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**OPTIMIZATION OF MULTIPLE RESERVOIR USES
THROUGH REAERATION – LAKE CASITAS, USA
A CASE STUDY (*)**

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1. SITE DESCRIPTION

Casitas Dam, a 102-m-high earth filled structure, creates a maximum 80-m-deep, 310×10^6 m³ reservoir. The dam is located in Southern California, USA, on Coyote Creek about 3 km above the junction of the creek and the Ventura River. The reservoir collects and stores flows from the Coyote Creek drainage as well as receiving diverted water from the Ventura River. Except for rare flood events, all releases made from Casitas Dam are made into a closed pipeline distribution system. Water from the reservoir is used for domestic, municipal, industrial, agricultural, and recreational purposes. Because all releases are conveyed through a single system, all releases must be of domestic quality. Hydraulic structures at the dam include an uncontrolled concrete lined chute spillway with a maximum discharge capacity of 210 m³/s, and the outlet structure which includes a multilevel intake that supplies water both to a 1 220-mm hollow-jet valve and to the distribution system.

(*) *Optimisation des utilisations multiples d'une retenue à l'aide de l'aération – cas de la retenue Casitas, aux Etats-Unis.*

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Maximum capacity of the hollow-jet valve is 16 m³/s, and the maximum capacity of the distribution system is 3.4 m³/s. Typical releases into the distribution system are less than 1.0 m³/s.

Dam construction was completed in 1959. Total inflow to the reservoir has averaged 32×10^6 m³ per year. The reservoir filled for the first time in 1978. The dam was constructed by the U.S. Bureau of Reclamation. It is operated by the Casitas Municipal Water District of Oak View, California.

Casitas Reservoir is located in the mountainous ranges west of the Valley of California which borders the Pacific Ocean. The climate in and near Lake Casitas is warm, dry, temperate. Extreme temperatures are moderated by the Pacific coast, less than 12 km away. Precipitation averages about 300 mm per year in the form of rain occurring almost exclusively in winter, with only infrequent traces of snow. Monthly average ambient temperatures range from a low of about 13° C for January to a high of about 21° C for August. The annual average air temperature is about 17° C. Winds are mostly light averaging about 12 km/hr.

The Casitas watershed includes a direct drainage area of 85 km². Most of the land in the direct drainage (Coyote Creek) is in public domain. Development in the direct drainage is limited and the watershed is managed to minimize point source and non-point source pollution. Only non-body-contact (fishing, boating) reservoir uses are allowed. The indirect drainage (Ventura River) has an area of 193 km². Much of the land within this drainage is either in public domain or large estate ranches. The indirect drainage does however include numerous small holdings and a human population of approximately 10 000. Vegetation in both drainages is chaparral dominated by scrub oak and annual grasses. There is considerable threat of brush fires in autumn and winter when vegetation becomes very dry.

2. RESERVOIR CONDITIONS PRIOR TO AERATION

Casitas Reservoir is monomictic being isothermal from late December to late February. During the spring, summer, and much of the fall the reservoir is horizontally layered or density stratified which is caused by temperature with warm surface or epilimnion water and cool deep or hypolimnion water. Other water quality parameters such as algal growths and dissolved oxygen are influenced by the density stratification and thus also stratify. The water is alkaline having pH values mostly greater than 7.3 and less than 8.5. Total dissolved solid concentrations are mostly between 410 and 460 mg/l. In the years prior to aeration, strong thermal stratification resulted in stagnation of the entire hypolimnion which led to water quality problems to water users as well as a loss of suitable habitat for aquatic life. Prior to aeration, Casitas was anaerobic (no dissolved oxygen) below 18 m from July through late December or early January [1]. Temperatures in the epilimnion exceeded

24° C in summer and cooled to near 13° C in the winter. Temperatures at 12 m depth remained below 16° C year round. The anaerobic conditions resulted in the presence of manganese and hydrogen sulfide below 6 m. These entered solution from the bottom sediments. A manganese concentration of 2.5 mg/l was measured September 24, 1963. Nuisance blue-green *Anabaena Flos-Aquae* blooms reached very high levels in surface waters in each of the 3 years before the 1969 initiation of reaeration.

