SURVEY OF REAERATION NEEDS ON BUREAU OF RECLAMATION PROJECTS

by

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Denver, Colorado

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UNITED STATES GOVERNMENT

Memorandum

Memorandum

Denver, Colorado

TO : Chief, Division of General Research,
Regional Director, Region 1, 2, 3, 4, 5, 6, 7

DATE: June 30, 1972

FROM : E. J. Carlson

SUBJECT: Completion of Study Team Report

The report, "Survey of Reaeration Needs on Bureau Projects," was prepared from data obtained mainly from Regional Personnel. Copies of the report are being furnished to all regional offices. By this memorandum regional offices are asked to review the report and make suggestions for changes and additions.

The information may be helpful in starting projects which will be required in the near future to meet states' water quality standards. Problem areas in one region may serve as reminders for future problem areas in other regions.

The Reaeration Research Program Management Team is available to assist Bureau offices in solving problems caused by oxygen deficiency in reservoirs, lakes, streams, canals, and aquifers.

The information in the report will also be used by other public agencies and private companies and individuals. The report includes survey-type information and does not reflect policy of the Bureau.

E. J. Carlson

ACKNOWLEDGMENT

The survey of reaeration needs on Bureau of Reclamation Projects was conducted in the Hydraulics Branch under the supervision of the Reaeration Research Program Management Team. Team members are Danny L. King, Hydraulics Branch, Team Manager; E. Tom Scherich, Hydraulics Structures Branch; Dale A. Hoffman, Applied Sciences Branch; and Robert F. Wilson, Hydrology Branch.

Response to the reaeration needs questionnaire was furnished promptly by all Regions. Information was assembled by water quality personnel in the Regions.

Several suggestions were given by engineers at the Engineering and Research Center.

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PURPOSE

A questionnaire survey of Bureau of Reclamation regions and the Engineering and Research Center offices was made to determine the extent of problems in Bureau of Reclamation and other reservoirs, streams, canals, and aquifers due to lack of dissolved oxygen. From the information gathered, research needs for reaeration will be determined and a research plan developed by the Reaeration Research Program Management Team.

CONCLUSIONS

1. Dissolved oxygen (DO) measurements have been made on many reservoirs, lakes, streams, and on a few canals within the regional areas. The number of locations where DO data are available varies widely among regions. DO measurements on aquifer discharge or recharge water are very sparse.

2. All regions have problems in reservoirs because of DO deficiency. Regions 1, 2, and 4 indicate problems in streams caused by DO deficiency.

3. Although the questionnaire revealed only a few reaeration operations, an improved quality of water in certain Bureau reservoirs and streams may be required in the near future to meet state standards, as evidenced by the substantial list of problem areas. It may also be necessary to incorporate reaeration facilities in future designs for new construction.

4. Reaeration operations have been conducted on two large reservoirs, Lake Casitas and Lake Cachuma in California, Region 2. Problems were encountered and the success of the reaeration operations varied. Region 2 personnel propose that the reaeration operations on these two reservoirs be studied thoroughly.

5. Research is needed to improve the efficiency of reaeration methods on large streams and on large bodies of water. Operations have been limited almost entirely to destratification; other alternatives should be considered and evaluated.

APPLICATION

Information obtained through the questionnaire and personal contacts is made available for use by the Reaeration Research Program Management Team and by Bureau of Reclamation offices interested in reaeration problems. The information will also be used by other public agencies and private companies and individuals.

INTRODUCTION

When the physical environment of natural water courses is changed by project development for increased water use, the conditions for natural reaeration of water sometimes change. Maintenance of good quality for the greatly increased use of project water, or for change to a higher use (e.g., agricultural to municipal) may require introduction of artificial reaeration methods. Research studies have shown that reaeration of streams and water impoundments is feasible; however, development of improved reaeration methods and devices is needed. A wide range of problems is associated with reaeration of large flows and volumes in streams, reservoirs, canals, and aquifers.

SUMMARY FROM REAERATION QUESTIONNAIRE

A summary of information supplied from all regions in answer to the questionnaire is shown in Table 1. A complete tabulation of all information received is given in the Appendix. The number of locations where dissolved oxygen was measured on impoundments and streams varied rather widely from region to region. All regions indicated one or more problems due to dissolved oxygen deficiency in reservoirs and streams, but indicated no problems occurring in canals and aquifers due to DO deficiency. Five regions have locations on reservoirs and streams where reaeration operations are presently being conducted. At present no reaeration operations are being conducted by the Bureau on canals or in connection with aquifer discharges or recharges.

MAJOR PROBLEMS

The following major problems were identified:

1. Low DO levels in reservoirs due to local areas of bottom deposits with high biochemical oxygen demand (BOD); eutrophication, ice cover and stratification inhibiting atmospheric reaeration, dissolved iron and manganese, and high concentrations of nutrients and warm temperatures with associated algae blooms.

2. Low DO levels in streams due to heavy BOD loading, inadequate waste treatment, high nutrient levels, and low DO releases from reservoirs.

Table 1

REAERATION QUESTIONNAIRE SUMMARY

Region	Number of locations where DO data are available				Number of locations where problems exist because of DO deficiency				Number of locations where reaeration operations are planned or presently conducted			
	Reservoirs	Streams	Canals	Aquifers	Reservoirs	Streams	Canals	Aquifers	Reservoirs	Streams	Canals	Aquifers
1	9	24	16	1	3	4	0	0	0	2/ 1	0	0
2	12	6	2	0	5	3+	0	0	3/ 2	0	0	0
3	6	2	0	0	4/ 2	0	0	0	0	0	0	0
4	27	1/ 36	0	2	8	1	0	0	5/ 1	0	0	0
5	4	0	0	0	6/ 1	0	0	0	0	0	0	0
6	4	17	0	0	1	0	0	0	1	0	0	0
7	36	73	3	0	7/ 7+	0	0	0	8/ 7	0	0	0
TOTAL	98	158	21	3	27+	8+	0	0	11	1	0	0

1/ Many locations on streams in Wyoming are not included. They were primarily grab samples.
2/ Reaeration at fish hatchery on a stream.
3/ See proposal for Lake Casitas and Lake Cachuma.
4/ Includes Las Vegas Bay problem on Lake Mead, Nevada.
5/ Reaeration tried but unsuccessful on Navajo Lake near Cedar City, Utah.
6/ Lake of the Arbuckles, Arbuckle Dam, near Sulphur, Oklahoma, suggested for reaeration research study.
7/ Many small lakes have fish kills due to low DO caused by ice cover.
8/ Different methods on lakes in Colorado, Nebraska, and Wyoming.

MAJOR REAERATION OPERATIONS

Lake Casitas

The largest manmade reservoir in Southern California, Lake Casitas, is an impoundment resulting from construction of Casitas Dam on Coyote Creek, a tributary to the Ventura River. Casitas Dam and its distribution facilities were built by the Bureau of Reclamation during 1956-59 under contract with the Ventura River Municipal Water District. Lake Casitas, described as "warm monomictic" or "second order tropical" has a storage capacity of 252,000 acre-feet. It undergoes an annual cycle of temperature stratification. In addition to Coyote Creek water, Ventura River water is also stored in Lake Casitas by transfer through Robles-Casitas Canal from Robles Diversion Dam constructed upstream on the Ventura River.

