10/5/10 Bd Mtg. Item 7
Oroville Facilities
Deadline: 9/24/10 by 12 noon

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Via email and U.S. mail

Jeanine Townsend
Clerk to the Board
California State Water Resources Control Board
1001 I Street
Sacramento, CA 95814

RE: Butte County's Comments on the Matter of Water Quality Certification for the Department of Water Resources Oroville Facilities (Federal Energy Regulatory Commission Project No. 2100)

Dear Ms. Townsend:

This letter provides Butte County's (Butte's) comments on the State Water Resources Control Board's July 2, 2010 draft water quality certification ("July 2010 draft certification"), the third public draft addressing the Department of Water Resources' (DWR's) application to the Federal Energy Regulatory Commission (FERC) for a new license to operate the Oroville Facilities ("Oroville project," FERC Project 2100).

On July 29, 2009, Butte County ("Butte") submitted detailed comments on the State Board's first public draft, prior to DWR's August 2009 withdrawal and resubmission of its application for water quality certification. On February 16, 2010, Butte provided further comments addressing the State Board's second public draft, dated January 21, 2010. History repeated itself on July 20, 2010, as DWR once again withdrew and resubmitted its application. Butte's first two comment letters and their accompanying exhibits are appended to these comments, and are incorporated here as Exhibits 1 and 2 in Butte's submission on the current draft. The great majority of Butte's earlier comments are equally applicable to the July 2010 draft certification.

I. Summary and Overview

DWR's application for water quality certification, its *sixth* in connection with the same proposed project, is unprecedented in this Board's water quality certification proceedings. Dissatisfied with the State Board's exercise of its independent authority to protect water quality, DWR has repeatedly withdrawn and resubmitted its application for certification under section 401 of the Clean Water Act. Butte again strongly concurs in the State Board's conclusion that "certain measures as written" in the March 2006 Settlement Agreement are "either not enforceable, will not protect the beneficial uses, or will not meet water quality standards in a timely manner." (Draft certification, p. 4.) Butte opposes any attempt by DWR and the State Water Contractors organization (SWC) to weaken the State Board's conditions of certification. As the State Board found, "[b]eneficial uses currently impacted by the project may not be reasonably protected if the proposed measure has a management plan with unclear or unenforceable standards, an excessively long period prior to implementation, or unspecified implementation dates." (Draft certification, p. 4.)

Moreover, Butte appreciates the State Board's forceful defense of its independent authority in its July 9, 2010 Response to Comments document, which eloquently rebuts strained attempts by DWR and the SWC to weaken and derail that authority. The Response to Comments document (RTC) includes the critical recognition that, in independently determining whether the Oroville facilities will meet water quality standards and setting conditions of certification, "the Board is not bound" by contrary legal conclusions in DWR's EIR. (*Id.* at p. 5.) For example, the Board correctly concludes it is not bound by DWR's untenable assertion in its EIR that current operation of the Oroville facilities "has no adverse affect" [sic.] on "all beneficial uses specified in the Basin Plan for Project Waters." (*Id.* (citing DEIR, p. 4.2-15.)

With that credit given, the State Board's July 2010 draft certification and responses to comments, and its accompanying findings and mitigation measures, still do not come to terms with other concerns Butte and others have raised about the water quality consequences of DWR's application. As detailed below, the State Board must consistently implement its own advice, and take further steps to ensure it is not relying upon faulty assessment, unclear or unenforceable schedules, excessive periods prior to implementation, and vague implementation dates. In particular:

(1) The Board must take further steps to ensure water quality protection in the context of climate change.

(2) The Board must take further steps to ensure water quality protection in the context of a changing State Water Project.

(3) The Board must take further steps to ensure water quality protection against toxic contaminants, notably methyl mercury and polychlorinated biphenyl (PCBs).

(4) The Board should not authorize the Deputy Director to summarily weaken certification conditions protecting water quality by utilizing "approval by inaction."

These steps are needed to counteract deficiencies in the proposed conditions and supporting environmental review. As the State Board appreciates, certification cannot occur unless it can determine under section 401 that the project protects all beneficial uses and complies with all the mandatory objectives in the in the Water Quality Control Plan for the Central Valley-Sacramento and San Joaquin River Basins (Basin Plan). On core issues such as climate change and the changing context of the State Water Project, key contentions of DWR are no more defensible than the discredited claim that the Oroville facilities' current operation does not adversely effect the beneficial uses specified in the basin plan. Notwithstanding any general desire the State Board may have to achieve speedy implementation of certification conditions, the State Board remains bound to fully enforce section 401 of the Clean Water Act, and thereby fulfill the Congressional mandate "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." (33 U.S.C. § 1251(a).)

II. The State Board properly defended its authority to establish clear and enforceable water quality standards.

A. The State Board cannot waive or defer its Clean Water Act enforcement obligations.

Under the enforcement regime Congress established in the Clean Water Act, it is the State Board's duty under section 401 of the Clean Water Act (33 U.S.C. §1341) to fully enforce water quality standards and implementation plans promulgated by the State Board. (33 U.S.C. § 1313.) DWR must also demonstrate compliance with the State Board-approved objectives in the Basin Plan. Though called "objectives," compliance with these standards and their implementation program is mandatory. (*See State Water Res. Control Bd. v. Office of Admin. Law* (1993) 12 Cal. App. 4th 697, 701-02.) The Basin Plan standards also apply to the entirety of project operations. (*PUD No. 1 v. Wash. Dep't of Ecology* (1994) 511 U.S. 700, 711-12.)

The Board has correctly noted that to issue a section 401certification, DWR must demonstrate to the Board that DWR will achieve

> compliance with all water quality objectives in the Basin Plan... as well as with other water quality objectives that the Project may affect. DWR must also demonstrate that the Project does not impair the beneficial uses of the Feather River or Lake Oroville. If the Project does not comply with one or more of the water quality objectives, then DWR must describe the actions that it will take to bring its Project into compliance with the applicable water quality requirements in order to protect and maintain the beneficial uses.

Exhibit 1 to Butte's July 29, 2009 letter (Ex. 1), pp. 1-2.

B. The State Board properly resisted attempts to deprive it of authority to fully protect water quality in its certification decision.

Butte commends the State Board for its eloquent rebuttal, in its July 9, 2010 Response to Comments, to the continuing attempts by DWR and SWC to deprive the Board of its authority to fully protect beneficial uses and ensure compliance with standards referenced in the Basin Plan.

First, the State Board correctly recognizes that the "reasonable protection" standard, used for setting water quality objectives, cannot substitute for "reasonable assurance" that the project will not violate water quality standards. Federal regulations implementing section 401 require water quality certification to include "a statement that there is a *reasonable assurance that the activity will be conducted* in a matter which will not violate applicable water quality standards." (40 C.F.R. § 121.2(a)(3)(emphasis added).) "Reasonable" here refers to the level of certainty a project will comply rather than "the level of compliance itself"; that term provides DWR no cover to claim that its violation of water requirements is in a "reasonable" manner. (RTC, p. 4.) Moreover, the Porter-

Cologne Act's "reasonable protection" standard, "used for *setting* water quality objectives," provides no basis to authorize noncompliance "in *applying* the standards" in the Basin Plan. (*Id.* (emphasis in original).)

Second, the State Board's independent authority to test whether the Oroville Facilities meet state water quality standards (including beneficial uses) is not bound by the assertion in DWR's EIR that current Oroville operations do not adversely affect beneficial uses. (DEIR, pp. 4.2-15.) Butte's analysis in earlier comment letters corroborates the Board's observation that "there is substantial evidence in the EIR and the application for water quality certification that *current operation does not protect certain beneficial uses.*" (RTC, p. 5; see also pp. 9-10 (discussing water temperature).) Under CEQA, where a responsible agency is generally authorized to rely upon the lead agency's EIR when a challenge to that EIR is pending, any approval from the responsible agency nonetheless remains "at the applicant's risk" prior to the final decision in the action. (Pub. Res. Code, § 21167.3.)

While risky under CEQA, DWR's statements about Basin Plan compliance in the EIR simply do not govern the State Board's "exercise of its independent authority" to determine whether "operation of the Oroville Facilities will meet state water quality standards, including beneficial uses." (RTC, p. 5.) In fulfilling these legal responsibilities, the State Board is "not bound" by "a legal conclusion such as this in the EIR." (*Id.*)

Third, the Settlement Agreement, which Butte did not sign due to its neglect of key issues raised by the county and others, does not override the State Board's independent duty to ensure that Basin Plan standards and other water quality requirements are met. Rather, "[a] contractual agreement among settlement parties to the measures is not sufficient to satisfy the State Water Board's independent duty to ensure that water quality is adequately protected." (RTC, pp. 5-6, citing *Central Delta Water Agency v. State Water Resources Control Board* (2004) 124 Cal.App.4th 245, 265.)

Fourth, the State Board is authorized to ensure that DWR honors the requirements of certification. Thus, DWR's claim that enforcement of certification provisions can only be accomplished through FERC's procedures "would render water quality certifications essentially pointless: a federal agency is unlikely to use its limited resources and discretionary prosecutorial powers to enforce a state provision that it did not add to its permit in the first place. If the state could not enforce its conditions of certification, the state would have to deny certification for many projects it might otherwise approve. If the state lacked authority to enforce the conditions it sets to meet water quality objectives, the state would not have 'reasonable assurance' that the activity will comply with water quality objectives (See Wat. Code, § 13160)." (RTC, pp. 14-15.)

By contrast, DWR's crabbed reading of the State Board's enforcement power cannot be reconciled with the Porter-Cologne Act's granting of state water quality enforcement authority (Wat. Code, § 13385(a)(5).) DWR's effort to truncate the powers of its fellow state agency is also irreconcilable with the Clean Water Act, which recognizes that enforcement of water quality certification provisions are "appropriate requirements of state law" (33 U.S.C. § 1341(d); see also 33 U.S.C. §§ 1365, 1370, 1341(a)(2) (discussing state enforcement authority).)

Fifth, in fulfilling its duty to protect beneficial uses, the State Board is not rigidly limited by either the assessment in DWR's EIR or the precise FERC/ DWR project boundaries. In defense of its inclusion of Habitat Expansion Agreement (HEA) conditions in the requirements of certification

(Condition S9), the State Board recognized that "in the exercise of its Water Code and public trust responsibilities, the State Water Board is not bound by legal conclusions regarding beneficial use protection in the EIR…." (RTC, p. 11.) Moreover, whether or not FERC ultimately changes is project boundaries, the State Board must ensure that impacts are appropriately mitigated and that the project protects beneficial uses. (*Id.*, citing *Lake Erie Alliance for the Protection of the Coastal Corridor* (W.D. Penn. 1981) 526 F.Supp. 1063, 1074, affd. mem. (3d Cir. 1983) 725 F.2d 668, cert. den. (1983) 464 U.S. 916. ("state certification under the Clean Water Act is set up as the exclusive prerogative of the state and is not to be reviewed by any agency of the federal government"); State Water Board Order WR 2002-0002, at pp. 11-12; State Water Board Order WR 2008-0025, at pp. 18-22.)

Lastly, the State Board retains reserve authority to revisit its water quality certification conditions. That conclusion reinforces the Clean Water Act, which recognizes and maintains states as the primary authority over water quality within their boundaries. (33 U.S.C. § 1251(b).) By contrast, the SWC's denial of that authority would leave unfulfilled part of the mandate of section 401, which anticipates that water quality certifications will operate on an ongoing basis. (33 U.S.C. § 1341(d); see also RTC, p. 23.)

III. The State Board must ensure water quality protection in the context of climate change.

A. The State Board's cursory discussion of climate change dishonors its recognition elsewhere that climate change is a pivotal water quality issue.

As detailed in Butte's previous comment letters, a central obstacle to lawful water quality certification is the paucity of serious assessment of climate change in the context of the proposed 50-year renewal of DWR's operating license. Oroville, as the SWP's primary storage and power generation facility, plays a central role in SWP operations. Changing climatic conditions will impact Oroville's flood control, reservoir storage levels, upstream and downstream flow levels, water temperatures, power generation, water quality, fisheries, and recreation.

Despite previous efforts in written comments to ensure that the Board's decision on water quality certification would be grounded in a thorough assessment of climate change, the July 2010 draft certification evades the issue again. The Board's Responses to Comment provide only three scant paragraphs in response to Butte's concerns, relying almost exclusively upon repetition of sweeping assertions in DWR's EIR that contradict or avoid what DWR and others have articulated elsewhere. (RTC, p. 27; see Exhibit 1 to this letter, pp. 4-8.) But as the Board is aware, climate change is closely related to a host of pivotal water quality concerns, including adverse effects on aquatic life and wildlife, as well as additional pollution and sedimentation. (State Board Strategic Update 2008-2012, pp. 2-3.) Before issuing any water quality certification for the project, the Board must first fulfill its commitment to consider "the impacts of climate change in our decision-making." (*Id.*, p. 7.)

B. In making its certification decision, the State Board is not bound by the faulty assumptions about climate change in DWR's EIR.

Rather than independently assessing climate change for its water quality certification decision, the State Board in its responses to comments relies heavily on the assumption that the Board "must act under" the EIR that DWR prepared as lead agency. (RTC, p. 27.) The Board repeats almost verbatim the summary conclusions of the EIR as to climate change, including the assumption that modeling for temperature and flow conditions was based upon a "wide range of climate scenarios, including climate change scenarios." (*Id.* (citing FEIR, p. 5-130.) The Board also relies upon the monitoring program for water quality, which contains no specific requirements relating to climate change (S12), and the general reservation of authority to make changes in response to changed regulatory environmental conditions. (RTC, p. 27.)

Rather than uncritically relying upon DWR's assertions as to climate change, the Board should recognize—as it did when addressing the issue of Basin Plan compliance—that these assumptions in the EIR do not govern the State Board's "exercise of its independent authority" to determine whether "operation of the Oroville Facilities will meet state water quality standards, including beneficial uses." (RTC, p. 5.) Read in context, several of DWR's key assertions about climate change in its EIR are no more factual or defensible than DWR's discredited statement that existing Oroville operations protect all beneficial uses. For example:

- Rather than consistently reporting the conclusions of its own studies and others showing that climate change could alter the timing and quantity of precipitation and runoff into Lake Oroville, changing both the operation of the Oroville project and its environmental impacts, the EIR anomalously asserts that "[t]hese future environmental conditions *are independent of the Oroville Facilities and its [sic.]operations.*" (FEIR, p. 3-27 (emphasis added).)

- Rather than recognizing that hydrologic variability is likely to increase in the future, as its own studies have consistently shown, DWR presumes that hydrologic variability from the previous century "is *expected to continue in the foreseeable future.*" (FEIR, p. 3-28 (emphasis added).)

- Rather than drawing on the analytical and modeling techniques that DWR has employed in other reports on climate change, including reports addressing the Feather River watershed, DWR summarily concludes that "any discussion of potential changes to operation of the Oroville Facilities necessitated by climate change *would be speculative* at this time." (*Id.* (emphasis added).)

- Rather than calling for a full analysis of the project informed by the consequences of climate change, the EIR suggests that there would be "further opportunities in the future, at the next relicensing period" to "make more definitive statements about the extent of climate change." (FEIR, p. 3-27.) The "next relicensing period" referenced here would take place *thirty to fifty years after project implementation.*

C. DWR's key assumptions about climate change in the context of the project cannot serve as the basis for the State Board's water quality certification.

1. Climate change is not "independent" of the Oroville project's water quality consequences.

Each of the EIR's four key assumptions about climate change highlighted above no more credible than DWR's denial of Basin Plan violations in existing Oroville Operations. The puzzling assertion that the environmental consequences of climate change for Oroville are "independent" of Oroville facilities and operations runs counter to DWR's own more candid analyses. Indeed, just prior to the assertion of "independence," the EIR concedes that DWR's 2006 Progress Report "indicates that regional climate changes could result in future changes to both quantity and timing of precipitation in the region and runoff into Lake Oroville and other SWP and Central Valley Project (CVP) reservoirs, which, over the long term, could affect water quantity, water quality, aquatic resources, recreation, cultural resources, and agricultural practices." (FEIR, p. 3-27; see also Exhibit 1, p. 6; 2006 Progress Report, p. 4-49.)

Other DWR reports corroborate the conclusion that the climate change is anything but "independent" of the Oroville project's water quality consequences. In its science-based studies, such as the May 2009 report *Using Future Climate Projections to Support Water Resources Decision-Making in California,* DWR found that "Lake Oroville, the backbone of the SWP, receives much of its inflow from the upper Feather River basin in the Sierra Nevada mountain range ... Because snow melting and sublimation are heavily dependent on temperatures, it is important to the operation of Lake Oroville to know how projected future climate conditions can affect both the timing and quantity of flows arriving there." (*Id.,* pp. 25, 26.) In that study, DWR used a physical model of the upper Feather Basin to gauge the effect of increased air temperature on precipitation, snow pack, and runoff.

2. Twentieth-century hydrology is not "expected to continue in the foreseeable future."

The EIR's suggestion that the range of hydrologic variability from the previous century is "expected to continue in the foreseeable future" (FEIR, p. 3-28) is contrary to a vast body of climate change literature that is familiar to DWR and is now shaping statewide policy. For example, in the May 2009 report DWR prepared for the California Climate Change Center, *Using Future Climate Projections to Support Water Resources Decision-Making in California,* DWR noted that "future hydrologic variability will be similar to historic variability ... no longer holds true under climate change." (*Id.*, p. 24.) DWR's 2009 California Water Plan Update appends DWR's October 2008 report entitled *Managing an Uncertain Future,* which discusses statewide climate change adaptation strategies. That report similarly noted: "California has invested in, and now depends upon, a system that relied on historical hydrology as a guide for future water supply and flood protection. However, *due to climate change, the hydrology of the past is no longer a reliable guide to the future."* (*Id.*, p. 4 (emphasis added).)

In short, with the exception of the present proceeding, DWR has abandoned the unsupported assumption in the EIR that twentieth century hydrology is a reliable guide for future water planning. This belies the State Board's attempt, in its responses to comments, to rely on the "wide range" of climate scenarios ostensibly studied to model compliance with temperature and flow conditions. (RTC, p. 27.) Read in context, DWR's claim to have studied a wide range of scenarios (FEIR, p. 5-138 and Appendix E) merely means that it applied its modeling only to the range of twentieth-century hydrologic conditions. DWR refused to acknowledge in the EIR, much less study, the project's water quality impacts in light of the now-standard assumption that last century's hydrological range is no longer a "reliable guide" for assessment of future impacts.

Moreover, Appendix E poses further limitations that undermine its usefulness in modeling the future consequences of climate change. For example, it assumes recent historic exports and current Delta flow requirements, factors that are overwhelmingly likely to change in the future (see section IV, *supra*). It appears to assume the use of a river valve that is no longer operable. By its own terms, Appendix E is insufficient to frame the State Board's decision on water quality certification because it presupposes that no analysis is needed where the project made an incremental improvement over existing conditions. Even assuming *arguendo* that this approach satisfied CEQA, which Butte will contest in the pending action challenging DWR's EIR, this assumption renders the modeling unable to evaluate whether the proposed project fully protects beneficial uses. (RTC, p. 5.)

3. Assessment of project operation in the context of climate change would not be "speculative."

Without candid assessment of Oroville project operation in the context of climate change, the State Board will lack a reliable gauge of what conditions and enforcement measures are needed to safeguard water quality and protect beneficial uses referenced in the Basin Plan. DWR's argument in its EIR that further assessment now would be "speculative" begs the question, because it relies upon the same Appendix E assumptions discussed and discredited above. The argument that further assessment is unnecessary also rests upon the dubious assumption that DWR, and by inference the State Board, "need not consider" the Oroville project in connection with downstream operation of the State Water Project. (FEIR, p. 3-27.)

The State Board's three-paragraph rejection of climate change concerns (RTC, p. 27) fails to consider the vast body of literature that could have provided rigor and structure to this assessment. In addition to the sources cited in Butte and Plumas Counties' comment letters, the State Board should include in its assessment the 19 reference sources listed in Volume 4 of DWR's 2009 California Water Plan update, which include numerous government reports as well as scholarly analyses. (See http://www.waterplan.water.ca.gov/cwpu2009/index.cfm.) Taken together, these sources demolish the contention that serious analysis of climate change and project operation can here be avoided as speculative. That assessment is crucial. As noted in a 2003 Pacific Institute summary of literature on climate change and California water resources, attached as Exhibit 3 to this letter, the consequences of climate change, even in the short term, can profoundly affect water quality (*Id.*, p. 18.)

As discussed in previous comment letters, the Attorney General has adamantly criticized similar avoidance of the subject when assessing matters of a comparatively smaller scale, such as the San Bernardino General Plan and the proposed bottling plant in McCloud. While climate change remains an evolving science, DWR's own climatologists are also well aware that effective mitigation and adaptation strategies depend upon rigorous climate change assessment. (See http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v4c02a16_cwp2009.pdf.)

Moreover, before it finalizes water quality certification, the State Board must fully consider other available data and analysis that underscore concerns about climate change and project operation. In its September 24, 2010 comments submitted to the Board, Plumas County summarizes the June 15, 2010 public presentation of Gary Freeman, principal hydrologist for Pacific Gas and Electric Company, to the Almanor Basin Watershed Advisory Committee. The information presented included the following data:

- Over the 50-year span from 1960 to 2009, the trend in the Feather River Basin shows a decrease in average annual runoff of 400,000 acre-feet of water.
- Over the same 50-year period, winter nighttime mean minimum temperatures have increased 6.7°F in the Lake Almanor Basin and 9.2°F in the East Branch watershed of the North Fork Feather River (compared to 2.3°F statewide).

- The April 1 snowpack at the main ski area in the Lake Almanor basin has declined 59 percent since 1949.

Butte concurs with Plumas that "these trends over the past half century further belie the assertions in the EIR that both the weather extremes and the weather variability that have been observed over the past hundred years will 'continue for the foreseeable future'." (Plumas County comments, September 24, 2010, p. 1.) Butte also attaches as Exhibit 4 several further analyses, by Mr. Freeman and others, that should be reviewed in connection with the State Board's climate change assessment.

4. Rigorous assessment of the consequences of climate change for project-related water quality cannot be deferred for thirty to fifty years.

The State Board's cursory summary of its reasons for not delving further into climate change (RTC, p. 27) fails to mention DWR's most egregious ground for rationalizing its superficial assessment: that "more definitive statements" about climate change could be provided at the next relicensing period, thirty to fifty years from now. This is a remarkable evasion, considering that an appellate court, with the Attorney General's support, recently set aside a one-year deferral of a specific mitigation plan because it undermined CEQA's goals of full disclosure and informed decision-making. (*Communities for a Better Environment v. City of Richmond* (2010) 184 Cal.App.4th 70.)

Outside the CEQA context, it should be even clearer that this avoidance, if accepted by the State Board, is inconsistent with the finding that project conditions protect water quality. In addition to immediately providing its own analysis of climate change in reference to the protection of beneficial uses, the State Board should, if it later certifies the project, require periodic review of the conditions of certification to determine whether information about climate change requires further adjustment to protect water quality.

D. The conditions of certification do not adequately safeguard against climate-change related water quality risks.

The State Board asserts that in a previous discussion of climate change and previous comments, Butte did not "articulate additional conditions" that would bolster compliance with water quality standards in the context of climate change. (RTC, p. 27.) That is because climate change is a foundational issue, whose analysis in the context of water quality protection is likely to affect the quantity, timing and temperature of flows. Butte did not want to create the impression that interlineating several phrases could substitute for full assessment of what compliance with water quality standards requires.

With that said, Butte believes that once the State Board analyzes climate change, further conditions of certification could be imposed that would help ensure that climate change does not undermine compliance with these standards. At present, the State Board relies upon a water quality mitigation program that is silent on climate change, and its general reservation of authority to impose further conditions. But as the State Board concluded in the context of HEA requirements, "[a] reservation of authority is not sufficient to fulfill the State Water Board's responsibilities to ensure that water quality standards are met." (RTC, p. 12.) Moreover, prudence dictates that if the State Board wishes to address climate change, it should do so clearly when making its section 401 decision and imposing conditions of certification (See *Karuk Tribe of Northern California v. California Regional Water Quality Control Board* (2010) 183 Cal.App.4th 330.)

Drawing in part from Plumas' and CSPA's September 24, 2010 comments, Butte provides additional suggestions to address water quality concerns arising from climate change:

1. Water quality monitoring (S12) should be modified to require periodic review, at the outset and least every five years thereafter, of the conditions of certification to account for climate change, with authority to adjust the conditions where needed to ensure compliance with water quality standards.

2. Modeling that DWR and others have commenced in portions of the Feather River system should be expanded to cover the whole watershed, and clarify the available range of options for project operation and climate change adaptation.

3. Sufficient carryover storage should be required so that the cold water pool is maintained in Lake Oroville, and water quality standards are protected. (That result would no longer simply depend on the "indirect" consequence of temperature requirements that may be subject to objections of "infeasibility").

4. Operational efficiency should be improved through adequate real-time monitoring and data collection for the watershed serving Lake Oroville.

5. Watershed restoration programs should be encouraged in the Feather River watershed, as suggested in Plumas County's comments.

IV. The State Board must ensure water quality protection in the context of a changing State Water Project.

A. The State Board is not bound by the faulty premise in DWR's EIR that operation of Oroville facilities can be segregated from SWP operation.

In its comments on the Oroville DEIR, the State Board faulted the DEIR for failing to "include an adequate discussion of the impact of State Water Project (SWP) operations on the Proposed Project." (FEIR, p. 4-41.) The State Board also observed then that changes to the timing or quality of water deliveries could affect the ability of the Lake Oroville cold water pool to protect anadromous fish, and the extent of the project's cumulative impacts. (FEIR, p. 4-41.)

Unfortunately, rather than continuing to press for that robust analysis, the 2009 and 2010 iterations of the draft water quality certification appear closer to the evasive generalization that DWR used to respond to the State Board's comments on the DEIR; namely, that "[a]nalysis of future changes to State Water Project (SWP) statewide operations is outside the scope of the EIR." (FEIR, p. 4-51.) For reasons discussed above in connection with Basin Plan compliance and climate change, the State Board cannot be bound by that faulty conclusion in making its water quality decision.

The Oroville project is an integral and interconnected part of the State Water Project. (Wat. Code, § 12934(d).) Releases from Lake Oroville must serve a variety of purposes, including (1) compliance with Bay-Delta water quality standards; (2) satisfaction of obligations under environmental laws such as the Clean Water Act and federal and state Endangered Species Acts; and (3) release of water, as available, to meet the needs of State Water Project contractors. (*See* DEIR at p. 2-5.)

Operation of the Oroville project is closely tied to downstream needs. If those downstream constraints change, or if DWR discovers that operational changes are necessary to meet existing constraints or comply with legal requirements, changes to the Lake Oroville release schedule are likely to follow. Fundamental changes in statewide operations appear to be increasingly likely. (See, e.g., *Natural Resources Defense Council v. Kempthorne* (E.D. Cal. 2007) 2007 U.S. Dist. Ct. LEXIS 42263, 91968; *Pacific Coast Federation of Fishermen's Associations v. Gutierrez* (E.D. Cal. 2008) 2008 U.S. Dist. LEXIS 31462; E. HANAK, MYTHS OF CALIFORNIA WATER—IMPLICATIONS AND REALITY 23 (Public Policy Institute of California (2009) (DWR's own data suggest that Delta smelt restrictions alone are likely to reduce Delta exports by an average of twenty to thirty percent).)

As discussed in Butte's February 2010 comments, this year is a dynamic one for the State Water Project. That statement is even truer now. A decade after *Planning and Conservation League v. Department of Water Resources* (2000) 83 Cal.App.4th 892, DWR finally adopted the "Monterey Plus" amendments to the State Water Project, and these statewide amendments are once again subject to litigation challenge. Moreover, the State Board's recommendations for Delta flow criteria also brought attention to the role of the Oroville facilities, and the maintenance of the cold water pool.

B. The "normal operation" of the project lacks cohesive definition.

Even though Oroville Reservoir is the State Water Project's most prominent storage facility, the draft certification appears to operate on the premise that the operation of Oroville facilities can be segregated from SWP operation. The surest sign that this attempted segregation fails is by reference to section S8(e) of the July 2010 Draft Conditions. In pertinent part, section S8(e) provides:

> If the April 1 runoff forecast in a given water-year indicates that Oroville Reservoir will be drawn to elevation 733 feet (approximately 1,500,000 acre-feet) under normal operation of the Project, then the minimum flows in the HFC may be reduced on a monthly average basis, in the same proportion as the respective monthly deficiencies imposed upon State Water Project deliveries to the State Water Contractors for agricultural use; however, in no case shall the minimum flow releases be reduced by more than 25 percent.

Despite some rearranged clauses, this section is effectively the same as former draft section S8(d), the version that Butte and the California Sportfishing Protection Alliance (CSPA) criticized in the first iteration of draft conditions. As with the former version, the "normal operation" of the project in section S8(e) remains fundamentally ambiguous. In light of such recent developments the Delta species decline, enforcement of endangered species law, and the onset of climate change, considerable controversy exists over whether the "new" normal or some older version should prevail. CSPA's comments elaborate further on the resulting tension and ambiguity.

C. The State Board's report and public comments on Delta flow criteria undermine the contention that future operation of the Oroville facilities can be segregated from SWP operation.

In its responses to comments addressing Oroville's relationship to the SWP, the State Board relies heavily on the premise that the temperature requirements in the conditions of certification will indirectly maintain the cold water pool and prevent against environmental harm. (RTC, p. 24.) But the conditions leave ambiguous under what circumstances DWR and individual water contractors may argue that it is "infeasible" to maintain the temperature requirements.

If there were any doubt that the operation of the Oroville project, and its water quality implications, should be considered in the context of changes in SWP operation, this summer's proceedings on Delta flow recommendations would remove that doubt. (See State Board, *Report for the Development of Flow Criteria for the Sacramento- San Joaquin Ecosystem* (final report adopted August 3, 2010).) These proceedings undermine the EIR's premise of separation between these subjects. In comments dated July 29, 2010, DWR stated that "[b]y taking a narrow focus on Delta outflow and ignoring the consequences on cold water reserves in upstream reservoirs, these flow criteria recommendations would have a severe adverse impact on anadromous fisheries upstream of the Delta." The SWC organization, likewise, argued that enforcement of the Delta flow requirements could affect the maintenance of cold water pools (making this argument express in the case of Lake Shasta, but leaving ambiguous whether the same applied to Lake Oroville).

D. Comments of federal agencies recognize the strong connection between SWP operation and Oroville water quality.

Butte understands that at present, the National Marine Fisheries Service (NMFS) is considering the appropriate approach to take in its final Oroville biological opinion, addressing DWR's attempt to weaken the requirements and others' claims that the opinion's "no jeopardy finding" is inconsistent with the OCAP biological opinion. Notably, in their comments on the State Board's draft Delta flow criteria, both NMFS and the United States Fish and Wildlife Service also noted the need to consider the relationship between implementation of the Delta flow criteria and the maintenance of the cold water pool. 1

V. The 2010 Draft Certification weakens public accountability over enforcement of water quality conditions.

A. The Deputy Director should not have the opportunity to weaken minimum flow and temperature requirements.

The July 2010 certification conditions allow the Deputy Director, Division of Water Rights discretion to avoid what had been more straightforward conditions of approval. For example:

- Section S8(b) gives the licensee an additional opportunity to persuade the Deputy Director that it "cannot feasibly meet" the water temperature requirements for the Low Flow Channel in Table S8

1 As articulated by CSPA in its September 24, 2010 comments, (1) maintenance of the cold water pool must be made more than "indirect"; (2) replacement of the damaged river valves must be more fully addressed.

using "current facilities."

- Section S8(c) weakens the earlier requirement of facilities modification plans by giving the Deputy Director further discretion to approve facility modifications, determine that it is not "feasible" to meet Table S8, or authorize the licensee to "comply with alternate temperature requirements."
- Section S8(f), which addresses minimum flow and temperature requirements in the High Flow Channel, qualifies the requirement that that the licensee shall operate the project to protect cold beneficial use by adding the term "to the extent reasonably achievable." It would apparently not require the applicant to show that compliance is impossible or unreasonable.

Without effective enforcement of minimum flow and temperature requirements, the conditions of approval cannot assure compliance with the Basin Plan, and cannot lawfully support section 401 certification. The net effect of these changes, which elevate the Deputy Director's discretion to relax the applicable standards, will be to inject additional uncertainty into the ability of the certification conditions to enforce the referenced minimum flow and temperature requirements. That uncertainty thwarts the present draft's ability to certify compliance with Clean Water Act and Basin Plan standards.

B. The Deputy Director's approval by inaction is not an equivalent public process.

In February 2010 comments, Butte argued that the Deputy Director should not have the authority to automatically "approve" the licensee's requests by inaction, where no determination has been made on the merits of the request. The Board responds that the public process is equally protective, because Butte and other members of the public can still comment prior to the decision.

Default approval is far from an "equivalent" procedure. The public accountability of these provisions, whose enforcement is crucial to achieving effective water quality protection under section 401, would also be weakened by the prospect that the Deputy Director could approve changes by fiat. In a period of budget and time pressures, the mechanism of "approval by inaction" could significantly diminish water quality enforcement, because it would provide the Deputy Director an "easy out" to render approvals without investing heavily in resources, making determinations on the merits, or answering to the public.

VI. The 2010 Draft Certification fails to provide assurance that approach to problems stemming from methyl mercury, PCBs and other contaminants will meet water quality standards and the requirements of the Basin Plan.

A. The 2010 Draft Certification fails to protect the public from PCBs and other contaminants.

Butte's earlier comments discussed the crucial need for additional steps to provide reasonable assurance that DWR's approach to problems stemming from methyl mercury, PCBs and other contaminants will meet water quality standards. As those comments explained in detail, DWR's own technical documents supporting its Oroville EIR confirm that Basin Plan standards have not been met. The July 2010 draft conditions fail to provide that assurance as well, and notably fail to address any of Butte's substantive analysis relating to PCBs. The conditions that are present do not adequately address the major public health problems involved, and add questionable new conditions and contingencies. Butte incorporates its prior comments in this regard. The responses to comments also apply the wrong standard in asserting that the project "does not add" toxic contaminants; what matters is whether water quality requirements are met, including compliance with Basin Plan standards. Finally, while it questions whether any further mitigation is feasible, the Board has never specifically responded to the mitigation measures Butte proposed first in its July 2009 comments.

B. The Comprehensive Water Quality Monitoring Program fails to ensure Basin Plan compliance and protect public health.

In section 12(n), the term "conduct studies and, if appropriate" weakens the Deputy Director's responsibility to manage methyl mercury and delays implementation of methyl mercury containment/management. This condition implies that methyl mercury contamination is not a serious issue; studies need to be undertaken to evaluate if methyl mercury is a problem before managing it, and only then if *appropriate*. No time frame is specified for these referenced studies; "appropriate" is also not defined. On the whole, the new language remains more vague than what was generally described in the first draft certification document.

VII. Conclusion

For the foregoing reasons, Butte urges the State Board not to grant DWR its requested certification on the present application. Should the Board move forward with that certification, the proposed conditions should not be weakened, and Butte's further suggestions outlined here should be incorporated.

Respectfully submitted,

/s./

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July 29, 2009

Via email and U.S. mail
Dorothy Rice
Executive Director, California State Water Resources Control Board
1001 I Street
Sacramento, CA 95814

RE: Butte County's Comments on the Matter of Water Quality Certification for the Department of Water Resources Oroville Facilities (Federal Energy Regulatory Commission Project No. 2100)

Dear Director Rice:

This letter provides Butte County's (Butte's) comments on the State Board's draft water quality certification, which addresses the Department of Water Resources' (DWR's) application to the Federal Energy Regulatory Commission (FERC) for a new license to operate the Oroville Facilities ("Oroville project," FERC Project 2100). The State Board has not provided a formal comment period. However, Butte County requested, and State Board staff provided, the draft certification that was current on July 9, 2009 ("draft certification"). We appreciate the opportunity to comment.

I. Summary and Overview

The decision to re-license DWR's Oroville project for the next half-century is one of the most momentous in the history of Butte County's environment and economy. Oroville Dam is the State Water Project's primary power generation facility, and Lake Oroville is its "keystone" water storage facility. http://www.water.ca.gov/swp/facilities/Oroville/index.cfm. The Oroville Facilities since their 1968 completion have "altered the hydrology and geomorphology of the Feather River, and impacted the water quality and anadromous fisheries." (Draft certification, p. 1.) They have also imposed millions of dollars annually on Butte in uncompensated environmental and service costs. As detailed below, sensitivity to the environmental and institutional context of the water quality certification decision can help ensure that the next 50 years of history at Oroville will prove to be more equitable and environmentally sustainable than the legacy of the first licensing period.

Butte commends the State Board for its recognition that "certain measures as written" in the March 2006 Settlement Agreement are "either not enforceable, will not fully protect the beneficial uses, or will not meet water quality standards in a timely manner." (Draft certification, p. 4.) Butte strongly opposes any attempt by DWR to weaken the State Board's conditions of certification. As the Board noted, "[b]eneficial uses currently impacted by the project may not be reasonably protected if the proposed measure has a management plan with unclear or unenforceable standards, an excessively long period prior to implementation, or unspecified implementation dates." (Draft certification, p. 4.)

Adoption of more rigorous conditions in place of vague ones invokes the State Board's independent duty under section 401 of the Clean Water Act (33 U.S.C. §1341) to enforce water quality standards and implementation plans promulgated by the State Board. (33 U.S.C. § 1313.) That duty reflects the mandate of the Clean Water Act (33 U.S.C. §§ 1251-1387) "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." (33 U.S.C. § 1251(a).) DWR must also demonstrate compliance with the State Board-approved objectives in the Water Quality Control Plan for the Central Valley-Sacramento and San Joaquin River Basins (Basin Plan). Though called "objectives," compliance with these standards and their implementation program is mandatory. (*See State Water Res. Control Bd. v. Office of Admin. Law* (1993) 12 Cal. App. 4th 697, 701-02.) The Basin Plan standards also apply to the entirety of project operations, not just dam discharges. (*PUD No. 1 v. Wash. Dep't of Ecology* (1994)511 U.S. 700, 711-12.)

The Board has noted that to issue a section 401certification, DWR must demonstrate to the Board that DWR will achieve

> compliance with all water quality objectives in the Basin Plan… as well as with other water quality objectives that the Project may affect. DWR must also demonstrate that the Project does not impair the beneficial uses of the Feather River or Lake Oroville. If the Project does not comply with one or more of the water quality objectives, then DWR must describe the actions that it will take to bring its Project into compliance with the applicable water quality requirements in order to protect and maintain the beneficial uses.

Exhibit 1 to this letter (Ex. 1), pp. 1-2.

With appreciation for the Board's advocacy of clear and enforceable standards, Butte outlines grounds to exercise caution before advancing to final approval of the Oroville project's section 401 certification. First, DWR's request for certification should be denied without prejudice as procedurally inadequate. Lead agency DWR's Final EIR is the subject of pending CEQA challenges by Butte and Plumas Counties, which have been consolidated and are pending in the Yolo County Superior Court. (*County of Butte v. Department of Water Resources,* c/w *Plumas County v. Department of Water Resources (Butte v. DWR)*, Yolo County Superior Court, No. CV 09-1258.) However, DWR has failed, in almost a year, to produce the administrative record, which CEQA ordinarily requires in 60 days. (Pub. Res. Code, § 21167.6(b).) That delinquency has deprived Butte of the opportunity to review documents in that still-incomplete record that may be relevant to the Board's section 401decision.

Second, DWR's request for certification does not disclose a fundamental EIR deficiency: refusal to analyze the consequences of climate change. A responsible agency ordinarily assumes that the lead agency's Final EIR complies with CEQA, but any project approval remains "at the applicant's risk pending final determination" of the actions. (Pub. Res. Code, § 21167.3; see also 14 Cal. Code Regs., § 15233.) Here, the State Board must also independently assess whether DWR's project provides reasonable assurance of compliance with federal and state water quality standards. DWR did not simply refuse to analyze climate change; it reneged on the approach DWR and other agencies have consistently advocated elsewhere. That failure undermined the environmental review, and precludes a finding under section 401 that the project protects beneficial uses and meets water quality objectives.

Third, DWR's refusal to study the Oroville project in the context of other State Water Project operations also undermined the integrity of the environmental review. Despite objections from the State Board, Butte, and others during public comment, DWR improperly attempted to sever the Oroville Project analytically from other foreseeable changes in State Water Project operations. That faulty analysis left major unresolved issues about the nature of project operations, which prevent a final certification that the project is now appropriate for water quality certification.

Fourth, additional steps are needed to address the accumulation of toxic substances within the Oroville Facilities. Despite improvements over DWR's proposed approach, further steps are needed to provide reasonable assurance of compliance with water quality standards and the Basin Plan. This is the case on a matter of pivotal public health importance: accumulation of toxic substances such as methyl mercury and PCBs (polychlorinated biphenyl) within the Oroville Facilities. Before the Board renders its final section 401 certification, nearby communities deserve a more probing examination of whether these substances' intrusion into local fish and the food chain is related to high local cancer rates. Lastly, the treatment of pathogens and water temperature needs further refinement.

II. DWR's request for certification is procedurally inadequate.

A. Procedurally inadequate requests for certification should be denied without prejudice.

The State Board may deny without prejudice applications with "some procedural inadequacy (e.g., failure to provide a complete fee or to meet CEQA requirements)". (23 Cal. Code Regs., § 3837(b); see also 23 Cal. Code Regs., § 3836 (where "the federal period for certification will expire before the certifying agency can receive and properly review the necessary environmental documentation'); *Clean Water Act section 401 Water Quality Standards Certification for Tract Map 30921, City of Moreno Valley, Riverside County* (Regional Water Quality Control Board, Santa Ana Region, June 10, 2008) (earlier application "was denied without prejudice pending resolution of inconsistencies and omission" in environmental document prepared for CEQA compliance).)

B. DWR's extraordinary delay in preparing the CEQA record removed the opportunity to review documents germane to the State Board's section 401 review.

A key purpose of the Oroville Final EIR is for the State Board to "use the information" to "prepare terms and conditions" for its certification decision (FEIR, pp. 1-3 to 1-4.) Yet almost a year after Butte and Plumas Counties filed CEQA cases, DWR has still failed to produce the administrative record, violating a clear requirement of CEQA (Pub. Res. Code, § 21167.6(b).) The original due date, 60 days after Butte's request for record preparation, passed on October 27, 2008. Although CEQA allows the parties to stipulate to a later due date, the last deadline achieved by stipulation passed on February 27, 2009. DWR is now more than six months delinquent in preparing the record.

The CEQA record, when it arrives, will likely include materials highly relevant to the State

Board's water quality determination. In part, Butte challenges DWR's defective assessment of water quality impacts and mitigation. (Ex. 2 (Butte petition), ¶ 55.e (water quality impacts); ¶ 62.e (failure to mitigate water quality impacts).) Final action to approve the project's section 401certification would deprive Butte of the opportunity to review potentially thousands of pages of relevant documents.

Following Butte's inquiries, DWR announced on July 8, 2009 an anticipated record completion date of September 15, 2009, but stated that the actual date could be later if, for example, there are "unforeseen technical problems." Ex. 3. On July 17, 2009, Butte again emphasized the unfairness of deferring the CEQA record until the State Board was required to act on the section 401certification. Butte noted that "it strains credulity to believe that the extensive record DWR is preparing will have no documents bearing upon the State Board's water quality determination that are worthy of public review." Butte also offered to stipulate to a record extension until September 15, provided that DWR (1) advised the State Board that it was withdrawing its request for section 401 certification; and (2) did not request further action from the State Board on section 401 certification until the completed administrative record in this action has been available for at least 60 days. (Ex. 4.)

DWR refused Butte's offer in a letter dated July 23, 2009. This DWR letter belatedly recognized that documents in its forthcoming CEQA record may have a bearing upon the State Board's water quality determination. Moreover, by DWR's own recognition, two major sections of the record—staff files and email—have not been completed even in index form. (Ex. 5.)

Since information germane to the section 401certification decision has yet to be made available to Butte or to the State Board, DWR's application should be denied without prejudice. (23 Cal. Code Regs., § 3836(b); 3837(b)(2).) Butte requests that the Board leave the record for the State Board's certification decision open for at least 60 days after the *Butte v. DWR* petitioners receive the CEQA record. The integrity of the State Board's section 401 review requires that DWR not be able to achieve premature final certification before Butte has had a fair opportunity to review the same records that were available to DWR.

III. DWR's request for certification lacks an assessment of the Oroville Project in the context of climate change.

A. California authorities uniformly recognize the need for project assessments to analyze climate change, including its relationship to water quality.

1. Legislation and Litigation

The "harms associated with climate change are serious and well recognized." (*Massachusetts v. Environmental Protection Agency* (2007) 549 U.S. 497, 521.) As the California Legislature recognized when it enacted the landmark 2006 global warming legislation, AB 32, "[g]lobal warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California." (Health & Saf. Code, § 38501.) Legislation, executive orders from the past several years, as well as actions of the California Attorney General and other state agencies, have reflected California's recognition of the harmful environmental impacts associated with climate change, their relationship to water quality, and the need to integrate climate change analysis into project review and decision-making. See, e.g., Executive Order S-3-05 (June 1, 2005) ("California is particularly vulnerable to the impacts of climate change"); OPR Technical Advisory, *CEQA and*

Climate Change: Addressing Climate Change through CEQA Review (June 19, 2008), http://www.opr.ca.gov/index.php?a=ceqa/index.html ("OPR Technical Advisory").

2. State Board Strategic Update

On September 2, 2008, the State Board adopted its Strategic Update 2008-2012, which commits the Board to consider "the impacts of climate change in our decision-making." (*Id*., p. 7.) Goal 4 of the Strategic Update commits the Board to "describe the connections between water quality, water quantity, and climate change, throughout California's water planning processes." (*Id*., p. ii.) The Strategic Update also embodies the Board's clear understanding that climate change is closely connected to water quality problems:

> It is widely recognized that changes in temperature and precipitation patterns will impact water availability and quality. Higher air temperatures lead to increases in water demand and changes in hydrologic conditions, resulting in drought and greater levels of wildfires, and reduced snow pack, earlier snowmelt, and a rise in sea level that may cause more seawater intrusion. Higher water temperatures reduce dissolved oxygen levels, which can have an adverse effect on aquatic life. Where river and lake levels fall, there will be less water for dilution of pollutants (i.e., reduced assimilative capacity). Increased frequency and increased intensity of rainfall will produce more pollution and sedimentation due to runoff. In addition, more frequent and intense rainfall may overwhelm pollution control facilities that have been designed to handle sewage and stormwater runoff under assumptions anchored in historical rainfall patterns.

(*Id*., pp. 2, 3.)

3. DWR Studies and Reports

Similarly, DWR has acknowledged in several studies and reports (available through the Department's website, http://www.water.ca.gov/publications/) that climate change is occurring, will have major effects on California's water resources generally and the State Water Project in particular, and must be addressed in any water supply planning study.

- A May 2009 report DWR prepared for the California Climate Change Center, *Using Future Climate Projections to Support Water Resources Decision-Making in California*, assessed possible climate change impacts to State Water Project and Central Valley Project operations, using 12 future climate projections. The report predicted significant reductions in annual Delta exports and reservoir carryover storage, with heavier reliance on groundwater pumping. It noted that the assumption that "future hydrologic variability will be similar to historic variability … no longer holds true under climate change." (*Id*., p. 24.) And it found that "Lake Oroville, the backbone of the SWP, receives much of its inflow from the upper Feather River basin in the Sierra Nevada mountain range … Because snow melting and sublimation are heavily dependent on temperatures, it is important to the operation of Lake Oroville to know how projected future climate conditions can affect both the timing and quantity of flows arriving there." (*Id.,* pp. 25, 26.) DWR used a physical model of the upper Feather Basin to gauge the effect of increased air temperature on precipitation, snow pack, and runoff.

- In an October 2008 report, *Managing an Uncertain Future*, DWR projected that Sierra snow pack would experience a 25 to 40 percent reduction by 2050. (*Id*, p. 4.) The report noted a wide range of water quality consequences from climate change. Noting that hydrologic variability would probably increase in the new century, DWR candidly recognized that "California has invested in, and now depends upon, a system that relied on historical hydrology as a guide for future water supply and flood protection. However, *due to climate change, the hydrology of the past is no longer a reliable guide to the future."* (*Id.*, p. 4 (emphasis added).)

• In July 2006, DWR published a report entitled *Progress on Incorporating Climate Change into Management of California's Water Resources* ("Progress Report"). The Progress Report acknowledges that climate change is already occurring, is affecting California's hydrology, and will heavily impact water storage projects. The study notes, "DWR is working with other agencies and researchers to provide leadership in incorporating climate change impacts and risks into the planning and management of California's precious water resources." (*Id.* at VII.) It presents modeling analysis of the effects of multiple climate change scenarios upon the CVP and SWP—including effects on water temperatures, and Lake Oroville inflow, outflow, and storage. (*Id.*, 4-49.)

• In its 2005 *California Water Plan Highlights*, DWR committed that it "will evaluate management responses to potential impacts of global climate change on the State Water Project and California's hydrology" and "will work with climate change experts to develop alternative flow data to help State and regional planners test potential effects of global climate change on different management studies." (*Id.* at 5-16.) DWR stated that it would use as a performance measure its "[p]rogress in implementing of the plan responding to the impact of global climate change on the management of the State Water Project." (*Id.*)

• In a 2005 California Water Plan appendix, *Accounting for Climate Change*, DWR's Maurice Roos wrote "the prospects of significant changes warrant examination of how the State's water infrastructure and natural systems can accommodate or adapt to climate changes…." While acknowledging some uncertainty, the report closed by stating that "[i]t is time to try to quantify the effects of projected climate change on California's water resources. (*Id.* at 14.) The report also identified changes to be addressed in the Oroville proceeding: "a logical extension would be to apply the new temperature models to evaluate the affect (sic) of a changed climate and runoff scenario, beginning with Lake Oroville and the Feather River." (*Id.*, p. 13.)

These reports confirm the importance of changing climatic conditions to the Oroville project assessment. DWR repeatedly recognized that climate change is occurring and will have major effects on Oroville and SWP operation. DWR also suggested that the tools to conduct analysis of those changes already exist and are improving. This analysis was essential, for changing climatic conditions undisputedly will impact flood control operations, reservoir storage levels, upstream and downstream flow levels, water temperatures, power generation, water quality, fisheries, flood risk, and the value of Lake Oroville and the Feather River as recreational resources.

4. California Attorney General's Enforcement Actions

Emphasizing the potentially devastating consequences of global warming in California to public health, natural resources and infrastructure, the Attorney General's website identifies a number of water-related impacts, including large losses of Sierra snow pack, habitat destruction, and water contamination. Quoting a May 2009 report of the California Climate Change Center, *The Future is Now*, it posits that "[a]bundant evidence now shows that climate change is not just a future problem, but it is already observable now, with measurable impacts for the state's citizens, natural resources, and economic sectors ... The consequences of taking no action on adaptation and mitigation would be costly for California and the world." (http://ag.ca.gov/globalwarming/impact.php.)

The Attorney General has also filed numerous comment letters with agencies whose environmental reviews did not analyze or mitigate global warming impacts. (http://ag.ca.gov/globalwarming/ceqa/comments.php.) He sued, and later settled with, San Bernardino County based upon its failure to analyze climate consequences of a general plan amendment. The Attorney General argued the county made no attempt "to quantify or even to estimate" current levels of greenhouse gas emissions, and increases in these levels from General Plan. (http://ag.ca.gov/globalwarming/pdf/SanBernardino_complaint.pdf.) In other cases, such as Nestle's then-proposed water bottling plant in McCloud, California, the Attorney General has threatened to sue private companies over the failure to analyze project-related global warming impacts. (http://ag.ca.gov/newsalerts/release.php?id=1591.) The Attorney General also assists those who wish to take climate change seriously by providing mitigation lists and modeling tools. (http://ag.ca.gov/globalwarming/ceqa/modeling_tools.php.)

B. DWR's Oroville EIR evaded assessment of climate change and water quality, ignoring state policy and the recommendations in its own studies.

Oroville, as the SWP's primary storage and power generation facility, plays a central role in SWP operations. Changing climatic conditions will impact Oroville's flood control, reservoir storage levels, upstream and downstream flow levels, water temperatures, power generation, water quality, fisheries, and recreation. Yet DWR's EIR evades analysis of climate change, particularly in its relationship to water quality. DWR's DEIR contains very little discussion of the water quality consequences of operating the project in the context of a changing climate. Indeed, its water quality impacts discussion is almost entirely predicated upon modeling exercises that assumed the *non-existence* of climate change. *See* DEIR pp. 5.2-11 to 5.2-12, App. E at 49.

DWR's Oroville Final EIR evades the issue again, relying upon excuses that are strikingly similar to those DWR and the Attorney General have justly criticized in other settings. For example:

- Rather than recognizing that hydrologic variability is likely to increase in the future, as its own studies have consistently shown, DWR presumes that hydrologic variability *from the previous century* "is expected to continue in the foreseeable future." (FEIR, p. 3-28.)

- Rather than drawing on the analytical and modeling techniques that DWR has employed in other reports on climate change, including reports addressing the Feather River watershed, DWR summarily concludes that "any discussion of potential changes to operation of the Oroville Facilities necessitated by climate change *would be speculative* at this time." (*Id.* (emphasis added).)

- The FEIR suggests that there would be "further opportunities in the future, at the next relicensing period" to "make more definitive statements about the extent of climate change." (FEIR, p. 3-27.) The "next relicensing period" referenced here would take place *half a century after project implementation.*

C. Unresolved climate change issues prevent a conclusion that the project is now appropriate for water quality certification.

The State Board's draft water quality certification does not address climate change. But the certification relies upon DWR's EIR, whose attempted deflection of serious climate change assessment to future generations infected all key elements of the Final EIR, including assessment of the environmental setting, direct and cumulative impacts, feasible alternatives, and mitigation. Due to this error, the FEIR is predicated upon a hypothetical future that DWR knows to be dangerously false. That critical omission also prevents a finding under section 401 that the project meets water quality standards and protects beneficial uses.

IV. DWR's request for certification lacks a thorough assessment of the Oroville project in the context of a changing State Water Project.

A. The Oroville project is an integral and interconnected part of the State Water Project that must be analyzed to take account of changing conditions.

The Oroville project is an integral and interconnected part of the State Water Project. (Wat. Code, § 12934(d).) As the DEIR's executive summary explains, "water stored in Lake Oroville is released from the Oroville project to meet a variety of statutory, contractual water supply, flood management, fishery, water quality, and other environmental obligations. These contractual, flood management, fishery, water quality, and other environmental obligations are defined in numerous operating agreements that specify timing, flow limits, storage amounts, and/or constraints on water resources." (DEIR at ES-3.)

Releases from Lake Oroville must serve a variety of purposes, including (1) compliance with Bay-Delta water quality standards; (2) satisfaction of obligations under environmental laws such as the Clean Water Act and federal and state Endangered Species Acts; and (3) release of water, as available, to meet the needs of State Water Project contractors. (*See* DEIR at p. 2-5.) Operation of the Oroville project is closely tied to downstream needs. If those downstream constraints change, or if DWR discovers that operational changes are necessary to meet existing constraints or comply with legal requirements, changes to the Lake Oroville release schedule are likely to follow.

B. DWR's environmental review improperly attempted to sever the Oroville Project analytically from other foreseeable changes in State Water Project operations.

Having initially recognized the interconnectedness of Oroville Project and the DWP, DWR implausibly proceeded to portray them as analytically distinct. The DEIR described the Oroville Project as "consistent" with existing commitments, and offered the sweeping statement that "no changes to the contractual obligations or to the general pattern of these releases are anticipated." (DEIR at ES-3.) Similarly, the DEIR asserts that the Settlement Agreement was structured "so as not to affect the SWP's ability to meet future water supply needs." (FEIR, ES-3, 5.2-14.)

In its EIR comments, the State Board faulted the DEIR for failing to "include an adequate discussion of the impact of State Water Project (SWP) operations on the Proposed Project." (FEIR, p. 4-41.) As two illustrations of possible impacts, the Board's letter noted that changes in the quantity or timing of water deliveries could affect the coldwater pool in Lake Oroville, used to protect anadromous fish in the Feather River, and could result in cumulative impacts in combination with the proposed project. (*Id.*) Rather than providing this analysis, the FEIR responds with the generalization that "[a]nalysis of future changes to State Water Project (SWP) statewide operations is outside the scope of the EIR." (DEIR, p. 4-51.)

That response misses the mark. In light of factors ranging from population pressures and climate change to the Sacramento-San Joaquin Delta's pelagic organism decline, downstream deliveries are overwhelmingly likely to change in the future, and these pressures will bring upstream changes to project operation in the Feather River and Lake Oroville. The EIR should have analyzed the Oroville project under a foreseeable range of changing circumstances, and considered what impacts will occur in the Lake Oroville area should changes in downstream deliveries necessitate changes in upstream management. The DEIR should have explored alternatives or mitigation capable of ensuring that changing downstream needs will not result in adverse environmental impacts in the project area. Without that analysis, it is impossible to ascertain, in the face of a changing State Water Project, that implementation of the Oroville project will meet water quality requirements and serve the beneficial uses referenced in the Basin Plan, as required under section 401.

C. Unresolved issues in the operation of the Oroville project within the State Water Project prevent a conclusion that the project is now appropriate for water quality certification.

If recent discussions of the relationship between the Oroville project and the Operations Criteria and Plan (OCAP) are any indication, fundamental questions remain about how the Oroville project would operate in practice. In its FEIR, DWR failed to analyze how changing conditions in the Delta will affect the timing or volume of water releases from its Oroville Facilities. Even though DWR was aware of recent judicial decisions invalidating the Operating Criteria and Plan (OCAP) Biological Opinions (BO) for salmonids and Delta smelt, it avoided serious new analysis, based upon speculation that Oroville releases would be "one of many" inputs to Delta hydrology. (FEIR, p. 3-39.)

A recent exchange of letters illustrates differing views of how the Oroville project would operate. On July 6, 2009, the National Marine Fisheries Service (NMFS) issued its Draft BO for the Oroville Dam relicensing. While NMFS made a finding of non-jeopardy for the species studied (Sacramento River Winter-Run Chinook Salmon, CV spring-run Chinook salmon, CV steelhead, and Southern DPS of North America green sturgeon), the Draft BO set forth "reasonable and prudent measures" (RPMs) to reduce the effects of the project's incidental take of these species. In a letter to NMFS dated July 9, 2009, DWR argued that the RPMs had the potential to "significantly affect project operations," affecting water supply, power generation, and even "DWR's ability to implement the relicensing settlement." (Ex. 6.)

By contrast, a letter submitted by the California Sportfishing Protection Alliance (CSPA) on July 21, 2009 takes NMFS to task for issuing a finding of non-jeopardy in its Oroville Dam Draft BO. CSPA contends that the finding of non-jeopardy for Oroville, the "major storage reservoir for the SWP," is inconsistent with NMFS' previous jeopardy finding on the BO for the combined operations of the CVP and SWP. (Ex. 7.) CSPA also argues that the RPMs for the Oroville BO are vague and lack the OCAP BO's specific performance measures and timelines, particularly in the conditions protecting water temperatures. (*Id.*)

Lastly, CSPA argued that the disconnect between the OCAP BO and the Oroville Draft BO is especially problematic "in light of the Settlement Agreement's allowance for DWR to ease the flow requirements from the Oroville facilities should Oroville drop below 1.5 million acre-feet in storage." Ex. 6. According to CSPA, the Oroville Draft BO has a "regulatory gap," because it lacks any defined restriction on human action to avoid operation of Oroville at low pool. This CSPA argument is also of direct relevance to DWR's request for section 401 certification, because a version of the same allowance appears as Condition S8(d) of the State Board's draft conditions:

> If the April 1 runoff forecast in a given water year indicates that, *under normal operation of Project 2100*, Oroville Reservoir will be drawn to elevation 733 feet (approximately 1,500,000 acre-feet), minimum flows in the HFC may be diminished on a monthly average basis, in the same proportion as the respective monthly deficiencies imposed upon deliveries for agricultural use from the Project; however, in no case shall the minimum flow releases be reduced by more than 25 percent.

(Draft certification, p. 29 emphasis added).)

Notably, neither the EIR nor the draft certification defines the "normal operation" of the Oroville project. In light of such recent developments the Delta species decline, enforcement of endangered species law, and the onset of climate change, considerable controversy could ensue over whether the "new" normal or some older version should prevail. Moreover, the disagreement between DWR and CSPA shows that Oroville project operation remains unclear in its SWP context. When NMFS issues its final BO, the restrictions on DWR may remain in the same place, or may become more or less stringent than they are today. Each of these outcomes would bring different terms to Oroville operation, with potentially different implications for water quality. In the face of this continuing uncertainty over what is "normal," final certification under section 401 would be premature.

V. Additional steps are needed to provide reasonable assurance that DWR's approach to problems stemming from methyl mercury, PCBs and other contaminants will meet water quality standards.

A. Overview

DWR's Draft and Final EIR both reveal substantial water quality problems. Accumulation and magnification of toxic substances within the Oroville Facilities, including PCBs (polychlorinated biphenyl) and methyl mercury, are of great public health concern to the County, and are not adequately addressed within either the EIR or the draft certification.

PCBs and methyl mercury contamination in fish commonly consumed by the public has been linked to numerous alarming health effects, including decline in children's IQ and motor skills when a mother is exposed. Early exposure has also been found to trigger Parkinson's and Alzheimer's disease, and children exposed prenatally to PCBs have had compromised immune systems, high infection rates, and weak responses to vaccinations. (Cone, "Scientists Warn of Toxic Risk to Fetuses," *Los Angeles Times*, May 25, 2007(http://articles.latimes.com/2007/may/25/nation/na-fetuses25).) PCBs and methyl mercury are also widely considered to be carcinogens. (See Centers for Disease Control, www.atsdr.cdc.gov/tfacts46.html#bookmark06; Environmental Protection Agency, www.epa.gov/waste/hazard/tsd/pcbs/pubs/effects.htm.)

Cancer clusters in the Oroville area and a 2009 California Department of Public Health report (hereinafter "DPH report," available at http://www.ehib.org/project.jsp?project_key=OROV01) inform Butte's concern that the accumulation of PCBs, methyl mercury and other toxins in fish consumed by the public in the project area may pose a significant human health risk. In 2004 and 2005, the Oroville area experienced an unexpected spike in the number of citizens diagnosed with pancreatic cancer—24— more than twice the expected amount. (See "Grief, Fear Touch Families hit by Pancreatic Cancer," *Sacramento Bee*, Jan. 31, 2008, http://www.redorbit.com/news/health/1236498/grief_fear_touch_families_hit_by_pancreatic_cancer/.) The number of cases since then has also exceeded expectations.

In 2008, the California Department of Public Health partially investigated the cancer clusters. The DPH study noted that 44 percent of the participants diagnosed with pancreatic cancer had consumed non-commercially caught fish, most caught in the Oroville region. (DPH report, p. 19.) Yet, because only one person ate fish more than once a week, DPH concluded that the data "would not suggest that the group would be receiving much exposure from fish consumption." (DPH report at p. 19.) On this basis, DPH generalized that "[l]ocally caught fish were generally not eaten," among the cancer patients. (DPH report at p. 2.) This statement is misleading, since a significant portion of pancreatic cancer patients did eat locally caught fish, a greater proportion than some of the other environmental risk factors that were analyzed.[1] (DPH report at p. 19.) Moreover, the DPH study only investigated diagnoses of pancreatic cancer, and did not look for other health risks associated with PCBs and methyl mercury, such as liver cancer and impacts on prenatally exposed children.

The Oroville community continues to express its concern with the possible link between the fish contaminated with PCBs and methyl mercury caught and consumed from the Oroville facilities and the disturbing spike in area cancer rates. The presence of cancer clusters in the Oroville region, and the DWR data showing biomagnification of these toxins in fish tissue at the project site, ring an alarm bell that DWR and the State Board cannot lawfully ignore.

B. DWR has not met requirements for certification under the Clean Water Act and Basin Plan.

As the State Board's draft certification acknowledges, protection of the beneficial uses identified in the Basin Plan requires "effluent limitations and other limitations on discharges of pollutants from point and nonpoint sources to the Feather River and its tributaries." (Draft Certification, p. 2.)

DWR must demonstrate compliance with Basin Plan objectives in order for the State Board to issue its water quality certification. (DEIR at p. 4.2-14.) One listed beneficial use for Lake Oroville and the Feather River is "Recreation-Contact," composed of activities including bank fishing, boat

[1] PCBs that bioaccumulate in fish have been found even more carcinogenic than commercial mixtures commonly encountered by workers. Thus the consumption of PCB-contaminated fish may expose people to PCB mixtures even more toxic than the PCB mixtures contacted by workers and released into the environment. (www.epa.gov/waste/hazard/tsd/pcbs/pubs/effects.htm.)

fishing, swimming, water skiing and wakeboarding, and use of personal watercraft. (DEIR at 4.2-15.) Other beneficial uses relevant to the County's concerns regarding contamination are within the broad categories of wildlife and spawning/fisheries habitat, irrigation, municipal and domestic water supply, and non-contact recreation. (DEIR, pp. 4.2-15 to 4.2-18.)

Based upon DWR's data in the Draft EIR and Final EIR, as well as supporting studies and outside research including the NOAA biological opinion, DWR has not shown that the water quality standards will be met under the operating procedures proposed in the EIR and Settlement Agreement. Further, as detailed below, the mitigation measures outlined in the Settlement Agreement, even as conditioned under the State Board's draft certification, provide no assurance that water quality objectives in the basin plan will be timely met.

1. DWR's operating plans for the Oroville Facilities fail to meet water quality standards established in the Basin Plan.

The basin plan provides for three broad categories of regulation to meet water quality targets in the Sacramento and San Joaquin River basins: provisions against increases in suspended sediment discharges, provisions against deposition of material that adversely affects beneficial uses, and provisions against deposition of substances that produce detrimental effects to humans, plants, animals, and aquatic life. Basin plan objectives of particular concern to Butte in reference to the public health concerns raised in these comments include regulation in the following categories:

- <u>Chemical constituents</u>: the basin plan calls for "Less than maximum contaminant levels (MCLs) for inorganics, fluoride, organics, secondary MCL consumer acceptance levels, and secondary MCLs-ranges." (DEIR, p. 4.2-20.) (See 23 CFR Tables 64431-A and B; 64444-A, 644449-A and B.)

- <u>Pesticides:</u> the basin plan calls for "No adverse affect on beneficial uses; total identifiable persistent chlorinated hydrocarbon < detectable; < allowable by applicable antidegradation policies." (DEIR, p. 4.2-20.)

- <u>Toxicity</u>: the basin plan calls for concentrations of toxins to be "Free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal or aquatic life." (DEIR, p. 4.2-21.)

As outlined below, the studies conducted by DWR in support of its EIR, in particular, Study Plan W1, "Project Effects on Water Quality Designated Beneficial Uses for Surface Waters" ("Study W1"), and Study Plan W2, Phase 2 Report, "Contaminant Accumulation in Fish, Sediments and the Aquatic Food Chain," ("Study W2") find that present water quality conditions do not meet basin standards.[2] Neither DWR nor the SWRCB has argued that the Settlement Agreement or the draft

[2] The aquatic toxicity data of Study W1 indicates that complete ceriodaphnia mortality was observed at several locations even after TIE testing (Targeted Toxicity Identification Evaluation). The key language of the report is data "suggesting non polar organic contaminants were contributing to observed toxicity." (Study W1 at p. 5-32.) Non-polar organic contaminants include PCBs. Given this alarming data, DWR must conduct sufficient testing to ascertain the source of aquatic mortality.

certification's conditions will enable Oroville project operations to meet basin objectives implemented under to the Clean Water Act

2. DWR's own studies and findings outline a significant public health risk stemming from the contaminants and operating system of the project.

The data collected by DWR for its EIR underscore the risk from bioaccumulation of contaminants within the Oroville facilities. The DEIR summarily states that "[c]urrent operations of the Oroville Facilities supports and reasonably protects, or has no adverse effect on (as in the case of coldwater spawning in Lake Oroville), all beneficial uses specified in the Basin Plan for Project waters." (DEIR 4.2-15.) Yet despite this statement, DWR's studies support a conclusion that contaminants in the Middle and North Fork of the Feather River are amplified by the operation of the Oroville facilities Study W2, entitled *Contaminant Accumulation in Fish, Sediments and the Aquatic Food Chain* (Study Plan W2, Phase 2 Report), found that "impoundment of the reservoir created conditions in which sediments possibly laden with contaminants are trapped…may contribute to bioaccumulation in downstream organisms." (Study W2, p. 1-2.)

3. DWR found elevated levels of PCBs in fish tissue samples and admitted the likely role of the reservoir in amplifying bioaccumulation of the toxin in local species.

PCB levels in fish tissue in the project area exceed EPA standards, and DWR confirmed that the operation of the reservoir likely created this effect. PCBs "were detected in all fish and crayfish species from all water bodies that were sampled… spotted bass collected from both South Fork arms of Lake Oroville and largemouth bass collected from the Feather River both upstream and downstream from Thermalito Afterbay Outlet to the Feather River, contained total PCBs (as the sum of Aroclors) that exceeded the MTRL [maximum tissue residue level] and screening values of the USEPA and OEHHA." (DEIR, p. 4.2-35.)

Study W2 admits the role of the reservoir in creating conditions for bioaccumlation, noting that "it is clear that coho accumulate PCB's at an increased rate after removal from the hatchery for stocking into Lake Oroville." (Study W2, p. 6-2.)[3] As discussed above, PCBs, methyl mercury and other toxins accumulate and biomagnify at and because of the operations of the Oroville project facilities. Were Lake Oroville and its associated facilities not impeding the flow of these toxins, they would most likely be flushed out into the Bay-Delta before they have a chance to accumulate within the tissue of fish at dangerous levels. (Study W2, p. 1-2; Study W2, p. 6-2.)

4. DWR found elevated levels of methyl mercury throughout the project area.

Methyl mercury is also present throughout the Oroville project area. Indeed, the DEIR admits the presence of methyl mercury and its introduction into the ecosystem and food chain: "methyl mercury was found over the majority of sampling locations… Stations with elevated TOC [total

[3] Without explanation or evidence, DWR speculates that "PCB levels in anadromous Chinook salmon and steelhead….indicate[] uptake of these contaminants most likely occurred during their extended migrations through the Delta and Pacific Ocean." (Study W2, p. 6-3.)

organic carbon] have higher methyl mercury concentrations, signifying greater biomass availability and possibly leading to increased rates of mercury biotransformation." (DEIR, p. 4.2-34 to 35.)

Mercury**,** originally released by upstream gold mining, is most likely transformed into methyl mercury due to action at the reservoir. Increased water temperature is generally associated with an increased presence of bacteria. The presence of "sulfate-reducing bacteria (SRB) in anoxic waters and sediments are the major producers of methylmercury in aquatic systems."[4] A high level of SRBs, particularly in the still water areas of the project, likely contributes to the increase of methyl mercury. Operation of the reservoir also increases water temperature in certain areas, thus indirectly (via the SRBs) increasing methylation of mercury. DWR concedes that "the methylation process may have increased where Lake Oroville now resides due to the reservoir environment." (Study W2, p. 6-4) Yet DWR appears unwilling to address the problem: "Very little can be done to reduce the mercury problem, short of identifying and remediating a large but unknown number of mine sites." (Study W2 at p. 6-4.)

DWR has studied mercury cycles in reference to the Yuba River and Englebright Reservoir and "the assumption is that mercury cycling in other Sierra Watersheds, including the Feather River system is similar to that found in the Yuba. Therefore, much but clearly not all of the mercury remaining from historic gold mining may be unavailable for downstream transport and biomagnification in the Bay-Delta Estuary." (Study W2, p. 1-2). Implicit in this statement is that mercury is not found downstream in the Delta because it is trapped at Lake Oroville, where it accumulates and biomagnifies among the fish species at the various Oroville project sites.

DWR's findings regarding the facilities' impacts on amplifying methyl mercury and PCB impacts may have been more conclusive had DWR's studies been more complete. Instead, the study admits that there was inadequate sampling of fish, noting that "not all sites contained the originally targeted species, nor could the desired numbers of fish be collected at each site." (Study W2, p. 4-1.) In short, even though DWR recognized the reservoir's operations may contribute to bioaccumulation, the agency failed to exhaustively study the issue.

C. DWR cannot provide reasonable assurance that the Settlement Agreement's mitigation measures adequately address the contaminant problem.

Despite the presence of PCBs, methyl mercury and other toxic substances throughout the project area and their accumulation at unsafe levels in commonly consumed fish, DWR concludes its treatment of these water quality issues in the DEIR by stating, "historical water quality data did nor reveal any upward or downward trends for the various water quality parameters." (DEIR, p. 4.2-43.) DWR's premise that water quality has been historically poor in the project area informed its next conclusion, that "[t]here are no reasonably foreseeable actions upstream of Oroville that would result in future changes in water quality other than water temperature." (DEIR, p. 4.2-43.)

Likewise, the Final EIR states that land use practices "upstream of Lake Oroville are expected to continue and result in the continued release of metals into the Feather River and Lake Oroville. These metals would continue to be transported to through the water column, accumulate in the fish and

[4] http://aem.asm.org/cgi/content/full/69/9/5414.

be sequestered within the sediments trapped in Lake Oroville." (FEIR, p. 2-63.) Despite admitting that the dam facilitates toxic accumulation in fish, DWR asserts that the proposed project would not "result in a change to either the rate or the amount of mercury accumulation with the FERC project boundary," and claims that such accumulation is "part of the environmental baseline and would continue to occur at the same rate under all Project alternatives." (FEIR, p. 5-138.)

DWR also claims that there are "no practicable mitigation measures for mercury accumulation." That premise ignores the State Board's direction to numerous Bay Area cities and water districts, to implement just such a clean up.[5] DWR cannot escape responsibility by claiming that a public health hazard is part of the project baseline. Moreover, despite DWR's premise of no practicable mitigation, the State Board has outlined practicable measures for similar problems.[6]

D. Mitigation measures outlined by DWR in the Settlement Agreement are inadequate to timely address significant public health risks stemming from the water quality violations created and exacerbated by the Project.

The Settlement Agreement calls for two measures to address the concerns outlined in these comments, A112- Comprehensive Water Quality Monitoring Program and A114- Public Education Regarding Risks of Fish Consumption. (*See* Draft Certification, p. 3.) Condition S12 in the draft certification only modestly supplements the water quality mitigation measures in the Settlement Agreement, and the problem of timeliness remains unresolved. While most of the provisions in the program will be implemented in the first 1-2 years following licensure, the Water Quality Bioassay Monitoring Plan (WQBMP) would not be implemented until nearly four years after license issuance.

In the first five years of the program, the SA and State Board conditions calls for the production of an annual report on water quality conducted by the Licensee. At the end of this five-year period, the Deputy Director will consider modifications and approve a final version of the Program. Within six months of the approval of this final report, the Water Chemistry Monitoring Plan (WCMP) will begin to be implemented, *nearly six years* after the issuance of the license. Not until three years after approval of the final report—eight or nine years following licensure— will the Fish Tissue Bioaccumulation Monitoring Plan (FTBMP) begin to be implemented.[7] Because the Settlement

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[5] The State Board issued Tentative Order NO. R2-2008-00XX in relation to NPDES Permit No. CAS612008 for various Bay Area cities and water districts on December 14, 2007. Within that order, the State Board required permittees to control PCBs and outlined provisions for quantifying and reducing PCB loads and their effects through on-site treatment efforts, source control, and other management efforts. (Tentative Order at pp. 70-71.)

[6] Another practicable mitigation measure would be for DWR to instigate "planned high flow events" in order to increase water releases consistent with the natural hydrograph. Such releases would remove bioaccumulating toxic materials, including non polar organic contaminants such as PCBs, from the spawning and fishery habitat below the dam. The State Board should require DWR to study such an effort.

[7] The deadline for the submission of the annual reports to the Deputy Director, etc. on "May 30 of the following year" (S12.c) could also push the deadlines for the programs back by almost one year. For example, if the Program is implemented June 5, 2010, the first annual report would not be required to

Agreement language is vague, these calculations assume that approval and implementation of the program occurs within nine months of the issuance of the license.

In addition to the slow-moving timeline, enough ambiguity exists in the measures as drafted to allow state agencies to further delay implementation of studies and programs vital to protecting the health of the citizens of Butte County. The time frame for consultation with various agencies is not specified ,which could extend the preparation process beyond the specified six-month period, unless it is assumed that the consultation is to take place within the specified time.

E. Conditions imposed by the State Board in its Draft Certification strengthen those outlined in the Settlement Agreement, but should be implemented sooner and on a mandatory basis.

The State Board "determined that certain measures as written in the SA are either not enforceable, will not fully protect the beneficial uses, or will not meet water quality standards in a timely manner. Beneficial uses currently impacted by the Project may not be reasonably protected if the proposed measure has a management plan with unclear or unenforceable standards, and excessively long period prior to implementation, or unspecified implementation dates." (Draft certification, p.4.) Butte concurs with the State Board's assessment of the Settlement Agreement measures and the need for speedy implementation and enforceable standards.

The State Board's condition S12 outlines a nearly identical water quality monitoring program which requires the addition of cyanobacteria and cyanotoxins to DWR's monitoring efforts. S13 and S14 call for planning regarding public health pathogen protection and public education. The State Board's condition S14 requires DWR to provide funding for fish tissue consumption advisories, "should it become necessary based on additional data collection." (Draft Certification, p. 13) Butte does not agree that fish tissue consumption advisories need further study, and urges the State Board to make this condition mandatory immediately should the project be issued a license.

Condition S14 also includes "a reservation of authority" for the State Board to develop a methyl mercury management plan, pending data showing that "the Project increases methylation rates." (*Id.*) The State Board is correct to note the need for a management plan. However, given the data already collected by the DWR for the EIR, including the likely link between reservoir operations and methylation, the County believes that there is no reason to delay development of a methyl mercury management plan.

F. The State Board can strengthen the mitigation conditions it imposes through the certification process without burdening DWR.

The draft certification states "[i]t is not appropriate, however, to require consultation with the Ecological Committee as a condition of this water quality certification" (p. 4). It is questionable why the Ecological Committee (EC) cannot be consulted on water quality issues when this is an area where

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be submitted until May 30, 2012. Thus, the WCMP would be implemented about seven years after license issuance, and the FTBMP would be implemented about 10 years after license issuance.

members of the EC would have expertise.[8] Butte is a member of the EC and believes that the local government members of the EC have an important role to play in assisting DWR in meeting water quality standards. Therefore, Butte urges the State Board to maintain the Settlement Agreement's commitment to consultation with local governments on the EC, while also requiring consultation with other state agencies as appropriate.

VI. The draft conditions on pathogens and water temperature should be revised.

In addition to the contaminant issues discussed above, Butte offers the following comments on pathogens and water temperature in the draft certification.

A. Pathogen Public Health Protection

Under the settlement agreement, DWR (in consultation with the relevant agencies) has discretion over whether or not a public education program about bacteria in the water is necessary. However, DWR monitoring of bacteria at recreation areas has found "consistently high fecal coliform level that exceeded Department of Health Services (DHS) guidance and Basin Plan objectives" (Draft Certification at p. 13). Furthermore, "nearly every sample from two sites in the North Forebay, and many sites in the South Forebay, exceeded DHS and USEPA criteria for enterococcus bacteria" (Draft Certification at p. 13). In the SA, DWR is required to monitor bacteria levels but is not required to take any action, except notifying the public, if there are unsafe levels of bacteria. Butte urges the State Board to make the public education component mandatory, and require that DWR fund the program.

B. Water Temperature Conditions.

The State Board imposes condition S8, requiring water temperature compliance within 10 years. (Draft Certification, p.28.) This modifies the SA, which stated that the water temperature targets could also be reached upon completion of facilities modifications (Draft Certification at p. 10), but does not have a specific time frame, thus possibly prolonging indefinitely compliance with water temperature targets. The Board's condition is an improvement from the SA, but a 10 year period is not timely. The County recommends a shorter time period of 5 to 7 years. Furthermore, the draft certification does not state when facilities modifications would be completed. (Draft Certification at p. 10.) Based on this indefinite completion of facilities modifications, it is unclear what mechanisms will be used to reach the water temperature targets in 10 years.[9]

Currently, project operation would not completely protect cold-water beneficial uses. The State

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[8] For full list of members, see Appendix C, Section 2.1 of the Settlement Agreement.

