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FIELD STUDIES ON SEDIMENT-WATER ALGAL NUTRIENT INTERCHANGE PROCESSES AND WATER QUALITY OF UPPER KLAMATH AND AGENCY LAKES

CLEAN WATER

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CORVALLIS, OREGON

FIELD STUDIES ON SEDIMENT-WATER ALGAL NUTRIENT INTERCHANGE PROCESSES AND WATER QUALITY OF UPPER KLAMATH AND AGENCY LAKES

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A. R. Gahler

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United States Department of the Interior
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Pacific Northwest Water Laboratory
200 Southwest Thirty-fifth Street
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A Working Paper presents results of investigations which are to some extent limited or incomplete. Therefore, conclusions or recommendations--expressed or implied--are tentative.

CONTENTS

PREFACE

The purpose of this Working Paper is to report data collected for a research project on interchange of algal nutrients between sediment and overlying water in Upper Klamath Lake and to present the results from a field experiment on nutrient interchange.

The objective of part of the investigation was to follow lake conditions at several representative locations in order to determine when interchange might occur and whether or not it could be measured in the lake water. No attempt was made to monitor the water quality of the entire lake system. This would have been beyond the scope of the problem and impossible from the standpoint of available manpower. No attempt has been made to interpret the water quality data except in relationship to interchange mechanisms.

In many lakes, an increase in nutrients is noted under anaerobic conditions, therefore, more measurements were made when it was anticipated that these conditions would likely develop under the ice and in late summer or autumn when the algae died.

During the period of this investigation no other organization made a systematic study of chemical, physical, and algal properties of the lakes. Therefore, it is felt that these data will be useful to those future workers on Upper Klamath and Agency Lakes who may wish to compare lake conditions with water quality in the past. These data are in a sense a continuation and expansion of the reports by Phinney, Bond, Miller, and other investigators of Upper Klamath Lake.

Information on sediments will be treated in a separate report because of the diverse reasons for examination of the sediments and because of the length of the report.

ABSTRACT

Studies of algal nutrient interchange between sediment and water under environmental conditions were carried out in Upper Klamath Lake, Oregon, from July 1967 to March 1969. Experimental "pools" of lake water in contact with the sediment and experimental pools of water not exposed to the sediment were compared with the open lake from November 1967 to June 1968.

Water quality measurements in Agency and Upper Klamath Lakes were made to determine whether interchange processes could be observed directly in the water, to establish conditions for laboratory interchange tests, and to compare lake conditions with the experimental pools. Data were obtained from July 1967 to March 1969 on pH, conductivity, temperature, dissolved oxygen, chemical composition, and phytoplankton.

Interchange definitely occurred when <u>Oscillatora</u> floated to the lake surface with attached sediment which contained soluble nitrogen and phosphorus compounds. A plastic-bottomed pool of water not exposed to sediment exhibited higher oxygen content under the ice and had less phytoplankton growth in spring than the pools exposed to sediments. The effects of gas evolution, wind, currents, fish, boating, benthos, diffusion, etc., on the shallow lakes was not quantitatively determined, but it seems quite probable that anything that stirs the sediment causes interchange of nutrients.

INTRODUCTION

The intense growth of algae for about eight months each year in the eutrophic Upper Klamath and Agency Lakes in Oregon has been attributed in part to release of nutrients from the bottom sediments to the overlying water.

A study to evaluate the influence of lake sediments on algal growth and to determine the conditions under which nutrient release or uptake might occur was started in the summer of 1967 by the Sediment-Water Nutrient Interchange Section of the National Eutrophication Research Program, Corvallis, Oregon.

It is the purpose of this paper to report results from the field experiments and lake observations and to publish water quality data of the lakes which have not been placed into an information retrieval system, yet are useful for present and future investigators of this body of water. These data augment those reported by Phinney (5, 6), Bond (1), the Oregon State Sanitary Authority (4), Miller and Tash (3), and Jewett (2).

This paper contains information pertaining to conditions under the ice. Winter data have not previously been reported for these lakes. These and all other data were obtained during an investigation designed to determine whether nutrient interchange processes were detectable under various lake conditions. Information pertaining to soluble nutrients in the interstitial water of the sediments, and the composition and characteristics of sediment cores will be published in another report.

