Appendix D-4

Estimated Pit 3/4/5 Hydropower Generation Reduction Attributable to US Forest Service Preliminary 4(e) Condition Minimum Instream Flows

Matt Smeltzer & Xiao-Qing Zeng

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2171 E. Francisco Blvd., Suite K San Rafael, California 94901 (415) 457-0701
FAX: (415) 457-1638 email: sr@stetsonengineers.com

3104 East Garvey Avenue, Suite A West Covina, California 91791 (626) 967-6202
FAX: (626) 331-7065 email: wc@stetsonengineers.com

2659 W. Guadalupe Rd., Suite D2 Mesa, AZ 91791 (480) 839-5910
FAX: (480) 839-6560 email: mesa@stetsonengineers.com

1900 – Pit 3/4/5 May 12, 2003 Reply to: San Rafael
(FERC #233)

Ms. Kathy Turner
Hat Creek Ranger District
P.O. Box 220
43225 Hwy 299E
Fall River Mills, CA 96028

Re: Estimated Pit 3/4/5 Hydropower Generation Reduction Attributable to US Forest Service Preliminary 4(e) Condition Minimum Instream Flows

Dear Ms. Turner:

This letter documents the Lake Britton reservoir operations model results Stetson Engineers used to estimate hydropower generation reduction attributable to the US Forest Service's October 2002 Preliminary 4(e) Condition minimum flow requirements in the Pit 3 and Pit 4 Project bypassed reaches. We also compare our hydropower generation reduction results with estimates FERC made in its March 2003 DEIS and recommend several changes to FERC's analysis.

Summary and Recommendations

FERC estimated in its DEIS that providing the interim minimum instream flow requirements outlined in the Forest Service's Preliminary 4(e) Conditions (namely 400 cfs and 450 cfs in the Pit 3 and Pit 4 Project bypassed reaches, respectively) and in the Forest Service's 10(a) recommendations (500 cfs in the Pit 5 reach) would reduce the Pit 3/4/5 Project's 1,948,700,000 kWh total annual average generation by 208,100,000 kWh, or 10.7 percent.

Stetson's Lake Britton reservoir operations model analysis estimates that the interim measures outlined in the Forest Service's Preliminary 4(e) flow conditions would reduce total annual average Pit 3/4/5 Project generation by 78,000,000 kWh, or 4.0 percent of total Project generation.

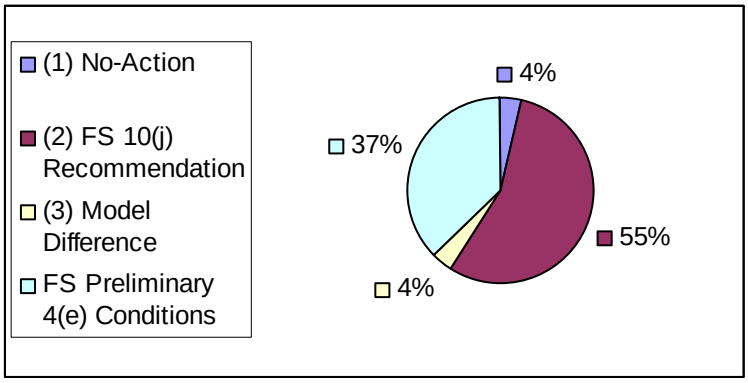
Our independent analysis therefore indicates that FERC overestimated hydropower generation reduction attributable to the Forest Service's Preliminary 4(e) flow conditions by 130,100,000 kWh -- a 63 percent overestimate. Although FERC did not completely document its modeling analysis methods and assumptions in its DEIS, our review of the DEIS suggests that FERC's 130,100,000 kWh overestimate has at least three components:

(1) FERC included power generation reduction attributable to implementing the No-Action alternative (baseline) in its estimate of total Pit 3/4/5 Project hydropower generation reduction

attributable to the Forest Service's Preliminary 4(e) flow conditions. Our independent model analysis shows that implementing the No-Action Alternative (current minimum flow requirements) would in and of itself reduce the Pit 3/4/5 Project's total historical annual average hydropower generation by about 7,900,000 kWh, or 0.4 percent of total Pit 3/4/5 Project generation. This amount of generation reduction should have been excluded from the estimated reduction due to the FS Preliminary 4(e) flow conditions.

