Research Project Technical Completion Report

OKLAHOMA WATER RESOURCES RESEARCH INSTITUTE

A-065-OKLA

# WATER QUALITY IMPROVEMENT IN SMALL PONDS

James E. Garton, Prof.
Richard E. Punnett, Grad. Asst.
Agricultural Engineering Department
Oklahoma State University

Period Covered by Research Investigation

July 1, 1976 -- September 30, 1978

The work upon which this report is based was supported in part by funds provided by the United States Department of the Interior, Office of Water Resources Research, as authorized under the Water Resources Research Act of 1964.

**SELECTED WATER RESOURCES ABSTRACTS**
**INPUT TRANSACTION FORM**

1. Report No. | 2. | 3. Accession No.

W

4. Title

WATER QUALITY IMPROVEMENT IN SMALL PONDS

5. Report Date
6.
8. Performing Organization Report No.

7. Author(s) James E. Garton, Richard E. Punnett.

10. Project No.
A-065-OKLA

9. Organization

OKLAHOMA WATER RESOURCES RESEARCH INSTITUTE
OKLAHOMA STATE UNIVERSITY

11. Contract/Grant No.
14-34-0001-8038

13. Type of Report and Period Covered

12. Sponsoring Organization

15. Supplementary Notes

16. Abstract

A simple method of determining destratifier design criteria was developed for water quality improvement in small ponds using a Garton pump. The method is based upon two major objectives: (1) to penetrate to the bottom of the pond with downward pumped surface waters; and (2) to pump a volume of water equal to the normal hypolimnion every two days.

The data are presented in tabular form. From the table the advantage of using larger diameter pumps is apparent.

17a. Descriptors

destratifier, water quality, hypolimnion, pumps

17b. Identifiers

Lake of the Arbuckles
Ham's Lake
Stillwater, Oklahoma
Pine Creek Reservoir ,Hugo, Oklahoma

17c. COWRR Field & Group V-G

18. Availability | 19. Security Class. (Report) | 21. No. of Pages
20. Security Class. (Page) | 22. Price

Send To:

WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D. C. 20240

Abstractor AUTHOR | Institution OKLAHOMA WATER RESOURCES RESEARCH INSTITUTE

Definition of Terms:

- $A$ - area of pump impeller
- $D$ - diameter of pump impeller
- $g$ - gravitational constant
- $H$ - maximum depth of the pond
- $Q$ - flow rate through the pump
- $V$ - velocity of water through the pump impeller
- $\Delta\rho$ - density difference of the water at the impeller depth and the bottom water density
- $\rho$ - density of water at the impeller depth

WATER QUALITY IMPROVEMENT IN SMALL PONDS

Objectives and Extent of Achievement of the Objectives:

The objectives of the study were:

1. To identify the parameters that are important in improvement of water quality by artificial destratification.
2. To augment available data with additional physical tests that will permit development of prediction criteria necessary for destratifier design for a given lake.

The objectives were achieved by combining past experiments, current modeling research, and additional prototype studies. A method of predicting destratifier design criteria was developed which may be used for small ponds (maximum depth of 12m and surface area of 64 ha). The type of destratifying device is a "Garton pump" as described by Quintero and Garton (1973).

Background:

Summer thermal stratification prevents the natural surface to bottom mixing in reservoirs. Biological respiration and chemical reduction processes deplete the oxygen in the bottom waters resulting in water quality deterioration. Water purification problems occur where the reservoirs are used as municipal or private water supplies. The volume of water available for fish habitat is also decreased by the establishment of anoxic bottom waters. A natural autumn turnover may suddenly mix the entire body of water resulting in a low overall concentration of dissolved oxygen which may kill fish.

Artifical destratification may be mechanically accomplished to eliminate thermal stratification and thereby improve the water quality in situ. This approach has been shown effective by Strecker, et al. (1977).

Design criteria for mechanically destratifying a given reservoir have not been presented in previous publications.

## Experimental Considerations

Earlier studies revealed the need to know (1) what pumping rate was required to successfully destratify a reservoir, and (2) what discharge velocity was required (for a given pump diameter) to penetrate to the bottom of the reservoir.

