Bypass Reach resulting from a flushing flow. Predicted effects were then compared to observed data.

3.4 SHASTA CRAYFISH TEMPERATURE MONITORING

In addition to the relicensing and compliance monitoring programs associated with the Pit 1 Project in the early 1990s, PG&E monitored water temperature at or near Shasta crayfish population sites in 1991 and 1992. Temperature recorders were deployed at Big Lake Springs, Lava Creek outflow, Spring Creek upstream of Spring Creek Road Crossing, Fall River at Spring

Creek Road Bridge, and South Big Lake Levee Cove between September 1991 and September 1992. These stations were chosen because they were reasonably accessible, and they captured some of the range of conditions found at Shasta crayfish population sites. In situ water temperature measurements were also taken during crayfish surveys conducted for the Pit 1 relicensing crayfish surveys.

In coordination with CDFW, water temperature was monitored at most Shasta crayfish locations between 2009 and 2012 (Spring Rivers 2010, 2011, 2012). Temperature recorders were deployed at Thousand Springs (2/7/2009 – 6/9/2010), Spring Creek (2/20/2009 – 2/24/2010), Ja She Creek (1/21/2011 – 4/17/2012), Big Lake Springs (2/28/2009 – 2/9/2010), South Big Lake Levee Cove (2/28/2009 – 3/10/2010), upper Pit River in the Pit 1 Bypass Reach (7/7/2009 – 11/23/2009), lower Pit River in the Pit 1 Bypass Reach (7/7/2009 – 11/23/2009), Sucker Springs Creek (3/10/2009 – 3/4/2010), Crystal Lake (1/25/2011 – 2/5/2012), and Rock Creek (3/11/2009 – 3/7/2010). A full year of temperature data was generally recorded at each location except for the Pit 1 Bypass Reach, where the recorders were removed for the winter until after spring runoff. Figure 3-2 show the monitoring locations of the temperature study.

3.5 2012 Pit 1 Bypass Reach Spring Inflow Study

This section provides the methods of the Pit 1 Bypass Reach Spring Inflow Study, including both field surveys and installation of temperature arrays in the summer of 2012. The purpose of this field component was to quantify the combined area and quality of coldwater habitat in the Pit 1 Bypass Reach under the summer minimum instream flow release of 150 cfs.

3.5.1 Field Surveys

The Pit 1 Bypass Reach between Big Eddy and the Pit 1 Powerhouse tailrace was surveyed to document the number, location, and temperature of all visibly identifiable springs, and to estimate and/or measure discharge. The specific conductivity of each spring was measured as a potential indicator of the spring source (i.e., groundwater versus subsurface movement of river water). Instantaneous measurements of water temperature were taken at each spring inflow, including multiple measurements between the spring source and the mainstem. The majority of instantaneous measurements were taken at mid-day (10:00 to 16:00) during July 24, 2012 through September 5, 2012. The spatial extent of the coldwater plume where the spring flows into the river (i.e., refugia habitat) was assessed using a rapid-readout digital thermometer to locate the edge of coldwater habitat for all visibly identifiable springs with water temperatures less than or equal to 18 °C.

3.5.2 Continuous Monitoring Temperature Arrays

Temperature sensor arrays (i.e., TempLine and/or Campbell loggers with 6–15 sensors each) were installed in four coldwater spring areas in late June and early July. The arrays were installed prior to the warmest period of the summer in order to define the spatial extent, diel temperature patterns, and thermal regime of coldwater refugia in the Pit 1 Bypass Reach throughout the summer period. The diel cycle is the natural pattern of water temperatures that occur as a result of meteorological conditions (primarily air temperature) over a daily cycle. Typically, water temperatures exhibit near-dawn minima and late-afternoon maxima. For the purpose of this investigation, the diel cycle or change was defined as the difference between the maximum and minimum hourly average water temperature for each day.

The arrays were installed as early as possible and left in place through September in an effort to capture the influence of the cooler (June and September) and warmer (July-August) periods of mainstem river temperatures on coldwater refugia. Prior to array installation, single VEMCO Minilog sensors were installed at three array sites and one additional location during late April in the event that the arrays could not be installed early enough in the season. At each site, one VEMCO was placed in the spring and one was placed in the refuge area at the mouth of the spring. The VEMCO sensors could be installed earlier than the arrays, because they are less susceptible to displacement by high flow events. The temperature data from these sensors supplemented the data from the temperature arrays. All of the temperature monitoring equipment was left in place through September 30, 2012.

Temperature array locations were selected in order to monitor groundwater springs that (1) range in size from smaller to larger; (2) create coldwater habitat where Shasta crayfish are found; (3) interact with mainstem river temperatures that are warmer than in the lower Pit 1 Bypass Reach; and (4) lower the mainstem river temperature in the bypass reach. The following springs were selected: (1) downstream Shasta Spring (RR #10, River Kilometer (RK) 86.82, 13.8 °C, ~3 cfs); (2) upstream Surge Spring (RL #30, RK 84.24, 14.0 °C, ~0.1 cfs); (3) Surge Spring (RR

#31, RK 84.24, 13.4 °C, ~3 cfs); and (4) PG&E Spring (2004 Coldwater Refugia Study site, RR #34, RK 83.88, 15.5–16.4 °C, 4.9 cfs). The single VEMCO sensors were installed at the downstream Shasta Spring, Surge Spring, and PG&E Spring sites and at one site where arrays were not installed. The latter site, upper Shasta Spring (RR #9, RK 86.86, 15.1 °C, ~5 cfs), is where one Shasta crayfish was found during September 2008. Temperatures at this site were also monitored during July through September in 2009 (Figure 3-2, Station 09-PR-01).

Temperature data were analyzed to determine the area and quality of Cold (<15–17 °C), Marginally Cold (17.1–18 °C), Cool (18.1–19 °C), and Warm (>19 °C) habitat in the Pit 1 Bypass Reach under the current summer flow regime, which combines the current 150 cfs minimum instream flow release from the Fall River and the Pit River flows.

Table 3-1. Description of hydrologic regime classification and associated monitoring periods, and water year conditions.

Period Designation	Hydrologic Regime	Data Period	Source	Water Year Qualification
Pre-1993	Original license condition, no release from Fall River through Lower Fall River to the Pit River. Also prior to Muck Valley operations.	1990	PG&E 1993	Critically Dry
		1991	PG&E 1993	Critically Dry
		1992	PG&E 1993	Critically Dry
Pre-2003	Represents conditions before current Pit 1 Project releases, but after the start of Muck Valley Operations. No release from Fall River through the Lower Fall River to the Pit River.	June-Sept 1995	Unpublished PG&E	Wet
Post-2003	Current license conditions, 150 cfs summer releases from Lower Fall River to the Pit River. Muck Valley operations affect flow regime in the Pit 1 Impoundment and into the Pit 1 Bypass Reach.	June-Oct 2004	PG&E 2004b	Below Normal
		June-Oct 2005	PG&E 2005	Above Normal
		June-Oct 2006	PG&E 2006b	Wet
		June-Oct 2007	PG&E 2007	Dry
		June-Oct 2008	PG&E 2008	Critically Dry
		June-Oct 2009	PG&E 2010c	Dry
		June-Oct 2010	PG&E 2011b	Below Normal
		June-Oct 2011	PG&E 2012c	Wet

Table 3-2. Monitoring station description and monitoring history.

Station ID		Station Description	Monitoring History	Latitude	Longitude
1990–95	2004–2011				
P7	--	Pit River downstream of Pit Weir	1990–1992	40°59'50.21"N	121°26'08.61"W
BE	PR2	Pit River downstream of Big Eddy	1992, 1995, 2004–2011	40°59'00.06"N	121°26'48.18"W
P8	PR3	Pit River downstream of Pit River Falls	1992, 1995, 2004–2009	40°59'13.48"N	121°28'23.62"W
P9	PR4	Pit River at Pit 1 Footbridge upstream of the Pit 1 Powerhouse	1992, 1995, 2004–2011	40°59'20.94"N	121°29'40.79"W
P10	--	Pit River downstream of the Pit 1 Powerhouse	1990–1992	40°59'23.75"N	121°30'12.38"W
--	PR5	Pit River downstream of the Pit 1 Powerhouse	2004–2011	40°59'22.51"N	121°30'21.68"W

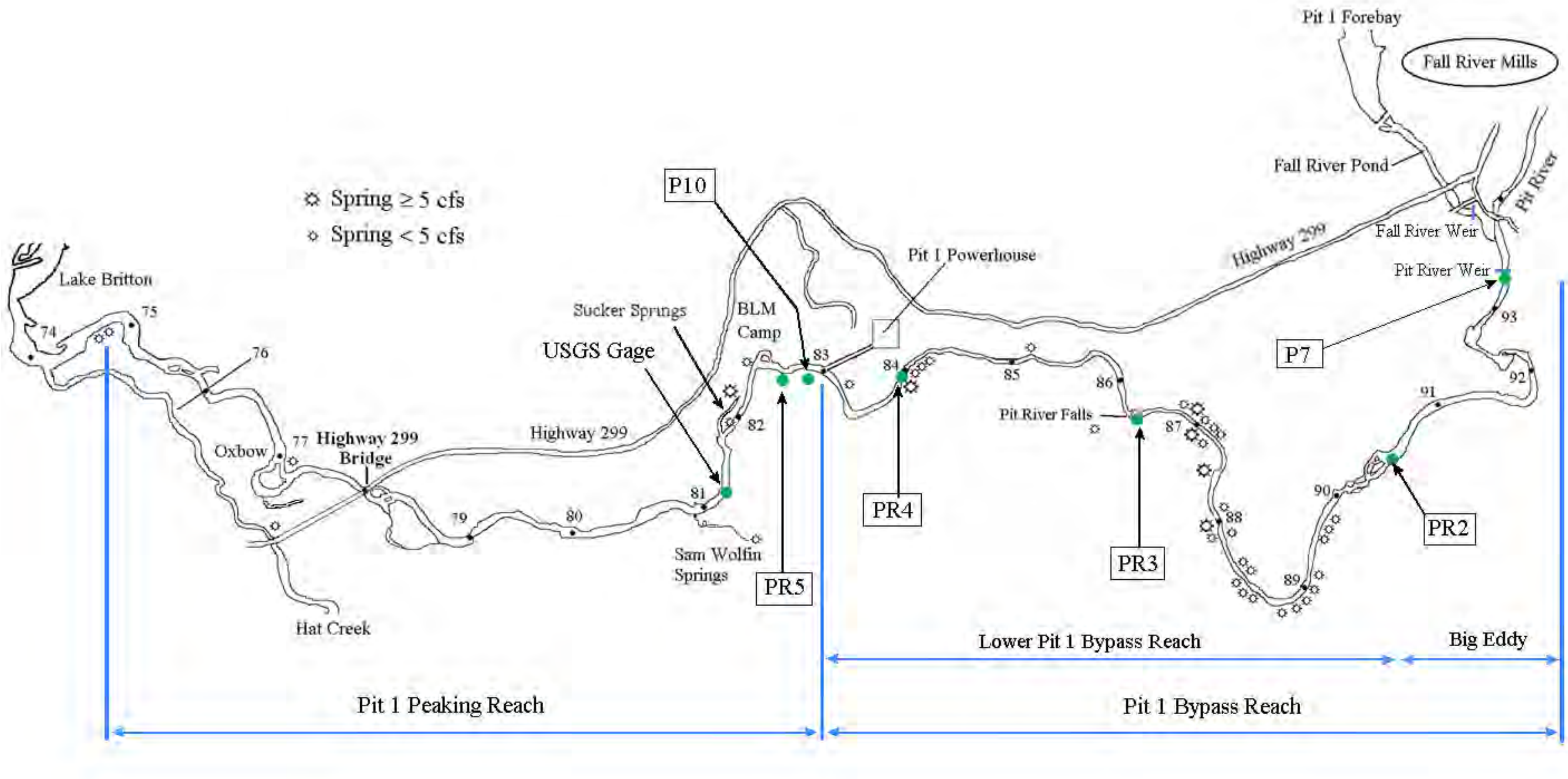


Figure 3-1. Water quality monitoring station locations and springs in the Pit 1 Bypass and Pit 1 Peaking reaches.

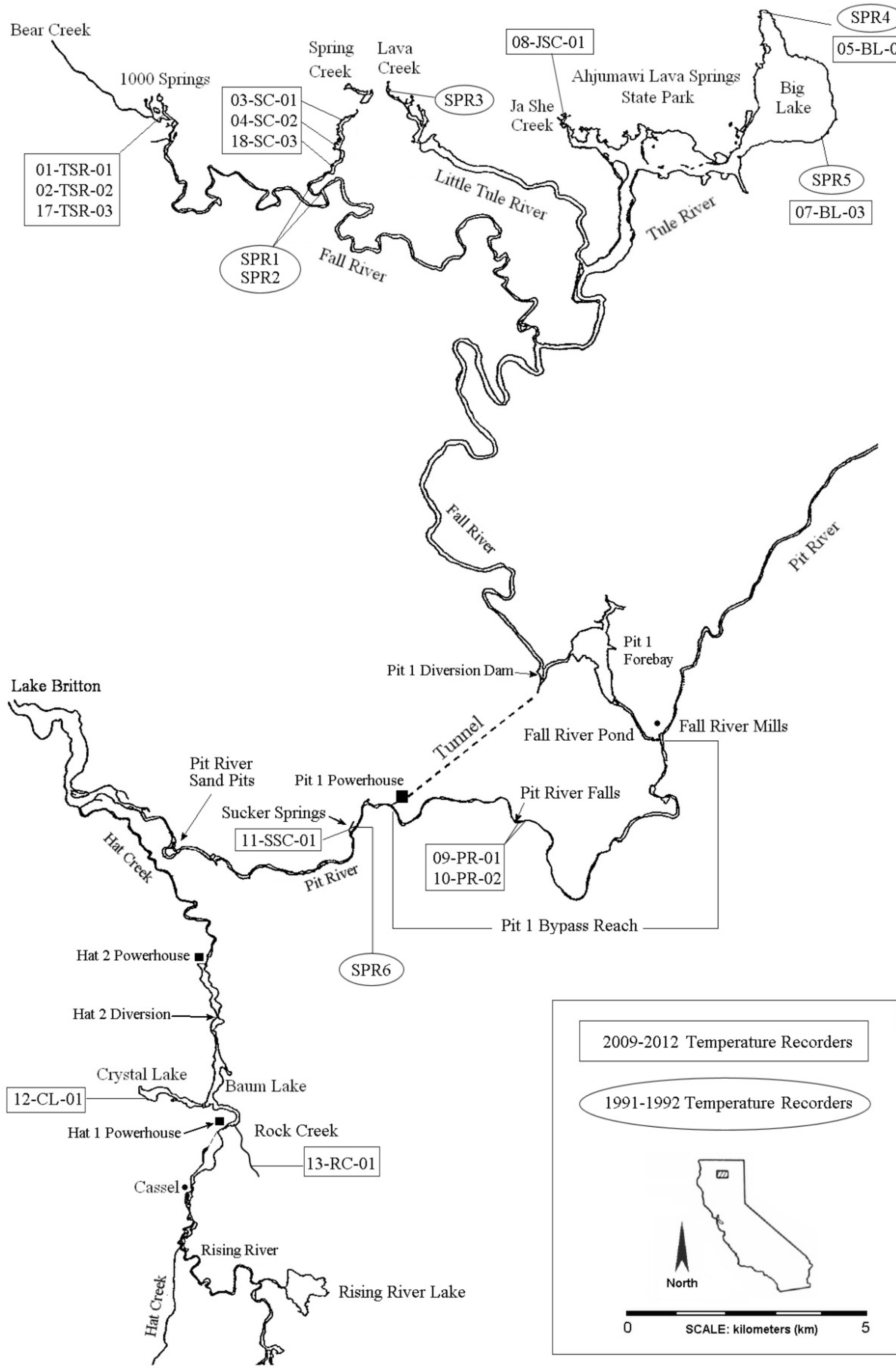


Figure 3-2. Locations of water temperature recorders in the Fall River, Hat Creek, and Pit River in 1991–1992 (circled) and 2009–2012 (squared).

4.0 RESULTS

4.1 MONITORING SETTING

4.1.1 Meteorology

The Pit River drainage in northeastern Shasta County has a Mediterranean climate, with hot summers, cold winters, and the majority of precipitation falling between October and April. Meteorological data from the Hat Creek Powerhouse No. 1 were used to characterize regional summer air temperatures relative to long-term temperature data for all monitoring periods. These data are summarized in Table 4-1. A complete listing of data used to generate Table 4-1 is contained in Appendix C.

These data indicate there were four one-month periods that exhibited extreme air temperature conditions (i.e., classified as either Hot [10% exceedance] or Cold [90% exceedance]) during the various monitoring periods (Table 4-1). All four of these extreme-condition months occurred in either June (1995, 2005), or September (1991, 2005). The months of primary interest to this investigation are July and August, and air temperatures during these months did not exhibit extremes during any of the monitoring efforts (Table 4-1).

4.1.2 Regional Hydrology

The Department of Water Resources (DWR) hydrological classification for the greater Sacramento River Basin for each monitoring period is presented in Table 4-2 (CDEC 2012b). As indicated by these data, the available monitoring periods cover a complete spectrum (wet to critically dry) of runoff conditions. The upper Pit River watershed often exhibits conditions that are different than those characterizing the greater Sacramento River Basin as defined by the DWR runoff index. For this reason, a regional perspective of ambient conditions is detailed in the following section.

Data presented in Table 4-2 indicate that the 1990–1992 monitoring efforts were conducted during a series of consecutive dry and critically dry water years (CDEC 2012b). The 1995 data were collected during wet-year conditions (CDEC 2012b). The 2004–2011 monitoring periods cover a wider spectrum than the other two periods, consisting of one wet, two above normal, one below normal, and four dry/critically dry water-year types (Table 4-2) (CDEC 2012b).

Table 4-2 also includes a summary of air temperature classifications. This information, combined with the regional runoff data, produces a simple matrix that allows comparison of the thermal and hydrological setting characterizing each monitoring period.

Data from the Pit River downstream of the Pit 1 Powerhouse (USGS Gage 11355010) were used to characterize runoff conditions in the Pit 1 Project area during the various monitoring periods (USGS 2012). This location captures all flows from both the Pit and Fall Rivers before entering Lake Britton. These data are summarized in Table 4-3. A complete listing of the stream flow data used to generate Table 4-3 is included in Appendix D.

4.1.2.1 Muck Valley Operations

Between the 1990–1992 monitoring efforts for the Pit 1 Project relicensing and the issuance of the new license in 2003, no change in management of diversion flows associated with the Pit 1 Project occurred. Beginning in 1993, however, the flow regime in the Pit River upstream of the Pit 1 Project was altered by the full-time operations of the Muck Valley Hydroelectric Project (FERC License No. 8296-CA), which is owned by Malacha Hydro Limited Partnership. Collett Reservoir, which was added in 1991, provides 7,800 acre-feet of off-stream storage for high spring flows that are released later in the season to enhance lower summer flows for power generation and fisheries. A regulatory afterbay was also added below the tailrace of the existing Muck Valley Hydroelectric Project at this time. When the Pit River discharge exceeds 50 cfs at the Muck Valley diversion gage, Muck Valley can divert that flow in excess of 50 cfs up to 625 cfs to the Muck Valley Powerhouse and/or Collett Reservoir. All downstream water rights must be fulfilled prior to operating this facility. When the Pit River is less than 50 cfs at the diversion (i.e., reduced-period-operating regime), Muck Valley uses only water from Collett Reservoir and generally runs Monday through Friday (shutting down Saturday through Sunday) during the peak power demand hours of 1200 to 1800 for as long as the storage lasts (Martin personal communication 1995).

The reduced-period-operating regime used by this facility creates a complicated pattern of flow fluctuations in the Pit River. A diurnal cycle is created by the facility operating only during a portion of the day and a weekly cycle is created by the 5-day operating period. A maximum release (over a 24-hour period) of 140 cfs on weekdays and 70 cfs on weekends is allowed from the Muck Valley Powerhouse afterbay during peaking operations or when flows in the Pit River at the Muck Valley diversion are less than 50 cfs. Monitoring at Big Eddy conducted by PG&E in 1995 (PG&E unpublished data) confirmed the general change in hydrologic regime created by Muck Valley operations. Figure 4-1 presents stream flow from the 1995 monitoring effort, and illustrates the effect of Muck Valley Powerhouse operations on the flows in the Pit 1 Bypass Reach.

4.1.3 Project Hydrology

As discussed in Section 1.2.1, the Pit 1 Bypass Reach is composed of two sections with significantly different channel morphologies. The upper Big Eddy section is a low gradient morphology, while the Canyon section has a significantly higher gradient. Figure 4-2 presents a longitudinal profile illustrating the change in gradient within the Project reaches.

4.1.3.1 Pit 1 Bypass Reach

The hydrologic regime of the lower Pit 1 Bypass Reach has been monitored using seasonally installed continuous flow monitoring systems at two locations. The upstream station is located at the downstream end of Big Eddy (PR2), and characterizes flows for the low-gradient segment of the bypass reach, before entering the canyon (Figure 3-1). This station characterizes the flow entering the bypass reach from all upstream sources, specifically releases from the Fall River and flows from the upper Pit River entering the Pit 1 Project area through the Pit River Weir. The downstream station is located at the Pit 1 Footbridge (PR4) and characterizes flows at the downstream end of the lower Pit 1 Bypass Reach (Figure 3-1). The primary purpose of this station is to quantify the volume of accretion flows occurring in the lower Pit 1 Bypass Reach. Flow data from these two stations have been used to identify a significant volume (estimated at 100 cfs) of non-point accretion (spring flow) within this section of the Pit 1 Bypass Reach. Figure 4-3 shows mean daily stream flow from the two seasonal stations for the 2004 monitoring period that included two flushing flow events. The approximately 50 cfs decrease in flow in mid-September was a scheduled low-flow release to allow for fishery studies. Figure 4-4 shows mean daily stream flow from the two seasonal stations for the 2010 monitoring period that highlights the effects of Muck Valley operations.

In 1991, a series of peak-to-peak time-of-travel (TOT) studies were conducted in support of water temperature modeling efforts. TOT was determined using a fluorescent dye tracer (PG&E 1993a). Travel times were measured for two flow conditions in the two primary segments of the Pit 1 Bypass Reach. TOT was determined for a low flow (approximately 35–45 cfs at Big Eddy) and for a moderate flow of 600 cfs (test release from Pit 1 Forebay). Under low-flow conditions, the TOT test was not completed for the segment between the Fall River confluence and the downstream end of Big Eddy because of the very long travel time at low flow (41.9 hours without reaching 25% dye passage). A calculated TOT for this low-flow condition was made using the 600-cfs TOT results and an exponential curve fit to define channel morphology. The calculated low-flow (42 cfs) TOT was 166 hours. Travel time through the Big Eddy segment at 600 cfs required a total of 14.9 hours for peak dye passage. The lower Pit 1 Bypass Reach exhibited much shorter time-of-travel characteristics. Travel time from Big Eddy to the Pit 1 Footbridge required 6.5 hours for peak passage under the low-flow condition (estimated at 42 cfs at Big Eddy). Travel time for this reach required 3.3 hours for peak passage at the 600 cfs flow. The dissimilarity in TOT between the two segments by an order of magnitude reflects differences in channel morphology and stream gradients in the Pit 1 Bypass Reach (Figure 4-2). Figure 4-5 compares TOT curves for each segment in the Pit 1 Bypass Reach.

4.1.3.1.1 Summer Period Stream Flow Regime

Table 4-4 summarizes June-through-September mean daily stream flow data from all monitoring periods for the Big Eddy (PR2) and Pit 1 Footbridge (PR4) stations. In order to compare hydrologic regimes among monitoring periods, mean daily stream flow data from the July-August period were ranked as percent exceedance and compared by station for each of the three hydrologic regimes (Figure 4-6). As expected, summer flows were significantly lower during the Pre-1993 regime compared with those from either the Pre-2003 or Post-2003 regimes. Comparing the average flow at Big Eddy with average flow from the Pit 1 Footbridge for either the Pre-1993 or the Post-2003 regimes indicates that spring accretion flows have remained constant at approximately 100 cfs.

4.1.3.2 Pit 1 Peaking Reach

4.1.3.2.1 Summer Period Stream Flow Regime

Table 4-4 summarizes June-September mean daily stream flow data from all monitoring periods for the Pit River downstream of Pit 1 Powerhouse (USGS Gage, USGS 2012). Peaking operations are the primary influence of Pit 1 Project operations on the summer hydrologic regime in this reach. The current peaking regime was evaluated using 15-minute interval data from the USGS Gage on the Pit River downstream of Pit 1 Powerhouse for the 2008–2011 periods. Figures 4-7 through 4-10 present 15-minute interval data from 2008 through 2011 (June through September period), respectively. As these figures illustrate, base flows during the summer are relatively stable in the range of 900 to 1,100 cfs. During periods of peak energy demand, available storage from Pit 1 Forebay is used to temporarily increase flows through Pit 1 Powerhouse. These peaking events temporarily increase flows to near 2,000 cfs. Although the exact magnitude, duration, and timing of these peaking events are determined by power demand, peaking flows followed a similar pattern. This peaking flow pattern is illustrated in Figures 4-11 through 4-14, each of which represents a 48-hour period from July of 2008 through 2011. As illustrated, base flows are maintained throughout most of the 24-hour day. Flows, however, are increased in the late morning/early afternoon (1100–1400 hours) and remain elevated for three to four hours (1700–1900 hours), before returning to base flow.

The magnitude of peak flow events during the June-through-September period were evaluated using daily range in flow as an indicator of the peak. In an effort to separate peaking activity from other fluctuations in flow, peaking flows were defined as diel changes in flow exceeding 350 cfs. No attempt was made to define average duration as part of this analysis. The results of the peak flow frequency analysis from the Pit River downstream of Pit 1 Powerhouse are summarized in Table 4-5. As indicated, the maximum increase in flow resulting from peaking activities was calculated to be 1,459 cfs on September 2, 2011. Using the stage-flow rating for the USGS Gage, this peak event would have generated a change in stage of 1.69 feet (USGS 2012). Peaking operations were further quantified using a frequency analysis. Results of this analysis are summarized in Table 4-5 and compared in Figure 4-15. Peaking flows ranged from 360 to 1,459 cfs for the June-September 2008–2011 periods. The average peaking flow during this period was 707 cfs. The average peak flow would translate to a change in stage of 0.90 feet (assuming a base flow of 1,000 cfs).

4.2 RELICENSING-COMPLIANCE MONITORING

4.2.1 Water Temperature

4.2.1.1 Pit 1 Bypass Reach

Table 4-6 summarizes June-through-September mean daily water temperature data from all monitoring periods. Mean daily water temperatures from three stations in the Pit 1 Bypass Reach are compared in Figures 4-16 and 4-17 for the 2004 and 2010 June-through-September monitoring periods, respectively. These figures are included to illustrate the relationship between each station with regard to summer water temperatures. A similar graphic comparison for each monitoring year is included in Appendix E. As indicated by these figures, mean daily water temperatures are warmest in the Big Eddy section of the bypass reach (PR2), and continue to cool as they move through the canyon, with the downstream end of the lower Pit 1 Bypass Reach (Pit 1 Footbridge PR4) exhibiting the coolest water temperatures in the Pit 1 Bypass Reach.

In order to compare the thermal characteristics of each hydrologic regime, mean daily water temperature data in July and August were ranked using a frequency analysis. The results of this analysis are discussed as percent exceedance. Exceedance is defined as the percent of total observations that exceed a value over the period evaluated. For example, 10% exceedance indicates that 10% of water temperatures exceeded the specified value, while 90% were less than the specified value.

Results of the frequency analysis are summarized in Table 4-7. Figure 4-18 compares the mean daily water temperature statistics from four stations in the Pit River for each of the three hydrologic regimes. As indicated in this figure, the thermal conditions at Big Eddy (PR2) have remained relatively constant through the various changes in hydrologic regimes. The average July-August water temperature from the 1990–1992 monitoring period was 22.1 °C, compared with a July-August average of 22.0 °C and 22.2 °C for the 1995 and 2004–2011 monitoring periods, respectively (Table 4-7). This suggests that summer thermal conditions in the Big Eddy section of the bypass reach have been relatively insensitive to changes in flow regime from either Muck Valley operations or Pit 1 Project releases into the Fall River (minimum instream flows and flushing flows). The lack of sensitivity to change in summer flow regime is likely related to the low-gradient deep-pool morphology of the Pit River in the Big Eddy section of the Pit 1 Bypass Reach. The river in this section has a relatively long travel time even at moderate flows (14.9 hours at ± 600 cfs Fall River release), and as a result, reaches a state of thermal equilibrium under any flow other than high-flow conditions. This effect is further compounded and complicated by the effects of the Pit River Weir, which by design backs water into the very low-gradient reach upstream of the weir to mimic the backwatering effect the Fall River confluence used to have. The backwatering effect of the Pit River Weir slows the travel time and reduces the volume of Fall River releases, particularly of small-to-moderate releases, into the Pit 1 Bypass Reach and reduces their cooling effects on the upper Big Eddy portion of the Pit 1 Bypass Reach. At very low Pit River inflow rates (not uncommon during summer months), water released from Fall River may be drawn upstream toward Pittville due to agricultural pumping. While Muck Valley operations has not significantly altered summer thermal conditions in the Big Eddy section, it should be noted that Muck Valley operations does add additional volume of water (thermal mass) that have implications downstream in the canyon section where cooling associated with the colder springs occurs. This implication is clearly shown in PR3 data.

Pit River Falls (PR3) is the intermediate station in the Pit 1 Bypass Reach, and as indicated in Figure 4-18, exhibited a thermal shift as a result of the Post-2003 hydrologic regime. Average July-August water temperatures at Pit River Falls during the 1990–1992 monitoring period was 19.8 °C, compared with a July-August average of 21.0 °C for the 2004–2009 monitoring period (Table 4-7). On average, the shift equates to July-August water temperatures being 1.2 °C warmer at this station during the Post-2003 regime when compared with the Pre-1993 regime.

Pit 1 Footbridge (PR4) represents conditions at the downstream end of the Pit 1 Bypass Reach, and as indicated in Figure 4-18, also exhibited a thermal shift as a result of the Post-2003 hydrologic regime. Average July-August water temperatures at Pit 1 Footbridge during the 1990–1992 monitoring period was 18.4 °C, compared with a July-August average of 20.2 °C for the 2004–2009 monitoring period (Table 4-7). On average, the shift equates to July-August water temperatures being 1.8 °C warmer at this station during the Post-2003 regime when compared with the Pre-1993 regime.

Based on the average July-August water temperatures, the thermal conditions at Big Eddy (PR2) have remained relatively constant through the various changes in hydrologic/water year regimes. In contrast, the increased flows from the Pit 1 Project (Fall River releases) and from Muck Valley operations have resulted in summer period water temperatures in the lower Pit 1 Bypass Reach being warmer when compared with water temperatures from the Pre-1993 period. This warming is attributed to the higher flows reducing the influence of coldwater spring accretion on mainstem water temperatures.

4.2.1.2 Flushing Flow Events

A detailed evaluation of the effect of Fall River flushing flow events on the thermal regime of the Pit 1 Bypass Reach was performed on data from the August 2008 flushing flow event. This event was used as it illustrates the typical pattern of influence that flushing flow events have on mainstem water temperatures. The thermal effects on mainstem Pit River water temperatures associated with July and August flushing flow events in 2005, 2006, 2007, 2008, and 2009 are contained in the associated annual compliance monitoring reports (PG&E 2005, 2006a, 2007, 2008, 2010b).

Figure 4-19 compares the hourly average temperature data with stream discharge from Station PR2 in the Pit 1 Reach. As indicated, the flushing flow event generated a significant change in the pattern of diel water temperature. The diel cycle at Station PR2 did not return to pre-event patterns following the event (due primarily to significant change in climatic condition). During the flushing flow test, water temperatures at the end of Big Eddy (PR2) showed a daily average temperature reduction of approximately 0.7°C (comparing August 15 with August 16 daily average value, meteorologically driven change affected a longer comparison). Figure 4-20 presents data isolating Station PR4 during the same August 2008 event. As discussed, this station represents conditions in the terminal end of the Pit 1 Reach, and reflects conditions downstream of the cooling accretion sources. Figure 4-20 also plots the trend in daily average air and water temperature during the flushing flow event. As indicated, the flushing flow event caused the diel cycle to be altered such that the maximum daily water temperature was not appreciably altered, but the minimum daily water temperature was significantly raised. The resultant was an increase in the daily average temperature at PR4 of approximately 0.8°C (comparing August 15 with August 16 daily average value, meteorologically driven change affected a longer comparison). Air temperatures following the event dropped significantly and are largely responsible for the minimized diel cycle and much lower daily average temperature observed after the event ended.

The change in stage associated with the flushing flow events was also evaluated (PG&E 2009a). Using stage data from the August 2008 flushing flow event, the maximum hourly average change in stage on the rising limb of the hydrograph was calculated at 0.37 feet, which equated to a change in flow of 126 cfs. The maximum change in stage from pre-event conditions was 1.53 feet. The period required to reach peak stage from initial arrival of the flow event was approximately 10 hours. The maximum hourly average change in stage on the receding limb of the hydrograph was calculated at 0.22 feet, which equated to a change in flow of 85 cfs. The return of stage to pre-event levels required approximately 15 hours from the initial point of stage recession.

The effects of the July 2009 flushing flow on the thermal regime at the two Pit River Shasta crayfish locations upstream of the Pit River Falls were also examined (Figure 4-21). At the upstream location (Logger ID 09-PR-01), a large coldwater spring complex creates coldwater refugia habitat with measurable lower summer water temperatures as compared to the mainstem river temperature (Figure 4-21). Mean daily water temperature at this location was fairly stable and minimally affected by air temperature. The downstream Shasta crayfish location (Logger ID 10-PR-02) does not have direct spring influence, however, the mainstem river temperature is cooled by springs upstream, including the large coldwater spring complex at the upper Shasta crayfish location. Mean daily water temperature at this location was highest in the summer months and was clearly affected by air temperature (Figure 4-21). The July flushing flow increased the mean daily and/or altered the diel pattern of water temperature at these two locations (Figure 4-22).

In the spring-influenced upper location, the July flushing flow event resulted in a sudden increase in water temperature (Figure 4-22a, Logger ID 09-PR-01). During the week prior to the event, mean (± standard error) daily water temperatures (based on hourly readings) in the spring area ranged from 15.7 ± 0.2 °C to 17.2 ± 0.2 °C. Similarly, during the week after the event, mean daily water temperatures ranged from 15.9 ± 0.1 °C to 17.2 ± 0.1 °C. Shasta crayfish in the spring area experienced a mean daily water temperature difference (between the maximum and minimum temperature) of 1.6 ± 0.1 °C and 1.2 ± 0.1 °C, respectively. On the two days of the flushing flow, mean daily water temperatures ranged from 16.0 ± 0.5 °C to 20.4 ± 0.3 °C with a mean daily water temperature difference of 4.5 ± 0.8 °C. On July 18, the flushing flow resulted in a 3.4 °C increase in water temperature from 0800 to 2100. Water temperature barely decreased overnight and increased again the next morning. On July 19, water temperature decreased 5.4 °C within the 9-hour period between 1500 to 2400 (Figure 4-22a).

At the lower non-spring-influenced location, the July flushing flow altered the diel water temperature pattern and eliminated the cooler night time temperatures that can provide critical thermal relief (Figure 4-22b, Logger ID 10-PR-02). During the week prior to the July flushing flow, mean (± standard error) daily water temperatures (based on hourly readings) in the ranged from 19.8 ± 0.1 °C to 22.4 ± 0.2 °C; mean daily difference was 2.6 ± 0.1 °C. Similarly, during the week after the July flushing flow, mean daily water temperatures ranged from 20.8 ± 0.1 °C to 23.4 ± 0.1 °C; mean daily difference was 2.6 ± 0.05 °C. On the two days of the flushing flow, mean daily water temperatures ranged from 21.2 ± 0.05 °C to 22.8 ± 0.1 °C, with a mean daily difference of 1.5 ± 0.1 °C (Figure 4-22b).

The effects of the August 2009 flushing flow event on the thermal regime at the two Pit River Shasta crayfish locations were similar to those of the July 2009 flushing flow event (Figure 4-21). At the spring-influenced upper location, the flushing flow resulted in a sudden increase in water temperature (Figure 4-23a, Logger ID 09-PR-01). During the week prior to the August flushing flow, mean (± standard error) daily water temperatures in the spring area ranged from 15.9 ± 0.1 °C to 17.0 ± 0.1 °C, with a mean daily difference of 1.1 ± 0.1 °C. Similarly, during the week after the event, mean daily water temperatures ranged from 15.7 ± 0.1 °C to 16.8 ± 0.1 °C; mean daily difference was 1.1 ± 0.04 °C. On the two days of the flushing flow, however, mean daily water temperatures ranged from 15.7 ± 0.2 °C to 18.4 ± 0.04 °C, with a mean daily difference of 2.8 ± 0.1 °C (Figure 4-23a).

At the lower non-spring-influenced location, the August flushing flow muted the maximum and minimum daily water temperatures and eliminated the diel thermal refugia (Figure 4-23b, Logger ID 10-PR-02). During the week prior to the August flushing flow, mean (± standard error) daily water temperatures in this mainstem location ranged from 19.2 ± 0.2 °C to 21.3 ± 0.3 °C, with a mean daily difference of 2.1 ± 0.2 °C. Similarly, during the week after the event, the mean daily water temperatures ranged from 18.1 ± 0.1 °C to 20.0 ± 0.1 °C, with a mean daily difference of 1.9 ± 0.1 °C. On the two days of the flushing flow, mean daily water temperatures ranged from 18.7 ± 0.2 °C to 19.8 ± 0.1 °C, with a mean daily difference of only 1.1 ± 0.05 °C (Figure 4-23b).

During summer flushing flows in July and August 2009, temperature monitoring documented the resultant increase in temperature and loss of thermal refugia habitat at the two Pit River Shasta crayfish locations upstream of the Pit River Falls during summer pulsed flows. Summer flushing flows increased the maximum daily water temperatures and resulted in rapid and substantial changes in the temperature within the area influenced by coldwater springs (Logger ID 09-PR-01). In the mainstem habitat (Logger ID 10-PR-02), summer flushing flows in the Pit 1 Bypass Reach muted the maximum and minimum daily water temperatures, overwhelmed the effects of fluctuating day-to-night air temperatures, and eliminated diel thermal refugia.

4.2.1.3 Pit 1 Peaking Reach

Table 4-6 summarizes June-through-September mean daily water temperature data from this reach for all monitoring periods. In order to compare the thermal characteristics of each hydrologic regime, mean daily water temperature data from the July-August period were ranked using a frequency analysis. Results of the frequency analysis are summarized in Table 4-7. These data are compared for each of the three hydrologic regimes in Figure 4-18. As indicated in this figure, the thermal conditions in the Pit River downstream of Pit 1 Powerhouse (Station PR5) station have remained relatively consistent through the various changes in hydrologic regimes. Average July-August water temperatures during the 1990–1992 monitoring period was 19.7 °C, compared with a July-August average of 19.8 °C for the 2004–2011 monitoring period (Table 4-7). This is not unexpected due to the large year-round flow of water from the Fall River to the Pit River at this location (via Pit 1 Powerhouse). This influx of flow would overwhelm any thermal influences from the Pit 1 Bypass Reach. This suggests that thermal conditions in the Pit River downstream of Pit 1 Powerhouse are relatively insensitive to changes in flow from either the Fall River (i.e., minimum instream flows and flushing flows) or Muck Valley.

4.2.2 Water Quality

Water quality parameters monitored as part of PG&E's compliance monitoring (FERC License Article 401, SWRCB 401 Certification Conditions 16 and 17) include dissolved oxygen (DO), DO percent saturation, pH, specific conductivity (SpC), total dissolved solids (TDS), and turbidity. An analysis of changes in water quality resulting from the implementation of the Fall River minimum instream flows will not be presented as part of this investigation. The results from the 2004–2011 monitoring efforts are contained in annual reports submitted to the SWRCB (PG&E 2004a, 2005, 2006a, 2007, 2008, 2010b, 2011b, 2012c). A complete summary analysis of the 2004–2008 water quality information was presented as part of the five-year summary report compiled by PG&E in 2009 and presented to resource agencies in April 2009 (PG&E 2009a). The summary report included a comparison of the results from the 2004–2008 compliance monitoring effort with the 1990–1992 data set (PG&E 2009a). Past monitoring indicated that the water quality parameter of primary concern in the Pit 1 Bypass Reach was dissolved oxygen in the Big Eddy section. The five-year summary report concluded that DO levels in this section of the Pit River had been positively influenced under the Post-2003 regime (PG&E 2009a).

Table 4-8 summarizes the results of dissolved oxygen sampling conducted during the various monitoring efforts. Figure 4-24 presents the results of a frequency analysis used to compare DO levels in the Pit River during the three hydrologic regimes. The results of the frequency analysis highlight the extreme range in DO levels present in the Big Eddy section of the Pit 1 Bypass Reach during the Pre-1993 regime (1990–1992 data set). DO levels in the lower Pit 1 Bypass Reach were less extreme, but did exhibit minimum levels that were periodically at or below Basin Plan objectives (CVRWQCB 2007). In comparison, DO levels from the Post-2003 period (2004–2011 data sets) exhibited a significant reduction in the range of DO levels observed at Big Eddy. DO conditions at Pit River Falls (PR3) and Pit 1 Footbridge (PR4) in the lower Pit 1 Bypass Reach also exhibited a reduction in overall range, remaining above Basin Plan objectives at all times. Average DO levels in the lower Pit 1 Bypass Reach, however, were similar to those measured during the Pre-1993 regime (Figure 4-24).

4.3 2004 Coldwater Refugia Study

The main findings of the 2004 Coldwater Refugia Study were that at base flow, the PG&E Spring created areas of Cold (defined as <15–17 ºC), Marginally Cold (defined as 17.1–18 ºC), and Cool (defined as 18.1–19 ºC) habitat in the Pit River that extended beyond the area delineated by the arrays of temperature sensors (PG&E 2009b). During the flushing flow, however, the entire Cold (<15–17 ºC) habitat disappeared, and the Marginally Cold and Cool (17.1–19 ºC) habitat made up less than half the area delineated by the sensors. More than half the area's substrate was covered by Warm water with temperatures greater than 19 °C or and water temperature increased by as much as 3.6 ºC at individual sensors during the flushing flow. Figure 4-25 presents the observed effect of flushing flows on thermal refugia from the 2004 Coldwater Refugia Study.

4.3.1 Jet-Plume Simulations

The results of the Jet/Plume analysis of the 2004 Coldwater Refugia Study data found that there was a rapid and substantial change in both the temperature and spatial area of coldwater habitat at the mouth of the spring during a flushing flow event. The degree to which water temperatures increased and the spatial extent of the reduction in thermal refugia were greatly dependent on the water temperature and flow volume of the spring, as well as the water temperature and flow volume in the main channel. Under the modeled base-flow condition (mainstem flow of 277 cfs and average water temperature of 19.8 ºC), the plume bent rapidly in the downstream direction with the 18.5 °C isotherm contour extending downstream about 100 feet from the mouth of the spring and spreading 3 to 5 feet laterally from the centerline of the mouth of the spring. Under the flushing flow condition (mainstem flow of 977 cfs and average water temperature of 21.5 ºC), both the length and the width of the same isotherm contour was reduced by more than half compared with the base-flow condition (PG&E 2009b).

4.4 Shasta Crayfish Temperature Monitoring

The results of the previously unpublished 1991-1992 temperature monitoring at or near Shasta crayfish population sites are presented as mean daily water temperature from October 1991 through September 1992 in Figure 4-26. The results of the 2009–2012 temperature monitoring are presented as mean daily water temperature for either the 2009-2010 or 2011-2012 annual period, depending on station, in Figure 4-27. Appendix F provides a summary of mean hourly water temperature, including mean, minimum, maximum, and mean diel fluctuation annually and monthly, for 1991-1992 (Table F-1) and 2009–2012 (Table F-2).

The 1991–1992 Big Lake Springs and Sucker Springs Creek data illustrate the consistency of water temperatures at the spring inflow areas with little change in water temperature during the course of a day or a year (Figure 4-26, Appendix F). The 2009–2012 temperature monitoring at Thousand Springs, Spring Creek, Big Lake Springs, Ja She Creek, Sucker Springs, Crystal Lake, and Rock Creek verify the consistency of water temperatures in the spring areas (Figure 4-27, Appendix F). Based on mean hourly water temperature data at spring inflow areas (i.e., Big Lake Springs and Sucker Springs Creek in 1991–1992; Thousand Springs Fish Trap, Spring Creek, Big Lake Springs, Ja She Creek, Sucker Springs, Crystal Lake, and Rock Creek in 2009–2012), mean diel temperature fluctuations ranged from a minimum of 0.0 ºC to a maximum of 0.4 ºC (Appendix F). The annual range of water temperatures (i.e., maximum hourly water temperature minus minimum hourly temperature for the year) at these spring inflow areas ranged from a minimum of 0.1 ºC in Big Lake Springs (2009-2010) to a maximum of 1.9 ºC in Sucker Springs Creek (2009-2010).

The temperature recorders placed farther away from the spring inflow areas (i.e., Spring Creek, Fall River, and Lava Creek in 1991–1992, Thousand Springs Upper Fall River Crayfish Barrier and Thousand Springs Upper Shasta crayfish location in 2009–2012) showed a slightly greater range of temperatures. The majority of Shasta crayfish locations are either at or near spring inflows and thus have relatively constant water temperatures. Although water temperature variation is greater downstream of the spring sources, the standard deviation in annual temperature at most locations where Shasta crayfish are found was generally less than two degrees.

Both the 1991-1992 and the 2009–2012 water temperature studies show that the majority of Shasta crayfish locations are strongly influenced by spring accretion with relatively constant, cool, water temperatures throughout the year (Figures 4-26 and 4-27). Water temperatures, however, were not the same at all springs, with mean annual water temperatures that ranged from 9.5 to 13.1 °C at different spring locations.

The 1991-1992 and the 2009–2012 water temperature data also showed the greater temperature range experienced in areas without spring influence. At South Big Lake Levee Cove, which is in the upper Tule River–Big Lake area away from the springs, the thermal regime is dramatically different than the spring-influenced locations (Figures 4-26 and 4-27). Both the lower Pit River and South Big Lake Levee Cove exhibited more diel temperature fluctuations and a much greater annual temperature range than the other Shasta crayfish locations that are influenced and moderated by springs. South Big Lake Levee Cove had diel temperature fluctuations that ranged from a minimum of 0.0 ºC to a maximum of 3.9 ºC with mean diel temperature fluctuations of 1.7 ºC in 1991-1992 and 1.6 ºC in 2009-2010. The annual range of water temperatures at South Big Lake Levee Cove was 20.8 ºC in 1991–1992 (Figure 4-26, minimum hourly water temperature of less than 5.0 ºC [minimum sensor range], maximum hourly water temperature of 25.8 ºC). In 2009-2010, the annual range of water temperatures at South Big Lake Levee Cove was 24.6 ºC (Figure 4-27 (minimum hourly water temperature of 2.3 ºC, maximum hourly water temperature of 26.9 ºC). Although the annual range of temperatures at South Big Lake Levee Cove is large, water temperatures generally increase or decrease gradually over the course of the year with an average change in the mean daily water temperature of 0.4 °C per day in 2009–2010. The maximum increase in mean daily water temperature per day, which was 1.8 °C, occurred when mean daily water temperatures were still cool during spring of 2009. During the summer, nighttime water temperatures at South Big Lake Levee Cove were at least 0.6 °C cooler,[10] and generally between 1.0 and 3.7 °C cooler than the maximum daily water temperatures on days when mean daily water temperature were at least 20 °C. These cooler

---

10 The only exception between February 28, 2009 and March 10, 2012 was August 7, 2009 when the diel temperature range was only 0.6 °C.

nighttime water temperatures likely provide critical thermal refugia during the summer in areas without spring influence.

A comparison of water temperatures at the two Pit River locations in the Pit 1 Bypass Reach shows both the cooling and mediating effects of the large coldwater spring inflow at upper Pit River as compared to the non-spring-influenced lower Pit River location (Figure 4-27). With the exception of the two flushing flow events that create warm temperature spikes on July 18-19 and August 29-30, water temperature at the upper Pit River location is relatively constant around 16 °C (mean ± standard deviation = 16.3 ± 0.5 °C) throughout the summer, during July, August, and September (Figure 4-27). Mean diel temperature change at the upper Pit River location was 1.3 ± 0.5 °C in July and August. In comparison, the water temperature at the lower Pit River location, which is in the mainstem Pit River without any spring influence, is 3.5 °C warmer and considerably more variable (mean ± standard deviation = 19.9 ± 1.7 °C) throughout the summer, during July, August, and September (Figure 4-27). Mean diel temperature change at the lower Pit River location was 1.3 ± 0.5 °C in July and August.

The third location where Shasta crayfish have been found in the lower Pit 1 Bypass Reach is at the approximately 3 cfs Surge Spring a short distance upstream of the Pit 1 Powerhouse tailrace opposite the Surge Tank Overflow. In April 2012, the spring temperature was 13.4 °C as compared to the temperature in the mainstem Pit River, which was 18.0 °C.

Data from the Pit 1 Project Relicensing-Compliance Monitoring Programs (see Section 4.2.1), provides information on the thermal conditions during 1990-1992 and 2004-2011in the Pit 1 Bypass Reach at mainstem Shasta crayfish locations without any spring influence, such as the lower Pit River. The Pit River Falls (Station PR3) is just downstream of the lower Pit River location and the Pit 1 Footbridge (Station PR4) is just downstream of the Pit 1 Footbridge Shasta crayfish location. In order to determine the thermal regime experienced by Shasta crayfish in the mainstem Pit 1 Bypass Reach in 1990-1992 and 2004-2011, a series of longitudinal profiles were developed for the months of June, July, August, and September (Figures 4-28 through 4-31). These longitudinal profiles compare the 50% exceedance water temperatures from the Pre-1993 (1990-1992) period with those from the Post-2003 (2004-2011) period. The temperature profiles in Figures 4-28 through 4-31 are indicative of conditions in the mainstem as would be found at the lower Pit River location or the Pit 1 Footbridge Shasta crayfish location; they are not specific to thermal refugia associated with coldwater springs, such as the upper Pit River location, or the effect of pulse flow events on spring sources as a result of inundation.

4.5 2012 Pit 1 Bypass Reach Spring Inflow Study

4.5.1 Field Survey Results

During July through early October 2012, a total of 48 spring inflows were mapped and characterized in terms of temperature, conductivity, and discharge. The mapped spring inflows were clustered into the following ten major spring-inflow regions of the Pit 1 Bypass Reach (Figure 4-32): (1) downstream (d/s) of Big Eddy ledges (d/s Ledges), (2) upstream (u/s) of the first island (u/s Island), (3) downstream of the first island (d/s Island), (4) the first big spring (Big Spring 1), (5) the second big spring (Big Spring 2), (6) upstream of Pit River Falls where Shasta crayfish have been documented (Shasta), (7) below Highway 299 river overlook (Overlook), (8) across from the Pit 1 surge tank overflow (Surge), (9) the PG&E water supply springs (PG&E), and (10) upstream of the Pit 1 Powerhouse tailrace beneath the powerlines (Powerlines). Each spring-inflow region (Region) included one or more spring inflows that were individually mapped and characterized. Individual spring inflows within each region were usually contiguous and were categorized as separate inflows based on water temperature and/or specific conductivity readings. The spring inflows are listed by Region and described in Table 4-9. Table 4-10 provides a summary of spring habitat characteristics by Region, including the number, estimated discharge, and refuge area associated with inflows that were characterized as Cold (<15–17 °C), Marginally Cold (17.1–18 °C), Cool (18.1–19 °C), and Warm (>19 °C). The total estimated discharge from all 48 spring inflows mapped in the Pit 1 Bypass Reach was 79 cfs (Table 4-10). Spring accretion flow in the Pit 1 Bypass Reach is approximately 100 cfs, so the estimated discharge from the field survey is a little low. This is likely due to in-channel spring accretion and underestimation of discharge from seeps and complex spring system, which are difficult to estimate.

Based on instantaneous measurements of water temperature in the middle of the day (10:00 to 16:00), mainstem Pit River water temperatures ranged from 19.0 °C to 23.0 °C and averaged

21.1 °C during the main field survey (i.e., July 24, 2012 through September 5, 2012). Mainstem specific conductivity readings ranged from 160 µS to 167 µS.

Between late July and early October, spring water temperatures ranged from 12.8 °C to 22.1 °C and spring conductivities ranged from 125 µS to 252 µS (Table 4-9). Of the 48 spring inflows characterized in the Pit 1 Bypass Reach, 28 (58%) were colder than the mainstem and 20 (42%) were as warm or warmer than the mainstem. Although the water colder than the mainstem represents groundwater spring discharge, the inflows that are as warm or warmer than the mainstem Pit River are likely generated by surface water (Pit River or other tributary sources) that have gone subsurface or from leaks in penstocks/diversion tunnels, etc. Most (79%) of the colder springs had specific conductivities equal to or lower than the mainstem river (i.e., 170 µS). These were all located in the reach between Big Spring 1 and Powerlines in the lower two-thirds of the Pit 1 Bypass Reach (Figure 4-32). Six colder springs located in the upper regions of the Pit 1 Bypass, however, had specific conductivities higher than 200 µS. All of the warmer springs were located above Pit River Falls and all had specific conductivites ranging from 160 µS to 219 µS.

Springs categorized as Cold (<15–17 °C), Marginally Cold (17.1–18 °C), and Cool (18.1–19 °C) accounted for 50%, 4%, and 4% of the total number of springs, respectively (Figure 4-33). These colder spring inflows accounted for more than half (49% Cold, 9% Marginally Cold, and 1% Cool) of the total estimated spring discharge (79 cfs) and provided approximately 564 m^2 of Cold refugia, 254 m^2 of Marginally Cold refugia, and 280 m^2 of Cool refugia (Table 4-10, Figure 4-33). Given that spring accretion flow in the Pit 1 Bypass Reach is approximately 100 cfs and the estimated discharge from the field survey was only 79 cfs, approximately 21 cfs of spring inflow is unaccounted for. Assuming the missing spring discharge is comprised of the same ratio of Cold, Marginally Cold, Cool, and Warm spring inflows, the refuge areas can be scaled to 711 m^2 of Cold refugia, 321 m^2 of Marginally Cold refugia, and 352 m^2 of Cool refugia (Table 4-10, Figure 4-33). The Shasta and PG&E spring regions provided the most Cold and Marginally Cold refugia, and the Big Spring 1, Shasta, and PG&E regions provided the Cool refugia.

Additional instantaneous water temperatures and specific conductivities were measured at five Cold Spring inflows and five Warm Spring inflows in early October, 2012, when mainstem water temperatures were 1–2 °C cooler and mainstem conductivities were 2–4 µS lower than in early September (Table 4-11). These springs were all located between the downstream Ledges and downstream Island spring-inflow regions (Figure 4-32). In the upper spring-inflow regions, springs categorized as Cold were 0.8–2.6 °C cooler with specific conductivities 2–22 µS higher in October than in September. These springs all had specific conductivities higher than 200 µS on both survey dates. In contrast, four of the five springs categorized as Warm experienced no change or were 0.2 °C warmer in October than in September; the fifth spring was 0.1 °C cooler in October than in September. Two of these Warm Springs had slightly higher (2–8 µS) specific conductivites and three had lower (2–26 µS) specific conductivities in October than in September. All of these Warm springs had conductivity readings lower than 200 µS on both survey dates.

Instantaneous water temperatures were also measured at the Powerlines Spring (RR #13) on two occasions in July to determine if this long spring run experienced significant diel temperature flucutations. The Powerlines Spring (RR #13), which is a Cold, low-conductivity (156 µS, measured on July 27, 2012) spring in the lower Pit 1 Bypass Reach just upstream of the Pit 1 Powerhouse tailrace (Figure 4-32), experienced significant diel changes in water temperature (Table 4-11). This spring was 16.0 °C on the afternoon of July 26, 2012 and 14.4 °C the following morning. The refuge area for this spring, which could be affected by diel fluctuations in spring temperature, was only mapped in the morning.

4.5.2 Temperature Array Results

The locations of the four spring inflow areas chosen for temperature array monitoring are shown in Figure 4-32. Cartesian grids showing the locations (x and y coordinates in meters) of temperature sensors at each site and the mean monthly water temperature readings for each sensor are presented in Figures 4-34 through 4-37. The blue and green temperature zones shown in each figure represent the Cold (<15–17 °C) and Marginally Cold (17.1–18 °C) refuge areas, and the orange (18 °C) and red (19 °C) temperature zones represent mixing and mainstem areas. Water temperature differences at all sites were more pronounced during July when mainstem water temperatures were highest, and less pronounced in September when mainstem water temperatures were lower.

Mean daily water temperatures for each of the 17 sensors (15 TempLine and 2 VEMCO) at downstream Shasta Spring and 6 sensors (Campbell) at upstream Surge Spring are shown in Figure 4-38. Mean daily water temperatures for the 16 sensors (14 TempLine and 2 VEMCO) at Surge Spring and 17 sensors (15 TempLine and 2 VEMCO) at PG&E Spring are shown in Figure 4-39. Mainstem water temperatures during July through September were similar at all sites; mean daily temperatures ranged from ~17 °C to ~22 °C, with diel fluctations averaging 2.5 °C. Spring temperatures were similar at the Surge Spring sites, which are part of the same spring complex. At these sites, mean daily spring temperatures remained at a nearly constant 13.3 °C, with diel fluctuations averaging 0.2 °C. In contrast, mean daily spring temperatures at downstream Shasta Spring ranged from 14.5 °C to 15.2 °C with diel fluctuations averaging 0.7 °C. At PG&E Spring, an additional spring inflow from upstream (i.e., Spring RL #33, upstream PG&E Spring) affects water temperatures in the refuge area (see Figure 4-32). Water temperatures near the mouth of the PG&E Spring and immediately downstream (i.e., purple line in Figure 4-39 representing sensors V1, V2, 1, 2, 3, 9, 10, 11, and 12) remained relatively stable at 16.1 °C, while temperatures at the mouth of the upstream PG&E Spring (i.e., solid blue line representing sensor 5 in Figure 4-39) ranged from 15.5 °C to 16.6 °C with diel fluctuations averaging 0.5 °C.

Diel differences in spring and refuge areas at the four sites where VEMCO sensors were installed (i.e., upper Shasta, downstream Shasta, Surge, and PG&E springs) are illustrated for the period of April 26 through September 30 in Figure 4-40. Differences between minimum daily and maximum daily temperatures were lower in springs than at the mouth of springs (i.e., within the refuge area). Diel fluctuations at the PG&E Spring site, however, were not much higher in the refuge area. As stated earlier, this sensor (sensor V2 in Figure 4-37) was positioned 4 meters out from the PG&E Spring inflow, but immediately downstream from the upstream PG&E Spring (RL #33) inflow. In the spring areas and the PG&E Spring refuge area, diel differences in water temperature were greater during April, May, and June than during July through September. Temperature spikes were particularly high at downstream Shasta Spring before and on June 1 (date flows increase from 75 cfs to 150 cfs) and at Surge Spring before June 30.

The effect of Muck Valley operations can be seen on temperatures within the spring inflow channels in the downstream Shasta Spring (RR#10) and Surge Spring (RL#31), as shown in

Figure 4-40. The temperature fluctuations within the spring inflow channels coincide with the pulses of warm water from Muck Valley operations during the early season. The effect of Muck Valley operations on the spring temperatures provides a smaller scale example of the effects of summer flushing flows.

Table 4-1. Summary of mean monthly air temperatures from Hat 1 Powerhouse and percent exceedance[1] rankings.

	Mean Monthly Air Temperatures - Hat Creek PH No. 1[2]											
	June			July			August			September		
Year	Mean (°C)	Exceedance (%)	Class	Mean (°C)	Exceedance (%)	Class	Mean (°C)	Exceedance (%)	Class	Mean (°C)	Exceedance (%)	Class
2011	16.5	72%	Blw Norm	20.6	59%	Norm	19.8	46%	Norm	17.4	27%	Abv Norm
2010	15.4	97%	Cold	20.7	48%	Norm	18.8	78%	Blw Norm	15.4	75%	Blw Norm
2009	16.8	57%	Norm	20.7	52%	Norm	19.1	74%	Blw Norm	17.5	24%	Abv Norm
2008	16.7	64%	Norm	20.8	46%	Norm	20.9	18%	Abv Norm	16.4	54%	Norm
2007	17.6	42%	Norm	19.5	83%	Blw Norm	19.2	66%	Norm	14.3	87%	Blw Norm
2006	18.8	16%	Abv Norm	21.3	31%	Norm	18.4	87%	Blw Norm	15.1	77%	Blw Norm
2005	13.8	100%	Cold	21.8	25%	Abv Norm	19.8	45%	Norm	13.3	100%	Cold
2004	18.0	29%	Abv Norm	20.7	50%	Norm	19.3	60%	Norm	15.0	78%	Blw Norm
1995	15.5	93%	Cold	19.7	79%	Blw Norm	19.9	42%	Norm	17.8	10%	Abv Norm
1992	18.5	22%	Abv Norm	20.2	74%	Blw Norm	20.8	19%	Abv Norm	16.3	56%	Norm
1991	16.4	75%	Blw Norm	22.3	14%	Abv Norm	19.9	41%	Norm	18.9	1%	Hot
1990	16.7	62%	Norm	21.8	24%	Abv Norm	20.0	40%	Norm	16.8	41%	Norm
Period of Record												
Maximum	21.0	--	--	23.5	--	--	21.8	--	--	19.9	--	--
Minimum	13.8	--	--	17.6	--	--	16.5	--	--	13.3	--	--
Average	17.3	--	--	20.7	--	--	19.7	--	--	16.3	--	--
Data Years	85			88			86			88		

[1] Exceedance is defined as the percent of total observations that have exceeded this value in the period of record.

[2] National Weather Service cooperative station (HTC) - operated by PG&E. (http://www.calclim.dri.edu/ccda/data.html).

Table 4-2. Monitoring setting information.

Water Year	Watershed Runoff: DWR Runoff Index[1]	Watershed Runoff: Sac. River Basin Water Year Type[1]	Watershed Runoff: Flow into Lake Britton (cfs)[2]	Watershed Runoff: Pit River Water Year Type[3]	Air Temperature Classification, Hat Creek PH No. 1[4]: June	July	August	Sept.
2011	10.5	Wet	1984	Abv Norm	Blw Norm	Norm	Norm	Abv Norm
2010	7.1	Blw Norm	1271	C Dry	Cold	Norm	Blw Norm	Blw Norm
2009	5.8	Dry	1338	C Dry	Norm	Norm	Blw Norm	Abv Norm
2008	5.2	C Dry	1456	Dry	Norm	Norm	Abv Norm	Norm
2007	6.2	Dry	1367	C Dry	Norm	Blw Norm	Norm	Blw Norm
2006	13.2	Wet	2646	Wet	Abv Norm	Norm	Blw Norm	Blw Norm
2005	8.5	Abv Norm	1686	Abv Norm	Cold	Abv Norm	Norm	Cold
2004	7.5	Blw Norm	1599	Blw Norm	Abv Norm	Norm	Norm	Blw Norm
1995	12.9	Wet	2895	Wet	Cold	Blw Norm	Norm	Abv Norm
1992	4.1	C Dry	1149	C Dry	Abv Norm	Blw Norm	Abv Norm	Norm
1991	4.2	C Dry	1418	Dry	Blw Norm	Abv Norm	Norm	Hot
1990	4.8	C Dry	1367	C Dry	Norm	Abv Norm	Norm	Norm
Average	--	--	1887		--	--	--	--
Maximum	--	--	2914 (1998 WY)		--	--	--	--
Minimum	--	--	1149 (1992 WY)		--	--	--	--
Data years	--	--	36		--	--	--	--

[1] As defined by Dept. Water Resources for the greater Sacramento River basin. Index is based on an average from 8-stations (http://cdec.water.ca.gov/).