(2) FERC included hydropower generation reduction attributable to the Forest Service's 10(a) recommended minimum flows in the Pit 5 Project bypassed reach in its estimate of total Pit 3/4/5 Project hydropower generation reduction attributable to the Forest Service's Preliminary 4(e) flow conditions. Our independent model analysis shows that implementing the Forest Service's 10(a) recommended minimum flow in the Pit 5 reach would in and of itself reduce the Pit 3/4/5 Project's total historical annual average hydropower generation by about 113,790,000 kWh, or 5.8 percent of total Pit 3/4/5 Project generation. This generation reduction should have been excluded from the estimated reduction due to the FS Preliminary 4(e) flow conditions.

(3) FERC's operational model analysis differed from our reservoir operations model analysis in several aspects including period of record analyzed, and therefore attributed an additional 8,410,000 kWh reduction in total Pit 3/4/5 Project hydropower generation to the Forest Service's Preliminary 4(e) flow conditions, or 0.4 percent of total Pit 3/4/5 Project generation.



The chart at left breaks out the four components of FERC's 208,100,000 kWh (10.7 percent) estimate of Pit 3/4/5 Project hydropower generation reduction attributable to the Forest Service's Preliminary 4(e) flow conditions, including the three components that produce a 130,100,000 kWh or 63 percent overestimate.

Accordingly, FERC's hydropower generation reduction analysis procedure should be revised to:

(1) Quantify power generation differences between the historical regulated case and the "No-Action" baseline case, and clarify that these differences are attributable to implementation of the "No-Action" Alternative and are excluded from FERC's estimates of hydropower generation reduction attributable to various other flow proposals and recommendations;

(2) Separate power generation reduction attributable to Forest Service's Preliminary 4(e) flow conditions in the Pit 3 and Pit 4 Project bypassed reaches and its (non-mandatory) 10(a) flow recommendations in the Pit 5 reach; and,

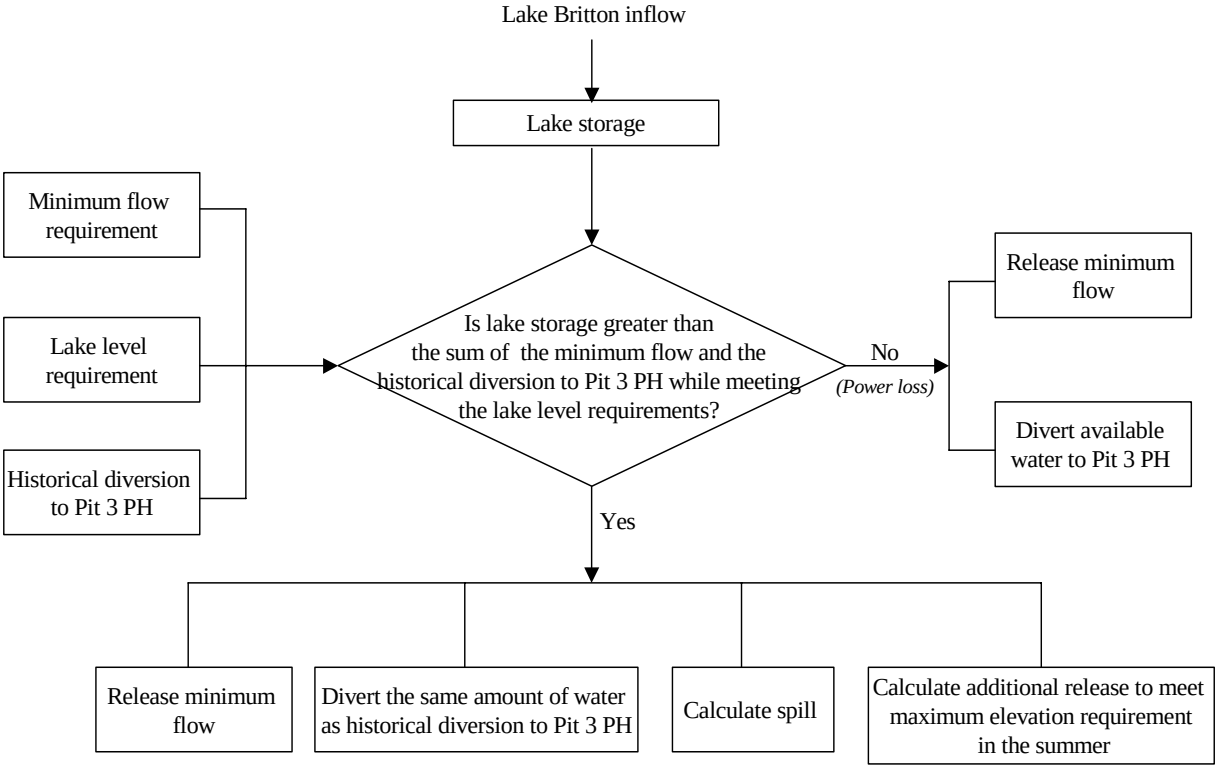
(3) Document FERC's operational model analysis methods and assumptions in order to allow an independent evaluation of the procedure and reasonable comparison with our independent reservoir operations model analysis, including an explanation of model logic and assumptions