Casitas Reservoir has always been known as a good warm water fishery (large-mouth bass, redear sunfish, and channel catfish) and a reliable winter rainbow trout fishery as the area provides over 1.5 million visitor use days of recreation. Catchable size rainbow trout were stocked during winter months (after October) when conditions allowed their survival (e.g. temperatures below 20° C). Previous to aeration trout did not survive summer since the only waters with sufficient dissolved oxygen to support cold water fish were in the epilimnion where temperatures often exceeded 25.5° C [1]. In addition, optimum habitat for warm water species was restricted to the upper 4 to 6 m of the epilimnion for months at a time resulting in a much reduced population of both warm water fishes and the food species they require.

3. SELECTIVE WITHDRAWAL

To assist with management of delivered water quality, a multilevel intake to the outlet structure was included in the original design. Depending on reservoir conditions, multilevel intakes allow for selection and withdrawal (selective withdrawal) of water of desired quality from the reservoir. This depends on the presence of acceptable water in the reservoir.

When the reservoir is density (and water quality) stratified it is possible to withdraw water from distinct layers. The vertical position and thickness of the withdrawal layer is a function of the vertical position of the intake, the size of the intake, the withdrawal discharge, the density stratification profile, and reservoir geometry. If intakes are positioned at various elevations in the reservoir (multilevel), it allows for selection of the horizontal layer from which water is withdrawn. Numerous studies have been conducted to define vertical thickness of the withdrawal layer [2, 3, 4]. Smith, et al., [4] characterize the withdrawal layer with :

$$\frac{Q}{\sqrt{\frac{g}{p} \frac{dp}{dz} h^6}} = 1.0$$

Where : Q = the discharge through the outlet
 p = the density at the elevation of the outlet
 h = half withdrawal layer thickness
 g = gravitation constant
 z = vertical coordinate

The above equation is appropriately applied when the intake dimensions are small as compared to total reservoir width and depth, when approach geometries to the intake are not constricted, and when the vertical density gradient in the reservoir is linear (this is never the case, but the equation allows for consideration of density gradient influences). Note that when the density gradient (dp/dz) is small or approaches zero the resulting withdrawal layer thickness is large. In the extreme for a fully mixed or homogeneous reservoir the thickness of the withdrawal layer is the total reservoir depth. Likewise when the density gradient is large (in zones with substantial vertical temperature change) the resulting thickness of the withdrawal layer is reduced.

Discharge also influences withdrawal layer thickness with larger discharges yielding greater thickness. In the extreme, large discharges can yield withdrawal from the full reservoir depth. The point to be made is that the location and thickness of the withdrawal layer depends on both the intake and its discharge and the reservoir and its stratification pattern. Reservoir stratification patterns in turn are a function of withdrawals, inflows, climatic conditions, oxygen demand, and numerous other dynamic parameters.

Because reservoir makeup will change through the seasons and from year to year, to position intakes and study intake influence on the reservoir and on releases, a reservoir mathematical model such as CE-QUAL-R1 [5] or WQRRS [6] should be used. These models yield hydrodynamic and thermodynamic simulations with insight into possible water quality responses of the reservoir. They consider seasonal and can consider annual variations in climatic and hydrologic influence. The models are complex and require an experienced user. To be properly applied they require hydrologic, morphologic, climatic, water chemistry, and biological data both to initially establish the model and to verify model accuracy.

The multilevel intake structure at Lake Casitas is shown in Fig. 1 and 2. The intake structure, resting on the upstream face of the dam, contains a 1.22-m-diameter intake pipe and nine screened intake ports each gated by a 686-mm by 686-mm high-pressure slide gate. Flow enters the intake pipe, passes down the pipe to the toe of the dam, enters a 2.44-m-diameter pressure tunnel which is controlled by a 1 220-mm by 1 220-mm emergency closure slide gate. The flow then passes to a 1.30-m-diameter outlet pipe contained in a 2.44-m horseshoe tunnel. The 1.30-m outlet pipe supplies the 1 220-mm hollow-jet valve and the distribution system. Each of the nine multilevel intakes is individually covered by a removable, semicircular screen. The screens can be individually removed and brought by track up the dam face using a drum hoist located on the dam crest. The nine 686-mm by 686-mm slide gates are hydraulically operated with the controls located in a control house on the dam crest. The nine intakes are located at 7.3-m vertical intervals with the invert of the lowest intake located at eleva-

tion 106.7 m, 12.0 m above the reservoir bottom, and the invert of the upper intake located at elevation 165.2, 7.6 m below the spillway crest.