[9] The water temperature targets in settlement agreement Table 2 be achieved *after* facilities modifications. DWR will use the river valve, among other measures, to control water temperature, as necessary. DWR has agreed to study refurbishment or replacement options for the river valve, but DWR reserves sole discretion in deciding to replace or refurbish it. (Draft Certification, p. 9.) A clear time frame is not established for assessing the river valve. It is also unclear if the river valve is included under facilities modifications, which has a study and implementation plan, but the "SA does not state when the facilities modifications will be completed," making it impossible to assess how DWR will meet temperature targets in the designated time period. (Draft Certification, p. 10.)

Board recognizes "it is necessary to require more specific timelines in the water quality certification for completion of measures to improve water temperature" to protect cold-water beneficial uses (Draft Certification, p. 10). In the event that water targets cannot be met due to uncontrollable forces, a provision of the draft certification states that if the Deputy Director finds a pattern of exceeding water temperatures adversely affecting fishing resources, the Deputy Director *may* require the Licensee file a plan to address the issues but is not *required* to do so. (Draft Certification at p. 30.) In light of the likelihood that climate change will impact water temperature, and water temperature's link to other significant public health concerns, addressing these issues should be mandatory upon the Deputy Director's finding of a pattern of high water temperatures impacting fishery resources.

VII. Conclusion

For the foregoing reasons, Butte urges the State Board not to grant DWR its requested certification on the present application. Should the Board move forward with that certification despite this recommendation, the proposed conditions should not be weakened, and Butte's further suggestions outlined here should be incorporated.

Respectfully submitted,

/s./

Roger B. Moore
Counsel to Butte County

cc: Russ Kanz

EXHIBIT 1

200612195006 Received FERC OSEC 12/19/2006 10:01:00 AM Docket# P-2100-000, ET AL.

State Water Resources Control Board

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Linda S. Adams
Secretary for Environmental Protection

Arnold Schwarzenegger
Governor

December 19, 2006

Magalie R. Salas, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Dear Ms. Salas:

COMMENTS ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE OROVILLE FACILITIES, FERC #2100

State Water Resources Control Board (State Water Board) staff have reviewed the Draft Environmental Impact Statement (DEIS) prepared by the Federal Regulatory Energy Commission (Commission) for the Oroville Facilities (Project), FERC #2100, to determine: 1) if the impacts and/or benefits of the Project and alternatives are disclosed; and 2) if the DEIS fully discloses whether the alternatives will meet the water quality standards.

Basin Plan/Comprehensive Plans
The Department of Water Resources (DWR), the licensee, must obtain water quality certification from the State Water Board, pursuant to Section 401 (a)(1) of the Federal Clean Water Act (CWA) (33 U.S.C. §1341) before the Commission can issue a new license for the Project. DWR must demonstrate that the Project will comply with the Water Quality Control Plan for the Central Valley Region before certification can be issued. Under section 303 of the CWA and under the Porter-Cologne Water Quality Control Act, the Central Valley Regional Water Quality Control Board has adopted, and the State Water Board and U.S. Environmental Protection Agency (USEPA) have approved, the *Water Quality Control Plan for the Sacramento and San Joaquin Rivers* (Basin Plan) (Central Valley Regional Water Quality Control Board, 1998). The Basin Plan designates the beneficial uses of waters to be protected along with the water quality objectives necessary to protect those uses. Beneficial uses designated for Lake Oroville include municipal and domestic supply, irrigation, power generation, contact and non-contact recreation, freshwater habitat (cold and warm), spawning habitat (cold and warm), and wildlife habitat. Beneficial uses for the Feather River from the fish barrier dam to the Sacramento River are municipal and domestic supply, irrigation, contact and non-contact recreation, canoeing and rafting, migration (cold and warm), freshwater habitat (cold and warm), spawning habitat (cold and warm), and wildlife habitat.

In order for the State Water Board to issue water quality certification for the Project, DWR must demonstrate compliance with all water quality objectives in the Basin Plan under its control, as well as other water quality objectives that the Project may affect. DWR must also demonstrate that the Project does not impair the beneficial uses of the Feather River or Lake Oroville. If the Project does not comply with one or more of the water quality objectives, then DWR must describe the actions that it will take to bring its Project into compliance with the applicable water quality requirements in order to protect and maintain the beneficial uses.

An application for water quality certification must describe steps that have been or will be taken to avoid, minimize, or compensate for the loss of or significant adverse impact to the beneficial uses of waters of the State. Cal. Code Regs., tit. 23, §3856(h)(6). Section 10(a)(2) of the Federal Power Act requires the Commission to consider the extent to which a project is consistent with the Basin Plan, which is a comprehensive plan (DEIS page 375). The Environmental Consequences section of an EIS must discuss the possible conflicts between the proposed action and the objectives of federal, regional, State, and local land use plans, policies, and controls (NEPA regulations §1502.16). State Water Board staff have determined that the DEIS does not adequately and fully evaluate the ability of the alternatives to comply with the water quality requirements in the Basin Plan. The DEIS contains overly broad statements about compliance with the Basin Plan without providing adequate supporting documentation. For example, on page 375, the DEIS concludes there are no conflicts between the Project and seventeen comprehensive and other resource plans. Information to support this conclusion, however, is not provided. The final EIS must disclose whether the Project under the baseline condition will comply with the Basin Plan, and must address whether the alternatives will meet the water quality requirements in the Basin Plan.

Baseline
It is important to differentiate existing conditions from the no-action alternative. Using existing conditions as the baseline may be appropriate under NEPA, but doing so may obscure the ongoing impacts of the Project, and may render the EIS less valuable to the Commission as a decision-making tool. Existing conditions are different from the no-action alternative because current operations are different from continued operation under the existing license. Another difference between existing conditions and the no-action alternative is that existing conditions represent environmental conditions at a fixed point in time, whereas under the no-action alternative there will be changes in the environment. The no-action alternative should be compared to existing conditions and the other alternatives in order to show what will happen if the proposed action is not taken. The final EIS should use existing conditions as the baseline, describe the baseline, and clearly define the no-action alternative.

Alternatives
The range of alternatives is too narrow and the alternatives are not adequately described. The DEIS evaluates three alternatives: the baseline or no-action alternative; DWR's proposal; and the Commission staff alternative. As stated above, the difference between the baseline condition and the no-action alternatives must be described. The

screening process used to select the alternatives must also be provided. The Commission staff alternative is a slightly modified version of DWR's proposal, and, as a result, the DEIS evaluates only one major alternative. The DEIS therefore provides little basis for comparison to the no-action alternative or baseline. The final EIS should include a reasonable range of alternatives that may be feasibly carried out based on technical, economic, and environmental factors.

The description of DWR's alternative for water temperature in the low flow and high flow channels is incomplete. The DEIS (table on pages 26 and 27) implies that DWR would be required to meet the temperature requirements for the High Flow Channel (HFC). The Settlement Agreement (SA) does not require DWR to meet the temperature requirements listed in the table. These temperatures (Table 2 in the SA) are targets that will be used to develop temperatures that can be feasibly achieved. The final EIS should fully describe the alternative to allow a thorough comparison with other alternatives, including the baseline condition.

Under Section B108 of the SA, DWR is required to develop a reconnaissance study of potential facilities modifications to address temperature habitat needs for anadromous fish in the Low Flow Channel (LFC) and HFC. The alternatives for consideration include Palermo Canal improvements, Hyatt intake extension, replacement of the river valves with valves specifically designed to incrementally control water releases, construction of a diversion canal around or through the Thermalito Afterbay, and construction of an alternative Thermalito Afterbay Outlet and channel. These alternatives should be evaluated in the final EIS.

The description of the pump back operations described in section 2.1.3.4. is incomplete. Pump back operations impact water temperature in the Project and in the HFC. A more thorough description of historic pump back operations, including the timing, flow, and duration, should be included. This background information is needed to describe how this operation impacts water temperature and water quality, and how future Project operations will impact pump back operations.

Water Quantity and Quality

<u>Affected Environment</u>
It is important to compare the current flow regime with the pre-dam hydrology to understand the impact of the alternatives on beneficial uses affected by geomorphic processes, water quality, and fisheries. The DEIS compares the current flows in the LFC with the pre-dam hydrology (page 69-70). Flows in the HFC are not compared with the pre-dam condition. A comparison with pre-dam conditions should be included in the final EIS.

The DEIS conclusion that water temperatures generally meet the Basin Plan objectives (page 78) is not supported by evidence in the record. Studies have shown it is unlikely that adult Chinook salmon can use the Feather River below the Thermalito Afterbay

Outlet except as a migration corridor (Department of Water Resources, 2004). Water temperature monitoring in 2002 and 2003 showed that the temperature of water released from Thermalito Afterbay was as much as 11.3°F higher than that of incoming water (Department of Water Resources, 2005). DWR concluded that increased incidence of disease, developmental abnormalities, increased in-vivo egg mortality, and temporary cessation of migration could occur due to elevated water temperatures in some areas of the lower Feather River (Department of Water Resources, 2004).

The statement on page 87 of the DEIS that there is no current Office of Environmental Health Hazard Assessment (OEHHA) fish consumption advisory for the Feather River is incorrect. OEHHA issued a draft health advisory including safe eating guidelines for fish from the Lower Feather River (Butte, Yuba, and Sutter Counties). The advisory contains an evaluation of elevated mercury levels in fish from the lower Feather River and provides safe eating guidelines for these water bodies (http://www.oehha.ca.gov/fish/so_cal/pdf_zip/FeatherCRNR081006.pdf).

Page 13 of the DEIS states that the baseline and no-action alternative will be discussed in the affected environment section. All of the current impacts of the Project have not been included in this section. The impact of reduced water temperature on rice production should be included. DWR conducted monitoring for bacteria at recreation areas during 2002 and 2003. Samples from the North Forebay Recreation Area beach had consistently high fecal coliform levels that exceed Department of Health Services (DHS) guidance and Basin Plan objectives. Results also showed that nearly every sample from two sites in the North Forebay, and many sites in the South Forebay exceeded DHS and U.S. Environmental Protection Agency criteria for enterococcus bacteria (Department of Water Resources, September 2004). This information should be included in this section. In 2005 a large bloom of the blue-green algae *Anabaena flos-aquae* was observed in the Middle Fork Feather River arm of Lake Oroville. *Anabaena flos-aquae* can produce toxins (anatoxin-a, a neurotoxin) at levels hazardous to public health, pets, and wildlife. *Anabaena flos-aquae* may also have the ability to produce compounds that create taste and odor problems in water. At this time it is not known if this algal bloom produced toxins or caused taste and odor problems. Phosphorus has been measured in Lake Oroville at levels that can produce algae blooms (Department of Water Resources, September 2004). The impact on water quality and recreation of large algae blooms in Lake Oroville should be disclosed in the final EIS.

<u>Environmental Effects</u>
The general statement on page 96 of the DEIS that waters in the Project area meet the water quality standards for temperature, dissolved oxygen, nutrients, pH, and metals is not supported by documentation in the DEIS or other available information. The Feather River is listed as an impaired water body for mercury on the Clean Water Act section 303(d) list. Mercury was found in 214 individual fish sampled from the Project, with values ranging as high as 1.26 mg/kg. The USEPA criteria is 0.3 mg/kg for the

protection of human health. Temperature, as previously stated in the section on affected environment, is also impaired.

The DEIS does not make a sufficiently clear distinction between the impacts of flow and the impacts of Project operations on water temperature. The DEIS also does not adequately discuss water temperature impacts on the HFC. Water temperature in the LFC and HFC are impacted by both flow and Project operations. Improvements to water temperature can be made through changes in flow as well as through physical changes in Project facilities and operations. This distinction is important because changes in operations may have a greater impact on water temperature than Project improvements.

The SA includes provisions to complete a reconnaissance study of potential facilities modifications to improve water temperature by the end of 2006. The staff analysis on page 97 of the DEIS states that "without knowing which of the facility modifications would be implemented at this time, staff can only analyze the effects that would exist under the interim and post–facility modification temperature requirements." The facility modifications proposed in the reconnaissance study, however, are also part of the proposed Project and should also be evaluated. Construction of these facilities, as well as operational changes, may have significant environmental impacts. These potential impacts must be described and evaluated. As discussed above, alternatives that include these proposed projects for evaluation should be developed and included in the final EIS.

DWR delivers water to rice growers from several different points in Thermalito Afterbay. After construction of Oroville Dam, water temperatures became less suitable for rice cultivation during the early irrigation season and typically have not met the threshold required for rice production during the summer (Department of Water Resources, July 2004). Resolution of this issue could require physical changes at the Thermalito Afterbay to control temperature. The impacts and benefits of alternatives to improve water temperature for rice production should be evaluated and included in the final EIS.

The DEIS concludes that improving water quality within the North Forebay swim area, and specifically within the cove, would allow the beach to remain open to the public throughout the peak season. Despite identifying this impact of water quality on swimming, and the need to improve water quality, the DEIS did not identify alternatives to avoid or reduce the impact. Alternatives that will mitigate or reduce this impact should be developed and included in the final EIS.

Aquatic Resources

Affected Environment

The DEIS contains a discussion of Ceratomyxosis and states that *Ceratomyxa shasta*, and a myxosporean parasite are prevalent in waters of the Thermalito Complex and Lake Oroville (page 125). The intermediate host of *C. shasta* is the polychaete

Manayunkia speciosa that produces myxospores that infect fish. Project operations can impact rate of infection by increasing the preferred habitat for the polychaete and through increased stress from elevated water temperature. The final EIS should include a discussion of the impacts of Ceratomyxosis on anadromous fish in the Feather River and other fish in Lake Oroville. Additional studies may be needed to determine if the Project increases the spread of this disease.

Threatened and Endangered Species

Fish Species

The DEIS does not adequately describe impacts of the current Project on spring-run Chinook salmon (page 160). Construction of the Project has restricted the spatial separation of spring and fall run Chinook salmon. The reduction in spawning habitat has increased the rate of redd superimposition, which has impacted spring run salmon that spawn a few weeks prior to fall run. In addition, the Feather River Fish Hatchery has not separated spring and fall run fish when collecting eggs. This has resulted in introgression (genetic interbreeding) at a very high rate. The hatchery produces spring-run Chinook salmon that is genetically more similar to fall-run (page 137). Article A105 of the SA requires DWR to develop a weir construction and operations plan consistent with the Project biological opinion(s). Actual construction of the weir is not required until 12 years after license issuance. The impact of waiting 12 years to install the weir, and the potential impact of the weir on all species of fish in the Feather River should be described. Monitoring and mitigation measures may be required to avoid impacts to species other than salmon. In addition, water quality impacts from construction of the weir should be described.

The DEIS concludes that under current operations water temperatures are consistent with those that "may increase incidence of disease and mortality, in-vivo egg mortality, and developmental abnormalities occurring during spawning migrations and pre-spawning holding" (page 179) and that excessively high water temperatures downstream of the outlet have precluded steelhead rearing. The DEIS concludes that the proposed measures to support anadromous fish will improve water quality except under the most extreme conditions. It is impossible, however, to analyze the water temperature impact of potential facilities modifications being developed by DWR on anadromous fish. As stated above, the SA only includes temperature targets, not the actual temperatures that will be achieved. The actual temperatures that can be achieved will not be known until alternatives are developed and modeled. Because the actual temperatures that will be achieved are unknown, the benefits of those temperatures on anadromous fish cannot be evaluated at this time. If this is the case, the final EIS should disclose that the impact of the proposed Project is not known.

Conclusion
State Water Board staff appreciates the opportunity to comment on this DEIS. Please contact me at (916) 341-5341 if you need additional information or would like to discuss these comments.

Sincerely,

Russ J. Kanz
Staff Environmental Scientist

cc: FERC Service List

Beth Lawson
Sharon Stohrer
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References:

Central Valley Regional Water Quality Control Board. 1998. Water quality control plan for the Sacramento and San Joaquin River Basins, Forth Edition. September 15, 1998

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State Water Resources Control Board

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Alan C. Lloyd, Ph.D.
Agency Secretary

Arnold Schwarzenegger
Governor

March 30, 2006

Magalie R. Salas, Secretary
Federal Energy Regulatory Commission
888 First Street, N. E.
Washington, DC 20426

Dear Ms. Salas:

COMMENTS ON NOTICE OF APPLICATION AND APPLICANT PREPARED ENVIRONMENTAL ASSESSMENT, OROVILLE FACILITIES, FERC #2100

State Water Resources Control Board (State Water Board) staff have reviewed the Application for New License and Preliminary Draft Environmental Assessment (PDEA) prepared by the Department of Water Resources (DWR) for the Oroville Facilities (Project), Federal Energy Regulatory Commission (Commission) #2100. By notice issued September 12, 2005, along with subsequent extensions, FERC has requested that comments and recommendation for the Project be submitted by March 31, 2006. After reviewing the PDEA, State Water Board staff identified several problems that may limit the adequacy of the document for compliance with the National Environmental Quality Act (NEPA).

<u>Baseline</u>
The PDEA prepared for the Project does not adequately describe the baseline conditions as required under NEPA. To adequately evaluate the significance of impacts, it is important to establish a baseline against which alternatives can be evaluated. The baseline needs to be differentiated from the no-action alternative (i.e., what will occur without the federal action). However, the baseline can be, but is not necessarily, the no-action alternative. Another difference between existing conditions and the no-action alternative is that existing conditions represent environmental conditions at a fixed point in time, whereas the no-action alternative represents conditions where changes will be made to the environment. The no-action alternative should be compared to existing conditions and the other alternatives in order to show what will happen if the proposed action is not taken. It is also important to determine if the baseline condition is static, improving, or degrading over time. In particular, DWR has not adequately described the baseline conditions for water quality in the PDEA. While the PDEA mentions that the Project alters water temperature in the Feather River, the impact of water temperature alteration on anadromous fish is not adequately described (PDEA page 5.4-31 and Table 5.5-6). The Commission needs to use and describe existing conditions as the baseline and clearly define the no-action alternative in the NEPA document.

Water Quality Certification
It is important to remember the analysis of water quality impacts in NEPA and the California Environmental Quality Act (CEQA) may be different from that required to obtain water quality certification. For this Project, the on-going impairments to water quality may not be considered significant impacts under either NEPA or CEQA. However, before the State Water Board can issue water quality certification for the Project, DWR must demonstrate that the operation of the Project can comply with the water quality standards in the Water Quality Control Plan for the Sacramento and San Joaquin River Basins (Basin Plan).

Settlement Agreement
On March 21, 2006, a number of parties signed a settlement agreement for the licensing of this Project. State Water Board staff will review the settlement agreement to determine if the proposed measures will achieve compliance with the water quality standards in the Basin Plan. If the proposed measures alone will not result in compliance with the water quality standards, State Water Board staff will condition any water quality certification to ensure that the Project will meet the water quality standards. Finally, because the PDEA was prepared prior to the execution of the settlement, the protection, mitigation, and enhancement measures from the settlement were not analyzed in the document. The Commission should analyze the settlement conditions as a Project alternative in its NEPA document.

Cumulative Impacts
The Oroville Facilities are part of the State Water Project, which is a very large water supply system that is coordinated with the federal Central Valley Project. These coordinated projects have regional cumulative impacts on water quality, fisheries, and flood control. It is reasonable and foreseeable that the State Water Project and the federal Central Valley Project will make changes to the operation of their projects to address their impacts on water quality, fisheries, and flood control. Currently, there is a great deal of concern over the pelagic organism decline (POD) in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Flow and water quality are two of the issues being studied that may be causing the POD. It is important to consider the impact these issues may have on the future operation of this Project.

Please note that Russ Kanz has been substituted for Sharon Stohrer as a contact with the State Water Board. If you have any questions you may call me at (916) 341-5341.

Sincerely,

Russ J. Kanz
Staff Environmental Scientist

EXHIBIT 2

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Butte County
Superior Court
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Sharol Strickland Clerk
By ~~CHRISTENSEN~~ Deputy

SUPERIOR COURT OF THE STATE OF CALIFORNIA

COUNTY OF BUTTE

COUNTY OF BUTTE, a political subdivision of the State of California;
Petitioner,

v.

DEPARTMENT OF WATER RESOURCES, a public agency of the State of California;
Respondent,

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD; CALIFORNIA DEPARTMENT OF BOATING AND WATERWAYS; CALIFORNIA DEPARTMENT OF FISH AND GAME; CALIFORNIA DEPARTMENT OF PARKS AND RECREATION; CITY OF OROVILLE; TOWN OF PARADISE; FEATHER RIVER RECREATION AND PARKS DISTRICT; OROVILLE PARKS COMMISSION; OROVILLE REDEVELOPMENT AGENCY; ALAMEDA CONTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT, ZONE 7; ALAMEDA COUNTY WATER DISTRICT; ANTELOPE VALLEY–EAST KERN WATER AGENCY; CASTAIC LAKE WATER AGENCY; CENTRAL COAST WATER AUTHORITY; COACHELLA VALLEY WATER DISTRICT;

Butte County Case No. 144283

PETITION FOR WRIT OF MANDATE

[NO FILING FEE REQUIRED (Gov. Code, § 6103)]

COUNTY OF KINGS; CRESTLINE-LAKE ARROWHEAD WATER AGENCY; DESERT WATER AGENCY; EMPIRE WEST SIDE IRRIGATION DISTRICT; KERN COUNTY WATER AGENCY; LITTLEROCK CREEK IRRIGATION DISTRICT; METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA; MOJAVE WATER AGENCY; NAPA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT; OAK FLAT WATER DISTRICT; PALMDALE WATER DISTRICT; SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT; SAN GABRIEL VALLEY MUNICIPAL WATER DISTRICT; SAN GORGONIO PASS WATER AGENCY; SANTA CLARA VALLEY WATER DISTRICT; SOLANO COUNTY WATER AGENCY; STATE WATER CONTRACTORS, INC.; TULARE LAKE BASIN WATER STORAGE DISTRICT; AMERICAN RIVERS; AMERICAN WHITEWATER; BERRY CREEK CITIZENS ASSOCIATION; CALIFORNIA STATE HORSEMEN'S ASSOCIATION; CALIFORNIA STATE HORSEMEN'S ASSOCIATION REGION II; CHICO PADDLEHEADS; CITIZENS FOR FAIR AND EQUITABLE RECREATION; FEATHER RIVER LOW FLOW ALLIANCE; INTERNATIONAL MOUNTAIN BICYCLING ASSOCIATION; LAKE OROVILLE BICYCLIST ORGANIZATION; OROVILLE AREA CHAMBER OF COMMERCE; OROVILLE DOWNTOWN BUSINESS ASSOCIATION; OROVILLE ECONOMIC DEVELOPMENT CORPORATION; OROVILLE RECREATION ADVISORY COMMITTEE; OROVILLE ROTARY CLUB; ARTHUR G. BAGGETT,JR.; D.C. JONES.

Real Parties in Interest.

Petitioner County of Butte ("Butte") prays for this Court to issue its writ of mandate directed against respondent Department of Water Resources ("DWR") on the following allegations:

INTRODUCTION

1. This petition challenges the failure of respondent Department of Water Resources (DWR) to comply with the California Environmental Quality Act (CEQA, Pub. Res. Code, § 21000, et seq.) when it certified its Final Environmental Impact Report (FEIR) and rendered final approval of a project that would extend for 50 years the operating license for its Oroville hydroelectric facility (FERC Project 2100). DWR serves as state lead agency for the relicensing project, while the Federal Energy Regulatory Commission (FERC) serves as federal lead agency. Originally licensed in 1957, the Oroville facility, located within Butte County on the Feather River, generates annual net power benefits that FERC has valued at almost $26 million annually. Oroville is also the key northern water storage facility in the DWR-managed State Water Project (SWP), which provides water, valued conservatively in hundreds of millions of dollars annually, to state water contractors serving more than 23 million Californians.

2. Although DWR's FEIR represents that its project, a 2006 Settlement Agreement submitted to FERC (SA, or "the project"), has "near-unanimous" support, that asserted consensus excluded Butte County, which has borne millions of dollars annually in environmental and services costs stemming from Oroville operations, which costs DWR has never mitigated. It also excluded Plumas County, the Feather River's northernmost county of origin, as well as other public entities and environmental organizations.

3. The Oroville facility, while providing benefits largely concentrated in southern California, and south of the Bay-Delta estuary (Delta), has created substantial environmental, land management, and water use impacts within Butte County, as well as major socioeconomic impacts producing significant environmental consequences. While the 50-year license renewal proposed in the project would perpetuate and compound those impacts, DWR failed to provide any meaningful mitigation for them. Butte does not seek to undermine the benefits of Oroville operations, but

rather, through the imposition of feasible mitigation measures and the full enforcement of DWR's CEQA duties as state lead agency, seeks redress for harmful inequities burdening Butte.

4. Four foundational errors so seriously distorted DWR's analysis that they fatally compromised the FEIR's ability to inform decision-making. The first is DWR's avoidance of rigorous climate change assessment. The California Attorney General has emphasized elsewhere that project applicants must rigorously assess climate change to comply with CEQA. In its 2005 California Water Plan Update and recent reports to the Governor of California, DWR has written repeatedly that climate change will have a major effect on SWP operations. Oroville, as the SWP's primary storage and power generation facility, plays a central role in SWP operations. Changing climatic conditions will impact Oroville's flood control, reservoir storage levels, upstream and downstream flow levels, water temperatures, power generation, water quality, fisheries, and recreation.

5. Rather than rigorously assessing climate change, DWR's Oroville FEIR presumes that hydrologic variability from the previous century "is expected to continue in the foreseeable future" and that it would be "speculative" to further analyze other climate change scenarios. The FEIR also suggests that there would be "further opportunities in the future" to address climate change at the "next relicensing period"—in other words, *half a century after project implementation.* DWR's attempted deflection of serious climate change assessment to future generations infected all key elements of the FEIR, including assessment of the environmental setting, direct and cumulative impacts, feasible alternatives, and mitigation. Due to this error, the FEIR is predicated upon a hypothetical future that DWR knows to be dangerously false.

6. A second foundational error undermines the FEIR. Oroville operations are tied to the Delta, because Oroville facilities provide environmental water to the Delta, and their releases directly affect Delta water quality. But in its FEIR, DWR failed to analyze how changing conditions in the

Delta will affect the timing or volume of water releases from its Oroville facilities. Even though DWR was aware of recent judicial decisions invalidating the Operating Criteria and Plan (OCAP) Biological Opinions (BO) for salmonids and Delta smelt, it avoided serious new analysis, based upon speculation that Oroville releases would be "one of many" inputs to Delta hydrology.

7. In a third foundational error, the FEIR does not identify as potentially significant impacts from perpetuating old operating rules through its new decision-making. For example, it assumes the no-project alternative will create no impacts because old rules would remain in place. But that assumption is specious, because reauthorizing an old operating scheme can significantly change the environmental status quo. If the old operating scheme was causing declines in the quality of recreational resources or wildlife habitat, for example, a choice to perpetuate those rules could lead to additional environmental harms far exceeding those that already have occurred. Moreover, the changed context for SWP operation, due to such factors as climate change and Delta conditions, is likely to render the rest of the environment vastly different in the future.

8. The FEIR's fourth foundational error is its failure to address the project's environmentally significant socioeconomic consequences for Butte. Butte County is among the most financially distressed counties in California, and is the only such county to have received the state designation of "acute fiscal distress" three times since 1990. Butte has nonetheless spent millions of dollars per year providing government services necessitated by Oroville operations while also losing millions annually in lost tax revenue due to Oroville operations. Yet DWR refused to provide any mitigation to Butte of the project's environmentally significant socioeconomic impacts, based upon the indefensible conclusion that the project would not result in any significant direct or cumulative impacts. DWR also refused to provide feasible mitigation of these impacts at negligible cost to SWP beneficiaries.

9. The FEIR contains numerous other CEQA errors, including failure to provide a consistent and accurate project definition, and failure to address and mitigate numerous other project impacts.

PARTIES, VENUE AND JURISDICTION

10. Petitioner County of Butte (Butte) is a political subdivision of the State of California, charged by the California Constitution with the duty to protect the environment and economy of the people and resources within its jurisdiction. The Oroville facility addressed in this petition is located entirely inside Butte County, and has imposed significant environmental impacts upon Butte County, including but not limited to impacts to land management, water use, and socioeconomic impacts with environmental consequences. DWR's project addressed in this petition, if approved and implemented, would continue and exacerbate these impacts to Butte over the 50-year period proposed for DWR's new operating license on FERC Project No. 2001.

11. Respondent Department of Water Resources (DWR) is a department of the State of California charged with the duty to operate and manage the SWP consistently with state law. DWR operates and manages the SWP by constructing, maintaining and owning its facilities, and by contracting with each of 29 local state water contractors, including petitioner Butte. The Oroville facility is an integral part of the SWP. Wat. Code, § 12934(d). DWR serves as state lead agency for the project, and is the proponent of the FERC project application to continue operation of the hydroelectric component of its Oroville operations for an additional 50-year period (FERC Project No. 2100). In its review of that application, FERC serves as federal lead agency.

12. DWR's FEIR and final state project approval would also likely prejudice other agencies' decision-making relating to the license, including that of the State Water Resources Control Board (State Board), which will rely on DWR's FEIR as a responsible agency under Public Resources Code section 21167.3 in its review of compliance with section 401 of the Clean Water Act.

13. Butte does not believe that there are any "recipients of an approval" from DWR's FEIR and final Oroville project decision that would qualify them as real parties in interest as the California Legislature intended that term to apply in Public Resources Code section 21167.6.5. Nonetheless, in an abundance of caution, and because at least one court has applied the "recipients of approval" term loosely (*County of Imperial v. Superior Court* (2007) 152 Cal. App. 4th 13), Butte here names as real parties in interest those parties that conceivably might contend they qualify as "recipients of an approval" receiving specific benefits under California law based upon DWR's final project decision. These named real parties in interest include the following:

a. Real party in interest California State Water Resources Control Board, a public agency organized under California law, is the California state entity charged with reviewing DWR's pending application for water quality certification for the project as required under section 401 of the federal Clean Water Act. For DWR's section 401application to be complete, it was first required to submit a certified EIR on the proposed project to the State Board, which would utilize that EIR acting as a responsible agency.

b. Real parties in interest California Department of Boating and Waterways, Department of Fish and Game (DFG), and Department of Parks and Recreation (DPR) are state agencies organized under the laws of California. They are signatories to the 2006 Settlement Agreement (SA) referenced as the project in DWR's FEIR. DWR has identified the California Department of Boating and Waterways as a CEQA state responsible agency, and identified DFG and DPR as CEQA trustee agencies.

c. Real parties in interest City of Oroville and Town of Paradise are political subdivisions of the state of California. They are signatories to the SA.

d. Real parties in interest Feather River Recreation and Parks District; Oroville Parks Commission; Oroville Redevelopment Agency; Alameda Conty Flood Control and Water

Conservation District, Zone 7; Alameda County Water District; Antelope Valley–East Kern Water Agency; Castaic Lake Water Agency; Central Coast Water Authority; Coachella Valley Water District; County of Kings; Crestline–Lake Arrowhead Water Agency; Desert Water Agency; Empire West Side Irrigation District; Kern County Water Agency; Littlerock Creek Irrigation District; Metropolitan Water District of Southern California; Mojave Water Agency; Napa County Flood Control and Water Conservation District; Oak Flat Water District; Palmdale Water District; San Bernardino Valley Municipal Water District; San Gabriel Valley Municipal Water District; San Gorgonio Pass Water Agency; Santa Clara Valley Water District; Solano County Water Agency; and Tulare Lake Basin Water Storage District are public agencies organized under the laws of California. They are signatories to the SA.

e. Real party in interest State Water Contractors, Inc. (SWC), is a non-profit association of 27 public agencies in California, organized under California law, that purchase water under contract from the SWP. SWC is a signatory to the SA. Butte and another SWP contractor, the Plumas County Flood Control and Water Conservation District are not members of SWC.

f. Real parties in interest American Rivers; American Whitewater; Berry Creek Citizens Association; California State Horsemen's Association; California State Horsemen's Association Region II; Chico Paddleheads; Citizens for Fair and Equitable Recreation; Feather River Low Flow Alliance; International Mountain Bicycling Association; Lake Oroville Bicyclist Organization; Oroville Area Chamber of Commerce; Oroville Downtown Business Association; Oroville Economic Development Corporation; Oroville Recreation Advisory Committee; and Oroville Rotary Club are, to the best of petitioners' knowledge, non-profit organizations organized under the laws of California. They are signatories to the SA.

g. Arthur G. Baggett. Jr. and D.C. Jones are, to the best of petitioners' knowledge, individuals residing within the State of California. They are signatories to the SA.

14. Pursuant to Code of Civil Procedure section 393(b), venue for this action is appropriate in Butte County, the location of the Oroville facilities and DWR's project. The affirmative acts of DWR recorded in its July 22, 2008 notice of determination resulted in wrongs that were felt, at least in large part, in Butte County.

15. This verified petition for writ of mandate is authorized by, and arises under, Public Resources Code section 21168 and Code of Civil Procedure section 1094.5, *et seq.*

PROCEDURAL HISTORY

History of the Oroville Facility

16. The original federal license for the Oroville facility—previously the Feather River Project of the Oroville Division, State Water Facilities—was issued in 1957. FERC's predecessor as licensor, the Federal Power Commission, issued the 50-year license for the Oroville facility (Project No. 2100) to DWR's predecessor as licensee, the California Water Project Authority (Authority). In 1956, the Legislature abolished the Authority, and DWR succeeded as licensee. The Authority's 1952 application that led to issuance of the Oroville facility's license represented that "provision will be made to make payment for or replace improvements destroyed or injured by the proposed works."

17. During the 1950s, the Authority and DWR repeatedly made assurances to Butte and its citizens, attempting to allay concerns about negative impacts of the Oroville facility within the county and region. Along with other proponents of the facility, they argued that short-term losses to Butte, including loss of local lands and the resultant tax base, would eventually be outweighed by economic gains to Butte and the state.

18. The Oroville facility, constructed between 1961 and 1968, is located on the Feather River in the Sierra Nevada foothills in Butte County, California. Oroville Dam is five miles east of the City of Oroville and about 130 miles northeast of San Francisco. As part of the SWP, the facility's

operation is not simply for power generation, but for flood management, power generation, water quality improvement in the Delta, recreation, and fish and wildlife enhancement. However, few of the benefits from Oroville's operation extend to Butte. For example, with respect to flood protection, levies constructed along the Feather River after a 1907 flood already provided flood protection to Butte prior to construction of the Oroville facility. By contrast, the facility's storage of water above Lake Oroville introduces an additional flood risk.

19. In operation since 1968, the Oroville facility encompasses 41,200 acres and includes Oroville Dam and Reservoir, Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and the Thermalito Pumping-Generating Plant with combined licensed generating capacity of approximately 762 megawatts. Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-foot (maf) capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level. Other project features include Thermalito Diversion Dam, the Feather River Fish Hatchery, the Fish Barrier Dam, Thermalito Forebay, Thermalito Afterbay, the Oroville Wildlife Area (OWA), and recreation facilities.

20. As the host county and sole location of the Oroville facility, Butte has consistently absorbed the vast majority of its negative consequences. In 1974, FERC recognized that "farms, mines, homes, schools, roads and trails of a 'golden historical past' were inundated to create the project." (Order on Revised Recreation Plan, September 22, 1994.) DWR never compensated Butte for lost taxes on the improvements it destroyed. Those destroyed improvements included Big Bend, a 70-megawatt privately-owned hydroelectric plant that previously served as the economic and social hub for the community of Las Plumas. Notwithstanding substantial harm to the county, DWR does not pay taxes on the Oroville facility and has declined to make payments lieu of taxes (PILOT).

21. The Oroville facility has directly and negatively affected the environment and economy of Butte, creating significant impacts on land management, water resources and social impacts. The

facility uses county natural resources and infrastructure (such as roads, bridges and traffic controls), and relies on county government services such as law enforcement, fire protection, emergency services and "first responder" services. These burdens have fallen heavily on Butte, because in California, county governments provide almost all the services required to meet the health and welfare needs of county residents, and the public safety of citizens living in and visiting the unincorporated areas of the county.

Federal Proceedings on DWR's License Application

22. On January 11, 2001, FERC issued a letter order approving DWR's request to use the alternative licensing procedures (ALP) defined in 18 C.F.R. § 4.34(i), for relicensing of the Oroville facility.

23. On January 26, 2005, DWR filed an application with FERC for a new license to own, operate and maintain the Oroville facility for an additional 50 years, pursuant to the Federal Power Act, 16 U.S.C. §§ 791 (a)-825(r). DWR submitted a Preliminary Draft Environmental Assessment (PDEA) along with its license application.

24. In several filings submitted to FERC addressing this application, Butte documented extensive impacts of the originally proposed project on the county.

25. On September 12, 2005, FERC issued notice of filing DWR's license application and its accompanying environmental assessment.

26. On March 26, 2006, DWR filed an Offer of Settlement (Settlement, or SA) with FERC, which replaced the proposed action identified in its January 26, 2005 license application. Although the SA records DWR's concurrence with several dozen stakeholders, DWR did not reach agreement with other stakeholders that had intervened in the FERC proceeding, including Butte. Butte, which participated in earlier discussions, was excluded from the final discussions culminating in the SA.

27. In additional filings submitted to FERC addressing the SA, Butte documented its grounds for concluding that the SA failed to include key stakeholders, failed to address important project impacts, imposed inappropriate impediments on FERC's ability to monitor license implementation, and failed to protect public safety and the public interest.

28. On September 26, 2006, FERC issued its Draft Environmental Impact Statement (DEIS) for relicensing of the Oroville facility. Butte and other stakeholders submitted detailed comments on the DEIS. In addition, stakeholders commented on the DEIS at a public meeting in Oroville on November 8, 2006.

29. Acting as federal lead agency, FERC issued its Final EIS (FEIS) for the Oroville relicensing project on May 18, 2007. DWR's license application remains pending at FERC.

DWR's Final Environmental Impact Report and Project Decision

30. Acting as state lead agency, DWR determined that preparation and certification of an EIR addressing the March 21, 2006 SA would be required to comply with CEQA. On May 21, 2007, DWR issued its Draft EIR addressing its pending application before FERC to obtain a new 50-year license for FERC Project No. 2100. The DEIR defined the SA as the project under review.

31. DWR received more than 50 comment letters on the DEIR during the public comment period between May 21, 2007 and August 20, 2007. DWR also received extensive comments at a public hearing in Oroville on June 21, 2007.

32. Butte submitted timely written comments to DWR addressing DWR's DEIR for the project. In addition to providing detailed comments on each chapter of the DEIR, Butte identified several overarching problems with the DEIR thwarting its ability to serve as a decision-making document under CEQA:

- The DEIR failed to address the project's perpetuation and compounding of the tremendous socioeconomic inequities imposed on Butte by Oroville's operation, the environmental consequences of these inequities, and the mitigation needed to remedy them.

- The DEIR failed to address the adverse impacts of preserving present operating terms for the Oroville facility for the net 50 years.
- The DEIR employed a flawed methodology for assessment of cumulative impacts, discounting small contributions that, taken collectively, could be cumulatively considerable.
- The DEIR failed to analyze the impacts of changing climatic, social and environmental conditions on the SWP, and how those changes could affect the environmental consequences of DWR's Oroville project.

33. Butte's comments on the DEIR documented extensive economic and environmental costs to Butte associated with Oroville project operations, highlighting the unfairness to the county that the proposed project would perpetuate. Butte included with its comments two detailed studies addressing these issues: *Socio-Economic Impacts of the Oroville Facilities on Butte County, California* (2006), and *Operational Impacts of the Oroville Project on Butte County* (2006) (respectively, attachments A and B to Butte's comments). Butte also cited numerous reports in which DWR and other researchers recommended assessment of climate change and water resources far more rigorous than that provided in the DEIR.

34. DWR issued its FEIR for the project in June 2008. The FEIR perpetuated most of the serious errors identified in comments on the DEIR. For example, the FEIR did not identify any significant socioeconomic and public services impacts to Butte from the project, and declined to mitigate these effects on Butte. The FEIR also posited that it would be "speculative" to provide the more rigorous climate change assessment that Butte and other commenters had requested.

35. On July 22, 2008, DWR filed its Notice of Determination for the project, and also adopted its findings and mitigation monitoring program for the project.

EXHAUSTION OF REMEDIES AND PRESENT LACK OF LEGAL REMEDY

36. Petitioner Butte timely participated in the proceedings of respondent DWR, to raise the objections that form the substance of this petition for writ of mandate. Petitioner has exhausted all remedies and has no remaining remedy at law to challenge or set aside the final orders of respondent. Butte also performed all conditions precedent to filing this action, complying with Public Resources Code section 21167.5 by providing notice of this action to the DWR Director on August 20, 2008.

CAUSES OF ACTION

COUNT ONE: Faulty project definition

37. Petitioners reallege and incorporate by reference the allegations of paragraphs 1 through 36.

38. CEQA requires the lead agency reviewing a project to provide a consistent, stable and accurate definition of the project under review. Under CEQA Guideline section 15124, the FEIR's description of the project must also contain sufficient specific information to allow the public and reviewing agencies to evaluate and review the project's environmental impacts. The FEIR must not employ a tautological description of the project objectives that skews the project toward project approval.

39. The FEIR inaccurately describes the project setting and objectives, as well as existing and foreseeable project conditions. The FEIR's project definition is inconsistent, unstable and inaccurate in at least the following respects, amounting to a failure to proceed as required by CEQA:

a. The project definition, which focuses on "continued operation and maintenance of the proposed project for electric power generation," obscures DWR's other purposes in obtaining a project license. That definition is not consistent with references elsewhere in the same FEIR, which recognize that DWR's project management must also "meet existing commitments and comply with regulations pertaining to water supply, flood management, the environment, and recreational opportunities." Those duties stem in part from DWR's responsibilities as SWP project manager under the Burns-Porter Act, Wat. Code, §§ 12930, *et seq.*

b. The FEIR erroneously claims that the project "is consistent with existing commitments" to supply water and meet environmental objectives downstream, and that no change to release schedules is anticipated. If downstream environmental requirements change, or if upstream hydrology changes, consistency with downstream commitments could produce a very different set of release schedules. Due to climate change and Bay-Delta problems related to fisheries and water quality, such changes are not only foreseeable in future SWP operation, but highly likely. Delta-related constraints on SWP operations include DWR's obligation to release sufficient water to comply with Delta water quality standards; its obligation to release water at temperatures and in amounts sufficient to satisfy obligations under environmental laws like the Clean Water Act and federal and state Endangered Species Acts; and its commitment to release water, as available, to meet the needs of its contractors.

c. The FEIR inaccurately describes support for the proposed project, which it characterizes as "near unanimous."

d. The project description does not describe the full effects of, among other project impacts, management of the Oroville Wildlife Area, the closure of Foreman Creek and the Instream Structural Placement Program.

COUNT TWO: Faulty assessment of the environmental setting

40. Petitioners reallege and incorporate by reference the allegations of paragraphs 1 through 39.

41. CEQA requires that an EIR include an accurate description of the existing environment in the vicinity of the project from a local and regional perspective. CEQA Guidelines, § 15125.

42. The EIR failed to accurately describe the environmental setting of the project, in at least the following respects: climate change, flood control benefits, Bay-Delta fisheries, water quality issues, land use, recreational facilities, population, housing, public services, law enforcement and criminal justice, the financial and socio-economic status of Butte County, water temperature, and agricultural resources.

COUNT THREE: Faulty definition and use of project baseline

43. Petitioners reallege and incorporate by reference the allegations of paragraphs 1 through 42.

44. CEQA requires that an EIR accurately represent and assess existing baseline conditions. An accurate baseline allows the EIR to properly evaluate changes, and the resulting impacts, produced by the project.

45. The FEIR inaccurately represents existing baseline conditions at the Oroville facility, predicating them upon historic rather than existing conditions. It fails to assess the resource degradation that has already occurred as a result of its current operations. By underestimating the nature and significance of current project conditions, DWR distorted the significance of environmental impacts resulting from the proposed project.

46. DWR's analysis resulting from this inadequate baseline enabled DWR to evade responsibility for mitigating significant effects in violation of CEQA. Acting in reliance upon an EIR inadequately prepared in this respect, DWR failed to proceed as required by CEQA.

COUNT FOUR: Faulty assessment of no-project alternative.

47. Petitioners reallege and incorporate by reference the allegations of paragraphs 1 through 46.

48. CEQA requires a lead agency to analyze a no-project alternative. Under CEQA guidelines, when the project is the revision of an existing regulatory plan, the no-project alternative must embrace the continuation of the existing plan, policy or operation into the future. CEQA Guidelines, § 15126.6.

49. The EIR erroneously assumes that the no-project alternative will create no impacts because old rules would remain in place. This assumption is unwarranted, given the declining environmental conditions within the project area under the "old rules," as well as impacts that can reasonably be expected in the foreseeable future (independent of any revision of Oroville operations due to climate change and changes in SWP operations).

50. The Oroville Project EIR's no-project alternative thus fails to acknowledge and analyze what would reasonably be expected to occur if the project does not proceed. By failing to identify and analyze a proper no-project alternative, respondent DWR failed to proceed as required by CEQA.

COUNT FIVE: Failure to include a reasonable range of alternatives.

51. Petitioners reallege and incorporate by reference the allegations of paragraphs 1 through 50.

52. CEQA requires that an EIR describe a reasonable range of alternatives that could feasibly attain most of the project's basic objectives, while avoiding or lessening any significant effects of the project. CEQA Guidelines § 15126.6.

53. The FEIR fails to include a reasonable range of alternatives that could substantially lessen significant environmental impacts of the project, while feasibly attaining most of its basic objectives. The two action alternatives studied (the SA and the FERC staff alternative) are highly similar and would produce similarly significant impacts. Alternatives that should have been analyzed include an alternative mitigating economic and ecological impacts within the host county and watershed, and an alternative designed to meet project objectives within changing conditions including climate change and changing State Water Project operations. By acting in reliance upon an EIR that lacked an assessment of feasible and environmentally advantageous alternatives, DWR failed proceed as required by CEQA.

COUNT SIX: Failure to analyze and consider climate change and other significant environmental effects.

54. Petitioners reallege and incorporate by reference the allegations of paragraphs 1 through 53.

55. CEQA requires that an EIR identify and describe the project's direct, indirect, and long term significant environmental effects. The FEIR's failure to evaluate the project's significant impacts undermines its value of the EIR as an informational document, and constitutes a failure to proceed as CEQA requires, in at least the following respects:

a. Climate change: The FEIR fails to analyze the potential of climate change to magnify the project's acknowledged environmental effects, including water quality, in-stream habitat protection, flood control, and recreation. In changing climate conditions, operational changes proposed by DWR may cause impacts that would not occur under older conditions; perpetuating Oroville operations for 50 years may cause impacts never previously seen. The FEIR superficially discusses climate change, and improperly confines that discussion to its cumulative impacts analysis. For example:

- DWR's premise that it would not be "reasonably feasible" to provide further analysis of climate change in the FEIR cannot be reconciled with DWR's own commitment in other settings to integrate climate change science into project assessment, DWR's recognition in other settings of the foreseeably major consequences of climate change for SWP supply and operations, DWR's use of climate change modeling in other settings, and the Attorney General's positions taken on CEQA's requirements for climate change assessment in connection with other applicants' projects.
- DWR's premise that further climate change assessment is not reasonably feasible also cannot be reconciled with other California actions and laws, including Executive Order S-3-05 (global warming) and AB 32.
- Assessment of potentially significant impacts with reasonably feasible analysis is required under CEQA. DWR failed to comply with CEQA in acting in reliance upon an EIR lacking required analysis of potentially significant climate change impacts.

b. Recreation: The FEIR fails to adequately analyze secondary impacts to recreation including fluctuations in reservoir levels, downstream flows, water quality and water temperature, stemming from operational changes to the SWP and climate change.

c. Transportation and traffic: The FEIR uses a faulty traffic index to calculate the impact of additional use on local roadways, ignoring the deteriorated condition of existing roads, and the overall impact of increased traffic.

d. Air quality: The FEIR fails to adequately analyze air quality impacts resulting from, amongst other factors, increased traffic and impacts stemming from traffic on asbestos-containing unpaved roads.

e. Water resources and quality: The FEIR fails to provide analysis demonstrating that the project will improve upon currently deteriorating conditions including low dissolved oxygen levels, electrical conductivity, bacterial concentrations, mercury concentration in fish tissues, and foreseeable future impacts due to the effects of climate change. The FEIR fails to adequately evaluate project impacts on Delta fisheries and water quality, and on water, fisheries and wildlife above Oroville Reservoir.

f. Government services and socioeconomic effects: The FEIR's summary denial of any environmentally significant socioeconomic consequences of the project for Butte constitutes a failure to proceed as CEQA requires. That denial also cannot be reconciled with FERC's Oroville Relicensing FEIS, which concluded that the project's operation in Butte "would likely continue to have a direct negative fiscal effect," and that "[a]ny negative effects on Butte County's fiscal condition would likely continue." The FEIR avoids analysis of impacts of the project by ignoring, or erroneously dismissing the effects of new demands on Butte's project-related government services. The EIR underestimates the impact of recreational visitors on government expenditures, failing to accurately disclose the conclusions of studies indicating significantly higher fiscal impacts.

COUNT SEVEN: Failure to adequately analyze climate change and other significant cumulative environmental effects.

56. Petitioners reallege and incorporate by reference the allegations of paragraphs 1 through 55.

57. CEQA requires the lead agency to assess the cumulative impacts of the project. Cumulative impacts from several projects refer to the change in the environment which results from the incremental impact of the project when added to other closely related past, present, and reasonably foreseeable probable future projects. Cumulative impacts can result from individually minor but collectively significant projects taking place over a period of time. CEQA Guidelines, § 15355. Even when the individual effects of a project are limited, CEQA requires them to be analyzed where they are "cumulatively considerable," meaning that the incremental effects of an individual project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects. Pub. Res. Code, § 21083(b)(2). CEQA requires in inquiry into significant adverse environmental impacts, whether they are project-specific, or caused by combination with the impacts of other projects.

58. The FEIR fails to assess cumulative impacts in the manner required by CEQA. It fails to assess the significant cumulative impacts of perpetuating old rules through the proposed project, which may lead to additional harms, exacerbating those that have already occurred. DWR's analysis concludes that these impacts are not significant because they represent incremental change. This method of analysis violates CEQA's mandate that agencies consider the incremental effects of a project in connection with the effects of past, current, and future projects.

59. The EIR also fails to adequately consider the cumulative impact of climate change, which, when considered together with the project's other effects, significantly compounds the environmental impacts of the project.

COUNT EIGHT: Failure to mitigate project impacts

60. Petitioners reallege and incorporate by reference the allegations of paragraphs 1 through 59.

61. CEQA requires that a project EIR identify and describe all feasible mitigation measures to reduce the potentially significant environmental effects of a project. CEQA Guidelines § 15126(c). Under CEQA, public agencies should not approve projects as proposed if there are feasible alternatives or feasible mitigation measures available which would substantially lessen the significant environmental effects of such projects. Pub. Res. Code, § 21002. DWR must also adopt an adequate mitigation monitoring plan.

62. The FEIR and mitigation monitoring plan fail to identify, describe and adopt feasible mitigation measures that could substantially lessen significant environmental impacts of the project, including but not limited to the following respects constituting a failure to proceed as CEQA requires:

a. **Government services and socioeconomic effects.** DWR fails to identify and develop mitigation measures addressing the significant project-related impacts on petitioner Butte, including environmentally significant socioeconomic impacts and additional government services necessitated by project operation. Significant impacts include, but are not limited to deterioration of county roads, strain on law enforcement and emergency services, increased social services expenses, and population and visitation impacts. These impacts are directly caused by changes in the physical environment resulting from the proposed project.

b. Recreation. DWR fails to identify and develop mitigation measures to reasonably address significant impacts on recreation including, but not limited to bacterial contamination, the closure of Foreman Creek, mercury accumulation in fish tissue, and the Instream Structural Placement Program.

c. **Water resources and quality.** DWR fails to provide mitigation measures adequately addressing project impacts to water resources and water quality.

d. **Climate change.** DWR's proposed mitigation and mitigation monitoring plan fail to adequately account for the consequences of climate change on project operations.

COUNT NINE: Failure to respond to comments

63. Petitioners reallege and incorporate by reference the allegations of paragraphs 1 through 62.

64. CEQA requires that a lead agency's response must demonstrate a "good faith" reasoned analysis in response to the environmental issues raised by commenters. Pub. Res. Code § 21091(d)(2)(B); CEQA Guidelines § 15088.

65. In its FEIR, DWR failed to provide the good-faith analysis CEQA requires in response to comments. As one illustration, the EIR fails to respond to pivotal comments on the draft EIR addressing climate change. DWR responds with conclusory statements unsupported by factual information to assert that any discussion of changes to Oroville Project operations necessitated by climate change would be speculative. DWR further claims, without any factual support, that the variability of California's hydrology excuses the need to conduct thorough analysis of the project's direct, indirect and cumulative contribution to climate change.

COUNT TEN: Improper deferral of environmental analysis

66. Petitioners reallege and incorporate by reference the allegations of paragraphs 1 through 65.

67. CEQA requires sufficient analysis in an EIR to provide decision-makers with enough information to take environmental consequences into account. Mitigation measures included within an EIR, but deferred for later elaboration must be feasible and an agency must commit to specific performance criteria to ensure compliance.

68. DWR's EIR for the Oroville project improperly defers for further study recreational impacts including, but not limited to the closure of Foreman Creek and the Instream Structural Placement Program. The mitigation measures as described within the Oroville Project EIR are not specific in their performance criteria, yet they assume that such measures will reduce environmental impacts to less than significant levels. By deferring description and analysis of these mitigation measures, DWR has denied decision-makers and the public necessary information to evaluate the environmental impacts of the project, and failed to proceed as CEQA requires.

COUNT ELEVEN: Approval of defective and legally inadequate findings

69. Petitioner realleges and incorporates paragraphs 1-68.

70. CEQA requires the lead agency to makes specific findings in connection with its approval of a project. (CEQA Guidelines, § 15091.) These findings must be supported by substantial evidence in the record, and must present some explanation to supply the logical step between the ultimate finding and the facts in the record.

71. DWR adopted findings failing these requirements of CEQA, including but not limited to: (1) DWR's conclusion that "the proposed project is consistent with existing commitments to meet statutory, contractual water supply, flood management and environmental requirements…."; (2) DWR's conclusion that its project has "near-unanimous support"; (3) DWR's refusal to adopt specific findings and mitigation measures addressing environmentally significant impacts relating to socioeconomic impacts and climate change.

PREJUDICAL ABUSE OF DISCRETION.

72. Petitioner re-alleges and incorporates paragraphs 1-71.

73. Each of the unlawful actions alleged above constitutes an abuse of respondents' discretion and failure to proceed in the manner required by law. Each abuse of discretion is prejudicial to the rights of petitioner and the public. DWR's faulty CEQA assessment deprived petitioners of

favorable alternatives and feasible mitigation measures that DWR could have adopted to protect the environment and economy of Butte County.

PRAYER FOR RELIEF

WHEREFORE, petitioner County of Butte prays that this Court:

1. Issue its writ of mandate setting aside the orders of respondent, including its certification of the FEIR as adequate;

2. Enjoin DWR's project until and unless respondent Department of Water Resources lawfully approves the project in the manner required by CEQA, including enforceable mitigation measures to prevent environmental and related socioeconomic harm within the County of Butte;

3. Award petitioner costs, and attorneys' fees under section 1021.5 of the Code of Civil Procedure; and

4. Grant such further relief that the Court deems just.

Dated: August 21, 2008.

Respectfully submitted,

BRUCE ALPERT, COUNTY COUNSEL

ROSSMANN AND MOORE, LLP
ANTONIO ROSSMANN
ROGER B. MOORE
JENNIFER SEIDENBERG

By: ______________________
Bruce Alpert

Attorneys for Petitioner COUNTY OF BUTTE

VERIFICATION

I, Bruce Alpert, am counsel to petitioner County of Butte and am authorized to make this verification on behalf of the County of Butte. I have read the above petition for writ of mandate and verify that its contents are true and correct to the best of my knowledge and belief. I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Dated: August 21, 2008

EXHIBIT 3

EDMUND G. BROWN JR.
Attorney General

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July 8, 2009

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RE: *County of Butte v. Department of Water Resources, et al.*
Plumas County, et al. v. California Department of Water Resources
Yolo County Superior Court Consolidated Case No. CV09-1258

Dear Counsel:

On Monday July 6, 2009, I received an inquiry from Roger Moore asking when the Department of Water Resources anticipates lodging the administrative record. The Department of Water Resources informs me that it will have the record completed, certified, and lodged by September 15, 2009. This date assumes: (1) staff encounters no unforeseen technical problems in finalizing the record in electronic format once staff are done organizing, reviewing, and processing the materials; and (2) the Department begins immediately to finalize and electronically paginate those sections of the record that it deems complete, and for which it has received no comments from the parties as to content.

As you are aware, the Department of Water Resources has circulated draft indices of most sections of the record in an effort to keep the parties informed of the Department's progress and to provide an opportunity for comment prior to the Department lodging the record. The Department had hoped that by providing draft indices of topically organized sections of this record in advance of lodging, it would be possible for the parties to identify and resolve concerns over record content, avoiding costly motions.

To date, however, the Department of Water Resources has received no comments from any party on the indices that have been circulated with my letters of April 23, 2009, May 21, 2009, and June 19, 2009. While the Department of Water Resources continues to be willing to discuss record content concerns with the parties, it is necessary for the Department to immediately finalize as many sections of the record that it can and begin electronic pagination to meet a September 15, 2009, lodging date. For this reason, the Department will begin finalizing and electronically paginating those sections of the record for which it has previously circulated draft indices and received no comments. The Department of Water Resources anticipates sharing one additional draft index, hard copy correspondence, within the next week, and will take comments on this section until July 24th. Due to time constraints with the production process, the Department does not anticipate sharing a draft index of the record section with internal staff files. As I have previously disclosed, the Department will not be indexing email.

I hope this information is helpful. Please contact me if you would like to discuss further.

Sincerely,

DANAE J. AITCHISON
Deputy Attorney General

For EDMUND G. BROWN JR.
Attorney General

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EXHIBIT 4

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July 17, 2009

Via email and U.S. Mail
Danae J. Aitchison, Deputy Attorney General
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Re: Record completion in *County of Butte v. Department of Water Resources* c/w *County of Plumas v. Department of Water Resources* (Yolo County Superior Court, Consolidated Case No. CV09-1258)

Dear Danae:

On behalf of petitioner Butte County, this letter continues our discussion of respondent Department of Water Resources' inability to complete the administrative record in the above-referenced consolidated cases, despite the requirement of CEQA for DWR to do so (Pub. Res. Code, § 21167.6(b).) As we discussed, the first anniversary of the filing of these consolidated actions will pass on August 21, 2009. The original due date for record preparation passed on October 27, 2008, and the last due date achieved by stipulation passed on February 27, 2009. When we spoke on July 6, I emphasized the need for DWR to commit to a date certain for record completion, which we hoped would be this month. I reiterated this request in a message sent to you this Wednesday, July 8.

Your July 8, 2009 letter to me announces an anticipated completion date of September 15, 2009, but suggests that the actual date could be later if, for example, there are "unforeseen technical problems." That date would provide no opportunity for Butte and Plumas Counties, and other members of the public, to study the record before the State Water Resources Control Board must act on DWR's application for water quality certification under section 401 of the Clean Water Act. As you are aware, one of the purposes of the EIR under challenge in this action is to inform that review. Months ago, Butte and Plumas Counties expressed concern that DWR was seeking to expedite section 401certification even as it sought to postpone completion of the CEQA record. Yesterday Butte County received the State Board's 21-day notice for its certification decision.

We are aware of DWR's view, expressed in a March 2, 2009 letter to counsel, that section 401 certification does not have "any bearing" on the timing of DWR's record completion. That perspective relies upon Public Resources Code section 21167.3, which ordinarily allows a responsible agency to rely on the lead agency's EIR for its CEQA determinations, with any approvals at the applicant's risk of set-aside pending final determination of the CEQA action. That provision does not exonerate the State Board from its duty to ensure that any certification conforms to other provisions of law, including section 401 of the Clean Water Act. It strains credulity to believe that the extensive record DWR is preparing will have no documents bearing upon the State Board's water quality determination that are worthy of public review.

For the foregoing reasons, Butte County would be willing to agree to extension of the deadline for the record to September 15, 2009, provided that DWR (1) advises the State Board that it is withdrawing its present request for section 401 certification (as it has done before when documentation remained incomplete); and (2) does not request further action from the State Board on section 401 certification until the completed administrative record in this action has been available for at least 60 days. That agreement would not waive the counties' opportunity to object to further extension requests.

We have spoken with counsel for Plumas County, and verified that Plumas County's views correspond to those expressed here.

Respectfully,

/s./

Roger B. Moore
Counsel for Butte County

cc: Michael Jackson
Thomas Berliner
John Schlotterbeck
Margaret M. Sohagi
Emily Cote
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EXHIBIT 5

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RE: *County of Butte v. Department of Water Resources, et al.*
Plumas County, et al. v. California Department of Water Resources
Yolo County Superior Court Consolidated Case No. CV09-1258

Dear Counsel:

This letter responds to Roger Moore's letter of July 17, 2009, stating that Butte County would be willing to agree to a September 15, 2009, lodging date for the administrative record on two conditions: (1) if DWR withdraws its application for a section 401 certification from the State Water Resources Control Board; and (2) if DWR requests no further action on the section 401 certification by the Water Board until the administrative record in these cases has been available for 60 days. The Department of Water Resources has considered Butte County's position, and at this time does not plan to withdraw its application for a section 401 certification from the Water Board. The Department's proposed September 15, 2009, lodging date for the record in these cases is based solely on the ability of Department staff to complete the record, including the computer processing time necessary to have the record available on DVD for the court and the parties. As we have previously stated, the Department is prepared to lodge the record on September 15, 2009, absent unforeseen technical difficulties. While the timing of the section 401 certification process has in the past and may continue to change, it does not affect how rapidly the Department can complete the administrative record for the CEQA litigation.

While Mr. Moore states that, "it strains credulity to believe that the extensive record DWR is preparing will have no documents bearing upon the State's Board's water quality determination that are worthy of public review," the Department of Water Resources has never made such a claim. Please recall that the Department of Water Resources has provided extensive draft indices of all sections of the administrative record, excluding indices of only email and staff files. The submitted indices include literally thousands of documents that have been publicly accessible on the Oroville Facilities Relicensing website for many years. These documents have been and continue to be available to the public and to the Water Board for its administrative process. The formulation of such documents into a California Environmental Quality Act litigation record is not a precondition to their use and availability.

Sincerely,

Danae J. Aitchison

DANAE J. AITCHISON
Deputy Attorney General

For EDMUND G. BROWN JR.
Attorney General

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EXHIBIT 6

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July 9, 2009

Rodney R. McInnis
Southwest Regional Administrator
NOAA National Marine Fisheries Service
501 West Ocean Boulevard, Suite 4200
Long Beach, CA 90802

Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Re: **Oroville Facilities, FERC Project No. 2100-134, TN 2009/02370; Request for Thirty-Day Comment Period for Draft Biological Opinion for Endangered Species Act Section 7 Consultation**

Dear Regional Administrator McInnis and Secretary Bose:

By letter dated July 31, 2007, the Federal Energy Regulatory Commission (Commission or FERC) requested formal consultation with the National Oceanic Atmospheric Administration's National Marine Fisheries Service (NMFS) under Section 7 of the Endangered Species Act with regard to the Commission's relicensing of the California Department of Water Resources' (DWR) Oroville Facilities, Project No. 2100 (Project).[1] In its letter, the Commission explained that its Final Environmental Impact Statement for the relicensing, issued May 18, 2007, concluded that the proposed action is likely to adversely affect the federally listed threatened Central Valley (CV) spring-run Chinook salmon (*Oncorhynchus tshawytscha*) and the CV steelhead (*O. mykiss*), and adversely modify critical habitat for these species.[2] The Commission's letter also concluded that the proposed action may affect, but is unlikely to adversely affect, the threatened Southern Distinct Population Segment (DPS) of North American green sturgeon (*Acipenser medirostris*).[3] Accordingly, the Commission's July 2007 letter

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1 Letter from Timothy J. Welch, FERC, to Rodney R. McInnis, NMFS, Project No. 2100-134 (issued July 31, 2007) (hereinafter, July 2007 Letter).

2 *Id.* at 1; *see* Final Environmental Impact Statement §§ 3.3.5, 5.5.2, Project No. 2100-052 (issued May 18, 2007) (hereinafter, Final EIS).

3 July 2007 Letter at 2. Although the Commission's Final EIS had concluded that the proposed action would have no effect on the green sturgeon, Final EIS § 3.3.5, at p. 190, the Commission's July 2007 Letter noted that it

requested NMFS's concurrence with its determination regarding the North American green sturgeon and asked NMFS to prepare and submit its biological opinion on listed salmonids.[4]

On July 6, 2009, NMFS submitted its Oroville Dam Draft Biological and Conference Opinion (Draft BO) to the Commission.[5] The Draft BO concludes that the Commission's proposed action is not likely to jeopardize Sacramento River winter-run Chinook salmon, CV spring-run Chinook salmon, CV steelhead, and the Southern DPS of North American green sturgeon or adversely modify designated or proposed critical habitat.[6] As part of the Incidental Take Statement, however, the Draft BO sets forth several "reasonable and prudent measures" (RPMs) that "NMFS believes . . . are necessary and appropriate to minimize the effect of incidental take of Sacramento River winter-run Chinook salmon, CV spring-run Chinook salmon, CV steelhead, and North American green sturgeon resulting from the proposed action."[7]

When preparing the Draft BO, NMFS provided DWR an opportunity to review early versions of the Draft BO both to ensure the accuracy of the factual information set forth in the Draft BO, and to assess possible effects of the RPMs on proposed license measures contained in the long-standing relicensing settlement agreement, to which NMFS is a party.[8] DWR appreciates the opportunity to work through these issues with NMFS and believes that the Draft BO has been improved as a result of the consultation. DWR remains concerned, however, that the RPMs set forth in the Draft BO may have the potential to significantly affect Project operations, including water supply and/or power generation, as well as DWR's ability to implement the relicensing settlement agreement. Accordingly, DWR is in the process of developing a hydrologic model to analyze effects that implementation of the RPMs would have on Project operations. The results of this modeling effort are expected to be completed by around July 17, 2009.

Given DWR's ongoing analysis, and the importance of understanding the operational impacts of the RPMs on the Project and the settlement, DWR believes that the two-week comment period on the Draft BO established by NMFS would not give DWR or other parties a meaningful opportunity to comment.[9] Rather, DWR believes that a thirty-day comment period – commencing the day after the Draft BO was filed with FERC – is warranted.[10] This will allow DWR to complete and distribute its quantitative analysis, which will better inform its comments on the Draft BO as well comments from FERC and possibly others. Because the Section 7 consultation process is not the only remaining matter to complete prior to the Commission's

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had modified this conclusion based on the Final Biological Assessment, which DWR submitted to NMFS on July 6, 2007, documenting observations of green sturgeon in the vicinity of the Project's Thermalito Afterbay in 2006. July 2007 Letter at 2.

4 July 2007 Letter at 2.

5 Oroville Dam Draft Biological and Conference Opinion, Project No. 2100-134 (filed July 6, 2009) (hereinafter, Draft BO).

6 Draft BO §§ 8, 9.

7 *Id.* § 10.3, at p. 263.

8 Settlement Agreement for Licensing of the Oroville Facilities, Project No. 2100-052 (filed Mar. 24, 2006).

9 Letter from Rodney R. McInnis, NMFS, to Kimberly D. Bose, FERC at 2, Project No. 2100-134, TN 2009/02370 (filed July 6, 2009).

10 As the Draft BO was filed with FERC on July 6, 2009, the thirty-day comment period requested herein would extend through Wednesday, August 5, 2009.

action on DWR's relicensing application, granting a thirty-day comment period on the Draft BO would not cause a delay in the overall relicensing schedule.[11]

For these reasons, DWR respectfully requests NMFS and the Commission to establish a revised, thirty-day comment period for the Draft BO, commencing on July 7, 2009 – the date following NMFS's submission of the Draft BO to the Commission.

If you have any questions regarding this request, please do not hesitate to contact the undersigned.

Respectfully submitted,

Michael A. Swiger
Counsel to the California Department
of Water Resources

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[11] The California State Water Resources Control Board has not yet issued its water quality certification under Section 401 of the Clean Water Act, a prerequisite to Commission action.

CERTIFICATE OF SERVICE

Pursuant to Rule 2010 of the Rules of Practice and Procedure of the Federal Energy Regulatory Commission, I hereby certify that I have this day caused the foregoing document to be served upon each person designated on the official service list compiled by the Secretary in this proceeding.

Dated at Washington, DC, this 9th day of July, 2009.

/s/ Mealear Tauch
Mealear Tauch
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EXHIBIT 7

California Sportfishing Protection Alliance
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July 21, 2009

Rod McInnes, Regional Administrator
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
501 West Ocean Blvd, Suite 4200
Long Beach, CA 90802-4312

RE: COMMENTS on the Oroville Dam Draft Biological Opinion, Oroville Facilities P-2100-134, TN 2009/02370

Dear Mr. McInnes:

Thank you for the opportunity to comment on the Oroville Dam Draft Biological and Conference Opinion (Draft BO for Oroville), filed with the Federal Energy Regulatory Commission on July 6, 2009 (accession number 20090708-0149).

In preface to these comments, CSPA points out that it has reviewed NFMS's Biological and Conference Opinion for the Central Valley Project and State Water Project Operations and Criteria Plan for salmon, steelhead and green sturgeon (OCAP BO). CSPA supports the OCAP BO as providing minimum requirements needed to avoid extirpation of the listed species it considers, and begin their recovery.

CSPA does not understand, however, how NMFS can issue a jeopardy finding in the OCAP BO on the combined operations of the CVP and SWP, but then issue a no jeopardy finding in the Draft BO for Oroville that addresses a central feature of combined CVP and SWP operations, and the major storage reservoir for the SWP, which has over 3 million acre-feet of storage and additional storage upstream.

Moreover, the analysis in the OCAP BO and that in the Draft BO for Oroville appear fundamentally disconnected. While the OCAP BO sets a number of actions with specific requirements, performance measures and timelines, the Draft BO for Oroville, in conformance with the Oroville Settlement Agreement, includes reconnaissance studies and processes for improvements in lieu of potential defined measures. This is most notable in the respective conditions for measures to protect water temperatures.

The OCAP BO recognizes a fundamental reality: recovery of Central Valley salmonids depends on restoring salmonids to the habitat upstream of Central Valley rim dams.

Reliance on habitat below rim dams is unsustainable in the face of climate change. Yet while the OCAP BO requires pilot projects for re-introductions of salmon and steelhead upstream of Shasta Reservoir, and steelhead upstream of Folsom Reservoir, to be functioning on the ground by dates certain, the Draft BO for Oroville contemplates only the Habitat Expansion Agreement with no defined timeline for implementation.

Moreover, the Draft BO for Oroville analyzes the condition of the listed species in the Feather River watershed according to the inadequate standard of the FEIS and FEIR for the relicensing of the Oroville Facilities. These documents ask not whether the ongoing operation of the project will jeopardize listed species, but merely rather whether or not the proposed action represents an improvement over existing conditions. That is not the standard.

The Draft BO for Oroville presents the Habitat Expansion Agreement as the reason for a no jeopardy finding for spring-run Chinook for the Feather River drainage. Apparently, increasing the geographic range of spring-run chinook is supposed to reach a threshold of no jeopardy because expanded range will offset the possibility of a catastrophic event such as a fire in the Mill Creek, Deer Creek , and Butte Creek region. However, there is no certainty that an HEA will achieve the desired results, or even that those results if achieved would warrant a no jeopardy finding. It appears to us that the appropriate finding would be a jeopardy finding with a Reasonable and Prudent Alternative to mitigate jeopardy, including a backstop should the HEA fail to reach a threshold needed to eliminate jeopardy.

Even assuming adequate mitigation for spring-run Chinook under the HEA, there is a broader assumption that steelhead will also benefit from the HEA. This assumption is yet another step removed, especially if a trap and haul approach is used under the HEA for spring-run. Under such circumstances, will NMFS also require trap and haul for steelhead, or will it be satisfied with unproven channel modifications and unspecified flows to enable the benefits of those modifications, in the area downstream of the project? A requirement for a defined amount of spawning escapement for spring-run does not appear to mitigate the effects of the proposed action on Central Valley steelhead.

The facility modifications contemplated in the Oroville Settlement Agreement do not appear to provide room for a temperature control device should the finding of investigation during the first few years of the new license term be that such a device is needed. The estimated total cost to DWR of temperature modifications at Oroville is not to exceed $60 Million (Section 108.4f). However, the Lake Shasta temperature control device completed in 1994 cost $100 Million. A Final BO for Oroville should specify that the measures needed to meet the required temperatures in the Feather River downstream of Oroville, using whatever means are necessary, without reference to a cost cap.

Over the last week, a Draft 401 Certification dated June 23, 2009 has been made available by State Water Resources Control Board. This Draft 401 Certification includes specific timelines and standards required to protect beneficial uses, including many that are pertinent to listed species. At minimum the Final BO for Oroville should line up with the requirements set forth in the Draft 401 insofar as these requirements affect listed species.

The disconnect between the BO for OCAP and the Draft BO for Oroville becomes particularly problematic in light of the Settlement Agreement's allowance for DWR to ease the flow requirements from the Oroville facilities should Oroville drop below 1.5 million acre-feet of storage. The storage in Lake Oroville is a combined function of meteorological conditions and human action. However, the Draft BO for Oroville makes no defined standard or restriction on human action to avoid operation of Lake Oroville through OCAP that would reduce the likelihood of operation of Oroville at low pool, either episodically or chronically. CSPA believes that this flaw is inherent in disconnecting the Biological Opinions for OCAP and Oroville, and that this flaw is exacerbated by the lack of defined standards for operation of Oroville in either document. This flaw leaves a regulatory gap that is backstopped only by a discussion process among DWR, NMFS and resource agencies other than NMFS. While NMFS contemplates a re-initiation of consultation is the event that temperature requirements in the Lower Feather River fail to be met on a repeated basis, the threshold for that re-initiation, and the possible remedies, are completely open to debate and even to legal argument.

The Feather River Technical Team and the Green Sturgeon Technical Subcommittee have no apparent ability to address the overall operation of the SWP under OCAP. There does not even appear to be a defined relationship between these entities and the OCAP Water Operations Management Team (WOMT), as there is for the other technical teams for other watersheds that are defined in the OCAP BO. Again, this situation amounts to a regulatory gap that gives unwarranted latitude to DWR and its operation of Lake Oroville. Given the severe drawdown of Oroville in 2008-2009, and the current operation of the reservoir out of which water is flowing at 18,000 af per day and appears headed to drop below 1.5 million acre-feet of storage on about August 1 of this year, the issue appears to CSPA to be chronic.

The Final BO for Oroville should set numeric standards for operation to preserve the cold water pool, not simply a process for how to carry out damage control once threshold numbers are passed.

The two week comment period for review of the Draft Biological Opinion for Oroville is inadequate to provide time for comments. This is one of the few issues on which we agree with DWR. Our comments at this time have therefore been limited to high level issues. Given an appropriate comment period for a 300 page document, which must be considered in the context of the OCAP BO of well over 1000 pages with appendices, our comments would surely be more extensive.

Thank you for the opportunity to comment on the Oroville Dam Draft Biological and Conference Opinion for the proposed action of relicensing the Oroville Facilities.

Respectfully submitted,

Chris Shutes
FERC Projects Director
California Sportfishing Protection Alliance

cc:

Kimberley Bose, Secretary
Federal Energy Regulatory Commission
(via e-filing)

Howard Brown, NMFS

Russell Strach, NMFS

Russ Kanz, SWRCB

Service list

CERTIFICATE OF SERVICE

I hereby certify that I have on this day provided a true copy of these comments on the National Marine Fisheries Service's Draft Biological Opinion for Oroville Dam to the Service List for the above referenced proceeding, P-2100-134.

Berkeley, California
July 21, 2009

Chris Shutes

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February 16, 2010

Via email and U.S. mail
Russ Kanz
Division of Water Rights, California State Water Resources Control Board
1001 I Street
Sacramento, CA 95814

RE: Butte County's Comments on the Matter of Water Quality Certification for the Department of Water Resources Oroville Facilities (Federal Energy Regulatory Commission Project No. 2100)

Dear Mr. Kanz:

This letter provides Butte County's (Butte's) comments on the State Board's January 21, 2010 draft water quality certification ("2010 draft certification"), which addresses the Department of Water Resources' (DWR's) application to the Federal Energy Regulatory Commission (FERC) for a new license to operate the Oroville Facilities ("Oroville project," FERC Project 2100). On July 29, 2009, Butte County submitted detailed comments on the State Board's then-current draft, prior to DWR's withdrawal and resubmission of its application for water quality certification. Butte County's July 29, 2009 comment letter and its accompanying exhibits are appended to these comments, and are incorporated here as part of Butte's submission on the current draft. The great majority of Butte's earlier comments are equally applicable to the 2010 draft certification.

I. Summary and Overview

Once again, Butte concurs in the State Board's conclusion that "certain measures as written" in the March 2006 Settlement Agreement are "either not enforceable, will not fully protect the beneficial uses, or will not meet water quality standards in a timely manner." (Draft certification, p. 4.) Butte strongly opposes any attempt by DWR to weaken the State Board's conditions of certification. As the Board aptly noted, "[b]eneficial uses currently impacted by the project may not be reasonably protected if the proposed measure has a management plan with unclear or unenforceable standards, an excessively long period prior to implementation, or unspecified implementation dates." (Draft certification, p. 4.)

With that credit given, Butte is dismayed to discover that the State Board has failed to address key concerns addressed in its July 29, 2009 submission in its 2010 draft certification, as well as its accompanying findings and mitigation measures. In some important respects described below, the current draft conditions are weaker than the ones they replaced, expanding the Board's discretionary authority to reject certain conditions, and allowing "authorization by inaction" to weaken certain water quality protections. The State Board has thus far failed to fully heed its own advice, proposing unclear or unenforceable schedules, excessive periods prior to implementation, and vague implementation dates.

Moreover, for reasons articulated in Butte's earlier letter that remain applicable here, three systemic problems left unaddressed in the 2010 draft certification—failure to analyze project operation in the context of climate change, failure to analyze the project in the context of other State Water Project (SWP) operations, and failure to adequately address the accumulation of toxic substances (notably methyl mercury and polychlorinated biphenyl (PCBs)—continue to undermine the State Board's supporting environmental review, and prevent the State Board from rendering a lawful finding under section 401 that the project protects all beneficial uses and complies with all the mandatory objectives in the in the Water Quality Control Plan for the Central Valley-Sacramento and San Joaquin River Basins (Basin Plan). Notwithstanding any general desire the State Board may have to achieve speedy implementation of certification conditions, the State Board remains bound to fully enforce section 401 of the Clean Water Act, and thereby fulfill the Congressional mandate "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." (33 U.S.C. § 1251(a).)

II. The State Board cannot waive or defer its Clean Water Act enforcement obligations.

Under the enforcement regime Congress established in the Clean Water Act, it is the State Board's duty under section 401 of the Clean Water Act (33 U.S.C. §1341) to fully enforce water quality standards and implementation plans promulgated by the State Board. (33 U.S.C. § 1313.) DWR must also demonstrate compliance with the State Board-approved objectives in the Basin Plan. Though called "objectives," compliance with these standards and their implementation program is mandatory. (*See State Water Res. Control Bd. v. Office of Admin. Law* (1993) 12 Cal. App. 4th 697, 701-02.) The Basin Plan standards also apply to the entirety of project operations. (*PUD No. 1 v. Wash. Dep't of Ecology* (1994)511 U.S. 700, 711-12.)

The Board has correctly noted that to issue a section 401certification, DWR must demonstrate to the Board that DWR will achieve

> compliance with all water quality objectives in the Basin Plan… as well as with other water quality objectives that the Project may affect. DWR must also demonstrate that the Project does not impair the beneficial uses of the Feather River or Lake Oroville. If the Project does not comply with one or more of the water quality objectives, then DWR must describe the actions that it will take to bring its Project into compliance with the applicable water quality requirements in order to protect and maintain the beneficial uses.

Exhibit 1 to Butte's July 29, 2009 letter (Ex. 1), pp. 1-2.

III. The 2010 Draft Certification weakens public accountability over enforcement of water quality conditions.

A. The 2010 Draft Certification allows the Deputy Director additional discretion to avoid standard minimum flow and temperature requirements.

