Barnes, Peter@Waterboards

From:	Dick Daniel <dadaniel@peoplepc.com>
Sent:	Friday, March 20, 2015 8:41 AM
To:	Barnes, Peter@Waterboards
Subject:	RE: Re: Camanche Reservoir report.

Thanks Peter I really think pumping air into the lake would provide a significant benefit.. I also note that in response to my comments about the history of trout populations in the river, the representative of the white water group gave me 1940's article about stocking pond raised trout. Maybe a solid pond rearing program will help them reach their objectives

Dick the old guy

-----Original Message-----
From: "Barnes, Peter@Waterboards"
Sent: Mar 18, 2015 11:08 AM
To: Dick Daniel
Subject: RE: Re: Camanche Reservoir report.

Mr. Daniel,

Thank you. I will make sure to add this information to your previous comments.

Sincerely,

Peter Barnes
Engineering Geologist
Water Quality Certification Program
Division of Water Rights
State Water Resources Control Board
Phone: (916) 445-9989
Email: Peter.Barnes@waterboards.ca.gov

From: Dick Daniel [mailto:dadaniel@peoplepc.com]
Sent: Thursday, March 12, 2015 9:56 AM
To: Barnes, Peter@Waterboards
Subject: Fw: Re: Camanche Reservoir report.

I suggested something like this to mitigate impacts of cold water releases at Almanor. It is proven technology, and relatively cheap. I don't know why PG&E doesn't like it

Dock Daniel

Barnes, Peter@Waterboards

From: Aaron Seandal <aseandel@frontiernet.net>
Sent: Sunday, March 08, 2015 2:29 PM
To: McReynolds, Scott@DWR; Carl Felts; Charles Plopper; Chris Mayes; Courtney Gomola; Dick Daniel; Gina Johnston; Jonathan Kusel; Lorena Gorbet; Nils Lunder; Peggy Fulder; Ryan Burnett; Sherrie Thrall
Subject: Re: Camanche Reservoir report.
Attachments: Camanche overview for CALMS tour-final.pdf

Hi all:

I read the Camanche Reservoir report that Scott sent with great interest given the results achieved in improving the Dissolved Oxygen, improving the fish habitat and in containing the algal output by 80% in that reservoir.

Someone should send a copy of this report to the SWRCB and to P.G.E. with a request to evaluate the methodology employed in Camanche as an another alternative to consider in the DEIR.

Aaron

From: mailto:Scott.McReynolds@water.ca.gov
Sent: Thursday, March 05, 2015 1:52 PM
To: Aaron Seandal ; Carl Felts ; Charles Plopper ; Chris Mayes ; Courtney Gomola ; Dick Daniel ; Gina Johnston ; Jonathan Kusel ; Lorena Gorbet ; Nils Lunder ; Peggy Fulder ; Ryan Burnett ; Sherrie Thrall
Subject: RE: Getting there---a letter to be sent to Peter Barnes, SWRCB, from the group.

Hi everyone,

I am glad I was able to attend last evening's meeting to discuss 2105, 2014 WQ report and what we may endeavor to accomplish with the monitoring program this coming season. I had mentioned a potential alternative for dealing with hypolimnetic oxygen depletion observed for some time in Lake Almanor. Attached is a nice summary describing the "Speece-Cone (HOS)" solution that has been in operation within Camanche Reservoir near Lodi, operated by EBMUD for 27 years. The report shows great success in increasing suitable fish habitat, as well as several other WQ benefits including:

1. Increased DO in the cold water pool,
2. Decreased H2S/ methyl mercury production
3. Decreased ammonia and nutrients
4. Decreased algal blooms by 80%
5. Improved downstream water quality/fishery habitat for chinook,
6. Improved power generation potential/water supply (See economics section) This should be attractive to PG&E interests

Please take a look at this and I would especially like Gina's take on the chlorophyll and algae discussions and the potential to address these current issues in Almanor.

These benefits could make this an attractive alternative that PG&E might consider, especially if there are the added benefits of increased operational flexibility and ability to recover potential lost power Gen revenue; In the EBMUD example, these economic benefits essentially pay for the operation of this system.

I attended this conference and was able to tour the site. I immediately thought of Lake Almanor since it is similar in size and experiences many of the same problems that led to this solution.