Studies conducted on Lake of the Arbuckles (Punnett, 1978) revealed definite depth of penetration limitations imposed by the thermal-density layers within a lake. The study showed the water quality improvement in the lake to be limited to the depth of mixing.

It is felt by the authors that for successful mechanical destratification the pump plume must initially penetrate to the bottom of the reservoir and that the flow rate of the pump should be dependent upon the volume of the hypolimnion.

## Experimental Equipment:

Two Garton pumps of different sizes were used in this study. The larger pump had an impeller diameter of 1.829 m and a capacity of 1.648 cms. The larger pump was powered by a five hp gasoline engine to permit a variable speed operation. The smaller pump had an impeller diameter of 1.067 m and a capacity of 0.625 cms. A one hp electric motor was used to operate the smaller pump.

## Modeling Studies

Moon (1978) studied the relationship between the parameter $\frac{V}{\sqrt{g\,\Delta\rho/\rho H}} \times \frac{D}{H}$ and the dilution factor for point destratification at lake outlet. He determined that the dilution factor reached a maximum near a parameter value of 0.25.

Research Procedures:

The first series of tests were conducted to determine a proper pump flow rate for a given hypolimnetic volume. Ham's Lake, located near Stillwater, OK, was used for this test series. In 1976, the lake was allowed to stratify thermally before operation of the larger pump began. The pump had the capability of pumping the volume of the initial hypolimnion every 1.5 days. After 32 hours of operation the lake was destratified. On July 9, the larger pump was turned off and on July 19, the smaller pump was put into operation. The pump had the capability of pumping the "normal" hypolimnetic volume every 4.0 days. The smaller pump reestablished and maintained destratification.

In 1978, the smaller pump was put into operation at Ham's Lake prior to strong thermal stratification when the thermal difference, top to bottom was about 1°C. The smaller pump was operated until July 8. On July 11 the larger pump began operating.

The second series of tests were conducted at Pine Creek Reservoir, near Hugo, Oklahom. This series of test was used to determine depth of penetration relationships. The larger pump was used for this series since Moon (1978) had conducted model studies of this particular pump. The prototype depth of penetration results were compared to the modeling results observed by Moon.

During each test series, the temperature and dissolved oxygen, (D.O.) profiles were used to determine the effect of each test.

Results:

The temperature and D.O. profiles taken at Ham's Lake in 1976 and 1978 are given in Figures 1 and 2. In 1976, the larger pumping capacity was sufficient to maintain thermal and chemical destratification (as indicated by D.O.) through the early summer period. The smaller pumping capacity was sufficient to maintain destratification throughout the late summer period. In 1978, the smaller pumping