Water usage from Lake Casitas is now 15,000 acre-feet annually, with 80 percent being used for municipal and industrial purposes and the remainder for irrigation. In a service area of 93,000 acres, about 50,000 people and numerous industries receive all or a portion of their supply from Lake Casitas, creating a constant demand for water of good quality.

During the period 1962-67, problems occurred due to high temperature, taste and odor, low level of dissolved oxygen, and relative high organic content due to algae and other organisms.

During this period, quality control attempts included: (1) controlling algae blooms with applications of copper sulfate and citric acid to a 20- to 30-foot strip around the periphery of the reservoir, (2) selecting best depths for withdrawal, and (3) practicing dual chlorination. In spite of these attempts to achieve improved quality water, complaints from water users were still received.

In 1968, reaeration was selected as the best method of improving the water quality, and a reaeration system has been in operation since June 6, 1968. The preliminary report, "Aeration Improved Casitas Reservoir Quality," by Richard H. Barnett, Senior Engineering Technician, Ventura River Municipal Water District,[1]* gives a detailed description of the reaeration treatment conducted during 1968-70. The report includes costs, advantages, and disadvantages of the reaeration studies.

Lake Casitas is one of the largest bodies of water where artificial reaeration has been tried. The data are sufficiently complete to

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* Numbers designate references at the end of the narrative.

give a picture of what happened on a larger reservoir where extensive reaeration operations were performed. There were, however, some problems, such as an increase in the average temperature of the lake, and increased amounts of dissolved manganese due to circulation over the bottom muds.

Lake Cachuma

Bradbury Dam, which impounds Lake Cachuma, was constructed by the Bureau of Reclamation on the Santa Ynez River, 25 miles northwest of Santa Barbara, California. Storage began in 1953. The reservoir has a storage capacity of 205,000 acre-feet; it furnishes 11,000 acre-feet of water for municipal and industrial use annually to the city of Santa Barbara through Tecolote Tunnel. Lake Cachuma is considered a tropical lake.

The quality of Cachuma water deteriorated with time due to algae blooms. Seepage water in Tecolote Tunnel contributed to the hydrogen sulfide taste and odor problems. Temperature stratification, low dissolved oxygen, chemicals, phytoplankton, and zooplankton added to the problem.

Chemical treatment to control growth of algae was used, but it was costly and produced harmful effects on fish. An uncontrolled study, including air injection on a limited scale, may have caused increased populations of phytoplankton which reduced the quality for municipal and industrial use.

An air injection study of the U.S. Geological Survey and Santa Barbara County Water Agency during March to October, 1968, is described in detail in the preliminary unpublished report, "Elimination of Stratification at Lake Cachuma, California," by N. W. Busby, U.S. Geological Survey.[2] An effort was made to destratify the lake by induced circulation with compressed air injections. There were three specific goals: (1) to increase dissolved oxygen content of deeper reservoir water; (2) to prevent bad taste and odor, and (3) to measurably reduce phytoplankton population. These goals were not accomplished by the air injection.

Miscellaneous

Numerous small-scale reaeration operations were reported, particularly at fish hatcheries and at small reservoirs where there was winterkill of fish due to a frozen surface.

NORMAN DAM - NORMAN PROJ OK

RELATED WATER QUALITY PROBLEMS

The information below, regarding water quality problems at other locations, was received after returns from the reaeration questionnaires were assembled.

Navajo Reservoir, New Mexico

Fish kills in the channel downstream and near the stilling basin of Navajo Dam and Reservoir have been observed. Reports noted fish kills in February 1965, August 1967, and April 1968. During these times, the auxiliary outlet works which discharges freely and deeply into the spillway stilling basin pool was used. There is some indication that the fish were killed due to supersaturation of nitrogen in the water leaving the stilling basin. Measurement of dissolved gases is planned.

Tehama-Colusa Canal near Red Bluff, California

The Tehama-Colusa Fish Facilities were designed and constructed by the Bureau of Reclamation in and near the upper 2-1/2 miles of Tehama-Colusa Canal. The dual- and single-purpose spawning channels were first put into operation during the summer of 1971, by the Bureau of Sport Fisheries and Wildlife. The oxygen level of the water flowing through the spawning gravels must be maintained high enough to support life in the salmon eggs and ensure growth of the young salmon fry after they hatch. Dissolved oxygen measurements are made regularly in connection with salmon spawning operations in the dual- and single-purpose channels.

Cheney Reservoir near Cheney, Kansas

Municipal and industrial waters are furnished to Wichita, Kansas, by the Bureau-constructed Cheney Dam and Reservoir. A study was conducted to determine the effect of impoundment on the quality of water in Cheney Reservoir. During November 1964 and September 1967, the water department of the city of Wichita collected physical, chemical, and biological data from Cheney Reservoir. Under contract with the Bureau of Reclamation, Colorado State University evaluated the collected data. The results are given in the report, "Evaluation of the Effect of Impoundment on Water Quality in Cheney Reservoir," by J. C. Ward and S. Karaki, Hydrology Paper, Colorado State University, March 1970.[3]

The height of Cheney Dam above streambed is 86 feet making the reservoir comparatively shallow. Cheney Reservoir did not stratify during the study, and the dual-level outlet structure was not effective in controlling the quality of water for the city of Wichita. No reaeration operations have been conducted at Cheney Reservoir.

Facilities are provided to chemically pretreat the water for the purpose of controlling odor and taste.

Grand Coulee Dam, Washington

Memoranda and news releases have discussed the problem of nitrogen supersaturation on the Columbia River. Recent reports indicate that water flowing over Grand Coulee spillway is a contributor to the nitrogen supersaturation problem on the Columbia River; however, many questions remain unresolved. An extensive monitoring program is now underway.

RESEARCH NEEDS

Priority

1. Develop methods and procedures for improving the quality of hypolimnion waters and, accordingly, low-level releases into streams and canals.

2. Evaluate the application of destratification, in comparison with other reservoir water-quality control measures.

3. Develop and evaluate more efficient methods for preventing winterkill in small reservoirs.

4. Develop high-efficiency devices for in-stream reaeration.

RESEARCH OPPORTUNITIES

1. Table 1 lists more than 27 reservoirs and 8 streams at which problems exist because of low DO. Each of these sites presents an opportunity for reaeration research.

2. Pending destratification tests at Lake of the Arbuckles present an opportunity for participation by the Program Management Team and the subsidiary work group, methods and devices team.

3. The problem of water quality in Las Vegas Bay, Lake Mead, suggests application of reaeration and/or destratification techniques.

4. The proposal for continued research at Lake Casitas and Lake Cachuma should be considered. A copy of the proposal is included in the Appendix to this report as part of Region 2

information sent in with the questionnaire. The research proposal recommends that a plan be developed to study the effects of air injection at both Lake Casitas and Lake Cachuma. The Region 2 office could provide a study plan for their proposed research.

5. At all three sites (Arbuckle, Casitas, and Cachuma), alternatives to destratification should be considered and possibly tested.