I will send the link to the WDL/DWR WQ website on Monday-

-Scott

Scott McReynolds
O:(530) 529-7304 Mobile: (530)570-6317
Scott.McReynolds@water.ca.gov

A SUMMARY FOR CALMS OCTOBER 2014 CONFERENCE ATTENDEES WHO PARTICIPATED IN THE CAMANCHE RESERVOIR FIELD TRIP TO OBSERVE THE HYPOLIMNETIC OXYGENATION SYSTEM (HOS) USING A SPEECE CONE

By **Alex Horne**, past President of CALMS, professor emeritus of Ecological Engineering, University of California, Berkeley (anywaters@comcast.net). 15 October 2014

NOTE: THIS IS A SUMMARY OF SIX PAPERS FOR CALMS MEMBERS. I EXPECT TO SUBMIT THESE PAPERS TO NALMS JOURNAL LAKE AND RESERVOIR MANAGEMENT IN DECEMBER 2014. YOU CAN FREELY QUOTE FROM THIS PAPER WITH ME AS THE SOURCE, BUT IT SHOULD NOT BE USED AS ORIGINAL MATERIAL FOR PUBLICATIONS IN PEER-REVIEWED JOURNALS SINCE THAT WOULD COMPROMISE MY ABILITY TO PUBLISH

Abstract

Over the past 20 years, a Hypolimnetic Oxygen System (HOS) using a 23-ft-high Speece Cone in Camanche Reservoir has proven to be an efficient way to prevent fish kills which historical resulted in the loss of 300,000 hatchery fish in the late 1980s. The HOS uses between 2 and 8 tons/day oxygen, driven by a 140-HP electric water pump. The mode of action is by suppressing sediment anoxia and associated nutrient-releasing reactions driven by low redox potential. Such reactions release hydrogen sulfide, methyl mercury, iron, manganese, ammonia and phosphate. Within a year of startup, nutrients and algae, including colonial blue-green genera, were substantially reduced and water clarity greatly increased. Turbidity and heavy metals declined substantially in the reservoir's deep outlet. Fish habitat in the reservoir expanded to include most of the hypolimnion. The trophic state improved from eutrophic to mesotrophic or oligotrophic (depending on the index). The cost benefit ratio averaged 1:27, primarily due to a doubling of the returns of Chinook salmon in the Mokelumne River and increased water availability during dry periods. With HOS, the dam outflow attains its downstream oxygen standard and the additional hydropower revenue roughly balances the HOS' O&M costs. HOS is not a one-time, permanent cure; rather, the current desirable trophic state in Camanche Reservoir relies on oxygenation for about 95 days/year.

The situation

Camanche Reservoir (7,680 acres) is a multi-purpose reservoir on the mid-Mokelumne River, a tributary to the Sacramento-San Joaquin Delta. Its primary purpose is water supply for a downstream salmonid fish hatchery, but additional benefits include irrigation, flood control, hydropower, and public recreation. It allows Pardee Reservoir, just upstream, to function primarily as a water supply for 1.3 million people in the East Bay Municipal Water District (EBMUD) service area around Oakland (**Figure 1**). The hatchery directly below the dam serves as mitigation for the loss of spawning gravels for Chinook salmon and the endangered steelhead trout although some original spawning sites remain in the river below the dam. The main commercial and sport fish is the Chinook salmon. Because cool water is the most influential physical factor influencing steelhead and Chinook salmon hatcheries in warm locations, they often are supplied by cold hypolimnetic water. Unfortunately, some reservoirs have poor water quality in the hypolimnion, generally associated with low dissolved oxygen (DO) concentrations. The situation is less manageable in reservoirs like Camanche where there is only one bottom outlet rather than a multiple outlet tower.

In autumn 1987 and 1989, sudden deaths of about 300,000 young hatchery fish about 8 cm long occurred. A criminal complaint against EBMUD was filed by a county attorney based on statements by the California Department of Fish and Game (CDFG) who considered the district's release of water downstream as harmful to the fish. An added complication was that CDFG thought that the main cause of the fish kills was the low reservoir level (21 m vs. 27 m as max depth), which destabilized the reservoir, leading to a fall turnover that mixed turbid, anoxic water into the dam outlet. The difference in reservoir level and thus volume was important. The difference between 21 and 27 m is 92,450 acre-feet–enough to supply 185,000 homes or 14% of EBMUD's customers for a year. In droughts EBMUD often mandates water rationing so water is scarce everywhere.