[2] Annual average discharge from the Pit River downstream of Pit 1 Powerhouse (USGS Gage 11355010, USGS 2012).

[3] Classification type based on State water year type definitions (CDEC 2012b).

[4] National Weather Service cooperative stations - operated by PG&E. (http://www.calclim.dri.edu/ccda/data.html).

Table 4-3. Summary of stream flow data from the Pit River downstream of Pit 1 Powerhouse (USGS Gage).

	Mean Monthly Stream Flow- Pit River downstream of Pit 1 Powerhouse [1]											
	June			July			August			September		
Year	Flow (cfs)	Exceedance[2] (%)	Class	Flow (cfs)	Exceedance[2] (%)	Class	Flow (cfs)	Exceedance[2] (%)	Class	Flow (cfs)	Exceedance[2] (%)	Class
2011	2287	9%	Wet	1245	52%	Norm	1137	69%	Norm	1123	83%	Blw Norm
2010	1296	63%	Norm	1010	94%	Dry	1085	83%	Blw Norm	1121	86%	Blw Norm
2009	1181	92%	Dry	1069	89%	Blw Norm	1069	86%	Blw Norm	1049	92%	Dry
2008	1447	49%	Norm	1137	77%	Blw Norm	1097	80%	Blw Norm	1123	83%	Blw Norm
2007	1135	97%	Dry	1073	86%	Blw Norm	1047	89%	Blw Norm	1125	77%	Blw Norm
2006	1653	29%	Abv Norm	1371	26%	Abv Norm	1291	32%	Norm	1324	32%	Norm
2005	1720	23%	Abv Norm	1217	54%	Norm	1139	66%	Norm	1181	69%	Norm
2004	1194	89%	Blw Norm	1042	92%	Dry	1043	92%	Dry	1075	89%	Blw Norm
1995	2452	6%	Wet	1619	6%	Wet	1359	26%	Abv Norm	1291	46%	Norm
1992	1012	100%	Dry	1004	97%	Dry	976.7	94%	Dry	1027	97%	Dry
1991	1280	69%	Norm	1190	63%	Norm	1118	74%	Blw Norm	1040	94%	Dry
1990	1463	43%	Norm	1102	83%	Blw Norm	1099	77%	Blw Norm	1134	74%	Blw Norm
Period of Record												
Maximum	4582			1809			1618			1628		
Minimum	1012			954			828			784		
Average	1621			1276			1225			1272		
Data Years	36			36			36			36		

1 Monthly average discharge from the Pit River downstream of Pit 1 Powerhouse (USGS Gage 11355010, USGS 2012).

2 Exceedance is defined as the percent of total observations that have exceeded this value in the period of record.

Table 4-4. Summary of Pit 1 Project stream flow data.

Station	Statistic / Exceedance	1990–1992					1995					2004–2011				
		June	July	Aug.	Sept.	July-August	June	July	Aug.	Sept.	July-August	June	July	Aug.	Sept.	July-August
PR2 – Big Eddy	Minimum (cfs)	9.7	26.5	16.8	20.4	16.8	451	108	76.4	71.6	76.4	157	129	153	89.0	129
	90% (cfs)	15.4	31.7	27.5	24.8	27.5	474	117	82.0	75.5	92.3	186	152	165	147	163
	75% (cfs)	17.1	41.1	32.3	26.9	33.4	516	170	92.4	80.2	130	238	179	174	170	177
	Average (cfs)	24.3	134	85.2	30.8	103	658	253	151	109	211	401	242	228	201	235
	50% (cfs)	25.5	49.7	38.0	30.6	41.5	614	258	179	111	191	317	222	199	192	207
	25% (cfs)	30.0	82.9	45.9	34.6	52.1	854	281	191	124	261	515	263	249	234	253
	10% (cfs)	33.0	347	163	36.6	345	< 903	409	211	143	367	860	317	305	263	313
	Maximum (cfs)	39.3	631	626	44.2	631	< 903	502	233	159	502	< 903	879	837	393	879
PR4 – Pit 1 Footbridge	Minimum (cfs)	132	136	135	133	135	--	--	--	--	--	252	245	250	205	245
	90% (cfs)	132	137	136	134	136	--	--	--	--	--	272	261	276	258	273
	75% (cfs)	134	140	137	134	137	--	--	--	--	--	326	288	284	277	286
	Average (cfs)	135	218	196	135	208	--	--	--	--	--	442	354	335	306	345
	50% (cfs)	134	143	138	135	142	--	--	--	--	--	409	323	305	302	312
	25% (cfs)	136	163	143	135	151	--	--	--	--	--	503	378	333	338	362
	10% (cfs)	137	388	278	136	394	--	--	--	--	--	749	444	417	355	433
	Maximum (cfs)	138	707	725	138	725	--	--	--	--	--	1038	858	918	467	918
Pit River below Pit 1 PH (USGS Gage)	Minimum (cfs)	888	866	719	783	719	1510	1380	1160	1200	1160	885	928	929	919	928
	90% (cfs)	977	978	935	989	949	2169	1400	1280	1229	1300	1100	999	1030	1040	1014
	75% (cfs)	1050	1010	975	1040	990	2293	1440	1300	1263	1365	1150	1050	1050	1070	1050
	Average (cfs)	1252	1082	1038	1081	1063	2452	1619	1359	1291	1489	1489	1145	1113	1140	1129
	50% (cfs)	1150	1095	1040	1090	1075	2540	1600	1360	1280	1435	1305	1110	1090	1120	1100
	25% (cfs)	1295	1138	1108	1140	1120	2650	1690	1415	1310	1598	1685	1230	1150	1180	1180
	10% (cfs)	1747	1199	1150	1160	1190	2721	1950	1460	1341	1809	2194	1343	1280	1300	1296
	Maximum (cfs)	2360	1400	1390	1190	1400	2790	2180	1510	1540	2180	2930	1650	1410	1480	1650

Table 4-5. Summary of peak flow frequency analysis from the Pit River downstream of Pit 1 Powerhouse.

Station	Statistic / Exceedance	2008 (June-September)		2009 (June-September)		2010 (June-September)		2011 (June-September)	
		Mean Daily Flow (cfs)	Peaking Flow (cfs)	Mean Daily Flow (cfs)	Peaking Flow (cfs)	Mean Daily Flow (cfs)	Peaking Flow (cfs)	Mean Daily Flow (cfs)	Peaking Flow (cfs)
Pit River downstream of Pit 1 Powerhouse	Maximum	2520	1150	1320	820	1778	1360	2930	1459
	10 % Exceedance	1294	790	1212	799	1304	800	2547	770
	50 % Exceedance	1130	750	1069	735	1088	690	1176	700
	Average	1199	737	1091	668	1126	711	1444	711
	90 % Exceedance	1068	618	1026	388	988	668	1091	623
	Minimum	1034	380	930	360	963	383	997	363

Note: All data for the Pit River downstream of Pit 1 Powerhouse (USGS Gage 11355010, USGS 2012).

Table 4-6. Summary of Pit 1 Project mean daily water temperature data

Station		Monitoring Year (June-September)											
		1990	1991	1992	1995	2004	2005	2006	2007	2008	2009	2010	2011
P7	Maximum (°C)	25.1	24.8	23.6	--	--	--	--	--	--	--	--	--
	Minimum (°C)	12.7	14.9	17.4	--	--	--	--	--	--	--	--	--
	Average (°C)	20.7	21.1	20.4	--	--	--	--	--	--	--	--	--
	Data periods	122	118	122	0	0	0	0	0	0	0	0	0
PR2	Maximum (°C)	--	24.6	24.6	24.5	24.2	24.7	25.0	24.0	23.2	24.0	24.9	23.9
	Minimum (°C)	--	20.3	16.7	15.6	15.6	15.0	15.4	13.8	16.2	16.4	16.1	12.7
	Average (°C)	--	22.2	21.1	20.7	21.0	20.7	20.8	20.7	20.5	20.6	20.6	20.6
	Data periods	0	51	120	113	122	115	122	122	122	122	122	122
PR3	Maximum (°C)	21.3	21.5	21.6	--	22.6	23.3	22.6	22.3	22.3	22.5	--	--
	Minimum (°C)	13.8	18.2	16.5	--	16.0	15.4	15.7	14.7	16.4	16.1	--	--
	Average (°C)	19.1	20.1	18.7	--	20.1	19.9	19.9	19.7	19.8	19.8	--	--
	Data periods	119	34	119	0	122	122	117	122	122	122	0	0
PR4	Maximum (°C)	19.8	20.4	21.9	--	21.4	23.0	21.7	21.4	21.6	21.7	20.7	21.6
	Minimum (°C)	13.5	15.3	15.1	--	15.6	15.1	15.5	14.3	16.0	15.8	16.1	13.0
	Average (°C)	17.7	17.9	17.3	--	19.3	19.3	19.2	19.0	19.1	19.3	18.7	19.2
	Data periods	122	122	112	0	122	122	122	122	122	122	122	122
P10	Maximum (°C)	21.8	21.6	21.6	--	--	--	--	--	--	--	--	--
	Minimum (°C)	11.8	15.0	15.3	--	--	--	--	--	--	--	--	--
	Average (°C)	18.3	19.3	18.6	--	--	--	--	--	--	--	--	--
	Data periods	122	73	122	0	0	0	0	0	0	0	0	0
PR5	Maximum (°C)	--	--	--	--	21.6	22.8	21.2	21.4	21.5	21.7	22.2	21.4
	Minimum (°C)	--	--	--	--	13.8	13.3	13.8	13.0	14.9	14.3	15.4	12.9
	Average (°C)	--	--	--	--	18.7	18.5	18.2	18.5	18.5	18.8	18.7	18.7
	Data periods	0	0	0	0	122	122	122	122	122	122	122	122

Table 4-7. Summary of mean daily water temperature frequency analysis.

Station	Statistic / Exceedance	1990–1992					1995					2004–2011				
		June	July	Aug.	Sept.	July-August	June	July	Aug.	Sept.	July-August	June	July	Aug.	Sept.	July-August
P7 – Pit Weir	Minimum (°C)	12.7	18.8	18.7	16.6	18.7	--	--	--	--	--	--	--	--	--	--
	90% (°C)	18.1	20.0	19.9	17.5	19.9	--	--	--	--	--	--	--	--	--	--
	75% (°C)	19.0	21.6	20.5	17.9	20.9	--	--	--	--	--	--	--	--	--	--
	Average (°C)	20.0	22.4	21.6	18.9	22.0	--	--	--	--	--	--	--	--	--	--
	50% (°C)	19.9	22.5	21.6	18.9	22.1	--	--	--	--	--	--	--	--	--	--
	25% (°C)	21.3	23.4	22.6	19.8	23.1	--	--	--	--	--	--	--	--	--	--
	10% (°C)	22.2	24.3	23.4	20.3	24.0	--	--	--	--	--	--	--	--	--	--
	Maximum (°C)	23.6	25.1	24.7	21.6	25.1	--	--	--	--	--	--	--	--	--	--
PR2 – Big Eddy	Minimum (°C)	19.2	19.7	19.5	16.7	19.5	15.6	20.9	19.6	16.7	19.6	12.7	20.4	19.0	13.8	19.0
	90% (°C)	20.0	20.3	20.3	17.3	20.2	16.1	21.7	20.3	18.3	20.9	17.6	21.7	20.4	15.9	20.8
	75% (°C)	20.3	21.8	20.7	18.0	21.1	16.8	22.2	20.9	18.7	21.3	19.0	22.3	20.9	17.0	21.5
	Average (°C)	21.9	22.4	21.9	19.1	22.1	19.3	22.6	21.5	18.8	22.0	19.9	22.9	21.6	18.2	22.2
	50% (°C)	22.7	22.5	22.0	19.0	22.3	18.4	22.8	21.5	18.9	22.2	20.0	22.9	21.7	18.5	22.2
	25% (°C)	23.0	23.3	22.7	20.1	23.1	21.9	23.1	22.1	19.1	23.0	21.2	23.6	22.2	19.4	23.1
	10% (°C)	23.3	23.6	23.4	20.7	23.6	24.2	23.3	22.5	19.3	23.2	22.1	24.2	22.7	20.0	23.8
	Maximum (°C)	24.6	24.6	24.0	21.7	24.6	24.5	23.9	23.2	19.5	23.9	23.4	25.0	24.0	21.7	25.0
PR3 – Pit Falls	Minimum (°C)	13.8	18.3	17.9	16.5	17.9	--	--	--	--	--	17.0	19.9	18.5	14.7	18.5
	90% (°C)	17.7	19.0	18.3	16.8	18.4	--	--	--	--	--	18.2	20.7	19.3	16.0	19.7
	75% (°C)	18.2	19.5	18.7	17.2	19.0	--	--	--	--	--	18.8	21.1	19.8	16.6	20.4
	Average (°C)	18.8	20.2	19.2	17.5	19.8	--	--	--	--	--	19.6	21.6	20.4	17.7	21.0
	50% (°C)	19.2	20.4	19.2	17.5	19.8	--	--	--	--	--	19.7	21.6	20.5	18.0	21.0
	25% (°C)	19.5	21.1	19.8	17.9	20.7	--	--	--	--	--	20.3	22.1	20.9	18.7	21.7
	10% (°C)	19.8	21.2	20.3	18.2	21.1	--	--	--	--	--	21.3	22.4	21.4	19.0	22.2
	Maximum (°C)	20.2	21.6	20.7	18.4	21.6	--	--	--	--	--	22.3	23.3	22.4	20.3	23.3

Table 4-7. (Continued)

Station	Statistic / Exceedance	1990–1992 June	1990–1992 July	1990–1992 Aug.	1990–1992 Sept.	1990–1992 July-August	1995 June	1995 July	1995 Aug.	1995 Sept.	1995 July-August	2004–2011 June	2004–2011 July	2004–2011 Aug.	2004–2011 Sept.	2004–2011 July-August
PR4 – Pit 1	Minimum (°C)	13.5	17.0	16.5	15.1	16.5	--	--	--	--	--	13.0	18.9	17.7	14.3	17.7
Footbridge	90% (°C)	16.1	17.7	16.8	15.5	17.1	--	--	--	--	--	17.3	19.8	18.7	15.8	19.1
	75% (°C)	16.8	18.3	17.3	15.9	17.7	--	--	--	--	--	18.2	20.2	19.2	16.4	19.6
	Average (°C)	17.4	19.1	17.8	16.3	18.4	--	--	--	--	--	18.9	20.7	19.7	17.2	20.2
	50% (°C)	17.6	19.1	17.8	16.2	18.2	--	--	--	--	--	19.1	20.6	19.7	17.4	20.2
	25% (°C)	18.1	19.7	18.2	16.6	19.2	--	--	--	--	--	19.7	21.2	20.1	18.2	20.7
	10% (°C)	18.6	20.3	18.9	17.0	19.8	--	--	--	--	--	20.6	21.5	20.5	18.5	21.3
	Maximum (°C)	19.4	21.9	20.1	17.6	21.9	--	--	--	--	--	21.6	23.0	21.6	19.4	23.0
P10 – below	Minimum (°C)	11.8	16.6	16.6	15.3	16.6	--	--	--	--	--	--	--	--	--	--
Pit 1 PH	90% (°C)	16.6	18.6	17.0	15.5	17.7	--	--	--	--	--	--	--	--	--	--
	75% (°C)	17.4	19.7	17.9	15.7	19.0	--	--	--	--	--	--	--	--	--	--
	Average (°C)	18.2	20.2	19.0	16.4	19.7	--	--	--	--	--	--	--	--	--	--
	50% (°C)	18.1	20.5	19.3	16.4	19.9	--	--	--	--	--	--	--	--	--	--
	25% (°C)	19.6	21.1	20.1	17.1	20.6	--	--	--	--	--	--	--	--	--	--
	10% (°C)	20.1	21.4	20.7	17.3	21.2	--	--	--	--	--	--	--	--	--	--
	Maximum (°C)	20.8	21.8	21.0	18.1	21.8	--	--	--	--	--	--	--	--	--	--
PR5 - below	Minimum (°C)	--	--	--	--	--	--	--	--	--	--	12.9	18.8	16.5	13.0	16.5
Pit 1 PH	90% (°C)	--	--	--	--	--	--	--	--	--	--	16.3	19.5	17.9	14.5	18.5
	75% (°C)	--	--	--	--	--	--	--	--	--	--	17.4	19.9	18.7	15.5	19.1
	Average (°C)	--	--	--	--	--	--	--	--	--	--	18.2	20.4	19.2	16.4	19.8
	50% (°C)	--	--	--	--	--	--	--	--	--	--	18.4	20.5	19.2	16.6	19.8
	25% (°C)	--	--	--	--	--	--	--	--	--	--	19.4	20.9	19.7	17.3	20.5
	10% (°C)	--	--	--	--	--	--	--	--	--	--	20.1	21.4	20.1	18.0	21.1
	Maximum (°C)	--	--	--	--	--	--	--	--	--	--	21.1	22.8	21.5	19.0	22.8

Table 4-8. Summary of Pit 1 Project dissolved oxygen data.

		Monitoring Year (June-September)											
Station		1990	1991	1992	1995	2004	2005	2006	2007	2008	2009	2010	2011
P7	Maximum (mg/L)	13.3	8.0	19.2	--	--	--	--	--	--	--	--	--
	Minimum (mg/L)	7.0	3.1	9.8	--	--	--	--	--	--	--	--	--
	Average (mg/L)	10.3	6.0	12.9	--	--	--	--	--	--	--	--	--
	Sample No.	4	4	3	0	0	0	0	0	0	0	0	0
PR2	Maximum (mg/L)	--	--	18.5	8.2	8.3	8.4	7.9	8.3	8.7	8.2	8.0	8.1
	Minimum (mg/L)	--	--	3.7	6.2	7.1	6.2	7.2	7.0	6.8	6.8	7.1	7.4
	Average (mg/L)	--	--	13.0	7.1	7.6	7.6	7.5	7.7	7.8	7.4	7.5	7.8
	Sample No.	0	0	4	6	9	8	8	8	7	8	4	4
PR3	Maximum (mg/L)	8.8	10.4	9.1	--	9.0	10.0	8.6	8.5	9.8	8.1	--	--
	Minimum (mg/L)	5.4	8.0	6.6	--	7.3	6.6	7.8	8.0	7.7	7.5	--	--
	Average (mg/L)	7.6	8.9	8.1	--	8.0	8.2	8.2	8.3	8.5	7.9	--	--
	Sample No.	4	3	4	0	9	8	6	5	7	4	0	0
PR4	Maximum (mg/L)	9.2	10.2	9.8	--	8.8	9.4	8.7	8.8	9.4	8.6	8.9	8.8
	Minimum (mg/L)	5.6	6.3	6.4	--	7.4	6.9	7.8	7.3	7.7	7.5	7.9	8.3
	Average (mg/L)	7.9	8.4	8.3	--	8.0	8.2	8.2	8.2	8.4	7.9	8.4	8.5
	Sample No.	4	4	3	0	9	9	8	8	7	7	4	4
P10	Maximum (mg/L)	8.4	8.6	11.4	--	--	--	--	--	--	--	--	--
	Minimum (mg/L)	5.0	6.7	6.1	--	--	--	--	--	--	--	--	--
	Average (mg/L)	7.5	7.9	8.9	--	--	--	--	--	--	--	--	--
	Sample No.	4	4	4	0	0	0	0	0	0	0	0	0
PR5	Maximum (mg/L)	--	--	--	--	8.7	9.1	9.0	9.4	9.7	8.6	8.6	9.3
	Minimum (mg/L)	--	--	--	--	7.5	7.8	8.4	8.1	7.7	7.8	7.8	8.2
	Average (mg/L)	--	--	--	--	8.3	8.6	8.7	8.8	8.7	8.2	8.2	8.9
	Sample No.	0	0	0	0	9	9	8	8	7	8	4	4

Table 4-9. Spring inflows mapped in the Pit 1 Bypass Reach during Summer/Fall 2012

Region	Survey Date	Spring Identification Number [1]	River Kilometer	Temperature (°C)	Specific Conductivity (µS)	Spring Type [3]	Length of Spring Inflow Area (m)	Estimated Discharge (cfs)
downstream (d/s) Ledges	9/5/2012	RL #1	89.40	22.1	183	Warm Spring	42	2.5
	9/5/2012	RL #2	89.36	22.1	194	Warm Spring	33	1.0
	9/5/2012	RL #3	89.32	14.8	201	Cold Spring Pool	5	0.1
	9/5/2012	RL #4	89.29	13.2	233	Cold Spring Pool	10	0.1
	9/5/2012	RL #5	89.26	14.1	252	Cold Spring Pool	20	0.1
upstream (u/s) Island	9/5/2012	RL #6	89.07	21.4	192	Warm Spring	12	0.3
	9/5/2012	RL #7	89.00	21.1	194	Warm Spring	30	0.8
	9/5/2012	RL #8	88.94	19.4	200	Warm Spring	10	0.2
	9/5/2012	RL #9	88.92	20.3	200	Warm Spring	40	0.3
	9/5/2012	RL #10	88.82	18.7	202	Cool Spring Pool	0	0.1
	9/5/2012	RL #11	88.80	14.4	238	Cold Spring Pool	0	0.1
	9/5/2012	RL #12	88.77	20.6	207	Warm Spring	25	0.5
	9/5/2012	RL #13	88.65	20.4	206	Warm Spring Pool	60	0.1
	9/5/2012	RL #14	88.60	12.8	219	Cold Spring Pool	0	0.1
downstream (d/s) Island	8/9/2012	RL #15	88.45	19.9	214	Warm Spring	2	0.1
	8/9/2012	RL #16	88.31	19.8	218	Warm Spring	1	0.1
	8/9/2012	RL #17	88.29	19.6	219	Warm Spring	50	2.0
	8/9/2012	RL #18	88.18	19.5	206	Warm Spring	6	0.1
	8/9/2012	RR #1	88.20	20.1	210	Warm Seep	4	0.1
	8/9/2012	RR #2	88.14	21.1	193	Warm Spring	4	0.1
Big Spring 1	8/9/2012	RR #3	87.92	20.6	197	Warm Spring	30	2.5
	8/7/2012	RL #19	87.86	17.7	170	Marginally Cold Spring	35	2.0
	8/7/2012	RL #20	87.75	17.9	163	Marginally Cold Spring	35	5.0
	8/9/2012	RR# 4	87.70	20.1	188	Warm Spring	5	0.1
Big Spring 2	8/9/2012	RL #21	87.45	19.5	188	Warm Spring	9	5.0

Table 4-9. (continued)

Region	Survey Date	Spring Identification Number [1]	River Kilometer	Temperature (°C)	Specific Conductivity (µS)	Spring Type [3]	Length of Spring Inflow Area (m)	Estimated Discharge (cfs)
Shasta	8/2/2012	RR #5	87.15	13.9	152	Cold Spring	75	1.7
	7/30/2012	RR #6	86.97	15.0	152	Cold Spring	34	2.0
	7/30/2012	RR #7	86.94	14.6	145	Cold Spring	21	0.5
	7/30/2012	RR #8	86.92	14.3	151	Cold Spring	62	3.0
	7/26/2012	RR #9	86.86	15.1	125	Cold Spring	33	5.0
Array Site	7/26/2012	RR #10	86.82	13.8	150	Cold Spring	49	3.0
	10/2/2012	RL #22	87.11	14.5	156	Cold Spring	10	1.0
	8/2/2012	RL #23	87.05	15.9	153	Cold Spring	5	0.2
	8/2/2012	RL #24	87.04	16.5	138	Cold Spring	10	0.6
	8/2/2012	RL #25	87.03	18.2	148	Cool Spring	10	0.5
	8/2/2012	RL #26	87.02	19.6	160	Warm Spring	35	10.0
	8/2/2012	RL #27	86.99	19.8	162	Warm Spring	22	3.0
	8/2/2012	RL #28	86.96	19.4	169	Warm Spring	60	4.0
Overlook	7/31/2012	RR #11	85.20	13.1	156	Cold Spring	67	3.0
	7/31/2012	RR #12	85.15	15.6	160	Cold Spring	20	0.1
Surge	7/25/2012	RL #29	84.32	13.7	140	Cold Spring	27	2.0
Array Site	7/25/2012	RL #30	84.24	14.0	155	Cold Spring	1	0.1
Array Site	7/25/2012	RL #31	84.24	13.4	153	Cold Spring	42	3.0
PG&E	7/27/2012	RL #32	84.00	14.2	155	Cold Spring Run	8	1.0
	7/24/2012	RL #33	83.88	15.6	159	Cold Spring Run	1	0.9
Array Site	7/24/2012	RL #34	83.88	16.4	162	Cold Spring Run	4	4.9
	7/24/2012	RL #35	83.84	16.4	162	Cold Spring Run	18	5.7
Powerlines	7/27/2012	RR #13	83.10	14.4	156	Cold Spring Run	4	0.7

[1] RL signifies a river-left spring inflow and RR indicates a river-right spring inflow

[2] Springs are categorized as Cold (<15–17 °C), Marginally Cold (17.1–18 °C), Cool (18.1–19 °C), or Warm (>19 °C). Spring pools are lentic side channel habitats with no defined inflow; spring runs are spring-fed creeks that are often more susceptible to ambient temperature fluctuations.

Table 4-10. Summary of spring habitat characteristics by Region

Region	Cold (<15–17 °C)			Marginally Cold (17.1–18 °C)			Cool (18.1–19 °C)			Warm (>19 °C)	
	Number of Inflows	Discharge (cfs)	Refuge Area (m^2)	Number of Inflows	Discharge (cfs)	Refuge Area (m^2)	Number of Inflows	Discharge (cfs)	Refuge Area (m^2)	Number of Inflows	Discharge (cfs)
d/s Ledges	3	0.3	10.0	0	0.0	10.0	0	0.0	0.0	2	3.5
u/s Island	2	0.2	4.5	0	0.0	2.5	1	0.1	3.0	6	2.2
d/s Island	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	6	2.5
Big Spring 1	0	0.0	0.0	2	7.0	25.0	0	0.0	94.0	2	2.6
Big Spring 2	0	0.0	0.0	0	0.0	0.0	0	0.0	2.0	1	5.0
Shasta	9	17.0	209.5	0	0.0	124.5	1	0.5	100.1	3	17.0
Overlook	2	3.1	6.0	0	0.0	10.0	0	0.0	10.0	0	0.0
Surge	3	5.1	27.0	0	0.0	28.5	0	0.0	19.5	0	0.0
PG&E	4	12.5	306.0	0	0.0	53.0	0	0.0	51.1	0	0.0
Powerlines	1	0.7	1.0	0	0.0	1.0	0	0.0	0.0	0	0.0
SUM	**24**	**39**	**564**	**2**	**7**	**254**	**2**	**1**	**280**	**20**	**33**
Scaled to 100 cfs		**49**	711		**9**	**321**		**1**	**352**		**33**
Total Number of Inflows: 48											
Total Discharge: 79 cfs											

Note: Cold spring inflows create Cold, Marginally Cold, and Cool refugia habitat; marginally cold spring inflows create Marginally Cold and Cool refugia habitat; and cool spring inflows create Cool refugia habitat.

Table 4-11. Seasonal/diel differences in instantaneous water temperature and specific conductivity at 11 spring inflows

Region	Location	Date	Time	Mainstem Temperature (°C)	Mainstem Specific Conductivity (µS)	Spring Temperature (°C)	Spring Specific Conductivity(µS)	Temperature Differences
Cold Springs								
d/s Ledges	RL #3	9/5/2012	11:22	19.4	171	14.8	201.0	
d/s Ledges	RL #3	10/1/2012	12:20	17.6	167	14.0	203.0	0.8 °C colder in October
d/s Ledges	RL #4	9/5/2012	11:30	19.7	169	13.2	233.0	
d/s Ledges	RL #4	10/1/2012	14:00	18.2	166	11.5	236.0	1.7 °C colder in October
d/s Ledges	RL #5	9/5/2012	12:00	19.7	169	14.1	252.0	
d/s Ledges	RL #5	10/1/2012	14:00	18.2	166	11.5	260.0	2.6 °C colder in October
u/s Island	RL #11	9/5/2012	13:55	20.3	170	14.4	238.0	
u/s Island	RL #11	10/1/2012	15:30	18.3	167	13.6	260.0*	0.8 °C colder in October
d/s Island	RL #14	9/5/2012	14:40	20.3	170	12.8	219.0	
d/s Island	RL #14	10/1/2012	16:00	18.5	167	10.7	222.0	2.1 °C colder in October
Powerlines	RR #13	7/26/2012	16:00	22.0	168	16.0		
Powerlines	RR #13	7/27/2012	9:00	19.0	167	14.4	156.0	1.6 °C diel fluctuation
Warm Springs								
d/s Ledges	RL #1	9/5/2012	10:45	19.1	171	22.1	183.0	
d/s Ledges	RL #1	10/1/2012	12:00	17.6	167	22.3	191.0	0.2 °C warmer in October
d/s Ledges	RL #2	9/5/2012	11:00	19.1	171	22.1	194.0	
d/s Ledges	RL #2	10/1/2012	12:00	17.6	167	22.1	168.0*	No Change
u/s Island	RL #6	9/5/2012	13:15	20.2	169	21.4	192.0	
u/s Island	RL #6	10/1/2012	14:30	19.0	167	21.6	190.0	0.2 °C warmer in October
u/s Island	RL #7	9/5/2012	13:20	20.2	169	21.1	194.0	
u/sIsland	RL #7	10/1/2012	14:30	18.2	166	21.0	196.0	0.1 °C colder in October
u/s Island	RL #8	9/5/2012	13:30	20.2	169	19.4	200.0	
u/s Island	RL #8	10/1/2012	15:00	19.0	167	19.4	198.0	No Change

* Large discrepancies in conductivity between dates may due to differences in sampling location within the spring or spring complex.

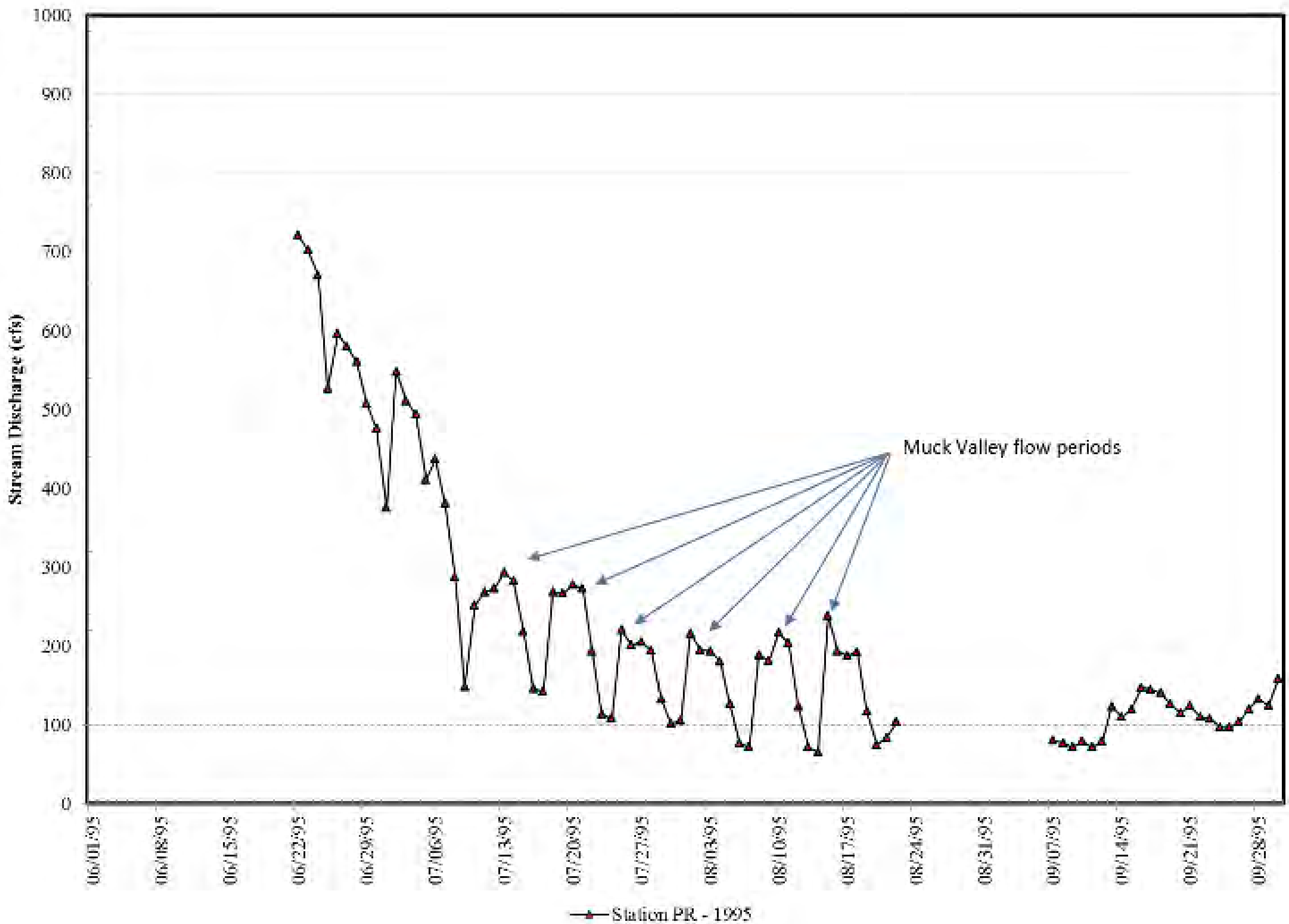


Figure 4-1. Mean daily stream flow from Big Eddy (PR2) station highlighting the effect of Muck Valley Powerhouse operations on flows in the Pit 1 Bypass Reach from June through September 1995.

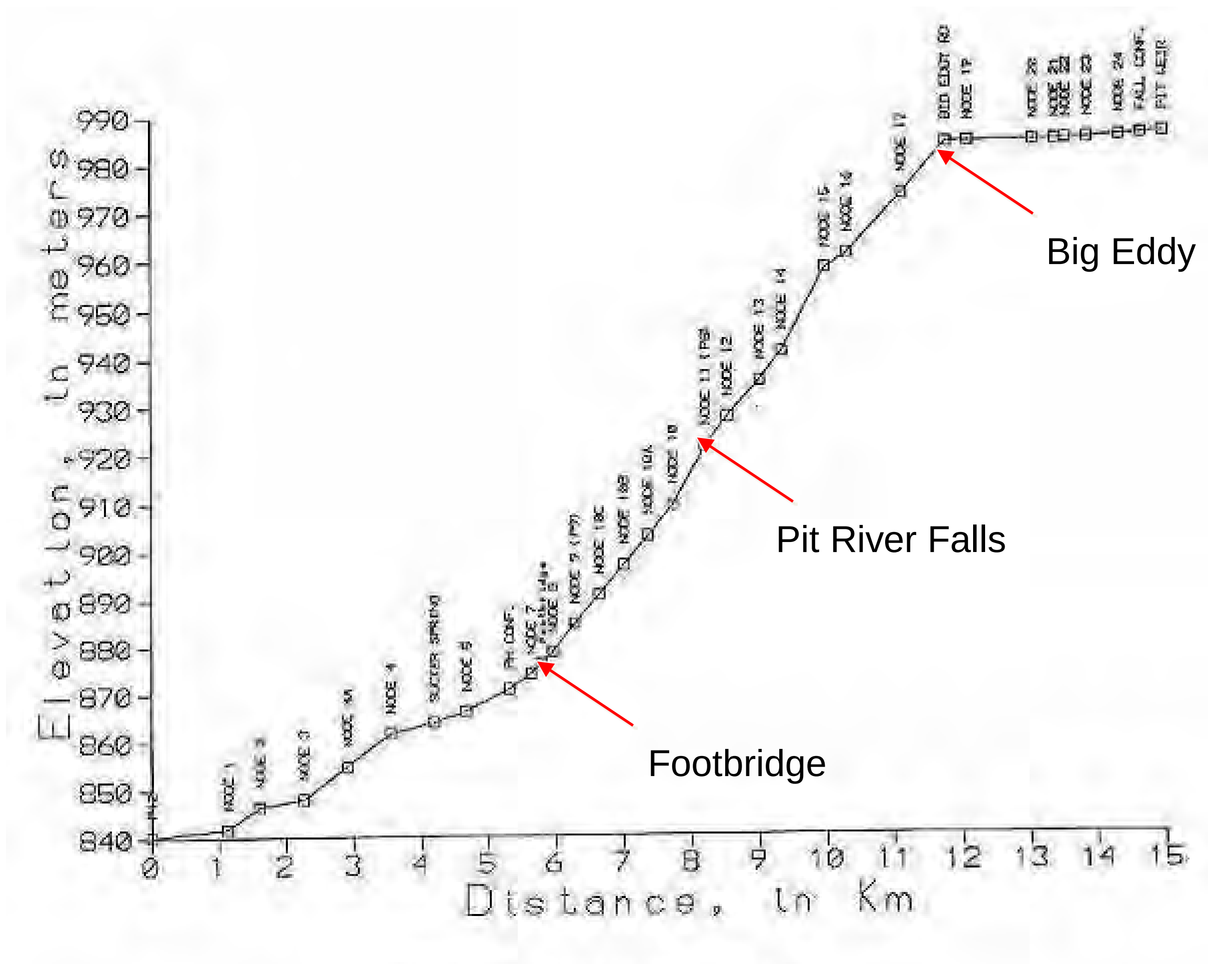


Figure 3-2. Elevation view of the study site.

Figure 4-2. Gradient of the Pit River in the Pit 1 Bypass (reproduced from Pit 1 Relicensing – Water Resources Investigation, Volume 1, Page 3–31, PG&E 1993a).

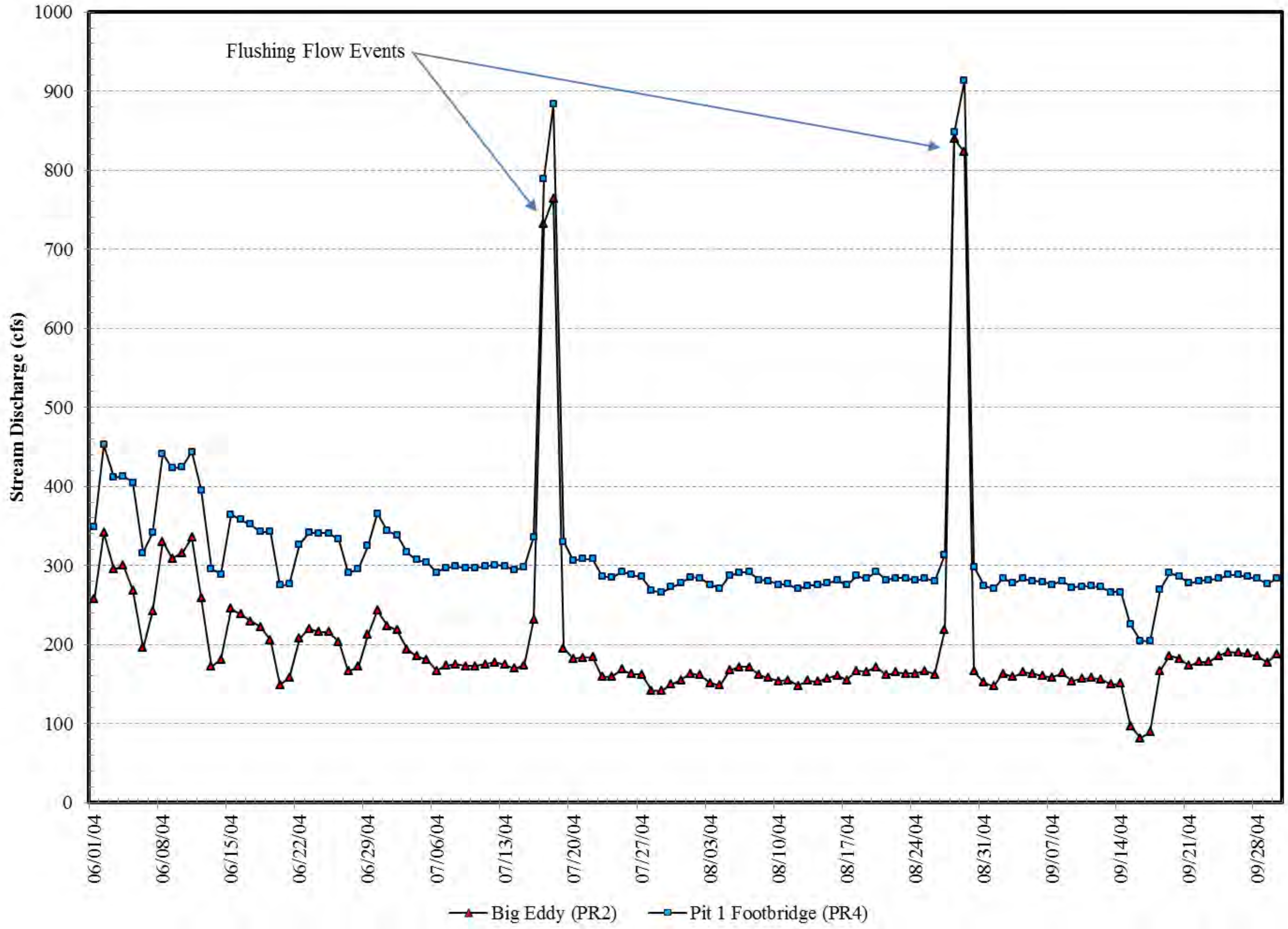


Figure 4-3. Comparison of mean daily stream flow from two stations in the Pit 1 Bypass Reach from June through September 2004.

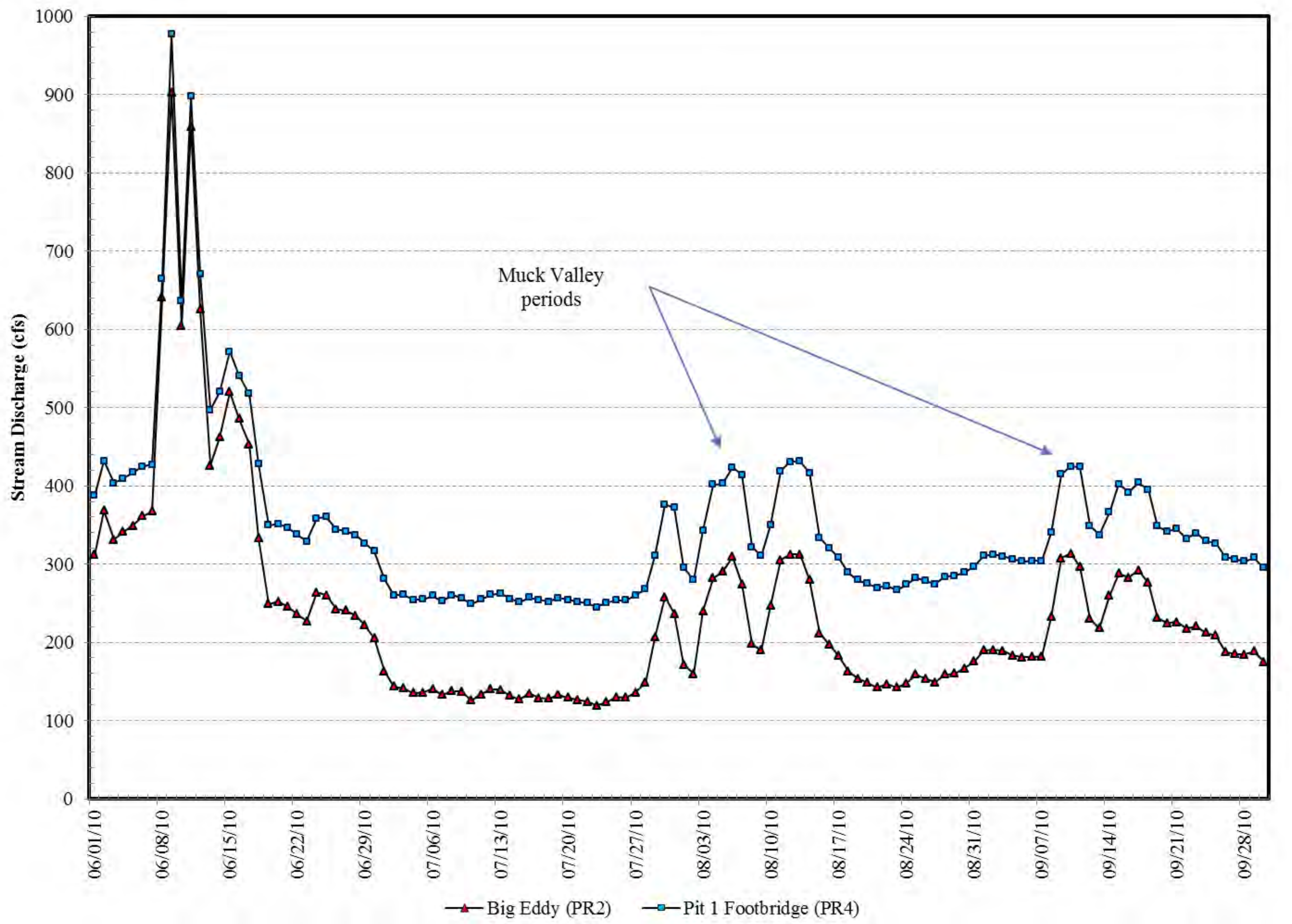


Figure 4-4. Comparison of mean daily stream flow from two stations in the Pit 1 Bypass Reach from June through September 2010.

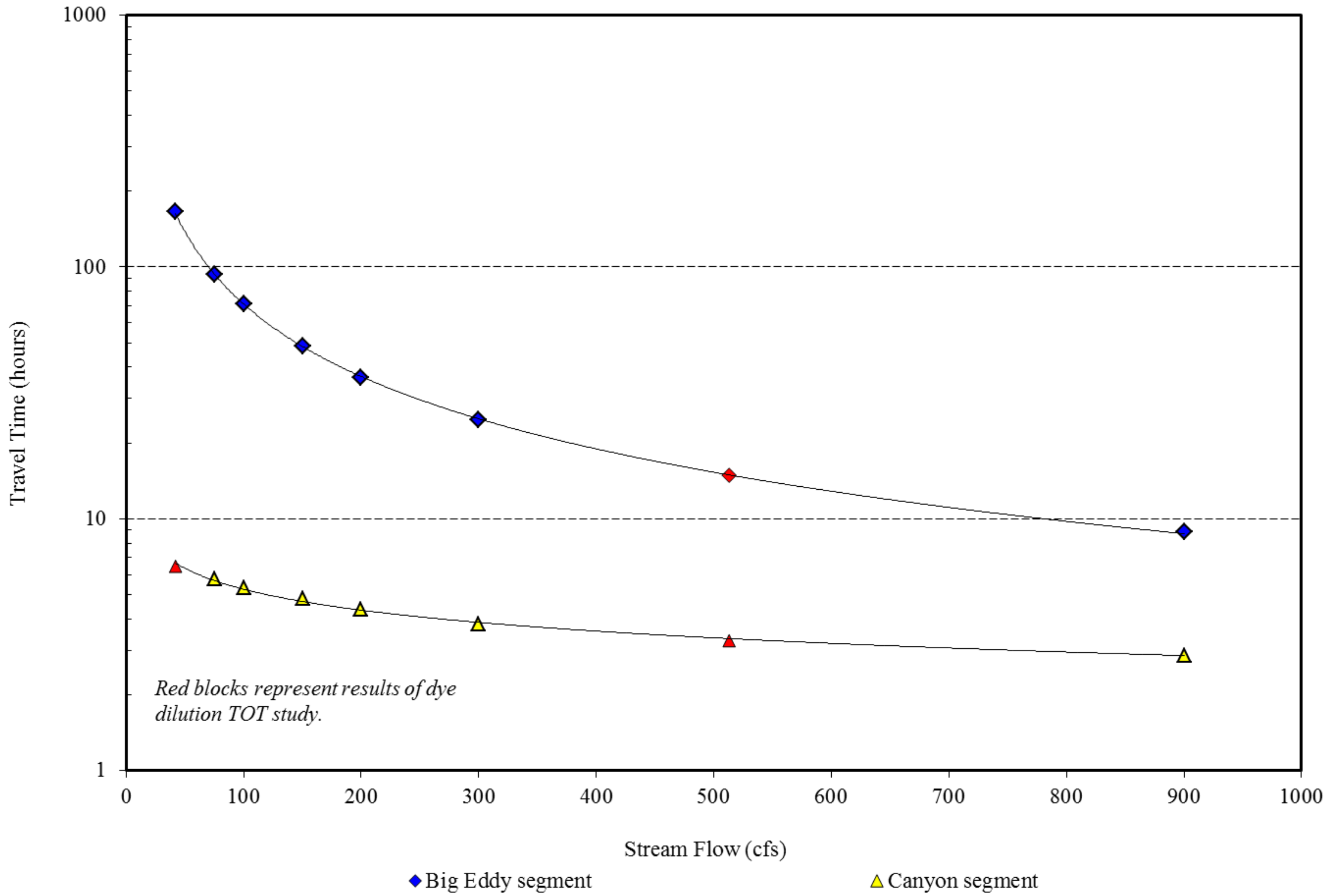


Figure 4-5. Comparison of time-of-travel curves for the Big Eddy and lower Pit 1 Bypass Reach.

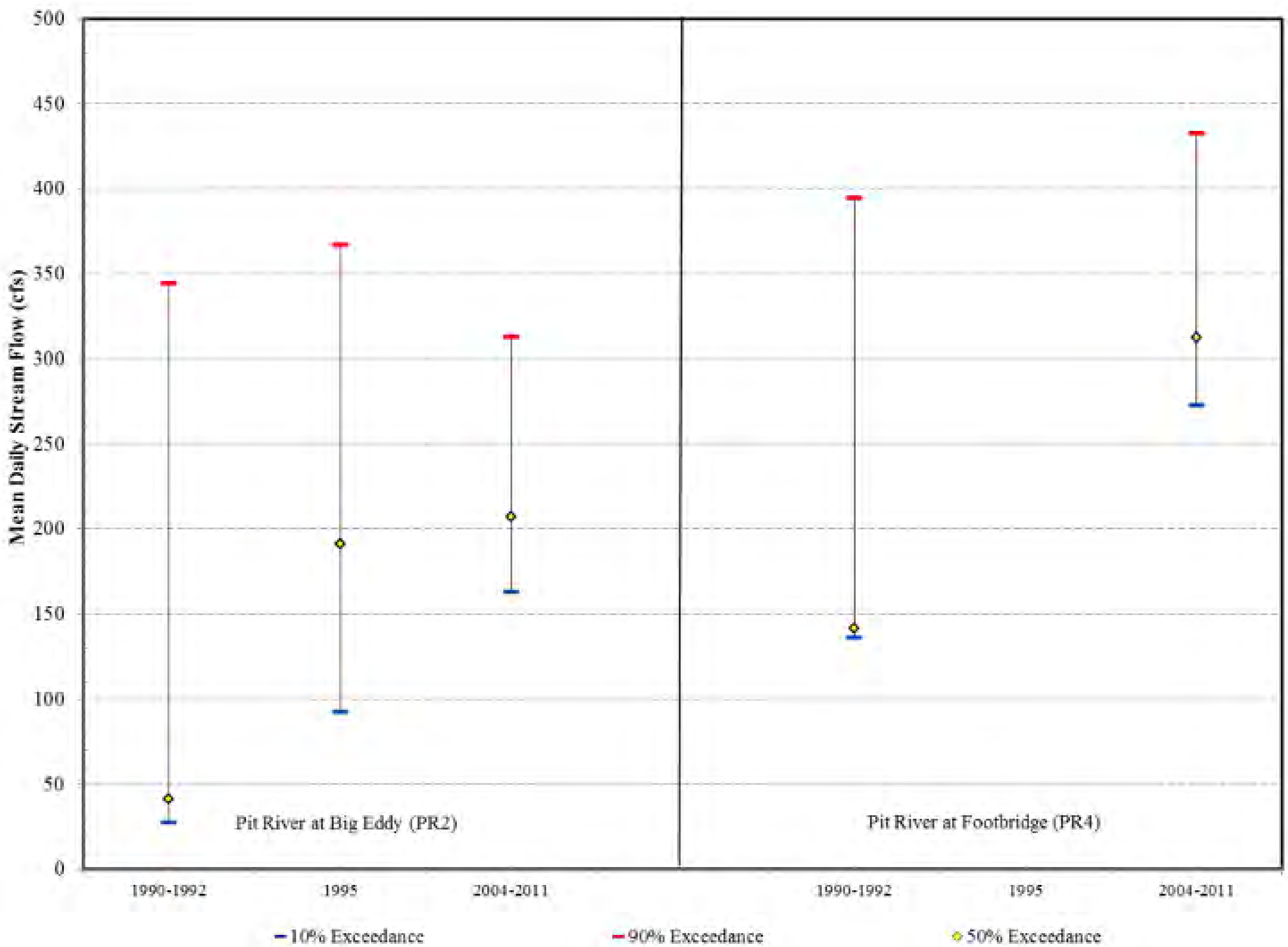


Figure 4-6. Comparison of mean daily flow distribution from two stations in the Pit 1 Bypass Reach.

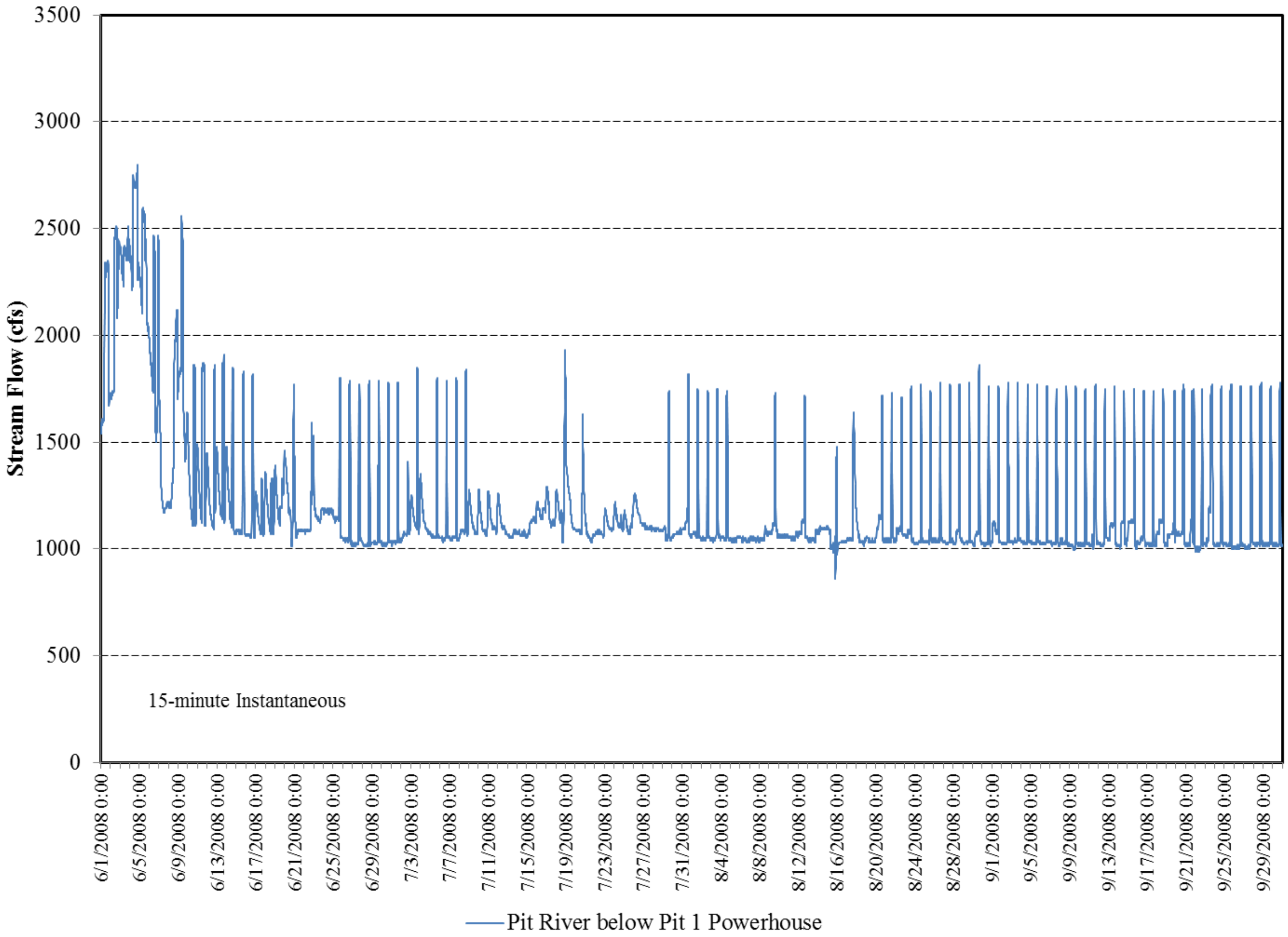


Figure 4-7. Instantaneous (15-minute interval) stream flow data from the Pit River downstream of Pit 1 Powerhouse (USGS Gage) from June through September 2008.

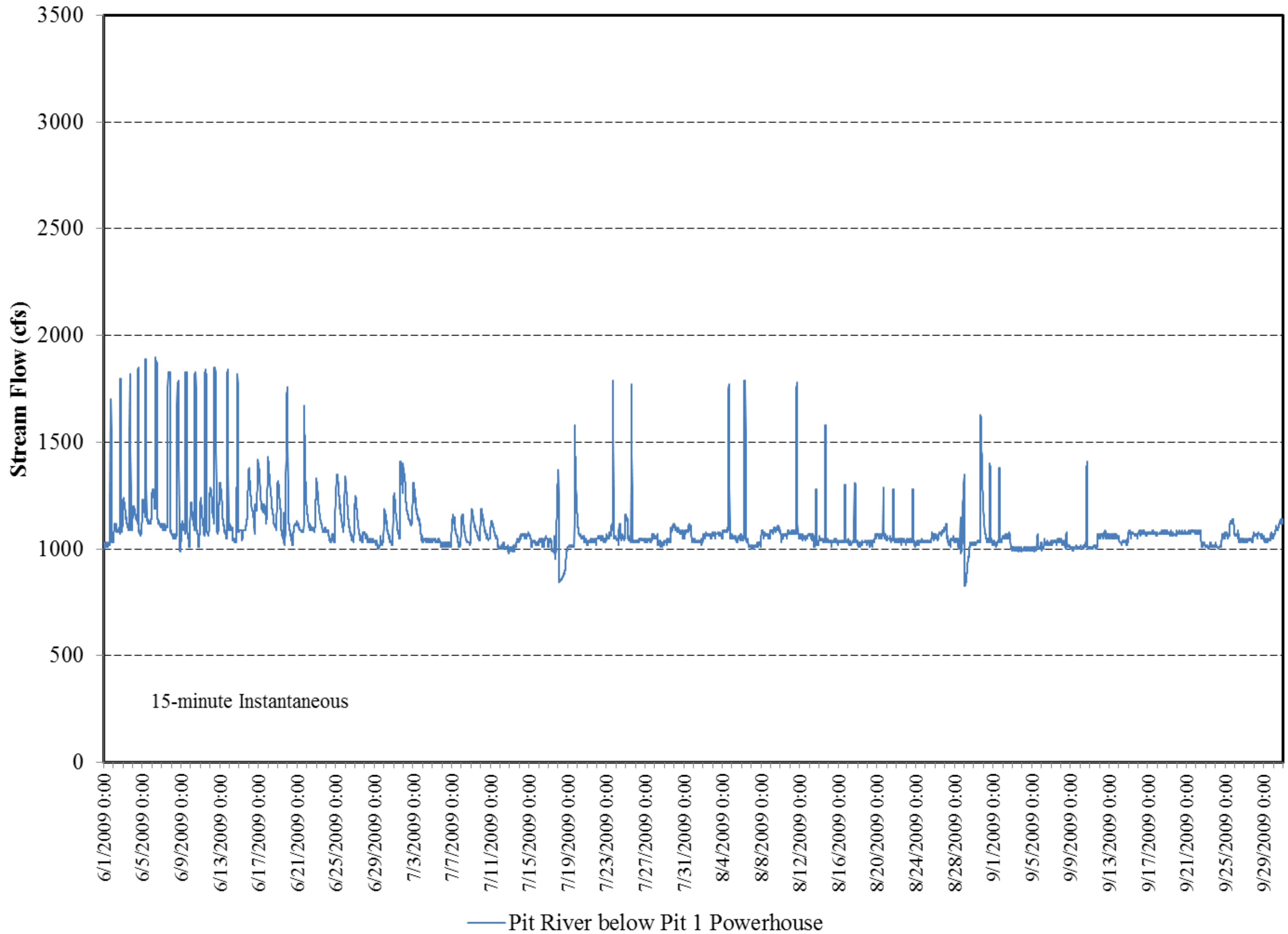


Figure 4-8. Instantaneous (15-minute interval) stream flow data from the Pit River downstream of Pit 1 Powerhouse (USGS Gage) from June through September 2009.