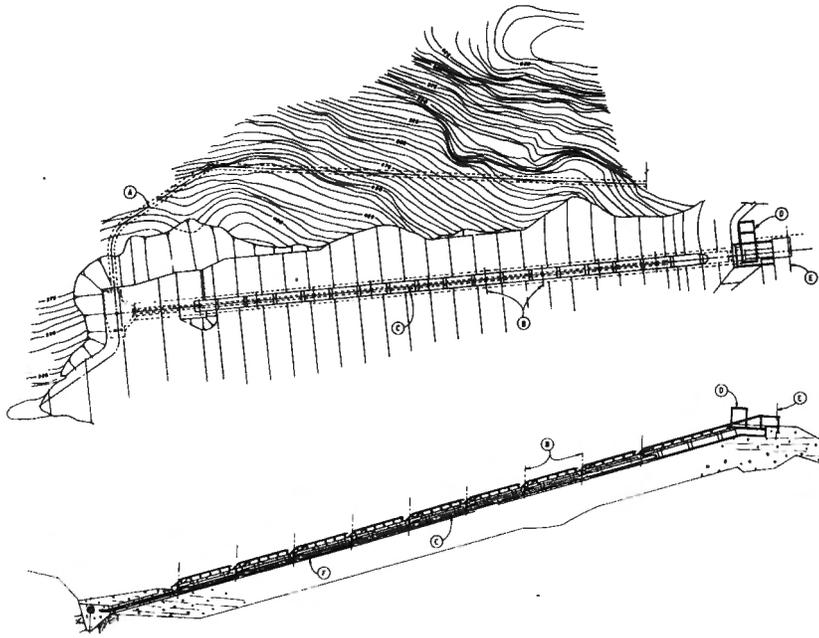


Fig. 1

Multilevel intake

Prise d'eau à multi-niveaux

- | | |
|-------------------------------------|--|
| (a) Outlet works tunnel | (a) <i>Galerie de vidange</i> |
| (b) Intakes for high pressure gates | (b) <i>Prises pour vannes à haute pression</i> |
| (c) 1.22-m-diameter pipe | (c) <i>Tuyau de 1,22 m de diamètre</i> |
| (d) Hoist frame | (d) <i>Structure pour l'engin de levage</i> |
| (e) Dam axis | (e) <i>Axe du barrage</i> |
| (f) 2.44-m-diameter pipe | (f) <i>Conduite de 2,44 m de diamètre</i> |

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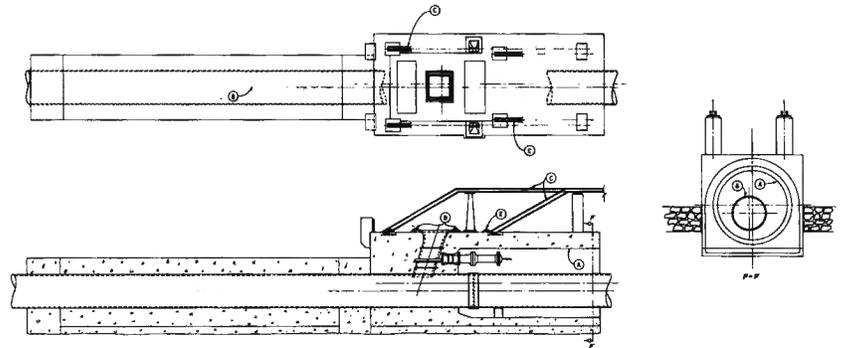


Fig. 2

Outlet works intake

Ouvrages de vidange

- (a) 2.44-m-diameter conduit
- (b) 1.22-m-diameter intake pipe
- (c) Bulkhead and screen track
- (d) Bulkhead seat
- (e) Screen seat

- (a) *Conduite de 2,44 m de diamètre*
- (b) *Tuyau de prise de 1,22 m de diamètre*
- (c) *Batardeau et voie de la crépine*
- (d) *Siège du batardeau*
- (e) *Siège de la crépine*

As noted, prior to the use of reaeration (1959 through 1968) water below a depth of 18 m and at times as little as 10 m was anaerobic with unacceptable concentrations of manganese and hydrogen sulfide. In addition, surface water experienced heavy algae blooms, high temperatures, and pH levels of 8.5 or higher. Both anoxic conditions and the blooms created taste and odor problems that made the water undesirable for domestic use and below optimum for desired aquatic life.