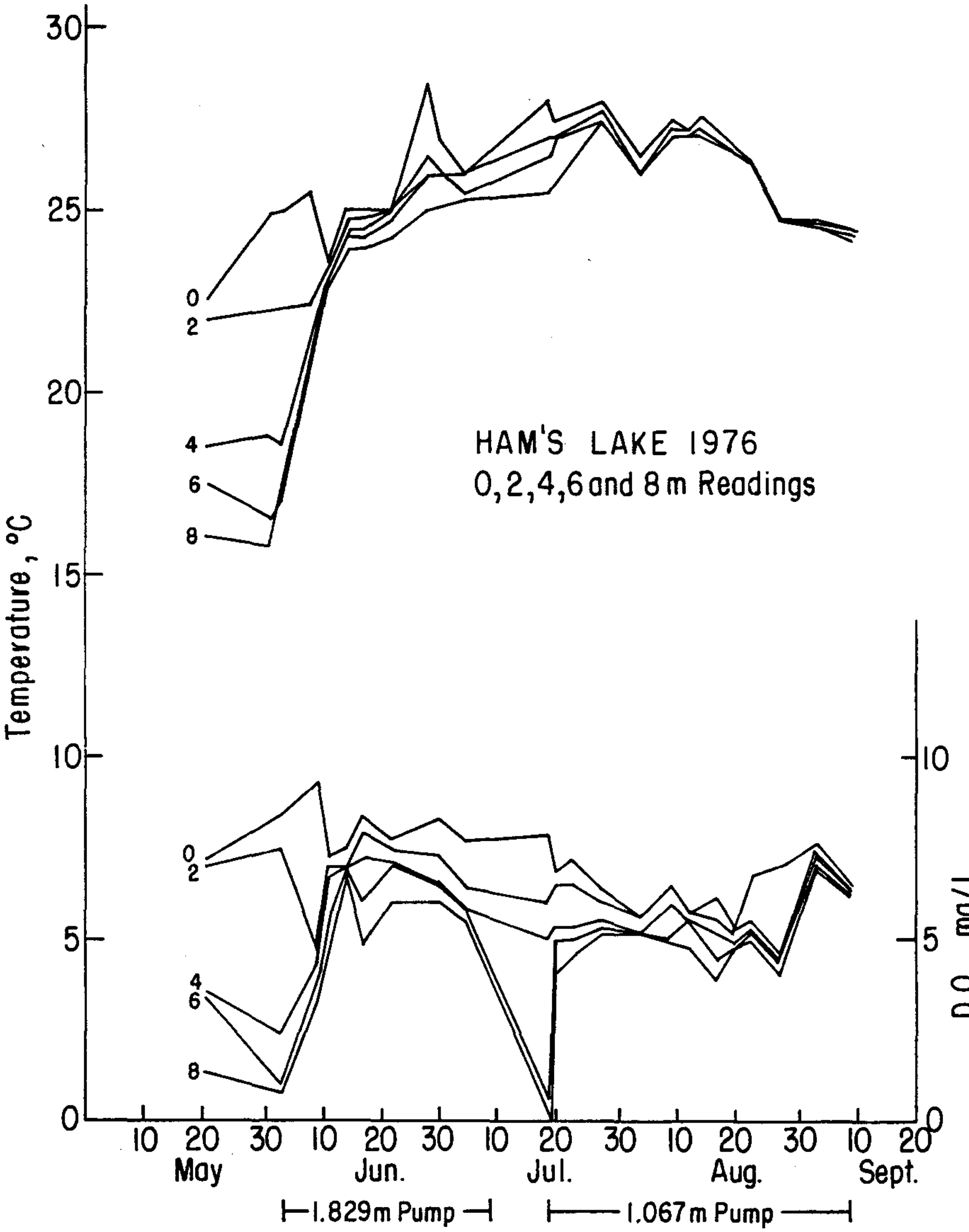


Figure 1. Temperature and D.O. profiles for 1976

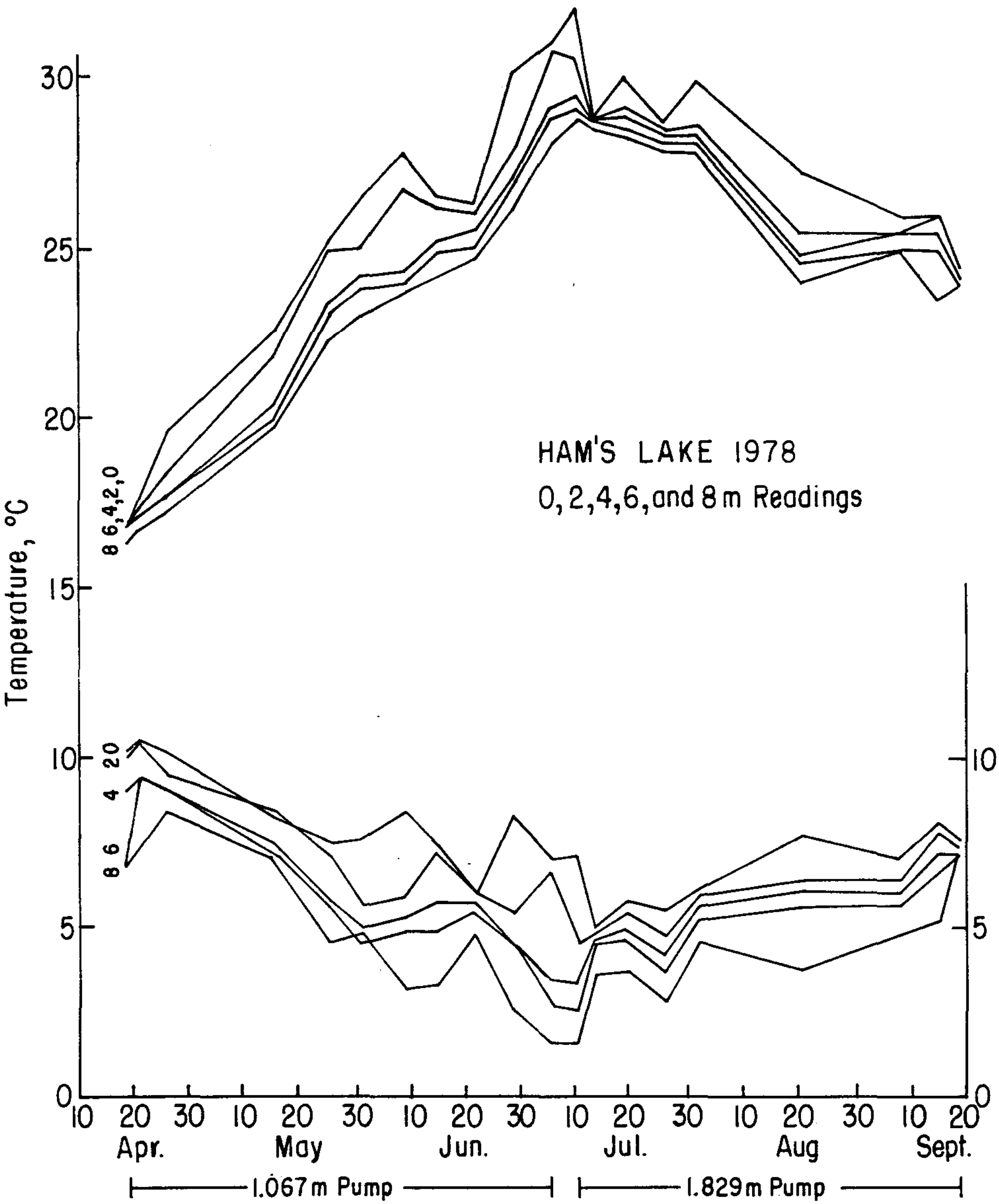


Figure 2. Temperature and D.O. profiles for 1978

capacity was not sufficient to maintain chemical destratification (as shown by increased D.O. depletion) during the early summer period. These results indicate that the pumping rate should be able to pump the normal hypolimnetic volume in a period of less than 4.0 days (1.5 days being sufficient).

Depth of penetration tests results conducted at Pine Creek Reservoir for different flow velocities through the larger pump, for velocities of 0.332, 0.461 and 0.553 mps, the depth of penetration was 6.5, 7.5 and 8.5 m. The prototype results of the $\frac{V}{\sqrt{g \frac{\Delta\rho}{\rho} H}}$ vs $\frac{H}{D}$ parameters are shown in Figure 3 with the relationship as given by Moon (1978).

<u>Discussion</u>:

The 1976 and 1978 destratification of Ham's Lake indicated that a pumping device should have the capability of pumping a volume, equal to that of the normal hypolimnion, approximately every 1.5 to 2.0 days. The prototype studies of depth of penetration agreed with model studies conducted by Moon (1978). The parameter $\frac{V}{\sqrt{g \frac{\Delta\rho}{\rho} H}} \times \frac{D}{H} = 0.25$ is felt to be sufficient guide to determining various velocity and impeller diameter relationships for a given condition.

To simplify the selection of a Garton pump for any pond, Table I is presented. Table I was based upon the following assumptions:

1. $\frac{\phantom{V}}{\sqrt{g\, \Delta\rho/\rho\, H}} \times \frac{D}{H} = 0.25$
2. $g = 9.81$ m/sec$^2$
3. $\Delta\rho/\rho = 0.0025$ (or a temperature range of about 27° to 16°C)
4. Hypolimnion volume pumped every 2 days
5. Hypolimnion volume equal to 0.3 of lake volume
6. $\frac{\text{Depth x Area}}{4.0}$ = Volume of Lake
7. Power calculations based on fan laws and performance curves for Acme DCH 1.829 m and 1.067 m fans in air.