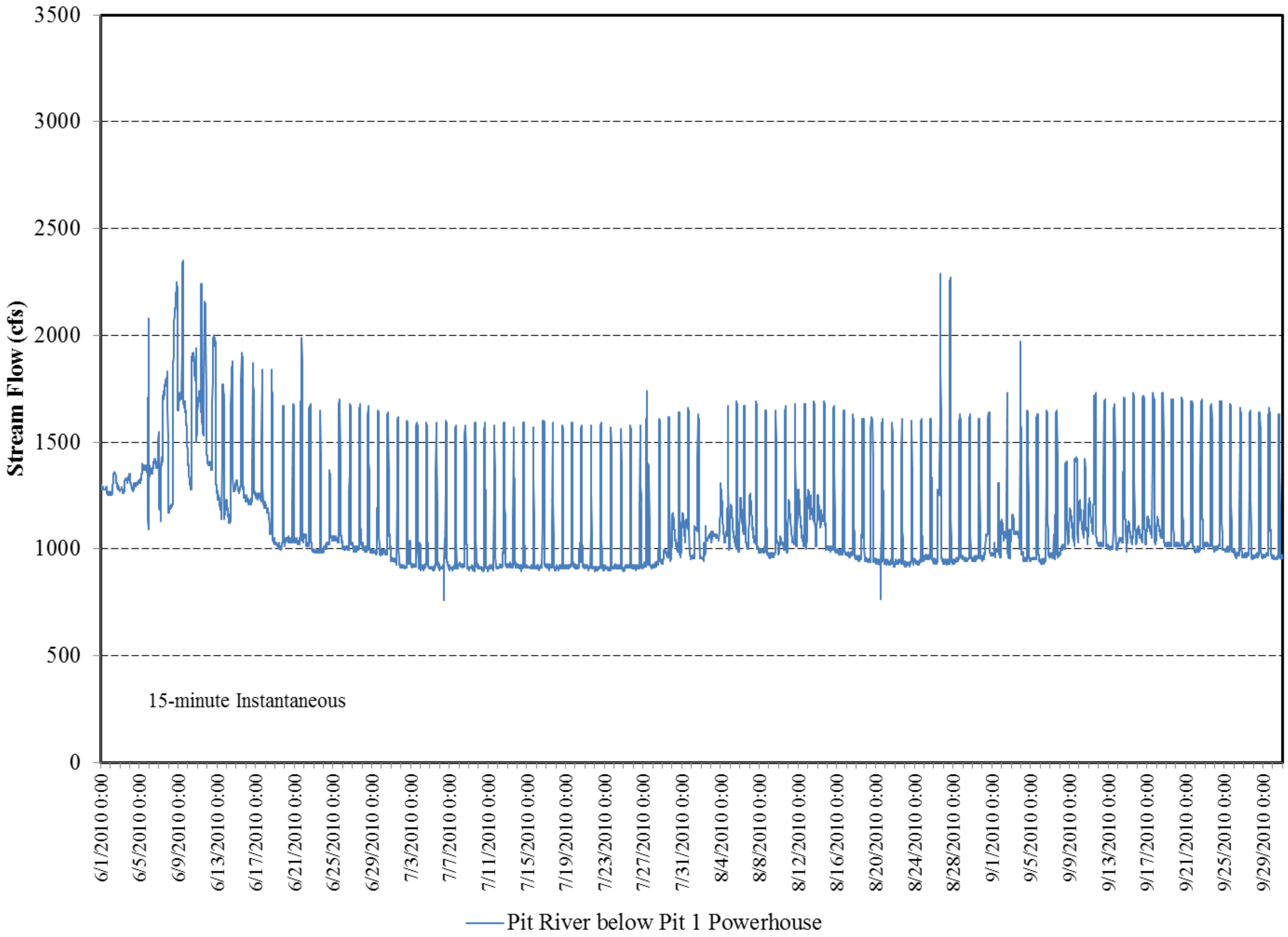


Figure 4-9. **Instantaneous (15-minute interval) stream flow data from the Pit River downstream of Pit 1 Powerhouse (USGS Gage) from June through September 2010.**

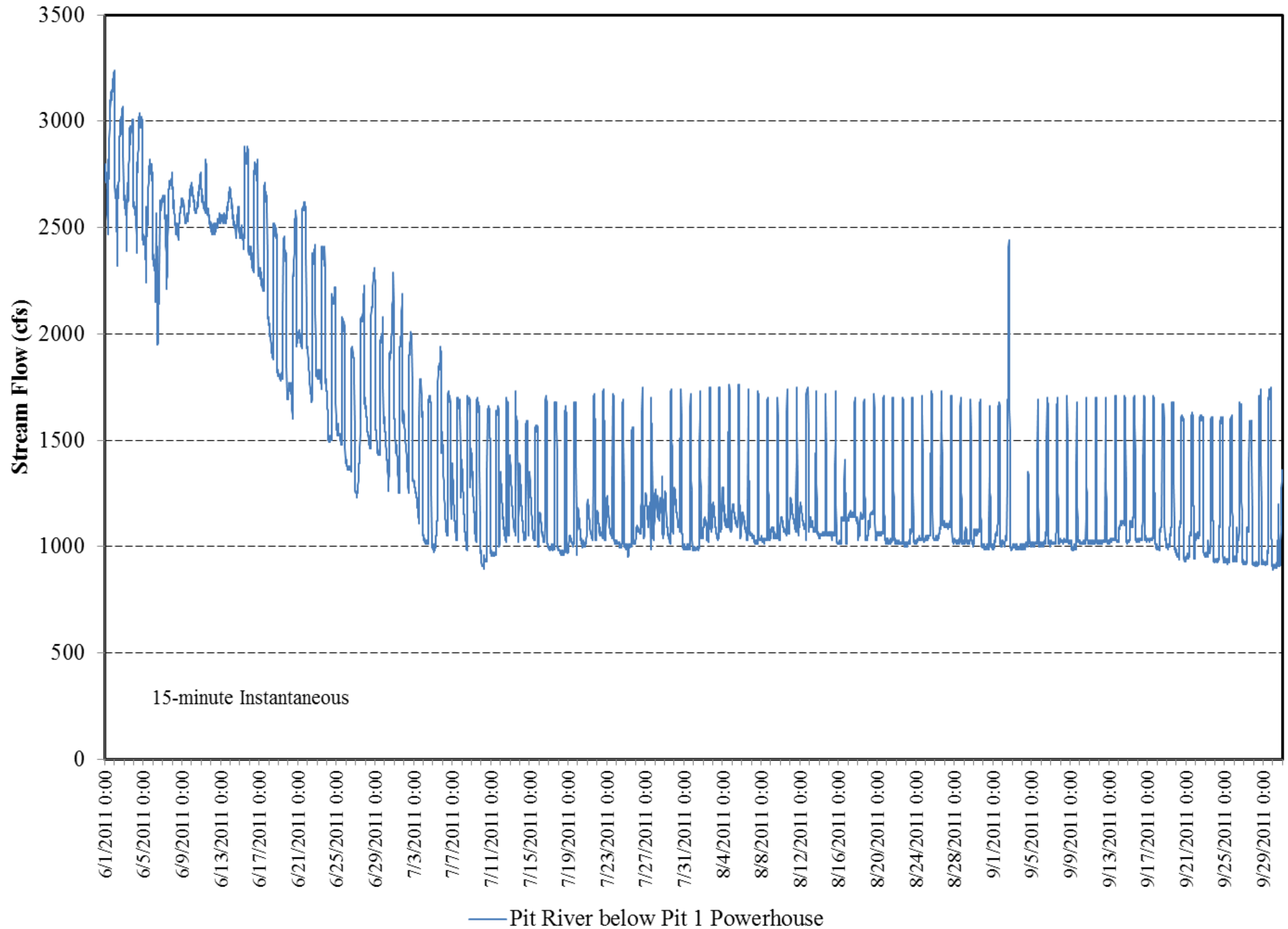


Figure 4-10. Instantaneous (15-minute interval) stream flow data from the Pit River downstream of Pit 1 Powerhouse (USGS Gage) from June through September 2011.

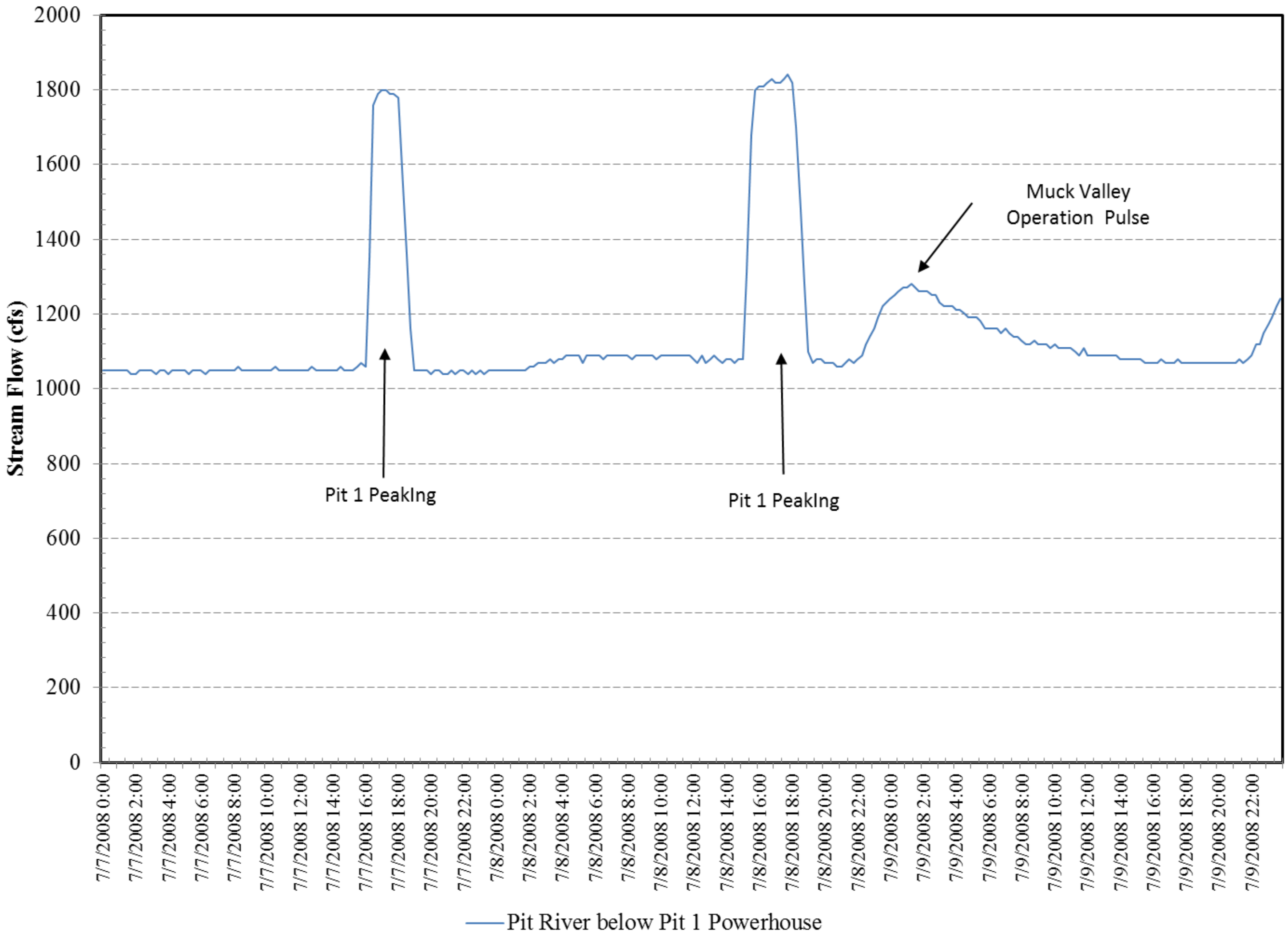


Figure 4-11. Example of peaking operation on stream flow in the Pit River downstream of Pit 1 Powerhouse (USGS Gage) July 7–9, 2008.

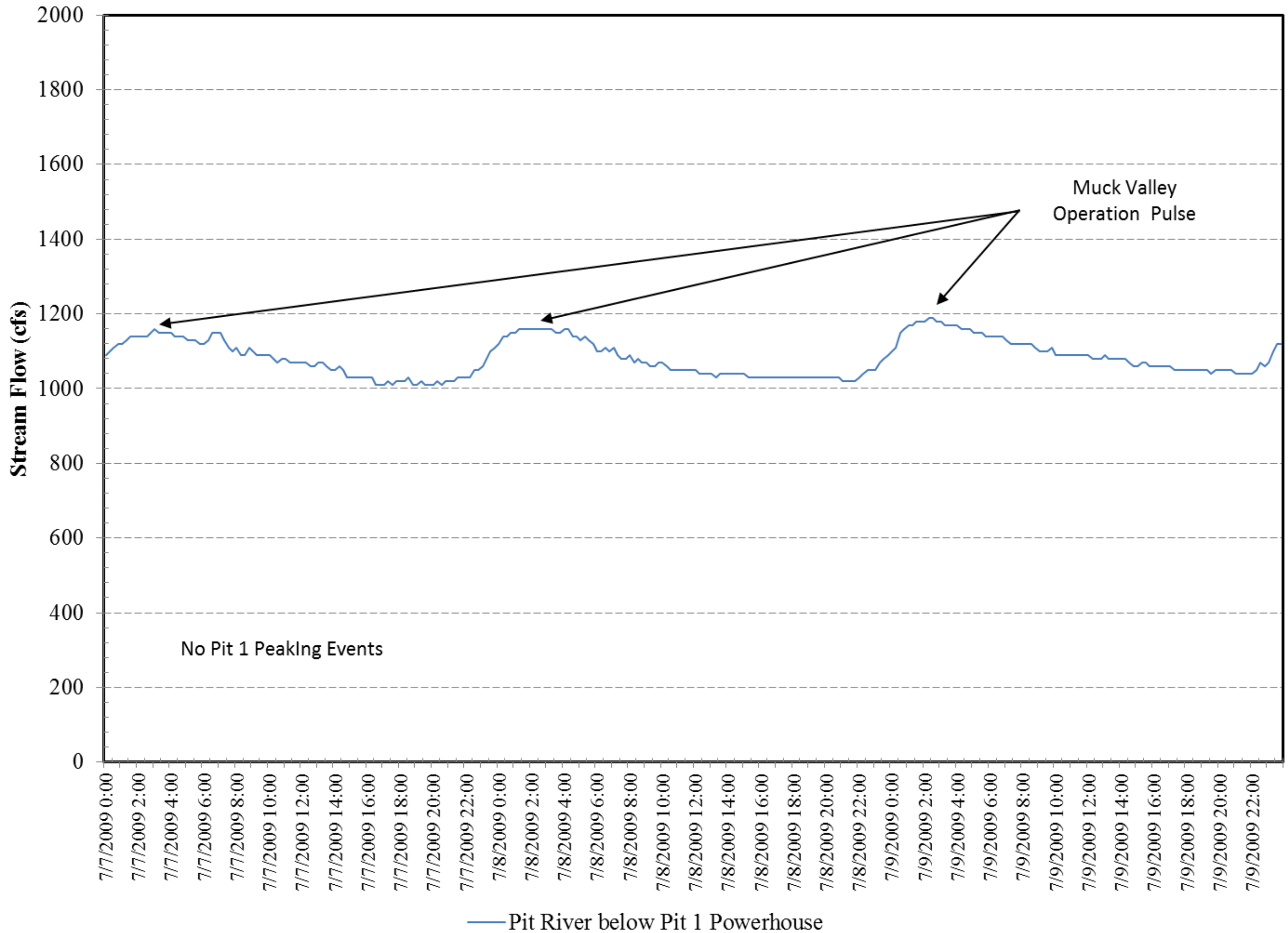


Figure 4-12. Example of peaking operation on stream flow in the Pit River downstream of Pit 1 Powerhouse (USGS Gage) on July 7–9, 2009.

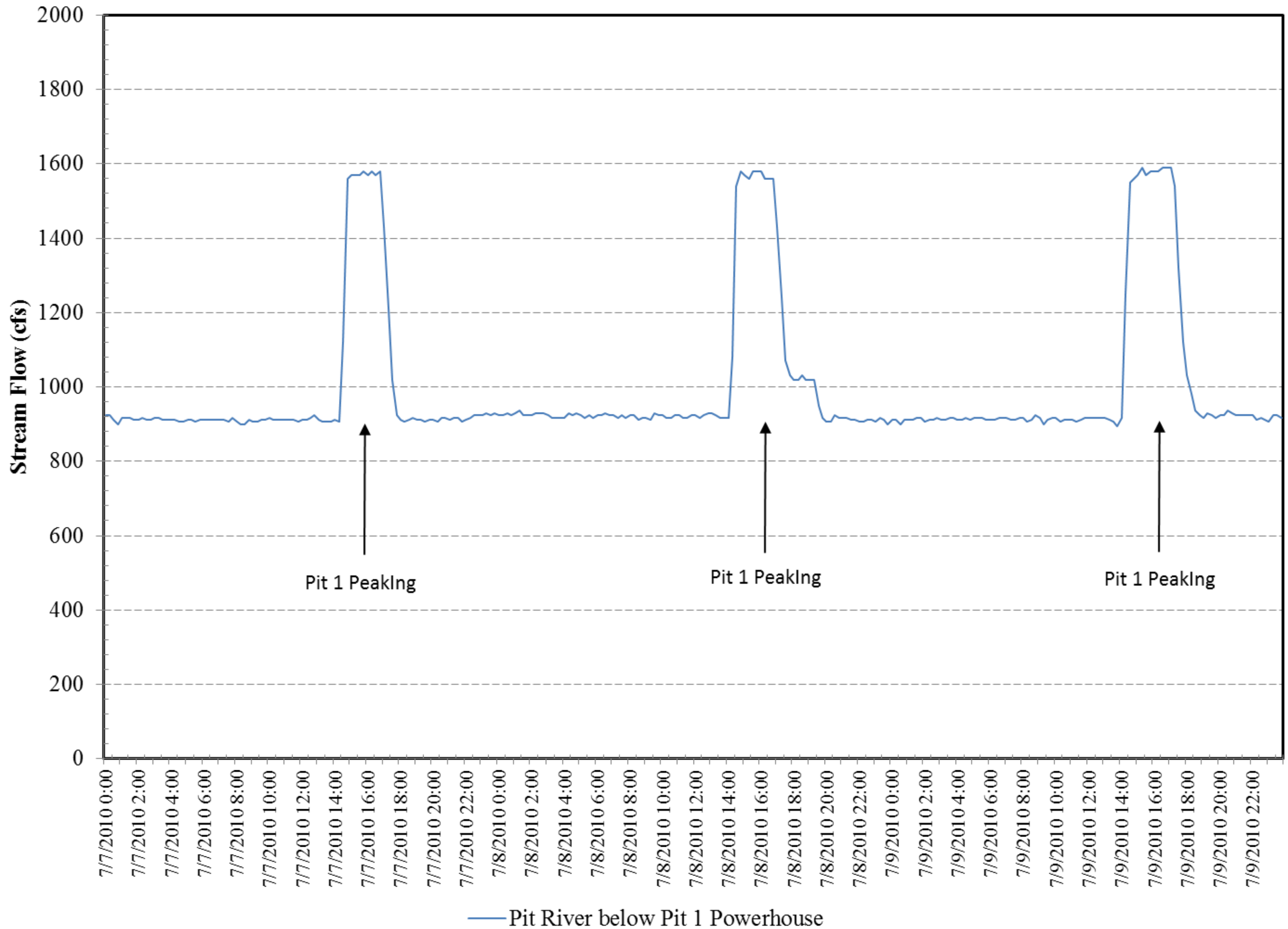


Figure 4-13. Example of peaking operation on stream flow in the Pit River downstream of Pit 1 Powerhouse (USGS Gage) on July 7–9, 2010.

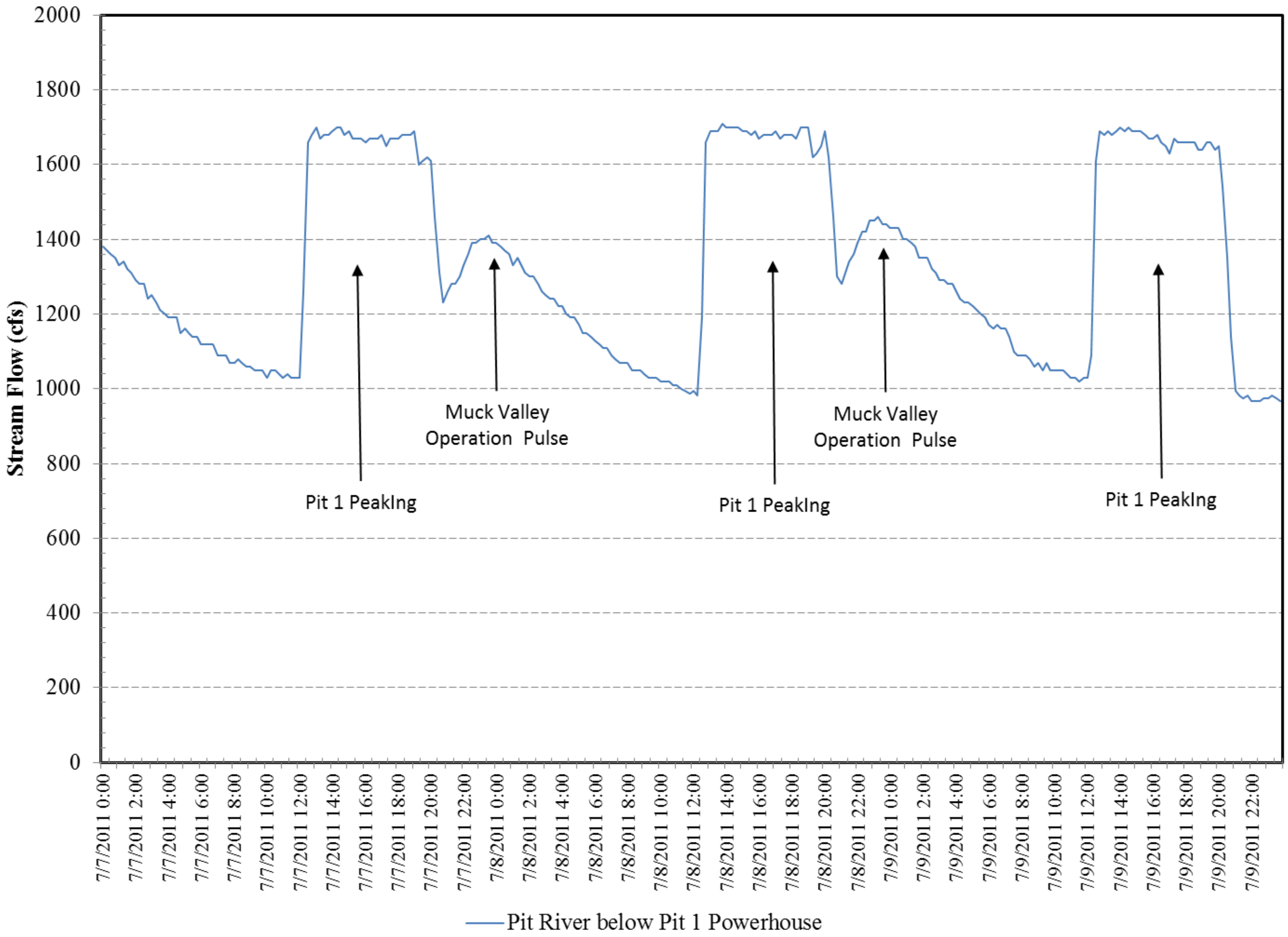


Figure 4-14. Example of peaking operation on stream flow in the Pit River downstream of Pit 1 Powerhouse (USGS Gage) on July 7–9, 2011.

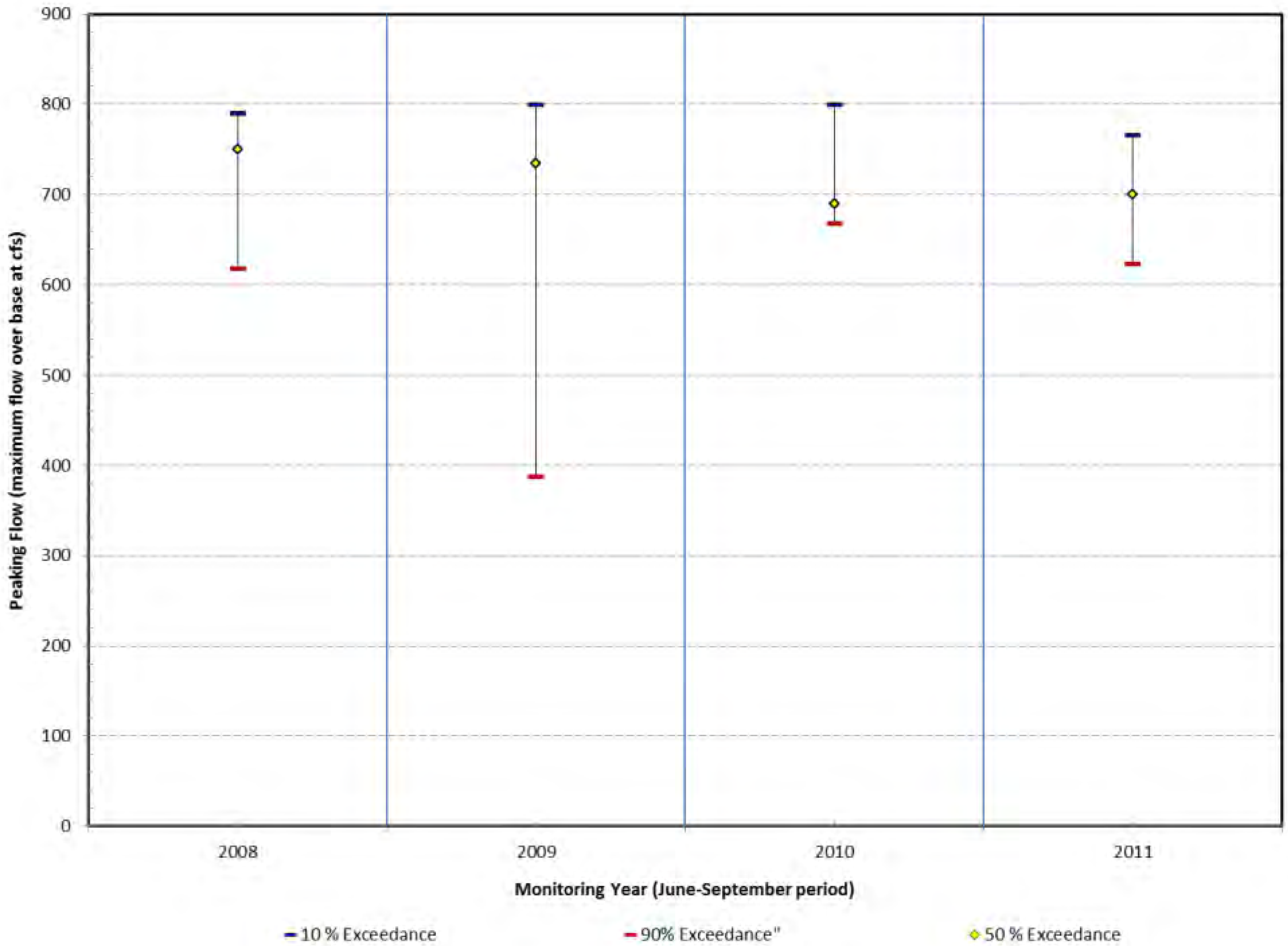


Figure 4-15. Distribution of peaking flows (daily change greater than 350 cfs over base flow) as measured at the Pit River downstream of Pit 1 Powerhouse (USGS Gage) from June through September period.

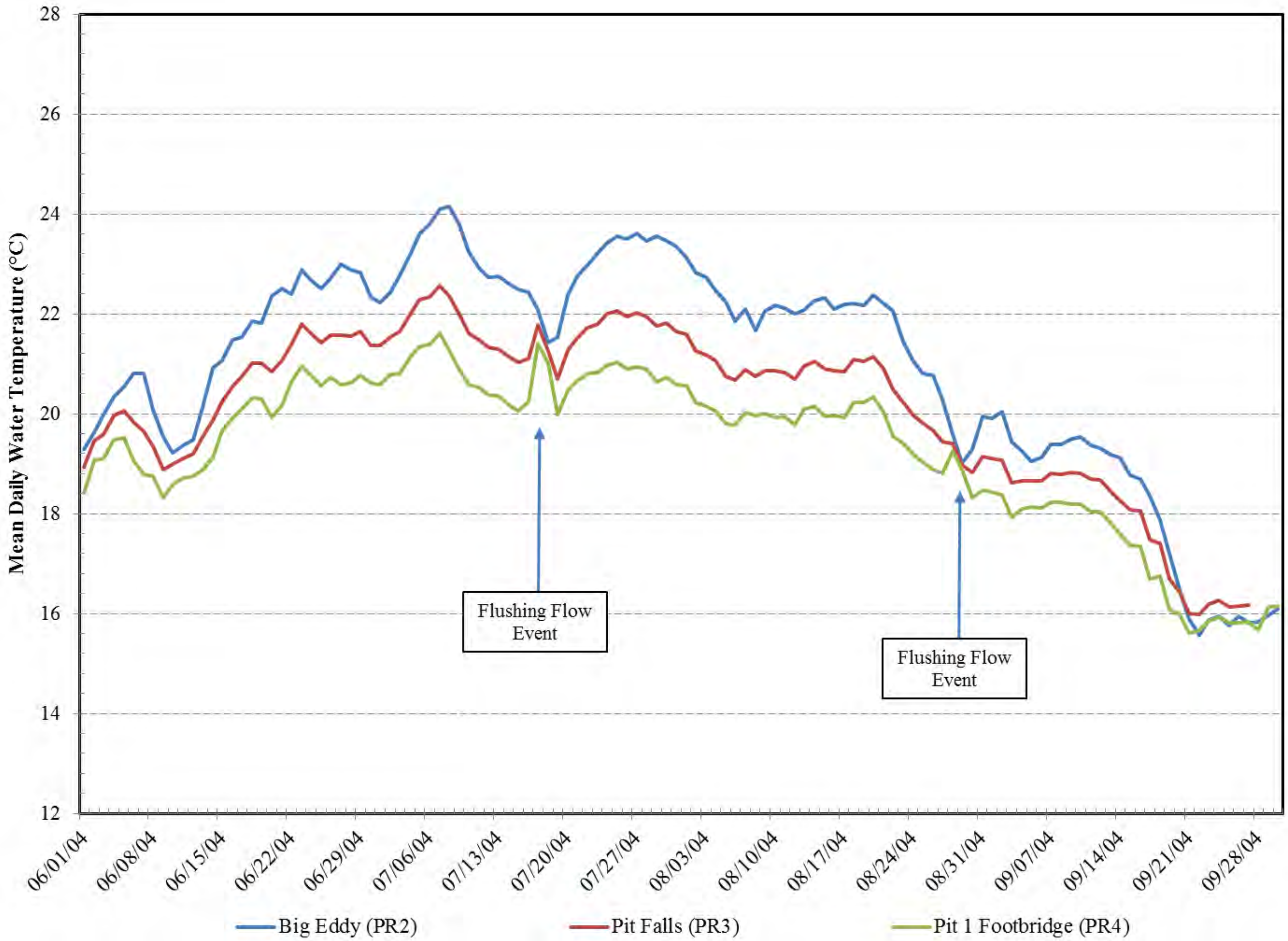


Figure 4-16. Comparison of mean daily water temperatures from three stations in Pit 1 Bypass Reach from June through September 2004.

Figure 4-17. Comparison of mean daily water temperatures from two stations in Pit 1 Bypass Reach from June through September 2010.

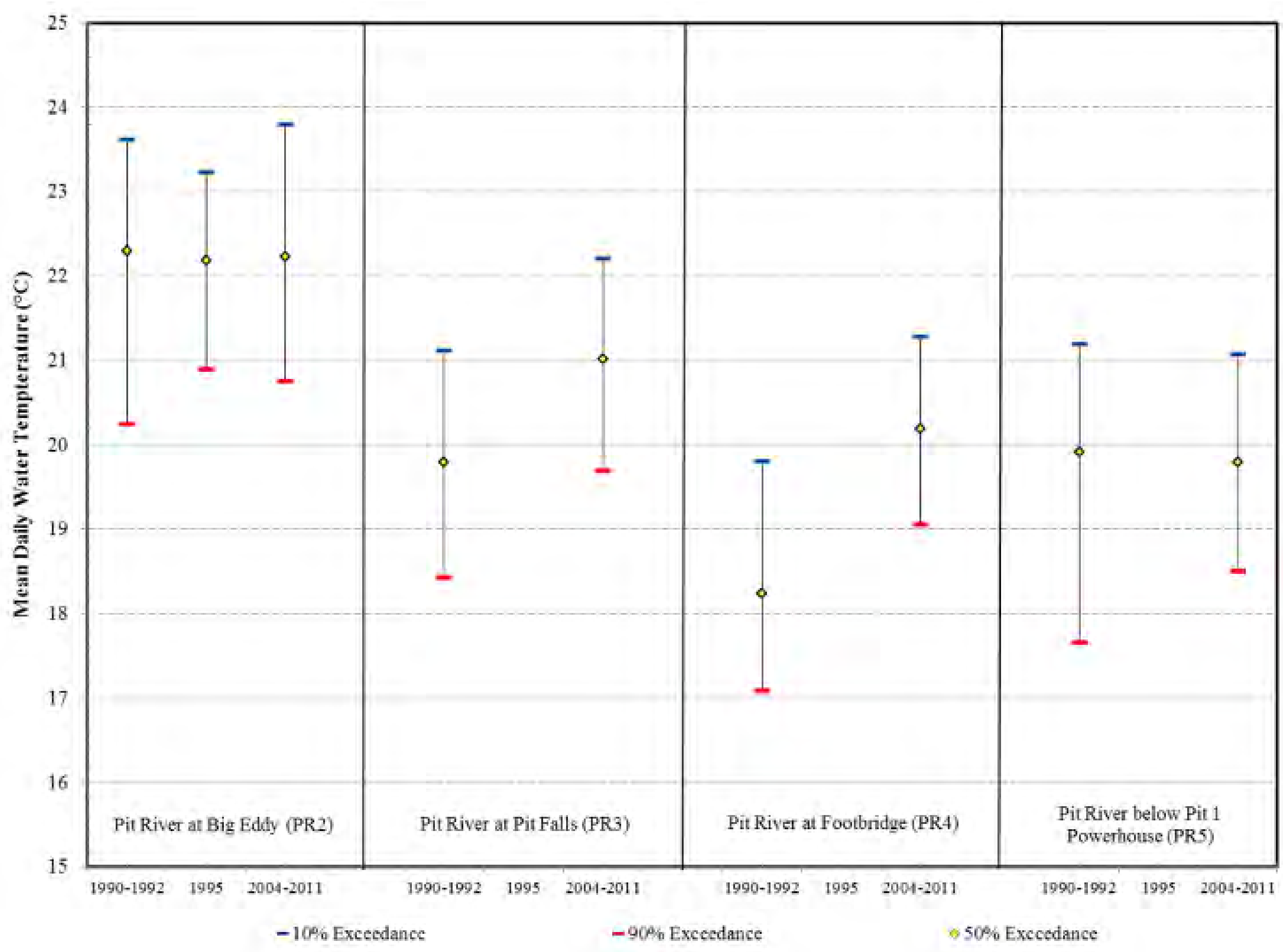


Figure 4-18. Comparison of mean daily water temperature distribution from four stations in the Pit River.

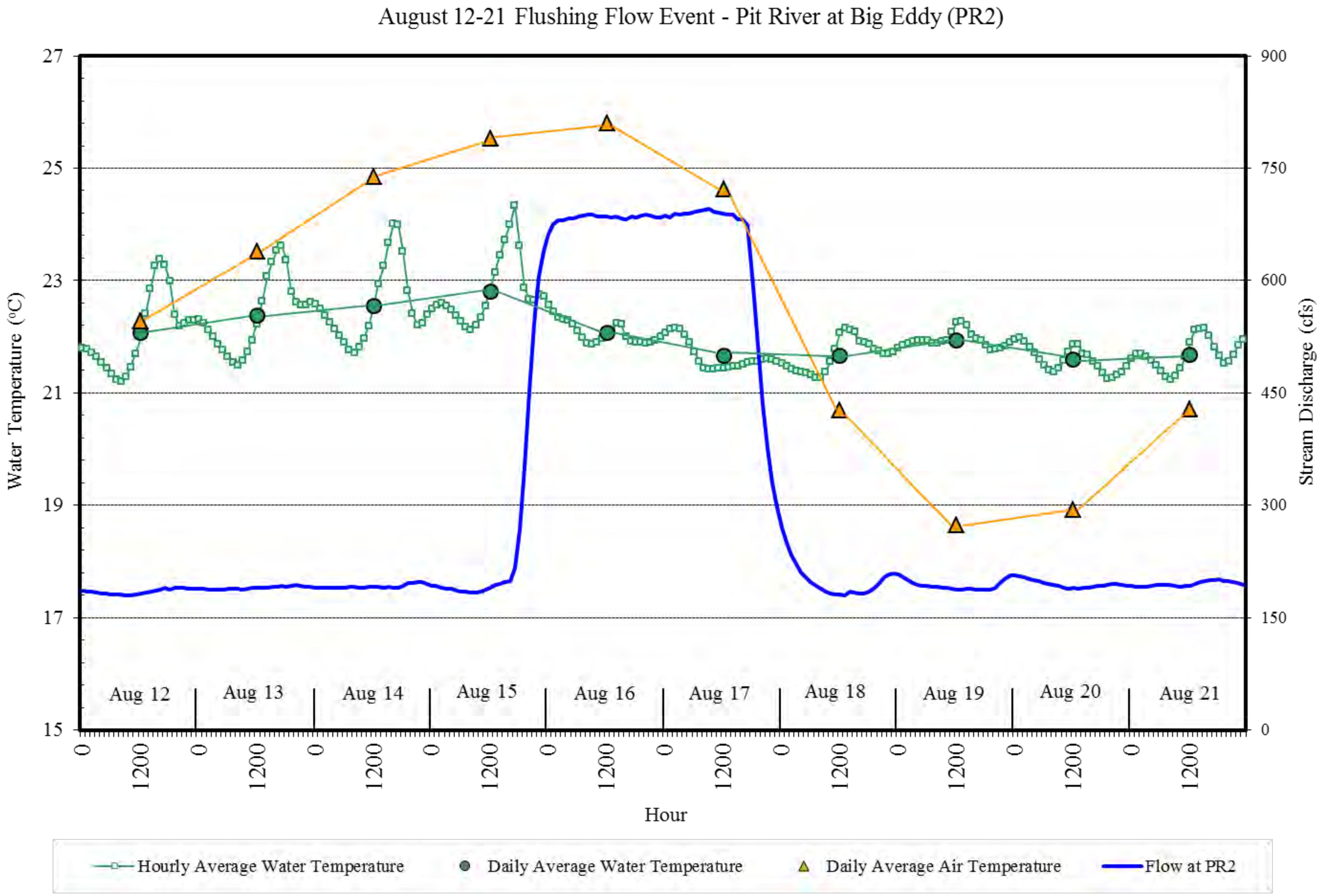


Figure 4-19. Detailed evaluation of flushing flow event at Big Eddy - August 2008.

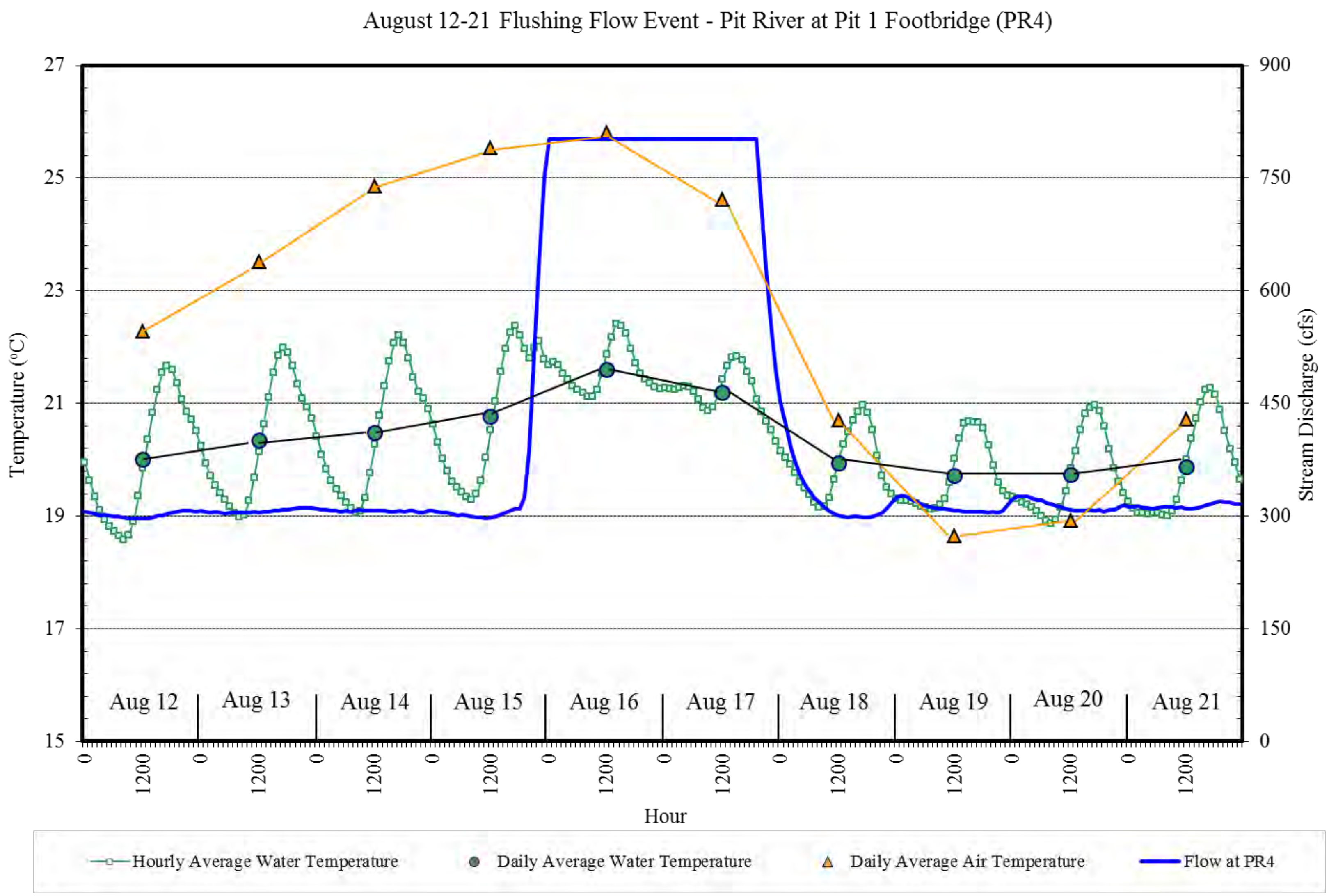


Figure 4-20. Detailed evaluation of flushing flow event at Pit 1 Footbridge - August 2008.

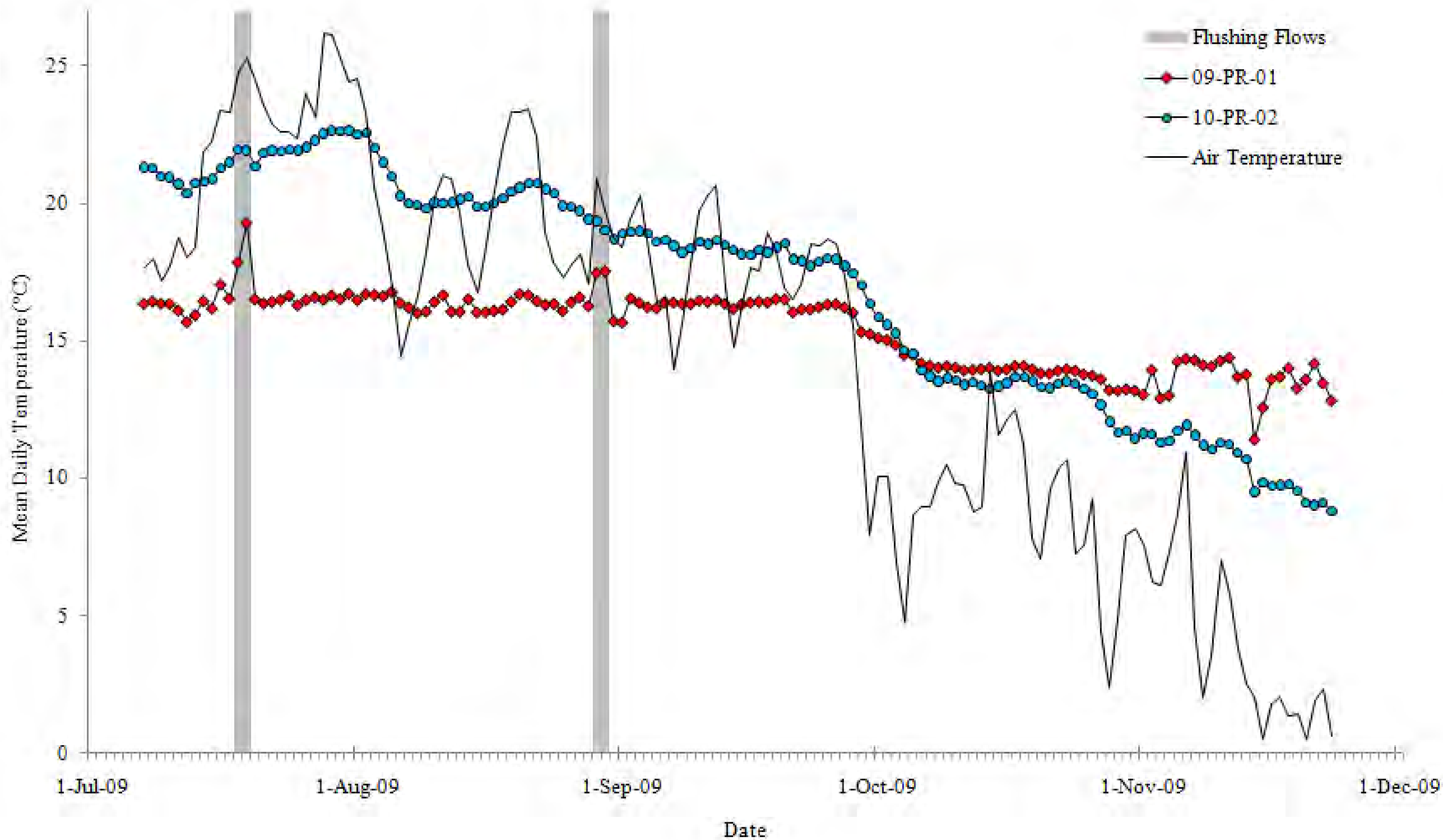


Figure 4-21 Mean daily water temperatures at the two Pit River Shasta crayfish locations upstream of Pit River Falls (Logger IDs 09-PR-01 and 10-PR-02) and mean daily air temperature in 2009. Grey bars indicate flushing flow events on July 18-19 and August 29-30, 2009.

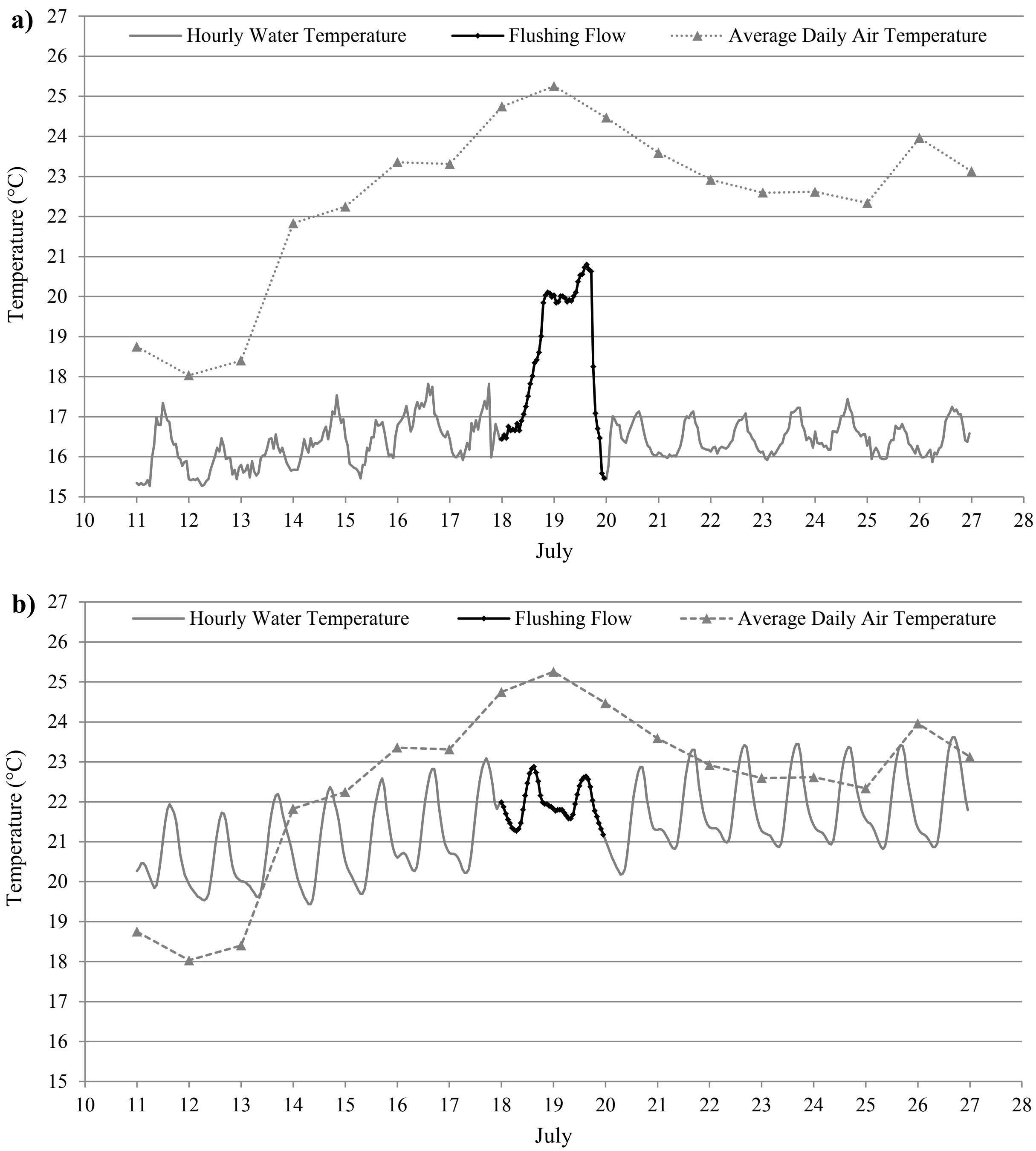


Figure 4-22. Hourly water temperatures one week prior and one week after the July 2009 flushing flows at the two Shasta crayfish locations upstream of Pit River Falls (a) spring-influenced upper Pit River location (Logger ID 09-PR-01) and (b) non-spring-influenced lower Pit River location (Logger ID 10-PR-02).

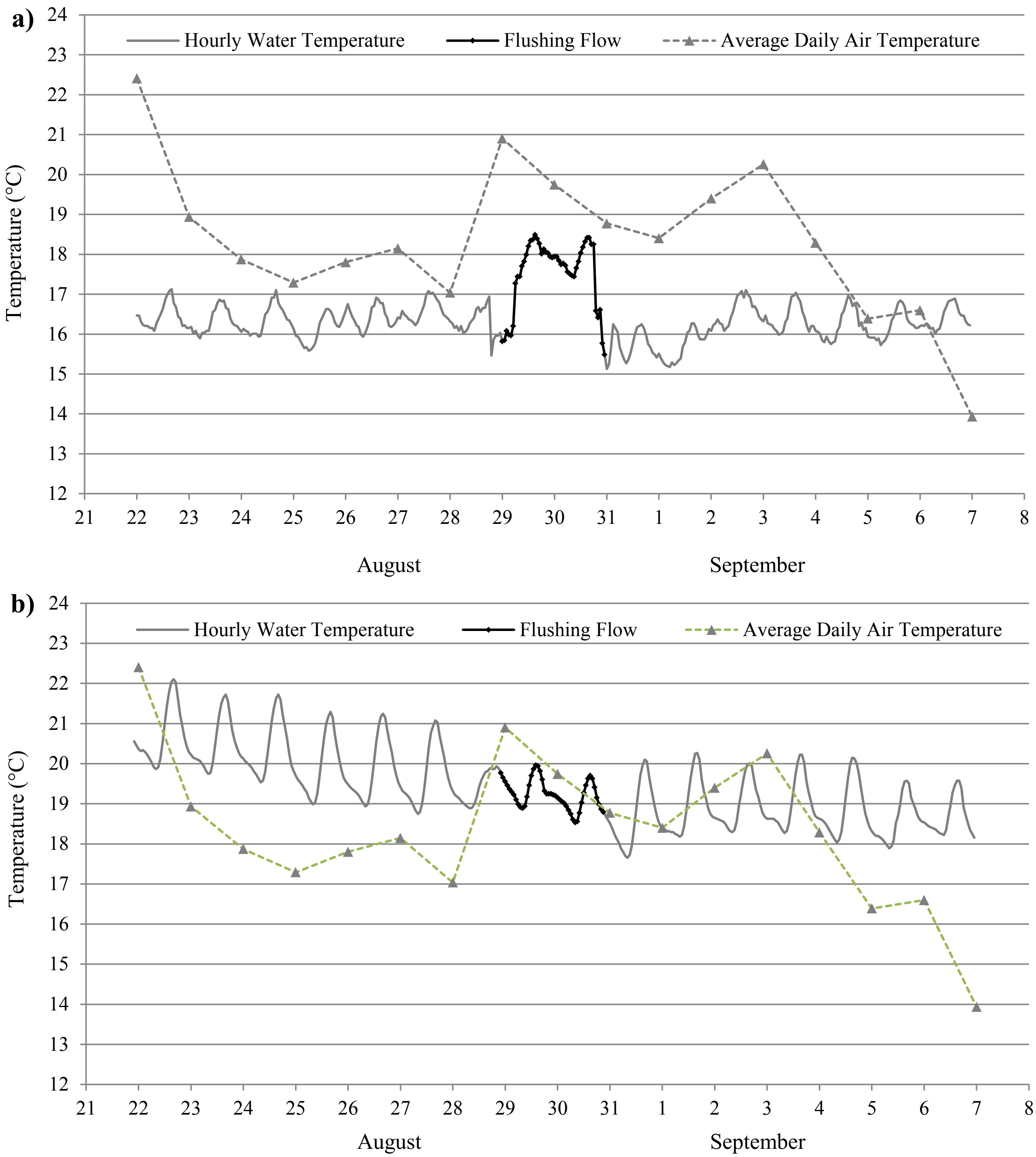


Figure 4-23. Hourly water temperatures one week prior and one week after the August 2009 flushing flows at the two Shasta crayfish locations upstream of Pit River Falls (a) spring-influenced upper Pit River location (Logger ID 09-PR-01) and (b) non-spring-influenced lower Pit River location (Logger ID 10-PR-02).

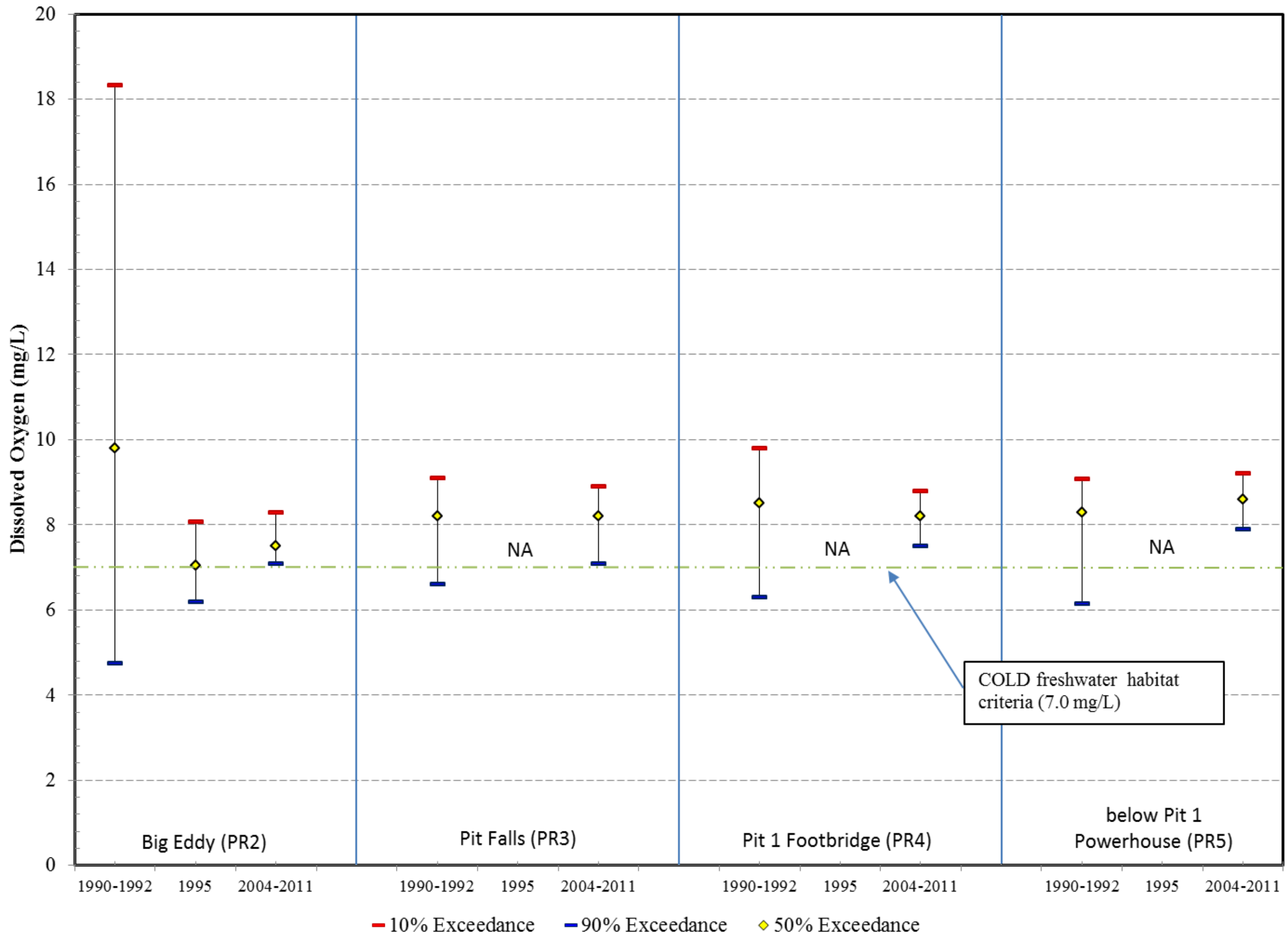


Figure 4-24. Comparison of dissolved oxygen distribution from four stations in the Pit River.

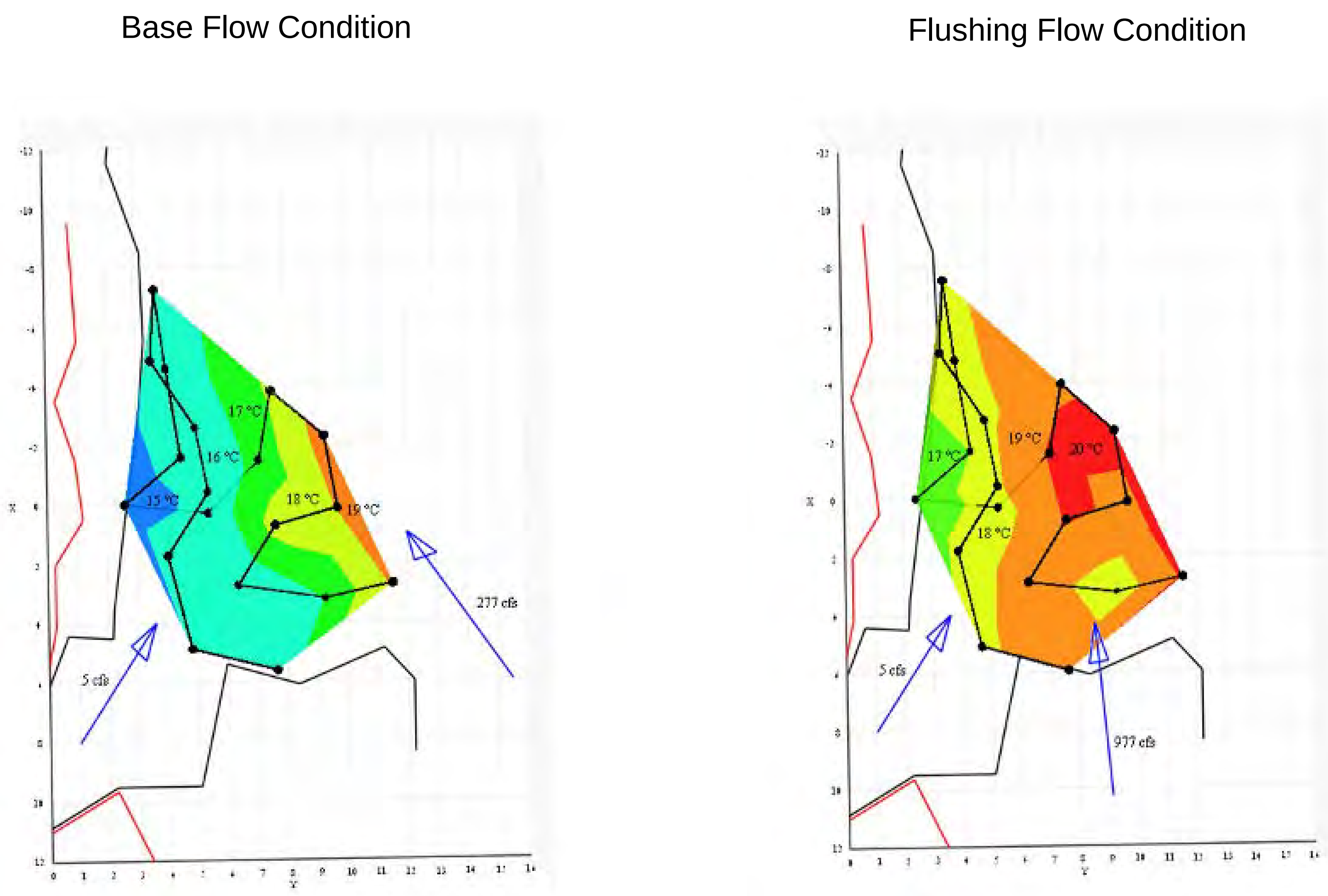


Figure 4-25. Observed effect of flushing flows on thermal refugia from the 2004 Coldwater Refugia Study.