The data in the Tables are listed according to stations which are designated by a capital letter, a number, and a small letter (e.g., Y1b, 09d). The station position can be located on the map of Agency and Upper Klamath Lakes (Figure 1) by using coordinates: numbers are north and south, capital letters progress alphabetically from east to west, and small letters indicate relative position in each square.

Samples of lake water were taken most frequently at two locations: at a site in Howard Bay (09d) where experimental pools were installed in late October 1967, and at the Pelican Marina near the outlet of Upper Klamath Lake (Y1b; see Figure 1). The outlet was sampled frequently to compare the general lake condition with that in specific locations under study. Other locations (Agency [M35a] and Buck Island [V7d]) were sampled occasionally in cooperation with Dr. R. Pacha of Oregon State University who is studying sediment-bacteria-water interactions under a Federal Water Pollution Control Administration research grant.

The analytical procedures used in the laboratory and field are given in Table 1, and the chemical description of water quality at the surface and directly above the sediment is presented in Table 2.

Data relating to pH, water transparency, qualitative information on algal conditions, and special limnological observations are shown in Table 3 (pH is also tabulated in Table 2); temperature and oxygen profile data in Table 4 and 5; quantitative information on

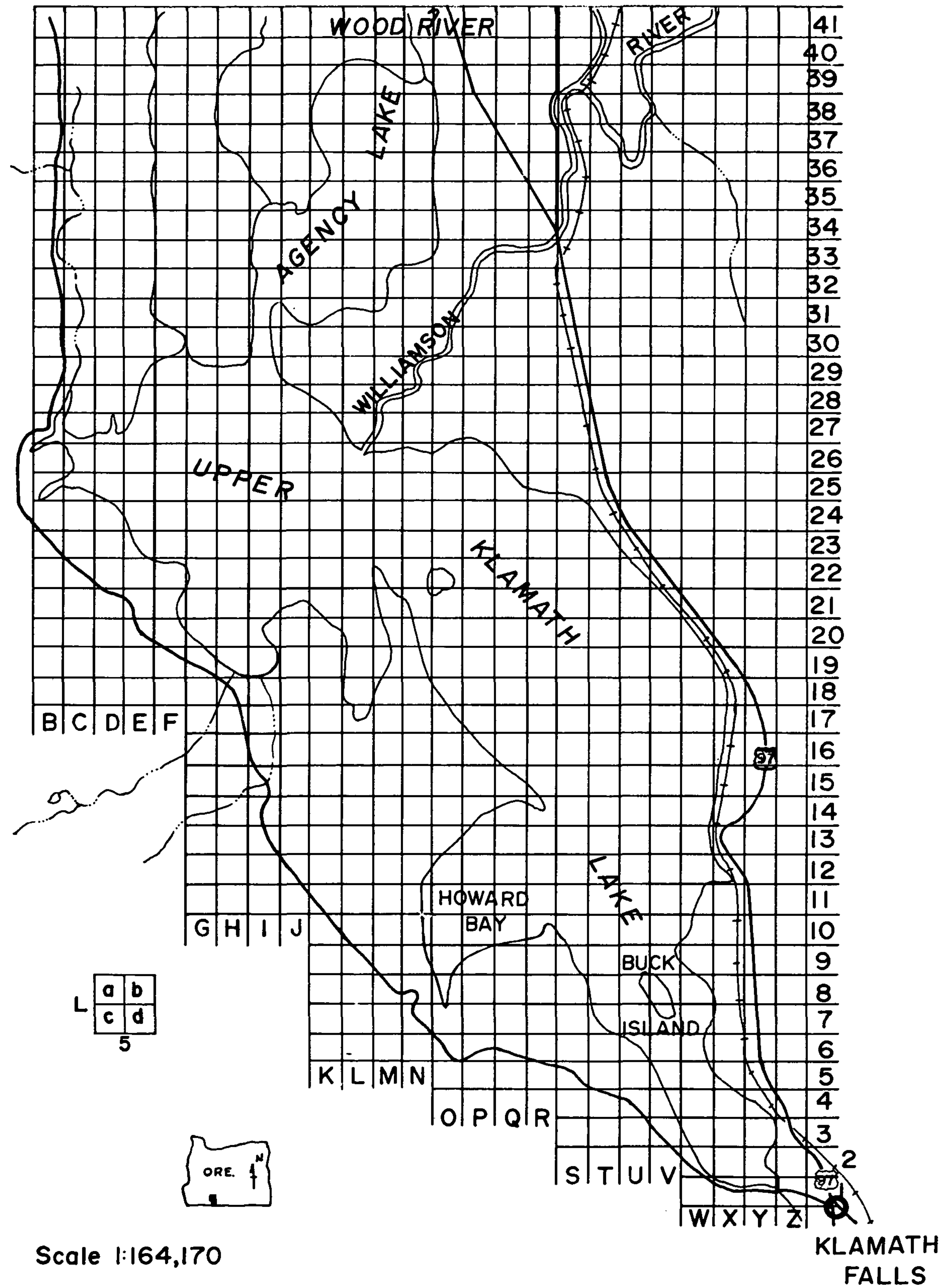

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FIGURE 1 ···· MAP OF UPPER KLAMATH LAKE SYSTEM algae during the winter months, Table 6; conductivity data from Howard Bay in winter, Table 7; comparison of chemical data of surface and bottom water from some of the experimental pools and adjacent lake water, Table 8; and selected profile data for temperature and oxygen in the experimental pools and lake, Table 9.

Concentration expressions for the various chemical and physical measurements are listed in Table 1. Appropriate abbreviations and notes appear at the end of each table.

Upper Klamath and Agency Lakes are located in South Central Oregon east of the Cascade Mountains. Part of the drainage from the watershed of about 3,800 square miles flows through Wood River and other tributaries into Agency Lake which drains southward into Upper Klamath Lake. The Williamson River is the only other large tributary for Upper Klamath Lake. The lake, in turn, empties into the Klamath River which runs eventually into the Pacific Ocean. The shallow (mean depth 8 feet), 120 square-mile lake system, and tributaries have been described quite fully by others (1, 3) (see also, Figure 1). The water level in the lakes is controlled so that the altitude of the surface varies only from 4,136 to 4,143 feet.