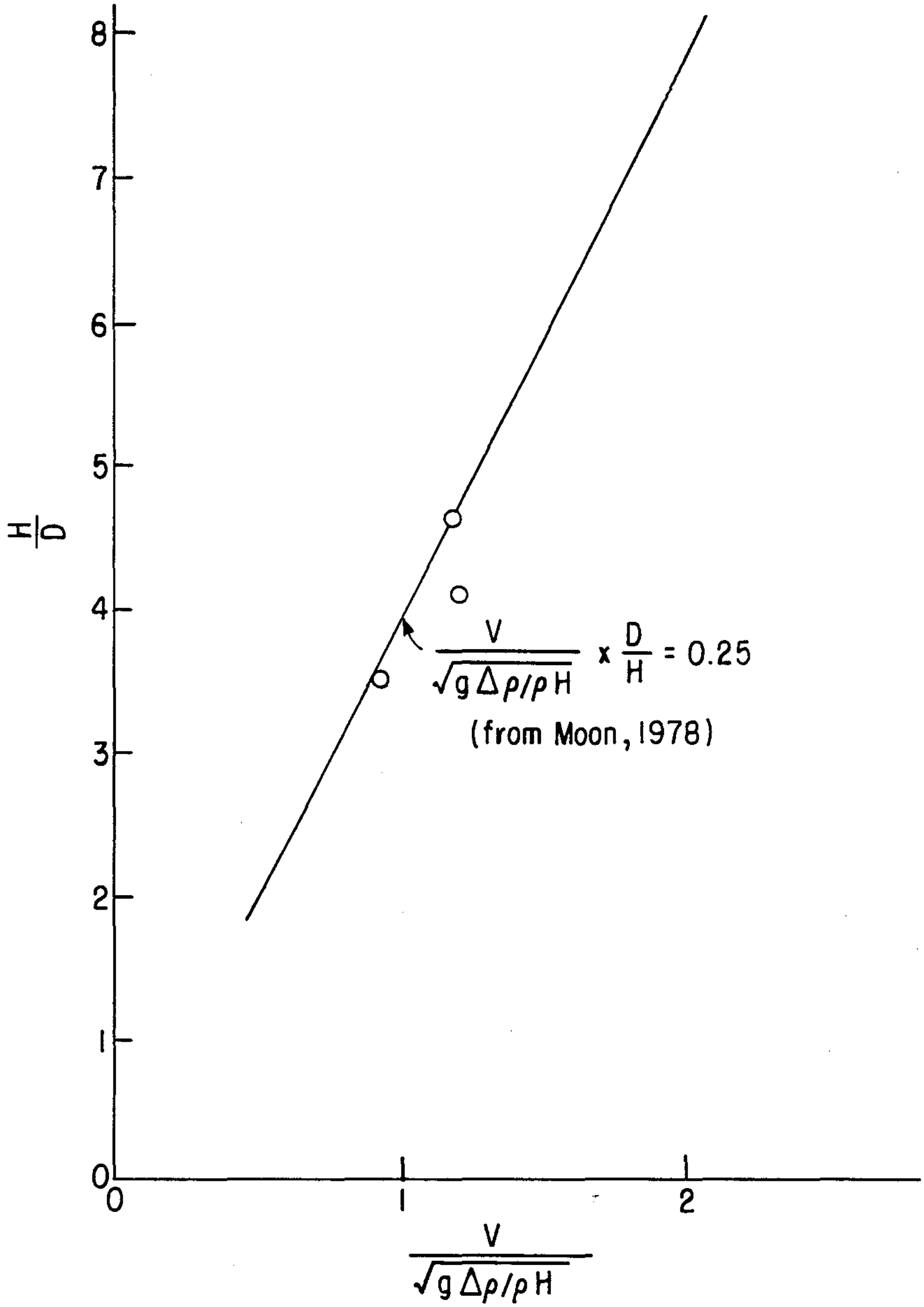


Figure 3. $\frac{V}{\sqrt{g\frac{\Delta e}{e}H}}$ vs. $\frac{H}{D}$

Table 1. Lake Destratifier Design based on $\frac{V}{\sqrt{g\ \Delta\rho/\rho H}} \times \frac{D}{H} = 0.25$ for Oklahoma conditions.
(for pump with orifice plate)