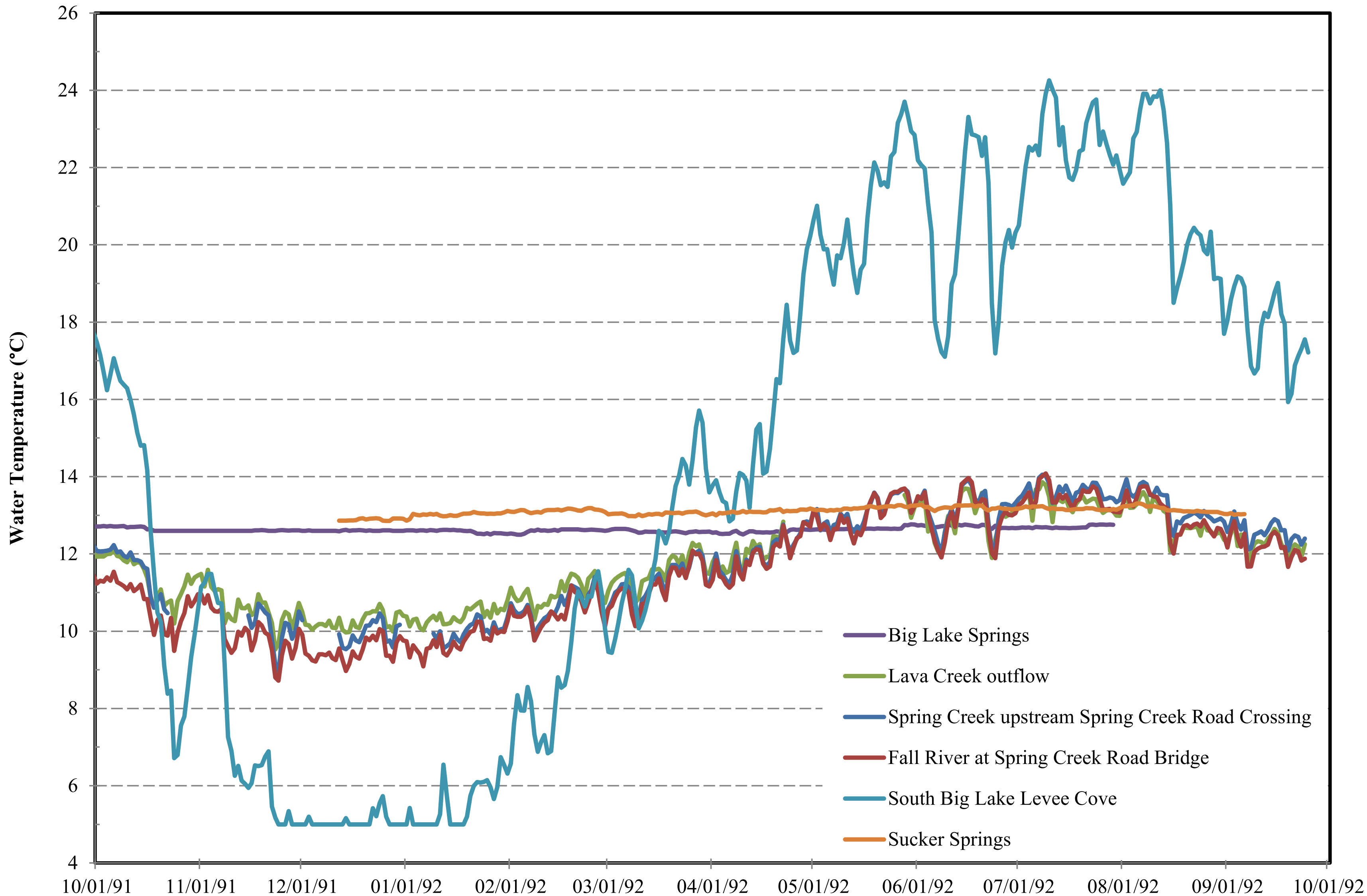


Figure 4-26. Mean daily water temperatures at or near Shasta crayfish populations in 1991 and 1992.

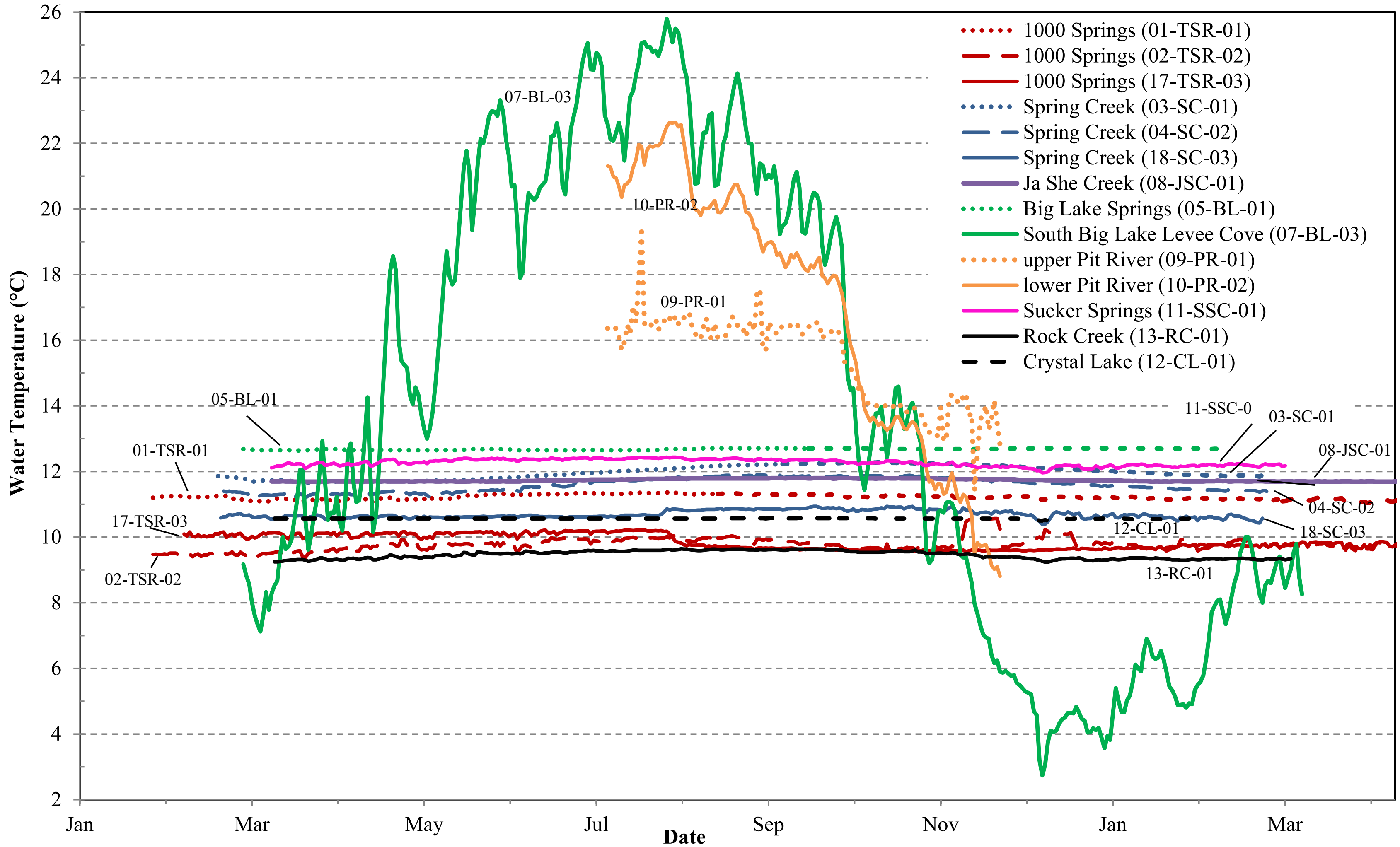


Figure 4-27. Mean daily water temperatures at Shasta crayfish locations monitored between 2009 and 2012.

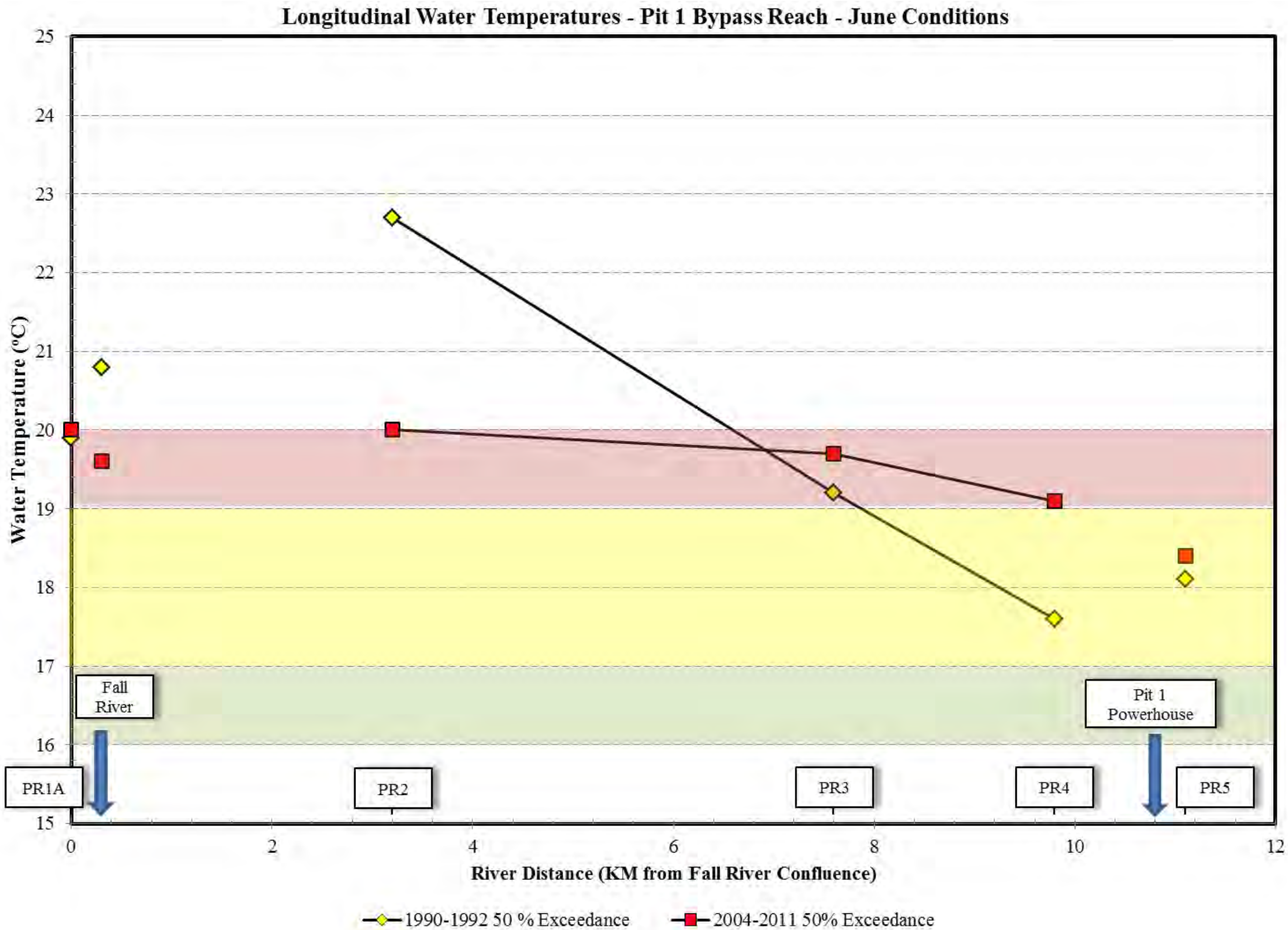


Figure 4-28. Longitudinal profile of June water temperature conditions compared with proposed Shasta Crayfish thermal criteria.

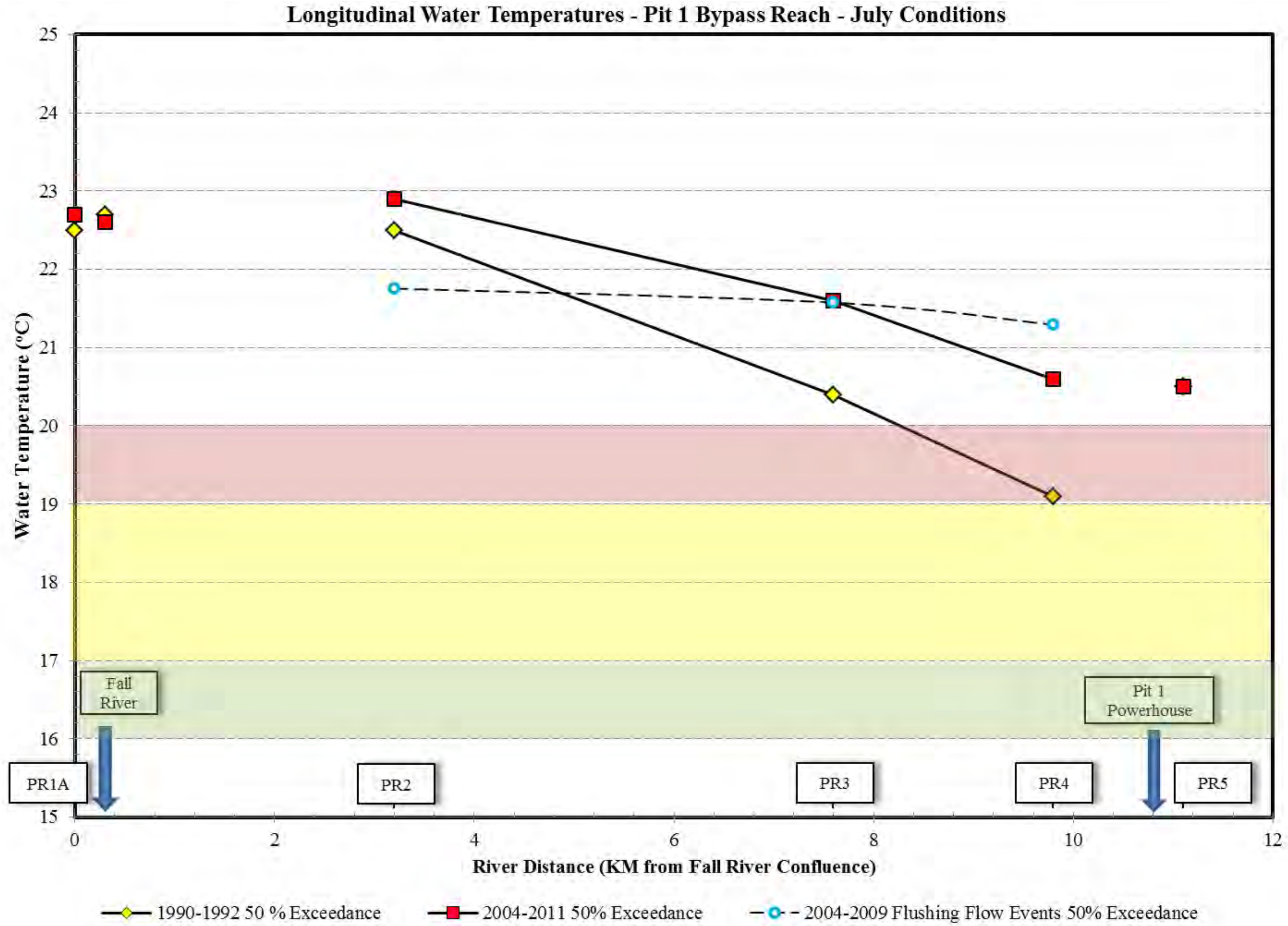


Figure 4-29. Longitudinal profile of July water temperature conditions compared with proposed Shasta Crayfish thermal criteria.

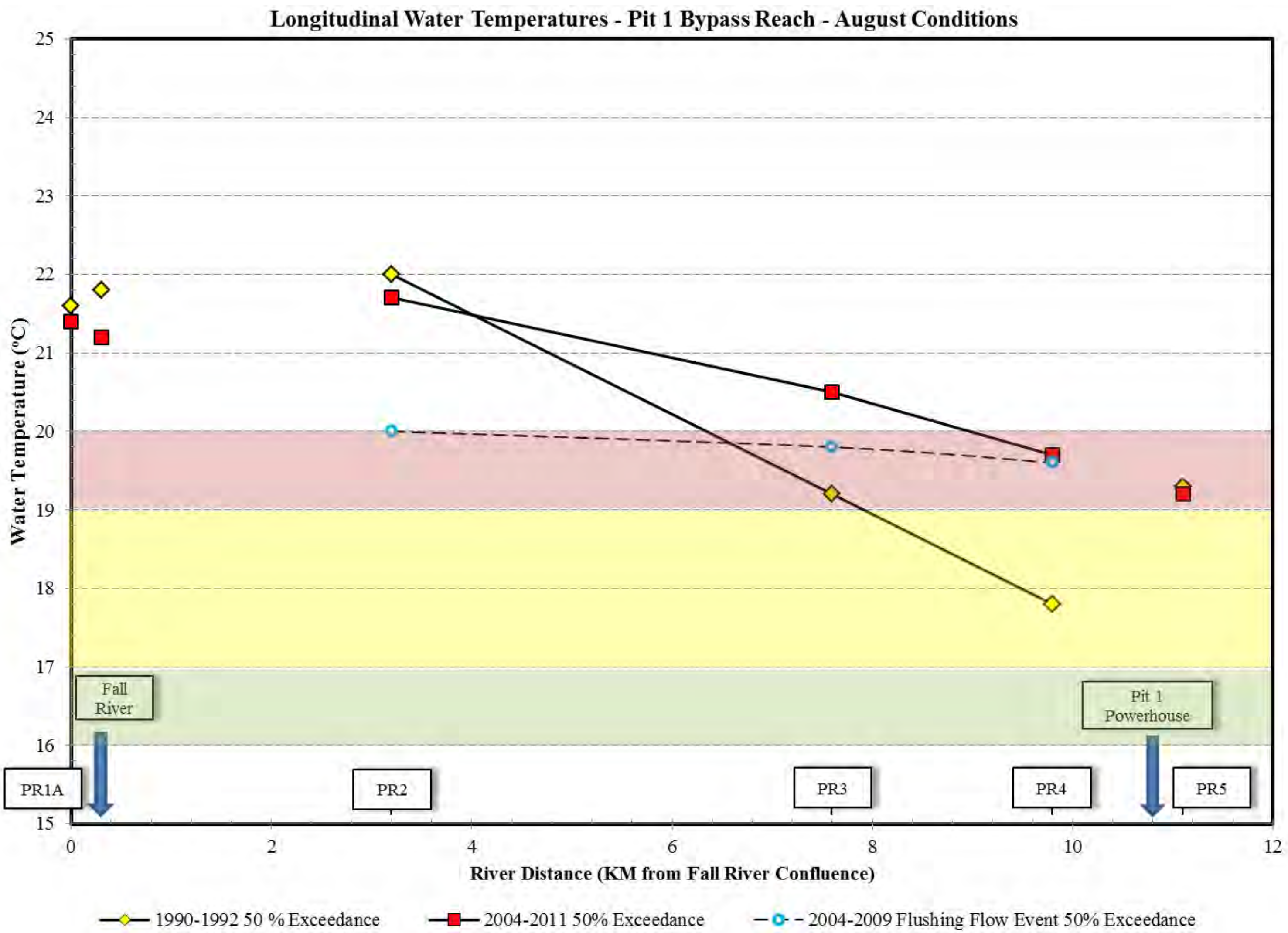


Figure 4-30. Longitudinal profile of August water temperature conditions compared with proposed Shasta Crayfish thermal criteria.

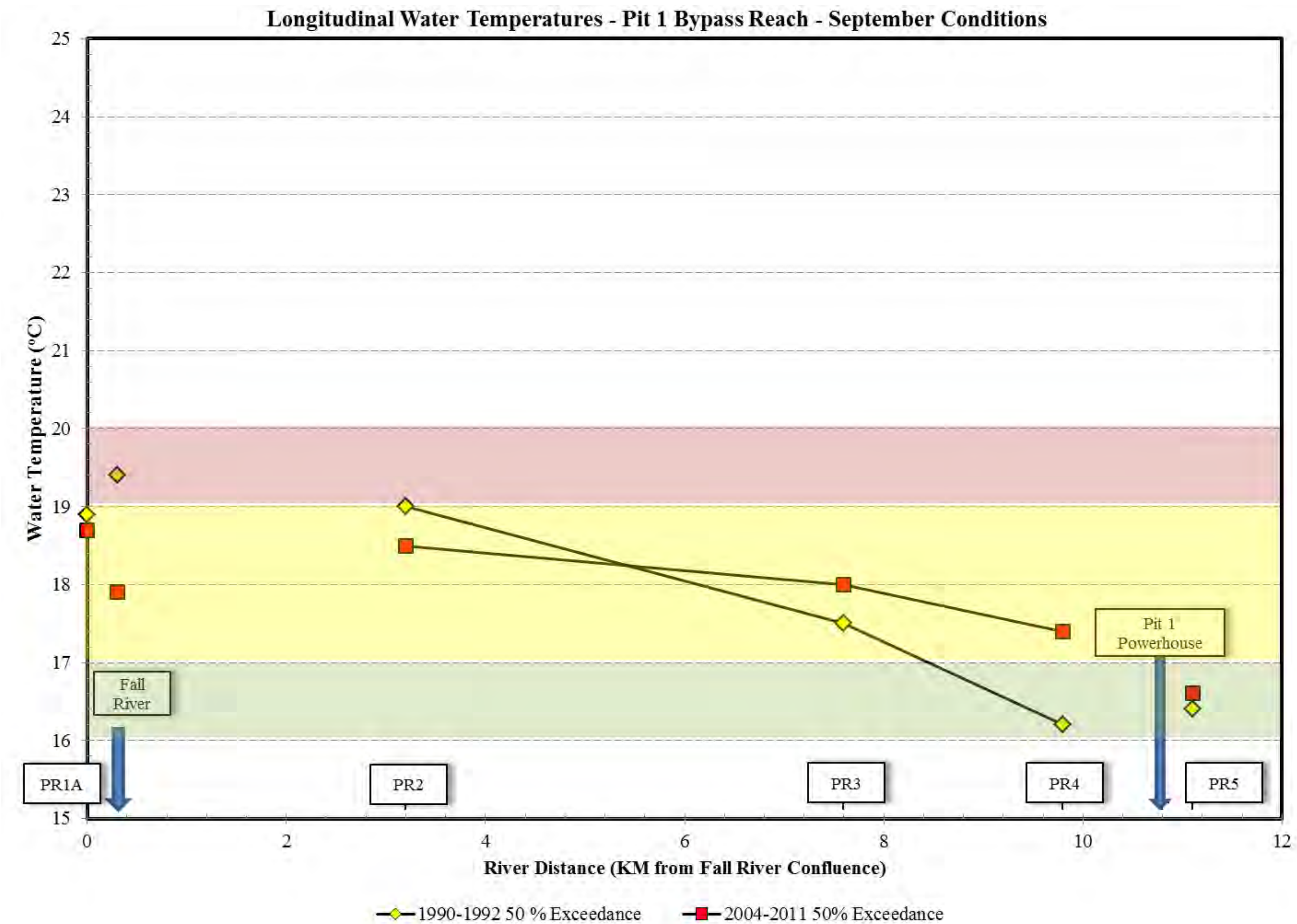


Figure 4-31. Longitudinal profile of September water temperature conditions compared with proposed Shasta Crayfish thermal criteria.

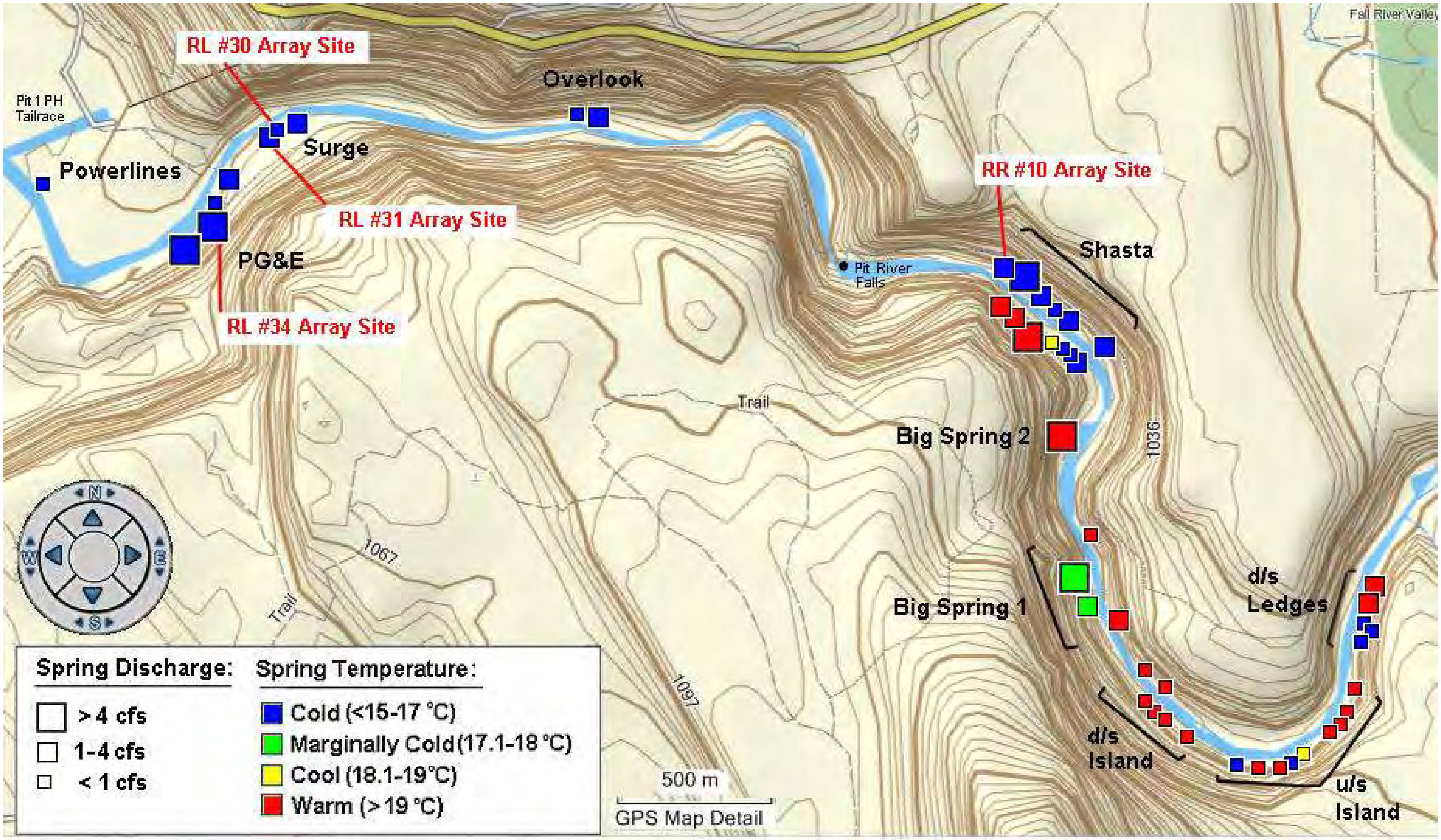


Figure 4-32. Locations of 10 major spring inflow regions and 4 temperature array monitoring sites.

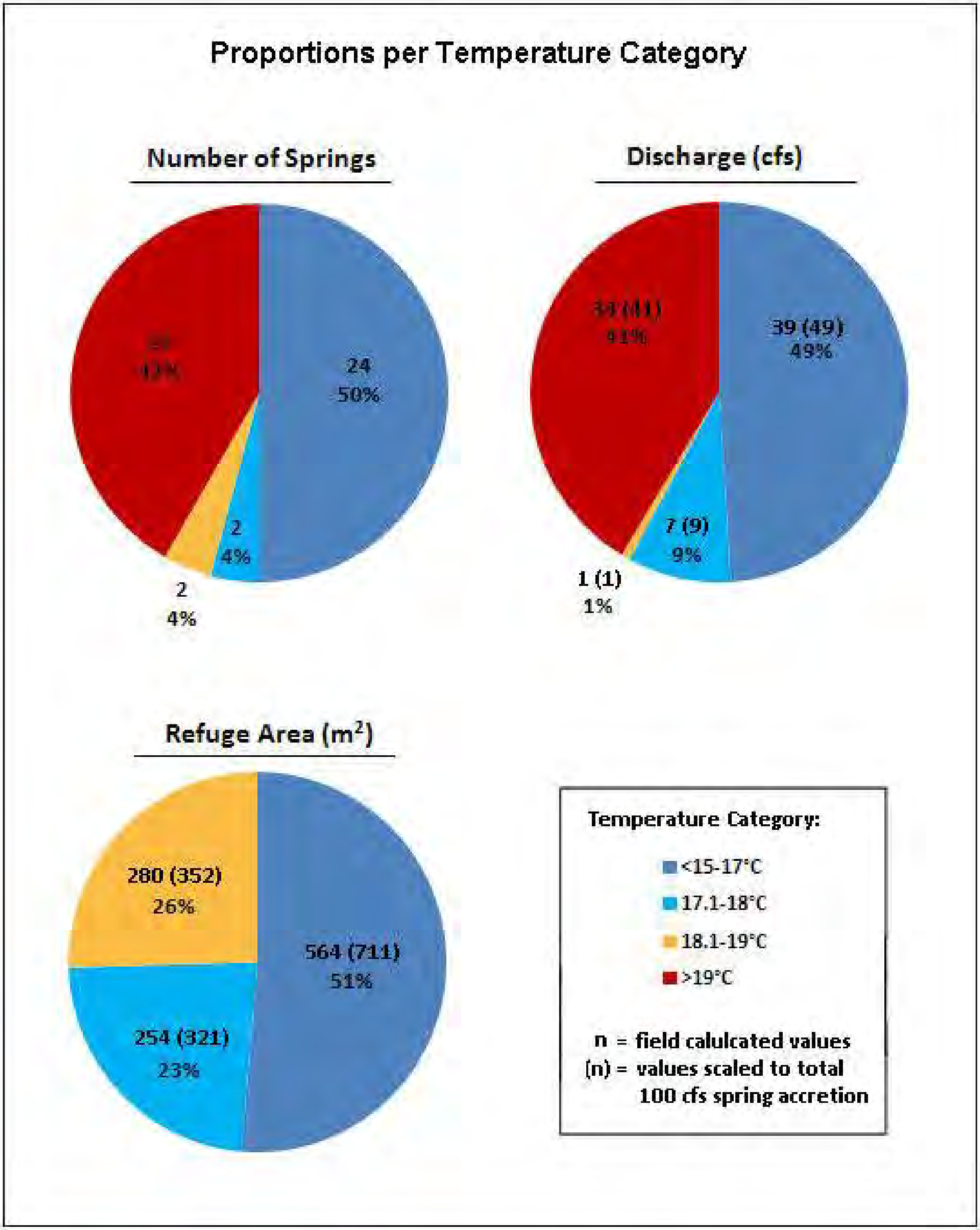


Figure 4-33. Pie charts showing proportions of cold, marginally cold, cool, and warm springs in the Pit 1 Bypass Reach.

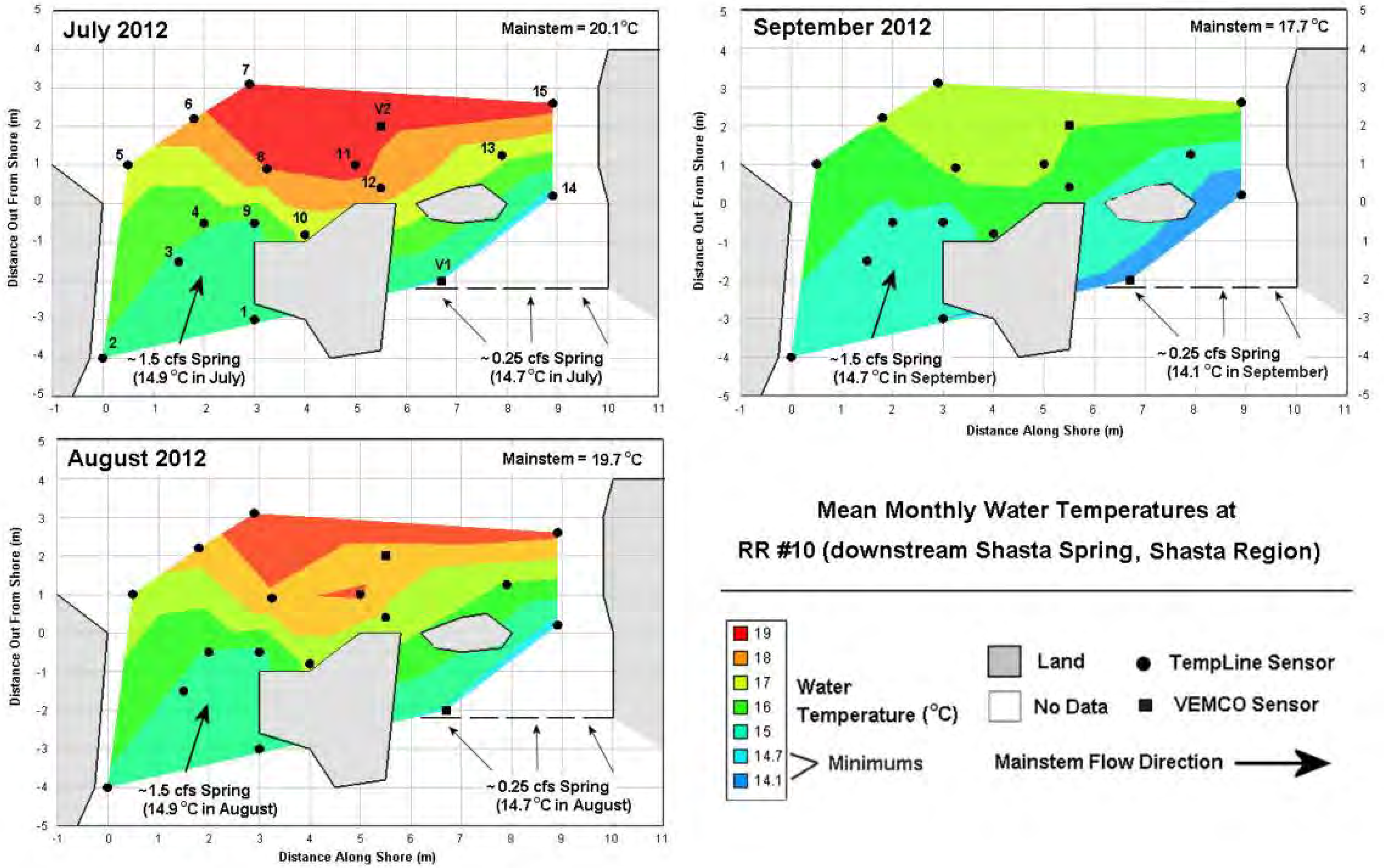


Figure 4-34. Cartesian grids showing mean monthly water temperatures for the 18 sensors at downstream Shasta Spring.

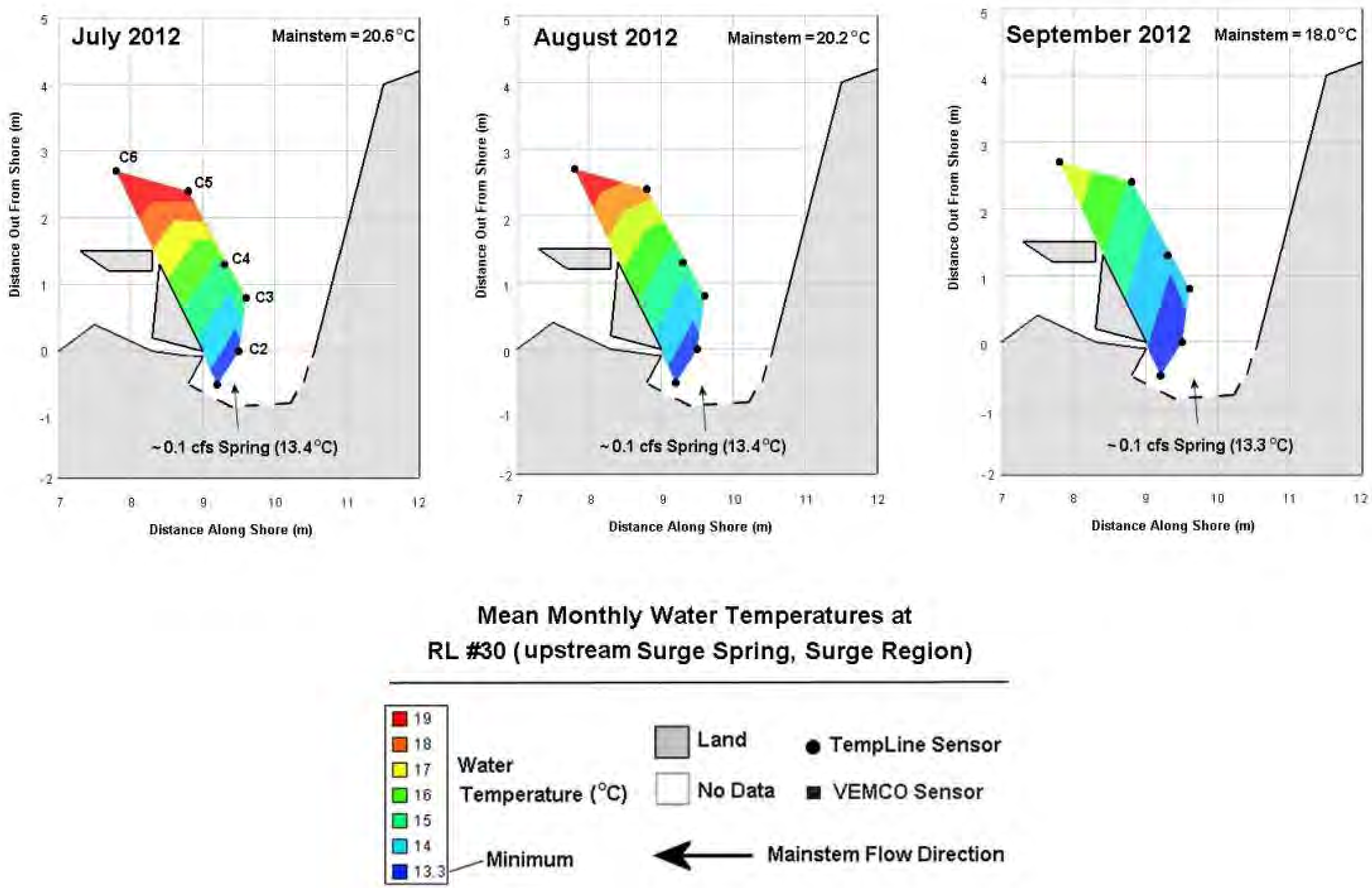


Figure 4-35. Cartesian grids showing mean monthly water temperatures for the 6 sensors at upstream Surge Spring.

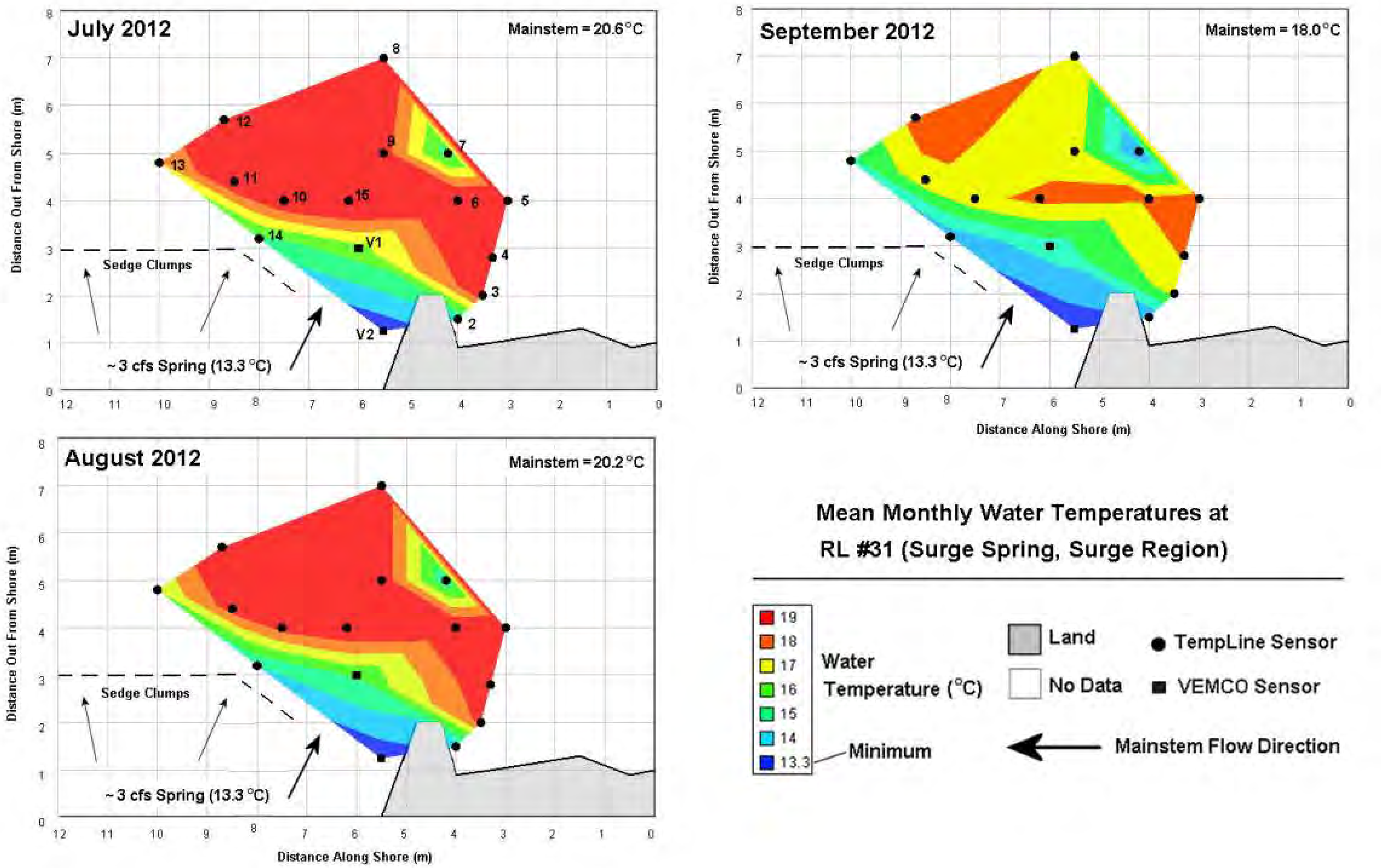


Figure 4-36. Cartesian grids showing mean monthly water temperatures for the 17 sensors at Surge Spring. (Note: underwater spring at Sensor 7).

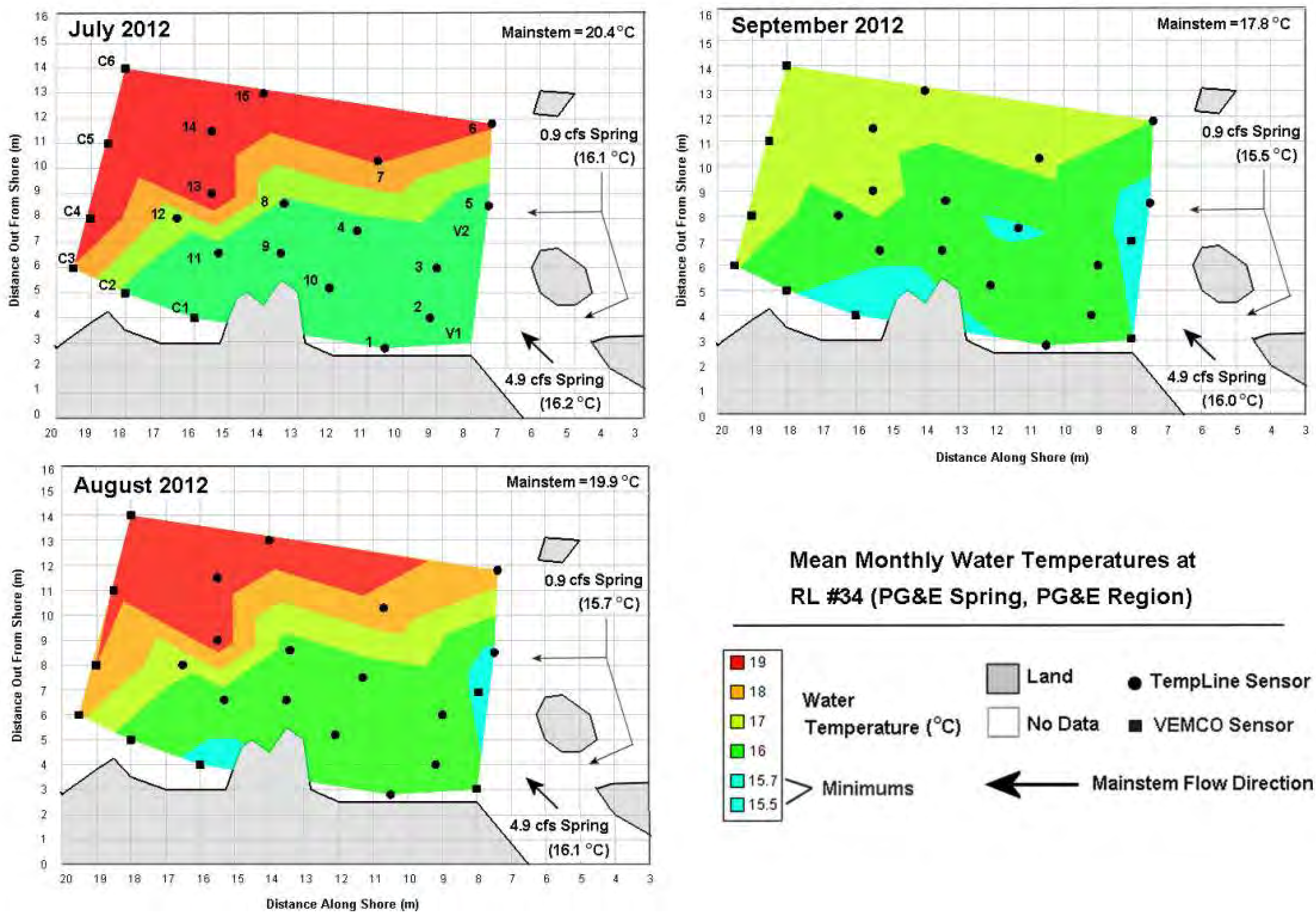
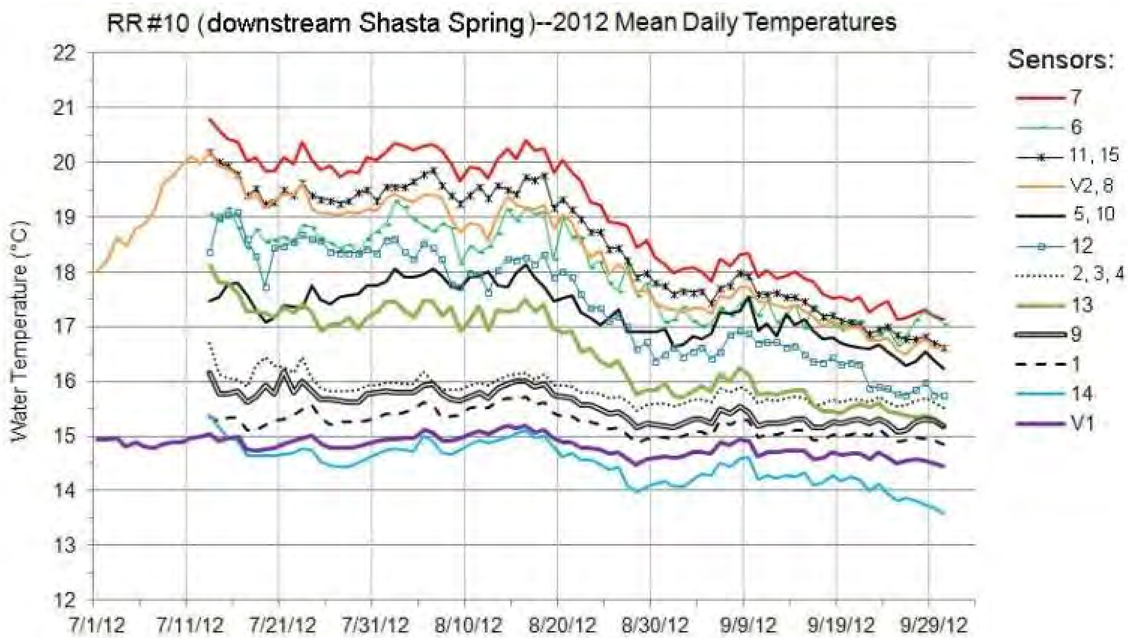
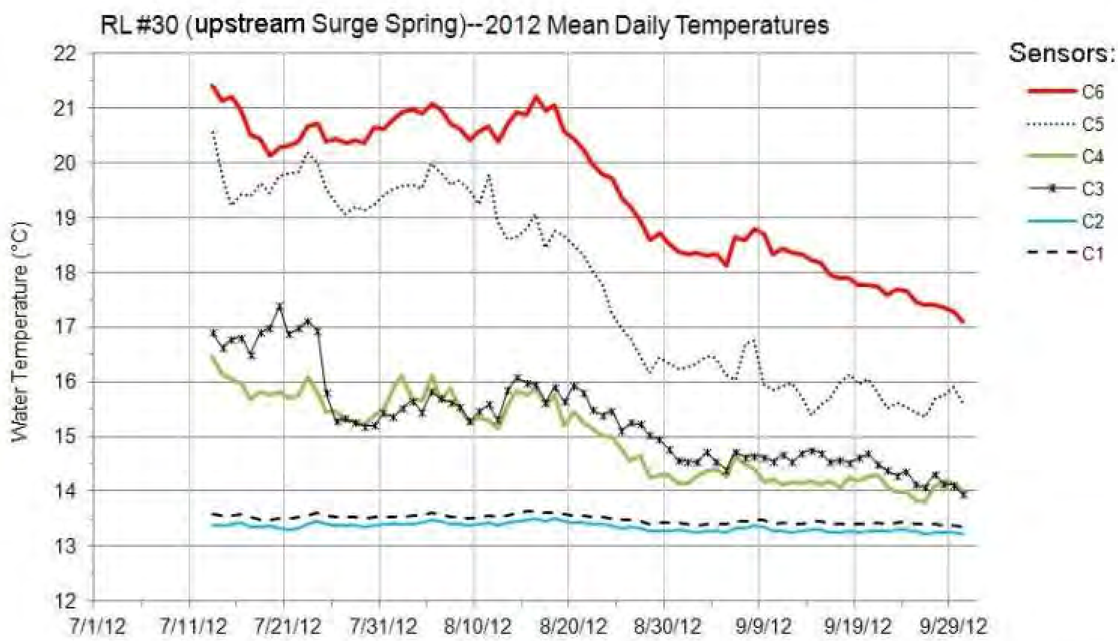


Figure 4-37. Cartesian grids showing mean monthly water temperatures for the 18 sensors at PG&E Spring.





Note: For clarity, sensors with similar temperature readings are represented by one line.

Figure 4-38. Mean daily water temperatures at downstream Shasta Spring and upstream Surge Spring

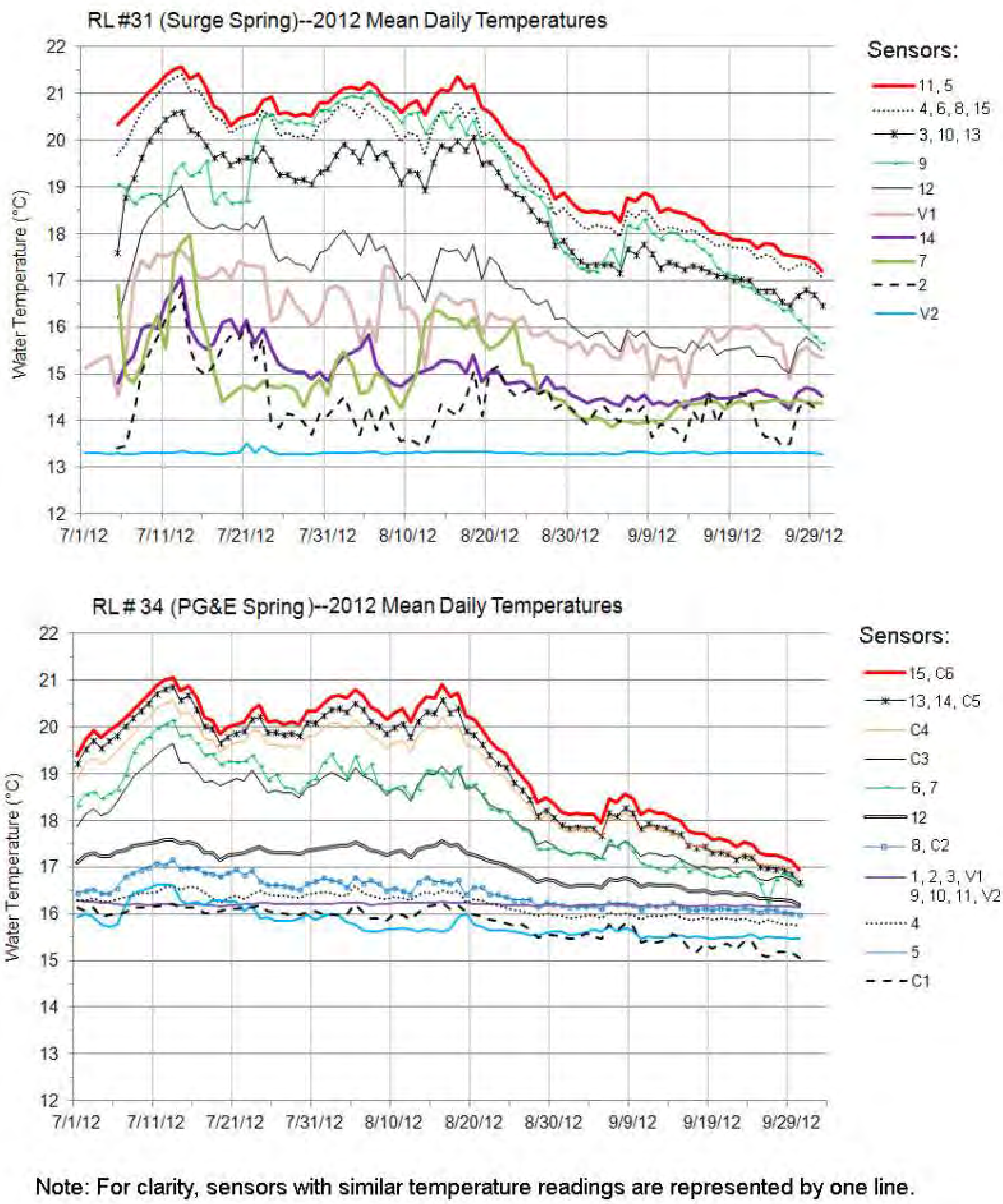


Figure 4-39. Mean daily water temperatures at Surge Spring and PG&E Spring.

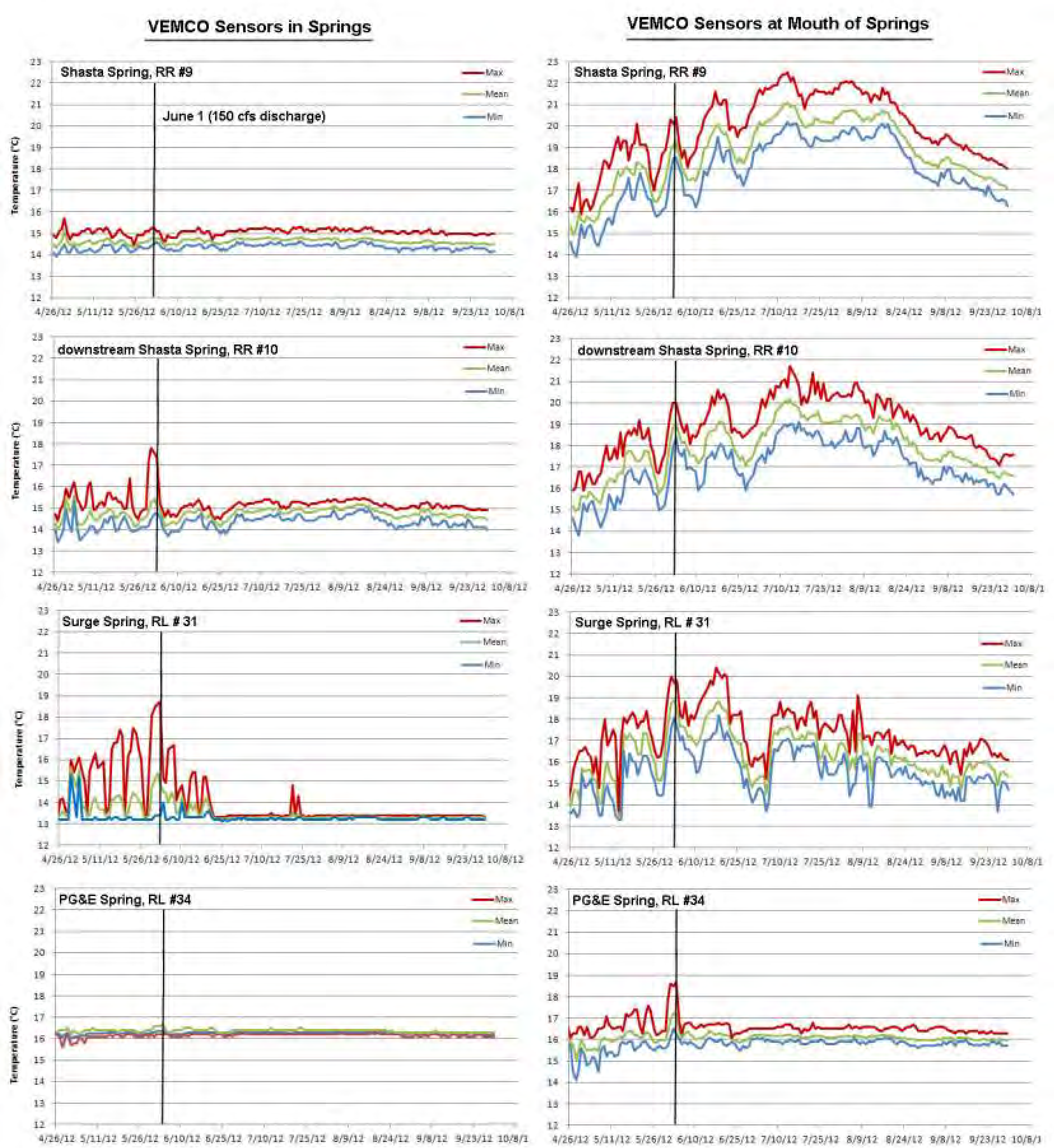


Figure 4-40. Mean, minimum, and maximum daily water temperatures at four sites with VEMCO sensors.

5.0 DISCUSSION

The purpose of the Shasta Crayfish Study is to evaluate the potential impacts of current operations of the Pit 1 Project on Shasta crayfish, including the effects of non-native crayfish, changes in Shasta crayfish habitat during flushing flows, the effect of daily peaking flows on Shasta crayfish, and other potential impacts to Shasta crayfish in the Pit 1 Peaking Reach and Pit 1 Bypass Reach. A primary objective of this investigation is to quantify the change in thermal conditions during flushing flows in the Pit 1 Bypass Reach of the Pit River. In addition, the effects of peaking flows on the Pit River downstream of the Pit 1 Powerhouse (Pit 1 Peaking Reach) and other potential impacts of Pit 1 Project operations on the Pit 1 Peaking Reach and Pit 1 Bypass Reach are investigated.

This section synthesizes the data outlined in the previous sections into a quantitative analysis of the influence these changes have had on the water quality and habitat conditions in the Pit 1 Project reaches, particularly in both spring and non-spring influenced areas occupied by Shasta crayfish.

5.1 PIT 1 BYPASS REACH

With a Mediterranean climate, the mainstem Pit River does not receive significant precipitation during summer so it would not naturally experience sudden changes in temperature or flow in the summer. After winter spring runoff has ceased, changes in flow in the Pit River in the summer are anthropogenic. These anthropogenic changes in summer period flow regime (flushing events, or other pulsed flows (e.g., Muck Valley) can result in sudden changes in temperature.

Stream flow at the Big Eddy station was used throughout the water resource analyses as the comparative reference for all changes in the hydrologic regime. Unless otherwise indicated, all analysis will be limited to the thermally critical July and August period.

5.1.1 Effect of Flow on Thermal Regime

Data from the annual 2004–2011 compliance monitoring (PG&E 2004a, 2005, 2006a, 2007, 2008, 2009a, 2010b, 2011b, 2012c) established that mainstem water temperatures in the lower Pit 1 Bypass Reach had been warmed under the Post-2003 license-required flow regime (Figures

4-28 through 4-31). Additionally, analysis of the influence of flushing flow events on water temperatures through the lower Pit 1 Bypass indicated that the thermal regime became essentially isothermal at high temperature levels under sharp temperature change during these events, further reducing the amount of cooling that occurred in this section of the reach.

In order to quantify the amount of cooling occurring in the lower Pit 1 Bypass Reach, the mean daily change (Delta-T) between Big Eddy (PR2) and the two downstream stations (Pit River Falls [PR3] and Pit 1 Footbridge [PR4]) was determined. Delta-T for the entire lower Pit 1 Bypass Reach (Delta-T_T) was calculated by subtracting the mean daily water temperature at the Big Eddy (PR2) station from mean daily water temperature at the Pit 1 Footbridge (PR4) station. Delta-T for the intermediate portion of the lower Pit 1 Bypass Reach (Delta-T_F) was calculated by subtracting the mean daily water temperature at the Big Eddy (PR2) station from mean daily water temperature at the Pit River Falls (PR3) station. The results of the various Delta-T calculations are summarized for all monitoring periods in Table 5-1.

The relationship between average daily flow at the Big Eddy (PR2) station and Delta-T_T is compared for each of the monitoring years in Figures 5-1 through 5-11. These figures highlight the influence that hydrologic conditions have on Delta-T_T in the Pit 1 Bypass Reach.

While these figures illustrate conditions during the entire summer (June-September), the period of maximum Delta-T_T is generally the July-August period. Ambient conditions in June (cool meteorology and elevated runoff) are such that the warming of water in the lower Fall River and Big Eddy is still limited. Similarly, ambient conditions (cooling meteorology) in September also reduce heating influences.

Further evaluation of the trends in Delta-T_T in Figures 5-1 through 5-11 illustrate that flow pulses, either large pulses such as those occurring during Fall River flushing flows, or smaller pulses such as those generated by Muck Valley operations, reduce Delta-T_T commensurate with the relative magnitude of the individual event.

Figures 5-1 through 5-3 illustrate Delta-T_T from the 1990–1992 monitoring periods. As illustrated, base flows in Big Eddy were rather static at levels less than 50 cfs. Delta-T_T values during these monitoring years were over −4 °C (negative equals cooling through the reach) 50% of the time (Table 5-1). These figures also highlight the effect of short-duration high-flow events on Delta-T_T. High flows in August 1991, July 1992, and August 1992 reduced Delta-T_T to levels of less than −2 °C.

Figures 5-4 through 5-11 illustrate Delta-T_T from the 2004–2011 monitoring periods. As illustrated, base flows in Big Eddy were influenced by the 150-cfs Fall River minimum instream flow, as well as the weekly pulse flows from the Muck Valley operations at various times during this period. Delta-T_T values during these monitoring years were typically less than −2.3 °C 50% of the time. Flushing flows, which occurred annually from 2004 through 2009 in compliance with the Pit 1 License conditions (June, July, and August) further reduced Delta-T_T to levels of less than −1 °C.

5.1.2 Effect of Flow on Diel Water Temperature Cycle

Another anticipated effect of increased flows on the thermal regime in the Pit 1 Bypass Reach was the possible alteration of the diel water temperature cycle. In order to evaluate the effect that flow had on the observed diel cycle at the Pit River Falls (PR3) and the Pit 1 Footbridge (PR4) in the lower Pit 1 Bypass Reach, daily values of the diel cycle for July and August were plotted against mean daily flow from the Big Eddy (PR2) station. Figure 5-12 presents scatter-plot diagrams from 2004 and 2009. Similar scatter-plot diagrams for all monitoring years are contained in Appendix G. These figures plot stream flow at Big Eddy (PR2) against the average diel cycle at Pit River Falls (PR3) and Pit 1 Footbridge (PR4). As indicated by these figures, the relationship between diel cycle and flow is poorly defined under low flow conditions. Higher flows (greater than 500 cfs) typically generate diel cycles that exhibit a smaller range in temperature. These figures highlight the strong influence ambient meteorological conditions exert on the diel water temperature cycle in the Pit 1 Bypass Reach during low flow periods (Appendix G).

