BEFORE THE PUBLIC UTILITY COMMISSION OF OREGON

In the Matter of the Request of	)	
	)	
PACIFIC POWER & LIGHT	)	
(dba PACIFICORP	)	UE-170
	)	
For a General Rate Increase in the	)	
Company's Oregon Annual Revenues	)	
(Klamath Rate Case Portion of this Proceeding	)	

Rebuttal Testimony of

Balance Hydrologics, Inc.

on behalf of

Oregon Natural Resources Council, Pacific Coast Federation of Fishermen's Associations, and WaterWatch of Oregon

February 6, 2006

Q: **PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.**
A: My name is Barry Hecht. My business address is Balance Hydrologics, Inc., 841 Folger Avenue, Berkeley, CA 94710.

Q: **WHAT IS YOUR OCCUPATION AND BY WHOM ARE YOU EMPLOYED?**
A: I am a Principal Hydrologist and Geologist and am currently employed by Balance Hydrologics, Inc., as a consulting Hydrologist.

Q: **WOULD YOU PLEASE STATE YOUR EDUCATIONAL BACKGROUND AND EXPERIENCE?**
A: I have a B.S. in Earth Sciences and a B.A. in Geography and Regional Planning from the University of California, Santa Cruz, 1970x and an M.A in Physical Geography, University of California, Berkeley, 1972. I have had diverse professional experience in watershed investigation, hydrogeology, and environmental analysis addressing a wide variety of water-, water-quality and sediment-related issues throughout the western states and currently design and implement multifaceted hydrological investigations. I was the Team Leader for this investigation. My resume is attached as Exhibit ONRC et al./201.

Q: **DO YOU HOLD PROFESSIONAL REGISTRATION IN OREGON?**
Yes. Since 1991, I have held registration as a geologist (G1262) and as a certified engineering geologist (E1262), issued by the State of Oregon, Board of Geologist Examiners.

Q: **WERE YOU ASSISTED IN THIS INVESTIGATION AND REPORT BY OTHERS?**
A: Yes. This analysis was a team effort and I was assisted in this analysis by Bonnie J. Mallory, Hydrologist/Geochemist for Balance Hydrologics, Inc., and by Stacey A. Porter, Geomorphologist/Hydrologist for Balance Hydrologics, Inc. Their

resumes are enclosed as Exhibit ONRC et al./202 and Exhibit ONRC, et al./203, respectively.

Q: **ON WHOSE BEHALF ARE YOU TESTIFYING IN THIS PROCEEDING?**

A: I am testifying on behalf of Pacific Coast Federation of Fishermen's Associations, Oregon Natural Resource Council and WaterWatch of Oregon in this proceeding.

Q: **WHAT IS THE PURPOSE OF YOUR TESTIMONY?**

A: We were asked to review the technical merit of selected testimonies given before the Public Utility Commission of Oregon related to the request for a general rate increase from Pacific Power & Light (Docket No. UE 170). Our review has focused on the assumptions and methodologies used to arrive at the conclusions in the testimonies of Edward Bartell and Louis T. Rozaklis (on behalf of the Klamath Off-Project Water Users, Inc.). We also question some of the methods presented in the testimony of Marc Van Camp (on behalf of the Klamath Water Users Association) which was used in energy value calculations by Donald W. Schoenbeck (on behalf of the Klamath Water Users Association).

Q: **WOULD YOU PLEASE SUMMARIZE YOUR FINDINGS AND CONCLUSIONS?**

A: We found that both the testimony of Edward Bartell and Louis T. Rozaklis and were flawed as well as incomplete, and based on assumptions and methodologies that were not well supported or which inaccurately described real conditions.

Mr. Bartell overemphasizes water 'added' by agriculture, but does not recognize water diverted from Upper Klamath Lake to Yonna and Swan Valleys ("Pine Flat") and other de-facto off-Project areas. He claims return flows from the Lost River system as beneficial because they are 'avoided losses,' but does not acknowledge the substantial diversions for summer irrigation from the Klamath watershed to the Lost River watershed by the Klamath Project. He also attributes gains related to non-agricultural uses (such as the Lower Klamath Lake railroad dike) and does not seem to recognize that summer water is more valuable.

Mr. Rozaklis made assumptions leading to calculations on purported "additions to water flows" to Upper Klamath Lake or to Keno that also lead to flow figures that are far too high. He creates a distinction between the shallow and deeper aquifers that makes little difference in terms of the effects of using wells for water supply. It is the deep aquifer that drives the surface-water system of the Klamath Basin, and that always has done so. It makes little sense to act as if withdrawals from the deep aquifer do not diminish surface flows. He relied on currently contested evapotranspiration figures for marshlands and wetlands that were too high. He also did not account for transit losses in his water balance, and presented an unreasonable pre-development condition.

Mr. Van Camp uses a paper water-right basis of computation, which does not evaluate actual streamflows and is not compatible with other analyses. He also claims water added by transportation, urban, timber-management, and other uses as attributable to agricultural users, and does not recognize that additions through the Lost River Diversion may not be attributable to agriculture.

Since Mr. Schoenbeck used Mr. Van Camp's values without adjustment or qualification in his own calculations, his calculations also greatly over-estimate supposed power production benefits from the purported additional flows.

As seen from our own analysis, on a month-by-month basis those purported power production benefits either do not exist or are considerably less valuable than the testimony of Mr. Rozaklis, Mr. Van Camp and Mr. Schoenbeck would indicate.

We have enclosed our full written report on this analysis as Exhibit ONRC et al./204. Appended to our report is the most recent assessment of the state of wetland-plant evapotranspiration estimates developed by Prof. Robert A Gearhart, a collaborator of ours in other Klamath Basin work, and upon which we drew in part in our testimony. In addition, we relied to some degree in that analysis on a prior Balance Hydrologics report, Hecht, B., and Kamman, G., 1996. *Initial assessment of pre- and post-Klamath Project hydrology on the Klamath River and impacts of the project on instream flows and fishery habitat.* This report is also enclosed as Exhibit ONRC et al./205.

Q: DOES THIS CONCLUDE YOUR TESTIMONY?

A: Yes.

Balance Hydrologics, Inc.

BARRY HECHT
Principal Hydrologist/Geologist

Education

PhD Cand.	Geography, University of California, Berkeley, 1975
M.A.	Geography, University of California, Berkeley, 1972
B.S.	Geology (Honors), University of California, Santa Cruz, 1970
A.B.	Geography and Regional Planning (Honors), University of California, Santa Cruz, 1970

Registrations and Certifications

Registered Geologist: California (3664), Alaska (232), Oregon (1262)
Certified Engineering Geologist: (1245) California, Oregon (E1262)
Certified Hydrogeologist: California (50)
Registered Environmental Assessor: California (22)
Certified Ground Water Professional (235), National Ground Water Well Association
Certified Professional Geologist (7786), American Institute of Professional Geologists

Summary of Experience

Mr. Hecht has directed geologically-oriented investigations of complex hydrologic, water quality, and sediment issues for more than 30 years, in both surface and ground water systems.

Experience

1988-Present — Principal, Balance Hydrologics, Inc.

Directs and conducts investigations of geology geomorphology, ground water, water quality, sedimentation and sediment quality. Principal areas of activity are habitat hydrology, aquifer recharge and other surface/ground water interaction, channel stability, and effects of land-use practices on surface and shallow ground waters. Responsible for overall technical direction and integration of the firm.

1982-1988 — Chief Hydrologist and Geologist, Kleinfelder

Responsible for investigations of hydrologic, hydrogeologic and geologic investigations, firm-wide. Directed studies of sediment transport and water quality conditions as they affected streams and wetland habitats for federal, state and local agencies. Supervised studies and analyses of ground water movement or quality at both the site and regional scale. Directly managed firm-wide alluvial hydrology program, providing integrated analysis of surface and ground waters in alluvial systems. Led firm's pesticide mitigation group, including managing remedial investigations at a pesticide-formulator Superfund site, plus major leachability studies at golf courses, cut flowers and row crop sites.

1977-1982	Principal Hydrologist, H. Esmaili & Associates
	Responsible for hydrologic, geomorphic and geologic investigations at HEA. Directed sediment transport and water quality monitoring programs in many western states. Established a sedimentologic laboratory. Directed multi-disciplinary groundwater investigations in several areas of California, Oregon and Idaho; led radionuclide and hazardous waste migration studies. HEA merged into Kleinfelder, August 1982.
1973-1977	Doctoral studies at U. C. Berkeley. Woodrow Wilson Fellow, and U.C. Santa Cruz. Lecturer in Environmental Studies and Director of student field program.
	Primary research in hydrology and geomorphology. Served as scientific assistant at the USGS Bedload Research Project near Pinedale, WY. Worked with USFS personnel at Idaho Panhandle National Forest in field surveys of channel geometry and sediment transport rates. Taught courses in hydrology, field methods, geomorphology, and watershed management. Field instruction programs were carried out for 150 students with three-member staff team. Led resource-planning team for Ahtna, Inc., Copper Center, AK.
1968-1972	Santa Cruz County Planning Department, California. Assistant Planner.
	Compiled geologic and hydrologic data, coordinated aquifer management, drafted quarry ordinance and chaired County's Watershed Committee.

Other Long-Term Professional Activities

2001- present	Lead hydrologist, California Tiger Salamander Recovery Team (USFWS)
2000- present	Technical Evaluation Committee Member, CalFed
1998- present	Co-Principal Investigator: Vernal pools of Southern California (EPA grant)
1973- present	Instructor, University of California Extension (intermittent)
1983- present	Instructor, San Francisco State University Extension (intermittent)
1982- 1992	Member, Upper Sacramento River Salmon and Steelhead Advisory Committee
1972- 1975	Member, also Chairman, Santa Cruz County Watershed Committee

Professional Affiliations
American Geophysical Union
American Water Resources Association
Association of State Floodplain Managers
Association of Ground Water Scientists and Engineers
Groundwater Resources Association of California
Society of Wetland Scientists
American Society of Agricultural Engineers
Association of Environmental Professionals
California Watershed Management Council
Northern California Geological Society

Expert Testimony
EPA Administrative Law Hearings
USDA Forest Service
California State Water Resources Control Board
California, Coastal Commission
City of Santa Barbara
Joint Federal/State Land Use Planning Commission (Alaska)
State of Alaska, Department of Natural Resources
Marin Municipal Water District
Montecito Water District
Cenaliulriit (Southwest Alaska Coastal Zone Management District)
Yurok Tribe of Northern California
Santa Maria Ground Water Basin Adjudication
Civil Litigation (Miscellaneous)

Publications

“Strategies addressing hydromodification of channels within highly-erosive or unstable terrain.” Geol. Soc. Am. Cordilleran Section Annual Meeting, May 2005. (with J. Gartner, S. Chartrand, E. Ballman

“Sequential changes in physical conditions affecting aquatic habitat in the upper Carmel River, California, following the Marble-Cone Fire of August 1977.” Proceedings of the California Riparian Symposium, September 1981. University of California Press. pp. 134-142.

“Deformation along a postulated branch of the Hayward Fault, Berkeley: Faulting or landsliding?” Proceedings of the Conference on Earthquake Hazards in the Eastern San Francisco Bay Area. California Division of Mines and Geology Special Publication No. 62, March 1982. pp. 217-226 (with D. Hoexter, C. Levine, and G. Collier).

“Appropriate uses of sediment source tracing in habitat assessments of mountain streams.” Proceedings of the American Fishery Society's Assessment of Impacts of Hydropower Development Conference, May 1985. Denver, CO. pp. 416-422.

“Cumulative contribution of roadbed erosion to spawning gravel abundance in a mountain stream.” Proceedings of the California Watershed Management Conference, November 1986. Sacramento, CA. p. 154.

“Effects of riparian woodland on flood conveyance: Case of the Pajaro River." Proceedings of the California Watershed Management Conference, November 1986. Sacramento, CA. pp. 165-166 (with M. Woyshner).

“Recovery of aquatic habitat values following a catastrophic flood.” Proceedings of the Eighteenth Geomorphology Symposium, 1986. Oxford, OH (with M. Woyshner).

“Sedimentology and recharge of a Sierran glacial valley aquifer.” Proceedings of the International Mountain Watershed Symposium, June 1988. Lake Tahoe, CA. pp. 78-84 (with G. Jett.)

“Streamflow, nitrate, and sediment budgets for Squaw Valley, California” Proceedings of the International Mountain Watershed Symposium, June 1988. Lake Tahoe, CA. pp. 152-178 (with M. Woyshner).

“Vernal pool relationships in the Eastern Central Valley, California.” Proceedings of the Chico Vernal Pool Conference, American Association for the Advancement of Science and the Botanical Society of America, July 1989. Chico, CA. CSU Chico, Studies from the Herbarium No. 8, pp. 49-60 (with W.T. Hanes, L.P. Stromberg).

“Natural restoration of normal bed conditions for steelhead spawning and rearing after a major storm: Corralitos and Brown Creeks, Santa Cruz County, California.” Proceedings of the Ninth Annual California Salmon, Steelhead and Trout Restoration Conference, February, 22-24, 1991. Santa Cruz, CA. pp. 24-26 (with M. Woyshner).

“Diversity as opportunity: Bed-habitat conditions in pools and riffles downstream from channel confluences.” Proceedings of the American Fisheries Society 26th Annual Conference, February 7-9, 1991. South San Francisco, CA. pp. 20-22.

“Response of riparian-zone shallow ground water to water-level changes in streams tributary to Mono Lake” Program with Abstracts, History of Water Symposium, University of California White Mountain Research Center, September 1991. Bishop, CA. pp. 34-35 (with A. Finnerty, I. Flaschka, M. Napolitano).

"Sediment quality of tailings ponds - considerations for reclamation planning." Proceedings of the Ninth Annual Dredging and Placer Mining Conference. Reno, NV. May 18-20, 1992, 19 pp.

"Creep and downslope movements in the Hayward fault zone in North Berkeley: Ten years later." Proceedings of the 1992 Conference on Earthquake Hazard, Eastern San Francisco Bay Area, California Division of Mines and Geology Special Report 113, pp. 121-129 (with D.F. Hoexter, K. Knudsen, D.M. Laduzinsky and G. Fiedler).

"South of the spotted owl — Restoration strategies for episodic channels and riparian corridors in central California." Proceedings of the Society of Wetlands Scientists, Western Wetlands Conference, March 25-27, 1993. Davis, CA. pp. 104-117.

"Area-wide wastewater management for the San Lorenzo River watershed, California." Proceedings of the Seventh National Symposium on Individual and Small Community Sewage Systems. American Society of Agricultural Engineers, Dec. 11-12, 1994. Atlanta, GA. 10 pp. (with J. Ricker, N. Hantzsche, and H. Kolb).

"Approaches to in-situ calculation of floodplain roughness." Proceedings of the Association of State Floodplain Managers 20th Annual Conference, June 10-14,1996. San Diego, CA. p. 142-148 (with J. Owens).

"Potential effectiveness of shallow leachfields in reducing nitrogen loadings to ground and surface waters from deep trench leachfield in areas of sandy soils." Presentation to the California Environmental Health Association, 1996 Annual Convention. Oakland, CA (with C. White, J. Ricker, and P. Gill).

"Sources of nitrogen at low flow in the San Lorenzo River, California, and costs of alternatives for its control." In prep for submittal to *Ground Water* (with C. White and J. Ricker).

"Episodic sedimentation as a model for geomorphic effects of dam removal in Central and Southern California." Proceedings of "Modeling Dam Removal: Tools for Decision Makers." San Francisco State University and Bay Delta Modeling Forum Workshop. Sacramento, California, June 30, 1999 (in press)

"Guidelines for evaluating dam removal or modification to improve fish habitat": Presentation to the 1999 American Fisheries Society Annual Meeting, Charlotte, North Carolina, September 1. 1999 (with Michael McGowan, Robert Abbott and Bruce Lord)

"Drought, fire and geology: Key watershed influences in Northern Santa Lucia Mountains." Proceeding of the Peninsula Geological Society Spring Field Trip 2000: Salinia/Naciamiento Amalgamated Terrance Big Sur Coast, Central California.

"Baseline hydrologic geomorphic assessments as tools for watershed and floodplain management" Proceedings of the Floodplain Management Association, 22nd semi-annual Spring Conference." (with E. Stein and K. Schwarz)

"Developing an assessment method to address impacts from urbanization on stream channel stability." Am. Water Resources Assoc. 2003 National Conference Proceedings, in press (with G. Palhegyi and S Porter)

"Sources and pathways of ground-water flow to granitic canyon streams as inferred from variations in dry season baseflow Carmel River watershed, California." Sept. 24 version, Proceedings of the 13th Annual Groundwater Resources Association Meeting, Sep. 23-24, 2004 (with S. Brown and M. Woyshner)

"Sensitive species and storm inflows: Two new frontiers of karst hydrogeology." Proceedings of the 13th Annual Groundwater Resources Association Meeting, Sep. 23-24, 2004. (with S.M. Chartrand)

"Stormwater inflows and sensitive species: New frontiers of karst hydrogeology." GSA Annual Meeting, 2004, GSA Abstracts with Programs, Vol. 36, No. 5. (with S.M. Chartrand)

"Maintaining recharge to springs and seeps downgradient from an urbanizing area: An example from Bodega Bay, California": Proceedings of the 13th Annual Groundwater Resources Association Meeting, Sep. 23-24, 2004. (with C. White, and G. Porras)

"Field-based geomorphic methods for assessing the impacts of hydromodification on stream channels." 7th Biennial State of the San Francisco Estuary Conference, 2005 (with S. Porter, S. Brown, and J. Owens)

"Sediment transport trends in watersheds west of San Francisco Bay." 7th Biennial State of the San Francisco Estuary Conference, 2005 (with J. Owens, S. Brown and S. Chartrand)

"Bear Creek water quality study, 1999-2002, Woodside, San Mateo County, California." 7th Biennial State of the San Francisco Estuary Conference, 2005 (with C. White, J. Owens, B. Mallory, and D Shaw)

"Spring-supported wetland and riparian habitat, a core for managing bedrock ground water." 7th Biennial State of the San Francisco Estuary Conference, 2005 (with M. Woyshner, T. Yurovsky and G. Irving)

"Estimation of passage flows for anadromous fish through critical riffles in Stevens and Coyote Creeks, Santa Clara County, California." 7th Biennial State of the San Francisco Estuary Conference, 2005 (with E. Ballman and S. Chartrand)

BONNIE J. MALLORY
Hydrologist/Geochemist

Education

M.F.S.	Environmental Chemistry, Yale University, New Haven, Connecticut, 1999.
B.S.	Natural Resources and Environmental Studies (Honors), University of Minnesota, Twin Cities, 1995.

Summary of Experience

Ms. Mallory applies her diverse experience in watershed investigation, aquatic chemistry, and environmental analysis addressing a wide variety of water- and sediment-related issues with emphasis on nonpoint sources of pollution and water-quality enhancement. She designs and implements multifaceted wetland hydrologic investigations. Her current research focuses on factors affecting chemistry of surface and ground water, at both the watershed and project scales.

Experience

2000-present — Geochemist/Water-Quality Specialist, Balance Hydrologics, Inc.

Conducts field and analytical studies related to nonpoint source pollution in both rural and urban settings. Designs and sites BMPs for nutrient and sediment control. Participates in geomorphic and geochemical assessments of salmonid habitat and other sensitive fish and reptile species. Maps and describes naturally-occurring and anthropogenic elevated concentrations of salts, cadmium, mercury, and other constituents. Measures and monitors streamflow water quality and sediment quality. Models effects of land use or water diversions on stream flow and water quality.

1997-2000 — Research Fellow, Yale University, School of Forestry and Environmental Studies, New Haven, Connecticut

Designed and conducted a research project using chemical tracers to quantitatively apportion nonpoint sources of pollution in two watersheds. Combined field study, trace element measurement, statistical analysis and GIS analysis to develop an assessment of overall watershed health and identify areas of particular concern.

1996-1997 — Project Manager, Minnesota Pollution Control Agency, St. Paul, Minnesota

Negotiated agreements and implemented enforcement actions to ensure that responsible parties took action to clean up leaking underground storage tank (LUST) sites. Worked with team members to develop a scope of work for remedial investigations.

1995-1996	Chemist, Minnesota Department of Natural Resources, St. Paul, Minnesota Processed fish collected from lakes and rivers for mercury and PCB analysis. Managed database for the Minnesota Fish Contaminant Program and prepared data for publication in the Fish Consumption Advisory Book.
1994-1995	Wildlife Pathology Intern, Minnesota Department of Natural Resources, St. Paul, Minnesota Inspected fish hatcheries for the state fish and wildlife pathology laboratory. Responsible for cell culture, virology and bacteriology analysis.
1994	Intern, Minnesota Department of Natural Resources, St. Paul, Minnesota Surveyed and assessed streams for trout habitat quality. Performed fish culture and fish stocking. Analyzed forest regeneration data. Conducted state park interpretive services. Performed wildlife surveys, prescribed burns for prairie enhancement and invasive exotic species identification. Developed informational brochures for the Whitewater Valley public outreach program.

Professional Affiliations
American Geophysical Union
American Water Resources Association

Publications

“Refinement and application of a tracer technique to identify nonpoint sources of pollution at the Hudson River NERR site.” 1999 Spring Meeting American Geophysical Union, Supplement to Eos, 1999, Vol. 80, No. 17: S107. (with G. Benoit)

Abstracts

“Bear Creek water quality study, 1999-2002, Woodside, San Mateo County, California.” 7th Biennial State of the San Francisco Estuary Conference, 2005 (with C. White, J. Owens, D. Shaw and B. Hecht)

STACEY A. PORTER
Geomorphologist/Hydrologist

Education

M.S. Geography, University of Illinois, Urbana, Illinois, 2002.
B.S. Geography, Texas A&M University, College Station, Texas 1998.

Summary of Experience

Stacey Porter is a geomorphologist with a diverse background in watershed management and water resource issues. Ms. Porter combines her knowledge of fluvial systems with field investigation to assess and manage for bank and channel stability, with particular expertise in urban environments. Ms. Porter also designs, implements and monitors habitat enhancement features.

Experience

2001-Present Geomorphologist/Hydrologist, Balance Hydrologics, Inc.

Manages several projects covering a diverse range of water resource investigations, including stream and wetland restoration design and construction, development of stormwater BMPs, park and trail planning, and long-term hydrologic monitoring. Responsible for assessing and providing management strategies for controlling sediment sources, quantifying channel geometry and bed conditions, planning placement and recruitment of large woody material in streams for habitat enhancement, and evaluating slope stability and cumulative effects of land uses or management practices, including hydromodification.

2000- 2001 Teaching Assistant, University of Illinois at Urbana, Illinois

Organized weekly laboratories and created curriculum for introductory physical geography course. Taught landform interpretation using aerial photographs and topographic maps.

2000 Research Assistant, University of Illinois, Urbana, Illinois

Conducted research on the effects of large woody debris jams on three dimensional flow velocities and channel morphology. Surveyed stream cross-sections, tracked woody debris movement, measured point velocities using an Acoustic Doppler Velocimeter (ADV), and collected bed sediment samples for a large interdisciplinary EPA Water and Watersheds project focusing on the effects of woody debris on streamflow and channel morphology.

1999-2000 Research Assistant, University of Illinois, Urbana, Illinois

Managed a large local climate database for the Illinois State Water Survey. Conducted research on regional future climate change using historical climate data. Created future climate scenario maps and prepared reports outlining methodologies and major findings.

Professional Affiliations

American Association of Geographers
American Geophysical Union

Publications

"Stream geomorphology, bank vegetation, and three-dimensional habitat hydraulics for fish in Midwestern agricultural streams." Water Resources Research, v. 39, no 8, 1218, 2003 (with B.L. Rhoads and J.S. Schwartz).

"Developing a regional solution to stormwater management for Thompson Creek Watershed based on stream characteristics, hydromodification management and stream water quality." Proceedings of the American Water Resource Association. (with G. Palhegyi, D. Sen and others).

Abstracts

"Planning and design of stormwater basins." Presented at the Association of Bay Area Governments (ABAG) Conference. (with E. Ballman).

"Developing an assessment method to address impacts from urbanization on stream channel stability: Geomorphology." Presented at the American Water Resources Association Conference. (with B. Hecht and G. Palhegyi).

"Quantifying hydraulic habitat in human-impacted agricultural streams, East Central Illinois - A statistical analysis of hydraulic variability in two stream reaches with differing morphologies." Presented at the American Association of Geology Conference, 2001.

"Field-based geomorphic methods for assessing the impacts of hydromodification on stream channels." 7th Biennial State of the San Francisco Estuary Conference, 2005 (with S. Brown, J. Owens and B. Hecht)

Balance
Hydrologics, Inc.

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February 3, 2006

205203

Glen Spain, Northwest Regional Director
Pacific Coast Federation of Fishermen's Associations (PCFFA)
P.O. Box 11170
Eugene, OR 97440-3370

Dear Mr. Spain:

You have asked that we review the technical merit of selected testimonies given before the Public Utility Commission of Oregon related to the request for a general rate increase from Pacific Power & Light (Docket No. UE 170). We have reviewed the testimonies of Edward Bartell and Louis T. Rozaklis (on behalf of the Klamath Off-Project Water Users, Inc.), with less emphasis on the testimony of Marc Van Camp and Donald W. Schoenbeck (on behalf of the Klamath Water Users Association).

We understand that the Commission is on a tight time schedule, and have responded as best we can. We do call to your attention, and the Commission's, that the period allotted for our review has been less than 2 weeks. This seems disproportionate to the time obviously spent in developing and polishing the testimony, and a more systematic review might have been attainable with a little more time. Additionally, the materials which we have been asked to review are based fundamentally on other primary reports, which themselves require review, if only to assess whether the data taken from the primary documents are, in fact, reasonable and representative. Further complicating review, the testimony provided is primarily in the form of opinions, lacking computational backup and/or requiring considerable inquiry into other sources. Key elements are cited to tables in the ongoing Bureau of Reclamation 'Natural Flow Study' -- itself under frequent and radical revision – which may no longer be valid.
Given the limited time, our review has focused on the assumptions and methodologies used to arrive at the conclusions in the testimonies. Numerical review and quantitative analysis simply could not be completed with the materials provided and within the tight timeframe allotted.

1. Comments on Bartell Testimony

a. Lost River

Many of the limitations inherent in Mr. Bartell's testimony can be encapsulated from one of his statements:

"The fixed power rates also allow farmers to divert water out of closed drainage basins into the Klamath River. For example, the Pine Flat area is a closed basin. As a closed basin, precipitation or drainage from irrigation causes excess water. This water is pumped out of this closed basin and enters the Lost River System. In the wintertime, the entire flow of the Lost River and tributaries is diverted to the Klamath River via the Lost River Diversion Channel. In the summertime, water in the Lost River becomes part of the Klamath Project and thereby could lessen diversions out of Upper Klamath Lake or the Klamath River". Bartell, p.13

We find this testimony misleading in several respects:

1. He states that all of the water in the Lost River system during winter is diverted into the Klamath River. This is not correct.

2. He is implying that winter water in the Klamath River is equal in value to summer water. This is not correct in several respects. Narrowly, not all winter water goes through the power-generation system.[1] Narrowly, the demand for power is higher in summer. More broadly, summer water has high value for maintaining aquatic habitat (including for species of recognized national significance and for sustaining the culture of residents along the river below Iron Gate), as well as for maintaining water quality, in a manner allowing for both flexibility of power-pool management and environmental quality throughout the overall Klamath River system. In essence, he is confirming that most of the additional water coming in from the Lost River system enters in **winter,** when the flows are of limited or negative value for habitat or other traditional lower-river uses.

3. Mr. Bartell's statement claims additional summer water in the form of water whose diversion from the Klamath watershed is **avoided;** in fact, no additional water is created. Neither Mr. Bartell nor Mr. Rozaklis account for the fact that irrigated agriculture in the Klamath Project and off –Project areas **removes many tens of thousands of acre feet each year** from the Klamath River for summer irrigation for use in the Lost River, Yonna and Swan Valley and other adjacent watersheds.

[1] On an apples to apples basis, the probability that an acre foot of winter water on average will be able to generate power is a little more than 50 percent, based on Rozaklis' Table 15, and recognizing that Iron Gate is by far the largest of the facilities (note - Not in terms of cfs generating capacity). Additionally, summer flow is more useful for generating peaking power.

Failure to account for this use and loss of water from surface flows moving down the river severely undermines their analyses of the amounts, if any, of water added to the Klamath River from agriculture in the basin. Absent agriculture in the lower Lost River basin and Tule Lake, there would be neither a need nor a means to divert this water out of the Klamath system**.** That it "could lessen diversion out of Upper Klamath Lake or the Klamath River" confirms that water is being moved out of the Klamath watershed and into the Lost River basin, Yonna, Swan Valley and other watersheds and at the time of year when it is needed most for power and for aquatic and human habitat needs (including water quality) downstream, as noted above. Neither the Bartell or Rozaklis testimonies account for this factor.

4. The Bartell testimony seems to be claiming all of the benefits realized in the powerhouses from Lost River flows as attributable to agriculture. Yet we note that water flowed from the Lost River system to the Klamath River system naturally at times prior to the Klamath project. Mr. Bartell does not account for this fact.

b. Hydrogeology

Mr. Bartell argues that water returning to the streams from lands irrigated from wells in areas upstream of Upper Klamath Lake is water 'added' by agricultural practices. Water can, in fact, be added by pumping deep water in some geologic settings, but not in those prevailing north and east of the lake, where (1) underlying rocks are permeable with reasonably rapid cycling of ground water, where (2) the hydrogeologic setting is such that there is not a sharp downward gradient, and (3) where topographically lower points nearby where a local or regional aquifer can drain to the surface-water network. Each of these conditions are met upstream of Upper Klamath Lake. On these factors, we note:

(1) The volcanic rocks are generally permeable at the regional scale, as reflected in a summary document prepared by the Oregon State Engineer:

> *"The principal aquifer is a confined one in broken, cavernous or cindery lava and volcanic sediments. These permeable beds are overlain and confined by fine-grained laucstrine sediments and impervious volcanic rocks. In Sprague River, Swan Lake, and Yonna Valleys, irrigation wells that tap the confined aquifers yield a few hundred to 3,000 gpm (gallons per minute). Flowing wells occur in all areas except Swan Lake Valley. The most extensive area of flowing wells is in the Sprague River valley, where about 25 wells, some flowing more than 2,000 gpm, supply water for irrigation"* (Leonard and Harris, 1974, p. 2)

(2) The hydrogeologic setting is one where there is no sharp downward gradient that could convey water into deep basins where residence times can be centuries

or longer – sometimes much longer, such as beneath the Great Plains, central Australia, or northern Africa. The presence of flowing ('artesian') wells indicates that regional gradient may actually be upward, implying that ground water cannot physically move into very deep zones; rather, it will flow to a topographic low where it enters the surface-water network. As noted by Leonard and Harris (1974, p. 17):

> *"Within Klamath Basin, the general circulation of ground water in the deeper zone is from north to south and from the uplands toward the valleys. All the lowlands are areas of discharge where ground water is discharged by upward seepage from confined aquifers. . ."*

With only very minor exceptions, there is nowhere in the Klamath Basin above Iron Gate other than the surface water network or wells for ground water to discharge. Substituting pumping for discharge to the streams, lakes and marshes does not make new water. It simply changes when the water arrives. And, in our opinion, for most of the water pumped, that change may be several years or even a number of months.[2]

(3) Flow can, and does move, to the surface-water network in the lowlands, as described by Leonard and Harris, 1974. The Sprague River Valley is about 200 feet above UKL, not far to the southwest. The aquifers of the upper Williamson watershed are even higher, and the Wood River Valley slopes steeply toward the lake, and to other intervening low points. The same dynamic also applies to adjacent portions of the Lost River watershed as well as downstream from UKL, where springs have been pouring into the lake and Klamath River over geologic time.

(4) The fact that groundwater discharges to create surface streamflows in many areas of the upper basin greatly undermines Bartell's conclusion that groundwater pumping is a source of "added water" that augments surface flows in the Klamath River.

c. Bartell references

Portions of Mr. Bartell's testimony are based on his interpretation of work by USGS hydrologists John Risley and Antonin Laenen (1999). Bartell quotes Risley and Laenen as supporting the position that agricultural practices have increased the flows in the

[2] In earlier work, we found (Hecht and Kamman, 1996, Exhibit 205 attached to our testimony, discussed further below) that the effects of a very wet year gradually diminishes over a period of several years, based on multiple-regression model results which decay below the threshold of discernment after 5 years.

Williamson+Sprague system. This is not correct. These hydrologists conclude their report noting that:

> *"However, relating specific land-use activities to changes in runoff is impossible to assess using available data owing to the size and geologic complexity of the basin and to the paucity of historical land- and water-use data for local areas."* (p. 22; also, KOPWU 107/ Bartell 28)

A statement of this type does not seem to provide a basis for claiming 'added water' in any significant amount. Further, neither they nor other USGS staff have followed up with further work on the issues that they have left unresolved, among which are (a) differences in the number of high-recharge years between the two periods[3], (b) testing of alternative hydrologic explanations[4], (c) recently identified shifts in the timing of seasonal runoff, and other causes. As it turns out, each of these are in themselves sufficient to potentially negate the findings under further review. And the volumes of water involved are a small fraction of those claimed by Bartell and by others as allegedly added water. Further – as with all other winter water – not all such flows will actually enter the power-generation facilities, nor are they of equal value for power generation or environmental considerations and offsets; no difference in summer flow volume was found on the (upper) Williamson system and only a small amount on the Sprague with neither (once again) found attributable to agriculture or any other specific land use. Any statement that these authors, or that USGS and affiliated agencies, support the claim of added water, let alone the volumes involved, is not correct.

We have included two graphics from one of earlier reports which show that the period from 1918 through 1950 was, in some important hydrologic respects, a period drier than normal, while the subsequent period was wetter[5]. Figure 1 uses USBR computations to show that long-term accumulated precipitation reached a minimum in 1950, and increased substantially since that time. Figure 2 uses the nearest record (Yreka)

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[3] High-recharge or very wet years have a disproportionate effect on flows, one that can persist for several years. Balance Hydrologics staff (Hecht and Kamman, 1996, Appendix A) previously used a multiple-regression model to show that summer flows in the Klamath River at the outlet from the Klamath Basin (Keno gage) were discernibly elevated for up to 5 years following years of significantly above-average recharge. Since there are unequal numbers of high-recharge years during the two periods under inquiry (as one example, there were no years exceeding 20 inches at Klamath Falls from 1918 to 1950, but 5 such years from 1950 through 1996), this fact alone may account for much or all of the observed differences.

[4] The authors note that their work is solely a statistical exploration, and that no processes have been identified to account for differences found to be statistically significant but not understood. When dealing with small differences in large numbers, hydrologists normally proceed by testing a number of alternative hypotheses, and then identify specific processes which may be causes for such differences.

[5] "….persistent low flows during the 1840s were probably the most severe in the past 250 years, but that flows during the 1930s were nearly as 3xtreme. The period from 1950 to 1967 is anomalous in the context of this record for having no notable multiyear drought events" (Gedalof and others, 2004).

extending earlier than establishment of the Klamath Falls station in 1914. It suggests that there is a long-term pattern of climatic fluctuations which may bear very directly on claims of agriculturally-added water.[6]

[6] We note that failure to account for multi-decadal fluctuations in climate and streamflow has been the downfall of a number of important water-resource agreements, among them the Colorado Compact.

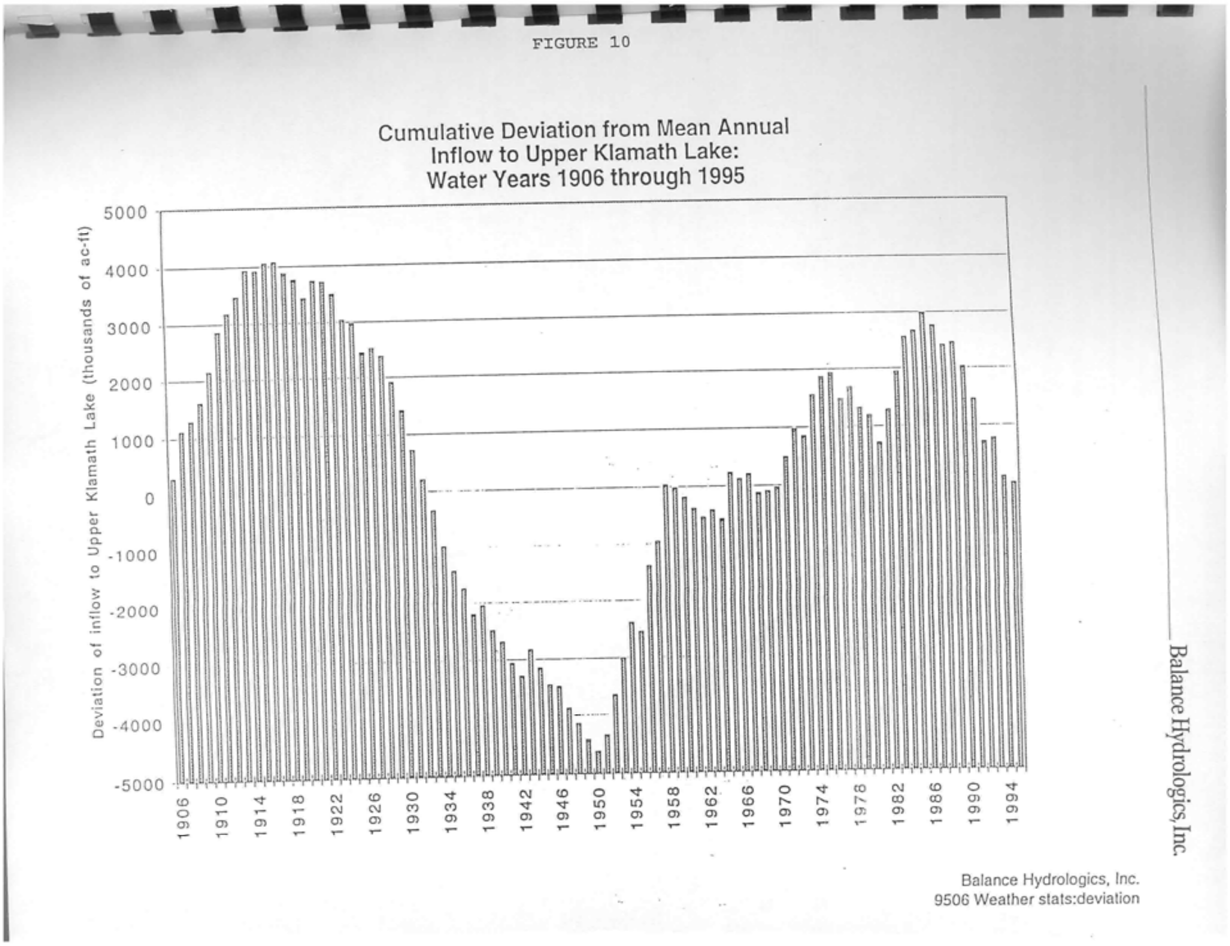
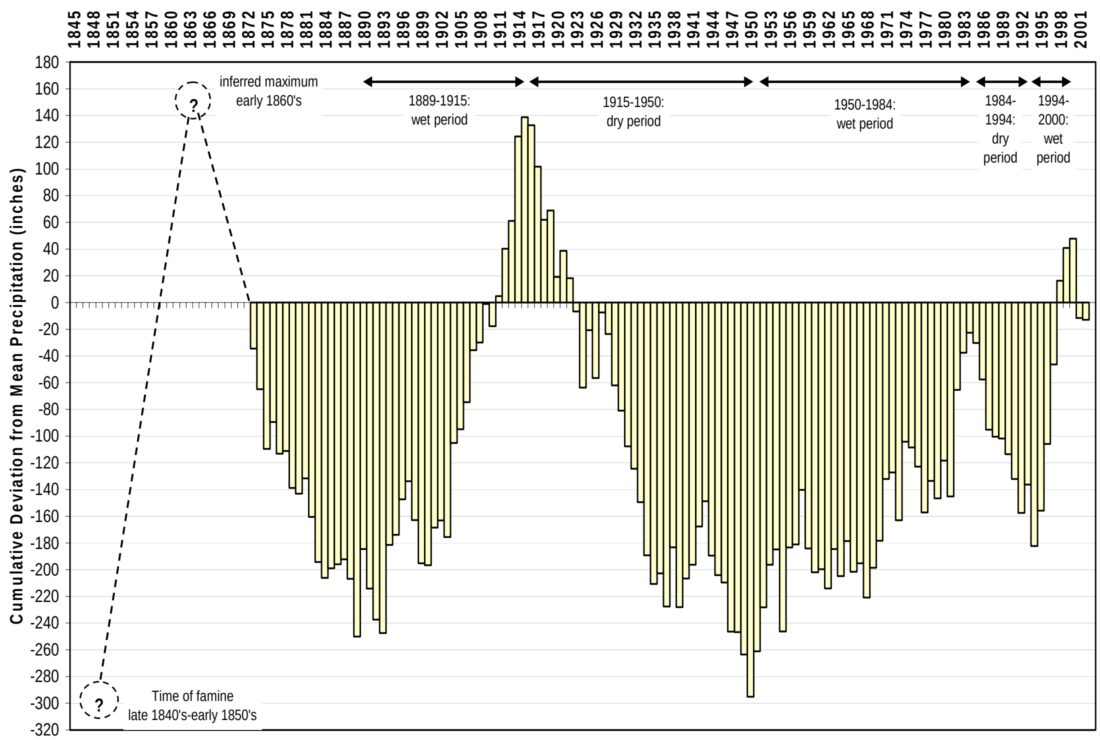


Figure 1. Cumulative deviation from mean annual inflow to Upper Klamath Lake



Source: 1873-1948 DWR Bulletin #58 and others
1948-1994 EarthInfo "NCDC Summary of the Day" CD-ROM
1994-2003 CDEC, http://cdec.water.ca.gov

Balance Hydrologics, Inc.