During this period efforts were made to use the multilevel intake to selectively withdraw from below the surface algae blooms but above the deep anoxic water. Thus efforts were made to draw from a narrow (approximately 5-m thick) zone with exclusion of water from above or below. Because of the 7.3-m spacing between intakes, precise positioning of an intake to match the desired withdrawal layer was not possible. In addition withdrawal layer thickness was likely greater than 5 m. As a result, and in spite of all precautions, manganese was often drawn into the distribution system where it precipitated following chlorination. Extensive flushing of distribution lines often failed to remove the manganese from the system. Consequently, under these reservoir conditions where water with acceptable quality was extremely limited, use of selective withdrawal by itself yielded little improvement.

This is not to say that selective withdrawal offers little usefulness at all sites and under all conditions. At various sites, selective withdrawal has often been successfully used to exclude localized zones having taste and

odor problems from release, or to exclude turbid density flows, or to release water of optimum temperature. However, if little or no water of acceptable quality is available, a solution other than selective withdrawal must be sought.

4. REAERATION

With selective withdrawal not proving effective the Casitas Municipal Water District looked at other alternatives to upgrade reservoir water quality. Numerous devices and techniques are available to either treat or rectify the problems associated with lake stratification and hypolimnion oxygen depletion. Options include reaeration of the reservoir, reaeration and treatment of the release as it passes through the outlet structure, or reaeration and treatment of the withdrawn water prior to its delivery. Numerous techniques are available for each of the above. The appropriate device or technique for use at any site is a function of the biological, chemical, and physical characteristics of the site and of the treatment objectives and cost. Careful engineering concern should be given to treatment technique or device selection.

A diffused air injection reaeration system (pneumatic diffuser) was designed and installed in the reservoir. The rising bubbles function as a pump, lifting the oxygen depleted water to the surface where it mixes with the oxygen rich epilimnion. The bulk of the oxygenation results from this mixing with very little (less than 10 percent) of the hypolimnion oxygenation resulting from direct gas transfer from the rising bubbles. The mixing action not only results in hypolimnion oxygenation but also results in mixing or redistribution of other water quality parameters. In particular, the temperature distribution is modified with warming of the deeper water and cooling of surface water (Fig. 3). Surface cooling is less pronounced than hypolimnion warming because of the constant interaction of the surface with the atmosphere.

With time, the pneumatic diffuser design, and resulting reservoir impact was refined. The diffusers were positioned approximately 25 m above the bottom and were operated from start of stratification development in the spring to fall turnover.

With respect to delivered water quality, a large deep water zone of high quality water was created through reaeration. Virtually all delivered water taste and odor problems were eliminated. Taste and odor causing algae blooms were still present in the upper 15 to 18 m of the reservoir. However, by withdrawing water from a depth of 30 m or greater, taste and odor problems were avoided.