Low DO is a common cause of fish kills, but the Camanche hatchery water was fully aerated mechanically and had high DO. As in many other fish kills, the active agent in sudden mass fish kills was not obvious. However, hydrogen sulfide H_2S has long been known as a rapid toxic agent so was initially assumed to be the toxic agent. This assumption was later proven correct.

This summary paper for CALMS members summarizes the successful solutions to for the two causes of the fish kills (H_2S in 1987; destratification in 1989). Many people were involved in solving the Camanche fish kills problem but EBMUD staff closely working with Prof. Horne were CALMS member Rod Jung, his boss Hubert Li, a number of EBMUD staff expert in fisheries and reservoir operations as well as civil engineers Bill Faisst and Bob Grace at Brown & Caldwell Engineers in Walnut Creek and then-graduate student Marc Beutel (now professor of Civil Engineering, Washington State University).

Action Taken

- A **Hypolimnetic Oxygen System (HOS)** which has worked for 27 years through drought, normal, and wet years. Pure oxygen is supplied as a gas to a submerged gas solubilization system (a Speece Cone) which releases a dense, bubble-free plume that hugs the bottom mud and inhibits the production of H_2S (and likely also methylmercury, because the same kind of bacteria produce these two compounds under anoxic conditions).
- A **Cool Pool,** dry year management system was devised guaranteeing a minimum volume of cool (<16.4^{o}C) water for the hypolimnion. The method was construed based on a large number of measurements of temperature and DO in the reservoir rather than a mathematical model.

The Speece Cone HOS

There are two common types of systems for adding oxygen to water: aeration (air is 20% O_2) and oxygenation (100% O_2). In turn there are two main methods of oxygenation (unconstrained bubble plumes and bubble free plumes). The need at Camanche Reservoir was to reduce toxic

H_2S released from the sediments in summer without provoking early destratification that would send warmer water downstream and cause serious fish problems. The key to the method was to create a layer of well-oxygenated hypolimnion water whose density was unchanged by oxygenation so that it would hug the sediment-water interface. Thus a cool, bubble-free pure oxygen plume directed horizontally was chosen over a buoyant bubble plume. The alternative unconstrained bubble plume (Mobley-TVA system, Mobley Engineering, Norris, TN) is used for general hypolimnion oxygenation in deep reservoirs, including several in the Bay Area. This kind of plume is buoyant and rises so has less effect on sediments.

A Submerged Down-flow Contact Oxygenation system was used consisting of a 7-m-high cone, 4.8-m-wide at the base (Speece Cone) with a submerged electric pump (**Figure 2**). It was designed by Professor Richard Speece (Dept. Engineering, Vanderbilt University, TN) and CALMS members Bill Faisst, and Alex Horne. Nowadays, the firm associated with Dick Speece is ECO_2, Indianapolis, IN. In a Speece Cone, low-DO water is pumped down the cone and a stream of pure oxygen bubbles injected to rise inside the cone. The counter-flowing streams rapidly dissolve the bubbles and the highly oxygenated discharge was directed horizontally up-reservoir via a 45-m-long manifold. The cone is in the deepest water (~ 27 m) so that hydraulic pressure almost triples the mass of oxygen dissolved. The resulting cone is able to transfer over 8 tonnes (~18,000 lbs) of oxygen/day to the water. It was installed in spring 1993, within a year of initial design. The rest of the system consists of a 104-KW, 1-m^3/h (140-HP, 35-cfs) submersible water pump, a large on-shore liquid oxygenation tank, and an evaporator, the underwater oxygen pipeline and electrical conduits to the deepest part of the lake, and a 45-m-long diffuser manifold raised on legs 4.5 m above the lake bed to release highly oxygenated water horizontally up-reservoir via 90 orifices, each 5-cm diameter.

Performance of the Speece Cone & Cool Pool in Camanche Reservoir

The two management strategies (HOS & cool pool) have been successful. H_2S is no longer detected. There have been no water-quality based hatchery fish kills in 20 years since HOS was installed. The criminal lawsuit was settled and inter-agency cooperation has improved greatly.