5.1.3 Effect of Flow on Water Quality

As discussed in Section 4.2.2, no attempt was made to evaluate all water quality parameters with regard to changes in flow regime and the effect of these changes on water quality in the Pit 1 Bypass Reach. Results of the annual compliance monitoring effort indicates that water quality in the lower Pit 1 Bypass Reach meets all applicable Basin Plan criteria (PG&E 2004a, 2005, 2006a, 2007, 2008, 2009a, 2010b, 2011b, 2012c). The only parameter of concern was DO levels in the Big Eddy section. While DO levels in the Big Eddy section of the Pit 1 Bypass Reach are sensitive to changes in flow regime, the DO levels in the lower Pit 1 Bypass Reach are relatively unaffected by the same level of change in flow regime (PG&E 2009a).

5.1.4 Effect of Flow on Coldwater Refugia

Summer flushing flows result in rapid and substantial changes in both the temperature and spatial area of coldwater habitat at spring outflow areas. The degree to which water temperatures increased and the spatial extent of the reduction in thermal refugia are greatly dependent on the water temperature and flow volume of the spring, as well as the water temperature and flow volume in the main channel (PG&E 2009b). The spatial area of coldwater refugia (defined by isotherms of equal water temperature) under base-flow conditions were substantially reduced under flushing flow conditions. For instance, the area of the 18.5 ºC isotherm was reduced from more than 600 square feet to less than 100 square feet during the flushing flow event. The cold-jet from the spring bends rapidly with cross flow (mainstem flow) and evolves into a strong 'bending jet' region under all flow conditions. The coldwater refugia are therefore expected to occur in narrow bands confined to the river edge downstream of the mouth of each spring.

The reduction in size and quality (warmer water temperature) of refugia during summer flushing flow events and flow pulses associated with Muck Valley operations would be even more pronounced at springs smaller than the PG&E Spring, because the warmer river water would more easily overwhelm and dilute the smaller coldwater plumes created by these springs.

5.1.4.1 Stream Flow Velocity

A poorly defined aspect of the effects of increased Pit River flows on coldwater refugia is the qualitative measurement of point velocity in either the springs entering the mainstem or the mainstem in the vicinity of the spring sources. There are little or no data available that documents the point velocity of springs entering the mainstem other than the PG&E Spring used as part of the 2004 Coldwater Refugia Study. It is assumed that measuring these values would be difficult as the flows are comparatively small, point velocities low, and the channels poorly defined.

As with velocities from the spring sources, there are little data associated with changes in stream velocity relative to change in flow at locations in the mainstem Pit River with known populations of Shasta crayfish. The only data source identified as part of this investigation was the 1992 *Pit River Bald Eagle Habitat Availability Study* (IFIM) conducted as part of the Pit 1 Relicensing effort (PG&E 1993b). The study contained data from one station (Transect 52 – series of 10 transects) near springs where Shasta crayfish have been found approximately 0.3 miles upstream of the Pit River Falls. Data from habitat simulations using transect data from this location were used to define anticipated changes in velocity occurring over a range of main channel stream flow.

Figure 5-13 compares the average estimated velocity for a range of flows based on model output. The results of this evaluation indicate that changes in flow between 20 and 100 cfs produced the greatest change in average mainstem velocity (from 0.3 feet/second to 0.8 feet/second). Flows of 150 cfs are calculated to produce average velocities equal to 1.00 feet/second at this location. Shasta crayfish are known to prefer areas with little to no velocity, such as pools, runs, or in the lower velocity microhabitats such as river margins and in areas protected by large substrate or underneath layers of substrate (USFWS 1998, Ellis 1999). It is suggested that higher average velocity in the mainstem Pit River translates into higher velocities at the channel margins. As illustrated by the jet-plume model analysis, higher mainstem velocities translate into a reduction in the spatial area of the cold water refugia generated by the cool spring inflows.

5.2 PIT 1 PEAKING REACH

The Pit 1 Peaking Reach is a high-volume reach that contains the combined flows of the Pit and Fall rivers. None of the monitoring efforts instrumented multiple stations in this reach; as a result it was not possible to evaluate the effect of current peaking operations on water temperature over the entire length of the reach. However, because the total volume of flow in the Pit 1 Peaking Reach is so much greater than the volume of spring accretion flow, the springs do not significantly affect water temperatures in the mainstem Pit River in this reach. These spring sources would provide coldwater refugia as localized habitat near their confluence with the mainstem as well as downstream of the confluence for a limited distance.

5.2.1 Effect of Peaking on Thermal Regime

As discussed in Section 4.2.1.3, mean daily summer water temperatures in the Pit River downstream of Pit 1 Powerhouse for the Pre-1993 (Station P10) and Post-2003 (Station PR5) conditions were similar (Figure 4-18). This suggests that the volume of flow entering the Pit River from the Fall River system via Pit 1 Powerhouse is large enough to be insensitive to changes in thermal regime occurring upstream in the Pit 1 Bypass Reach.

During all monitoring years, the average summer (June-September) flows in the Pit River downstream of Pit 1 Powerhouse ranged from 719 to 2,930 cfs (Table 4-4). The majority of this large flow volume is derived from the Fall River, including the increased flow associated with peaking operations. As such, it is not anticipated that peaking operations would affect the thermal regime in the Pit River downstream of the Pit 1 Powerhouse.

In order to determine if water temperatures at this location were indeed affected by peaking operations, the diel cycle values for the July-August period were plotted against mean daily range in flow as measured at the USGS Gage on the Pit River downstream of Pit 1 Powerhouse. The resultant scatter-plot diagrams are presented in Figures 5-14 through 5-17. As indicated in these figures, the relationship between diel cycle and change in flows is weak.

In an effort to further quantify the influence of peaking flows on the diel cycle, a frequency analysis comparing the diel cycle associated with four peaking flow ranges (350–500, 500–750, 750–1,000, and greater than 1,000 cfs) was performed. Figure 5-18 presents the results of this frequency analysis for the 2008–2011 July-through-September periods. The average diel cycle is not significantly affected by the magnitude of flow associated with the peaking operations. In general, the average diel temperature changes were within the same range (between 1 to 2 °C) regardless of flow. There appears to be a slight relationship between a greater diel water temperature cycle and peaking flows over 750 cfs; this is probably an artifact resulting from the fact that maximum demand for power (maximum peaking flow) would occur during peak air temperature events, which may be associated with larger diel cycles.

This analysis indicates that transient flow increases associated with peaking operations at Pit 1 Powerhouse do not significantly affect the diel cycle in the Pit 1 Peaking Reach.

5.2.1.1 Anticipated Effect of Peaking on Coldwater Refugia

The primary effect of peaking operations appears to be related to changes in stream stage during the period of peaking operations. As discussed in Section 4.2.1.3, changes in stage associated with peaking operations averaged 0.90 feet during the period evaluated (June through September 2008–2011), with a maximum change in stage of 1.69 feet.

No specific data are available related to how change in stage affects the spatial extent of coldwater refugia habitats in Pit 1 Peaking Reach. These habitat areas may have always been confined to smaller areas that are associated with the confluence of the coldwater spring source with the mainstem Pit River. This assumption is based on the fact that this reach is downstream of the Project diversion and not subject to low-flow conditions (less than 700 cfs under new license); therefore the expansion of coldwater refugia habitats downstream of the spring confluence areas would not have occurred. This is a different scenario than what is observed in the lower Pit 1 Bypass Reach, which has developed more extensive areas of coldwater refugia due to prolonged periods of reduced summer flows related to Project diversion.

5.3 SHASTA CRAYFISH

Both the Pit 1 Bypass Reach and the Pit 1 Peaking Reach have historically contained populations of Shasta crayfish, however, Shasta crayfish have not been found in the Pit 1 Peaking Reach since 1978. A remnant Shasta crayfish population survived the initial invasion of non-native northern crayfish into the Pit 1 Peaking Reach in the 1960s. In 1978, Shasta crayfish comprised only 3% of the crayfish population at the Sand Pits in the Pit 1 Peaking Reach with 8 Shasta crayfish and 297 northern crayfish (Table 2-1). After the non-native signal crayfish invaded the Pit 1 Peaking Reach in the 1980s, neither Shasta crayfish nor non-native northern crayfish have been found during numerous surveys conducted between 1991 and 2005. Although peaking operations under the previous Project license may have affected Shasta crayfish habitat in the Pit 1 Peaking Reach, the Shasta crayfish population in the Pit 1 Peaking Reach persisted under peaking flows for more than three decades (1945 through at least 1978) prior to the introduction of signal crayfish to the reach. There are no plans to reintroduce Shasta crayfish to the Pit 1 Peaking Reach because signal crayfish have been well-established for more than three decades, and eradication of non-native crayfish from the Pit River is not feasible. As such, the Pit 1 Project peaking operations under the 2003 license do not directly affect the species.

In the lower Pit 1 Bypass Reach upstream of the Pit River Falls, a self-sustaining population of Shasta crayfish comprised of all age classes including young-of-year was documented in 2005. The finding of only one adult male Shasta crayfish and non-native crayfish populations that had doubled (northern crayfish) or tripled (signal crayfish) during an exhaustive survey of the substrate in same area during the most recent survey in September 2008, raised concerns that recent changes to the hydrologic regime as a result of Pit 1 Project 2003 license had negatively affected habitat conditions and the Shasta crayfish population in the lower Pit 1 Bypass Reach. Therefore the evaluation of effects of current Pit 1 Project operations are focused on the thermal regime of the lower Pit 1 Bypass Reach.

5.3.1 Temperature Preferences

There have not been any experimental studies to determine temperature tolerances or preferences of Shasta crayfish, and such studies likely would not be granted agency authorization given the current population size and status of the species. This document examines all existing data and observations related to temperature tolerances or preferences of Shasta crayfish, which include: (1) temperature data collected in the 1990s from locations where Shasta crayfish were found at that time; (2) temperature data collected since the 2003 license from known Shasta crayfish locations regardless of whether the population is extant or appears to have been extirpated since the 1990s; (3) field observations of mortality from Shasta crayfish locations in the 1990s; (4) incidental observation from Shasta crayfish in captivity; and (5) temperature physiology of crayfish based on experiments with other crayfish species.

The vast majority of Shasta crayfish live in areas that are strongly influenced by spring accretion and have relatively constant, cool, water temperatures throughout the year with little diel or annual fluctuations. Shasta crayfish have a long evolutionary history of living in these stable, cold, spring-fed environments (Ellis 1999). With the Mediterranean climate of the area, Shasta crayfish living in non-spring areas, such as the lower Pit River, experience gradual seasonal changes, but not sudden changes in temperature as would be associated with summer high-water events. As such, there has been no evolutionary pressure for the Shasta crayfish to develop a tolerance for rapid environmental temperature changes.

The ability to survive rapid environmental temperature changes is not consistent among crayfish species and sudden temperature increases or high temperatures can result in physiological changes that can stress or kill individuals (Thorp and Wineriter 1981, White 1983, Layne et al. 1985, Mundahl 1989, Chung et al. 2012). Based on incidental observations during the few attempts to maintain Shasta crayfish in captivity, the Shasta crayfish is not a species adapted to short-term fluctuations in temperature. During a series of ecological studies at the University of California, Berkeley Richmond Field Station, in which effects of signal crayfish on the behavior of Shasta crayfish were studied, Shasta crayfish and signal crayfish were exposed to short-term increases in water temperature when there was unseasonably warm weather in the fall of 1992 (Mojica et al. 1993). High mortality of Shasta crayfish occurred when water temperatures in the experimental ponds reached 20 °C.

Mojica et al. (1993) also found that Shasta crayfish are considerably less tolerant of warmer temperatures and sudden temperature changes than signal crayfish. Further evidence for the different temperature tolerances of these two species was provided by an incident that occurred at the Crystal Lake Fish Hatchery during a Shasta crayfish captive rearing study. When algae clogged the coldwater inflow and temperature in the hatchery experimental raceways reached 95°F (35 °C) during the summer of 2006, all Shasta crayfish perished, but the signal crayfish in the same raceway did not (Spring Rivers 2011, Shasta Crayfish Technical Review Committee/Recovery Team 14 September 2010 Meeting Summary). In thermal studies of signal crayfish and two species of European crayfish, signal crayfish were found to have a higher temperature tolerance (maximum upper thermal tolerance of 38 °C) and growth rate compared to the other species (Firkins and Holdich 1993). Sudden temperature changes and increased temperatures can differentially decrease survival of Shasta crayfish, compared to non-native crayfish, and further increase the competitive advantage of non-native crayfish over Shasta crayfish.

Thorp and Wineriter (1981) found that crayfish mortality was higher in more variable temperature regimes with higher maximum temperature (range = 10–25 °C; mean = 17.5 °C) than under a constant temperature (either 10 °C or 17.5 °C) and approximated mortality under a constant 25 °C. Although growth was more related to mean temperature, mortality was more related to maximum temperature during a variable regime (Thorp and Wineriter 1981). As such the greater range and higher maximum temperatures experienced by Shasta crayfish throughout much of the upper Tule River–Big Lake area, including South Big Lake Levee Cove, contributes to the higher mortality rate observed there. The mean percentage of animals found dead during field surveys in the 1990s was 22 percent (± 8% standard deviation) in the six upper Tule River–Big Lake locations as compared to a mean mortality rate of 6 percent (± 17% standard deviation) of Shasta crayfish observed in all (n=75) locations (Ellis 1999).

Although Shasta crayfish populations can persist in warmer habitats, individuals in these population experience higher levels of stress and mortality, particularly if additional stressors, such as non-native species are present or sudden temperature changes occur. Neither the upper Tule River–Big Lake area away from the springs nor the mainstem Pit River would naturally experience sudden changes in temperature or flow in the summer. Anthropogenic summer flushing or other pulsed flows, however, do result in sudden changes in temperature. At a minimum, these elevated temperatures increase stress and mortality of Shasta crayfish and increase the competitive advantage of non-native species, such as signal crayfish that have a greater tolerance for warmer temperatures and sudden temperature changes.

5.3.2 Temperature Criteria for the Lower Pit 1 Bypass Reach

Temperature criteria for Shasta crayfish in the Pit 1 Bypass Reach were developed using the following data sources: (1) temperature data collected in the 1990s and since the 2003 license from known Shasta crayfish locations regardless of whether the population is extant or appears to have been extirpated since the 1990s (see Section 4.4); (2) the 2004 Coldwater Refugia Study (PG&E 2009b, see Section 4.3); and (3) the 2012 Pit 1 Bypass Reach Spring inflow study (see Section 4.5) were used to delineate the range of mean daily water temperatures in July-August that would create coldwater refugia habitat for Shasta crayfish in the lower Pit 1 Bypass.

Shasta crayfish have been found in areas without spring inflow, where water temperatures gradually warmed to as high as 25.8 °C in the summer. These areas, however, exhibited higher mortality (22% ± 8% standard deviation), compared with the colder, spring-influenced areas (6% mortality ± 17% standard deviation). This indicates that optimal temperatures for Shasta crayfish are cooler.

Within the Pit 1 Bypass Reach, the mainstem of the Pit River begins to be strongly influenced by groundwater spring sources about 2.25 kilometers downstream of the terminal end of Big Eddy. This is the area where the first large coldwater spring area (approximately 15 cfs, 13.8–15.1 °C) enters the Pit 1 Bypass Reach; this spring is located at kilometer 87.15 on the north side about 600 meters upstream of the Pit River Falls. Shasta crayfish have only been found in the reach downstream of this first large coldwater spring area. Based on the presence of a healthy Shasta crayfish population in 2005, the conditions in the mainstem Pit River at the lower Pit River location (Station PR3) as shown in the longitudinal temperature profiles (Figures 4-28 through 4-31) were at least marginally suitable for Shasta crayfish in 1990-1992. Conditions for the Shasta crayfish population at the lower Pit River location in 2004-2011 were even more marginal due to warmer water temperatures under the Post-2003 license-required flow regimes. With the exception of July, water temperatures at the lower Pit River location in1990-1992 were less than 19.2 °C (Figures 4-28 through 4-31).

Based on the Coldwater Refugia Study, coldwater springs create areas of Cold (<15–17 ºC), Marginally Cold (17.1–18 ºC), and Cool (18.1–19 ºC) refugia habitat in the lower Pit 1 Bypass Reach under the current summer minimum instream flow of 150 cfs. These areas provide refugia from the average July-August mean daily water temperature of the mainstem Pit River in the lower Pit 1 Bypass Reach of 21.0 °C immediately downstream of the Pit River Falls and 20.2 °C at the Pit 1 Footbridge under the Post-2003 license-required flow regimes in 2004-2011 (PG&E 2009a). These proposed thermal criteria are superimposed as color bands on Figures 4-28 through 4-31 to illustrate how water temperatures associated with each hydrologic regime fall within the criteria through the Pit 1 Bypass Reach. For the lower Pit River location, higher summer temperatures between 19.1 and 20 °C primarily in July would create increasingly stressful conditions for Shasta crayfish. Cooler nighttime temperatures would provide a thermal refugia to help make these conditions more sustainable during the heat of the summer. With increasingly warmer temperatures, however, the mortality rate also continues to increase until it become greater than the rate of reproduction and the population dwindles. The presence of additional stressors, such as non-native crayfish or summer pulsed flows, will have an additive effect. Rapid increases in temperature, with no coldwater refugia, can stress or kill individuals.

Because of the large coldwater springs inflows at the upper Pit River location, conditions for Shasta crayfish at the upper Pit River location during both the 1990-1992 and 2004-2011 periods would be significantly better than at the lower Pit River location.

5.3.3 Effects of Summer Flushing Flows

The 2003 FERC license requires PG&E to release three summer flushing flows each year. This was done between 2003 and 2009 prior to the temporary suspension of flushing flows. Summer flushing flows significantly reduce the quality, spatial extent, and duration of coldwater refugia available for Shasta crayfish. Summer flushing flows can result in the elimination of all Cold (<15–17 °C) habitat and an almost two-thirds reduction in the area of all Shasta crayfish habitat cooler than 19 °C. During a flushing flow, almost two-thirds of the coldwater refugia area is covered by warm water with temperatures greater than 19 °C. Based on the reduction in habitat found during the 2004 Coldwater Refugia Study and habitat measurements taken during the 2012 field studies, summer flushing flows would eliminate all 564 to 711 m^2 of Cold refugia in the lower Pit 1 Bypass Reach (Table 4.10). During summer flushing flows, Shasta crayfish habitat would be reduced to between 362 to 457 m^2 ($^1/_3$ of the 1098 to 1394 m^2 of habitat less than 19 °C, Table 4.10) of Marginally Cold and Cool refugia with temperatures between 17.1 to 19 °C.

Flushing flows also result in a rapid, large change in stage that, not only washes out the spring effect at the "normal' mainstem confluence, but pushes the cold water/warm water interface up into the spring inflow channel a good distance depending on the orientation angle of the spring relative to the mainstem. This was shown by the effects of Muck Valley operations on temperatures within the spring channel (Figure 4-34). The flushing flow may have longer term influences on the spring temperatures as the river water bleeds out the high bank substrate over a longer period.

Flushing flows significantly alter the diel cycle because they overwhelm the effects of fluctuating day-to-night air temperatures, increase the minimum daily water temperatures, and eliminate the thermal refuge created by the cooler nighttime temperatures in both mainstem and spring-influenced areas. Cooler nighttime water temperatures can provide needed relief from thermal stress in the bypass reach during the thermally critical July and August period. Because minimum daily water temperatures increase, mean daily water temperatures increase almost one degree Celsius during flushing flows. Within areas influenced by coldwater springs, summer flushing flows also increase the maximum daily water temperature and result in rapid and substantial changes in the temperature, with sudden temperature increases by as much as several degrees Celsius. Without acclimation, Shasta crayfish have not undergone the molecular, physiological, and behavioral changes and adaptations that enhance their ability to function and survive in the new thermal environment.

5.3.4 Effects of Pit 1 Peaking Flows

The primary effects of peaking operations are related to changes in stream stage during the period of peaking operations. During the period evaluated (June-September 2008–2011), the average change in stage was 0.90 feet and the maximum change in stage was 1.69 feet.

Although changes in stage may have a small effect on the spatial extent of coldwater refugia habitats in Pit 1 Peaking Reach, these habitat areas have always been confined to smaller areas due to the high-flow conditions (greater than 700 cfs) in the reach. The available data indicate that peaking operations do not alter either the thermal regime or water quality of the Pit 1 Peaking Reach.

Potential Shasta crayfish habitat in the mainstem of the Pit 1 Peaking Reach only occurs within the wetted channel of the lowest base flows. During the Pre-2003 period, this reach experienced significantly larger changes in flow during peaking operations than under current license conditions. As such, the 2003 FERC license may have slightly increased the amount of potential Shasta crayfish habitat in the Pit 1 Peaking Reach as compared to conditions prior to 2003.

Peaking operations are by definition, transient in effect, occurring over a period of hours. The transient nature of these peaking periods would not have created opportunity for coldwater refugia to become established and populated in the mainstem channel as occurred in the Pit 1 Bypass Reach, which is a reduced-flow reach. It is assumed that existing Shasta crayfish habitat would have remained within the main spring flow source channel, and the area immediately adjacent to the confluence of the spring source with the mainstem river. It is likely that these coldwater areas associated with the confluence of the two sources were the habitat areas affected by peaking operations.

5.3.5 Effects of Non-native Crayfish

The most serious known threat to the continued existence of Shasta crayfish is non-native crayfish, which are predators, competitors, and potential sources of new diseases and pathogens. The signal crayfish invasion has resulted in rapid, drastic declines in the abundance of the native crayfish.

In addition, rapid environmental temperature changes, such as those resulting from summer flushing flows in the Pit 1 Bypass Reach, benefit non-native species at a cost to Shasta crayfish. Signal crayfish are more physiologically robust and more able to survive rapid environmental temperature changes than Shasta crayfish. Because they can acclimate faster, sudden environmental temperature changes would likely increase the competitive advantage of signal crayfish over Shasta crayfish (Seebacher and Wilson 2006). In some locations, such as South Big Lake Levee Cove, Shasta crayfish were surviving under marginal conditions until the invasion of non-native crayfish.

The invasions of non-native signal crayfish into this native crayfish community are highly successful and appear likely to result in the replacement and extinction of the Shasta crayfish if measures are not taken to develop and protect refuge populations (Ellis 1999, Spring Rivers 2009).

Table 5-1. Summary of Delta-T analysis through Pit 1 Bypass Reach.

Reach	Statistic / Exceedance	Monitoring Year (July-August Period)										
		1990	1991	1992	2004	2005	2006	2007	2008	2009	2010	2011
Big Eddy to Pit River Falls [Delta-T_F][1]	Minimum (°C)	-0.6	-1.0	-1.0	-0.5	-0.6	-0.9	-0.2	-0.7	-0.4	--	--
	90% (°C)	-1.1	-1.1	-1.8	-1.0	-0.9	-1.1	-0.9	-0.9	-0.9	--	--
	75% (°C)	-1.8	-1.4	-1.9	-1.2	-1.1	-1.3	-1.1	-1.0	-1.0	--	--
	Average (°C)	-2.7	-1.5	-2.7	-1.3	-1.3	-1.5	-1.2	-1.1	-1.1	--	--
	50% (°C)	-2.7	-1.6	-2.7	-1.3	-1.4	-1.5	-1.2	-1.1	-1.2	--	--
	25% (°C)	-3.5	-1.9	-3.5	-1.5	-1.6	-1.8	-1.5	-1.2	-1.5	--	--
	10% (°C)	-4.0	-2.1	-3.8	-1.6	-1.7	-2.2	-1.6	-1.2	-1.6	--	--
	Maximum (°C)	-4.3	-2.3	-4.3	-1.8	-2.3	-2.4	-1.8	-1.4	-1.7	--	--
Big Eddy to Pit 1 Footbridge [Delta-T_T][2]	Minimum (°C)	-1.8	-2.3	-2.2	-1.0	-1.1	-1.5	-0.7	-1.3	-0.9	-1.5	-0.9
	90% (°C)	-2.5	-3.3	-2.8	-1.7	-1.6	-1.7	-1.7	-1.6	-1.5	-1.8	-1.7
	75% (°C)	-3.4	-3.6	-3.4	-2.0	-1.8	-2.0	-1.8	-1.7	-1.6	-2.3	-1.7
	Average (°C)	-4.1	-4.0	-3.9	-2.2	-2.1	-2.3	-2.1	-1.8	-1.8	-2.8	-1.9
	50% (°C)	-4.2	-4.0	-4.2	-2.2	-2.2	-2.3	-2.1	-1.9	-1.9	-2.9	-1.9
	25% (°C)	-5.1	-4.7	-4.9	-2.5	-2.5	-2.7	-2.3	-2.0	-2.3	-3.4	-2.1
	10% (°C)	-5.5	-4.8	-6.0	-2.7	-2.6	-3.2	-2.6	-2.1	-2.4	-4.0	-2.2
	Maximum (°C)	-5.8	-5.4	-6.4	-2.9	-3.3	-3.4	-2.8	-2.3	-2.6	-4.3	-3.5

1 –Calculated as the difference between mean daily water temperatures from station downstream of Pit River Falls (PR3) with mead daily water temperature from Big Eddy station (PR2).

2 –Calculated as the difference between mean daily water temperatures from station downstream of Pit 1 Footbridge (PR4) with mead daily water temperature from Big Eddy station (PR2).

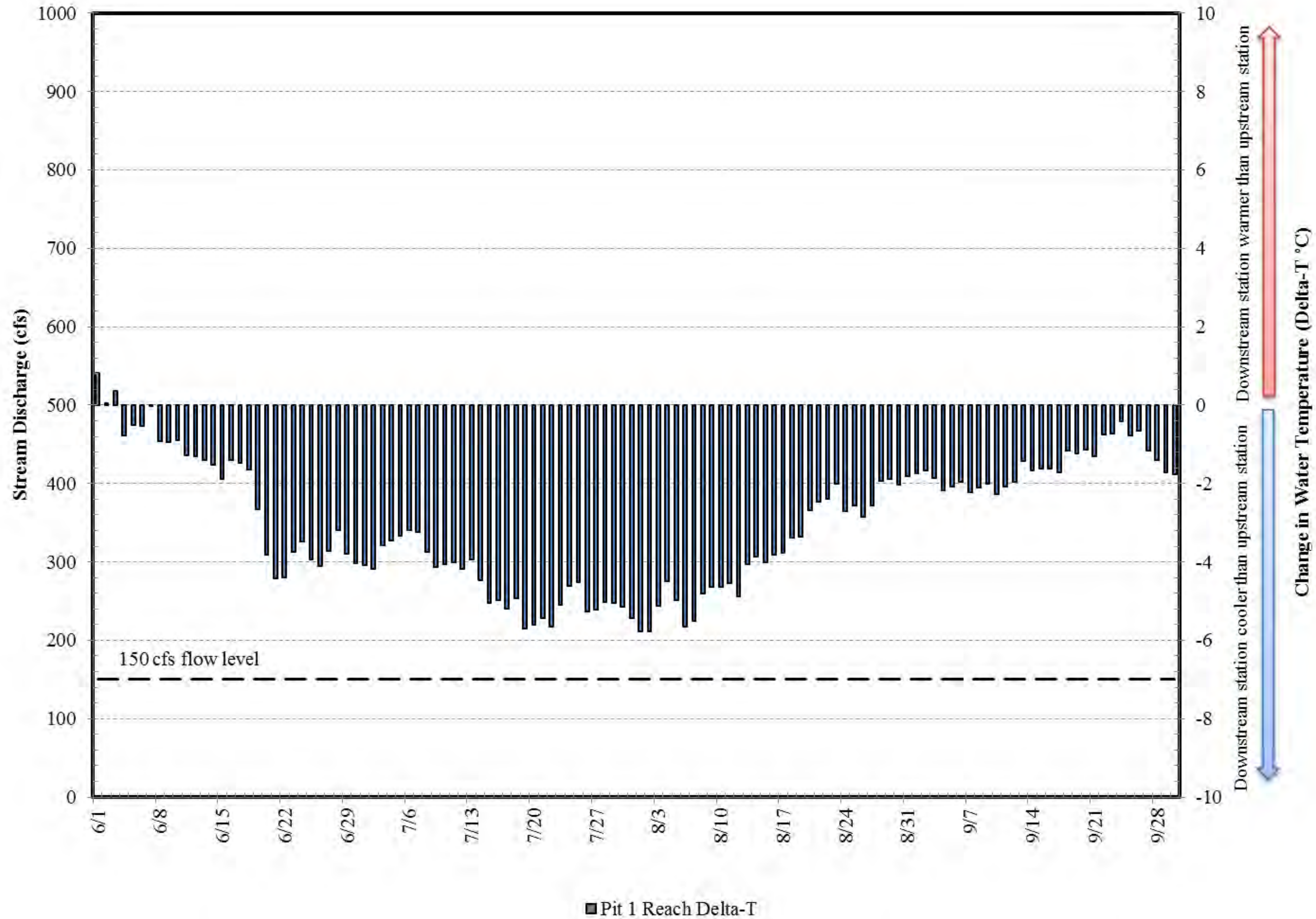


Figure 5-1. Delta-T_T through the lower Pit 1 Bypass Reach in 1990.

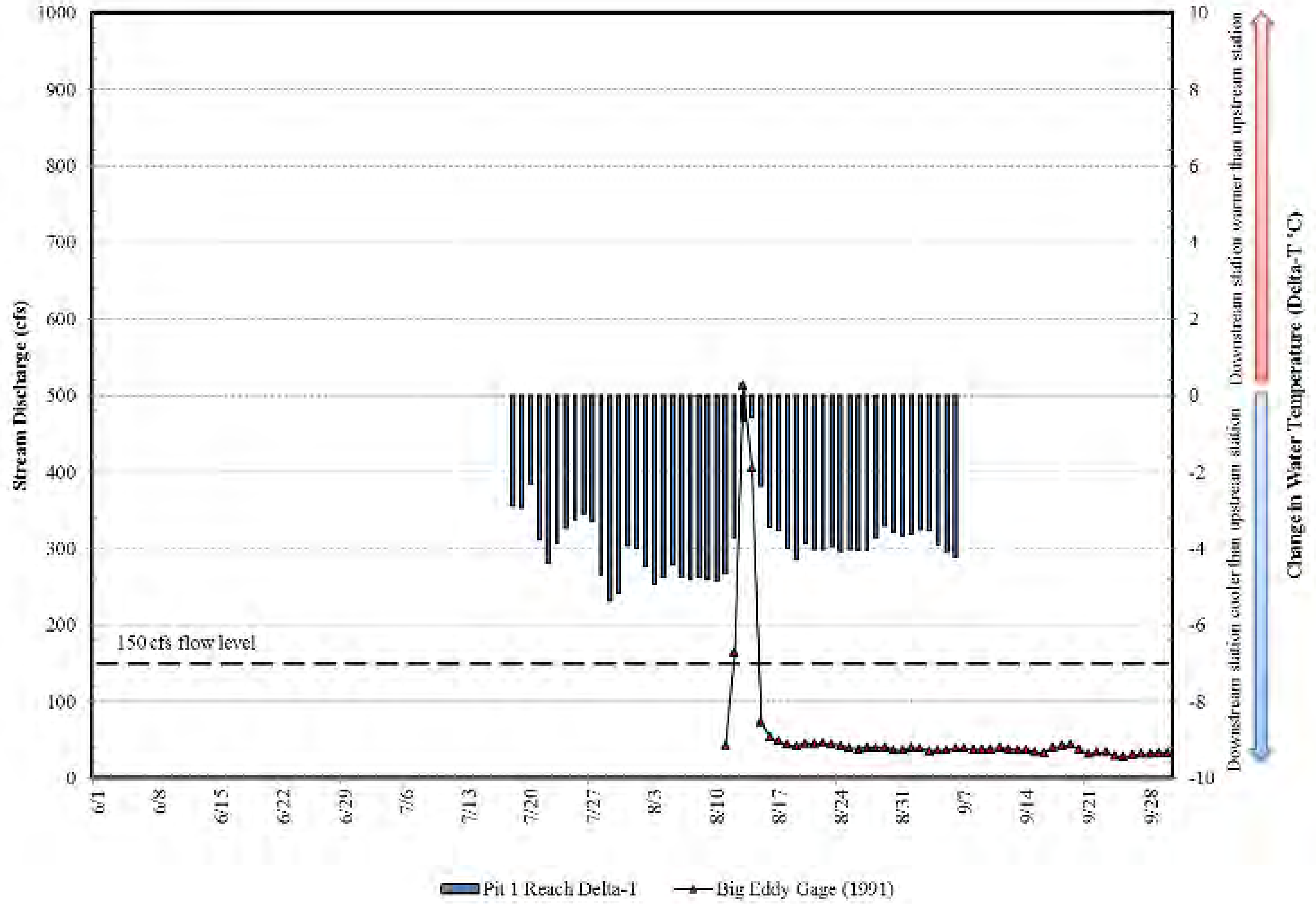


Figure 5-2. Comparison of mean daily flow in Pit River at Big Eddy (PR2) versus Delta-T_T through the lower Pit 1 Bypass Reach in 1991.

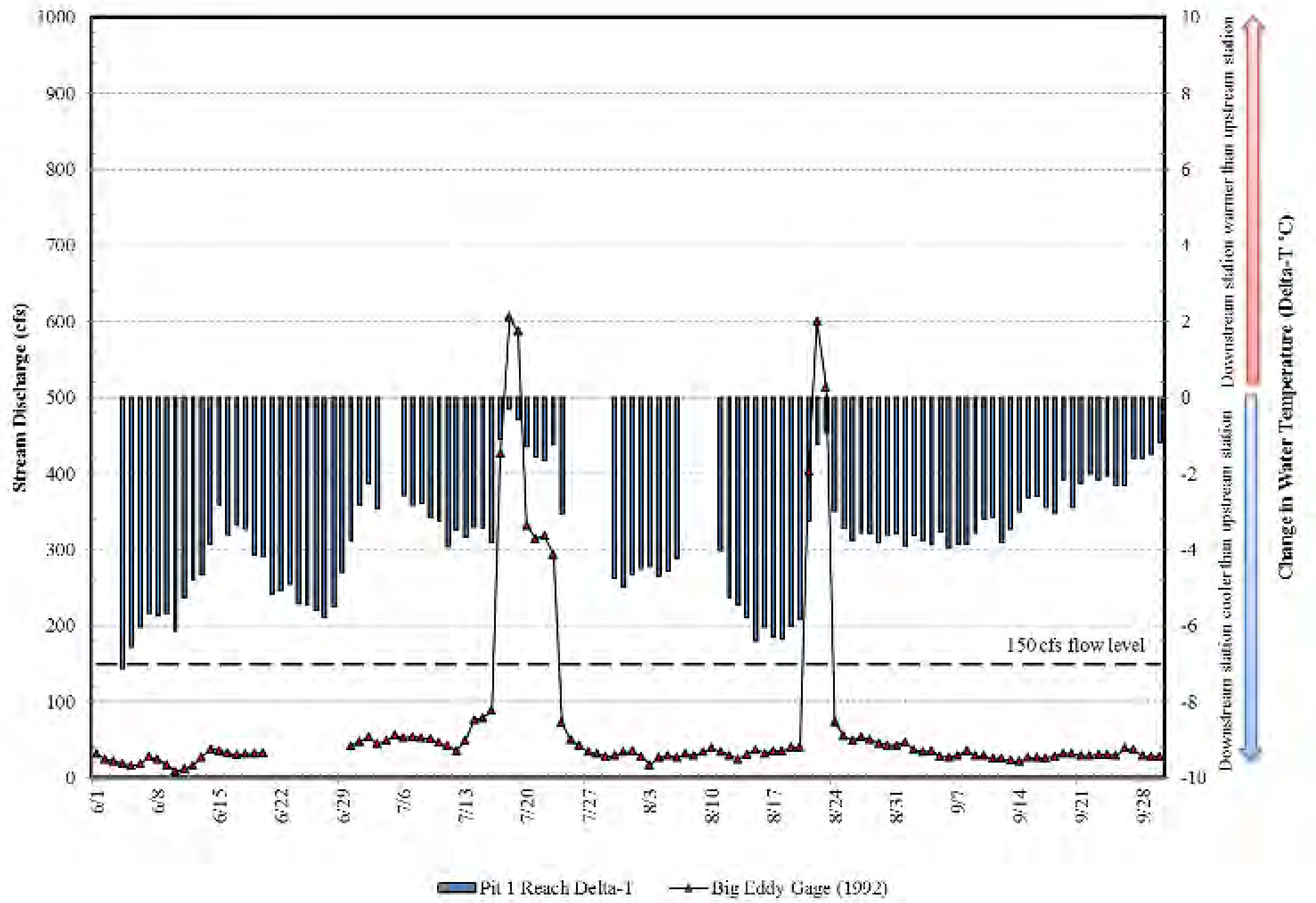


Figure 5-3. Comparison of mean daily flow in Pit River at Big Eddy (PR2) versus Delta-T_T through the lower Pit 1 Bypass Reach in 1992.

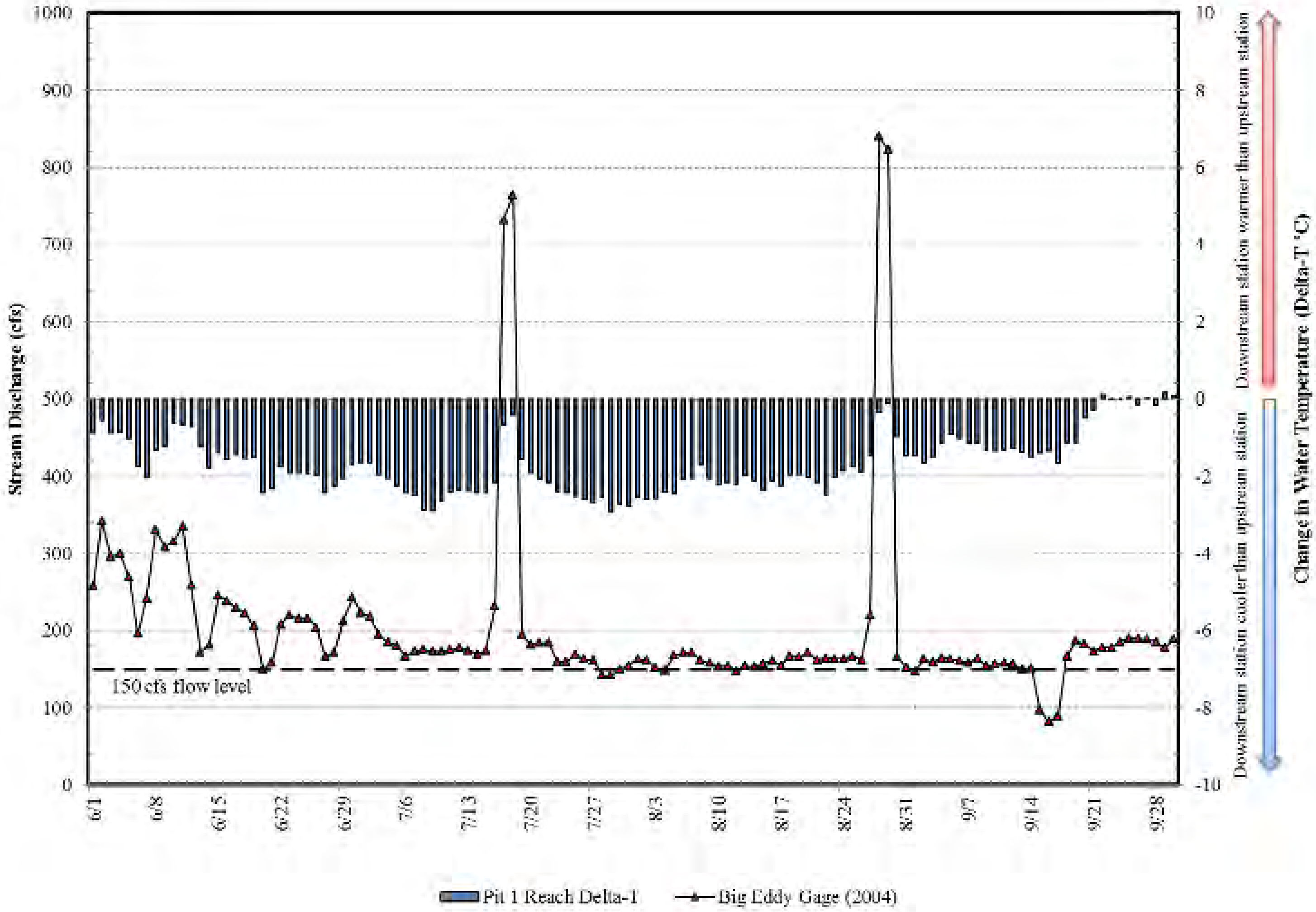


Figure 5-4. Comparison of mean daily flow in Pit River at Big Eddy (PR2) versus Delta-T_T through the lower Pit 1 Bypass Reach in 2004.

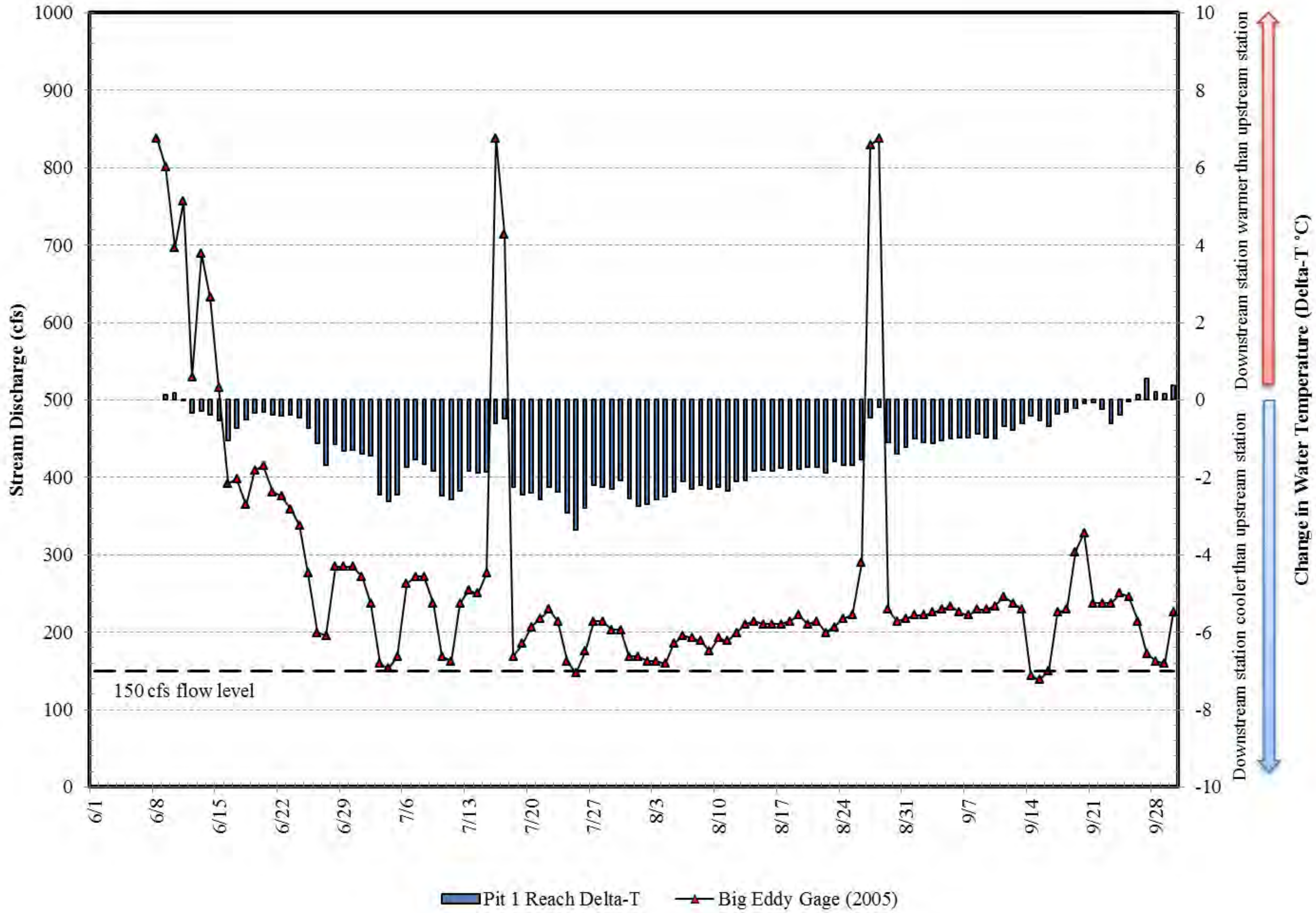


Figure 5-5. Comparison of mean daily flow in Pit River at Big Eddy (PR2) versus Delta-T_T through the lower Pit 1 Bypass Reach in 2005.

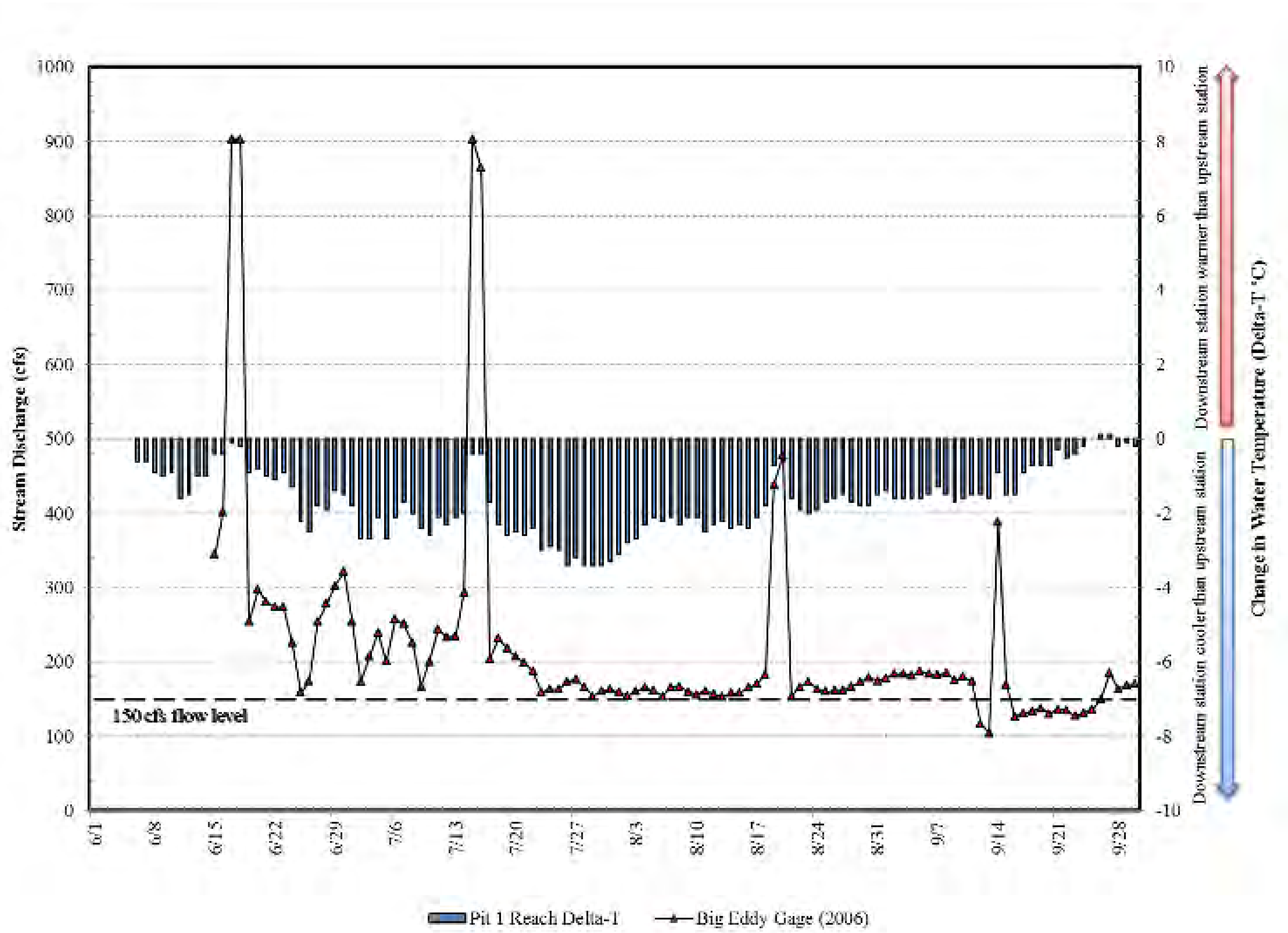


Figure 5-6. Comparison of mean daily flow in Pit River at Big Eddy (PR2) versus Delta-T_T through the lower Pit 1 Bypass Reach in 2006.

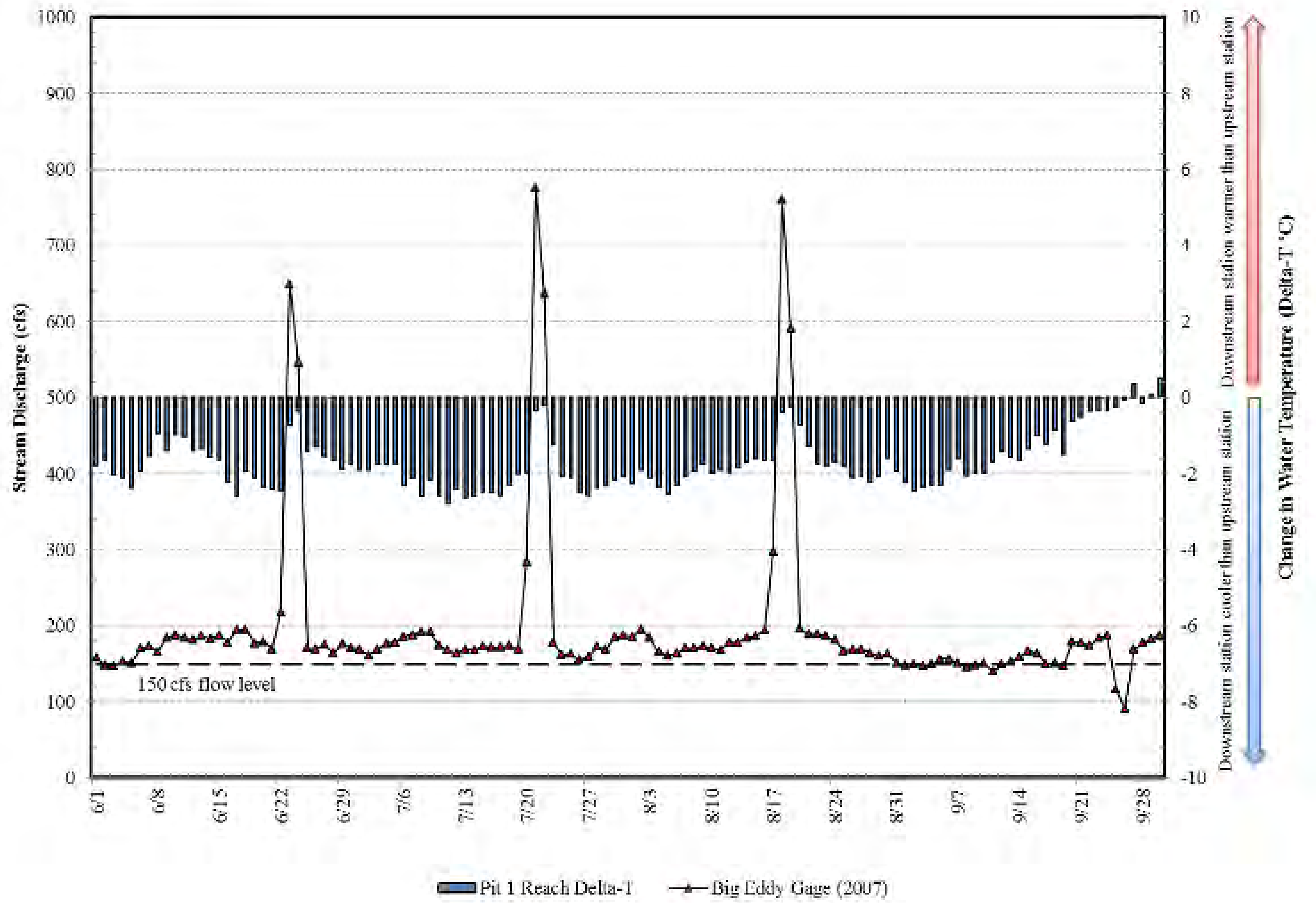


Figure 5-7. Comparison of mean daily flow in Pit River at Big Eddy (PR2) versus Delta-T_T through the lower Pit 1 Bypass Reach in 2007.

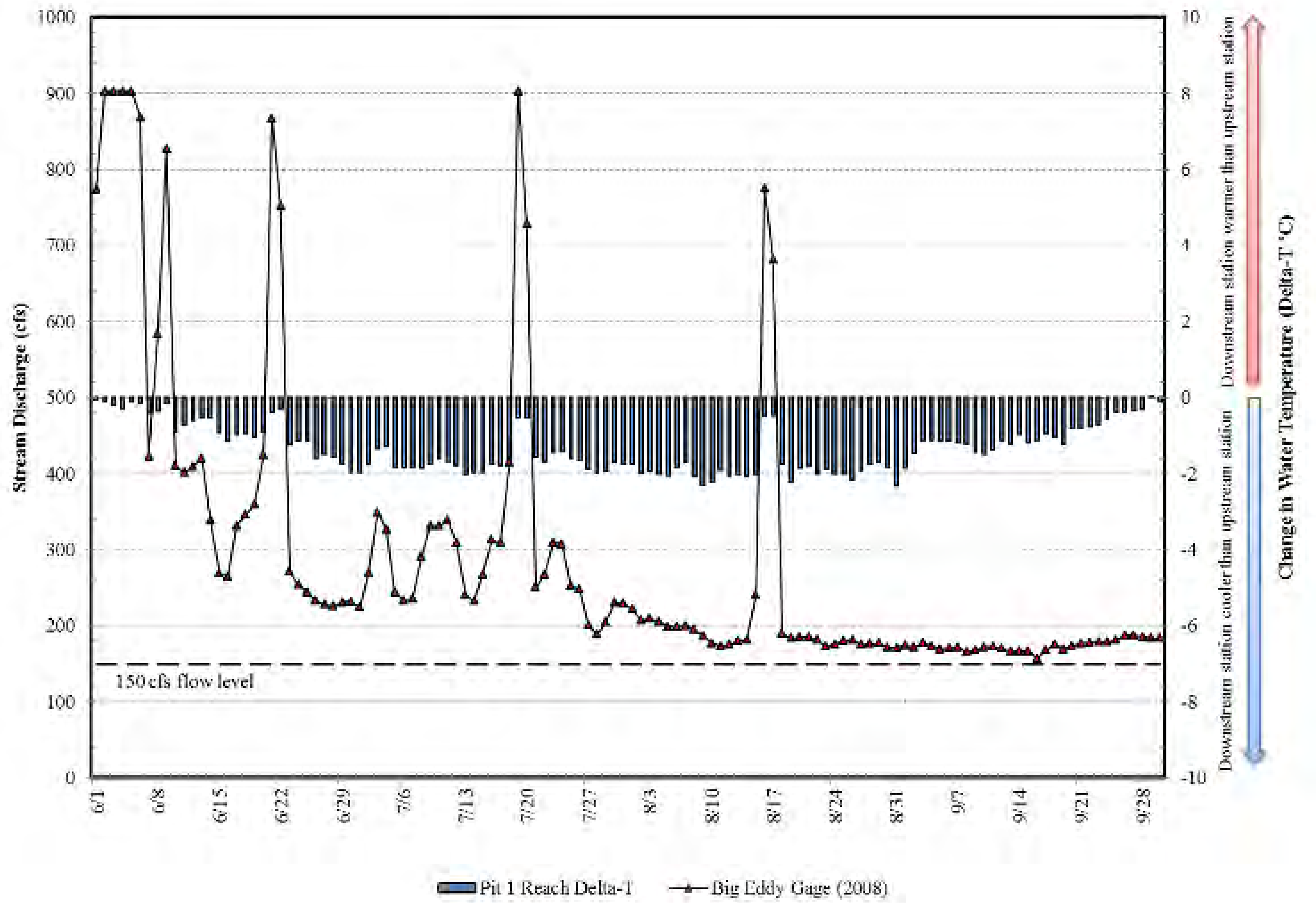


Figure 5-8. Comparison of mean daily flow in Pit River at Big Eddy (PR2) versus Delta-T_T through the lower Pit 1 Bypass Reach in 2008.

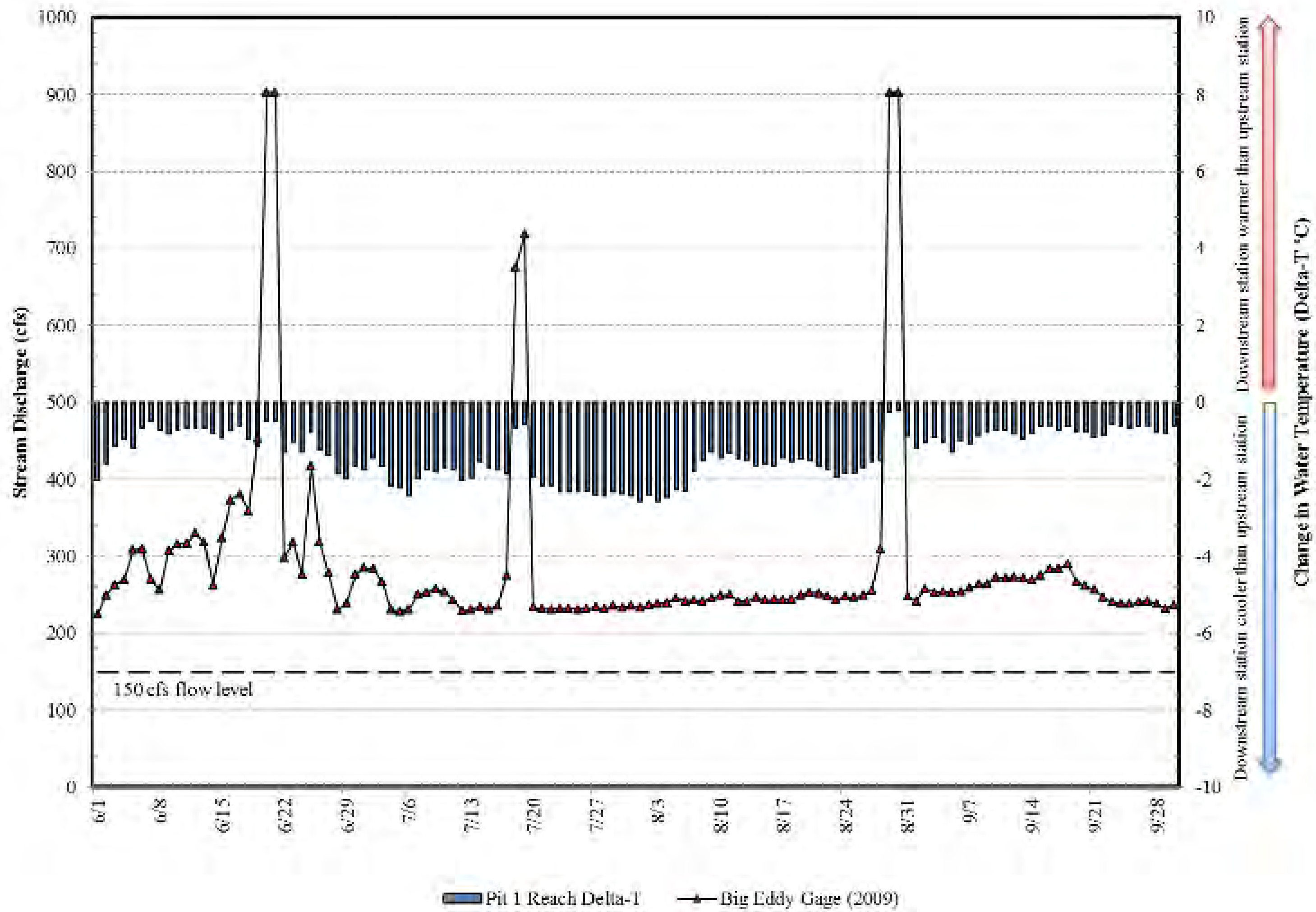


Figure 5-9. Comparison of mean daily flow in Pit River at Big Eddy (PR2) versus Delta-T_T through the lower Pit 1 Bypass Reach—2009.

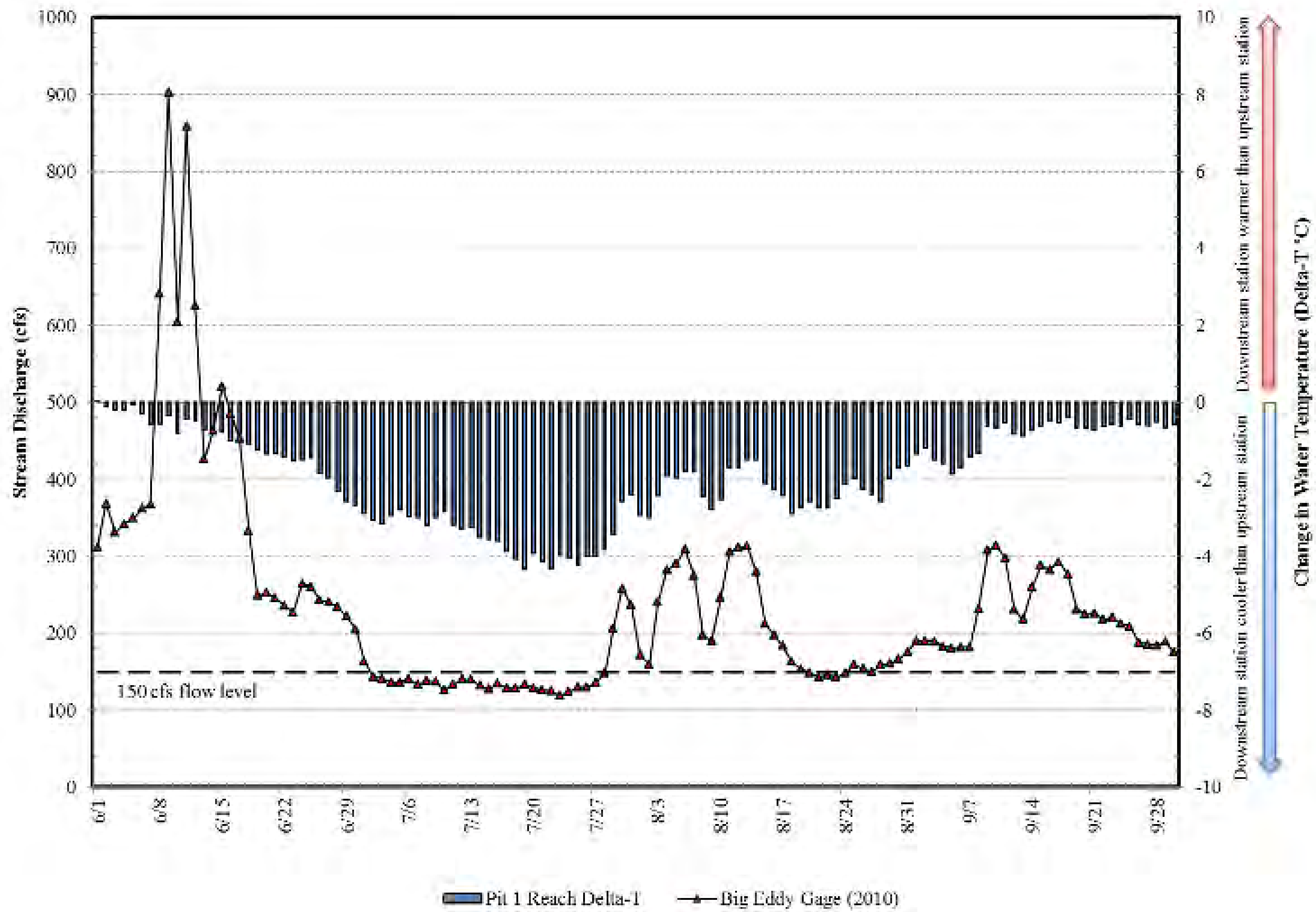


Figure 5-10. Comparison of mean daily flow in Pit River at Big Eddy (PR2) versus Delta-T_T through the lower Pit 1 Bypass Reach—2010.