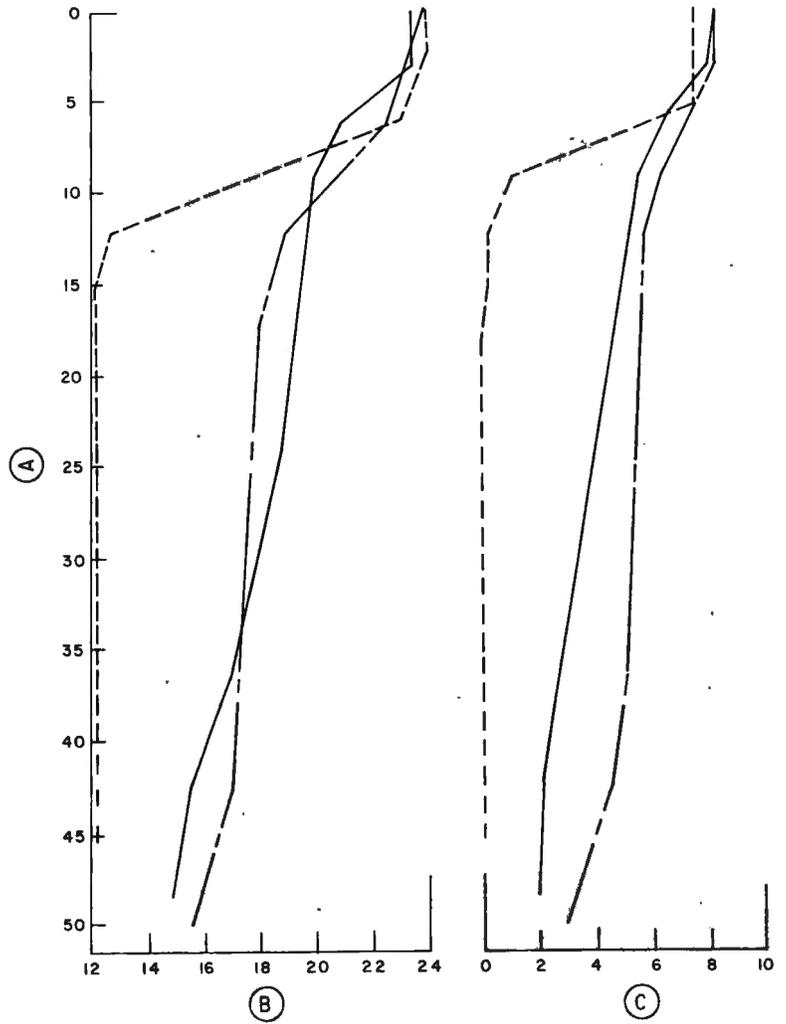


Fig. 3

Réservoir profiles

Profils de la retenue

- (a) Depth - meters
- (b) Temperature - °C
- (c) Dissolved oxygen - mg/l
- pre-diffuser
- concentrated bubbles
- · - dispersed bubbles

- (a) Profondeur - mètres
- (b) Température - °C
- (c) Oxygène dissous - mg/l
- Pré-diffuseur
- Bulles concentrées
- · - Bulles dispersées

Starting in 1976, 8 years after the original diffuser system was installed, a research program was begun at lake Casitas. The effort was directed at defining (through monitoring) the impact of pneumatic diffuser operation on the physical, chemical, and biological characteristics of the reservoir. The effort was also directed at evaluating the destratification and oxygenation efficiencies of pneumatic diffusers as a function of the air flow rate. Physical, chemical, and biological characteristics of the reservoir were closely monitored over the years 1976, 1977, 1978, and 1979. The diffuser was operated at a different air flow concentration each of the 4 years. From the reservoir monitoring, destratification or mixing influences and reaeration or oxygenation influences were determined. With this information and knowing available or consumed energy, efficiencies were determined. A summary report on these efficiencies and the pneumatic diffuser system design is available [7]. A detailed report on diffuser design has been drafted to be published soon.

5. PNEUMATIC DIFFUSER DESIGN

A drawing of the diffuser system used is shown in Fig. 4. The diffusers were supplied air by two 56-KW electric motor-driven rotary screw, single-stage, positive displacement compressors. Each compressor had a discharge capacity of 9.0 std. m³/min. The air was delivered to the diffuser through 520-m of 76-mm-diameter pipe which was suspended approximately 0.3 m below the water surface, from floats.