While most of the 2010 certification conditions remain the same as in the draft Butte addressed last year, several key conditions are weakened by allowing the Deputy Director, Division of Water Rights further discretion to avoid what had been more straightforward conditions of approval. For example:

- Section S8(b) gives the licensee an additional opportunity to persuade the Deputy Director that it "cannot feasibly meet" the water temperature requirements for the Low Flow Channel in Table S8 using "current facilities."
- Section S8(c) weakens the earlier requirement of facilities modification plans by giving the Deputy Director further discretion to approve facility modifications, determine that it is not "feasible" to meet Table S8, or authorize the licensee to "comply with alternate temperature requirements." Section S8(f), which addresses minimum flow and temperature requirements in the High Flow Channel, qualifies the requirement that that the licensee shall operate the project to protect cold beneficial use by adding the term "to the extent reasonably feasible." It would apparently not require the applicant to show that compliance is impossible or unreasonable.

Without effective enforcement of minimum flow and temperature requirements, the conditions of approval cannot assure compliance with the Basin Plan, and cannot lawfully support section 401 certification. The net effect of these changes, which elevate the Deputy Director's discretion to relax the applicable standards, will be to inject additional uncertainty into the ability of the certification conditions to enforce the referenced minimum flow and temperature requirements. That uncertainty thwarts the present draft's ability to certify compliance with Clean Water Act and Basin Plan standards.

B. The 2010 Draft Certification allows the Deputy Director to "approve" the licensee's requests by inaction.

In numerous certification conditions, the 2010 Draft Certification allows the Deputy Director to automatically "approve" the licensee's requests by inaction, even where no determination has been made on the merits of the request. For example:

- Section S8(b), addressing "interim operations plans" submitted by licensees claiming they cannot "feasibly meet" the Table S(b) temperatures for the Low Flow Channel, provides that "[i]f, within 90 days, the Deputy Director does not either act on the request for approval or identify the need for additional information or actions, the shall be deemed approved."
- Numerous other provisions have also been revised to allow for similar or identical approvals by inaction. These include, to name several, section S8(c) (facility modification and operations plan), S8(f) (interim plan to protect cold beneficial use), section S8(g) (strategic plans in conference years), S10(a) (warm water fishery habitat plan), S12(b), (c) (water quality monitoring), S13(e) (public health plan at North Forebay recreation area), S15(c) (wildlife area management plan), S19 (protection of Elderberry Longhorn Beetle).

The public accountability of these provisions, whose enforcement is crucial to achieving effective water quality protection under section 401, would also be weakened by the prospect that the Deputy Director could approve changes by fiat. In a time of budget and time pressures, the mechanism of "approval by inaction" could significantly diminish water quality enforcement, because it would provide the Deputy Director an "easy out" to render approvals without investing heavily in resources, making determinations on the merits, or answering to the public.

C. The 2010 Draft Certification weakens the timing requirements in some conditions of approval.

In some cases, the 2010 conditions propose time conditions that appear to be less stringent than their predecessors. For example, in the condition addressing the fish weir program, section S5(e) allows the Phase 2 plan to be filed in eight years instead of five; section 5(g) allows installation in twelve years instead of six. In the condition addressing the Feather River Fish Hatchery, Table S7A's required temperatures come ten years later rather than "upon license issuance."

IV. The 2010 Draft Certification is fatally deficient, because the State Board has evaded assessment of climate change and water quality.

Despite extensive discussion in Butte's July 29, 2009 comments, the 2010 Draft Certification (including the findings and mitigation) have failed entirely to account for the consequences of climate change for project-related water quality issues. Oroville, as the SWP's primary storage and power generation facility, plays a central role in SWP operations. Changing climatic conditions will impact Oroville's flood control, reservoir storage levels, upstream and downstream flow levels, water temperatures, power generation, water quality, fisheries, and recreation. These wide-ranging impacts make it untenable to finesse climate change simply by focusing on reactive conditions of approval. Simply stated, without analysis of project operations in the context of a changing climate, the State Board will lack the foundation to conclude that the project will not impair the beneficial uses of the Feather River and Lake Oroville. Climate change assessment is therefore not simply a CEQA issue; it is central to whether section 401 water quality certification can occur.

DWR's Oroville Project EIR evades analysis of climate change, particularly in its relationship to water quality. DWR's DEIR contains very little discussion of the water quality consequences of operating the project in the context of a changing climate. Indeed, its water quality impacts discussion is almost entirely predicated upon modeling exercises that assumed the *non-existence* of climate change. *See* DEIR pp. 5.2-11 to 5.2-12, App. E at 49.

DWR's Oroville Final EIR evades the issue again, relying upon excuses that are strikingly similar to those DWR and the Attorney General have justly criticized in other settings. For example:

- Rather than recognizing that hydrologic variability is likely to increase in the future, as its own studies have consistently shown, DWR presumes that hydrologic variability *from the previous century* "is expected to continue in the foreseeable future." (FEIR, p. 3-28.)

- Rather than drawing on the analytical and modeling techniques that DWR has employed in other reports on climate change, including reports addressing the Feather River watershed, DWR summarily concludes that "any discussion of potential changes to operation of the

Oroville Facilities necessitated by climate change *would be speculative* at this time." (*Id.* (emphasis added).)

- The FEIR suggests that there would be "further opportunities in the future, at the next relicensing period" to "make more definitive statements about the extent of climate change." (FEIR, p. 3-27.) The "next relicensing period" referenced here would take place thirty to fifty years after project implementation.

Despite its awareness of the paucity of project-related climate change analysis, the State Board's draft water quality certification *still* does not address climate change. Rather, the certification only relies upon DWR's EIR, whose attempted deflection of serious climate change assessment to future generations infected all key elements of the Final EIR, including assessment of the environmental setting, direct and cumulative impacts, feasible alternatives, and mitigation. Due to this error, the assessment of water quality impacts is predicated upon a hypothetical future that DWR knows to be dangerously false. Without correction, that fatal omission prevents a finding under section 401 that the project meets water quality standards and protects beneficial uses.

V. The 2010 Draft Certification still lacks a thorough assessment of the Oroville project in the context of a changing State Water Project.

The Oroville project is an integral and interconnected part of the State Water Project. (Wat. Code, § 12934(d).) Releases from Lake Oroville must serve a variety of purposes, including (1) compliance with Bay-Delta water quality standards; (2) satisfaction of obligations under environmental laws such as the Clean Water Act and federal and state Endangered Species Acts; and (3) release of water, as available, to meet the needs of State Water Project contractors. (*See* DEIR at p. 2-5.)

Operation of the Oroville project is closely tied to downstream needs. If those downstream constraints change, or if DWR discovers that operational changes are necessary to meet existing constraints or comply with legal requirements, changes to the Lake Oroville release schedule are likely to follow. Fundamental change in statewide operations appear to be increasingly likely. (See, e.g., *Natural Resources Defense Council v. Kempthorne* (E.D. Cal. 2007) 2007 U.S. Dist. Ct. LEXIS 42263, 91968; *Pacific Coast Federation of Fishermen's Associations v. Gutierrez* (E.D. Cal. 2008) 2008 U.S. Dist. LEXIS 31462); E. HANAK, MYTHS OF CALIFORNIA WATER—IMPLICATIONS AND REALITY 23 (Public Policy Institute of California (2009) (DWR's own data suggest that Delta smelt restrictions alone are likely to reduce Delta exports by an average of twenty to thirty percent).

At present, 2010 shows signs of becoming an extremely dynamic year for State Water Project operations, with correspondingly major implications for the future of Oroville operations. As just a few additional illustrations:

- On February 1, 2010, DWR certified the Final EIR for the post-Monterey Amendments restructuring of the State Water Project, anticipated for almost a decade since *Planning and Conservation League v. Department of Water Resources* (2000) 83 Cal.App.4th 892. (See http://www.water.ca.gov/environmentalservices/monterey_plus.cfm.)
- A February 11, 2010 federal court ruling enforced pumping restrictions to assist Delta smelt. See http://www.recordnet.com/apps/pbcs.dll/article?AID=/20100211/A_NEWS/2110325.
- On March 15, 2010, the National Academy of Sciences is expected to issue its first report on

two biological opinions (of the Fish and Wildlife Service and NMFS, respectively) affecting both State Water Project and the Central Valley Project's respective water operations. (See http://www8.nationalacademies.org/cp/projectview.aspx?key=49175.)

In its July 29, 2009 comments, Butte reminded the State Board that in its comments on the Oroville DEIR, the State Board faulted the DEIR for failing to "include an adequate discussion of the impact of State Water Project (SWP) operations on the Proposed Project." (FEIR, p. 4-41.) The State Board observed then that changes to the timing or quality of water deliveries could affect the ability of the Lake Oroville coldwater pool to protect anadromous fish, and the extent of the project's cumulative impacts. (FEIR, p. 4-41.) Unfortunately, rather than continuing to press for that robust analysis, the 2009 and 2010 iterations of the draft water quality certification appear closer to the evasive generalization that DWR used to respond to the State Board's comments on the DEIR; namely, that "[a]nalysis of future changes to State Water Project (SWP) statewide operations is outside the scope of the EIR." (FEIR, p. 4-51.) Thus, even though Oroville Reservoir is the State Water Project's most prominent storage facility, the draft certification appears to operate on the premise that the operation of Oroville facilities can be segregated from SWP operation. The surest sign that this attempted segregation fails is by reference to section S8(e) of the 2010 Draft Conditions. In pertinent part, section S8(e) provides:

> If the If the April 1 runoff forecast in a given water-year indicates that Oroville Reservoir will be drawn to elevation 733 feet (approximately 1,500,000 acre-feet) under normal operation of the Project, then the minimum flows in the HFC may be reduced on a monthly average basis, in the same proportion as the respective monthly deficiencies imposed upon State Water Project deliveries to the State Water Contractors for agricultural use; however, in no case shall the minimum flow releases be reduced by more than 25 percent.

Despite some rearranged clauses, this section is effectively the same as former draft section S8(d), the version that Butte and the California Sportfishing Protection Alliance (CSPA) criticized last July. As with the former version, the "normal operation" of the project in section S8(e) remains fundamentally ambiguous. In light of such recent developments the Delta species decline, enforcement of endangered species law, and the onset of climate change, considerable controversy exists over whether the "new" normal or some older version should prevail. When NMFS issues its final Biological Opinion for the Oroville Project, the restrictions on DWR may remain in the same place, or may become more or less stringent than they are today (as advocated, respectively, by CSPA and DWR).

Each of these outcomes would bring different terms to Oroville operation, with potentially different implications for water quality. In the face of this continuing uncertainty over what is "normal," final certification under section 401 would be premature. As the entity legally responsible for ensuring that section 401's standards are met prior to issuing its final certification, the State Board cannot leave it to NMFS or any other entity to ensure that Lake Oroville's coldwater pool is protected, and all cumulative impacts the project in the context of SWP operations are addressed.

The State Board may deny without prejudice applications with "some procedural inadequacy (e.g., failure to provide a complete fee or to meet CEQA requirements)". (23 Cal. Code Regs., § 3837(b); see also 23 Cal. Code Regs., § 3836 (where "the federal period for certification will expire before the certifying agency can receive and properly review the necessary environmental documentation'); *Clean Water Act section 401 Water Quality Standards Certification for Tract Map 30921, City of Moreno Valley, Riverside County* (Regional Water Quality Control Board, Santa Ana Region, June 10, 2008) (earlier application "was denied without prejudice pending resolution of inconsistencies and omissions" in environmental document prepared for CEQA compliance).) Here, the State Board should take the time to develop a clearer understanding about how State Water Project operations will impact Oroville water quality issues.

VI. The 2010 Draft Certification fails to provide assurance that approach to problems stemming from methyl mercury, PCBs and other contaminants will meet water quality standards and the requirements of the Basin Plan.

A. The 2010 Draft Certification fails to protect the public from PCBs and other contaminants.

Butte's earlier comments discussed the crucial need for additional steps to provide reasonable assurance that DWR's approach to problems stemming from methyl mercury, PCBs and other contaminants will meet water quality standards. As those comments explained in detail, DWR's own technical documents supporting its Oroville EIR confirm that Basin Plan standards have not been met. The 2010 draft conditions fail to provide that assurance as well, and notably fail to address any of Butte's analysis relating to PCBs. The conditions that are present do not adequately address the major public health problems involved, and add questionable new conditions and contingencies.

B. The Comprehensive Water Quality Monitoring Program fails to ensure Basin Plan compliance and protect public health.

In section 12(n), the addition of the term "conduct studies and, if appropriate" weakens the Deputy Director's responsibility to manage methyl mercury and delays implementation of methyl mercury containment/management. This condition implies that methyl mercury contamination is not an serious issue, and that studies need to be undertaken to evaluate if methyl mercury is a problem before managing it, and only if *appropriate*. No time frame is specified for these referenced studies; "appropriate" is also not defined. In Section 12(n), the fourth line, "the plan would incorporate…approval or modification" has been changed to "the Deputy Director…shall be deemed approved." On the whole, the new language appears more vague than what was generally described in the previous draft certification document.

C. **The Pathogen Public Health Protection Program fails to ensure Basin Plan compliance and protect public health.**

In section 13(e), "study" is changed to "schedule." This indeterminately extends the amount of time before risks are evaluated, and there are no time frame or content specifics for the schedule (i.e., when the schedule takes place, what will be scheduled, and if the schedule must include an evaluation study).

D. The public education program fails to protect against risks of fish consumption.

In Section 14 (a), the term "protect" is changed to "advise." The Deputy Director's responsibility is reduced to merely advising ,and not protecting the public from consumption of contaminated fish. As revised, the condition would focus on education about the risks associated with consumption of contaminated fish.

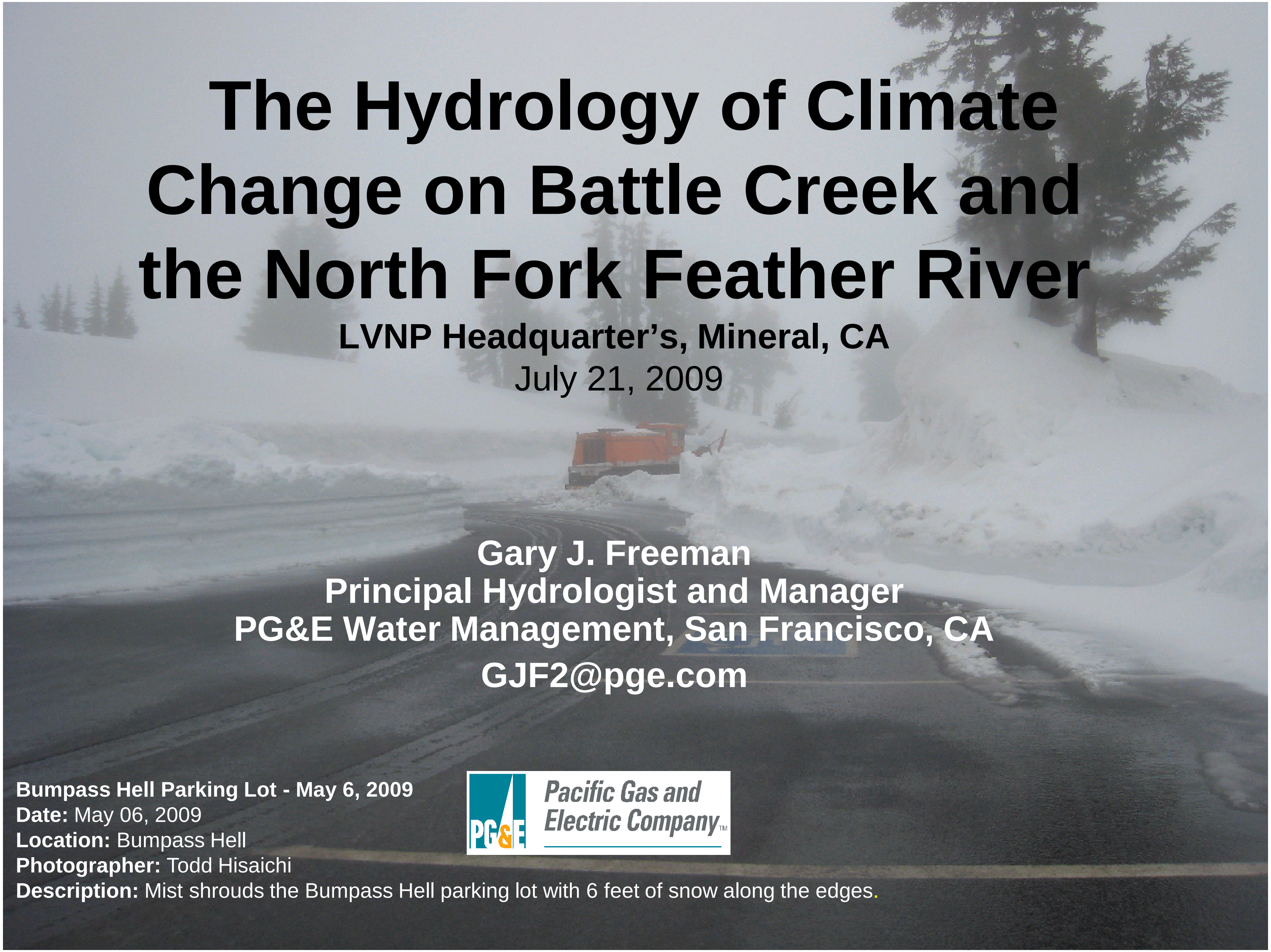
VII. Conclusion

For the foregoing reasons, Butte urges the State Board not to grant DWR its requested certification on the present application. Should the Board move forward with that certification despite this recommendation, the proposed conditions should not be weakened, and Butte's further suggestions outlined here should be incorporated.

Respectfully submitted,

/s./

Roger B. Moore
Counsel to Butte County



The Hydrology of Climate Change on Battle Creek and the North Fork Feather River

LVNP Headquarter’s, Mineral, CA

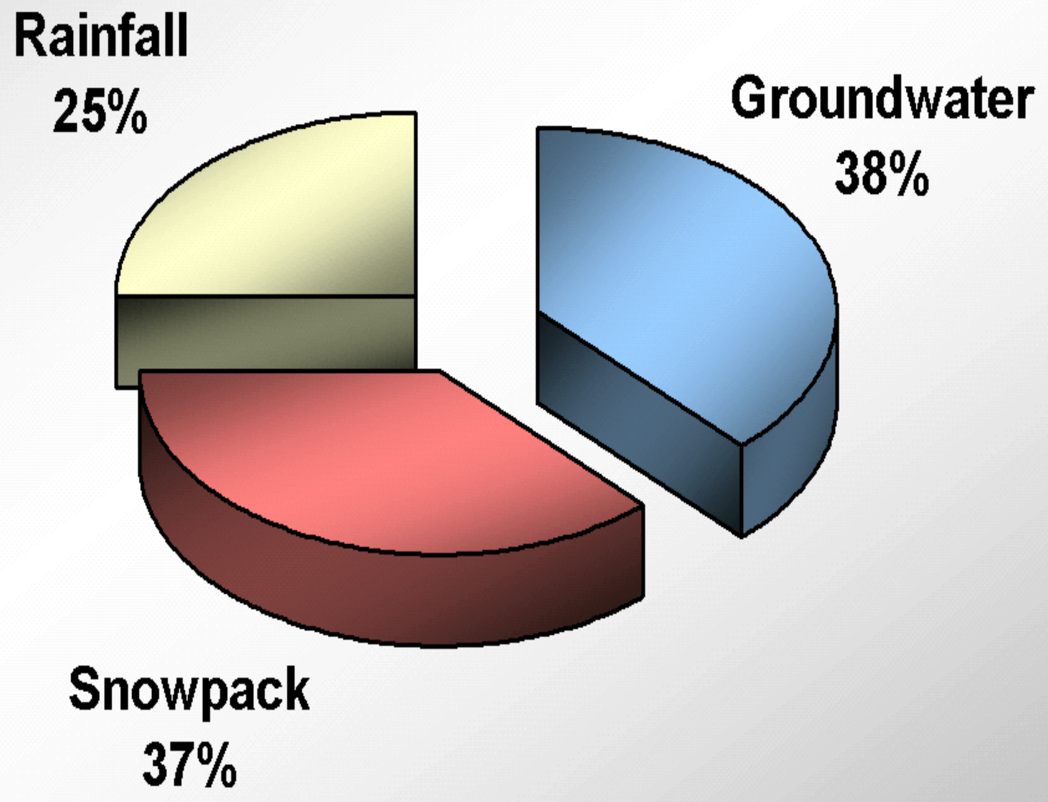
July 21, 2009

Gary J. Freeman
Principal Hydrologist and Manager
PG&E Water Management, San Francisco, CA
GJF2@pge.com

Bumpass Hell Parking Lot - May 6, 2009
Date: May 06, 2009
Location: Bumpass Hell
Photographer: Todd Hisaichi
Description: Mist shrouds the Bumpass Hell parking lot with 6 feet of snow along the edges.

Pacific Gas and Electric Company™

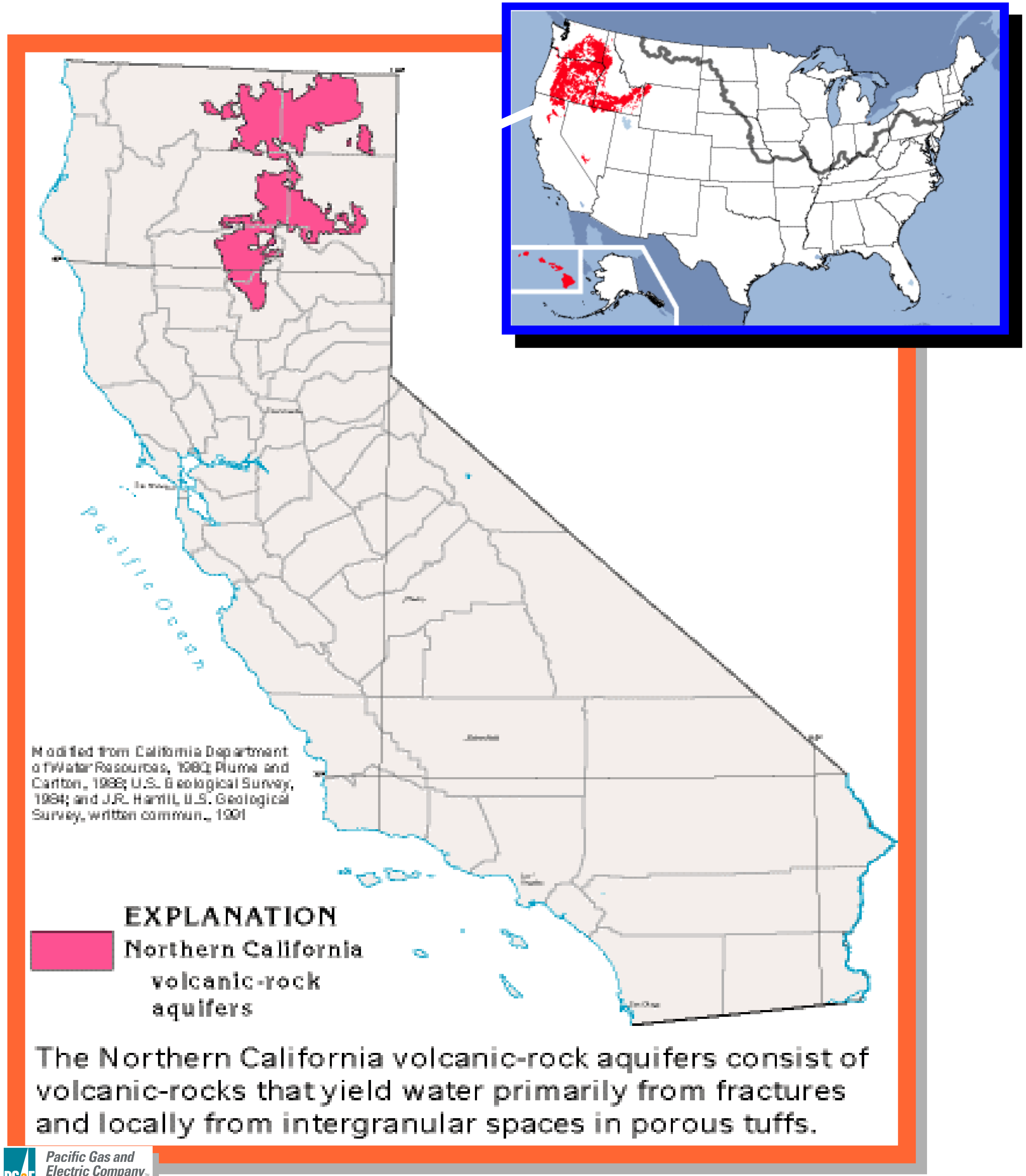
Historical Sources of Runoff for PG&E's Hydroelectric System



The PG&E Hydroelectric System

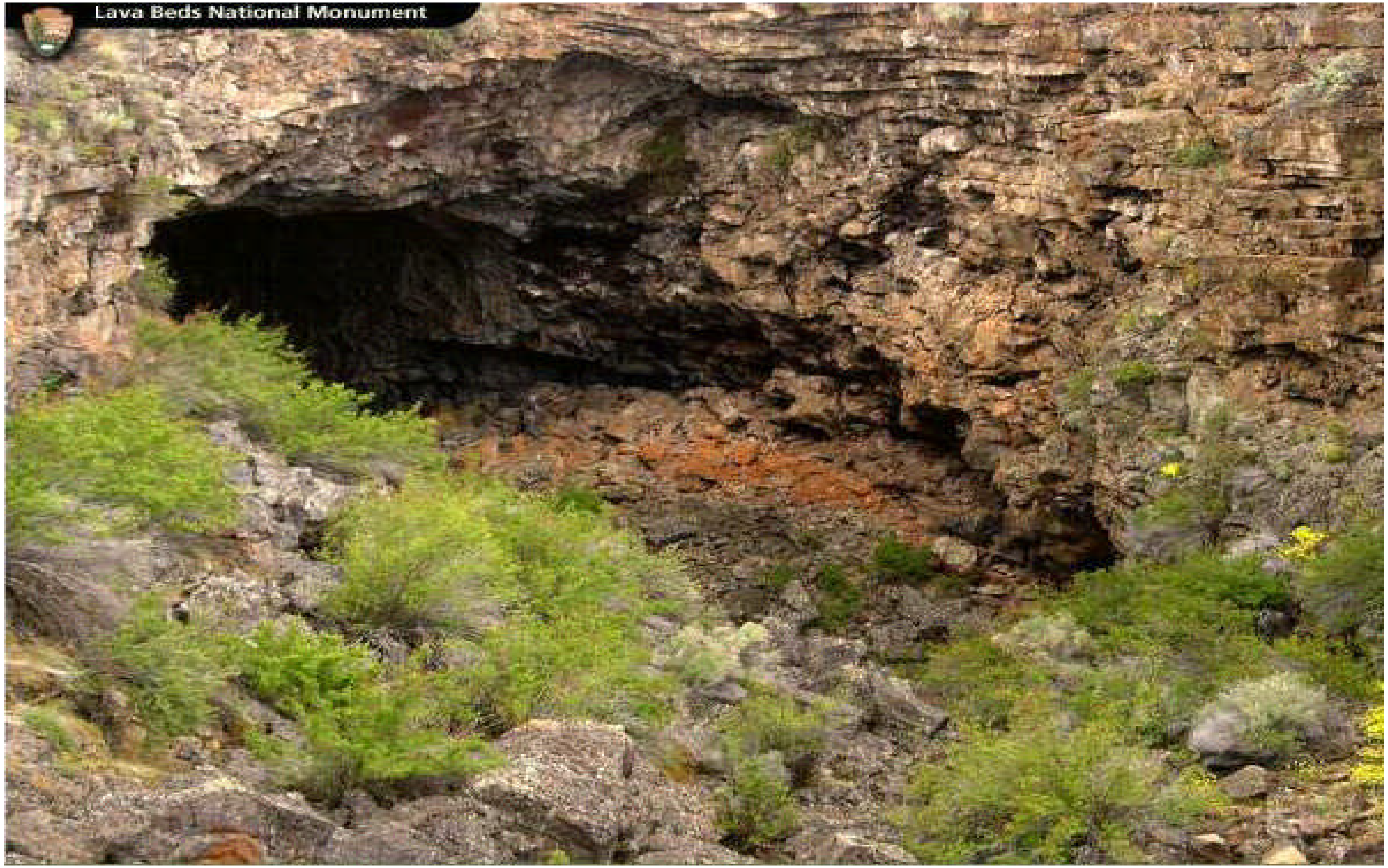
- 68 Powerhouses; 110 Generating Units; Total Generation Capacity of 3,896 MW
- Approximately 2.3 Million acre-feet of Reservoir Capacity
- 99 Reservoirs, 174 Dams
- 184 Miles of Canals; 44 Miles of Flumes; 135 Miles of Tunnels; 19 Miles of Pipe
- 140,000 Acres of Land
- 26 FERC Licenses; 3 Unlicensed Projects
- Hydroelectric System Extends 500 Miles from Mt Shasta to Bakersfield
- Provides about Five Percent of California's Electric Energy

Northern California's Volcanic Rock Aquifers

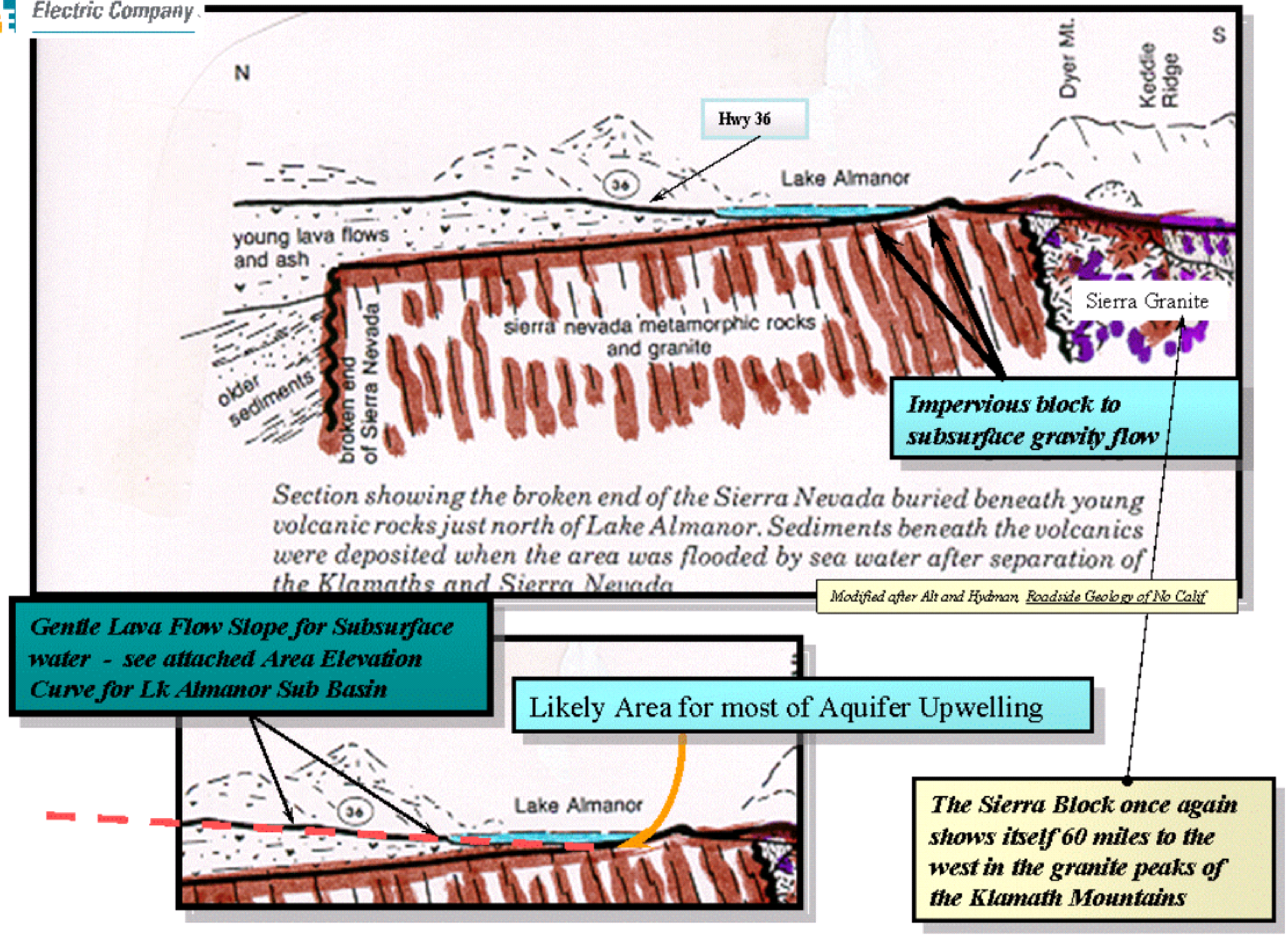


The Seasonal Ground Water Contribution To PG&E's Hydro Resource Mix

Layers of Fractured Volcanics



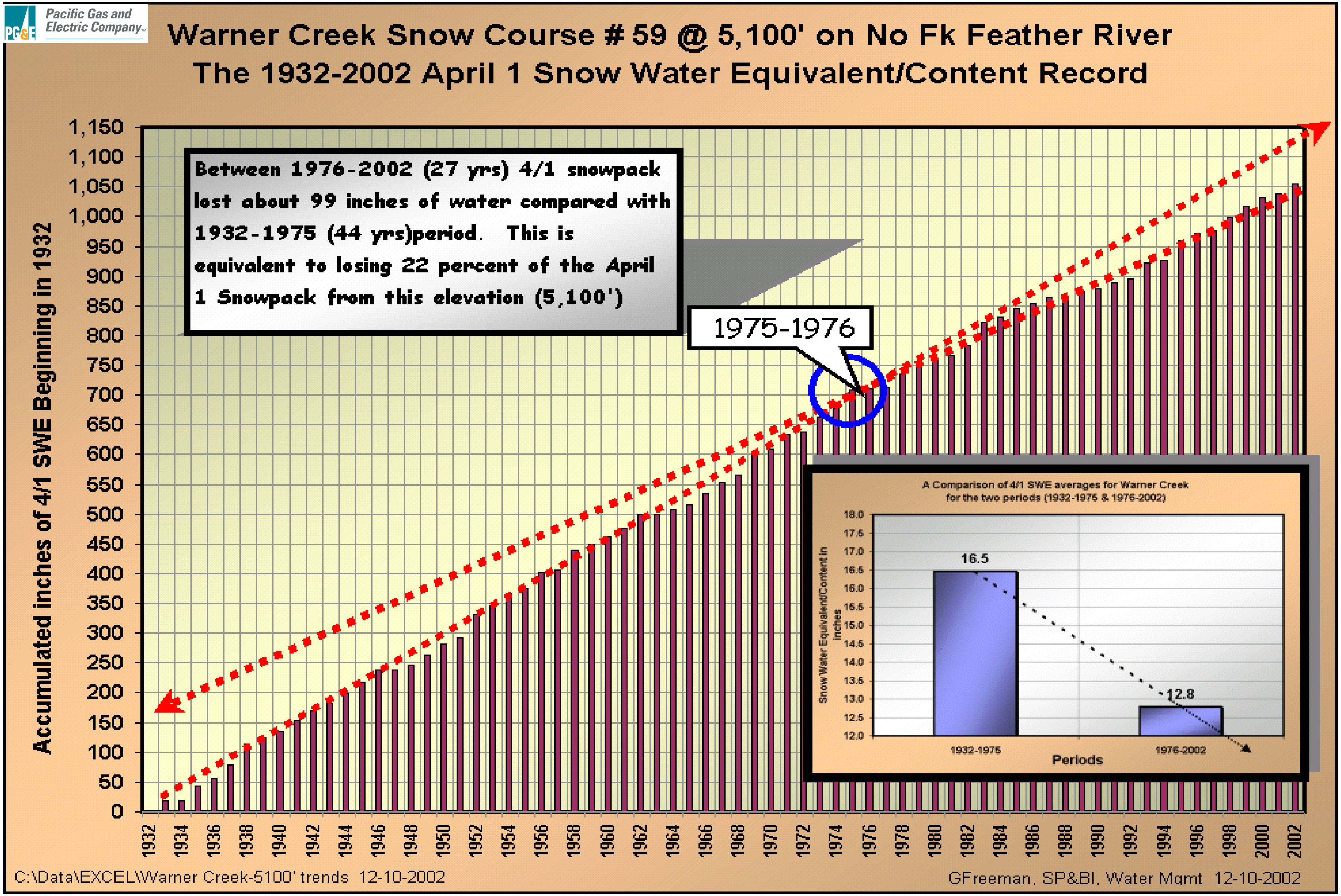
Pacific Gas and Electric Company

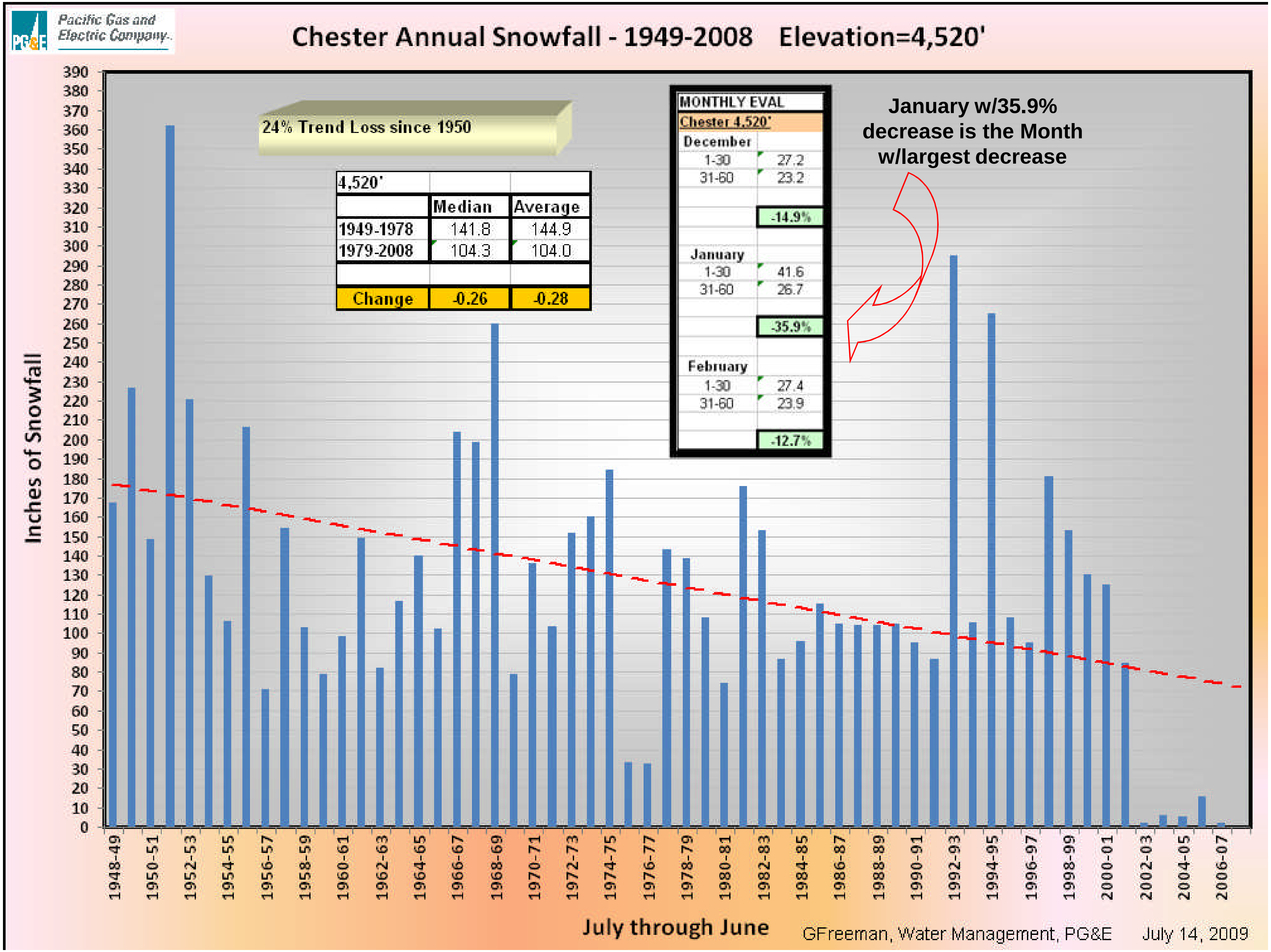


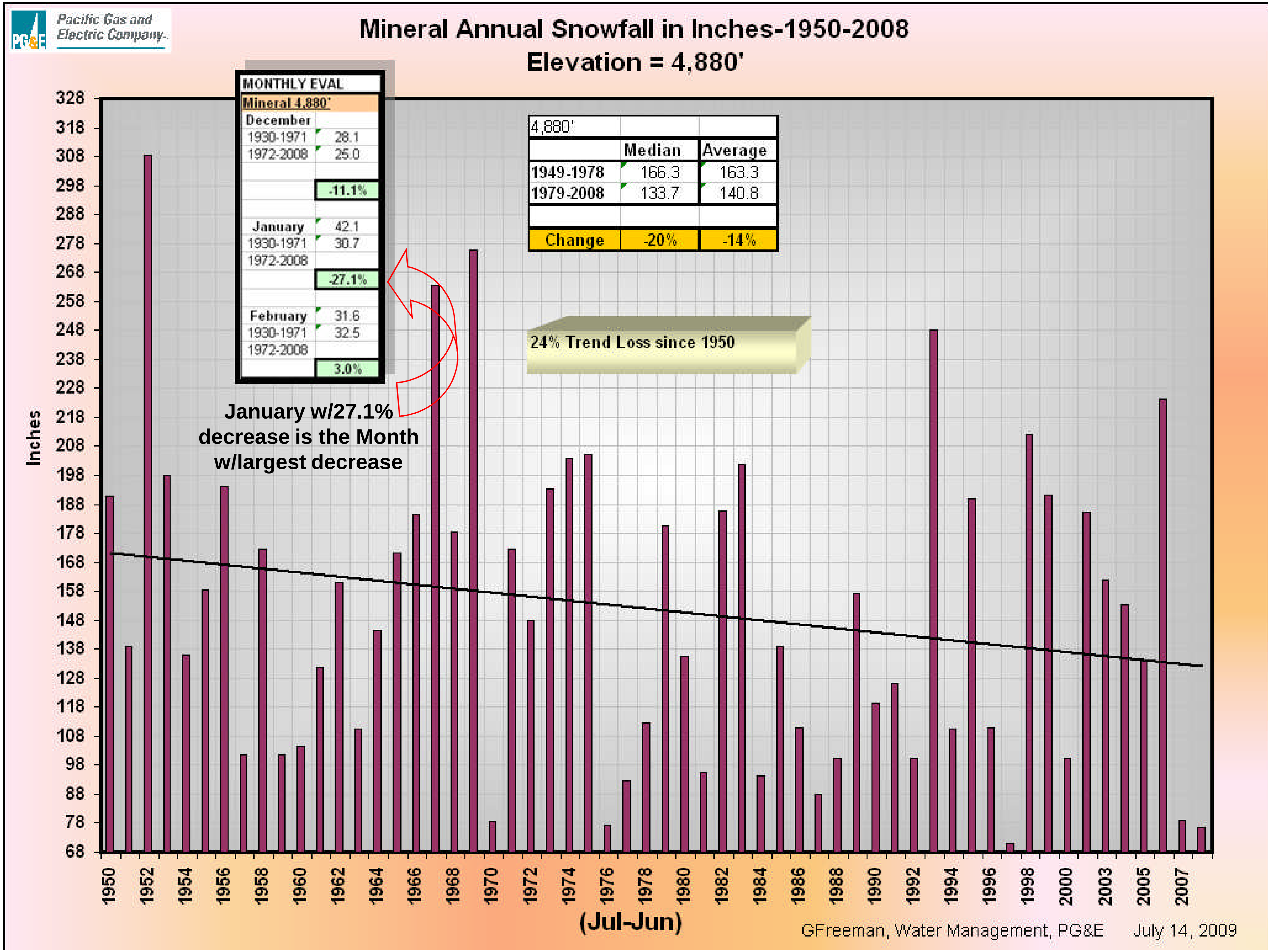
Climate Change

- Warming in recent Years
- Higher Snow Lines
- Possibly Periodic Cycles
- ENSO
- More Floods in recent Years
- Less Low Elevation Snow since 1950

For the 5,100 Feet Elevation in the northern Sierra – A possible change in the snowpack appears to have possibly occurred about the mid-late 1970's

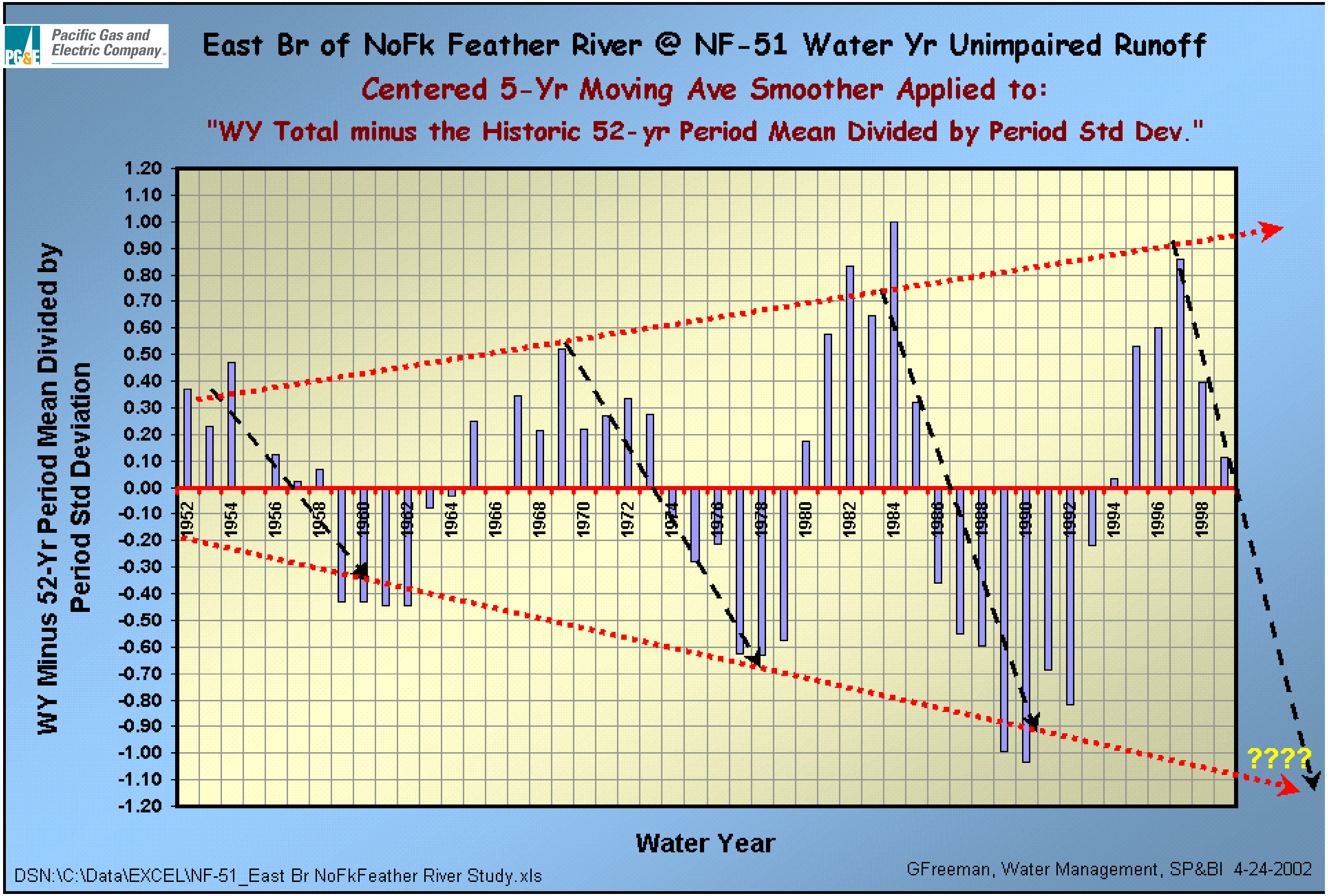


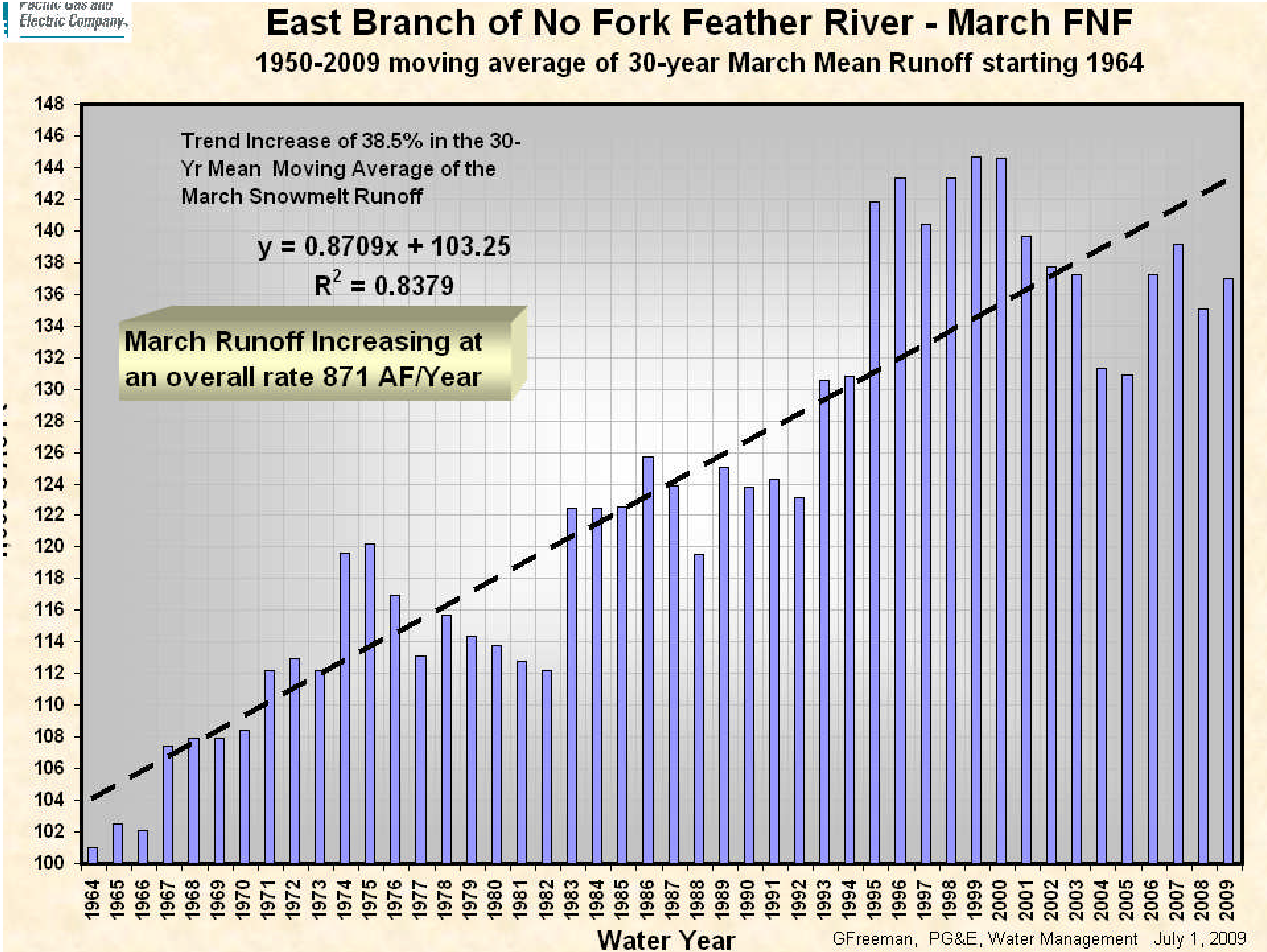

Pacific Gas and Electric Company
Chester Annual Snowfall - 1949-2008 Elevation=4,520'
24% Trend Loss since 1950
4,520'
Median Average
1949-1978 141.8 144.9
1979-2008 104.3 104.0
Change -0.26 -0.28
MONTHLY EVAL
Chester 4,520'
December
1-30 27.2
31-60 23.2
-14.9%
January
1-30 41.6
31-60 26.7
-35.9%
February
1-30 27.4
31-60 23.9
-12.7%
January w/35.9% decrease is the Month w/largest decrease
Inches of Snowfall
July through June
GFreeman, Water Management, PG&E
July 14, 2009



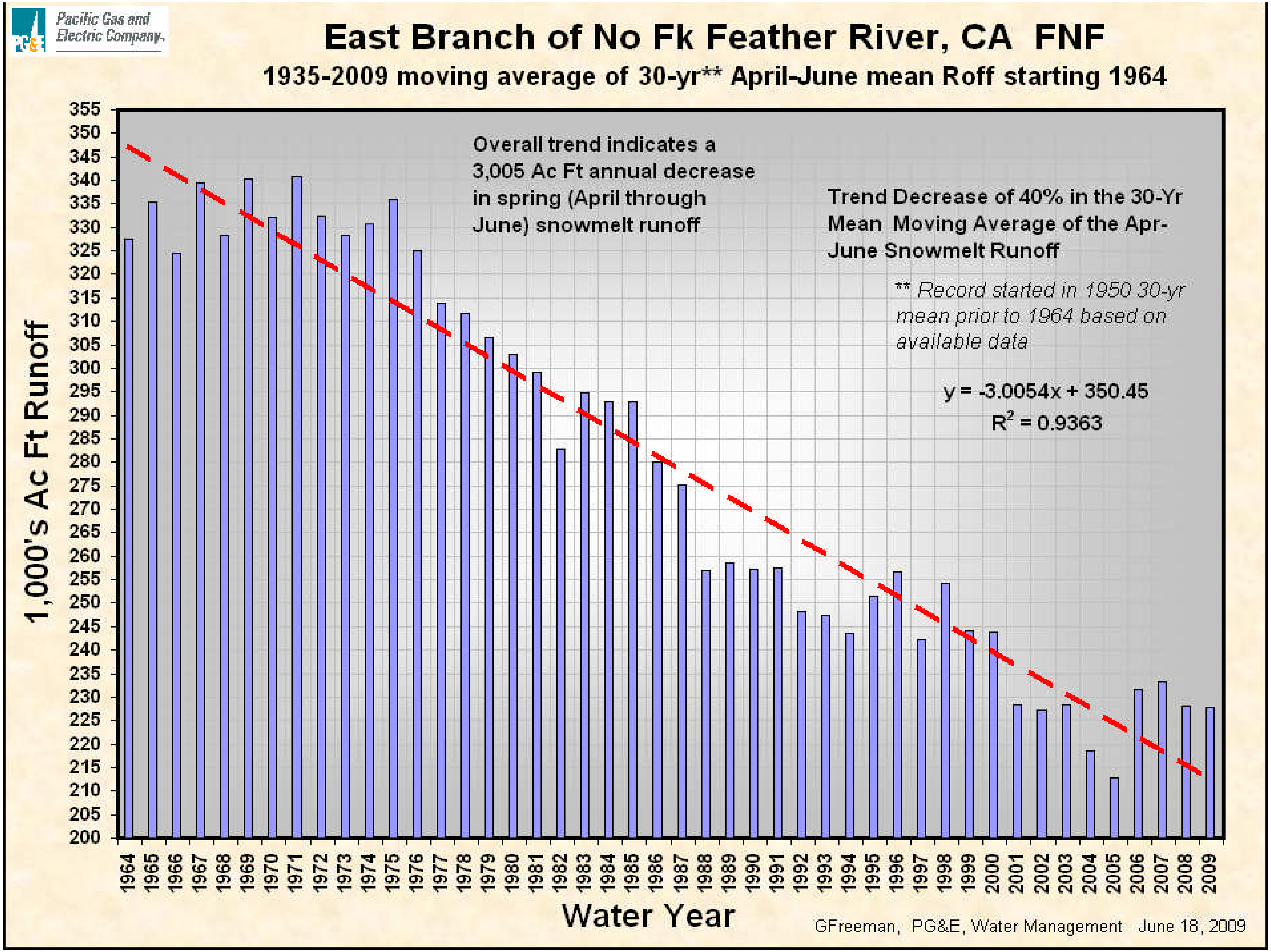
Pacific Gas and Electric Company
Mineral Annual Snowfall in Inches-1950-2008
Elevation = 4,880'
MONTHLY EVAL
Mineral 4,880'
December
1930-1971 28.1
1972-2008 25.0
-11.1%
January 42.1
1930-1971 30.7
1972-2008
-27.1%
February 31.6
1930-1971 32.5
1972-2008
3.0%
4,880'
Median Average
1949-1978 166.3 163.3
1979-2008 133.7 140.8
Change -20% -14%
24% Trend Loss since 1950
January w/27.1% decrease is the Month w/largest decrease
Inches
(Jul-Jun)
GFreeman, Water Management, PG&E
July 14, 2009

Increasing Magnitude in 15-Year Variance Oscillation for Annual Runoff for successive wet/dry Periods affects Runoff forecasting, planning, and commitments

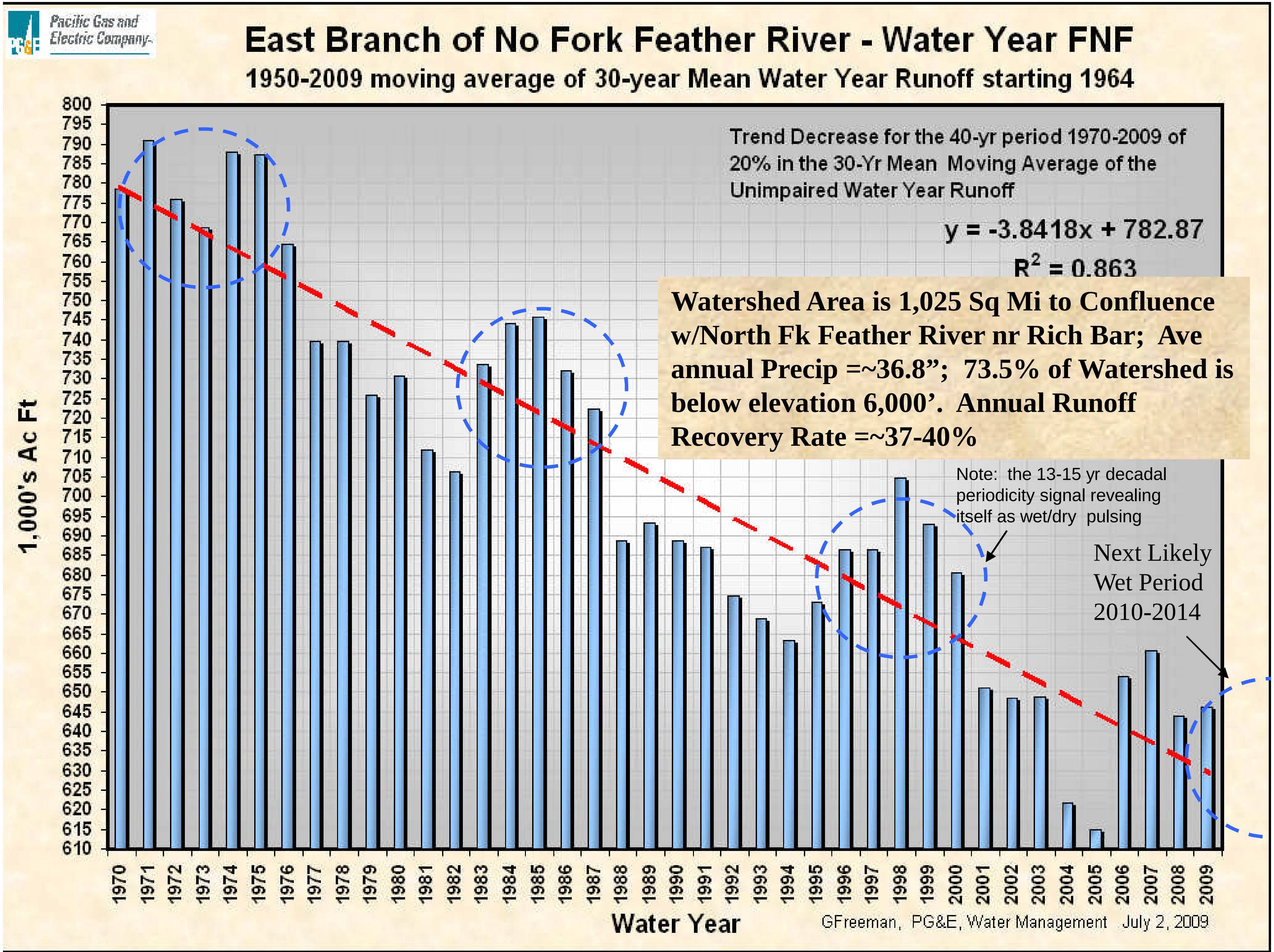


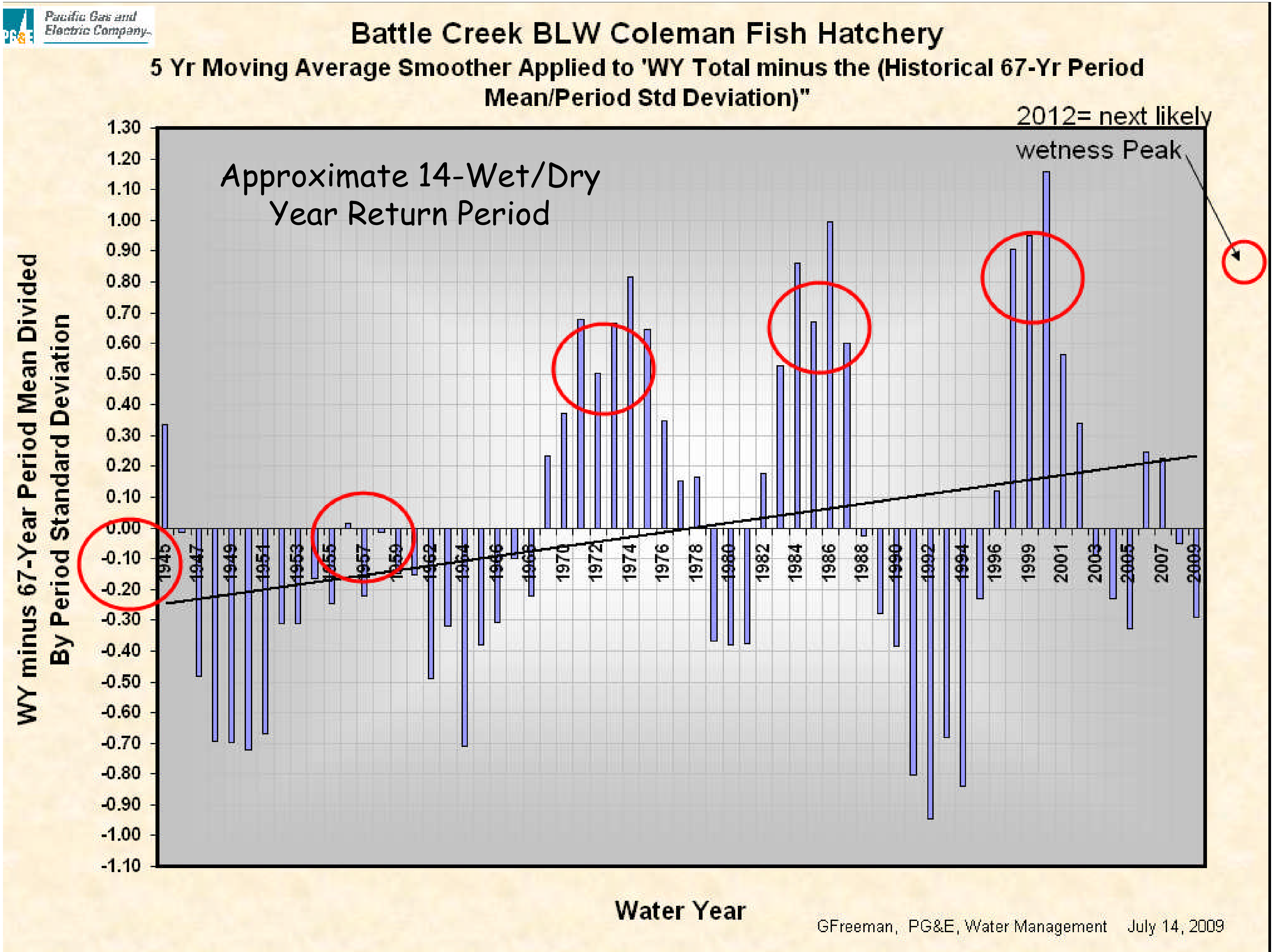


Pacific Gas and Electric Company
East Branch of No Fork Feather River - March FNF
1950-2009 moving average of 30-year March Mean Runoff starting 1964
Trend Increase of 38.5% in the 30-Yr Mean Moving Average of the March Snowmelt Runoff
y = 0.8709x + 103.25
R2 = 0.8379
March Runoff Increasing at an overall rate 871 AF/Year
148
146
144
142
140
138
136
134
132
130
128
126
124
122
120
118
116
114
112
110
108
106
104
102
100
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Water Year
GFreeman, PG&E, Water Management July 1, 2009



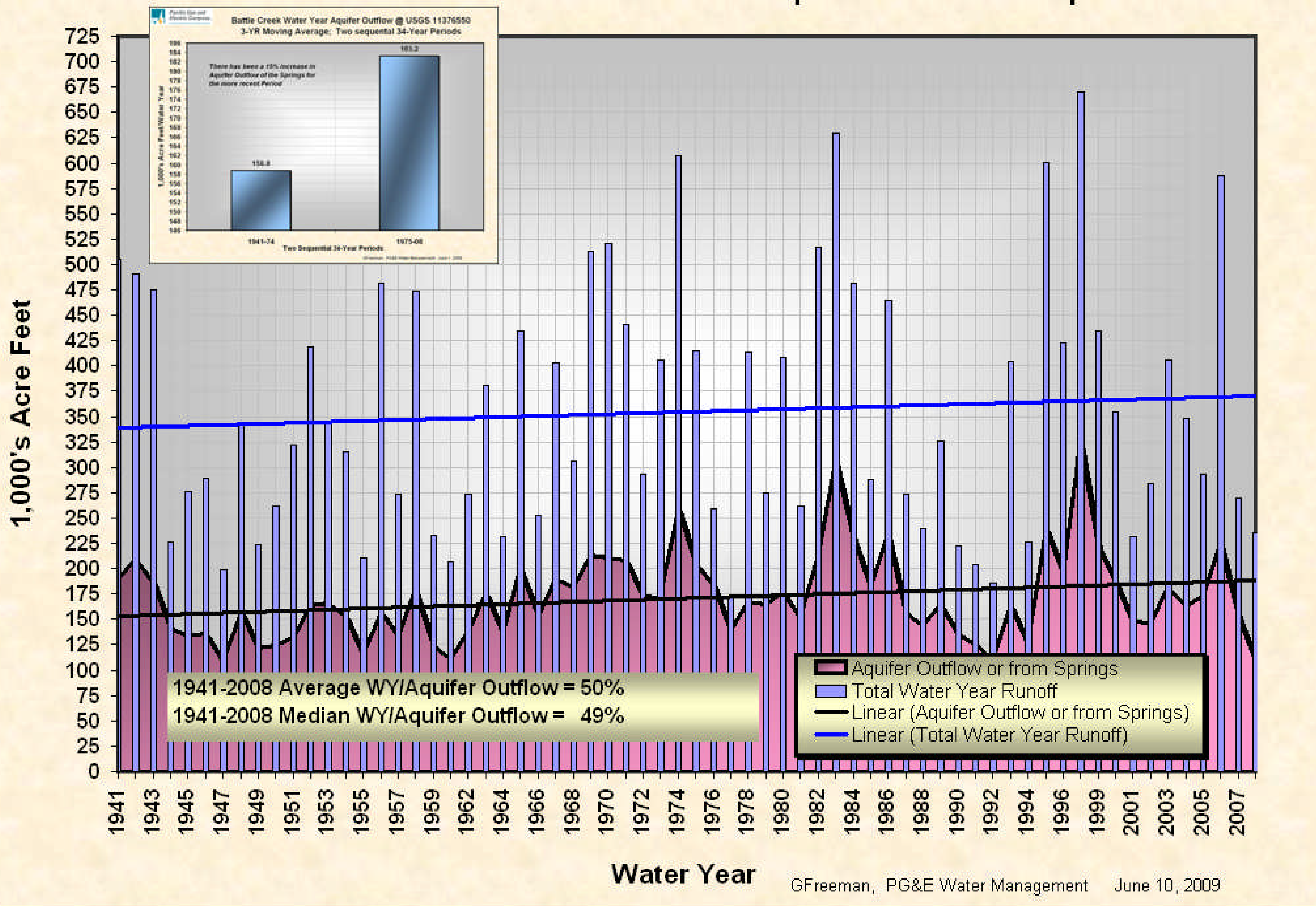
Pacific Gas and Electric Company
East Branch of No Fk Feather River, CA FNF
1935-2009 moving average of 30-yr** April-June mean Roff starting 1964
Overall trend indicates a 3,005 Ac Ft annual decrease in spring (April through June) snowmelt runoff
Trend Decrease of 40% in the 30-Yr Mean Moving Average of the Apr-June Snowmelt Runoff
** Record started in 1950 30-yr mean prior to 1964 based on available data
y = -3.0054x + 350.45
R² = 0.9363
1,000's Ac Ft Runoff
Water Year
GFreeman, PG&E, Water Management June 18, 2009

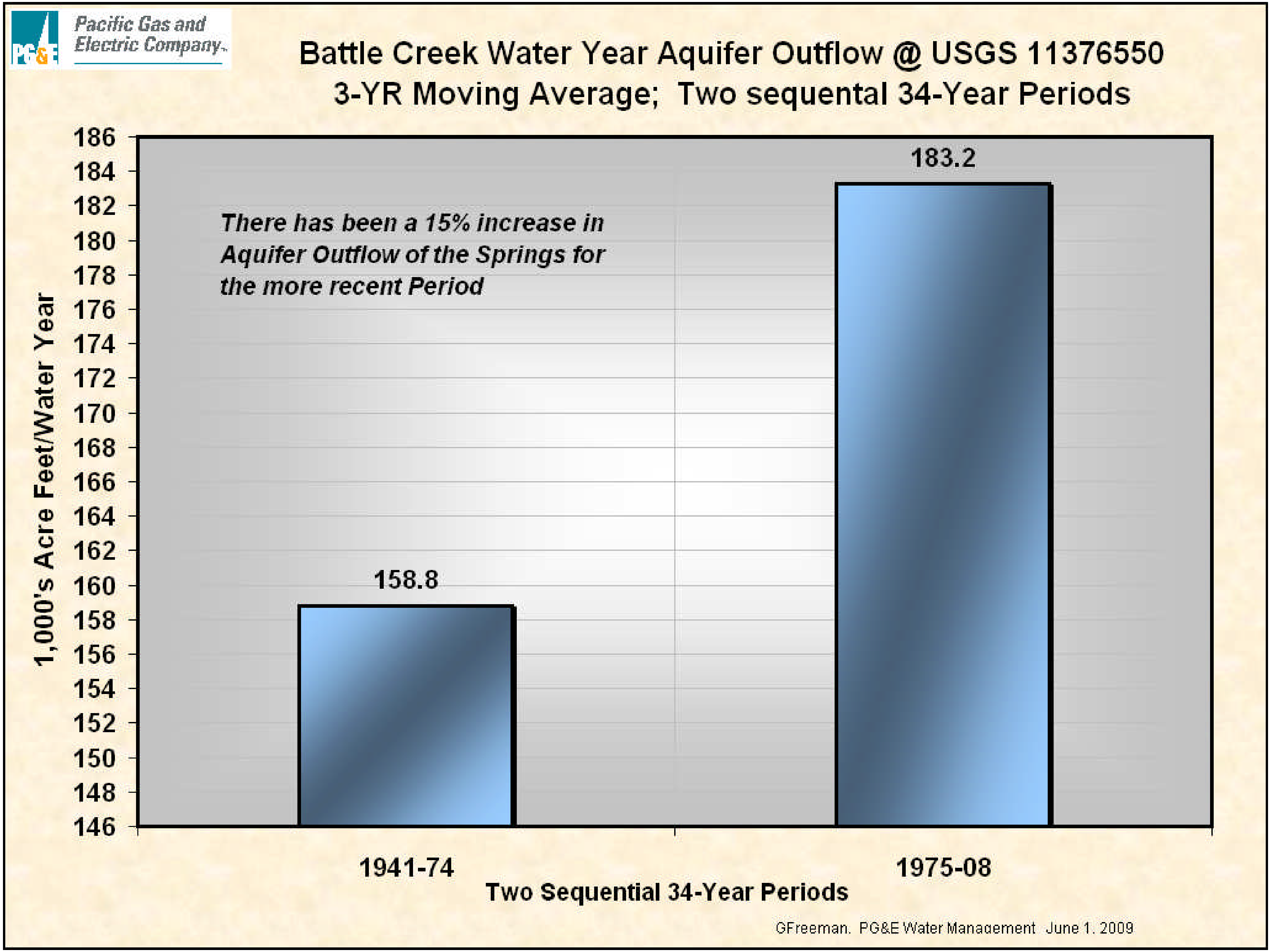

Pacific Gas and Electric Company
PG&E
East Branch of No Fork Feather River - Water Year FNF
1950-2009 moving average of 30-year Mean Water Year Runoff starting 1964
Trend Decrease for the 40-yr period 1970-2009 of 20% in the 30-Yr Mean Moving Average of the Unimpaired Water Year Runoff
y = -3.8418x + 782.87
R2 = 0.863
Watershed Area is 1,025 Sq Mi to Confluence w/North Fk Feather River nr Rich Bar; Ave annual Precip =~36.8"; 73.5% of Watershed is below elevation 6,000'. Annual Runoff Recovery Rate =~37-40%
Note: the 13-15 yr decadal periodicity signal revealing itself as wet/dry pulsing
Next Likely Wet Period 2010-2014
1,000's Ac Ft
Water Year
GFreeman, PG&E, Water Management July 2, 2009



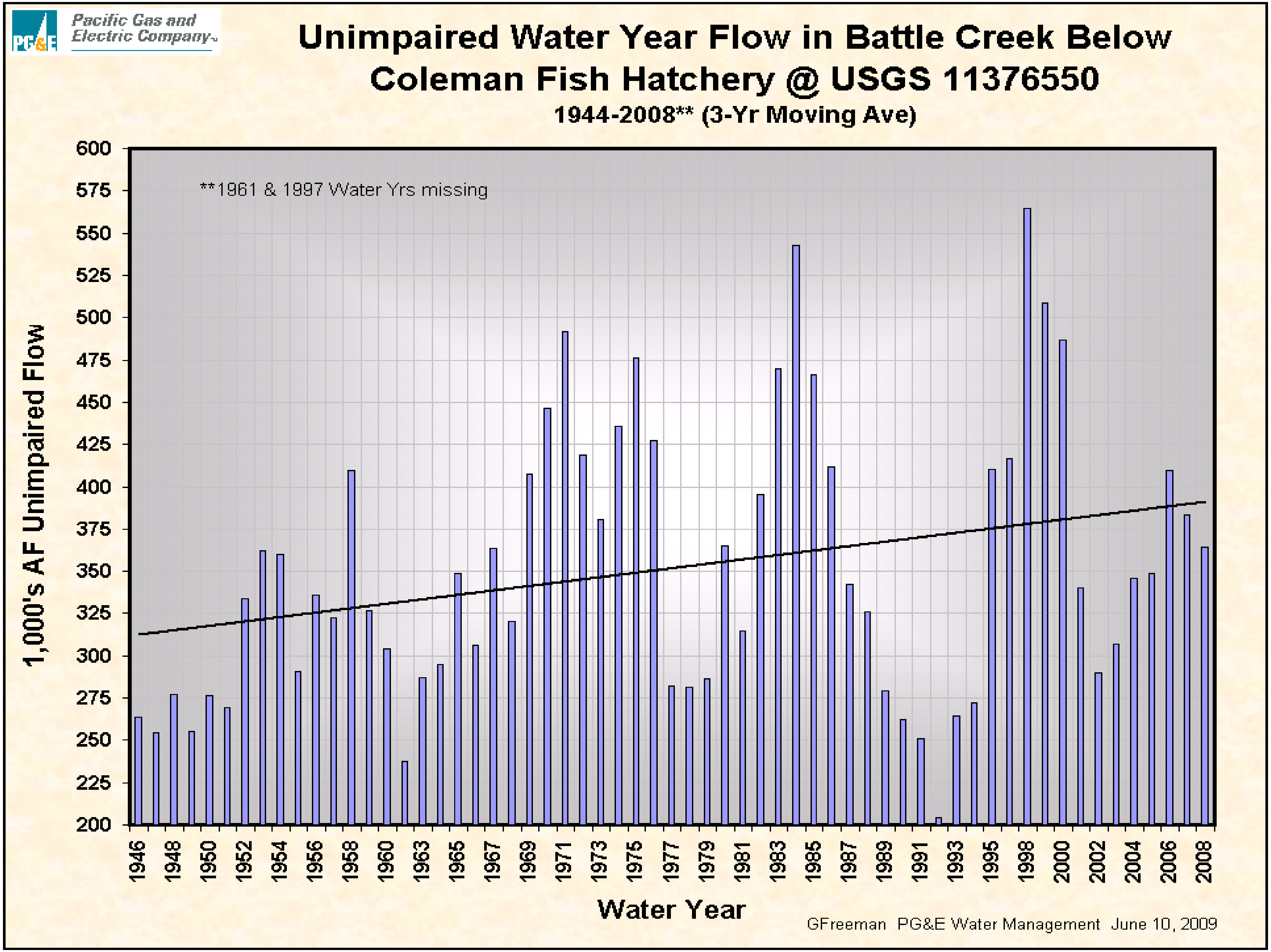
Pacific Gas and Electric Company
Battle Creek BLW Coleman Fish Hatchery
5 Yr Moving Average Smoother Applied to 'WY Total minus the (Historical 67-Yr Period Mean/Period Std Deviation)"
2012= next likely wetness Peak
Approximate 14-Wet/Dry Year Return Period
WY minus 67-Year Period Mean Divided By Period Standard Deviation
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
-0.60
-0.70
-0.80
-0.90
-1.00
-1.10
1945 1947 1949 1951 1953 1955 1957 1959 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1999 2001 2003 2005 2007 2009
Water Year
GFreeman, PG&E, Water Management July 14, 2009

Battle Creek BLW Coleman Fish Hatchery 1941-2008 Water Year total flow includes the charted Aquifer Outflow Component