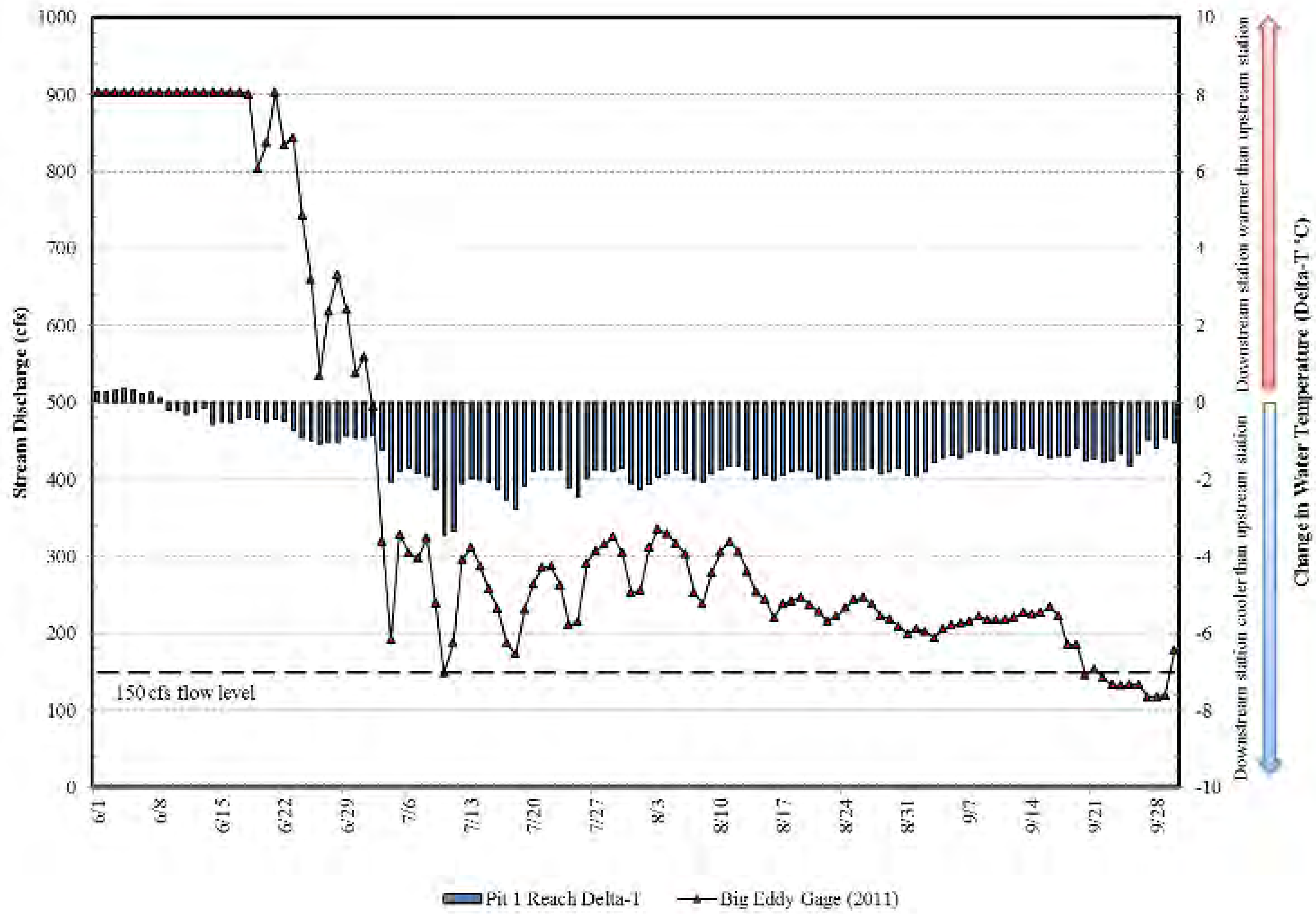


Figure 5-11. Comparison of mean daily flow in Pit River at Big Eddy (PR2) versus Delta-T_T through the lower Pit 1 Bypass Reach—2011.

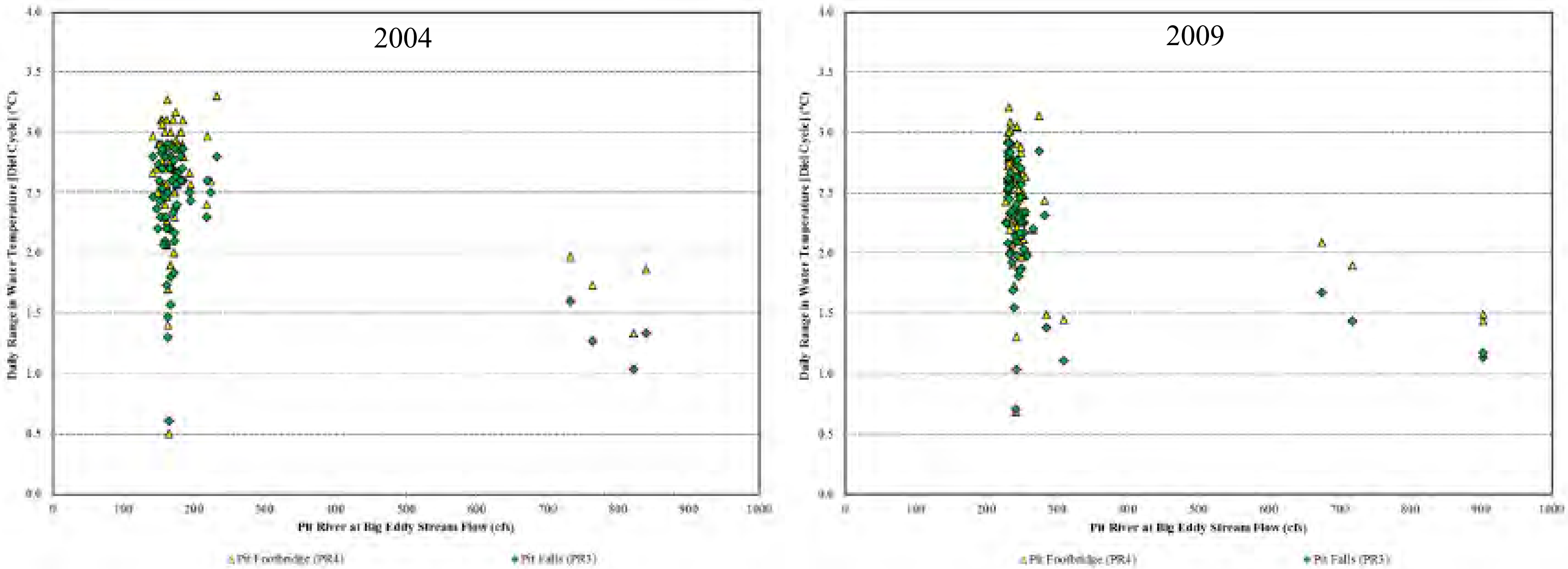


Figure 5-12. Diel water temperature patterns observed at two stations in the Pit 1 Bypass Reach in 2004 and 2009.

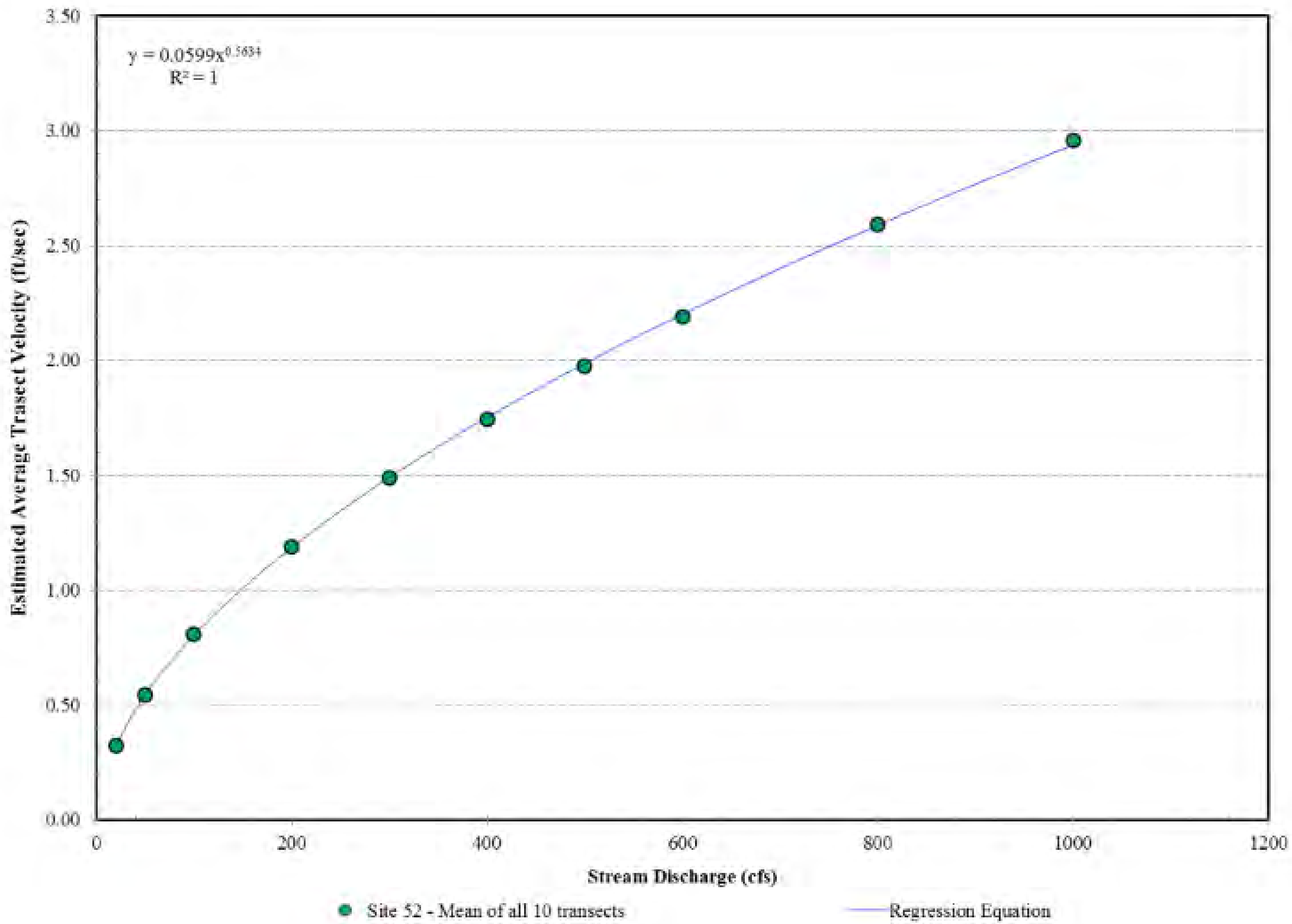


Figure 5-13. Calculated mean velocity curve for the Pit River near spring area upstream of Pit River Falls (IFIM Transect 52 [PG&E 1993b]).

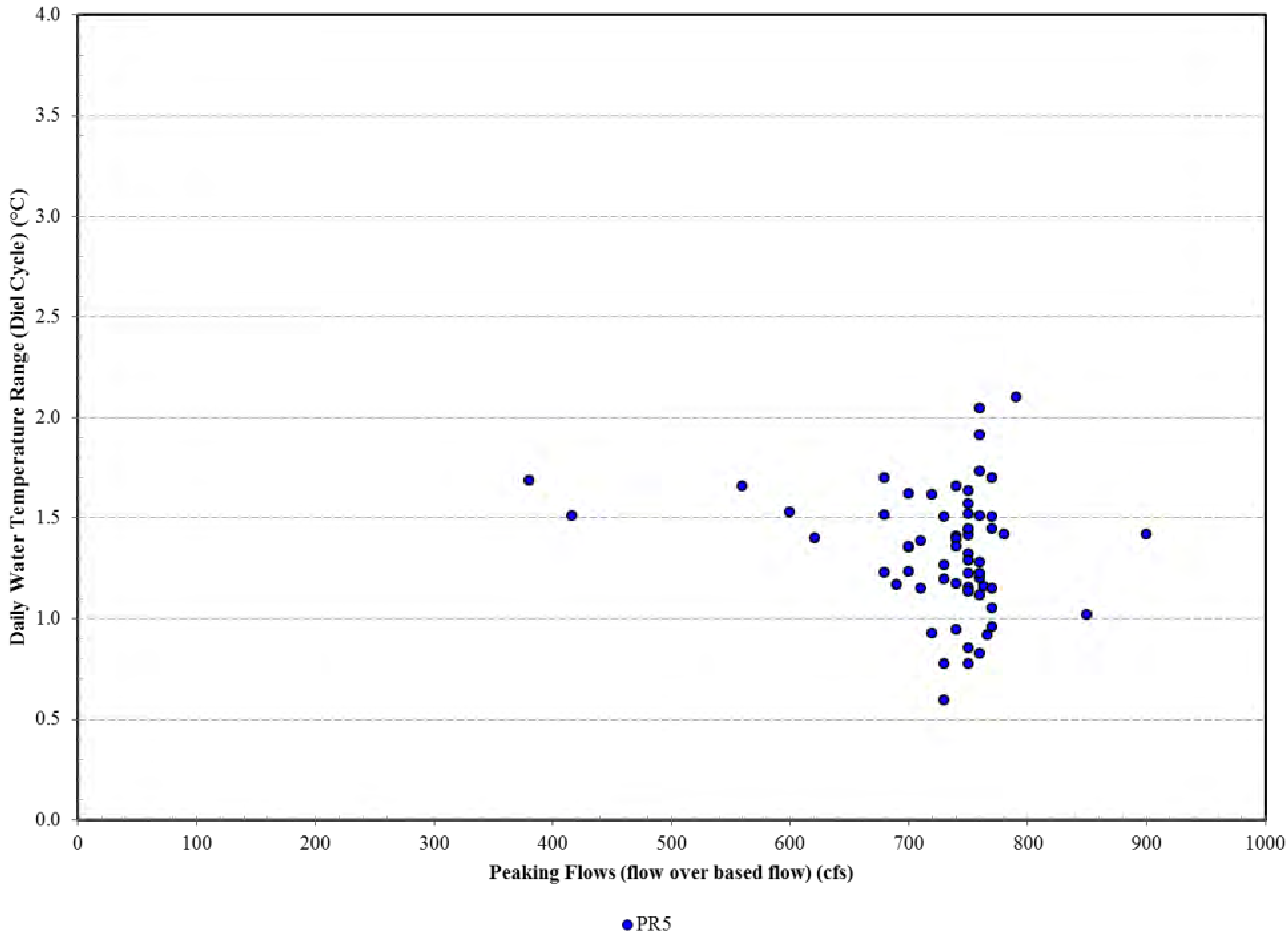


Figure 5-14. Comparison of diel water temperature cycle with peaking flow from the Pit River downstream of Pit 1 Powerhouse – 2008.

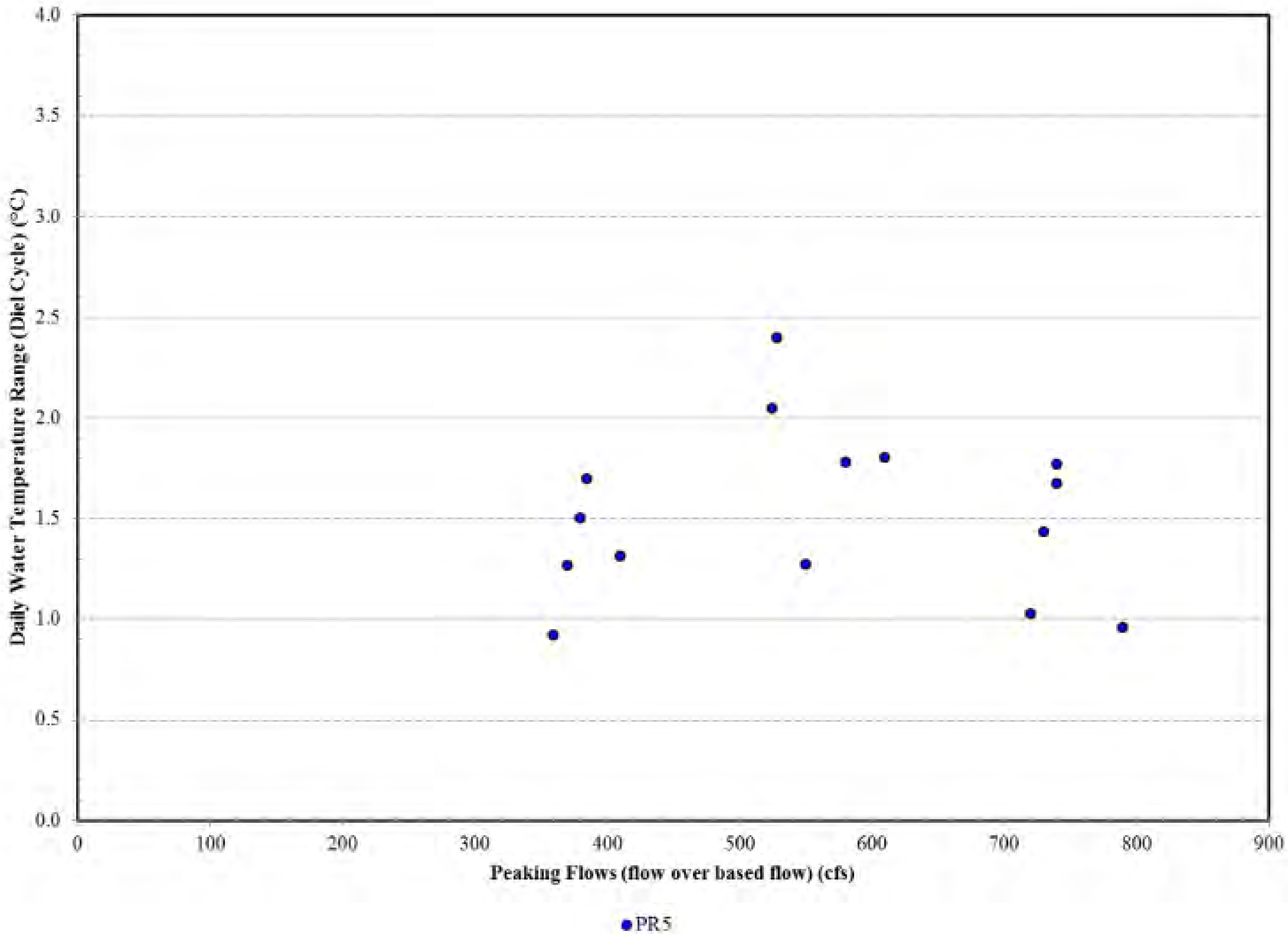


Figure 5-15. Comparison of diel water temperature cycle with peaking flow from the Pit River downstream of Pit 1 Powerhouse – 2009.

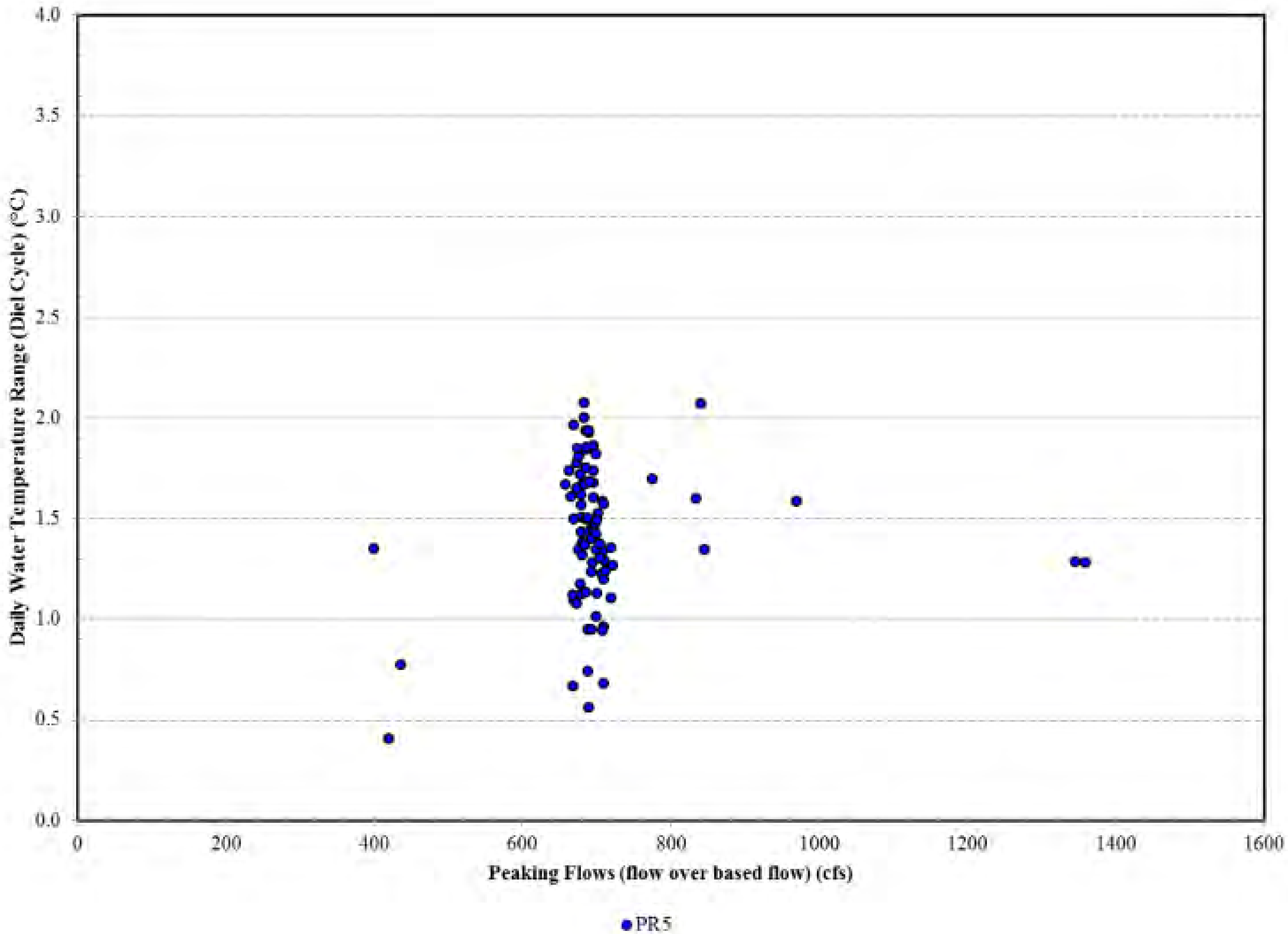


Figure 5-16. Comparison of diel water temperature cycle with peaking flow from the Pit River downstream of Pit 1 Powerhouse – 2010.

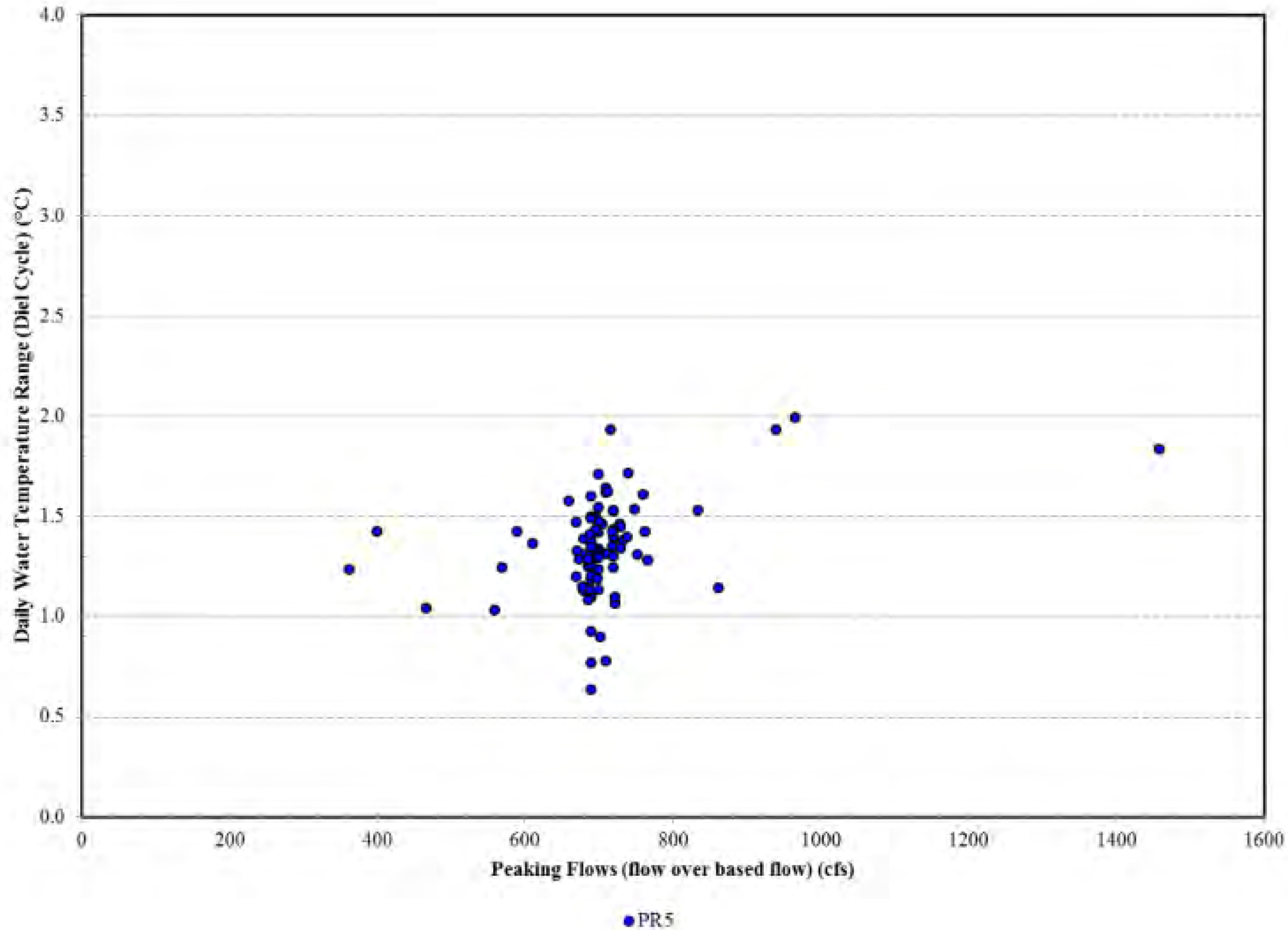


Figure 5-17. Comparison of diel water temperature cycle with peaking flow from the Pit River downstream of Pit 1 Powerhouse – 2011.

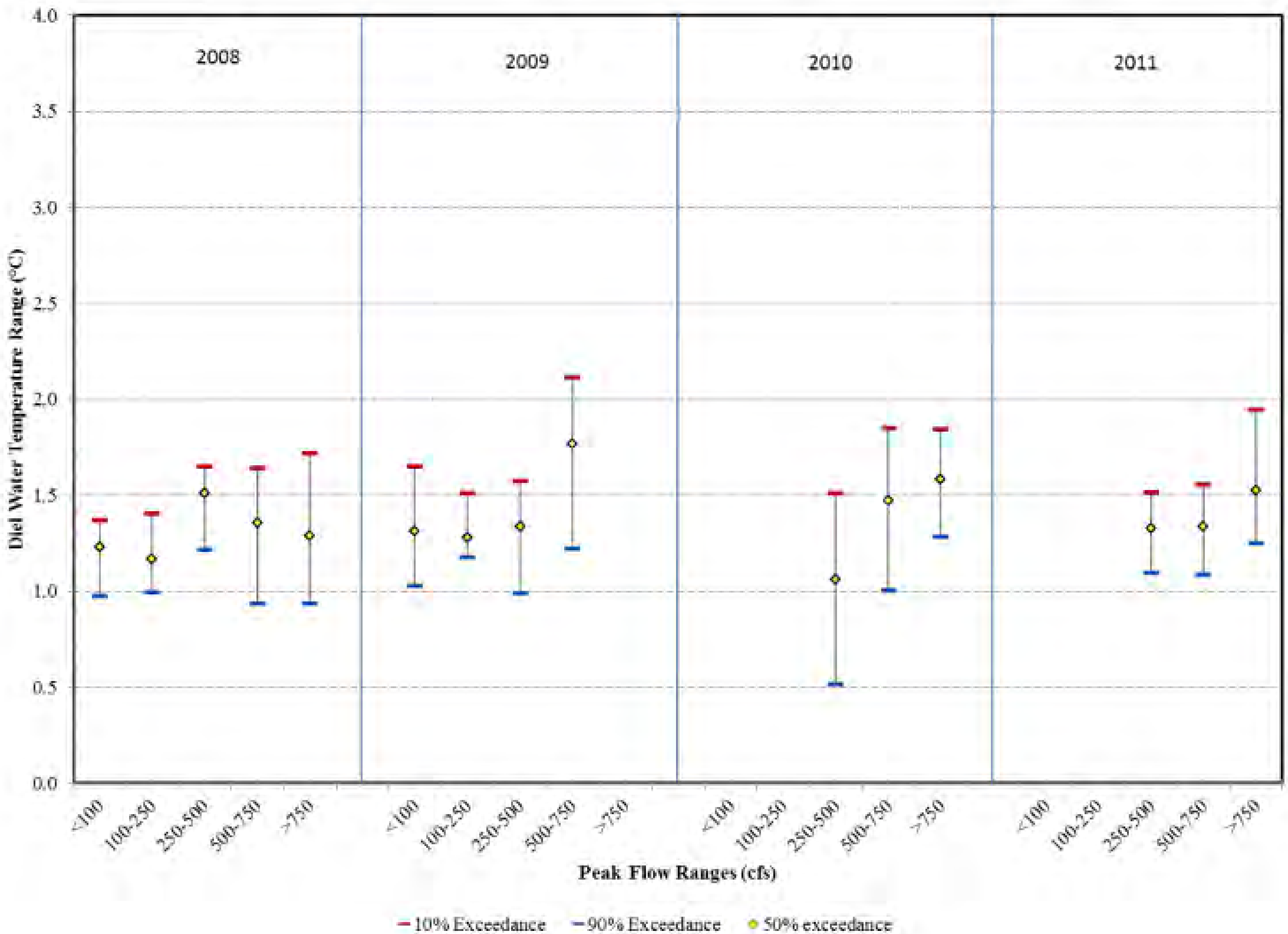


Figure 5-18. Diel water temperature cycle distribution as a function of peaking flows (4 ranges) Pit River downstream of Pit 1 Powerhouse (2008–2011).

6.0 CONCLUSIONS

The goal of the Shasta Crayfish Study Plan is to develop information on the potential impacts of current Pit 1 Project operations on Shasta crayfish in the Pit 1 Bypass Reach and downstream of Pit 1 Powerhouse (Pit 1 Peaking Reach), including: (1) the impact of non-native crayfish on Shasta crayfish; (2) the effects of flushing flows on Shasta crayfish habitat in the Pit 1 Bypass Reach; and (3) the effect of daily peaking operations at the Pit 1 Powerhouse on potential Shasta crayfish habitat in the Pit 1 Peaking Reach.

The biggest known threat to the continued existence of Shasta crayfish is non-native crayfish, which are predators, competitors, and potential sources of new diseases and pathogens. Signal crayfish are more physiologically robust and more able to survive rapid environmental temperature changes than Shasta crayfish. Because they can acclimate faster, sudden environmental temperature changes, such as those resulting from summertime flushing flows, would likely increase the competitive advantage of signal crayfish over Shasta crayfish.

Summer flushing flows required by Condition 13 of the 401 Certification significantly reduce the quality, spatial extent, and duration of coldwater refugia available for Shasta crayfish in the Pit 1 Bypass Reach. In addition, summer flushing flows significantly alter the diel cycle, increase the minimum daily water temperatures, and eliminate the thermal refuge created by the cooler nighttime temperatures in both mainstem and spring-influenced areas, which can provide needed relief from thermal stress during the thermally critical July and August period. Within areas influenced by coldwater springs, summer flushing flows result in rapid and substantial changes in the temperature that benefit non-native species at a cost to Shasta crayfish.

Shasta crayfish have not been documented in the Pit 1 Peaking Reach since 1978. There are no plans to reintroduce Shasta crayfish to the Pit 1 Peaking Reach because signal crayfish have been well-established for more than three decades, and eradication of non-native crayfish from the Pit River is not feasible. Therefore, the Pit 1 Project peaking operations under the 2003 license do not affect the species.

Potential Pit 1 Project effects will be evaluated through ESA consultation with USFWS. Management actions to protect Shasta crayfish and their habitat continue to be evaluated in consultation with the TRC.

7.0 REFERENCES

CDEC. 2012a. California Data Exchange Center (http://cdec.water.ca.gov/). Department of Water Resources. Hat Creek PH 1 – Station ID = HTC

CDEC. 2012b. California Data Exchange Center (http://cdec.water.ca.gov/cgi-progs/iodri/WSIHIST). Department of Water Resources. Water Year Index

California Regional Water Quality Control Board, Central Valley Region (CVRWQCB). 2007. The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board Central Valley Region, Fourth Edition, revised October 2007 (with approved amendments), The Sacramento River Basin and the San Joaquin River Basin (http://www.swrcb.ca.gov/rwqcb5/water_issues/basin_plans/).

Chung, Y. S., R. M. Cooper, J. Graff, and R. L. Cooper. 2012. The acute and chronic effect of low temperature on survival, heart rate and neural function in crayfish (*Procambarus clarkii*) and prawn (*Macrobrachium rosenbergii*) species. Open Journal of Molecular and Integrative Physiology 2:75–86.

Cossins, A. R. and K. Bowler. 1976. Resistance adaptation of the freshwater crayfish and thermal inactivation of membrane-bound enzymes. Journal of Comparative Physiology B: Biochemical, Systemic, and Environmental Physiology 111:15-24.

Daniels, R. A. 1978. Distribution, status, and life history of *Pacifastacus fortis*. unpublished final report to United States Forest Service, 14 pp.

Daniels, R. A. 1980. Distribution and status of crayfishes in the Pit River drainage, California. Crustaceana 38:131–138.

Ellis, M. J. 1994. 1993 Annual Report for the Shasta crayfish, *Pacifastacus fortis* and rough sculpin, *Cottus asperrimus* (Federal Fish and Wildlife Permit PRT–755945, State of California Department of Fish and Game MOU). prepared for Pacific Gas & Electric Company, Technical and Ecological Services, 3400 Crow Canyon Road, San Ramon, CA 94583. unpublished report to the United States Fish and Wildlife Service and the California Department of Fish and Game, 31 pp.

Ellis, M. J. 1996. Crayfish surveys and monitoring, Progress report II for a recovery and management plan of the endangered Shasta crayfish, *Pacifastacus fortis*, in northeastern California. prepared for California Department of Fish and Game, Inland Fisheries Division, Endangered Species Project, Contract No. FG3071IF. unpublished report 90 pp.

Ellis, M. J. 1999. Species invasions and replacements in a native crayfish community. Ph.D. Dissertation, Department of Biology, The University of Michigan, Ann Arbor, Michigan. 230 pp.

Ellis, M. J. and T. F. Hesseldenz. 1993. Survey of crayfish, sculpin, and their habitat in the Fall River and midreaches of the Pit River drainage, northeastern California. Prepared for Pacific Gas and Electric Company, Technical and Ecological Services, San Ramon, CA. 66 pp.

Eng, L. L. and R. A. Daniels. 1982. Life history, distribution, and status of *Pacifastacus fortis* (Decapoda: Astacidae). California Fish and Game 68:197–212.

Erman, D. C., T. Light, C. A. Myrick. 1993. Survey of the status of the Shasta crayfish (*Pacifastacus fortis*) in Northeastern California (1991 study year). unpublished final report for California Department of Fish and Game: September 1993, 47 pp.

Firkins, I. and D. M. Holdich. 1993. Thermal studies on three species of freshwater crayfish. Freshwater Crayfish 9:241-248.

Fisher, H. B., E. J. List, R. C. Y. Koh, J. Imberger, and N. H. Brooks. 1979. Mixing in Inland and Coastal Waters, Academic Press.

Layne, J. R. Jr., M. L. Manis, and D. L. Claussen. 1985. Seasonal variation in the time course of thermal acclimation in the crayfish *Orconectes rusticus*. Freshwater Invertebrate Biology 4:98–104.

Light, T. 1991. Biology, distribution, and status of the endangered Shasta crayfish (*Pacifastacus fortis*) of northeastern California. unpublished Senior Thesis submitted in partial fulfillment of the degree of bachelor of science in conservation and resource studies University of California, Berkeley, December 16, 1991. 35 pp.

Light, T., J. Clarke, and D. C. Erman. 1991. Survey of the status of the Shasta crayfish (*Pacifastacus fortis*) in northeastern California. unpublished report to the California Department of Fish and Game, 42 pp.

Light, T., D. C. Erman, C. A. Myrick, and J. Clarke. 1995. Decline of the Shasta crayfish (*Pacifastacus fortis* Faxon) in northeastern California. Conservation Biology 9:1567–1577.

Macdonald, P. D. M., and T. J. Pitcher. 1979. Age-groups from size-frequency data: a versatile and efficient method of analyzing distribution mixtures. Journal of the Fisheries Research Board of Canada 36:987–1001.

McMahon, B.R. 2002. Physiological adaptation to environment. Chapter 9 in Biology of Freshwater Crayfish. Blackwell Science Ltd. Carlton, Victoria. 327–376.

Mojica, C. L., J. B. Mire, and D. C. Erman. 1993. The effects of *Pacifastacus leniusculus* on the behavior of the endangered Shasta crayfish (*Pacifastacus fortis*) in an experimental setting. University of California, Berkeley. Final Report for the California Department of Fish and Game (FG9515). 28 pp.

Mundahl, N. D. 1989. Seasonal and diel changes in thermal tolerance of the crayfish *Orconectes rusticus*, with evidence for behavioral thermoregulation. The North American Benthological Society. 8(2)173–179.

Pacific Gas and Electric Company (PG&E). 1993a. Water resources investigation for the Pit 1 Hydroelectric Relicensing Project (FERC 2687). Technical and Ecological Services, San Ramon, CA. March 26, 1993.

PG&E. 1993b. Pit River bald eagle habitat availability study. Pacific Gas and Electric Company's Pit 1 Hydroelectric Project (FERC No. 2687). Prepared by EA Engineering, Science, and Technology of Lafayette, California. Prepared for Pacific Gas and Electric Company, Technical and Ecological Sciences, 3400 Crow Canyon Road, San Ramon, California 94583. Final March 1993.

PG&E. 2003. Water Quality Monitoring Plan Addressing License Article 401 as it Relates to California Water Resources Control Board Water Quality Certificate Conditions 16 and 17. San Ramon, California. September 2003.

PG&E. 2004a. Pit 1 Water Quality Monitoring Results 2004 - Addressing License Article 401 As it relates to California State Water Resources Control Board Water Quality Certificate Conditions 16 and 17 - Pit No. 1 Hydroelectric Project FERC Project No. 2687 – TPS Report No. 026.11-04.17.

PG&E. 2004b. Shasta Crayfish Management Plan Addressing License Articles 409 and 412. Pit No, 1 Hydroelectric Project FERC Project No. 2687. September 2003.

PG&E. 2005. Pit 1 Water Quality Monitoring Results 2005 - Addressing License Article 401 As it relates to California State Water Resources Control Board Water Quality Certificate Conditions 16 and 17 - Pit No. 1 Hydroelectric Project FERC Project No. 2687 – TPS Report No. 026.11-05.

PG&E. 2006a. Pit 1 Water Quality Monitoring Results 2006 - Addressing License Article 401 As it relates to California State Water Resources Control Board Water Quality Certificate Conditions 16 and 17 - Pit No. 1 Hydroelectric Project FERC Project No. 2687 –. Prepared by: Tim Sagraves (ATC Associates) and Spring Rivers Ecological Sciences LLC for PG&E's Technical Project Support – Environmental Services.

PG&E. 2006b. Crayfish Barrier Plan addressing License Article 413. Pit No. 1 Hydroelectric Project, FERC Project No. 2687. Final December 2006.

PG&E. 2007. Pit 1 Water Quality Monitoring Results 2007 - Addressing License Article 401 As it relates to California State Water Resources Control Board Water Quality Certificate Conditions 16 and 17 - Pit No. 1 Hydroelectric Project FERC Project No. 2687 –. Prepared by: Tim Sagraves (ATC Associates) and Spring Rivers Ecological Sciences LLC for PG&E's Technical Project Support – Environmental Services.

PG&E. 2008. Pit 1 Water Quality Monitoring Results 2008 - Addressing License Article 401 As it relates to California State Water Resources Control Board Water Quality Certificate Conditions 16 and 17 - Pit No. 1 Hydroelectric Project FERC Project No. 2687 – Prepared by: Tim Sagraves (ATC Associates) and Spring Rivers Ecological Sciences LLC for PG&E's Technical Project Support – Environmental Services.

PG&E. 2009a. Pit 1 Project, FERC No. 2687 - Water Quality Monitoring - Five-year Summary Report 2004–2008. Addressing License Article 401 and California State Water Resources Control Board Water Quality Certificate Conditions 16 and 17. – Prepared by: Tim Sagraves (SES) and Spring Rivers Ecological Sciences LLC for PG&E's Technical Project Support – Environmental Services.

PG&E. 2009b. A biological evaluation of thermal effects from summer flushing/whitewater flows on spring-influenced aquatic habitat in the Pit 1 Bypass Reach. Prepared by Spring Rivers Ecological Sciences LLC and Pacific Gas and Electric Company. Pacific Gas and Electric Company, San Ramon, California. May 2009.

PG&E. 2010a. Pit 1 flushing flow effectiveness monitoring plan summary report. Prepared by Spring Rivers Ecological Sciences LLC of Cassel, California. Prepared for Pacific Gas and Electric Company Environmental Services, 3401 Crow Canyon Road, San Ramon, California 94583. June 2010.

PG&E. 2010b. Pit 1 Water Quality Monitoring Results 2009 - Addressing License Article 401 As it relates to California State Water Resources Control Board Water Quality Certificate Conditions 16 and 17 - Pit No. 1 Hydroelectric Project FERC Project No. 2687

PG&E. 2010c. Water quality monitoring plan amendment addressing License Article 401 as it relates to CWRCB Water Quality Certificate Conditions 16 and 17. February 2010.

PG&E. 2011a. Pit 1 flushing flow effectiveness monitoring plan 2010 annual report. Prepared by Spring Rivers Ecological Sciences LLC of Cassel, California. Prepared for Pacific Gas and Electric Company Environmental Services, 3401 Crow Canyon Road, San Ramon, California 94583. March 2011.

PG&E. 2011b. Pit 1 Water Quality Monitoring Results 2010 - Addressing License Article 401 As it relates to California State Water Resources Control Board Water Quality Certificate Conditions 16 and 17 - Pit No. 1 Hydroelectric Project FERC Project No. 2687

PG&E. 2012a. Pit 1 Shasta Crayfish Study Plan – pursuant to the California State Water Resource Control Board Order WQ 2010-0009-Exec. Pit No. 1 Hydroelectric Project FERC Project No. 2687

PG&E. 2012b. Pit 1 flushing flow effectiveness monitoring plan 2011 annual report. Prepared by Spring Rivers Ecological Sciences LLC of Cassel, California. Prepared for Pacific Gas and Electric Company Environmental Services, 3401 Crow Canyon Road, San Ramon, California 94583. March 2012.

PG&E. 2012c. Pit 1 Water Quality Monitoring Results 2011 - Addressing License Article 401 As it relates to California State Water Resources Control Board Water Quality Certificate Conditions 16 and 17 - Pit No. 1 Hydroelectric Project FERC Project No. 2687

Payette, A. L., and I. J. McGaw. 2003. Thermoregulatory behavior of the crayfish *Procambarus clarki* in a burrow environment. Comparative Biochemistry and Physiology - Part A: Molecular & Integrative Physiology. 136(3):539–556.

Petersen, J. L. and B. May. 2008. Population and Conservation Genetics of Shasta crayfish *(Pacifastacus fortis)*. University of California Davis. Prepared for California Department of Fish and Game. May 2008.

Petersen, J. L. and B. May. 2011. Mitochondrial DNA analysis of Shasta crayfish *(Pacifastacus fortis)*. University of California Davis. Prepared for California Department of Fish and Game.

Petersen, J. L. and B. May. 2012a. Genetic Management Plan — Shasta crayfish *(Pacifastacus fortis)*. University of California Davis. Prepared for California Department of Fish and Game. June 2012

Petersen, J. L. and B. May. 2012b. Addendum to 2011 Report: Mitochondrial DNA analysis of Shasta crayfish *(Pacifastacus fortis)*, including experimentation to identify non- or minimally-invasive means of sampling DNA. University of California Davis. Prepared for California Department of Fish and Game. June 2012.

Seebacher, F. and R. S. Wilson. 2006. Fighting fit: thermal plasticity of metabolic function and fighting success in the crayfish *Cherax destructor*. Functional Ecology 20:1045–1053.

Spring Rivers Ecological Sciences (Spring Rivers). 2001. Shasta crayfish surveys in Ahjumawi-Lava Springs State Park. Prepared for California Department of Parks and Recreation, Northern Buttes District, 400 Glen Drive, California CA 95966. December 2001, 40 pp..

Spring Rivers Ecological Sciences LLC (Spring Rivers). 2004. Shasta Crayfish Technical Review Committee 2003 Annual Report. Prepared for Pacific Gas and Electric Company, Technical and Ecological Sciences, 3400 Crow Canyon Road, San Ramon, California 94583. May 2004.

Spring Rivers. 2005. Shasta Crayfish Technical Review Committee 2004 Annual Report. Prepared for Pacific Gas and Electric Company, Technical and Ecological Sciences, 3400 Crow Canyon Road, San Ramon, California 94583. May 2005.

Spring Rivers. 2006. Shasta Crayfish Technical Review Committee 2005 Annual Report. Prepared for Pacific Gas and Electric Company, Technical and Ecological Sciences, 3400 Crow Canyon Road, San Ramon, California 94583. May 2006.

Spring Rivers. 2007. Shasta Crayfish Technical Review Committee 2006 Annual Report. Prepared for Pacific Gas and Electric Company, Technical and Ecological Sciences, 3400 Crow Canyon Road, San Ramon, California 94583. March 2007.

Spring Rivers. 2008. Shasta Crayfish Technical Review Committee 2007 Annual Report. Prepared for Pacific Gas and Electric Company, Technical and Ecological Sciences, 3400 Crow Canyon Road, San Ramon, California 94583. May 2008.

Spring Rivers. 2009. Shasta Crayfish Technical Review Committee Summary Report. Prepared for Pacific Gas and Electric Company Environmental Services, 3401 Crow Canyon Road, San Ramon, California 94583. May 2009.

Spring Rivers. 2010. Shasta Crayfish Technical Review Committee 2009 Annual Report. Prepared for Pacific Gas and Electric Company Environmental Services, 3401 Crow Canyon Road, San Ramon, California 94583. May 2010.

Spring Rivers. 2011. Shasta Crayfish Technical Review Committee 2010 annual report. Prepared for Pacific Gas and Electric Company Technical and Scientific Support, Land and Environmental Management, 3401 Crow Canyon Road, San Ramon, California 94583. May 2011.

Spring Rivers. 2012. Shasta Crayfish Technical Review Committee 2011 annual report. Prepared for Pacific Gas and Electric Company Technical and Scientific Support, Land and Environmental Management, 3401 Crow Canyon Road, San Ramon, California 94583. May 2012.

Stillman, J. H. 2004. A comparative analysis of plasticity of thermal limits in porcelain crabs across latitudinal and intertidal zone clines. International Congress Series 1275C:267–275.

Thorpe, J. H., and S. A. Wineriter. 1981. Stress and growth response of juvenile crayfish to rhythmic and arrhythmic temperature fluctuations. Archives of Environmental Contamination and Toxicology. 10:69–77.

USFWS. 1998. Shasta crayfish recovery plan. United States Fish and Wildlife Service, Portland, Oregon, USA.

USGS. 2012. United States Geological Survey, California Water Science Center. 11355010 Pit River below Pit No. 1 PH near Fall River Mills, CA. (http://ca.water.usgs.gov/data/waterdata/).

White, R. 1983. Effects of acute temperature and acclimation temperature on neuromuscular function and lethality in crayfish. Physiological Zoology. 56(2):174–194.

APPENDIX A

STATE OF CALIFORNIA

STATE WATER RESOURCES CONTROL BOARD

ORDER WQ 2010-0009-EXEC

ORDER WQ 2012-0008-EXEC

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

ORDER WQ 2010-0009-EXEC

In the Matter of the Request to Amend Water Quality Certification for the

PIT 1 HYDROELECTRIC PROJECT FOR

PACIFIC GAS AND ELECTRIC COMPANY

FEDERAL ENERGY REGULATORY COMMISSION PROJECT NO. 2687

SOURCE: Pit River

COUNTY: Shasta

ORDER APPROVING TEMPORARY SUSPENSION OF FLUSHING FLOW REQUIREMENTS

BY THE EXECUTIVE DIRECTOR:

The State Water Resources Control Board (State Water Board) issued water quality certification for the Pit 1 Hydroelectric Project, Federal Energy Regulatory Commission (FERC or Commission) No. 2687 on December 4, 2001. This water quality certification was incorporated in the license issued March 19, 2003. Condition 13 of the water quality certification requires Pacific Gas and Electric Company (PG&E) to release flushing flows to control vegetation growth in the Fall River Pond. The flows are required to be released during one weekend in each of May or June, July, and August to reduce nuisance aquatic growth and control mosquito populations in the Fall River Pond. Condition 14 of the water quality certification requires PG&E to monitor the effectiveness of the flushing flows and allows the Deputy Director for Water Rights[1] to modify or terminate the monitoring requirements.

The U.S. Fish and Wildlife Service (FWS) submitted a letter (received May 21, 2009) to the State Water Board requesting suspension of the flushing flows for the summer of 2009 because of concerns the flows were facilitating the decline of Shasta crayfish (*Pacifastacus fortis*). The Shasta crayfish was listed as endangered under both the California and Federal Endangered Species Acts in 1988. In 2003, PG&E formed a technical review committee (TRC) to oversee management activities throughout the range of the crayfish. The FWS formed the Shasta Crayfish Recovery Team that includes a subset of the TRC members. According to The Recovery Plan for Shasta Crayfish the primary threats to Shasta crayfish are the introduction and expansion of non-native species of crayfish and fishes, and disturbances related to land use practices. The FWS Biological Opinion (BO) provided to the Commission on October 24, 2002, included an incidental take statement with terms and conditions to minimize incidental take of Shasta crayfish. The BO concluded that approval of a new license for operation of the Pit 1 Hydroelectric Project, as proposed in the final Environmental Assessment, would not

[1] The State Water Board now refers to the Chief of the Division of Water Rights as the Deputy Director for Water Rights.

jeopardize the continued existence of the Shasta crayfish. On June 17, 2009, the State Water Board responded to FWS's request, advising FWS that if PG&E determines the flushing flows are no longer necessary for controlling aquatic vegetation and mosquito production in Fall River Pond, PG&E could request termination of the flushing flows pursuant to Condition 14 of the water quality certification.

On June 24, 2009, PG&E submitted a request to the State Water Board to amend the water quality certification to remove Conditions 13 (flushing flows) and 14 (flushing flow effectiveness monitoring). The request is based on monitoring results showing that surface vegetation in the Fall River Pond has been reduced under new license conditions that require a higher base flow of 150 cubic feet per second. In addition to requiring PG&E to monitor the effectiveness of releasing flushing flows to control aquatic vegetation and mosquito production in Fall River Pond, Condition 14 also allows the Deputy Director for Water Rights to modify or terminate the flushing flow monitoring program after review of the 5-year monitoring report prepared by the licensee. PG&E monitored the effectiveness of flushing flows at reducing aquatic vegetation from 2005 to 2008. The results indicate that increased base flows may be more effective at reducing vegetation than flushing flows. Additional monitoring may be required to isolate the effectiveness of the base flows without flushing flows at reducing aquatic vegetation and mosquito production.

By letter dated August 28, 2009, State Water Board staff notified PG&E that before an amendment of the water quality certification can be considered, the State Water Board must comply with the California Environmental Quality Act (CEQA). State Water Board staff provided PG&E with a Memorandum of Understanding (MOU) for the preparation of environmental documents.

The FWS submitted a letter to the Commission dated December 17, 2009, stating that the BO issued on October 24, 2004 has expired, and there is no authorized incidental take for Shasta crayfish for the Project. FWS also stated its belief that flushing flows are likely resulting in take, and are facilitating the decline of the endangered Shasta crayfish in the Pit 1 Bypass Reach.

By letter dated April 15, 2010, Commission staff submitted a letter to the State Water Board requesting a temporary suspension of the flushing flows for 2010. The Commission's letter recognized that the Commission cannot unilaterally amend a water quality certification condition.

PG&E has monitored Shasta crayfish populations at multiple locations within the Project and the Hat Creek Hydroelectric Projects. The TRC Summary Report, May 2009, (Report) includes a summary of surveys that have been conducted on population characteristics. Three locations on the mainstem Pit River within the Pit 1 Project area have been surveyed. No live Shasta crayfish have been found at the Canyon Spring site. In 1978, eight Shasta crayfish were found at Sand Pit, none were found in 2004-2007 surveys, and the site was not surveyed in 2007-2009. At the Pit River Falls site, four Shasta crayfish and many fantail crayfish were observed in 1995, and 21 were found in 2004-2007 along with 10 signals and 12 fantails. During the 2008 survey, one dead Shasta crayfish was found along with 29 signals and 23 fantails. The Report states that there has been a general decline in Shasta crayfish distribution and abundance at all sites. Introduced Signal crayfish have continued to expand their range and are now abundant through almost all of the Shasta crayfish habitats. Most efforts at recovery have involved measures to exclude invasive crayfish species.

While the flushing flows have provided an incidental whitewater recreational opportunity, a precautionary approach to endangered species protection is warranted, and it is reasonable to temporarily suspend flushing flows for 2010 and 2011 while the CEQA process is completed for a permanent suspension of these flows. The State Water Board's conclusion that amendment of the water quality certification to remove the flushing flows requires compliance with CEQA was based on the potential for a significant environmental impact by removing this requirement permanently. If the requirement for flushing flows is suspended for a limited period, with adequate safeguards to prevent the suspension from becoming permanent except after full compliance with CEQA, there will not be any significant impacts. The State Water Board has determined the temporary suspension of flushing flows will not have a significant environmental effect and is categorically exempt from the requirements to prepare environmental documents under California Code of Regulations section 15307 (Actions by Regulatory Agencies for Protection of Natural Resources). A Notice of Exemption will be filed for this action.

This temporary amendment to the water quality certification shall be dependent on PG&E's timely completion of the required CEQA documentation (pursuant to the most recently provided MOU). In addition to undertaking sufficient studies, through the CEQA process, to determine whether there would be significant impacts due to permanent elimination of the requirement for flushing flows, PG&E shall conduct sufficient studies to evaluate the potential for flushing flows to cause a "take" in violation of either the federal or California Endangered Species Acts.

ORDER

IT IS HEREBY ORDERED THAT:

1. PG&E shall finalize the CEQA MOU within 60 days of issuance of this order.

2. PG&E shall continue monitoring the effectiveness of the higher base flows at controlling aquatic vegetation and mosquito production in Fall River Pond during 2010 and 2011 consistent with the procedures in the Flushing Flow Effectiveness Monitoring Plan.

3. Within 120 days of issuance of this order, PG&E shall submit a proposed Shasta crayfish study plan to the Deputy Director for Water Rights for modification or approval. The study plan shall be developed in cooperation with appropriate Resource Agencies, including State Water Board Staff. The study shall evaluate the impact of non-native crayfish, changes in Shasta crayfish habitat during flushing flows, the effect of daily peaking flows on Shasta crayfish, and other potential impacts to Shasta crayfish in the Pit 1 Peaking Reach and Bypass Reach. The goal of the study is to develop information on potential impacts of current operations on Shasta crayfish.

7·06·10
Date

Dorothy Rice
Executive Director

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

ORDER WQ 2012-0008-EXEC

In the Matter of the Request to Amend Water Quality Certification for the

PIT 1 HYDROELECTRIC PROJECT FOR

PACIFIC GAS AND ELECTRIC COMPANY

FEDERAL ENERGY REGULATORY COMMISSION PROJECT NO. 2687

SOURCE: Pit River

COUNTY: Shasta

ORDER APPROVING EXTENSION OF THE TEMPORARY SUSPENSION OF FLUSHING FLOW REQUIREMENTS

BY THE EXECUTIVE DIRECTOR:

1.0 PROJECT BACKGROUND

The State Water Resources Control Board (State Water Board) issued a water quality certification for the Pit 1 Hydroelectric Project (Project), Federal Energy Regulatory Commission (Commission) Project No. 2687 on December 4, 2001. This water quality certification was incorporated into the license issued by the Commission on March 19, 2003. Condition 13 of the water quality certification requires Pacific Gas and Electric Company (PG&E or Licensee) to release flushing flows to control vegetation growth in the Fall River Pond. The flows are required to be released during one weekend in each of May or June, July, and August to reduce nuisance aquatic growth and control mosquito populations in the Fall River Pond. Condition 14 of the water quality certification requires PG&E to monitor the effectiveness of the flushing flows and allows the Deputy Director for Water Rights to modify or terminate the flushing flow monitoring program after review of the 5-year monitoring report prepared by the Licensee.

The Shasta crayfish was listed as endangered under both the California and Federal Endangered Species Acts in 1988. U.S. Fish and Wildlife Service (FWS) issued a Biological Opinion (BO) for the Project on October 24, 2002, that included an incidental take statement with terms and conditions to minimize incidental take of Shasta crayfish. The BO concluded that approval of a new license for operation of the Project with flushing flows, as proposed in the final Environmental Assessment, would not jeopardize the continued existence of the Shasta crayfish.

In 2003, PG&E formed a technical review committee (TRC) to oversee management activities throughout the range of the Shasta crayfish. The FWS formed the Shasta Crayfish Recovery Team that includes a subset of the TRC members which developed a Recovery Plan for Shasta Crayfish (Recovery Plan). The Recovery Plan identified the introduction and expansion of non-native species of crayfish and fish as well as disturbances related to land use practices as

Sha:

primary threats to the continued existence of a viable Shasta crayfish population in the Pit River. The Recovery Plan aims to stabilize and protect the existing populations of Shasta crayfish so that the species may recover and be reclassified as threatened and ultimately delisted. PG&E monitored Shasta crayfish populations at multiple locations within the Project and the Hat Creek Hydroelectric Projects. The TRC Summary Report (Report), dated May 2009, includes a summary of surveys conducted on Shasta crayfish population characteristics. Three locations on the mainstem Pit River within the Project area were surveyed. The Report indicates that there has been a general decline in Shasta crayfish distribution and abundance at all sites.

On July 6, 2010, following requests from PG&E and FWS, the State Water Board approved Order WQ 2010-0009-EXEC approving temporary suspension of flushing flow requirements.

2.0 HISTORY OF SUSPENSION OF FLUSHING FLOWS

FWS submitted a letter (received on May 21, 2009) to the State Water Board requesting the suspension of flushing flows for the summer of 2009 due to concerns that the flows were contributing to the decline of the local Shasta crayfish (*Pacifastacus fortis*) population.

On June 17, 2009, the State Water Board responded to FWS's request for suspension of flushing flows, advising FWS that if PG&E determines the flushing flows are no longer necessary for controlling aquatic vegetation and mosquito production in Fall River Pond, PG&E could request termination of the flushing flow conditions in the water quality certification.

PG&E monitored the effectiveness of flushing flows at reducing aquatic vegetation from 2005 to 2008. Data collected during this period indicate that increased base flows may be more effective than flushing flows for reducing unwanted vegetation. On June 24, 2009, PG&E submitted a request to the State Water Board to amend the water quality certification to remove Conditions 13 (flushing flows) and 14 (flushing flow effectiveness monitoring) based on data showing that surface vegetation in the Fall River Pond has been reduced under the 150 cubic feet per second base flow required in the current license conditions. In a letter dated August 28, 2009, State Water Board staff notified PG&E that before an amendment of the water quality certification can be considered, the State Water Board must comply with the California Environmental Quality Act (CEQA).

FWS submitted a letter to the Commission dated December 17, 2009, stating that the BO issued on October 24, 2004, expired, and there is no authorized incidental take for Shasta crayfish for the Project. FWS also stated that flushing flows are likely resulting in take, and are facilitating the decline of the endangered Shasta crayfish in the Pit 1 Bypass Reach.

In a letter dated April 15, 2010, Commission staff submitted a letter to the State Water Board requesting a temporary suspension of the flushing flows for 2010. The Commission's letter recognized that the Commission cannot unilaterally amend a water quality certification condition.

While the flushing flows provide an incidental whitewater recreational opportunity, a precautionary approach to endangered species protection is warranted, and the State Water Board determined it would be reasonable to temporarily suspend flushing flows for 2010 and 2011 while the CEQA process is completed for a permanent suspension of these flows. The State Water Board and PG&E entered into a Memorandum of Understanding (MOU) for the preparation of environmental documents, which was executed on July 7, 2011.

3.0 2012 REQUEST

In a letter dated March 22, 2012, PG&E requested that the State Water Board's order temporarily suspending flushing flows be extended through 2012 because PG&E has not completed the studies needed to properly evaluate the impacts of permanently suspending flushing flows. PG&E proposes that a one-year time extension would be sufficient to complete the studies. FWS staff supported PG&E's request for this extension in an email dated March 27, 2012. On April 25, 2012, State Water Board staff noticed PG&E's request to extend the temporary suspension of flushing flows and the State Water Board's intention to take action no sooner than 21 days thereafter. No comments were received during this period.