REFERENCES

1. Preliminary unpublished report, "Aeration Improved Casitas Reservoir Quality," by Richard H. Barnett, Ventura River Municipal Water District, California, 1970

2. Preliminary unpublished report, "Elimination of Stratification at Lake Cachuma, California," by N. W. Busby, U.S. Geological Survey, 1970. Prepared in cooperation with the Santa Barbara County Water Agency

3. "Evaluation of the Effect of Impoundment on Water Quality in Cheney Reservoir," by J. C. Ward and S. Karaki, Hydrology Paper, Colorado State University, March 1970

4. "Reaeration of Streams and Reservoirs, Analysis and Bibliography," by D. L. King, USBR Report REC-OCE-70-55, 1970

APPENDIX

1. Letter with "Questionnaire to Determine Reaeration Needs on Bureau Projects" sent to all regions.

2. Information, resulting from questionnaire, received from each region.

Letter with "Questionnaire to Determine Reaeration Needs on Bureau Projects" sent to all regions.

OPTIONAL FORM NO. 10
MAY 1962 EDITION
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UNITED STATES GOVERNMENT

Memorandum

Memorandum

TO : Regional Director, Region 1, 2, 3, 4, 5, 6, 7 DATE: November 16, 1971

FROM : Acting Chief, Division of General Research

SUBJECT: Survey to determine reaeration needs on Bureau projects

An interdisciplinary team was formed early this year to investigate the Bureau's needs for research in reaeration of rivers, reservoirs, and reservoir releases. With the assistance of a state-of-the-art report based on a literature review, the team formulated specific research needs and prepared a preliminary outline for a research program. Formation of a Reaeration Research Program Management Team (PMT) was also recommended. The PMT was formed in August 1971. A primary objective is to develop information and criteria which will be of specific and immediate value to designers, planners, and operating personnel.

Enclosed is a questionnaire by which the PMT is requesting your help in identifying problems on Bureau water projects in your region that are caused by lack of dissolved oxygen. The problem areas listed on the questionnaire are not necessarily complete. Any additional problems that you know of should be identified.

The information is needed to help determine the dissolved oxygen problem areas in which research on reaeration should be conducted. Possible field sites for reaeration experiments will also be determined by the PMT from the results of the questionnaire.

We suggest that the task of completing the questionnaire be given to one or two people; possibly a water quality expert in your region and/or the Regional Research Coordinator, who will be the continuing contacts in your region for future activities by the reaeration team. Results of the initial survey and future work will be made available to you. It is important that the questionnaire be returned as complete as possible by December 20, 1971.

Members of your staff interested in the general problem area of reaeration are encouraged to visit with team members during travel to the E&R Center.

Team members are: Danny L. King, Hydraulics Branch, Team Manager
Erwin T. Scherich, Hydraulic Structures Branch
Dale A. Hoffman, Applied Sciences Branch
Robert F. Wilson, Hydrology Branch

Howard J. Cohan

Enclosure

Copy to: Commissioner, Attention: 400, 700, 1500
Director of Design and Construction, E&R Center
Chief, Division of Water O&M, E&R Center
Chief, Division of Planning Coordination, E&R Center

QUESTIONNAIRE TO DETERMINE REAERATION NEEDS ON BUREAU PROJECTS

Please Return questionnaire before December 20, 1971.

To: E. J. Carlson, Code 1532, Building 56
E&R Center, Bureau of Reclamation
Denver Federal Center
Denver, Colorado 80225

This questionnaire is asking for your help to identify and locate problems caused by lack of dissolved oxygen. This questionnaire pertains to non-Bureau projects in your region at which obvious problems due to lack of dissolved oxygen are occurring, as well as projects operated by the Bureau, projects proposed by the Bureau, and projects constructed by the Bureau and now operated by others.

If data are readily available we would appreciate having them or knowing about them. Do not attempt to collect additional quantitative data for the purpose of answering this questionnaire.

For further information regarding the questionnaire, you may contact E. J. Carlson at the E&R Center in Denver by FTS (303) 234-3997.

Existing and expected future state water-quality standards are the basis for determining reaeration needs in cases where problems are not obvious nor well defined.

Dissolved oxygen deficiencies in streams and reservoirs result from oxygen demand in bottom deposits, sewage and industrial waste discharges, dying algae blooms, and other causes. Low dissolved oxygen is often evidenced by bad taste and odor in municipal and industrial water supplies and by fish kills.

QUESTIONNAIRE

Locations where DO is or has been measured*

1. List the lakes and reservoirs at which DO data are available.

Name of lake or reservoir	Location Nearest town, state

* Omit locations at which data are published and widely available, such as from STORET.

2. List the streams and locations on each stream at which DO data are available.

Name of stream	Location Nearest town, state

3. List the canals and locations on each canal at which DO data are available.

Name of canal	Location Nearest town, state

4. List water supplies from ground-water aquifers at which DO data are available.

Name of aquifer	Location Nearest town, state

Problems caused by DO Deficiency

5. List the lakes and reservoirs at which a problem exists because of low DO content.

Name of lake or reservoir	Location Nearest town, state	Brief description of problem	Solution being sought, if any

6. List the streams and locations on each stream at which a problem exists because of low DO content.

Name of stream	Location Nearest town, state	Brief description of problem	Solution being sought, if any

7. List the canals and locations on each canal at which a problem exists because of low DO content.

Name of canal	Location Nearest town, state	Brief description of problem	Solution being sought, if any

8. List water supplies from ground-water aquifers at which a problem exists because of low DO content.

Name of supply	Location Nearest town, state	Brief description of problem	Solution being sought, if any

Reaeration Operations

9. List locations where reaeration operations are presently being conducted or have been conducted in the past - including reservoirs, streams, canals, and ground-water supplies.

Name	Location Nearest town, state	Brief description of method used, results obtained, and data or source of data, if available

10. Make any additional comments or suggestions concerning present and future reaeration needs that are not applicable to the questions above. If additional space is needed for any question, use additional sheets.

Contact person or persons (one or two) in the region.

Name(s):

Title(s):

Address(es):

Telephone number(s):

INFORMATION RESULTING FROM QUESTIONNAIRE

RECEIVED FROM EACH REGION

Locations where DO is or has been measured (excluding locations at which data are published and widely available) such as from STORET.

1. List of lakes and reservoirs at which DO data are available.

Region 1

Name of lake or reservoir	Location Nearest town, state
American Falls Reservoir	American Falls, Idaho
Milner Reservoir 1/	Burley, Idaho
Brownlee Reservoir (Idaho Power Company)	Baker, Oregon
Franklin D. Roosevelt (Grand Coulee Reservoir)	Coulee Dam, Washington
Billy Clapp Lake	Soap Lake, Washington
Potholes (outlet to Potholes Canal)	Warden, Washington
Moses Lake	Moses Lake, Washington
Agency Reservoir	Klamath Falls, Oregon
Upper Klamath Lake	Klamath Falls, Oregon

Region 2

Name of lake or reservoir	Location Nearest town, state	
Lake Clementine	Auburn, California	
Folsom Lake	Folsom, California	Data on STORET but presently locked in
Lake Natoma	Folsom, California	
Lake Berryessa	Winters, California	
Lake Cachuma	Santa Barbara, California	
Lake Casitas	Ventura, California	
Los Banos Reservoir	Los Banos, California	
San Luis Reservoir	Los Banos, California	
Oroville Reservoir	Oroville, California	Unpublished data available from California DWR Central Distribution
Frenchman Reservoir	Vinton, California	
Antelope Reservoir	Susanville, California	
Lake Davis	Portola, California	

1/ May be in STORET.