The diffusers consisted of seven 30-m-long lengths of 51-mm-diameter PVC pipe which were hung end to end from the surface supply line. The 51-mm-diameter line was large enough that friction losses did not affect air distribution. Each 30-m length was individually valved to allow adjustment of operating diffuser length. The 30-m lengths also allowed easier handling. Each diffuser was supplied air from the surface supply line by a 25-mm-inside-diameter hose. The diffusers were hung at a depth of 45 m. The diffusers were suspended approximately 25 to 30 m above the bottom to prevent disturbance of bottom sediments. Reservoir monitoring indicated that mixing influence extended approximately 3 m below the diffuser, and consequently it is recommended that diffuser placement be at least 3 to 6 m above the bottom. To release the air bubbles and create the bubble curtain, 1-mm-diameter orifices were drilled in the 51-mm-diameter PVC pipe at 0.3-m centers

It was found that this design could be both effective and efficient depending on unit air flow rate (air flow rate per unit length of diffuser). Analysis of the design, however, indicated that numerous factors may in-

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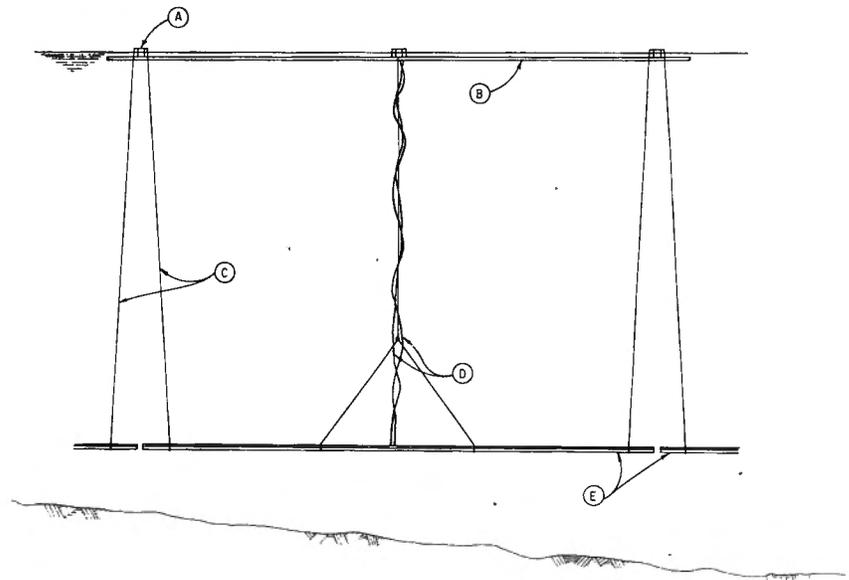


Fig. 4

Pneumatic diffuser aerator

Aérateur à diffuseur pneumatique

- (a) Surface floats
- (b) Surface supply line
- (c) Suspension cables
- (d) Air supply hoses
- (e) 30-m length placed end to end

- (a) *Flotteurs en surface*
- (b) *Ligne d'alimentation en surface*
- (c) *Câble de suspension*
- (d) *Tuyaux d'alimentation en air*
- (e) *Sections de 30 m de longueur placées bout à bout*

fluence diffuser efficiency. Certainly selection of compressor type, sizing of distribution and diffuser lines, and diffuser orifice sizing and spacing should be carefully done. A factor of major significance is diffuser submergence. Although not field evaluated in this study, analysis indicates that pneumatic diffusers are best suited for deep reservoir applications. Certainly for shallow reservoirs (less than approximately 20 m deep) other reaeration options may be more efficient.

The design guidelines and efficiency curves developed in the Casitas studies have since been applied in the design of pneumatic diffusers for two other sites. At both sites the diffusers have been constructed, operated, and found to yield desired reservoir impact.

6. RESERVOIR CONDITIONS WITH REAERATION

Although Casitas remains a monomictic reservoir, turnover now occurs in two stages. Water temperature begins dropping in August and by mid-October the upper 30 to 45-m are isothermal at 20° C. At that point the aeration system is turned off and natural turnover occurs. This is achieved when temperatures reach about 15° C in late December or early January. A minimum water temperature of 12 to 13° C occurs in early February (similar to conditions prior to aeration).

What is different is that during summer the reservoir is partially, but never totally, destratified. Temperatures in the upper 6 m are between 20 to 23° C. That is about 1 to 2° C below the maximum temperatures before aeration began. Temperatures from the epilimnion to a depth of 43 m remain at or above 16° C which is 4 to 7° higher than before. Between 43 and 37 m depth a thermocline or temperature transition layer exists. Below 61 m temperatures below 16° C are found (similar to conditions before aeration). Thus the epilimnion was deepened and warmer water was found in the area between the epilimnion and the diffusers.