Figure 2. Cumulative deviation from mean annual precipitation at Yreka, California: rainfall years 1873 through 2003. Inferred 1840's to 1873.

2. Comments on Rozaklis Testimony

Mr. Rozaklis presents a claim for increased Klamath River flows/supplies from Off-Project lands on the order of 130,000 acre-feet per calendar year[7]. He proposes two primary increased supply sources: 1) agricultural return flows from lands irrigated with ground water (73,000 acre-feet per calendar year) and 2) differences between evapotranspiration from historical marshlands which were drained and converted to agricultural lands (58,000 acre-feet per calendar year). Rozaklis also suggests that draining of marshlands and clearing of forests for rangeland creation can increase annual stream flows.

a. Ground water

We make note of a number of assumptions made by Mr. Rozaklis to estimate increased supply from ground-water supplied off-project agricultural lands:

- He notes the presence of shallow and deep aquifers, and concludes that only the shallow aquifers are directly connected to the surface-water hydrologic system.

This assumption is unwarranted and simply incorrect given the hydrogeology of the Upper Klamath Basin. First, it merits mention that the extent of the shallow aquifers is relatively limited. They are prevalent mainly in the agricultural valleys, and even there they are discontinuous. Usefully generalized, the main aquifer(s) are the volcanic rocks to which Rozaklis refers as the deep aquifer, but which are exposed at the surface or are freely recharged from the surface over most of the topographic watersheds (c.f. Leonard and Harris, 1974, text and plates; USGS, 2005), most specifically in the Williamson+Sprague watershed.

In our comments on Mr. Bartell's testimony, the fundamental hydrogeologic linkage between ground water in the deep aquifer and the surface-water

[7] It is important to note that most hydrologic reporting occurs for a period defined as a water year, which begins on October 1 and ends on September 30 of the named year. In contrast, Rozaklis chose to use the calendar year as the basis for his annual estimates.

system of the Klamath basin was described. Just as a logic check on the 'openness' of the system, we note that -- prior to irrigated agriculture -- the streams flowed, the springs sustaining the two endangered sucker species flowed at levels at least as high as at present, and the Klamath basin above the Shasta River or Iron Gate was a main source of summer or dry-year water to the entire Klamath watershed (Hecht and Kamman, 1996). This hydrologic system continues in the presence of agriculture and other human activities. The notion that it could be sustained by shallow aquifers of limited extent is not correct.

- Rozaklis assumes pumping ground water does not deplete stream flows, and that the irrigation (and return flows) come from aquifer storage, which is treated as inexhaustible. In his words:

"While the hydrogeology of the Upper Klamath Basin is complex and not completely understood, it is reasonable to conclude that the amounts of irrigation well pumping from this aquifer, as estimated above, generally do not affect surface stream flows in a direct and immediate manner. While irrigation wells developed in this lower basalt aquifer generally exhibit minor fluctuations in water levels associated with seasonal pumping, long-term water levels in these wells are generally declining, with periodic increases that correspond to extended regional climatic wet periods (USGS, 2005c). Well hydrographs for typical off-Project irrigation wells are shown in Figure 2 and Figure 3. These downward trends indicate that well pumping generally does not directly deplete stream flows; instead it reduces aquifer storage, which is in turn partially replenished during periods of unusually high precipitation, when stream flows are substantially above average. Therefore the return flows from groundwater supplied KOPWU lands are net gains to the stream system from the perspective of PacifiCorp's hydropower generation capacity." KOPWU/202 Rozaklis/15

If depletion from storage is the primary mechanism by which water is 'added' to the flows below Keno, then depletion should logically approach the 78,000 acre feet per year of claimed added water from the combined Williamson+Sprague watersheds. It does not, however, even making assumptions favorable to this hypothesis in the following calculation:

Using data from the well that he identified as representative (Fig. 2), we calculate the actual depletion as follows:

a. Assume entire ground water in the entire watershed (1,920,000 acres, or 3000 square miles) is lowered:

b. At the rate shown in his Figure 2 (approximately 0.25 ft/yr over the period shown)
c. With a storativity of 0.01 (or, one percent of aquifer is drainable water), as estimated by Leonard and Harris…

…a computational depletion of 4800 acre feet per year (afa) for the 45-year record over the entire watershed may be calculated. Realistically, this value is an overestimate, as it should be adjusted for 1) declines in water level associated with pumping in nearby wells (also known as "well interference") and not related to depletion, 2) little likelihood of the entire watershed being depleted by pumpage in the small fraction of its area from which water is pumped, and 3) the likelihood that a lower mean storativity may prevail (since portions of the deep aquifer--including those most heavily pumped -- are confined, and a value of 0.01 is very high relative to those typical of confined aquifers), an actual depletion of 1000 to 3000 afa may be more reasonable.

Mr. Rozaklis' hypothesis that the claimed added water comes from long-term storage in the aquifer must be rejected. Assuming that the well he chose is representative, only a few percent of addition of 78,000 afa he postulates originating from the Williamson+Sprague watershed can serve as the source of the claimed added water. Combined with his incorrect assumption of ground water moving through the volcanic aquifers being in long-term storage, this portion of his testimony appears incorrect on two separate and independent hydrogeologic grounds.

Use of deeper ground water sources can – and usually does -- significantly and persistently lower stream flows, especially late-summer and dry-year flows, which have particular value for habitat and bank stability, as well as power generation, factors not considered by Rozaklis. The links between pumping from the 'deep aquifer' and streams are considered above in our discussion of Mr. Bartell's testimony. It is our professional judgment that pumping groundwater in the off-project area diminishes and does not augment streamflows in any appreciable degree.

- He assumes that ***all*** excess water returns as stream flow either directly as surface returns (40%) or indirectly as subsurface returns (60%). He also may assume that no losses affect return flows as calculated at the field site during passage through ditches or by other means to the surface-water system and all the way downstream through Iron Gate.

The Rozaklis testimony does not include any estimation of water loss that occurs as a result of water transit (transmission losses) or field application processes. Pumped ground water travels through an extensive array of irrigation canals, laterals, and drains in the Klamath Basin. Water is then applied to the fields via sprinkler systems or field flooding. Both water conveyance and application activities promote water loss through evaporation and evapotranspiration (ET). These losses, which can be quite significant, are not accounted for in Rozaklis' water budget.

Application losses

Burt and others (2002) conducted a review of evaporation research in order to compute evaporation amounts for irrigated agriculture in California. One of the key outcomes of their study was a compilation of work done to estimate spray losses from sprinklers, an important component of applied water which is neither consumed by crops nor captured as return flow in drainage systems. Spray droplet evaporation losses range from 1% to 4% for typical sprinkler systems and can be even higher in sprinkler systems with high pressures. Under high wind conditions spray droplet evaporation can be considerably higher. Although the conversion from surface to spray irrigation reported by Mr. Rozaklis would likely increase irrigation efficiencies and decrease the amount of ground-water pumping, it is unlikely that it would have any impact on stream flows.

Conveyance losses

Excess water applied to croplands returns to the irrigation system and is often re-used for downgradient properties multiple times before finally reaching the main stream network. There are numerous ways in which water will be lost from the system during this transit process, including,

a) evaporation of water in open ditches and storage ponds,
b) evapotranspiration of water in ditches and tributaries that have vegetated banks or in-stream vegetation,
c) water loss to the deep ground water aquifer via leaks and seepage in the ditch system.

Estimates of transit loss can be quite substantial and should not be overlooked when calculating the amount of runoff generated from agricultural lands. Rozaklis assumes that all irrigation return flows and shallow, subsurface ground water are eventually returned to the creek, but makes no mention of evaporation and ET losses that occur when water is transported from the creek through the irrigation canal and drain systems, nor of potential losses to the deep aquifer. It is also important to note that because return flows are often re-used on multiple fields, the potential for total water loss is increased because the same water is subject to evaporation and ET losses with each application.

Kent (1905) conducted a study of irrigation losses from seepage, evaporation, and ET on the Adams ditches, the Ankeny, and the Mitchell lateral, located in the Klamath Basin. Kent measured discharge along sections of these irrigation ditches (from 1.5 to 6.5 miles apart), subtracted diversion flows, and calculated total water loss for a single irrigation application in July and August. Total water losses ranged from 10 to 20% of total discharge. These losses accounted for both evaporative processes and seepage during transit. Seepage losses do not necessarily equate to a complete loss to the system, as some seepage will eventually return to the creeks via subsurface pathways. However, this study emphasizes that losses do occur along irrigation ditches, canals, and drains, and can account for a significant amount of water that should be included in any water budget study of the Klamath Basin.

A more recent study conducted by Burt and Freeman (2003) addresses several hydrologic issues of the Upper Klamath Basin. In this study, estimates of evaporative loss during transit for irrigation purposes for several Project areas in the Klamath Basin were made. Evaporation and ET losses for three years, 1999 through 2001 were calculated. Average annual evaporation and ET losses in canals equaled 11,155 acre-feet per year. Using a GIS database and a number of supporting references, Burt and Freeman (2003) estimated the total canal and drain surface area within the Klamath Project as 3,543 acres, feeding and draining approximately 115,000 acres of irrigated fields. Thus, annual evaporative losses amount to 3.14 feet per acre of canal.

We did some simple calculations of potential water losses due to ET and evaporation of water transported in irrigation canals and ditches to support off-Project agriculture:

- We assumed a similar ratio of canal and drain surface area to irrigated fields as that measured by Burt and Freeman (2003). Burt and Freeman (2003) measured 3,543 acres of conveyance system supporting 115,000 acres of irrigated fields or 0.03:1. Rozaklis reports 70,736 acres of off-Project ground water-supplied agricultural fields and 65,665 acres of drained irrigated lands. A comparable irrigation network for the off-Project lands would be 2122 acres of canals and ditches supporting ground water-supplied fields and 1970 acres of canals and ditches supporting the drained irrigated fields.

- We used Burt and Freeman's (2003) calculated annual evaporative loss of 3.14 feet, which accounts for evaporation and ET in canals and ditches.

The table below illustrates that irrigation transit loses to ET alone amount to approximately 12,849 acre-feet per year, or almost 10% of Rozaklis' estimate of annual flow increases resulting from off-Project lands. Our calculation does not account for water losses to the deep aquifer or compounded loss occurring due to re-use of return flows on multiple agricultural fields. Therefore, our calculations likely underestimate the error in Rozaklis calculations.

Table 1. Conveyance losses

	Total acreage of croplands (acres)	Ratio of Project conveyance system to irrigated acres	Estimated surface area of irrigation canals and ditches (acres)	Total estimated annual ET (acre-feet)	Total annual water loss due to ET and evaporation (acre-feet)	Rozaklis estimates total annual increased flow (acre-feet)
Ground water-supplied off-Project agricultural lands	70,736	0.03:1	2122	6,663	12,849	130,000
Off-Project drained irrigation lands	65,665	0.03:1	1970	6,186		

b. Marshland conversion

Mr. Rozaklis suggests that conversion of 65,665 acres of marshlands adjacent to lakes and rivers to off-Project irrigated fields results in annual flow increases of over 58,000 acre-feet per calendar year. This is based on the overarching assumption that ET losses from agricultural lands are less than ET losses from wetlands. We question a number of the supporting assumptions go into his calculations:

- Rozaklis assumes that half (18,500 acres) of the drained wetland acreage in the off-Project lands located around Upper Klamath Lake and along the Klamath River near Keno was open water in pre-development conditions.

The rationale for this assumption is based on the current elevation of the agricultural field relative to adjacent lakes and rivers (see Rozaklis Section 4.2.1). No maps were provided as reference. In making this assumption, Rozaklis neglected consideration of an important consequence of farming in highly organic peat soils such as many of those of the Klamath Basin. When peat soils are drained and exposed to the atmosphere they oxidize and compact, and/or are reduced in thickness by wind erosion; thus, the land surface is permanently lowered with each yearly cycle. Prior to draining, these marshlands would have had a higher elevation than the water surface. Thus, it may be erroneous to factor open water surface evaporation from half of the acreage on the pre-development side of the equation.

Additionally, reviewers of the USBR Natural Flow study have provided data revealing that open water in the Upper Klamath Basin was heavily populated with wocus, a yellow pond lily (Gearheart, 2005). Wocus communities act to shade open water and have relatively low ET rates when compared to emergent aquatic plants such as tules and cattails. This fundamental fact is not incorporated in Rozaklis' analysis.

- Rozaklis bases his ET estimates on methods described in the November 2005 USBR "Natural Flow of the Upper Klamath River" study (USBR, 2005). ET for permanently flooded marshes are estimated using the modified Blaney-Criddle method, incorporating the USBR's monthly crop coefficients for tules and cattails, with ET results adjusted downward to reflect differences with work done by Bidlake and Payne.

There are a number of concerns with Rozaklis basing his wetland ET rates on the estimations made by the USBR's report that is still undergoing review by the National Academy of Science. Outlined below are some of the major flaws with the USBR's method of calculating wetland marsh evapotranspiration that bias the values toward increased wetland evapotranspiration and over-estimation of historical (pre-agriculture) water losses.

1. It is assumed in the USBR report and Rozaklis' testimony that the species composition for all of the wetland marsh areas were historically dominated by tules and cattails. This is an inaccurate assumption that does not take into account the diversity of the marsh areas of the Klamath Basin. For instance, Gearheart (2005) summarizes the historical importance of yellow pond lily (Woncus spp.), which has a much lower evapotranspiration rate than tule and cattail and actually reduces open water evaporation because it floats on the water surface.

2. It is also questionable to use the Blaney-Criddle method (which was developed for agricultural crops) for calculating evapotranspiration for aquatic macrophytes because wetland plant species respond to

seasonality differently than crops. Crops are supplied with water via irrigation pathways during the dry, summer months when natural water sources are scarce to maximize consumptive use and growth, whereas wetland plants will uptake less water during their growth season when under moisture stress, such as occurs during dry years. Further, wetland plants senesce earlier in the season, curtailing late-summer ET. This is an important difference that is not addressed in Rozaklis' study. While we know that quite a number of fields have gone dry in the Klamath basin during recent droughts, wetland plants generate fewer losses than crops during such periods, when water is of particular value.

3. Section 5 of Hecht and others (2005) describes in detail specific flaws with the USBR's estimated values for wetland ET. This section is attached as Appendix I.

As evidenced by the lack of confidence in the USBR ET estimates and summarized in the Gearheart (2005) memo, experts on wetland ET are still far from agreement on the appropriate method to employ (see for example Drexler and others, 2004). Unfortunately, wetland crop coefficients have not been developed for the species mix and climate characteristics which existed in the Upper Klamath Basin during pre-development conditions for simple substitution in the Rozaklis tables, and, it would be presumptuous for us to make such estimates.

c. Other considerations

It is not clear whether the tables included in his testimony include irrigation of lands, most notable in the Williamson+Sprague watershed with surface water, either from certificated or unadjudicated water rights. Obviously, there is extensive irrigation with surface water in the area, which diminishes streamflows and ultimately results in reduced water in the Klamath River for hydropower and other uses. He may have noted these during his field work in the area. To the extent off-project lands are irrigated mainly with diversions of surface waters, many of which are not converted wetlands, these factors would logically diminish any claims of added water and undermine Mr. Rozaklis calculations and conclusions.

Finally, we note, as Mr. Bartell, that his testimony does not mention the water diverted to irrigation by the Klamath Project from Upper Klamath Lake and from the Klamath watershed above Keno. He does generalize his Williamson+Sprague work to these watersheds, and seems to include return flows from this irrigation in the added water claimed. Not mentioning these summer diversions, and their importance to the overall system, is not correct.

3. Comments on Van Camp Testimony

We have a number of concerns with the testimony give by Mr. Van Camp:

a. "…all of the effects of Klamath Project facilities are experienced between Upper Klamath Lake and Keno"

   It may have been better to say 'from the shores of Upper Klamath Lake through Keno.'

   As it stands, this statement seems to conflict with that of Mr. Bartell -- who notes diversions from Upper Klamath Lake to Yonna Valley, among others -- and Mr. Rozaklis, who notes that a number of land owners within the Klamath Project, with lands with demands totaling several thousand acre-feet per year, are becoming de-facto off-project irrigators due to decisions made by the Project.

   Equally, the Project makes many of the decisions how to operate UKL, which affects losses within the Klamath River surface-water system. We note, as well, that the Project accommodates its operation of the Lake to conform with water levels needed for listed species – further altering, and generally, reducing flows which might otherwise be claimed as added to power generation.

b. Mr. Van Camp's analysis is based on water rights, and not on actual flows. It differs fundamentally from the basis used in comments on behalf of the off-Project users. As often happens when rights are the emphasis rather than use, inconsistencies come into play. For example, Mr. Van Camp asserts rights both for consumptive use and for conveyance. The more losses during either, the larger he contends that the rights would be. If the Commission were to follow this logic, it would be rewarding the users and the Project for efforts not to diminish conveyance losses, which seems to us to be counter to the Project's objectives and probably to public policy regarding water and water quality[8].

c. He bases his statement of rights on the period 1997-2000, an unusually wet period when more acreage would have been irrigated than during drier years such as 1992, 1994, 2001 and 2002.

d. Claiming that KWUA should benefit from all gains between Link River and Keno ignores the role of non-Klamath Project influences, among them:

   1) Much additional flow through Keno was created by construction of the railroad dike across the Klamath Straits, limiting many tens of thousands or hundreds of thousands of acre-feet of winter overflow into Lower Klamath Lake. We emphasize that this change occurred two decades before Bureau of Reclamation irrigation commenced in Klamath Basin;
   2) Additional water enters this reach of the river from urban and industrial areas in and around Klamath Falls and the north shore of Lake Ewauna;
   3) Flows from the Lost River Diversion, discussed above in our discussion of Mr. Bartell's analysis.
   4) Additional inflows from forested and other non-irrigated lands.

e. Ignoring inflows from ground water near or downstream from Keno, including the possibility that ground water moved from Lower Klamath Lake, Tule Lake, and other depressions through the fractured volcanic aquifer into the Klamath River downstream from Keno.

In summary, Mr. Van Camp's testimony is not based on actual flows, resulting in claiming excessive benefits and not mentioning certain environmental obligations. It would be erroneous to use his estimates without revision or qualification in energy value calculations such as those computed by in the testimony by Mr. Schoenbeck for the Klamath Water Users Association.

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[8] It is our understanding that both the Klamath Project and KWUA have committed to water-conservations measures, such as those mandated in the NMFS Biological Opinion on Klamath Project diversions for 2002 through 2012.

4. Conclusions

- Bartell:
    - Overemphasizes water 'added' by agriculture, but has yet to recognize that water is diverted from Upper Klamath Lake to be consumed in Yonna and Swan Valleys ("Pine Flat") and other de-facto off-Project areas, and from the Klamath River system, such as summer flows to the Lost River, Lower Klamath Lake (LKL) and other Klamath Project areas through the A Canal, North Canal, Ady Canal and other facilities
    - Attributes gains to agriculture that are actually related to non-agricultural uses (such as the railroad dike across the Klamath Straits curtailing inflows to LKL, and the Lost River Diversion facilities, which likely would have been built in the absence of agriculture).
    - Does not seem to recognize that summer water is more valuable.
- Rozaklis:
    - Creates a distinction between the shallow and deeper aquifers that makes little difference in terms of the effects of using wells for water supply. It is the deep aquifer that drives the surface-water system of the Klamath Basin, and that always has done so. He notion that withdrawals from the deep aquifer do not diminish surface flows is contrary to the actual hydrogeologic setting.
    - Does not account for conveyance and application losses, which can be considerable
    - Does not present a believable pre-development condition. It is unreasonable to assume that half of the converted acres in the Upper Klamath Lake area and along the Klamath River near Ken were historically open water.

- Uses wetland ET estimates taken from an ongoing study by the USBR which have now been questioned by the study work group and are currently under review by the National Academy of Sciences.

- Does not account for effects of surface water diversions and irrigation with surface waters on streamflows available for power generation.

- Van Camp

  - Uses a paper water-right basis of computation, which does not evaluate actual streamflows and is not compatible with other analyses.

  - Claims incremental flows not ascribable to Project or KWUA operations, or which reasonable would have happened without these operations.

None of these authors seem to fully recognize:

1. Not all water moving to Iron Gate actually gets there.

2. There are a number of legal constraints arising in recent years to the ability of the Bureau of Reclamation to provide any additional flows from the Project or off-Project lands to PacifiCorp for power production. Among these legal constraints are ESA-mandated minimum Upper Klamath Lake levels now required under the U.S. Fish and Wildlife Biological Opinion for Lost River and Shortnosed Suckers, and minimum in-river target flows at Iron Gate Dam under the National Marine Fisheries Service Biological Opinion for Coho Salmon. These ESA-mandated constraints have substantial affects on river flows available for power generation, were not considered by Bartell, Rozaklis or Van Camp in their analyses, and can considerably diminish any value from whatever additional inflows, if any, might exist.

Closing

Please feel free to contact us if you would like to discuss these concerns in further detail.

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Appendices

I. Hecht and others (2005), Section 5
II. Gearheart (2005), memorandum

APPENDIX I. 5. Comments on evapotranspiration and evaporation estimates

5.1 Evapotranspiration Adjustments

The conceptual model for determining ET losses due to natural marshes, riparian areas, and croplands is well developed but it is deficient in certain parameter estimations and basic assumptions. The critical considerations for determining ET losses from wetlands and riparian areas in the Lower and Upper Klamath Lake (LKL, UKL) undepleted natural flow study area are listed below:

- Representative wetland ET model with wetland plant coefficients
- Statistically valid mass transfer ET values-multiple sites
- ET values representative of various types of wetland plants
- Inundated in-lake wetland areas and wetland areas in LKL and contributing watersheds to UKL
- Historic extent and composition of wetlands adjacent to UKL, LKL, and upstream watersheds
- Change in the in-lake wetland acreage during periods of unregulated lake levels
- Role of saturated soils in the wetland areas in terms of ET losses

Understanding that it is difficult to reconstruct vegetative patterns, extent of lake and wetland inundation, and missing climatological data, it, therefore, is critical to be able to test the variance in estimating these factors. The approach taken in the cropland ET losses is a good example of non-parity in the model. As an example, crop coefficients for agricultural crops are distributed in sub-components of the model (for example the Sprague watershed) based upon the types of crops irrigated. On the other hand the wetlands ET equivalent factor (see Table 3 of Attachment A in USBR Report) is generalized to the dominant species in the wetlands (tules-cattail, salt grass, etc). There are other wetland plant communities along with open water sections that are included in these "designated areas". There are several issues related to this observation:

1) does it make a difference in the estimated ET losses for marshes and riparian areas, and,

2) is it a biased analysis if the level of detail in assigning ET losses from wetlands is different than irrigated agricultural land?

Another assumption to be evaluated in the model is the extent to which the in-lake wetland areas increased due to the lower lake elevation and its hydroperiod variation (Figure 5.2). It is an established fact that wetland plant coverage is enhanced by 1) lower hydroperiods and/or 2) seasonal varying hydroperiods. Other species such as Wocus spp., for example, were known to dominate certain in-lake wetland areas. This raises the question of whether the Wocus plant community and perhaps other plant communities might be found in the now existing open water sections of the regulated lake.

5.1.1 Wetland Crop Coefficients

The value of the crop coefficient for various plants during various periods of the growing season for a particular plant appears to be divided into three phases; 1) initial stage, 2) mid-season stage and, 3) late season stage. For agricultural crops, specific values are given for various climate zones. There is not an equivalent table of coefficients for wetland plants. The model assumes that the shape of the crop coefficient curve over the growing period is the same for both agricultural and wetland plants. This assumption needs to be evaluated both in terms of the length of the growing period and the changes in the crop coefficient during mid-season to late season stages. In the case of wetlands plants that are not water limited, the rate of transpiration is reduced as the plants enter into their physiological senescence. The shape of the crop coefficient curve for wetland plants does not follow the same shape as the crop coefficient for agricultural crops.

5.1.2 The Concept of 'Methodology'

Attachment A of the Report deals with the assumptions and methodologies used to determine evaporation and evapotranspiration from the various historic and project affected land uses, vegetated coverings, and water surfaces within the scope of the study. At the top of page A-2 a conclusion is reached which is unsubstantiated and without reference, "…marshes around UKL and LKL transpire significant amounts of water by photosynthesis." While it is well known that plants transpire water by photosynthesis it is a bit premature in a methodology section of a water balance to come to a conclusion. A suggestion would be to simply state what the model will do and how it will do it. The next sentence suffers from a different deficiency in that the sentence structure makes it appear that riparian and marsh vegetation along river corridors and irrigated agriculture are similar. It is my understanding that this is a methodology section, which should simply state, without assessment, the sources of water loss by E and ET. A suggestion would be to rewrite this section as objectively as possible. The last sentence should be broadened to include lake, marsh, and riparian areas that E and ET was estimated to include in the water balance.

5.1.3 Blaney-Criddle

The Blaney-Criddle (no wind or humidity) method, developed by SCS (now NRCS), provides seasonal crop consumptive use estimates and may be used for monthlies.

U = K Sfi

f-tp/100

U = seasonal consumptive use in inches

t = mean monthly temp

p = mean monthly percent of daytime hrs

K = seasonal consumptive use for a crop

Stand density, height, and areal extent have been reported by many investigators to have a great deal of influence on the rate of water loss from a vegetated water body (Anderson and Idso 1985, Hammer 1989, Idso and Anderson 1988, Kadlec et al. 1988). These vegetative characteristics are probably the most important and least quantifiable factors when relating ET to ETo and comparing ET rates between different species.

Hammer (1989) states that "evapotranspiration losses from dense emergent stands are generally lower than evaporative losses from open water surfaces because of plant influences on the microclimate near the water surface within a stand of vegetation." Higher losses may be the case for limited periods during the growing season, however, plant structure substantially reduces evaporation losses from exposed water surfaces by shading the surface, and by occupying a substantial portion of surface area. Dense emergent stands also obstruct air movement near the waters surface such that relative humidity is near saturation for some distance above the water surface and the saturated air is not exchanged with drier air. This process can reduce wetland ET. Transpiration losses are also reduced by limited air movement around plant stems and leaves, maintaining high humidities near plant surfaces.

In our previous review of the Undepleted Flow study we stated the known shortcomings of the Blaney-Criddle method with respect to estimating wetland vegetation ET (Hecht and others, 2004). The discussion will not be repeated in this review but we recommend that the USBR review that section in the report. The importance of data availability for a model is recognized as important, but the accuracy of the model to estimate the marsh ET is the overriding criteria. For example, the evaporation component of marsh ET is not developed in a manner that allows for a careful review.

The evaporation of the water from a marsh follows different processes than evaporation from soil in irrigated agriculture. Variation in ET from different plant species has primarily been attributed to vegetative structure (linear-erect vs. broadleaf and emergent vs. floating) and to differences in stomatal conductance to water vapor. The type of vegetative cover greatly influences shading and wind effects which in turn affect air and water temperatures, humidity, and solar radiation reaching the water surface (Otis 1914, Kadlec et al. 1988, Snyder and Boyd 1987). These factors influence the evaporation component of ET. Snyder and Boyd (1987) reported a reduction in water temperature of 2 to 4°C in vegetated tanks compared to open water tanks due to daytime shading. Kadlec et al. (1988) found that free surface evaporation from evaporation pans placed within the vegetation is strongly influenced by plant cover type due to its shading effects. The greatest water losses in their study occurred in areas with the most open cover (meadow) and the lowest losses were from the densest (Leatherleaf).

Cover type also influences the degree of daily and seasonal variation of evapotranspiration (Otis 1914). The importance of water temperature in a marsh and within the area of marsh water advection should not be discounted as an insignificant factor. For example, the wetlands of the Klamath Lake Wildlife Refuge are fed to some extent by springs both on the edges and within the wetlands (Figure 5.3). This upwelling of spring water is much cooler than the lake open water temperature in the summer. This internally loaded cold water volume along with the waters in the wetland cooled shading effect of the wetland plants makes the water temperature within the wetlands cooler than the lake water temperature. To some extent the spring addition of cooler water might have existed in the wetlands at the mouth of the Williamson River. In the case of all wetlands in the basin the summer water temperature in the wetlands could have been 3 to 5 degrees cooler than the open water lake temperature (Gearheart, 1999).

It is recognized that within the last few years the accuracy for estimating evapotranspiration have improved due to methods which are more complex. In spite of these methods and the large number of older methods, wetland ET estimates remain poorly characterized. This is partly due to the variability and complexity of wetlands. Most of the methods used to estimate ET assume uniform vegetation and adequate fetch.

- **Recommendation: The plant coefficient for wetland plants should be adjusted monthly based on wetland transpiration (ET) rates. It has been observed that wetland plant crop ET rates (crop coefficient) diminish faster in the late season than irrigated crop late season crop coefficients. BOR should identify monthly wetland plant crop coefficients for those aquatic plants commonly found in the basin and compare these results with the results found in the first draft. If crop coefficient can not be found then BOR should develop a rational for estimating these monthly ETc values.**

5.1.4 Capillary Rise

The value of 1.8 feet of capillary rise used in the model to extend wetland ET as the lake level decreases is reportedly based upon hydraulic characteristics of peat soils. The question is if this value is derived from peat soils which have already been drained, oxidized, and perhaps compressed or do they represent the soil-sediment-detrital layer below the wetland communities under condition of seasonal and or annual inundation. General understanding of capillary action as a function of particle size suggests that the capillary rise would be less than 1.8 feet under conditions normally found in the wetlands.

- **Recommendation: The USBR should verify and reference the use of 1.8 feet for determining the capillary rise in the wetlands during periods of lake level decrease. If 1.8 feet is deemed appropriate, then full justification should support the capillary rise value used in the model. There are several general soil types found in the Upper**

Klamath Lake historic wetland areas. The USBR should justify using one value for capillary rise based upon the known soil types.

5.2 Effective Wetland Surface Areas for Estimates

An assumption is made by the USBR (which is neither referenced nor justified) that the effect of lake lowering on the effective level of the water under the wetlands can be accounted for by lagging, by one month, the water levels under the wetlands. This assumption does not include any consideration for the slope of the wetland. For example, if the slope of the wetland is 0.5 %, then a 1.8 ft reduction in distance from the plant roots to subsurface water level would occur within 360 feet of the lake/wetland margin[9]. At 1 % slope, the 1.8 foot difference would occur with in 180 feet of the lake/wetland margin. The slope of the marginal wetlands surrounding UKL increases in the upper reaches of the watershed. The techniques used in this study do not account for this slope factor, which consequently results in an over estimation of the ET from these wetlands.

A second factor not considered or not fully justified is the reduction in physiological need for water by these plants (photosynthetic process) during the period in which lake levels are decreasing. Even at the assumed 1.8 foot effective lake elevation correction, the plants could be reducing their need for water. If the 80% adjustment to the Blaney-Criddle crop factor is to account for this reduced plant need, then justification needs to be included in the report. It is highly probable that the plant physiological need for water is considerable less in the mid- to late growing season, while at the same time, normal plant senescence, which is genetically determined (see Section 5.4), is increasing.

A question also arises when partitioning the lake areas (UKL and LKL) into inlake wetlands and open water as to the amount of open water in the wetland areas. As can be seen in IR photographs (Figure 5.4) open water exists in the Klamath Lake Wildlife Refuge. Whether this condition is significant in the pre and post conditions that are modeled in this study is a question the model developers should address.

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[9] The model uses 1.8 feet as the capillary rise factor.

5.3 Evaporation Considerations

The evaporation component of the model uses the Hargreaves Method, an acceptable method commonly used in water resource management when only temperature incident radiation data are available. This method requires a minimum of information and has proven to be accurate enough for lake and irrigation management applications. The Kimberly-Penman Method is generally considered to provide more accurate evaporation estimates but requires a higher level of data inputs. Work conducted in India by Moges and others (2002) attempted to compare PET estimates using six available evaporation models, one of which was a modified Hargreaves Method. They found that the Penman-equivalent method can be estimated using a modified Hargreaves Method with an efficiency of 28 to 96%. This highlights the extreme variability that is inherent to the Hargreaves Method and suggests the need for further calibration and sensitivity analysis of the USBR evaporation estimates. Typically, the longer the daily moving average used, the closer the Hargreaves Method estimates come to the more complicated Kimberly-Penman method.

Several correction factors were applied to the Hargreaves Method by the USBR in an effort to estimate evaporation from the open waters of the lakes. The comparison of the Hargreaves to the Kimberly-Penman daily values from the AgriMet station is one example. For the period March 31, 1999 to December 1, 2001, the Hargreaves method gave a lower estimate of open water evaporation than the Kimberly-Penman. The adjustment in the form of an extended polynomial equation (4^{th} order) brought the overall difference to an R^2 of 0.92. With only a visual observation it appears (comparison of Figure D-2 graphs) that the fourth order equation is generally underestimating evaporation during the warmer months (growing season period). There is neither discussion of this seasonal effect in the report nor any attempt to apply a correction. The polynomial fit is essentially trading off “good fit” fall and winter evaporation with poorer fit spring and summer evaporation. The important information to know for the use in the model’s sensitivity analysis is the error in the USBR-developed methodology during the period of concern (late spring and summer).

- **Recommendation: The USBR should test the condition of open water sections within the wetland in terms of trading off evaporation from the open water and evapotranspiration in the wetlands to see if there is a significant difference. A correlation relationship should be developed between the Kimberly-Penman and Hargreaves for the growing period/summer months. The results of this new**

correlation should be use to adjust values of evaporation. The independent parameters used in the Kimberly-Penman and Hargreaves should then be used to determine the error range to be used in the sensitivity analysis and or Monte Carlo simulation.

5.4 Definition of Senescence

Plant senescence is a highly regulated and complex process during which the plant reclaims as many mobilizable nutrients as possible from the senescing tissues. Plant senescence is the final event in the growth and development of a plant which ultimately leads to the death of a particular organ or whole plant. The senescence in plants is a highly regulated, genetically programmed and developmentally controlled process. Genetic and molecular analyses suggest that the cell death associated with senescence is a form of programmed cell death, however, little is known about the senescence signal and its detection. Clearly aquatic macrophytes detect the onset of short days in the autumn and the whole plant senesces to reroute materials into the seeds representing the next generation. In other plants or in individual plant organs, the signal and its transduction are not as well understood.

The leaves of aquatic macrphytes senesce in a seasonal manner to survive harsh winters or severe droughts. Annual plants undergo leaf senescence mainly during their reproductive stage. Leaf senescence is highly predictable and essential for plant survival. It is a programmed, active process that enables the plant to use the nutrients from photosynthetic tissue for the development seeds or for growth in the next season. While genetically programmed conditions in aquatic macrophyes are the primary signal for senescence, water stressed conditions can accelerate the process within the natural life cycle of the plant. Normally water stressing of aquatic macrophytes by processes such as: lowering of lake elevation, drought conditions, or wetland drainage can initiate the programmed senescing process. In other cases water stressing of plants leads to limited to no reproduction of the plant.

- **Recommendation: The USBR should incorporate wetland plant senescence in the model for both UKL and LKL. There seems to be some confusion in the December 2004 draft as to how plant senescence operates. For example, the USBR considers senescence to occur only when the environment is water-limited. However, plant senescence is a physiological occurrence that can be independent from the physical**

setting, meaning that even in wet years the plants will not transpire as much water during the summer/autumn months.

APPENDIX II.

TO:	John Hicks Bureau of Reclamation, Klamath Falls Oregon	Date 8/30/2005
SUBJECT:	Review of Attachment A and D Natural Flow of the Upper Klamath River	
FROM:	R.A. Gearheart, Ph.D., P.E. Hydro Resources International, Arcata, California Consultant for Yurok Tribe	

I appreciate the opportunity to submit these review comments on Natural Flow of the Upper Klamath River's Attachment A and D dealing with evapotranspiration assumptions and methods. These comments to the latest Attachements A and D (August 2, 2002) include information that has been forwarded to BOR personnel over the summer, some information submitted previously, and new review comments.

- **Aquatic Plant ET Rates**

This review attempted to present a methodology to estimate wetland plant ET by considering the plant community diversity in the Klamath Lake wetlands. An example of the range of aquatic plant coverage was determined for Hank's Marsh by using an aerial photograph and a planimeter. Three general plant community categories were measured for Hank's Marsh. Three categories cattail/bulrushes, and wocus coverage's were measured. This reviewer also sent under previous reviews a color infrared plate from Klamath Lake Marshes. It was this reviewer's understanding that either USFW or BOR perform an on the ground spectral analysis which could be used to determine aquatic plant community coverage and the extent of open water (Reference Mark Buettner- Ecological Restoration Office)

Below is an example of how a calculated ET rate (Blaney Criddle Method) can vary. This example has not been normalized to the data collected by Bidlake for local wetland species. This is shown only for the purpose of 1) showing that and agricultural engineering method is questionable when applied to aquatic macrophytes and 2) if wetland plant species have the range of variation found in terrestrial plants than plant coverage and specie specific ET rates need to be used. The full development of this example has been sent to Mark Spears earlier in the summer.

An example of the ET losses from a mixed aquatic community (including a percent of open water as seen in infra-red photos) is shown in Table A. A comparison of three aquatic plant communities and open water for a 1,000-acre site showed a significantly lower value than using cattail/tules and spike rush. The implication of this assumption is that using only two high to moderate plant types over estimated water losses from in-lake Klamath Lake marshes. This statement of only "moderate to high" consumptive uses marsh plant consumptives needs to be modified to include wocus and open water. It is a poor assumption that the wocus community "would not change the overall marsh consumption use values appreciably". The combination of lower ET rates along with percent distribution should be considered prior to arriving at a conclusion.

Table A-Example of Using Various Aquatic Plants ET Using Hank's Marsh Plant Coverage for an Example (1000 acre wetland)

	Rushes & sedges	Tules & cattails	Wocus				
Precipitation (Ac-ft)	ET Blaney - Criddle (inches)	ET Blaney - Criddle (inches)	ET Blaney - Criddle (inches)	Open water ET	ET (Ac-ft)	Storage (Ac-ft)	Water Balance Monthly (Ac-ft)
66.80	6.60	3.08	1.92	3.36	360.55	6562.699	6268.95
153.47	1.33	1.18	0.74	1.22	106.33	6562.699	6609.83
145.34	0.94	0.94	0.59	0.60	73.62	6562.699	6634.42
170.62	1.00	1.00	0.62	0.80	81.60	6562.699	6651.71
103.82	1.09	1.09	0.68	1.42	100.21	6562.699	6566.30
109.23	1.55	1.55	0.97	2.90	161.35	6562.699	6510.58
84.86	2.50	4.31	2.69	4.22	322.02	6562.699	6325.54
106.52	8.70	8.47	5.30	7.38	710.82	6562.699	5958.40
68.61	11.98	10.12	6.32	8.68	886.70	6562.699	5744.61

35.21	14.37	11.29	7.06	9.71	1015.70	6562.69 9	5582.20
45.14	14.19	9.88	6.18	8.28	925.70	6562.69 9	5682.13
65.00	11.29	7.32	4.58	5.51	692.59	6562.69 9	5935.11
						Total/year	

Total ET	**5437.20**

The use of the Blaney Griddle method is not an appropriate method for determining the consumptive losses for aquatic macrophytes. This reviewer has not been able to verify the "antidotal information", 1983 data (Ch2M-Hill), relating to aquatic macrophyte ET rates. It could be that plant coverage distribution is more important than the monthly ET rates. I have interacted with BOR hydrologist on this matter and did not received acknowledgement of an attempt to test a different approach. BOR hydrologist Mark Spears did state that he thought the Blaney-Criddle Method is not an appropriate method for estimating aquatic plant ET rates. Mark Spears also stated that BOR is working with USGS to perform a more exact ET method, surface energy/water balance technique (Bowen Ratio) for a different aquatic plants in the Upper Klamath Lake marshes (Bidlake 2000).

It is this reviewer's observation that specific plant coverage could be as important as the specific ET rate in determining water losses from wetlands. Both these factors plant coverage and specific plant ET rates need to be considered when altering inundations coverage due to lake level variation

This review attempted to present a methodology to estimate plant community diversity ET rates in the Klamath Lake marshes. Three general plant community categories were measured for Hank's Marsh. Three categories cattail/bulrushes, and wocus coverage's were measured; Table A This reviewer also sent under previous reviews a color infrared plate from Klamath Lake Marshes. It was this reviewer's understanding that either USFW or BOR perform on the ground spectral analysis library was performed. Reference Mark Buettner Ecological Restoration Office.