Because a potential for a significant environmental impact exists if flushing flows are permanently suspended, the State Water Board cannot amend the Project's water quality certification without subjecting the proposal to a CEQA analysis. If the requirement for flushing flows is suspended for a limited period, with continued monitoring of effects until a full CEQA analysis can be completed, significant impacts can be avoided. The State Water Board has determined the temporary suspension of flushing flows for one additional year will not have a significant adverse environmental effect and is categorically exempt from the requirements to prepare environmental documents under California Code of Regulations section 15307 (Actions by Regulatory Agencies for Protection of Natural Resources). A Notice of Exemption will be filed within five days from issuance of this action.

This temporary amendment to the water quality certification shall be dependent on PG&E's timely completion of the required CEQA documentation (pursuant to the most recently executed MOU) to determine the potential for significant impacts from the permanent elimination of the required flushing flows. PG&E shall also continue to conduct sufficient studies to evaluate the potential for flushing flows to cause a "take" in violation of either the Federal or California Endangered Species Acts.

ORDER

IT IS HEREBY ORDERED THAT:

1. PG&E shall continue the suspension of flushing flows through the 2012 calendar year.
2. PG&E shall continue monitoring the effectiveness of the higher base flows at controlling aquatic vegetation and mosquito production in Fall River Pond consistent with the procedures in the Flushing Flow Effectiveness Monitoring Plan.
3. PG&E shall implement and complete all studies required by the State Water Board for its CEQA analysis.
4. PG&E shall provide the FWS with any information that is in PG&E's possession that is required for the completion of an updated BO for the Project.

6/14/2012
Date

Thomas Howard
Thomas Howard
Executive Director

Sha:

APPENDIX B

FERC Project No. 2687 License Articles and California State Water Resources Control Board Conditions

FERC Project No. 2687 License Articles related to the flow and water quality

Article 401.

(a) Requirement to File Plans for Commission Approval.

The State Water Resource Control Board's (California Water Board) water quality certification requires the licensee to comply with terms and conditions and provide funding for measures contained in earlier agreements, without specifying that plans be developed and approved before implementing the measures; to develop plans and implement programs, without prior Commission approval; and report the results of monitoring studies, without submitting the reports to the Commission for approval. Each such plan and report shall also be submitted to the Commission for approval. These plans and reports are listed below.

California Water Board Condition No. (Appendix)	Plan/Report Name	Due Date from License Issuance
7	Water Supply Inlet or Well Water Supply	Unspecified
13	Flushing Flow Ramping	Unspecified
14	Flushing Flow Effectiveness Monitoring	Unspecified
16	Water Quality Monitoring	within 6 months of license issuance
17	Results of Water Quality Monitoring	by December 31 of each year
18	Eagle and Fish Monitoring	Unspecified

The licensee shall submit to the Commission documentation of its consultation with the California Water Board, copies of comments and recommendations made in connection with the plan or report, and a description of how the plan or report accommodates the comments and recommendations. If the licensee does not adopt a recommendation, the filing shall include the licensee's reasons, based on project-specific information. The Commission reserves the right to make changes to the plan or report. Upon Commission approval, the plan or report becomes a requirement of the license, and the licensee shall implement the plan or report or changes in project operations or facilities, including any changes required by the Commission.

(b) Requirement to File Documentation of Completion.

The licensee shall also file with the Commission documentation of completion, including as-built drawings as appropriate, of the following facilities or activities.

California Water Board Condition No. (Appendix)	Plan/Report Name	Due Date from License Issuance
7	**Water Supply Inlet or Well Water Supply**	**Unspecified**

(c) Requirement to File Amendment Applications.

Certain conditions in the Appendix contemplate unspecified long-term changes to project operations or facilities for the purpose of mitigating environmental impacts. These changes may not be implemented without prior Commission authorization granted after the filing of an application to amend the license. These conditions are listed below.

California Water Board Condition No. (Appendix)	Modification
17	Changes to required minimum flows to protect state beneficial uses
18	Operational changes to mitigate impacts to bald eagles or fish populations

Article 402.

The licensee shall operate the project to provide flows through the Pit 1 powerhouse to the project tailrace such that the total instantaneous flow in the Pit River downstream of the project tailrace is a minimum of 700 cubic feet per second, or greater, as measured at the U.S. Geological Survey gage 11-3550.10, located downstream of the tailrace, for the protection and enhancement of aquatic habitat in the Pit River, including the California floater (mussel) and montane peaclam, both federally-listed species of special concern, and resident fish.

Flows through the powerhouse may be temporarily modified if required by operating emergencies beyond the control of the licensee, and for short periods upon mutual agreement among the licensee, the California State Water Resources Control Board, the California Department of Fish and Game, and the U.S. Fish and Wildlife Service. If the flow is so modified, the licensee shall notify the Commission as soon as possible, but no later than 10 days after each such incident, and shall provide the reason for the modified flow.

Article 403 (in part).

Within 6 months of license issuance, the licensee shall file with the Commission, for approval, a plan to monitor flows below the Fall River Pond weir, flows in the Pit River downstream of the project tailrace, and ramping rates at the powerhouse to document compliance with the minimum flows required by California Water Board Conditions 8 and 13.

California State Water Resources Control Board
Water Quality Certificate Conditions

8. The Licensee shall make continuous flow releases from the Pit 1 Forebay into the Lower Fall River thence the Pit River and maintain the following instantaneous flows downstream of the Fall River Pond as measured at the Fall River Weir:

Dates	Required Flow (cfs)
Nov 1 through Nov 15	75
Nov 16 through May 15	50
May 16 through May 31	75
June 1 through Oct 31	150

Due to the combination of physical constraints imposed by the release facilities at the Pit 1 Forebay, the Licensee is granted an allowable deviation of minus 10% flow variability in the instantaneous release requirements. This will allow daily flows to vary occasionally below the required 50-150 cfs instantaneous flow requirement. However, the monthly average daily flow shall meet or exceed the minimum flow requirement. At no time shall the Licensee intentionally release less than the proposed flow except for public safety or other emergencies.

12. As a matter of public safety, the Licensee shall implement operating procedures that limit the generator-loading rate to a maximum of 2 MW/min. This equates to a loading period of approximately 32 minutes.

To reduce the potential for stranding aquatic organisms the Licensee shall implement operating procedures that limit generator-unloading rate to approximately 0.5 MW/min. This equates to an unloading period of approximately 120 minutes.

These proposed loading rates will apply during the periods of normal powerhouse operations. Unplanned conditions such as mechanical or electrical failures may occasionally result in a rate of change other than those proposed.

13. The Licensee shall control growth of aquatic vegetation and mosquito production in the Fall River Pond by releasing a continuous minimum fish/aquatic habitat release as described in Condition 8 and by releasing flushing flows through Fall River Pond for two consecutive days (Saturday and Sunday) three times per year. Flushing flows are defined as 1,250 cfs or the natural flow to the Pit 1 Forebay, whichever is less. The flushing flow will be released in May or June when warranted by vegetation growth in the Fall River Pond. The second flushing flow will be released in July, and the third flushing flow will be released at the end of August, prior to the Labor Day weekend. The releases will be made from approximately 2 a.m. Saturday morning and continue until approximately 3 p.m. the following Sunday afternoon and then be ramped down over a period of time. PG&E shall develop a vegetation flushing flow ramping plan in consultation with the Department of Fish and Game and the

California Water Board and obtain written approval of the plan by the Chief of the Division of Water Rights. The Licensee shall implement the flushing program as soon as practicable after issuance of the new license.

The Licensee shall provide as much advanced public notice as possible of a proposed flushing flow release but no less than 48 hours through a boat-a-phone or existing PG&E website.

14. The Licensee shall monitor the effectiveness of releasing flushing flows to control aquatic vegetation and mosquito production in Fall River Pond. The initial monitoring shall be for 5 years after the issuance of the new license. The Licensee shall develop a vegetation flushing monitoring program in consultation with the Fall River Mills Community Services District, Fall River Chamber of Commerce, the Pine Grove Mosquito Abatement District, and the Department of Fish and Game, and obtain written approval of the program by the Chief of the Division of Water Rights. The Chief of the Division of Water Rights may modify or terminate the flushing flow monitoring program after review of the 5-year monitoring report prepared by the licensee.

16. The Licensee shall prepare a water quality monitoring plan to be submitted to the Chief of the Division of Water Rights for written approval within 6 months of the issuance of the FERC license and shall implement the water quality monitoring plan in the first full summer monitoring season following approval of the monitoring plan. The water quality monitoring program shall be instituted for a term of no less than 5 years. The monitoring shall be used to determine the benefits/effects on water quality of the proposed flow releases outlined in terms 8 and 13. The monitoring shall include but not be limited to water temperature and dissolved oxygen (DO).

Water quality shall be monitored at eight locations:

- Fall River just downstream of Pit 1 Forebay
- Fall River Pond
- Lower Fall River just downstream of Fall River Pond
- Pit River at McArthur
- Pit River just downstream of Big Eddy
- Pit River just below Pit River Falls
- Pit River at the footbridge upstream of the Pit 1 powerhouse
- Pit River downstream of the Pit 1 powerhouse

Water quality shall be monitored from May 16 to October 31 of each year. Water temperature will be monitored continuously at each of the monitoring locations. The Licensee should use redundant temperature recorders to avoid a loss of temperature data. DO, pH, turbidity, and conductivity will be sampled twice per month. Sampling methods and analyses will be as described in the water quality monitoring plan.

To monitor seasonal and short-term changes in flow, which can affect temperature and water quality, flow shall be measured continuously during the monitoring period with pressure transducers installed at the lower end of Big Eddy and at the footbridge upstream of the Pit 1 powerhouse. The transducers will be calibrated against staff gage readings and periodic flow measurements at each location. These flow measuring sites shall be maintained for the term of the water quality monitoring program and are not intended to meet the rigorous requirements established by the USGS for USGS gages. Compliance with stream flow requirements will be monitored using USGS approved methods at a gage that will be constructed at the Fall River Weir.

The water quality data collected above will be supplemented with meteorological data collected at the Pit 1 Forebay and Pit 3 Intake.

17. The Licensee shall provide the Chief of the Division of Water Rights the results of the water quality monitoring program by December 31 of each year. At the end of the 5th year of monitoring, the Licensee shall provide the Chief of the Division of Water Rights a report summarizing the 5 years of water quality monitoring. The Licensee shall meet with the Chief of the Division of Water Rights or a designated representative within 60 days of the submittal of the summary report. The purpose of the meeting will be to review the monitoring results and to determine if the beneficial uses identified in the Basin Plan for the Pit River are reasonably protected. Reasonable protection of beneficial uses shall be measured by and limited to factors controllable by and related to the Pit 1 Hydroelectric Project operations in the lower Fall River below the Pit 1 Forebay and the Pit River and from the confluence with the Fall River to the confluence with the Pit 1 tailrace. The Chief of the Division of Water Rights in writing may modify or terminate the water quality monitoring program after review of the 5-year monitoring report prepared by the Licensee.

    If, based on the water quality data, the initial streamflow releases are not reasonably protective of the beneficial uses of the Fall River and Pit River as identified in the Basin Plan, the California Water Board reserves the authority to require the Licensee to make additional flow releases or other actions as required to protect the beneficial uses identified in the Basin Plan.

    If the Chief of the Division of Water Rights determines that additional flow releases are necessary to protect water quality within the diverted reach of the Fall and Pit River they shall be adaptively implemented in increments of 50 cfs and limited to the period in which the beneficial uses are affected. The 50 cfs shall be in addition to the initial flow requirements identified in condition 8. Water quality based on the new flow release schedule shall be monitored for three years.

    The results of the additional three years of monitoring shall be summarized and submitted to the Chief of the Division of Water Rights by December 31 of the year in which the third year of monitoring is completed. The Licensee can request to meet with the Chief of the Division of Water Rights or designated representative to discuss the monitoring results to determine if the beneficial uses of the Pit River are reasonably protected as described above.

If, at the end of first three year adaptive water quality management period, the Chief of the Division of Water Rights determines in writing that water quality in the Pit River is still not being reasonably protected for any season or part of the season, the Licensee shall release an additional 50 cfs from Fall River Weir in addition to the existing adaptive flow releases. The new flow schedule shall be monitored for three years. If at the end of the second three year adaptive water quality management period, the Chief of the Division of Water Rights determines in writing that water quality in the Pit River is still not being reasonably protected for any season or part of the season, the Licensee shall release an additional 50 cfs from Fall River Pond in addition to the existing adaptive flow releases. This adaptive approach to protecting water quality shall continue until the water quality flow releases have reached the following limits:

- The final adaptive water quality instantaneous flow releases shall not exceed a maximum of 200 cfs for the May 16 to May 31 period;
- The final adaptive water quality instantaneous flow releases shall not exceed a maximum release of 400 cfs for the June 1 to October 31 period;
- The instream flow release for November 1 to November 15 shall not exceed a maximum of 150 cfs; and the November 16 to April 30th period releases shall remain 50 cfs for the life of the new license.

APPENDIX C

REGIONAL METEOROLOGY DATA

Table C-1. Summer Air Temperature Rankings for Period of Record from NWS Station at Hat Creek Powerhouse No. 1 (June-July).

June						July				
Year	°C	Rank	Exceedance[1]	Index		Year	°C	Rank	Exceedance[1]	Index
1921	18.7	82%	18%	Abv Norm		1921	21.8	77%	23%	Abv Norm
1922	19.5	94%	6%	Hot		1922	22.2	85%	15%	Abv Norm
1923	15.7	13%	87%	Blw Norm		1923	20.8	53%	47%	Norm
1927	18.2	77%	23%	Abv Norm		1926	22.6	94%	6%	Hot
1928	17.6	55%	45%	Norm		1927	21.2	66%	35%	Norm
1929	16.6	32%	68%	Norm		1928	22.6	97%	4%	Hot
1930	17.7	61%	39%	Norm		1929	20.7	46%	54%	Norm
1931	17.9	69%	31%	Norm		1930	20.4	37%	63%	Norm
1932	19.8	96%	4%	Hot		1931	23.5	100%	0%	Hot
1933	17.8	65%	35%	Norm		1932	20.2	29%	71%	Blw Norm
1934	17.7	63%	37%	Norm		1933	22.5	91%	9%	Hot
1935	19.0	89%	11%	Abv Norm		1934	20.6	43%	58%	Norm
1936	17.6	56%	44%	Norm		1935	20.3	33%	67%	Norm
1937	18.0	73%	27%	Abv Norm		1936	21.5	72%	28%	Abv Norm
1938	19.7	95%	5%	Hot		1937	22.3	86%	14%	Abv Norm
1939	17.4	52%	48%	Norm		1938	22.8	98%	2%	Hot
1940	21.0	100%	0%	Hot		1939	22.1	83%	17%	Abv Norm
1941	16.7	40%	60%	Norm		1940	20.2	30%	70%	Blw Norm
1942	17.0	48%	52%	Norm		1941	21.9	79%	21%	Abv Norm
1943	15.5	8%	92%	Cold		1942	21.3	70%	30%	Abv Norm
1944	15.8	14%	86%	Blw Norm		1943	21.0	59%	41%	Norm
1945	17.9	70%	30%	Abv Norm		1944	21.2	64%	36%	Norm
1946	16.5	31%	69%	Norm		1945	22.5	92%	8%	Hot
1947	16.0	18%	82%	Blw Norm		1946	21.9	82%	18%	Abv Norm
1949	18.0	73%	27%	Abv Norm		1947	18.6	7%	93%	Cold
1950	17.2	51%	49%	Norm		1948	19.6	20%	81%	Blw Norm

June					July				
Year	°C	Rank	Exceedance[1]	Index	Year	°C	Rank	Exceedance[1]	Index
1951	18.6	81%	19%	Abv Norm	1949	21.2	68%	32%	Norm
1952	15.4	5%	95%	Cold	1950	22.3	89%	12%	Abv Norm
1953	14.2	1%	99%	Cold	1951	20.3	32%	68%	Norm
1954	15.8	15%	85%	Blw Norm	1952	22.6	95%	5%	Hot
1955	16.5	30%	70%	Blw Norm	1953	20.3	34%	66%	Norm
1956	16.6	33%	67%	Norm	1954	20.1	25%	75%	Blw Norm
1957	18.0	75%	25%	Abv Norm	1955	18.2	5%	96%	Cold
1958	16.5	27%	73%	Blw Norm	1956	20.9	57%	43%	Norm
1959	17.8	65%	35%	Norm	1957	19.1	10%	90%	Blw Norm
1960	19.2	90%	10%	Hot	1958	20.6	45%	55%	Norm
1961	18.8	87%	13%	Abv Norm	1959	20.8	55%	45%	Norm
1962	16.4	26%	74%	Blw Norm	1960	21.9	80%	20%	Abv Norm
1963	16.3	20%	80%	Blw Norm	1961	20.7	47%	53%	Norm
1964	15.5	6%	94%	Cold	1962	19.5	15%	85%	Blw Norm
1965	16.3	23%	77%	Blw Norm	1963	17.6	0%	100%	Cold
1966	15.9	17%	83%	Blw Norm	1964	19.9	23%	77%	Blw Norm
1967	16.7	38%	62%	Norm	1965	19.6	18%	82%	Blw Norm
1968	17.1	49%	51%	Norm	1966	17.8	1%	99%	Cold
1969	17.1	50%	50%	Norm	1967	21.0	62%	38%	Norm
1970	17.7	60%	41%	Norm	1968	20.6	44%	56%	Norm
1971	15.6	11%	89%	Blw Norm	1969	20.2	28%	73%	Blw Norm
1972	18.1	76%	24%	Abv Norm	1970	20.3	31%	69%	Norm
1973	17.5	54%	47%	Norm	1971	20.5	39%	61%	Norm
1974	17.7	63%	37%	Norm	1972	20.8	56%	44%	Norm
1975	16.8	43%	57%	Norm	1973	21.0	61%	39%	Norm
1976	15.7	12%	88%	Blw Norm	1974	19.4	14%	86%	Blw Norm
1977	20.4	99%	1%	Hot	1975	19.8	22%	78%	Blw Norm
1978	17.0	46%	54%	Norm	1976	21.2	67%	33%	Norm
1979	17.6	57%	43%	Norm	1977	21.1	63%	37%	Norm
1980	14.7	2%	98%	Cold	1978	21.3	71%	29%	Abv Norm
1981	18.8	86%	14%	Abv Norm	1979	20.4	36%	64%	Norm
1983	17.0	45%	55%	Norm	1980	20.7	48%	52%	Norm

June				
Year	**°C**	**Rank**	**Exceedance**[1]	**Index**
1984	16.4	24%	76%	Blw Norm
1985	20.0	98%	2%	Hot
1986	19.5	93%	7%	Hot
1987	19.3	92%	8%	Hot
1988	17.9	68%	32%	Norm
1989	18.7	83%	17%	Abv Norm
1990	16.7	38%	62%	Norm
1991	16.4	25%	75%	Blw Norm
1992	18.5	79%	22%	Abv Norm
1993	16.3	21%	79%	Blw Norm
1994	16.6	35%	66%	Norm
1995	15.5	7%	93%	Cold
1997	16.7	37%	63%	Norm
1998	16.1	19%	81%	Blw Norm
1999	15.6	10%	91%	Cold
2000	18.5	80%	20%	Abv Norm
2001	16.7	42%	58%	Norm
2002	17.7	61%	39%	Norm
2003	19.0	88%	12%	Abv Norm
2004	18.0	71%	29%	Abv Norm
2005	13.8	0%	100%	Cold
2006	18.8	85%	16%	Abv Norm
2007	17.6	58%	42%	Norm
2008	16.7	36%	64%	Norm
2009	16.8	43%	57%	Norm
2010	15.4	4%	97%	Cold
2011	16.5	29%	72%	Blw Norm

July				
Year	**°C**	**Rank**	**Exceedance**[1]	**Index**
1981	20.6	40%	60%	Norm
1982	19.4	13%	87%	Blw Norm
1983	18.0	3%	97%	Cold
1984	22.4	90%	10%	Abv Norm
1985	22.1	84%	16%	Abv Norm
1986	19.9	23%	77%	Blw Norm
1987	18.8	9%	91%	Cold
1988	23.3	99%	1%	Hot
1989	19.5	16%	84%	Blw Norm
1990	21.8	76%	24%	Abv Norm
1991	22.3	86%	14%	Abv Norm
1992	20.2	26%	74%	Blw Norm
1993	18.5	6%	94%	Cold
1994	22.5	92%	8%	Hot
1995	19.7	21%	79%	Blw Norm
1997	19.4	11%	89%	Blw Norm
1998	21.0	60%	40%	Norm
1999	17.9	2%	98%	Cold
2000	18.8	8%	92%	Cold
2001	20.4	38%	62%	Norm
2002	21.8	77%	23%	Abv Norm
2003	21.8	74%	27%	Abv Norm
2004	20.7	51%	50%	Norm
2005	21.8	75%	25%	Abv Norm
2006	21.3	69%	31%	Norm
2007	19.5	17%	83%	Blw Norm
2008	20.8	54%	46%	Norm
2009	20.7	48%	52%	Norm
2010	20.7	52%	48%	Norm
2011	20.6	41%	59%	Norm

1 Exceedance is defined as the percent of total observations that have exceeded this value in the period of record .

Table C-2. Summer Air Temperature Rankings for Period of Record from NWS Station at Hat Creek Powerhouse No. 1 (August-September).

August					September				
Year	°C	Rank	Exceedance[1]	Index	Year	°C	Rank	Exceedance[1]	Index
1921	20.4	71%	30%	Abv Norm	1921	16.9	63%	37%	Norm
1922	19.9	56%	44%	Norm	1922	17.6	84%	16%	Abv Norm
1923	21.5	91%	10%	Hot	1923	19.9	100%	0%	Hot
1926	20.0	60%	40%	Norm	1926	14.3	11%	89%	Blw Norm
1927	19.5	46%	54%	Norm	1927	14.7	15%	85%	Blw Norm
1928	20.5	73%	27%	Abv Norm	1928	16.4	47%	53%	Norm
1929	20.8	79%	21%	Abv Norm	1929	15.5	30%	70%	Blw Norm
1930	19.1	29%	71%	Blw Norm	1930	15.8	38%	62%	Norm
1931	21.8	100%	0%	Hot	1931	16.1	40%	60%	Norm
1932	20.2	67%	33%	Norm	1932	18.9	97%	4%	Hot
1933	21.1	88%	12%	Abv Norm	1933	15.6	34%	66%	Norm
1934	21.5	92%	8%	Hot	1934	17.6	83%	17%	Abv Norm
1935	21.0	84%	17%	Abv Norm	1935	18.1	94%	6%	Hot
1936	21.1	86%	14%	Abv Norm	1936	16.8	61%	39%	Norm
1937	20.2	65%	35%	Norm	1937	17.2	69%	31%	Norm
1938	20.2	62%	38%	Norm	1938	17.6	80%	20%	Abv Norm
1939	21.6	96%	4%	Hot	1939	17.5	75%	25%	Abv Norm
1940	21.6	95%	5%	Hot	1940	15.6	33%	67%	Norm
1941	19.3	38%	62%	Norm	1941	14.6	14%	86%	Blw Norm
1942	20.6	74%	26%	Abv Norm	1942	16.6	53%	47%	Norm
1943	18.3	11%	90%	Blw Norm	1943	18.9	98%	2%	Hot
1944	19.6	47%	53%	Norm	1944	18.1	95%	5%	Hot
1945	20.3	68%	32%	Norm	1945	17.5	77%	23%	Abv Norm
1946	21.0	85%	15%	Abv Norm	1946	16.0	39%	61%	Norm
1947	18.2	8%	92%	Cold	1947	16.9	66%	35%	Norm
1948	18.6	18%	82%	Blw Norm	1948	15.7	36%	64%	Norm

August					September				
Year	**°C**	**Rank**	**Exceedance**[1]	**Index**	**Year**	**°C**	**Rank**	**Exceedance**[1]	**Index**
1949	18.6	19%	81%	Blw Norm	1949	17.6	85%	15%	Abv Norm
1950	20.5	72%	28%	Abv Norm	1950	16.7	55%	45%	Norm
1951	20.2	66%	34%	Norm	1951	17.6	82%	18%	Abv Norm
1952	19.4	44%	57%	Norm	1952	17.6	87%	13%	Abv Norm
1953	18.5	15%	85%	Blw Norm	1953	18.0	92%	8%	Hot
1954	17.6	4%	97%	Cold	1954	14.0	3%	97%	Cold
1955	19.3	42%	58%	Norm	1955	14.8	17%	83%	Blw Norm
1956	18.1	7%	93%	Cold	1956	14.8	20%	81%	Blw Norm
1957	16.5	0%	100%	Cold	1957	15.5	28%	73%	Blw Norm
1958	21.7	98%	2%	Hot	1958	15.5	32%	68%	Norm
1959	18.4	12%	88%	Blw Norm	1959	14.3	10%	90%	Blw Norm
1960	19.2	36%	64%	Norm	1960	16.5	51%	50%	Norm
1961	20.2	64%	37%	Norm	1961	13.7	1%	99%	Cold
1962	18.7	20%	80%	Blw Norm	1962	16.7	54%	46%	Norm
1963	17.9	5%	95%	Cold	1963	16.8	62%	38%	Norm
1964	19.2	32%	68%	Norm	1964	14.2	8%	92%	Cold
1966	20.3	69%	31%	Norm	1965	13.9	2%	98%	Cold
1967	21.6	94%	6%	Hot	1966	16.2	43%	58%	Norm
1968	17.1	2%	98%	Cold	1967	17.6	86%	14%	Abv Norm
1969	18.8	24%	77%	Blw Norm	1968	15.5	28%	73%	Blw Norm
1970	19.2	33%	67%	Norm	1969	16.8	59%	41%	Norm
1971	20.7	78%	22%	Abv Norm	1970	14.9	21%	79%	Blw Norm
1972	19.6	51%	50%	Norm	1971	14.3	9%	91%	Cold
1973	19.1	26%	74%	Blw Norm	1972	14.1	5%	96%	Cold
1974	19.8	53%	47%	Norm	1973	15.5	31%	69%	Norm
1975	18.5	14%	86%	Blw Norm	1974	17.3	72%	28%	Abv Norm
1976	17.0	1%	99%	Cold	1975	18.1	93%	7%	Hot
1977	21.7	99%	1%	Hot	1976	17.1	68%	32%	Norm
1978	20.6	75%	25%	Abv Norm	1977	15.7	37%	63%	Norm
1979	18.3	9%	91%	Cold	1978	14.7	16%	84%	Blw Norm
1980	19.6	49%	51%	Norm	1979	17.5	77%	23%	Abv Norm
1981	21.1	87%	13%	Abv Norm	1980	16.7	57%	43%	Norm

August						September				
Year	°C	Rank	Exceedance[1]	Index		Year	°C	Rank	Exceedance[1]	Index
1982	19.6	47%	53%	Norm		1981	17.7	89%	12%	Abv Norm
1983	19.3	41%	59%	Norm		1982	15.3	24%	76%	Blw Norm
1984	20.6	76%	24%	Abv Norm		1983	17.1	67%	33%	Norm
1985	19.0	25%	75%	Blw Norm		1984	16.9	64%	36%	Norm
1986	21.4	89%	11%	Abv Norm		1985	14.2	7%	93%	Cold
1987	20.8	80%	20%	Abv Norm		1986	14.1	6%	94%	Cold
1988	21.6	93%	7%	Hot		1987	17.5	79%	21%	Abv Norm
1990	20.0	60%	40%	Norm		1988	17.3	71%	29%	Abv Norm
1991	19.9	59%	41%	Norm		1989	16.5	49%	51%	Norm
1992	20.8	81%	19%	Abv Norm		1990	16.8	59%	41%	Norm
1993	19.1	28%	72%	Blw Norm		1991	18.9	99%	1%	Hot
1994	19.2	34%	66%	Norm		1992	16.3	44%	56%	Norm
1995	19.9	58%	42%	Norm		1993	16.6	52%	48%	Norm
1997	18.6	16%	84%	Blw Norm		1994	16.7	55%	45%	Norm
1998	19.7	52%	48%	Norm		1995	17.8	90%	10%	Abv Norm
1999	17.9	6%	94%	Cold		1997	15.4	26%	74%	Blw Norm
2000	19.3	38%	62%	Norm		1998	17.9	91%	9%	Hot
2001	19.5	45%	55%	Norm		1999	16.5	48%	52%	Norm
2002	19.1	29%	71%	Blw Norm		2000	14.8	18%	82%	Blw Norm
2003	18.7	21%	79%	Blw Norm		2001	16.4	45%	55%	Norm
2004	19.3	40%	60%	Norm		2002	16.2	41%	59%	Norm
2005	19.8	55%	45%	Norm		2003	17.2	70%	30%	Abv Norm
2006	18.4	13%	87%	Blw Norm		2004	15.0	22%	78%	Blw Norm
2007	19.2	34%	66%	Norm		2005	13.3	0%	100%	Cold
2008	20.9	82%	18%	Abv Norm		2006	15.1	23%	77%	Blw Norm
2009	19.1	26%	74%	Blw Norm		2007	14.3	13%	87%	Blw Norm
2010	18.8	22%	78%	Blw Norm		2008	16.4	46%	54%	Norm
2011	19.8	54%	46%	Norm		2009	17.5	76%	24%	Abv Norm
						2010	15.4	25%	75%	Blw Norm
						2011	17.4	74%	27%	Abv Norm

1 Exceedance is defined as the percent of total observations that have exceeded this value in the period of record .

APPENDIX D

REGIONAL HYDROLOGY DATA

Table D-1. Mean daily stream flow from USGS Station 11-355010 - Pit River downstream of Pit 1 Powerhouse.

Water-Data Report 2011 11355010 Pit River below Pit No. 1 Power plant, near Fall River Mills, CA
DISCHARGE, CUBIC FEET PER SECOND WATER YEAR OCTOBER 2010 TO SEPTEMBER 2011 MEAN DAILY VALUES
[e, estimated]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	1,070	1,160	1,210	2,070	1,360	1,400	2,870	4,580	2,930	1,650	1,100	1,130
2	1,070	1,100	1,260	1,760	1,370	1,780	2,880	4,150	2,800	1,580	1,170	1,290
3	988	1,220	1,210	1,870	1,530	2,390	2,890	3,760	2,760	1,380	1,180	997
4	1,120	1,160	1,330	e1,830	1,220	2,730	2,810	3,400	2,750	1,240	1,220	1,040
5	977	1,240	1,240	e1,830	1,230	2,590	2,850	3,070	2,590	1,380	1,210	1,070
6	1,030	1,330	1,340	1,730	1,280	3,010	2,680	2,930	2,390	1,370	1,150	1,120
7	1,040	1,030	1,630	1,540	1,320	3,900	2,690	2,560	2,590	1,350	1,100	1,090
8	1,110	1,060	1,750	1,570	1,440	4,290	2,830	2,540	2,560	1,360	1,100	1,090
9	1,080	1,270	1,690	1,460	1,600	4,610	2,730	2,780	2,590	1,320	1,110	1,060
10	1,160	1,210	1,740	e1,550	1,610	4,290	2,610	2,990	2,650	1,150	1,140	1,080
11	1,070	1,240	1,700	1,580	1,560	4,210	2,480	3,040	2,600	1,220	1,180	1,090
12	1,100	1,320	1,750	1,490	1,460	4,250	2,460	2,950	2,510	1,290	1,270	1,090
13	1,080	1,240	1,710	1,530	1,330	4,020	2,040	2,990	2,580	1,290	1,140	1,100
14	1,090	1,190	1,790	1,380	1,170	3,680	2,520	2,710	2,550	1,260	1,110	1,170
15	1,100	1,250	1,850	1,350	1,000	3,600	2,280	2,700	2,600	1,230	1,100	1,190
16	1,100	1,220	1,860	1,210	1,620	5,270	2,160	2,700	2,510	1,210	1,110	1,160
17	1,090	1,150	1,930	1,830	1,790	6,120	1,660	2,840	2,370	1,160	1,180	1,120
18	946	1,250	1,840	2,300	1,840	6,780	1,890	2,980	2,150	1,120	1,140	1,170
19	950	1,260	1,920	2,580	1,600	6,160	2,910	3,030	2,010	1,180	1,170	1,180
20	1,140	1,230	2,070	2,740	1,440	5,120	4,230	2,910	2,020	1,060	1,120	1,140
21	1,190	1,250	2,380	2,670	1,380	4,350	5,020	2,910	2,230	1,230	1,120	1,130
22	1,190	1,190	2,180	2,400	1,370	3,720	5,810	2,830	2,000	1,190	1,080	1,250
23	1,200	1,340	2,280	2,140	1,660	3,480	6,110	2,780	2,010	1,190	1,120	1,110
24	1,070	1,320	2,070	2,030	1,650	3,260	6,660	2,760	1,800	1,110	1,100	1,140
25	1,170	1,300	1,880	1,880	1,620	3,190	6,860	2,730	1,680	1,090	1,160	1,120
26	1,150	1,240	1,820	1,830	1,620	3,070	7,060	3,040	1,530	1,130	1,140	1,150
27	1,170	1,320	1,950	1,790	1,370	3,080	6,840	2,820	1,670	1,200	1,150	1,160
28	1,200	1,220	2,080	1,790	1,350	3,130	6,140	2,960	1,810	1,170	1,090	1,120
29	1,200	e1,200	2,370	1,660	---	3,120	5,570	3,070	1,660	1,190	1,100	1,150
30	1,150	1,310	2,410	1,600	---	3,030	5,060	2,960	1,710	1,200	1,140	994
31	1,150	---	2,210	1,560	---	2,800	---	2,870	---	1,090	1,060	---
Total	34,151	36,820	56,450	56,550	40,790	116,430	113,600	93,340	68,610	38,590	35,260	33,701
Mean	1,102	1,227	1,821	1,824	1,457	3,756	3,787	3,011	2,287	1,245	1,137	1,123
Max	1,200	1,340	2,410	2,740	1,840	6,780	7,060	4,580	2,930	1,650	1,270	1,290
Min	946	1,030	1,210	1,210	1,000	1,400	1,660	2,540	1,530	1,060	1,060	994
Ac-ft	67,740	73,030	112,000	112,200	80,910	230,900	225,300	185,100	136,100	76,540	69,940	66,850

Table D-2. Monthly ranking of stream flow from USGS Station 11-355010 - Pit River downstream of Pit 1 Powerhouse (May, June, and July).

Year	May				June				July			
	cfs	Rank	Exceedance[1]	Index	cfs	Rank	Exceedance[1]	Index	cfs	Rank	Exceedance[1]	Index
1975	--	--	--	--	--	--	--	--	--	--	--	--
1976	1,604	47%	53%	Norm	1,374	47%	53%	Norm	1,308	65%	35%	Norm
1977	1,403	12%	88%	Blw Norm	1,266	26%	74%	Blw Norm	1,213	44%	56%	Norm
1978	2,226	62%	38%	Norm	1,310	41%	59%	Norm	1,273	56%	44%	Norm
1979	1,845	56%	44%	Norm	1,212	15%	85%	Blw Norm	1,186	35%	65%	Norm
1980	2,223	59%	41%	Norm	1,592	68%	32%	Norm	1,275	59%	41%	Norm
1981	1,417	21%	80%	Blw Norm	1,233	18%	82%	Blw Norm	1,131	21%	80%	Blw Norm
1982	2,702	76%	24%	Abv Norm	1,729	82%	18%	Abv Norm	1,555	91%	9%	Wet
1983	3,861	91%	9%	Wet	2,789	97%	3%	Wet	1,666	97%	3%	Wet
1984	2,715	79%	21%	Abv Norm	2,195	88%	12%	Abv Norm	1,465	82%	18%	Abv Norm
1985	1,522	38%	62%	Norm	1,452	56%	44%	Norm	1,347	68%	32%	Norm
1986	2,522	71%	30%	Abv Norm	1,645	71%	30%	Abv Norm	1,517	88%	12%	Abv Norm
1987	1,415	18%	82%	Blw Norm	1,332	44%	56%	Norm	1,261	53%	47%	Norm
1988	1,483	32%	68%	Norm	1,286	35%	65%	Norm	1,167	32%	68%	Norm
1989	1,530	44%	56%	Norm	1,248	21%	80%	Blw Norm	1,150	26%	74%	Blw Norm
1990	1,246	3%	97%	Dry	1,463	59%	41%	Norm	1,102	18%	82%	Blw Norm
1991	2,264	65%	35%	Norm	1,280	32%	68%	Norm	1,190	38%	62%	Norm
1992	1,050	0%	100%	Dry	1,012	0%	100%	Dry	1,004	3%	97%	Dry
1993	2,413	68%	32%	Norm	2,242	91%	9%	Wet	1,276	62%	38%	Norm
1994	1,411	15%	85%	Blw Norm	1,152	6%	94%	Dry	954	0%	100%	Dry
1995	6,883	100%	0%	Wet	2,452	94%	6%	Wet	1,619	94%	6%	Wet
1996	2,680	74%	27%	Abv Norm	1,679	76%	24%	Abv Norm	1,370	71%	30%	Abv Norm
1997	1,838	53%	47%	Norm	1,568	65%	35%	Norm	1,400	76%	24%	Abv Norm
1998	5,746	97%	3%	Wet	4,582	100%	0%	Wet	1,809	100%	0%	Wet
1999	2,832	82%	18%	Abv Norm	1,971	85%	15%	Abv Norm	1,506	85%	15%	Abv Norm

Year	May				June				July			
	cfs	Rank	Exceedance[1]	Index	cfs	Rank	Exceedance[1]	Index	cfs	Rank	Exceedance[1]	Index
2000	1,786	50%	50%	Norm	1,466	62%	38%	Norm	1,425	79%	21%	Abv Norm
2001	1,426	26%	74%	Blw Norm	1,277	29%	71%	Blw Norm	1,247	50%	50%	Norm
2002	1,527	41%	59%	Norm	1,249	24%	77%	Blw Norm	1,160	29%	71%	Blw Norm
2003	3,080	85%	15%	Abv Norm	1,387	50%	50%	Norm	1,194	41%	59%	Norm
2004	1,377	9%	91%	Dry	1,194	12%	88%	Blw Norm	1,042	9%	91%	Dry
2005	4,348	94%	6%	Wet	1,720	79%	21%	Abv Norm	1,217	47%	53%	Norm
2006	3,145	88%	12%	Abv Norm	1,653	74%	27%	Abv Norm	1,371	74%	27%	Abv Norm
2007	1,251	6%	94%	Dry	1,135	3%	97%	Dry	1,073	15%	85%	Blw Norm
2008	1,515	35%	65%	Norm	1,447	53%	47%	Norm	1,137	24%	77%	Blw Norm
2009	1,436	29%	71%	Blw Norm	1,181	9%	91%	Dry	1,069	12%	88%	Blw Norm
2010	1,420	24%	77%	Blw Norm	1,296	38%	62%	Norm	1,010	6%	94%	Dry
2011	3,011	84%	16%	Abv Norm	2,287	92%	8%	Wet	1,245	50%	50%	Norm

1 Exceedance is defined as the percent of total observations that have exceeded this value in the period of record .

Table D-3. Monthly ranking of stream flow from USGS Station 11-355010 - Pit River downstream of Pit 1 Powerhouse (August and September).

	August				September					Annual Total as Average Monthly Flow			
Year	**cfs**	**Rank**	**Exceedance[1]**	**Index**	**cfs**	**Rank**	**Exceedance[1]**	**Index**		**cfs**	**Rank**	**Exceedance[1]**	**Index**
1975	1,500				1,586								
1976	1,389	83%	17%	Abv Norm	1,338	69%	32%	Norm		1618	45%	55%	Norm
1977	1,238	51%	49%	Norm	1,284	46%	54%	Norm		1382	15%	85%	Blw Norm
1978	1,278	63%	37%	Norm	1,312	60%	40%	Norm		1845	61%	39%	Norm
1979	1,187	43%	57%	Norm	1,219	37%	63%	Norm		1546	39%	61%	Norm
1980	1,220	46%	54%	Norm	1,315	63%	37%	Norm		2255	70%	30%	Norm
1981	1,134	29%	72%	Blw Norm	1,163	26%	74%	Blw Norm		1422	21%	79%	Blw Norm
1982	1,361	74%	26%	Abv Norm	1,404	74%	26%	Abv Norm		2778	91%	9%	Wet
1983	1,563	97%	3%	Wet	1,623	97%	3%	Wet		2890	94%	6%	Wet
1984	1,439	86%	14%	Abv Norm	1,539	89%	12%	Abv Norm		2446	79%	21%	Abv Norm
1985	1,368	80%	20%	Abv Norm	1,528	86%	14%	Abv Norm		1829	58%	43%	Norm
1986	1,366	77%	23%	Abv Norm	1,508	83%	17%	Abv Norm		2726	88%	12%	Abv Norm
1987	1,240	54%	46%	Norm	1,249	43%	57%	Norm		1538	36%	64%	Norm
1988	1,164	34%	66%	Norm	1,190	34%	66%	Norm		1452	24%	76%	Blw Norm
1989	1,174	40%	60%	Norm	1,221	40%	60%	Norm		1745	55%	46%	Norm
1990	1,099	23%	77%	Blw Norm	1,134	23%	77%	Blw Norm		1367	9%	91%	Dry
1991	1,118	26%	74%	Blw Norm	1,040	6%	94%	Dry		1418	18%	82%	Blw Norm
1992	977	6%	94%	Dry	1,027	3%	97%	Dry		1149	0%	100%	Dry
1993	1,220	46%	54%	Norm	1,291	51%	49%	Norm		2181	67%	33%	Norm
1994	828	0%	100%	Dry	784	0%	100%	Dry		1210	3%	97%	Dry
1995	1,359	71%	29%	Abv Norm	1,291	51%	49%	Norm		2895	97%	3%	Wet
1996	1,275	60%	40%	Norm	1,289	49%	52%	Norm		2366	76%	24%	Abv Norm
1997	1,315	69%	32%	Norm	1,387	71%	29%	Abv Norm		2365	73%	27%	Abv Norm
1998	1,618	100%	0%	Wet	1,628	100%	0%	Wet		2914	100%	0%	Wet
1999	1,493	91%	9%	Wet	1,552	91%	9%	Wet		2661	85%	15%	Abv Norm

Year	August				September					Annual Total as Average Monthly Flow			
	cfs	Rank	Exceedance[1]	Index	cfs	Rank	Exceedance[1]	Index		cfs	Rank	Exceedance[1]	Index
2000	1,471	89%	12%	Abv Norm	1,476	80%	20%	Abv Norm		1911	64%	36%	Norm
2001	1,243	57%	43%	Norm	1,293	57%	43%	Norm		1482	30%	70%	Norm
2002	1,170	37%	63%	Norm	1,185	31%	69%	Norm		1524	33%	67%	Norm
2003	888	3%	97%	Dry	1,413	77%	23%	Abv Norm		1656	48%	52%	Norm
2004	1,043	9%	92%	Dry	1,075	11%	89%	Blw Norm		1599	42%	58%	Norm
2005	1,139	31%	69%	Norm	1,181	29%	72%	Blw Norm		1686	52%	49%	Norm
2006	1,291	66%	34%	Norm	1,324	66%	34%	Norm		2646	82%	18%	Abv Norm
2007	1,047	11%	89%	Blw Norm	1,125	20%	80%	Blw Norm		1367	9%	91%	Dry
2008	1,097	20%	80%	Blw Norm	1,123	17%	83%	Blw Norm		1456	27%	73%	Blw Norm
2009	1,069	14%	86%	Blw Norm	1,049	9%	92%	Dry		1338	6%	94%	Dry
2010	1,085	17%	83%	Blw Norm	1,121	14%	86%	Blw Norm		1271	4%	96%	Dry
2011	1,137	30%	70%	Norm	1,123	17%	83%	Blw Norm		1984	64%	36%	Norm

1 Exceedance is defined as the percent of total observations that have exceeded this value in the period of record .

APPENDIX E

WATER TEMPERATURE FIGURES

Figure E-1. Comparison of mean daily water temperatures from three stations in Pit 1 Bypass Reach from June through September 1990.

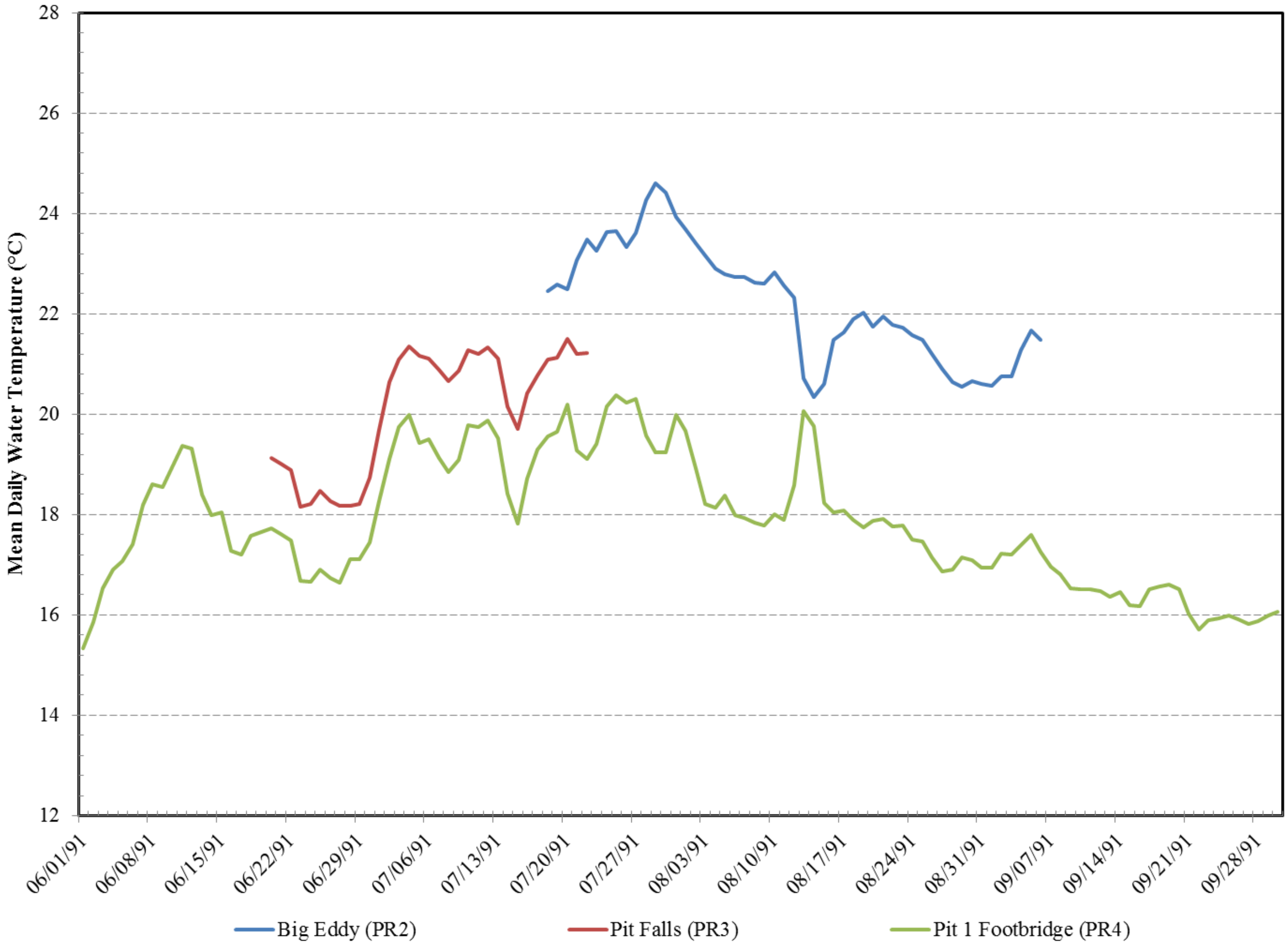


Figure E-2. Comparison of mean daily water temperatures from three stations in Pit 1 Bypass Reach from June through September 1991.

Figure E-3. Comparison of mean daily water temperatures from three stations in Pit 1 Bypass Reach from June through September 1992.

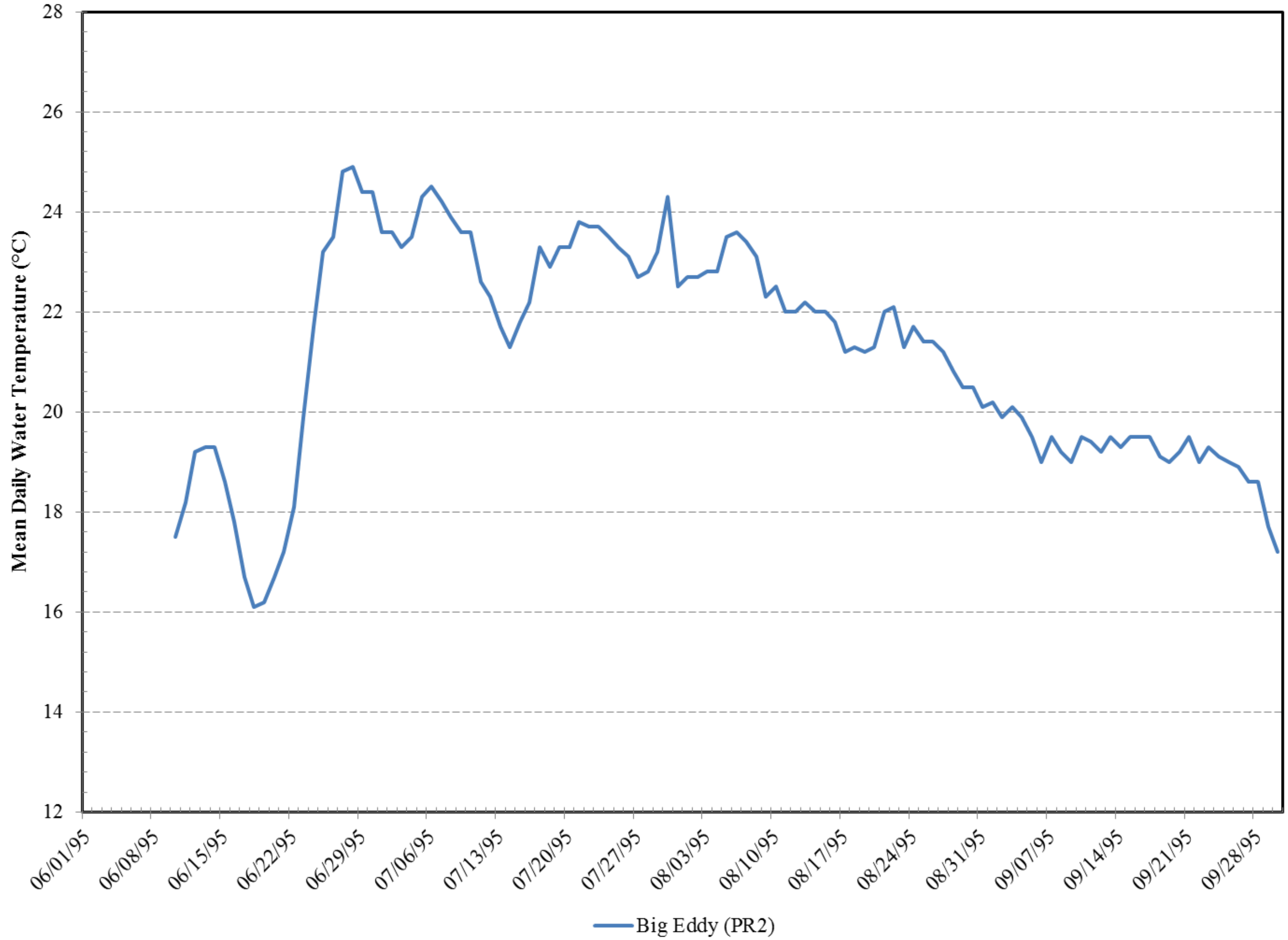


Figure E-4. Mean daily water temperatures from one station in Pit 1 Bypass Reach from June through September 1995.

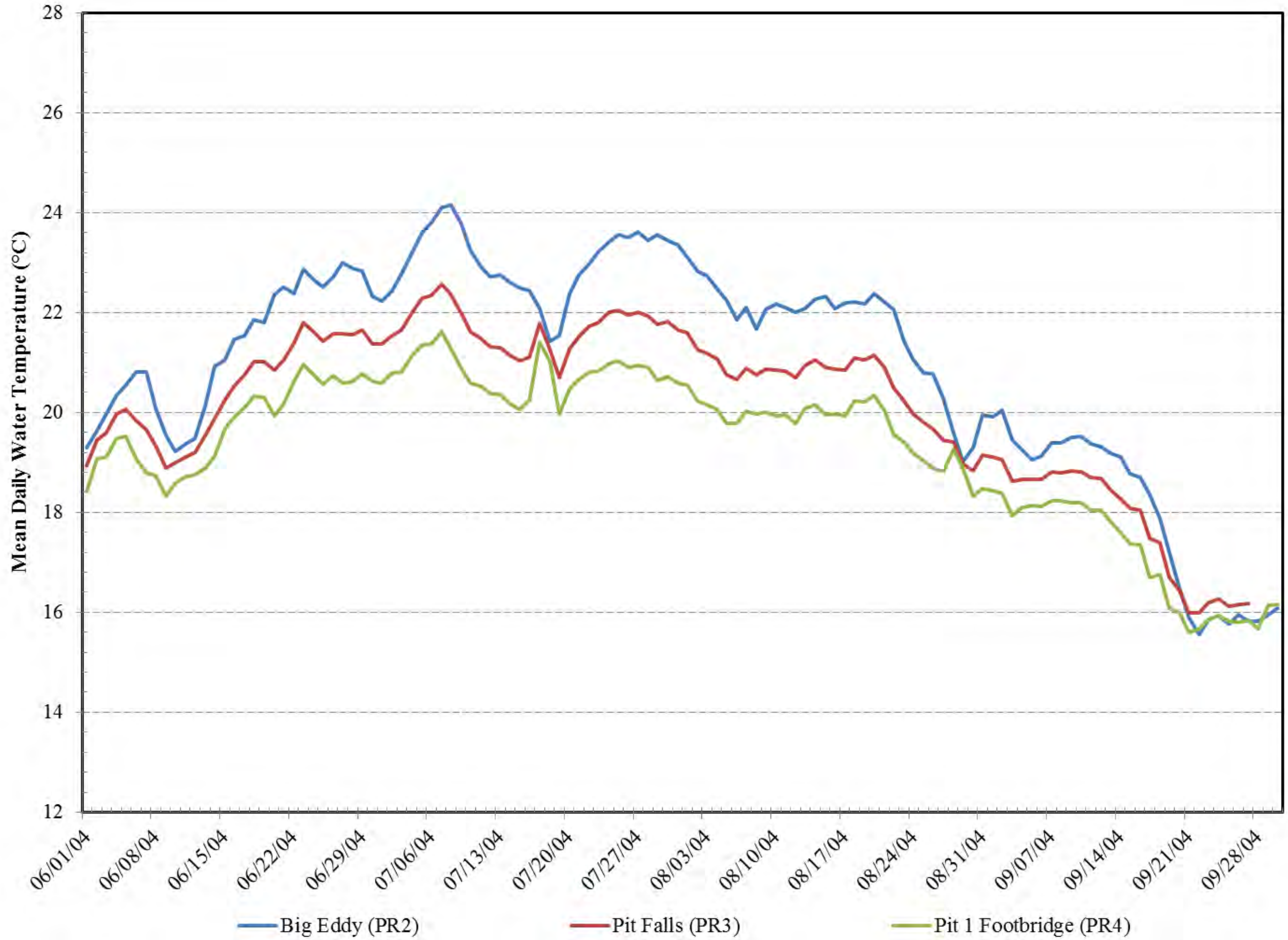


Figure E-5. Comparison of mean daily water temperatures from three stations in Pit 1 Bypass Reach from June through September 2004.

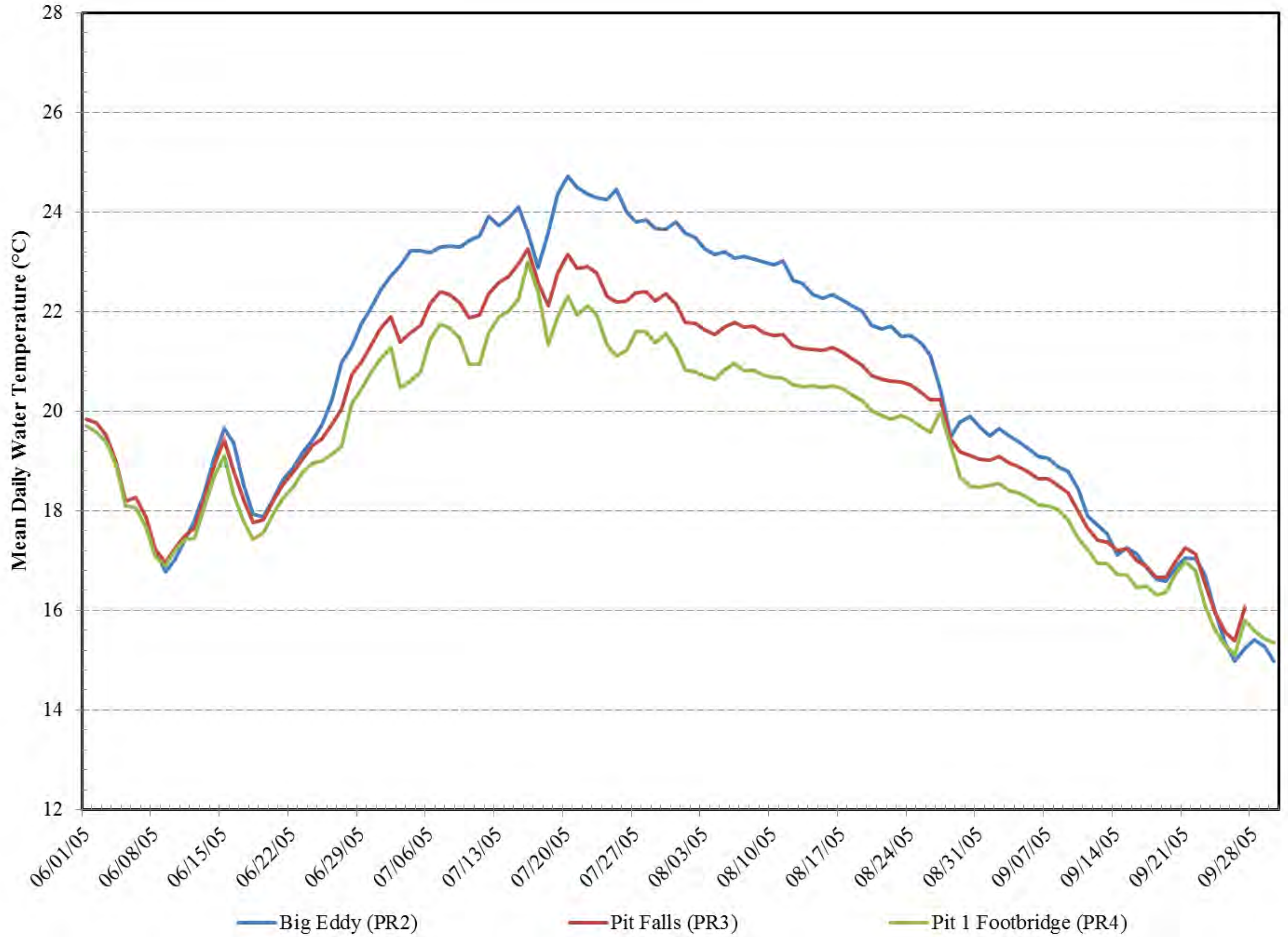


Figure E-6. Comparison of mean daily water temperatures from three stations in Pit 1 Bypass Reach from June through September 2005.

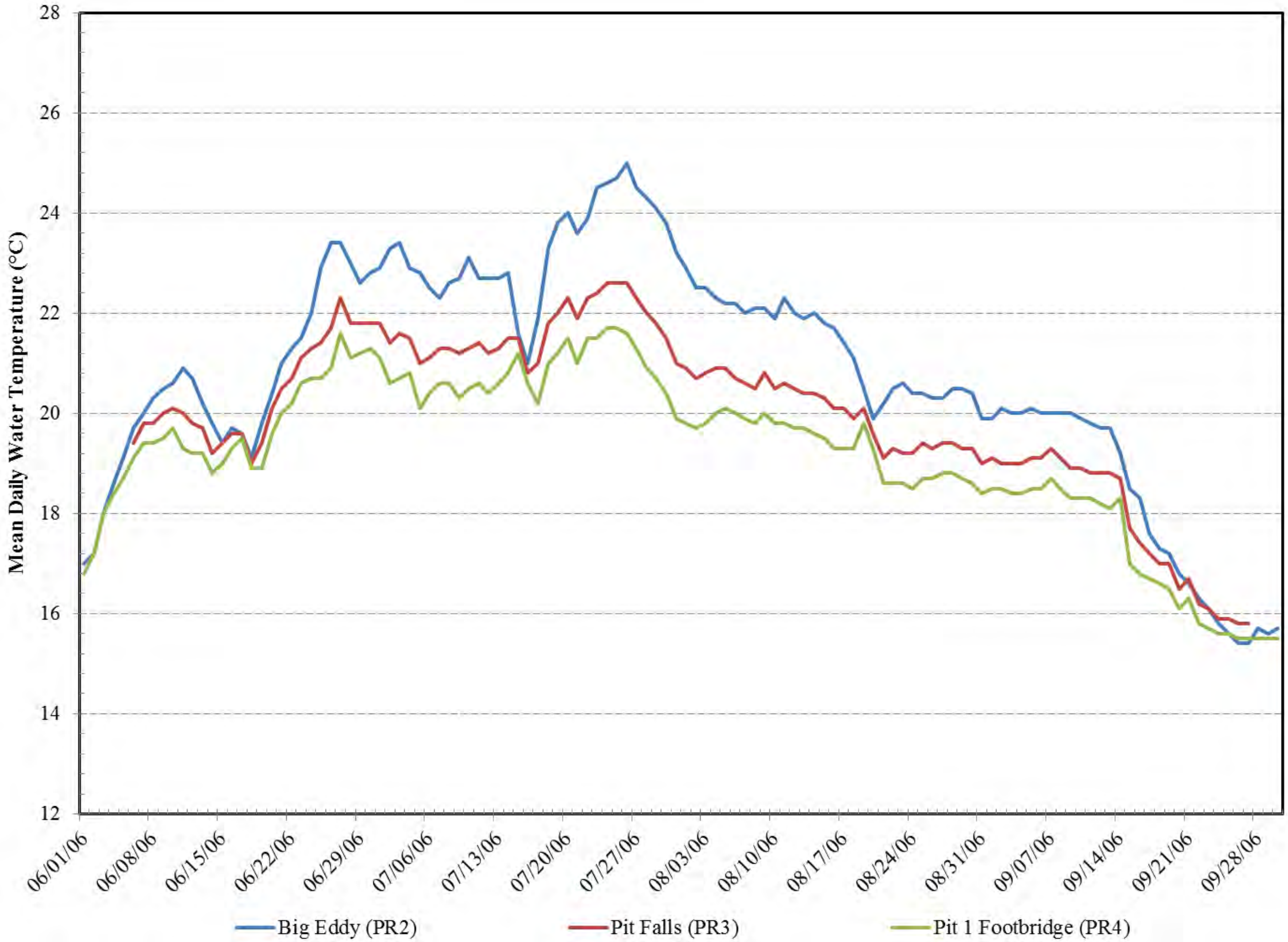


Figure E-7. Comparison of mean daily water temperatures from three stations in Pit 1 Bypass Reach from June through September 2006.