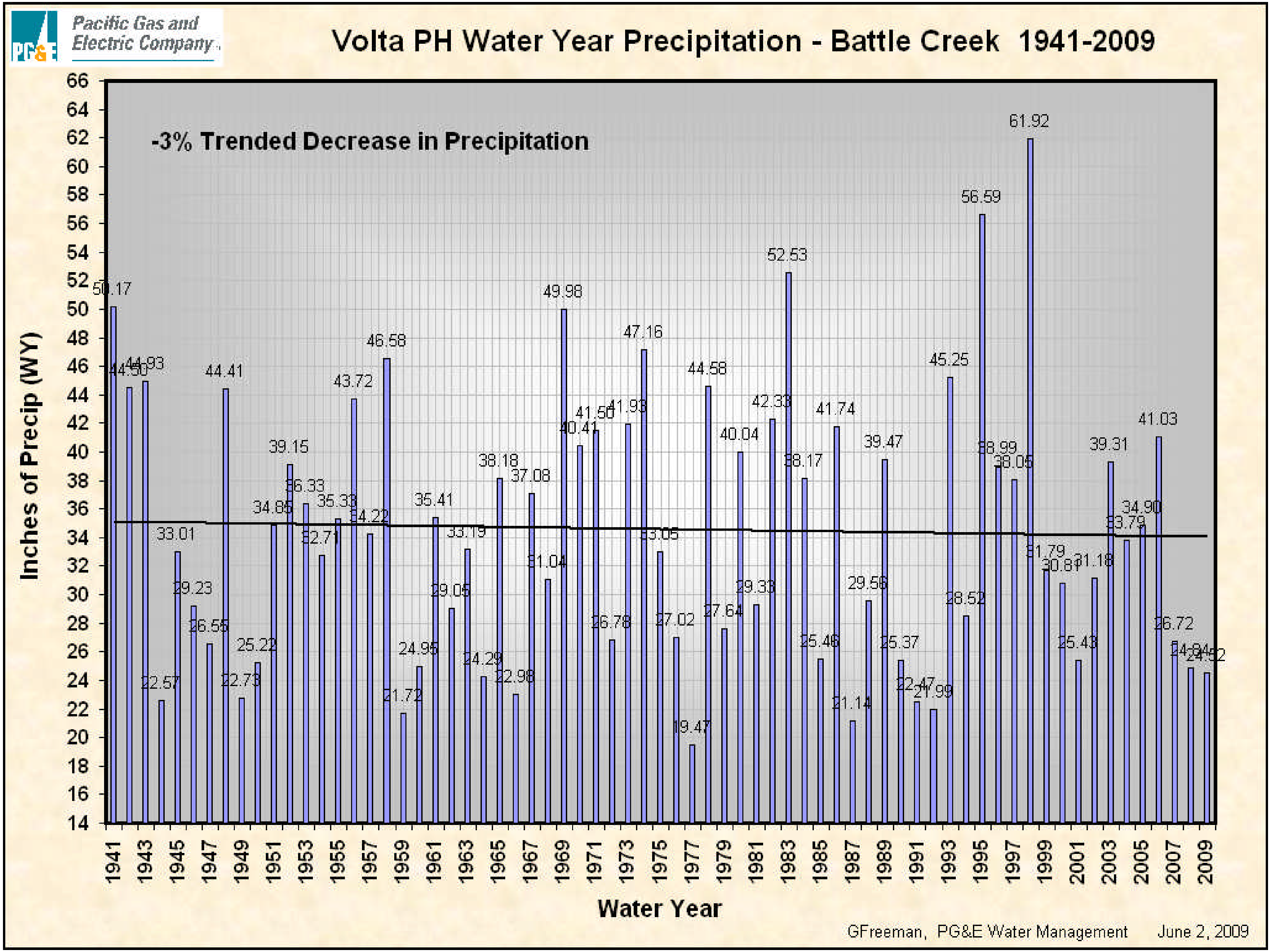


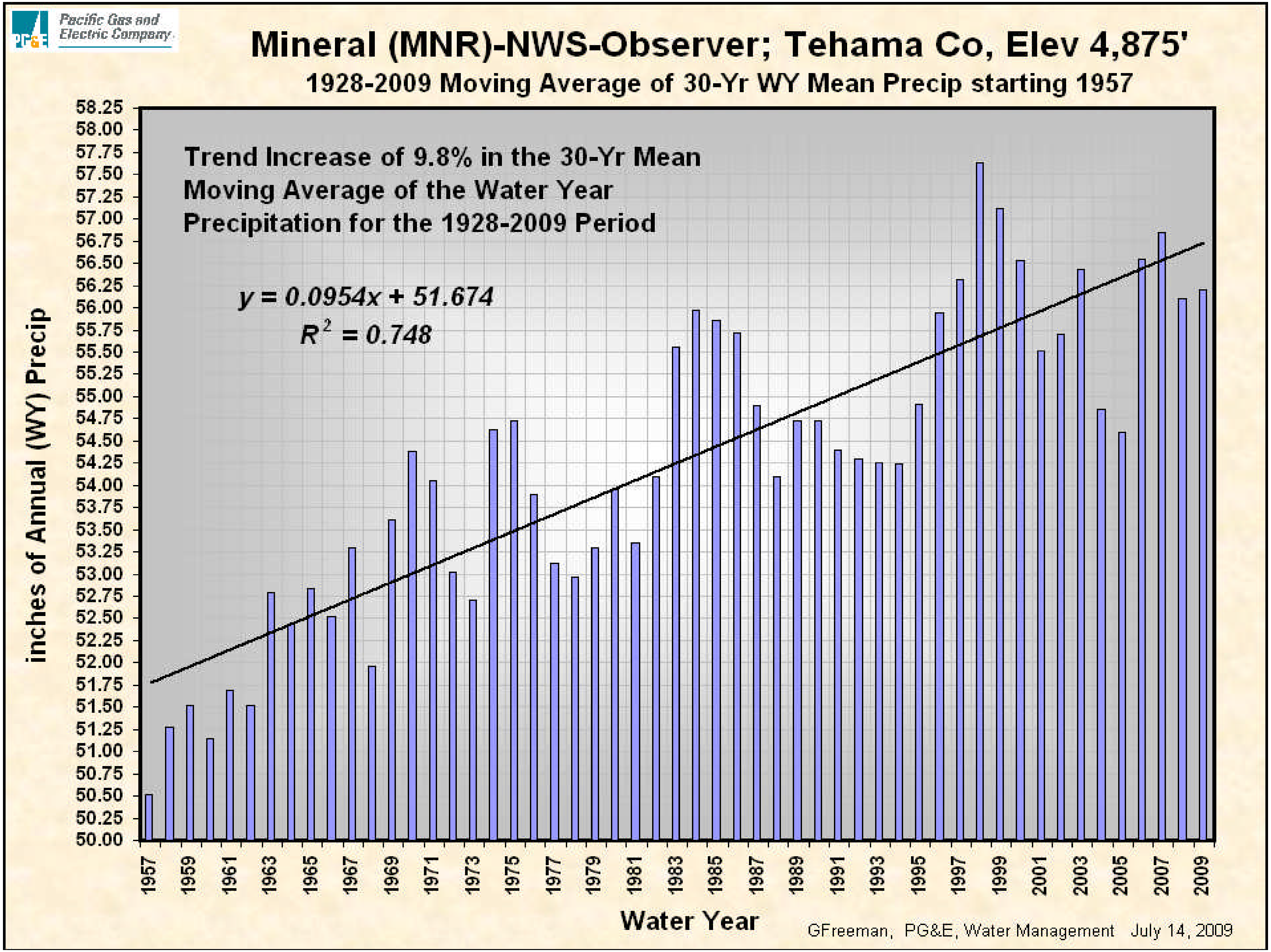


Pacific Gas and Electric Company
PG&E
Battle Creek Water Year Aquifer Outflow @ USGS 11376550
3-YR Moving Average; Two sequental 34-Year Periods
186
184
182
180
178
176
174
172
170
168
166
164
162
160
158
156
154
152
150
148
146
1,000's Acre Feet/Water Year
There has been a 15% increase in Aquifer Outflow of the Springs for the more recent Period
158.8
183.2
1941-74
1975-08
Two Sequential 34-Year Periods
GFreeman. PG&E Water Management June 1. 2009

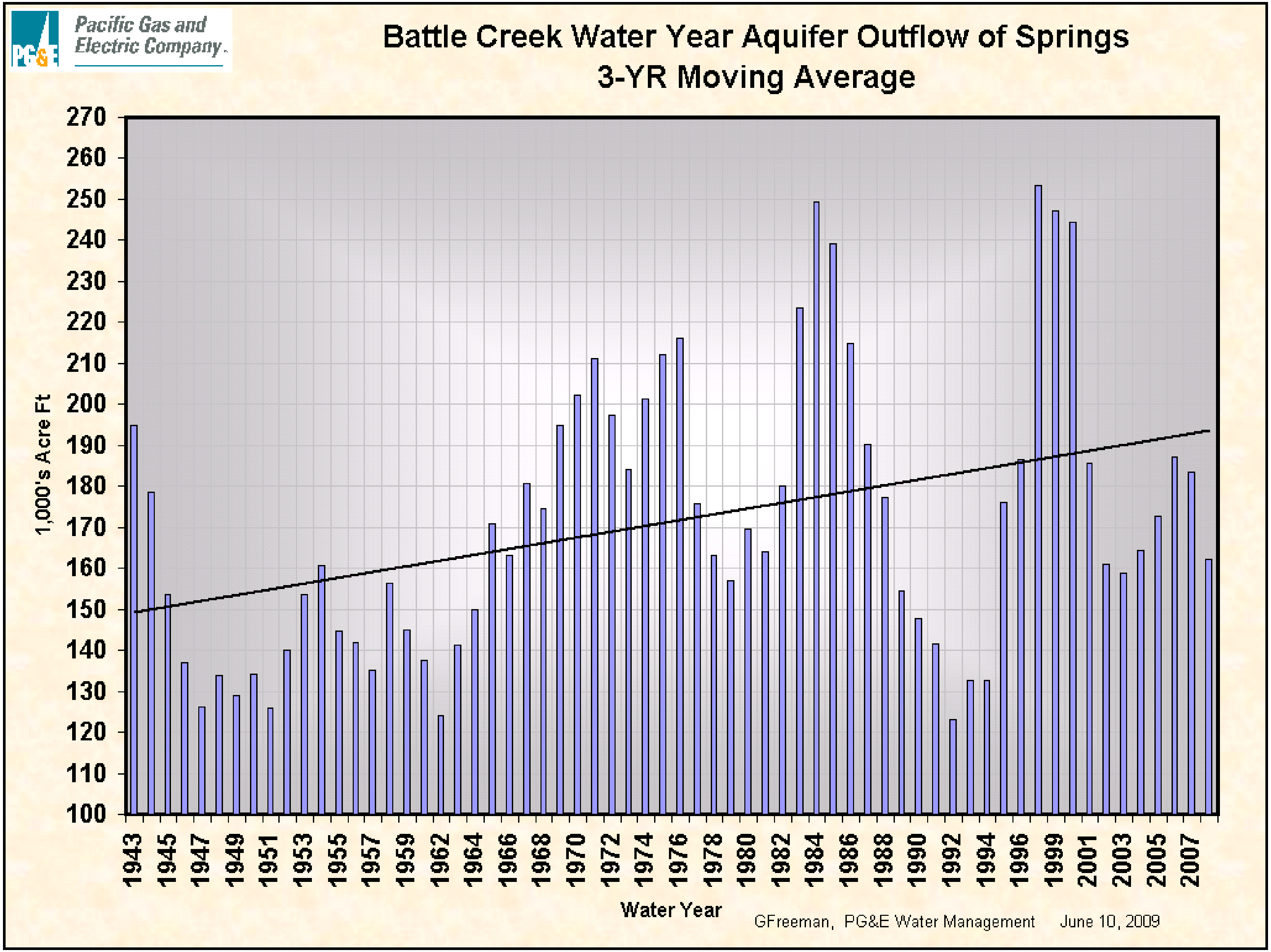


Pacific Gas and Electric Company
PG&E
Unimpaired Water Year Flow in Battle Creek Below Coleman Fish Hatchery @ USGS 11376550
1944-2008** (3-Yr Moving Ave)
**1961 & 1997 Water Yrs missing
1,000's AF Unimpaired Flow
600
575
550
525
500
475
450
425
400
375
350
325
300
275
250
225
200
1946
1948
1950
1952
1954
1956
1958
1960
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1998
2000
2002
2004
2006
2008
Water Year
GFreeman PG&E Water Management June 10, 2009

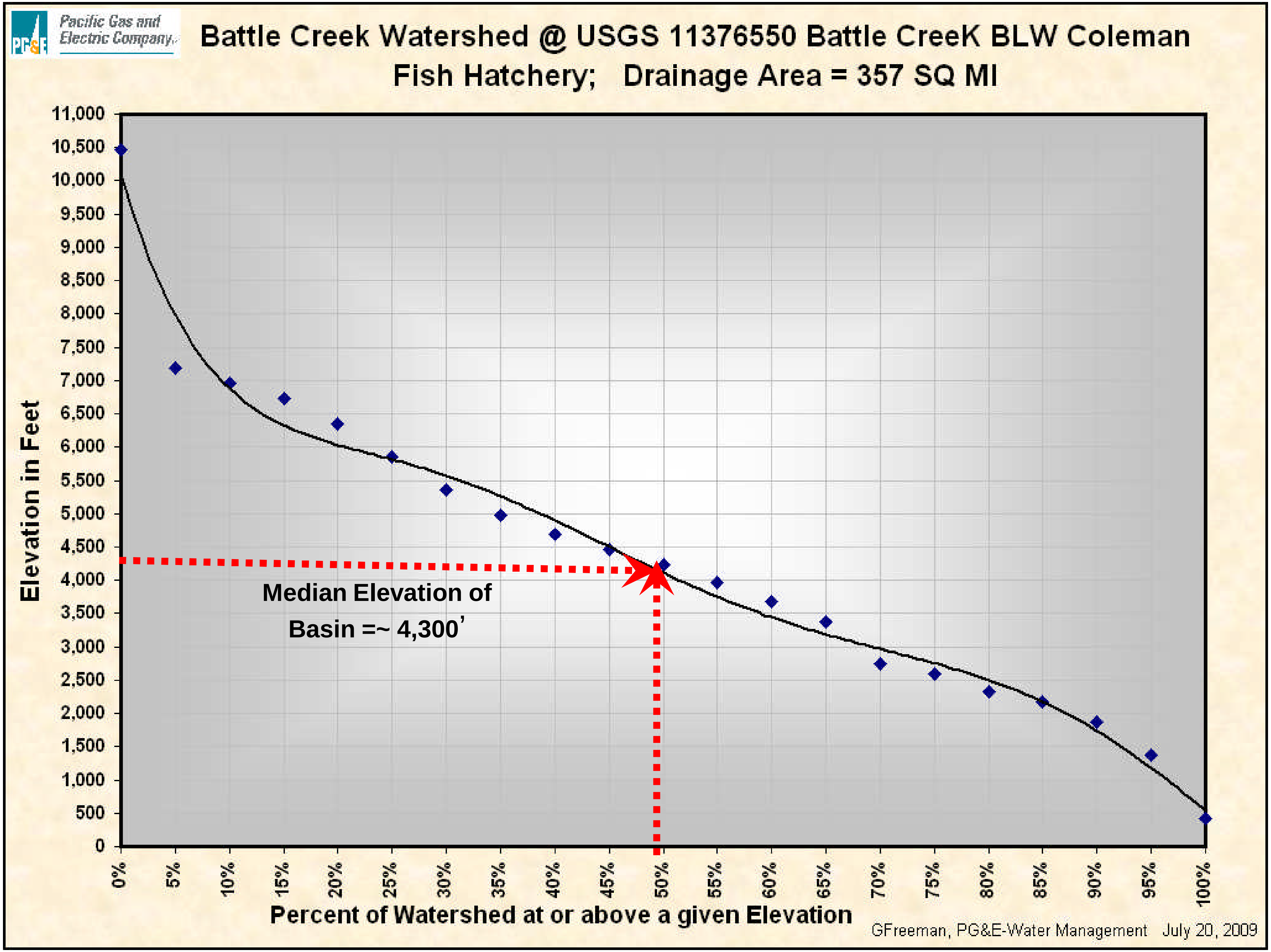

Pacific Gas and Electric Company
Volta PH Water Year Precipitation - Battle Creek 1941-2009
-3% Trended Decrease in Precipitation
Inches of Precip (WY)
Water Year
GFreeman, PG&E Water Management
June 2, 2009



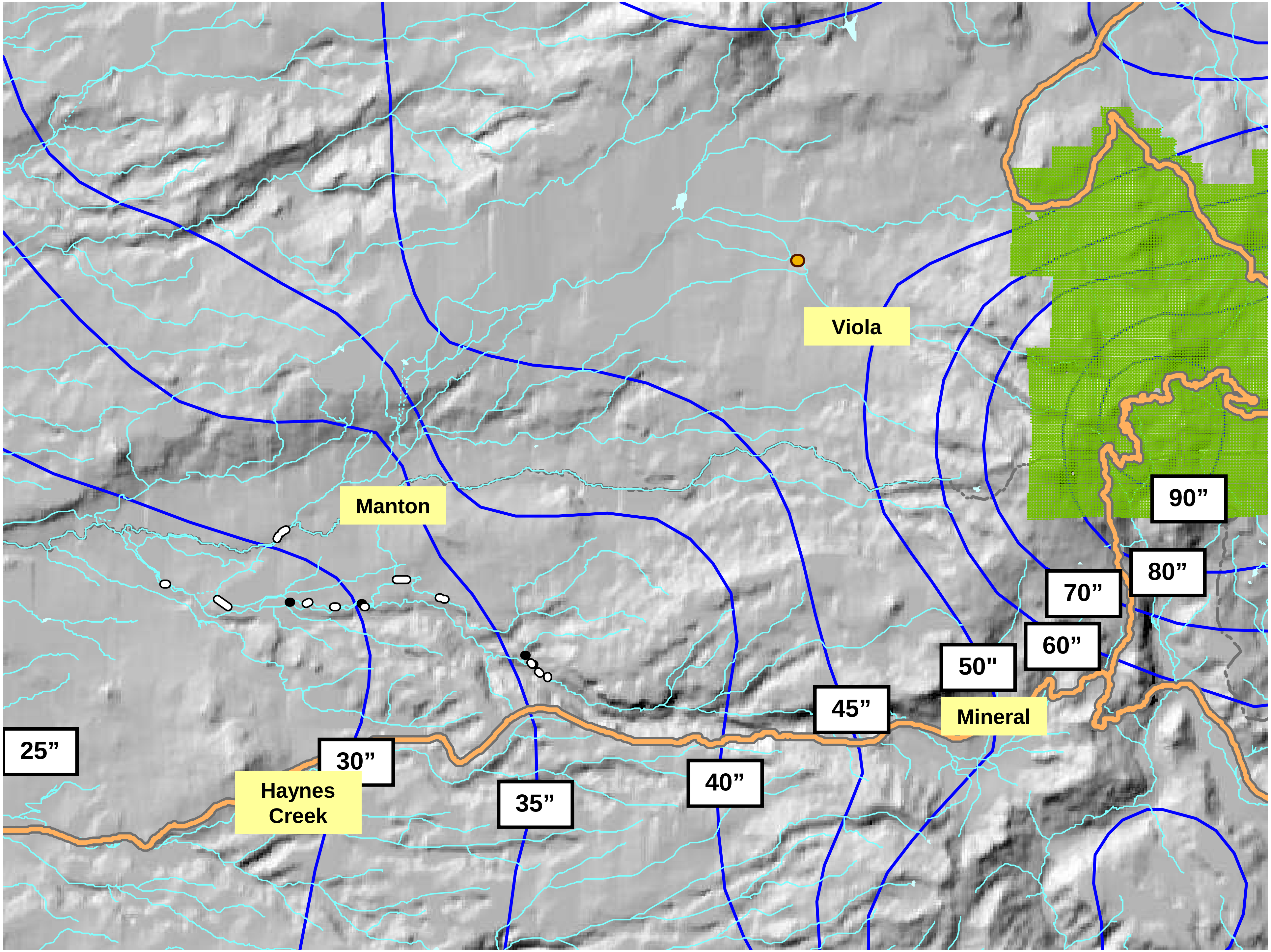
Pacific Gas and Electric Company
Mineral (MNR)-NWS-Observer; Tehama Co, Elev 4,875'
1928-2009 Moving Average of 30-Yr WY Mean Precip starting 1957
Trend Increase of 9.8% in the 30-Yr Mean Moving Average of the Water Year Precipitation for the 1928-2009 Period
y = 0.0954x + 51.674
R2 = 0.748
inches of Annual (WY) Precip
Water Year
GFreeman, PG&E, Water Management July 14, 2009



Pacific Gas and Electric Company
Battle Creek Water Year Aquifer Outflow of Springs
3-YR Moving Average
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
1,000's Acre Ft
1943
1945
1947
1949
1951
1953
1955
1957
1959
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1999
2001
2003
2005
2007
Water Year
GFreeman, PG&E Water Management
June 10, 2009



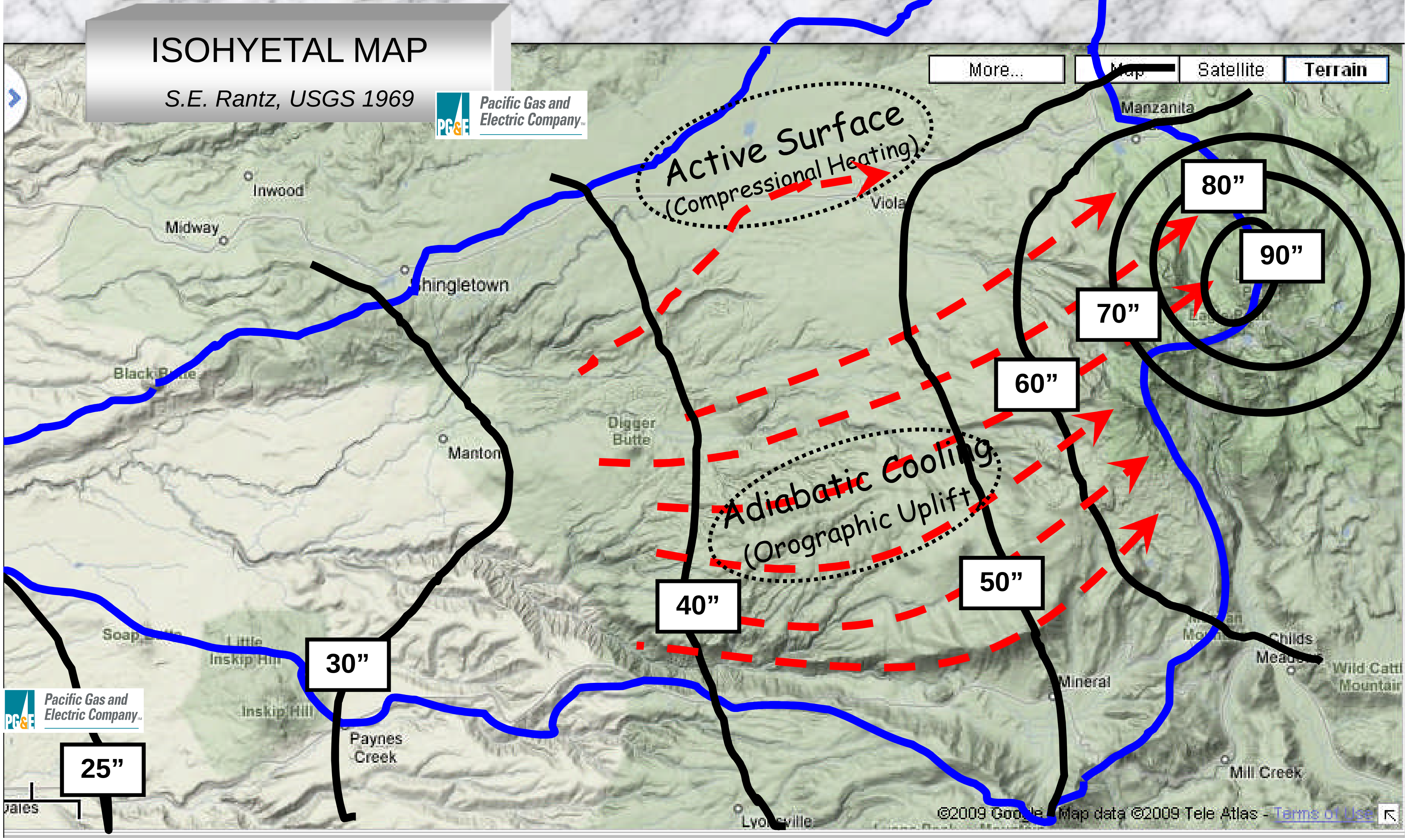
Pacific Gas and Electric Company
Battle Creek Watershed @ USGS 11376550 Battle CreeK BLW Coleman Fish Hatchery; Drainage Area = 357 SQ MI
Elevation in Feet
11,000
10,500
10,000
9,500
9,000
8,500
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Median Elevation of Basin =~ 4,300'
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
100%
Percent of Watershed at or above a given Elevation
GFreeman, PG&E-Water Management July 20, 2009


Viola
Manton
90"
80"
70"
60"
50"
Mineral
45"
40"
35"
30"
25"
Haynes Creek

Battle Creek Watershed

(357 Sq Mi @ USGS 11376550 BLW Coleman Fish Hatchery)

Adiabatic Cooling with Increased Precipitation in Recent Years



Pacific Gas and Electric Company

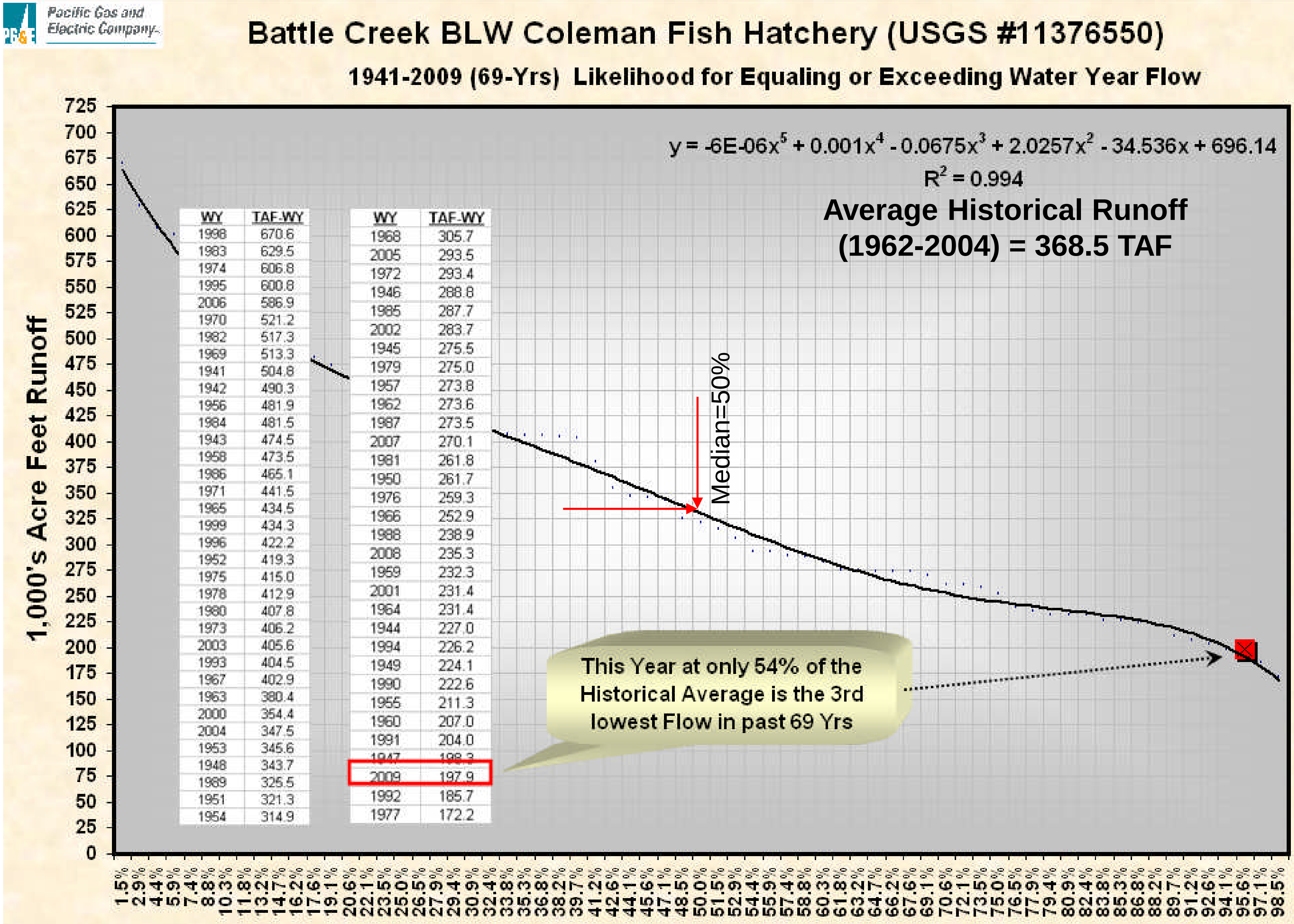
Water Balance for Battle Creek

@ USGS # 11376550

- Using the 1969 isohyetal map compiled by SE Rantz, USGS, compilation for basin mean precipitation = 48.33”
- From USGS Surface Water Records for USGS #11376550 Battle Creek BLW Coleman Fish Hatchery, the 1962 through 2004 Ave Water Year Runoff is 368,500 Acre Feet
- 368,500 Ac Ft Annual Roff/(357 Sq MI*53.333*48.33”Annual Precip Basin Ave) =***40% runoff Recovery Rate; 553,000 Ac Ft going to evapotranspiration! ….and likely groundwater leakage from basin!!***
  (I suspect that approx. 250 cfs year-round subsurface flow entering Sacramento R. and/or recharging Sac groundwater basin)
- Average Historical Water Year Aquifer Outflow of the springs accounts for 50% of flow BLW Coleman. This helps buffer the effects of successive dry years. During a very dry year such as 1977, aquifer outflow assumed an **80% of total Water Year runoff proportion**. *This is likely very important to maintaining cool/cold water temperatures.*
- *This year Water Year runoff is forecasted to be approx. 198 TAF or only 54% of historical 1962-2004 average. Aquifer outflow from springs is forecast at 70% of the Total Water Year runoff , contributing approximately 138 TAF.*

Battle Creek BLW Coleman Fish Hatchery (USGS #11376550)

1941-2009 (69-Yrs) Likelihood for Equaling or Exceeding Water Year Flow



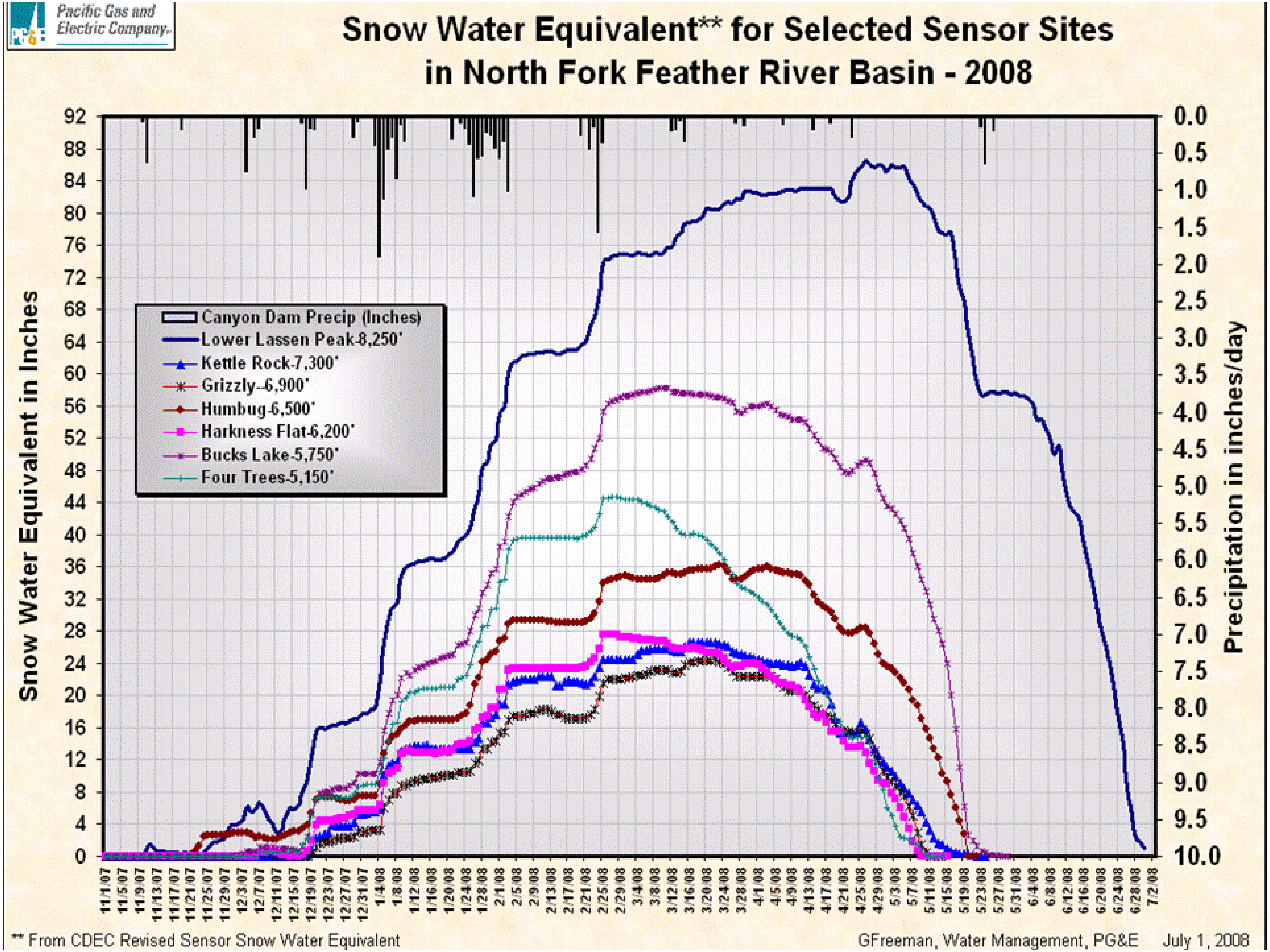
WY	TAF-WY
1998	670.6
1983	629.5
1974	606.8
1995	600.8
2006	586.9
1970	521.2
1982	517.3
1969	513.3
1941	504.8
1942	490.3
1956	481.9
1984	481.5
1943	474.5
1958	473.5
1986	465.1
1971	441.5
1965	434.5
1999	434.3
1996	422.2
1952	419.3
1975	415.0
1978	412.9
1980	407.8
1973	406.2
2003	405.6
1993	404.5
1967	402.9
1963	380.4
2000	354.4
2004	347.5
1953	345.6
1948	343.7
1989	325.5
1951	321.3
1954	314.9

WY	TAF-WY
1968	305.7
2005	293.5
1972	293.4
1946	288.8
1985	287.7
2002	283.7
1945	275.5
1979	275.0
1957	273.8
1962	273.6
1987	273.5
2007	270.1
1981	261.8
1950	261.7
1976	259.3
1966	252.9
1988	238.9
2008	235.3
1959	232.3
2001	231.4
1964	231.4
1944	227.0
1994	226.2
1949	224.1
1990	222.6
1955	211.3
1960	207.0
1991	204.0
1947	198.3
2009	197.9
1992	185.7
1977	172.2

GFreeman, PG&E, Water Management July 14, 2009

- PG&E's Helen Lake Cosmic Gamma Sensor -8,250' Elevation
- Primarily utilized for Monitoring Climate Change & Runoff Forecasting for both Battle Creek and North Fork Feather River
- Highest Automated snow sensor in CA north of the American River
- This site receives over 90" of Precipitation/Year
- Deepest snowcourse in the State.
- Available on CA DWR's California Data Exchange Center (CDEC)

http://cdec.water.ca.gov/cgi-progs/queryF?s=llp


Pacific Gas and Electric Company
Snow Water Equivalent** for Selected Sensor Sites
in North Fork Feather River Basin - 2008
Snow Water Equivalent in Inches
Precipitation in inches/day
Canyon Dam Precip (Inches)
Lower Lassen Peak-8,250'
Kettle Rock-7,300'
Grizzly--6,900'
Humbug-6,500'
Harkness Flat-6,200'
Bucks Lake-5,750'
Four Trees-5,150'
92 88 84 80 76 72 68 64 60 56 52 48 44 40 36 32 28 24 20 16 12 8 4 0
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
11/1/07 11/5/07 11/9/07 11/13/07 11/17/07 11/21/07 11/25/07 11/29/07 12/3/07 12/7/07 12/11/07 12/15/07 12/19/07 12/23/07 12/27/07 12/31/07 1/4/08 1/8/08 1/12/08 1/16/08 1/20/08 1/24/08 1/28/08 2/1/08 2/5/08 2/9/08 2/13/08 2/17/08 2/21/08 2/25/08 2/29/08 3/4/08 3/8/08 3/12/08 3/16/08 3/20/08 3/24/08 3/28/08 4/1/08 4/5/08 4/9/08 4/13/08 4/17/08 4/21/08 4/25/08 4/29/08 5/3/08 5/7/08 5/11/08 5/15/08 5/19/08 5/23/08 5/27/08 5/31/08 6/4/08 6/8/08 6/12/08 6/16/08 6/20/08 6/24/08 6/28/08 7/2/08
** From CDEC Revised Sensor Snow Water Equivalent
GFreeman, Water Management, PG&E July 1, 2008

Precipitation-Runoff Processes in the Feather River Basin, Northeastern California, with Prospects for Streamflow Predictability, Water Years 1971–97

By Kathryn M. Koczot, Anne E. Jeton, Bruce J. McGurk, and Michael D. Dettinger

In cooperation with the California Department of Water Resources

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Conversion Factors, Datum, Abbreviations, and Acronyms

CONVERSION FACTORS

Multiply	By	To obtain
acre	4,047	square meter
acre-feet (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	2.54	centimeter
inch per year (in/yr)	2.54	centimeter per year
mile (mi)	1.609	kilometer
square mile (mi^2)	12.590	square kilometer

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8.$$

DATUM

Vertical coordinate information is referenced to National Geodetic Vertical Datum of 1929 (NGVD 29). Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Altitude, as used in this report, refers to distance above the vertical datum.

Water Year constitutes a 12-month period from October 1 through September 30, and is designated by the year in which the period ends (for example, water year 1995 began October 1, 1994, and ended September 30, 1995).

ABBREVIATIONS

asl above sea level

ACRONYMS

ESP Ensemble Streamflow Prediction

FTO Feather River at Oroville

GIS geographic information system

HRU hydrologic response unit

MMS Modular Modeling System

NWSRFS National Weather Service River Forecasting System

PDO Pacific Decadal Oscillation

PRISM Parameter-Elevation Regressions on Independent Slopes Model

PRMS Precipitation-Runoff Modeling System

RMSE	root-mean-square error
SCCT	Snow Cover Comparison Tool

Organizations

CCSS	California Cooperative Snow Surveys Program
CDEC	California Data Exchange Center
CNRFC	National Oceanic and Atmospheric Administration's California-Nevada River Forecasting Center
DWR	California Department of Water Resources
HEC	U.S. Army Corps of Engineers Hydrologic Engineering Center
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NOHRSC	National Operational Hydrologic Remote Sensing Center
PG&E	Pacific Gas & Electric Company
SWP	California State Water Project
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey

Precipitation-Runoff Processes in the Feather River Basin, Northeastern California, and Streamflow Predictability, Water Years 1971–97

By Kathryn M. Koczot[1], Anne E. Jeton[1], Bruce J. McGurk[2], and Michael D. Dettinger[1]

Abstract

Precipitation-runoff processes in the Feather River Basin of northern California determine short- and long-term streamflow variations that are of considerable local, State, and Federal concern. The river is an important source of water and power for the region. The basin forms the headwaters of the California State Water Project. Lake Oroville, at the outlet of the basin, plays an important role in flood management, water quality, and the health of fisheries as far downstream as the Sacramento-San Joaquin Delta. Existing models of the river simulate streamflow in hourly, daily, weekly, and seasonal time steps, but cannot adequately describe responses to climate and land-use variations in the basin. New spatially detailed precipitation-runoff models of the basin have been developed to simulate responses to climate and land-use variations at a higher spatial resolution than was available previously. This report characterizes daily rainfall, snowpack evolution, runoff, water and energy balances, and streamflow variations from, and within, the basin above Lake Oroville. The new model's ability to predict streamflow is assessed.

The Feather River Basin sits astride geologic, topographic, and climatic divides that establish a hydrologic character that is relatively unusual among the basins of the Sierra Nevada. It straddles a north-south geologic transition in the Sierra Nevada between the granitic bedrock that underlies and forms most of the central and southern Sierra Nevada and volcanic bedrock that underlies the northernmost parts of the range (and basin). Because volcanic bedrock generally is more permeable than granitic, the northern, volcanic parts of the basin contribute larger fractions of ground-water flow to streams than do the southern, granitic parts of the basin. The Sierra Nevada topographic divide forms a high altitude ridgeline running northwest to southeast through the middle of the basin. The topography east of this ridgeline is more like the rain-shadowed basins of the northeastern Sierra Nevada than the uplands of most western Sierra Nevada river basins. The climate is mediterranean, with most of the annual precipitation occurring in winter. Because the basin includes large areas that are near the average snowline, rainfall and rain-snow mixtures are common during winter storms. Consequently, the overall timing and rates of runoff from the basin are highly sensitive to winter temperature fluctuations.

The models were developed to simulate runoff-generating processes in eight drainages of the Feather River Basin. Together, these models simulate streamflow from 98 percent of the basin above Lake Oroville. The models simulate daily water and heat balances, snowpack evolution and snowmelt, evaporation and transpiration, subsurface water storage and outflows, and streamflow to key streamflow gage sites. The drainages are modeled as 324 hydrologic-response units, each of which is assumed homogeneous in physical characteristics and response to precipitation and runoff. The models were calibrated with emphasis on reproducing monthly streamflow rates, and model simulations were compared to the total natural inflows into Lake Oroville as reconstructed by the California Department of Water Resources for April–July snowmelt seasons from 1971 to 1997. The models are most sensitive to input values and patterns of precipitation and soil characteristics. The input precipitation values were allowed to vary on a daily basis to reflect available observations by making daily transformations to an existing map of long-term mean monthly precipitation rates that account for altitude and rain-shadow effects.

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[1]U.S. Geological Survey

[2]Pacific Gas & Electric Company

The models effectively simulate streamflow into Lake Oroville during water years (October through September) 1971–97, which is demonstrated in hydrographs and statistical results presented in this report. The Butt Creek model yields the most accurate historical April–July simulations, whereas the West Branch model yields the least accurate simulations. Accuracy may reflect the quality of the streamflow measurements (or reconstructions) used in the calibration process. The overall simulated inflows to Lake Oroville reproduce reconstructed inflows with relative errors of –9 and –4 percent on monthly and annual time scales, respectively. The root-mean-squared errors of the simulated Lake Oroville inflows are 134,000 and 465,000 acre-feet for monthly and annual time scales, respectively. The accuracy of simulations appears to deteriorate for the period 1998–2000. Signatures of North Pacific decadal climate variations were observed in the Feather River Basin as a shift in the month of maximum streamflow (from April during the cooler Pacific decadal phase to March during the warmer decadal phase). The calibration period was dominated by the warmer (1977–98) phase. Since 1998, the simulations represent years in the newly re-established cool decadal phase. The response of the models to this subtle climatic fluctuation requires more evaluation.

Streamflow predictions for the April–July snowmelt season were made with the Feather River model using a standard “ensemble streamflow prediction” (ESP) methodology. In the ESP methodology, April–July weather records from past years were used to drive the model through its plausible range of April–July streamflow totals for the current year, yielding a probabilistic forecast. Retrospective “predictions” using the ESP method were compared to the actual flows for each year from 1971 to 2000 to evaluate the reliability of the ESP results. These comparisons indicate that ESP-estimated flow probabilities are more accurate for the largest and smallest flows and tend to underestimate the likelihood of intermediate flow rates. Presumably, these comparisons can provide a guide for adjusting the confidence levels for any given ESP forecast in the future.

Introduction

Background

The Feather River Basin, in Plumas, Butte, Lassen, Shasta, and Sierra Counties, California (fig. 1), is a valuable hydrologic resource for California. The basin is a major contributor to the California State Water Project (SWP), and the reservoir at the outlet of the basin, Lake Oroville, represents 8 percent of California’s reservoir capacity [California Department of Water Resources (DWR), 1998, 2000]. Lake Oroville plays an important role in flood management, water quality, and the health of fisheries, affecting areas downstream at least as far south as the Sacramento/San Joaquin River Delta. Two of the basin’s major tributaries have been developed for hydropower with the capacity of generating 3.7 percent of California’s peak daily electrical power demands (Gary Freeman, Pacific Gas & Electric Company, unpub. data, 2000). Improved understanding of how and why the Feather River discharge varies, and how the river responds to changing climatic conditions and land-management actions, will help water managers safeguard this resource.

Precipitation in California occurs principally from November through March, and in that period, water resources managers are responsible for forecasting streamflow, planning and managing reservoirs for winter floods, and measuring snowpack accumulation in basins such as the Feather. DWR managers, in particular, must plan for, and forecast, warm-season water availability. The primary source of warm-season streamflow is melting snow. DWR defines this snowmelt season as April 1–July 31, and assumes April 1 snowpack accumulations represent annual accumulations (California Department of Water Resources, 2000). During the snowmelt season, when flood-generating storms are rare, Lake Oroville receives about 40 percent of the annual total inflow (California Department of Water Resources, 2000).

DWR publishes summaries of warm-season water availability in California each month from February through May (http://cdec.water.ca.gov/snow/bulletin120/, accessed March 12, 2002; California Department of Water Resources, 2000). These summaries include streamflow forecasts for the April through July snowmelt season. Forecasts for the Feather River Basin are based on statistical relations between seasonal (and monthly) inflows to Lake Oroville and observed antecedent and expected streamflow, precipitation, and snowpack conditions. DWR and other water managers use these forecasts to plan summer water deliveries and to schedule releases from reservoirs.

In addition to seasonal forecasts, there is a growing need to improve medium-range (one week to one month) streamflow forecasts. Currently, in the Feather River Basin, DWR is making medium-range forecasts of total streamflow into Lake Oroville, and hydroelectric power operators are using their own suite of statistical models to manage power generation within the basin. Additionally, agricultural, fishery, logging, and local user groups may benefit from improved medium-range forecasts.

Figure 1. Feather River Basin, California, modeled areas, major tributaries and reservoirs, larger towns, county lines, selected peaks and valleys, and stations where streamflow or climate variables used in the models are measured or reconstructed.

In cooperation with DWR and with assistance from Pacific Gas & Electric Company (PG&E, the major hydropower operator in the basin, which provided calibration data and general information on climate and streamflow), physically based models of the Feather River Basin have been constructed and calibrated. The models were developed to simulate responses to climate and land-use variations at a higher spatial resolution than existing statistical or lumped models. Furthermore, by incorporating more information about the basin physical characteristics than is possible in statistical models, the physically based models may improve forecasts and increase understanding of the basin hydrology. The models are designed to simulate streamflow responses to variations of temperature, precipitation, and land cover, and are currently focused on simulating April–July streamflow totals.

Purpose and Scope

This report documents the distributed-parameter, physically based, Precipitation-Runoff Modeling System (PRMS; Leavesley and others, 1983) constructed for the Feather River Basin. The Feather River PRMS is composed of eight models representing eight drainages of the basin. Together, these models simulate streamflow from 98 percent of the basin above Lake Oroville. This report characterizes the Feather River watershed precipitation, temperature, snowpack evolution, and water and energy balances that determine streamflow rates from, and within, the basin above Lake Oroville. It further documents the new models developed to assess the (physically based) predictability of seasonal inflows to Lake Oroville.

Previous Studies

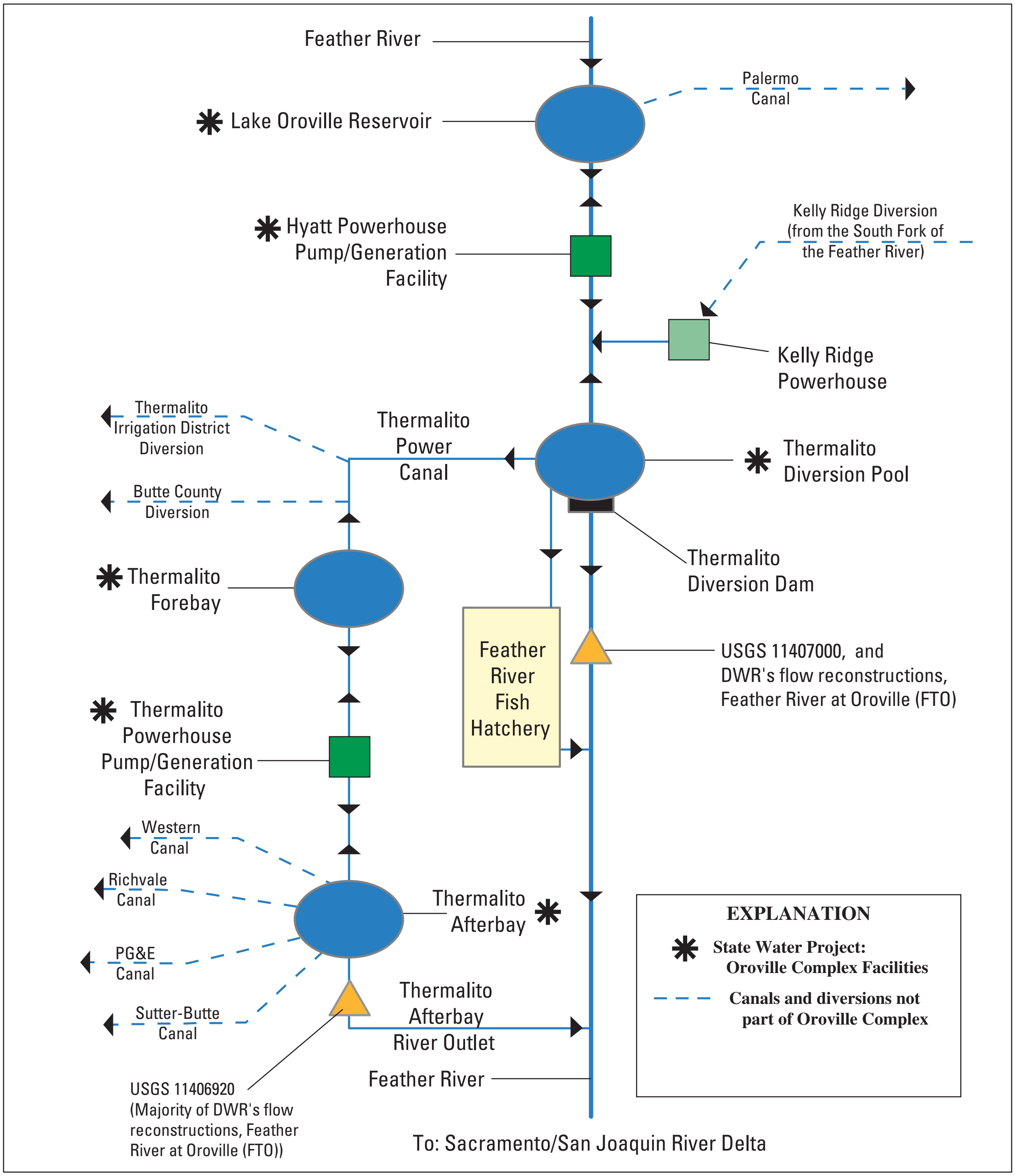
Lake Oroville storage and releases are a key part of the hydropower and water-supply facilities of the Oroville Complex (figs. 1 and 2; Sabet and Creel, 1991), which is a cornerstone and major source of flexibility of the SWP. The Oroville Complex is used to balance energy and resource demands so that SWP power contracts are satisfied with strategically timed power sales, reserve power capacity is maintained, and SWP water deliveries are met. Other uses of the Oroville Complex include flood control, irrigation, recreation, fish and wildlife enhancements, and reservoir releases to maintain downstream Feather River, Sacramento River, and Sacramento–San Joaquin Delta water-quality standards.

Many different methods have been developed and are used to forecast inflows to Lake Oroville. To put the modeling effort described herein into perspective, it is necessary to briefly review previous hydrologic modeling studies of the Feather River and other applications of the Precipitation-Runoff Modeling System (PRMS; Leavesley and others, 1983) modeling code used here.

Several statistical (regression) models are used by PG&E to simulate streamflow in the North Fork, South Fork, and West Branch of the Feather River Basin (fig. 1) for various timeframes. A monthly model (run from about January through August) is used to predict annual runoff based on antecedent runoff and on wetness-dependent scenarios of future runoff (based on historical analogs) to complete the year. The predicted annual totals are then disaggregated into monthly natural runoff amounts on the basis of historical flow patterns. PG&E also uses a daily statistical runoff model that combines recent estimates of daily (natural) flows with 10 days of weather forecasts followed by historical median precipitation rates to predict daily runoff. The model is calibrated to the existing record by a least-squares fitting technique.

The National Oceanic and Atmospheric Administration (NOAA) California-Nevada River Forecasting Center (CNRFC; http://www.wrh.noaa.gov/cnrfc/, accessed on Jan. 6, 2000) employs the National Weather Service River Forecasting System (NWSRFS) for flood and water-supply forecasting for the Feather River Basin. This system includes the Sacramento Soil Moisture Accounting Model (Burnash and others, 1973) and a snow accumulation and ablation component (Anderson, 1973). The physically based model spatially lumps basin characteristics and processes into two altitude bands within which snow is expected to accumulate and not accumulate, respectively. The model is calibrated for discharges at the Lake Oroville Dam (Miller and others, 2001). Daily, weekly, and seasonal streamflow forecasts are made using the Ensemble Streamflow Prediction (ESP) method (Day, 1985). ESP develops an ensemble of forecast scenarios by combining current model conditions (observed initial conditions) with temperature and precipitation observations from previous years. This procedure yields a probabilistic distribution of possible outcomes that can be analyzed by the forecaster.

DWR uses statistical models to forecast April through July and water-year volumes of estimated natural inflow to Lake Oroville. These forecasts generally are updated weekly from February through June. Forecasts are issued for probability levels ranging from 99 percent exceedence to 10 percent exceedence based on historical distributions of precipitation, snowpack accumulation, and model error subsequent to the forecast date. Snow-water content from 22 snow courses, 10 snow sensors, 8 precipitation gages, and prior runoff from the Feather River Basin have been regressed against historical runoff volumes to develop the DWR prediction model. Specifically, data from each station are divided by its historical mean (50-year average), then weighted (in the case of precipitation) by month, averaged for a group of stations for each basin, and raised to a power (if needed) to account for a nonlinear relation with runoff. The resulting basin indices of precipitation, snowpack, and prior runoff are used as predictors of runoff in a linear equation developed as a multiple linear regression (J. Pierre Stephens, DWR Resources Hydrology Branch, unpub. data, 2002). This same technique is used for about 30 other basins within California.



Modified from Sabet and Creel, 1991, and Rockwell and others, 1997.

Figure 2. Oroville Complex water-supply and hydropower facilities (including Lake Oroville), other improvements downstream from Lake Oroville including diversions for irrigation, and the locations of the U.S. Geological Survey streamflow stations from which monthly estimates of inflow to Lake Oroville are derived. The irrigation diversions and canals are NOT part of the Oroville Complex. Only the labels with an asterisk are part of the Oroville Complex. See Appendix A for components of reconstructed streamflow at the Feather River at Oroville (FTO).

The DWR forecasts streamflow for 1 to 20 days with physically based models that use observed and predicted precipitation and temperatures. The physically based models track snow and ground water in the basin. The models include HED71, which was developed by DWR (Buer, 1988) and the NWSRFS. During the spring snowmelt season, this latter model is operated in ESP mode for forecast leads of 20 or more days by blending 7 days of weather forecasts with historical weather traces. Previously, flood forecasting was done with other models, including U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) models and predecessors of the NWSRFS (J. Pierre Stephens, DWR Resources Hydrology Branch, unpub. data., 2002). Network flow modeling also has been used to simulate hydraulic operation and hydropower generation in the Oroville Complex on weekly and daily time scales (Sabet and Creel, 1991).

To run these various models, climate and hydrologic data are collected by DWR, PG&E, and others. Precipitation, air temperature, streamflow, and snow accumulations are routinely monitored in the basin. Some of these data are accumulated through the California Cooperative Snow Surveys Program (CCSS) and are made available to the public through the California Data Exchange Center (CDEC) web page (http://cdec.water.ca.gov).

Application of PRMS to the Feather River Basin was started in October 1996 by Bruce McGurk, under a grant from the DWR CCSS to the U.S. Department of Agriculture (USDA) Forest Service, Pacific Southwest Experiment Station. The goal was to develop a model of the five major forks of the Feather River to make historical and up-to-date predictions of daily inflows to Lake Oroville. Model areas were delineated and essential model parameters were estimated. In April 1997, an incomplete model was transferred to PG&E, and the goal was modified to include real-time updating of model inputs from telemetered data available to PG&E in all drainages except the Middle Fork of the Feather River. Natural streamflow records, which are not available publicly but required for calibration, were estimated by PG&E. Changes in management priorities and the approaching deregulation of the California energy market ended PG&E's efforts to develop this PRMS. In July 1999, PG&E provided data and parameter values to U.S. Geological Survey (USGS) staff, under a cooperative agreement with CCSS, for completing a model of the entire basin above Lake Oroville.

PRMS has been applied successfully in many settings, including basins in Colorado (Brendecke and Sweeten, 1985; Parker and Norris, 1989; Norris and Parker, 1985; Norris, 1986; Kuhn, 1989; Ryan, 1996), Kentucky (Bower, 1985), Montana (Cary, 1984), New Mexico (Hejl, 1989), North Dakota (Emerson, 1991), Oregon (Risley, 1994),West Virginia (Puente and Atkins, 1989), and Wyoming (Cary, 1991). PRMS models have been used to explore basin responses to climatic change (Hay and others, 1993; Ryan, 1996; Jeton and others, 1996; Wilby and Dettinger, 2000) and to land-cover changes (Puente and Atkins, 1989; Risley, 1994). PRMS has been used to model alpine basins of the Sierra Nevada that have physical characteristics similar to those of the Feather River Basin (Jeton and Smith, 1993; Jeton and others, 1996; Jeton, 1999a,b; Wilby and Dettinger, 2000). Knowledge gained in previous work, and especially in the construction and implementation of the other Sierra Nevada PRMS models (including parameter settings), was used to develop the Feather River PRMS models.

Acknowledgments

The authors gratefully acknowledge the diligent and patient assistance of Steven Markstrom and Roland Viger, USGS Denver, who provided modeling and geographic information system (GIS) computer programs and direction that made this modeling effort possible. Frank Gehrke, Chief of California Cooperative Snow Surveys at DWR, provided data, guidance, and motivation for this undertaking. Pierre Stephens of the DWR Resources Hydrology Branch provided vital information about DWR streamflow reconstructions, current streamflow forecasting methods, and the operation of the Oroville Complex. Pacific Gas & Electric Company, through Gary Freeman and co-author Bruce McGurk, provided climate data, reconstructed streamflows, and much guidance that made the study possible. The study was conducted by the USGS in cooperation with the California Department of Water Resources Cooperative Snow Surveys Program. Comparison of simulated and remotely sensed snow cover was funded through the National Aeronautics and Space Administration (NASA) Earth Science Information Partnership "Snow SIP" project at Scripps Institution of Oceanography.

Physical Characteristics of the Feather River Basin

Location and Land Cover

The Feather River above Lake Oroville drains about 3,600 mi^2 of the western slopes of the Sierra Nevada mountain range, between the Upper Sacramento and Yuba River Basins, north of Lake Tahoe and generally northeast of the city of Oroville, California (fig. 1). The Feather River Basin is bounded by Mt. Lassen to the northwest and the Diamond Mountains to the northeast. Altitudes range from about 843 ft at Oroville Dam to 9,525 ft near Mt. Lassen. Fifty-nine percent of the basin lies below the current average snowline altitude of 5,500 ft (fig. 3). The largest towns are Portola (population 2,227), Quincy (population 1,879), and Chester (population 2,316), according to the population census of 2000.

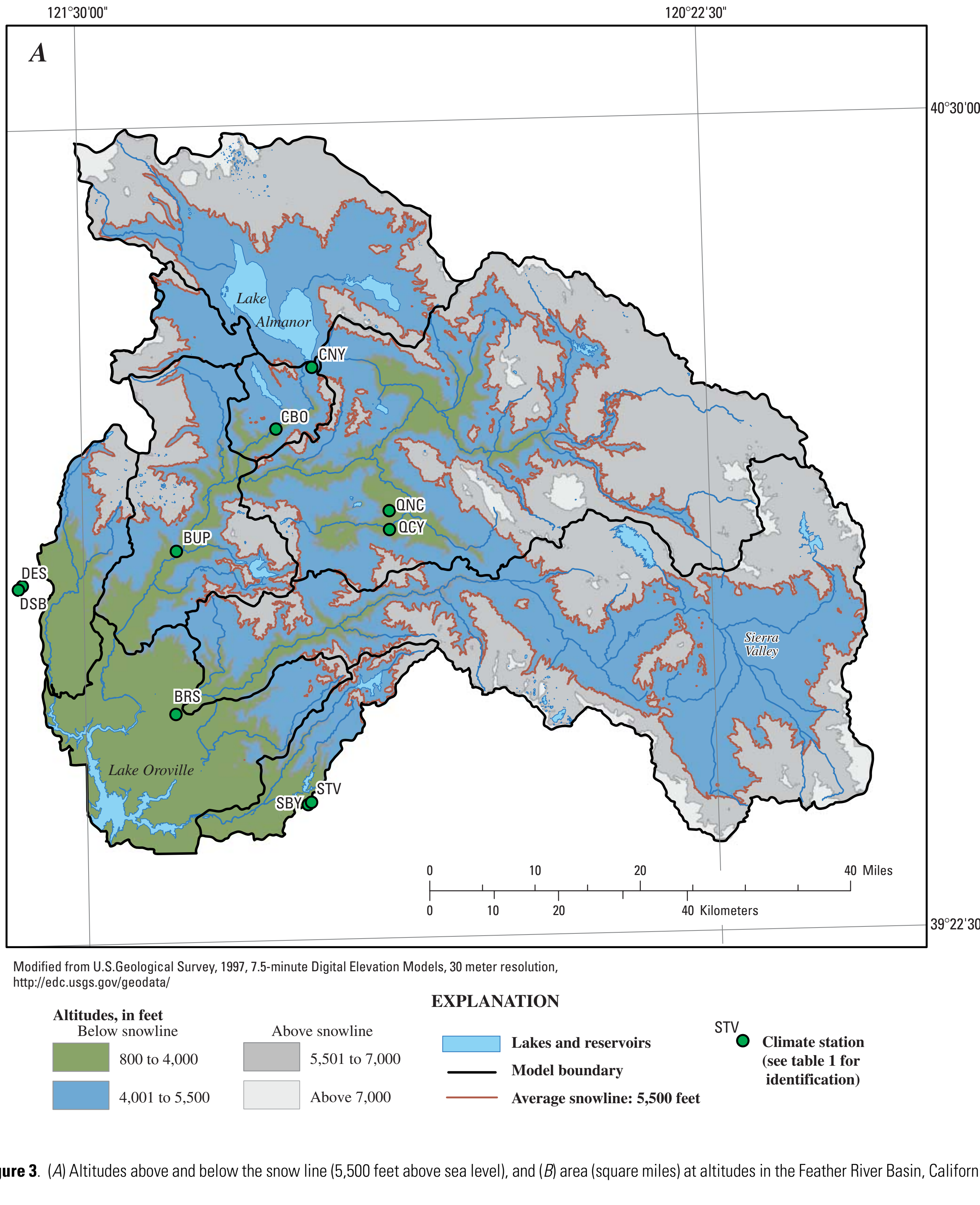


Figure 3. (*A*) Altitudes above and below the snow line (5,500 feet above sea level), and (*B*) area (square miles) at altitudes in the Feather River Basin, California.

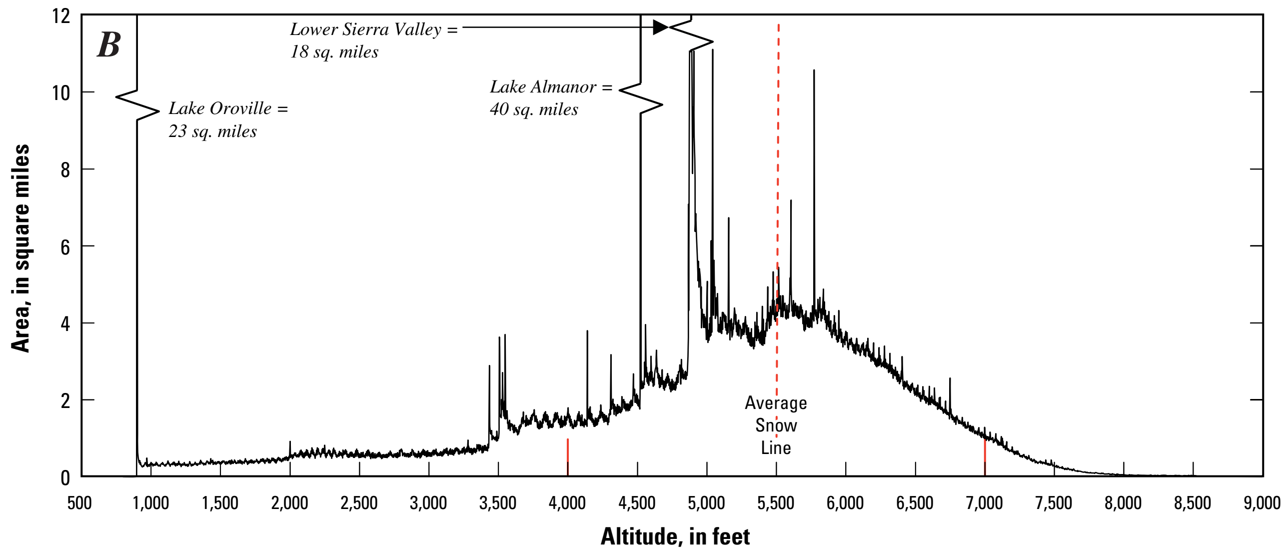


Figure 3.—Continued.

The Feather River Basin is drained by five major tributaries. Four of these—West Branch, North Fork, Middle Fork, and South Fork—flow directly into Lake Oroville. The fifth—the East Branch—is tributary to the North Fork, terminating near Belden (fig. 1). Where Lake Oroville now exists, the West Branch was once tributary to the North Fork, and therefore the designation for this western tributary remains "branch." The North and South Forks have been extensively engineered for hydropower generation, and numerous dams, reservoirs, penstocks, tunnels, and canals routinely move water from place to place (fig. 4). The largest reservoir is Lake Almanor (25,582 acres or 40 mi^2) on the North Fork.

Vegetation cover is predominantly coniferous trees, with some areas of shrubs and grasses mostly in the agricultural valleys (fig. 5). The basin contains parts of the Plumas, Lassen, and Tahoe National Forests, which include an active timber industry along the North Fork. There are two large irrigated agricultural areas in the basin (mapped in fig. 5 as shrubs and grasses)—Sierra Valley, east of Portola at the Middle Fork headwaters (149 mi^2), and Indian Valley in the East Branch drainage area (about 19 mi^2).

Geology and Soils

The Feather River Basin is located astride a north-south geologic transition in the Sierra Nevada—the transition between granitic bedrock that underlies and forms most of the central and southern Sierra Nevada and volcanic bedrock that underlies the northernmost parts of the Sierra Nevada and the Basin and Range Province (fig. 6*A*). In the Feather River Basin, volcanic rocks dominate in the north and west, and granitic and sedimentary rocks dominate in the south (Durrell, 1987; fig. 6*A*). The higher permeability of the volcanic rocks (Freeze and Cherry, 1979, table 2.2) allows more deep percolation of water and greater ground-water flow contributions to tributaries in the northern part of the basin. In PRMS, the ground-water flow is considered to be from the slower subsurface pathways beneath the local water table to the streams.

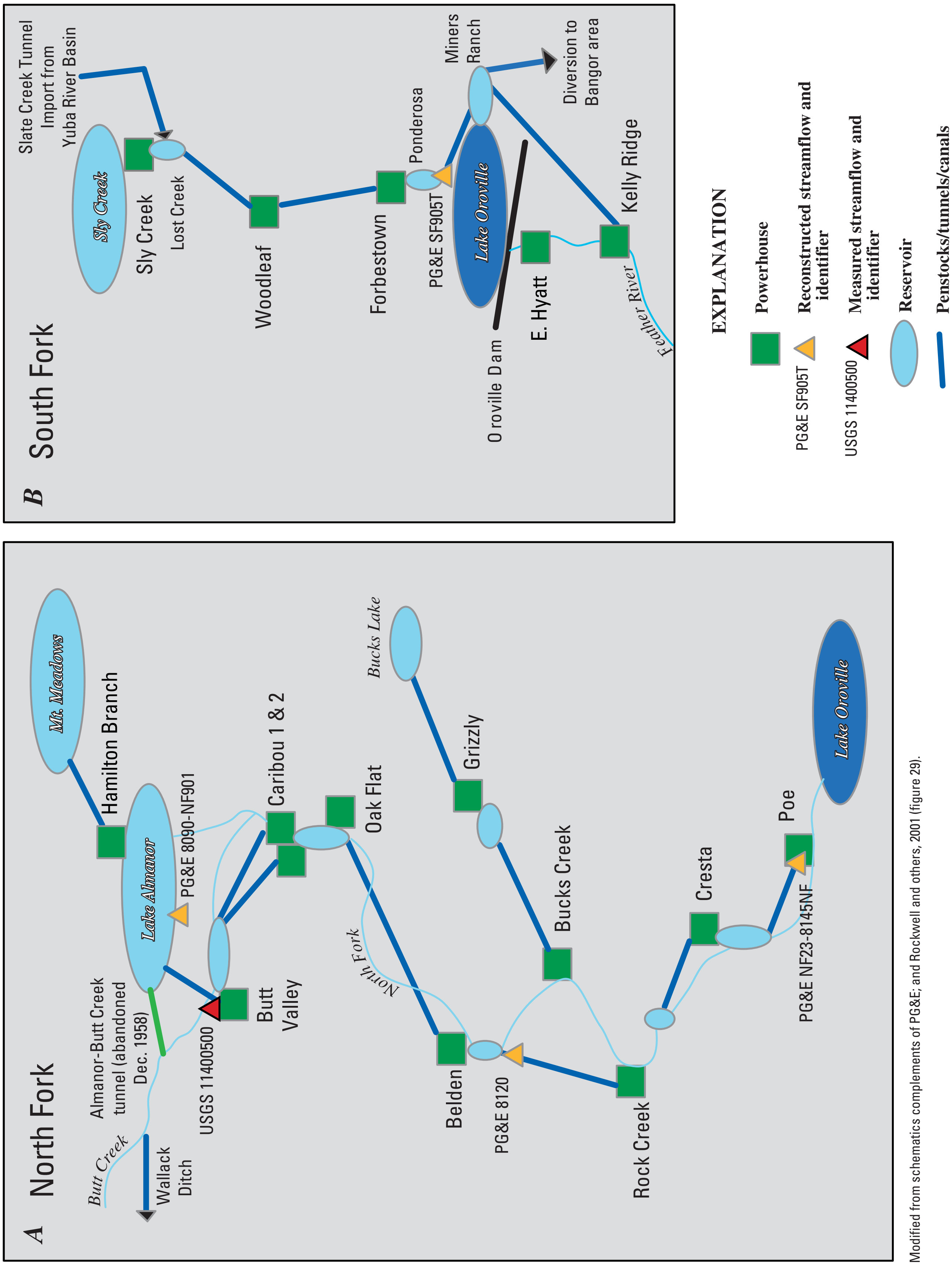
In this study, geology (Jennings and others, 1977; fig. 6*A*) is classified according to how it affects surface runoff, infiltration, and the transmission of water to streams. The classes are (1) volcanic formations (pyroclastic flows and volcanic mudflows); (2) sedimentary formations (shales, dolomites, Quaternary alluvium, playas, terraces, glacial till and moraines, marine and non marine sediments); and (3) intrusive igneous formations (granites and ultramafics). Volcanic formations are assumed to have the highest permeability (Freeze and Cherry, 1979, table 2.2) and contribute the highest amount of ground water to streams. Sedimentary formations, considered more permeable than igneous and less so than volcanic, are assumed to contribute water to streams from ground water, subsurface flow, and surface runoff. In PRMS, the subsurface flow is considered to be the pathways the soil-water excess takes in percolating through shallow unsaturated zones to stream channels, arriving at streams above the water table, and surface runoff is considered to be directly from snowmelt and rainfall. Intrusive igneous formations are considered to be the least permeable and assumed to produce the highest surface runoff rates to streams.

In this study, soil texture is categorized according to how it affects the transmission of water through the soil profile to streams, and how much storage of water it provides for evapotranspiration. Sand has a faster percolation rate than silt. In this study, the presence of vegetation cover (fig. 5) is assumed to indicate loam. Soil texture is presented in figure 6*B* (U.S. Department of Agriculture Forest Service, 1988, 1993, 1994; U.S. Environmental Protection Agency, 1998; http://www.essc.psu.edu/soil_info/index.cgi?soil_data&statsgo at 1:250,00 scale, accessed on Jan. 6, 2000).

Hydroclimatology

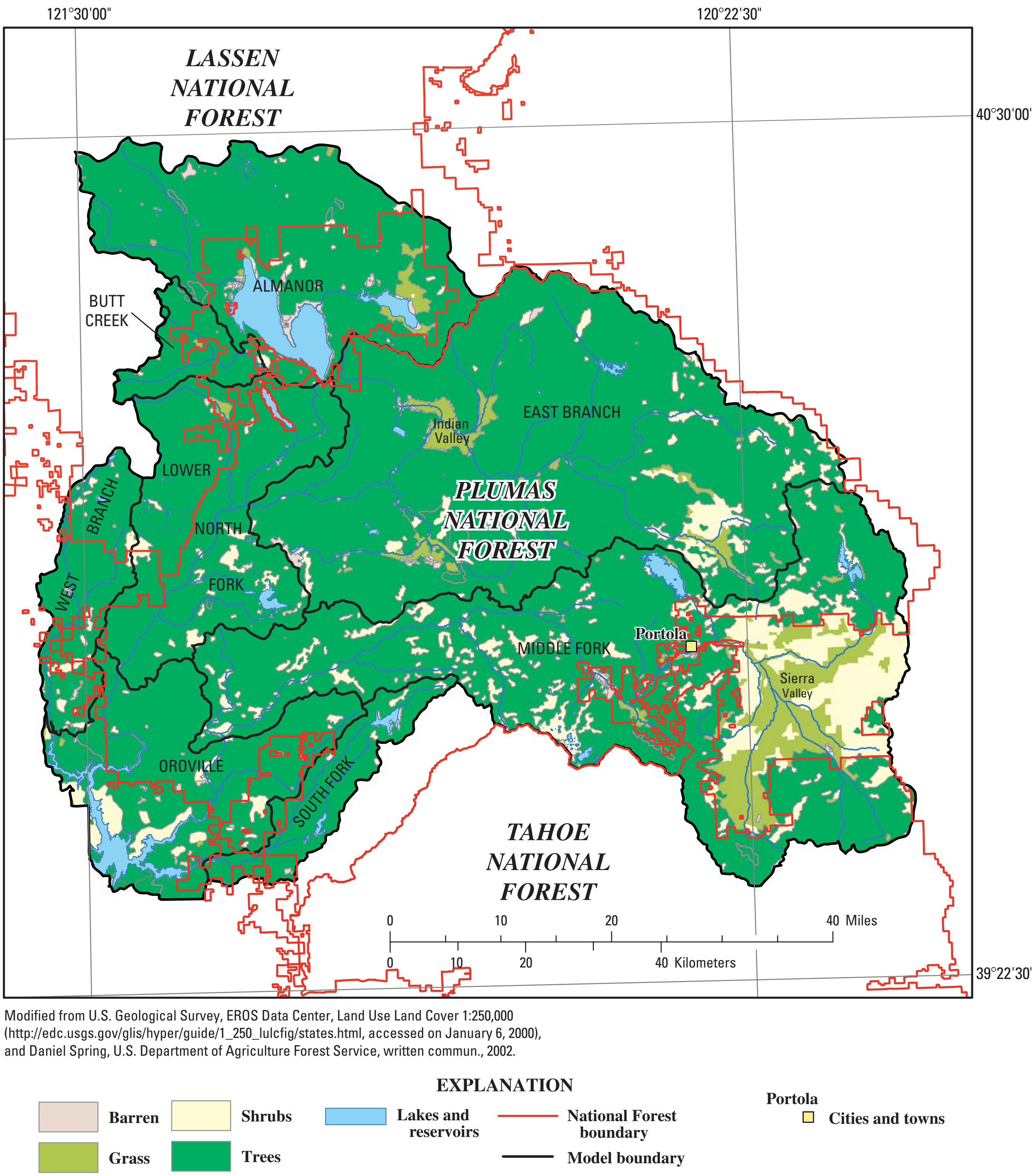
The Feather River Basin has a mediterranean climate, with warm, dry summers and cool, wet winters and springs. Precipitation occurs mostly during the cool season (winter and spring) and, in the higher altitudes, mostly as snow. Most of the basin lies at altitudes where winter temperatures can easily vary from below to above freezing. Therefore, streamflow fluctuations in the basin may be as dependent on temperatures as they are on precipitation rates, because snowmelt and the form of precipitation (rain, snow, or a mixture of both) are temperature dependent. Both precipitation and temperatures must be understood in order to characterize streamflow in this basin.

Data from 10 climate stations measuring temperature and/or precipitation and 2 stations measuring pan evaporation were used in this study (fig. 7; table 1). PRMS requires inputs of daily precipitation and daily maximum and minimum temperatures. Evaporation measurements, which are not required as input to PRMS, were used to gain an understanding of potential evaporation rates in the area. Station data may be retrieved from the California Data Exchange Center (CDEC) web page (http://cdec.water.ca.gov, accessed March 12, 2002) or from PG&E. CDEC is intended to provide access to data for immediate use, but most data are not reviewed. PG&E provides data for Bucks Creek Powerhouse (temperature and precipitation), Caribou Powerhouse (precipitation), and Canyon Dam (temperature).



Modified from schematics complements of PG&E; and Rockwell and others, 2001 (figure 29).

Figure 4. North Fork and South Fork Feather River powerhouses and locations of reconstructed streamflow, Feather River Basin, California.



Modified from U.S. Geological Survey, EROS Data Center, Land Use Land Cover 1:250,000 (http://edc.usgs.gov/glis/hyper/guide/1_250_lulcfig/states.html, accessed on January 6, 2000), and Daniel Spring, U.S. Department of Agriculture Forest Service, written commun., 2002.

Figure 5. Vegetation cover types and National Forests in the Feather River Basin, California.