Algae & trophic state. Since installation of HOS in 1992, DO in the hypolimnion remains well above zero and H_2S production in the sediments was suppressed. Prior to HOS, Camanche Reservoir was eutrophic with high chlorophyll, low water clarity and blue-green algal blooms caused by internal loading of nutrients from its anoxic sediments. HOS switched the reservoir's trophic state from eutrophic to mesotrophic or oligotrophic (depending on the indicators used). Nutrients in the hypolimnion and epilimnion declined rapidly. The annual average concentrations for chlorophyll and algae, including colonial blue-green algae species, fell by over 80% (**Figure 3**) and water clarity, as measured by Secchi disc depth, rose from 1.5 m to 5.3 m.

Fish. Twice as many Chinook salmon returned to the hatchery after HOS than before; a statistically significant difference. Following HOS, natural spawning in the river improved and the wild Chinook annual returns to the river almost doubled. Annual returns of adult steelhead, zero between 1976 and 1992, increased to an average of 278. Increased fish returns were not all directly due to elimination of H_2S, since ammonia, heavy metals and turbidity were virtually eliminated from the discharge by HOS. Other hatchery and river fishery improvements have been made but most of these depend on the improved overall water quality provided by HOS. In the reservoir before HOS, cold water fish were squeezed into a 2-m-thick band around the thermocline but fish moved throughout the hypolimnion after HOS.

Economics of HOS in Camanche Reservoir

The capital cost of construction and installation of HOS in 1992 was $1.3 million and the 20-year average annual O&M (1993-2013) was $75,385/year for a total 20-year amortized cost of $140,385/year. The HOS permitted summer-fall operation of a 10.7 MW hydropower plant. Without HOS, the oxygen needs of the river had to be met by bypassing the turbines and releasing water at the bottom of the dam penstock using a fixed cone valve also known as a Hall-Bunger valve. With HOS, the dam hydropower plant produces electricity whose value approximately balanced the cost of the HOS. The HOS is thus neutral with regard to revenue and carbon footprint. The HOS eliminated H_2S but also ammonia (>1 mg/L) and roughly halved heavy metals and turbidity. Thus, the major benefit of HOS to the Mokelumne River ecosystem is a well-oxygenated water supply free of toxicants during migration and spawning of adult Chinook salmon. The 4,100 additional salmon are worth $3.8 million/year to the recreational fishing industry. Some other improvements to the fishery were made over the last 20 years but, most required the clean water supply provided by HOS. The HOS economic benefit was thus taken as 50% of the fish increases or $1.9 million/year. Again, the costs of the HOS were small compared with the increased fish values.

One alternative solution to HOS was to store more water in the reservoir in dry periods. The monetary loss of holding 92,450 acre-feet of water from Oakland's drinking water supply during two droughts over 20 years averages $1.7 million/year. HOS appears to be an economically favorable method of preventing fish kills and reversing eutrophication relative to other possible solutions. HOS improved habitat for other river biota and in the reservoir expanded cold water fish habitat and increased water clarity. These three benefits have not been included in the economic analysis.

Summing up the three major economic benefits (increase in salmon, water savings, and power generation) over 20 years gives a cost/benefit ratio of 1:27. The HOS capital cost was < 1% of EBMUD's typical annual O&M budget so could be paid in cash, but if a 20-year loan had been taken to pay capital costs, the annual cost roughly doubles and the cost/benefit ratio drops to a still favorable 1:14 before rising to 1:51 in 2013 as the capital cost was paid off.