and model sensitivity of results to selected period of record and method used in preparing synthesized unimpaired Lake Britton inflow input data.

Supporting Analysis

Stetson Engineers prepared a Lake Britton reservoir operations model to estimate Pit 3 and Pit 4 powerhouse hydropower generation reduction caused by the "No-Action" Alternative, PG&E proposed minimum flows, and the Forest Service's Preliminary 4(e) flow conditions and lake level requirements (both for the Forest Service's interim "flat" 400-cfs and 450-cfs minimum flows, and the Forest Service's example for "shaped" minimum flows). Figure 1 depicts Stetson's Lake Britton reservoir operations modeling procedure. Stetson's model calculates daily unimpaired inflow to Lake Britton as the drainage area ratio adjusted sum of the historical gaged flows at Pit 4 powerhouse and below the Pit 4 dam, for the complete period of analysis (water years 1975-1999, inclusive). The model assumes daily historical flow diversion to the Pit 3 and Pit 4 powerhouses is the daily hydropower demand for the historical case and all alternatives. The historical case therefore produces no hydropower generation reduction because it produces the same daily hydropower generation at Pit 3 and Pit 4 powerhouses as the historical record (demand). Models of all alternatives use the reservoir elevation-storage capacity relationship from the 2000 bathymetric survey (R2 Resource Consultants 2001) to reflect current reservoir storage capacity.

Figure 1
Schematic Diagram of Stetson Engineers Lake Britton Reservoir Operations Model



Note:

1) Lake Britton inflow is estimated to be the sum of gaged flows at Pit 4 PH and below the Pit 4 Dam with modification of drainage area.

2) Historical diversion to Pit 3 PH is assumed to be power demand for model purpose to estimate power generation reduction under different minimum flow requirements

The "No-Action" Alternative model, or baseline case, assumes the current minimum flow and lake level requirements were in effect for the entire period of record (the lowest lake level is 2,724.5 feet NGVD or 2,744 feet PG&E datum). The PG&E Alternative includes the PG&E proposed minimum flows and current baseline case lake level requirements. The Forest Service's interim "flat" minimum flow alternative model includes the following flow and lake level requirements:

- The minimum flow at Pit 3 reach is 400 cfs;
- The maximum instantaneous reservoir water surface elevation of Lake Britton does not fall below 2,730.5 feet NGVD (or 2,750 feet PG&E datum);
- In the summer (June 1 – August 31), the maximum reservoir elevation does not exceed 2,736.5 feet NGVD (or 2,756 feet PG&E datum); and
- The minimum flow at Pit 4 reach is 450 cfs.

The Forest Service's example "shaped" minimum flow alternative model includes the same lake level requirements and minimum flow requirements are revised as follows to produce a minimum flow hydrograph shape that responds to natural climatic variability in real time and thereby closely mimics the timing of variability in the natural flow regime:

- The minimum flow at Pit 3 reach is 16.4 percent of the previous two-week-average Lake Britton inflow, with a maximum and minimum resulting minimum flow of 1,000 cfs and 300 cfs, respectively; and
- The minimum flow at Pit 4 reach is 17.1 percent of the previous two-week-average Lake Britton inflow, with a maximum and minimum resulting minimum flow of 1,000 cfs and 350 cfs, respectively.

For this example "shaped" minimum flow alternative, the 16.4 and 17.1 percentages were determined so as to produce the same hydropower reduction as the interim "flat" minimum flow alternative. The example "shaped" minimum flow alternative model results for the Pit 4 reach in 1983 (wet year), 1978 (normal year), and 1976 (dry year) are enclosed.