Region 3

Name of lake or reservoir	Location Nearest town, state
Lake Mead	Boulder City, Nevada
Theodore Roosevelt Lake	Phoenix, Arizona
Apache Lake	Phoenix, Arizona
Canyon Lake	Phoenix, Arizona
Sahuaro Lake	Phoenix, Arizona
Mittry Lake	Laguna, Arizona

Region 4

Name of lake or reservoir	Location Nearest town, state
Lake Powell	Page, Arizona
Flaming Gorge Reservoir	Dutch John, Utah
Blue Mesa Reservoir	Gunnison, Colorado
Navajo Reservoir	Farmington, New Mexico
Shadow Mountain Reservoir	Granby, Colorado
Green Mountain Reservoir	Kremmling, Colorado
Ruedi Reservoir	Basalt, Colorado
Navajo Lake	Cedar City, Utah
Scofield Reservoir	Scofield, Utah
Whitney Reservoir	Evanston, Wyoming
Minersville Reservoir	Beaver, Utah
Gooseberry Reservoir	Fairview, Utah
China Lake	Mountain View, Wyoming
Steinaker Reservoir	Vernal, Utah
Big Sand Wash Reservoir	Roosevelt, Utah
Echo Reservoir	Coalville, Utah
Porcupine Reservoir	Paradise, Utah
Lost Creek Reservoir	Croydon, Utah
Johnson Reservoir	Loa, Utah
Fish Lake	Loa, Utah
Starvation Reservoir	Duchesne, Utah
Strawberry Reservoir	Fruitland, Utah
Huntington North Reservoir	Huntington, Utah
Louis Lake	Lander, Wyoming
Upper Slide Lake	Jackson, Wyoming
Lake of the Woods	Dubois, Wyoming
Trail Lake	Dubois, Wyoming
Seminoe Reservoir	Sinclair, Wyoming

Region 4 - Continued

Flaming Gorge Reservoir*	Green River, Wyoming
East Allen Lake	Medicine Bow, Wyoming
West Carroll Lake	Laramie, Wyoming
Fontenelle Reservoir*	Fontenelle, Wyoming
Viva Naughton Reservoir	Evanston, Wyoming
Big Sandy Reservoir*	Pinedale, Wyoming
Cameahwait Reservoir	Riverton, Wyoming
Lower Slide Lake	Jackson, Wyoming
Jenny Lake	Jackson, Wyoming
Fremont Lake*	Pinedale, Wyoming
Yellowtail Reservoir	Lovell, Wyoming
Keyhole Reservoir	Moorcroft, Wyoming

Region 5

Name of lake or reservoir	Location Nearest town, state
Lake Meredith (Sanford Dam)	Sanford, Texas
Lake of the Arbuckles (Arbuckle Dam)	Sulphur, Oklahoma
Lake Travis (Marshall Ford Dam)	Austin, Texas
Cheney Reservoir	Cheney, Kansas

Region 6

Name of lake or reservoir	Location Nearest town, state
Big Bend Reservoir	Fort Thompson, South Dakota
Fort Randall Reservoir	Lake Andes, South Dakota
Garrison Reservoir	Garrison, North Dakota
Yellowtail Reservoir	Hardin, Montana

Region 7

Name of lake or reservoir	Location Nearest town, state
Atchison County State Lake	Atchison, Kansas
Brown County State Lake	Robinson, Kansas
Pottawatomie County State Lake No. 1	Blaine, Kansas

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* State of Wyoming data. Starred (*) reservoirs are in Region 4.

Region 7 - Continued

Douglas County State Lake	Lawrence, Kansas
Shawnee County State Lake	Grove, Kansas
Leavenworth County State Lake	Reno, Kansas
Bourbon County State Lake	Porterville, Kansas
Crawford County State Lake No. 2	Farlington, Kansas
Lyon County State Lake	Admire, Kansas
Sheridan County State Lake	Tasco, Kansas
Rooks County State Lake	Webster, Kansas
Ottawa County State Lake	Wells, Kansas
Jewell County State Lake	Ionia, Kansas
McPherson County State Lake	Roxbury, Kansas
Geary County State Lake	Junction City, Kansas
Washington County State Lake	Morrowville, Kansas
Pottawatomie County State Lake No. 2	Manhattan, Kansas
Lane County State Lake	Dighton, Kansas
Kearney County State Lake	Lakin, Kansas
Hamilton County State Lake	Syracuse, Kansas
Osage County State Lake	Scranton, Kansas
Pomona Reservoir	Michigan Valley, Kansas
Norton Reservoir	Norton, Kansas
Milford Reservoir	Junction City, Kansas
Lovewell Reservoir	Lovewell, Kansas
Cedar Bluff Reservoir	Ellis, Kansas
Kanopolis Reservoir	Ellsworth, Kansas
Wilson Reservoir	Russell, Kansas
Kirwin Reservoir	Glade, Kansas
Webster Reservoir	Webster, Kansas
Tuttle Creek Reservoir	Manhattan, Kansas
Carter Lake	Berthoud, Colorado
Horsetooth Reservoir	Fort Collins, Colorado
Lake Granby	Granby, Colorado
Shadow Mountain Lake	Grand Lake, Colorado
Grand Lake	Grand Lake, Colorado

2. List of streams and locations on each stream at which DO data are available.

Region 1

Name of stream	Location Nearest town, state
Teton River including Bitch and Canyon Creeks	St. Anthony, Idaho

Region 1 - Continued

Snake River	Blackfoot, Idaho
Snake River	American Falls, Idaho
Snake River	Rexburg, Idaho
Henrys Fork	Rexburg, Idaho
Portneuf River	Pocatello, Idaho
Yakima River	Yakima, Washington
Rocky Ford Creek	Ephrata, Washington
Upper Crab Creek	Moses Lake, Washington
Rickreall Creek	Rickreall, Oregon
Boise River	Boise, Idaho
Boise River	Caldwell, Idaho
Grande Ronde River	La Grande, Oregon
Pudding River	Silverton, Oregon
White River	near Government Camp, Oregon
Lower Crab Creek	Beverly, Washington
RCD Wasteway	Moses Lake, Washington
Lind Coulee Creek	Moses Lake, Washington
Winchester Wasteway	Ephrata, Washington
PE 16.4 Wasteway	Ringold, Washington
Crab Creek Lateral	Royal City, Washington
Frenchman Hills Wasteway	Ephrata, Washington
RB4C Wasteway	Vantage, Washington
Marion Drain	Toppenish, Washington

Region 2

Name of stream	Location Nearest town, state	
North Fork American River	Auburn, California	Data on STORET but presently locked in
Middle Fork American River	Auburn, California	
South Fork American River	Pilot Hill, California	
Lower American River	Sacramento, California	
Sacramento River	Sacramento, California	
San Joaquin River	Vernalis, California	