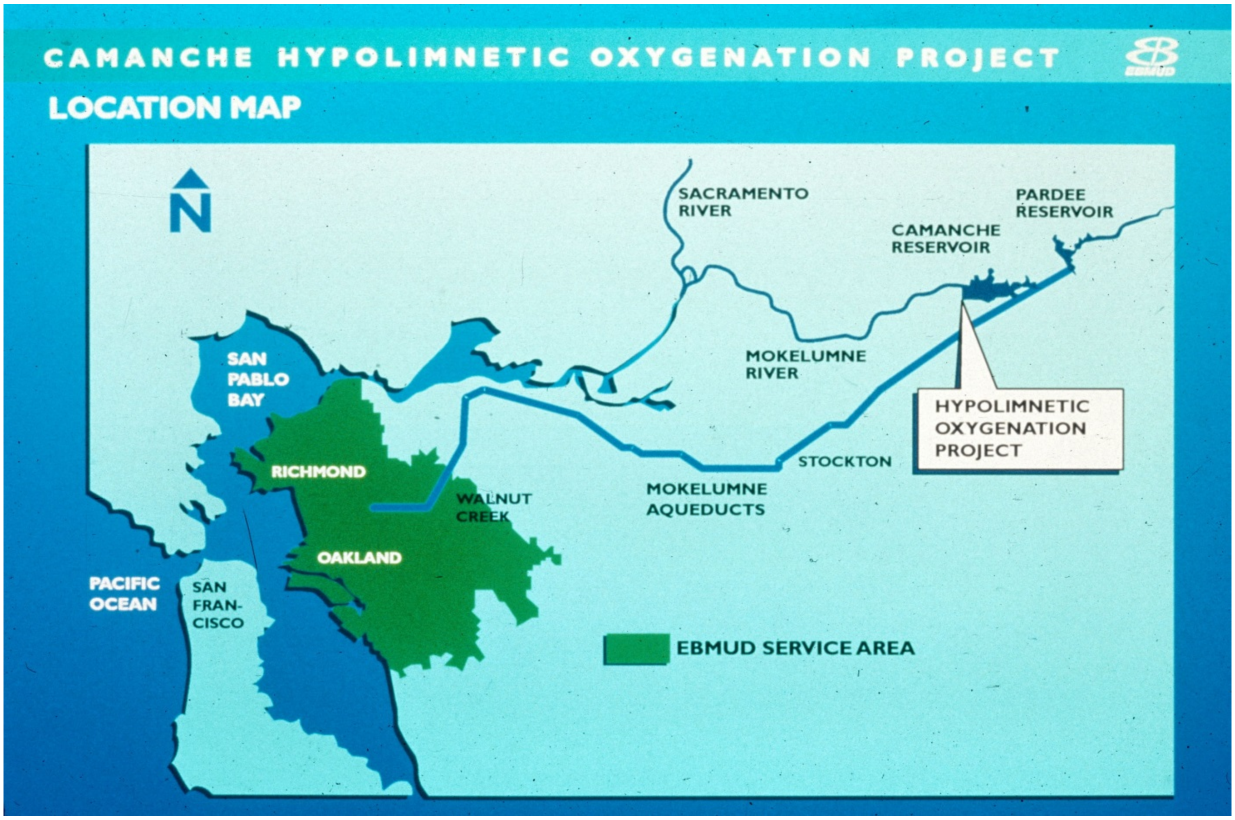

Figure 1. Camanche Reservoir, aqueducts, and service area location map.