**Diameter = 2.44m (8 ft)**

| Depth m | Velocity m/sec | Surface Area Ha | Approximate Fan Power Kilowatts | HP |
|---|---|---|---|---|
| 4 | 0.14 | 37 | 0.01 | 0.015 |
| 6 | 0.26 | 45 | 0.07 | 0.10 |
| 8 | 0.39 | 50 | 0.26 | 0.35 |
| 10 | 0.55 | 58 | 0.71 | 0.95 |
| 12 | 0.72 | 64 | 1.6 | 2.1 |
| **Diameter = 1.829m (6 ft)** | | | | |
| 4 | 0.19 | 27 | 0.015 | 0.02 |
| 6 | 0.34 | 33 | 0.10 | 0.13 |
| 8 | 0.52 | 39 | 0.35 | 0.47 |
| 10 | 0.73 | 43 | 0.95 | 1.3 |
| 12 | 0.96 | 47 | 2.2 | 2.9 |
| **Diameter = 1.22m (4 ft)** | | | | |
| 4 | 0.28 | 18 | 0.02 | 0.03 |
| 6 | 0.51 | 22 | 0.16 | 0.21 |
| 8 | 0.78 | 26 | 0.57 | 0.77 |
| 10 | 1.10 | 29 | 1.6 | 2.1 |
| 12 | 1.44 | 31 | 3.6 | 4.8 |
| **Diameter = 0.61m (2 ft)** | | | | |
| 4 | 0.56 | 8 | 0.05 | 0.06 |
| 6 | 1.02 | 10 | 0.28 | 0.38 |
| 8 | 1.57 | 12 | 1.0 | 1.4 |
| 10 | 2.19 | 13 | 2.8 | 3.8 |
| 12 | 2.88 | 15 | 6.5 | 8.7 |

These assumptions were made so that a destratifier could be designed based upon the maximum depth and surface area of a pond. By entering Table 1 at the known depth, the size of pump can be determined by checking the actual surface area with the tabulated value. After determining the size of pump, the velocity is used for selection of rpm with the aid of a manufacturers performance information.

If specific depth-volume data are available for a given pond. Then a more accurate determination of pump size can be made.

By assuming a pump diameter, the velocity through the impeller can be determined from the relationship $\frac{V}{\sqrt{g \frac{\Delta\rho}{\rho} H}} \times \frac{D}{H} = 0.25$. Knowing the velocity and diameter of the pump, the flow rate can be calculated from $Q = AV$ where $A = \frac{\pi}{4} D^2$. By multiplying the flowrate by a time equivalent to two days, the volume pumped in two days is determined. This volume should be equal to the normal hypolimnion.

<u>General</u>:

From Table 1 the advantage of using a large diameter pump can be seen. For example, if a pond were 12 m deep and had a small surface area of 15 ha, a 0.61 m diameter impeller is a sufficient destratifier. However, the 2.44 m diameter impeller would only use ¼ the power requirement to penetrate the same depth even though the actual flow rate is more than adequate.

The impeller should be located one to two m below the surface.

## REFERENCES


Quintero, J. E. and J. E. Garton. "A Low Energy Lake Destratifier". Trans. of the American Society of Agricultural Engineers, Vol 16, Nov. 5, 1973.

Strecker, R. G., J. M. Steichen, J. E. Garton, C. E. Rice. "Improving Lake Water Quality by Destratification". Trans. of the American Society of Agricultural Engineers, Vol 20, Nov. 4, 1977.

Punnett, R. E. "Destratification of Lake Arbuckle with a Cluster of Low Energy Pumps". (Unpublished M.S. Thesis, Oklahoma State University, Stillwater, Oklahoma, July, 1978)

Moon, J. J. Jr. "Enhancement of Release Water Quality by Localized Mixing - A Hydraulic Model Study". (Unpublished M.S. Thesis, Oklahoma State University, Stillwater, Oklahoma, December, 1978)