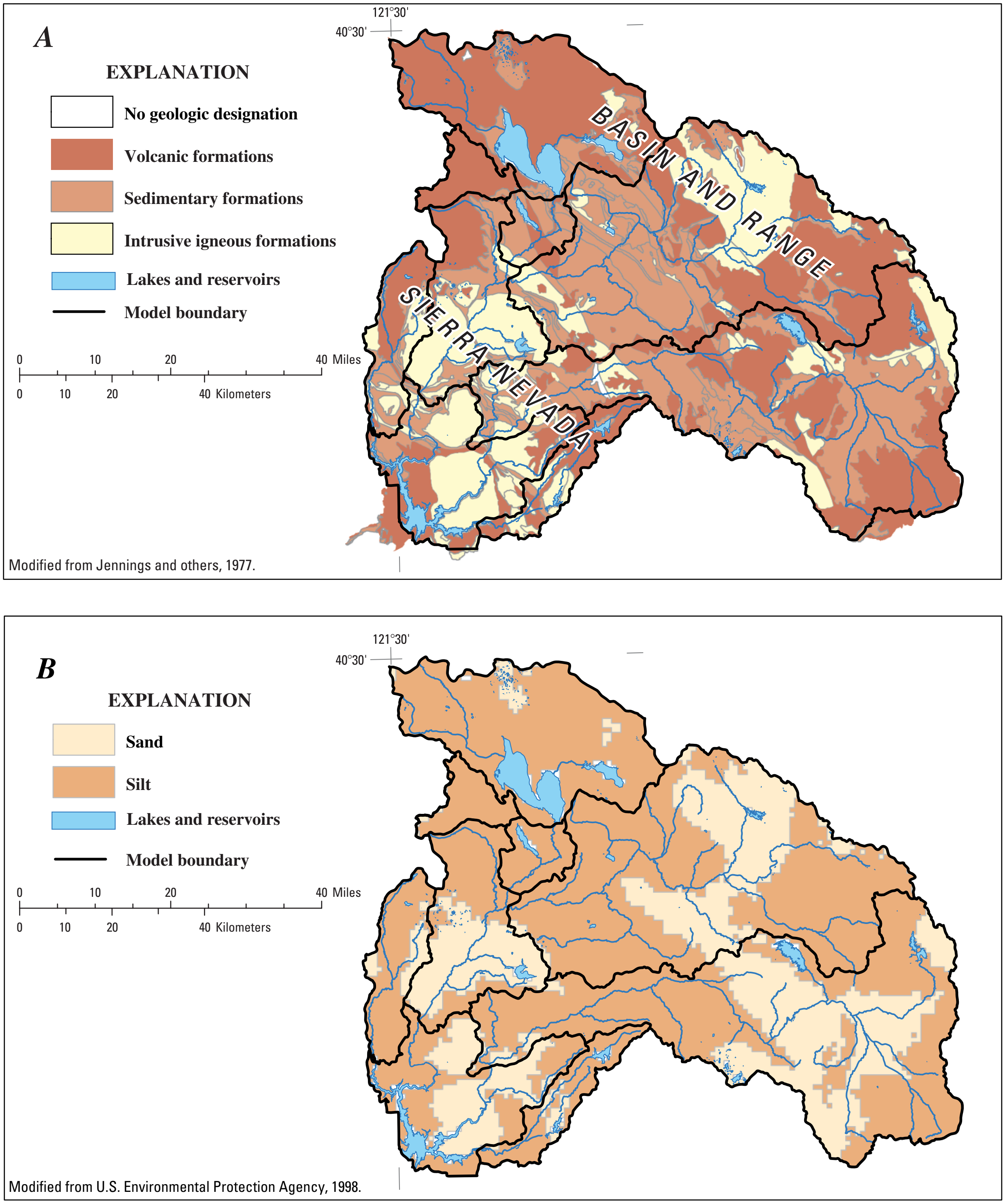
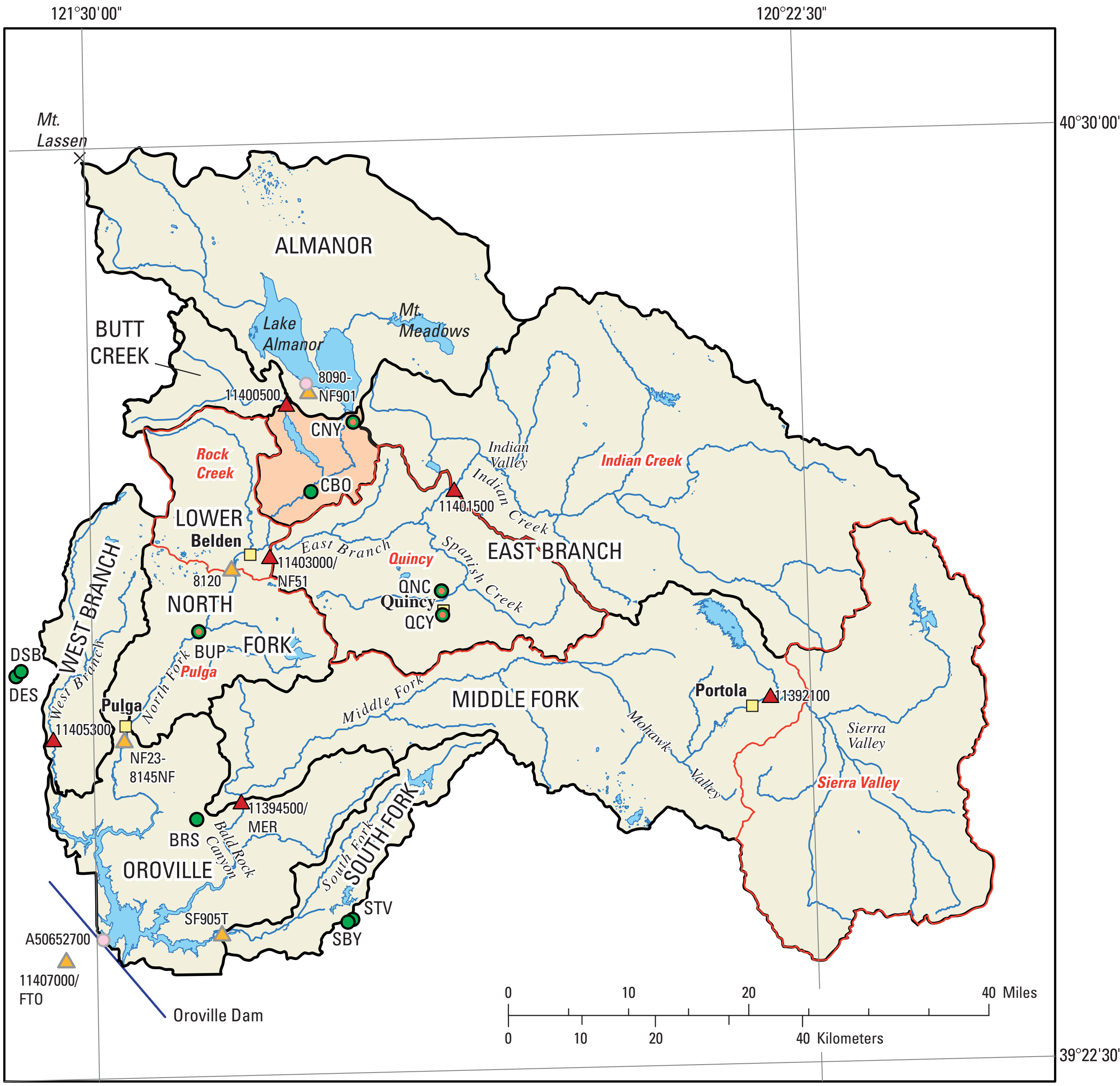


Figure 6. (*A*) Geology and (*B*) soil texture of the Feather River Basin, California.



Modified from the California State Water Resources Control Board Basin Plain Maps, The California Watershed Map CALWATER version 2.0, 1:500,000, subbasins, catchments, and planning watershed area units.

Figure 7. Modeled areas and supporting catchments, and streamflow and climate stations, in/near the Feather River Basin, California.

Table 1. Climate stations used in Precipitation-Runoff Modeling System (PRMS) models for the Feather River Basin, California. Pan evaporation stations are not listed.

[See figs. 3 or 7 for locations of climate stations. CDEC, California Data Exchange Center; DWR, California Department of Water Resources; PG&E, Pacific Gas and Electric; RS, Ranger Station; USFS, U.S. Forest Service; NOAA, National Oceanic and Atmospheric Administration; ft asl, feet above sea level]

Model	Temperature			Precipitation[1]			
	Climate station name	Identifying designation	Source of data	Climate station name[2]	Identifying designation	Station altitude (ft asl)	Source of data
Almanor	Canyon Dam	CNY	PG&E				
Butt Creek	Canyon Dam	CNY	PG&E	Brush Creek (DWR)	BRS	3,560	CDEC website
				Bucks Creek Powerhouse	BUP	1,760	PG&E
East Branch	Quincy RS (USFS)/ Quincy (DWR)	QNC to 9/30/97 thereafter QCY	CDEC website	Canyon Dam	CNY	4,560	CDEC website
				Caribou	CBO	2,986	PG&E
				Desabla (PG&E)	DSB	2,710	CDEC website
Lower North Fork	Bucks Creek Powerhouse	BUP	PG&E	Desabla (DWR)	DES	2,710	CDEC website
				Quincy (DWR)	QCY	3,408	CDEC website
Middle Fork	Quincy RS (USFS)/ Quincy (DWR)	QNC to 9/30/97 thereafter QCY	CDEC website	Quincy RS (USFS)	QNC	3,420	CDEC website
				Strawberry-NOAA	STV	3,808	CDEC website
				Strawberry-DWR	SBY	3,810	CDEC website
South Fork	Bucks Creek Powerhouse	BUP	PG&E				
West Branch	Bucks Creek Powerhouse	BUP	PG&E				
Oroville	Bucks Creek Powerhouse	BUP	PG&E				

[1]All precipitation stations are used in the procedure to compute model input from PRISM surfaces.

[2]Many precipitation records are ‘spliced.’ Early manual gages were replaced by telemetered gage (BUP), or manual gage supplemented by telemetered gage (Brush Creek RS (BCR)/BRS, DSB/DES, QNC/QCY, STV/SBY). Monthly precipitation totals from these pairs commonly differ by 10 percent. For example, QCY is significantly wetter than QNC.

The streamflow simulations developed in this study were calibrated against data from daily measured or reconstructed-streamflow stations (fig. 7; table 2). These sites include data from five catchments. In this study, catchments are subdrainages with measured streamflow used to establish initial parameter settings in some of the models. These records were provided by USGS (http://waterdata.usgs.gov/nwis, accessed March 12, 2002), PG&E (proprietary), and DWR (http://cdec.water.ca.gov/, accessed March 12, 2002).

The USGS rates the accuracy of its streamflow records on the basis of (1) the stability of the stage-discharge relation, (2) the accuracy of measurements of stage and discharge, and (3) the interpretation of records (Bonner and others, 1998). Accuracy levels of "good" indicate that about 95 percent of the daily discharges are within 10 percent of their true values. "Fair" indicates that 95 percent of the daily discharges are within 15 percent (Bostic and others, 1997).

Because PG&E has proprietary knowledge of the hydropower operations along the North and South Forks, PG&E reconstructed natural streamflows for some of the model areas. The proprietary reconstructed streamflows provided by PG&E for the Almanor, Lower North Fork, and South Fork drainages were computed using mass-balance calculations cross-referenced against nearby measured natural flows (for example, at Butt Creek). Daily flows from the Almanor drainage were estimated, from measured daily changes in lake storage and outflow, as apparent inflows to the lake. Reconstructed flows were accumulated in downstream directions and corrected for intervening diversions and impoundments to reconstruct natural flow at six gaging locations. PG&E estimates the accuracy of the reconstructed flows to be about 15 percent.

Total natural inflows to Lake Oroville were needed for comparison with the total simulated inflow, which is a summation of results from the eight models. Because natural daily inflow was not available, monthly reconstructions from DWR (Feather River at Oroville, FTO) were used (http://cdec.water.ca.gov). The FTO inflow station (http://cdec.water.ca.gov, accessed on March 12, 2002) is referenced to USGS gaging station 11407000 (fig. 2). The monthly FTO reconstructions were computed by DWR using measurements from USGS gaging stations 11407000, 11406920 (figs. 2 and 7, Appendix A) and many other gages. Monthly reconstructions include corrections for streamflow regulation above the gage (including exports, imports, and diversions for power and irrigation) and changes in storage and evaporation in the larger reservoirs. Imports from the Yuba and Little Truckee Rivers (fig.1 and 4) were explicitly taken into account. Prior to construction of the Oroville Dam and the Thermalito Complex downstream (in 1967, fig. 2), the 11407000 gage was located a few miles farther upstream with 17 mi^2 less contributing area (Markham and others, 1996). Although gaged streamflows in canals, releases from dams, and reservoir storage probably are accurate to within several percent most of the time, other aspects of the reconstructions, such as evaporation and assumed consumptive use, are much more uncertain. According to J. Pierre Stephens of CCSS, when streamflows exceed the Thermalito Powerhouse capacity (fig. 2), large flows are released at the Thermalito Diversion Dam. The net effect of moving the gage, and measurement accuracy, consumptive-use estimates, and regulation during high flows on reconstruction accuracy is uncertain. The USGS has not quantified the accuracy of the FTO reconstructions. However, DWR assumes that the calculated monthly reconstructed streamflow at FTO is within 5 to 10 percent of its true value most of the time (J. Pierre Stephens, DWR Resources Hydrology Branch, unpub. data, 2001).

Climate

The most significant limitation in the practice of snowmelt-runoff modeling is the scarcity of climate data and the need to extrapolate point measurements to areal values. Comparisons of snowmelt-runoff simulation models, which were made in 1986 (World Meteorological Organization, 1986), indicate that the distribution and temperature-dependent form of precipitation were the most important factors in producing accurate estimates of runoff volume. The orographic effect of increasing precipitation with increasing altitude can cause significant spatial variations of precipitation. Usually, these are accommodated by specifying long-term mean precipitation relations to altitude. However, the spatial variations in the relations may be large (Leavesley, 1989). Besides precipitation amount, snowpack modeling also requires that precipitation form be specified on a daily basis.

In PRMS, precipitation form (rain or snow) is dependent on daily temperatures and controlled by setting a snow-threshold temperature. Precipitation is assumed to be snow when the maximum daily temperature is below this threshold, and rain when the minimum temperature is above it. At intermediate temperatures, precipitation is computed in PRMS to be a mix of rain and snow. Temperature generally decreases with increasing altitude except where and when temperature inversions develop. In PRMS, temperature measurements are extrapolated over a basin by assuming a fixed lapse rate (the rate of temperature decrease upward through the atmosphere). In PRMS, constant monthly maximum and minimum temperature lapse rates are specified. However, these constants generally do not reflect the actual variability observed in daily lapse rates (Leavesley, 1989).

Table 2. Streamflow stations used in watershed modeling of the Feather River Basin, California.

[ID, identifying designation; mi^2, square miles. PG&E, Pacific Gas and Electric; USGS, U.S. Geological Survey; DWR, California Department of Water Resources]

Model	Sub-drainage model[1]	Model ID	Station name	ID[2]	Gaged area (mi^2)	Source of streamflow data	Collection method	Reconstructed-streamflow modification	Daily record used in study
Almanor		AC	Inflow above Almanor Canyon Dam	8090-NF901	488	PG&E	Reconstructed	At headwaters, no modification	10/1/69–9/30/97
Butt Creek		BC	Butt Creek below Almanor—Butt Creek Tunnel, near Prattville	11400500	69	USGS	Measured[3]		10/1/64–10/31/2001
East Branch		EB	East Branch of North Fork Feather River near Rich Bar, California/Flow at NF51 E. Branch NF Feather	11403000/NF51	1,025	USGS/PG&E	Measured		10/1/50–9/30/61 and 12/1/67–9/30/82, 10/1/82–10/31/2001
	Indian Creek	IC	Indian Creek near Crescent Mills	11401500	738	USGS	Measured		10/1/50–9/30/93
	Quincy	QC			287	USGS/PG&E	Reconstructed	QC flow = EB flow – IC flow	10/1/50–9/30/93
Lower North Fork		LO	Inflow above NF23-8145NF at Pulga	NF23-8145NF	290	PG&E	Reconstructed	LO flow = NF23-8145NF flow – EB flow –BC flow – AC flow	10/1/69–9/30/97
	Rock Creek	RC	Inflow above Rock Creek Diversion Dam	8120	112	PG&E	Reconstructed	RC flow = 8120 flow – EB flow –BC flow –AC flow	10/1/69–9/30/97
	Pulga	PC			178	PG&E	Reconstructed	PC flow = LO flow – RC flow	10/1/69–9/30/97
Middle Fork		MF	Middle Fork Feather River near Merrimac	11394500/MER	1,046	USGS/DWR	Measured		10/1/51–9/30/86, 10/1/86–10/31/2001
	Sierra Valley	SV	Middle Fork Feather River near Portola	11392100/no DWR ID	590	USGS/DWR	Measured		10/1/70–9/30/86
South Fork		SF	South Fork Outlet	SF905T	107	PG&E	Reconstructed	At headwaters, no modification	10/1/69–9/30/97
West Branch		WB	West Branch Feather River near Paradise	11405300	110	USGS	Measured		10/1/57–9/30/86

Table 2. Streamflow stations used in watershed modeling of the Feather River Basin, California—Continued.

[ID, identifying designation; mi^2, square miles. PG&E, Pacific Gas and Electric; USGS, U.S. Geological Survey; DWR, California Department of Water Resources]

Model	Sub-drainage model[1]	Model ID	Station name	ID[2]	Gaged area (mi^2)	Source of streamflow data	Collection method	Reconstructed-streamflow modification	Daily record used in study
Oroville		OR	No daily measured or reconstructed data	—	—	—	—		—
			Feather River at Oroville/Total inflow to Lake Oroville[4]	11407000/FTO	3,600	USGS/DWR	Reconstructed	Full basin, no modification	10/01/1901–11/2001 (monthly record)

[1]Used to develop parameter settings for the larger model, but not part of the final suite of models.

[2]See figure 7 for location.

[3]Measured at each gaging station as noted.

[4]Provided by DWR (computed using a water-budget approach), reconstructed from gage data measured below Thermalito Diversion Dam. These monthly values are compared with the combined simulated inflow from the PRMS models.

Spatial variation of temporal statistical means of precipitation and temperatures, and deviations of precipitation and temperature around their long-term means, must be specified when constructing watershed models. Spatial variations of the means are represented in PRMS through precipitation and temperature correction factors for each modeled area, which typically are specified as lapse rates to account for altitude differences. Deviations around the means are represented by imposing daily variations at each modeled area that are proportional (for precipitation), or additive (for temperatures), to the daily weather series from specified climate stations.

To allow for future real-time applications, data from climate stations that reported measurements on a daily basis were preferred for the Feather River PRMS models. Ten daily real-time climate stations were used for this study. All ten report real-time precipitation. Of these, one station manually reports daily precipitation measurements, and nine are telemetered. Three of the telemetered stations are also manually observed. Temperature is reported on a real-time basis at three of the ten climate stations. Temperature and precipitation data measured at these 10 climate stations were used in this study (fig. 7; table 1). The period of record began as early as October 1, 1937, but most records span 1969 to October 1, 2001.

The climate stations available for this study are concentrated on the western, wetter side of the basin, below Lake Almanor (figs. 7, 8). Therefore, some bias toward higher precipitation probably exists (fig. 8*A*). Also, the three temperature stations used in this study (fig. 7, table 1), are located in lower altitude, warmer areas so that biases in temperature may exist. Increasing the number and distribution of real-time data-collection stations could improve model accuracy and streamflow prediction performance.

Precipitation

The Feather River Basin receives about 45 in. of precipitation per year, as interpolated by the Parameter-Elevation Regressions on Independent Slopes Model (PRISM) of Daly and others (1994; 30-year mean-average, 1961–90). Annual precipitation varies from a low of 13 in. on the rain-shadow side of the Sierra Nevada in the Middle Fork headwaters, to a high of 125 in. near Mt. Lassen (in the upper reaches of the North Fork in the Almanor drainage; fig. 8*A*). The drier areas are in the southeastern third of the basin (fig. 8*A*). These include Lake Oroville and areas to the east, the eastern half of the East Branch, and most of the Middle Fork. The wettest areas, which can receive more than 85 in. per year, are near Mt. Lassen and in a band immediately above Lake Oroville. The wettest areas include the headwaters of West Branch, Bucks Lake, Table Mountain, and La Porte Bald Mountain, all of which are about 6,000 ft above sea level (asl) (figs. 3, 8*A*). An intermediate amount of precipitation falls in the middle of the basin and around the Lake Oroville drainage.

Monthly patterns of precipitation are generally similar to the annual pattern (selected months shown in figs. 8*B–E*; Daly and others, 1994). In October, precipitation averages 1 to 2 in. in the eastern drier areas and 2 to 6 in. in wetter areas. In November (fig. 8*B*) and December, the basin averages from 1.75 to 6 in. in drier areas and about 16 to 20 in. in wetter areas. January (fig. 8*C*), which historically is the wettest month, averages 23 in. of precipitation on Grizzly Mountain and Mt. Lassen but only about 3 in. of precipitation in Sierra Valley. Less precipitation falls in February through March but, nevertheless, averages as much as 14 in. over the wetter areas. By April, most of the basin averages between 2 and 6 in. of precipitation, except on the wetter peaks (6 to 8 in.) including Mt. Lassen (12 in.). By May (fig. 8*D*), the basin averages between 0.25 to 6 in. of precipitation. The months June through September (fig. 8*E*) are historically very dry, averaging less than 2 in. in most of the basin.

PRISM is designed to map climate in complex environmental regimes, including high mountainous terrain and rain shadows, such as found in the Feather River Basin (Daly and others, 1994). PRISM uses point measurements, digital elevation models, and other spatial data to generate gridded estimates of monthly and yearly precipitation. PRISM fits separate precipitation/altitude relations to neighboring stations with the same topographic aspect to generate interpolated values. This is a departure from simply applying a single altitude-dependent precipitation measurement to similar altitudes within the basin. Thus, PRISM is automated to adjust its frame of reference to accommodate local and regional climatic differences and rain shadows to create a pattern of precipitation (Daly and others, 1994). Because precipitation varies strongly with topography, and few long-term precipitation measurements are reported real-time in the Feather River Basin, PRISM simulations are well suited for use in this study. The mean-monthly PRISM simulations were generally found to be within 1 in. of the measurements at stations in the Feather River Basin (figs. 9*B*, *C*).

During the cool season, days with measurable precipitation are common in the basin. The number of days of precipitation in each month was computed from observations at the 10 precipitation stations used in this study (table 1). From November to April, precipitation fell about every 1 out of 2 days. In May, precipitation occurred 4 out of 10 days. During June-September, precipitation occurred 1 or 2 days out of 10, and in October, 3 out of 10 days.

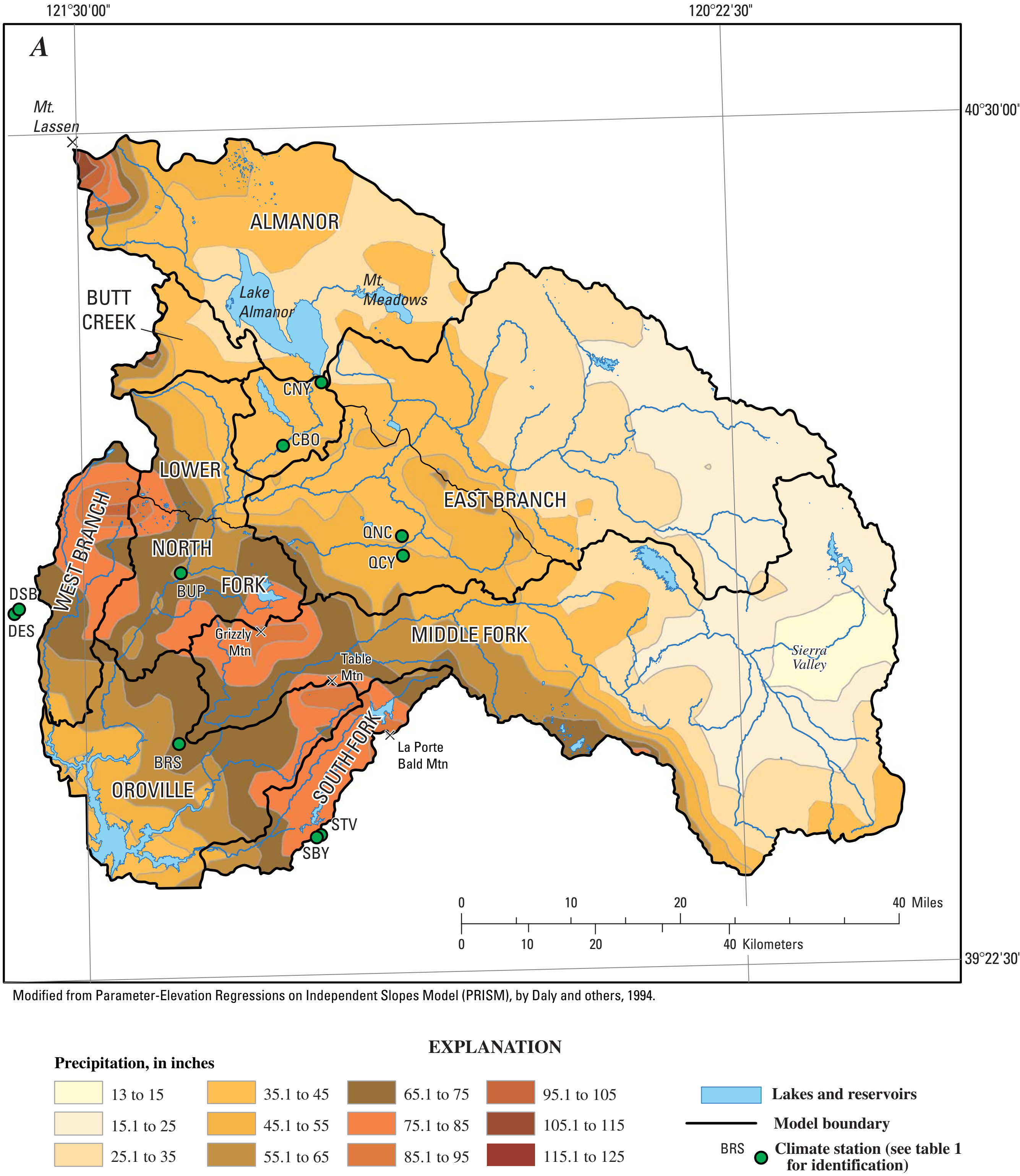


Figure 8. Distributions of precipitation over the Feather River Basin, California, including (*A*) 30-year mean-annual, and selected 30-year mean-monthly, (*B*) November, (*C*) January, (*D*) May, and (*E*) September patterns.

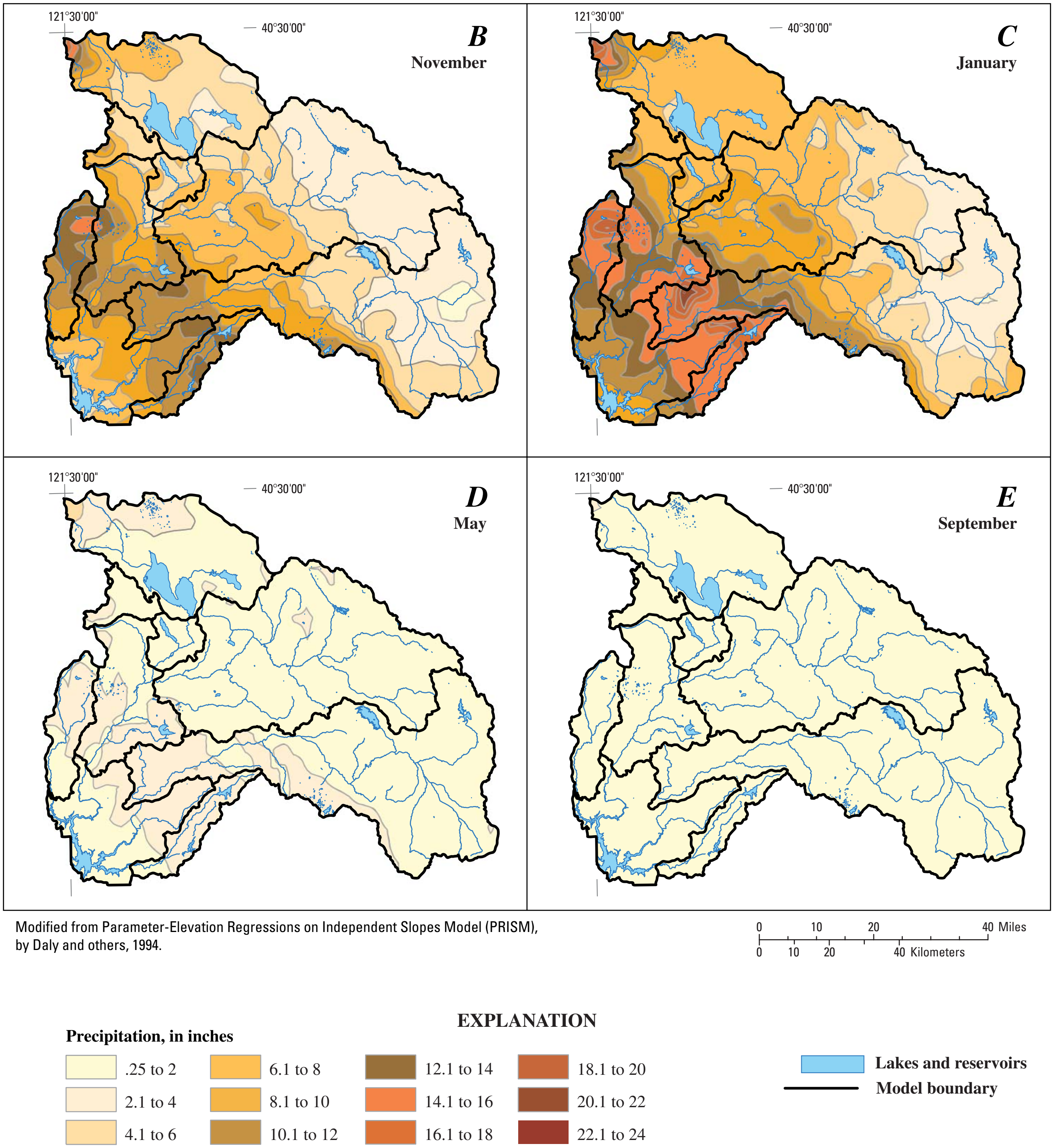


Figure 8.—Continued.

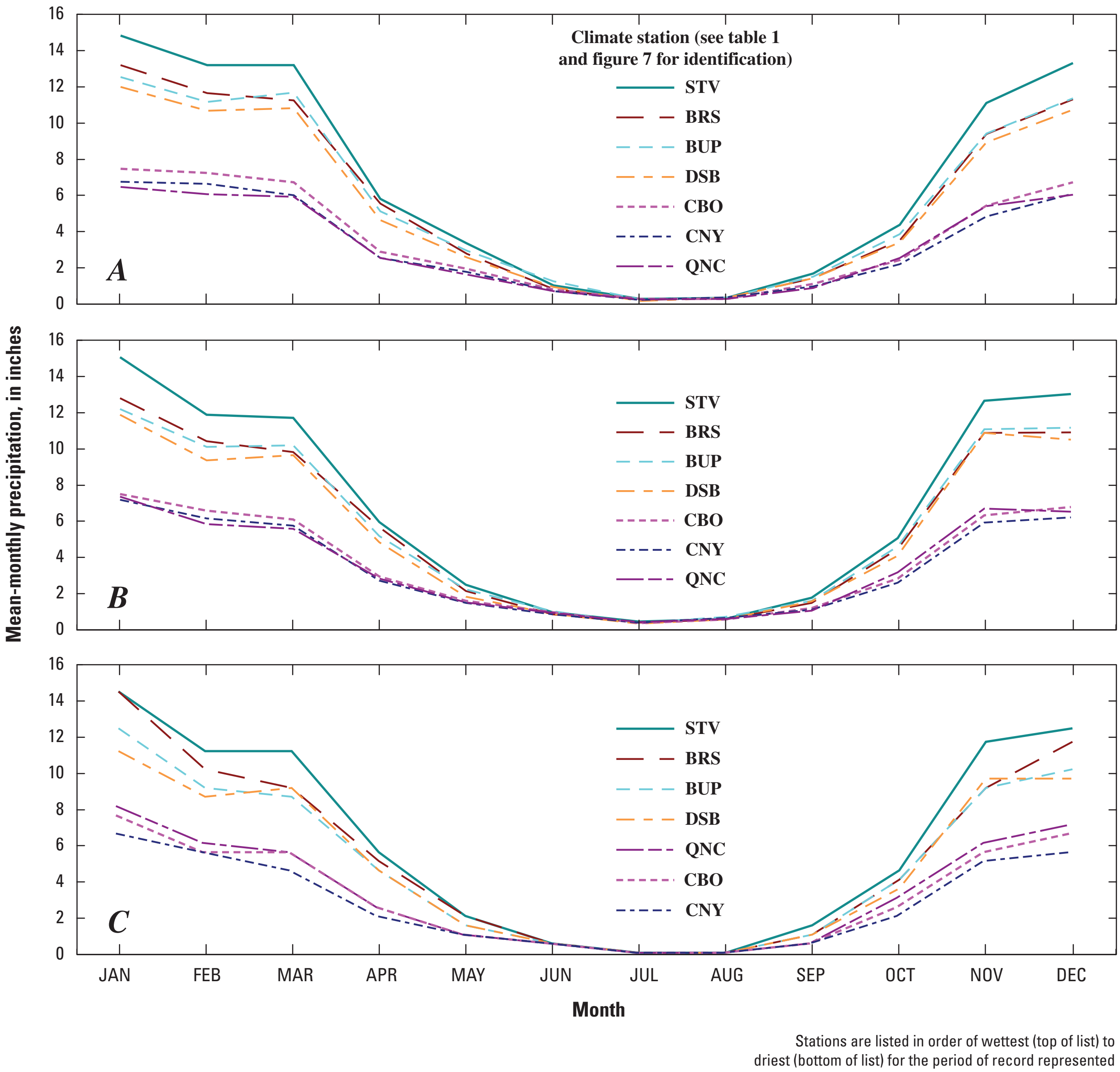


Figure 9. Mean-monthly precipitation (in inches) for the Feather River Basin measured at climate stations (*A*) during the modeling period 1971–97, (*B*) measured in the 1961–90 period, and (*C*) estimated from Precipitation-Elevation Regressions on Independent Slopes Model (PRISM, Daly and others, 1994) at locations of the precipitation stations for 1961–90. Stations are listed in order of wettest (top of list) to driest (bottom of list) measurements for the period of record presented.

PRISM simulations of orographic and rain-shadow patterns agree with the precipitation measurements in the basin. Historically, Canyon Dam (CNY), Caribou (CBO), and Quincy (QNC and QCY) receive the least precipitation (table 1; figs.8*A*, 9). Much more precipitation (as much as two to three times that of the driest stations) falls on Strawberry Valley (SBY and STV), Brush Creek (BRS), Buck Creek Powerhouse (BUP), and Desabla (DSB and DES). The Desabla stations are located outside the study area, on the windward side of the ridge bounding the western edge of the Feather River Basin (fig. 8*A*). On a daily basis, the Desabla stations measure a wider range of precipitation (wetter or drier) than other stations, and may be exposed to slightly different weather patterns.

Precipitation was analyzed using descriptive statistics and graphing to understand how precipitation compares between gage sites, and generally how storms may vary over the basin. There is considerable variation in daily precipitation between climate stations. However, monthly-mean values for water years 1971–97 were closely correlated ($r > 0.90$), especially from September through May. In summertime (June–August), the correlation decreased to about $r = 0.80$ (fig. 10) because summer rainfall is light and intermittent over the basin. Throughout the year, the poorest correlations (table 3) were typically between the drier Quincy stations (QCY, QNC) and the wettest stations, Desabla (DES), Brush Creek (BRS), and Strawberry (STV). As with the monthly comparisons, the precipitation stations were found to be closely correlated on a water-year-mean scale (generally above 0.90; table 3). Lower correlations between water-year means were observed between the Quincy (QCY, QNC) and wetter stations (DES, BRS, STV), but were still above 0.75. These results show that for a month or year, precipitation variations are generally similar and uniformly timed among the 10 measurement stations.

Temperature

It is important to understand the spatial and temporal distribution of temperatures when studying and predicting streamflow. Based on daily temperatures, PRMS computes heat balances, solar radiation, precipitation form, snowmelt and accumulation, sublimation, evapotranspiration, and other critical elements (Leavesley and others, 1983). Temperatures vary from one station to another due to local effects (wind, cloud cover, instrument shading, and aspect), and decrease with altitude. Also, temperature changes seasonally, and from year to year, and even from decade to decade.

In model operation, daily temperature measurements are extrapolated to each area using a specified monthly lapse rate. Temperature lapse rates were initially estimated to be 3.6 degrees Fahrenheit (^{o}F) per 1,000 ft of altitude change (Jeton, 1999b). Lapse-rate parameter settings were then adjusted at specific sites during model calibration.

Temperature records for the three stations used in this study date from at least the 1950s. The stations are centrally located and in the lower altitudes of the basin, below the snow line (figs. 3 and 7; table 1). The stations are Bucks Creek Powerhouse (BUP) at 1,760 ft, Quincy (QNC-QCY) at 3,408 ft, and Canyon Dam (CNY) at 4,560 ft above sea level. The average daily minimum and maximum temperatures at CNY, the highest of these stations, were 33 and 60 ^{o}F; respectively. At the lowest station, BUP, the corresponding averages were 46 and 71 ^{o}F. Temperatures at QNC-QCY are generally between the other two. Occasionally, however, temperature inversions cause QNC-QCY to register temperatures cooler than those at CNY.

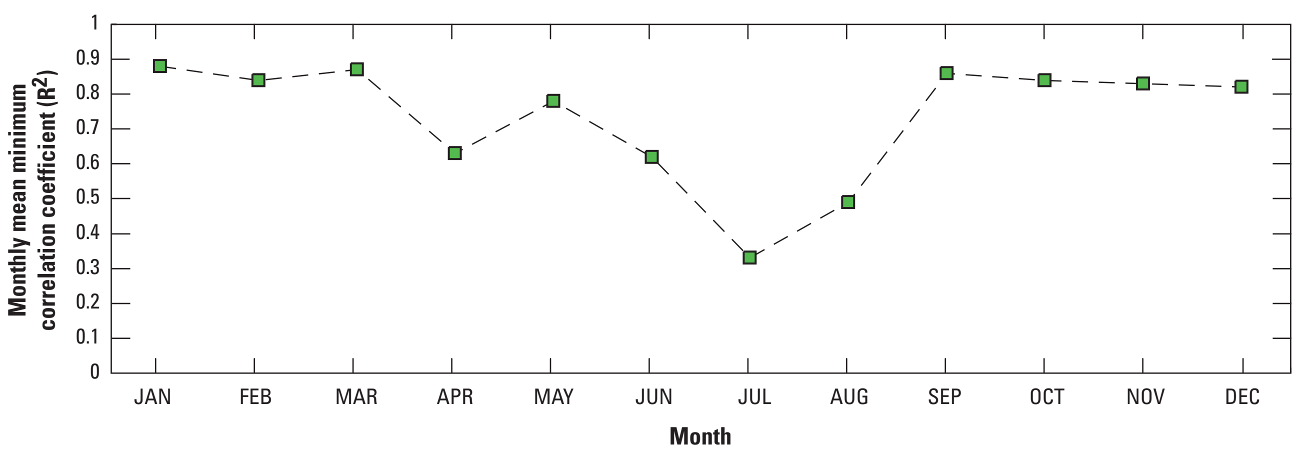


Figure 10. Minimum correlation of precipitation measurements (monthly means) between stations used in watershed modeling of the Feather River Basin, California, water years 1971–97. Trend lines were added to assist the reader in visualizing results and do not reflect actual data.

Table 3. Correlation of precipitation (water-year means) between stations used in watershed modeling of the Feather River Basin, California, water years 1971–97.

[Because of limited reported data, Strawberry-DWR (SBY) was not included in this analysis; see table 1 for climate station identifying designation; DWR, California Department of Water Resources]

Climate station	BRS	BUP	CBO	CNY	DES[1]	DSB	QCY[2]	QNC	STV
BRS	1.00	0.94	0.94	0.93	0.96	0.95	0.89	0.75	0.95
BUP		1.00	0.98	0.97	0.99	0.97	0.94	0.86	0.99
CBO			1.00	0.98	0.98	0.95	0.94	0.84	0.98
CNY				1.00	0.98	0.94	0.97	0.89	0.98
DES					1.00	1.00	0.93	0.87	0.99
DSB						1.00	0.90	0.80	0.97
QCY							1.00	0.97	0.97
QNC								1.00	0.89
STV									1.00

[1]Computations based on available data, water years 1989–97.
[2]Computations based on available data, water years 1988–97.

These temperature stations may not be entirely representative of conditions in model areas in which they were used as a surrogate for temperature, but the other stations that might replace them are not yet reporting on a real-time basis. There are local environmental conditions which may affect temperature at these stations. BUP (fig. 8; table 1) is located in a very narrow valley affected by winter storms that reportedly funnel up the canyon (Gary Freeman, Pacific Gas & Electric Company, unpub. data, 1999). CNY (below Lake Almanor Dam; fig. 7) is in one of the drier areas of the basin. Because the U.S. Forest Service stopped reporting temperatures for QNC mid-water year (October through September) 1998, QCY (operated by DWR) was used to continue its record. For the period October 1997–May 1998, QCY had average maximum daily temperatures 4 to 10 ^{o}F warmer than those of QNC and minimum temperatures of 3 ^{o}F warmer. The differences in temperature between the two gages may be due to location or to calibration. QCY is located in the town of Quincy, whereas QNC is located on the lee of a ridge, 3 mi north of town.

Double-mass analyses (Linsley and others, 1975) of the daily temperatures between climate stations located inside and outside the basin showed no unusual breaks in the slope of graphed results during the model calibration period, October 1, 1970, through September 30, 1997. This indicated that the instrumentation measured similar (parallel) temperature variations at all stations. Therefore, temperatures appear to have been measured in consistent ways throughout the calibration period. However, after the calibration period, a break was observed in the Quincy records in about November 1998, indicating an increase in minimum daily temperatures measured at the new station, QCY, as compared with the old station, QNC.

Temperature determines the form of precipitation (rain only, snow only, or rain-on-snow mixture). To get a sense of the variations in precipitation form, the percentage of days when temperatures were above and below freezing was compiled. The percentages of freezing days in all recorded data are shown in tables 4 (full year) and 5 (precipitation days only). Most notably, on days with precipitation, maximum daily temperatures in December–February at the CNY station were above freezing over 80 percent of the time, and minimum temperatures were below freezing over 80 percent of the time. Thus, on most winter days, temperatures fluctuated around and near freezing. Precipitation form must vary considerably in the middle altitude areas of the basin. Although snow may accumulate even when surface temperatures are a few degrees above freezing, precipitation on most occasions within the Feather River Basin probably takes the form of rain, or rain-on-snow, during the daytime and then snow at night. At higher altitudes (for example, CNY), there are more days with consistently freezing temperatures and, therefore, more snow. Monthly estimates of mean-maximum and mean-minimum temperatures are given in tables 6 and 7. In the Feather River Basin, January is the coldest month with a daily measured extreme of –24 ^{o}F, and July is the warmest with a daily measured extreme 115^{o}F.

Evaporation

Pan evaporation is not required as input to PRMS because it is computed within the models. However, pan-evaporation records from various sites within the basin provide an indication of the potential for evapotranspiration and so aid in calibrating the models. Typically, less evaporation occurs at higher altitudes. In the Feather River Basin, pan-evaporation rates have been measured at Oroville Dam (station #A50652700; California Department of Water Resources, 1979; fig. 7) and Lake Almanor (Jim Trask, University of California at Davis, unpub. data, 2000; fig. 7). The mean-annual rate at Oroville Dam (900 ft asl), during water years 1960–76, is 67.5 in. The mean-annual rate at Lake Almanor (4,500 ft asl) is about 45 in.

Table 4. Period-of-record percentages of days with maximum (first number) and minimum (second number) temperatures less than or equal to freezing, at climate stations in the Feather River Basin, California.

[ID, identifying designation; ft asl, feet above sea level; CDEC, California Data Exchange Center; DWR, California Department of Water Resources; PG&E, Pacific Gas and Electric; RS, ranger station; USFS, U.S. Forest Service]

Temperature station	ID	Source	Altitude (ft asl)	Period of record	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Bucks Creek Powerhouse	BUP	PG&E	1,760	1/1/59–10/31/01	0, 0	0, 6	1, 25	0, 29	0, 19	0, 11	0, 4	0, 0	0, 0	0, 0	0, 0	0, 0
Quincy RS (USFS)/ Quincy (DWR)	QNC/ QCY	DWR, CDEC website	3,420/ 3,408	10/1/37–10/31/01	0, 58	0, 73	2, 82	2, 81	1, 78	0, 73	0, 59	0, 24	0, 6	0, 3	0, 10	0, 28
Canyon Dam	CNY	PG&E	4,560	10/1/37–10/31/01	0, 40	1, 79	11, 91	14, 94	6, 93	1, 90	0, 70	0, 28	0, 4	0, 0	0, 0	0, 6

Table 5. Period-of-record percentages of days with observed precipitation with maximum (first number) and minimum (second number) temperatures less than or equal to freezing, at climate stations in the Feather River Basin, California.

[ID, identifying designation; ft asl, feet above sea level; CDEC, California Data Exchange Center; DWR, California Department of Water Resources; PG&E, Pacific Gas and Electric; RS, ranger station; USFS, U.S. Forest Service]

Temperature station	ID	Source	Altitude (ft asl)	Period of record	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Bucks Creek Powerhouse	BUP	PG&E	1,760	1/1/59–10/31/01	0, 1	0, 8	1, 24	1, 26	0, 21	0, 15	0, 7	0, 1	0, 0	0, 0	0, 0	0, 0
Quincy RS (USFS)/ Quincy (DWR)	QNC/ QCY	DWR, CDEC website	3,420/ 3,408	10/1/37–10/31/01	0, 34	0, 53	2, 68	2, 67	2, 63	0, 60	0, 48	0, 21	0, 5	0, 1	0, 1	0, 10
Canyon Dam	CNY	PG&E	4,560	10/1/37–10/31/01	0, 34	2, 67	12, 85	14, 88	9, 88	2, 85	0, 69	0, 34	0, 8	0, 0	0, 0	0, 6

Table 6. Period-of-record mean-monthly maximum (first number) and minimum (second number) temperatures, at climate stations in the Feather River Basin, California.

[DWR, California Department of Water Resources; RS, Ranger Station; USFS, U.S. Forest Service]

Temperature station	Period of record	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Bucks Creek Powerhouse	1/1/59–10/31/01	74, 49	58, 41	49, 36	50, 36	56, 37	62, 39	69, 43	77, 49	86, 56	93, 61	92, 60	86, 56
Quincy RS (USFS)/ Quincy (DWR)	10/1/37–10/31/01	72, 32	56, 28	46, 25	47, 24	52, 26	58, 29	65, 32	74, 37	82, 42	90, 44	89, 41	83, 37
Canyon Dam	10/1/37–10/31/01	64, 34	48, 28	40, 24	39, 22	43, 23	49, 26	57, 30	67, 36	76, 42	85, 47	84, 45	77, 41

Table 7. Mean-monthly maximum (first number) and minimum (second number) temperatures, water years 1971–97, at climate stations in the Feather River Basin, California.

[DWR, California Department of Water Resources; RS, Ranger Station; USFS, U.S. Forest Service]

Temperature station	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
Bucks Creek Powerhouse	74, 49	58, 41	49, 36	50, 36	57, 38	63, 40	70, 44	78, 49	86, 55	93, 61	92, 60	86, 56
Quincy RS (USFS) / Quincy (DWR)	72, 31	56, 27	46, 24	47, 23	54, 26	59, 30	66, 32	75, 37	84, 42	91, 44	90, 43	84, 38
Canyon Dam	64, 35	48, 28	40, 24	40, 22	44, 24	49, 28	58, 31	68, 37	76, 43	84, 48	83, 46	76, 41

Streamflow

Hydrographs of tributary streamflow show a similar response to the climatic variations within the basin (fig. 11). The magnitudes differ, but all display a similar signature: higher winter flows with less dramatic springtime snowmelt peaks than are typically encountered in the higher altitude basins of the southern Sierra Nevada. Higher winter flows (January-March) are due to frequent warmer-than-freezing temperatures (tables 4, 5, 6, and 7), which result in sudden winter runoff from rain and melting snow. In the Feather River Basin, owing to winter melt and a portion of precipitation falling as rain, less snowpack remains by April, and thus the spring snowmelt produces lower peaks than seen in typical hydrographs of the southern Sierra Nevada. By July, most snow in the Feather River Basin has melted. Summer streamflow comes from subsurface and ground-water flows. By October, regardless of the part of the basin evaluated, streamflow rates are at their minimum.

Streamflow has been measured at the mouth of the Feather River Basin near the city of Oroville since 1901 (USGS 11407000), and at areas within the basin since the 1950s (table 2). During the 20th century, the river and all its reaches were increasingly developed for hydroelectric power production and irrigation. These uses impede or change streamflow, and thus measurements at gaging stations no longer reflect natural streamflow. Where hydropower has been developed in the basin, natural streamflows have been reconstructed by DWR (Appendix A) and PG&E (proprietary) using knowledge of impoundments, evaporation, and diversions. The USGS has not quantified the uncertainty of these reconstructions.

Lake Oroville has a capacity of 3,538,000 acre-ft of water and, in the average water year, DWR's reconstructed inflows to Lake Oroville (Feather River at Oroville (FTO), table 2; fig. 1) have been about 4,539,000 acre-ft (from water years 1906–2000, http//: cdec.water.ca.gov), with a standard deviation of 2,127,000 acre-ft. During the 95 water years evaluated here, the total annual inflow equaled or exceeded the maximum storage capacity of Lake Oroville 58 times. Historically, maximum monthly inflow to Lake Oroville has occurred as early as December and as late as May, but, most often, maximum monthly inflows occurred in March or April. Over the 95-year period of reconstructed data, 1906–2000, the maximum mean-monthly inflow to Lake Oroville (FTO) was in April. The minimum inflow typically occurred in September (table 8).

Table 8. Mean-monthly reconstructed inflow to Lake Oroville (FTO), California, water years 1906–2000

[FTO, California Department of Water Resources streamflow reconstruction site: Feather River at Oroville, California]

Month	Mean-monthly inflow, in acre-feet	Maximum monthly inflow, in acre-feet	Minimum monthly inflow, in acre-feet	Standard deviation, in acre-feet
Oct.	105,665	855,300	40,225	83,341
Nov.	188,073	1,240,390	57,400	187,820
Dec.	350,047	1,997,200	61,803	385,630
Jan.	517,128	2,539,490	69,429	521,346
Feb.	567,797	2,677,102	88,900	404,159
Mar.	692,632	2,282,679	91,640	441,250
April	733,687	1,830,000	99,940	372,853
May	673,486	1,700,000	101,000	391,825
June	354,865	1,121,710	63,900	240,286
July	161,558	391,800	62,700	75,080
Aug.	104,546	197,330	57,800	29,481
Sept.	89,580	157,899	52,500	22,322

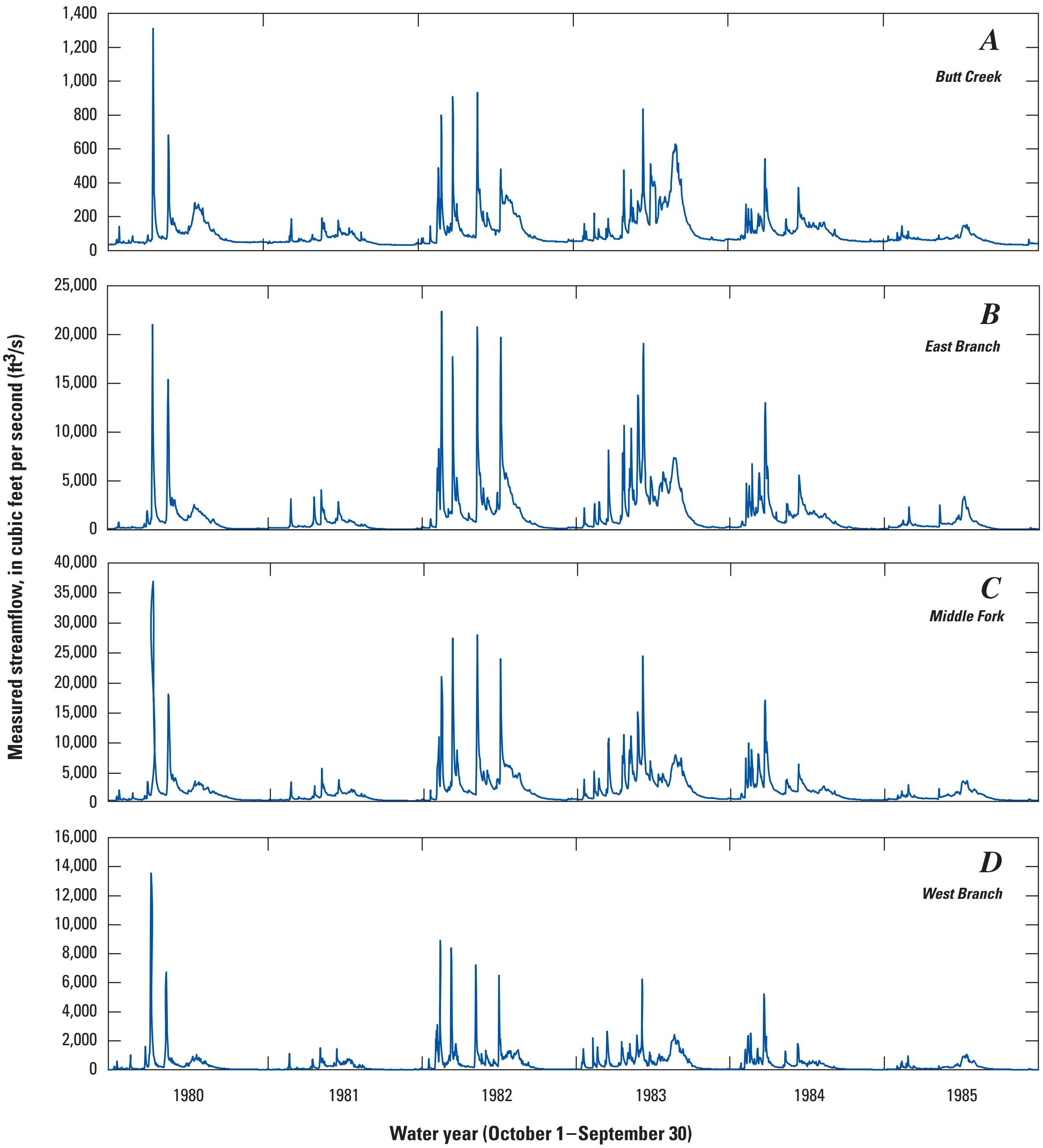


Figure 11. Daily measured streamflow, Feather River Basin, California, water years 1980–85, for (A) Butt Creek, (B) East Branch, (C) Middle Fork, and (D) West Branch. Y-axes vary.

Table 9. Mean-seasonal reconstructed inflow to Lake Oroville (FTO), California, water years 1906–2000

[FTO, California Department of Water Resources streamflow reconstruction site: Feather River at Oroville, California]

Streamflow season	Mean volume, in acre-feet	Minimum volume, in acre-feet	Maximum volume, in acre-feet	Standard deviation, in acre-feet	Percent of annual volume
October–December	643,785	168,060	2,713,700	520,062	14
January–March	1,777,556	275,660	4,684,328	1,049,563	39
April–July	1,923,596	391,850	4,676,000	1,009,089	43
August–September	194,126	110,300	343,310	48,577	4
Total	4,539,065				

Measured and reconstructed tributary streamflows during water years 1971–97 were compared with DWR's FTO reconstructions to get a sense of the contribution of water from different parts of the basin. The East Branch and Middle Fork drainages straddle the Sierra Nevada rain shadow. Their western sides received the most precipitation (fig. 8*A*), and were measured as contributing more to streamflow than their eastern sides. On average, the West Branch contributed 5 percent of FTO, the Middle Fork 22 percent, and the South Fork 5 percent. The average North Fork inflow was 53 percent of FTO. From subareas in the North Fork drainage, the East Branch was estimated to contribute 16 percent, the Lower North Fork 20 percent, Butt Creek 2 percent, and Almanor 15 percent of FTO. The Oroville modeled area (fig. 7) contributed about 15 percent of FTO. This contribution was calculated by assessing PRISM estimates of precipitation (fig. 8*A*), then subtracting inflows estimated by other models from DWR's FTO reconstructions. This was done because measured or reconstructed streamflow does not exist for the Oroville model area.

The Feather River Basin streamflow is analyzed in this report according to the seasons defined by DWR forecasts: (1) October–December, during which the primary source of streamflow is from rain and early snowmelt, (2) January–March, during which the basin receives the most precipitation, (3) April–July, during which the main source of streamflow is snowmelt, and (4) August–September, during which the main sources of streamflow are from subsurface and ground-water flows. During the 1906–2000 period, 43 percent of the reconstructed inflow to Lake Oroville (FTO) occurred during the April–July snowmelt period, 39 percent during January through March, 14 percent during October through December, and only about 4 percent during August through September (table 9).

The seasonality of streamflow in the Feather River has varied on interdecadal time scales. For example, the long-term (1906–97) mean of Lake Oroville inflow peaked in April (fig. 12), but during the 1971–97 modeling period the mean-monthly inflow to Lake Oroville peaked in March (fig. 12). This earlier, March peak during 1971–97 also was observed in streamflows from the East Branch, Middle Fork, South Fork, and West Branch tributaries (table 10). The peak of the North Fork tributary during 1971–97 lagged to April–May, although flow in these months was only slightly higher (1 to 1.5 percent) than in March (table 10).

The shift in the mean month of peak FTO streamflow reconstructions, as seen in figure 12, corresponds to warmer conditions in recent decades. This warming may correspond to an influence on the Feather River Basin climate by Pacific Decadal Oscillation (PDO). PDO is a long-term sea-surface temperature fluctuation of the North Pacific Ocean, which—along the west coast of North America—is seen to abruptly become warmer or cooler every 20 to 30 years (Mantua and others, 1997). Between 1949 and 1976, the North Pacific climate was characterized by a warm wedge of higher than normal sea-surface temperatures in the central-to-western North Pacific and a horseshoe pattern of lower-than-normal sea-surface temperatures along the west coast of North America (cool PDO). In contrast, between 1977 and 1998, the west Pacific Ocean was cool and the ocean along the west coast of North America was warm (warm PDO). These distributions of warm and cool water affect atmospheric temperature and reflect long-term changes in the paths of storms and winds across the United States. In 1999, the Pacific Ocean along the west coast of North America appears to have returned to the PDO phase that dominated the earlier (cool) 1970–76 period, which—if true—can be expected to influence the hydroclimatology of the Feather River Basin for years to come (Cayan and others, 2001; Dettinger and others, 2001; Schmidt and Webb, 2001; McCabe and Dettinger, 2002; http://topex-www.jpl.nasa.gov/science/pdo.html, accessed on Dec. 10, 2002).

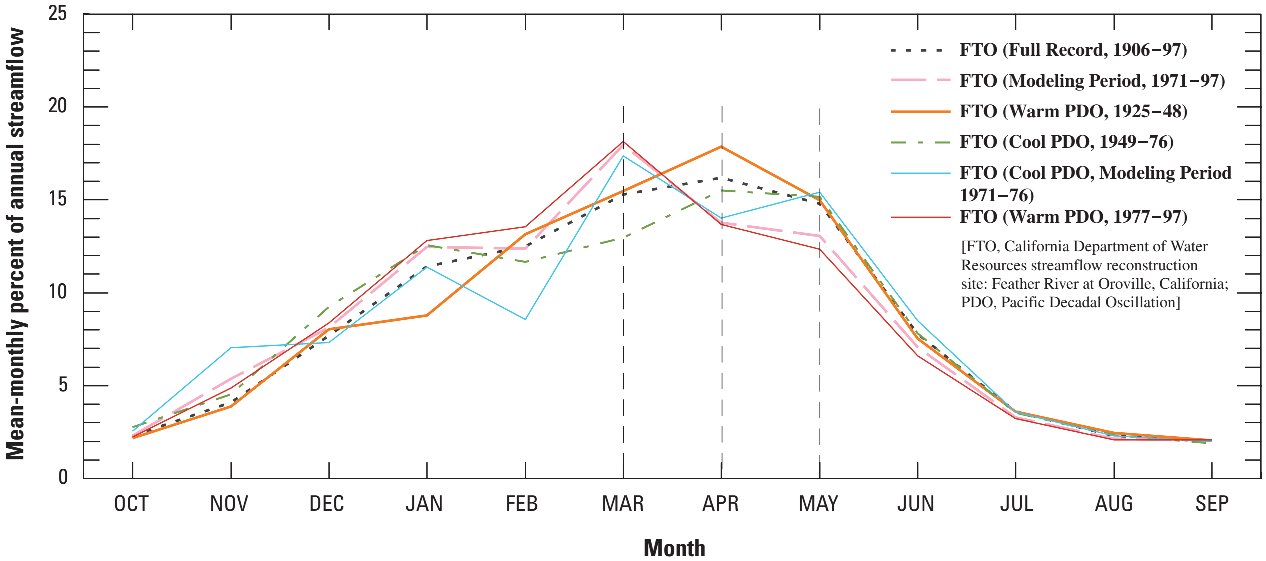


Figure 12. Historical mean-monthly peak variations in reconstructed inflow to Lake Oroville (FTO), California.

Table 10. Mean-monthly reconstructed (R) or measured (M) streamflow for areas modeled as percent of annual total, water years 1971–97, and Lake Oroville (FTO) 1906–2000; peak monthly streamflow listed in bold italics.

[FTO, California Department of Water Resources streamflow reconstruction site: Feather River at Oroville, California]

Month	North Fork of the Feather River				Middle Fork	South Fork	West Branch	Total Lake Oroville inflow (FTO 1971–97)	Total Lake Oroville inflow (FTO 1906–2000)
	Almanor	Butt Creek	East Branch	Lower North Fork					
	R	M	M	R	M	R	M	R	R
Oct.	4.9	4.3	1.5	2.8	1.7	0.9	0.5	2.3	2.3
Nov.	7.1	5.8	4.4	5.8	5.2	5.3	6.7	5.4	4.1
Dec.	7.8	6.9	7.1	7.4	8.0	8.3	9.7	8.1	7.7
Jan.	8.9	9.5	14.1	10.4	11.3	12.4	16.6	12.5	11.4
Feb.	10.0	9.9	14.2	11.7	13.8	13.2	17.6	12.4	12.5
Mar.	13.1	13.6	***20.8***	14.7	***18.4***	***18.2***	***18.1***	***18.0***	15.3
April	12.6	***14.7***	16.0	14.4	14.9	15.7	13.0	13.8	***16.2***
May	***14.5***	14.4	13.0	***16.5***	14.1	16.9	11.9	13.1	14.8
June	9.2	8.2	5.4	8.7	7.6	6.7	4.9	7.1	7.8
July	4.7	4.6	1.6	3.3	2.5	1.4	0.6	3.3	3.6
Aug.	3.4	4.2	0.9	2.2	1.4	0.5	0.1	2.1	2.3
Sept.	3.7	3.9	1.0	2.2	1.2	0.5	0.2	2.1	2

To determine whether the PDO affected Feather River Basin streamflow timing, the FTO record was evaluated for various PDO periods (fig. 12). The "warm" (1977–98) phase of PDO was expected to result in warmer conditions in the basin (Dettinger and others, 2004) and in an earlier peak monthly streamflow. Conversely, the "cooler" (1949–76) PDO would result in later peak streamflow, as the basin would be cooler and more precipitation would fall as snow, and snow would melt later in the year. The data plotted in figure 12 confirm these expectations, and also show that streamflow timing of the Feather River has come earlier in recent decades (1970s–90s), as has occurred in rivers throughout California and the western United States (Dettinger and Cayan, 1995; Cayan and others, 2001). Thus, simulations of seasonal cycles of Feather River Basin streamflow may be sensitive to the climate during the period of record utilized.

The model calibration period (1971–97) used here straddles these PDO phases, with most years from the recent warm (1977–98) PDO phase. The beginning years (1971–76) of the model calibration period, however, presumably were influenced by the earlier cool (1949–76) PDO. The mean FTO inflows during the 1971–76 period (fig. 12) display a seasonality that is less smooth because fewer years were averaged. Results, however, display a broad April peak similar to the cool PDO (1949–76) period. The modeling period was dominated by the warm (1977–98) PDO, which may bias study results towards warmer conditions in the basin.

Watershed Modeling

Conceptually, a watershed system, such as that found in the Feather River Basin, can be described in terms of a few key hydrologic processes that, working in combination, result in observed daily streamflow variations (Beven, 2001). These processes are represented mathematically in such models as PRMS (http://wwwbrr.cr.usgs.gov/mms/html/prms_page.html, accessed on Jan. 1, 1999; Leavesley and others, 1983, 2002; Leavesley and Stannard, 1995).

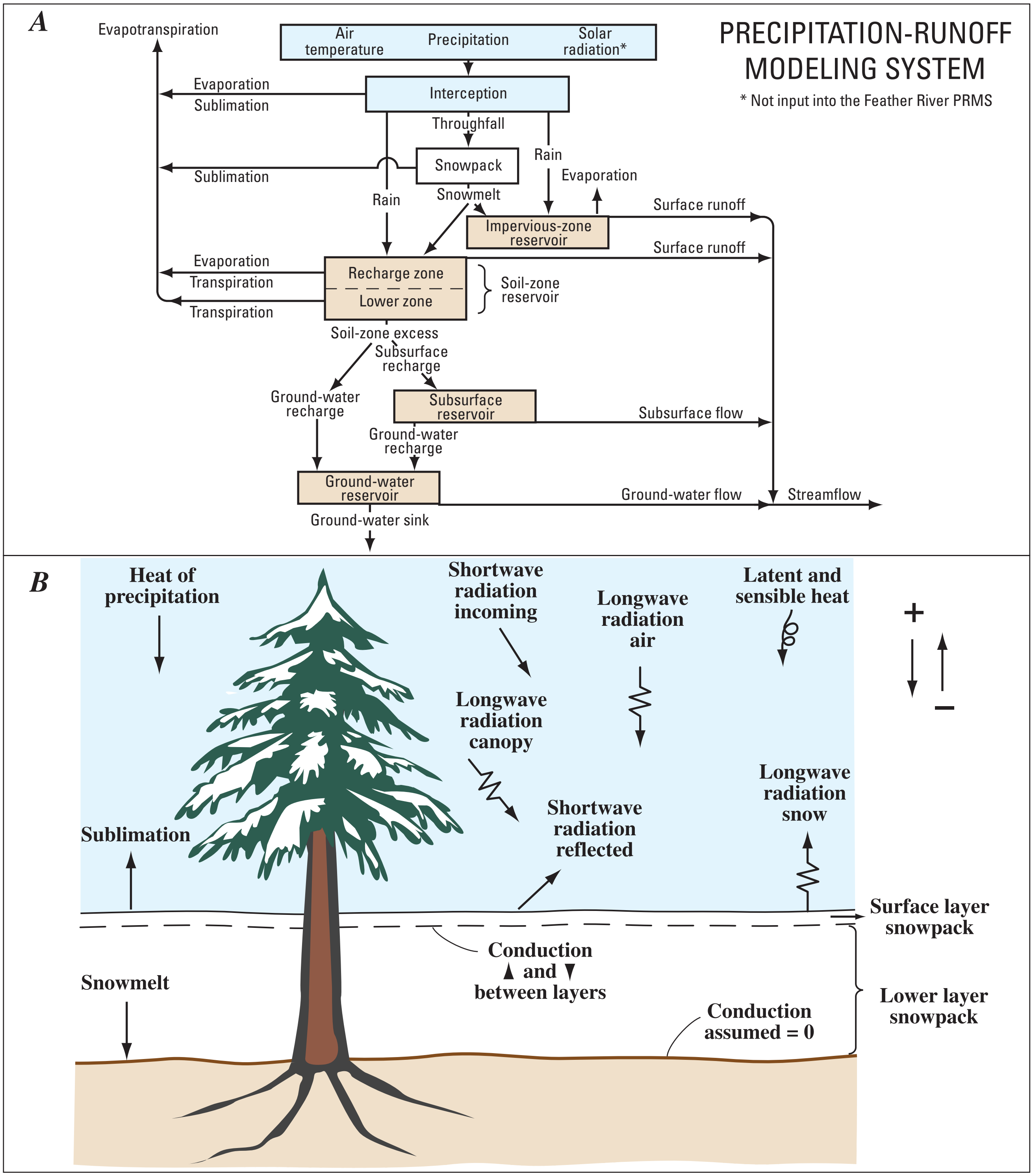
PRMS is a distributed-parameter, physically based watershed model that was developed to evaluate the effects of various combinations of climate and land use on watershed response (Leavesley and Stannard, 1995). Responses to climatic events and land-cover changes are simulated in terms of water and energy balances, streamflow regimes, flood peaks and volumes, soil-water relations, and ground-water recharge. A basic assumption in PRMS is that streamflow travel time, from the headwaters to the outlet of a defined model area, is less than or equal to the daily time step, and thus these daily streamflows need not be explicitly routed along river channels. Hydrologic components of the system, including streamflow, are computed on daily time steps.

The current PRMS is part of the Modular Modeling System (MMS) (http://wwwbrr.cr.usgs.gov/mms/; Leavesley and others, 1996). MMS combines a library of subroutine modules to simulate components of the hydrologic system including water, energy, and biogeochemical processes. PRMS is the combination of modules that was described by Leavesley and others (1983) and has been used for many modeling studies since.

Spatial Representation

In PRMS, spatially distributed hydrologic properties and responses are represented by partitioning the watershed into spatial subdivisions on the basis of land characteristics such as slope, aspect, altitude, vegetative cover (type and density), soil (type and depth), geology, and climate (daily temperature and precipitation distributions). Hydrologic processes within each subdivision, including streamflow generation, are assumed to vary uniformly in response to temperature and precipitation. In order to justify this simplification, the subdivisions, called hydrologic response units (HRUs), typically are delineated to encompass land properties that are as spatially homogeneous as is practical. HRUs may consist of noncontiguous or contiguous areas of similar land properties. Water and energy balances are computed each day for each HRU on the basis of the HRU physical and hydrologic characteristics and the weather on that day. These balances represent fluxes through the snowpack, vegetation canopies, land surface, and soil through the root zone of the HRU. In PRMS, percolation down through the bottom of the root zone enters two conceptual reservoirs, a "subsurface reservoir" and a shallow "ground-water reservoir," which affect the timing of the overall simulated streamflow (Leavesley and others, 1983)(fig. 13*A*). In the Feather River PRMS models, each HRU is contiguous and, with the exception of Butt Creek, has its own HRU-scale subsurface and ground-water reservoirs. In Butt Creek, as in other PRMS applications, the reservoirs have been assumed to underlie multiple HRUs (for example, Jeton and others, 1996). Thus, in the Feather River PRMS models, water balances are computed for each HRU, including all surface and subsurface components. The smallest spatial scales at which climatic variations or land-cover changes can be imposed in the model is the HRU scale. The sum of the individual responses of all HRUs, weighted on a unit-area basis, produces the daily watershed response and streamflow.

For flexibility, the Feather River Basin was modeled as eight separate drainages representing the major tributaries (fig. 7). The sum of the simulated daily flows from these eight separate models represents the total inflow to Lake Oroville.



Modified from Leavesley and others, 1983 (figures 2 and 9).

Figure 13. Precipitation-Runoff Modeling System (PRMS) conceptually illustrated, including (*A*) schematic diagram of the conceptual water system and inputs, and (*B*) components of the snowpack energy-balance equations (Leavesley and others, 1983).

Watershed Processes

For PRMS modeling, the watershed system is conceptualized as a series of heat and water reservoirs whose outputs combine to produce the total system response and, therefore, daily streamflow (fig. 13*A*; Leavesley and others, 1983). System inputs are daily precipitation, minimum and maximum daily air temperature, and (if available) solar radiation. Precipitation falls, is reduced by interception in the plant canopy, and becomes a net precipitation rate delivered to the watershed surface. Temperature drives the processes of evaporation, transpiration, sublimation, and snowmelt, and determines the form of any precipitation (snow, rain, or a mix). A rain/snow mixture is computed using maximum and minimum daily temperatures, and temperature thresholds bracketing precipitation type (all rain or all snow). If precipitation is considered a mixture, rain is assumed to occur first and the portion occurring as rain is computed using a user-specified monthly adjustment factor.

In the Feather River Basin, long-term observations of daily solar radiation are not available. Therefore, as in many previous applications, solar radiation is estimated in PRMS each day on the basis of air temperatures and the presence or absence of precipitation. The estimation method used was developed for the Rocky Mountain region, and it is most applicable in regions where predominantly clear skies prevail on days without precipitation (Frank and Lee, 1966; Swift, 1976). On days with precipitation, a temperature threshold is used to distinguish between days when precipitation is from convective storms and days when precipitation is from frontal storms. Convective storms are typically of short duration and have more solar radiation than do days with frontal storms (Leavesley and others, 1983). PRMS distributes solar radiation to each HRU on the basis of latitude, slope, and aspect.

Snowpack components of PRMS simulate the initiation, accumulation, and depletion of snow on each HRU (fig. 13*B*). The snowpack is simulated both in terms of its water storage and as a dynamic-heat reservoir (Leavesley and others, 1983; Obled and Rosse, 1977; Anderson, 1968, 1973). A snowpack water balance is computed within each HRU each day, and a snowpack energy balance is computed each day and night. The snowpack is simulated as a two-layered system, with a 1-to 2-in. (3-to 5-cm) surface layer that interacts directly with the atmosphere, and a lower layer that is the underlying snowpack. In nonmelt conditions, when the surface layer is less than 32 °F, the surface layer temperature is computed using air temperature. When the temperature of the surface layer reaches 32 °F, an energy balance is computed between the snow interface and the atmosphere. The energy balance includes radiation, condensation, and the heat content of the precipitation falling on the snowpack. In nonmelt conditions, heat is transferred between the surface layer and the lower layer by conduction. When the surface layer temperature increases to greater than or equal to 32 °F, snowmelt occurs. Heat moves from the surface layer to the lower layer by the mass-transfer of heat stored in rain and melt water. The water is refrozen in the lower layer until the temperature of the lower layer is increased to 32 °F. Once the temperatures of the upper and lower layers increase to 32 °F, the entire snowpack is in a melt state and melt water from both the upper and lower layers moves out of the bottom of the snowpack. Conduction of heat across the soil-snow interface is assumed negligible in comparison with the energy exchange at the air-snow interface and is set to zero. The conceptual snowpack system and the components of the snowpack energy-balance equations are shown in figure 13*B*.

In PRMS, areas with impermeable surfaces that permit no infiltration into soil or ground water are represented by impervious-zone reservoirs (fig. 13*A*). These reservoirs have specified maximum retention-storage capacities that must be satisfied before surface runoff will be simulated. Snow and rain can accumulate on these surfaces. The retention storage is depleted by evaporation when the area is snow free.

In PRMS, the soil-zone reservoir (fig. 13*A*) represents that part of the soil mantle that can lose water to the atmosphere through evaporation and transpiration. The average rooting depth of the predominant vegetation covering the soil surface defines the depth of this zone. Water storage in the soil-zone reservoir is increased by infiltration of rainfall and snowmelt and depleted by evapotranspiration. Maximum retention storage occurs at field capacity; minimum storage is assumed to be zero and occurs at wilting point. The maximum available water-holding capacity (the difference between field capacity and wilting point) of the soil-zone reservoir is specified by the user. The soil-zone reservoir is treated as a two-layered system. The upper layer is termed the recharge zone and has user-specified depth and water-storage characteristics. Losses from the recharge zone are assumed to occur from evaporation and transpiration; losses from the lower zone occur only through transpiration (Zahner, 1967). In PRMS the maximum available water-holding capacity of the lower zone is the difference between the soil-zone reservoir and the maximum available water-holding capacity of the recharge zone. In PRMS both the recharge and lower zones are filled at equal rates until the water-holding capacity is met. When the soil-zone reservoir reaches the maximum available water-holding capacity, all additional infiltration is routed to the subsurface and ground-water reservoirs (Leavesley and others, 1983).

In PRMS, infiltration into the soil-zone reservoir depends on the daily snowmelt or net rainfall rates, soil field capacities, specified maximum infiltration rates (for snow), and antecedent soil-moisture conditions. Surface runoff occurs where net applications of liquid water to the soil surface exceed defined infiltration thresholds. Infiltration thresholds are defined depending on whether the water is derived from rain (by PRMS) or snowmelt (by the user; Leavesley and others, 1983).

In PRMS, the subsurface reservoir (fig. 13*A*) represents the pathways that the soil-water excess takes in percolating through shallow unsaturated zones to stream channels, arriving at the streams above the water table (Leavesley and others, 1983). Inflow to a subsurface reservoir occurs when the maximum available water-holding capacity of the soil-zone reservoir is exceeded, and this excess is greater than the recharge rate to the ground-water reservoir. Subsurface flow into the river varies relatively rapidly, in response to infiltration changes, but not as rapidly as the occasional surface-runoff events. Thus, the subsurface reservoir contributes to the gradual recessions of flow lasting a few days following a storm or snowmelt episode.

In PRMS, the ground-water reservoir (fig. 13*A*) represents the slower subsurface pathways beneath the local water table to the streams. Recharge to the ground-water reservoir can occur from both the soil-zone and subsurface reservoirs (fig. 13*A*). Recharge from the soil-zone reservoir has a daily user-specified upper limit and occurs only when the maximum available water-holding capacity of the soil-zone reservoir is exceeded. Recharge from the subsurface reservoir to the ground-water reservoir is computed as a function of the volume of water stored in the subsurface reservoir each day. The model representation of the ground-water reservoir is designed to respond more slowly to hydrologic fluctuations than the surface runoff or the subsurface reservoirs. The ground-water reservoir typically provides most of the seasonal flow recessions each year.

Movement of water through the ground-water system to points beyond the modeled basin can be represented in PRMS by a ground-water sink that removes water from the ground-water reservoir at a rate that is a function of storage there. In most of the Feather River PRMS models, this sink is set to zero; the sink is nonzero in the Sierra Valley of the Middle Fork model.

Model Areas

The Feather River Basin was modeled as eight separate drainages. The results of these models sum to simulate total inflow to Lake Oroville (fig. 7, table 11). Several of the models used parameter settings developed in calibrations of smaller subdrainages, referred to herein as "subdrainage models." These subdrainage models were preliminary and used solely to arrive at a better understanding of a particular part of a drainage model. The current models assume a constant land-surface and plant canopy throughout the simulation.

Streamflow data are available to calibrate and verify the models, except for the area below Lake Almanor ("Not Modeled" in fig. 7; table 11) and the area surrounding Lake Oroville ("Oroville Model" in fig. 7; tables 2, 11). Further, the "Not Modeled" area was excluded from this study because it did not significantly contribute to Lake Oroville inflow. The "Not Modeled" area is similar in size to the Butt Creek drainage, which generates 2 percent of the annual inflow to Lake Oroville. However, the "Not Modeled" area likely produces less streamflow because it receives less precipitation (fig. 8*A*) and is at warmer, lower altitudes (fig. 3). In contrast, the area around Lake Oroville was modeled. Although this area lacks measured or reconstructed streamflow for calibration, it receives a significant amount of precipitation (fig. 8*A*). The area around Lake Oroville was estimated to generate about 15 percent of annual inflow to Lake Oroville. The estimation was made by subtracting model simulations from FTO reconstructions.

North Fork Tributary of the Feather River

The North Fork drainage (1,947 mi^2, including lakes) was modeled in four sections: Almanor and Butt Creek in the north, the East Branch in the east, and the Lower North Fork in the south (fig. 7, table 11). Each has different topography, land cover, and climatic conditions and is similar enough in its physical characteristics to stand alone. Each has a long record of streamflow data available for calibration. Simulations from these models are summed to estimate the total inflow from the North Fork tributary to Lake Oroville.

Butt Creek and Almanor

The headwaters of the North Fork originate above Lake Almanor, as a series of tributaries that drain meadows and surrounding mountains, including the highest point in the basin, Mt. Lassen (fig. 7). Altitudes decline from about 9,500 ft near Mt. Lassen to about 4,300 ft asl just below Lake Almanor (fig. 3). Precipitation is greatest near Mt. Lassen (about 95 to 125 in. per year; fig. 8*A*), which is the wettest part of the Feather River Basin. The driest part of the entire North Fork drainage is adjacent to this wet area. It receives as little as 25 in. of precipitation a year (fig. 8*A*).

The Butt Creek and Almanor drainages are underlain by permeable and porous volcanic formations (fig. 6*A*). In late summer, when precipitation and snowmelt is minimal or nonexistent, base flow into these streams is relatively large, which results in a smoother hydrograph and a greater amount of streamflow, as compared to the other drainages (fig. 11*A*). In PRMS, base flow is considered to be the movement of shallow ground water to a stream channel.

Streamflow records used in calibrating the Almanor PRMS model have been reconstructed by PG&E at Lake Almanor (PG&E 8090-NF901; table 2; fig. 7). The Almanor drainage contains Lake Almanor and the Mt. Meadows Reservoir (fig. 7). At Lake Almanor and Mt. Meadows Reservoir, estimates of precipitation gain and evaporation loss were roughly the same, and the net contribution of these lakes to streamflow was negligible. Consequently, the two reservoirs were not included in the model.

Table 11. Feather River Basin models, modeling period, altitude range, and drainage area; area of the basin not modeled listed in italics.

[ft asl, feet above sea level; —. not applicable]

Model	Modeling period	Altitude range (ft asl)	Drainage area	
			Square miles	Acres
[North Fork modeled as four drainages]				
Almanor	10/1/70–9/30/97	4,523–9,525	[1]442	283,389
Butt Creek	10/1/70–9/30/97	4,316–7,698	69	44,205
East Branch	10/1/70–9/30/97	2,381–8,357	1,025	656,503
Lower North Fork	10/1/70–9/30/97	1,345–7,190	290	186,191
Area not modeled, excluding lakes	—	*2,460–6,353*	*73*	*46,442*
[Other modeled drainages]				
Middle Fork	10/1/70–9/30/97	1,580–8,735	1,046	669,595
South Fork	10/1/70–9/30/97	971–7,449	107	68,906
West Branch	10/1/70–9/30/97	899–7,016	142	90,823
Oroville	10/1/70–9/30/97	843–6,137	[2]314	201,336
TOTAL AREA MODELED			3,435	2,200,948

[1]Excluding Lake Almanor and Mountain Meadows Reservoir, which are about 48 square miles of the North Fork drainage.
[2]Excluding Lake Oroville, which is about 25 square miles of the Oroville drainage.

Streamflow records from Butt Creek (USGS 11400500; table 2) were used in calibrating the Butt Creek PRMS model. The accuracy of these streamflow data was reported as “good” in the early part of its record, but uncertain after 1969, when data collection was turned over to PG&E. The PG&E records since 1970 have been reviewed by the USGS. The Butt Creek streamflow record was not corrected for improvements above and below the gage that affect natural streamflow. The Lake Almanor-to-Butt Valley powerhouse conduit, which is opened for short periods several times a year, releases water just below the station, causing sharp flow surges at the gage (Markham and others, 1996). The Wallack ditch above 11400500 (fig. 4) diverts several cubic feet per second during the irrigation season into the Lower North Fork model area. The abandoned Lake Almanor-Butt Creek tunnel (fig. 4) leaks, adding to natural flow at a rate of 4,700 to 8,200 acre-ft per year, amounting to a 6 to 17 percent increase (USGS gaging station 11400500 Butt Creek below Almanor-Butt Creek Tunnel, near Prattville, California; U. S. Geological Survey Water-Data Reports, 1965–2001). Appropriate data were not available to make measurement corrections. Because Butt Creek only produces about 2 percent of annual inflow to Lake Oroville, the 11400500 data were considered an acceptable approximation of natural flow and were used for calibration.