To determine average annual hydropower generation reduction, Stetson's reservoir operations model calculates average annual flow in the Pit 3 and Pit 4 powerhouse penstocks under the various alternatives and compares to the historical average powerhouse flows. The arithmetic difference in average annual powerhouse flows is the annual flow reduction shown in Table 1 in cfs and acre-feet. Annual flow reduction is converted to annual hydropower generation reduction by multiplying annual flow reduction (cfs) by static head (ft) by turbine efficiency (%) and various conversion factors summarized in Table 1 notes. Stetson back-calculated turbine efficiencies to the third significant figure for Pit 3 and Pit 4 powerhouses (determined to be 81.5% and 79.5%, respectively) using historical (WY 1975-1999) annual average flow in the powerhouses determined from USGS gage records (2,274 and 2,503 cfs, respectively) and historical annual average Pit 3 and Pit 4 hydropower generation for the same period of record

(434,900,000 kWh and 563,300,000 kWh, respectively) from PG&E's February 25, 2003 Exhibit H. These historical annual generation values were also reproduced in FERC's DEIS as the historical Pit 3 and Pit 4 generation components of the Pit 3/4/5 Project's total 1,948,700,000 kWh average annual hydropower generation. Model estimated hydropower generation reduction at each powerhouse under each flow alternative is compared directly to the individual powerhouse's historical generation and to the total 1,948,700,000 kWh historical Project generation to quantify percentage generation reduction (Table 1).

Table 1
Estimated Hydropower Generation Reduction at the Pit 3 and Pit 4 Powerhouses (WY 1975-1999)

Alternatives	Historical Regulated[1]		No-Action (baseline)[2]		PG&E Proposed Minimum Flows [3]		FS Proposed Minimum Flows and Lake Level Requirements			
							"Flat" Minimum Flow [4]		"Shaped" Min Flow [5]	
	Pit 3 PH	Pit 4 PH	Pit 3 PH	Pit 4 PH	Pit 3 PH	Pit 4 PH	Pit 3 PH	Pit 4 PH	Pit 3 PH	Pit 4 PH
Static Head (feet)	315	382	315	382	315	382	315	382	315	382
Historical Annual Average Diversion to the Powerhouse (cfs)	2,274	2,503	2,274	2,503	2,274	2,503	2,274	2,503	2,274	2,503
New Annual Average Diversion to the Powerhouse (cfs)	2,274	2,503	2,255	2,484	2,255	2,456	2,127	2,246	2,127	2,246
Annual Flow Reduction (cfs)	0	0	19	19	19	47	147	257	147	257
Annual Flow Reduction (acre-feet)	0	0	13,800	13,800	13,800	34,000	106,400	186,100	106,400	186,100
Annual Hydropower Reduction (kWh) [6]	0	0	3,600,000	4,300,000	3,600,000	10,600,000	28,000,000	57,900,000	28,000,000	57,900,000
Annual Hydropower Recuction (%) [7]	0	0	0.84 %	0.74 %	0.84 %	1.89 %	6.47 %	10.26 %	6.47 %	10.26 %
Annual Hydropower Reduction (%) [8]	0	0	0.18 %	0.22 %	0.18 %	0.54 %	1.44 %	2.97 %	1.44 %	2.97 %

(1) Minimum flow at Pit 3 reach varies, minimum flow at Pit 4 reach varies
(2) Minimum flow at Pit 3 reach = 150 cfs, minimum flow at Pit 4 reach = 150 cfs
(3) Minimum flow at Pit 3 reach = 150 cfs, minimum flow at Pit 4 reach = 200 cfs
(4) Minimum flow at Pit 3 reach = 400 cfs, minimum flow at Pit 4 reach = 450 cfs
(5) Minimum flow at Pit 3 reach = 16.4% of previous two-week-average flow into Lake Britton (maximum 1,000 cfs, minimum 300 cfs).
Minimum flow at Pit 4 reach = 17.1% of previous two-week-average flow into Lake Britton (maximum 1,000 cfs, minimum 350 cfs)
(6) Assumes turbine efficiency for Pit 3 and Pit 4 powerhouses is 81.5% and 79.5%, respectively. Hydropower (kWh) = Static head (ft) × Flow (cfs) × Turbine efficiency ÷ 8.814 × 0.746 × 24 × 365. Lake level fluctuation has insignificant effect on hydropower generation because of high static head.
(7) Percentage of average annual historical regulated hydropower generation at the Pit 3 powerhouse (434,900,000 kWh) and Pit 4 powerhouse (563,300,000 kWh), respectively. (Historical annual average generation as estimated by PG&E in Exhibit H and published by FERC in its March 2003 DEIS.)
(8) Percentage of total Pit 3/4/5 Project average annual power generation (1,948,700,000 kWh). (Historical annual average generation as estimated by PG&E in Exhibit H and published by FERC in its March 2003 DEIS.)