Region 3

Name of stream	Location Nearest town, state
Salt River (below Stewart Mountain Dam)	Phoenix, Arizona
Hunters Hole Creek	Gadsden, Arizona

Region 4

Name of stream	Location Nearest town, state
Colorado River below Glen Canyon Dam	Page, Arizona
San Juan River	Farmington, New Mexico
Fryingpan River	Basalt, Colorado
Gunnison River	Gunnison, Colorado
Colorado River	Granby, Colorado
Blue River	Kremmling, Colorado
Jordan River	Salt Lake City, Utah
Delores River	Cisco, Utah
Colorado River	Cisco, Utah
Green River	Greendale, Utah
Green River	Jensen, Utah
Duchesne River	Randlett, Utah
White River	Watson, Utah
Price River	Woodside, Utah
Green River	Green River, Utah
San Rafael River	Green River, Utah
San Juan River	Bluff, Utah
Virgin River	Littlefield, Arizona
Dirty Devil River	Hanksville, Utah
Escalante River	Escalante, Utah
Virgin River	St. George, Utah
Bear River	Utah-Wyoming State Line
Bear River	Woodruff, Utah
Bear River	Randolph, Utah
Bear River	Border, Wyoming
Thomas Fork River	Idaho-Wyoming State Line
Rainbow Inlet Canal	Dingle, Utah
Bear Lake Outlet Canal	Paris, Idaho
West Cache Canal	Cornish, Utah
Bear River	Cornish, Utah
Bear River	Utah-Idaho State Line
Cub Creek	Franklin, Idaho
Worm Creek	Fairview, Idaho
Malad River	Woodruff, Utah
Bear River	Brigham City, Utah

Region 5

None

Region 6

Name of stream	Location Nearest town, state
Beavais Creek	St. Xavier, Montana
Belle Fourche River	Elm Springs, South Dakota
Bighorn River	Bighorn, Hardin, and St. Xavier Montana
Big Sioux River	Sioux City, Iowa; Sioux Falls, South Dakota
Castle Creek	Hill City, South Dakota
Cheyenne River	Wasta, South Dakota
Clark Fork River	Laurel, Montana
James River	Lamour, Oaks, and Jamestown, North Dakota
Joe Creek	Fort Thompson, South Dakota
Medicine Creek	Fort Thompson, South Dakota
Milk River	Glasgow, Montana
Missouri River	Culbertson and Fort Benton, Montana; Bismarck, Mandan, and Williston, North Dakota; Pierre, Mobridge, and Yankton, South Dakota
Pipestone Creek	Pipestone, Minnesota
Powder River	Moorhead, Montana
Rock River	Rock River, Iowa
White River	Whitney, Nebraska; Kadoka, South Dakota
Yellowstone River	Billings, Corwin Springs, Custer, Huntley, Laurel, Pompeys Pillar, and Sidney, Montana

Region 7

Name of stream	Location Nearest town, state
South Fork Nemaha River	Bern, Kansas
Wolf River	Sparks, Kansas
Kansas River	Kansas City, Kansas
Indian Creek	Leawood, Kansas
Big Blue River	Stanley, Kansas
Marais Des Cygnes River	Trading Post, Kansas
Prairie Dog Creek	Woodruff, Kansas
Smoky Hill River	Weskan, Kansas

Region 7 - Continued

Little Blue River	Hollenberg, Kansas
Sappa Creek	Lyle, Kansas
Prairie Dog Creek	Norton, Kansas
Republican River	Scandia, Kansas
Republican River	Concordia, Kansas
South Fork Republican River	St. Francis, Kansas
North Fork Solomon River	Portis, Kansas
South Fork Solomon River	below Webster Dam, Kansas
South Fork Solomon River	Osborne, Kansas
Solomon River	outlet to Glen Elder Dam, Kansas
Smoky Hill River	outlet to Cedar Bluff Reservoir, Kansas
Arikaree River	Haigler, Nebraska
South Fork Republican River	Benkelman, Nebraska
Dismal River	Mullen, Nebraska
Dismal River	Dunning, Nebraska
Cedar River	Fullerton, Nebraska
Ponca Creek	Verdel, Nebraska
Keya Paha River	Naper, Nebraska
Schlagel Creek	Valentine, Nebraska
Long Pine Creek	above Seven Springs, Nebraska
Plum Creek	at Ainsworth Canal, Nebraska
Snake River	above Shelbourn Bridge, Nebraska
Snake River	below Merritt Reservoir, Nebraska
Plum Creek	Johnstown, Nebraska
Long Pine Creek	above Highway No. 20, Nebraska
Long Pine Creek	above Willow Creek, Nebraska
Niobrara River	Niobrara, Nebraska
North Platte River	Wyoming-Nebraska State Line
North Platte River	Lisco, Nebraska
Horse Creek	Lyman, Nebraska
Sheep Creek	Morrill, Nebraska
Pumpkin Creek	Bridgeport, Nebraska
Niobrara River	Dunlap, Nebraska
Niobrara River	Colclessen, Nebraska
Bone Creek	Ainsworth, Nebraska
Bone Creek	Long Pine, Nebraska
Middle Loup River	Milburn, Nebraska
Middle Loup River	Comstock, Nebraska
Middle Loup River	St. Paul, Nebraska
Republican River	Trenton, Nebraska
Frenchman Creek	Culbertson, Nebraska
Red Willow Creek	Indianola, Nebraska
Medicine Creek	Cambridge, Nebraska
Republican River	Orleans, Nebraska
Republican River	below Harlan County Dam, Nebraska

Region 7 - Continued

Republican River	Superior, Nebraska
Platte River	Duncan, Nebraska
Platte River	Overton, Nebraska
North Dry Creek	Kearney, Nebraska
Wood River	Chapman, Nebraska
Laramie River	Laramie, Wyoming
Laramie River	Howell, Wyoming
Spring Creek	Laramie, Wyoming
North Platte River	between Kortes Dam and Pathfinder Reservoir, Wyoming
North Platte River	Alcova, Wyoming
Bates Creek	Alcova, Wyoming
North Platte River	Mills, Wyoming
Middle Fork Casper Creek	Bucknum, Wyoming
Casper Creek	Casper, Wyoming
North Platte River	below Guernsey Reservoir, Wyoming
North Platte River	below Whalen Diversion Dam, Wyoming
Rawhide Creek	Lingle, Wyoming
Colorado River	near Shadow Mountain Lake, Colorado
Olympus Tunnel Inlet	Estes Park, Colorado
Big Thompson River	Drake, Colorado

3. List of canals and locations on each canal at which DO data are available.

Region 1

Name of canal	Location Nearest town, state
Rosa Canal	Sunnyside, Washington
Sunnyside Canal	Sunnyside, Washington
Prosser Canal	Prosser, Washington
Kennewick Canal	Prosser, Washington
Wapato Canal	Wapato, Washington
Main Canal	Soap Lake, Washington
West Canal	Ephrata, Washington
West Canal	Royal City, Washington
East Low Canal	Ephrata, Washington
Potholes Canal at Headworks	Moses Lake, Washington
Potholes Canal at Mile 38.0	Mesa, Washington
Potholes Canal at Mile 65.8	Pasco, Washington
Scootenay Wasteway (East Low Canal)	Mesa, Washington
New York Canal	Boise, Idaho
Ridenbaugh Canal	Boise, Idaho
Deer Flat Low Line	Nampa, Idaho