East Branch

The East Branch is east-west trending and flows into the North Fork near Belden (fig. 7; table 11). The eastern headwaters are in the foothills at the eastern side of the Sierra Nevada (6,000 ft), although still west of the Pacific Crest. The headwater tributaries combine to form Indian Creek, which flows between canyon walls into Indian Valley (about 3,600 ft asl), and then through steep forested canyon walls of the Plumas National Forest (fig. 5). In the western third of the drainage, Indian Creek joins Spanish Creek to form East Branch, and then flows into the North Fork (fig. 7). The eastern side of the East Branch drainage is in a rain shadow (15 to 35 in. of precipitation per year). In contrast, the western side receives as much as 85 in. per year (fig. 8*A*).

The East Branch drainage is modeled as a single PRMS model and is calibrated against measured streamflows (USGS 11403000; table 2). To manage the varying precipitation patterns, parameters were determined initially from the Quincy (to the west) and Indian Creek (to the east) subdrainages (fig. 7, table 2). Streamflow at station 11403000 was measured by PG&E and reviewed by the USGS. The accuracy is uncertain. Records used for the Indian Creek subdrainage (11401500) are considered "good" (1969–93). However, natural streamflow in the Indian Creek subdrainage was obstructed by Round Valley and Antelope Valley reservoirs (fig. 1). Also, water is diverted upstream from 11401500 for irrigation of about 11,800 acres, of which 9,700 acres are in and around Indian Valley (fig. 7; Mullen and others, 1987). The measured streamflow data were not corrected to remove these influences.

Lower North Fork

In the southern half of the North Fork drainage, the North Fork tributary flows south from Lake Almanor (4,500 ft asl) through steep, forested canyon walls of the Plumas National Forest (fig. 5), past the East Branch confluence near Belden, and down into Lake Oroville (900 ft asl). Precipitation on the Lower North Fork drainage is high (55 to 105 in. per year; fig. 8*A*). Generally each year, numerous winter storms funnel up the canyon and are concentrated over this area (Gary Freeman, Pacific Gas & Electric Company, unpub. data, 1999; fig. 8*A*).

The Lower North Fork PRMS model was calibrated to reconstructed streamflow records (NF23-8145NF; table 2). Reconstructed streamflow was corrected to remove any inflow from upstream drainages of Butt Creek, Almanor, and East Branch. Further, water year 1994 was removed because reconstructed flows in that year were suspect. Therefore, the model is calibrated to simulate streamflow solely from the Lower North Fork model area (fig. 7). Accounting for hydropower structures (fig. 4), PG&E has reconstructed natural flows at Poe Powerhouse (NF23-8145NF; fig. 4) and Rock Creek Powerhouse (8120; fig. 4), and has computed flows for the entire Lower North Fork PRMS model (NF23-8145NF; table 2; fig. 7). The Lower North Fork model uses parameters determined in models of subdrainages (Rock Creek and Pulga, fig. 7, table 2) made possible by the existence of an intermediate reconstruction site (PG&E 8120). Parameter estimations from the subdrainage models provided added control in the calibration process of the Lower North Fork model.

Middle Fork

The Middle Fork tributary is east-west trending and, like the East Branch, straddles the Sierra Nevada (fig. 7, table 11). The headwaters of the Middle Fork are in the eastern mountains surrounding Sierra Valley. Sierra Valley is a broad alluvium-filled agricultural plain (149 mi^2) with surrounding mountains that reach about 8,700 ft asl. Due to irrigation, infiltration into the alluvium, and low precipitation, very little streamflow escapes this valley (USGS 11392100; fig. 7). From Sierra Valley, the river flows westward, through a ridge to Portola, meanders through Mohawk Valley (about 4,375 ft asl; fig. 7), through the steep forested canyon walls of the Plumas National Forest (fig. 5) and Bald Rock Canyon (fig. 1), and finally into Lake Oroville. The Middle Fork drainage receives an uneven pattern of precipitation. The western side receives the most precipitation. The Sierra Valley is in a rain shadow and is the driest part of the Feather River Basin, receiving only about 15 in. of precipitation per year (fig. 8*A*).

The Middle Fork drainage is represented by a single PRMS model and is calibrated against measured streamflow (USGS 11394500; table 2, fig. 7). Parameters from a model of the Sierra Valley subdrainage (calibrated to USGS 11392100 data) were used in the final Middle Fork PRMS model (figs. 7 and 8). This subdrainage model was constructed to better simulate the physical characteristics of the Sierra Valley. In the Middle Fork model, the Sierra Valley and surrounding mountains were simulated as one HRU. To simulate infiltration losses from streamflow into the deep alluvium, the Sierra Valley HRU was modeled with a ground-water sink.

The USGS 11394500 records used to calibrate the Middle Fork PRMS model are considered "good" for 1969-86 (fig. 7; table 2). This gage was operated by the USGS prior to 1986 and by DWR since then. No estimate of record accuracy after 1986 is available. No record of accuracy is available for streamflow used to calibrate the Sierra Valley subdrainage model (USGS 11392100; table 2, fig. 7). Streamflow records were not corrected for upstream obstructions to natural flow. Streamflow has been partly regulated by Lake Davis and Frenchman Lake (fig. 1). Irrigation diversions of about 1,000 acres exist between 11392100 and 11394500 (Mullen and others, 1987). Diversions exist in the Sierra Valley for irrigation, and about 6.6 acre-ft per year of irrigation water is imported to Sierra Valley from rivers south of the study area (J. Pierre Stephens, DWR Resources Hydrology Branch, unpub. data, 2001).

South Fork

The South Fork drainage consists of steep forested terrain of the Plumas National Forest (fig. 5) and is northeast-southwest trending. It flows directly into Lake Oroville. Although smallest in size (107 mi^2), this drainage receives some of the highest precipitation in the Feather River Basin (fig. 8*A*). Altitude ranges from 971 to 7,449 ft asl (fig. 3; table 11).

The South Fork drainage is represented by a single PRMS model and has been calibrated against reconstructed streamflow (PG&E SF905T; fig. 7; table 2). The reconstructed streamflow was corrected for hydropower obstructions to natural flow (fig. 4) and for reservoirs at Little Grass Valley, Sly Creek, and Lost Creek (fig. 1).

West Branch

The West Branch is represented by a single PRMS model and is calibrated against measured streamflow (USGS 11405300; table 2, fig. 7). The gage is located a few miles upstream from Lake Oroville. The drainage is north-south trending and is heavily forested with evergreen trees and (in the south) some shrubs (fig. 5). This is one of the wettest areas in the Feather River Basin (fig. 8*A*). Streamflow records from 1969–86 for 11405300 are considered “good” (fig. 7, table 2). Since 1986, only low flows have been measured by DWR and record accuracy is uncertain. Owing to scant streamflow data, the calibration/verification period of this model is water years 1971–86.

Measured streamflow recedes in late summer to very low rates (fig. 11*D*) and is not sustained by base flow to the extent that other Feather River tributaries are. Flow is regulated upstream from11405300 by Snag Lake (also known by PG&E as “Round Valley Reservoir”) and Philbrook Reservoir (fig. 1). Canals divert water from the headwaters of West Branch (above 11405300) into the Butte Creek Basin (west of the study area) for PG&E powerhouse use (Mullen and others, 1987). Streamflow is diverted for summertime irrigation. Because streamflow has not been corrected to account for upstream developments, values for simulated streamflow for the summer and (especially) fall are expected to exceed the measured flow values.

Oroville

The Oroville drainage is driest near Lake Oroville and wettest adjacent to other models (figs. 7, 8*A*, table 11). However, overall, the modeled area receives a significant amount of precipitation. No measured or reconstructed streamflow exists for the calibration of Oroville model, but the area contributes a significant amount of streamflow to Lake Oroville.

The Oroville model surrounds Lake Oroville (fig. 7, table 11). PRMS is not well suited to simulate streamflow from large lake surfaces. Evaporation from Lake Oroville equals or slightly exceeds precipitation, and thus the lake does not effect a net change in streamflow. Therefore, the lake area is not included in the Oroville model. Parameters were estimated from similar HRU characteristics in the seven calibrated models.

Parameters

The long-term climate and land-surface characteristics of the eight PRMS models are quantified by a large number of model parameters. Spatial variations of these characteristics are represented by HRU-specific and reservoir-specific (fig. 13*A*) parameters. Other properties that are homogeneous over the whole model area are quantified by nondistributed parameters (table 12). Parameters are specified as constants or monthly values. All parameters are independent of daily fluctuations of the temperature and precipitation inputs.

Sources of key model parameters are presented in table 12. The designation “calibrated” means that the initial estimates of the parameter values were adjusted during iterative model runs to minimize differences between simulated and measured or reconstructed streamflows. “Computed” values were first derived from the literature (Black, 1996) and then revised prior to calibration to reflect conditions specific to the Feather River Basin. “GIS derived” parameters are computed directly from spatial data.

Table 12. Source of parameter values for selected Hydrologic Response Unit [HRU] (distributed) and whole-model (nondistributed) Precipitation-Runoff Modeling System (PRMS) parameters for the Feather River Basin, California (modified from Jeton, 1999b).

[GIS, Geographic Information System; MF, Middle Fork; SF, South Fork]

Model parameter	Description of parameter	Range of values (or cover type)	Source of parameter value				
			GIS derived[1]	Computed[2]	Literature[3]	Default value[4]	Calibrated[5]
	HRU (distributed) parameters						
CAREA_MAX	Maximum area contributing to surface runoff (decimal percent)	0.0001–0.01					X
COV_TYPE	Vegetation cover type (bare soil, grasses, shrubs, trees)	Grasses, shrubs, trees	X				
COVDEN-SUM	Vegetation cover density (decimal percent) for summer	0.23–0.78	X				
COVDEN-WIN	Vegetation cover density (decimal percent) for winter	0–0.76	X				
GWFLOW_COEF	Ground-water routing coefficient to obtain the ground-water flow contribution to streamflow	0.001–0.5					X
GWSINK_COEF	Ground-water sink coefficient to compute the seepage from each reservoir to a ground-water sink	0–.05					X
GWSTOR_INIT	Storage in each ground-water reservoir at the beginning of the simulation (in inches)	0.001–20					X
HRU_AREA	HRU area (in acres)	382–14,774 (excluding Sierra Valley 325,118 acres)	X				
HRU_DEPLCRV	Index number for snowpack depletion curve	1		X			
HRU_ELEV	Mean HRU altitude (in feet)	1,067–7,257	X				
HRU_GWRES	Index number for ground-water reservoir	1–111		X			
HRU-PERCENT_IMPERV	HRU impervious area as a decimal percent of the total HRU area	0– 0.10 percent	X				
HRU_PSTA	Index number of the precipitation station time series to compute rain and snow on HRU	1–111		X			
HRU_RADPL	Index number of the solar radiation plane	1–111		X			
HRU_SLOPE	HRU slope in decimal percent (vertical feet/horizontal feet)	0.02–0.66	X				
HRU_SSRES	Index number of the subsurface reservoir receiving excess water from the HRU soil zone	1–111		X			
HRU_TSTA	Index number of the temperature station used to compute HRU temperatures	1–3		X			
IMPERV_STOR_MAX	Maximum impervious retention storage for the HRU (in inches)	0.02 (SF only), 0.20 (all others)				X	
JH_COEF-HRU	Air temperature coefficient used in the Jensen-Haise (1963) potential-evapotranspiration computations for each HRU	13–17		X			
RAD_TRNCF	Transmission coefficient for short-wave radiation through the winter canopy (decimal percent)	0.12– 0.99		X			
SMIDX-COEF	Coefficient in the nonlinear contributing area algorithm (computing surface runoff)	0.01–0.03				X	
SMIDX_EXP	Exponent in nonlinear contributing area algorithm (computing surface runoff)	0.10–0.30				X	

Table 12. Source of parameter values for selected Hydrologic Response Unit [HRU] (distributed) and whole-model (nondistributed) Precipitation-Runoff Modeling System (PRMS) parameters for the Feather River Basin, California (modified from Jeton, 1999b)—Continued.

[GIS, Geographic Information System; MF, Middle Fork; SF, South Fork]

Model parameter	Description of parameter	Range of values (or cover type)	Source of parameter value				
			GIS derived[1]	Com-puted[2]	Litera-ture[3]	Default value[4]	Cali-brated[5]
SNAREA_THRESH	Maximum snow water equivalent below which the snow-covered area depletion curve is applied	5–25		X			
SNOW_INTCP	Snow interception storage capacity for the major vegetation type on an HRU (in inches)	0–0.35			X		
SNOWINFIL_MAX	Maximum infiltration rate for snowmelt (in inches per day)	3–8					X
SOIL2GW_MAX	Amount of soil water excess for an HRU that is routed directly to the associated ground-water reservoir each day (in inches)	0.05–0.25					X
SOIL_MOIST_INIT	Initial value of available water in soil profile (in inches)	0.09–5.54		X			
SOIL_MOIST_MAX	Maximum available water-holding capacity of soil profile (in inches)	1.00–11.08		X			
SOIL_RECHR_INIT	Initial value for available water in the soil recharge zone, (in inches) (upper soil zone)	0.06–3.32		X			
SOIL_RECHR_MAX	Maximum value for available water in the soil recharge zone (in inches)	0.17–5.54		X			
SOIL_TYPE	HRU soil type (sand, loam, or clay)	Sand or loam	X				
SRAIN_INTCP	Summer interception storage capacity for the major vegetation type on an HRU (in inches)	0.05–0.35			X		
SS2GW_RATE	Coefficient to route water from the subsurface to ground-water reservoir	0.01–0.1					X
SSRCOEF_LIN	Linear subsurface routing coefficient to route subsurface storage to streamflow	0.01–0.04					X
SSRCOEF_SQ	Nonlinear subsurface routing coefficient to route subsurface storage to streamflow	0.01–0.03					X
TMAX_ADJ	HRU maximum temperature adjustment in Fahrenheit (°F) to HRU temperature, based on slope and aspect of HRU	–3 (MF only), 0 (all others)				X	
TMIN_ADJ	HRU minimum temperature adjustment in Fahrenheit (°F) to HRU temperature, based on slope and aspect of HRU	–3 (MF only), 0 (all others)				X	
TRANSP_BEG	Month to begin summing maximum temperature for each HRU; when sum is greater than or equal to TRANSP_TMAX transpiration begins	February – April			X		
TRANSP_END	Last month for transpiration computations	July–November			X		
TRANSP_TMAX	Temperature index to determine the specific date of the start of the transpiration period	500				X	
WRAIN_INTCP	Winter rain interception storage capacity for the major vegetation type on an HRU (in inches)	0–0.35			X		

Table 12. Source of parameter values for selected Hydrologic Response Unit [HRU] (distributed) and whole-model (nondistributed) Precipitation-Runoff Modeling System (PRMS) parameters for the Feather River Basin, California (modified from Jeton, 1999b)—Continued.

[GIS, Geographic Information System; MF, Middle Fork; SF, South Fork]

Model parameter	Description of parameter	Range of values (or cover type)	Source of parameter value				
			GIS derived[1]	Computed[2]	Literature[3]	Default value[4]	Calibrated[5]
	Selected non-distributed parameters						
ADJMIX_RAIN	Monthly factor to adjust rain proportion in a mixed rain/snow event (decimal percent)	0.50–1					X
JH_COEF	Monthly air temperature coefficient used in the Jensen-Haise (1963) potential evapotranspiration computations	0.011–0.014					X
RAIN_ADJ	Monthly factor to adjust precipitation (rain) to each HRU (decimal percent)	0.70–1.20					X
SNOW_ADJ	Monthly factor to adjust precipitation (snow) to each HRU (decimal percent)	0.70–1.25					X
TMAX_ALLSNOW	Maximum temperature (ºF) below which all precipitation is simulated as snow	31–35					X
TMAX_ALLRAIN	Maximum temperature (ºF) above which all precipitation is simulated as rain	38–43					X
MELT_LOOK	Julian date to start looking for spring snowmelt	60–61					X
MELT_FORCE	Julian date to force snowpack to spring snowmelt	60–120					X
TMAX_LAPSE	Monthly maximum temperature lapse rate (ºF) representing the change in maximum temperature per 1,000 feet of altitude change for each month	3.3–4.75					X
TMIN_LAPSE	Monthly minimum temperature lapse rate (ºF) representing the change in minimum temperature per 1,000 feet of altitude change for each month	3.3–4.75					X

[1]Computed in geographic information system (GIS) from digital coverages.

[2]Computed from climatological data or other measured data.

[3]Obtained from the literature as estimated or empirical estimates (Black, 1996, table 4-1, p. 93).

[4]Parameters that are considered constant, as provided by Leavesley and others (1983).

[5]Parameters that (a) cannot be estimated from available data and are adjusted during calibration or (b) have initial estimates from measured or published data that were adjusted during calibration.

Model Development

The ARC/INFO (Environmental Systems Research Institute, 1992) geographic information system (GIS) was used to manage spatial data and to characterize model drainages and HRUs in terms of slopes, aspects, altitudes, vegetation cover densities and types, soil types and depths, geology, and the distribution of precipitation. These analyses provided estimates of many spatially varying HRU-specific model parameters. The methods used to develop parameter estimates were similar to methods used by Battaglin and others (1993), Frankoski (1994), Jeton and Smith (1993), Jeton and others (1996), Jeton (1999a,b), Ryan (1996), and Viger and others (1996, 1998).

Model-Area Delineations

The eight PRMS models (table 11), and the HRUs within the models (fig. 14), were first delineated by Bruce McGurk for the USDA Forest Service. PRMS models and HRUs were based on the CALWATER State Water Resources Control Board standardized watershed boundaries (http://www.watershed.org/news/spr_94/calwater_gis.html, accessed on Dec.18, 2001). These were modified with the GIS WEASEL tool (Viger and others, 1996, 1998; http://wwwbrr.cr.usgs.gov/projects/SW_precip_runoff/weasel/, accessed on Jan. 6, 2000) to better reflect the basic hydrologic concepts used in PRMS and the locations of streamflow gages. The Butt Creek catchment was delineated from the drainage for USGS 11400500 gage (U.S. Geological Survey, 1965; digitized from USGS topographic quadrangles). Other minor revisions were made as model development proceeded.

HRUs were delineated as approximately homogeneous polygons within the model areas, with more emphasis on drainage divides and hydrography than on other physical characteristics. Measurements of the physical characteristics of altitude, slope, aspect, vegetation, and soils were averaged to estimate HRU-scale parameters. This is in contrast to the earlier studies by Jeton (1999a,b) and Jeton and others (1996) in other study areas in which HRUs were delineated as noncontiguous cell clusters. HRU land areas ranged from 382 to 14,774 acres (not including the Sierra Valley HRU, which encompassed 325,118 acres; table 13).

Table 13. Model Hydrologic Response Unit (HRU) counts and ranges within each model of specified-HRU areas, mean altitudes, mean slopes, and mean aspects.

[ft asl, feet above sea level]

Model	Total number of HRUs	HRU ranges			
		Area (acres)	Altitude (ft asl)	Slope (decimal percent)	Aspect (degrees)
Almanor	45	901–14,774	4,555–7,257	0.02–0.25	21–310
Butt Creek	6	6,063–12,081	4,722–5,985	0.07–0.30	25–358
East Branch	111	1,100–13,539	3,586–6,554	0.09–0.55	0-–358
Lower North Fork	37	1,506–10,458	3,083–6,319	0.16–0.66	14–359
Middle Fork	58	1,793–14,311 (Sierra Valley: 325,118)	3,083–6,437	0.13–0.57	21–358
South Fork	15	2,524–8,149	2,067–5,943	0.19–0.42	139–354
West Branch	11	7,960–8,310	1,883–5,941	0.20–0.40	168–267
Oroville	41	382–10,122	1,067–5,130	0.18–0.57	4–354

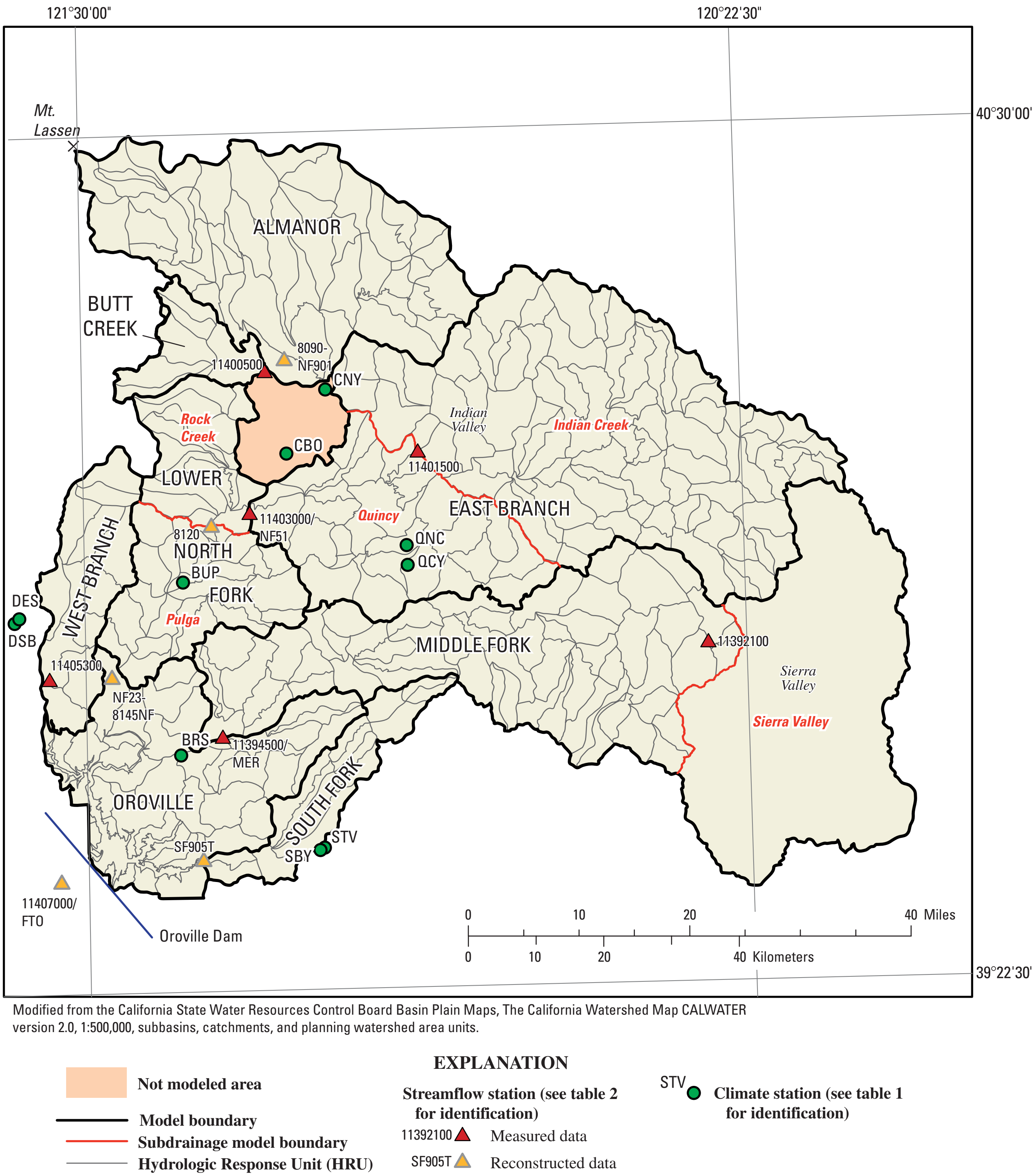


Figure 14. Hydrologic response units (HRUs) and model areas delineated for the Feather River Basin Precipitation-Runoff Modeling System (PRMS), California.

Precipitation Estimates for Hydrologic Response Units (HRUs)

In PRMS (Leavesley and others, 1983), as in most snowmelt models (World Meteorological Organization, 1986), the established method for assigning daily precipitation rates to models was to define lapse rates for the change in precipitation between lower and higher altitude climate stations. This method was not applicable for the Feather River Basin. The precipitation stations used in the present models were located only in the lower altitudes. Further, a portion of the basin was in the rain shadow of the Sierra Nevada, and precipitation stations in the rain shadow could not be correlated with stations outside the rain shadow. Winter storms funnel up the Lower North Fork (Gary Freeman, unpub. data, Pacific Gas & Electric Company, 1999), releasing most of their moisture before reaching Lake Almanor (fig. 8). Finally, because the Feather River Basin spans about 1 degree of latitude and longitude (fig. 1), on a given day, weather can differ considerably across the basin. A review of precipitation measurements showed that, in a single day, part of the basin can receive a downpour while another part is dry. Over the course of many days, storm movements could be tracked as precipitation totals rose and fell across the basin's climate stations.

For the present study, a technique was developed to combine measured daily precipitation variations with long-term mean precipitation estimates from the PRISM method (Daly and others, 1994). The PRISM surfaces offer full coverage of the basin area and account for topographic changes, including rain shadow. This new procedure is called the "draper" method because the monthly averaged PRISM precipitation surface was adjusted to account for daily precipitation patterns by mathematically "draping" the PRISM averages over the measurements at reporting precipitation stations (fig. 15).

The draper method requires the following input data: (1) precipitation measurements located by latitude and longitude, (2) location of the HRU centroids by latitude and longitude, and (3) mean-monthly HRU-averaged precipitation totals, in inches, from mean-monthly PRISM surfaces (http://www.ocs.orst.edu/prism/state_products/ca_maps.html, accessed May 1, 2001) for each month of the year.

Each day, precipitation measurements were converted to percentages of the long-term daily normal for the corresponding climate station and month of year. If three or more measurements were available for a given day, a plane was fitted, by linear regression between the day's precipitation percentage and the latitude and longitude of the observations (fig. 15*A*). The resulting "percent of normal" plane was then used to tilt the appropriate monthly PRISM surface (fig.15*B*) which represented "normal" precipitation rates. This created a tilted PRISM surface for each day simulated (fig. 15*C*). The tilted PRISM surface was then sampled at HRU centroids to obtain HRU-scale precipitation values for each day.

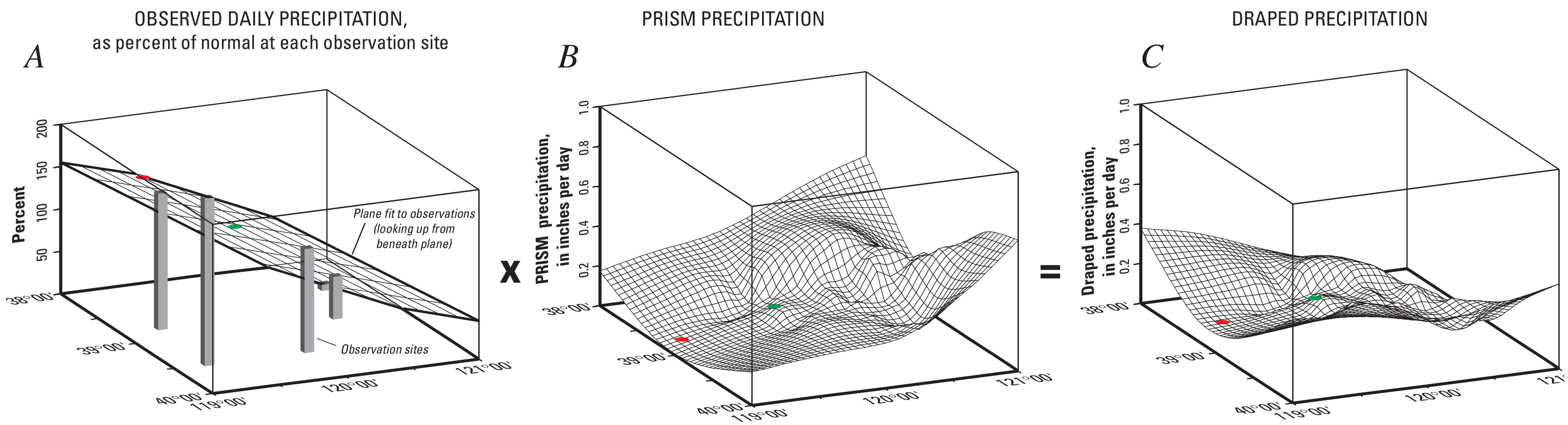
On days with only one or two observations of precipitation, the PRISM surface was not tilted, because three points are required to define a plane. Rather, average precipitation was computed by uniformly scaling up or down the monthly PRISM surface, according to the average "percent of normal" plane for that day's observations. Then, HRU precipitation was estimated by sampling that scaled map by HRU centroids.

For days with no precipitation data, the HRU precipitation was estimated to be the normalized daily PRISM precipitation for the given month. The normalized daily PRISM precipitation is the measurement obtained at the HRU centroid from the PRISM surfaces as noted above.

Model Calibration and Error Analysis

The most pressing use of the Feather River PRMS models may be to simulate (and eventually, forecast) year-to-year variations of inflows to Lake Oroville during the critical April–July snowmelt season. Therefore, calibration focused primarily on simulating flows during the April–July snowmelt season, secondly on monthly simulations, and finally on daily flow characteristics. The calibration period, chosen on the basis of available streamflow records, was generally wetter than the long-term average; thus the calibration may be better suited for wet rather than dry, climatic conditions. Of the eight models built, seven were calibrated to reconstructed or measured data (table 2). Parameter values for the Oroville model were based on those of the other seven. The calibration period is 1971–97, except for the West Branch model, which was calibrated to streamflow from 1971–86. Because calibration included the entire period of record, no separate verification period exists. The models were calibrated individually and the results were summed. This sum was compared to the monthly Lake Oroville FTO reconstructed streamflow. The comparison was not used in model calibration.

Some of the model sensitivities to parameter values can be understood from previous modeling studies in the Sierra Nevada (Jeton and others, 1996; Jeton, 1999a,b). Sensitivity analyses of the East Fork Carson River model (an eastern north-central Sierra Nevada watershed) have shown that streamflow simulations are most sensitive to (1) the snow-threshold temperature that determines precipitation form (tmax_allsnow; table 12); (2) the precipitation-correction factor for snow (similar to a precipitation lapse rate); (3) the monthly evapotranspiration coefficients for the Jensen-Haise potential-evapotranspiration computations (Jensen and Haise, 1963); (4) the coefficient for transmission of solar radiation through winter plant canopies to snow surfaces; and (5) the monthly temperature lapse rates. The models are sensitive to lapse rates for both maximum and minimum temperatures.



The red and green dots represent centers of hydrologic response units (HRU). Block ***A*** shows a computed plane of daily percent-of-normal measurements fit to actual daily precipitation measurements which are represented as bars. The normal measurements are considered to be the mean-monthly PRISM estimates for the month of interest. Block ***B*** shows an example of an unaltered mean-monthly PRISM surface. Block ***C*** shows the result of the mean-monthly PRISM surface corrected to fit the daily percent-of-normal plane shown in Block ***A***. An estimate of daily precipitation is then sampled at the red and green dots in Block ***C***, which represent daily precipitation at the HRU centroid.

Figure 15. Draper method to estimate daily precipitation from Parameter-Elevation Regressions on Independent Slopes Model (PRISM) surfaces, including (*A*) observed daily precipitation as a percent of normal at each observation site, (*B*) an example of a mean-monthly PRISM precipitation surface, and (*C*) resulting draped precipitation estimates.

Calibration of the Feather River PRMS models revealed other sensitivities. The models were found to be highly sensitive to the temperature threshold above which all precipitation falls as rain (tmax_allrain, table 12). The models also are sensitive to the flow-routing coefficients for subsurface and ground-water reservoirs, which control rates of flow from these reservoirs to the stream channel (affecting the timing of streamflow). Parameters that determined flows to and from the ground-water reservoirs were adjusted to fit observed shapes of seasonal recessions of streamflow.

No single calibration of the PRMS model will simulate all flow regimes with equal accuracy. Ideally, the Feather River PRMS simulations should have (1) little to no bias (table 14), (2) small simulation errors of volume and timing, and (3) realistic parameter values reflecting the conditions being modeled (Leavesley and others, 1983). In watershed modeling, common measures of simulation error are the sum of errors or bias, the sum of the absolute values of the errors, and the sum of the square of the errors. Absolute errors and errors squared tend to be dominated by a few large events (Troutman 1985; Haan and others, 1982), unless normalized by the reconstructed or measured flows to form “relative error” (table 14). The unnormalized root-mean-square error (RMSE) provides a common measure of the magnitude of simulation errors (table 14) that complements the relative measures provided by the bias and relative errors reported in table 14.

Calibration of PRMS models is an iterative process where, after each adjustment of model parameters, simulated flows are compared with measured or reconstructed flows visually and statistically. After initial parameters are set (table 12), the models are run and the simulated hydrograph is compared with measured or reconstructed flows, with special attention paid to matching flow volume and the timing of peak discharge. For the Feather River PRMS models, 19 parameters (marked as “calibrated” in table 12) were adjusted one at a time during calibration. When a good visual match was achieved, supporting statistics were computed for different time scales. Parameter adjustments were made as necessary and the fit of the hydrographs was compared again. The goal of this process was to maintain a good visual fit between the hydrographs and to keep biases and relative errors below 10 percent (established as an acceptable fit in previous work; Jeton,1999a,b).

Statistics at each time scale were computed from the difference between mean simulated and observed (measured or reconstructed) flows. Periods with missing data from the Lower North Fork, Middle Fork, and West Branch were not included in the statistics. The Lower North Fork model was further evaluated by excluding water year 1994, because reconstructed flows in that year are suspect. Finally, the sum of simulated flows from the eight models (including the Oroville Model) were compared with FTO reconstructions.

Model-calibration biases, relative errors, and RMSEs for the seven calibrated models are given in table 14 for three time increments: seasonal, monthly, and annual (water year) streamflows. On all three time scales, the overall biases, relative errors, and RMSEs are suitably low, especially for April–July snowmelt season totals, indicating acceptable simulations during the 1971–97 period. Poorer fit with large bias and relative error (especially in the East Branch) was obtained for August–September flows. Slightly larger errors in the East Branch model can be explained by reservoir storage and irrigation practices. The August–September season contributed only about 4 percent of the total annual inflow to Lake Oroville (table 9).

In the Almanor and Butt Creek models, bias and relative error are relatively large and indicate systematic under-simulation of October–December streamflow. These drainages are presumed to be more heavily influenced by underlying volcanic formations than are the other drainages. These influences may produce deeper ground-water reservoirs than the ones represented in PRMS and thus may limit how well simulations match the measured and reconstructed flows. However, these errors are from a season with low streamflows and thus are not of great practical concern.

During the season of most interest to water managers, the April–July snowmelt season, a very good fit was achieved (table 14). Relative errors are highest in the West Branch model, probably owing to the measured flows used in the calibration. The flows measured at the West Branch gaging station could not be corrected for human interventions upstream, including small reservoirs and diversions for irrigation. PRMS, which simulates natural flows, therefore would be expected to have large relative errors in that season.

Simulated and measured or reconstructed daily hydrographs are shown for each model in figure 16. The daily statistics (fig. 16 insets) show that—with the exception of the West Branch model, which has a high relative error—simulations are similar to measured and reconstructed flows. No measured or reconstructed daily streamflow data exist for the Oroville model, and only simulations are shown in that hydrograph.

The mean-monthly percentages of annual streamflows are accurately simulated in most months (fig. 17). Some models tend to simulate higher than measured or reconstructed streamflows in April and under-simulate by May. The Lower North Fork model simulates higher streamflows later in the season. However, in all of the models, the overall volume closely simulates measured or reconstructed streamflow data, with RMSEs ranging from 0.7–1.6 percent.

The mean-monthly percentage of simulated inflow to Lake Oroville for water-years 1971–97 was compared with DWR’s FTO reconstructions (fig. 18). Figure 18 illustrates the contribution of each individual model to total Lake Oroville inflow. The combined simulated inflows from the eight models satisfactorily match the monthly graphed distribution of the FTO reconstructions, with a RMSE of 0.84 percent.

Table 14. Calibration statistics, Feather River Basin, California, water years 1971–97.

[RMSE, root-mean-square error; ft^3/s, cubic feet per second; FTO, California Department of Water Resources (DWR) streamflow reconstruction site: Feather River at Oroville, California]

Model	Seasonal												Monthly			Annual		
	Oct.–Dec.			Jan.–Mar.			Apr.–July			Aug.–Sept.								
	Bias[1] (percent)	Relative error[2] (percent)	RMSE[3] (ft^3/s), except for FTO (acre-feet)	Bias (percent)	Relative error (percent)	RMSE (ft^3/s) except for FTO (acre-feet)	Bias (percent)	Relative error (percent)	RMSE (ft^3/s) except for FTO (acre-feet)	Bias (percent)	Relative error (percent)	RMSE (ft^3/s) except for FTO (acre-feet)	Bias (percent)	Relative error (percent)	RMSE (ft^3/s) except for FTO (acre-feet)	Bias (percent)	Relative error (percent)	RMSE (ft^3/s) except for FTO (acre-feet)
Almanor	–4.1	–16.3	376	7.6	0.7	463	1.2	3.7	241	–8.7	–4.5	118	1.5	–3.9	494	1.5	–0.6	154
Butt Creek	–10.9	–22.7	33	–1.0	–5.8	36	0.5	–0.6	27	–15.5	–16.6	12	–3.1	–11.7	41	–3.2	–6.0	15
East Branch	6.1	–14.0	240	–1.2	0.4	604	3.4	10.0	351	52.4	49.8	94	2.8	10.7	591	2.7	1.6	204
Lower North Fork[4]	7.7	1.7	192	–10.5	–5.8	443	0.7	4.2	234	14.6	7.8	230	–1.6	4.6	515	–1.4	–1.6	123
Middle Fork	–0.2	–9.0	389	–3.4	5.1	837	–5.8	–6.8	503	–24.7	17.2	143	1.7	2.1	884	1.9	3.9	220
South Fork	4.2	19.5	63	7.4	18.5	140	6.7	11.6	125	35.1	21.7	16	7.5	18.7	164	7.3	7.9	57
West Branch[5]	–9.0	–13.6	72	–10.2	11.2	193	–6.6	26.4	86	16.3	48.5	5	–8.3	47.9	160	–8.2	11.1	68
FTO[6]	10.0	0.2	267,666	–4.9	–1.4	410,633	–3.7	–3.3	285,259	–16.4	–21.4	57,279	–3.2	–9.1	133,871	–3.2	–3.6	465,328

[1]Equation used for bias calculation: $\frac{\Sigma(s-o)}{\Sigma o} x100$.

[2]Equation used for relative error calculation: $\frac{\Sigma\left[\frac{(s-o)}{o}\right]}{N} x100$.

[3]Equation used for root-mean-square error (RMSE): $\sqrt{\frac{\Sigma(s-o)^2}{N}}$.

For all equations:

s is simulated mean streamflow, in cubic feet per second,

o is observed (measured or reconstructed) mean streamflow, in cubic feet per second, and

N is number of measured or reconstructed values greater than 0 cubic feet per second.

[4]Lower North Fork reconstructed data for 1994 was suspect, and this year was excluded from the analyses.

[5]West Branch calculations for 1971–86 only, corresponding to available measured data.

[6]FTO reconstructed inflow to Lake Oroville was provided by DWR, (http://cdec.water.ca.gov/ accessed March 12, 2002), and compared with combined simulated inflow for water years 1971–97. RMSE is in acre-feet.

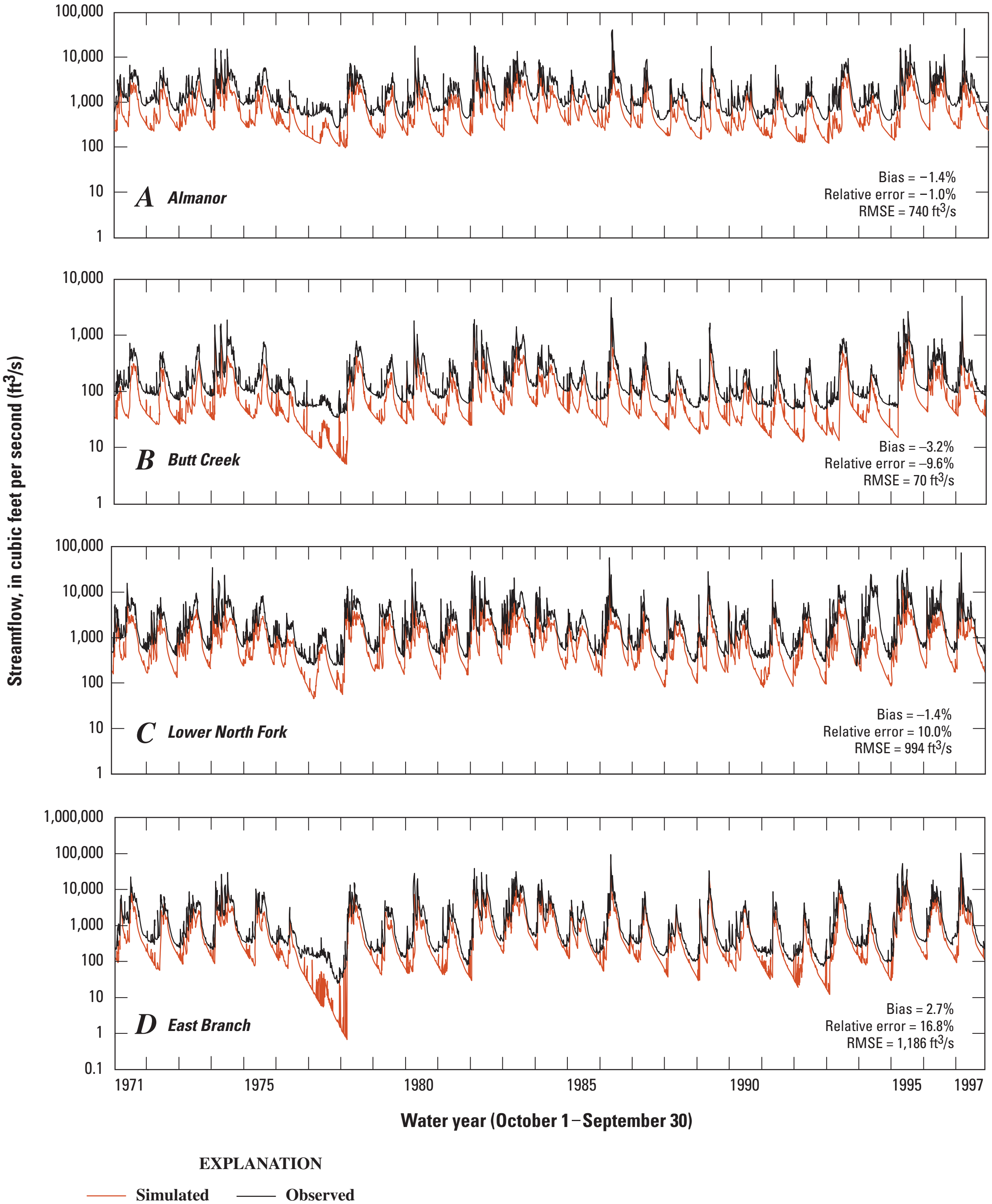
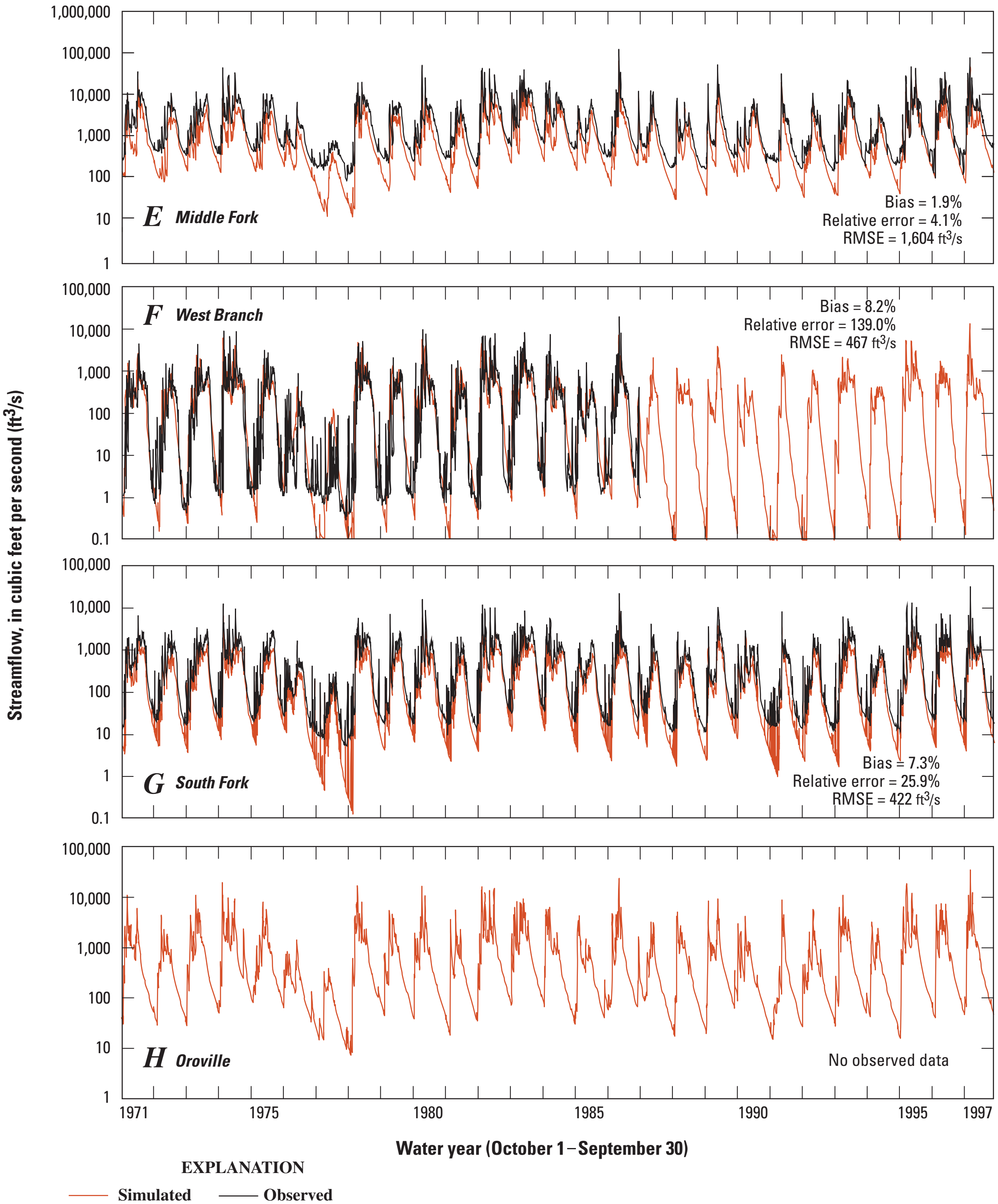


Figure 16. Daily streamflow hydrographs showing model simulations and observed (measured or reconstructed) streamflow, water years 1971–97, including (*A*) Almanor, (*B*) Butt Creek, (*C*) Lower North Fork, (*D*) East Branch, (*E*) Middle Fork, (*F*) West Branch, (*G*) South Fork, and (*H*) Oroville. Y-axes vary. RMSE, root-mean-square error.



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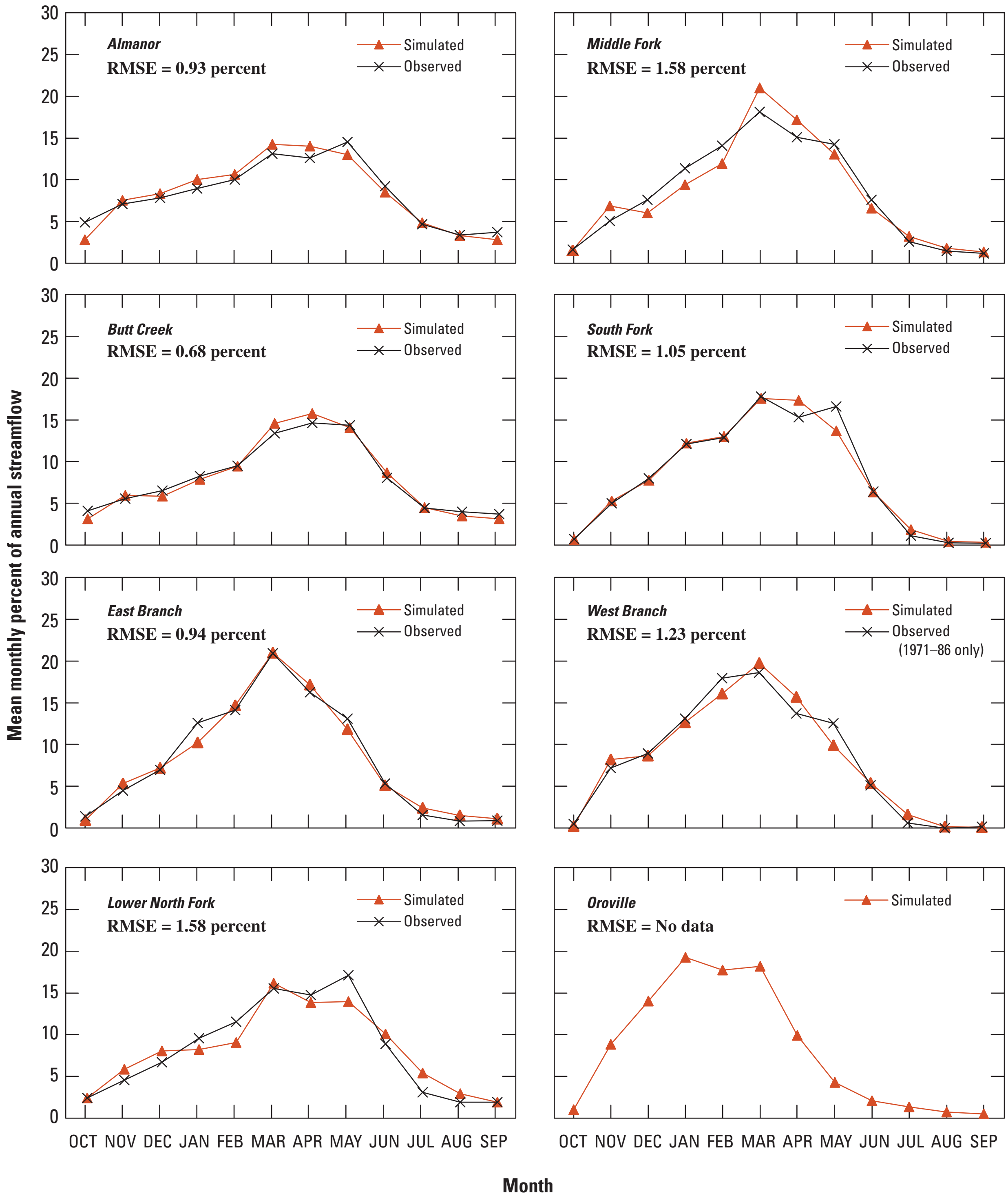


Figure 17. Mean-monthly percentages of annual streamflow for individual models, water years 1971–97. Observed streamflow is measured or reconstructed flow.

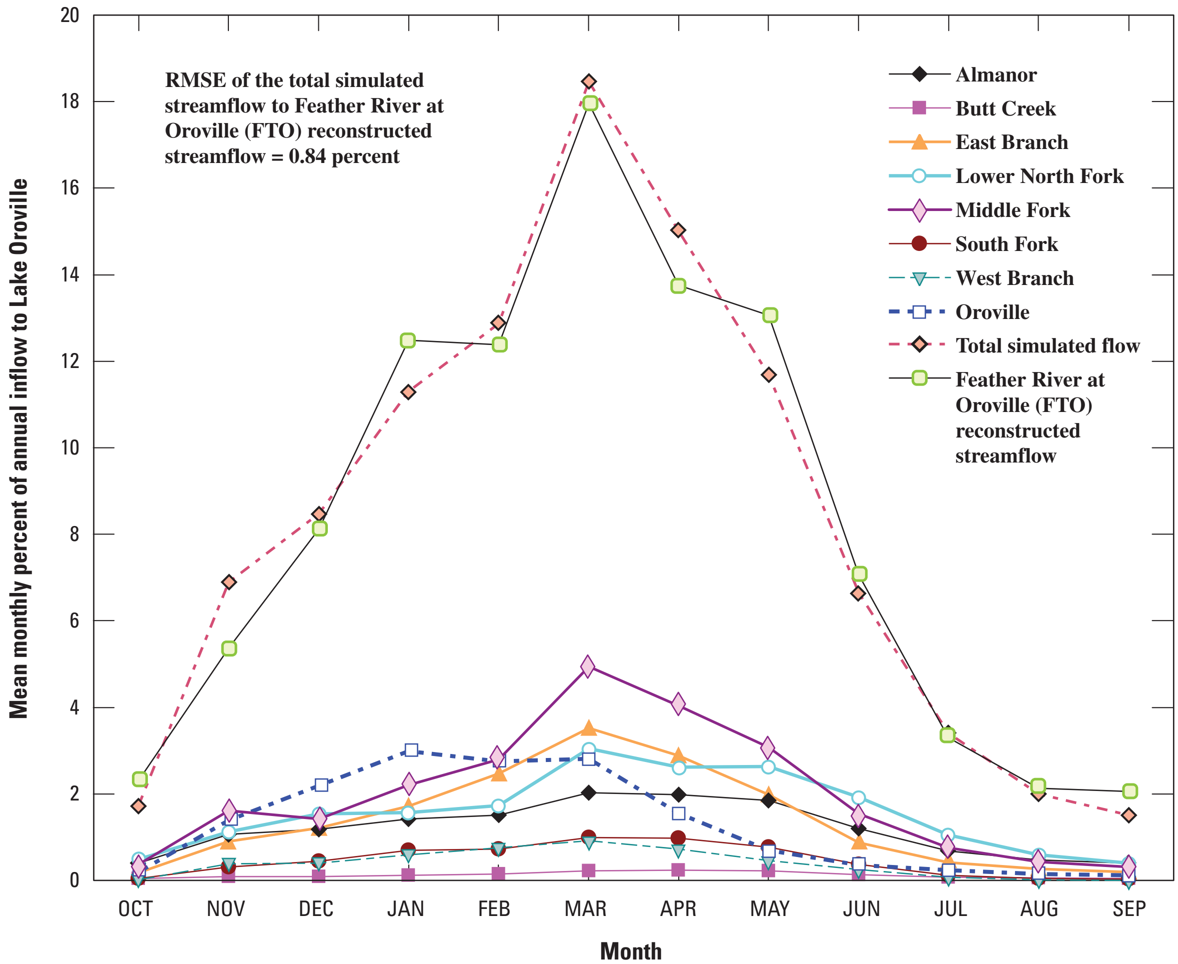


Figure 18. Mean-monthly percentages of simulated inflows to Lake Oroville and the Feather River at Oroville (FTO) reconstructed streamflow, water years 1971–97. RMSE, root-mean-square error.

Model simulations of seasonal volumes of flow into Lake Oroville were also compared with DWR's FTO reconstructions for selected seasons (January–March and April–July; fig. 19). A comparison of the January–March model simulations to FTO reconstruction volumes yields a RMSE of 410,852 acre-feet with flow volumes ranging from about 200,000 to 4,800,000 acre-feet (fig. 19). A comparison of April–July model simulations to FTO reconstruction volumes yields a RMSE of 289,963 acre-feet with flow volumes ranging from about 300,000 to 4,300,000 acre-feet (fig. 19). Based on the RMSEs and a visual comparison of the graphed data, model simulation totals reasonably match the FTO reconstruction volumes on this time scale.

The graph of total annual simulated inflow volumes closely tracks the phase and volume of FTO reconstructions for water years 1971–97, resulting in a RMSE of 465,328 with flow volumes ranging from about 200,000 to 9,400,000 acre-feet (table 14, fig. 20). A small bias and relative error of less than –4 percent were calculated for this annual comparison (table 14).

Three additional years of simulation (1998–2000), beyond the calibration period, were later compared to FTO annual reconstruction volumes (fig. 20). Overall, the timing of simulated streamflow is in phase with the FTO reconstructions. However, the modeled streamflow volumes after 1997 are too low when compared to FTO reconstruction volumes, with a higher RMSE of 633,544 acre-feet, higher relative error of –9.3 percent and a higher bias of –11.1 percent as compared to calibration statistics for 1974–1997 (table 14; fig. 20). This departure could be explained by the influence of the PDO on the Feather River Basin. The PDO entered a cool phase beginning about 1998, cooling basin temperatures. Cooler basin temperatures would shift peak streamflow to April–May. The models were calibrated mostly to conditions during the warmer phase PDO (1977–98), during which peak streamflow occurs by March (Koczot and Dettinger, 2003).

As mentioned, a double-mass analysis of old and new Quincy climate station temperatures revealed a change in the record in about November 1998. The Quincy temperatures are important inputs to the East Branch and Middle Fork models, which provide 40 percent of the inflow to Lake Oroville. Thus, the changes at the Quincy climate station could partially explain the recent systematic simulation errors for the years 1998–2000.

Simulated and Remotely Sensed Snow Cover Comparison

Snow cover simulated in PRMS on the Lower North Fork was compared, at the HRU level, with remotely sensed snow cover from the National Operational Hydrologic Remote Sensing Center (NOHRSC; http://www.nohrsc.nws.gov, accessed on Jan. 10, 1999; fig. 21). Comparisons such as these may be used in PRMS calibrations to determine how well snowpack accumulation and melt are being simulated. The comparison used a GIS tool—the Snow Cover Comparison Tool (SCCT; Koczot and Dettinger, 1999)—developed for this purpose.

A comparison of a NOHRSC snow cover map and simulated Lower North Fork snow-water content is shown for March 15, 1996, in figure 21. The NOHRSC imagery has a resolution of 0.68 mi (1,100 m), whereas the Lower North Fork simulation has an effective resolution of 0.02 mi (30 m).

Figure 21 shows areas where the PRMS simulations and NOHRSC remotely-sensed indications of snow are in agreement (the "both snow" and "both no snow" categories), and in disagreement (the "snow simulated only" or "snow remotely sensed only" categories). Despite the different resolutions of the imagery and model, the PRMS simulations and NOHRSC snow cover in this example agree in 80 percent of the study area. Examples where there is not an agreement include HRUs 14 and 23, where NOHRSC simulated snowcover and PRMS did not. Such disagreements can provide the starting point for identifying model errors that could not be recognized in a calibration based on only a single streamflow gage at the outflow from the model area.

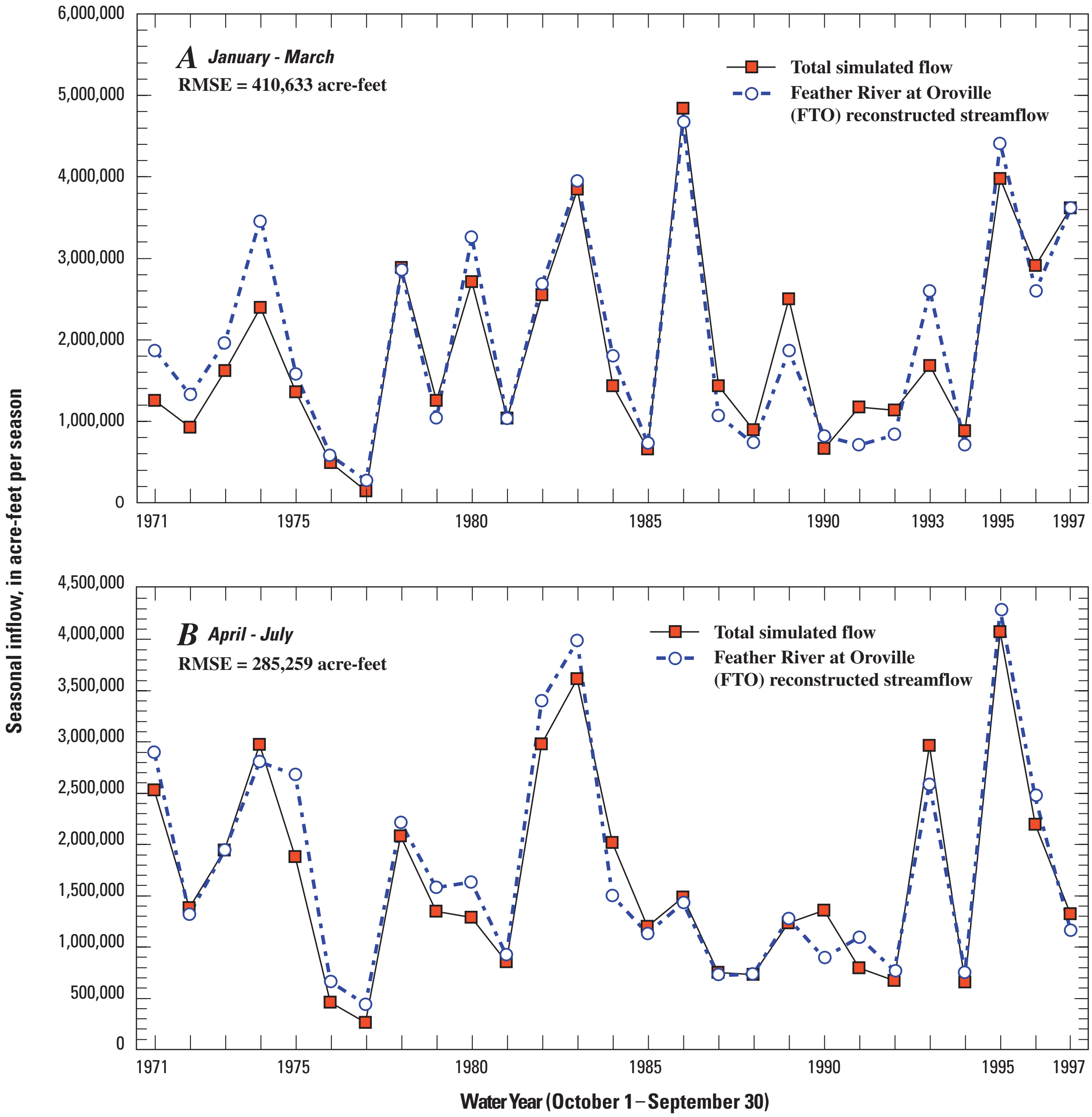


Figure 19. Seasonal streamflow into Lake Oroville in water years 1971–97, including (A) January–March, and (B) April–July. Y-axes vary. RMSE, root-mean-square error.

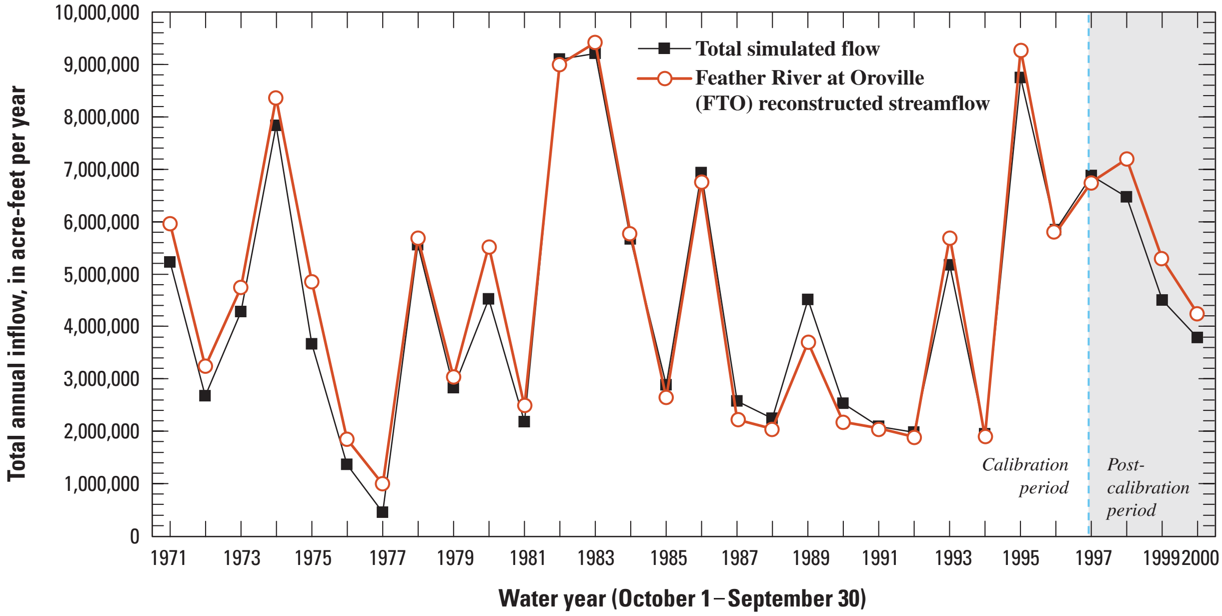


Figure 20. Total annual inflow to Lake Oroville, water years 1971–2000.

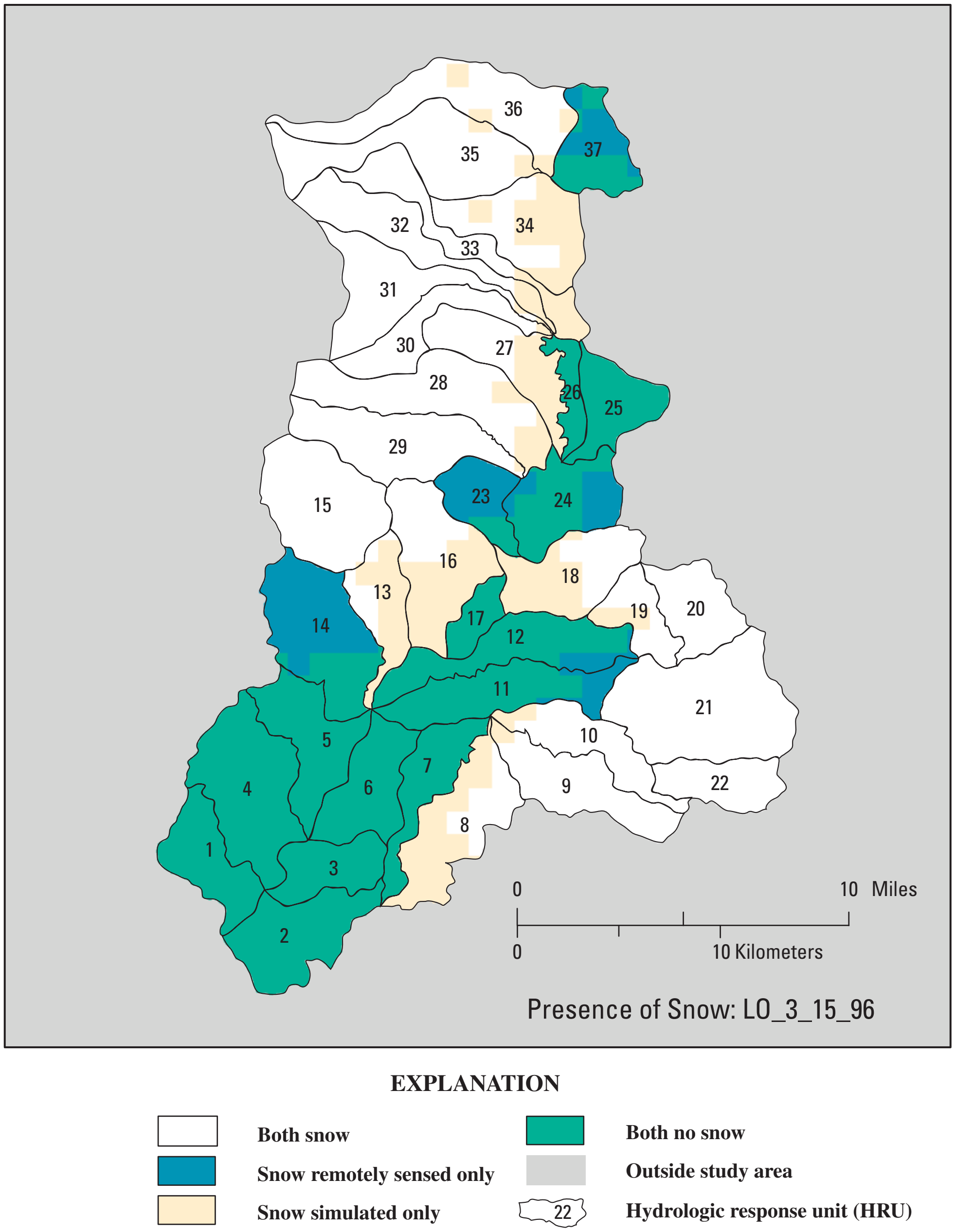


Figure 21. Simulated and remotely sensed snow cover for the Lower North Fork Model, March 15, 1996.

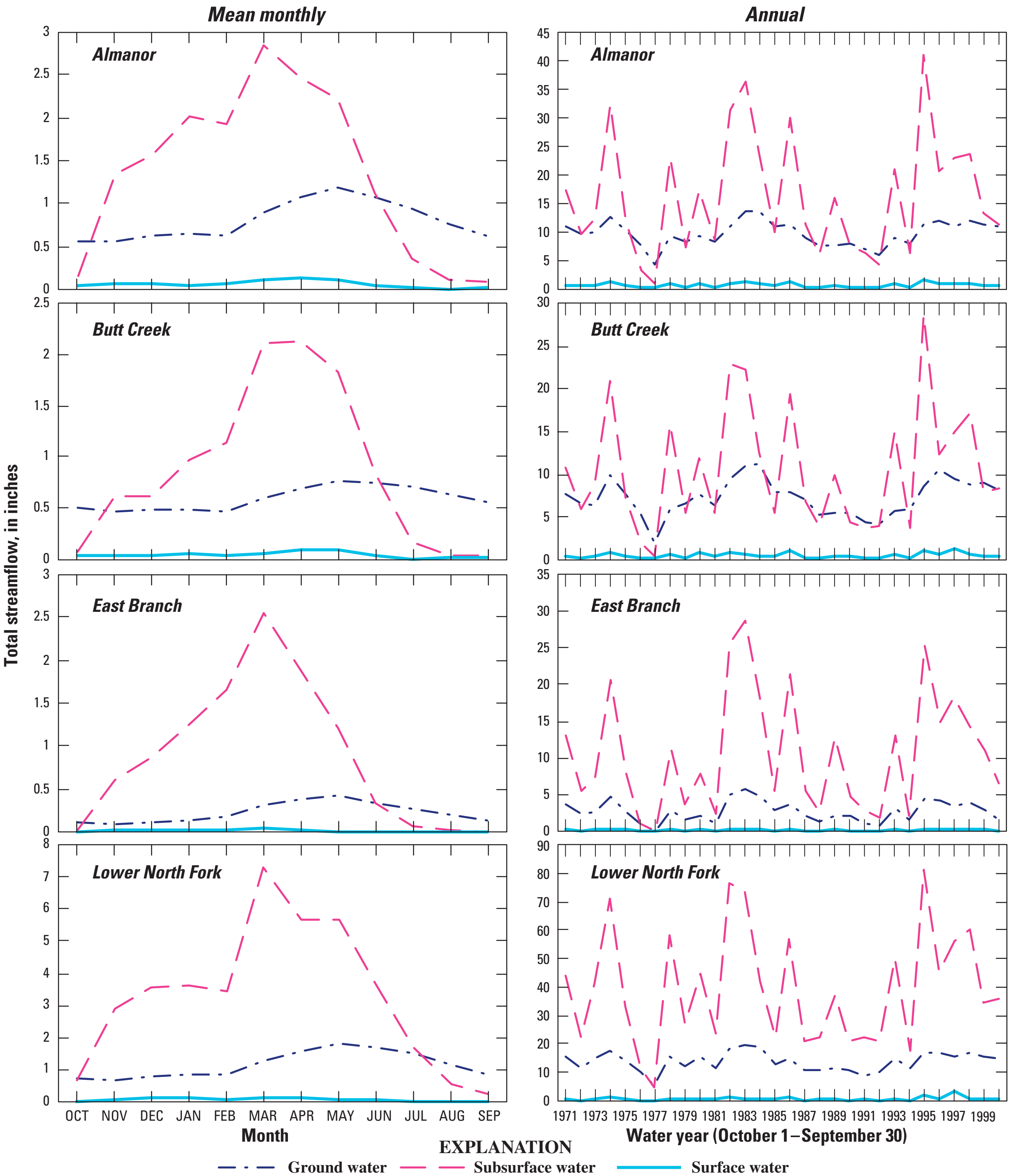
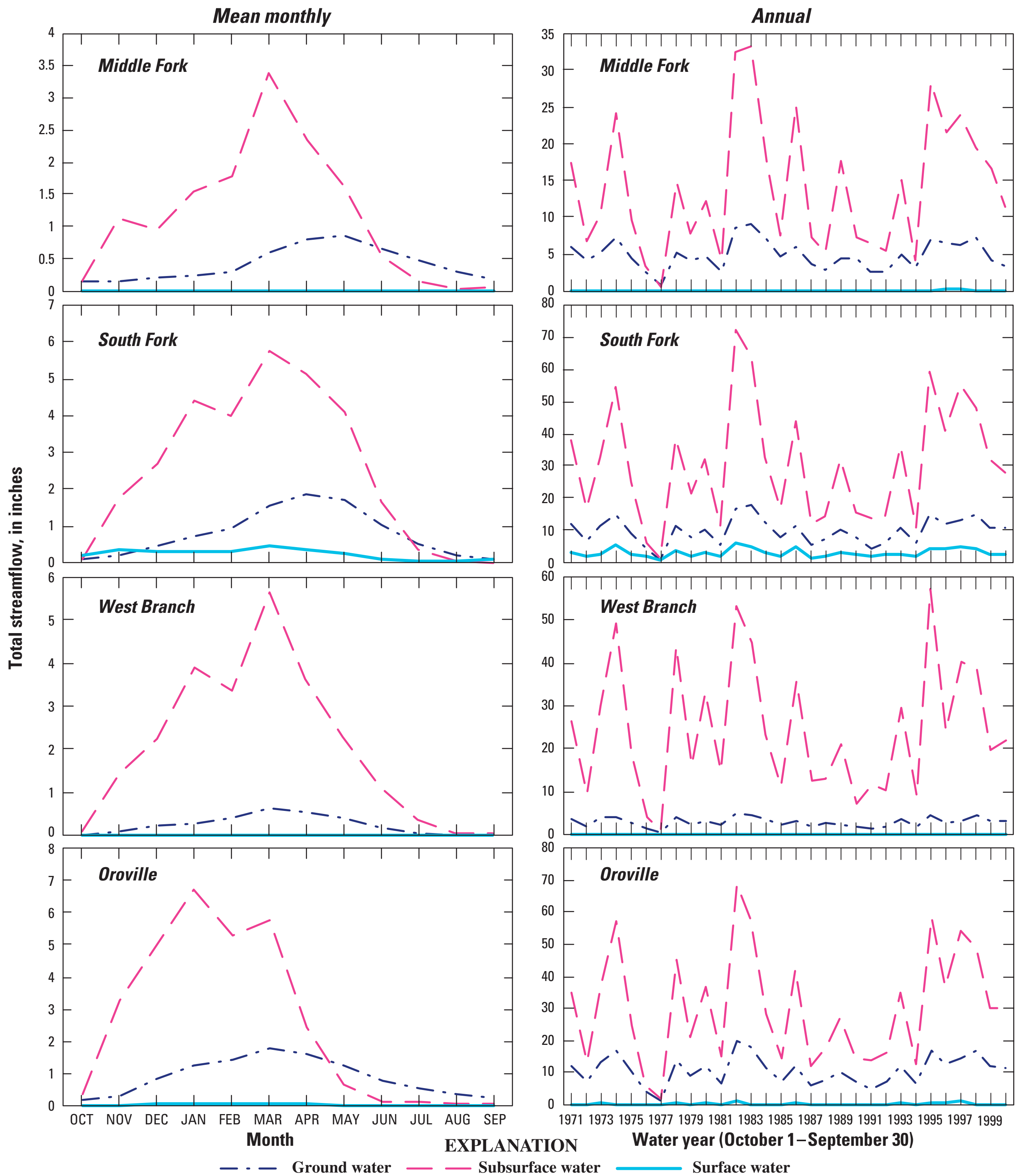


Figure 22. Components of streamflow: mean-monthly flow during water years 1971–97 (left panels) and annual flows during 1971–2000 (right panels). Y-axes vary.



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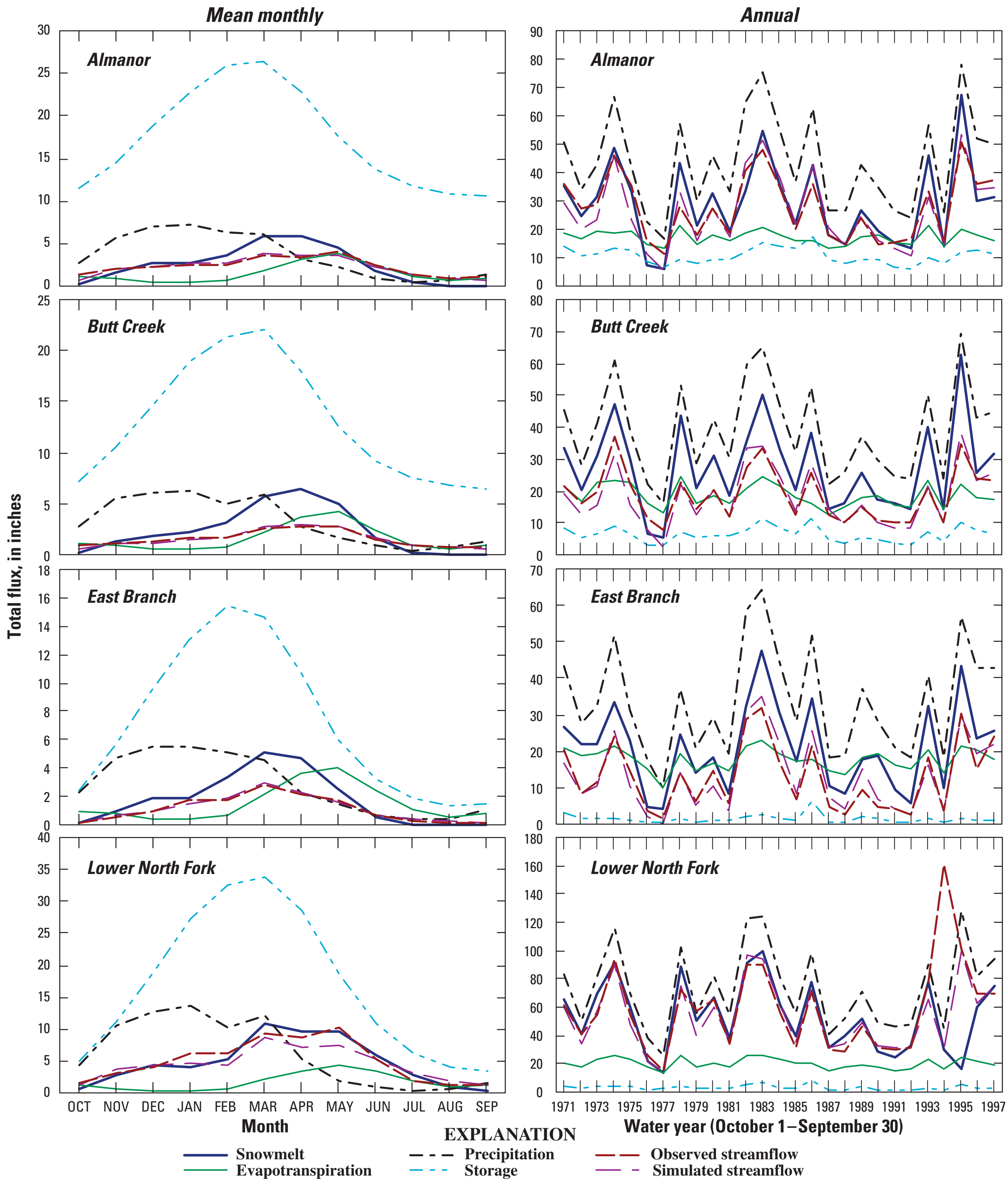

Figure 23. Water-budget components: mean-monthly (left panels) and annual (right panels) values, water years 1971–97. Storage values plotted are not fluxes, but rather are averages of the storage at the end of each month, in inches; other components reported as inches/year or inches/month. Y-axes vary. Observed streamflow is measured or reconstructed flow.