An example of the ET losses from a mixed aquatic community (including a percent of open water as seen in infra-red photos) is shown in Table A A comparison of three aquatic plant communities and open water for a 1,000 acre site showed a significantly lower value than using cattail/tules and spike rush. The implication of this assumption is that using only two high to moderate plant types over estimated water losses from in-lake Klamath Lake marshes. This statement of only "moderate to high" consumptive uses marsh plant consumptives needs to be modified to include wocus and open water. It is a poor assumption that the *Wocus spp.* community would not significantly change the overall marsh ET consumption by reducing the wetland water consumptive use. The combination of lower ET rates along with percent distribution should be considered prior to arriving at a conclusion.

Recommendation- BOR should contact ERO and USFWS to obtain data on aquatic plant distribution to be used to estimate ET rate for the distribution and coverage of various wetland plants prior to the implementation of the BOR irrigation project. Plant specific ET rates should be used for the major aquatic plants found in the wetlands of Upper Klamath Lower Klamath Lake wetlands.

- **Historic occurrence of yellow pond lily (Wocus spp.) and other UKL wetland references**

One of the most important food sources for all the Klamath's was the wocus, or yellow pond lily, as evidenced by the fact that the month in which the wocus is harvested, August, marks the beginning of the Klamath year (Stern 1965). Wocus grow on open, shallow water within marshlands, and the Klamath's' reliance on the wocus would seem to indicate the presence of a substantial amount of appropriate wetland habitat in the upper Williamson. *Some estimates run as high as 10,000 acres of wocus-dominated wetland in the Klamath Marsh area alone.* The wocus ripened in late summer and early fall, and often-different tribal communities would come together to harvest the wocus in reed or dugout canoes. The wocus could be eaten in a variety of ways, but much of it was ground into flour and stored for winter use.

Klamath Marsh has always been a dynamic system, changing in size in response to local climate changes. There is clear evidence in the historic record that the hydrology of Upper Klamath Marsh and its associated effects on marsh plant communities was notably different during the late 1800s from what it is today. *Historically (i.e. late 1800s), water levels were higher, there was a greater area of open water, willow thickets were more prevalent, and the extent of the deep water wocus plant community was much greater than is the case in present times (USFS 1998, USFS 1997, Weddel et al 1998).* It is readily accepted that human intervention with the landscape has played a role in these changes. What is less clear is the extent to which natural climate cycles have played a participating role in this change.

Many hypotheses have been put forth regarding One of the earliest descriptions of the marsh, by Williamson and Abbot in August 1857, described the marsh as "*a strip of half submerged land, about twelve miles long and seven miles broad … covered by clumps of tule and other aquatic plants separated by sheets of water" (approximately 52,000 acres)* (USFS 1997). Map 3-1 illustrates the areas of the Upper Williamson River sub basin that were covered by Government Land Office (GLO) notes and maps in 1892 and 1893. Map 3-2 and Map 3-3 show the historic GLO maps overlain onto current day USGS quadrangle maps (Military Crossing and Wildhorse Ridge quadrangles). GLO notes associated with these maps indicate the edge of open water at an elevation of 4,515 feet in the vicinity of Military Crossing, where water depths were observed to be between 2 to 4 feet (USFS 1997). The GLO information was recorded when water levels were at their lowest during the course of the year, suggesting that this area of open water was permanent. *Coville estimated that in 1902 the marsh contained a solid growth of 10,000 acres of wocus (Coville 1904 from Weddell et al 1998). This is indicative of a large area of water too deep for emergent vegetation to develop, as wocus prefer water depths from approximately 3 to 8 feet (USFS 1997). An example of a wocus plant community is shown in Photo 3-2, a historic photo of the wocus harvest. Coville provided the following description of the wocus plant community. "The plant is so vigorous and has such a habit of growth as usually to occupy an area suited to it to the complete exclusion of other characteristics and conspicuous marsh plants, such as tule and cattail. but these plants are for the most part submerged in the water, are inconspicuous, and subsidiary in their relationship to the waterlily, and in no effective or important way contest its spread. The principal of these latter plants are bladderwort (Utricularia vulgaris), mare's tail (Hippuris vulgaris), and pondweed (Potamogetan natans) and other species."*

Coville 1904 from Weddell et al 1998

A 1912-1913 report prepared by the Bureau of Indian Affairs (BIA) *estimated the area of the marsh at 30,000 acres and described it as being "engulfed with water at all times" and covered with tule, slough grass (Beckmanniasyzigachne), and wocus growths* (BIA in Clyde-Criddle-Woodward, Inc. 1976 as cited in Weddell et al 1998). *Average water depths in tule and wocus areas were estimated at less than two feet,* with channels of greater depth located throughout the marsh. A ring of wet meadow community dominated by sour marsh grass was also observed (BIA in Clyde-Criddle-Woodward, Inc. 1976 as cited in Weddell et al 1998). Map 3-2 and Map 3-3 show that the marsh of the late nineteenth century, in many places, extended far beyond its current boundaries. The GLO maps also *show sizeable willow thickets, particularly where streams enter into the marsh.* According to climatic records (described in detail in Section 2), many of the historic descriptions were recorded during a cool/wet climate cycle, which began in the early 1900s and lasted until approximately 1916). In contrast, the period between 1916 and 1931

was a warm/dry climate cycle characterized by drought. The effects of this drought period on the marsh are telling. For example, USFS (1997) reported that Big Springs Creek completely dried up during a drought in the early twentieth century. A narrative report during this time period (circa 1930) describes the drought as follows: [The marsh is in] a sad state. Ranchers and livestock men were compelled to put down wells and otherwise provide water. Grasshoppers and rodents plagued the then dry marsh. It was possible to travel by saddle horse and automobile over much of the present marsh area.
USDI Fish and Wildlife Service 1960 as cited in Weddell et al 1998

From the mid-1920s to 1930 (during the known period of drought) the quantity of permitted irrigated land acreage in the Upper Williamson River basin (i.e., above confluence with the Sprague River) increased from less than 1,000 acres to approximately 10,000 acres (Risley and Laenen 1999). This significant increase in irrigation may have been a result of an increase in land available for agriculture due to the

Extent of Wetland Inundation UKL

Some sources describe Kirk Reef as a natural control structure for water levels in Upper Klamath Marsh (USFS 1998, USFS 1995a) and there is some debate as to whether it was lowered in the past with the intent of lowering water levels in the marsh. In their Big Bill Watershed Analysis, USFS (1998) indicated the reef was lowered around 1908 by an estimated 5 to 10 feet from its estimated historic elevation of 4,528 feet mean sea level (USFS 1995a). However, in a separate Watershed Analysis, USFS (1997) states that "channel morphology upstream from the control point at Kirk does not support the idea that any potential modification of the Kirk Reef had affected marsh surface elevation." Whether or not Kirk Reef was intentionally lowered is still a question; however, *there is no readily observable evidence to support the idea that modifications to the Kirk Reef have affected water levels in the marsh.*

Following this period of drought, there was a long wet/cool climate cycle that extended from the early 1930s to the mid-1960s. A 1955 USFWS report described the marsh as containing *9,900 acres of shallow marsh and 15,000 acres of deep marsh* (USDI Fish and Wildlife Service 1955, as cited in Weddell et al 1998). *This description of marsh conditions is very similar to those for the marsh at the beginning of the 1900s, both in overall acreage and habitat types.* The comparison between these two time periods is notable because the period from the early 1900s through the 1940s was a period of substantial agricultural development within the marsh area (USFS 1998). This agricultural development included the construction of the Kittredge Canal, major water diversion feature that was dug during the 1940s (Walt Ford pers. comm. 2004). This canal was used to pump water from the north end of the marsh to the south end of the marsh during the spring high water season. This allowed for cattle grazing of the north marsh area. Later in the year, when water levels were naturally lower, a secondary canal diverted water back to the north end in order to irrigate pasture grasses and provide water for cattle (Walt Ford pers. comm. 2004). Although the refuge stopped this practice in the1990s and the pumps have since been removed, the ditch system still remains (Walt Ford, pers. comm 2004). A new warm/dry cycle began in the mid-1960s and has been a brief cool/wet cycle during the late 1990s). As in previous years, it appears this climate trend may be affecting water levels in the marsh. A 1975 Draft Conceptual Plan for the Klamath Forest Wildlife Refuge provided the following description of refuge lands:

…present refuge vegetation is dominated by dense stands of hard stem bulrush, [while] open water vegetation interspersion is virtually non-existent with *an estimated 10 percent of the marsh consisting of open water.*

Anon. 1975 as cited by Weddell 1998

"Tules growing in the lakes and marshes gave the *maklaks* a versatile material. They made canoes of tules, built homes with tules arranged on a framework of poles, covered communal storage pits with tule mats, wore tule leggings and tule sandals, and wove tules into baskets to sift wocus through. Shells of dried wocus seeds yielded a dye for tules used in basket-making.

Great quantities of wocus were stored in those mat-covered pits. Ten thousand acres of the lily grew in Klamath Marsh alone, providing a food so abundant that *maklaks* depended on it to survive when other foods were not available. Also helping the *maklaks* to survive harsh winters at 4,000 feet, with fierce winds and heavy snows, was the faith that their creator had provided them everything they needed." One of the most important food sources for all the Klamaths was the wocus, or yellow pond lily, as evidenced by the fact that the month in which the wocus is harvested, August, marks the beginning of the Klamath year (Stern 1965). Wocus grow on open, shallow water within marshlands, and the Klamaths' reliance on the wocus would seem to indicate the presence of a substantial amount of appropriate wetland habitat in the upper Williamson. Some estimates run as high as 10,000 acres of wocus-dominated wetland in the Klamath Marsh area alone. The wocus ripened in late summer and early fall, and often different tribal communities would come together to harvest the wocus in reed or dugout canoes. The wocus could be eaten in a variety of ways, but much of it was ground into flour and stored for winter use.

Ref.-The Oregon History Project, Oregon Historical Society, Subtopic: Inhabiting the Land: Life on the Waters, Stephen Most, 2003

Some reported ratios evapotranspiration losses over evaporation losses (Numbers less than 1.0 mean that those plants actually reduce water loss.) On the other hand, floating-leaved plants, such as duckweeds and lotus, that have flat, often overlapping leaves, reduces evaporation, because there is less exposed water for evaporation, but also, because the structure and habit is different from immersed and floating plants, do not transpire as much water as would evaporate in the same area. Therefore, lakes with many floating-leaved plants will lose less water than will open water lakes. Lakes covered with duckweed will hold water for a longer time than will open water lakes. Below is a list of aquatic plants with their respective relative ET rate compared to open water. Generally the data shows that the taller the plant the greater the ET rate, using open water as reference (0.0 datum), Table B.

Table B-Example of Aquatic Plant ET rates normalized to openwater evaporation

Eichhornia crassipes (water hyacinth) transpires 1.26, 1.62, and 2.7 times the amount of water as would evaporate over open water
Typha latifolia (cattail) 1.75, 1.8, 2.5, 2.0
Acorus calamus 2.0
Scirpus validus (bulrush) 1.9
Panicum rigidulum (panic grass) 1.58
Juncus effusus (rush) 1.52
Carex lurida 1.33
Alternanthera philoxeroides (alligatorweed) 1.26
Pontederia cordata (pickerelweed) 1.2
Justicia americana 1.17
Nymphaea odorata (water lily) 1.0
Lemna minor (small duckweed) 0.9
Wolffia columbiana (water meal) 0.89
Spirodela polyrhiza (giant duckweed) 0.85

Recommendation-For purposes of review of the model a weighted average ET rate for aquatic plants and openwater should be tested in a model run to determine the sensitivity of this approach compared to the existing assumptions. This method has been demonstrated in an example sent earlier to BOR.

Recommendation-The Wocus plant (yellow water lily) found in Upper Klamath Lakes and environs needs to be considered in these analysis due to its wide distribution and coverage during the period of natural flows. It is this reviewers assumption, that due to its low ET rate compared to emergent aquatic plants such as tules and cattails, that inclusion of Wocus plant coverage and its associated realistic ET rate could be a significant factor in the water balance of the Upper Klamath Lake. Documentation for this recommendations and historic narratives concerning its distribution and wetland coverage around Upper Klamath Lake is found in the following paragraphs.

ET References

Price, J.S., J.M. Waddington. 2000. Advances in Canadian Wetland Hydrology and Biogeochemistry. Hydrological Processes, Hydrol. Process. 14, 1579-1589.

Eitzinger, J., D. Marinkovic, J. Hosch. Sensitivity of Different Evapotranspiration Calculation Methods in Different Crop-Weather Models.

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Bidlake, William R. 2000. Evapotranspiration from a Bulrush-Dominated Wetland in the Klamath Basin, Oregon. Journal of the American Water Resources Association, Vol. 36, No. 6.

Hellsten, Seppo. 2000. Environmental Factors and Aquatic Macrophytes in the Littoral Zone of Regulated Lakes. Dissertation presented to the Faculty orf Science, University of Oulu.

- **<u>Pore Water/Capillary Groundwater Availability for Rooted Aquatic Plants</u>**

The pore water in the wetland peat material is extracted by the wetland plants as transpiration and any surface water is subjected to evaporation losses. As the lake level goes down the replacement water that

flows into the wetlands could be water that has not been accounted for the water balance i.e., inflow, precipitation, and stored volume. It appears that the conceptual model does include or justify a ground water connection to the upland wetlands that were historically connected to the lake. The replacement water in the peat sediment that support the wetland plants could be coming from upgradient groundwater/peat storage elements. Horizontal wetland/ peat horizontal velocities have been estimated to be 0.01 to 1 meter per day (Baird, et.al., 2004; McKenzie, et.al. 2002; Wisem W., 2000). This upgradient replacement volume to the wetland peat storage appears to have either not been accounted for the water balance or considered to be insignificant. Some proportion of this replacement could have come from the lake storage but a significant quantity could have been supplied by upgradient shallow seepage/groundwater sources. Implication of this processes on the water balance is that the ET volume calculated for fringe wetlands ET during the period of lake drawdown might be overstated.
It seems to this reviewer that the slope of groundwater/saturated sediments should be considered when determining the effect of lake level drawdown when estimating the transpiration (ET I guess) of the rooted aquatic macrophytes. The suggest method for showing that effect is start at considering that effect.

Saturated soils, which would have existed in the historic wetland and riparian areas of the Upper Klamath Basin, are a storage component in the water balance of a system. For example the drained lake bed muck (found in the Williamson River Delta) can hold 6.84 inch per foot of soil and 2.04 hydroscopic inch per foot of soil (NCRS Soil Survey for Klamath County). This is opposed to saturated soils in the Poe Valley which can hold 1.35 ft. per foot of soil and 1.09 hydroscopic inches per foot. In other words the lake bed mucks can hold about 5 times more water in a saturated condition than the Poe Valley soils. This amounts to about 25,000 ft^3 of water per acre ft. or $25x10^6ft^3$ of water per 1,000 acre-ft. This is water available for transpiration by the rooted aquatic macrophytes and for lateral drainage to rivers, streams, and lake as the lake elevation falls. The water that moves as inter-flow in the wetland detritus and soil could at a rate of between 1 to 200 ft./day depending on the bulk density of the detrital mat and soils. Hydraulic conductivities have been measured in the vegetated mat of wetland systems in Florida that are on the order of 50 to 100 ft./day.

In the case of the lake-head mucks at the mouth of the Williamson, approximately 7,000 acres there would be approximately $175x10^6$ ft^3 of water in the top one foot of soil under saturated condition. At a lateral flow rate of 50 ft/day it would take about 100 days for the flow originating one mile away, given sufficient slope, to reach the lake and about 20 days for the flow originating 1,000 feet from the river/lake. This slow release of water from the vegetated could serve as a significant desynchronization of inflow into a lake if sufficient lake margin wetland exist

This saturated pore water and detrital water serves as a significant storage component in the system that meters stored runoff water slowly into the lake over he growing season. It appears that this desynchronization of stored water has not been considered in the BOR Undepleted Natural Flow Study of the Upper Klamath Basin.

Recommendation:

BOR should include and evaluate processes in their conceptual model that utilizes upgradient replacement volume for a proportion of the fringe wetlands ET demand during the low lake level conditions. This process should be evaluated as to its significant in the overall water budget. This would require estimating horizontal hydraulic conductivities of the peat/wetland detritus layer in those wetland areas not inundated by surface lake volume (references are included that might serve as a starting point in estimating horizontal conductivities in peat soil).

References for Pore Water Recommendation

Baird, A.J. et. al., Special Issue of *Hydrological Processes* Wetland Hydrology and Eco-Hydology, Hydrological Processes, 18, 211-212 (2004), John Wiley Interscience, 2004.

McKenzie, J.M., et.al., Heuristic numerical models of the hydrological controls over vertical solute transport in a domed peat bog, Jura Mountatins, Switzerland, Hydrological Processes, 16, 1047-1064 (2002), John Wiley Interscience, 2002.

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SOFIA, Ground Water Recharge and Discharge in the Central Everglades, USGS.

INITIAL ASSESSMENT OF PRE- AND POST-KLAMATH PROJECT HYDROLOGY ON THE KLAMATH RIVER AND IMPACTS OF THE PROJECT ON INSTREAM FLOWS AND FISHERY HABITAT

Prepared on behalf of:

The Yurok Tribe

Prepared by:

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March 1996

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INITIAL ASSESSMENT OF PRE- AND POST-KLAMATH PROJECT HYDROLOGY ON THE KLAMATH RIVER AND IMPACTS OF THE PROJECT ON INSTREAM FLOWS AND FISHERY HABITAT

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EXECUTIVE SUMMARY

1. Salmon, steelhead, and other anadromous fish sustained by instream flows of the Klamath River are central to the economy and culture of the Yurok People. These fisheries are in decline. The Bureau of Reclamation's Klamath Project (Project) has had a major impact on the character of seasonal flows in the Klamath River below Iron Gate Dam that in turn has negatively affected fish habitats.

This report summarizes our initial findings regarding how the Project has changed flows in the Klamath River below Iron Gate Dam. It supports analyses and findings which we presented at the Klamath Project Operations Plan (KPOP) meeting on January 16, 1996, and at subsequent technical forums. Our findings may be revised and expanded once we have (a) a better functional grasp of Bureau of Reclamation models, presently undocumented, being used to develop the March 1996 KPOP, (b) further refined an unimpaired flow record in the upper Klamath basin, and (c) obtained additional in-depth information from the research of aquatic biologists on the constraining ecological factors of the river. Our approach may also change as new information becomes available describing water quality and related effects on fish populations.

2. Instream flow needs to sustain tribal trust fisheries are likely to emulate to some degree those which prevailed prior to the Project, as well as prior to a number of subsequent changes in natural flows in other portions of the watershed. The anadromous fish species crucial to the Yurok Tribe were well-adapted to the natural flows in the Klamath River prior to diversions by the Project. Hence, we developed estimates of pre-Project (i.e., pre-1912) flows and how they have changed since inception of the Project. Relative to pre-Project flows, the overall effects of the the Project are an increase in winter flows and a decrease in late-spring and summer flows. These changes may adversely affect both spawning and rearing of salmonids and may compound water-quality constraints to summer habitat in the river. Project operations and other land and water uses during early fall also result in a slight increase in October and November flows in most years, which may impair spawning and egg incubation of fall-run chinook.

3. Under pre-Project conditions, the Klamath basin above Keno seems to have provided about 30 to 40 percent of late-spring and summer flows at the mouth of the Klamath

River, based on detailed analysis of two pairs of hydrologically-similar years (1908/1985 and 1918/1987).

4. There are important long-term cycles in both rainfall and runoff which must be understood to know how the Project has affected and will affect the Klamath River fishery. We have analyzed both rainfall and runoff records of these cycles using conventional hydrologic techniques. Significantly wetter-than-normal conditions occurred during the decades prior to about 1915 and about 1984; sustained dry periods extended from 1915 to 1950 and from about 1987 to the present. Yet there seems to be little or no general appreciation of these cycles reflected in most of the KPOP technical documents or related reports which we have read, and it is likely that provisions modifying operations during such cycles will not be included in the March 1996 KPOP document. Planning for multi-year drier-than-normal periods is needed to avoid undue adverse effects on the downstream fishery, as well as on other users of Project water.

5. Numerous pervious units within the thick sequence of volcanic rocks beneath the upper Klamath basin act like a large reservoir for the Klamath River, storing runoff and maintaining fairly steady outflows to the streams and lakes during seasonal and short-term droughts. Other portions of the Klamath River watershed do not have the extensive aquifers which can maintain flows through multiple dry years.

6. Differences between pre- and post-Project flows have progressively been widening during the past 30 to 50 years. Summer flows below Iron Gate Dam or Keno have become an increasingly small fraction of those in the river at various points downsteam. During drought years, the proportion of summer and early-fall flows originating in the upper basin have progressively lessened, apparently due to water-management decisions made in each successive drought. During the past six years, both daily and monthly minimum flows released by the Project have at times fallen sharply lower than at any time since Iron Gate Dam began operations in the early 1960s.

7. Principal impacts on water-quality which currently affect fish populations seem to be (a) nutrients, elevated temperatures, and indirect effects on dissolved oxygen and pH of the growth which they stimulate, and (b) the wider, shallower channel of the river and the reduced stability of the bed in which eggs of the tribal trust species incubate. While informative as to cause, the pertinent data are sparse and poorly controlled. No information is available on pesticide concentrations in the runoff from the first storms of the

wet season; such data are needed not only because of the susceptibility of the many eggs and swim-up fry in the river at such times, but also because the Project operations have increased the proportion of such 'first-flush' flows entering the stream and have diminished the ability of wetlands to retain and attenuate pesticide and nutrient concentrations. It seems prudent to assess these implied constraints before attempting further biological evaluations which presume suitable water-quality and stable bed conditions conducive to fish propagation and growth.

8. Knowledgeable use of ground water, restoration of a portion of the pre-Project wetland functions and areas, and active recharge of selected aquifer units can help alleviate a number of these Project-related changes which adversely affect fish (including, i.e., undesirable shifts in the annual pattern of flows, disproportionate impacts during droughts, and water-quality constraints). In some cases, increased power generation may more than offset much of the costs of these restorative measures.

9. Important efforts are underway in the upper Klamath basin to increase on-farm efficiency of water use and to reduce further pesticide inflows to the two downstream national wildlife refuges. These efforts merit fullest encouragement and are consistent with management of the tribal-trust species.

10. As measured at Klamath, changes in summer flows associated with the Project are larger (both proportionately and in absolute terms) than those associated with the Trinity Project. Both changes cumulatively affect the condition and use of mainstem habitat within the full length of the Yurok Reservation downstream from the mouth of the Trinity River.

1. INTRODUCTION

This report was prepared by Balance Hydrologics, Inc. (Balance) for Alexander & Karshmer, Attorneys at Law, counsel to the Yurok Tribe on behalf of the Yurok Tribe of Northern California. Its principal aim is to describe the historical nature and quality of instream flows of the Klamath River that sustain (but today sustain only at risk) the anadromous fish species central to the economy and culture of the Yurok People. These fisheries are widely considered to be in decline.

Presented in this report are analyses of hydrologic, geologic, and water-quality conditions developed to identify the extent to which these instream flows depend on or are influenced particularly by the Project. They accompany a report by Trihey & Associates which presents instream-flow recommendations for tribal trust species in the Klamath River below Iron Gate Dam. Balance was asked to prepare the hydrologic, geologic and related analyses to establish the extent to which these needs are influenced by waters used, impounded, or diverted by the Klamath Project. Trihey and Balance were asked to develop a first approximation of the timing and amounts of water that can be released to the Klamath River at Iron Gate Dam to meet the near-term instream-flow needs of the anadromous species of the Klamath River. The two firms were also asked to begin considering what operations of the Klamath Project and other Bureau of Reclamation projects in the Klamath watershed will eventually be needed to meet instream flow and related environmental needs over the longer term. Balance was also asked to evaluate water-quality factors which may affect such instream flows and to suggest approaches to physical solutions that might help ensure that other important water needs of the Project area are satisfied in years when there is no surplus water available. The six primary goals of this study were:

1) to characterize and quantify pre-Project flows in the upper basin for Trihey & Associates, which has been developing instream flow recommendations for anadromous fisheries in a companion study;

2) to develop an understanding of the long-term hydrologic patterns experienced in the basin and what effects they have had and could have;

3) to characterize the importance of sustaining flows emanating from the upper Klamath basin (above Iron Gate Dam) during summers and during dry years, critical periods for certain anadromous species;

4) to identify and describe how Project operations have changed Klamath River flows and to begin considering how proposed changes in operations may further impact flows; and

5) to assess water-quality considerations likely to affect near- and long-term instream-flow needs and to identify some of the more crucial data gaps; and

6) to identify approaches to physical solutions which meet the needs of the anadromous and Upper Klamath Lake fisheries while also helping provide for the consumptive water needs of Project irrigators and wildlife refuges during years when there is no surplus water available for these more junior water-rights holders.

Balance was asked to initiate this study after the Bureau of Reclamation indicated that it did not know how to quantify the reserved water rights of the Yurok Tribe (Mike Belchik, personal communication, November 27, 1995), even though this information was needed to complete the Klamath Project Operations Plan (KPOP). This report and the companion study by Trihey & Associates are intended to provide easier reference to materials presented to Reclamation and other KPOP participants on January 16, 1996. It does not, however, include all technical contributions by the Yurok Tribe or its counsel. As additional data and information become available, the Tribe (a) may seek revision of the analyses included in this document, and (b) may make additional technical comments regarding the hydrology (including water quality) affecting the fisheries and the river upon which they depend.

Specifically, this report presents a description of Klamath River pre-Project hydrology, the changes in flow and water quality on the river due to construction and operation of the Project, a description and discussion of the importance of the upper basin geology to flows in the river, a description of long-term climatic conditions within the upper Klamath basin, and proposed physical solutions which would promote a distribution of flows on the river more representative of pre-Project conditions which were and would be more favorable to the fisheries. This study was completed in close association with Trihey & Associates and their investigation to characterize an instream flow schedule on the upper Klamath River which would best sustain anadromous fisheries on the Klamath River downstream of Iron Gate Dam (Trihey & Associates, 1996). Our report provides much of the hydrologic background used by the Trihey staff to develop their recommendations.

2. GEOLOGIC AND HYDROLOGIC SETTINGS

The geologic and hydrologic setting of the upper Klamath Basin is unique relative to most other large northern California and southern Oregon rivers. As will be described in detail below, pervious volcanic rocks act as aquifers within the upper basin, sustaining flows in the Klamath River which were more conducive to fishery habitat than in other non-volcanic portions of the Klamath watershed. With the advent and development of the Project, the physical setting within the upper basin has been so modified that the important sustaining baseflows during summers and dry years seldom occur when especially needed by instream habitat. This transition is probably contributing to, if not directly causing, the degradation of several anadromous fisheries within the Klamath River system.

Throughout this and other sections of the report, we commonly reference a number of stream flow and precipitation gage records collected in the Klamath River basin. Almost all United States Geological Survey (USGS) gaging records from the Klamath River and tributaries were reviewed to some degree during this investigation. Stream gages with long-term records which most assisted us in our analyses included (from upstream to downstream): Link River at Klamath Falls, Oregon; below Keno Dam, Keno, Oregon; at Spencer Bridge near Keno; below the J.C. Boyle power plant near Keno; below Iron Gate Dam; near Seiad Valley, California; at Orleans, California; and at Klamath, California (Figure 1). We also repeatedly reference a record from a gage on the Trinity River at Hoopa, California, just above the confluence with the Klamath River. All precipitation records referenced throughout the report are presently recording rain gages maintained by the U.S. Weather Bureau and located at Yreka, California; Klamath Falls, Oregon; Medford, Oregon; and Lakeview, Oregon; although older records may have been collected under other aegises.

2.1 Geologic Setting

Straddling the Oregon/California border, the upper Klamath River basin includes approximately 4630 square miles of surface drainage area above Iron Gate Dam (see Figure 1). For purposes of this report, the upper Klamath basin is also considered to include a number of closed, interior-draining valleys, such as Lost River, Butte Valley, and Lower Klamath Lake. In Oregon, the Klamath River basin is located almost entirely in

Klamath County. In California the upper basin occupies the northeastern portion of Siskiyou County and northwestern portion of Modoc County. The main tributaries to the Klamath River within the upper basin are, from north to south, the Williamson, Wood, Sprague, and Lost Rivers.

Under natural conditions, i.e., similar to those which we call pre-Project, the upper basin was the principal source of flow for the lower basin during late summer and fall, in years of below-normal precipitation, and periods of extended drought.[1] The upper basin is underlain by water-holding volcanic rocks, which are the principal source of its disproportionate importance in sustaining flows during dry periods, even though coastal portions of the basin receive much greater precipitation. The upper basin is also at higher elevations, allowing seasonal accumulation as snow, and it is also the site of numerous lakes and wetlands which further store and gradually release the winter's precipitation. The following paragraphs describe these influences. In later sections, their relation to the historical changes in flows and to potential physical solutions is discussed.

The upper Klamath River basin lies within the northwest corner of what is known in geomorphic terms as the Basin and Range Province, immediately east of the Cascade Mountain range. Geologically, the basin consists of a complex series of northwest-southeast trending valleys occupying elongated crustal blocks bounded on both sides by faults and separated by uplifted crustal blocks or ridges. They developed in the late Pleistocene through extension and block faulting of the Basin and Range Province. Typically, the valleys are filled partially with deposits from alluvial fans and lacustrine (lake) clay sediments interbedded with occasional thin volcanic basalt flows. Beneath these surface deposits is a laterally extensive, thick sequence of basalt flows, commonly referred to as the "lower basalt unit," "the High Cascade Volcanics," or more recently the "Basin and Range Basalt." Most of the ridges between valleys are underlain by this lower basalt unit.

The basalts of the upper Klamath River basin commonly are columnarly jointed, fractured, and scoriaceous (covered by small cavities formed by the expansion of gas bubbles or steam during cooling of the lava flow). They are the most prolific water-bearing units in the upper Klamath River basin. Although some of the alluvial fans extending onto valley

[1] Throughout this report we refer to "normal" flow or rainfall conditions, which we define to be a reasonable range bracketing the long-term average for the entire period of available record. The extent of "reasonable range" will vary, depending upon the context and the parameter being described (e.g., rainfall, flow, ground-water levels, etc.).

floors can also serve as productive aquifers, they are not as thick and laterally extensive as the basalts. Typically, basin valleys are covered with a surface layer of fine grained lacustrine sediments which generally respond as low-permeability zones. The highly-permeable nature of the lower basalt unit flows (which predominate in the higher ridge-top areas) recharge and store an unusually high percentage of rainfall and runoff within the basin. The vast expanse and vertical thickness of these flows, together with the abundance of structurally controlled valleys, allow large quantities of seasonal runoff to be recharged and stored as ground water within the upper Klamath River basin. From this storage, the upper basin basalts provide a steady release of ground water through seeps and springs to marshes and tributaries, resulting in naturally high year-round flows uncommon to most other California and Oregon crystalline and sedimentary drainage basins. Analyses of long-term runoff records by Balance and by Craig Bienz, biologist with the Klamath Tribes (personal communication, 1996), indicate that the annual amount of runoff within the upper Klamath basin rivers depends on precipitation during the prior several years. We believe it will prove helpful to evaluate these flows using a weighted function of precipitation during the preceding four years, with current or more recent years weighted more heavily. Appendix A presents a description and example of this function.

In addition to the presence of volcanics, a fairly dependable snow pack occurs each year in the mountains surrounding the upper Klamath River. The combined effects of various snow and geologic conditions on seasonal runoff patterns are illustrated in Figure 2. Figure 2 is is a plot of mean monthly flow hydrographs for the Eel, upper Trinity, and upper Klamath Rivers. The Eel River, underlain by sedimentary and crystalline rocks with relatively little storage capacity, is a good example of a stream with a runoff pattern largely responsive to rainfall. The peak runoff events occur in the wet season followed by late season low flows. The upper Trinity River, also underlain predominantly by crystalline rock, is an example of a stream with a seasonal runoff pattern dictated by snowmelt, with peak runoff occuring during April, May, and June but also having late summer and fall low flows. In contrast, the upper Klamath River has a drainage area largely composed of often-permeable volcanic rocks with a relatively large storage capacity, resulting in a fairly uniform year-round baseflow in the rivers of the upper basin, as discussed above.

The contrast in runoff patterns between a volcanic and crystalline bedrock-influenced drainage can also be seen by comparing daily flows of the Sprague and Applegate Rivers. The Sprague River basin, located in the upper Klamath basin above Upper

Klamath Lake, is largely underlain by pervious volcanic units, while the Applegate River, located in the mountains to the west of the upper Klamath basin, drains crystalline, sedimentary, and non-basaltic volcanic rocks. The mean annual runoffs for the Sprague and Applegate Rivers are quite similar, even though the seasonal runoff distributions of the two rivers vary. Figure 3 is a plot of mean daily flow on the Sprague and Applegate Rivers for water year 1987. Compared to the Applegate River, the Sprague River has a more uniform runoff pattern characteristic of permeable volcanics; lower peak flows during high runoff periods and higher late season base flows. These more uniform and persistant flows on the Sprague can also be seen over multi-year periods. Figure 4 presents a flow hydrograph for the Sprague and Applegate Rivers for water years 1982 through 1990. Here again, runoff on the Sprague River is more uniform from year to year than that on the Applegate River, with lower peak flows during wet years like 1981 and higher sustained flows especially during relatively dry years like 1987 and 1988.

2.2 Long Term Climatic Record

Only a few long-term records have been identified to assist us in characterizing the long-term weather and runoff patterns for the upper Klamath River area: continuous annual precipitation records from 1872 through 1994 for Yreka, California (Figure 5) and from 1905 through 1994 for Klamath Falls, Oregon (Figure 6), and an estimate of annual runoff from the upper basin to Upper Klamath Lake for the period 1906-1995 used by Bureau of Reclamation staff in modeling (Figure 7). The rainfall records[2] were taken from two sources: the data for rainfall years 1871 through 1948 came from the California Department of Water Resources Bulletin 58, and the 1948 through 1994 period was taken from EarthInfo's CD ROM entitled, "NCDC Summary of the Day, West 1." The Bureau of Reclamation's inflow data were taken from the 1995 KPOP Workbook.[3]

[2]Precipitation data are presented (as is customary) for rainfall years, which end on June 30th of the named year. For example, rainfall year 1996 will end on June 30, 1996. Most other numerical data in this report are presented for water years, which end on September 30th of the named year. Water year 1996 (WY1996) will end on June 30, 1996. Little rainfall occurs in the Klamath basin during July, August, and September of most years.

[3]Based on the following assumption, "inflow - outflow = change in storage," the Bureau estimated the net inflow to Upper Klamath Lake from known historic changes in reservoir storage and measured outflow (i.e., evaporation and evapotranspiration are not dealt with as independent outflow variables). However, based on conversations with Reclamation staff, the only outflows considered were releases through Link River Dam and diversions to the A Canal. "Lesser" diversions, such as annual out-of-basin deliveries to the Rogue River Valley, were not considered. It is also unclear to us how the Bureau extended the inflow record back to 1906, since Link River Dam was not completed until 1920.

Precipitation and runoff records were analyzed to characterize long-term trends by tabulating the cumulative deviation from their long-term averages. The cumulative deviation for a given record is calculated in the following manner. First, the average for the the entire rainfall/runoff period of annual record is calculated. The long-term average is then subtracted from each annual rainfall/runoff value to calculate the annual deviation from the long-term norm; positive results indicate that the year had higher amounts of rainfall or runoff than the long-term average, negative results indicate that the year experienced lesser amounts. By keeping track of the chronological sum of annual deviations, the cumulative effects of prolonged wet or dry periods are easily identified.

Figures 8 through 10 are the results of this analysis and represent deviations from the long-term average for the Yreka, Klamath Falls, and Upper Klamath Lake inflow records, respectively. These figures clearly indicate similar long-term wet-and-dry cycles: a period of above-normal precipitation and runoff from approximately 1905 to 1917, followed by a long-term period of below-normal rainfall and runoff (1918 through 1950), followed by another period of above-normal rainfall and runoff (1951 to 1985). In addition, the Yreka precipitation record suggests a prolonged dry period extending from at least 1872 through the early 1890's.[4] Important oral-history evidence from interviews with Yurok tribe members indicates a period of below-normal rainfall during the late 1840s/early 1850s, with at least one drought year with consequences of far greater severity than recorded in recent times. Both traditional and historical sources identify a period of above-normal rainfall in the 1860s. These cycles are also indicated on Figure 8 and further described in Appendix B.

While there have been wet and dry cycles since 1960, the length and degree of these fluctuations has been markedly less than during the prior century (see Figures 8 and 10). The most recent drought period (1987 through 1992 or 1994) is also evident on the Yreka precipitation and Upper Klamath Lake inflow deviation curves in Figures 8 through 0,

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[4]These wet and dry cycles correspond approximately to periods of certain predominating atmospheric circulation patterns thought to have affected both annual precipitation and the magnitude and frequency of major storms in northwestern California (Coghlan, 1984). This study, by Redwood National Park Staff, made a distinction between periods with predominantly zonal circulation (typified by mid-latitude storms) and those with meridional circulation (typified by either high-latitude storms moving down the coast, or low-latitude storms originating near Hawaii). Based on these patterns and the regional hydrologic record, Coghlan recognized four periods: 1861 to 1890 — many severe storms (but perhaps less than normal rainfall); 1890 to 1915 — few major storms, but annual rainfall totals 'consistently well above the average;' 1915 to 1940, or possibly 1950 — precipitation 'well below average,' with 'uniformly small and infrequent flood events;' 1950 through the mid-1980s (time of publication) — prevailing meridional circulation, with above-average precipitation and number and size of storms.

respectively. However, it is quite noticeable how smooth and steady the cumulative runoff deviation curve is compared to the Yreka and Klamath Falls rainfall deviation records. The smoothness of the Upper Klamath Lake deviation record is directly related to the ground water storage capacities and persistent flows of the upper Klamath River basin discussed above. Thus, the geology of the upper Klamath River basin effectively smooths or dampens peaks in runoff associated with the seasonal and longer-term wet-and-dry cycles commonly seen in the Klamath River tributaries downstream of the Shasta River which drain non-basaltic type rocks.

For example, relatively high inflow totals to Upper Klamath Lake in 1910 and 1916 indicate that the upper Klamath lake drainage continued to release ground water from storage at above-normal rates even when rainfall totals for these years were below normal (normal being defined as the long-term averages). Conversely, inflow to Upper Klamath Lake is maintained at a fairly steady level throughout the 1938 to 1943 period, a time of above-normal rainfall. The effect of this increased rainfall is barely noticeable on the long-term runoff record to Upper Klamath Lake (Figure 10) as it occurs during a long-term drought cycle when ground water reserves were probably significantly depleted.

The existence of long-term wet-and-dry cycles can significantly affect the calculation of average basin rainfall and runoff. For example, if natural flow conditions on the Klamath River are characterized based on a historic record when rainfall and runoff were above normal (i.e., 1906 through 1918), estimates of average flow will be higher than those calculated from a record during a period of average rainfall and runoff. The implications of such an overestimation (or underestimation if calculated over a prolonged dry period) not only affect the characterization of normal conditions, but skew the characterization of wet, dry, and critically dry year-type conditions. However, if the only data set available does not represent average conditions, adjustments such as correction factors (or indices) can be derived from a longer-term record which coincides with the period of interest but which also is long enough to approximate average conditions. Similarly, rainfall and runoff extremes need to be accounted for when characterizing wet or critically dry conditions. A period of record which does not contain long-term wet or dry cycles will significantly underestimate extreme conditions.

Current operational criteria utilized by the Bureau of Reclamation are based on hydrologic assumptions developed and calibrated from periods of record beginning in 1960, when Iron Gate Dam began operation. Data from earlier years, when morepronounced and longer climatic cycles were prevalent, are not included. Operational decisions would benefit from applying a more representative range of cyclic and episodic conditions. Commitments of water made without due consideration of the traditional and historical record can disproportionately jeopardize resources depending on flows from the upper basin. They may also conflict with existing entitlements.

3. PRE- AND POST-PROJECT FLOWS ON THE KLAMATH RIVER

This section of the report presents the results of our analysis of pre- and post-Project flows. Characterization of these flows was required in order for Trihey & Associates to develop recommendations regarding instream fishery flow needs. This section of the report also documents changes to flow on the Klamath River as induced by completion and operation of the Project. We illustrate these changes in a variety of different ways.

3.1 Pre-Project Flows

The characterization of pre-Project flows on the Klamath River is important to understand the conditions under which fish have evolved and thus the conditions they will need for continued existence. The earliest and most reliable flow record for the Klamath River within the Project is from the USGS gage at Keno (1905 to 1914), although it is likely that flow at this gage even in 1906 was discernibly influenced by upstream diversions for irrigation. However, flows were probably not extensively altered from natural conditions until approximately 1912 , when the Lost River Diversion Dam was built. Thus, the 1905 through 1912 period is currently the best approximation of pre-Project "natural" flows at Keno. The mean monthly flows at Keno for the 1905 through 1912 period are presented in Table 1.

We believe that prior to the Project, flow on the middle reaches of the Klamath River was notably persistent, displaying relatively little seasonal variability in base flows relative to other nearby California and Oregon rivers. Figure 11 is a plot of mean monthly flows as a percentage of the mean annual flow for the period for the Klamath River at the Keno gage from 1905 through 1912. This figure illustrates how little mean monthly flows changed on the upper Klamath River throughout the year. Also plotted on this graph are the minimum and maximum monthly flows for the same period. Again, there is little variability in the distribution of flow during any given month, including rainy seasons which are typically characterized in most other river systems by high runoff.