Region 2

Name of canal	Location Nearest town, state
Delta Mendota Canal	near Tracy, Los Banos, and Mendota, California
California Aqueduct	near Byron, Los Banos, and Kettleman City, California

Region 3

None

Region 4

None

Region 5

None

Region 6

None

Region 7

Name of canal	Location Nearest town, state
Granby Pump Canal	Grand Lake, Colorado
East Portal Adams Tunnel	Estes Park, Colorado
Kirwin Main Canal	below Kirwin Dam, Kansas

4. List of water supplies from ground-water aquifers at which DO data are available.

Region 1

Name of aquifer	Location Nearest town, state
Snake Plain Aquifer	Rexburg, Idaho

Region 2

None

Region 3

None

Region 4

Name of aquifer	Location Nearest town, state
Auburn Hatchery	Auburn, Wyoming
Como Bluff Hatchery	Rock River, Wyoming
Daniel Hatchery*	Daniel, Wyoming
Dubois Hatchery	Dubois, Wyoming
Boulder Rearing Station*	Boulder, Wyoming
Clark Fork Hatchery	Belfry, Montana
Speas Rearing Station	Casper, Wyoming
Tillett Rearing Station	Lovell, Wyoming
Story Hatchery	Story, Wyoming
Tensleep Hatchery	Tensleep, Wyoming
Wigwam Rearing Station	Tensleep, Wyoming

Region 5

None

* State of Wyoming data. Starred (*) aquifers in Region 4.

Region 6

None

Region 7

None

5. List of lakes and reservoirs at which a problem exists because of low DO content.

Region 1

Name of lake or reservoir	Location, problem, solution sought, if any
American Falls Reservoir	American Falls, Idaho. Localized sludge beds caused by excessive loading: caused DO depression near sludge bed-water interface. Eutrophication occasionally causes generally low DO levels. Implementation of water quality standards may be adequate.
Milner Reservoir	Burley, Idaho. Low DO is caused by high BOD loading under ice and under normally low flow conditions. Correction possible by implementing water quality standards and maintaining a 600-cfs minimum flow.
Upper Klamath Lake	Klamath Falls, Oregon. Caused by widespread organic sediment high in nutrients, eutrophication, and ice cover. No solution available.

Region 2

Name of lake or reservoir	Location Nearest town, state	Brief description of problem	Solution being sought, if any
Los Banos Reservoir	Los Banos, California	Reduced fishery.	None.
Lake Cachuma	Santa Barbara, California	Reduced fishery and taste and odor due to dissolved manganese and iron.	Experimented with air injection during study period 1966-1970.
Lake Casitas	Ventura, California	Reduced fishery and taste and odor due to dissolved manganese and iron.	Air injection was started in 1968.
Jenkinson Lake	Placerville, California	Taste and odor and precipitation when domestic water is chlorinated.	Settling basin and control of chlorine application.
Clear Lake	Lakeport, California	Reduced fisheries and odors.	Studies to reduce algae blooms.

Region 3

Name of lake or reservoir	Location Nearest town, state	Brief description of problem	Solution being sought, if any
Lake Mead	Boulder City, Nevada	See below.	None.
Mittry Lake	Laguna, Arizona	See below.	Controlled releases of fresh water are made to the lake periodically.

Problem areas do develop during the hot summertime in years of particularly low runoff when some reservoirs and small ponds within Arizona dry up. Also, representatives of the Arizona Game and Fish

Department report that dissolved oxygen deficiency is a problem on some of the trout fishing lakes in the White Mountains during the winter months when the lakes freeze over. Dissolved oxygen data on these lakes are available from that agency.

Brief Description of Problem

Lake Mead

In the fall of the year a drop in DO has been observed in the intake waters to the Southern Nevada Water Project. This rapid decrease was followed by the appearance of taste and odor problems in the water supply to Las Vegas Valley. It is believed that this resulted from a turnover of the lake which caused the hypolimnion waters to be drawn into the project works.

Mittry Lake

As the summer temperatures rise the dissolved oxygen drops to a point where fish propagation could be stressed.

Region 4

Name of lake or reservoir	Location Nearest town, state	Brief description of problem	Solution being sought, if any
Lake Powell	Page, Arizona	DO at depth drops to about 3 ppm occasionally.	
Flaming Gorge Reservoir	Dutch John, Utah	DO is very low below 5800 feet elevation in reservoir.	
Navajo Lake	Cedar City, Utah	Summer blooms, winter ice.	
Gooseberry Reservoir	Fairview, Utah	Summer blooms, winter ice.	
Scofield Reservoir	Scofield, Utah	Summer blooms, winter ice.	
Whitney Reservoir	Evanston, Wyoming	Summer blooms, winter ice.	

Region 4 - Continued

Minersville	Beaver, Utah	Vegetative bloom.	
China Lake	Mt. View, Wyoming	Summer blooms.	
Flaming Gorge Reservoir	Green River, Wyoming	Low DO below thermocline and resulting H_2S concentration.	None.

Region 5

Name of lake or reservoir	Location Nearest town, state	Brief description of problem	Solution being sought, if any
Lake of the Arbuckles (Arbuckle Dam)	Sulphur, Oklahoma	Unable to chlorinate water and have residual municipal and industrial deliveries.	Aeration of reservoir water being considered.

Region 6

Name of lake or reservoir	Location Nearest town, state	Brief description of problem	Solution being sought, if any
Willwood Diversion Dam and Reservoir	Powell, Wyoming	Bottom sediments go concretic if not continuously sluiced and carefully operated.	Operating procedures being tightened up

Region 7

Name of lake or reservoir	Location Nearest town, state	Brief description of problem	Solution being sought, if any
Lake Granby	Granby, Colorado	See note below**	
Bourbon County State Lake	Porterville, Kansas	Low DO below 17 feet	None
Douglas County State Lake	Baldwin, Kansas	Low DO below 17 feet	None
Leavenworth County State Lake	Reno, Kansas	Low DO below 17 feet	None

** From: "Water-Quality Conditions in Grand Lake, Shadow Mountain Lake, Lake Granby" - EPA - December 1970.

"5. Temperature measurements showed that Lake Granby and Grand Lake had thermally stratified layers although thermoclines were not in evidence. Shadow Mountain Lake was generally isothermal as expected because of its shallow depth and the effects of mixing.