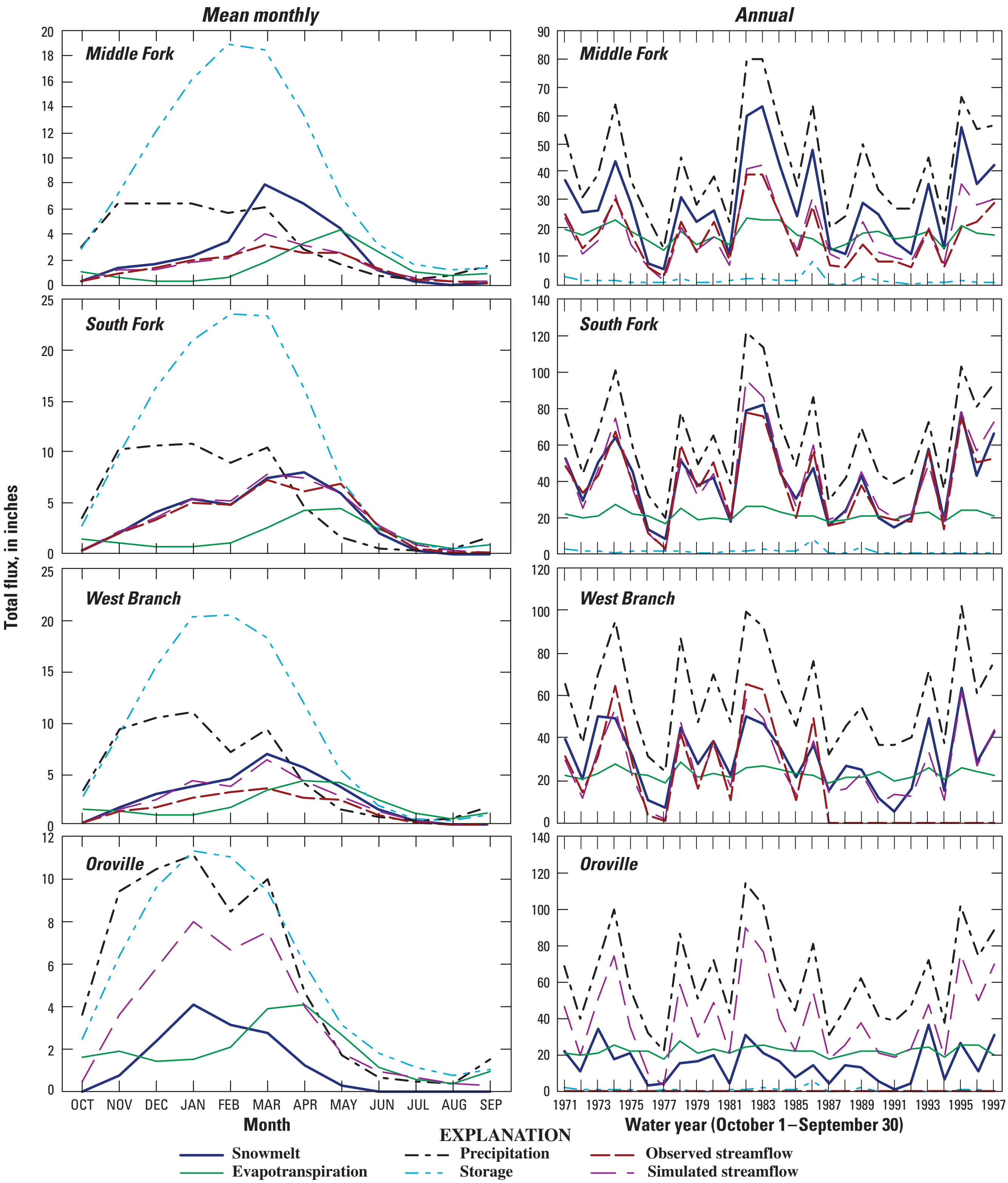

Figure 23.—Continued.

Applications of the Models

Water-Balance Assessment

In PRMS, the basin water budget consists of storage in snowpack, soil moisture, and ground water; inputs from precipitation and snowmelt; losses to evapotranspiration and recharge to the deeper aquifer system; and outflows to streams from surface, subsurface, and shallow ground-water reservoirs. About 60 percent of the water that enters the basin as precipitation leaves as streamflow to Lake Oroville. Nearly all the rest (except for small deep ground-water outflows from Sierra Valley) leaves the basin as evapotranspiration.

The major contributors of streamflow to Lake Oroville are the Lower North Fork and the Middle Fork (table 15, fig. 7). The simulated streamflow to Lake Oroville is primarily (72.4 percent) from subsurface flow with little surface runoff (overland flow; 2.3 percent). Ground-water flow contributes about 25.3 percent (table 16, fig. 22). Ground water makes the largest contribution to streamflow (relative to the models' overall area and flows) in the Almanor and Butt Creek models, because of ground-water-rich volcanic formations present in these basins (fig. 6*A*).

Mean-monthly and annual components of the water budget are shown in figure 23. Precipitation quickly increases from the summer lows to the highs of November through March. Evapotranspiration increases and decreases throughout the year governed by the availability of soil moisture and the vegetative life cycle (phenology). Evapotranspiration peaks by April–May in response to spring warming and vegetative growth. During the warmest months, evapotranspiration is limited by a decline in precipitation and soil moisture. Storage in soil, subsurface, and ground-water reservoirs is greatest during January through March.

In most of the Feather River PRMS models, the maximum streamflow occurs in March–May (fig. 17) and is overwhelmingly from subsurface flow fig. 22). However, in the lower altitude models of Oroville and West Branch (table 11), maximum streamflow occurs in January–March (fig. 17), corresponding with the rainy season. Generally, subsurface flow (fig. 22) is greatest in February–May (deriving from melting snow and rainfall) and declines from June through July, owing to low rainfall and little or no snowmelt. Therefore, in June–July, streams flow at much lower rates. In late June–September, when subsurface flow is at its lowest, the major contributor to streamflow is ground water.

Table 15. Percentages of annual inflow to Lake Oroville from modeled areas: simulated, and measured or reconstructed.

[PRMS; Precipitation-Runoff Modeling System; DWR, California Department of Water Resource; —, no data]

Model area	Percent of inflow to Lake Oroville, measured or reconstructed data[1]	Percent of simulated inflow into Lake Oroville[2]	Percent of inflow to Lake Oroville, DWR[3]
Almanor	15	14.9	18.0
Butt Creek	2	1.5	—
East Branch	16	16.5	—
Lower North Fork	20	18.1	—
North Fork[4]	53	51	56.0
Middle Fork	22	23.3	—
South Fork	5	5.5	6.0
West Branch	5	4.9	—
Oroville	[5]15	15.3	—

[1]Computed from annual measured or reconstructed streamflow data, as compared to FTO reconstructed data, water years 1971–97.

[2]Computed from PRMS annual output, water years 1971–97, excluding Lakes Almanor, Mt. Meadows, Oroville, and the area "not modeled."

[3] From DWR Bulletin 120-2-00 (California Department of Water Resources, 2000), computed from reconstructed streamflow data, water years 1941–90.

[4] Includes model areas Almanor, Butt Creek, East Branch, and the Lower North Fork.

[5] No measured or reconstructed data. This is the remainder of flow not accounted for from the other models.

Table 16. Average-annual simulated components of streamflow in the Feather River Basin, water years 1971–97, as inches/year (equal to streamflow volumes divided by drainage areas).

Model	Ground-water flow (inches)	Subsurface flow (inches)	Surface runoff (inches)
Almanor	9.8 (36 percent of model flow)	17.4	0.9
Butt Creek	7.1 (39 percent of model flow)	10.6	0.5
East Branch	2.7	10.5	0.2
Lower North Fork	13.7	38.8	0.7
Middle Fork	4.8	13.7	0.0
South Fork	9.5	30.0	2.9
West Branch	2.8	24.1	0.0
Oroville	10.4	29.7	0.3
Average cumulative inflow to Lake Oroville	7.6 (25.3 percent of flow)	21.7 (72.4 percent of flow)	0.7 (2.3 percent of flow)

The simulated annual water budgets for drainages and for the basin as a whole, are summarized in table 17. Storage (fig. 23; table 17) is reported as an average of the last daily estimate in the month or year of interest; other budget items are reported as long-term averages. Ground-water and subsurface storage are highest in the Almanor and Butt Creek drainages, and substantially less in other parts of the basin.

Within the Feather River Basin, the areas receiving the highest precipitation are not necessarily those highest in altitude (table 17; figs. 3, 23). The wettest modeled areas are Lower North Fork, South Fork, West Branch, and Oroville. Evapotranspiration, closely tied to precipitation, is higher in lower altitude basins. Per unit area, the largest contributions of streamflow come from the Lower North Fork and South Fork, which benefit from deep snowpacks and large volumes of snowmelt, and the upper reaches of the Oroville drainage (table 15). These reaches receive a high amount of precipitation.

In PRMS, snowmelt is simulated as an indirect contribution to streamflow because it is a source to surface, subsurface, and ground-water reservoirs. In the Feather River Basin as a whole, maximum snowmelt is simulated to occur in March–May. However, in the lower altitude Oroville model, maximum snowmelt occurs as early as January (fig. 23).

Seasonal Forecast Modeling using Ensemble Streamflow Prediction (ESP)

A modified version of the National Weather Services ESP program (Day, 1985) has been coupled with PRMS to provide forecasting capabilities that include short-term and seasonal forecasting for floods and water supply (Leavesley and Stannard, 1995). The ESP procedure uses historical or synthesized climate data to forecast future streamflow, starting with simulated initial hydrologic conditions at the beginning of the forecast period. When historical climate data are used, all past climatic events from the historical record are treated as examples of possible future climatic events. Future climate conditions, not yet witnessed in the historical record, can be included by adding in synthesized climate data series (Leavesley and Stannard, 1995).

Table 17. Average-annual simulated water-budget analysis in the Feather River Basin, water years 1971–97, with measured or reconstructed streamflow

Model	Snowmelt[1] (inches)	Precipitation (inches)	Evapo-transpiration (inches)	Storage[2], ground water and subsurface (inches)	Simulated streamflow (inches)	Measured or reconstructed streamflow (inches)
Almanor	30.9	45.7	17.5	10.9	28.1	27.7
Butt Creek	27.5	39.2	18.6	6.4	18.2	18.8
East Branch	21.0	33.8	17.8	1.4	13.4	13.0
Lower North Fork	53.4	73.5	20.2	3.3	53.9	58.8
Middle Fork	29.2	42.0	17.7	1.4	18.5	17.2
South Fork	40.8	63.9	21.6	1.0	42.3	39.4
West Branch	30.9	59.1	23.0	1.0	26.9	[3]18.7
Oroville	15.4	62.6	22.3	1.0	40.3	[4]N/A
Average for the Feather River Basin	31.1	52.5	19.8	3.3	30.2	[5]27.7

[1]Snowmelt contributes to other parts of the water budget, including evapotranspiration, storage and runoff. It is shown here to illustrate that it is a principle component of the hydrologic cycle.
[2]Average of last day-of-year storage estimate for each basin.
[3]West Branch measured streamflow data are for water years 1971–86 only, as available.
[4] No measured or reconstructed streamflow data are available for the Oroville model.
[5] Average of seven models as no observed runoff exists for Oroville model. Also, does not adjust for missing West Branch data.

The current implementation of ESP for the Feather River PRMS models is designed to predict streamflow for the April–July (snowmelt) season using historical data. Once initial conditions are established by simulating conditions up to the beginning of the forecast period, April–July streamflow is simulated using daily temperature and precipitation series from historical April–July periods. With each iteration, the model is re-initialized to use the initial conditions from the current March 31. Together, these simulations of the April–July streamflows compose an ensemble of streamflow predictions representing combinations of the current year's hydrologic conditions to date and observed examples of historical April–July weather. Maximum daily flows, seasonal volumes, and dates on which the flow decreases to user-specified thresholds can be extracted from each prediction hydrograph and used to produce probabilistic forecasts.

ESP results made from the Feather River PRMS were evaluated. Figure 24 shows the results of an ESP run for April 1, 1997, to July 31, 1997, using the initial conditions for March 31, 1997, and the historical input series from 1971, 1978, 1986, 1988, 1993, and 1996. The ensemble of predicted flows was sorted in PRMS to estimate the chance that a quantity of interest will occur. The likelihood is expressed as an exceedence-probability value: the probability that a particular flow level will be exceeded by the actual (observed) flow in 1997 is estimated by:

$$P(exceedence) = i/(N+1) \times 100$$

where

i = historical-trial rank order, in descending seasonal volume, and

N = total number of historical trials.

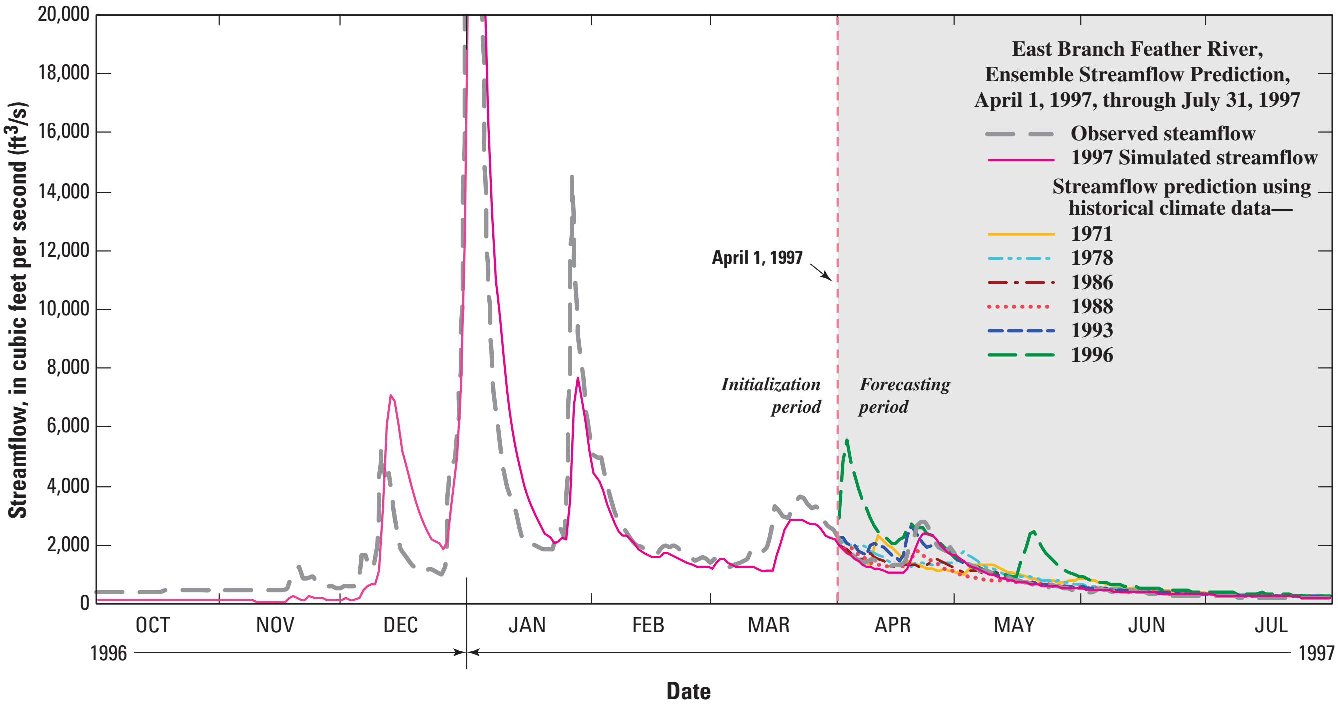

Figure 24. Ensemble Streamflow Prediction (ESP) runs. Observed streamflow is measured flow.

The ESP-exceedence probabilities thus computed tell only part of the story. A better understanding of the likelihood of a particular flow outcome can be obtained by evaluating the ESP-based probabilities from many past ensembles against the subsequent historical (observed) flows. To accomplish this, the ESP procedure was run for the eight models for each water year from 1971 to 2000, using initial conditions (March 31) of the year being forecasted in combination with climatic data from all the others. The simulated volumes are totaled to form ensembles of predictions of April–July inflow to Lake Oroville and are compared with the FTO reconstructions. Seasonal volumes for each “predicted” year (1971–2000) are ranked in descending order, along with the observed flow in the predicted year. The number of times in the 30 years that the observed flows exceeded the ESP flows at each ESP exceedence probability level is counted. These counts, transformed into frequencies and plotted against the ESP exceedence probabilities, provide a basis for correcting the model's ESP exceedence probabilities to reflect the historically accurate exceedence probabilities.

The results of the ESP evaluation for the PRMS models of April–July inflow to Lake Oroville are plotted in figure 25. Among the lowest exceedence probabilities (corresponding to the largest flow volumes), observed flows were larger than the 0 to 10 percent ESP flows in about 0 to 10 percent of the past 30 years. Thus, ESP exceedence probabilities for the largest ESP flows each year would have accurately reflected the exceedence probabilities of the observed flows under the conditions of the past 30 years. Observed flows were larger than the ESP flows at a wide range of (ESP) exceedence probabilities around the median. Thus, historically, the median flow value in a year's ESP ensemble would have been exceeded, by the real river, about 60 percent of the time rather than 50 percent of the time, and a reservoir operator would do well to interpret the median ESP projection in a given year as the 60th percentile exceedence level. Finally, among the highest exceedence probabilities (lowest flow volumes), the ESP exceedence percentiles are exceeded by observed flows somewhat less often than indicated by the ensembles, and an operator would do well to interpret the 90th-percentile flow prediction in a given year's ESP ensemble as a prediction of a flow at roughly the 80th percentile instead.

The graph shown in figure 25, then, can be used as a tool for adjusting the exceedence probabilities suggested by the ESP ensemble in a given year to more accurately reflect historical (observed) exceedence probabilities. When the reliability of the ESP ensembles have been corrected this way, the operator can use the current ESP predictions with more confidence.

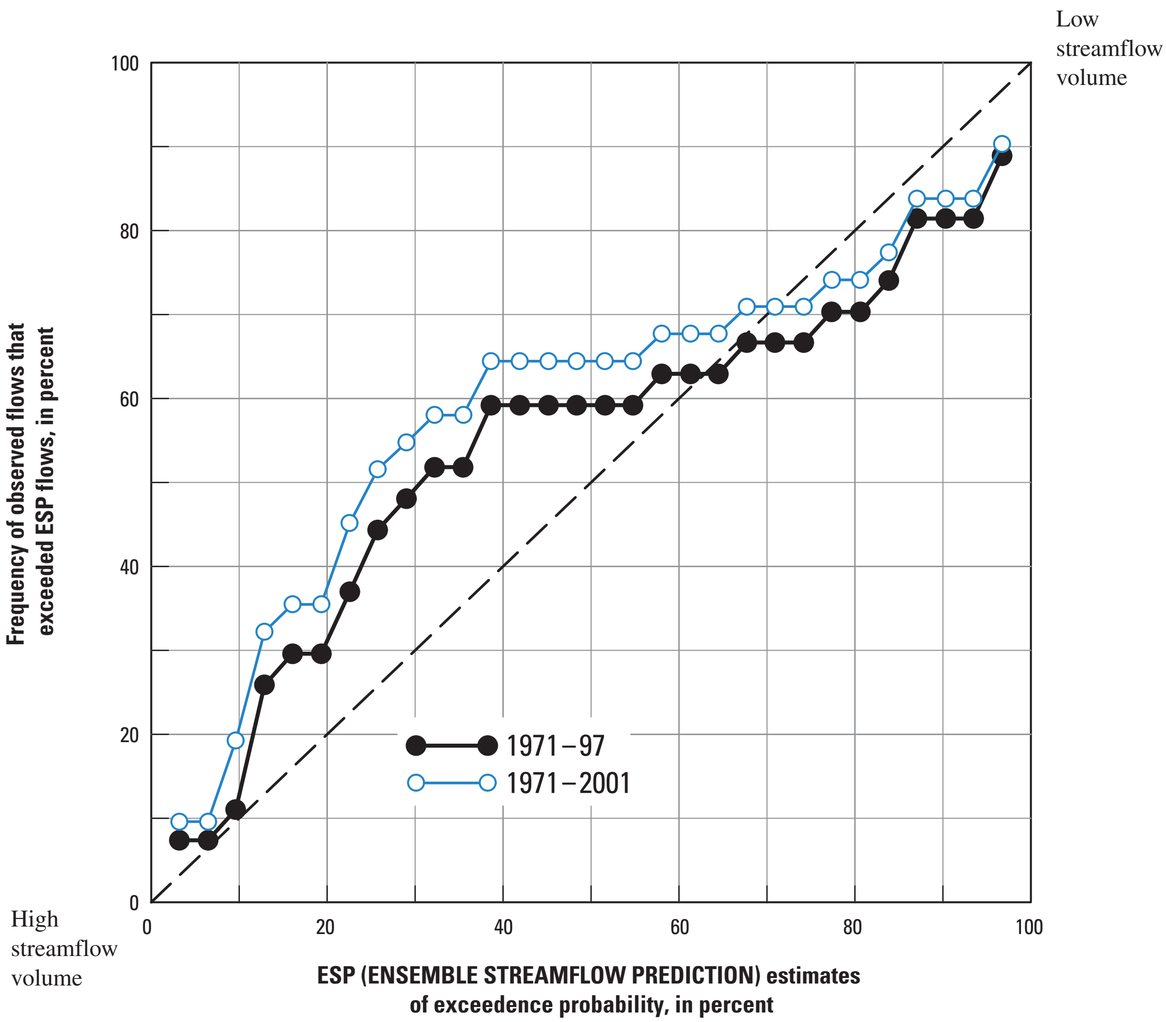

Figure 25. Probabilities of historical inflow to Lake Oroville for April–July forecasts.

Model Limitations

The Feather River PRMS models provide reasonable simulations of the long-term inflow contributions to Lake Oroville, as well as inflow at seven sites within the basin. The models, however, are limited by their spatial resolution (especially of altitude and temperature differences), by the focus of the calibration on seasonal totals of flow, by the lack of true unimpaired streamflow series for the river and its tributaries, and by the small number of real-time climate stations with long-term records available for use as model inputs. A significant limitation is the relatively short period of streamflow records, which prohibits calibration for a greater variety of climatic events (both wetter and dryer)

The large areas of Oroville, Almanor, and Mt. Meadows Lakes were not included in the models (fig. 1). Currently, PRMS is not designed to simulate an open-water body. A comparison of measured precipitation and estimates of pan evaporation showed that the input (precipitation) and output (evaporation) of these areas almost balance. Evaporation from Lake Oroville slightly exceeds precipitation on the lake surface.

Because much of the Feather River Basin is near the average snowline altitude of 5,500 ft, with 55 percent of the basin between 2,000 and 5,500 ft (fig. 3), slight variations in HRU temperature could make significant differences in simulating precipitation form, snow accumulation, and snowmelt. The altitudes encompassed by HRUs typically range over as much as 2,000 to 3,000 ft, with the average HRU altitude assigned as a parameter value (table 12). This may be too coarse to address temperature and other topographically mediated sensitivities well in the Feather River Basin. A comparison of the models developed in this study with models based on a more precise HRU altitude definition could help determine how much the altitudinal lumping limits the current models.

The models were calibrated primarily to the April–July snowmelt season, with secondary attention to monthly variation and then daily flow characteristics. These seasonal flows, and the available monthly FTO reconstructed inflow that was used for comparison with the summed simulations from the eight models, provide less temporal detail for calibration than would an application that focused on daily fluctuations. The models were not calibrated to extreme daily high and low streamflow events. Although the models performed well statistically on a daily and monthly basis (table 14, fig. 16), the models as calibrated can be used most confidently for simulating the April–July snowmelt season.

Half of the Feather River PRMS models were calibrated to reconstructed flows, and the total cumulative streamflow into Lake Oroville was compared with FTO reconstructions. While some error is present in the measured streamflow, errors in the reconstructed values may be larger or more systematic. Thus, in large part, simulations of the present models were compared to other reconstruction-algorithm models. Although the comparisons match well, it is not always clear which series (simulated or reconstructed) to believe.

The measured (gaged) streamflows used in calibration were not always representative of natural conditions. Extraneous factors altered natural flow. For example, in the West Branch model, hydrologic effects of irrigation diversions and reservoirs upstream from the gaging station could not be eliminated from the streamflow data used. The same is true for the East Branch and Middle Fork models. The Butt Creek gage measurements were influenced by a conduit from Lake Almanor that caused sharp streamflow peaks and by leakage from an abandoned tunnel upstream.

In order to provide options for real-time uses of the models, real-time climate stations were chosen as inputs. Available stations were clustered in the southwestern lower-to-intermediate altitude parts of the basin (fig. 3; fig. 7). This distribution made it difficult to make accurate estimates of temperature and precipitation on the eastern and northern sides, and in the parts of the basin at higher altitudes. However, given the encouraging calibration results (table 14), the current models and climate inputs appear to reasonably represent processes and climatic forces within the Feather River Basin. Improvements would be possible if new, accurate and reliable real-time stations were available in areas lacking stations.

Summary and Conclusions

The Feather River Basin and Lake Oroville form a large and crucial part of California's water-supply system. The basin is a major contributor of water to the California State Water Project and plays an important role in flood management, hydroelectric power production, water quality, and the health of fisheries downstream (as far as the Sacramento/San Joaquin River Delta). The basin has a mediterranean climate, and 55 percent of the basin is between 2,000 ft and the average snow line of 5,500 ft. Therefore, slight temperature changes affect the form of precipitation and the timing of snowmelt. The California Department of Water Resources (DWR) manages Lake Oroville for winter floods and summer streamflows during the April 1–July 31 snowmelt season, which is when about 40 percent of the average annual streamflow occurs. Existing statistical and physical models simulate streamflow, but cannot describe the effects of physical changes within the basin as well as the Precipitation-Runoff Modeling System (PRMS) models.

The objectives of this study were (1) to develop a new spatially detailed precipitation-runoff model of the basin that offers simulation capabilities at a higher spatial resolution than was available previously, and (2) to characterize and simulate the Feather River Basin in terms of daily rainfall, snowpack evolution, runoff, and water and energy balances that predict streamflow rates from, and within, the part of the basin above Lake Oroville.

The Feather River PRMS model simulates basin hydrologic response at two spatial scales: (1) as eight models within which hydrologic characteristics are represented in terms of 324 hydrologic-response units; and (2) as the sum of the eight models to represent overall inflow to Lake Oroville. The Feather River PRMS models were run on a daily time step and were calibrated primarily to simulate year-to-year variation of the April–July snowmelt-season flow totals, secondly for monthly variation, and thirdly to simulate daily flow characteristics. The modeling system does not capture all extreme high and low historical streamflow events.

The Feather River PRMS models were especially sensitive to parameters describing transmission of water to (and from) the subsurface and ground-water reservoirs. The models were also sensitive to small changes in temperature and precipitation. Climate data used in this study may have been biased: the real-time climate stations that were used are located at lower-to-intermediate altitudes and are concentrated in the southwestern part of the basin. Daily winter temperatures are frequently above freezing, which affects the mix of rain and snow during many storms, the formation of snow pack, and the relative amounts of winter and summer streamflow. Precipitation records for the basin were used to modify an existing long-term average precipitation map, to account for observed daily variations of east-west and north-south precipitation gradients across the basin. The use of these daily precipitation estimates improved the streamflow simulations.

Signatures of North Pacific decadal climate variations have been observed in the Feather River Basin as a shift in the month of maximum streamflow [from April during the cooler Pacific Decadal Oscillation (PDO) phase to March during the warmer decadal phase]. The calibration period was dominated by the warmer climatic (1977–98) phase, and the most recent simulations, shown in figure 20, were dominated by the newly re-established cool decadal phase since 1998. The response of the models to this subtle climatic fluctuation requires more evaluation.

Model calibrations focused on average to wet years (1971–97), with special attention to monthly and seasonal flows during the April–July snowmelt season (of most interest to water managers). Model simulations were calibrated against measured or reconstructed flow and, in sum, were compared with the DWR Feather River at Lake Oroville (FTO) reconstructions. Calibration biases, relative errors, and root-mean-square errors for daily, mean-monthly, seasonal, and mean-annual streamflows were computed. Periods with missing data and suspect data (Lower North Fork, Middle Fork, and West Branch) were removed in computing these statistics.

Overall, the calibration statistics indicated acceptable simulations during the 1971–97 period with low bias, relative error, and RMSE (table 14; figs. 16, 17, 18, and 19), with some explainable exceptions. Larger biases and relative errors of 50 percent in the August–September season, especially in the East Branch and West Branch models, likely were caused by reservoir storage and irrigation practices altering natural streamflow measurements but not accounted for in model simulations of natural streamflow. Statistics for October–December streamflow simulations were within acceptable ranges for a model focusing on calibration of the April–July snowmelt season. The Almador and Butt Creek models produced the largest relative errors (about −16 and −22 percent respectively), and Butt Creek produced the largest bias (about −11 percent) in this season. These models were influenced by underlying volcanic formations and may involve deeper ground-water reservoirs than were represented in PRMS. The daily statistics (fig. 16) indicated that the simulations closely mimicked measured and reconstructed flows, with the exception of a high relative error for the West Branch model that likely was due to unmodeled diversions.

The timing and quantity of simulated streamflows closely matched DWR FTO reconstructions when compared on a daily, monthly, seasonal, and annual basis. Monthly comparisons (averaged across the calibration period 1971–97), for individual models resulted in RMSEs under 2 percent. A good fit was achieved for the April–July snowmelt season, where the RMSE between model simulations and FTO reconstructions was computed as 285,259 acre-feet with flow volumes ranging from about 300,000 to 4,300,000 acre-feet (fig. 19). January–March seasonal inflow volumes into Lake Oroville closely simulated FTO reconstruction volumes with a RMSE of 410,633 acre-feet and flow volumes ranging from about 200,000 to 4,800,000 acre-feet. As mean-monthly percentages, the combined simulated inflow graphed closely to FTO reconstructions, with a RMSE of 0.84 percent. For water years 1971–97, the annual total simulated inflows also fit FTO reconstructions, resulting in a bias and relative error below –4 percent and a RMSE of 465,328 with inflow volumes ranging from about 200,000 to 9,400,000 acre-feet. However, after 1997 (post calibration period), a departure was seen that may reflect the Feather River Basin's sensitivity to PDO (and a change to a cool phase). Simulated volumes were less than FTO reconstructions.

Modeled contributions of inflow to Lake Oroville from surface runoff, and subsurface and ground-water flow were quantified. The major contributors of inflow according to the models are the Lower North Fork and the Middle Fork. Simulated streamflow is from subsurface flow (72.4 percent), ground-water flow (25.3 percent), and surface runoff (2.3 percent). In higher altitude models, the maximum streamflow (from subsurface flow) occurs in March–May. However, in the lower altitude models of Oroville and West Branch, maximum streamflow occurs in November–March corresponding with the rainy season. Storage is greatest in the Feather River Basin in January–March. Evapotranspiration peaks by April/May in response to spring warming and vegetative growth, and sharply declines in warm summertime months as soil-moisture storage empties and limits evapotranspiration. By June, owing to low rainfall and little to no snowmelt, the subsurface flow decreases rapidly and streams flow at much lower rates. In late June through September, when subsurface flow is at its lowest, the major contributor to streamflow is ground water.

Streamflow forecasts for the April–July snowmelt season can be estimated from predictions made with the Feather River PRMS models and a standard "ensemble streamflow prediction" (ESP) methodology. The April–July daily climate records from previous years are used to drive the model through a plausible range of April–July outcomes for the current year. Results are ranked by ESP as percentiles of exceedence of flow. Retrospective "predictions" by this method for each year from 1971 to 2000 were compared with the actual flows each year to evaluate the reliability of the ESP exceedence percentiles. The resulting comparisons of the simulated likelihoods of various flow totals to the number of times those simulated rates were exceeded suggests the model-predicted exceedence percentiles are most precise for the largest flows. The percentiles tend to underestimate the likelihoods of exceedence of most mid-range flow rates, and overestimate those of the lowest flows. Presumably, these comparisons can provide a guide for adjusting the confidence levels for any given ESP predictions in the future.

The current form of the Feather River Basin PRMS models provides an acceptable historical simulation of monthly and longer term flow within, and from, the basin. The models could be improved for a real-time application by a partial recalibration with focus on years (such as the present) that are from cool-PDO climate regimes. Further, a more comprehensive distribution of real-time climate stations would improve the representation of precipitation and temperature in the models. The current models assume a constant land-surface and plant canopy throughout the simulations. More detailed attention to historical (or projected) land-use changes and fire scars could provide improved simulations while also helping to quantify the hydrologic effects of such changes. More basically, greater control of temperature inputs to the models would be possible if the model HRUs were re-delineated on the basis of 1,000-foot altitude bands and on the 5,500-foot-altitude snowline. Each of these changes is feasible and would improve not only the models, but our understanding of, and ability to predict, Feather River Basin streamflows.

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Appendixes

Appendix A. Components of reconstructed natural streamflow of the Feather River at Oroville, California (FTO), computed as acre-feet per month.

Monthly reconstructed streamflow for the Feather River at Oroville (FTO) is currently computed by DWR as the sum of:

(1) + Measured streamflow at USGS 11407000.

(2) + Thermalito Afterbay releases to the Feather River, through the Thermalito Afterbay River Outlet (fig. 2)

(3) + Diversions at the Thermalito Complex (from the Afterbay to Western Canal, Richvale Canal, PG&E lateral, and Sutter-Butte Canal; fig. 2)

(4) + Thermalito Irrigation District and Butte County diversions (California Water Service) from the Thermalito Power Canal Diversion (less than 2 acre-feet per year; fig. 2)

(5) + Gain in storage of Thermalito Complex (Diversion Pool, Forebay and Afterbay)

(6) + Evaporation at Thermalito Afterbay, Thermalito Forebay, and Diversion Pool

(7) + Lake Oroville gain in storage

(8) + Lake Oroville evaporation loss only. Zero when raining

(9) + Palermo diversion (from Lake Oroville) and Bangor Canal diversion (from South Fork; fig. 4)

(10) + Oroville-Wyandotte Canal, also known as Forbestown Ditch (from South Fork), and Hendricks and Miocene Canals (from West Branch)

(11) + Storage gain at Lake Almanor, Mt. Meadows, Butt Valley, Bucks Lake, Frenchman, Antelope, Lake Davis, Little Grass Valley, and Sly Creek reservoirs

(12) + Estimated evaporation for reservoirs listed in item 11, computed as 1.4 times the Lake Almanor evaporation, based on a monthly capacity. The evaporation table is from the Great Western Power Company (PG&E predecessor)

(13) − Slate Creek Tunnel import from the Yuba River basin, which flows into the South Fork at the Sly Creek Reservoir

(14) − Little Truckee River import into Sierra Valley

(15) + Depletion for upstream irrigation and consumptive use

Notes: Monthly reconstructed streamflow (FTO) in the Feather River is estimated for the flow below Lake Oroville at USGS gaging station 11407000 (figs. 1, 2). Since construction of the Oroville Complex in 1967, the gaging station 11407000, in the channel below the Thermalito Diversion Dam, does not measure streamflow through the Oroville Complex (fig. 2). Therefore, diversions out of Feather River basin from Thermalito Afterbay and Forebay, and releases from the Thermalito Afterbay flowing to the Feather River through the Thermalito Afterbay River Outlet, are added to the total flow at station 11407000 (fig. 2; J. Pierre Stephens, DWR Resources Hydrology Branch, unpub. data, 2001). The monthly streamflow reconstructions are reported on the California Data Exchange Center website, in acre-feet per month (http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=FTO, accessed on June 6, 2002).

Appendix B. Programming for the draper method to estimate precipitation over Hydrologic Response Unit (HRU) surfaces from PRISM simulations, Feather River Basin, California.

The draper tool is compiled using a fortran77 compiler, either on a Unix or PC platform.

Input for #4 was computed using ARC/INFO by sampling 12 mean-monthly PRISM precipitation surfaces (http://www.ocs.orst.edu/prism/state_products/ca_maps.html, accessed on Jan. 1, 2000) at the HRU centroids.

Input files required are:

(1) Location of climate stations by latitude and longitude (example file: wsit.locs.update).

(2) Observed daily precipitation for these sites in inches (no data = –99)(example file: feather_ppt.txt)

(3) Location of the HRU centroid by latitude and longitude (example file: ac_centroids)

(4) Weighted-mean precipitation values, in inches, for each HRU sampled from each of the PRISM surfaces (for each of the 12 months) (example file: ac_ave_ppt)

Programming is attached. Draper is run by invoking the “draper” executable file at the command prompt.

Fortran program “draper.f” calls subroutine “trend.f” which in turn calls subroutine “inverse.f” to compute interpolated precipitation from the HRU coordinates on the trend-plane adjusted PRISM map.

wsit.locs.update

39.6920 121.3390 Brush Creek (DWR) - BRS
39.9170 121.3330 Bucks Creek Powerhouse - BUP
40.1670 121.0830 Canyon Dam - CNY
40.0830 121.1500 Caribou - CBO
39.8670 121.6170 Desabla (PG&E) - DSB
39.8720 121.6100 Desabla (DWR) - DES
39.9170 120.9500 Quincy (DWR) - QCY
39.9670 120.9500 Quincy RS (USFS) - QNC
39.5640 121.1060 Strawberry-DWR - SBY
39.5670 121.1000 Strawberry-NOAA - STV

feather_ppt.txt (4 lines required for header)

Real-time ppt stations, 1937/10/1 thru 1998/6/30 from Bruce McGurk. To present, updates from CDEC and PG&E.

Precipitation data for DRAPER program.

BRS BUP CNY CBO DSB DES QCY QNC SBY STV

year, month, day, Brush Creek (DWR), Bucks Creek PH, Canyon Dam, Caribou PH, DeSabla (PG&E), DeSabla (DWR), Quincy (DWR), Quincy RS (USFS), Strawberry-DWR, Strawberry-NOAA

1937	10	1	0.00	-99.00	0.16	-99.00	0.18	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	2	0.09	-99.00	1.19	-99.00	2.34	-99.00	-99.00	1.30	-99.00	-99.00
1937	10	3	0.46	-99.00	0.36	-99.00	0.00	-99.00	-99.00	0.05	-99.00	-99.00
1937	10	4	0.00	-99.00	0.32	-99.00	0.00	-99.00	-99.00	0.90	-99.00	-99.00
1937	10	5	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	6	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	7	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	8	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	9	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	10	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	11	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	12	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	13	0.00	-99.00	0.05	-99.00	0.14	-99.00	-99.00	0.20	-99.00	-99.00
1937	10	14	0.22	-99.00	0.88	-99.00	1.12	-99.00	-99.00	1.16	-99.00	-99.00
1937	10	15	0.30	-99.00	0.10	-99.00	0.25	-99.00	-99.00	0.10	-99.00	-99.00
1937	10	16	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	17	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	18	0.00	-99.00	0.04	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	19	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	20	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	21	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	22	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	23	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	24	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	25	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	26	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	27	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	28	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	29	0.00	-99.00	0.00	-99.00	0.28	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	30	0.00	-99.00	0.24	-99.00	0.21	-99.00	-99.00	0.00	-99.00	-99.00
1937	10	31	0.03	-99.00	0.10	-99.00	0.00	-99.00	-99.00	0.27	-99.00	-99.00
1937	11	1	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	11	2	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	11	3	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00
1937	11	4	0.00	-99.00	0.00	-99.00	0.00	-99.00	-99.00	0.00	-99.00	-99.00

ac_centroids

45

1	40.23135761	121.06362980
2	40.19690874	121.15221148
3	40.28509346	121.27800123
4	40.29808895	121.24026264
5	40.32818344	121.15530849
6	40.29461548	121.12225809
7	40.30088775	121.04523185
8	40.23574141	120.96246325
9	40.23903817	120.88863060
10	40.27289577	120.91551104
11	40.28629538	120.86656202
12	40.29943799	120.95356983
13	40.31974464	120.99936432
14	40.32525125	120.94899070
15	40.31658227	120.91982407
16	40.34020507	120.88986997
17	40.37039442	120.97665194
18	40.36611801	120.90502175
19	40.38488658	120.94880292
20	40.41379822	121.02713467
21	40.36547001	121.04684081
22	40.34408043	121.09091515
23	40.40513833	121.10453834
24	40.44216094	121.08757837
25	40.46594559	121.13003944
26	40.39605854	121.14512527
27	40.44009010	121.20020590
28	40.36639548	121.20930922
29	40.36447779	121.24049525
30	40.34976334	121.24918170
31	40.32700297	121.25956581
32	40.34477335	121.28695431
33	40.31583661	121.32320989
34	40.39119704	121.31053348
35	40.38586009	121.34453696
36	40.34665519	121.37535086
37	40.37664432	121.37887845
38	40.38336765	121.44731197
39	40.44377225	121.47195906
40	40.43186465	121.40332002
41	40.44609134	121.41162315
42	40.46472382	121.42098658
43	40.45293705	121.32635921
44	40.40741915	121.29593903
45	40.42621291	121.26546864

ac_ave_ppt

'ac_avg_ppt'

'HRU	jan_ppt	feb_ppt	mar_ppt	apr_ppt	may_ppt	jun_ppt	jul_ppt	aug_ppt	sep_ppt	oct_ppt	nov_ppt	dec_ppt'
1	6.8189	5.9305	3.8906	2.5438	1.5397	0.7651	0.2500	0.2500	0.7500	1.9805	4.1450	5.9444
2	6.6878	5.4930	5.1271	2.3724	1.2676	0.7500	0.2500	0.2937	0.7500	2.3795	5.2869	5.7002
3	6.2254	5.3616	4.8991	2.2518	1.3321	0.7500	0.2500	0.5685	0.7986	2.4548	5.1828	5.2934
4	5.9483	4.8237	4.3496	2.2275	1.2500	0.7500	0.2500	0.2500	0.7500	2.2500	4.7500	5.1574
5	6.5454	5.7132	4.9849	2.5098	1.5469	0.7500	0.2500	0.5283	0.9260	2.5272	5.3372	5.6906
6	6.3912	5.3538	4.2826	2.2993	1.3224	0.7500	0.2500	0.2673	0.7500	2.1894	4.5603	5.5480
7	6.7783	5.8707	3.5097	2.6839	1.6976	0.7792	0.2500	0.2500	0.7500	1.8256	3.7654	5.8663
8	7.1301	6.3362	4.2028	2.7842	1.7924	0.7968	0.2500	0.2500	0.7504	2.2794	4.5064	6.2655
9	6.9910	6.1917	4.2242	2.7500	1.7500	0.7500	0.2500	0.2500	0.7500	2.2384	4.6055	5.9746
10	6.8915	6.1794	3.7571	2.7500	1.7500	0.7500	0.2500	0.2500	0.7500	2.2500	4.2500	6.1377
11	6.7651	6.3039	3.7261	2.7500	1.8639	0.7525	0.2500	0.2500	0.7500	2.2363	4.1865	5.9568
12	7.1855	6.1004	3.8658	2.7500	1.7500	0.7521	0.2500	0.2500	0.7500	2.2500	4.2933	6.2500
13	6.9304	5.9116	3.7463	2.7500	1.7500	0.7500	0.2500	0.2500	0.7500	2.1483	4.1177	6.1043
14	7.2500	6.2500	4.2500	2.7500	1.7500	0.9872	0.2500	0.2500	0.7500	2.2523	4.7368	6.3188
15	7.0190	6.2500	3.7995	2.7500	1.7500	0.8498	0.2500	0.2500	0.7500	2.2500	4.2504	6.2500
16	6.6180	6.1805	3.6809	2.7415	1.7500	0.7887	0.2500	0.2500	0.7500	2.1764	4.1052	5.9351
17	6.6156	5.8937	3.8159	2.6288	1.7500	0.7827	0.2500	0.2500	0.7500	2.2161	4.2407	5.9330
18	6.5518	5.8075	3.4724	2.7399	1.7500	0.7516	0.2500	0.2500	0.7500	2.1192	3.8633	5.8498
19	6.4261	5.8117	3.4569	2.6898	1.7500	0.7500	0.2500	0.2500	0.7500	2.0807	3.8492	5.7773
20	6.5703	5.9657	4.1976	2.7408	1.7500	0.7500	0.2500	0.2500	0.7500	2.2500	4.5059	5.7520
21	6.7438	5.8848	4.0720	2.7333	1.7500	0.7500	0.2500	0.2500	0.7500	2.2292	4.3391	5.7500
22	6.7497	5.8863	4.3179	2.5748	1.6167	0.7500	0.2500	0.2547	0.7500	2.2357	4.6206	5.7673
23	6.8830	6.5043	5.3065	2.8917	2.0597	0.8440	0.2500	0.5309	0.9946	2.7205	5.6801	6.2513
24	6.8494	6.4469	5.1232	2.8259	1.9867	0.7954	0.2500	0.4395	0.9066	2.6886	5.5085	6.1522
25	7.0974	6.5568	5.4684	3.0565	2.1502	1.0372	0.2500	0.6469	1.1186	2.8539	5.7125	6.4266
26	6.9443	6.4974	5.5666	2.8770	2.0220	0.8219	0.2500	0.7457	1.1573	2.7709	5.9680	6.2150
27	7.5269	7.0445	6.1026	3.3795	2.3300	1.1998	0.2500	0.7500	1.2500	2.8326	6.3970	6.8549
28	6.7687	6.1010	5.4206	2.7246	1.7525	0.8519	0.2500	0.6957	1.0781	2.6483	5.8010	5.9872
29	6.4256	5.7712	5.1555	2.4468	1.5672	0.7502	0.2500	0.7298	0.9750	2.6269	5.5169	5.7383
30	6.2445	5.4240	4.7927	2.3079	1.4247	0.7500	0.2500	0.5542	0.8624	2.4680	5.1732	5.4728
31	6.2237	5.2388	4.6160	2.2500	1.2500	0.7500	0.2500	0.3728	0.7500	2.2590	4.8494	5.2615
32	6.3000	5.4805	4.9665	2.3072	1.3913	0.7500	0.2500	0.6923	0.8245	2.5028	5.3359	5.4984
33	6.4424	5.7331	5.3394	2.5277	1.6490	0.8030	0.2500	0.7499	1.0701	2.7315	5.7389	5.7658
34	6.8689	6.0694	5.4897	2.7781	1.7403	0.9632	0.2500	0.7500	1.1102	2.7153	5.8690	6.1850
35	7.7673	6.5274	6.0135	3.2023	1.9961	1.0334	0.2500	0.8248	1.2475	3.1611	6.4386	6.9849
36	7.2675	6.1343	5.8995	3.0256	1.7500	1.1540	0.2500	0.7500	1.2500	3.0006	6.3102	6.4885
37	7.9567	6.5279	6.2274	3.3466	1.9475	1.2002	0.2500	0.7885	1.2706	3.2450	6.6335	7.1150
38	10.3069	7.9948	8.0436	4.8397	2.6232	1.5365	0.2500	1.0246	1.5060	4.5082	8.8179	9.5401
39	17.2589	12.4426	12.3425	9.0173	4.3823	2.4601	0.2500	1.9517	1.8975	7.1152	14.5467	16.3912
40	12.2512	9.1200	8.5404	5.7586	3.2479	1.8044	0.2500	1.3069	1.5960	4.7741	9.2527	11.0308
41	12.4581	9.0967	8.4933	5.8964	3.4115	1.8885	0.2500	1.3724	1.6295	4.7856	9.2015	11.0641
42	12.4248	8.9668	8.3190	5.8672	3.5789	2.0035	0.2500	1.4257	1.6800	4.6930	9.0206	10.8943
43	9.2283	6.9149	6.0889	4.1779	2.7868	1.4984	0.2500	0.9763	1.3440	3.3190	6.5890	7.8860
44	7.4229	6.7102	5.9285	3.2259	2.0746	1.1129	0.2500	0.7500	1.2500	2.7066	6.3426	6.7274
45	7.8850	7.1650	6.1539	3.6252	2.3837	1.1887	0.2500	0.7500	1.2500	2.7959	6.6073	7.2189

draper.f

```
      parameter (nsit=10,ndays=36500,nhru=200)
      parameter (smooth=0.5,nmax=8,lwrk=1000)

      dimension sitlat(nsit),sitlon(nsit)
      dimension sitppt(ndays,nsit),w(nsit)
      dimension hrulat(nhru),hrulon(nhru)
      dimension hruppt(nhru),ppt(nsit)
      dimension pptlat(nsit),pptlon(nsit)
      dimension prism_hru(12,nhru)
      dimension nmon(12),mon(ndays),iy(ndays),id(ndays)
      dimension sit_mean(12,nsit),ncount(12,nsit)
      dimension tx(nmax),ty(nmax)

      character file*2,ap*8,cd*15,filnm*60

      data nmon/31,28,31,30,31,30,31,31,30,31,30,31/
      ap='ave_ppt/'
      cd='centroids_mike/'
      pi=4.*atan(1.)
      eps=1.e-20

      print *,'Enter name of file with',
     &   ' weather station lat longs'
      read(5,'(a60)') filnm
      open(14,file=filnm,status='old',readonly)

      print *,'Enter name of file with observed',
     &    ' daily precipitation for these sites'
      read(5,'(a60)') filnm
      open(16,file=filnm,status='old',readonly)
      read(16,*)
      read(16,*)
      read(16,*)
      read(16,*)

      print *,'Enter two-letter basin designator'
      read(5,'(a2)') file
      open(15,file=cd//file//'_centroids_mike',
     &     status='old',readonly)
      read (15,*) nru

      open(13,file=ap//file//'_ave_ppt',
     &    status='old',readonly)
      read (13,*)
      read (13,*)

      print *,'Enter output-file name'
      read(5,'(a60)') filnm
      open(17,file=filnm,status='unknown')
```

```
      do j=1,nsit
        w(j)=1.
      enddo

      do k=1,nru
        read(13,*) kk,(prism_hru(i,k),i=1,12)
        do i=1,12
          prism_hru(i,k)=prism_hru(i,k)/nmon(i)
        enddo
      enddo

      do k=1,nru
       read(15,*) ihru,hrulat(k),hrulon(k)
       hrulat(k)=hrulat(k)*pi/180.
       hrulon(k)=hrulon(k)*pi/180.
      enddo

      do j=1,nsit
       read(14,*) sitlat(j),sitlon(j)
       sitlat(j)=sitlat(j)*pi/180.
       sitlon(j)=sitlon(j)*pi/180.
      enddo

      do i=1,ndays
        read(16,*,end=99) iy(i),mon(i),id(i),
     &      (sitppt(i,j),j=1,nsit)
        im=mon(i)
        do j=1,nsit
         if(sitppt(i,j).ge.0.) then
          sit_mean(im,j)=sit_mean(im,j)+sitppt(i,j)
          ncount(im,j)=ncount(im,j)+1
         endif
        enddo
      enddo
 99   nday=i-1
      do i=1,12
        do j=1,nsit
          if(ncount(i,j).gt.0) then
           sit_mean(i,j)=sit_mean(i,j)/ncount(i,j)
          else
           sit_mean(i,j)=-99.
          endif
        enddo
      enddo

      print *,'Data read and averages calculated'

      iopt=0
      none=1
      do i=1,nday
        if(mod(i,30).eq.0)
```

```
     &     print *,'Interpolating on day ',iy(i),mon(i),id(i)
       n=0
       do j=1,nsit
         if(sitppt(i,j).ge.0..and.
     &         sit_mean(mon(i),j).gt.0.)then
           n=n+1
           ppt(n)=sitppt(i,j)/sit_mean(mon(i),j)
           pptlat(n)=sitlat(j)
           pptlon(n)=sitlon(j)
         endif
       enddo
       if(n.ge.3) then
        call trend(n,pptlon,pptlat,ppt,a,b,c)
        do k=1,nru
          xx=hrulon(k)
          yy=hrulat(k)
          call interpol(xx,yy,a,b,c,zz)
          hruppt(k)=zz*prism_hru(mon(i),k)
          if(hruppt(k).le.0.) hruppt(k)=0.
        enddo
       elseif(n.lt.3.and.n.gt.0) then
        avep=0
        do k=1,n
          avep=avep+ppt(k)/n
        enddo
        do k=1,nru
          hruppt(k)=avep*prism_hru(mon(i),k)
          if(hruppt(k).le.0.) hruppt(k)=0.
        enddo
       elseif (n.le.0) then
        do k=1,nru
         hruppt(k)=prism_hru(mon(i),k)
         if(hruppt(k).le.0.) hruppt(k)=0.
        enddo
       endif
      if(nru.ge.200) then
       nh=200
      else
       nh=nru
      endif
      write(17,10)iy(i),mon(i),id(i),(hruppt(k),k=1,nh)
      if(nru.gt.200) then
        write(17,11) (hruppt(k),k=201,nru)
      endif

 10   format(i5,2i3,200(1x,f6.1))
 11   format(10(t12,200(1x,f6.1)))
      enddo

      stop
      end
```

trend.f

```
subroutine trend(n,x,y,p,a,b,c)
      parameter (nsit=10)
      dimension x(1),y(1),p(1)
      dimension beta(3),xm(nsit,3)
      dimension xx(3,3),xy(3)

      do i=1,n
       xm(i,1)=1.
       xm(i,2)=x(i)
       xm(i,3)=y(i)
      enddo

      do j=1,3
        xy(j)=0
       do i=1,n
         xy(j)=xy(j)+xm(i,j)*p(i)
       enddo
      enddo

      do i=1,3
       do j=1,3
         xx(i,j)=0
         do k=1,n
           xx(i,j)=xx(i,j)+xm(k,i)*xm(k,j)
         enddo
       enddo
      enddo

      ithree=3
      call inverse(ithree,xx,xy,beta)

      a=beta(1)
      b=beta(2)
      c=beta(3)

return
      end
```

inverse.f

```
      subroutine inverse(n,x,y,b)
      dimension x(3,3),y(1),b(1)
      dimension indx(3)

      do i=1,n
        b(i)=y(i)
      enddo

      call ludcmp(x,3,indx,d)
      call lubksb(x,3,indx,b)

      return
      end

      subroutine ludcmp(a,n,indx,d)
      dimension indx(1),a(3,3),vv(3)
      tiny=1.0e-20

      d=1.
      do 12 i=1,n
        aamax=0
        do 11 j=1,n
          if(abs(a(i,j)).gt.aamax) aamax=abs(a(i,j))
11        continue
        if (aamax.eq.0.) print *,'Singular matrix'
        if (aamax.eq.0.) stop
        vv(i)=1/aamax
12      continue
      do 19 j=1,n
        do 14 i=1,j-1
          sum=a(i,j)
          do 13 k=1,i-1
            sum=sum-a(i,k)*a(k,j)
13          continue
          a(i,j)=sum
14        continue
        aamax=0.
        do 16 i=j,n
          sum=a(i,j)
          do 15 k=1,j-1
            sum=sum-a(i,k)*a(k,j)
15          continue
          a(i,j)=sum
          dum=vv(i)*abs(sum)
          if(dum.ge.aamax) then
            imax=i
            aamax=dum
          endif
```

```
16      continue
      if(j.ne.imax) then
        do 17 k=1,n
          dum=a(imax,k)
          a(imax,k)=a(j,k)
          a(j,k)=dum
17        continue
        d=-d
        vv(imax)=vv(j)
      endif
      indx(j)=imax
      if(a(j,j).eq.0.) a(j,j)=tiny
      if (j.ne.n) then
        dum=1./a(j,j)
        do 18 i=j+1,n
          a(i,j)=a(i,j)*dum
18        continue
      endif
19    continue
    return
    end

    subroutine lubksb (a,n,indx,b)
    dimension a(3,3),indx(1),b(1)

    ii=0
    do 12 i=1,n
      ll=indx(i)
      sum=b(ll)
      b(ll)=b(i)
      if(ii.ne.0) then
        do 11 j=ii,i-1
          sum=sum-a(i,j)*b(j)
11        continue
      elseif (sum.ne.0.) then
        ii=i
      endif
      b(i)=sum
12    continue
    do 14 i=n,1,-1
      sum=b(i)
      do 13 j=i+1,n
        sum=sum-a(i,j)*b(j)
13      continue
      b(i)=sum/a(i,i)
14    continue
    return
    end
```

Appendix C. Name, size, and description of data and parameter files used for the Feather River PRMS models.

File	Size (bytes)	Description
AC_draper_climateQ.data	1717823	Daily precipitation adjusted for each HRU, temperature, and observed streamflow—Almanor model input.
BC_draper_climateQ.data	537119	Daily precipitation adjusted for each HRU, temperature, and observed streamflow—Butt Creek model input.
EB_draper_climateQ.data	5368088	Daily precipitation adjusted for each HRU, temperature, and observed streamflow—East Branch model input.
LO_draper_climateQ.data	1446364	Daily precipitation adjusted for each HRU, temperature, and observed streamflow—Lower North Fork model input.
MF_draper_climateQ.data	3150909	Daily precipitation adjusted for each HRU, temperature, and observed streamflow—Middle Fork model input.
SF_draper_climateQ.data	803329	Daily precipitation adjusted for each HRU, temperature, and observed streamflow—South Fork model input.
WB_draper_climateQ.data	1019154	Daily precipitation adjusted for each HRU, temperature, and observed streamflow—West Branch model input
OR_draper_climateQ.data	1461010	Daily precipitation adjusted for each HRU, temperature, and observed streamflow—Oroville model input.
AC_feather.param	75127	PRMS parameter input file for Almanor model.
BC_feather.param	15485	PRMS parameter input file for Butt Creek model.
EB_feather.param	174248	PRMS parameter input file for East Branch model.
LO_feather.param	62969	PRMS parameter input file for Lower North Fork model.
MF_feather.param	94706	PRMS parameter input file for Middle Fork model.
SF_feather.param	29798	PRMS parameter input file for South Fork model.
WB_feather.param	24096	PRMS parameter input file for West Branch model.
OR_feather.param	69068	PRMS parameter input file for Oroville model.

Looking for Recent Climatic Trends and Patterns in California's Central Sierra

Gary J. Freeman

Introduction

Pacific Gas & Electric Company's (PG&E) water management team has historically assumed that future years, as a group of three or more successive years, were subject to the same level of climatic randomness characteristic of the past 25-50 years. There is increasing ongoing analysis that indicates that this may not always be the best assumption for future planning. With approximately 38% of its long term average annual hydroelectric generation derived from aquifer outflow, typical historic practice at PG&E, with regard to forecasting future seasonal runoff beyond the current year, has focused almost entirely on analyzing the current baseflow trend for the volcanic watersheds in northern California, such as in the Pit, McCloud, and upper North Fork Feather River watersheds. Historic climate randomness is then assumed for future seasonal precipitation and a multi-year baseflow forecast for a number of years forward is made for these northern watersheds. For the mid-to-high elevation headwaters, which overlay the central Sierra granites, the baseflow effect of prior years, is relatively minimal, and seasonal year-to-year randomness for historic precipitation has been assumed for input to multi-year runoff forecasts.

No attempts at PG&E have previously been made to utilize historic climate oscillation and trends as possible input to predict overall likelihood for precipitation in successive groups of upcoming years. Relatively recent analysis however, cautiously suggests that there may be relatively short precipitation cycles, which are approximately 14-16 years in length, and possibly longer term cycle and trend movements, which, while not necessarily helpful for defining wetness or dryness in the following year, may possibly provide helpful insight to better anticipate wetness for successive groups of years in terms of three or more years as a group. The apparent non-random subtle reflections of climatic cycling and trending was first noticed from the natural multi-year smoothing that accompanies baseflow trends and cycles of the large northern California volcanic springs that continuously contribute water as diminishing echoes of past wetness. Manga (1999) discusses timescales and groundwater discharge from the Cascade volcanics, which include those in northern California's Hat Creek drainage. A portion of the water, which is now emerging from underground storage to become surface runoff, may have come from seasonal precipitation that occurred many decades in the past. In this paper, an array of monthly and seasonal groupings of historic precipitation, snowpack and runoff are analyzed to reveal possible subtle signs of climatic oscillation and trending. While no attempt is made here to forecast future cycles of wetness based on observations of historic data, or being able to define the wetness for any given 1-2 years specifically, there may be potential for anticipating future wetness in terms of using successive groups of three or more years.

Repeating Climate Patterns in Wetness During the Past 100 Years

Recurring approximate 15-year oscillations in aquifer outflow rates from springs that contribute a large proportion of annual runoff into the Pit and McCloud rivers in northern California (Freeman 2001) provide possible clues that there may be multi-year periodicity to overall climate wetness and dryness as characterized by groups of successive years. This paper will illustrate some specific examples of precipitation, snowpack, and runoff that appear to support periodicity in wetness and dryness with amplitudes at about 7-8 years, and wetness and dryness, peaks and valleys respectively, utilizing three- and five-year grouped averages, each peak and valley being repeated approximately every 15 years. Some longer-term trends are also explored in this paper.

During either the wet or dry period, specific years were frequently observed to vary significantly from the three- or five-year average, but the group as a whole remained in relative harmony with the historic 15-year frequency. A review of aquifer outflow rates was utilized to identify the wet and dry amplitude peaks and valleys in terms of initially typing historic years. When applied to the 107-year, 1895 through 2001 Lake Spaulding precipitation record, grouping the year types into regular successive wet and dry three-year peaks and valleys according to rates of aquifer outflow, a relatively close matching relationship was found with the precipitation record. The apparent 15-year periodicity between successive recurring wet peaks and successive recurring dry valleys can be observed in Figure 1 for the 107-year period studied.

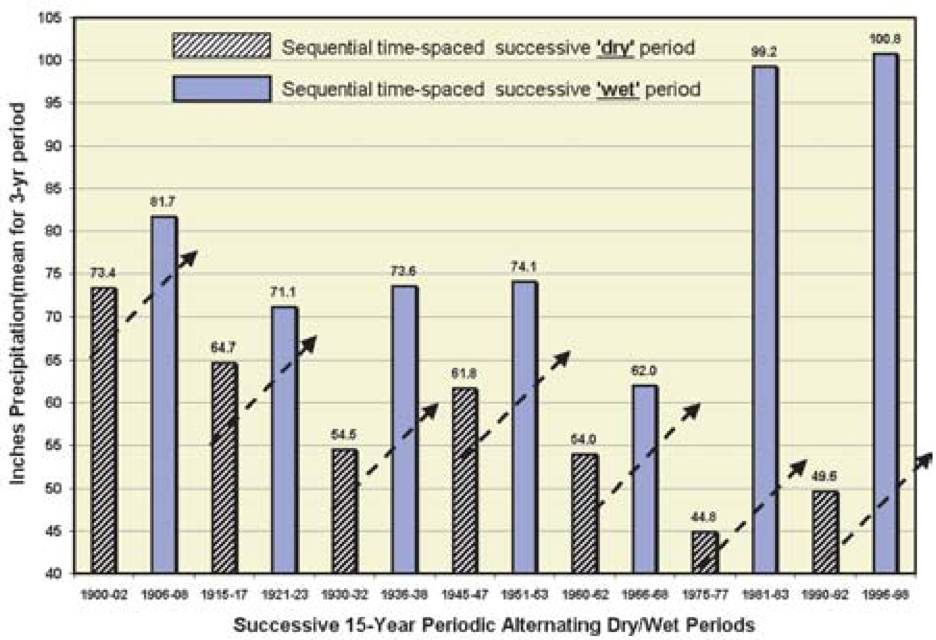

Figure 1 Lake Spaulding periodic oscillation of successive, sequential, time-spaced 3-year wet and dry groups of years. A sometimes subtle, but regular, oscillation appears to regularly repeat itself in terms of reaching a relative wetness maximum for the grouped years approximately every 15 years.

When other precipitation stations in both the central Sierra and southern Cascades near Mt. Shasta are combined and a five-year moving average smoother applied, the wet and dry oscillation again appears in a regular periodic manner, with some implied likelihood that the next dry valley for these three climate station will occur in or about 2005-2007 (Figure 2).

Spectral analysis can be applied to smoothed moving averages to reveal possible periodicity in wetness and dryness. This approach may reveal periodicity and show indication of the interval length, but in terms of prediction, this approach does not readily type the years into wet or dry groups such that the oscillation can be meaningfully extended forward in time from a specific year. Forecasts of periods, which reflect future periods of wetness and dryness based on past climate history, can be charted with possible implication that if the observed pattern continues, one may gain some skill for determining wet and dry groups of years forward of the present point in time. Such skill would be especially helpful for planning based on multiyear estimates of hydropower, water supply, and other longer-range hydro resource needs.

While individual years within the 3-5 year group are somewhat random in terms of being wet or dry, their moving average especially for the groupings reveals a somewhat regular oscillating pattern. A centered five-year moving average smoother was applied to the 1950 through 2001 Water Year flow for the east branch of the North Fork Feather River near Rich Bar, USGS 11403000 (Figure 3). This 52-year runoff record shows both the approximate 15-year periodicity in runoff and a possible longer-term trend toward increasing variance between high and low runoff periods.

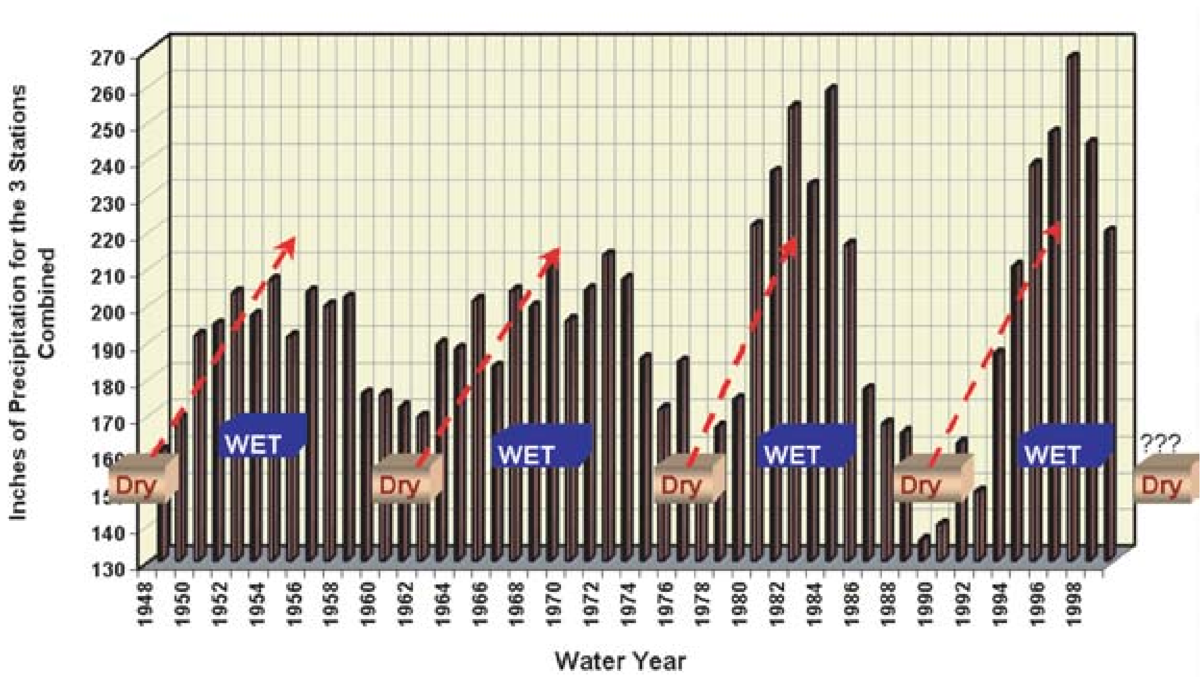

Figure 2 A five-year centered moving average smoother was applied to the combined water year precipitation of two central (Salt Springs, Lake Spaulding) and one northern California (Pit PH#5) climate stations. A regular periodic oscillation in wetness may provide some implied likelihood for predicting future wetness as a grouped set of years. In the past 30 years, two approximately 15-year oscillation periods, there appears to be increased difference between wetness and dryness amplitude compared with prior oscillations.

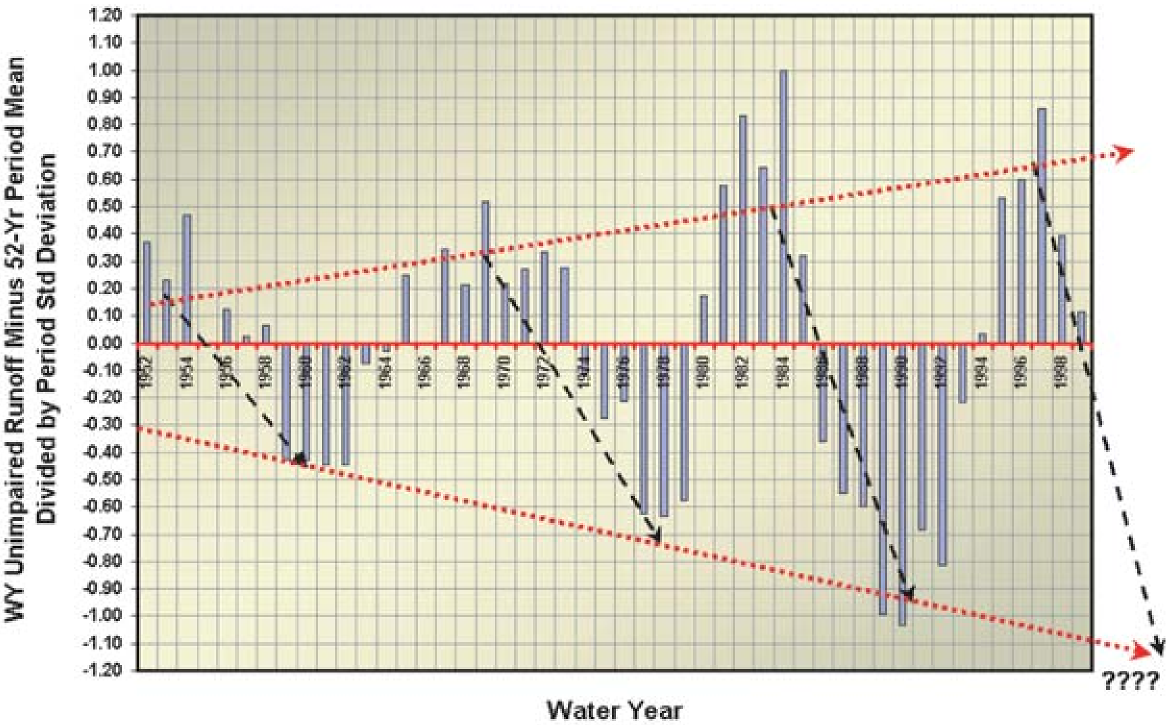

Figure 3 Recurring periods of greater and lesser-unimpaired runoff during the past 52 years on the east branch of North Fork Feather River. Increased period variability since about the mid-1970s, for the 52-year period, shows an increased variance in amplitude in recent years. Centered 5-year moving average applied.

Periods Within the Year also Show Recurring Runoff Patterns with Possible Long-Term Trends

In addition to the longer-term periodicity, there also appear to be trends and cycles (although less regular) that show up within the water year. The longer-term trend may possibly be due to earlier melt of the snowpack. The March runoff for the east branch of the North Fork Feather River (Figure 4) has increased while the May runoff (Figure 5) has decreased. Such trend change over the relatively brief span of approximately 50 years has potential to impact efficiently scheduling the water for hydroelectric production. The hydroelectric facilities were designed based on a runoff pattern for the Feather River typical of the early to mid-20th century. During the past 50 years the March runoff from the east branch of the North Fork Feather River, which represents about one-third the average annual runoff for the North Fork Feather River at Lake Oroville, has in recent years approximately doubled in quantity. In terms of hydroelectric scheduling, March flow releases from the large upstream storage reservoirs, Lake Almanor and Bucks Lake, have greatly decreased in recent years. This has in part resulted from an ongoing hydro scheduling practice to avoid when possible, the spill of upstream stored water from Lake Almanor past hydroelectric powerhouses along the lower reaches of the river that are already running at full capacity from the unimpaired east branch of the North Fork Feather River's March runoff. The approximate 15-year oscillation of grouped annual runoff observed in both the March and May months is most likely related to the similar wet/dry oscillation in annual precipitation. Seasonal precipitation amounts show an almost direct correlation with snowpack amount and therefore snowmelt runoff, which will in turn likely affect March and May runoff amounts. This observed shift in runoff timing has in general within the past 15-20 years supported a relatively recent practice by water planners for reduced draft from both Lake Almanor and Bucks Lake during the January through March period, while the late winter and early spring uncontrolled sidewater flows from low elevation headwater areas, which have trended upward in recent years, are being increasingly utilized to run power houses downstream of these two lakes.

The November through February period was divided by the combined November through February period and the April through July period utilizing the monthly computed unimpaired flow for the Yuba River at Smartville, as computed by the California Department of Water Resources, for the 102-year period 1901 through 2002. The data was standardized with a centered five-year moving average smoother and is shown in Figure 6. Figure 6 reveals a positive upward drift in the November through February flows compared with the April through July snowmelt period.

Increased winter runoff is reflective of an increased proportion of precipitation falling as rainfall over the watershed during the November through February period. The record period used was 1901 through 2002 (102 years).

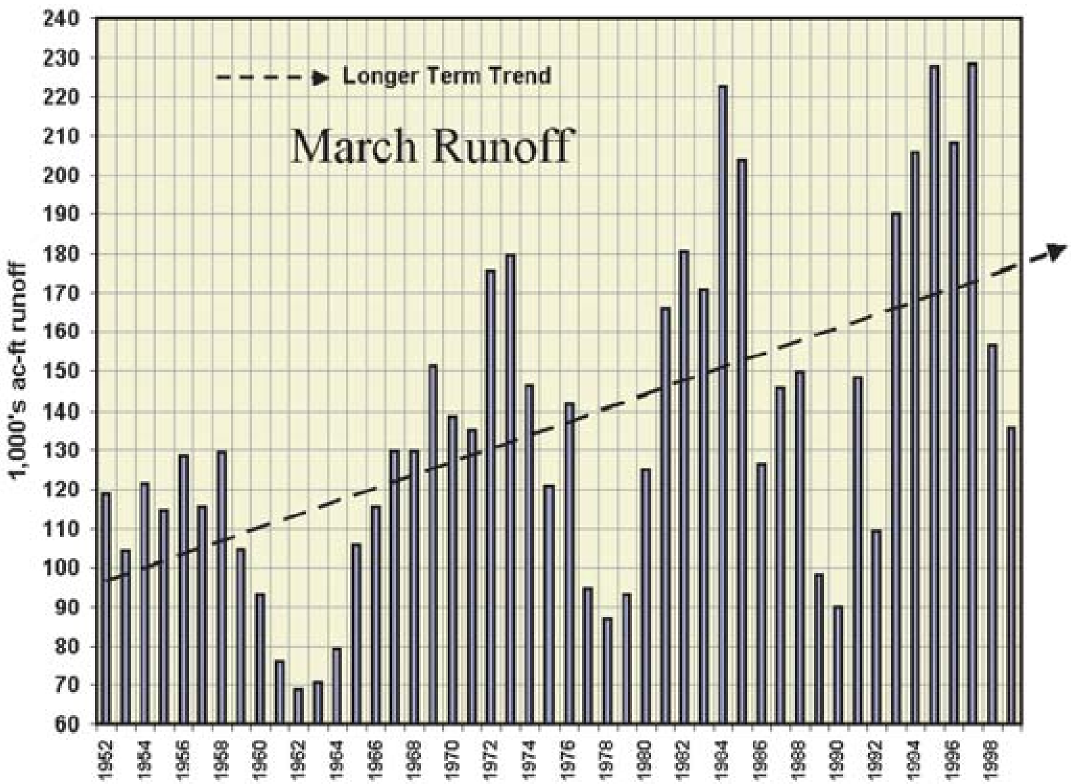

Figure 4 March unimpaired runoff for the east branch of the North Fork Feather River. Both a relatively short-term 14-16 year oscillation and longer-term trend toward increased March runoff in recent years appear on the chart. Centered 5-year moving average applied.

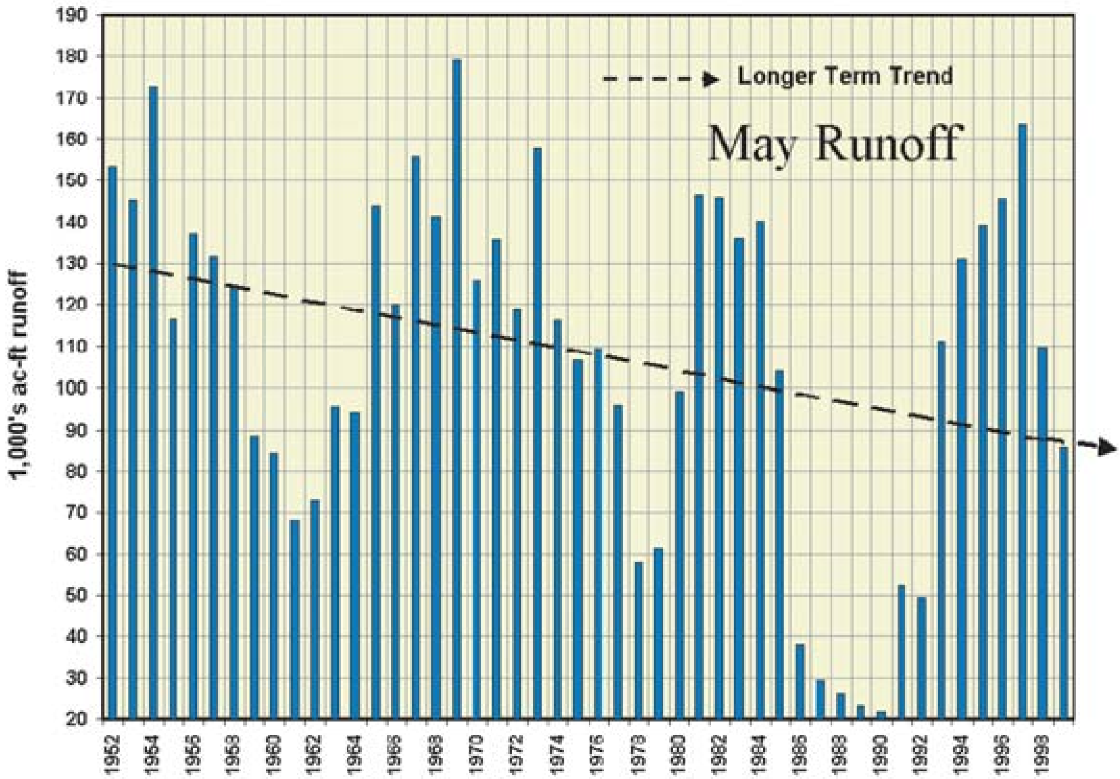

Figure 5 May unimpaired runoff for the east branch of the North Fork Feather River. Both relatively short-term 14-16 oscillation cycles and a longer-term trend toward decreased May runoff appear on the chart. Centered 5-year moving average applied.

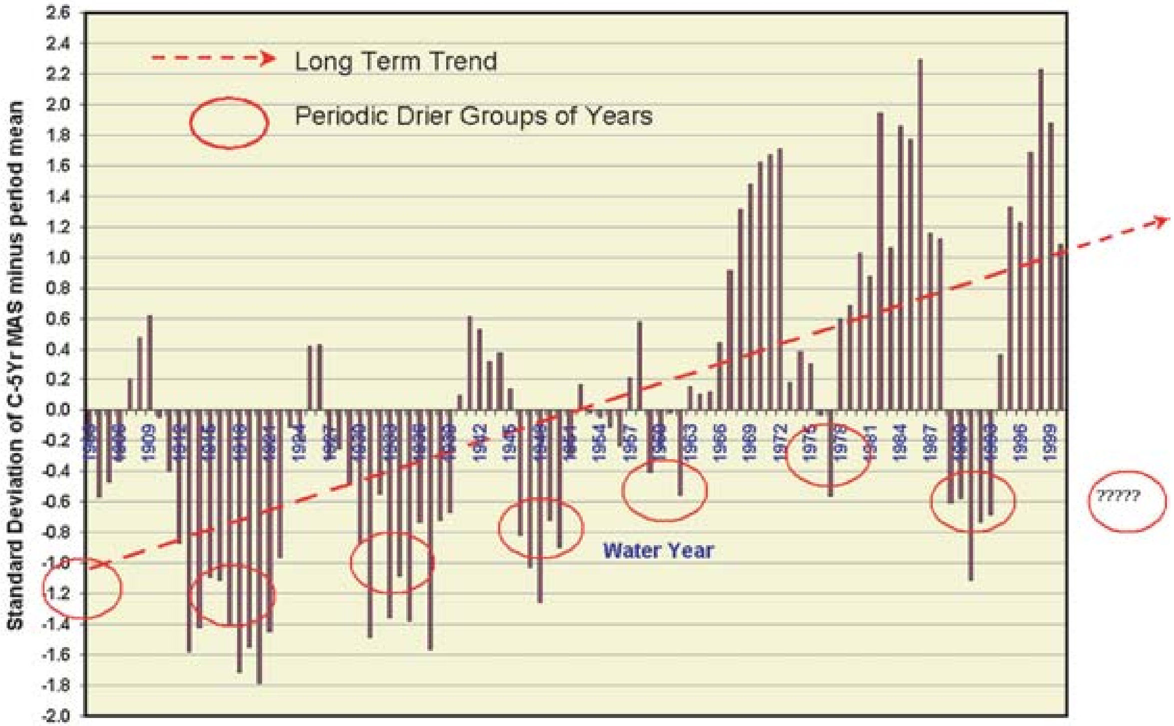

Figure 6 A drift in flow timing for the unimpaired runoff of the Yuba River at Smartville. Increased winter runoff in recent years appears reflective of an increased proportion of the annual precipitation falling as rainfall over the watershed during the November through February period. Record period used was 1901 through 2002 (102 years).