It should be noted here that Yreka rainfall and inflow to Upper Klamath Lake records suggest that the 1905 through 1912 period was one of slightly greater-than-average rainfall and runoff in much of the upper Klamath basin. Mean monthly and annual flow values at the Keno gage for 1905 to 1912 are slightly above the actual long-term averages, although the relative distribution of total annual flow throughout the year or the relative relationship between mean, minimum, and maximum monthly flows are unlikely to be affected. The annual values, however, can be normalized to a period of average rainfall using annual precipitation indices. We accomplished this by dividing the average flow/annual precipitation during the 1906 through 1912 period by the average flow/annual precipitation value derived over a long-term period. Indexing of this type is commonly applied by hydrologists in basin studies (cf. Bulls. 1, 58).

We derived such indices from the Bureau of Reclamation's annual inflow record for Upper Klamath Lake (1906 through 1995) and long-term annual precipitation records for Klamath Falls (1905 through 1994) and Yreka (1872 through 1994). Indices derived from precipitation records suggested that conditions between 1905 and 1912 were wetter in northern California at Yreka (index 1.21) than in southern Oregon at Klamath Falls (index 1.04); i.e., the higher the index above 1.0, the wetter the 1905-1912 period relative to the long-term average. If this trend of decreasing relative wetness to the north and east is extrapolated up into the upper Klamath basin, we could surmise that much of the upper basin experienced normal conditions (index of 1.0) during the 1905-1912 period.[5] The index derived from the Bureau of Reclamation's inflow record was 1.34 for this period, suggesting much wetter conditions than either of the rainfall records would suggest. However, this index is probably inflated for the following reason: inflow to Upper Klamath Lake has continuously decreased during the 20th century due to upstream diversions and withdrawals from the Sprague and Williamson River systems. This artificially reduces the long-term inflow average which, as the denominator in the index calculation, leads to an inflated index.

One of the key uses of the Keno pre-Project flow record has been to characterize "natural flow" conditions in the upper basin. Currently, anadromous fish are restricted from migrating any further upstream than Iron Gate Dam. Thus, all anadromous fishery-related flow issues on the upper Klamath River are restricted to discussions of flow emanating from Iron Gate Dam. To estimate pre-Project flows at Iron Gate Dam,

[5]We chose to use the Klamath Falls index because it is closer to the center of the upper basin and appears to be an accurate and primary record. It is preferable to the longer but more distant record from Yreka, which also includes data of lesser quality for the years 1911 and 1912. There were no established stream gages operating in the upper Klamath basin during 1905-1912; the estimates of inflows to Upper Klamath Lake constitute a record computed in several steps or ways from power company observations and with little subsequent review or reinterpretation.

historical accretions between Keno and Iron Gate Dams must be added to the Keno flow record. However, because no stream gaging was initiated at Iron Gate Dam until 1960, there is no simple way of estimating pre-Project accretions between the dams. On behalf of the Bureau of Reclamation, CH2M Hill has completed and presented the results of their analyses characterizing wet, normal, dry, and critical year accretions between Keno and Iron Gate. These analyses were completed using USGS flow records during post-Project conditions, specifically the period 1960 through 1995. Until a better method or approach is devised, these estimates are the best approximation of natural accretions between Keno and Iron Gate Dams.

After adding accretions to the pre-Project flows at Keno, we conclude that mean annual flow in the Klamath River at Iron Gate was approximately 1.8 million acre feet per year prior to inception of Project operations (Table 1). This value does not account for diversions upstream of the Keno gage during 1905-1912. The estimate is expressed as a value with two significant figures since that is the apparent precision of the data upon which it is based.

3.2 Post-Project Flows

3.2.1 Project History

Construction of numerous facilities associated with the Bureau of Reclamation's Project between Upper Klamath Lake and Shasta River have significantly altered natural flow patterns on both the upper and lower Klamath River. Key facilities constructed on this stretch of the Klamath River include: the A-Canal (1906/1907), the Lost River Diversion Dam (1912), Copco No. 1 Dam (1918), the Link River Dam (1921), Copco No. 2 Dam (1925), J.C. Boyle Hydroelectric Dam (1958), Iron Gate Dam (1962), and Keno dams (1967). Numerous other diversion dams, pumping plants, and hydroelectric facilities built on upper Klamath River tributaries also affect flow on the Klamath, but the ones listed above are the largest.

The first key Project[6] facility that significantly impacted flow on the Klamath River was

[6]The Klamath Project was authorized under provisions of the Reclamation Act of 1902 (32 Stat. 388). One of the first sub-projects to affect flow on the Klamath was initial construction of the Fall Creek Diversion Dam and powerhouse in 1902. Fall Creek is a tributary to the Klamath River located about 0.4 miles south of the Oregon/California border. We assume this sub-project's hydrologic and water quality effects were localized.

the A canal constructed in 1906 and 1907. It conveys water out of Upper Klamath Lake to areas to the southeast. In 1912, the Lost River Diversion Dam was constructed to direct potential flood waters from the Lost River to the Klamath River at rates up to 3,000 cfs. The next project facility built was Copco Dam No. 1, completed in 1918 on the Klamath River and located 35 miles downstream of Upper Klamath Lake. Link River Dam was constructed at the outlet of Upper Klamath Lake in 1921 and controls an active storage capacity of 465,000 ac-ft (draft KPOP "Key Facilities" technical memo, 1995). Link River Dam diverts water for the East Side and West Side power plants. In 1925 Copco Dam No. 2 was completed a quarter mile downstream of Copco No. 1. Each of the Copco dams impounds and regulates approximately 20,000 ac-ft of water for peak power generation. In 1958 the J.C. Boyle Dam was constructed one mile south of the Oregon/California border to store and divert water for the J.C. Boyle powerhouse. Iron Gate Dam, located about seven miles downstream of Copco No. 2 was completed in 1962 to regulate the peak flows from operation of upstream power plants and to divert water to its own powerhouse. The last project to be built on the main stem of the upper Klamath River was Keno Dam. Completed in 1967, it regulates flow of the Klamath River and maintains the elevation of Lake Ewauna.

Figure 12 illustrates how these dams alter the flow of the upper Klamath River. This figure presents hydrographs of mean and minimum monthly flows at the USGS gage at Keno, Oregon, operated from 1905 through the present. Although there is a break in the USGS record for this gage from 1915 to 1930, the 1905 to 1912 period documents flow on the Klamath River at Keno prior to completion of the Lost River Diversion Dam, while the 1930-to-present record illustrates how the flows changed after construction of the Lost River and Link River dams. The two most dramatic changes illustrated by Figure 12 are 1) reduction of minimum monthly flows by over an order of magnitude and 2) alteration of the natural seasonal variation of the flow hydrograph through regulation of the river to meet peak power and diversion needs. Even with the addition of accretions from downstream tributary inflow, changes in the Klamath River flow pattern occur at least as far downstream as the USGS gage near Seiad Valley (see Figure 13, which highlights the 1912-1926 period).

The cumulative effect of all these facilities on Klamath River flow mimics and even enhances the changes seen in the post-1930 hydrograph for the Keno gage. As designed, Iron Gate Dam helped mitigate the high variability of flows downstream from the Project facilities, but it did not restore the natural runoff pattern seen in the pre-1912 hydrograph (Figure 12).

3.2.2 Changes in Flow at a Station Over Time

Changes in flow induced by the Project have evolved steadily with time in direct response to the construction of dams, diversions, and agricultural development in the area. The main changes in flow on the Klamath are best exemplified by the progressive changes in mean monthly flows at Keno Dam. Figure 14 is a graph of average mean monthly flows at Keno during three different periods between 1905 and the early 1990's. The 1905 to 1920 period curve represents pre-Project conditions which are compared to curves for the post-Project periods 1921 to 1950 and 1951 to the early 1990's. The intermediate position of the 1921 to 1950 curve in Figure 14 illustrates the transitional change from pre-Project to current conditions, as well as the proportionately smaller winter and snowmelt peaks which typify this relatively drier period.

To analyze the effect of Project operations on Klamath River flow at a given station through time, we used another approach:

- We first selected and assessed USGS flow records on the Klamath which are long enough to include pre- and post-Project conditions. Pre-Project conditions were considered to be the period of record prior to the end of 1918, or 1912 for winter flows. USGS gages on the Klamath River meeting these requirements included the Keno, Seiad Valley, and Klamath gages. We also included the Hoopa gage on the Trinity River to assist us in distinguishing how Bureau of Reclamation operations in the upper Trinity basin affect flow on the Klamath River at Klamath.
- Next, we calculated exceedance intervals[7] for the years 1906 through 1995 using both the Yreka and Klamath Falls rainfall records and the Bureau of Reclamation's records of annual inflow to Upper Klamath Lake. Our objective here was to select similar pre- and post-Project water year types for comparison. We paid close attention both to matching water year types and to selecting years

[7]Exceedance intervals (typically calculated from statistical analysis of recorded total annual flow values and expressed as percentages) indicate the probability that a certain flow will be exceeded during any given year. For example, a 75% exceedence interval means that flow will be reached or exceeded 75% of the time and is representative of a dry year. For purposes of this report, we define wet, normal, dry, and critical years as those years having at least 20%, 50%, 75%, and 90% exceedance intervals.

which had experienced similar earlier short-term and long-term conditions (e.g. both 1916 and 1985 are years which experienced above-normal runoff, below-normal precipitation and were preceded by four to five years of above-normal precipitation and runoff). The pre- and post-Project years we selected for comparison included the 1916/1985 and 1918/1987 pairs for each of the stations discussed above, with the exception of the Keno gage, which is discussed below. According to our calculated percent exceedances, the 1916/1985 year pair approximates above-normal runoff conditions (approximately 33% exceedance) while the 1918/1987 pair represent below-normal runoff conditions (i.e., approximately 66% exceedance values).

Because the Keno gage was not in operation in 1916 or 1918, we selected the 1908/1985 year pair for analysis at Keno. According to our calculated percent exceedances, the 1908/1985 year pair also approximates above-normal runoff conditions (approximately 33% exceedance). No below-normal runoff analysis was performed for the Keno gage, due to a lack of sufficient records from the pre-Project period.

The final step of the analysis was to plot mean, minimum, and maximum monthly flow volumes at a given station for each of the year pairs selected and thus characterize observed project-induced changes in flow patterns.

Results

Results of our at-a-station analyses are presented on Figures 15 through 20. Comparison of mean, minimum, and maximum monthly flows at Keno for the 1908/1985 year pair is presented in Figure 15; flows at Seiad Valley for the 1916/1985 and 1918/1987 year pairs are presented in Figures 16 and 17, respectively; flows on the Klamath River at Klamath for the 1916/1985 and 1918/1987 year pairs are presented in Figures 18 and 19, respectively; and flows on the Trinity River at Hoopa for the 1918/1987 year pair are presented in Figure 20. From analysis of these plots, we made the following observations:

- The 1908/1985 year pair analyzed at Keno (Figure 15) indicates that prior to the Project, there was much less variability between mean, minimum, and maximum flows than after the project (as previously observed in Figures 11 and 12 and discussed above).

- Most figures presented above suggest that the timing of peak and low flows changes significantly after construction of the Project. For example, prior to the Project, flows were usually higher during the late spring/early summer months (May through July). Project operations decrease late spring and summer flows and increase flows in October and November, and perhaps in September.

3.2.3 Downstream Changes in Flow Patterns

Approach

We analyzed the effect of Project operations on downstream flow patterns in the Klamath River by comparing mean monthly flow hydrographs for each of the Keno, Seiad Valley, Klamath, and Hoopa gages for the years 1913, 1918, 1985, and 1987. Again, the 1913/1985 year pair approximates pre-and post-Project conditions during an above-normal runoff period, while the 1918/1987 year pair reflects conditions during a below-normal runoff period. We plotted together all available gage records from these four stations for each given year.

Results

Results of these analyses are presented on Figures 21 through 24: mean monthly flows for 1913 at all four stations are plotted in Figure 21, while flows for water year 1985 are presented in Figure 22; flows for water year 1918 at all gages except Keno (no record for this period) are presented in Figure 23 and for 1987 in Figure 24. In order to better illustrate changes during low flows, magnified scales are presented in the lower diagram of each figure.

Our analyses of downstream changes in flow on the Klamath River confirmed many of the findings from the at-a-station analyses presented in the preceding section. Specifically, Project operations reduce late spring and summer flows (May through July or August) and increase October, November, and possibly September flows.

3.2.4 Changes in Flow Recession Rates

We used two methods to analyze changes in flow recession rates following seasonal peak flows at the Klamath gage due to completion of the Project. First, we developed daily flow hydrographs for water years 1916, 1918, 1985, and 1987 for the Klamath

River at Klamath gage. Second, we developed graphs of monthly flow as a percentage of mean annual flow for the 1916/1985 and 1918/1987 year pairs (Figures 25 and 26, respectively). Once again, these figures suggest that Project operations alter the natural flow pattern on the Klamath River by reducing late spring/early summer flows while enhancing late summer/early fall flows.

3.2.5 Keno Flows as Percent of Flows at the Klamath River Mouth

The proportion of flows at the mouth of the river (as measured at the Klamath River at Klamath gage) originating in the upper Klamath basin above Keno has decreased over the years, largely as a result of the Project. Figure 27 shows how these flows have diminished by month for two wet periods, once preceding substantial Klamath Project diversions (1911-1913), and the other (1983-1985) being the most comparable recent period. During droughts, the proportion of flows at the mouth originating above Keno have progressively decreased, illustrated in this figure as a comparison of the 1976-1977 and 1991-1992 dry periods. We note that flows at Keno are also affected by diversions upstream of the Klamath Project, and there have been significant diversions from basins downstream as well.

4. CAUSES OF SEQUENTIAL CHANGES IN FLOWS

The processes leading to the changes in flow patterns discussed above are all related, directly or indirectly, to operation of the Project. The construction of Project dams and diversions obviously have a direct effect on Klamath River flow. These structures were also designed and are operated to store as much wet season runoff as possible for subsequent diversion in the summer. However, the relatively low storage volume of Project reservoirs does not come close to compensating for late season diversions. Thus, the decrease in summer flows are a direct effect of project diversions.

The Project has also been supplying progressively expanding and intensifying agricultural development. For example, even prior to the recent droughts, diversions into the A Canal have gradually increased over the years from about 190,000 acre feet in 1929 to about 290,000 acre feet in 1989 (c.f., Gearheart and others, 1995, fig. 3.3). Diversions tend to be greater during dry years, when irrigation demand is often highest, but this is also when the needs of the downstream fisheries are at their greatest.

Expanding agricultural activities both within and beyond the Project boundaries has also led to the draining of wetlands and lakes which, ironically, at one time provided stored water and which ultimately sustained late season flows in the Klamath River. The lakes and wetlands also retained much of the runoff from the first storms of the year, probably improving water quality and holding back some of the flows which now cause 'flashy' rises and falls of the river while most chinook eggs are in the gravels. The post-Project increases in storm runoff early in the rainy season are also attributable to decreased infiltration capacity of Project soils. The soils now retain considerable moisture from summer irrigation, and can absorb less rainfall. Additionally, many fields are pre-irrigated in October, further reducing infiltration from the early-season storms, and increasing the proportion of runoff.

During the wet season months, the Project effectively operates like a flood control project. Spreading peak runoff into the river and reducing the natural storage of water in the upper basin, it contributes to higher wet-season flows at the Keno gage today than during the pre-Project period. This has also led to the diversion of water not only to satisfy irrigation needs but also to sustain wetland habitat in the Lower Klamath Lake, Tule Lake, and to some extent, Clear Lake National Wildlife Refuges.

Historically, the latter two wetlands were sustained primarily by direct runoff from the Lost River and its tributaries. However, the draining of the Lost River system to the Klamath River during the wet season now requires that additional dry season diversions be made from the Klamath River to sustain refuge habitat at Lower Klamath and Tule Lakes.

5. CHANGES IN WATER QUALITY ASSOCIATED WITH THE PROJECT

5.1 Implications to Fisheries

Water quality affects the populations of several anadromous species, especially those resident during the summer months, such as spring-run chinook, coho, and steelhead. Principal water quality parameters of concern are:

- *Water temperature*: Water temperatures constrain summer rearing and fall spawning. Summer water temperatures often reach higher than acceptable levels for the rearing of most salmonid species; and occasionally they reach levels lethal to juveniles. Water temperatures are usually above those lethal to eggs until mid-October, and sometimes later.

During summer, intermittent water-temperature measurements in the Klamath River at sites downstream from the Iron Gate gage often record daily peaks above 25°C or 26°C during July and August (Clawson and others, 1986a), even during wet years. Temperatures above 24°C are thought to cause extreme physiological stress among young salmonids and are not acceptable; the California Department of Fish and Game will generally not plant salmon or steelhead when stream temperatures exceed 20°C.

The mortality of incubating salmonid eggs increases as water temperature rises from 13.3°C (56°F) to 15.6°C (60°F), often considered as the lethal limit. Since water temperatures downstream from Iron Gate Dam are reported to exceed this range through mid-October, the periods during which successful incubation occurs have narrowed markedly for spring-run chinook, which spawn from mid-August through late-October and for fall-run chinook, which spawn from mid-September through early-December.

The extent to which Project operations affect summer and fall water levels is complex, and remains unclear.[8] Certainly, key habitat areas and cool tributaries within which spring and fall chinook formerly spawned are no longer accessible. The presence and operations of Iron Gate Dam and Reservoir and other impoundments preclude the spawners' use of those cooler reaches fed by ground water which, prior to the Project, likely persisted in dry years and provided vital habitat. It is evident that water temperatures add to stresses imposed by other water-quality factors associated with the Project, described below, and that measures which might reduce summer and fall water temperatures could potentially offset other project effects and/or contribute to restoration of the summer-resident species and of chinook.

- *Nutrients and biostimulative effects:* Overall nitrogen and phosphorus concentrations in the main stem of the Klamath River are higher than reported in most coastal drainages (Clawson and others, 1986a; Regional Water Quality Control Board, Basin Plan, 1993) and likely are considerably higher than under pre-Project conditions. These nutrients stimulate growth of aquatic plants throughout the reaches downstream from Iron Gate Dam. Photosynthetic activity by the plants now creates large daily fluctuations in pH and dissolved oxygen concentrations, especially on warmer days (e.g., Figure 28). For much or most of many days, values of pH commonly exceed the objective of 8.5 units sought in the Basin Plan (Regional Water Quality Control Board, Basin Plan, 1993) . The Basin Plan's dissolved oxygen objective of 8 mg/l may not be met as concentrations fall below 5 mg/l for periods of several weeks at a time during the key summer months (see Figure 28), the level at which direct mortality of salmonids may be expected. Direct mortality can also be caused by un-ionized ammonia, which becomes increasingly lethal at high pH and elevated water temperatures.

- *Trace elements and related constituents:* We anticipate that trace elements from the Project area will not be a major concern, based on results of scattered analyses in the Oregon basins and more detailed analyses for the Alturas Valley (Clawson and

[8]The Klamath has probably always been a relatively warm river. Insolation (solar radiation) and ambient air temperatures are primary factors affecting water temperature in most rivers, including the Klamath; both of these climatic factors are independent of Project operations, and increasingly govern water temperatures with distance downstream from Iron Gate. On the other hand, it is reasonable to suppose that the anadromous species evolved so they could cope with this natural warming and that Project operations that compound or change the timing of warming and other stress factors have had and will continue to have an adverse effect on the long-term viability of the salmonid populations of this river.

others, 1986b) and for Shasta and Butte Valleys (Poeschel and others, 1986). Geologic conditions are generally not conducive to trace-element sources or mobility. One possible exception is agricultural drainage, in which occasionally-elevated levels of mercury and arsenic have been reported by federal scientists in the Tule Lake and/or LKL areas (Sorenson and Schwarzbach, 1991; [California] North Coast Regional Water Quality Control Board, 1993), but effects on fisheries in the Klamath River are unlikely.

In the mid-1950s, "drainage and leaching from abandoned copper, gold, and silver mines" were regarded as "major sources of surface water quality impairment" in the Klamath watershed (DWR, 1957). "Mine leaching ordinarily causes a considerable increase in mineral content and turbidity. Minor dredging operations on the Scott and Trinity Rivers also create a quality impairment of these major streams similar in nature to that caused by mine waste discharges" (ibid.). Recent water-quality analyses have, however, shown very low levels of trace elements in the main stem of the Klamath River, and it is unlikely that instream flows will be needed to control metals or drainage from abandoned mines, as is done on the Sacramento River.

- *Pesticides and other synthetic organic chemicals:* Summaries of work to date state that pesticides in current use in the Project area do not exert toxicity. A brief summary of contemporary thinking about Tule Lake effluent is included in a recent UC Extension document: "Based on results from an intensive monitoring effort conducted cooperatively by the United States Fish and Wildlife Services (USFWS) and the USGS in 1991 and 1992, pesticides in current use have not been detected in amounts of toxicological significance in water in the TID or Tule Lake." (Kaffka and others, 1995).

These findings are reasonable and consistent with the considerable efforts being made by the agricultural community in the Project area to control the quality of summer tailwater. These efforts also are helping to protect the quality of water in the Tule Lake and Lower Klamath Lake refuge areas. The findings should not, however, be taken to mean that no adverse effects on the Klamath River fishery should be expected, because no information seems to have been developed on the quality of runoff entering the Klamath, especially during the initial storms of each season.

Persistent compounds no longer in use, notably chlorinated hydrocarbons, may be of considerable habitat-management concern in certain channels, wetlands, and estuaries downstream from irrigated areas throughout California and Oregon. We have not yet seen the primary data collected by the field investigators, so we cannot develop an independent opinion as to potential effects in the Klamath River system.

The first-flush issue, concerning the quality of runoff during the initial storms of each season, calls for investigation as soon as possible. As discussed above, flows in the Klamath River during the initial months of the rainy season are greater than they were prior to the Project, and they constitute a much larger proportion of annual flows. If our inferences regarding the processes responsible for these recent fall 'peaks' are valid, runoff comes disproportionately from irrigated lands and the associated waterways. Additionally, these flows pass down the river during months when eggs are incubating in the gravels, or swim-up fry are emerging from the bed; these two life stages are especially susceptible to many pesticides from either former or current use. Finally, many of the physical solutions which we raise in the next section are based on retaining and/or recharging this early-season runoff; how these waters are routed and managed should depend very much on their quality.

5.2 Implications for Human Health

Summer flows are needed as well to protect the health of people who enter the Klamath River. We are told of one occurrence near Seiad Valley in which several individuals who spent considerable time in the river during the summer of 1994 contracted a disease which a local public-health official eventually attributed to a cattle-borne pathogen. Long term residents from this area believe that the source of this outbreak was likely the Scott River and attribute its occurrence to insufficient dilution in the Klamath River due to the very low flows which prevailed during the summer of 1994 (oral comm., Richard Myers, Yurok Tribal Council).

5.3 Need for Additional Water Quality Information

Key questions to resolve before making mid- or long-term decisions regarding instream flows include:

- How do operations of the Project affect downstream concentrations of biostimulants and related daily fluctuations of dissolved oxygen, pH, and un-ionized ammonia?
- What is the quality of runoff during the first fall storms? Do these waters contain constituents which may harm incubating eggs or adult spawners? Are

they suitable for retention and recharge?

- Are there concentrations of arsenic, selenium, or other trace elements which may impair beneficial uses in Lower Klamath Lake National Wildlife Refuge or in Tule Lake, or which may require supplemental diversions from other sources during dry years?

- How might the problem of excessive temperatures best (a) be quantified, and (b) be acted upon, through measures such as managing flows, small-scale alluvial pumping into sloughs, making the channel narrower and deeper, management of riparian woodlands along the main stem and tributaries?

- Are there lingering contributions from mining downstream from Iron Gate of heavy metals or other trace elements of concern from public health, fisheries, or regulatory perspectives?

6. PHYSICAL SOLUTIONS

Much of the work which we have previously presented to KPOP and further discuss in this report indicates that flows from the upper Klamath basin have been significantly changed by Project operations. At the request of the Yurok Tribal Council, which seeks to help guide the Project toward proactive and restorative measures, we have identified several proposed approaches or measures which may reduce the negative effects of Project operations on aquatic habitat. These efforts focus upon (a) diminished late-spring and summer flows and (b) increased runoff during the fall months, which together adversely affect habitat values during most years. Similarly, we continue to seek measures which will help emulate the pre-Project hydrologic functions, such as sustaining flows during dry seasons or more extended droughts. Proposed physical solutions are outlined and discussed below.

6.1 Increasing Water Storage in the Upper Klamath Basin

As described above, the Project and expansion of irrigated agriculture in the upper Klamath Basin have reduced the persistent and sustained outflow during summer and during droughts. Specifically, small reservoir volumes and flood control requirements preclude the retention of early season peak flows, while irrigation deliveries deplete critical summer flows. One approach to this set of problems would be to increase usable storage capacity of natural depressions, aquifers, and/or existing facilities in the upper basin.

Expanding the area and/or volume of Upper Klamath Lake would enable the retention of more early season runoff for release later in the season. If storage in Upper Klamath Lake is increased, it should be done in a manner consistent with public safety and with fish and wildlife needs. Where safe and where owners are willing, existing levees might be breached, reclaiming the natural marshlands which have been drained and cultivated. In addition to an increase in storage, this measure may benefit the habitat of Upper Klamath Lake sucker and salmonid species. These restored marshes would also likely act as buffers or filters to enhance water quality in the Lake, a benefit to all users. Smaller-scale pilot efforts have been proposed by the Klamath Basin Water Users Protective Association (1993), and are being pursued by a coalition of cooperators.

6.2 Ground Water Conservation and Use

Some of the most important losses of flow in the river associated with the Project are those occuring during summer months or during long-term droughts. During droughts, in years prior to the Project, the reliable, "spring-like" flows from upstream of Iron Gate Dam were especially important in sustaining fish in the California reaches. Summer baseflows in the mainstem Klamath River can be supplemented from deep aquifers, if needed, to meet reserved rights associated with instream flows. Basically, there are two approaches to augment river flows with ground water:

1) use of ground water by growers during dry years in lieu of water diverted from Upper Klamath Lake;

2) occasional direct discharge to the stream during the months of low flow from basins or aquifers remote from the rivers and lakes.

6.2.1 In-Lieu Pumpage and Conjunctive Use

In many valleys throughout the western states, irrigators draw upon ground water when surface supplies are not readily available. It will likely prove feasible to irrigate from ground water in many locations within the Project, particularly if the Project assisted in providing technical guidance and fiscal support for well construction and operation. A few of the many ways of providing such support are described in the next section.

Almost every valley within the upper Klamath River basin and within the Project boundaries serves as an actual or potentially productive ground-water basin capable of supporting at least partially an in-lieu or conjunctive-use program (see Figure 29). Table 2 lists a few of the key hydrogeologic characteristics and historic ground-water use data from the more developed ground-water supply areas upstream of Iron Gate Dam. Perhaps because surface water has been readily and economically available, relatively little hydrogeologic work has been done to characterize and quantify the ground water resources in the upper Klamath basin, and specific estimates of local ground water reserves within these valleys are sparse. The published estimates which do exist indicate that easily-developed reserves are, conservatively, in excess of 2,000,000 acre feet. At least some areas of high permeabilities and yields occur in most valleys (Table 2). In fact, both regular and supplemental (in-lieu) ground-water pumpage is increasing, sometimes rapidly, in several parts of the upper basin; for example, there were 36 pending applications for ground water in the Langell Valley, totalling 143.33 cfs, as of December 1993, which would approximately double local ground-water use (c.f., Gorham, 1994; CH2M-Hill, 1994).

The use of ground water during drier periods is consistent with both state and federal policies promoting conjunctive use. Oregon recognizes a water right to supplemental water when water from a primary entitlement is not available for any reason. While California has no equivalent category, the State Water Resources Control Board maintains policies which strongly encourage conjunctive use. Hence, regulatory incentives may effectively complement potential economic support (discussed below) to help locate willing participants for an in-lieu program.

6.2.2 Occasional Pumping Directly to Streams

A program of occasional pumping directly to streams of the upper basin, rotating among basins whose residents are prepared to participate in a program of this type, could help in maintaining flows needed to support anadromous fish during periods of short-term need. A more innovative approach than in-lieu pumpage, directly augmenting the Klamath River merits consideration in these areas because of the generally high rates of recharge, the large number of valleys among which such pumping might rotate, and the potential for creating income by generating power with the extra flow. The income and power benefits may make this approach attractive to the landowners and agencies whose interest is essential in realizing such a program.

In our presentations, we have spoken of a hypothetical block of about 35,000 to 40,000 acre feet as one which might meet key short-term needs for supporting fish populations, and as one which might realistically be obtained with a careful pumping program in any one of a number of likely ground-water basins. The most effective programs likely to be sustainable may be pumping for continuous periods of 60, 120, or 180 days during certain critical and/or dry years. A 'block' of 35,700 acre feet would provide 60 days of releases at 300 cfs, 120 days of releases at 150 cfs, or 180 days of releases at 100 cfs. Pumped water would be naturally replenished during subsequent normal or wet years. It will likely prove feasible, during certain critical years, to pump two (or perhaps more) 'blocks' without significant impacts, especially if pumpage is spread or rotated amongst 10 or 12 suitable hydrogeologic basins or units.

Properly implemented, pumping of this magnitude and type might temporarily lower water tables to a moderate degree. The added costs of pumping may be recoverable in part from power generated by routing supplemental flows through existing Project facilities below Keno; additionally, project power might be made available to offset pumping costs in both wells producing supplemental flows and in adjoining agricultural wells in which water levels may fall. In many cases, total lifts when pumping from supplemental water sources might average 30 to 60 feet, based on data in the existing hydrogeologic reports. The total lift includes approximately 25 to 50 feet of lift within the well, and an additional 5 to 10 feet of head loss in conveyance to an existing waterway. Pumped water released to the Klamath River is likely to generate electricity equivalent to at least 300 feet of fall during passage through the various reservoirs. Allowing for generation and transmission losses, it still seems that more power will be generated than will be used for supplemental pumpage, assuming that it can be freely wheeled and made available in diverse locations. Alternatively, project power may be made available by the Bureau of Reclamation and/or its contractors as the tribal reserved water rights are met. It seems reasonable and feasible that nearby irrigators receive some compensation for incremental pumping costs which they might sustain as part of an instream flow supplementation.

The principal effect of pumping for supplemental instream flows is lowering static water levels, principally during the irrigation season.[9] Related impacts are primarily additional pumping costs. A number of adverse local effects can also be induced, some of which can be quite significant if not mitigated.[10] Observations in the Poe, Langell, and Yonna Valleys (Gorman, 1994; Appendix 2) suggest that actual static water level depression will range from zero to ten feet , since that is the amount of water-level decline associated with much heavier pumpage during a drought cycle. In some cases, lowered water levels may reverse the direction of flow, resulting in streams recharging aquifers, which may have both

[9] Within-season water-level declines of five to ten feet are common in many other agricultural areas in the west, due to effects of pumping adjoining wells.

[10] Several public small water systems near the town of Bonanza experienced bacterial contamination. Subsequent investigation led to the tentative conclusion that the bacteria were present because water levels in the *shallow* local aquifer had been lowered below the local stream, from which the pathogens were introduced through high-permeability vesicular basalts. Both the effects of a long-term drought and substantial pumpage for irrigation are thought responsible. A recent OWRD report (Gorman, 1994) documents these issues and presents several reasonable alternatives to protect public health in Bonanza.

beneficial and adverse effects. Beneficial effects include inducing recharge to ground-water storage, especially if done early in the growing season.

6.2.3. Water Quality

Water quality of deep aquifers is likely to prove suitable for direct discharge to the Klamath River, although existing data are sparse. Occasional intensive augmentation could be used to control water temperature or dilute constituents of concern. Information available for trace elements is especially fragmentary, but it is unlikely that these constituents will constrain use of deep zones in most or all of the aquifers discussed. When temperatures of ground water are given, they are frequently reported to be in the mid-50s (°F), probably slightly higher than they actually will be when pumped, and eminently suited for release to local channels. In most cases, these waters will warm appreciably once in the stream, so only limited temperature benefits might be realized.

6.3 Increase Irrigation Efficiency and Other Measures

Any conservation measures continued or initiated by the agricultrual community which reduce the late season diversion of water from the Klamath River will assist fishery needs. There is substantial local interest in making on-farm water use more efficient. These efforts, involving irrigators, agricultural extension staff, and agency specialists, are supported in part by private grant funding.

6.4 Artificial Recharge

Recharging ground water with surface water (a) helps maintain water levels, and (b) increases the volume of water in storage within the upper basin. Ideally, recharge will emphasize use of runoff from the first storms of the year or waters remaining in several of the Lost River surface-storage facilities at the end of the irrigation season. In either case, recharge will help reduce the additional Project-related flows during November and December which may adversely affect habitat values.

In most cases, recharge within the upper Klamath basin can best be accomplished at a medium or small scale, through the more permeable soils and sediments beneath most channels and alluvial fans. Recharge may be accomplished through small ponds created by excavation and/or berming or through unlined ditches contoured across some of the more permeable alluvial fans or edge-of-valley areas. Alternatively, planned late-summer releases of flows from Clear Lake, Gerber Lake, or some of the many smaller facilities within the Project boundaries might increase percolation through the beds of the channels. Some larger recharge efforts may also be feasible, including a number of sites previously rejected for surface storage because of 'excessive leakage rates'; however, it is likely that smaller-scale, more localized projects will prove most successful. One reason for this assessment is that water quality is integrally linked to both the value and feasibility of recharge programs, and the waters recharged through the smaller projects will be of essentially natural quality.

7. CONCLUSIONS

We have characterized pre-Project flows on the upper Klamath River using USGS stream gaging records from Keno, Oregon for the period 1905-1912, supplemented by records from several other gages further downstream on the Klamath River and its main tributaries. A long-term rainfall record for Yreka, California suggests that 1905 through 1912 period was one of above-normal precipitation, averaging 121 percent of mean for the period of 1874 through 1994. The long-term rainfall record for Klamath Falls, Oregon suggests this was a period of normal precipitation, averaging 104 percent of the mean for the period of 1905 through 1994. Estimates of mean pre-Project flows at Iron Gate Dam were computed by normalizing the Keno stream flow record using the Klamath Falls precipitation record and adding the natural accretions between Iron Gate and Keno dams. The pre-Project flow estimate for Iron Gate, 1.8 million acre feet per year, was then used by Trihey & Associates to develop instream flow recommendations for anadromous fisheries using the Tennant (or "Montana") method.

We also used the long-term precipitation record at these two stations to describe several long-term (multi-year) wet and dry cycles which seem to have affected most or all of the Klamath basin, beginning in the late 1840's with a severe drought. This drought was followed by alternating long-term wet and dry cycles including periods of above-normal precipitation throughout the 1860's, from approximately 1905 through 1917, and 1951 through 1984; and periods of below-normal precipitation from approximately 1872 through the early 1890's, and from 1918 through 1950. The most-recent decade (1985 through 1995) has been one of generally normal conditions interspersed with short-term intense dry spells. Long-term wet and dry cycles need to be considered when understanding extreme conditions in the Klamath basin and their effect on fish and wildlife.

We found that the persistence and reliability of flows emanating from the upper Klamath basin prior to the project sustained much of the instream anadromous fishery during summers and dry years.

Based on analyses completed during this investigation, the Project has affected flow on the Klamath River in the following ways:

- A significant proportion of the reduction in flows at the mouth of the Klamath River from pre-Project conditions is attributable to the development and operation of the Klamath Project. Water-development projects on the Trinity River and other tributaries have also contributed substantially to the reductions in flow.

- The Project has also changed the seasonal distribution of flows, sometimes increasing fall and early-winter storm runoff, and usually decreasing summer flows.

- The increased fall and early-winter peak flows associated with the Project probably result from reduced areas of natural wetlands, the extensive network of drains (which speeds flows formerly detained in lowlying areas to the river), increased runoff from lands retaining soil moisture from late-summer and fall irrigations, and diversions of storm runoff from the Lost River system. Other processes, as well as areas beyond the Project boundaries, may also contribute. The increased early-winter storm crests are of concern because they can prematurely scour the gravels incubating chinook and other salmonid eggs.

- Under pre-Project conditions, during droughts, the upper Klamath basin was a vital source of sustained summer flow, probably contributing 35 to 40 percent (or more) of the flow at the mouth of the river. During the past 35 years, the proportion of flow originating from the upper basin has progressively decreased during the summers of droughts and dry years, such that it now often provides 5 to 10 percent of the flow at the mouth.

- Project development has contributed to diminished water quality in (and emanating from) the upper Klamath basin. Direct effects include an increase in nutrients and elevated water temperatures. Indirect effects include diminished dissolved oxygen and elevated pH values. All of these impacts probably have adverse effects on salmonids, especially during early life stages. Little or no data exist for certain other constituents which might reasonably affect instream flow needs.

Physical solutions which may help reduce the adverse effects of the Project on fish and wildlife while also helping irrigators and wildlife-refuge managers include:

- Increasing storage in Upper Klamath Lake, perhaps by restoring diked wetlands which ring major segments of the lake. Restoration may also increase the extent and reliable availability of habitat for both suckers and salmonids in the lake, and may also provide water-quality benefits during the fall months.
- Artificially recharging runoff to ground water, especially during the early-winter months. Small- to mid-scale local projects merit close evaluation. Reservoir sites previously investigated, and found to be "too leaky", might feasibly serve as retention or infiltration basins. Other valleys or lowlying areas of permeable volcanics rocks also should be considered.
- Conjunctively using ground water to supplement irrigation or instream flows during very dry summers or droughts.
- Enhancing on-farm and near-farm efficiency of water use.

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TABLE 1
ESTIMATED PRE-PROJECT MEAN MONTHLY AND ANNUAL STREAM FLOW:
Keno and Iron Gate Dams (all flows in cfs)

		Year Type							
		Wet	Normal	Wet	Normal	Wet	Wet	Normal	Wet
Month	Measured Mean Monthly Flow at Keno 1905-1912	Mean Monthly Flow at Keno Indexed Using Yreka Precipitation Record (index of 1.21) 1905-1912	Mean Monthly Flow at Keno Indexed Using Klamath Falls Precipitation Record (index of 1.04) 1905-1912	Mean Monthly Flow at Keno Indexed Using Inflow to Upper Klamath Lake Record (index of 1.35) 1905-1912	Normal Year Accretions Between Keno and Iron Gate [1]	Wet Year Accretions Between Keno and Iron Gate [1]	Indexed Mean Monthly Flow at Iron Gate (index 1.21) 1905-1912	Indexed Mean Monthly Flow at Iron Gate (cfs) (index 1.04) 1905-1912	Indexed Mean Monthly Flow at Iron Gate (cfs) (index 1.34) 1905-1912
October	1,236	1,021	1,188	916	348	324	1,345	1,536	1,240
November	1,518	1,255	1,460	1,124	349	446	1,701	1,809	1,570
December	1,915	1,583	1,841	1,419	517	550	2,133	2,358	1,969
January	2,295	1,897	2,207	1,700	620	657	2,554	2,827	2,357
February	2,670	2,207	2,567	1,978	764	868	3,075	3,331	2,846
March	3,027	2,502	2,911	2,242	693	1,195	3,697	3,604	3,437
April	3,326	2,749	3,198	2,464	659	951	3,700	3,857	3,415
May	3,182	2,630	3,060	2,357	567	759	3,389	3,627	3,116
June	2,630	2,174	2,529	1,948	401	525	2,699	2,930	2,473
July	1,809	1,495	1,739	1,340	408	363	1,858	2,147	1,703
August	1,202	993	1,156	890	347	374	1,367	1,503	1,264
September	1,060	876	1,019	785	351	307	1,183	1,370	1,092
Annual Avg. (cfs)	2,156	1,782	2,073	1,597	502	610	2,392	2,575	2,207
Annual Avg. (ac-ft)	1,560,780	1,289,901	1,500,750	1,156,133	363,438	441,567	1,731,468	1,864,188	1,597,701

Notes:
1. From CH2M Hill Draft Technical Memorandum entitled, "Biological Water Needs," November 26, 1995 (in KPOP Workbook).
2. See text for discussion of indexing.