6. The dissolved oxygen concentration in the near surface waters of all three lakes exceeded the 6.0 mg/l standard for cold water fisheries at all stations except for Station L-5 on Shadow Mountain Lake. The dissolved oxygen concentration at this sampling station, which is located near the west shore of the Lake between two marinas, was 5.6 and 5.2 mg/l on September 1 and 3, 1969, respectively. The dissolved oxygen concentrations were 3.0 mg/l or greater throughout the depths of all three lakes. Grand Lake and Shadow Mountain Lake had dissolved oxygen profiles approximating an orthograde pattern, but the profile in Lake Granby approached a clinograde pattern with concentrations of less than 6.0 mg/l in the hypolimnion. This oxygen deficit is caused by a natural deposition of oxidizable organic material in Lake Granby during spring runoff. Because much of the organic material is probably either suspended in natural runoff or photosynthesized in the lakes, the depletion of dissolved oxygen in the hypolimnion of Lake Granby is not readily correctable and will worsen with time. There is no data available which reflects the effects of this organic material upon the dissolved oxygen concentration of Lake Granby during other periods of the year. Since this lake is stocked regularly with game fish, the combined effects of the organic matter and ice cover on the dissolved oxygen concentrations and game fishery should be investigated."

Colorado, Nebraska, and Wyoming people indicate that they have many, many small reservoirs and lakes where chronic winterkill results from oxygen depletion under ice cover. Throughout the plains area DO deficits in small bodies of water often occur during warm weather and low water levels. Deep waters of all deep reservoirs in Region 7 very likely experience oxygen deficiencies but it is questionable that this in itself constitutes a problem.

Geary County State Lake	Junction City, Kansas	Low DO below 17 feet	None
Garnett City Lake	Garnett, Kansas	Low DO below 17 feet	None
Milford Reservoir	Junction City, Kansas	Low DO below 40 feet	None

6. List of streams and locations on each stream at which a problem exists because of low DO content.

Region 1

Name of stream	Location, description solution sought
Rickreall Creek	Rickreall, Oregon. Caused by low flow, low gradient, sewage plant effluent. Irrigation return flows from planned Monmouth-Dallas Project should improve stream velocity but reaeration of return flows may be needed. Tertiary sewage treatment needed.
Tualatin River	Hillsboro, Oregon. Low DO related to low flow, low gradient, heavy BOD loading, high nutrient levels. Improved sewage collection and treatment underway. Releases for water quality from Scoggins reservoir planned.
Snake River	Baker, Oregon. Eutrophication in deep reservoirs causes DO levels below fish tolerances. DO is rapidly replaced in turbulent streamflow below the dams, but fish hatcheries must reaerate.

Region 1 - Continued

Pudding River	Aurora, Oregon.	Low flow, low gradient, sewage, and food processing effluents cause low DO levels.	Implementation of water-quality standards is the only planned solution.

Region 2

Name of stream	Location Nearest town, state	Brief description of problem	Solution being sought, if any
Stockton Ship Channel - San Joaquin River	Stockton, California	Limits or prohibits salmon migration up the San Joaquin River. Cause of low DO partly due to canning wastes discharged in Stockton area.	Additional release of water from Delta Mendota Canal to flush the channel.
Various dead end sloughs in the Sacramento-San Joaquin Delta		Reduced fish habitat.	Provide release of water from proposed peripheral canal when constructed.
Morrison Slough	Gridley, California	Cannery wastes cause fish kills.	Presently court case.

Region 3

None

Region 4

Name of stream	Location Nearest town, state	Brief description of problem	Solution being sought, if any
Shoshone River	Cody, Wyoming	USBR diversion dam flushing, high silt, BOD load below dam.	Extended flushing and water-flow regulation.

Region 5

None

Region 6

None

Region 7

Readily available data show no trouble spots. State people indicated occasional problems related to wastewater discharges, which can be corrected by continuous adequate treatment. Also, some streams simply lack sufficient water, especially during late summer.

7. List of canals and locations on each canal at which a problem exists because of low DO content.

Region 1

None

Region 2

Name of canal	Location Nearest town, state	Brief description of problem	Solution being sought, if any
None existing now.			
Delta Mendota Canal in January 1970	Los Banos, California	Dairy wastes entering the canal caused a block of water with low DO during a canal dewatered period. When this block moved out during refilling, it trapped fish causing a fish kill.	Eliminated the dairy wastes from the canal.

Regions 3 through 7

None

8. List of water supplies from ground-water aquifers at which a problem exists because of low DO content.

Regions 1 through 7

Aware of no problems due to low DO.

Reaeration Operations

9. List of locations where reaeration operations are presently being conducted or have been conducted in the past - including reservoirs, streams, canals, and ground-water supplies.

Region 1

Reaeration reported used at a fish hatchery in Middle Snake River. Other hatcheries probably reaerate to replace inplant losses.

Region 2

Name	Location Nearest town, state	Brief description of method used, results obtained, and data or source of data, if available
Lake Cachuma	Santa Barbara, California	See USGS open-file report: Busby, M. W., "Elimination of Stratification at Lake Cachuma, Calif.," Garden Grove, California. 1970.
Lake Casitas	Ventura, California	See preliminary report: Barnett, Richard H., "Aeration Improves Casitas Reservoir Quality," Ventura River Municipal Water District, Ventura, California. 1971.

Region 3

None

Region 4

Name	Location Nearest town, state	Brief description of method used, results obtained, and data or source of data, if available
Navajo Lake	Cedar City, Utah	Reaeration tried but was unsuccessful.

Meeboer Lake, Laramie, Wyoming. Aeration equipment was in operation from November 13, 1968, to April 1, 1969. Although winter survival of trout was fair, the degree to which the aeration equipment contributed to this is unknown. Experiments with windmills were initiated in December 1969, to determine their effectiveness in keeping the lake ice free.

Region 5

Name	Location Nearest town, state	Brief description of method used, results obtained, and data or source of data, if available
Marshall Ford	Austin, Texas	Oxygen diffuser studies by University of Texas.

Region 6

None

Region 7

Name	Location Nearest town, state	Brief description of method used, results obtained, and data or source of data, if available
Lake Parvin	Log Cabin, Colorado	Helixor system - Colorado Game, Fish and Parks

Region 7 - Continued

Fremont Lake State Recreation area	Fremont, Nebraska	Perforated tubes - Nebraska Game and Parks Commission
Clear Lake	Brown County, Nebraska	Private sportsmen's group
Long Lake	Medicine Bow Basin, Wyoming	Windmill aerators - Wyoming Game and Fish Commission
Muddy Creek Reservoir	Medicine Bow Basin, Wyoming	Windmill aerators - Wyoming Game and Fish Commission
Meeboer Lake	Laramie Plains, Wyoming	Hinde system - Wyoming Game and Fish Commission
Road Canyon Reservoir	Creede, Colorado (Region 5)	Colorado Game, Fish and Parks
Brown Lake	Creede, Colorado (Region 5)	Colorado Game, Fish and Parks

10. Additional comments or suggestions concerning present and future reaeration needs that are not applicable to the questions above.

Region 1

EPA has suggested that a DO deficiency could develop in the Grande Ronde River in Oregon between La Grande and Elgin under conditions that would exist with the proposed project. Flow in the river at times would consist almost entirely of irrigation return flows. The needs in this case are twofold: (1) a better method for prediction of DO levels in irrigation return flows, particularly for buried tile drains, and (2) a study of the means of reaeration should a need actually develop. Reaeration is generally used to add a gas to water, but the process is equally useful for stripping a dissolved gas from water such as nitrogen when present in excessive amounts. This is a serious problem to fishery interests on the Columbia River system during spills over dams. USCE is now experimenting with techniques to prevent supersaturation, but reaeration might still be needed at places like Grand Coulee Dam and other dams for polishing (removing additional nitrogen by bubbling air through the water).