Figure E-8. Comparison of mean daily water temperatures from three stations in Pit 1 Bypass Reach from June through September 2007.

Figure E-9. Comparison of mean daily water temperatures from three stations in Pit 1 Bypass Reach from June through September 2008.

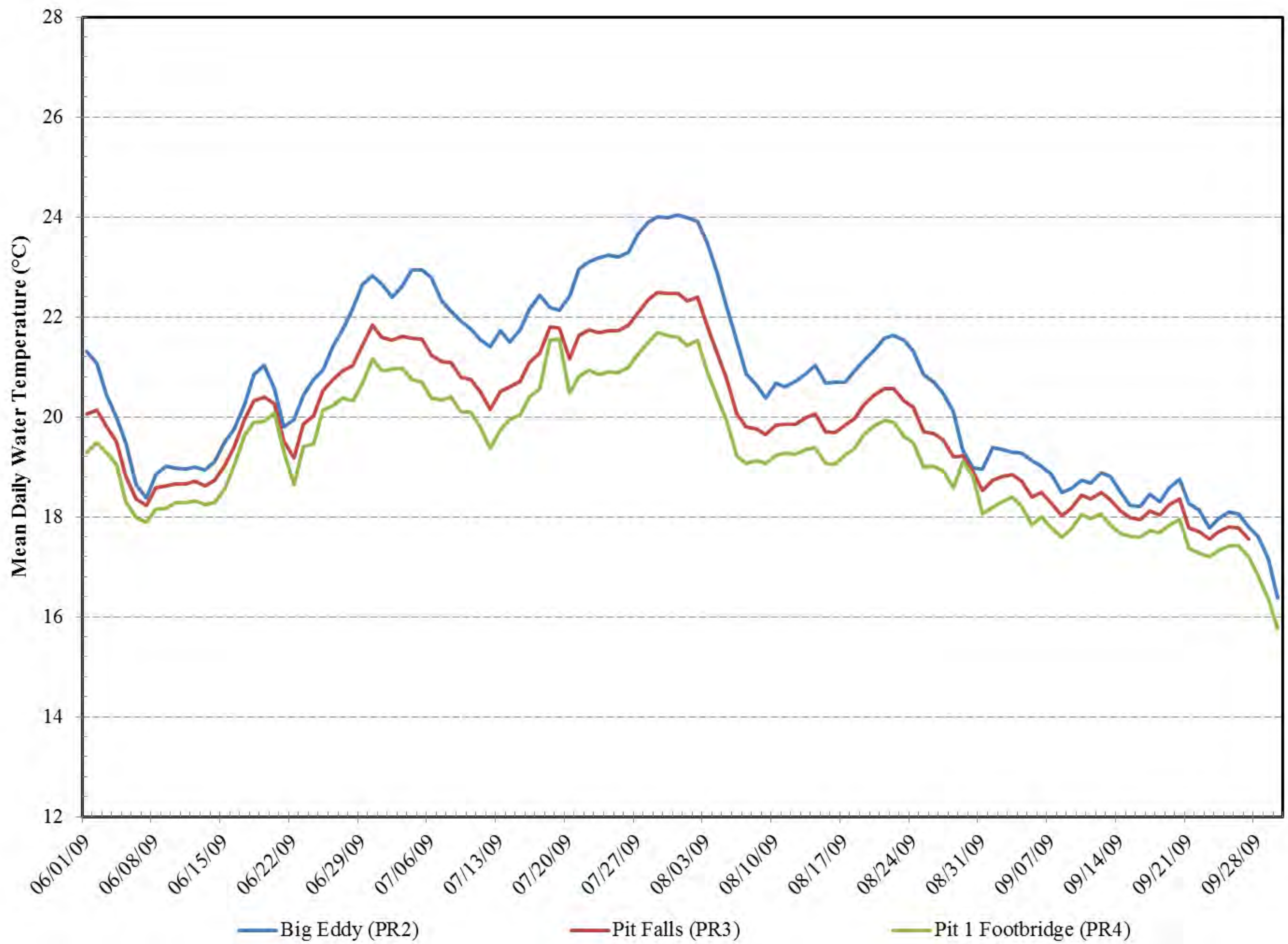


Figure E-10. Comparison of mean daily water temperatures from three stations in Pit 1 Bypass Reach from June through September 2009.

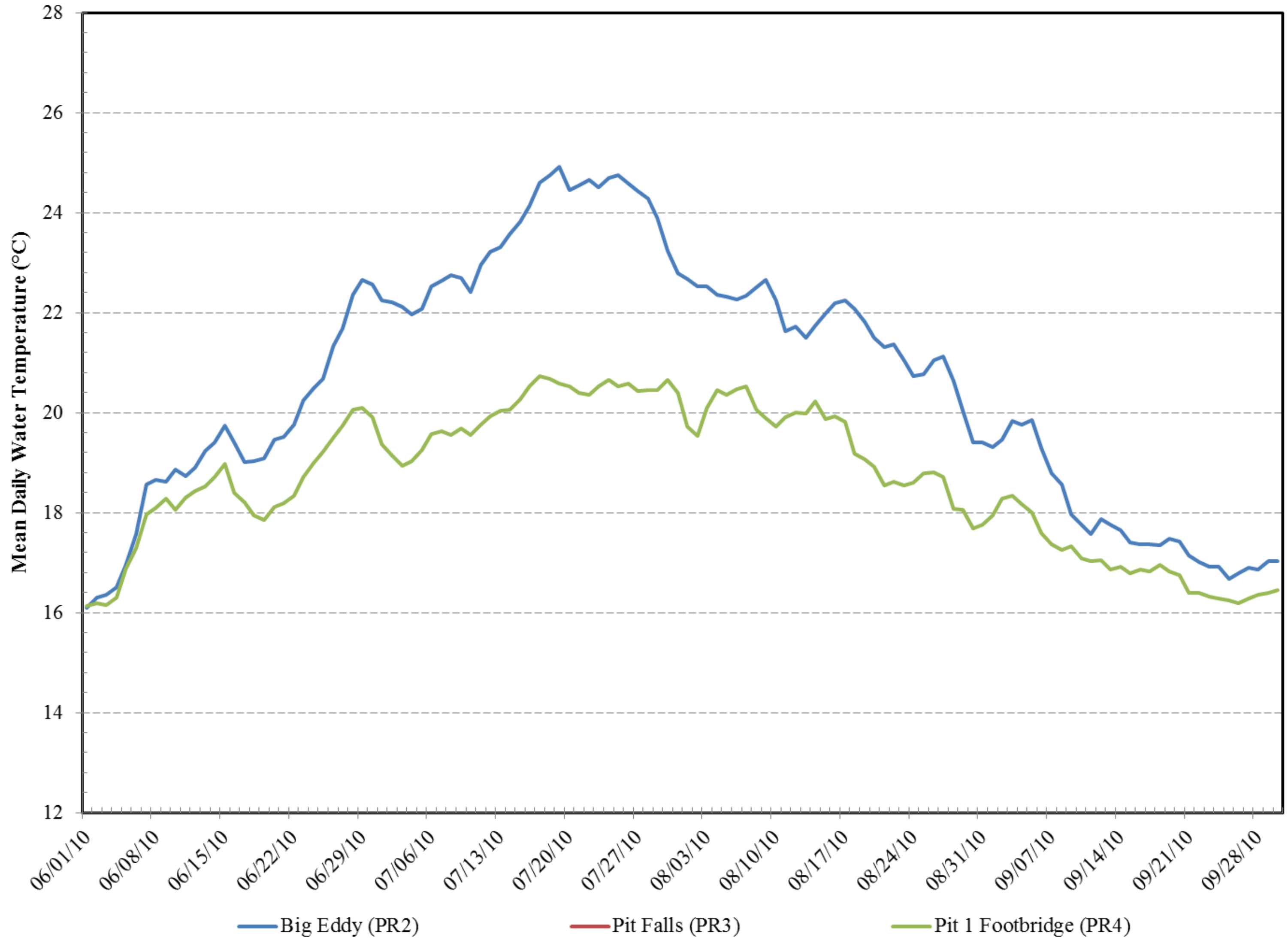


Figure E-11. Comparison of mean daily water temperatures from two stations in Pit 1 Bypass Reach from June through September 2010.

Figure E-12. Comparison of mean daily water temperatures from two stations in Pit 1 Bypass Reach from June through September 2011.

APPENDIX F

SUMMARY OF SHASTA CRAYFISH WATER TEMPERATURE MONITORING DATA

Table F-1. Summary of mean hourly water temperature data, including mean, minimum, maximum, and mean diel fluctuations (MDF) annually and monthly [a], collected in 1991 – 1992.

				1991								1992								
Site ID:	Site Name:		**Annual**	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
SPR1	Spring Creek upstream	Mean	**11.9**	-	-	-	-	*12.4*	11.8	10.1	10.0	9.9	10.5	11.1	11.8	12.9	13.1	13.5	13.2	12.5
	of Spring Creek Road	Min	**8.2**	-	-	-	-	*11.1*	9.4	8.2	8.8	8.6	9.0	9.3	9.5	10.3	11.1	11.7	11.1	10.7
	Crossing	Max	**15.2**	-	-	-	-	*13.8*	13.5	11.4	10.9	11.1	12.3	13.1	14.4	15.1	15.2	15.2	15.1	14.2
	9/26/1991 - 9/30/1992	MDF	**1.9**	-	-	-	-	*2.1*	1.9	1.3	0.9	1.3	1.5	2.1	2.6	3.3	2.6	2.4	2.4	2.4
SPR2	Fall River at Spring	Mean	**11.4**	-	-	-	-	*11.7*	10.9	10.0	9.4	9.6	10.3	10.9	11.7	12.8	13.0	13.3	13.0	12.2
	Creek Road Bridge	Min	**7.8**	-	-	-	-	*10.1*	8.3	7.8	8.1	8.2	8.7	9.1	9.2	10.1	10.6	11.3	10.4	10.0
	9/26/1991 - 9/30/1992	Max	**15.3**	-	-	-	-	*12.9*	12.8	11.5	10.4	11.1	12.5	13.2	14.3	15.2	15.3	15.1	14.8	13.7
		MDF	**2.2**	-	-	-	-	*2.5*	2.1	1.4	1.2	1.4	1.5	2.1	2.6	3.4	2.7	2.5	2.4	2.4
SPR3	Lava Creek Outflow	Mean	**11.7**	-	-	-	-	*12.2*	11.5	10.7	10.2	10.2	10.8	11.3	*11.9*	-	*13.0*	13.3	13.0	12.3
	9/26/1991 - 9/30/1992	Min	**8.6**	-	-	-	-	*10.5*	8.8	8.6	9.1	9.1	9.2	9.6	*9.5*	-	*10.5*	10.8	10.5	10.3
		Max	**17.0**	-	-	-	-	*14.7*	14.6	12.9	11.5	11.8	13.4	14.3	*15.4*	-	*16.9*	17.0	16.3	15.2
		MDF	**2.9**	-	-	-	-	*3.8*	3.1	1.9	1.4	1.7	2.0	2.9	*3.4*	-	*4.1*	5.1	4.7	4.0
SPR4	Big Lake Springs	Mean	**12.5**	-	-	-	-	*12.6*	12.6	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.6	12.6	*12.6*	-
	9/26/1991 - 8/4/1992	Min	**12.2**	-	-	-	-	*12.5*	12.5	12.5	12.2	12.4	12.4	12.4	12.4	12.5	12.5	12.5	*12.5*	-
		Max	**13.2**	-	-	-	-	*13.1*	13.2	12.6	12.7	12.7	12.7	12.8	12.8	12.8	13.2	13.2	*13.1*	-
		MDF	**0.2**	-	-	-	-	*0.5*	0.4	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.5	0.3	*0.6*	-
SPR5	South Big Lake	Mean	**14.2**	-	-	-	-	*17.9*	14.5	7.9	5.1	5.3	7.8	11.5	14.6	20.0	20.9	22.0	21.6	18.0
	Levee Cove	Min	**5.0**	-	-	-	-	*16.5*	5.9	5.0	5.0	5.0	5.2	8.5	11.9	15.8	15.9	16.7	16.8	14.6
	9/26/1991 - 9/30/1992	Max	**25.8**	-	-	-	-	*20.2*	19.9	12.3	6.4	7.5	12.1	15.2	19.3	24.1	24.8	25.7	25.8	21.5
		MDF	**1.7**	-	-	-	-	*2.0*	1.5	1.2	0.2	0.5	1.2	1.5	1.8	2.7	2.5	2.6	2.7	2.2
Pit1-P11	Sucker Springs Creek	Mean	**13.1**	*12.9*	13.0	13.1	13.0	*13.0*	-	-	*12.9*	13.0	13.1	13.1	13.1	13.2	13.2	13.2	13.2	*13.1*
	5/16/1991 - 9/30/1992	Min	**12.6**	*12.6*	12.8	12.8	12.8	*12.8*	-	-	*12.8*	12.8	12.9	12.8	12.8	12.9	13.0	13.0	12.9	*12.9*
		Max	**13.8**	*13.4*	13.5	13.6	13.5	*13.4*	-	-	*13.0*	13.3	13.4	13.5	13.6	13.7	13.8	13.7	13.7	*13.4*
		MDF	**0.4**	*0.5*	0.6	0.7	0.6	*0.3*	-	-	*0.1*	0.2	0.3	0.4	0.5	0.6	0.5	0.6	0.5	*0.4*

[a] Italicized values indicate data for partial months.

Table F-2. Summary of mean hourly water temperature data, including mean, minimum, maximum, and mean diel fluctuations (MDF) annually and monthly [a], collected between 2009 and 2012.

				2009 / 2011												2010 / 2012					
Site ID:	Site Name:		**Annual**	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
01-TSR-01	Thousand Springs	Mean	**11.2**	*11.2*	11.2	11.1	11.1	11.2	11.3	11.3	11.3	11.3	11.2	11.2	11.2	11.2	11.2	11.1	11.1	11.1	*11.2*
	Fish Trap	Min	**11.0**	*11.1*	11.0	11.0	11.0	11.0	11.2	11.2	11.2	11.2	11.1	11.1	11.1	11.1	11.0	11.0	11.0	11.0	*11.1*
	1/27/2009 - 6/9/2010	Max	**12.3**	*11.4*	11.4	11.4	11.5	11.6	11.5	12.3	11.5	11.5	11.5	11.4	11.3	11.3	11.4	11.5	11.5	11.5	*11.5*
		MDF	**0.2**	*0.2*	0.2	0.3	0.4	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.2	0.3	0.3	0.4	*0.3*
02-TSR-02	Thousand Springs	Mean	**9.8**	*9.5*	9.5	9.5	9.7	9.8	9.8	9.9	10.0	9.8	9.7	10.1	9.9	9.7	9.8	9.7	9.7	9.7	*9.8*
	Upper Fall River	Min	**9.1**	*9.2*	9.1	9.1	9.2	9.3	9.3	9.4	9.5	9.4	9.4	9.4	9.5	9.2	9.5	9.3	9.3	9.3	*9.4*
	Crayfish Barrier	Max	**10.9**	*10.0*	10.1	10.4	10.6	10.6	10.7	10.9	10.8	10.6	10.3	10.6	10.6	10.3	10.2	10.4	10.4	10.5	*10.6*
	1/27/2009 - 6/9/2010	MDF	**0.7**	*0.7*	0.6	0.7	0.9	1.0	0.9	1.1	1.0	0.9	0.6	0.4	0.5	0.4	0.4	0.6	0.7	0.8	*0.8*
17-TSR-03	Thousand Springs	Mean	**9.8**	-	*10.1*	10.1	10.1	10.1	10.1	10.2	9.7	9.6	9.6	9.6	9.6	9.7	9.7	9.8	9.8	9.7	*9.6*
	Upper Shasta Crayfish	Min	**9.3**	-	*9.8*	9.9	9.8	9.8	9.8	9.5	9.4	9.5	9.5	9.5	9.5	9.5	9.6	9.3	9.4	9.4	*9.4*
	Location	Max	**11.2**	-	*11.1*	11.1	11.2	11.0	11.1	11.2	10.9	10.1	10.0	9.8	9.9	10.2	10.5	10.8	10.5	10.1	*10.0*
	2/7/2009 - 6/9/2010	MDF	**0.6**	-	*0.7*	0.9	1.0	0.9	1.1	1.2	0.8	0.4	0.3	0.2	0.2	0.3	0.4	0.9	0.6	0.4	*0.3*
03-SC-01	Spring Creek	Mean	**12.0**	-	*11.8*	11.7	11.7	11.7	11.9	12.0	12.2	12.2	12.3	12.2	12.1	11.9	*11.9*	-	-	-	-
	Upper	Min	**11.6**	-	*11.6*	11.6	11.7	11.7	11.8	11.9	12.1	12.2	12.2	11.8	12.0	11.8	*11.8*	-	-	-	-
		Max	**12.6**	-	*12.1*	11.9	11.9	12.1	12.0	12.1	12.3	12.6	12.4	12.3	12.2	12.1	*12.1*	-	-	-	-
	2/19/2009 - 2/24/2010	MDF	**0.1**	-	*0.2*	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	*0.2*	-	-	-	-
04-SC-02	Spring Creek	Mean	**11.6**	-	*11.4*	11.3	11.3	11.4	11.5	11.7	11.8	11.9	11.8	11.8	11.6	11.5	11.4	-	-	-	-
	Middle	Min	**10.7**	-	*11.3*	10.7	10.9	10.9	11.2	11.4	11.4	11.6	11.6	11.5	11.5	11.4	11.3	-	-	-	-
		Max	**12.3**	-	*11.7*	11.7	11.7	11.8	12.1	12.1	12.3	12.3	12.3	12.1	11.9	11.8	11.7	-	-	-	-
	2/21/2009 - 2/28/2010	MDF	**0.4**	-	*0.3*	0.4	0.4	0.4	0.4	0.6	0.7	0.5	0.4	0.3	0.2	0.2	0.2	-	-	-	-
18-SC-03	Spring Creek	Mean	**10.7**	-	*10.7*	10.6	10.6	10.6	10.6	10.7	10.8	10.9	10.9	10.8	10.6	10.6	*10.6*	-	-	-	-
	Lower Fish Trap	Min	**10.1**	-	*10.4*	10.2	10.2	10.3	10.4	10.5	10.7	10.5	10.5	10.5	10.1	10.2	*10.1*	-	-	-	-
	2/20/2009 - 2/24/2010	Max	**11.5**	-	*11.2*	11.2	11.1	10.9	10.9	11.2	11.2	11.3	11.3	11.3	11.2	11.5	*11.3*	-	-	-	-
		MDF	**0.4**	-	*0.5*	0.5	0.6	0.4	0.2	0.1	0.4	0.3	0.5	0.6	0.6	0.6	*0.7*	-	-	-	-
05-BL-01	Big Lake Springs	Mean	**12.7**	-	*12.7*	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	*12.7*	-	-	-	-
		Min	**12.6**	-	*12.7*	12.6	12.7	12.6	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	*12.7*	-	-	-	-
	2/28/2009 - 2/9/2010	Max	**12.7**	-	*12.7*	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	*12.7*	-	-	-	-
		MDF	**0.0**	-	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	-	-	-	-

				2009 / 2011											2010 / 2012						
Site ID:	Site Name:		**Annual**	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
07-BL-03	South Big Lake	Mean	**13.9**	-	*9.2*	9.7	13.4	18.9	21.5	24.0	22.5	19.7	12.8	8.0	4.3	5.5	8.1	*9.0*	-	-	-
	Levee Cove	Min	**2.3**	-	*8.9*	6.4	9.4	12.5	16.9	20.7	18.9	14.0	8.8	4.9	2.3	3.5	5.4	*7.6*	-	-	-
	2/28/2009 - 3/10/2010	Max	**26.9**	-	*9.5*	14.8	19.9	24.4	26.6	26.9	26.0	22.4	16.3	13.0	5.9	7.3	11.1	*10.7*	-	-	-
		MDF	**1.6**	-	*0.6*	1.6	2.1	2.3	2.1	2.2	2.2	2.3	1.4	1.0	0.7	0.6	1.0	*1.0*	-	-	-
08-JSC-01	Ja She Creek	Mean	**11.7**	*11.7*	11.7	11.7	11.7	11.7	11.7	11.8	11.8	11.8	11.8	11.8	11.7	11.7	11.7	11.7	*11.7*	-	-
	Upper Fish Trap	Min	**11.7**	*11.7*	11.7	11.7	11.7	11.7	11.7	11.7	11.8	11.8	11.8	11.7	11.7	11.7	11.7	11.7	*11.7*	-	-
	1/21/2011 - 4/16/2012	Max	**11.9**	*11.8*	11.8	11.8	11.8	11.8	11.8	11.9	11.9	11.9	11.9	11.8	11.8	11.8	11.8	11.8	*11.8*	-	-
		MDF	**0.1**	*0.1*	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	*0.1*	-	-
09-PR-01	Pit River above Falls	Mean	**15.4**	-	-	-	-	-	-	*16.6*	16.4	16.2	14.0	*13.6*	-	-	-	-	-	-	-
	Upper Pit River	Min	**10.4**	-	-	-	-	-	-	*15.0*	15.1	14.7	12.7	*10.4*	-	-	-	-	-	-	-
	7/17/2009 - 11/23/2009	Max	**20.8**	-	-	-	-	-	-	*20.8*	18.5	17.2	15.7	*14.7*	-	-	-	-	-	-	-
		MDF	**1.1**	-	-	-	-	-	-	*1.8*	1.2	1.1	0.8	*0.9*	-	-	-	-	-	-	-
10-PR-02	Pit River above Falls	Mean	**17.0**	-	-	-	-	-	-	*21.6*	20.3	18.2	13.5	*10.5*	-	-	-	-	-	-	-
	Lower Pit River	Min	**8.4**	-	-	-	-	-	-	*19.4*	17.7	15.7	10.9	*8.4*	-	-	-	-	-	-	-
	7/17/2009 - 11/23/2009	Max	**24.1**	-	-	-	-	-	-	*24.1*	23.8	20.3	16.9	*12.3*	-	-	-	-	-	-	-
		MDF	**1.7**	-	-	-	-	-	-	*2.4*	2.0	1.9	1.2	*0.9*	-	-	-	-	-	-	-
11-SSC-01	Sucker Springs Creek	Mean	**12.3**	-	-	*12.2*	12.3	12.3	12.4	12.4	12.4	12.3	12.3	12.2	12.1	12.2	12.2	*12.2*	-	-	-
	above Pond 1 Weir	Min	**11.4**	-	-	*11.4*	12.0	12.1	12.2	12.2	12.2	12.1	12.1	12.0	11.9	12.0	12.0	*12.0*	-	-	-
	3/10/2009-3/4/2010	Max	**13.3**	-	-	*12.6*	12.8	12.7	13.3	12.7	12.6	12.6	12.5	12.4	12.3	12.3	12.5	*12.5*	-	-	-
		MDF	**0.3**	-	-	*0.5*	0.5	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.1	0.2	*0.3*	-	-	-
12-CL-01	Crystal Lake	Mean	**10.6**	*10.6*	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.5	10.6	*10.6*	-	-	-	-
	Southwest Cove	Min	**10.4**	*10.4*	0.0	0.0	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.5	10.4	10.4	*10.5*	-	-	-	-
	1/25/2011 - 2/5/2012	Max	**10.6**	*10.6*	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	*10.6*	-	-	-	-
		MDF	**0.0**	*0.0*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	-	-	-	-
13-RC-01	Rock Creek	Mean	**9.5**	-	-	*9.3*	9.4	9.5	9.5	9.6	9.6	9.6	9.5	9.4	9.3	9.3	9.3	*9.3*	-	-	-
	Upper Pool	Min	**9.2**	-	-	*9.2*	9.3	9.4	9.5	9.5	9.6	9.6	9.5	9.4	9.2	9.3	9.3	*9.3*	-	-	-
	3/11/2009 - 3/7/2010	Max	**9.7**	-	-	*9.4*	9.5	9.6	9.6	9.7	9.7	9.7	9.6	9.5	9.4	9.4	9.4	*9.4*	-	-	-
		MDF	**0.0**	-	-	*0.0*	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*	-	-	-

[a] Italicized values indicate data for partial months.

APPENDIX G

DIEL CYCLE VS FLOW FIGURES

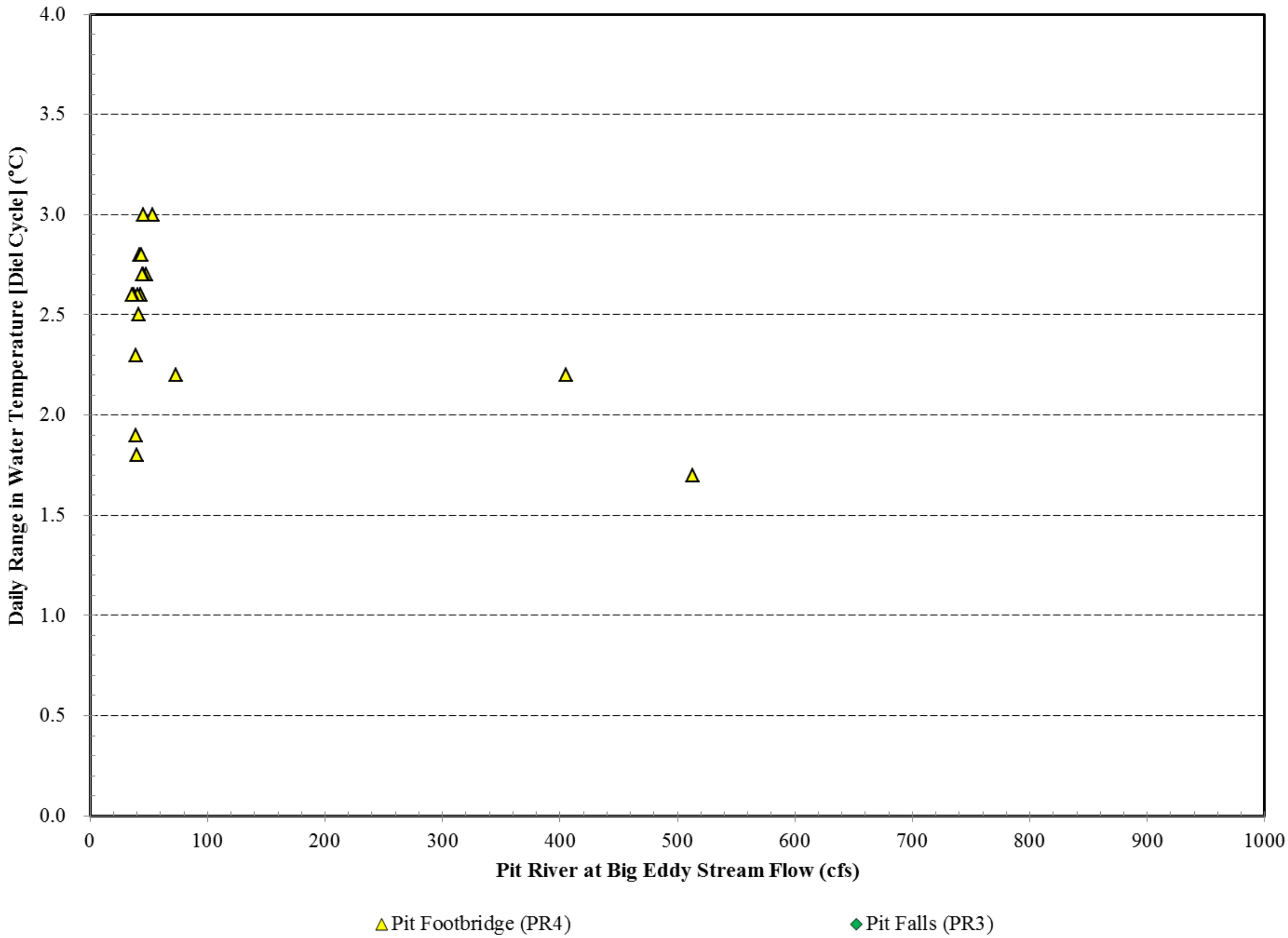


Figure G-1. Diel water temperature patterns observed at one station in the Pit 1 Bypass Reach in 1991.

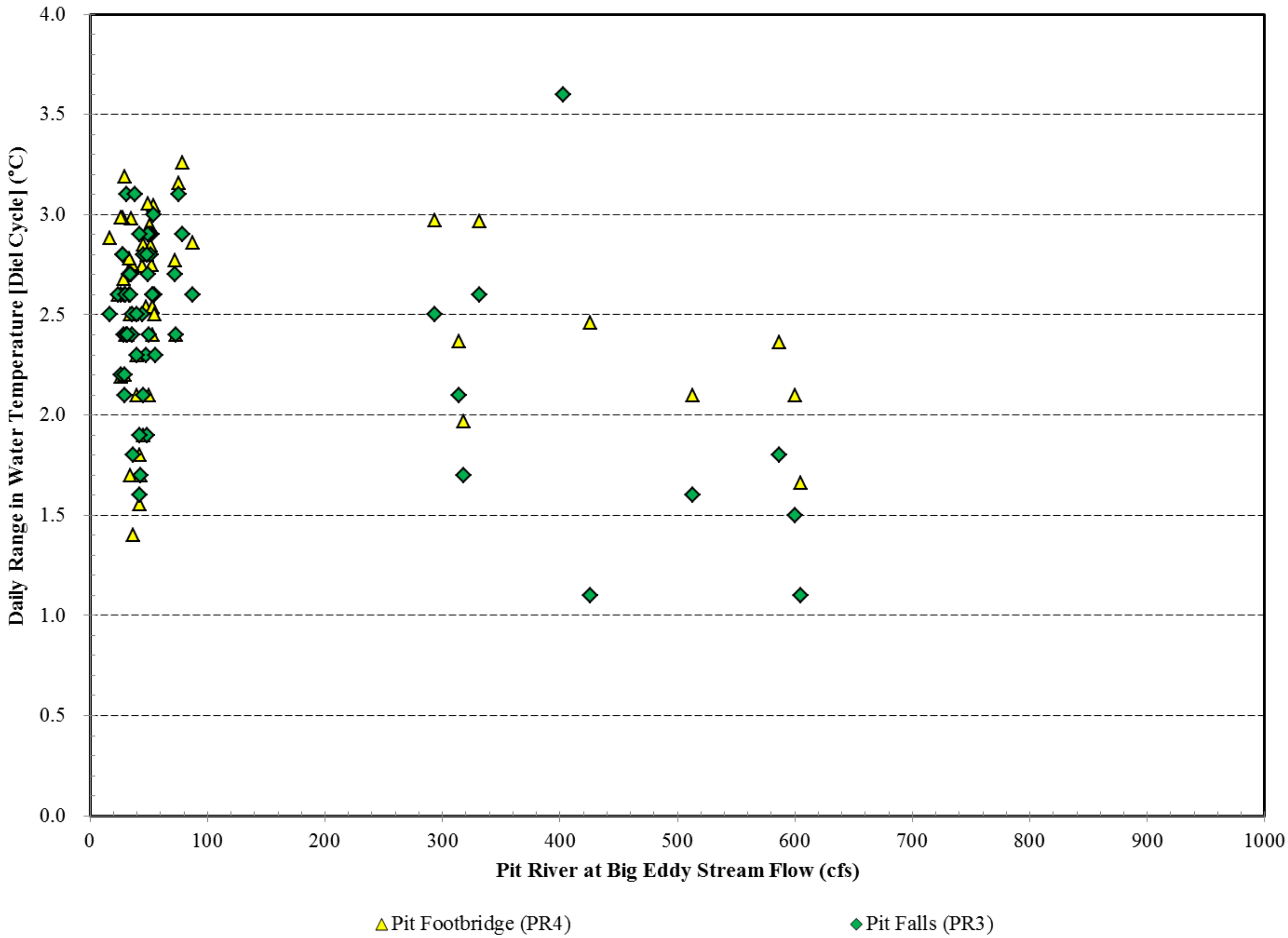


Figure G-2. Diel water temperature patterns observed at two stations in the Pit 1 Bypass Reach in 1992.

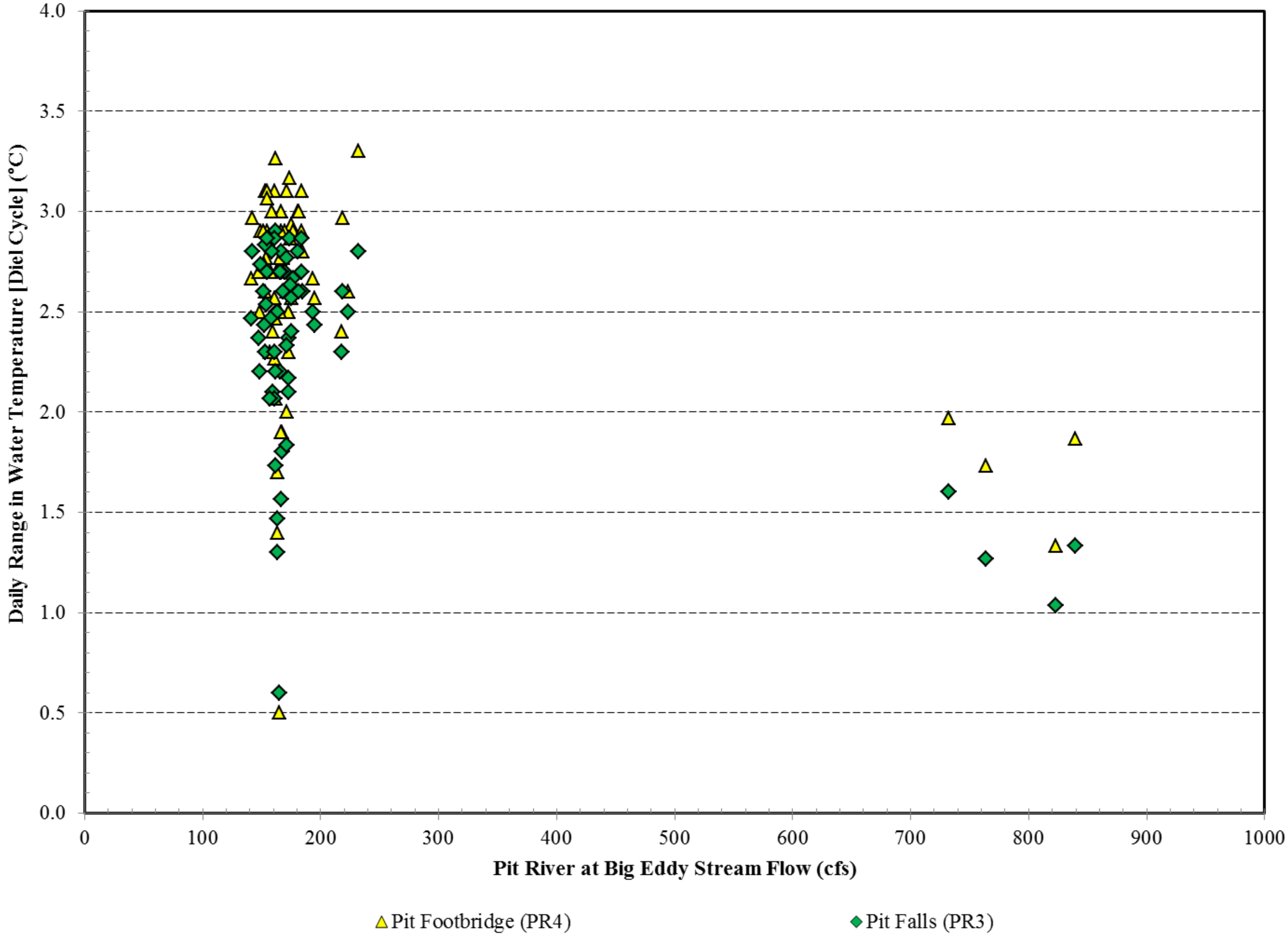


Figure G-3. Diel water temperature patterns observed at two stations in the Pit 1 Bypass Reach in 2004.

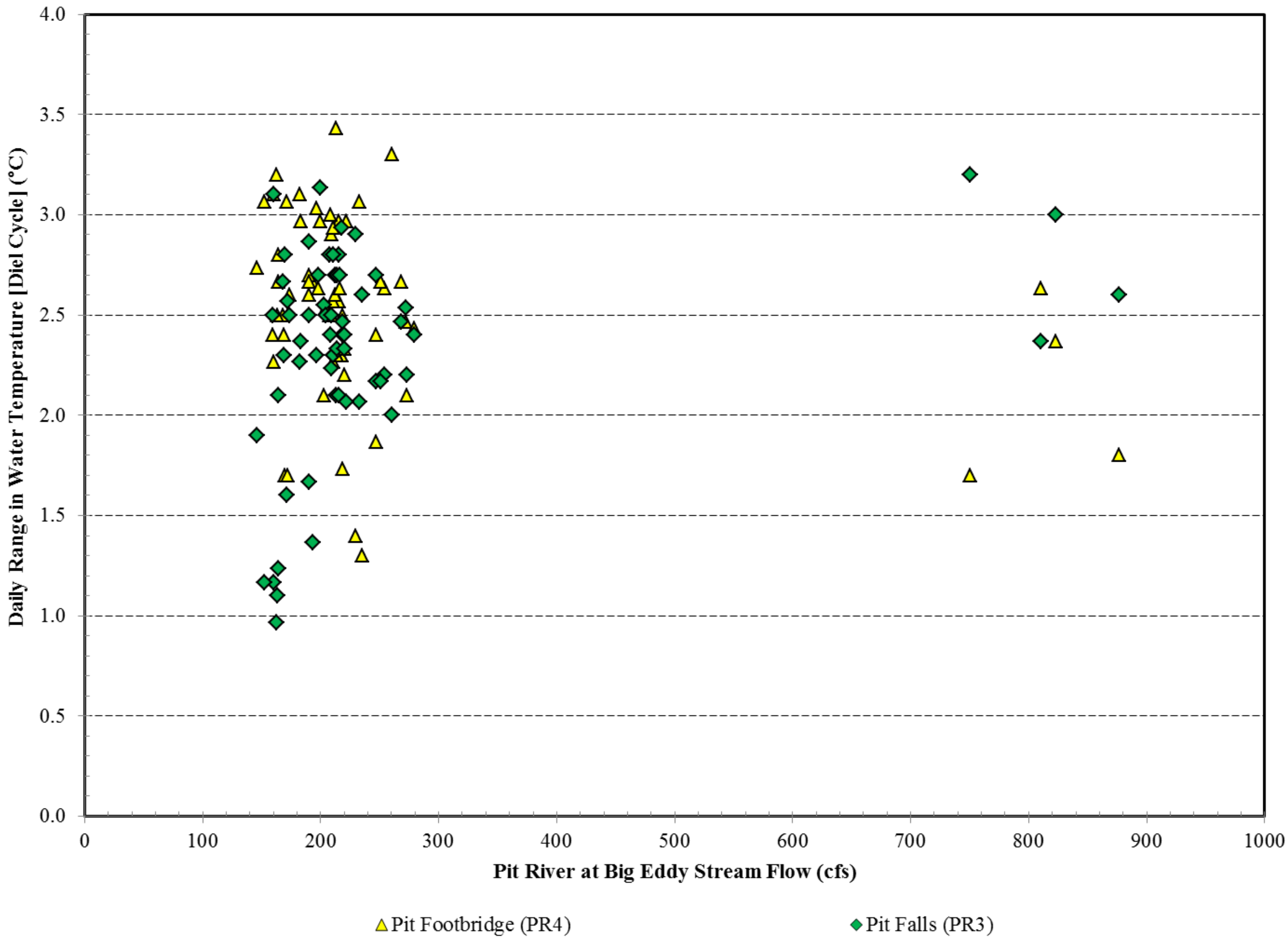


Figure G-4. Diel water temperature patterns observed at two stations in the Pit 1 Bypass Reach in 2005.

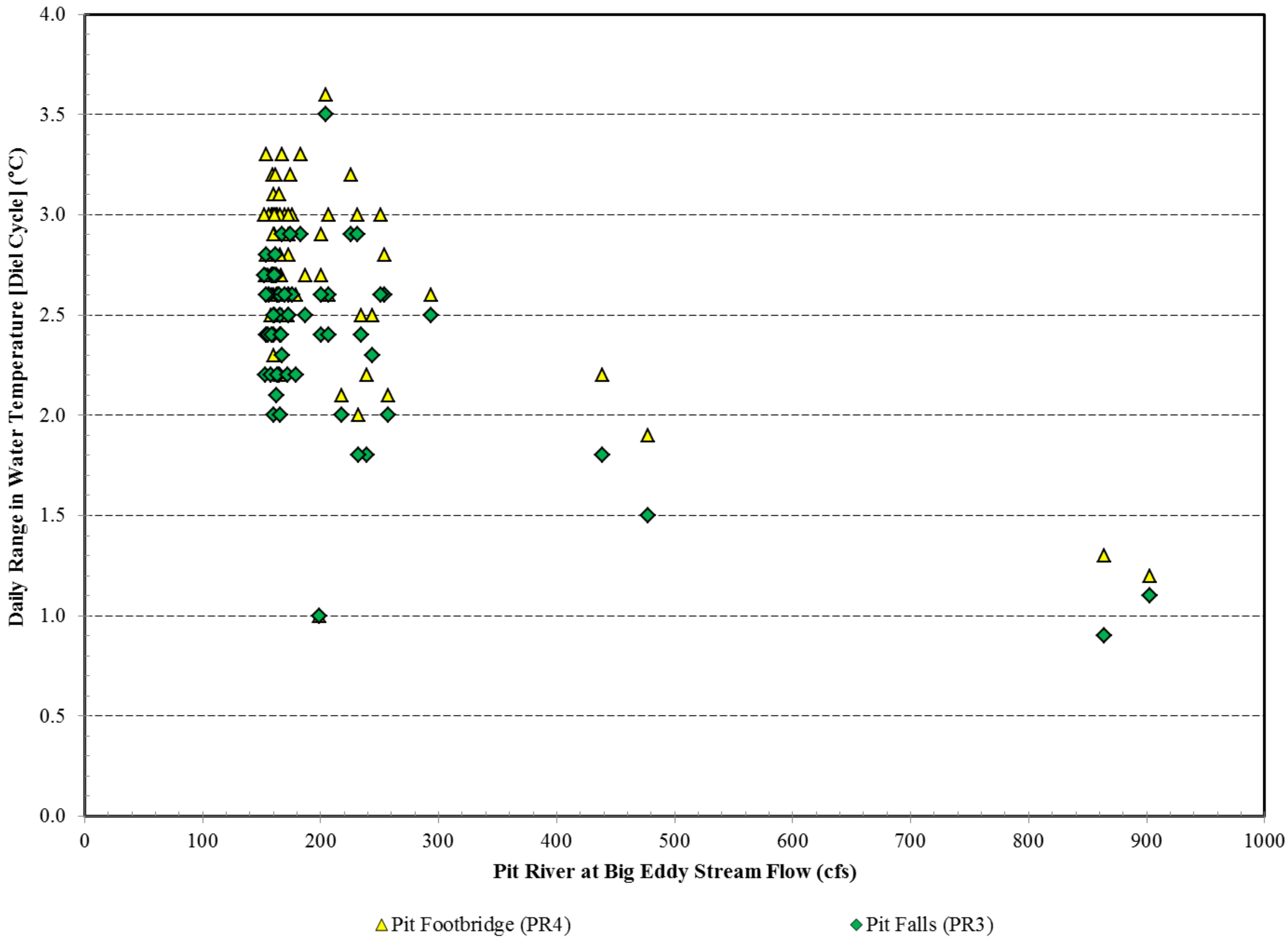


Figure G-5. Diel water temperature patterns observed at two stations in the Pit 1 Bypass Reach in 2006.

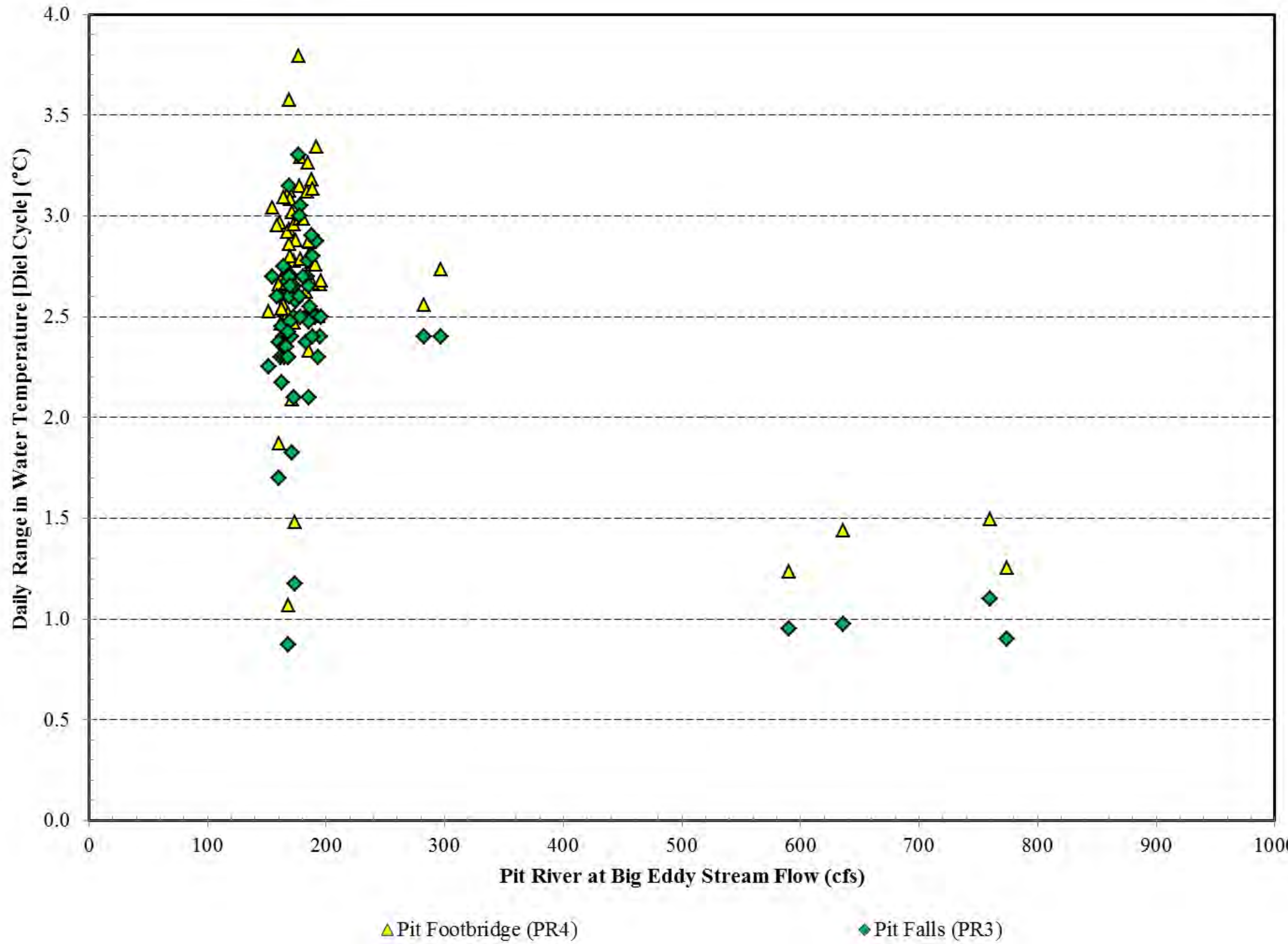


Figure G-6. Diel water temperature patterns observed at two stations in the Pit 1 Bypass Reach in 2007.

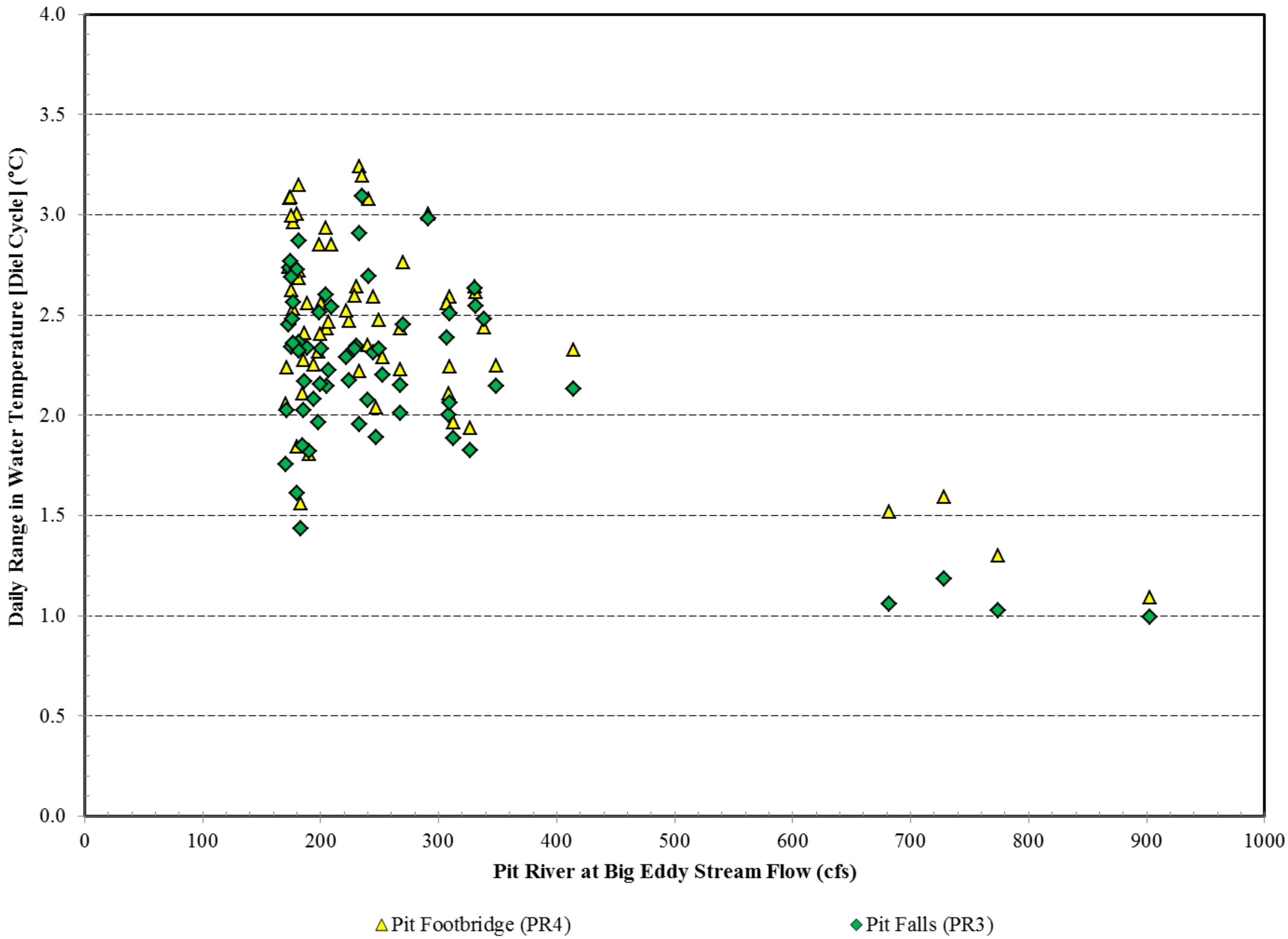


Figure G-7. Diel water temperature patterns observed at two stations in the Pit 1 Bypass Reach in 2008.

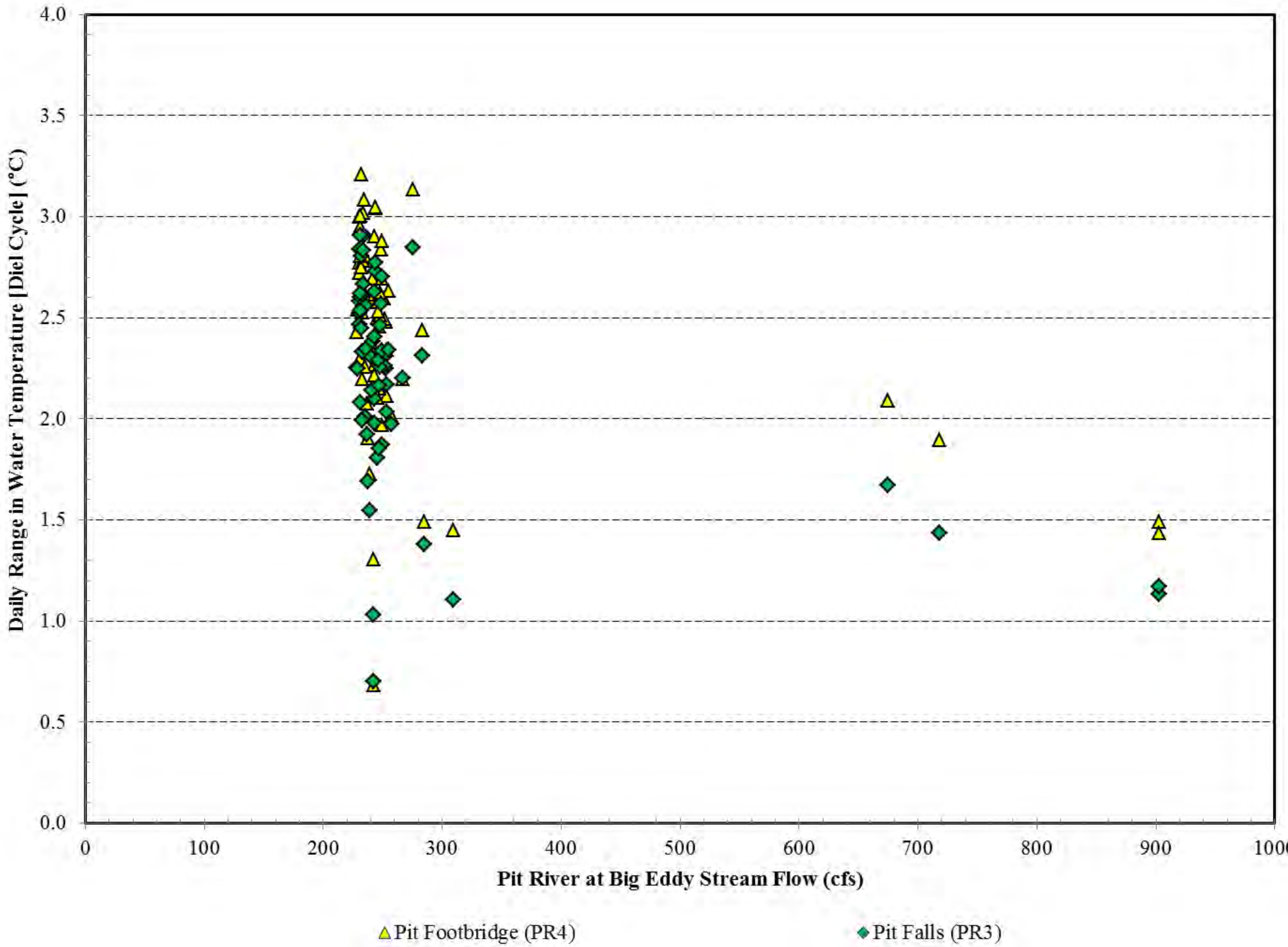


Figure G-8. Diel water temperature patterns observed at two stations in the Pit 1 Bypass Reach in 2009.

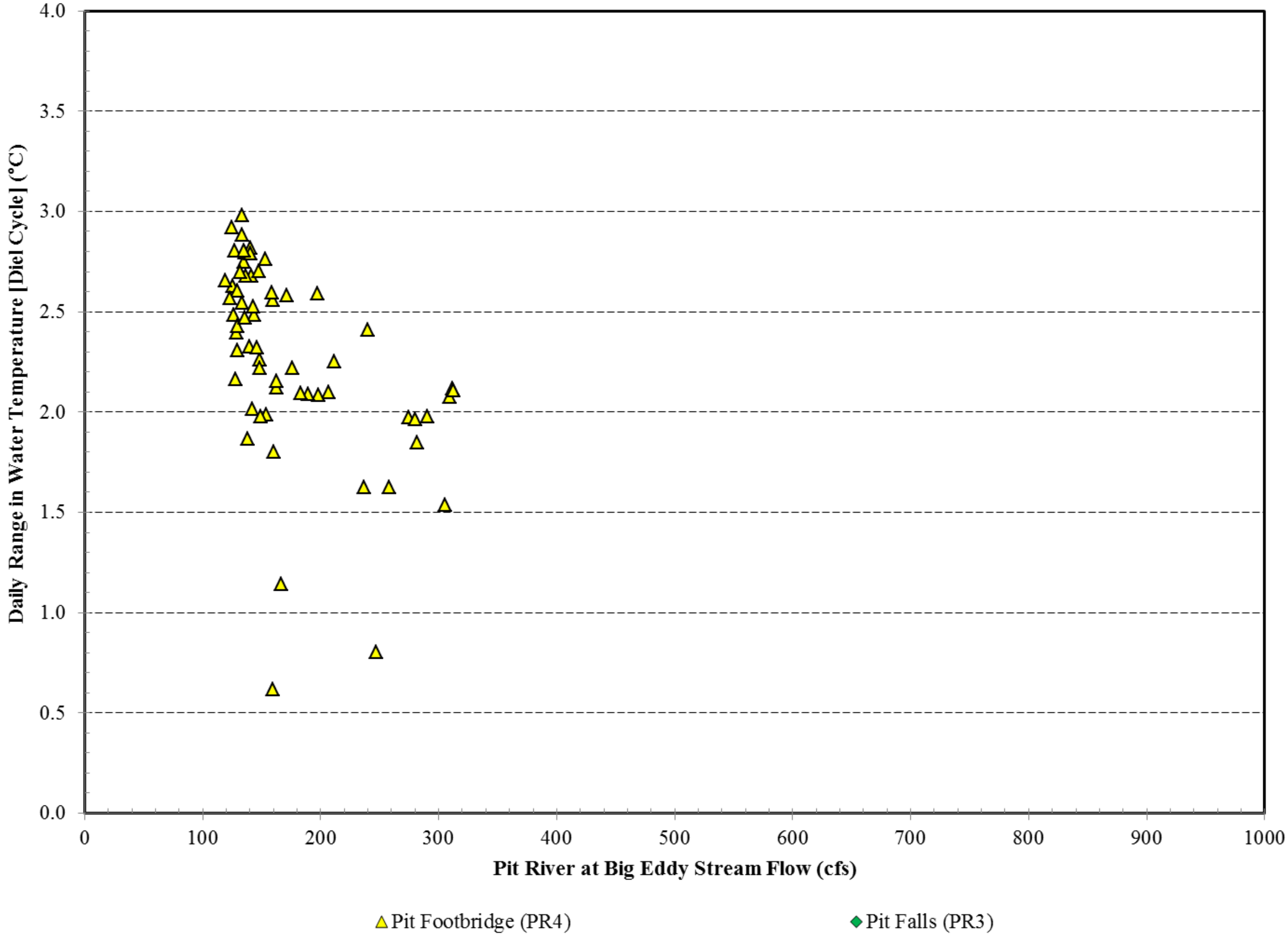


Figure G-9. Diel water temperature patterns observed at one station in the Pit 1 Bypass Reach in 2010.

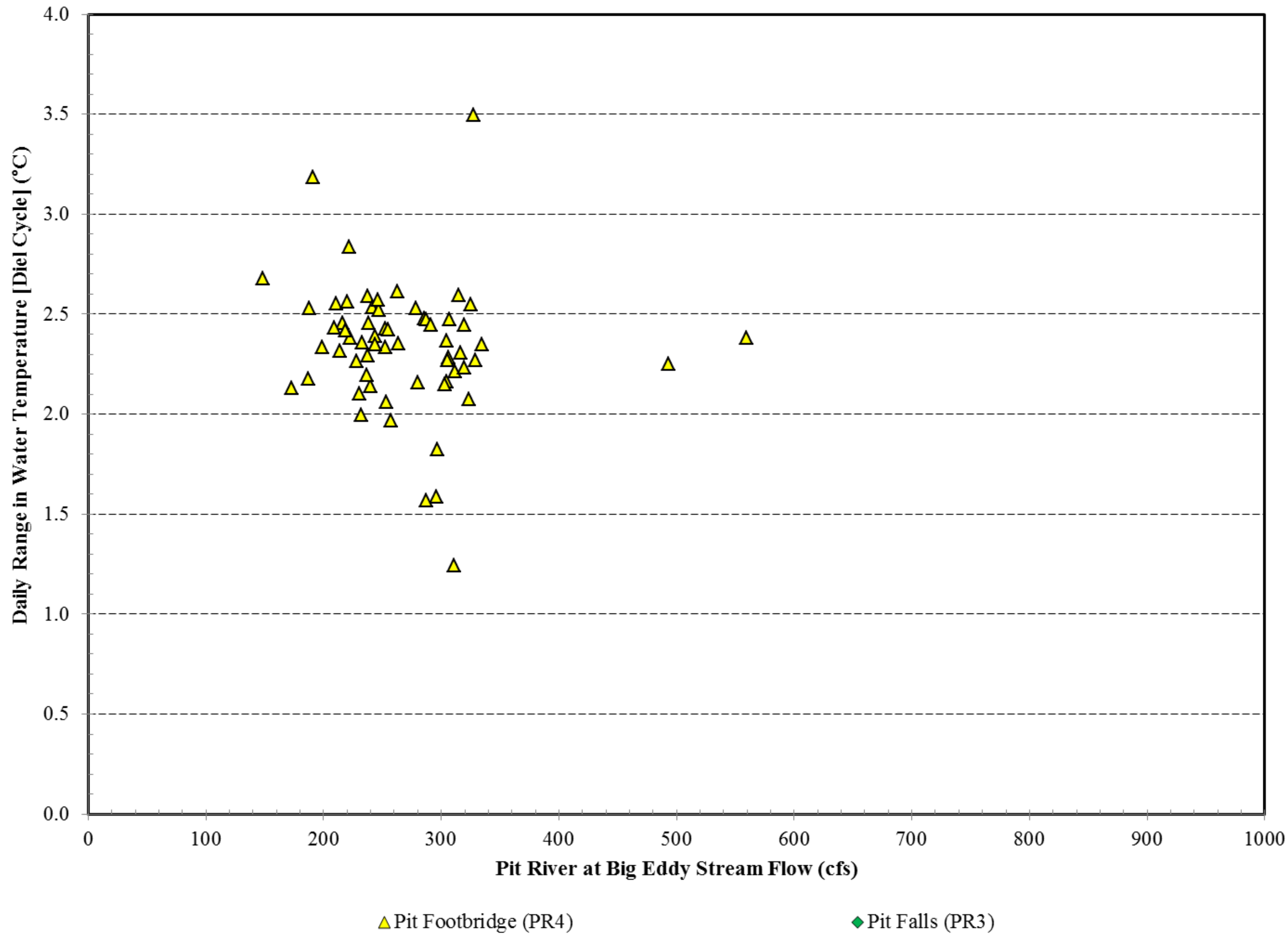


Figure G-10. Diel water temperature patterns observed at two stations in the Pit 1 Bypass Reach in 2011.