TABLE 2
HYDROGEOLOGIC CHARACTERISTICS AND HISTORIC PUMPAGE [1]
Upper Klamath River Ground Water Basins [2]

Basin [7]	Estimated Ground Water Pumpage [3] 1952-54 (ac-ft/yr)	1970-75 (ac-ft/yr)	1992 (ac-ft/yr)	Estimated Available Ground Water 1952-54 (ac-ft/yr)	1970-75 (ac-ft/yr)	Water Quality TDS (mg/l) [4]	Specific Capacity [5] (gpm/ft drwdn)	Well Yields (gpm)	Range of Depth to Water (ft bgs) [6]	Comments
Upstream of Upper Klamath Lake: OR (Williamson and Sprague Hydrologic Units)										
Klamath Marsh Area Klamath Marsh/N. Chiloquin Area		4,050 25,000			12,150	77 to 110	50 to 600+	1,000 to 4,000	55-135	8,000 ac-ft pumped during dry years
Wood River/S. Chiloquin and Upper Klamath Lake area		27,000								
Sprague River Valley Sprague River Valley/Sycan Marsh Area		24,100 60,000			72,300	84 to 230	11 to 460	800 to 4,000	6-60	90,000 ac-ft/yr seepage to river 150,000 ac-ft/yr subsurface outflow
Downstream of Upper Klamath Lake: CA (Lost River Hydrologic Unit)										
Swan Lake Valley		13,000			39,000	120 to 210	24 to 1,500	1,800 to 3,000	20-120	No natural outlet
Yonna Valley	6,000	13,500			40,500	120 to 260	20 to 3,000	few to 5,000	5-110	
Langell Valley		2,200	24,310		6,600	129 to 190	2 to 160	300 to 3,000	8-140	60,000 ac-ft/yr GW seepage to river
Poe Valley		3,800			11,400	140 to 220	15	800	8-140	30 cfs GW seepage to Lost River
Swan Lake/Yonna, Langell, and Poe Valleys		235,000								
Downstream of Upper Klamath Lake: CA										
Butte Valley	22,000	63,500		65,000	102,000	115 to 318	30 to 1,000	avg=1,300		40,000 ac-ft/yr subsurface outflow
Red Rock Valley	negligible 'til '54									3 irrigation wells installed 1954
Oklahoma Area							avg=50	10 to 1,300		Landuse limited by high GW table
Tule Lake Area							0 to 15			Upper gw zone poor quality
Downstream of Klamath Project: CA										
Shasta Valley	5,500						26 to 280	avg=1,300		Shasta Valley adjudicated (12/30/32)
Scott Valley	1,500			200 to 300 K			88 to 100	1,200 to 2,500	0-35	No overdraft, but pumping for irrigation depletes summer and fall flows. Adjudicated.

Notes:
1. Sources of data included: Leonard and Harris, 1974; Department of the Interior, 1981; Gorman, 1994; California DWR, Bulletin 83, 1964; California DWR, Bulletin 58, 1957; and Bartholomew et al., 1973.
2. No information reviewed for Williamson River Valley, Klamath Lake, Chiloquin, Sycan March, Bray Town, Clear Lake, Lava Beds National Monument, Modoc National Forest, Salmon River Valley, and Seiad Valley areas.
3. 1952-54 includes three wet years; 1970-75 was slightly wetter than normal; 1992 was a very dry year within a longer multi-year drought.
4. TDS is an abbreviation for total dissolved solids, a measure of salinity. Values below 500 mg/l are suitable for virtually all uses.
5. Specific capacity is a measure of relative well effectiveness, or of the propensity of an aquifer to yield water to a well being pumped. Values on this table are generally high to extremely high.
6. bgs is an abbreviation for below ground surface.
7. The California DWR has recently recognized several additional ground-water basins with significant resources, principally beneath the volcanic tablelands between the valleys: Modoc Plateau Recent Volcanic Area, Modoc Plateau Pleistocene Volcanic Area, and Fairchild Swamp Basin (Regional Board, 1993).

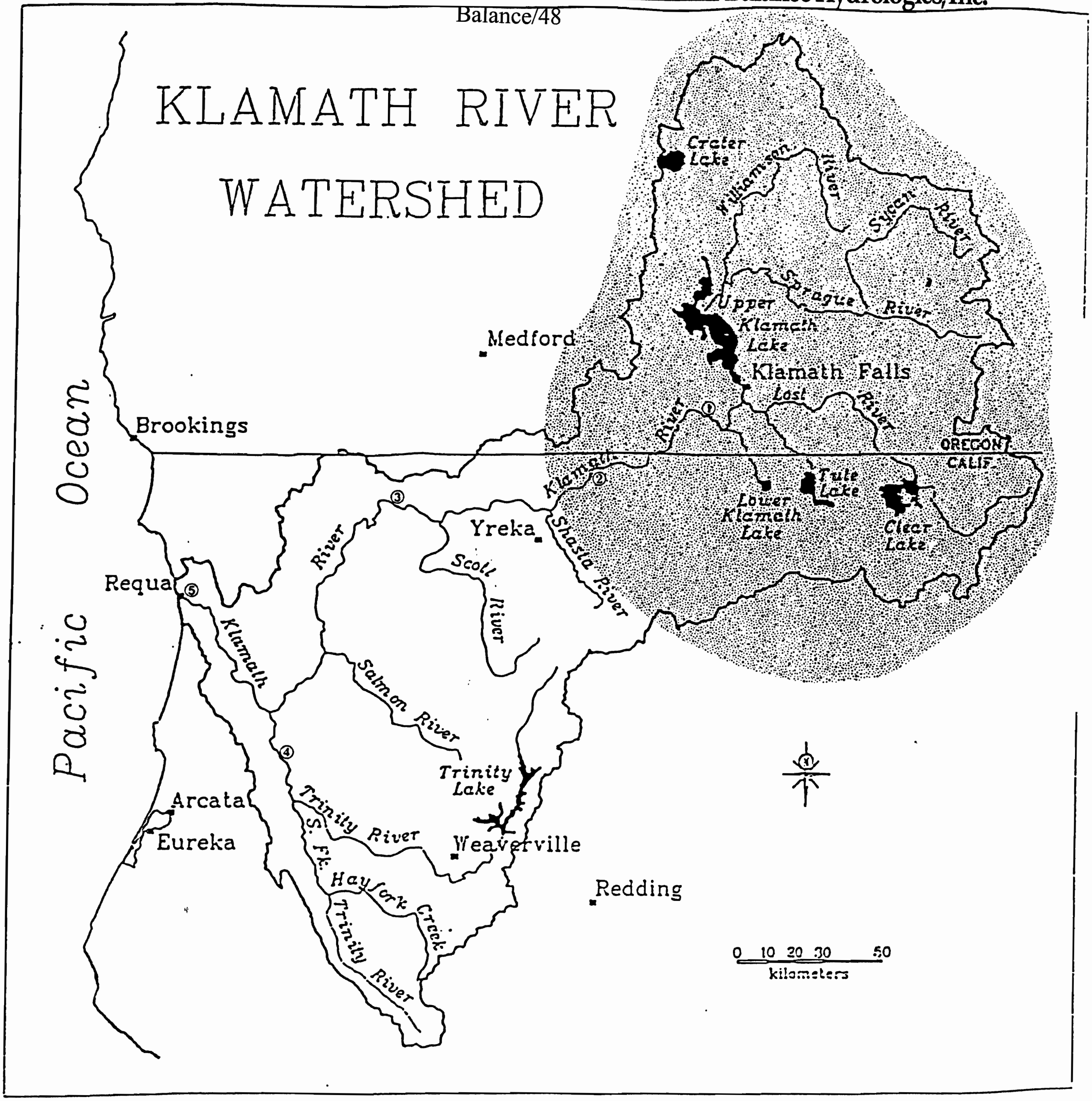


FIGURE 1: Map of Klamath River Watershed

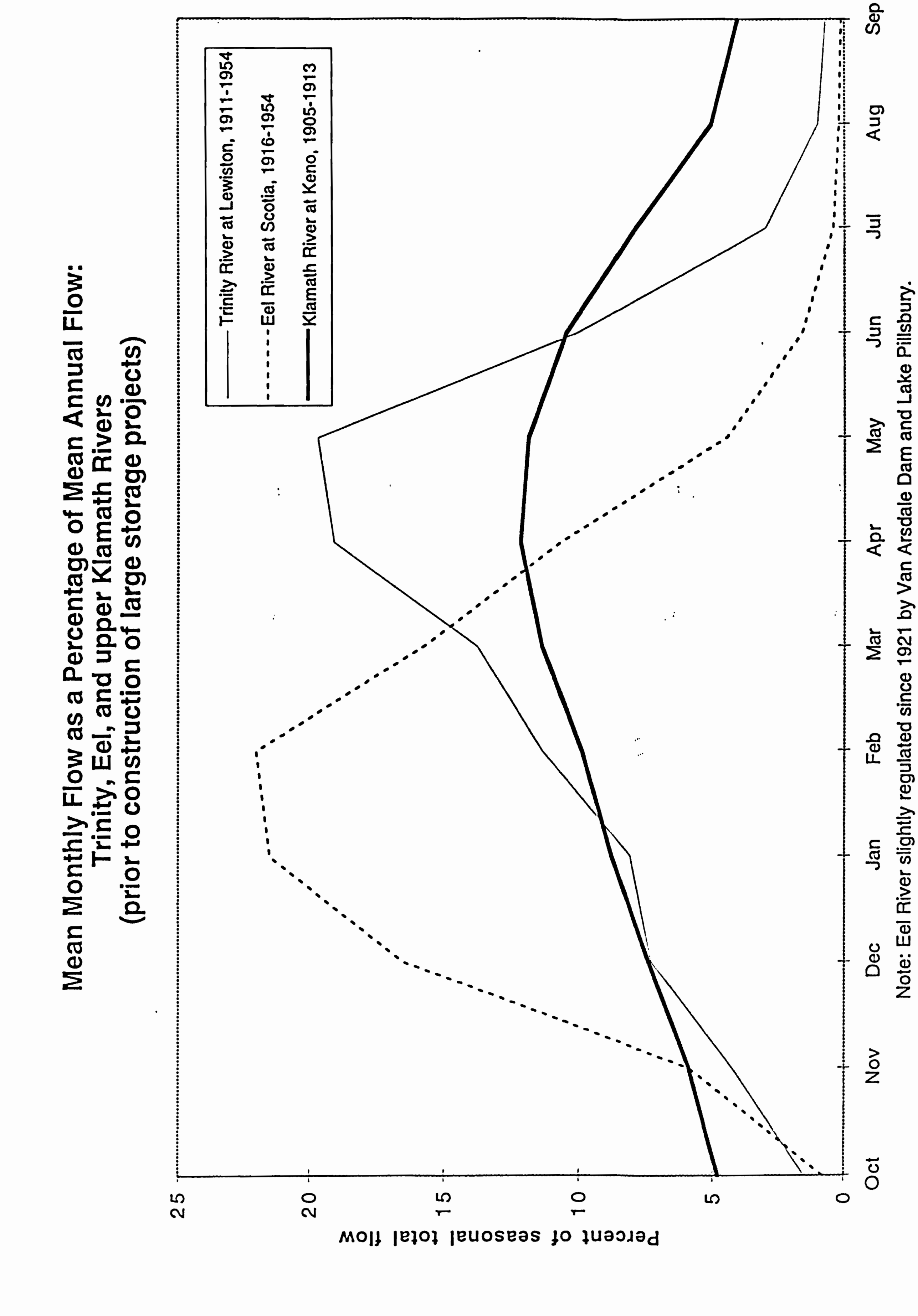
Key: Primary USGS Stream Gaging Stations referenced in this report:

① Klamath River at Keno
② Klamath River below Iron Gate Dam
③ Klamath River near Seiad Valley
④ Trinity River at Hoopa
⑤ Klamath River at Klamath

Shaded area indicates extent of upper Klamath River basin underlain by basalt bedrock. Note lateral extent of basalts extends well beyond drainage area boundaries.

Balance Hydrologics, Inc.

FIGURE 2

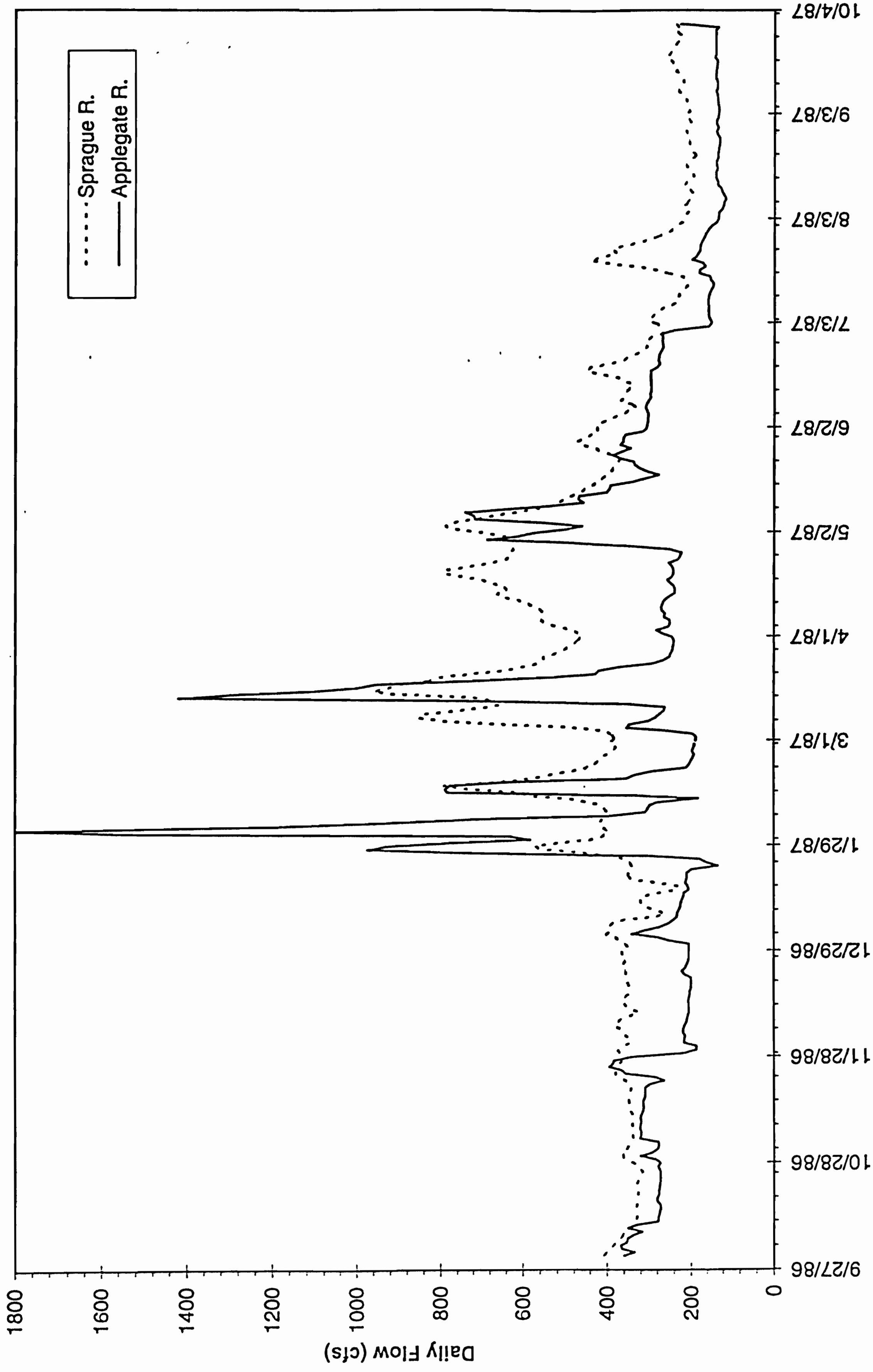


Balance Hydrologics, Inc.
9506 Percent to annual total:Figure 2

Balance Hydrologics, Inc.

Figure 3

Comparison of Mean Daily Flows for Sprague and Applegate Rivers: Water Year 1987

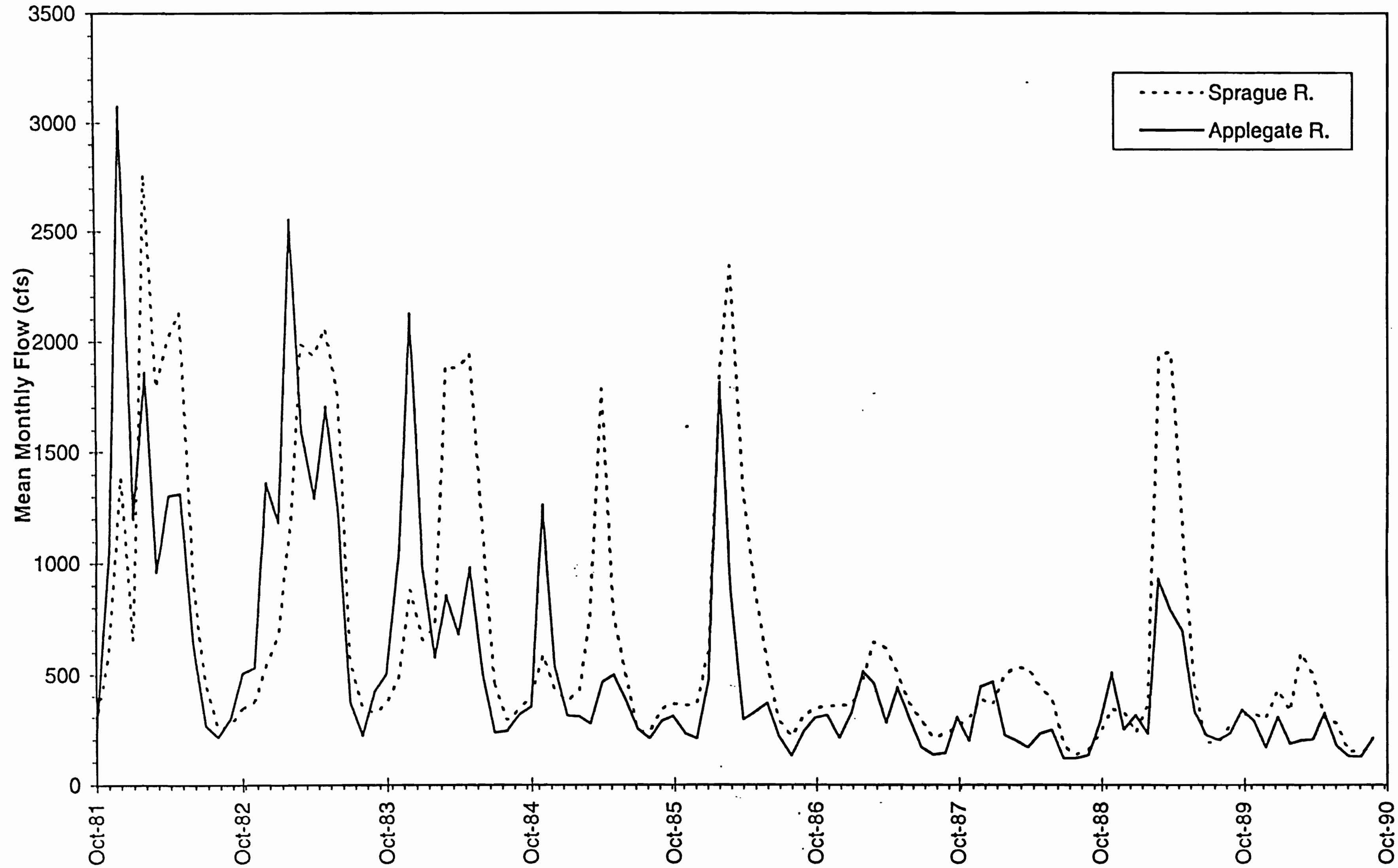


Source: USGS via Hydrosphere CD-ROM

Balance Hydrologics, Inc.
DAILY_Q.XLS, Sprague

Figure 4

Mean Monthly Flows for Sprague and Applegate Rivers: Water Years 1982-1990

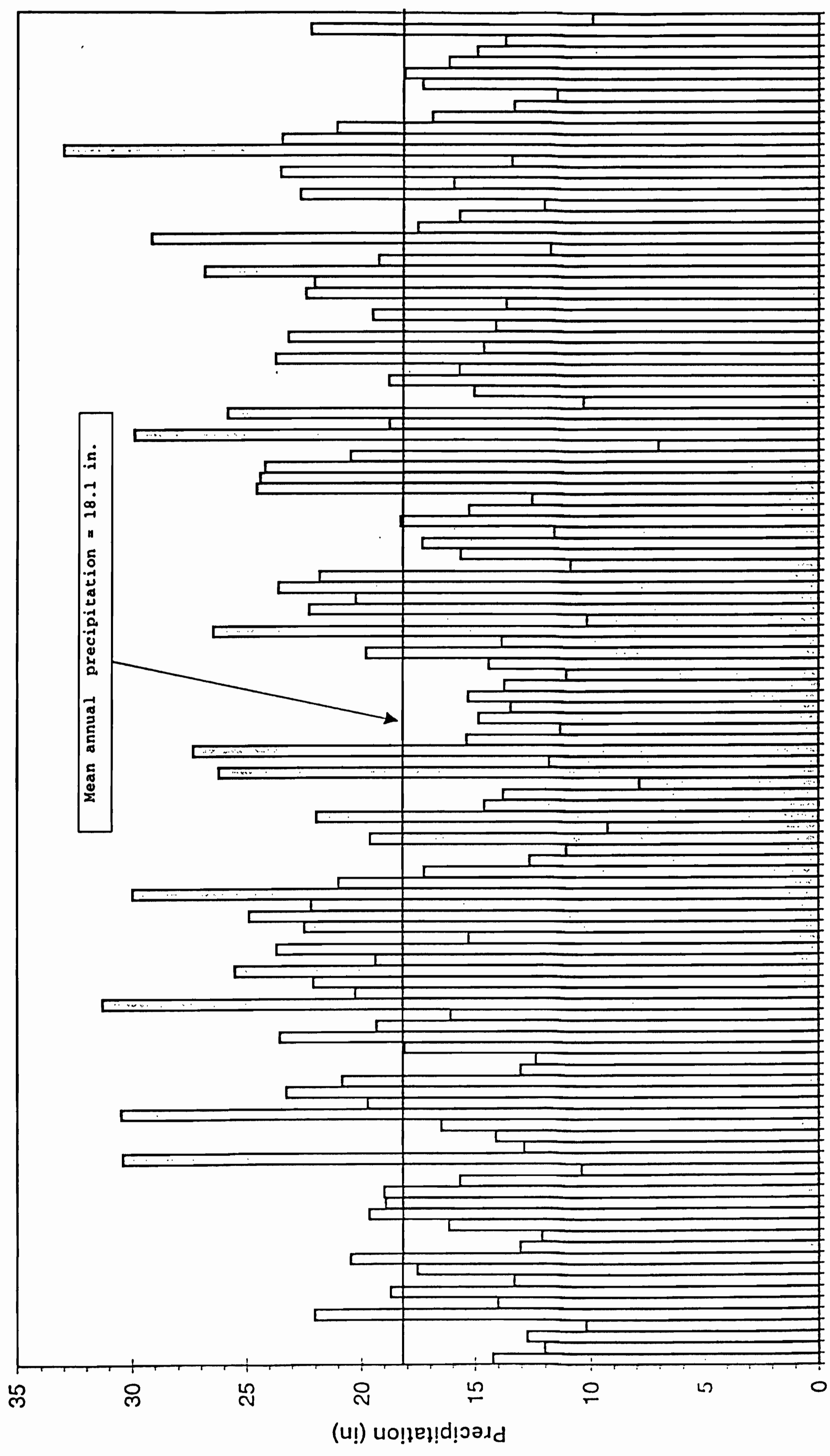


Source: USGS via Hydrosphere CD-ROM

Balance Hydrologics, Inc
SPRAGUE.XLS, Persist

FIGURE 5

Annual Precipitation at Yreka by Rainfall Year: 1872 through 1994

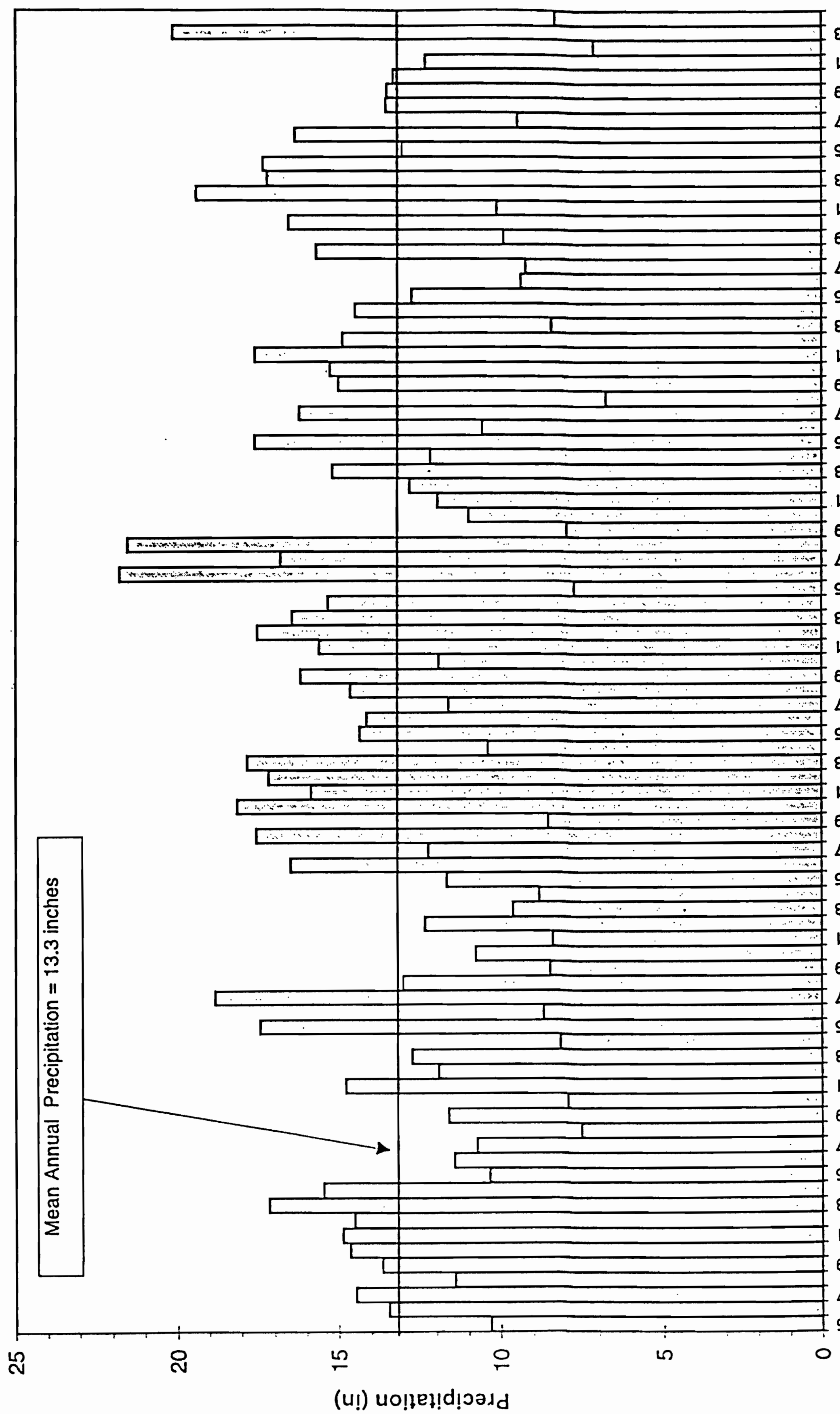


Source: 1871-1948 DWR Bulletin #58
1948-1994 EarthInfo "NCDC Summary of the Day" CD-ROM

Balance Hydrologics
YREKA.XLS, Chart4

FIGURE 6

Annual Precipitation at Klamath Falls by Rainfall Year: 1905 through 1994



Source: USGS via Hydrosphere CD-ROM

Balance Hydrologics, Inc.
KLAMFALL.XLS, Annual

FIGURE 7

Bureau of Reclamation Estimates of Annual inflow to Upper Klamath Lake: Water Years 1906 through 1995

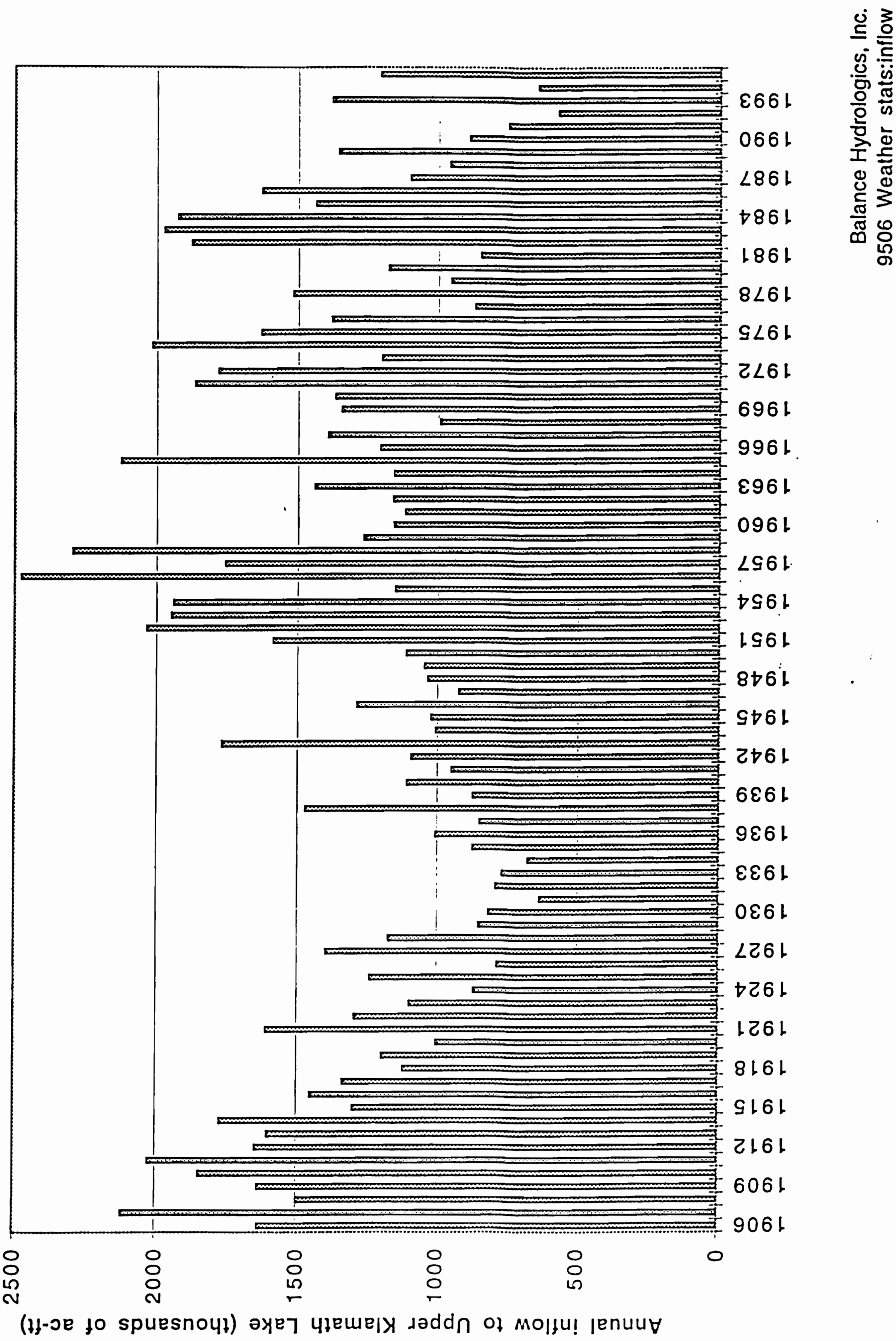
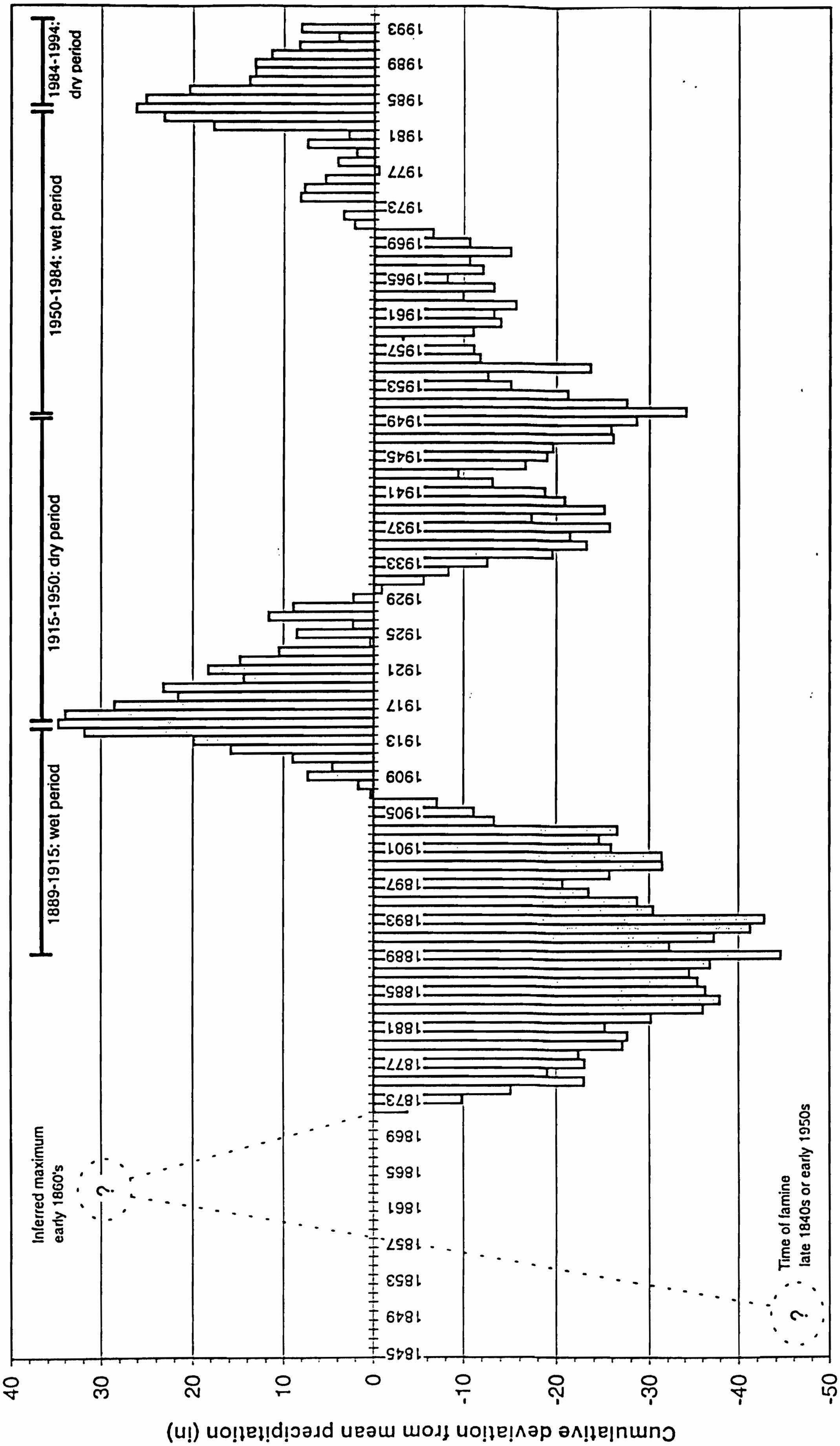


FIGURE 8

Cumulative Deviation from Mean Annual Precipitation at Yreka: Rainfall Years through 1994

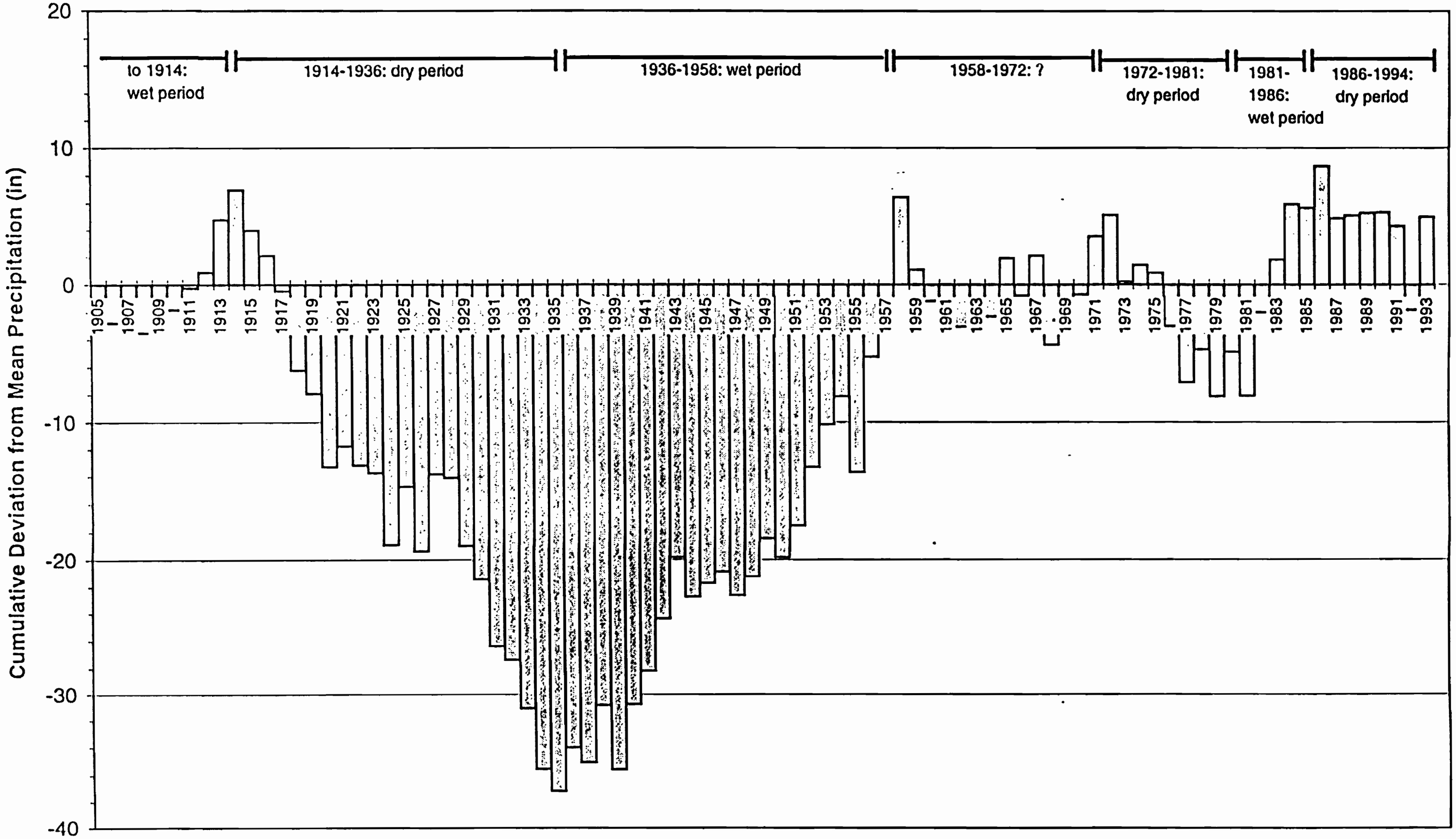


Source: 1871-1948 DWR Bulletin #58 and others
1948-1994 EarthInfo "NCDC Summary of the Day" CD-ROM

Balance Hydrologics
YREKA.XLS, deviate

FIGURE 9

Cumulative Deviation from Mean Annual Precipitation at Klamath Falls: Rainfall Years through 1994



Source: 1905-1953 DWR Bulletin #83
1928-1994 EarthInfo "NCDC Summary of the Day" CD-ROM