Dissolved oxygen concentrations were also greatly influenced by aeration. No anaerobic water was found in the upper 45 m. However, below the diffuser (45 m) the hypolimnion was anaerobic during stratification. After turnover occurs, dissolved oxygen concentrations exceed 8 mg/l throughout the water column. Before aeration, turnover concentrations declined to 5 mg/l below 30 m. In the most remote areas of the lake there was evidence of mixing; however, at these locations dissolved oxygen concentrations of below 1 mg/l were measured at times.

Water quality has changed significantly since aeration began. The manganese and hydrogen sulfide concentrations are now below detectable limits (manganese concentrations < 0.05 mg/l). However, below the diffuser manganese still accumulates. It does not influence either the quality of the water used for domestic purposes or the aquatic ecology. The water remains alkaline but somewhat less so as the pH is about 0.2 units lower than before aeration began [1]. Total dissolved solids, cation, and anion concentrations remain as before.

Perhaps most noticeable is the influence of aeration on biological factors. Blue-green algae (*Anabaena Flos-Aquae*) densities were reduced to one-eighth of the levels that occurred prior to aeration. Since this reservoir is a domestic water supply control of this nuisance species is essential. Thus applications of a mixture of copper sulfate and citric acid are made. While an average of eight treatments per year were made from 1959 to 1967, an average of only two and one-half treatments per year are now necessary. This indicated the reduction in reservoir eutrophication brought about by aeration.

As described, the reservoir is used as a trout fishery. However, since

aeration trout now survive and grow at phenomenal rates (25 mm per month) through-out the summer. Casitas is now noted as not only the only trout fishing lake in southern California, but also as a trophy trout fishery.

The peak months for large trout are July and August when trout were previously not found in the reservoir. They are especially abundant near the diffuser where temperatures are less than 22° C, dissolved oxygen concentrations greater than 5 mg/l and food (plantkon, shad, etc.) for trout is abundant. This area provides the optimum habitat for the entire food chain to thrive. Also, since aeration provides enough mixing to at least the upper 37 m of the reservoir, warm water fishes and their associated food chain have significantly more space to thrive. The result is that Casitas provides one of the best rates of fish caught per hour fished in the western United States.

Since 1979, yet another taste and odor problem has emerged. The pneumatic diffuser has continued to be used and has maintained high quality hypolimnion water through the summer and early fall. However, in the mid to late fall as turnover (surface cooling with elimination of temperature stratification) occurs, a taste and odor problem has extended down from the surface as the epilimnion deepens. The taste and odor have been found to be caused by attached filamentous blue-green algae which grows at 5 to 15 m of depth. By using selective withdrawal and going to deeper and deeper intakes as turnover progresses, the district is able to delay withdrawal of the taste and odor causing substance until total turnover occurs. At that time the substance is mixed throughout the reservoir volume ; and thus its concentration is diluted and therefore is less of a problem. Various algae control methods including fluctuation of water surface and chemical control may also be used to help with the problem.

7. CONCLUSIONS

The point to be made is that a reservoir with its physical, chemical, and biological structure will likely impact water quality. Depending on the use that the reservoir water is put to, the impact may or may not be a problem. If a problem develops, there are numerous corrective resource management, operational, and structural alternatives that can be applied. At Lake Casitas in its early years the reservoir experienced an anaerobic hypolimnion and fairly heavy algae blooms in the epilimnion which effectively made the reservoir a poor water source for 5 to 6 months out of the year. The available water quality created a difficult operational problem with respect to delivery of satisfactory water. Only a limited fishery could be maintained. However, through use of reaeration and selective withdrawal in conjunction with chemical algae controls, a reservoir which supplies high quality domestic water, which maintains a trophy trout fishery, and which draws very heavy recreational use has evolved.

Engineers and scientists should recognize that we possess the ability to constructively deal with reservoir and release water quality problems. Numerous treatment options are available and with proper engineering; optimized cost effective solutions to the problems can be found.