Region 2

See attached research proposal for Lake Cachuma and Lake Casitas Reservoirs, California.

Region 3

None

Region 4

None

Region 5

EPA initiated a monitoring program on the Lake of the Arbuckles (Arbuckle Dam) several years ago and we feel that this reservoir would be a good place to initiate an aeration research program to attempt destratification of the reservoir.

Region 6

Region 6 does not have any areas of serious dissolved oxygen deficiency within its sphere of influence. At the present time, we are considering operating procedures to improve sediment sluicing operation at the Willwood Diversion Dam near Powell, Wyoming, where sediment released after a period of storage under anaerobic conditions causes fish kills. This may be an application for reaeration if continuous sluicing does not, in itself, eliminate the problem.

Region 7

None

CONTACT PERSON OR PERSONS IN EACH REGION

Region 1

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Region 6

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Region 7

Dean M. Schachterle, Chief, Land Management and Recreation Branch, Building 20, Denver Federal Center, Denver, Colorado 80225, FTS Telephone Number 303-234-3358.

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REGION 2 RESEARCH PROPOSAL FOR DEVELOPING
DESTRATIFICATION TECHNIQUES - TO BE
UTILIZED AT LAKE CACHUMA AND LAKE CASITAS

Background Information

During the last several years, both Lake Casitas and Lake Cachuma have experienced low dissolved oxygen conditions during the late summer and early fall prior to the reservoir turning over. These conditions have reduced the habitat for fisheries native to the reservoirs and have at times caused iron and manganese ions to be dissolved creating taste and odor problems in the reservoir's domestic water supply.

Low dissolved oxygen conditions have been created by excessive algal production due to nutrient-rich waters coming into the reservoir and preimpoundment conditions. A large bank of nutrients, therefore, is available for algae growth. As the algae settles, a decomposing organic layer forms near the bottom of the reservoirs, thus utilizing the available oxygen supply below the thermocline. This generally occurs in depths greater than 40 to 50 feet which also corresponds to the depth below the thermocline.

During 1967, 1968, and 1969, a cooperative attempt was made by the U.S. Geological Survey and the County of Santa Barbara to develop a feasible means of aerating Lake Cachuma. These attempts have been relatively unsuccessful due to the lack of direction and knowledge. The initial work performed by the USGS was restricted to a plastic cylinder used as a model of the reservoir. Air was passed through the cylinder to determine the effectiveness that air injections would have in destratifying the reservoir. The results of this study are presented in a report [2] which is attached to the Reaeration Questionnaire. The results are not explicit and generally do not relate to the prototype. Following that work, the U.S. Geological Survey, in cooperation with the County of Santa Barbara and the Bureau of Reclamation*, engaged in a study of reaeration of Lake Cachuma. However, due to several reasons, the attempted reaeration of the reservoir was considered to be a failure. Some of these reasons were:

1. Insufficient power and air capacity;

2. Ineffective diffuser system (due to failure of the diffuser during the installation);

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* The Bureau's effort was restricted to the supply of equipment used in the study.

3. Ineffective management of the program;

4. Insufficient points of air injection.

In 1968 the Ventura County Water Agency, who operates Lake Casitas, began injecting air near the dam to control the taste and odor problems in the water delivered to their customers. The second report [1] attached to the Reaeration Questionnaire was prepared by Mr. Richard Barnett, and it describes the air injection system and the success which resulted from this effort. This approach to air injection has been empirical in nature and has not been fully evaluated as to the efficiency developed by the particular hardware that is being utilized. Generally, the entire reservoir has been affected to some degree by the air injection system which is located 1,500 feet above the dam. The effectiveness of this one-point injection system needs to be evaluated prior to any system that might be installed for similar purposes at Lake Cachuma.

Need for Further Research

As described above, there are additional questions that need to be answered as to how a reservoir with a capacity in excess of 200,000 acre-feet can be successfully reaerated. Besides these questions, the following should be considered:

1. Documentation of the environmental effects due to air injection must be accomplished, including the effect on the fishery and the water-quality conditions throughout the reservoir.

2. Determine the effects that induced air will have on making nutrients at the lower depths available for additional phytoplankton growth at the upper levels of the reservoir.

3. Determine the effect that the induced air has on the mean temperature of the reservoir water. It is suspected that by destratifying a reservoir of this size, the temperature of the reservoir water will rise. There should be some point in which an equilibrium will be reached and that point should be determined prior to reaeration.

4. Determine the relative effect of different diffusers used to integrate the injected air into the reservoir.

5. Determine criteria for setting the points of air injection. This criteria could include:

   a. Reservoir description

   b. Prevailing winds

c. Depth, and

d. Location of the outlet.

6. Document long-term trends due to air injection.

7. Determine what operation and maintenance effort will be necessary to maximize the effectiveness of the system.

8. Develop criteria which describe when air should be injected (i.e., all year, before a problem occurs, when a problem exists).

9. Evaluate and document the relative effect on the biota, especially the phytoplankton, which are present in the reservoirs. There are instances where the predominant species of phytoplankton will be affected and possibly changed due to availability of nutrients, mixing of water below and above the thermocline, and other environmental factors.

A Research Proposal

There is an unusual opportunity to study the effectiveness of air injection in two large reservoirs within a 20-mile radius of Santa Barbara, California. One reservoir, Lake Casitas, has been injected with compressed air for the last 3 years, and a sufficient amount of data is available to partially document the relative effect of air injection on water quality. The system has been fairly well developed and is being managed in an acceptable manner. The other reservoir, Lake Cachuma, has a need for reaeration. Any effort that will be exerted in studying Lake Cachuma and the effectiveness of air injection should be done with a greater amount of scientific control than witnessed thus far. The design of the system, the location of the diffusers, the documentation of the results, and the general overall operation of the system should be controlled by the Bureau of Reclamation in cooperation with the water districts.

There is an opportunity to study and evaluate Lake Casitas and Lake Cachuma which are of similar size. Lake Casitas is essentially an offstream storage facility, while Lake Cachuma is an onstream storage impoundment. These reservoirs have similar water-quality problems due to low dissolved oxygen conditions. Anaerobic conditions cause heavy metals to become dissolved resulting in taste and odor problems. Also, the low dissolved oxygen condition below the 40- or 50-foot level in both reservoirs obviously results in a reduced fishery habitat.

Any effort put forth by the Bureau will compliment the significant effort which has already been made at Lake Casitas and at Lake

Cachuma. The work performed at either of these two reservoirs could be applied to reservoirs throughout the West where dissolved oxygen or stratification problems are significant.

Recommendations

We recommend that an adequate research proposal and study plan be developed to study the effects of air injection at both Lake Casitas and Lake Cachuma. It appears that this plan may require a staff of four people: a biologist, an engineer, and two technicians to be stationed at Santa Barbara during the study period. If acceptable, this office could provide a study plan to justify research funding within the present fiscal year.