Table 1 shows that implementing the "No-Action" Alternative would reduce historical annual average generation at the Pit 3 and Pit 4 powerhouses by 3,600,000 kWh and 4,300,000 kWh, respectively, or by a total of 7,900,000 kWh (0.4 percent of total Pit 3/4/5 annual generation). Implementing the Forest Service's Preliminary 4(e) flow conditions would reduce historical annual average generation at the Pit 3 and Pit 4 powerhouses by 28,000,000 kWh and 57,900,000 kWh, respectively, or a combined total 85,900,000 kWh. Subtracting the 7,900,000 kWh portion

of this reduction that is attributable solely to implementing the ”No-Action” (baseline) Alternative, yields the result that implementing the Forest Service’s 4(e) flow and lake level requirements would reduce total annual average Pit 3/4/5 Project generation by 78,000,000 kWh, or 4.0 percent of total Project generation.

FERC estimated with its operational model that implementing the Forest Service 4(e) flow conditions would produce an annual flow reduction in the Pit 3 and Pit 4 powerhouses of 125,067 acre-feet (173 cfs) and 197,072 acre-feet (272 cfs), respectively (DEIS Table 22 at p. 81). By the hydropower calculation outlined above, these annual flow reductions convert to annual average Pit 3 and Pit 4 powerhouse generation reductions of 33,020,000 kWh and 61,290,000 kWh, respectively, or a total reduction of 94,310,000 kWh. FERC’s 94,310,000 operational model estimate is 8,410,000 kWh higher than Stetson’s reservoir operation model estimate of 85,900,000 kWh.

There are several potential differences between FERC’s model and Stetson’s model that would contribute to the observed difference in results, including: method of calculating daily unimpaired Lake Britton inflow; selected period of record of analysis; selection of historical or 2000 reservoir elevation-capacity relationship; implementation of historical or current (baseline) lake level requirements and alternative proposed lake level requirements; method of simulating reservoir spillway operations; including manual operation of bladder gates; etc. For example, it appears that FERC’s model uses the same method as Stetson’s for calculating daily unimpaired Lake Britton inflow, but because FERC’s model used a longer period of record in its analysis the average annual inflow to the Project is 22 cfs higher in Stetson’s model (Table 2).

Table 2
Summary of Average Annual Flow Data used in Stetson and FERC Analyses of Hydropower Generation Reduction (Source: USGS except where noted)

	Pit 3			**Pit 4**		
	Lake Britton Inflow [1] (cfs)	Pit 3 PH (cfs)	Below Pit 3 Dam (cfs)	Inflow [2] (cfs)	Pit 4 PH (cfs)	Below Pit 4 Dam (cfs)
Stetson Model (WY 1975-1999)	2,968	2,274	694	2,995	2,503	492
FERC Method (WY 1975-2001) (DEIS at p. 35)	2,944	2,273	671	2,971	2,487	484

(1) Calculated using the drainage area ratio adjusted sum of the gaged flows at Pit 4 PH and below Pit 4 dam.
(2) The sum of gaged flows at Pit 4 PH and below Pit 4 dam.

While this 22-cfs difference is only 0.7 percent of annual average Project inflow, it would produce a 23-cfs (3.3 percent) underestimate of historical average regulated flow in the Pit 3 reach and therefore would produce a comparable overestimate of the amount of water required to meet minimum flow requirements in the reach. As would therefore be expected, FERC’s 173-cfs

estimate of additional water required to meet Forest Service minimum flows in the Pit 3 reach (DEIS Table 22 at p. 81) was 25 cfs higher than Stetson's 147-cfs estimate (Table 1). Similarly, differences in period of record analyzed produced a 12-cfs (2.4 percent) underestimate of historical average regulated flow in the Pit 4 bypassed reach (Table 2), and FERC's 272-cfs estimate of the amount of additional water required to meet the Forest Service minimum flows in the Pit 4 reach (DEIS Table 22 at p. 81) was 15 cfs higher than Stetson's 257-cfs estimate (Table 1). Although, FERC did not completely document its operational model methods and assumptions, it appears from the above comparisons that FERC's use of a different period of record in its analysis is a significant, if not the most significant, contributor to observed differences in the hydropower generation results of the two models.