Balance Hydrologics
KLAMFALL.XLS, Deviate

FIGURE 10

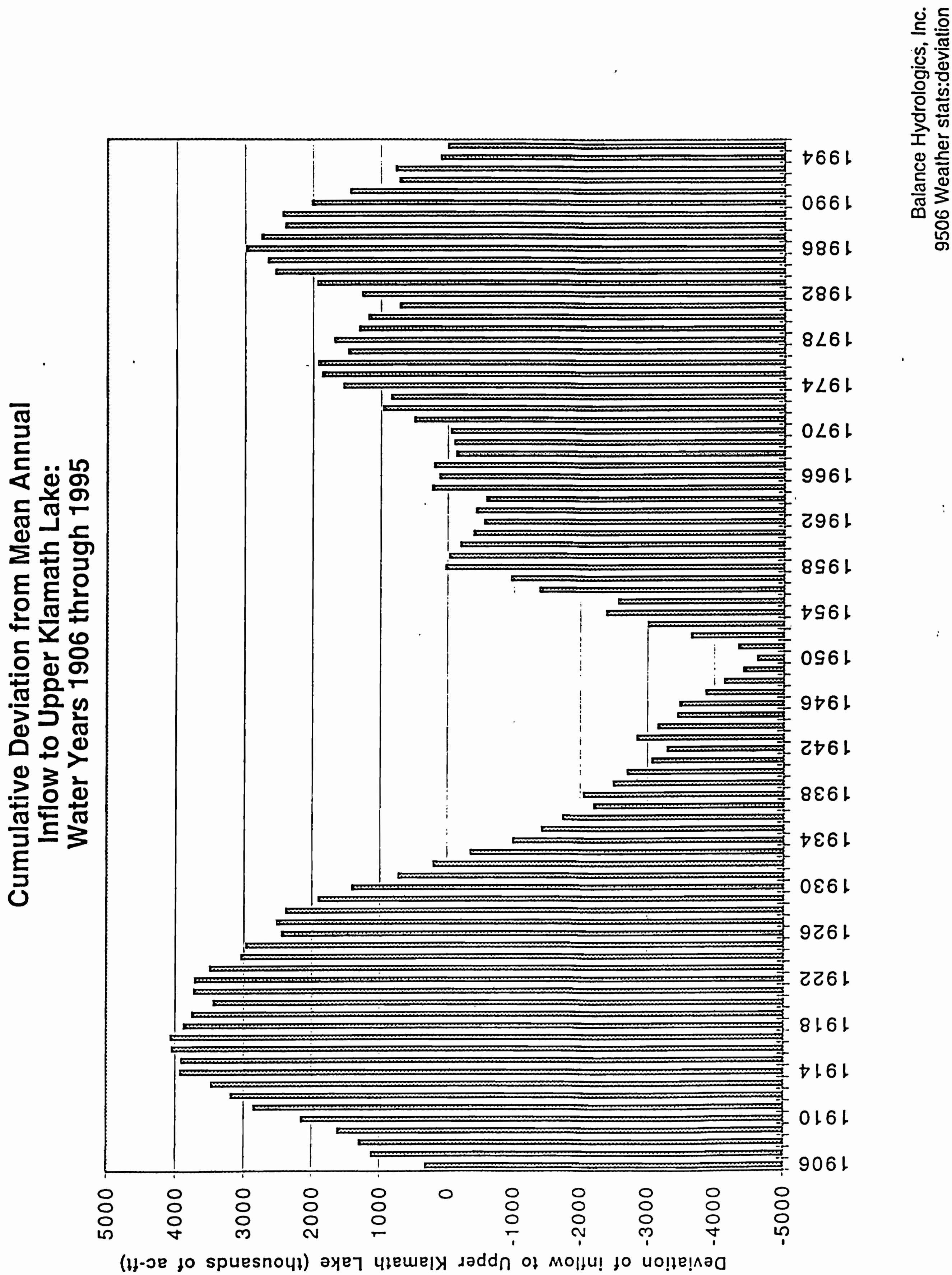
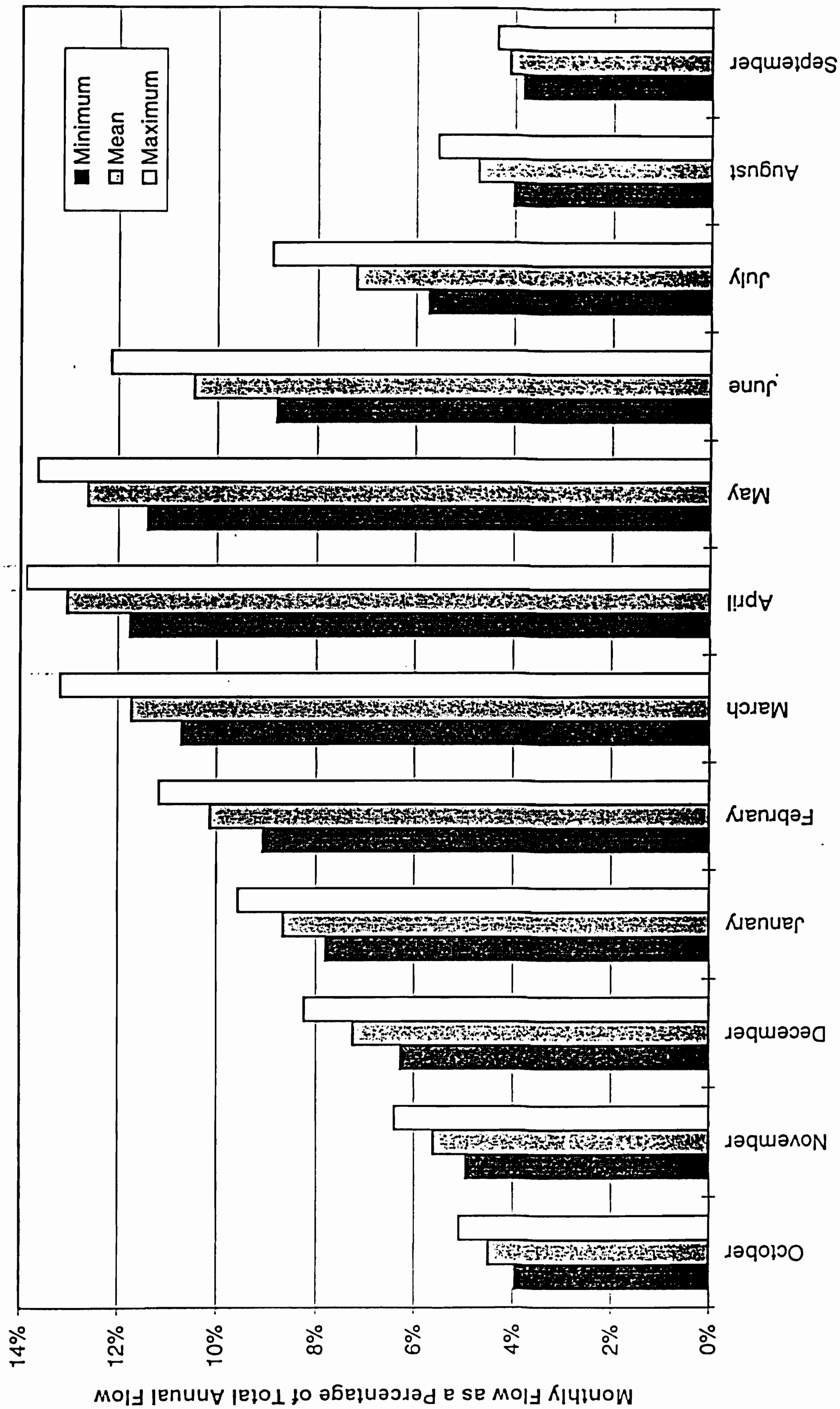

Cumulative Deviation from Mean Annual
Inflow to Upper Klamath Lake:
Water Years 1906 through 1995
Deviation of inflow to Upper Klamath Lake (thousands of ac-ft)
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
1906
1910
1914
1918
1922
1926
1930
1934
1938
1942
1946
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
Balance Hydrologics, Inc.
9506 Weather stats:deviation

FIGURE 11

Minimum, Mean, and Maximum Monthly Flows in Klamath River at Keno Gage as Percentage of Total Annual Flow: Water Years 1906 through 1912

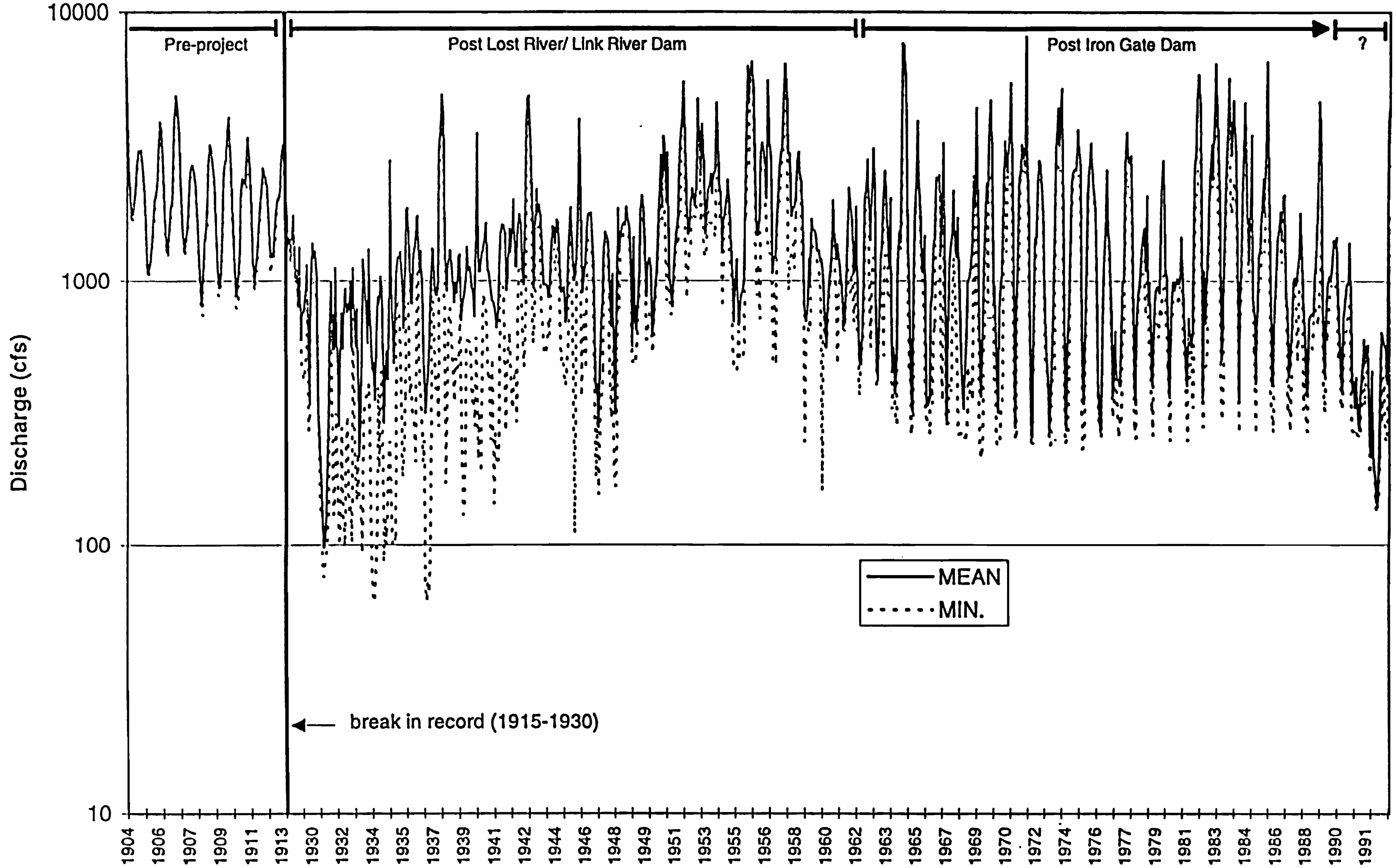


Source: USGS via Hydrosphere CD-ROM

Balance Hydrologics, Inc.
KENO.XLS, MMM

FIGURE 12

Monthly Flow in Klamath River at Keno Gage

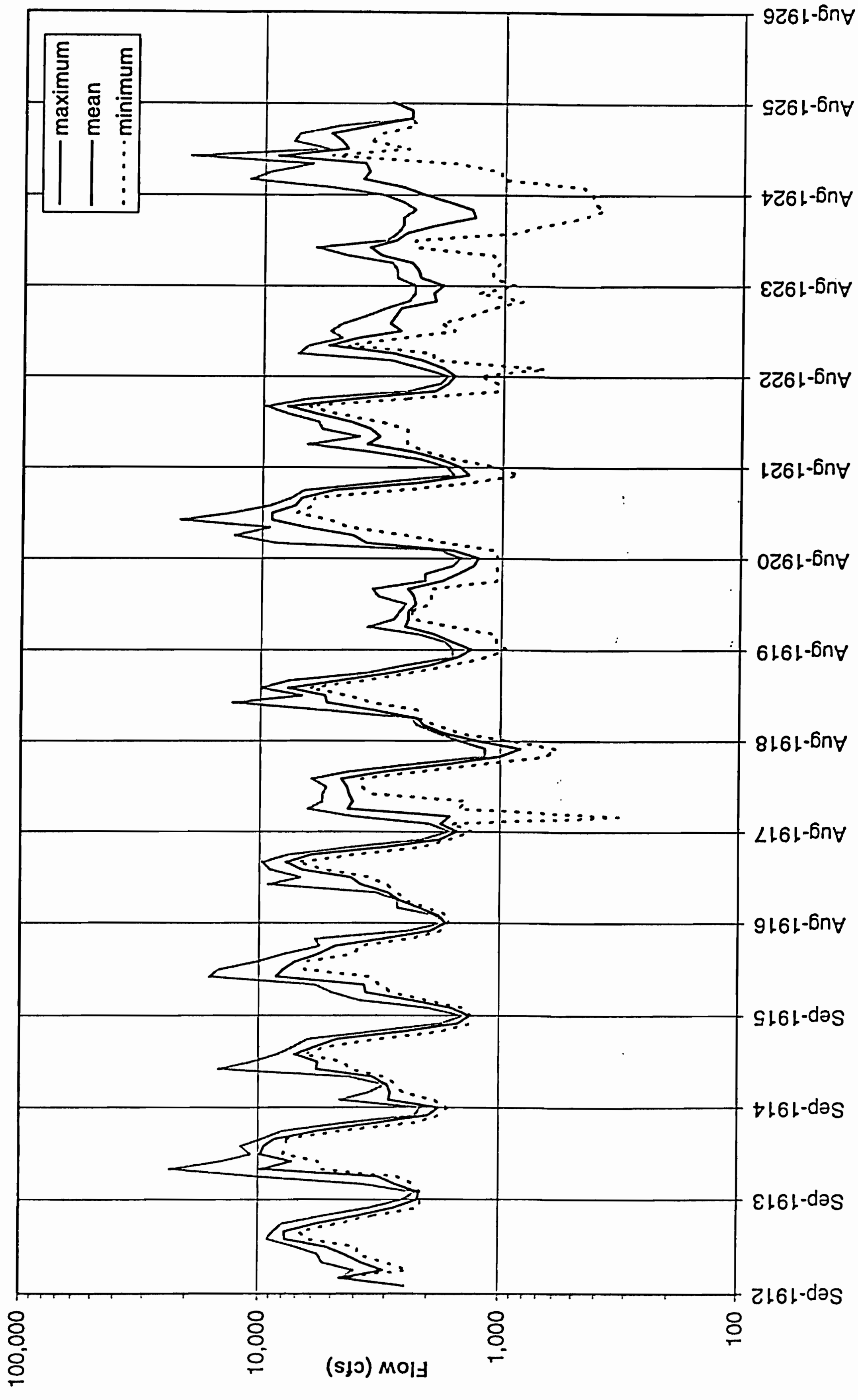


Source: USGS via Hydrosphere CD-ROM

Balance Hydrologics, Inc.
KENOMEAN.XLS, Chart2

FIGURE 13

Minimum, Mean, and Maximum Monthly Flow in Klamath River near Seiad Valley: Water Years 1913 through 1926

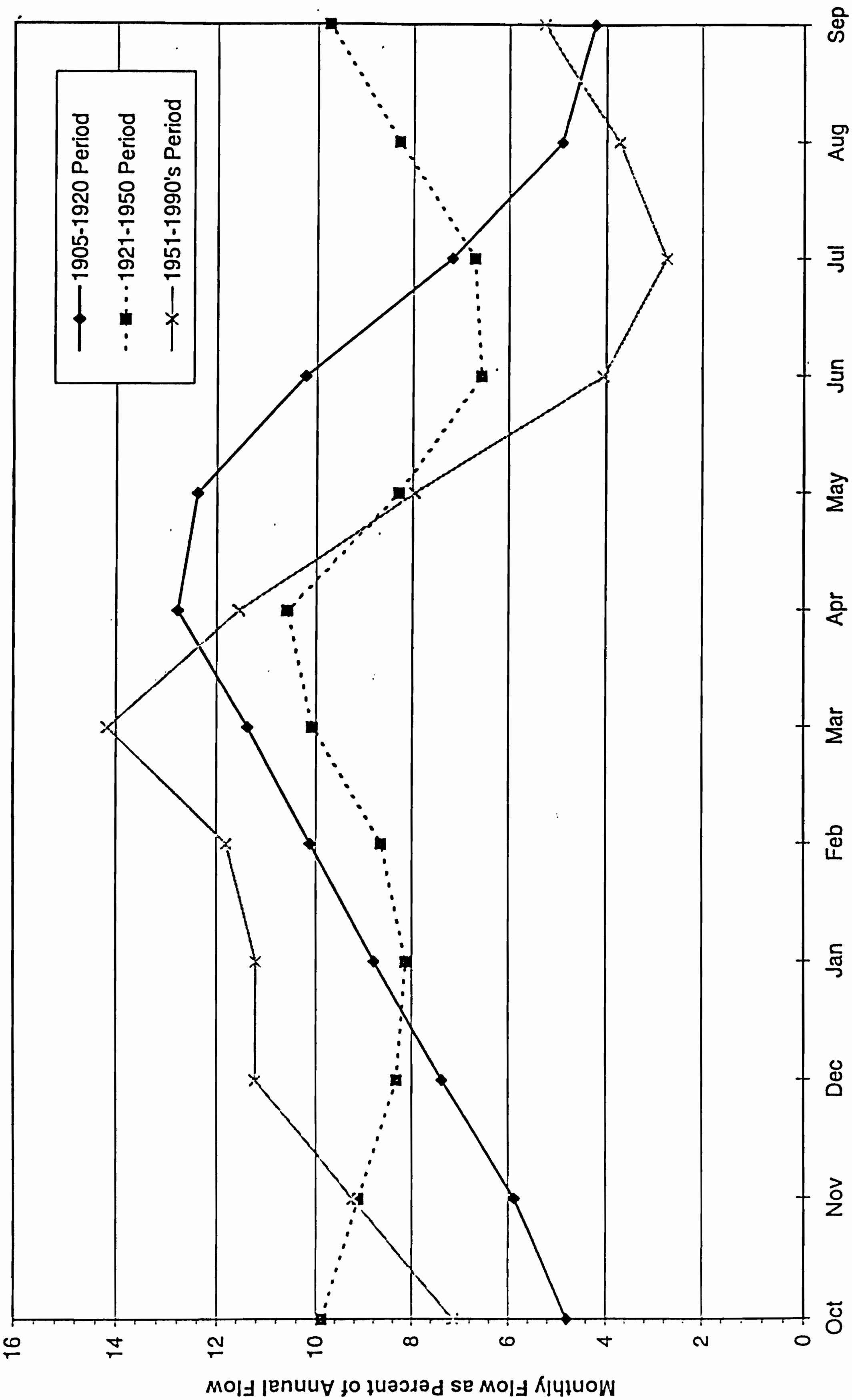


Source: USGS via Hydrosphere CD-ROM

Balance Hydrologics, Inc.
MONTHLYQ.XLS:Chart5 (2)

FIGURE 14

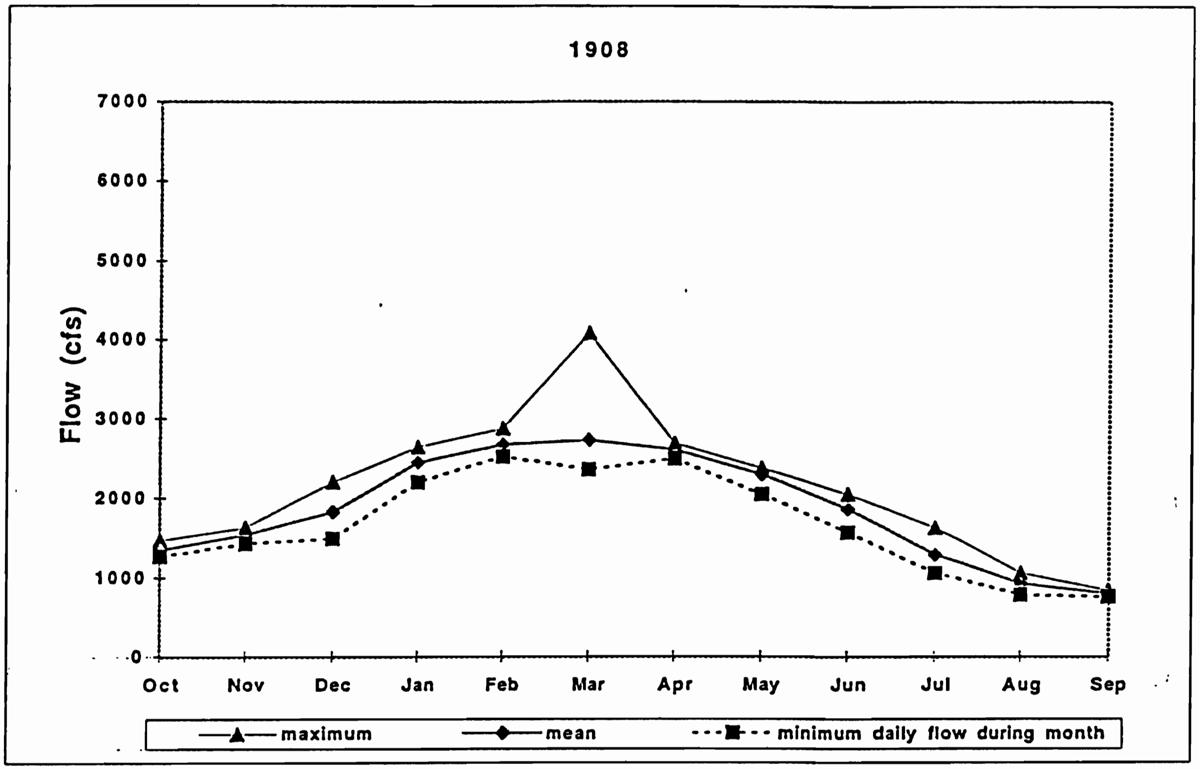
**Mean Monthly Flow for Selected Periods:
Klamath River at Keno/Spencer Bridge Gage
As Percentage of Annual Flow**

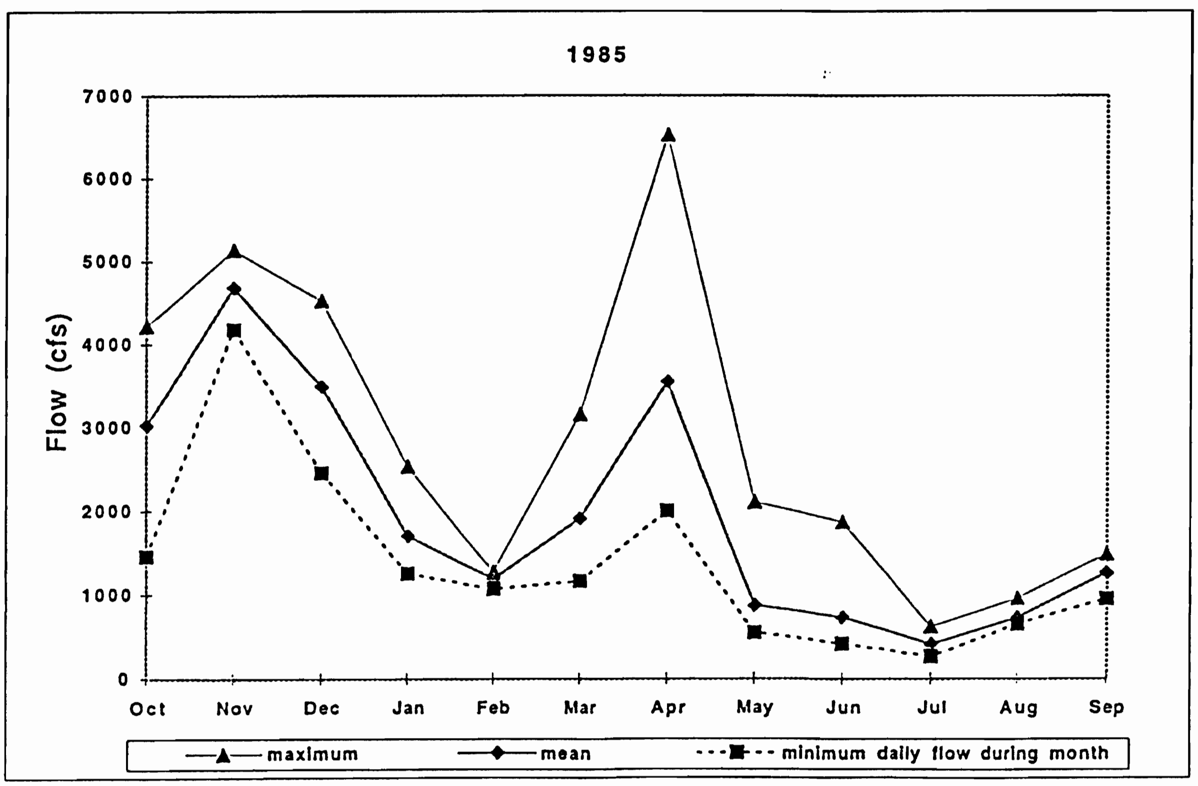


Source: USGS via Hydrosphere CD-ROM

Balance Hydrologics, Inc.
MONTHLYQ.XLS, Kno% (2)

Pre- and Post-Project Monthly Flows:
Klamath River at Keno Gage
(above normal runoff year)

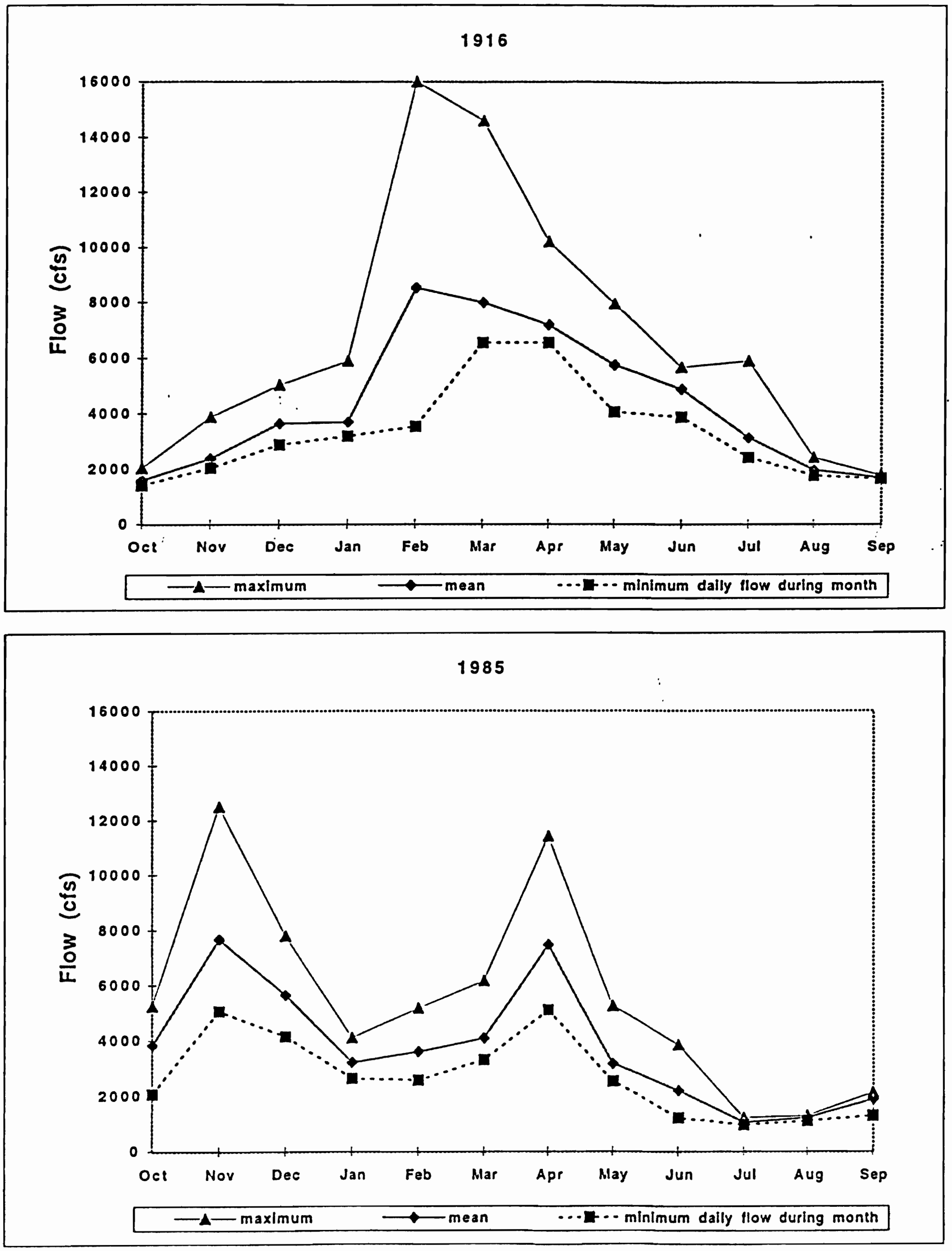




Source: USGS via Hydrosphere CD-ROM

Pre- and Post-Project Monthly Flows:
Klamath River at Seiad Valley Gage

(above normal runoff year)



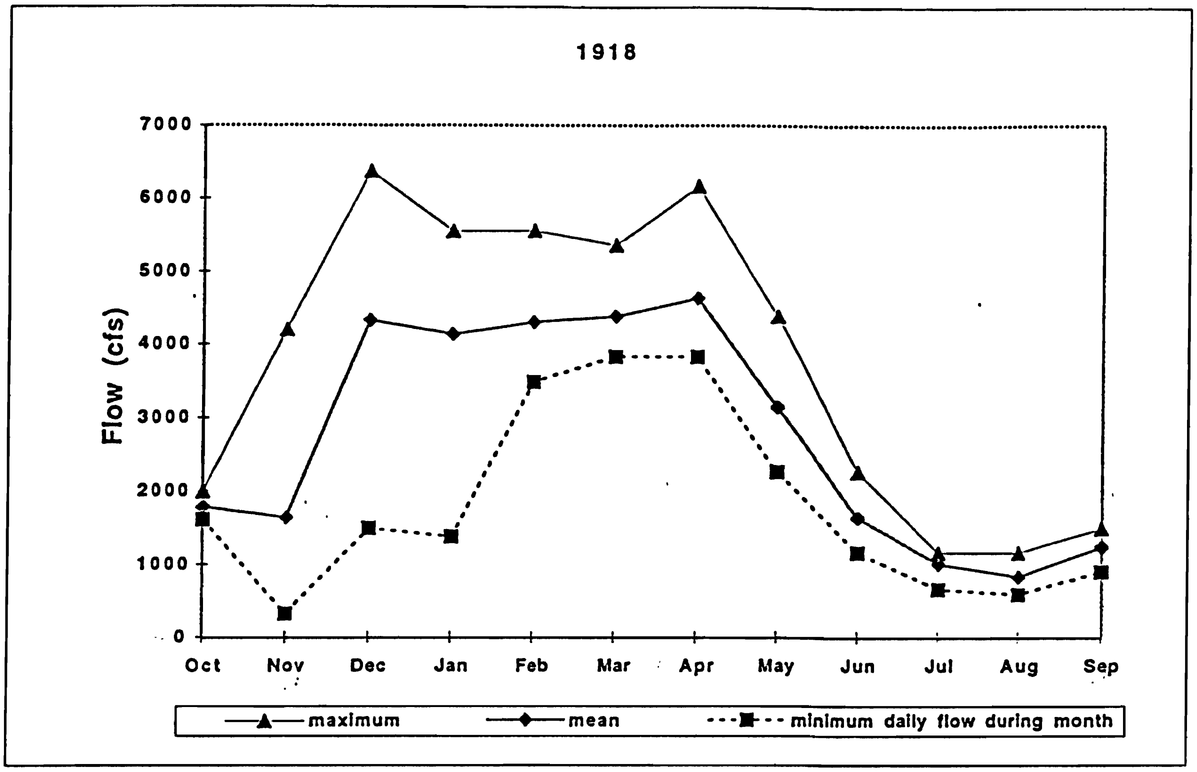
Source: USGS via Hydrosphere CD-ROM

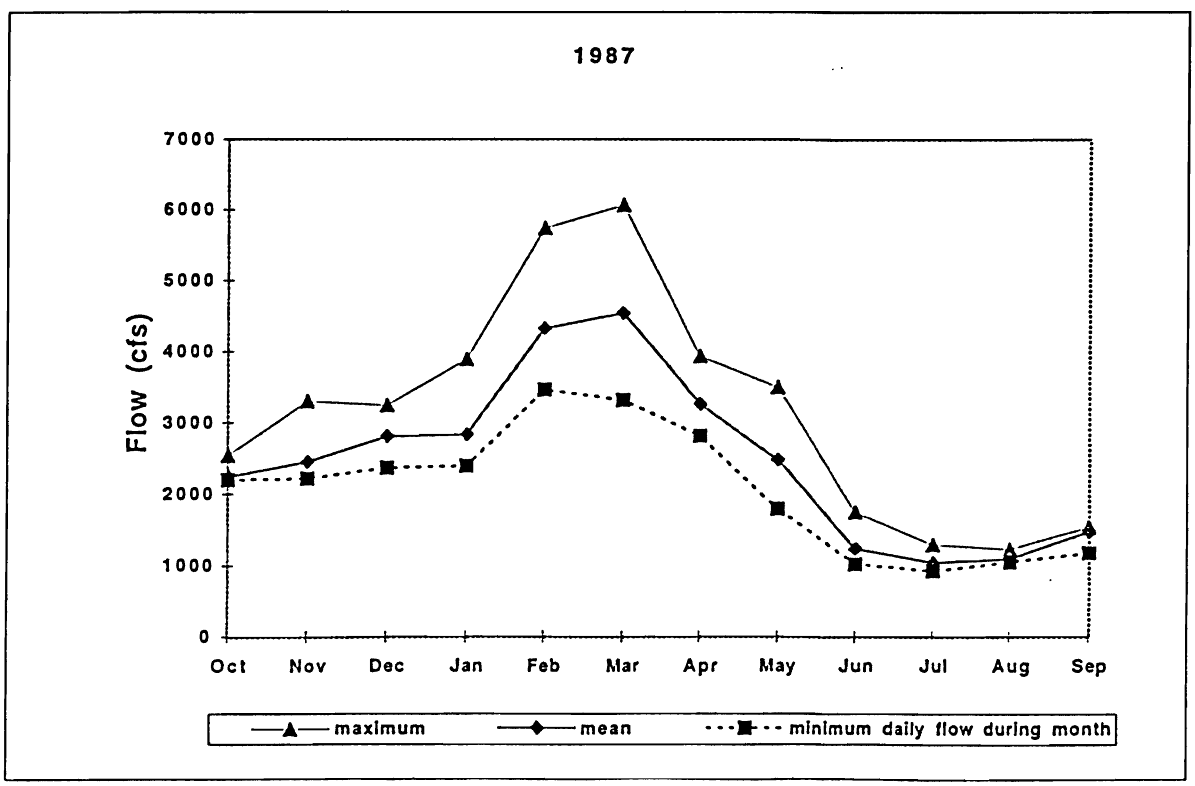
Balance Hydrologics, Inc.

FIGURE 17

Pre- and Post-Project Monthly Flows:
Klamath River at Seiad Valley Gage

(below normal runoff year)

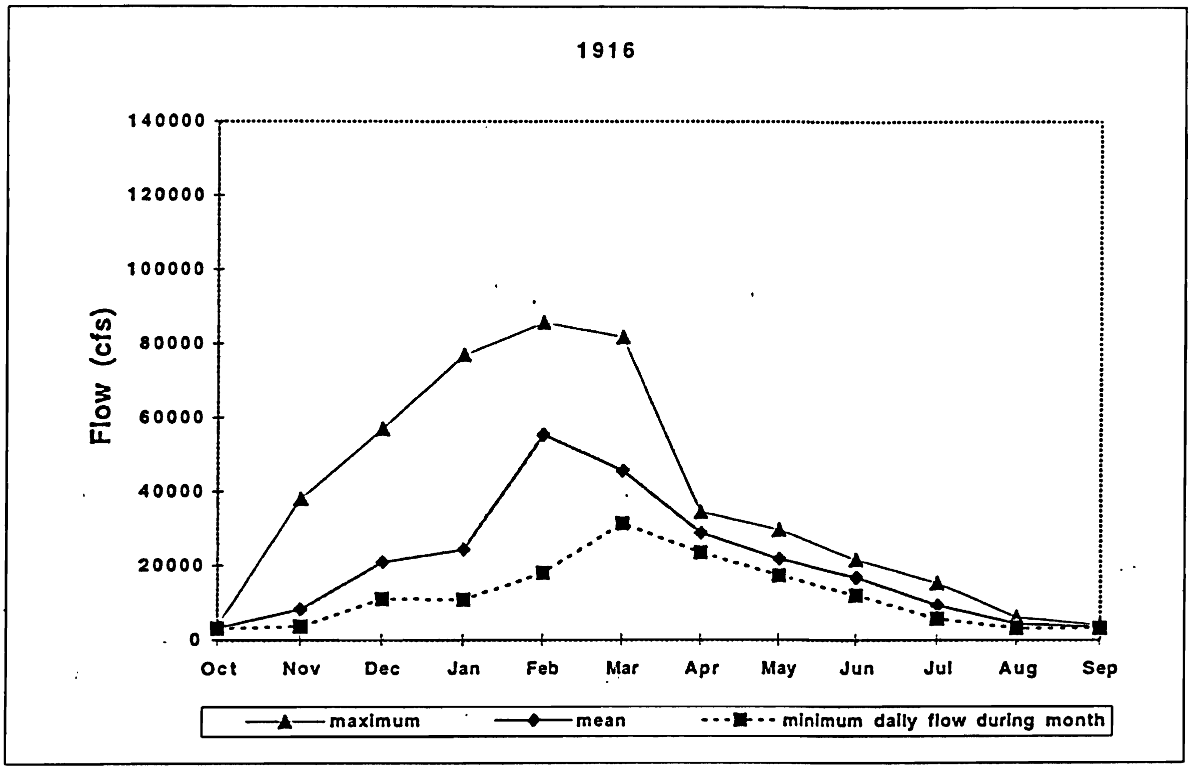


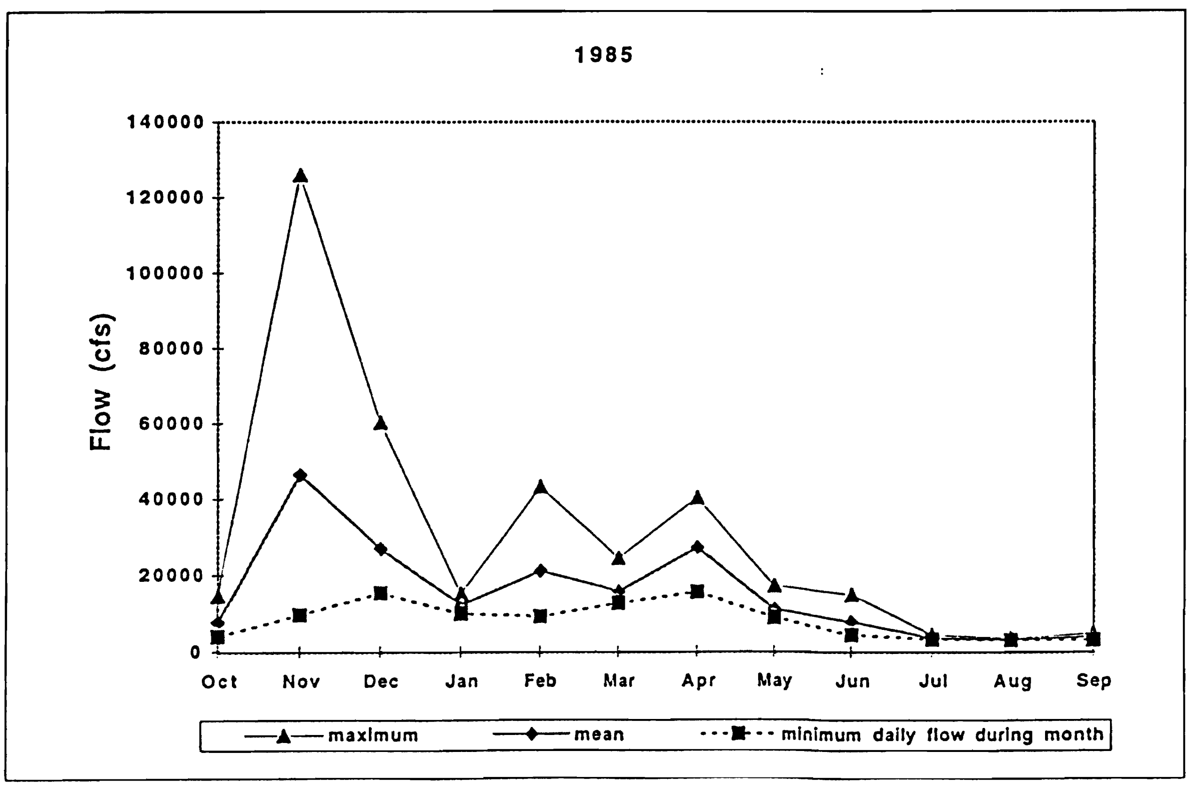


Source: USGS via Hydrosphere CD-ROM

FIGURE 18

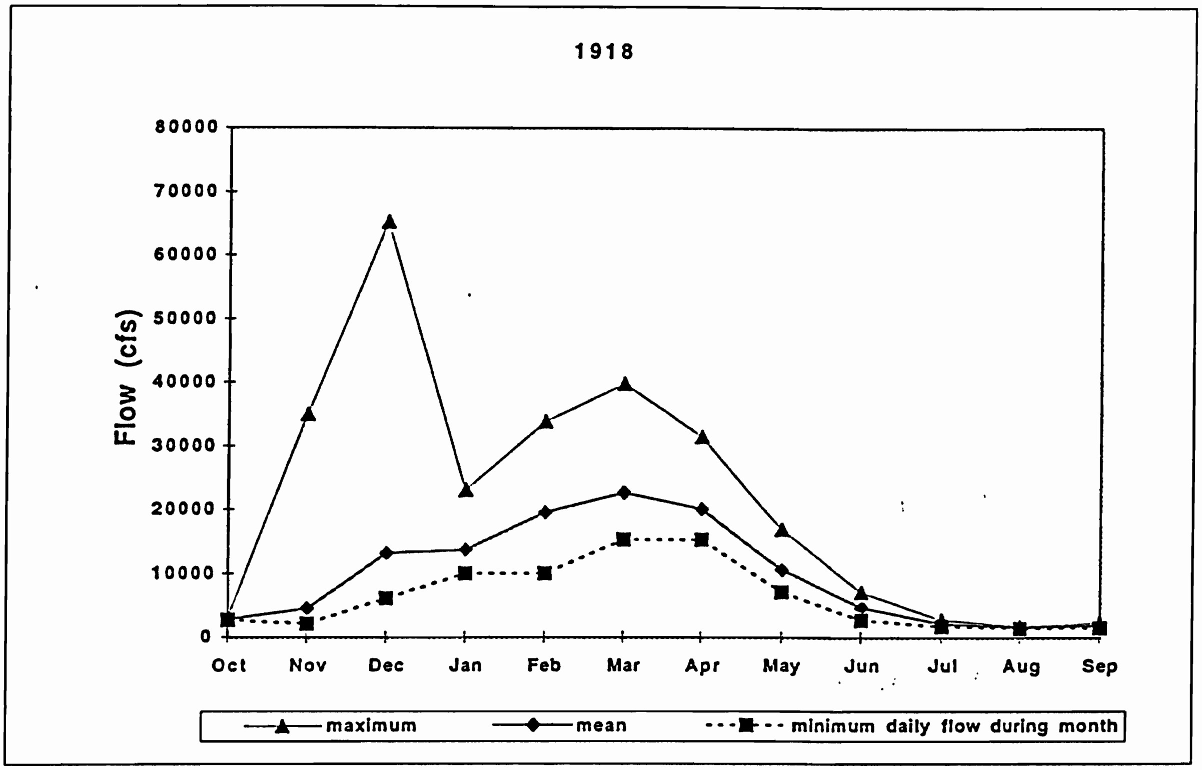
Pre- and Post-Project Monthly Flows
Klamath River at Klamath
(above normal runoff year)