A continuous shift of the April through July runoff into the winter months November through February was observed from the data analyzed. With winter runoff in the Sierra largely produced from frontal type winter storms, the magnitude of winter runoff is mainly dependent upon quantity of winter rainfall produced runoff. If such is the case then it should revel itself when charted over the past 102 years. Figure 7 illustrates an increased frequency of large rain-produced runoff events in the second half of the 20th century compared with earlier years. This appears consistent with recent research findings, which forecast a shift in spring snowmelt runoff to increased rainfall produced winter runoff (Cayan and others 2001). Figure 8 displays the November through February averages for the two periods. There was a 17% increase in the period averages for November through February runoff.

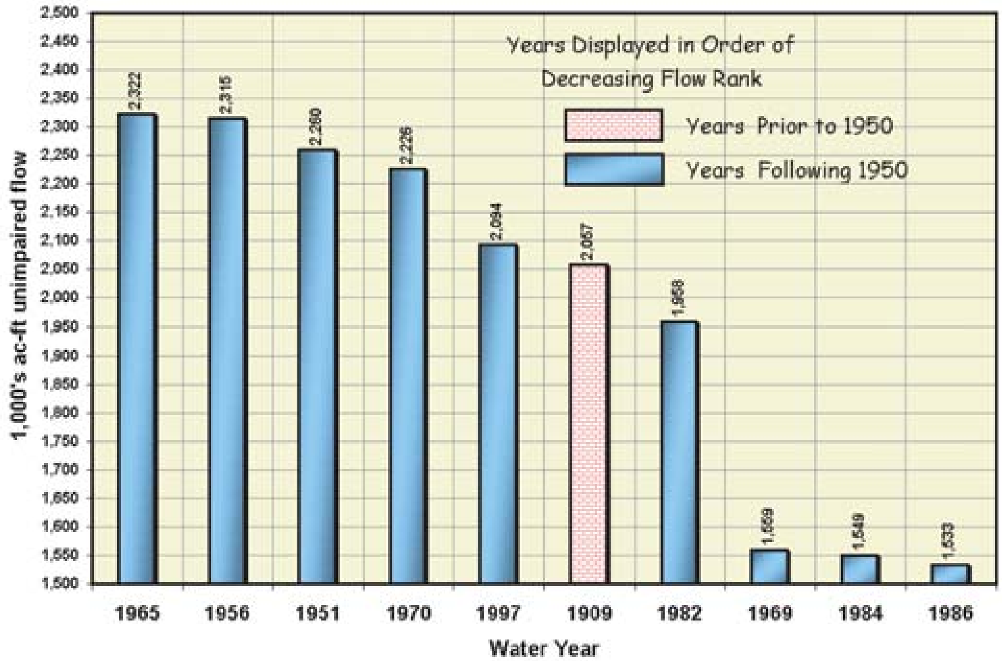

Figure 7 For the period 1901 through 2000, Yuba River at Smartville, only one year in the ten years of November through February unimpaired flows, which exceed 1,500,000 af, occurs prior to 1950. Recent years appear to have higher likelihood for more flow during the 4-month November through February winter period.

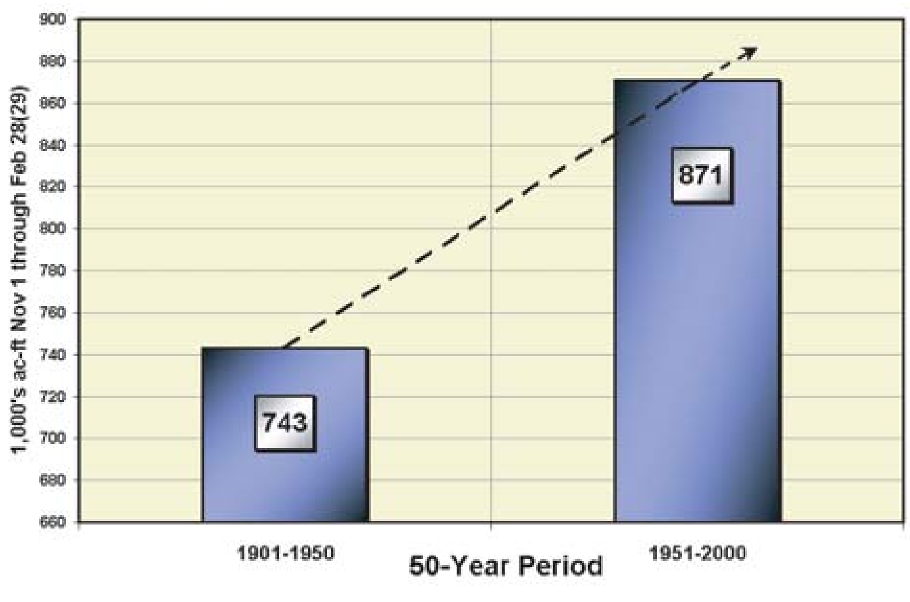

Figure 8 The mean flow of two successive November through February 50-year periods for the Yuba River at Smartville. There is a 17% increase in the more recent period.

The California Sierra Snowpack

California's snowpack likewise shows recurring patterns similar to that for both runoff and precipitation. A single snow course at Meadow Lake (#66) in the central Sierra at the 7,200 foot elevation readily revels relative consistency in regular recurring oscillation between wet and dry groups of years as shown in Figure 9. While no attempt is made here to explain a cause for the observed recurring multiyear oscillation, a significant amount of the seasonal snowpack variability may be explainable with indices of Pacific Ocean Climate such as PDO (McCabe and Cayan 2001).

In order to test that the centered five-year moving average produced pattern was not simply a moving average "produced-aberration", regularly spaced discrete groups of years were also charted to verify alternating wet/dry periods. This is displayed in Figure 10. The regularly occurring highs and lows are readily identifiable, but in some cases are relatively subtle and could possibly be easily overlooked unless one was specifically looking at the appropriate successive regularly occurring time blocks.

Seasonal snowpack is closely related to both precipitation amount and freezing levels for winter and spring storms. The author found that for moderate to high elevation snow courses in the central Sierra, the April 1 snow water equivalent exhibit oscillation patterns closely resembling those of both precipitation and runoff.

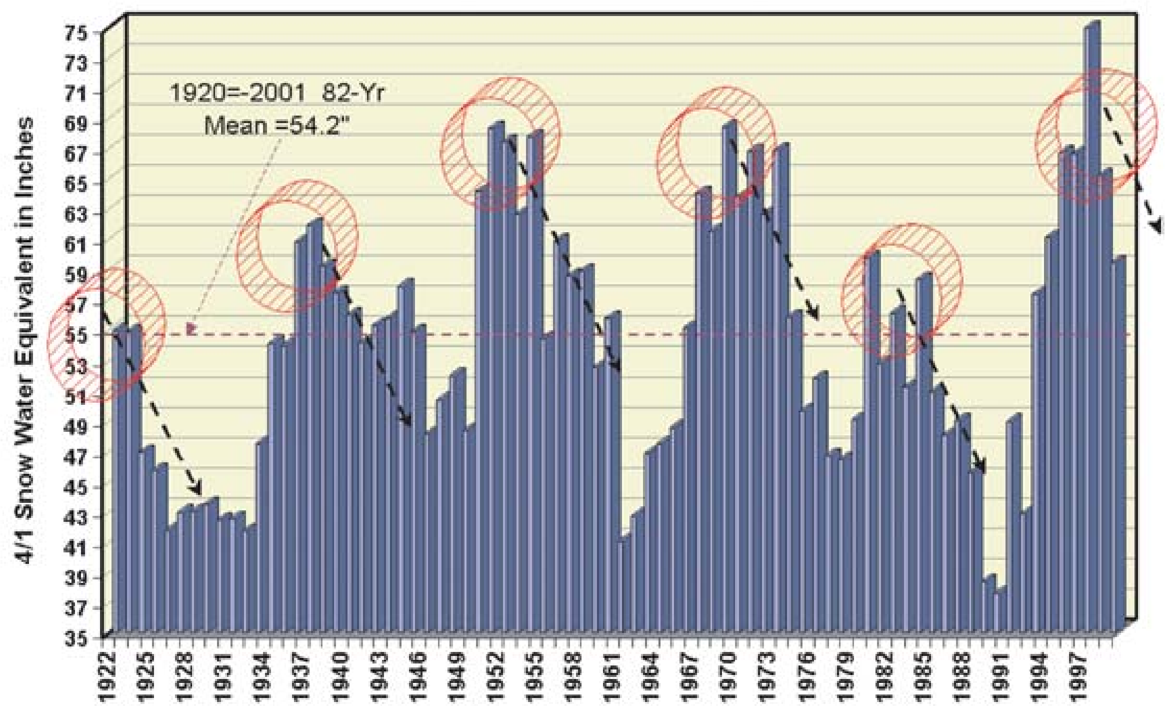

Figure 9 Meadow Lake snow course #66 in California's central Sierra Yuba River headwaters reveals a periodic oscillation in April 1 snow water equivalent (SWE) between periods of relative wetness and dryness. This snow course at the 7,200 foot elevation, unlike others at lower elevations, has not seen a reduction in snow water equivalent during the second half of the 20th century. Centered 5-year moving average applied.

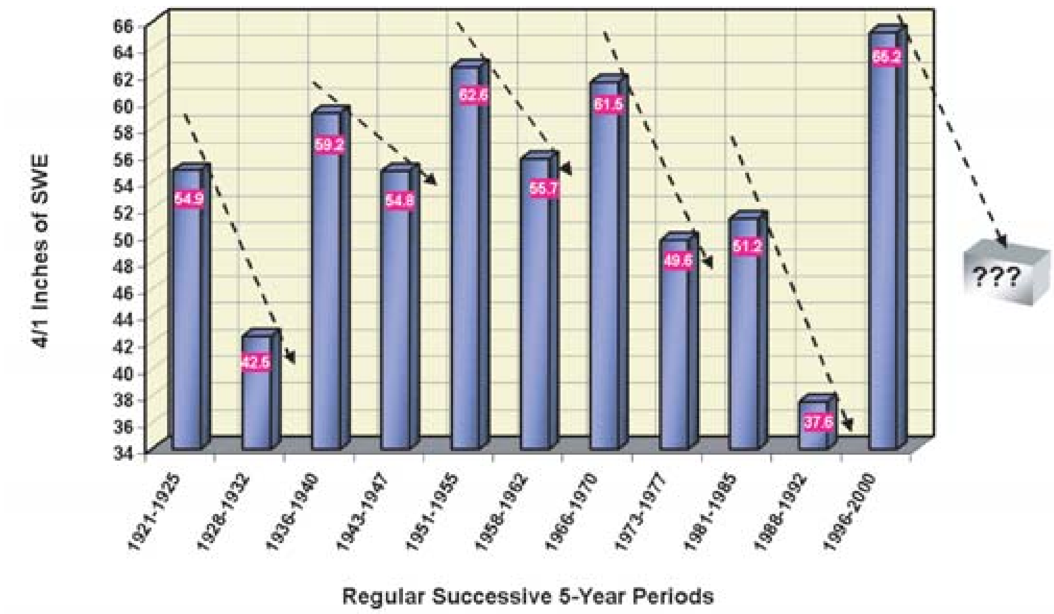

Figure 10 Meadow Lake #66 snow course — April 1 Snow Water Equivalent (*same original basic data set as used for Figure 10*). Discrete, successive 5-year groupings of regularly spaced years charted to show sometimes subtle, but regular, periods of wetness and dryness.

Comparison of the April 1 snow water equivalent for two snow courses on the south Yuba watershed for the period 1948 through 2002 — Lake Spaulding at the 5,200 foot elevation and Meadow Lake at the 7,200 foot elevation — reveals a downward trend for Lake Spaulding, the lower elevation snowpack (Figure 11). Meadow Lake, however, at the 2,000 foot higher elevation, approximately 10 miles northeast of Lake Spaulding, displays a near level trend line for the same 55-year period. The Lake Spaulding April 1 snow water equivalent is examined for a longer period (Figure 12). The April 1 snow water equivalent decreases from a mean of 24.4 inches for the 37-year period 1929 through 1965 to 19.8 inches for the 37-year period 1966 through 2002. This equates to a 19% drop in the mean for the more recent of the two periods (Figure 12). This long-term decreasing trend in low elevation snowpack and consequent decline in melt produced runoff appears consistent with that described elsewhere (Roos 1991).

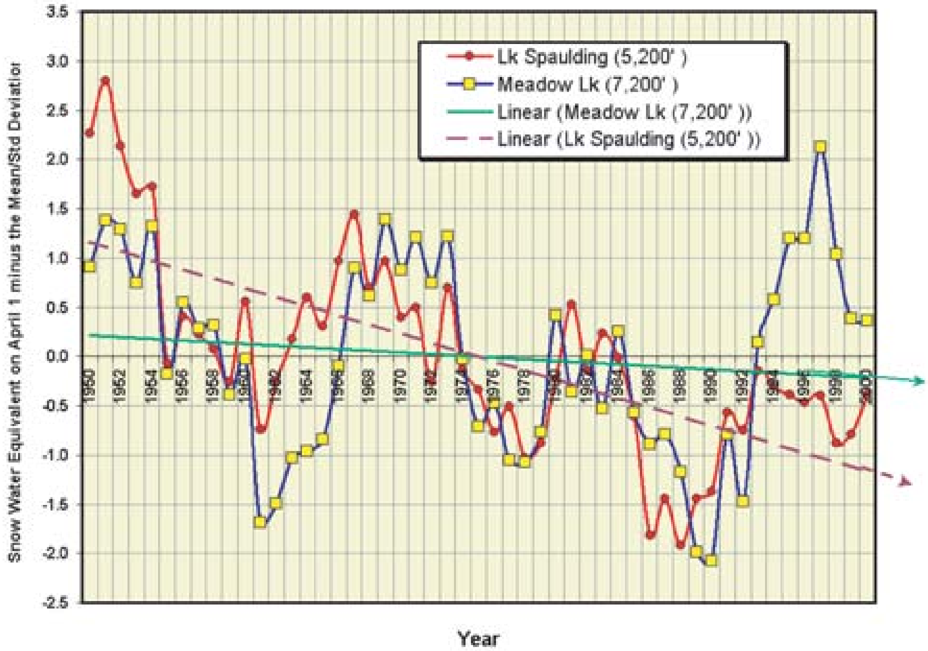

Figure 11 A comparison of the April 1 snow water equivalent for the two snow courses, Lake Spaulding #85 at the 5,200 foot elevation and Meadow Lake #66 at the 7,200 foot elevation in the headwaters in central California's Yuba River headwater drainage. Trend lines for each of the snow courses show a much steeper decline in recent years for the lower elevation Lake Spaulding snow course.

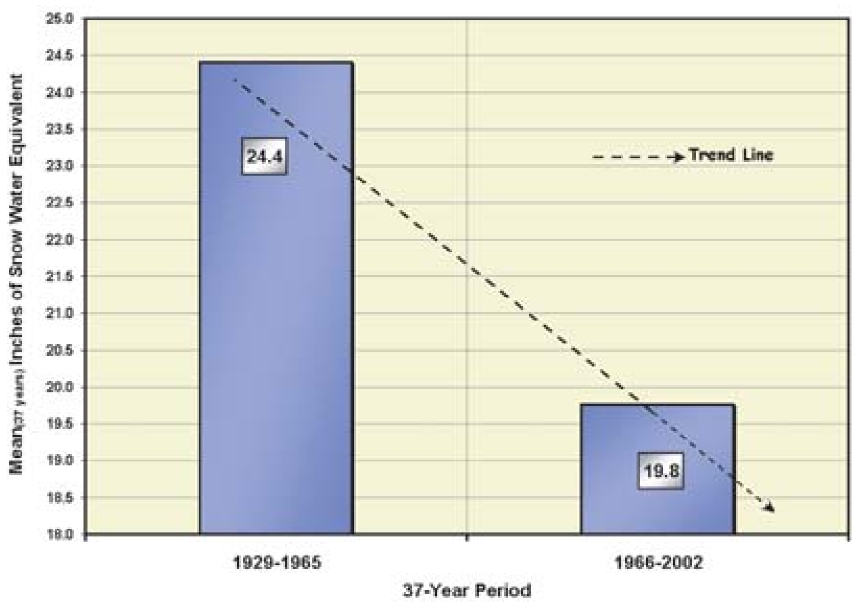

Figure 12 The April 1 snow water equivalent mean for two successive 37-year periods at the Lake Spaulding #85 snow course at the 5,200 foot elevation in California's central Sierra. This decrease in the April 1 SWE mean represents a 19% drop from the earlier period. No significant decline was observed to have occurred in the nearby snow course at Meadow Lake, which is 2,000 feet higher in elevation. The decline in low elevation snow in recent years may be indicative of a higher snowfall line with winter storm systems.

Conclusions

Analysis of historic hydrometeorological data reveals patterns that may have use in predicting future tendency toward wet or dry multiyear periods. If substantiated from additional research, such patterns may have potential use for long-range hydroelectric planning. Planning future outage schedules for hydroelectric facilities and reservoir carryover storage targets for multi-year storage reservoirs such as PG&E's Lake Almanor could benefit from increased skill in predicting upcoming years to have increased likelihood for more or less annual inflow. PG&E is already able to forecast approximately 40 % of its annual generation several years forward by making a baseflow forecast of anticipated relatively firm aquifer outflow from springs, which provide large relatively stable daily flows of the High Cascade and flood basalts of northern California. The apparent bimodal approximate 15-year oscillation pattern does not appear to provide much insight into predicting any given year's wetness in the future, but seems more useful for defining multi-year groupings as being in a wet or dry period as a grouping of three or more years. From the limited analysis presented here, precipitation, snowpack, and unimpaired runoff all appear to reflect this approximate 15-year oscillation in the central Sierra. The aquifer outflow of springs in northern California slightly lags these cycles and provides a natural moving average smoother of prior years annual precipitation variance.

Longer-term trends in apparent distribution shift of monthly runoff from the April through July snowmelt runoff period into the November through February period may be occurring from a trend toward reduced low elevation snowpack, possibly from an increased frequency of slightly warmer winter frontal storm cells during the second half of the 20th century. Since most of PG&E's hydroelectric system was designed based on historical flows prior to the mid-1960s, increased winter flows of higher magnitude are posing new challenges in monthly hydroelectric scheduling for reservoirs primarily designed to accommodate pre-1960s snowmelt quantities and annual year-to-year variance. Warmer conditions may shift reservoir filling from the late spring-early summer period toward holding additional water later into the winter-early spring period to increase assurance of filling from snowmelt. There is growing research that this trend is likely to continue (Knowles and others 2001; Snyder and others 2001). The reality of the limited observations discussed in this paper must await further, more thorough research, but the patterns and trends being observed tend to hint at possibility of a bimodal stochastic resonance effect. Regardless of the underlying forcing causes, the observed regularity of patterns appears helpful in making longer-range multiyear planning decisions.

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Looking for Recent Climatic Trends and Patterns in California's Central Sierra

Gary J. Freeman

Introduction

Pacific Gas & Electric Company's (PG&E) water management team has historically assumed that future years, as a group of three or more successive years, were subject to the same level of climatic randomness characteristic of the past 25-50 years. There is increasing ongoing analysis that indicates that this may not always be the best assumption for future planning. With approximately 38% of its long term average annual hydroelectric generation derived from aquifer outflow, typical historic practice at PG&E, with regard to forecasting future seasonal runoff beyond the current year, has focused almost entirely on analyzing the current baseflow trend for the volcanic watersheds in northern California, such as in the Pit, McCloud, and upper North Fork Feather River watersheds. Historic climate randomness is then assumed for future seasonal precipitation and a multi-year baseflow forecast for a number of years forward is made for these northern watersheds. For the mid-to-high elevation headwaters, which overlay the central Sierra granites, the baseflow effect of prior years, is relatively minimal, and seasonal year-to-year randomness for historic precipitation has been assumed for input to multi-year runoff forecasts.

No attempts at PG&E have previously been made to utilize historic climate oscillation and trends as possible input to predict overall likelihood for precipitation in successive groups of upcoming years. Relatively recent analysis however, cautiously suggests that there may be relatively short precipitation cycles, which are approximately 14-16 years in length, and possibly longer term cycle and trend movements, which, while not necessarily helpful for defining wetness or dryness in the following year, may possibly provide helpful insight to better anticipate wetness for successive groups of years in terms of three or more years as a group. The apparent non-random subtle reflections of climatic cycling and trending was first noticed from the natural multi-year smoothing that accompanies baseflow trends and cycles of the large northern California volcanic springs that continuously contribute water as diminishing echoes of past wetness. Manga (1999) discusses timescales and groundwater discharge from the Cascade volcanics, which include those in northern California's Hat Creek drainage. A portion of the water, which is now emerging from underground storage to become surface runoff, may have come from seasonal precipitation that occurred many decades in the past. In this paper, an array of monthly and seasonal groupings of historic precipitation, snowpack and runoff are analyzed to reveal possible subtle signs of climatic oscillation and trending. While no attempt is made here to forecast future cycles of wetness based on observations of historic data, or being able to define the wetness for any given 1-2 years specifically, there may be potential for anticipating future wetness in terms of using successive groups of three or more years.

Repeating Climate Patterns in Wetness During the Past 100 Years

Recurring approximate 15-year oscillations in aquifer outflow rates from springs that contribute a large proportion of annual runoff into the Pit and McCloud rivers in northern California (Freeman 2001) provide possible clues that there may be multi-year periodicity to overall climate wetness and dryness as characterized by groups of successive years. This paper will illustrate some specific examples of precipitation, snowpack, and runoff that appear to support periodicity in wetness and dryness with amplitudes at about 7-8 years, and wetness and dryness, peaks and valleys respectively, utilizing three- and five-year grouped averages, each peak and valley being repeated approximately every 15 years. Some longer-term trends are also explored in this paper.

During either the wet or dry period, specific years were frequently observed to vary significantly from the three- or five-year average, but the group as a whole remained in relative harmony with the historic 15-year frequency. A review of aquifer outflow rates was utilized to identify the wet and dry amplitude peaks and valleys in terms of initially typing historic years. When applied to the 107-year, 1895 through 2001 Lake Spaulding precipitation record, grouping the year types into regular successive wet and dry three-year peaks and valleys according to rates of aquifer outflow, a relatively close matching relationship was found with the precipitation record. The apparent 15-year periodicity between successive recurring wet peaks and successive recurring dry valleys can be observed in Figure 1 for the 107-year period studied.

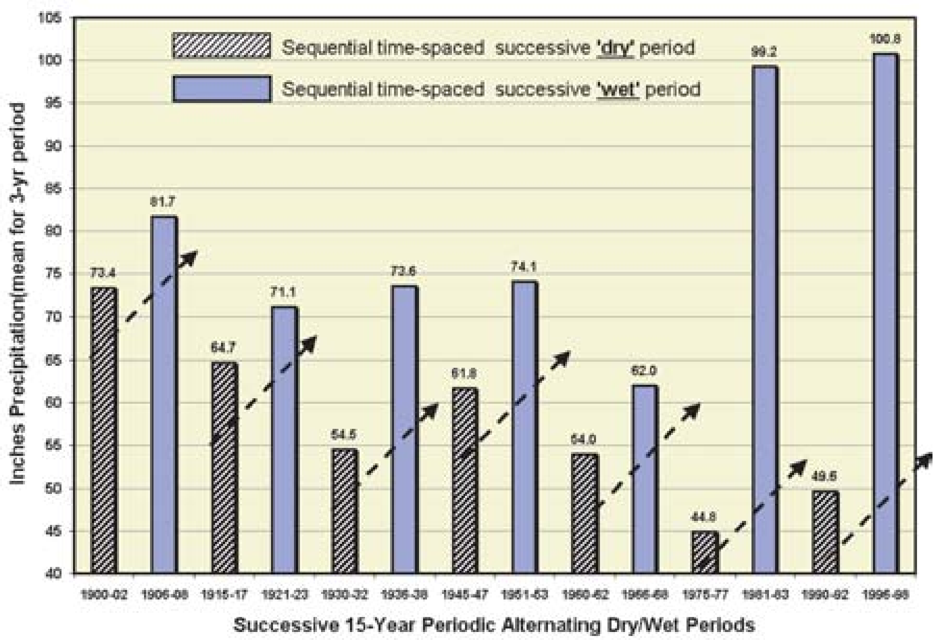


Figure 1 Lake Spaulding periodic oscillation of successive, sequential, time-spaced 3-year wet and dry groups of years. A sometimes subtle, but regular, oscillation appears to regularly repeat itself in terms of reaching a relative wetness maximum for the grouped years approximately every 15 years.

When other precipitation stations in both the central Sierra and southern Cascades near Mt. Shasta are combined and a five-year moving average smoother applied, the wet and dry oscillation again appears in a regular periodic manner, with some implied likelihood that the next dry valley for these three climate station will occur in or about 2005-2007 (Figure 2).

Spectral analysis can be applied to smoothed moving averages to reveal possible periodicity in wetness and dryness. This approach may reveal periodicity and show indication of the interval length, but in terms of prediction, this approach does not readily type the years into wet or dry groups such that the oscillation can be meaningfully extended forward in time from a specific year. Forecasts of periods, which reflect future periods of wetness and dryness based on past climate history, can be charted with possible implication that if the observed pattern continues, one may gain some skill for determining wet and dry groups of years forward of the present point in time. Such skill would be especially helpful for planning based on multiyear estimates of hydropower, water supply, and other longer-range hydro resource needs.

While individual years within the 3-5 year group are somewhat random in terms of being wet or dry, their moving average especially for the groupings reveals a somewhat regular oscillating pattern. A centered five-year moving average smoother was applied to the 1950 through 2001 Water Year flow for the east branch of the North Fork Feather River near Rich Bar, USGS 11403000 (Figure 3). This 52-year runoff record shows both the approximate 15-year periodicity in runoff and a possible longer-term trend toward increasing variance between high and low runoff periods.

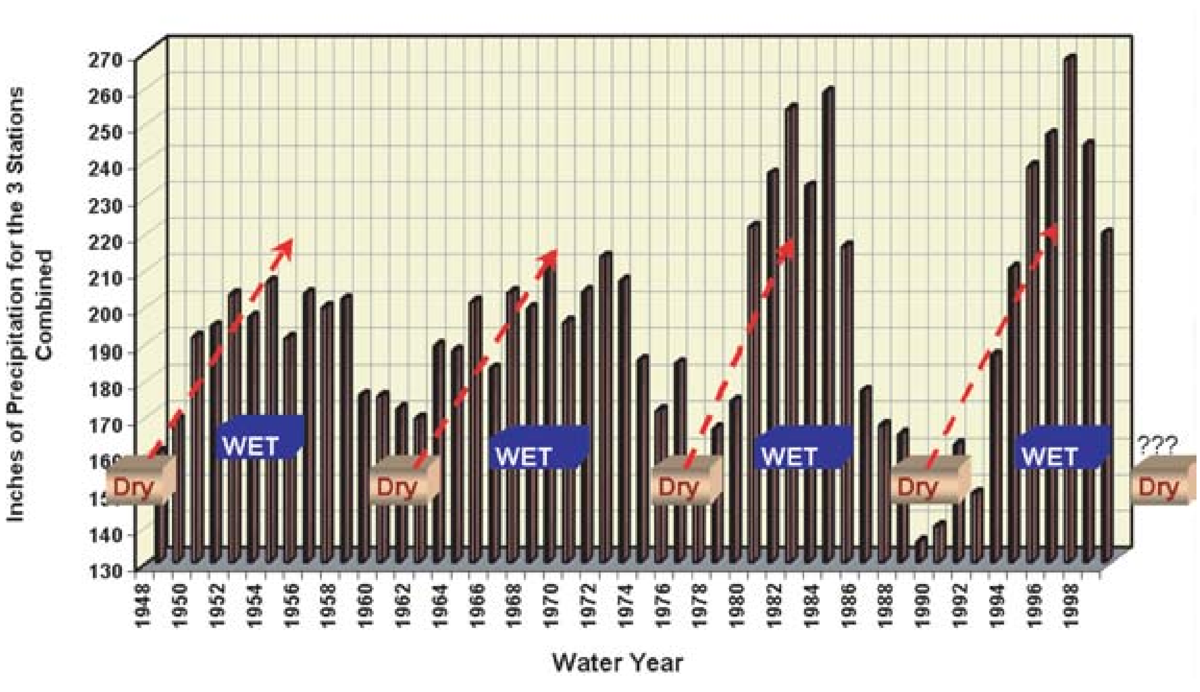


Figure 2 A five-year centered moving average smoother was applied to the combined water year precipitation of two central (Salt Springs, Lake Spaulding) and one northern California (Pit PH#5) climate stations. A regular periodic oscillation in wetness may provide some implied likelihood for predicting future wetness as a grouped set of years. In the past 30 years, two approximately 15-year oscillation periods, there appears to be increased difference between wetness and dryness amplitude compared with prior oscillations.

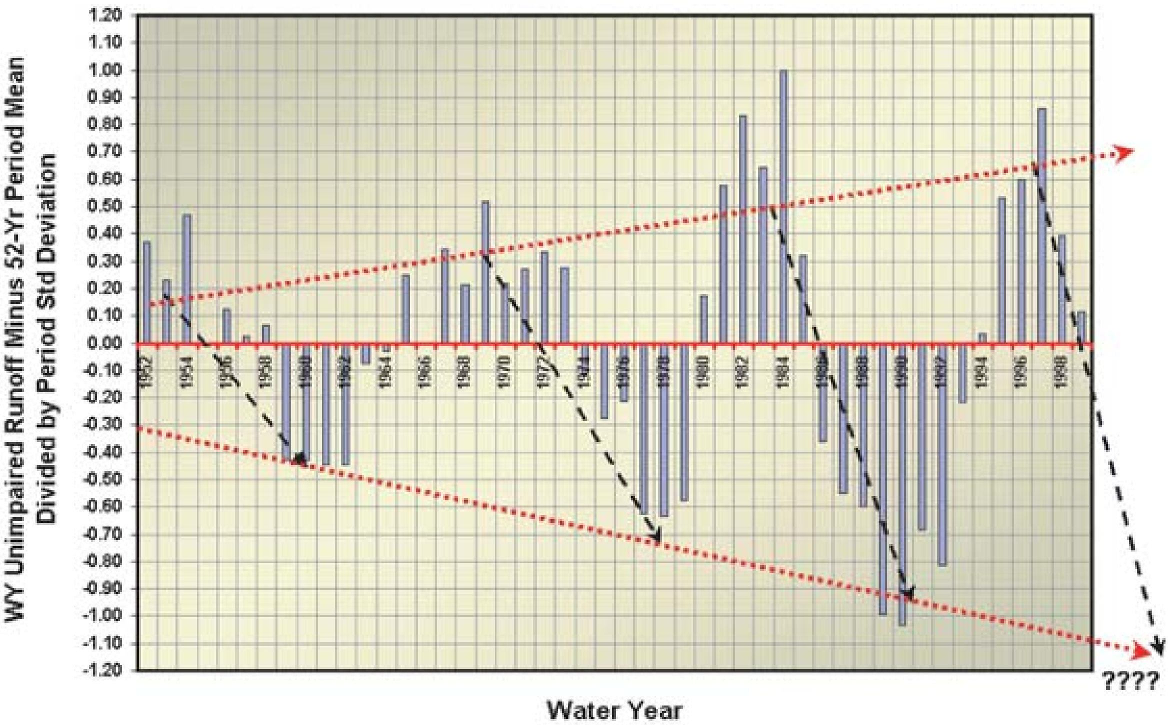


Figure 3 Recurring periods of greater and lesser-unimpaired runoff during the past 52 years on the east branch of North Fork Feather River. Increased period variability since about the mid-1970s, for the 52-year period, shows an increased variance in amplitude in recent years. Centered 5-year moving average applied.

Periods Within the Year also Show Recurring Runoff Patterns with Possible Long-Term Trends

In addition to the longer-term periodicity, there also appear to be trends and cycles (although less regular) that show up within the water year. The longer-term trend may possibly be due to earlier melt of the snowpack. The March runoff for the east branch of the North Fork Feather River (Figure 4) has increased while the May runoff (Figure 5) has decreased. Such trend change over the relatively brief span of approximately 50 years has potential to impact efficiently scheduling the water for hydroelectric production. The hydroelectric facilities were designed based on a runoff pattern for the Feather River typical of the early to mid-20th century. During the past 50 years the March runoff from the east branch of the North Fork Feather River, which represents about one-third the average annual runoff for the North Fork Feather River at Lake Oroville, has in recent years approximately doubled in quantity. In terms of hydroelectric scheduling, March flow releases from the large upstream storage reservoirs, Lake Almanor and Bucks Lake, have greatly decreased in recent years. This has in part resulted from an ongoing hydro scheduling practice to avoid when possible, the spill of upstream stored water from Lake Almanor past hydroelectric powerhouses along the lower reaches of the river that are already running at full capacity from the unimpaired east branch of the North Fork Feather River's March runoff. The approximate 15-year oscillation of grouped annual runoff observed in both the March and May months is most likely related to the similar wet/dry oscillation in annual precipitation. Seasonal precipitation amounts show an almost direct correlation with snowpack amount and therefore snowmelt runoff, which will in turn likely affect March and May runoff amounts. This observed shift in runoff timing has in general within the past 15-20 years supported a relatively recent practice by water planners for reduced draft from both Lake Almanor and Bucks Lake during the January through March period, while the late winter and early spring uncontrolled sidewater flows from low elevation headwater areas, which have trended upward in recent years, are being increasingly utilized to run power houses downstream of these two lakes.

The November through February period was divided by the combined November through February period and the April through July period utilizing the monthly computed unimpaired flow for the Yuba River at Smartville, as computed by the California Department of Water Resources, for the 102-year period 1901 through 2002. The data was standardized with a centered five-year moving average smoother and is shown in Figure 6. Figure 6 reveals a positive upward drift in the November through February flows compared with the April through July snowmelt period.

Increased winter runoff is reflective of an increased proportion of precipitation falling as rainfall over the watershed during the November through February period. The record period used was 1901 through 2002 (102 years).

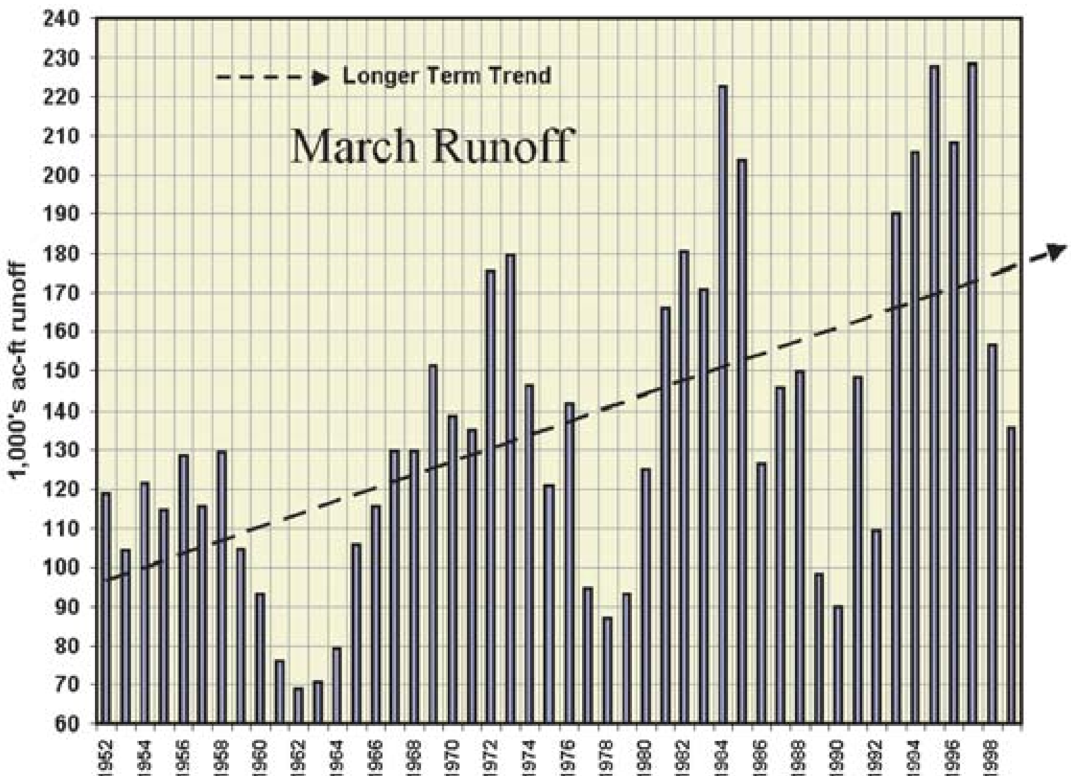


Figure 4 March unimpaired runoff for the east branch of the North Fork Feather River. Both a relatively short-term 14-16 year oscillation and longer-term trend toward increased March runoff in recent years appear on the chart. Centered 5-year moving average applied.

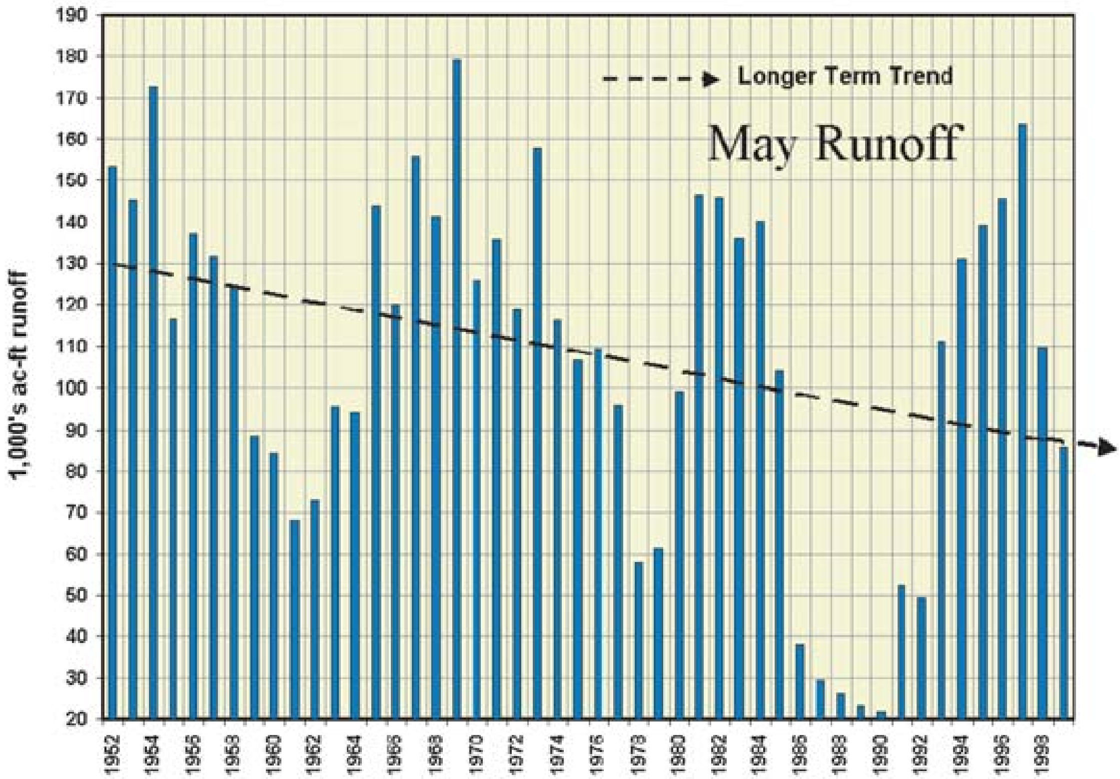


Figure 5 May unimpaired runoff for the east branch of the North Fork Feather River. Both relatively short-term 14-16 oscillation cycles and a longer-term trend toward decreased May runoff appear on the chart. Centered 5-year moving average applied.

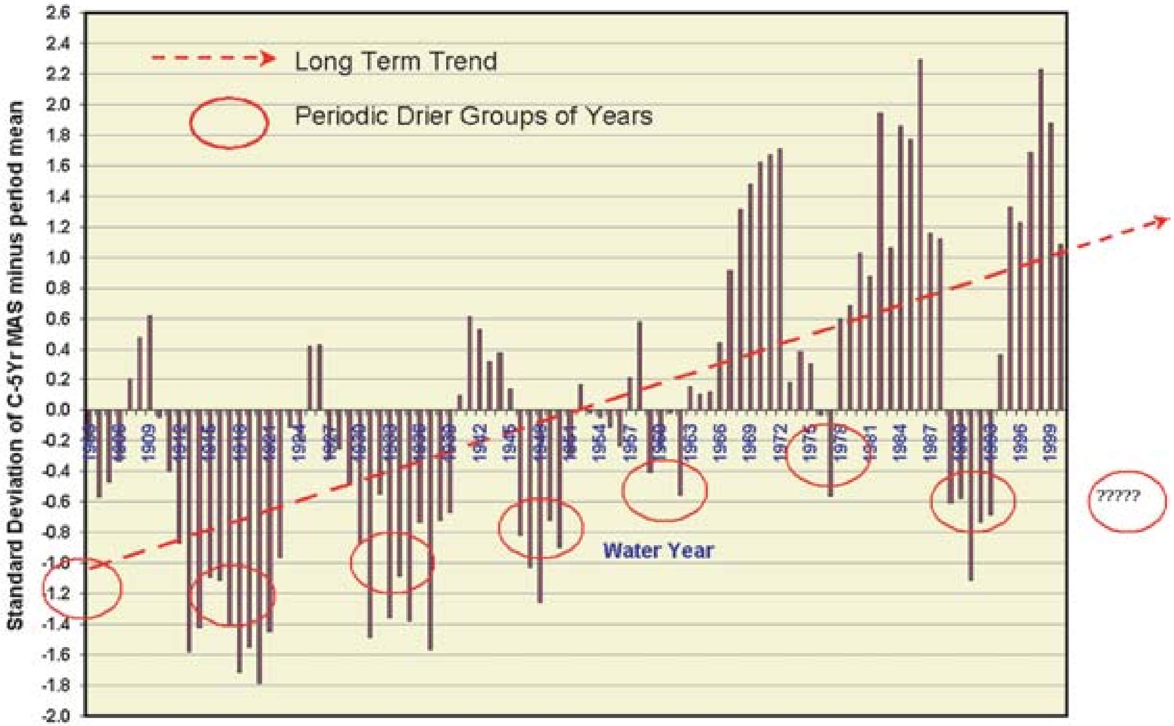


Figure 6 A drift in flow timing for the unimpaired runoff of the Yuba River at Smartville. Increased winter runoff in recent years appears reflective of an increased proportion of the annual precipitation falling as rainfall over the watershed during the November through February period. Record period used was 1901 through 2002 (102 years).

A continuous shift of the April through July runoff into the winter months November through February was observed from the data analyzed. With winter runoff in the Sierra largely produced from frontal type winter storms, the magnitude of winter runoff is mainly dependent upon quantity of winter rainfall produced runoff. If such is the case then it should revel itself when charted over the past 102 years. Figure 7 illustrates an increased frequency of large rain-produced runoff events in the second half of the 20th century compared with earlier years. This appears consistent with recent research findings, which forecast a shift in spring snowmelt runoff to increased rainfall produced winter runoff (Cayan and others 2001). Figure 8 displays the November through February averages for the two periods. There was a 17% increase in the period averages for November through February runoff.

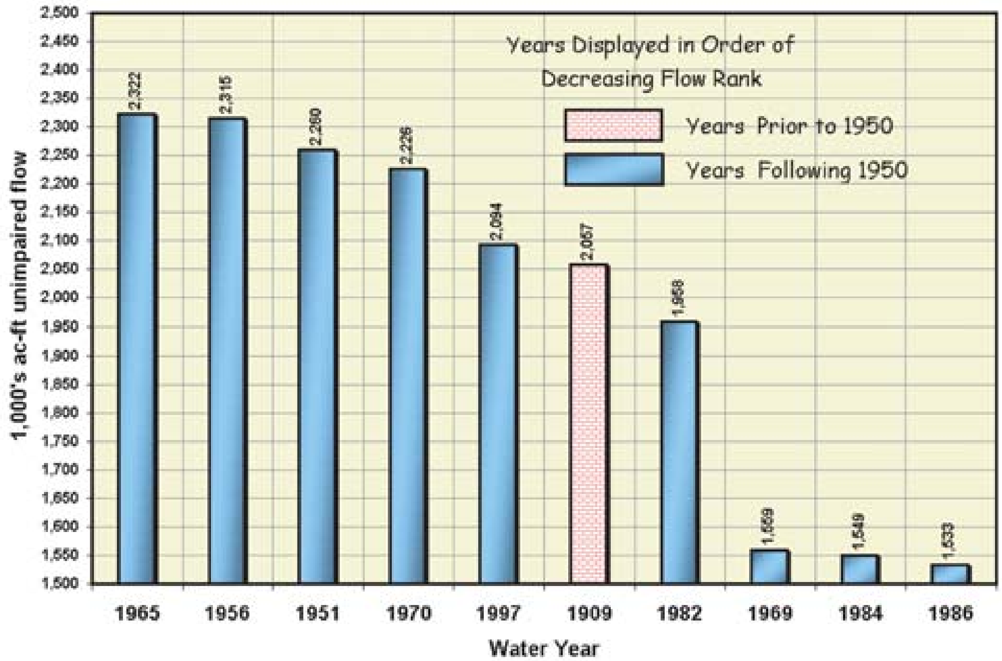


Figure 7 For the period 1901 through 2000, Yuba River at Smartville, only one year in the ten years of November through February unimpaired flows, which exceed 1,500,000 af, occurs prior to 1950. Recent years appear to have higher likelihood for more flow during the 4-month November through February winter period.

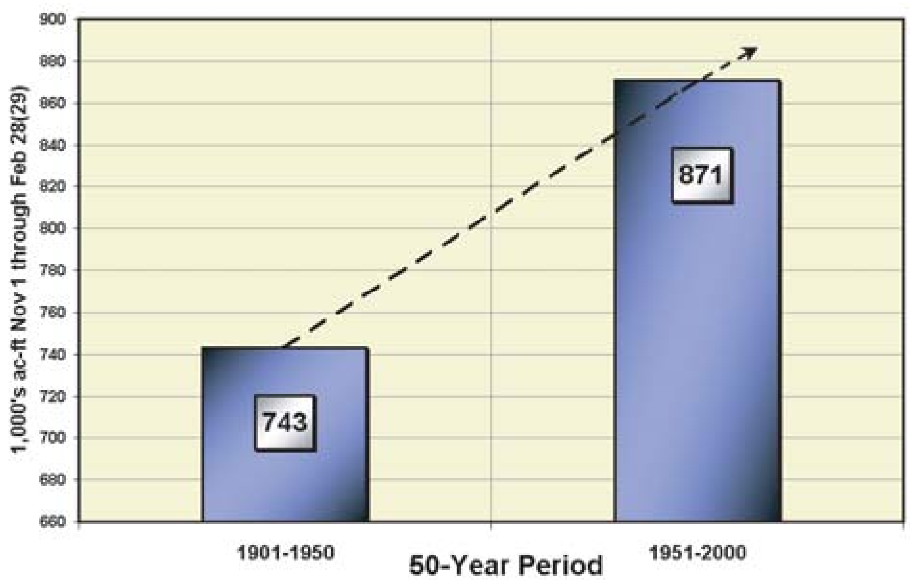


Figure 8 The mean flow of two successive November through February 50-year periods for the Yuba River at Smartville. There is a 17% increase in the more recent period.

The California Sierra Snowpack

California's snowpack likewise shows recurring patterns similar to that for both runoff and precipitation. A single snow course at Meadow Lake (#66) in the central Sierra at the 7,200 foot elevation readily revels relative consistency in regular recurring oscillation between wet and dry groups of years as shown in Figure 9. While no attempt is made here to explain a cause for the observed recurring multiyear oscillation, a significant amount of the seasonal snowpack variability may be explainable with indices of Pacific Ocean Climate such as PDO (McCabe and Cayan 2001).

In order to test that the centered five-year moving average produced pattern was not simply a moving average "produced-aberration", regularly spaced discrete groups of years were also charted to verify alternating wet/dry periods. This is displayed in Figure 10. The regularly occurring highs and lows are readily identifiable, but in some cases are relatively subtle and could possibly be easily overlooked unless one was specifically looking at the appropriate successive regularly occurring time blocks.

Seasonal snowpack is closely related to both precipitation amount and freezing levels for winter and spring storms. The author found that for moderate to high elevation snow courses in the central Sierra, the April 1 snow water equivalent exhibit oscillation patterns closely resembling those of both precipitation and runoff.

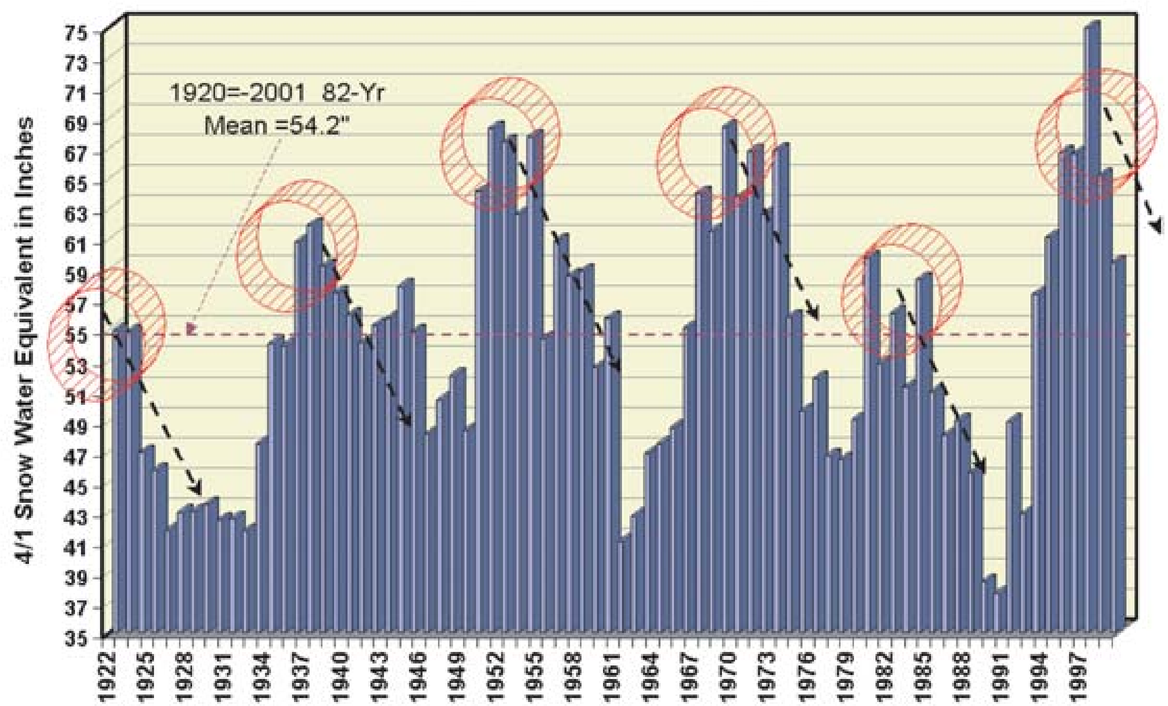


Figure 9 Meadow Lake snow course #66 in California's central Sierra Yuba River headwaters reveals a periodic oscillation in April 1 snow water equivalent (SWE) between periods of relative wetness and dryness. This snow course at the 7,200 foot elevation, unlike others at lower elevations, has not seen a reduction in snow water equivalent during the second half of the 20th century. Centered 5-year moving average applied.

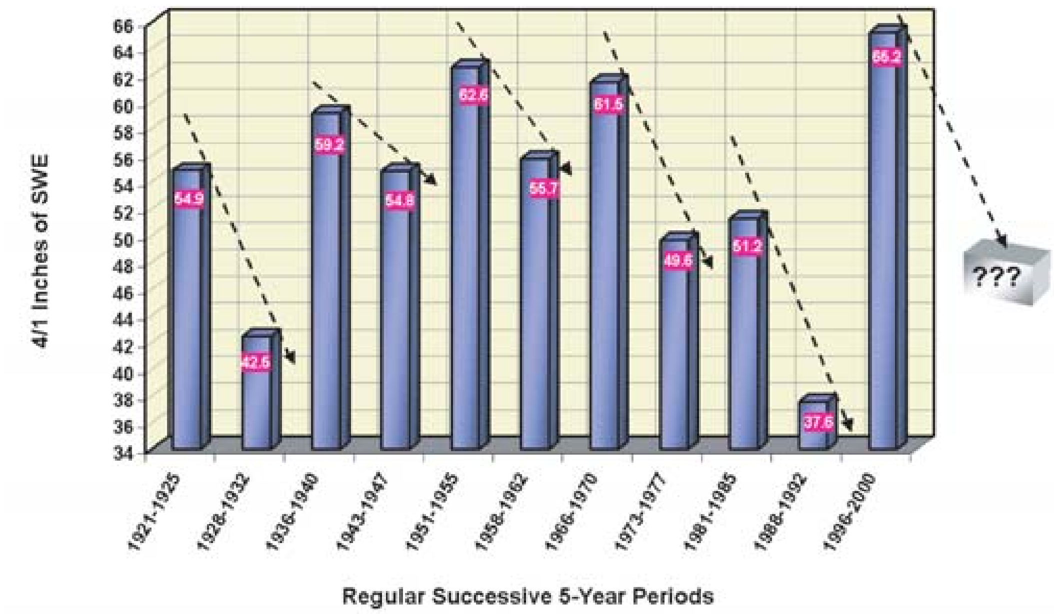
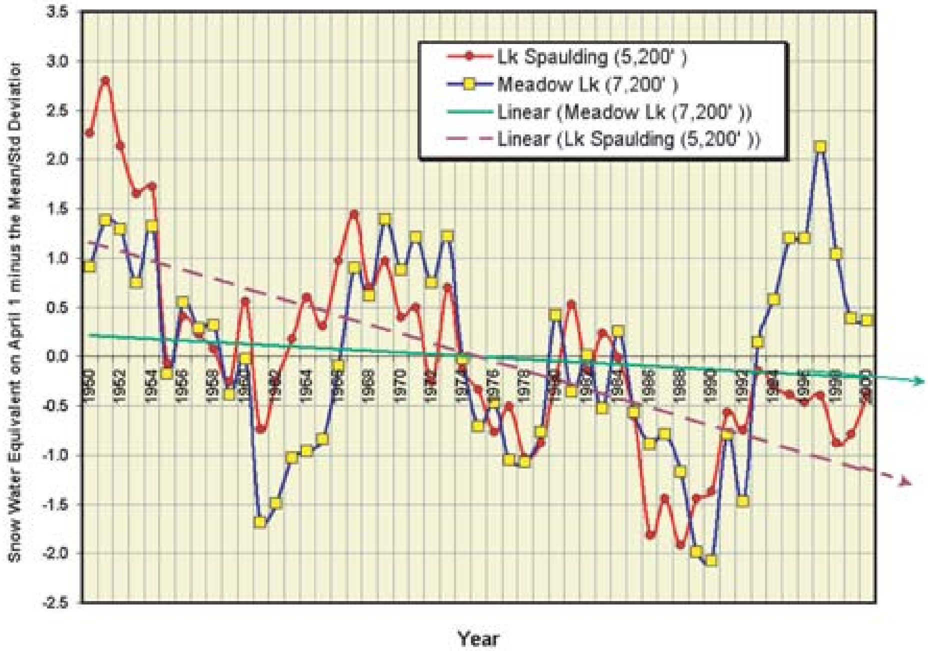


Figure 10 Meadow Lake #66 snow course — April 1 Snow Water Equivalent (*same original basic data set as used for Figure 10*). Discrete, successive 5-year groupings of regularly spaced years charted to show sometimes subtle, but regular, periods of wetness and dryness.

Comparison of the April 1 snow water equivalent for two snow courses on the south Yuba watershed for the period 1948 through 2002 — Lake Spaulding at the 5,200 foot elevation and Meadow Lake at the 7,200 foot elevation — reveals a downward trend for Lake Spaulding, the lower elevation snowpack (Figure 11). Meadow Lake, however, at the 2,000 foot higher elevation, approximately 10 miles northeast of Lake Spaulding, displays a near level trend line for the same 55-year period. The Lake Spaulding April 1 snow water equivalent is examined for a longer period (Figure 12). The April 1 snow water equivalent decreases from a mean of 24.4 inches for the 37-year period 1929 through 1965 to 19.8 inches for the 37-year period 1966 through 2002. This equates to a 19% drop in the mean for the more recent of the two periods (Figure 12). This long-term decreasing trend in low elevation snowpack and consequent decline in melt produced runoff appears consistent with that described elsewhere (Roos 1991).



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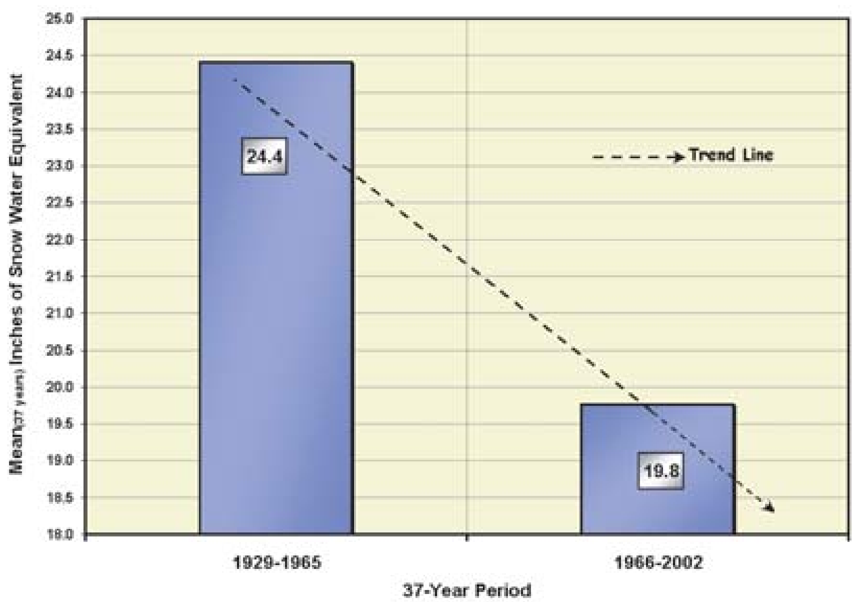

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1.7 TYPES OF DATA NEEDED TO IDENTIFY AND EVALUATE POTENTIAL IMPACT OF CLIMATE CHANGE ON PG&E'S HYDROPOWER OPERATIONS

Gary J. Freeman*
Pacific Gas and Electric Company

1. ABSTRACT

Pacific Gas and Electric Company (PG&E) forecasts and schedules seasonal runoff for it's 68 hydroelectric powerhouses (includes one pump storage facility) and an additional 19 powerhouses that belong to it's Partnership Irrigation Districts and Water Agencies. These powerhouses are located in California's Sierra Nevada and southern Cascade mountain ranges, which extend from the Kern River east of Bakersfield, north to the Pit River with headwater drainage just south of the Oregon border. A single PG&E powerhouse is located in the coast range east of Ukiah. Historically during the past 30 years, hydro generation has been derived from the following sources of runoff with an approximate averaged percentage of each source: 1) groundwater-38%, 2) snowpack-37%, and 3) rainfall-25% (Freeman, 2001). The PG&E hydroelectric system was mostly designed prior to the 1970's and built to accommodate a specific mix-ratio of rainfall- and snowmelt produced runoff with assumed 'design' timing and quantity of runoff along specific river reaches derived from the prior 'known' historical data period. The year-to-year variance was specific for that time series. Design and placement of seasonal storage reservoirs and diversion dams likely took elevation into consideration as it relates to precipitation type and timing of runoff. The anticipated proportion or ratio of rain and snowfall, as a factor that influenced runoff quantity and timing of inflow, was important for best determining reservoir size and location. However, a recent review of PG&E's water and climate data indicates that a change in runoff timing has taken place with a decrease in snowmelt-produced runoff during the past 50 years as compared with the first half of the 20th century. This change appears to be continuing in a trend-like manner toward decreasing runoff from snowmelt. The reduction in snowmelt runoff appears to be the result of a decreasing trend in the low elevation snowpack, with a corresponding increase in rain-produced runoff from the low elevation contributing drainage. The result is larger and more variable winter and early spring runoff with increased risk for reservoir filling from snowmelt alone. This paper will present some preliminary findings and discuss types of data needed, including data analysis that would be most useful to identify and further evaluate change in runoff timing and quantity. Some of the types of commonly collected hydrometeorological data and data calculations, which seem to best describe and track timing shift of unimpaired runoff for our hydroelectric system in California are: 1) aquifer outflow rates from northeastern California's volcanic drainages, 2) the winter and spring ratio of compiled subbasin unimpaired flows between diversion dams, including ratio variance, 3) the ratio of low to mid- elevation snowpack compared with high elevation snowpack, and 4) air temperatures. For all types of commonly collected hydrometeorological data, increased emphasis on improving data quality as it relates to the watershed in its entirety is needed. Improved data quality would likely lead to increased confidence in utilizing this data to identify climate change and to calculate possible impact on future hydroelectric generation production.

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2. INTRODUCTION

Hydroelectric scheduling and the runoff forecasting, which supports the process at PG&E is dependent on utilizing a historical climate and runoff time series that best represents and supports expectations for a given season's remaining weather uncertainty.

If the climate and runoff time series is not stationary, but instead its mean and variance changes significantly with time, then forecasters may need to identify and account for the change. In the case of runoff forecasting, a climate change is likely to also affect vegetative succession and possibly change evapotranspiration rate, with potential to further affect runoff over a period of time. The response of the watershed as a whole is increasingly complicated by climate change since it involves an overall water balance between vegetation transpiration, groundwater net transfer rates, infiltration capacity, interception losses, and other various type responses. Millar, et al (2001) for example has studied the effects of a changed snowline and melt timing in the Sierra on tree growth and invasion into formerly persistent snow-covered slopes. A change in forest vegetation type and distribution, as a result of climate change, may significantly change a basin's water balance with consequent runoff effect. In addition to long-term trend change in observed runoff, possible oscillation in wetness may also be taking place with grouped years in terms of relative wetness (Freeman, 2002).

Since seasonal runoff forecast schemes at PG&E continue to rely on utilizing a regression-based approach and a historic time series of climate and runoff variables, a review of possible effects on PG&E's hydroelectric system that included identifying data needs to identify and track climate change seemed appropriate. Others have performed similar type analysis on hydroelectric systems with regard to possible effects on hydroelectric systems in response to climate change. (Harrison, 1998, 2002).

3. THE CURRENT OBSERVED CLIMATE CHANGE SITUATION

Recent analysis at PG&E reveals that changes in the longer-term monthly distribution in mountain runoff for California's central and northern Sierra have occurred during the past century, most noticeably beginning about 1950 (Freeman, 2002). This agrees with findings of Cayan, et al, (2001). The effect appears likely to be the result of a change in precipitation form in response to warmer temperatures with a greater portion of the annual precipitation taking place in the form of rain. This seems to be a likely cause for the observed increase in rainfall-generated runoff during the November through March period and a consequent declining proportion of runoff from snowmelt during the April through July period (Snyder, et al, 2001;Roos, 1991). Figures 1 and 2 shows these unimpaired runoff trends for the central Sierra's Yuba River @ Smartville. A possible contributor to the observed shift in runoff timing may be an increased frequency of warmer temperatures, which possibly accompany winter storm fronts, with a consequent decrease in snow accumulation in the low elevation snow zone as illustrated with Figures 3 and 4. An increased proportion of winter precipitation in the form of rainfall seems a likely cause for the observed increase in runoff during the November through February Period since about 1950.

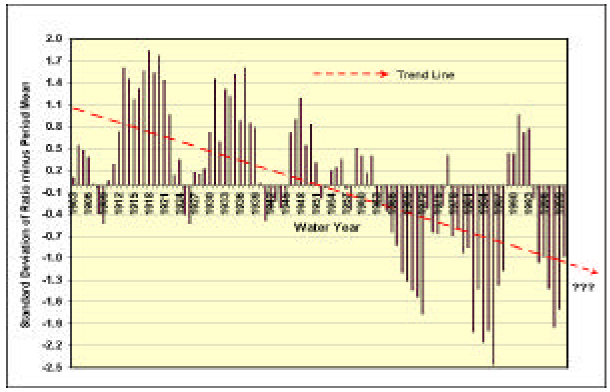

Figure 1. A declining trend in flow for the unimpaired April through July runoff of the Yuba River @ Smartville. Centered 5-yr moving average applied to the 1900-2002 data. Ratio of April through July period divided by sum of same period plus the November through February period.

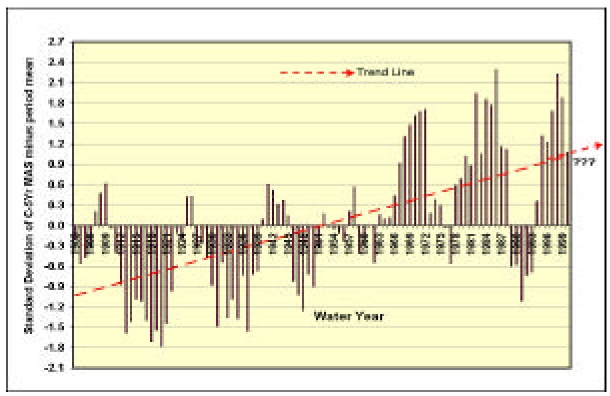

Figure 2. An increasing trend in flow for the unimpaired November through February runoff of the Yuba River @ Smartville. Centered 5-yr moving average applied to the 1900-2002 data. Ratio of November though February subtotal divided by sum of same period plus the April through July period.

4. POTENTIAL IMPACT ON PG&E's HYDROELECTRIC PRODUCTION

At this time PG&E's water management team has not observed any significant change in hydroelectric production that can be directly attributed to global warming or climate change. A review of current trends indicates that no significant generation impact is anticipated for the near future. Preliminary findings reveal that each of the watersheds, where PG&E hydroelectric projects are located, and the elevation bands within those basins react slightly different to climate change as observed to date. While the hydroelectric system was optimally designed with historical climate data, mostly prior to the mid-1960's, the system was designed to operate for large wetness variance, which included single year, weekly, and daily storage cycles type operation for 98 of its 99 reservoirs.

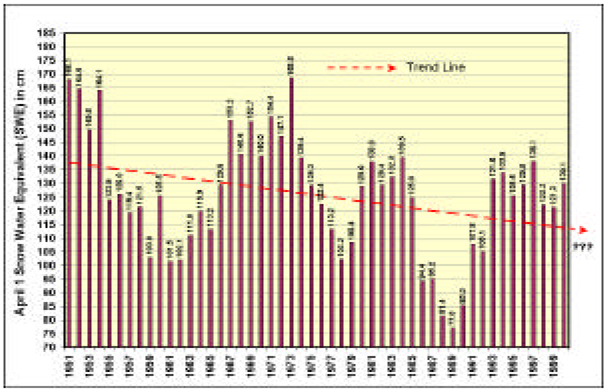

Figure 3. Letterbox snow course #49 (Elevation 1,707m) April 1 snow water equivalent (SWE). North Fork Feather River headwaters near Bucks Lake. Centered 5-Yr moving average smoother applied.

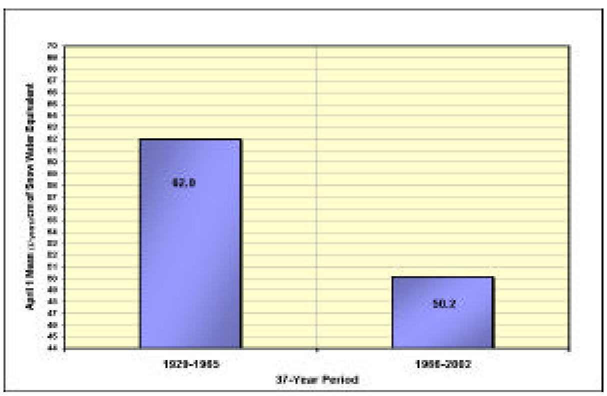

Figure 4. Lake Spaulding snow course #85 (Elevation 1,609m) - Yuba River headwaters in California's central Sierra near Highway 80. The April 1 snow water equivalent (SWE) means for two successive 37-year periods.

There is a single multi-year reservoir, Lake Almanor, located on the Feather River. Lake Almanor with $1{,}409.3 \times 10^6\ m^3$ storage capacity has approximately ten times the storage capacity compared with PG&E's next largest storage reservoir. The year-to-year annual- and monthly flow variance for the North Fork Feather River, in terms of flow quantity, greatly exceeds the anticipated effect of a shift of runoff from the spring snowmelt period into the November through February precipitation period or an earlier snowmelt starting in March rather than April. There is a long-term variance shift in runoff timing and quantity, but for the most part it does not exceed the expected short time-step variance that may exist for or within a given year. In addition, most of PG&E's reservoirs are located at relatively mid-to high elevations, which are mostly above the current influence of possible recent warming on snowpack accumulation.

PG&E's two most northern systems, the Pit-McCloud and North Fork Feather River Projects comprise approximately 55% of PG&E's average-year hydroelectric generation. A large area of low elevation headwater terrain characterizes these two northern California watersheds. For these two northern California drainages, a relatively large portion of the total watershed area would be affected from a slight elevation shift in freezing level. Watersheds further south with relatively higher elevation drainage would likely be less affected from climate change, which includes warming. The Pit-McCloud Rivers, which overlay volcanic flows have a substantial portion of the annual flow attributable to aquifer outflow from springs consisting primarily of prior year's precipitation, a portion of which may extend back in time several years.(Manga, 1999). With baseflow being a prime driver of flow timing and quantity for the Pit-McCloud Rivers, hydro operations for that system are less likely to be greatly affected from a shifting precipitation pattern compared with other low lying basins such as the North Fork Feather River, which has significantly less volcanic drainage. With nearly 90 percent of the north Fork Feather River Basin at or under 1,829 meters elevation, it can be expected that spills past diversion dams, especially along the lower elevation reaches of that river, from uncontrolled sidewater during the winter wet season, may possibly increase in frequency and quantity in the future if climate change continues with increased warming.

Since approximately 2/3 of the water year runoff from the North Fork Feather River is from uncontrolled sidewater which overlay non-volcanic drainage, the potential for an increase in winter rainfall-produced-runoff as a cause for more frequent spills from increased rainfall on the low elevation snow-zone seems likely. At this time No detailed type studies have been made at PG&E to determine the potential generation impact from long-term ongoing continuation of climate change. Operational response to future climate change would most likely first take place in probabilistic decision-making during the mid-November through March period, a time when most precipitation normally occurs each year. Probabilistic hydro scheduling based on remaining weather uncertainty would likely assume a gradual change over a period of years in probabilistic tradeoffs for deciding storage and release of water from reservoirs (Freeman, 1997). PG&E's seasonal runoff forecasting methodology utilizes a disaggregation routine as described by Grygier, et al, (1993) to subdivide the seasonal runoff forecast into monthly flows. If the historical monthly distribution of runoff has changed with time, then for the regression routine to work as originally intended, the routine should likely utilize a relatively recent, possibly weighted time series of monthly data, with heavier weighting for recent years.

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5. TYPES OF DATA BEING UTILIZED AT PG&E TO DESCRIBE AND TRACK THE RUNOFF TIMING SHIFT

5.1 RUNOFF

An early focus at PG&E was to track aquifer outflow rates on the Pit-McCloud Rivers in northern California. About 38 percent of PG&E's annual hydrogeneration is from aquifer outflow, a large portion that is from precipitation of past years. The springs, which contribute to flows in the McCloud and Pit Rivers are some of the world's largest, provide a natural lag of past climate revealing the effect of long-term pressure changes in the aquifer from net recharge and discharge. Trend over time can be revealed as well as a shorter-term subtle oscillation effect of grouped year variance (Freeman, 2001). Other analysis of runoff, precipitation, and snowpack trends and cycles (Freeman, 2002) revealed both long term trending and a shorter somewhat subtle 14-16 year wetness oscillation. The shift of runoff monthly runoff averages into the winter months during the last half of the 20th century posed the most concern as it may have possible potential to affect the hydroelectric scheduling value optimization process.

5.2 SNOWPACK

An analysis of the April 1 Snow water equivalent for the Lake Spaulding snow course in the central Sierra at the 1,609 meter elevation shows a significant decrease during the second half of the 20th century. This decrease in the April 1 SWE mean represents a 19-percent drop from the earlier period. No significant decline was observed to have occurred in a nearby snow course at Meadow Lake, which is 610 meters higher in elevation. The decline in low elevation snow in recent years may be indicative of a higher snowfall line with winter storm systems.

Likewise the Letterbox snow course #49 on the North Fork Feather River at the 1,707 meter elevation likewise reveals a significant decline in April 1 snow water equivalent during the past 50 years.

6. DATA QUALITY - ITS IMPORTANCE FOR TRACKING AND RESPONDING TO CLIMATE CHANGE.

Among the types of data which would likely be most indicative of accurately defining trends in climate change are compiled subbasin unimpaired natural flows from successive reaches of increasing drainage elevation or in other words the subbasin reaches between existing diversion dams as one moves upstream along the river. While the unimpaired flows for the entire river can be compiled reasonably accurately immediately below the large multipurpose reservoirs such as at Shasta, Oroville, Melones, Bullards Bar/Englebright, Millerton, and Pine Flat, it is much more difficult to provide accurate definition of upper subbasin reaches moving upstream in the watershed (Freeman, 1995).

PG&E computes daily and in some cases hourly subbasin reach flows for nearly 80 reaches in the Sierra as part of it's normal forecasting and hydro scheduling process. However, the calculation of reasonably accurate subbasin unimpaired flows for the lower reaches of the rivers, which have hydroelectric projects remains a challenge. The problem is primarily one of cumulative error uncertainty and the existing standards of how gaging flows are currently evaluated for revision.. Currently stream gaging is rated as excellent or good based on the "stand-alone" station record. Powerhouses remain for the most part un-reviewed by the US Geological Survey. However, accurate powerhouse flows synchronized in a manner that one powerhouse is aligned in terms of error uncertainty with an adjacent powerhouses is one of the largest obstacles in currently compiling reasonably accurate subbasin unimpaired sidewater flows between upstream diversion dams (Freeman, 1999). In order to compute a subbasin unimpaired flow between diversion dams, one generally needs a combination of: change in storage at the intervening pondage(s) (forebay or afterbay), 2 powerhouses, 2 diversion dam spills, 2 leakage and instream flows, and occasionally an import or export gage if water is entering or leaving the reach to or from elsewhere. At the minimum, there may be 5 gages within the calculation, but normally 7, and sometimes more measuring points are required for the computation of subbasin unimpaired inflow. The two Powerhouses and spills, when they occur, from the two diversion dams represent the largest sources of unaligned error uncertainty and noise in attempting to define intervening subbasin flow contribution. It is important that the time in which the readings are read is consistent and if there is significant time of travel between diversion dams, it is important to account for travel time accordingly.

A needed approach to identify and track the rate of flow regimen change with elevation requires that the current "stand-alone" gage station data quality review be expanded to include error alignment procedures with adjacent gages. All of the gages within a reach that have water flowing into and water leaving as well as the all successive reaches on a river must have error uncertainty alignment to successfully identify and track timing and quantity changes of flow contribution by elevation zone. Powerhouse flows require accurate flow monitoring on the individual units and accurate measuring of spills are needed at many locations. Currently the level of monitoring described above and data review which always includes adjacent gages is not a required standard and does not exist for nearly all dammed reaches of California's mountain rivers upstream of the large multi-purpose federal flood control facilities which are mostly located in or near the foothills rising from the Central Valley floor. Stream gages and Powerhouse flows define the total flow response between elevation bands from climate change including changing evapotranspiration demand with vegetation succession and response to climate change. Currently the flow measurement process for stream gages and powerhouses along the lower reaches of many Sierra Rivers, including the Pit and McCloud Rivers is inadequate for accurately compiling subbasin unimpaired flows between diversion dams. This current process of water data collection and review limits accurately determining the effect of successive reach increments of flow, and limits accurately tracking runoff changes by elevation band.

7. MONITORING SNOWPACK AND AIR TEMPERATURE DURING STORM EVENTS

There is currently a lack of relatively high elevation snow sensors in northern California. This part of California which transitions from the Sierra into the southern Cascades in the vicinity of Lake Almanor is characterized by much lower elevation headwater drainage than occurs further south in the central and southern Sierra. These northern California watersheds, particularly the Feather River drainage are likely to be the most impacted from snowpack declines in the low elevation snow zone. PG&E in cooperation with the National Park Service and the California Department of Water Resources are currently exploring the feasibility for installing a cosmic gamma snow sensor with temperature and solar radiation monitor at Helen Lake (2,499 meters elevation) to reference winter snow accumulation. With a unique pattern of orographic effects, Helen Lake on the south side of Mount Lassen has a reputation for being one of the deepest monitored snowpacks in California. It is hoped that if installed, the additional instrumentation and monitoring at this site, will provide a relatively well instrumented high elevation northern California reference benchmark for evaluating snow zone change in the Feather River, Cow-Battle Creeks, and Hat Creek drainages. In the central and southern Sierra, limited snow sensor monitoring in the high elevation headwater drainages, already exists..

8. CLIMATE STATIONS

In years prior to the changeover of high elevation, manually read climate stations that were utilized to gather precipitation and air temperature data to remote automated, non-visited stations, station data was cooperatively shared with the National Weather Service (NWS). An NWS cooperator visited the stations daily and standards for data collection in terms of both equipment and data collection quality were for the most part assured with regularly scheduled visits by the NWS station network specialists. Today that situation is changed with the removal of most lake tenders and powerhouse personnel from many of PG&E's mountain climate station sites. Automation and the ease of satellite telemetry have changed how climate data is collected at many mountain station sites. This change in methodology has contributed to additional uncertainty as to what is believable in terms of having significance for identifying and tracking climate change.

9. CONCLUSIONS

PG&E's water management team is aware that climate change is occurring and is planning for how to best work with runoff change in terms of best hydroelectric scheduling practice.

PG&E's hydroelectric system with its many relatively small reservoirs was designed during an era with less winter runoff and more spring and early summer snowmelt runoff. With about 55 percent of it's average annual hydroelectric production coming from the relatively low elevation drainage of the Pit and Feather Rivers hydroelectric systems, there is a need to understand how anticipated change in runoff timing will affect overall hydroelectric energy production. For the Feather River, it will likely increase winter high water events, both in frequency and magnitude with possible increased frequency of diversion dam spill and shut-down of hydroelectric facilities during high water to avoid damage. Sedimentation of powerhouse forebays is likely to occur at an increased rate compared with the past. At this time there is not a good understanding as to how aquifer outflow rates such as those, which contribute to the Pit and McCloud Rivers and to Lake Almanor, may be impacted by a rising snowline. Precipitation in the form of increased rainfall rather than snowfall may possibly affect overall infiltration capacity on the volcanics. Types of data needed to best monitor and track this change require improved methods of data quality collection and analysis. For flows, it will likely require moving beyond the current stand-alone station type analysis and possibly improvement in measurement of powerhouse flows. Data from multiple flow and storage gages needs to be analyzed as a group rather than as stand-alone stations to align water data in terms of error uncertainty such that while some error is unavoidable, the unimpaired flows of subbasin reaches can be reasonably defined for elevation bands within the watershed. Improvements in terms of standardizing the continuously increasing number of automated mountain climate station seems needed, and possibly locating additional snow sensors at some key locations would be helpful in defining relative change for specific locals in northern California.

At this time PG&E's water management team has not observed any significant change in hydroelectric production that can be directly attributed to global warming or climate change.

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