Please consider these data analyses and recommendations in your continuing evaluation of the Forest Service's Preliminary 4(e) flow conditions and lake level requirements, and please contact us if you have additional questions. Upon your request, Stetson can provide complete daily or monthly Lake Britton reservoir operations model input and output data in digital format to FERC in order to facilitate a more complete and accurate review and analysis by FERC of the Forest Service's interim "flat" and example "shaped" Preliminary 4(e) minimum instream flow conditions.

Sincerely,

Matt Smeltzer
Senior Engineer/Geomorphologist

Xiao-Qing Zeng
Senior Engineer/Hydrologist

Enclosures: References
Qualifications
Forest Service Example "Shaped" Hydrograph Model Results for Pit 4 Reach

References

R2 Resource Consultants, Inc. 2001. Geomorphology of the Pit River in the vicinity of the Pacific Gas and Electric Company's Pit 3, 4, and 5 Project. Prepared by R2 Resource Consultants, Redmond, Washington, for Pacific Gas and Electric Company Technical and Ecological Services, April 9, 2001.

Qualifications

Mr. Matt Smeltzer is a Senior Engineer and Geomorphologist for Stetson Engineers in San Rafael, California, and is Project Manager under contract to the US Forest Service to provide technical assistance in conjunction with the FERC hydropower relicensing proceedings for Pacific Gas and Electric Company's Pit 3/4/5 Project (FERC #233). Mr. Smeltzer assisted the Forest Service in preparing its October 2002 Preliminary 4(e) flow and gravel management conditions, and analyzing hydropower generation reduction attributable to various alternative flow regimes.

Mr. Smeltzer obtained a Bachelors of Science in Civil and Environmental Engineering with high honors from the University of Michigan, Ann Arbor in 1995, and a Master of Landscape Architecture in Environmental Planning from the University of California, Berkeley in 1998 where he conducted thesis research on instream flow management and sediment transport in the Owens River Gorge as a Graduate Research Fellow at the White Mountain Research Station in Bishop, California, with G. Mathias Kondolf as major Professor. As a Senior Engineer and Geomorphologist for Stetson Engineers since 1999, Mr. Smeltzer provides technical assistance with geomorphology, hydrology and reservoir operations modeling and engineering issues to the US Forest Service in connection with FERC hydropower relicensing proceedings on the Pit River and Upper Stanislaus River in California, Clackamas/Oak Grove Fork in Oregon, and the Baker/Skagit Rivers in Washington. Mr. Smeltzer assisted the Stanislaus National Forest in evaluating and independently operating the CHEOPS ™ hydrology model application to the Middle and South Forks Stanislaus River in connection with the Beardsley-Donnells and Spring Gap-Stanislaus Project relicensings. Mr. Smeltzer has concurrently maintained a Research Fellowship at UC San Diego and part-time Research Scientist and Lecturer appointments at UC Berkeley, where he frequently lectures, leads the Graduate Environmental Planning Studio, and periodically publishes peer-reviewed articles on stream restoration and management topics emphasizing appropriate applications of geomorphic analysis in regulated river management. Mr. Smeltzer's previous experience includes geomorphic and spawning gravel assessments of Mill Creek for the US Fish and Wildlife Service and Deer Creek for the Nature Conservancy, and detailed assessments of Butte Creek, Uvas Creek, Carmel River, and the Owens River. Mr. Smeltzer is a co-author with Matt Kondolf and others of the CALFED Fluvial Geomorphology White Paper, which included an inventory and assessment of spawning gravel augmentation project implementation and performance throughout the Sacramento-San Joaquin River watersheds, and more recently an Instream Gravel Mining Issues White Paper for the State of Washington, and a river and sediment management planning guidance document for the Guatemalan government.