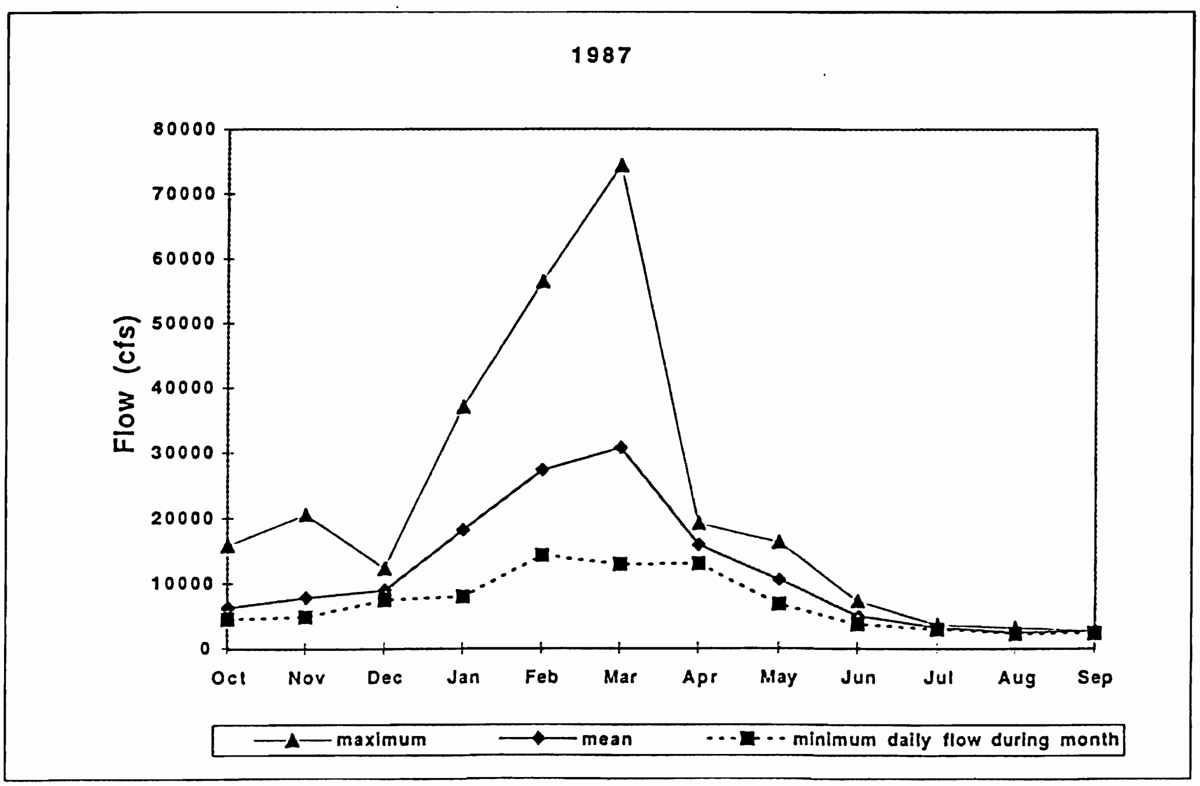




Source: USGS via Hydrosphere CD-ROM

Pre- and Post-Project Monthly Flows
Klamath River at Klamath
(below normal runoff year)

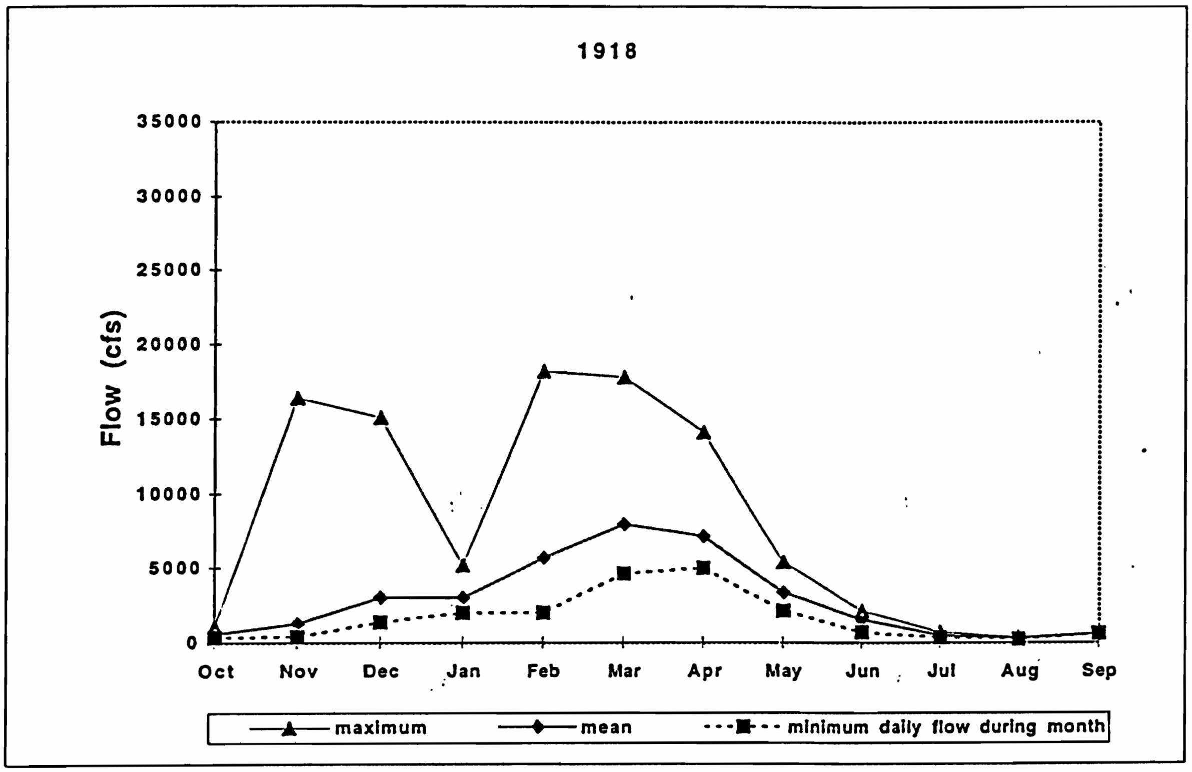


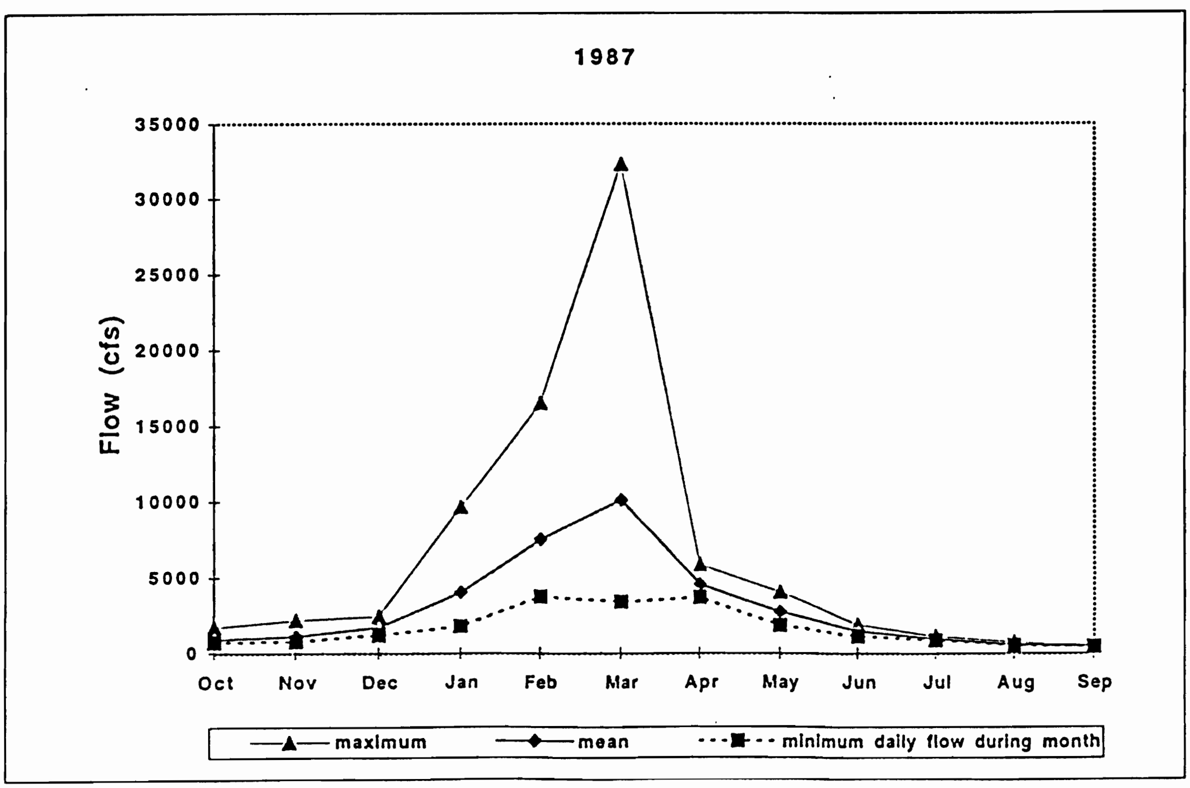


Source: USGS via Hydrosphere CD-ROM

FIGURE 20

Pre- and Post-Project Monthly Flows
Trinity River at Hoopa
(below normal runoff year)



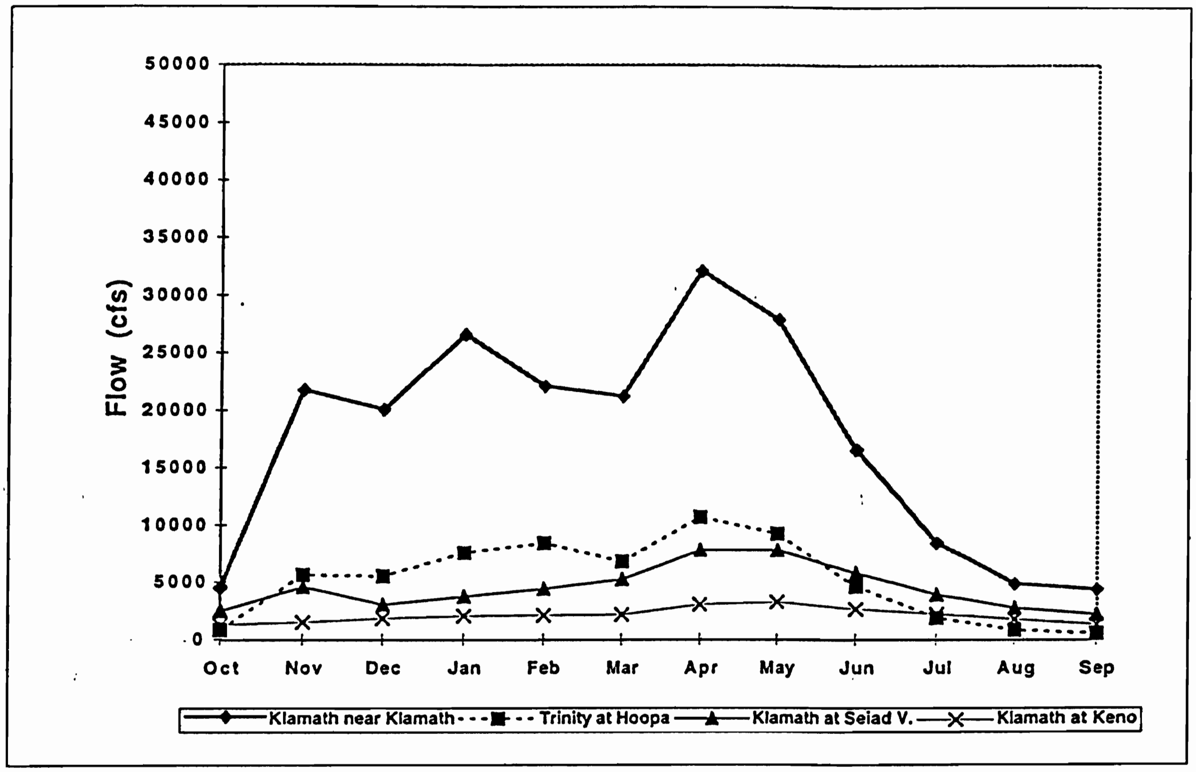


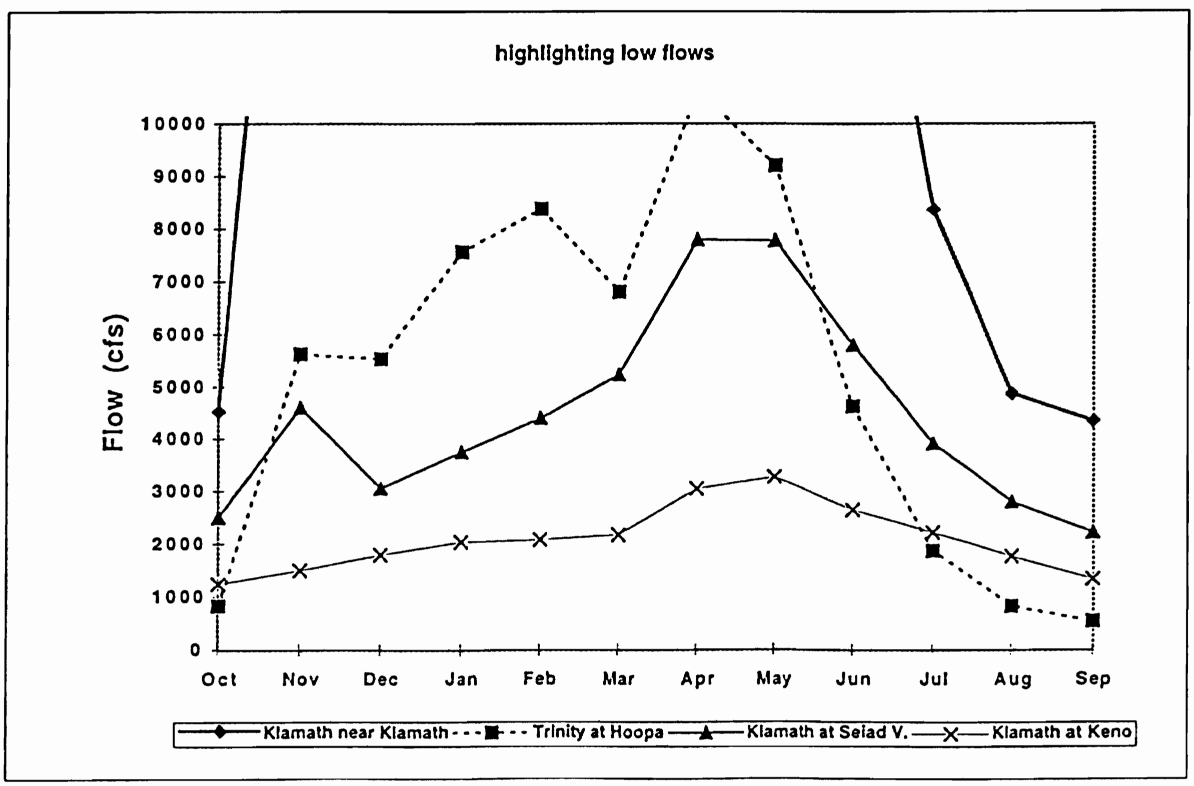
Source: USGS via Hydrosphere CD-ROM

Balance Hydrologics, Inc.
ATASTN2.XLS, Hoopa BN

FIGURE 21

Mean Monthly Flows: Klamath River Basin
WY1913
(above normal runoff year)





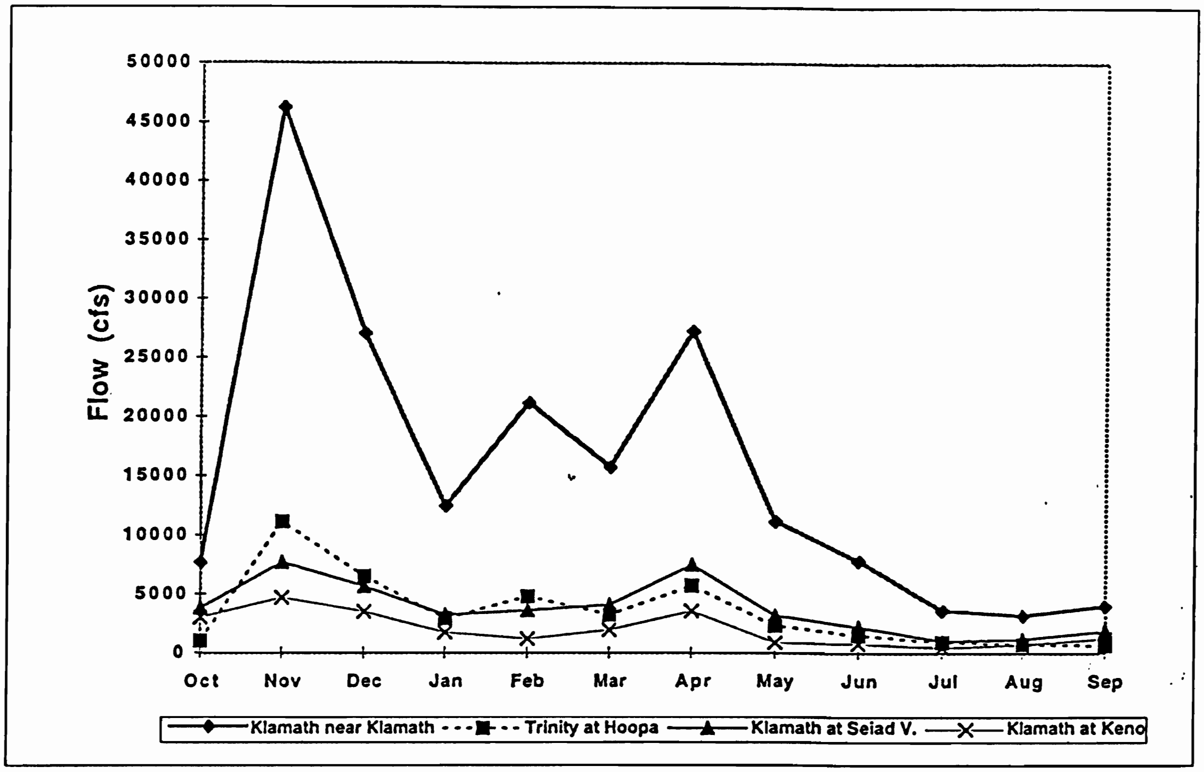
Source: USGS via Hydrosphere CD-ROM

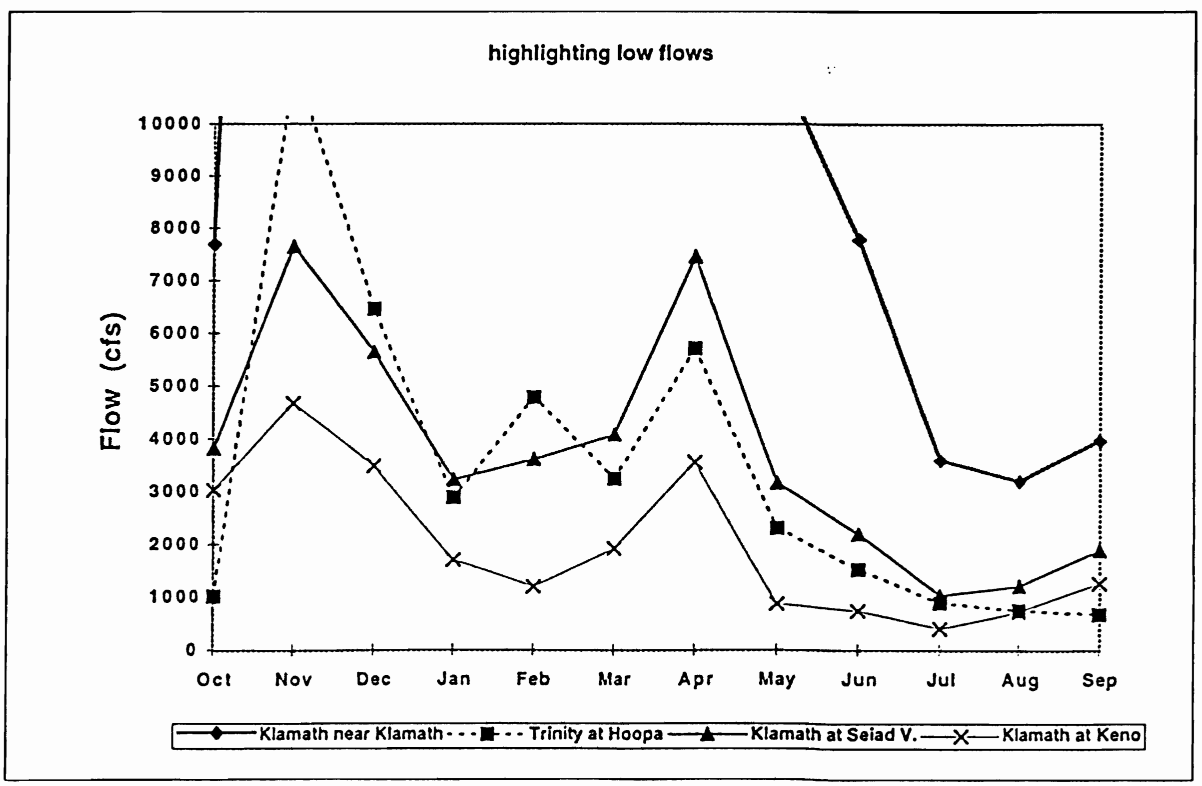
Balance Hydrologics, Inc.
ATASTN2.XLS, KRB1913

FIGURE 22

Mean Monthly Flows: Klamath River Basin WY1985

(above normal runoff year)



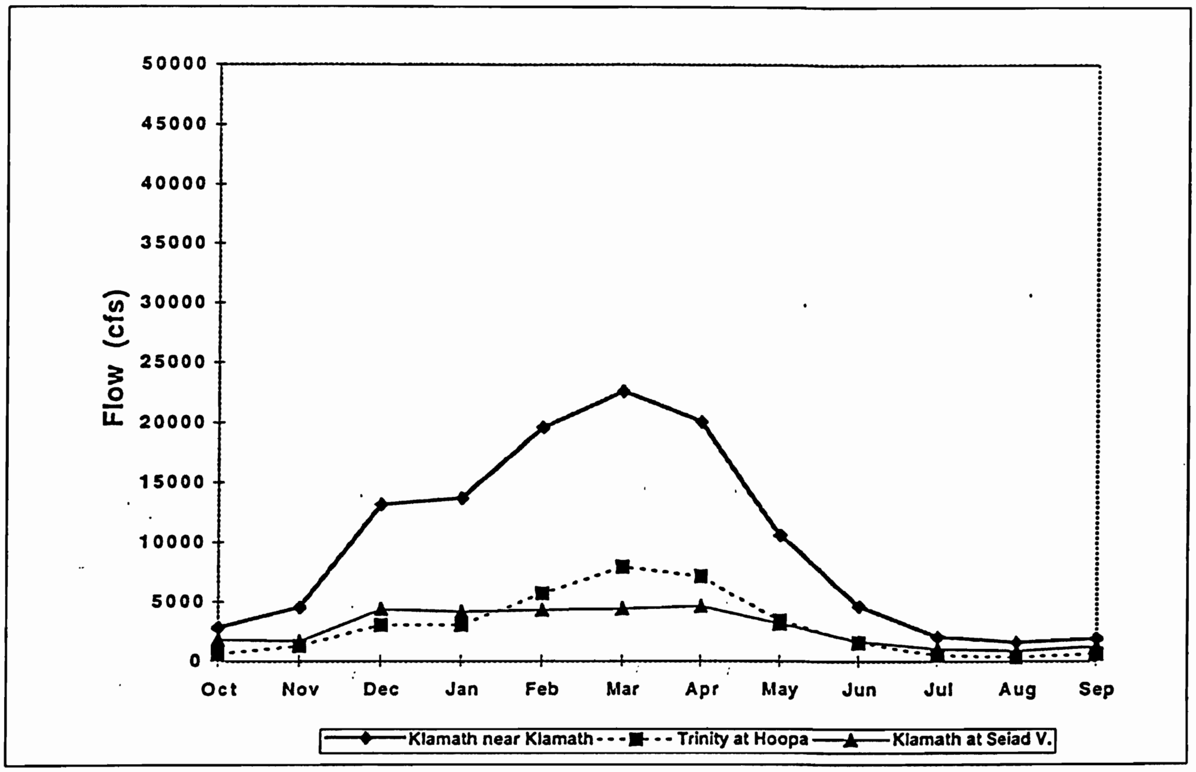


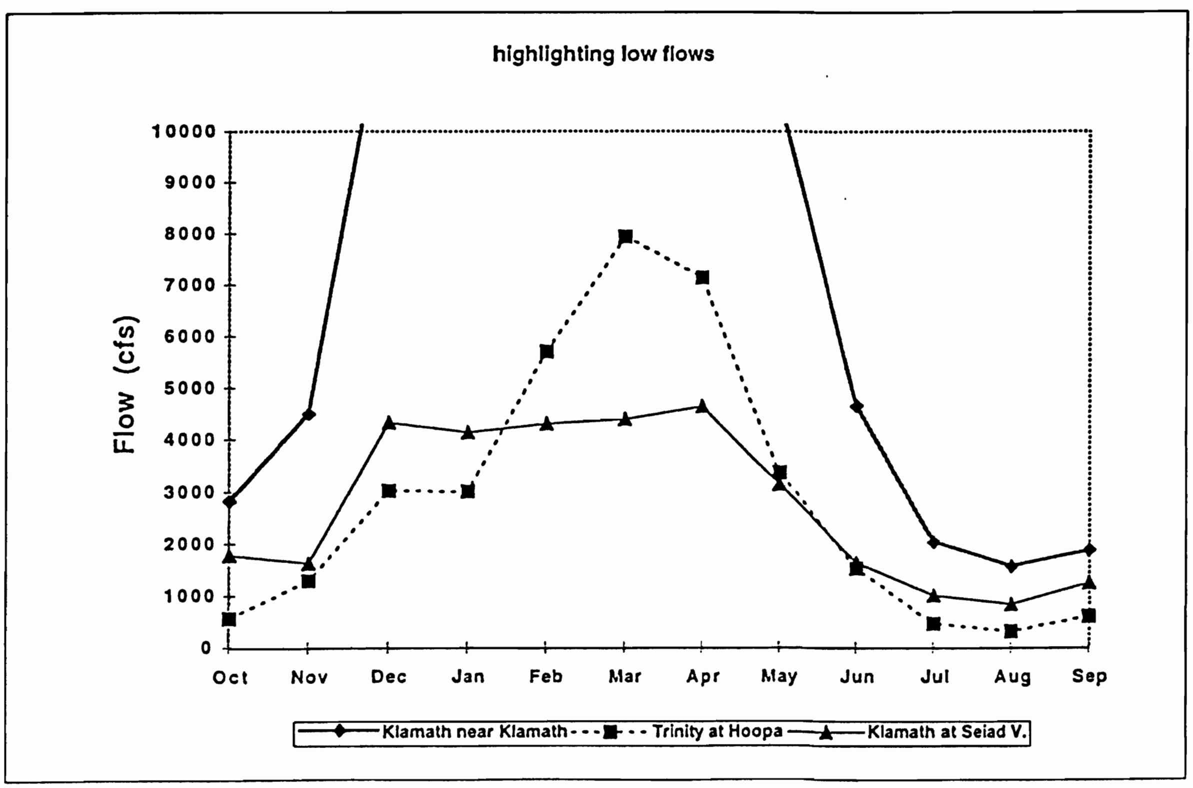
Source: USGS via Hydrosphere CD-ROM

FIGURE 23

Mean Monthly Flows: Klamath River Basin
WY1918

(below normal runoff year)



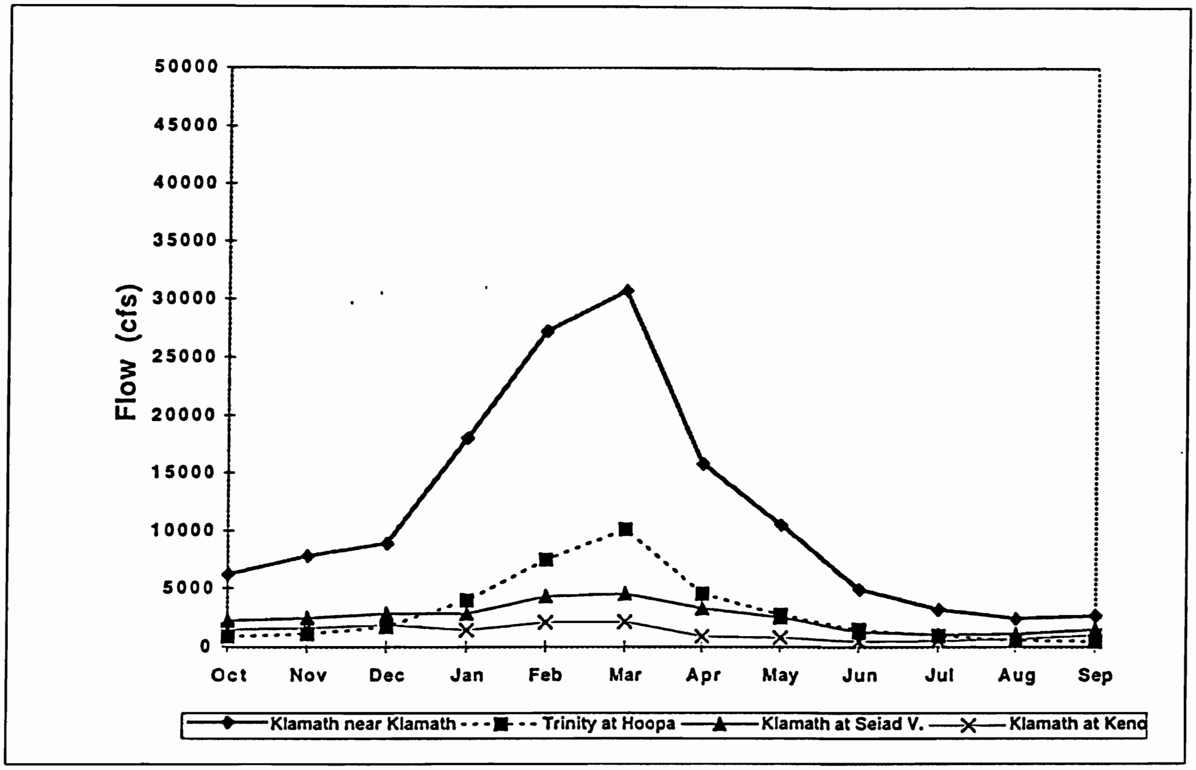


Source: USGS via Hydrosphere CD-ROM

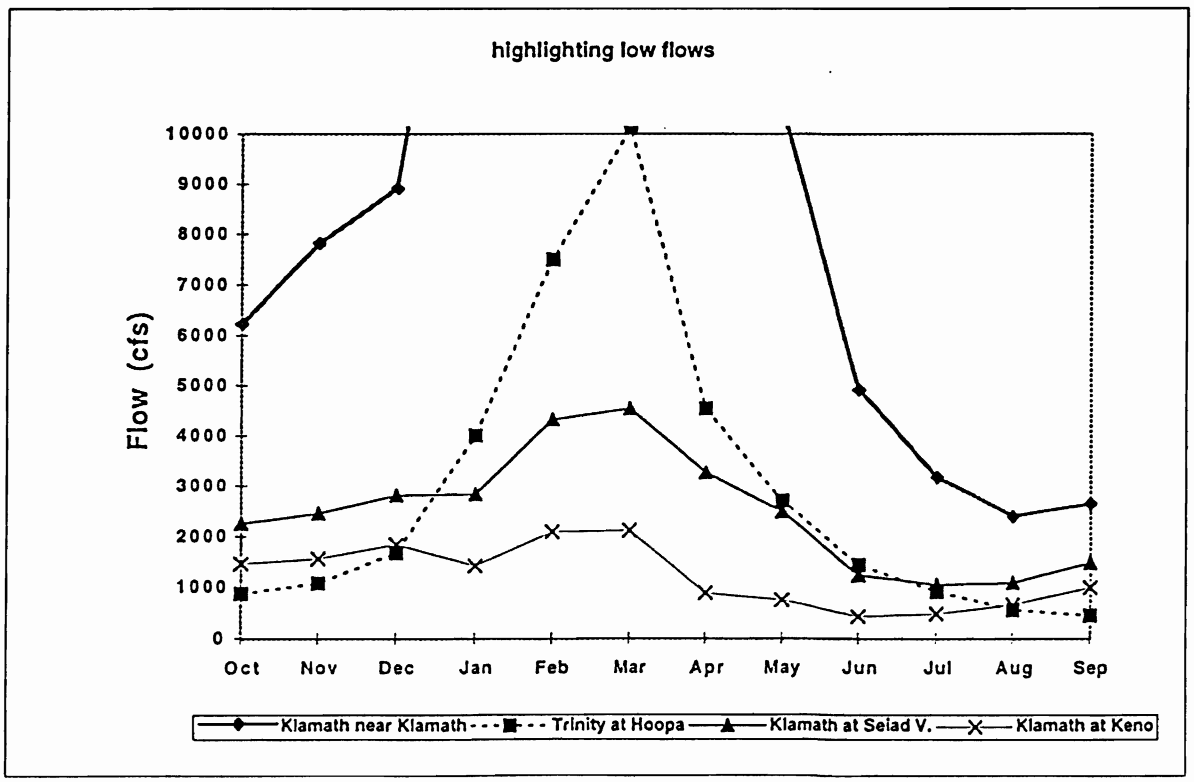
Balance Hydrologics, Inc.
ATASTN2.XLS, KRB1918