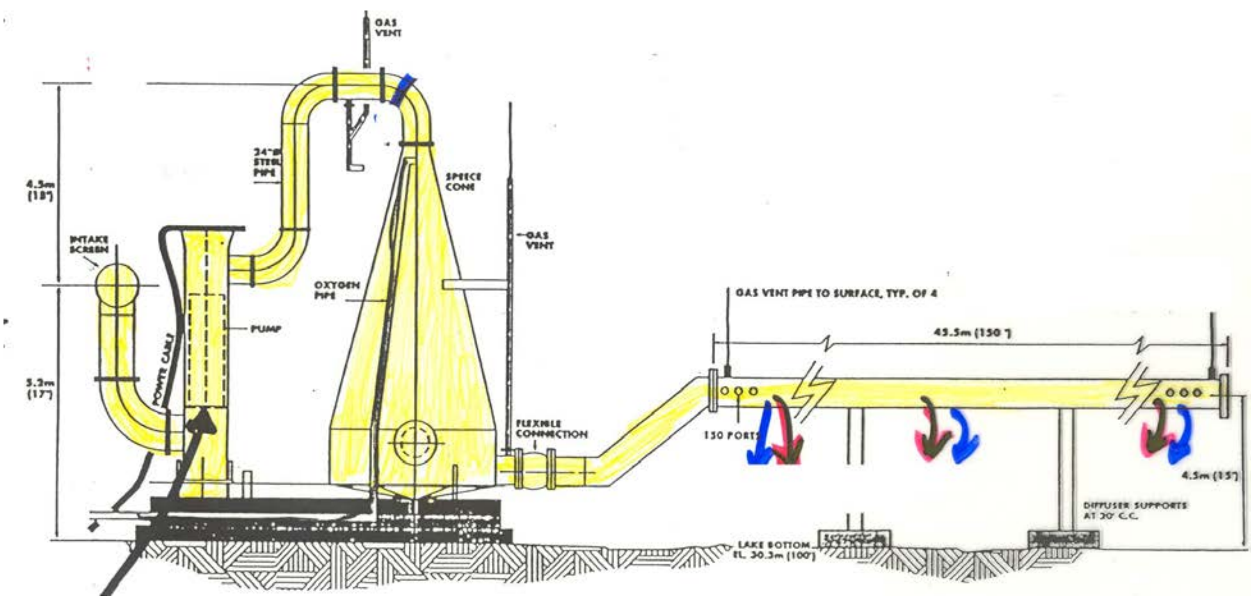

Figure 2. Speece Cone schematic.

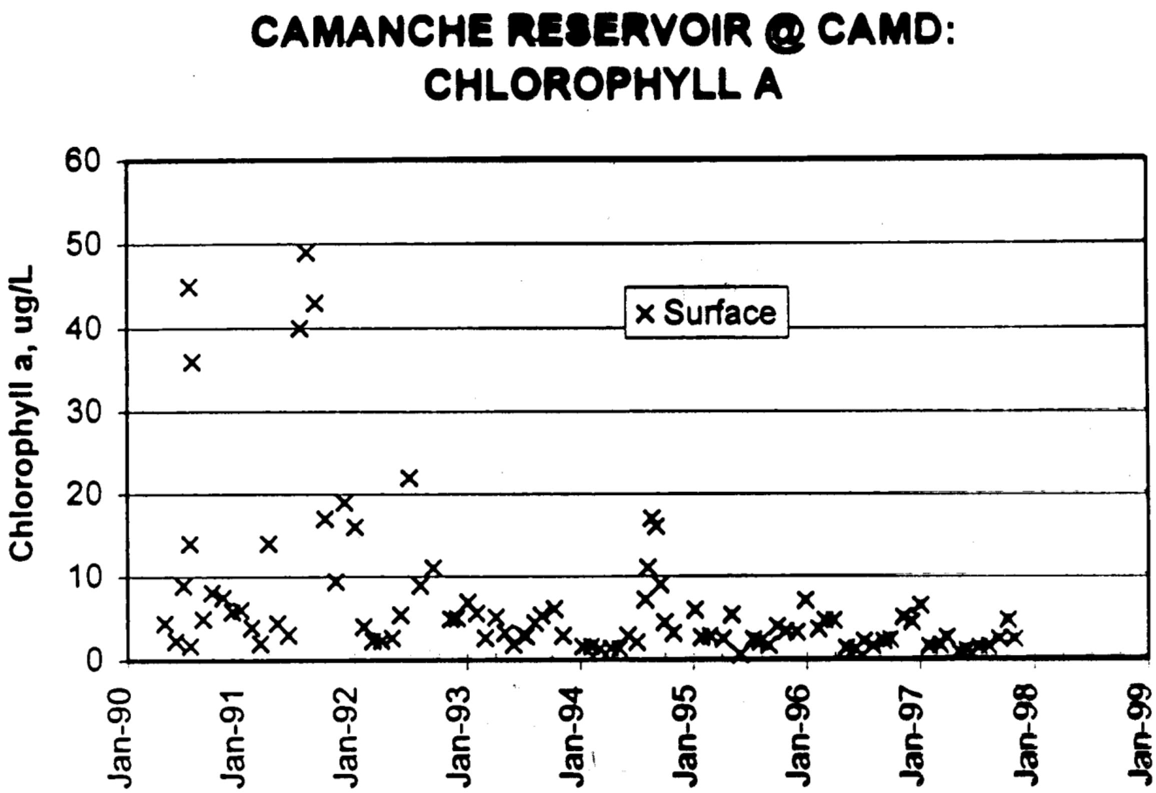

Figure 3. Reduction in Chlorophyll a concentrations in Camanche Reservoir surface waters, 1990-1997.