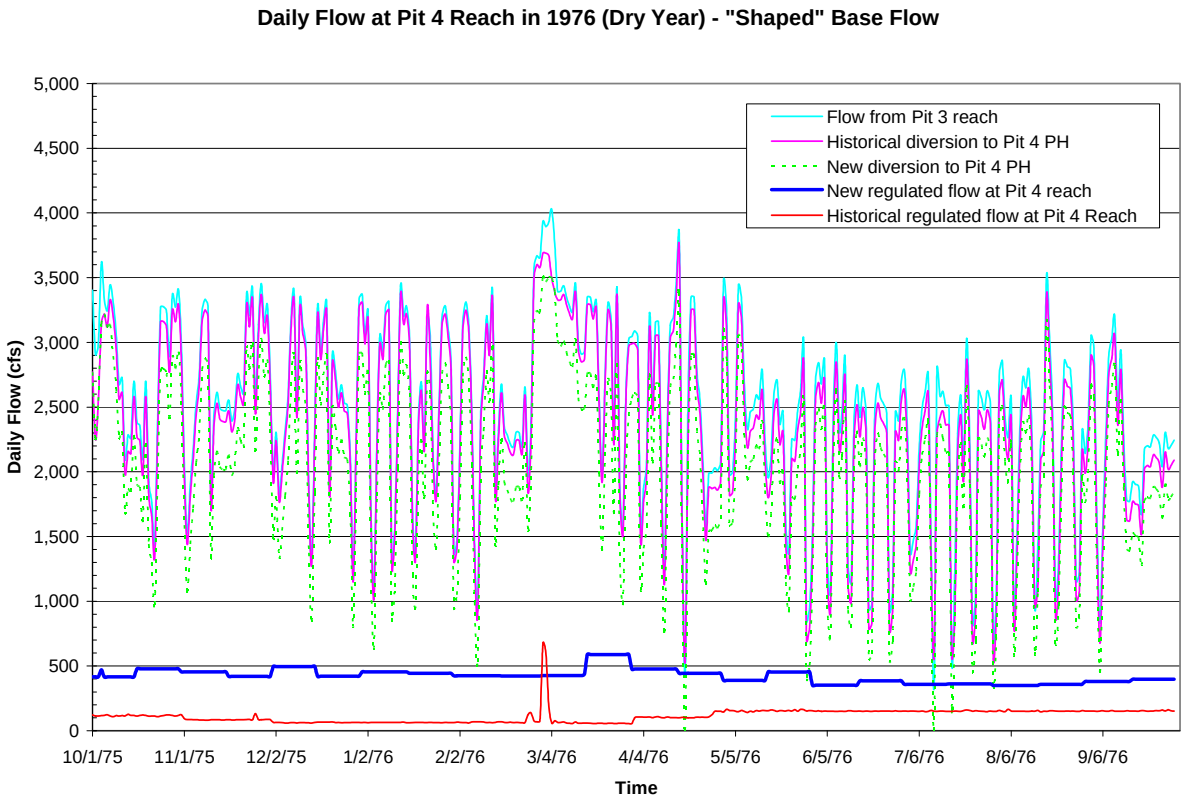
Dr. Xiao-Qing Zeng is a Senior Engineer and Hydrologist for Stetson Engineers in San Rafael, California, and is currently providing engineering and hydrologic modeling services to the US Forest Service in connection with FERC hydropower relicensing proceedings on the Pit River (FERC #233) and Upper Stanislaus River (FERC #2130) in California, and the Baker/Skagit Rivers (FERC #2150) in Washington. Dr. Zeng's work in these hydropower relicensings has included: regulated and unregulated flow analysis; evaluation of historical hydropower project impacts on instream flow, flood and freshet flows, flow duration, seasonal flow pattern, and flow ramping rate, etc.; development of a HEC-RAS hydraulic model to simulate unsteady flows in