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SUMMARY

Lake Casitas, a domestic, municipal, and industrial water supply reservoir is presented as a case study. The 80-m deep, $310 \times 10^6 \text{ m}^3$ reservoir in its early years experienced an anaerobic hypolimnion (typically below 10-m depth) with unacceptable concentrations of manganese and hydrogen sulfide, and experienced epilimnion (surface) algae blooms. These conditions occurred in the summer and fall and made it difficult to supply adequate quality water to the users. Selective withdrawal and reaeration systems were designed, constructed, and operated which corrected the water quality problems and allowed for delivery of high quality, taste and odor free water.

Selective withdrawal was achieved through use of a multilevel intake. The intake structure resting on the upstream face of the dam, contains nine screened and gated intake ports placed at 7.3-m centers. Although the intake allows withdrawal from limited vertical zones of the reservoir, and thus allows selection of release water quality, the intake by itself was not effective in improving delivered water quality. This was because very little water of adequate quality was present in the reservoir.

Efforts were then directed at improving reservoir water quality through use of reaeration. A pneumatic or diffused air system was designed and installed. The diffused air injection created vertical bubble plumes within the reservoir which resulted in partial vertical mixing. Hypolimnion water was upwelled or pumped to the surface by the bubbles where it mixed with the oxygen rich epilimnion. This resulted in the elimination of anaerobic conditions in all portions of the reservoir influenced by the diffuser. It allowed for withdrawal and delivery of high-quality water. It also yielded an improved fishery and created an attractive reservoir for recreational use.

Finally, a 5-year study was conducted to evaluate pneumatic diffuser influence of biological, chemical, and physical characteristics of the reservoir; to evaluate mixing or destratification efficiency and oxygenation efficiency of pneumatic diffusers as a function of air flow rate; and to optimize diffuser performance. Results of this study have been successfully applied at two other sites.

RÉSUMÉ

La retenue de Casitas, servant au stockage d'eau pour l'alimentation domestique, municipale et industrielle, est présentée ici comme un cas d'étude. Cette retenue, de 80 m de profondeur et d'un volume de 310×10^6 m³, avait souffert, au cours de ses premières années d'exploitation, d'un hypolimnion anaérobique (typiquement au-dessous de 10 m de profondeur), avec une concentration excessive de manganèse et d'hydrogène sulfuré, et d'un épilimnion (surface) avec floraison d'algues. Ces phénomènes se produisaient en été et à l'automne et rendaient difficile l'alimentation en eau de bonne qualité aux usagers. Des systèmes d'évacuation sélective et de réaération ont été conçus, construits et exploités pour résoudre ces problèmes et permettre de fournir une eau potable de très bonne qualité, sans goût ni odeur.

Les évacuations sélectives se font au moyen de prises à multi-niveaux. L'ouvrage de prise d'eau, situé sur le parement amont du barrage, comprend neuf ouvertures, équipées de vannes et de crépines, et placées tous les 7,3 m. Bien que la prise permette des évacuations à partir de zones verticales limitées de la retenue et qu'elle permette ainsi le choix de la qualité de l'eau fournie, la prise elle-même n'améliorait pas la qualité de cette eau.

Ceci résultait du fait que la retenue ne contenait que très peu d'eau de qualité acceptable. On s'efforça alors d'améliorer la qualité de l'eau de la retenue à l'aide de techniques de réaération. Un système pneumatique ou à air diffusé fut conçu et installé. L'injection d'air diffusé créait des panaches verticales de bulles d'air dans la retenue, qui assuraient un mélange vertical partiel. L'eau de l'hypolimnion était soulevée ou pompée jusqu'à la surface par les panaches, où elle se mélangeait avec l'épilimnion riche en oxygène. Ceci élimina les conditions anaérobiques dans toutes les parties de la retenue influencées par le diffuseur, permettant ainsi une alimentation en eau de haute qualité aux usagers. Ceci servit aussi à améliorer la pêche et à créer un lac pittoresque pour les loisirs.

Finalement, une étude fut entreprise sur 5 années pour évaluer l'influence du diffuseur pneumatique en fonction des caractéristiques biologiques, chimiques et physiques de la retenue ; pour évaluer l'efficacité du mélange ou de la déstratification et l'efficacité d'oxygénation par les diffuseurs pneumatiques en fonction du débit d'air ; et pour optimiser le fonctionnement des diffuseurs.

Les résultats de cette étude ont été appliqués avec succès à deux autres sites.