FIELD TEST FOR SEDIMENT-WATER NUTRIENT INTERCHANGE

Experimental Pool Design and Location

Ideally, tests of the interchange between sediment and water of the nutrients used by algae and aquatic plants should be performed in the lake so that the weather, radiation, temperature, wind, diffusion, currents, benthic organisms, sediment conditions, water quality, etc., are as nearly identical to that of the natural environment as possible. For the field interchange measurements, four 10 mil polyethylene pools 3 x 3 x 4 meters deep were installed in October 1967 in a wooden framework for support and protection. A site in Howard Bay (09d) away from highway traffic yet accessible in winter proved to be satisfactory. Two pools were bottomless so that the water was exposed to the sediment. The other two pools had plastic bottoms.

The pools were located about 10 meters from a dike. During the experiment the depth of the lake at the pools varied from 1.2 to about 2.75 meters. The plastic sides were folded over so that the top edge extended above the surface of the water from 30 to 45 cm. Each pool contained about 19,000 liters (5,000 gallons) of lake water during the experiment. The physical, chemical, and biological variables in the water of the pools were observed from the surface to the bottom at least monthly and compared with the surrounding lake water for about seven months until cracks and holes developed in the plastic.

Pools of this relatively large size were used so that the effects of biological growth on the sidewalls would be minimized and radiation effects would be similar to natural conditions. Larger pools of more durable material would have been desirable, but design was limited by available funds.

Much useful information was obtained from the field experiment, although it was not entirely successful because of defects which developed in the originally impervious plastic under the severe field conditions of thick ice and occasional high wind velocity.

Observations

The plastic walls were sufficiently flexible so that wave action against the pools was partially transmitted throughout the contained water mass, enhancing mixing. Temperature in the pools remained within ±1°C of the adjacent lake water (Table 8). Dissolved oxygen concentration before the ice formed on the lake in December 1967 and after melting of the ice the last week in February 1968 was usually within ±1.5 mg O/ℓ between pools and lake water at corresponding depths. However, under the ice and snow, the water in the plastic pools not exposed to the lake sediment contained more dissolved oxygen than the water in the pools exposed to the sediment (Table 9).