FIGURE 24

Mean Monthly Flows: Klamath River Basin
WY1987
(below normal runoff year)



highlighting low flows

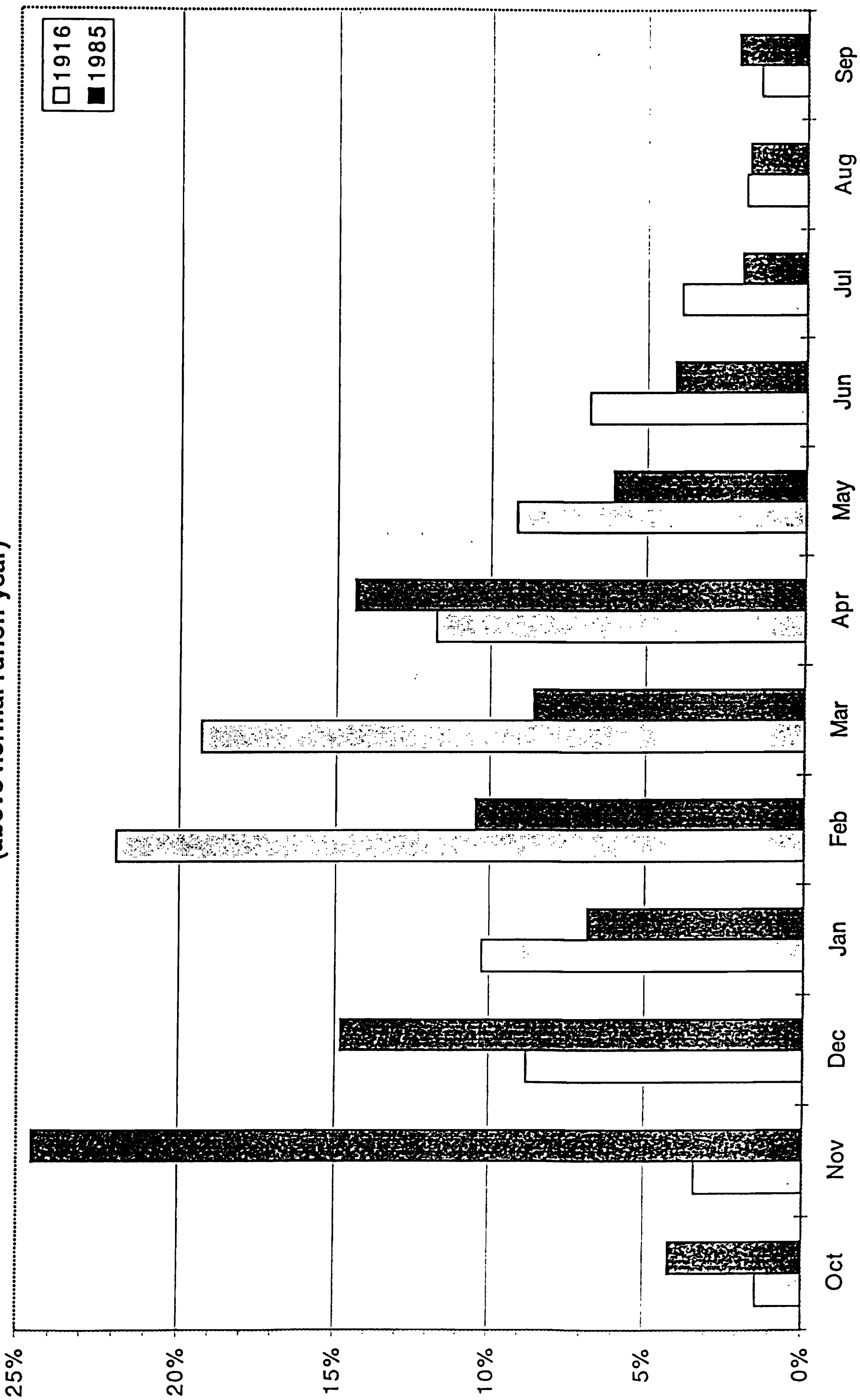


Source: USGS via Hydrosphere CD-ROM

Balance Hydrologics, Inc.
ATASTN2.XLS, KRB1987

FIGURE 25

**Mean Monthly Flow as Percent of Mean Annual Flow:
Klamath River near Klamath
(above normal runoff year)**



Source: USGS via Hydrosphere CD-ROM

Balance Hydrologics, Inc.
ATASTN2.XLS, 16,85

FIGURE 26

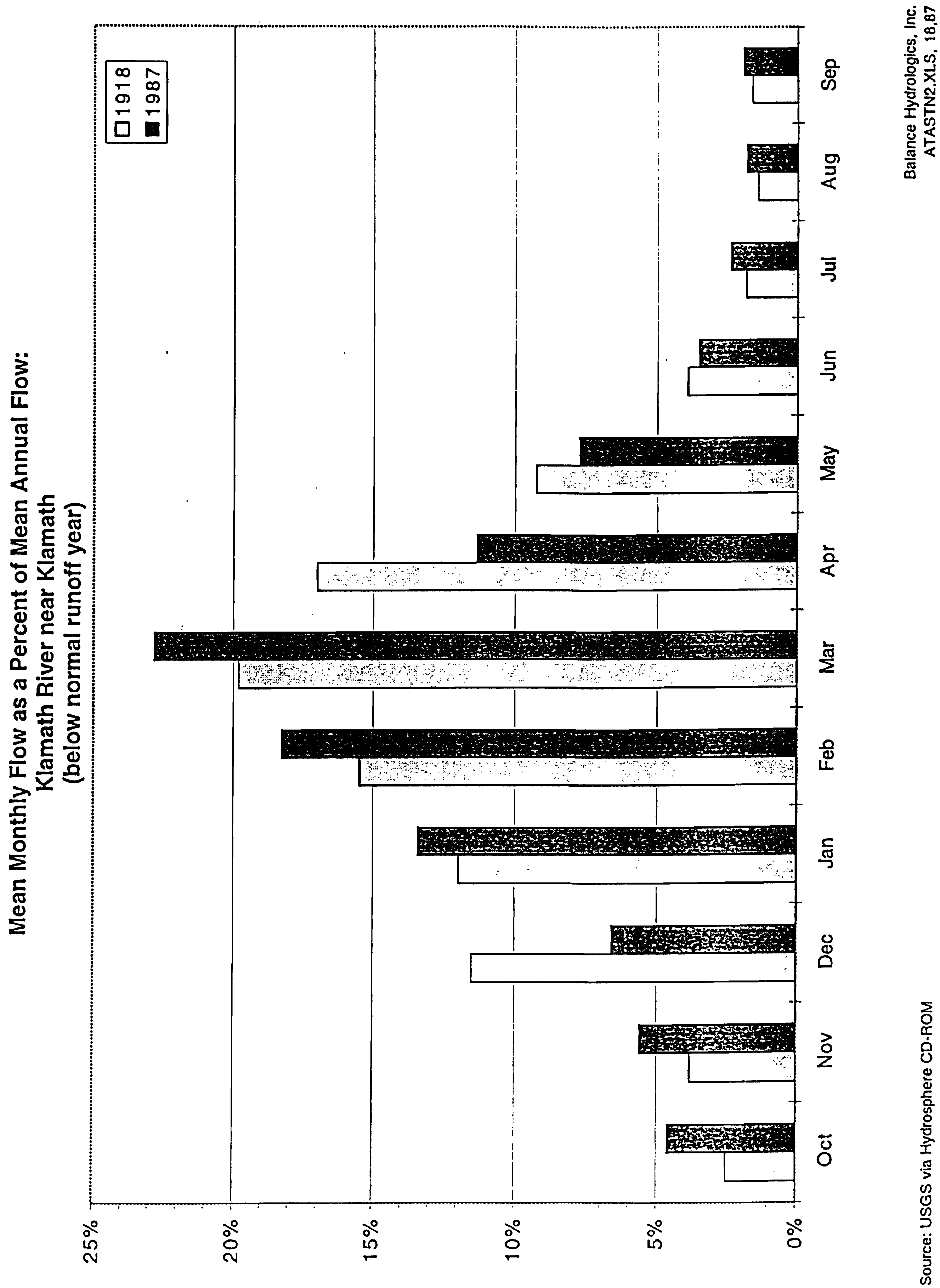
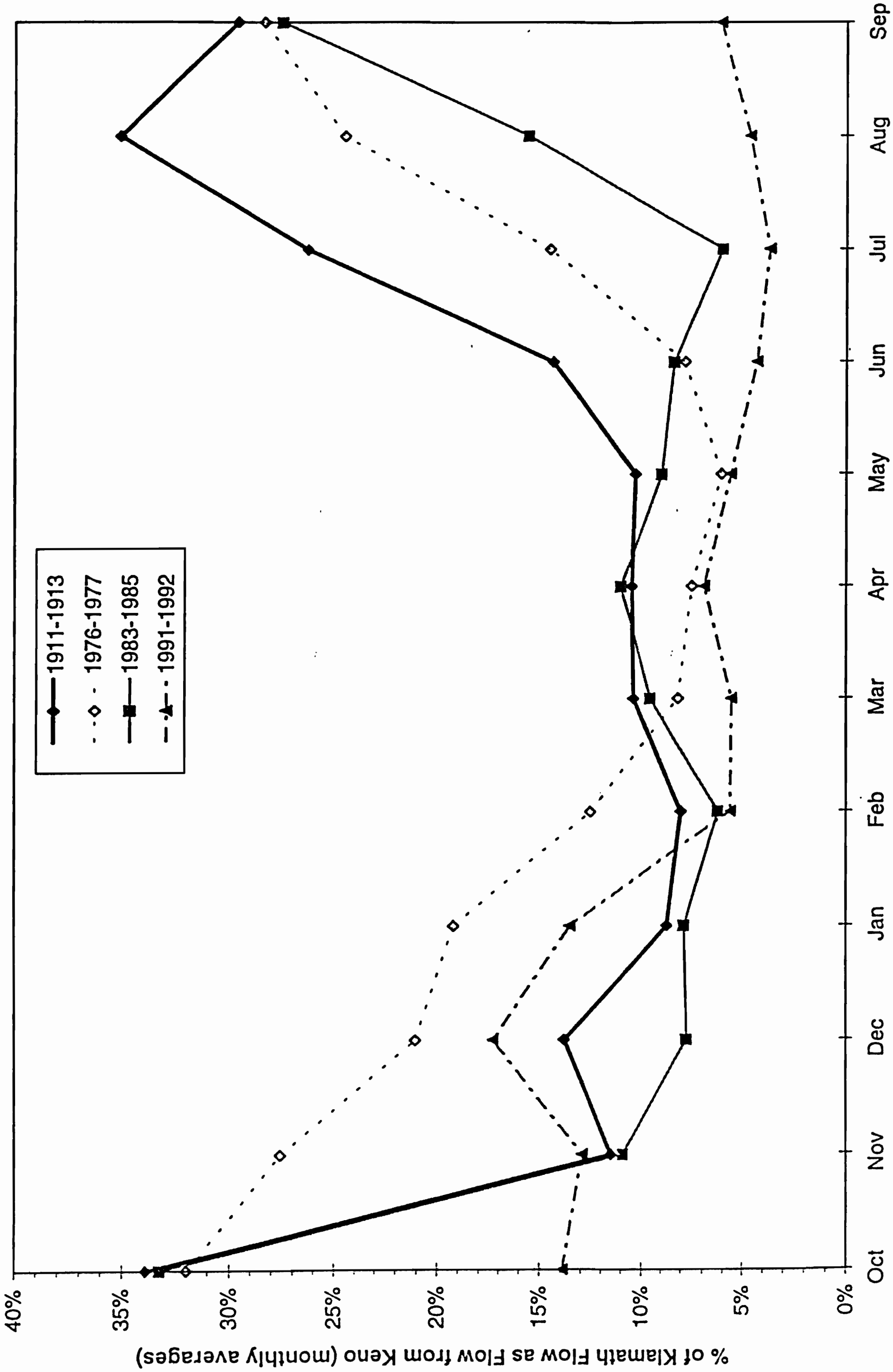

Mean Monthly Flow as a Percent of Mean Annual Flow:
Klamath River near Klamath
(below normal runoff year)
1918
1987
25%
20%
15%
10%
5%
0%
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Balance Hydrologics, Inc.
ATASTN2.XLS, 18,87
Source: USGS via Hydrosphere CD-ROM

FIGURE 27

Klamath River flow at Klamath as a percent of flow from Keno



Source: USGS via Hydrosphere CD-ROM

Balance Hydrologics, Inc.
DAILY_Q.XLS, Chart2

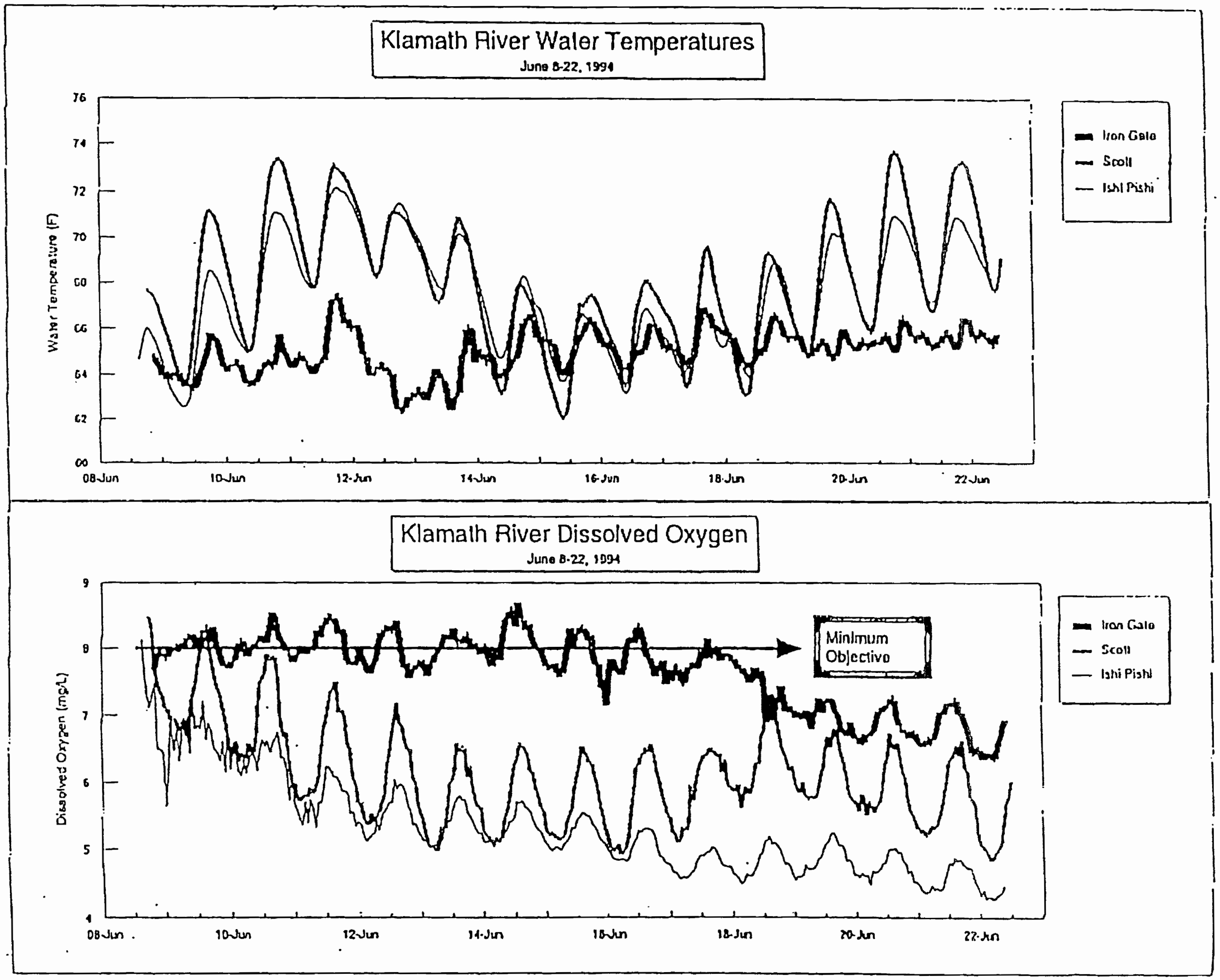


FIGURE 28: Temperature and dissolved oxygen measurements from the Klamath River at Iron Gate Dam, the confluence with the Scott River, and Ishi Pishi Falls (June 8-22, 1994)

(information courtesy of Karuk Tribe)

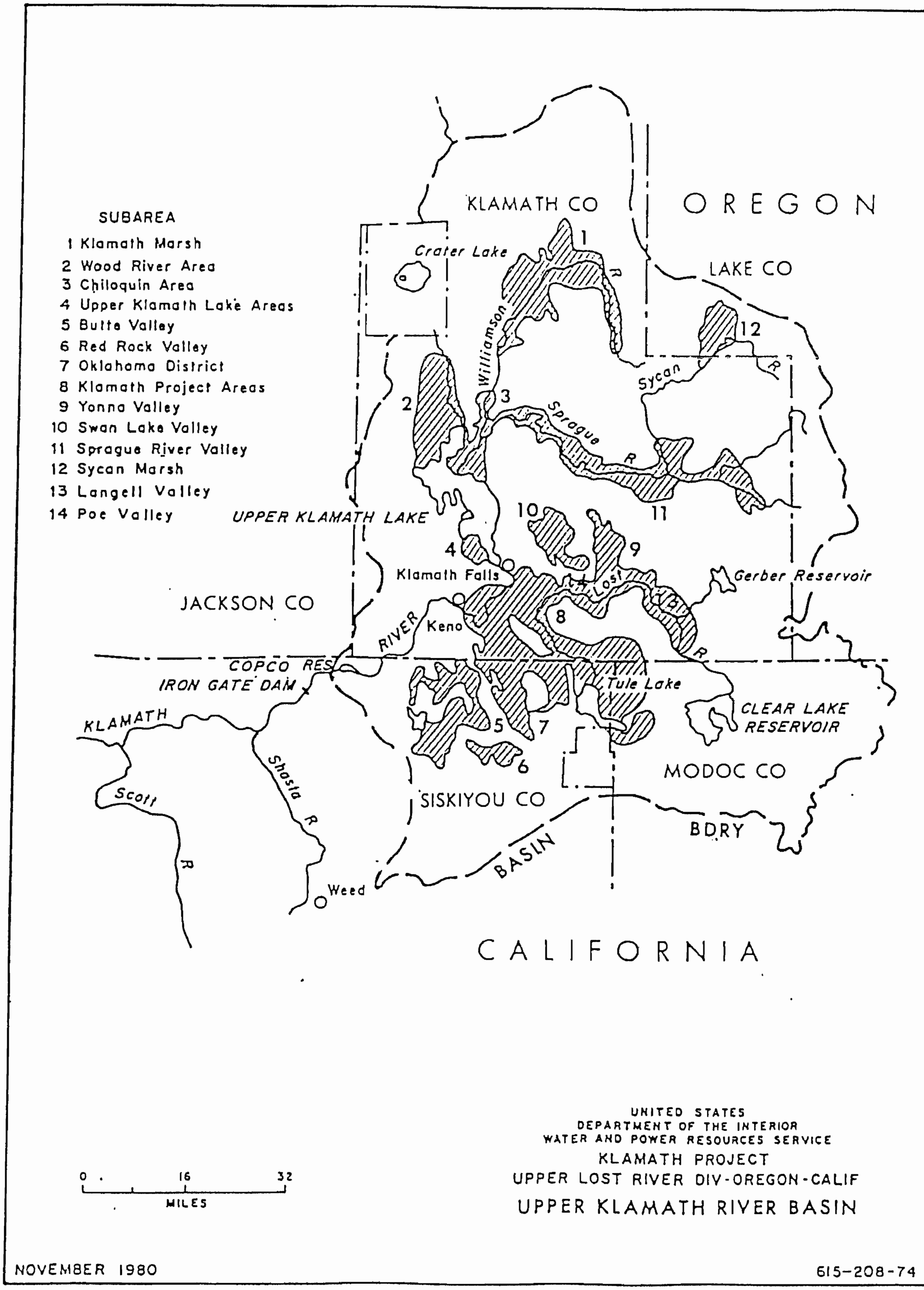


FIGURE 29: **Ground water basins in the upper Klamath River basin**

(source: US Dept. of Interior, 1981; Figure 1)

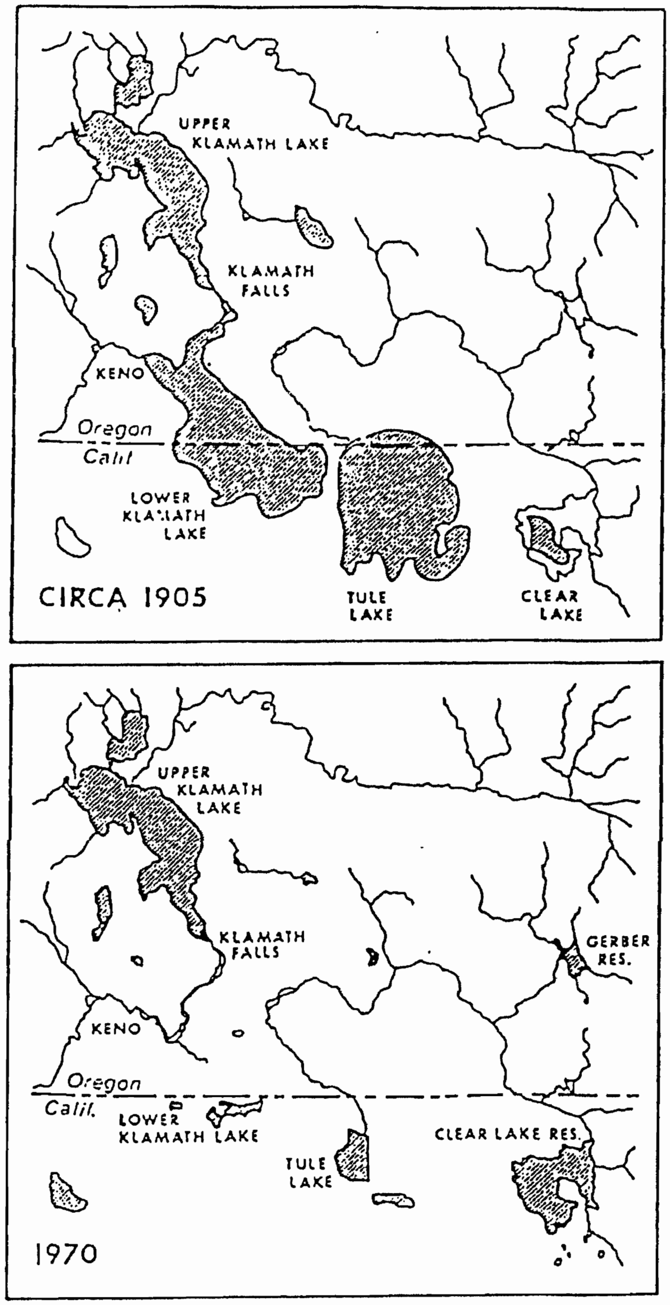


FIGURE 30: Changes in extent of lakes and perennial wetlands, upper Klamath basin

(source: US Army Corp of Engineers, 1979; Figure 4)

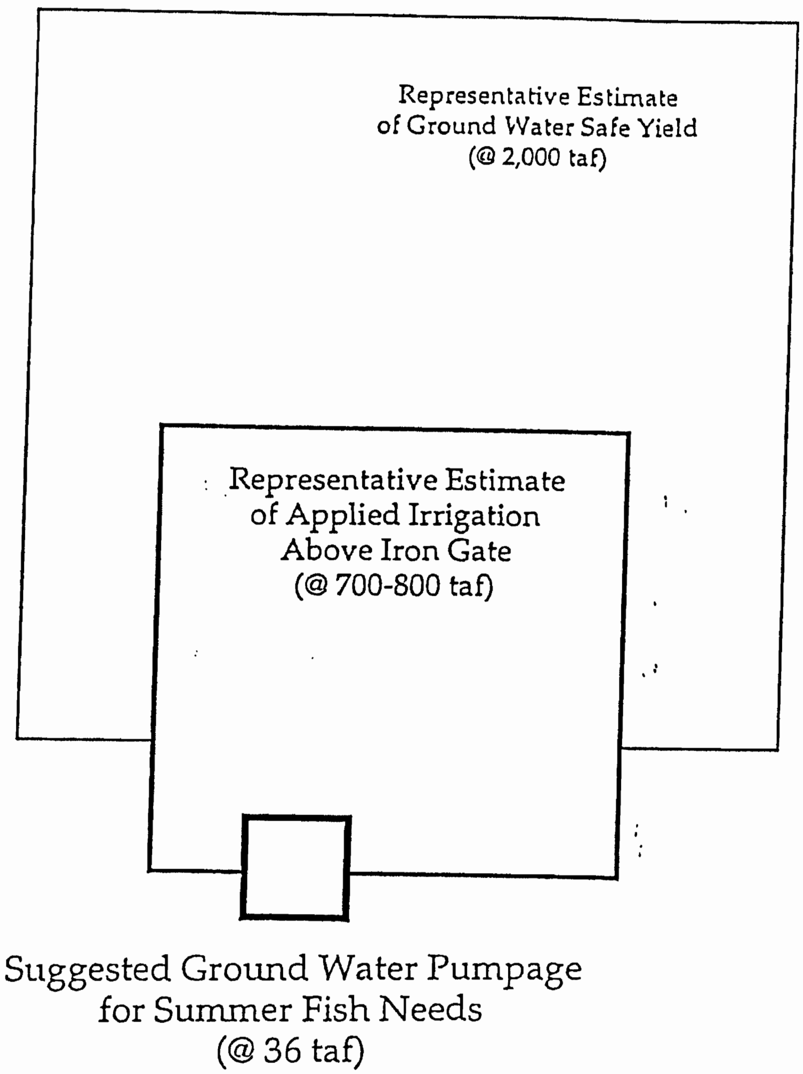


FIGURE 31: Comparison of dry-year pumpage, applied irrigation and representative estimate of ground-water safe yield, upper Klamath basin

APPENDIX A - RAINFALL/RUNOFF CORRELATIONS

Our analyses and investigations into the hydrology of the upper Klamath River basin led us to believe that runoff in the area which drains Upper Klamath Lake is dependent on rainfall and snowmelt from the preceding four to five years. We theorized that this carry-over effect should be prominent because of the extensive basalt bedrock geology in this region.

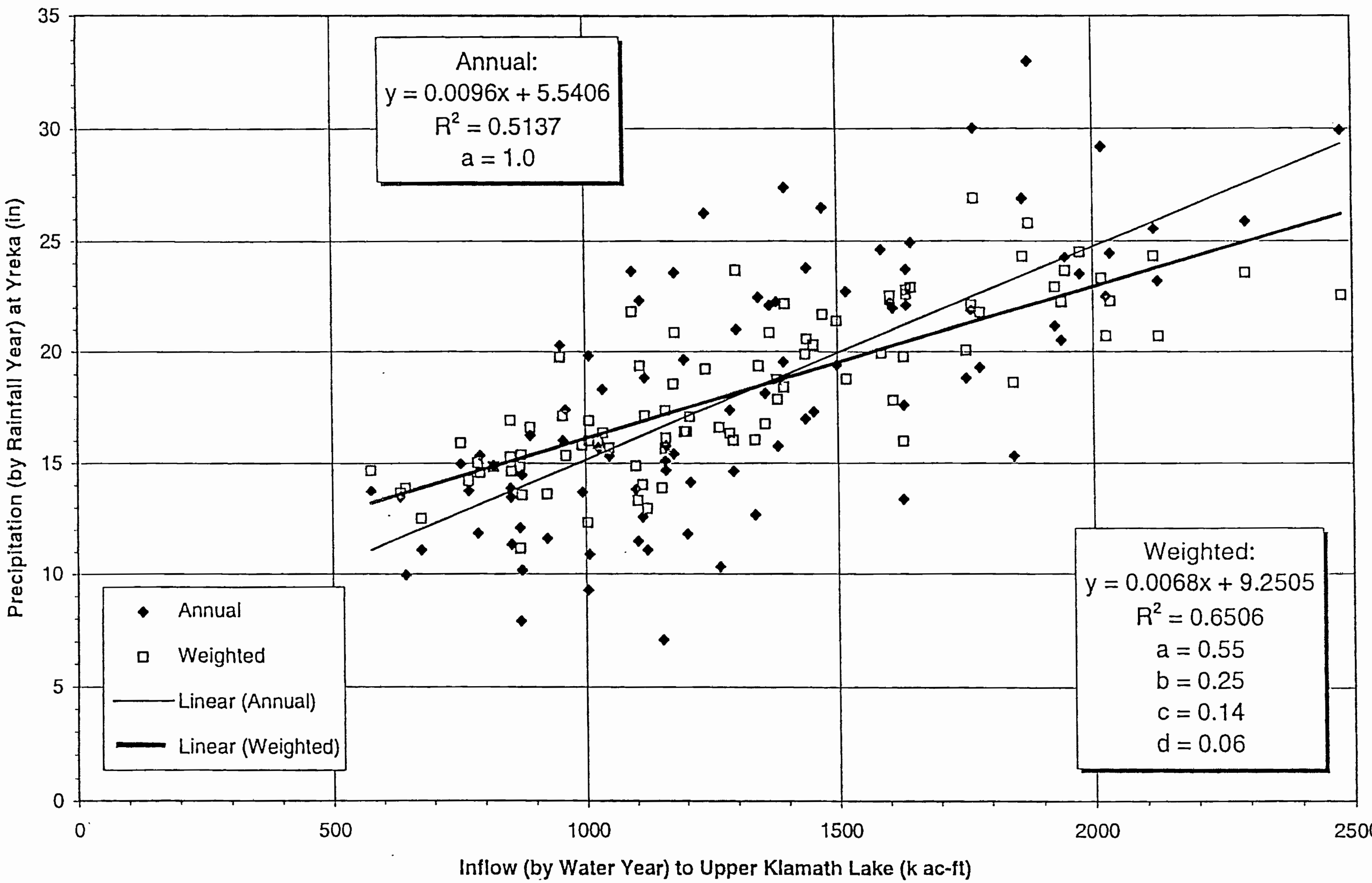
To test this theory, we compared the Bureau of Reclamation's inflow to Upper Klamath Lake record to precipitation records at Klamath Falls and Yreka. We compared these records in two important ways:

1. Direct correlation of annual (in water years) inflow to Upper Klamath Lake to annual (in rainfall years) precipitation.

2. Correlation of inflow to Upper Klamath Lake (by water year) to a weighted average of the four previous rainfall years. Weighting of previous-year rainfall was performed by assigning four scaling factors (**a**, **b**, **c**, and **d**) where **a** is the scaling factor for the current year, **b** is the factor for the previous year, **c** is the factor two years ago, and **d** is the factor for three years ago. In assigning values to these scale factors we specified that more recent years be weighted more heavily (i.e. **a**>**b**>**c**>**d**.)

We found that the direct correlation using only the current year of precipitation data yielded a lower correlation coefficient (R^2) than the correlation using weighted precipitation from four years (see attached example). This means that for precipitation records at both Klamath Falls and Yreka, a weighted average of the current and three previous years is a better predictor of flow into Upper Klamath Lake than is the current year's precipitation alone.

Correlation of Upper Klamath Lake Inflow to Precipitation at Yreka: 1906-1994



Source: Earth Info "NCDC summary of the day"

Balance Hydrologics, Inc.
PRECIPIT.XLS:Yrk-UKL

APPENDIX B - YUROK ELDER'S ACCOUNT OF DROUGHT AND FAMINE IN MID-19TH CENTURY

To: File 9506.11
From: Barry Hecht
Subject: Mid 1800's time of starvation, lower Klamath
Date: January 18, 1996

The following narrative was kindly passed on to me by Mary Jackson, a member of the Yurok Tribal Council. This is an account which she obtained from one of the older members of the tribe, "Auntie," whom Mary holds in high esteem. Auntie is currently 88 years old. She heard these accounts from her grandmother, and her grandmother was told by her grandmother. There was no mention of non-Indians during this time, so a reasonable window for dating the period of starvation would be in the early 1830s, prior to any non-Indian influence.

There was a great drought that lasted years. It was customary always to have a year's supply of food stored away, but hardly anyone was prepared for years of drought. Auntie was told by her grandmother that they had even resorted to boiling their shoes to make soup. Perhaps this is one reason why the Yurok people never waste any part of an animal or seafood or what they gather.

There was not enough spring salmon, not enough fall chinooks, or eels, or steelhead to feed everyone. The drought was sufficiently severe such that the oak trees did not produce acorns, and there were no berries to gather. Upriver there was little to eat. Many tribes from upriver headed for the mouth of the river, as it was rumored that seafood was available. This drought was so severe that it is still called "Tagah," which I understand means "they were starving." Quite a number of those who walked down the Klamath River did not survive. They were buried along the trail in shallow graves. Sufficient people died en route that the Yuroks make an effort not to excavate or dig along the sides of the old trails, so as not to disturb those who rest in these shallow graves.

Once, when Auntie was a child, erosion during a large storm disinterred a skeleton along the old trail. Her brother, her sister, and her grandmother came upon the skeleton. Her grandmother performed a ceremony and reburied the person properly. Paca said it was a young person from upriver, as the head was buried toward East, as was customary. Auntie asked, "How did you know it was a young person?" Her grandmother explained to Auntie that she could tell it was a young person because all of the teeth were there and they were not ground down.

BEFORE THE PUBLIC UTILITY COMMISSION OF OREGON

In the Matter of the Request of	)	
	)	
PACIFIC POWER & LIGHT	)	
(dba PACIFICORP	)	UE-170
	)	
For a General Rate Increase in the	)	
Company's Oregon Annual Revenues	)	
(Klamath Rate Case Portion of this Proceeding	)	

Rebuttal Testimony of

Kimberley Priestly

on behalf of

Oregon Natural Resources Council, Pacific Coast Federation of Fishermen's Associations, and WaterWatch of Oregon

February 6, 2006

Q: **PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.**

A: My name is Kimberley Priestly. My business address is WaterWatch of Oregon, 213 SW Ash St., Suite 208, Portland, Oregon 97204.

Q: **WHAT IS YOUR OCCUPATION AND BY WHOM ARE YOU EMPLOYED?**

A: I am the Assistant Director of WaterWatch of Oregon. I am licensed to practice law in Washington.

Q: **WOULD YOU PLEASE STATE YOUR EDUCATIONAL BACKGROUND AND EXPERIENCE?**

A: I have a B.S. in Business Administration from University of California, Berkeley and a law degree and L.L.M. in International Environmental Law from University of Washington. I am a member of the Washington Bar. I have over twelve years of experience working on Oregon water law and policy issues. My resume is attached to this testimony.

Q: **ON WHOSE BEHALF ARE YOU TESTIFYING IN THIS PROCEEDING?**

A: I am testifying on behalf of Pacific Coast Federation of Fishermen's Associations, Oregon Natural Resource Council and WaterWatch of Oregon as a rebuttal witness in this proceeding.

Q: **WHAT IS THE PURPOSE OF YOUR TESTIMONY?**

A: I was asked to review certain aspects of selected testimonies given before the Public Utility Commission of Oregon related to the request for a general rate increase from Pacific Power & Light (Docket No. UE 170). Specifically, my review was focused on the way that testimony by Edward Bartell and Louis T. Rozaklis (on behalf of the Klamath Off-Project Water Users, Inc.) accounted for different types of water rights and water use occurring in the Off-Project lands.

Q: **CAN YOU SUMMARIZE WHAT YOUR REVIEW FOUND?**

A: Yes, the central problem I found with the way that Edward Bartell and Louis T. Rozaklis account for water use is that both fail to account for any surface water that is diverted for agricultural irrigation in the Off-Project area. Because neither Mr. Bartell nor Mr. Rozaklis account for surface water diversions, surface water use and consumptive use of surface waters in the Off-Project area, I conclude their calculations and analyses regarding the alleged “increased [water] supply from Off-Project lands” (KOPWU/200, Rozaklis at 3 and elsewhere) are highly speculative and unreliable.

Mr. Bartell reports, anecdotally, that he has seen visible increases in flow that he attributes to farmers and ranchers pumping groundwater by using electricity, but his analysis fails to discuss or account for the reductions in streamflow that are also associated with irrigated agriculture, both from surface water diversions and the use of groundwater that is in hydraulic connection with surface streamflows. Similarly, while Mr. Bartell asserts that KOPWU’s evidence demonstrates Off-Project irrigation and drainage pumping “continues to provide a significant flow of water” for PacifiCorp’s hydroelectric generation, he fails to explain what the size of this flow would be, if it exists at all, in the absence of existing extensive use of surface water diversions for agriculture in the Off-Project area. Without analyzing these factors, it is impossible to evaluate, or put into context of any baseline flow, his claims of “increased” or “significant” flow. His analysis is deficient.

Likewise Mr. Rozaklis fails to account for surface water diversions for agriculture on irrigated Off-Project lands, yet he also claims an “increased [water] supply provided by off-Project agricultural lands” that is available for hydropower generation. KOPWU 202, Rozaklis at 6. Rozaklis’ analysis only considered groundwater, and failed to account for surface water used by irrigated agriculture in his analysis. Using Rozaklis’s numbers for groundwater irrigated acres and an estimate of the total irrigated acreage in the Off-Project area, I estimate that his analysis failed to include the approximately 170,000, or two-thirds, of the Off-Project area that is typically irrigated through the use of diversions from surface water sources. Because Rozaklis never accounts for the losses to streamflow resulting from these uses of surface water by irrigated agriculture in the Off-Project area, his estimate of “added” water from groundwater pumping analyzes only a fraction of total water diverted and used by irrigated agriculture in the Off-Project area. Accordingly, his analysis distorts any actual impact of Off-Project agriculture on surface water flows and the flows in the Klamath River used by PacifiCorp to generate power.

Rozaklis' analysis further appears simply to add assumed groundwater pumping from all supplemental groundwater rights in the Off-Project area, which significantly increases (by about 22%) the acreage from which he estimates return flow. This is a speculative assumption which ignores both the law and policy in Oregon regarding the use of supplemental water rights and whether such supplemental rights are ever actually used in any given water year. Rozaklis states that he did not attempt to quantify "the degree to which groundwater use has supplanted surface water use on off-Project lands," concluding that his "estimate of increased supply from groundwater-supplied off-Project lands is therefore conservative." If Rozaklis's "supplemental supply" rights are indeed supplemental groundwater rights, then his analysis is conjectural and speculative. Without analyzing whether the primary water rights were in fact unavailable and unused, he has no basis for assuming that use of the supplemental groundwater rights ever occurred.

Mr. Rozaklis characterizes his investigation as a "water budget approach". A true water budget would, at a minimum, account for both surface and groundwater appropriations. The United States Geological Survey is currently developing just such a water budget to estimate water use in the basin.

Given these data gaps and assumptions, I conclude Mr. Rozaklis testimony is speculative and unreliable.

Q: DOES THIS CONCLUDE YOUR TESTIMONY?

A: Yes.

Kimberley Priestley
213 SW Ash Street, Suite 208
Portland, OR 97204
(503) 295-4039

EDUCATION:

Legal:	**University of Washington School of Law** Juris Doctorate, June 1992 Member, Washington State Bar LL.M. International Environmental Law, June 1993 Ford Foundation Fellowship Recipient
Undergraduate:	**University of California, Berkeley** B.S. Business Admin./Economic Analysis & Policy, May 1988

WORK EXPERIENCE

11/93-2/05 9/05-present	**WaterWatch of Oregon, Assistant Director** Legal and policy work related to Oregon and Western Water Law; fundraising; legislative drafting and lobbying; public outreach; and media work.
Spring 1992	**American Rivers,** Legal Extern, Seattle, WA.
1991 & 1992 School year	**Research Assistant,** Professor Ralph Johnson, University of Washington School of Law.
Summer 1991	**Sierra Club Legal Defense Fund,** Legal Clerk, Seattle, WA.
Summer 1990	**Environmental Defense Fund,** Legal Clerk, Oakland, CA.

PUBLICATIONS: The National Wildlife Refuge System: Incompatible Recreational and Economic Uses of Refuge Lands, Spring 1992, University of Washington School of Law's Pacific Rim Law and Policy Journal.

Co-Author with Reed Benson, Making a Wrong Thing Right: Ending the "Spread"of Reclamation Project Water, Volume 9, 1994, Journal of Environmental Law and Litigation, University of Oregon.

Summary of Analysis by Kimberley Priestly Regarding Water Use and Water Rights Accounting in the Testimony of Mr. Rozaklis and Mr. Bartell

a) Summary

Rozaklis asserts that there is an "increased [water] supply provided by off-Project agricultural lands" that is available for hydropower generation. KOPWU 202, Rozaklis at 6. He quantifies this alleged increase in water by looking at groundwater pumping and loss of natural wetlands and marshes. However, he fails to account for losses in streamflow associated with surface water diversions in the Off-Project area which reduce the amount of water available downstream for PacifiCorp's hydropower generation.

Mr. Bartell similarly fails to account for surface water diversions by irrigated agriculture in the Off-Project area or elsewhere in the basin in his testimony.

b) Rozaklis Fails to Account for Streamflow Losses Resulting from Surface Water Diversions in the Off-Project Area

In concluding that there is an alleged increased water supply from Off-Project lands (KOPWU/200, Rozaklis at 3 and elsewhere), Mr. Rozaklis completely fails to account for reductions in streamflow from surface water diversions in the Off- Project lands.

Rozaklis states that groundwater pumping represents the sole irrigation supply for approximately 78% of the off-Project lands, and a supplemental supply for approximately 22% of the off-Project lands. KOPWU/202, Rozaklis at 6. He then provides the acreage of lands irrigated by these categories combined as 78,595 acres. Id. However, 78,595 acres only represents approximately 1/3 of the irrigated Off-Project acreage based on the published estimate for irrigated Off-Project acreage that I am familiar with which is 249,000 acres (see *ONRC et al*./103, McCarthy at 7)[1]. Irrigation is either done with groundwater or surface water. Assuming the accuracy of Mr. Rozaklis's numbers of Off-Project groundwater irrigated acreage and comparing that to estimates of total Off-Project irrigated acreage, Rozaklis fails to account for approximately 170,000 acres irrigated with surface water.

While determining the exact amount of surface water diversion occurring on Off-Project lands is beyond the scope of my analysis[2], the existence of at least some such diversions

[1] The total irrigated acreage in the Off-Project area likely varies somewhat from year to year.

[2] While I did not undertake a complete analysis of Off-Project surface water diversions, a cursory review of the Water Resources Department's Water Rights Information System data base shows a total of 247,005.300 acre-feet and 3,991.36 cfs of permitted and/or certificated surface water rights have granted for primary irrigation in the Klamath Basin.
http://apps.wrd.state.or.us/apps/wr/summary_reports/pod_summary/php.
This number does not include the unadjudicated pre-1909 water claims (the Klamath adjudication involves thousands of claims), which would increase these numbers substantially. The USGS estimates that as much as 1,000,000 acre feet of water may be used for irrigation of agricultural crops per year in the Klamath Basin. USGS, Klamath Basin Estimation of Water Use Work Plan,
http://or.water.usgs.gov/projs_dir/or007/klamplan.html. A draft Oregon State University/University of

is confirmed by Mr. Bartell's testimony where he identifies "low lift pumps that divert from surface water bodies" as one of the five types of irrigation systems in the Off-Project area (KOPWU/100, Bartell at 10) and by the fact that Rozaklis identifies only around 78,595 acres of Off-Project lands as having any associated groundwater rights when irrigated Off-Project lands total around 249,000 acres (see *ONRC et al.*/103, McCarthy at 7). Thus irrigation with surface water appears to be the spatially predominant method of irrigation on Off-Project lands. Given this, it is impossible to accurately determine whether there is a net addition or subtraction of water resulting from water use in the Off-Project area if the large amount of surface water diversions and associated consumptive uses are not accounted for.

Rozaklis's focus on the groundwater irrigated acreage while excluding surface water irrigated lands (from both permitted/certificated and unadjudicated rights) makes his conclusion of extra water provided from Off-Project lands highly speculative and unreliable. Even assuming for the sake of argument some amount of flow is contributed from groundwater pumping, if the consumptive use and other system losses associated with surface water diversions in the Off-Project area exceeds that amount, then there would be no "added" water from the Off-Project area and, in fact, agriculture in the Off-Project area would be reducing the amount of streamflow available for downstream hydropower generation by PacifiCorp. Because Rozaklis did not look at surface diversions, his statements about an "increased [water] supply provided by off-Project agricultural lands" that is available for hydropower generation is based on an incomplete analysis and may well be wrong. KOPWU 202, Rozaklis at 6 and elsewhere.

c) Rozaklis Overestimates Groundwater Pumping by Incorrectly Assuming the Use of Supplemental Groundwater Permits

Rozaklis appears to over-estimate the amount of groundwater pumping by including acres where groundwater is a "supplemental supply" in his totals for groundwater irrigated lands. KOPWU 202, Rozaklis at 9, Table 1. Rozaklis identifies 22% (17,501 acres) of Off-Project lands with groundwater rights as having an associated groundwater "supplemental supply". Rozaklis assumes that in the case where groundwater was a supplemental supply, it provided 50% of the irrigation supply.

Under Oregon water law, a supplemental water right may be approved for acreage already covered by an existing, or primary, water right (Rozaklis refers to primary groundwater rights as "sole supply"). A supplemental water right is defined as an additional appropriation of water to make up a deficiency in supply from an existing water right. OAR 690-300-010(52). In other words, a supplemental water right is only used when the water right holder cannot appropriate water to which he/she is legally

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California report found that the Klamath Project, including wildlife refuges, consumptively uses approximately 350,000 acre-feet of water annually; this number does not include consumptive uses on Off-Project lands. Water Allocation in the Klamath Basin: An Assessment of Natural Resources, Economic, Social and Institutional Issues, A Report (draft) Oregon State University and University of California, 12/14/01, at 11. Neither Mr. Bartell nor Mr. Rozaklis address consumptive use associated with surface water diversions in their testimony.

entitled under the primary right. Rozaklis assumes that supplemental groundwater rights provided 50% of the irrigation on lands where groundwater was a supplemental supply. However, Rozaklis states that he did not attempt to quantify "the degree to which groundwater use has supplanted surface water use on off-Project lands," concluding that his "estimate of increased supply from groundwater-supplied off-Project lands is therefore conservative." Given that it is it is possible that the supplemental water rights are rarely if ever used, it is likely that the opposite of his conclusion is true because without conducting such an analysis he has no basis for assuming that use of the supplemental groundwater rights on the 17,501 acres of Off-Project lands ever occurred.

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