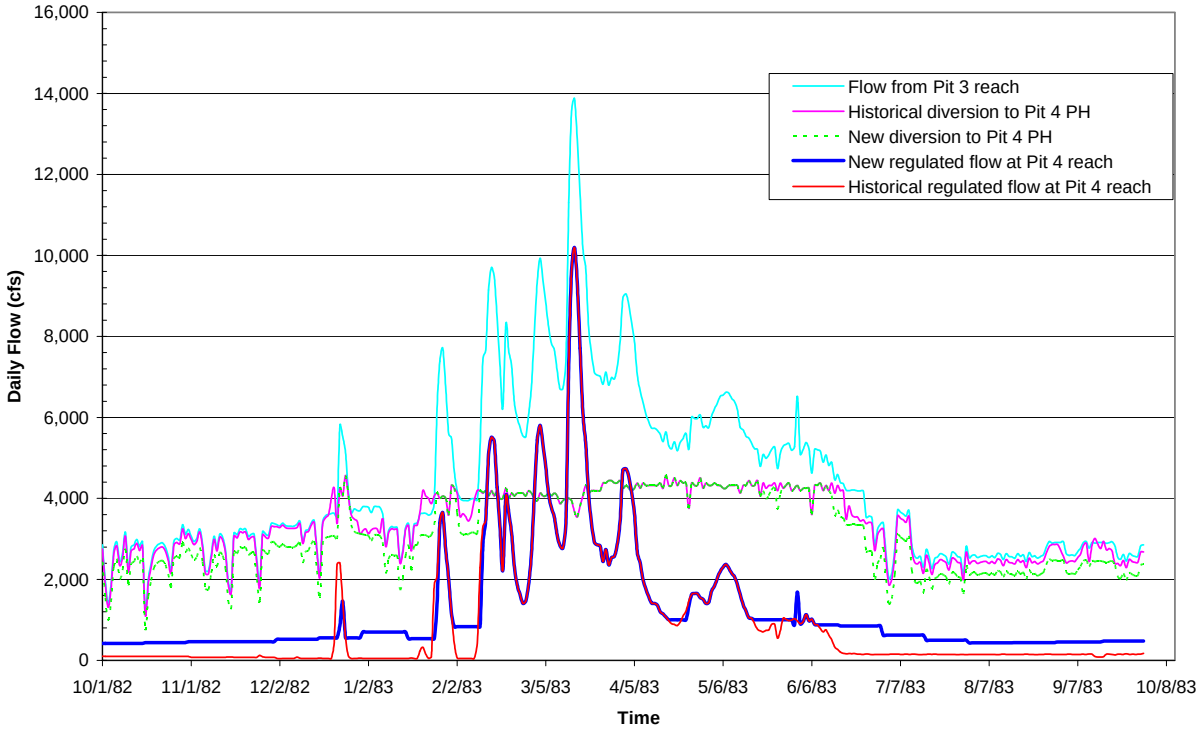
lower Skagit River; development of the Lake Britton reservoir operations model to analyze hydropower generation reduction under different minimum instream flows and lake level requirements; review of the calibration of a proprietary temperature model to assess its accuracy and appropriateness for use in determining minimum flows for the Pit River and South Fork Stanislaus River; etc.

Dr. Zeng earned a Bachelor of Engineering degree in Hydraulic Engineering (1989) from Tsinghua University (P.R. China), a Master degree in Hydraulics and Fluvial Dynamics (1992) from Yangtze River Academy (P.R. China), a Master degree in Applied Mathematical Sciences and a Ph.D. degree in Environmental Systems Analysis (2001) from University of Georgia. His Ph.D. program of study funded by the EPA/NSF Water and Watersheds Grant included water quality modeling of Lake Lanier, a Southeastern Piedmont impoundment in Georgia, and environmental planning analysis of coupled hydrologic, ecologic, and social effects of Lake Lanier watershed management. His dissertation specifically modeled watershed hydrology and reservoir nutrient cycling in Lake Lanier from two perspectives, the landscape or watershed scale and the lake or impoundment scale. He developed monitoring, characterization, modeling, and management approaches for both perspectives. He also developed a prototype web-based simulation model for reservoir water quality management – a novel means of building a direct communication bridge between environmental scientists and stakeholders and decision-makers.

Dr. Zeng has 6 years experience in environmental studies in China EPA and 5 years experience in the United States. He is a registered California Civil Engineer (License No. 64910). His areas of expertise include watershed modeling, hydrologic modeling, surface/ground water hydrodynamic modeling, reservoir operations modeling, water quality modeling, aquatic biogeochemical and food chain modeling, field investigation and experimental design to collect data for model calibration and evaluation, model uncertainty analysis, sediment-water interaction analysis, hydraulic analysis of wastewater ocean outfalls, environmental/water resources systems analysis using optimization techniques, environmental information technology, and engineering economic analysis.

Forest Service Example "Shaped" Hydrograph Model Results for Pit 4 Reach



Daily Flow at Pit 4 Reach in 1978 (Normal Year) - "Shaped" Base Flow

Daily Flow at Pit 4 Reach in 1983 (Wet Year) - "Shaped" Base Flow