Farm drainage water was pumped into the bay during February 1968 at a point 0.8 mile from the pools and flowed along the lake bottom past the pools. Thus, the oxygen and other variables measured in the lake did not represent typical conditions with which to compare the pools. The pools were apparently intact during the winter and early spring, since the conductivity did not vary appreciably from the time they had been filled with lake water in November until March when they were flooded as the lake level rose.

Dissolved oxygen in the water below 0.5 meter in the plastic-bottomed pool averaged 2.3 mg O/ℓ higher than in the pool where the water was exposed to the sediment, as shown in Table 9 for stations PBE and SBW on January 17 and 31, 1968. Compared with water sampling site N10b (Table 4) in Howard Bay on January 31, 1968, where the oxygen was less than 1.5 mg O/ℓ from surface to sediment, the oxygen in the plastic-bottomed pool averaged 5.8 mg O/ℓ higher than in the lake. This indicates that the sediments exert an oxygen demand upon the water. Presumably, the water at N10b at this time was not affected by the farm drainage water, since the conductivity was low and fairly uniform from top to bottom (Table 7).

In June, <u>Oscillatoria</u> floated to the surface carrying with it large portions of sediment about 8 to 15 cm thick. Small floating chunks were noted in the sediment-exposed pools, but not in the plastic-bottomed pools. This represented a sediment-water nutrient interchange mechanism which will be discussed in more detail under the section relating to Limnology of Upper Klamath and Agency Lakes.

Gas evolution from the bottom sediments occurred in the lake and sediment-exposed pools but not in the plastic-bottomed pools. The concentration of nutrients, if any, brought into the overlying water by the gassing process is not known.

On May 8, 1968, the phytoplankton crop in the plastic-bottomed pools was less than in the sediment-bottomed pools or in the lake as indicated by Secchi disc readings (157 cm as compared to 115 cm in the lake and sediment-exposed pools of water).

Examination of the winter chemical data in Table 2 does not show an increase in phosphorus, nitrogen forms, conductivity, alkalinity, etc., nor the presence of nitrite in the water directly over the sediment in winter as is usually described in the literature for conditions in lakes under the ice. Field tests for iron (II) in the bottom water were negative. The reason for this is not obvious. Since the sediments are mildly reducing in nature (E_h= -0.1 to +0.3 volt) and contain 1 to 2 percent iron on a dry basis, presence of Fe (II) was expected.

A decrease of soluble silicon concentration in the water was caused by a heavy growth of <u>Gomphonema</u>, a silicon consuming algae, on the inside walls of all the pools in April and May. The lake water contained approximately 10 mg SiO_2/ℓ at the May 8 sampling whereas all the pools contained only about 5 mg SiO_2/ℓ. This illustrates the effect of one type of growth on the sidewalls of an experimental pool.

Discussion

This test points out several problems in the measurement of sediment-water nutrient interchange in the field. The greatest problem in our experiment was the plastic used for pool construction which cracked and tore before completion of the test. The material must be sufficiently rugged to withstand ice and high wind velocity.

Pools should contain a sufficiently large volume of water so that sidewall effects such as Gomphonema growth will not greatly alter the equilibria of the biological and chemical systems. It is the opinion of the writer that pools ideally should contain at least two to three times more water than the 5000 gallon volume contained in this experiment.

To prevent splashing of lake water into the pools, a breakwater device should be designed around the edges of the pool to break the higher waves before they reach the pool and to prevent damage by floating objects. This was done by placing strips of wood (shiplap) on the surrounding framework. A fixed-position wavebreak, however, reduces the radiation reaching the pools when the lake level becomes lower. Much labor would be eliminated by incorporation of a flotation device to maintain the sides of the pool at a relatively constant height above the water. This would also reduce the difference in radiation on the water in the pools and the lake which would affect the photosynthetic processes.

Replacement of evaporated water in pools can be a problem where low-nutrient water is not readily available. If possible, only distilled water should be added.

Construction and placement of pools would be extremely difficult, if not impossible, in very deep lakes. In large lakes, several areas would need to be tested because of variability in sediments and uncertainty in placing experimental pools in representative locations. Even in Upper Klamath Lake, which was familiar to NERP personnel, the selected site was not as representative of the entire lake as desired.

The full effect of currents on interchange is difficult to measure in a pool unless artificial stirring is induced to simulate natural conditions. Similarly, the effect of fish and boats in a shallow lake is significant but difficult to evaluate. Although gas evolution was noted in the sediment-bottomed pools, but not in the plastic-bottomed pools, the concentration of nutrients brought into the overlying water by the gassing process is not known. Certainly some of the soluble nutrients present in the Howard Bay sediments would be released into the overlying water. The rising of *Oscillatoria* to the surface with attached clumps of sediment also causes nutrient release to the overlying water. This was measured in the lake in September 1968 (see Limnology of Upper Klamath and Agency Lakes).

In conclusion, from our experience in Upper Klamath Lake, it is difficult to quantitatively evaluate sediment-water algal nutrient interchange by use of experimental pools. The technique is costly, time-consuming, and subject to experimental problems. Therefore, new methods must be developed. Since NERP will be required in future restoration programs to evaluate the nutrient contribution of sediments from many lakes, estuaries, rivers, and reservoirs, it would be desirable to replace field tests with suitable laboratory interchange tests.

LIMNOLOGY OF UPPER KLAMATH AND AGENCY LAKES

General Discussion

To determine whether nutrient interchange could be measured in the field chemically or physically, to determine the variations in the lakes so that conditions for laboratory interchange studies could be established, and to compare lake conditions with the experimental pools, it was necessary to observe several parameters in the lakes. As a result, much interesting data have been accumulated which appear in the Appendix.

The water quality data are presented for July 1967 through March 1969 in Tables 1 through 7. Several interesting and important conditions were observed in the lakes during the period. Ice covered essentially the entire surface during the winter of 1967-68 from the first week of December to the last week in February, and in 1968-69 from the second week in December to the first week in April. Snow covered the ice much of the time during both winters. Below-normal precipitation during the winter of 1967-68 resulted in low water levels during the following summer and navigation was not possible throughout most of both lakes. Above-normal snowfall in the 1968-69 winter season rendered it impossible to drive to the experimental pool location.

According to reports in the literature nutrient release in some lakes is expected to occur when anaerobic conditions develop at the bottom during prolonged ice cover when no mixing occurs.

Chemical analysis of water just over the sediments during the period of ice and snow cover did not reveal significantly higher concentrations of phosphorus and nitrogen compounds over that found in the water just below the ice, even though the dissolved oxygen content was less than 1 mg O/ℓ for at least two weeks and no mixing occurred from wind action. No explanation for this can be given except that the lake did not follow the classical description of the iron-manganese-phosphate cycle during periods of low and high dissolved oxygen.

Sediment-water nutrient interchange occurred in June and September 1968 through an interesting and effective mechanism. *Oscillatoria*, which forms on the sediment and collects sufficient gas to cause it to be lifted to the lake surface along with attached sediment in pieces 30 cm or more in length and from 15 to 30 cm thick, was found floating throughout the lake system in June and throughout Howard Bay in September. This floating *Oscillatoria*, sediment, and other decomposing algae caused a very disagreeable odor in the bay. As a result, the water increased in conductivity (190 micromhos/cm), total phosphorus (1 mg P/ℓ), ammonia nitrogen (1.2 mg N/ℓ), total Kjeldahl nitrogen (4 to 12 mg N/ℓ), and decreased in dissolved oxygen (3 mg O/ℓ) as compared with the main portion of the lake. Many small dead fish, 4 to 8 cm long, were seen floating along with the *Oscillatoria* and other decaying algae. Much of the nutrients probably came from the sediment interstitial water when the sediment was lifted by the

Oscillatoria. The interstitial water from surface sediment samples taken in Howard Bay from June through October contained from 5 to 9 mg P/ℓ as orthophosphate and 20 to 86 mg N/ℓ as ammonia.

The unusually high conductivity observed in some areas of Howard Bay in January and February 1968 was probably the result of farm drainage water pumped into the bay from an adjacent ranch. Additional data to illustrate the influence on Howard Bay are shown in Table 7. In 1968, the drainage water (conductivity, 500 micromhos/cm) apparently flowed under the ice from a point near the end of the bay, along a dike near the experimental pools, and was still detectable 0.7 mile past the pools at P9a, a total of 1.5 miles from the drainage outlet. The flow pattern was not determined throughout the bay. However, the fact that the conductivity of the experimental pools at 09d filled in November with lake water remained at 185 micromhos/cm and the fact that sampling site N10b did not experience high conductivity, support the assumption that farm drainage water rather than sediment-water interchange processes caused the high conductivity. In February 1969 relatively high conductivity (200 to 500 micromhos/cm) below 1.5 meters was observed at N10b. It has been assumed that this effect resulted from farm drainage water accompanied by a change in lake currents from those in 1968. Weather conditions did not permit measurement at 09d.

The overall effect of farm drainage water and the interchange process upon Upper Klamath Lake sediments is uncertain. The conductivity of the agricultural drainage return water on January 30, 1968, was 500 micromhos/cm; but on March 2, 1968, after much melting of snow, it decreased to 255 micromhos/cm. The analysis of a sample of the yellow-colored return drainage water taken on March 2 was as follows (values in mg/ℓ): NO_3N, <0.05; NO_2N, <0.01; NH_3N, <0.1; total Kjeldahl N, 3.2; ortho P, 0.20; total P, 0.46; alkalinity, 68; soluble non-volatile organic carbon, 37; soluble silica, 7.0; calcium hardness, 88; total hardness, 90; chloride, 4; sulfate, 22; sodium, 23; potassium, 2.3; pH, 7.1. Although soil scientists regard phosphorus as relatively immobile in soil, sufficient phosphorus was present in this agricultural drainage water to support algal growth.

The effect of wind upon mixing and resuspension of the sediments with the overlying water has been described by Bond, Hazel, and Vincent (1). They concluded that the sediments were resuspended when the water mass movement had a velocity greater than 0.02 feet per second; this occurred when wind velocities were two to five miles per hour. With the concentrations of soluble phosphorus and nitrogen available in the sediment interstitial water, this process would appear to be an important factor in nutrient interchange.

In 1967 Aphanizomenon did not appear until August in Upper Klamath Lake, but in 1968 it developed in May. Furthermore, during the summer of 1968 the predominant algae forms changed from Aphanizomenon to Rivularia or to Anabaenopsis (Table 3).

Additional changes observed in the lake system during the 1967-69 period are summarized by the following discussion of specific chemical, physical and biological parameters. Refer to appropriate tables for specific data.

Lake Water Quality

Water Analyses

Sample Preservation -- All samples were collected and packed in ice. Alkalinity in most cases was titrated in the field or within about four hours in the laboratory. Mercuric chloride, which is sometimes added to stabilize the samples for nitrogen and phosphorus species, formed a copious precipitate and caused the algae to lyse. Therefore, nothing was added to preserve the water samples. In summer during conditions of much algal growth, the water for orthophosphate determination was filtered through a 0.45 micron membrane filter within a short time after collection and stored in ice before analysis.

The importance of analysis of samples as quickly as possible after collection from a highly eutrophic lake cannot be over-emphasized, since present sample stabilization techniques are not adequate to prevent changes in phosphorus, nitrogen, and soluble silica forms.

Oxygen -- The dissolved oxygen concentration varied appreciably throughout the lakes on the same day depending upon weather and algal conditions (Table 4). The bays of Upper Klamath Lake tended to be more variable than the main body of the lake. For example, on October 10, 1967, after several days of very little wind, the dissolved oxygen varied horizontally at the surface from less than 5 mg O/ℓ to about 15 mg O/ℓ in Howard Bay and decreased from the surface to the bottom.

On October 11 a cold front accompanied by moderately strong winds passed over the lake system causing vigorous wave action. This effectively stirred the shallow water so that on October 12 the dissolved oxygen and temperature were essentially the same from surface to bottom. However, there still remained horizontal differences between locations in the bay areas (3 to 11 mg O/ℓ) and in the main lake (10 to 12.5 mg O/ℓ).

The dissolved oxygen variation over a 24-hour period when Aphanizomenon growth was heavy is shown in Table 5 for three locations in Upper Klamath Lake. A change in oxygen concentration of about 5 or 6 mg O/ℓ occurred in Howard Bay but only 2 or 3 mg O/ℓ in the main body of the lake. As usual, there was considerable difference in the oxygen levels among the three locations.

During the winter of 1967-68 and 1968-69, after the ice had covered the lake for several weeks, dissolved oxygen decreased to 3 mg O/ℓ in Howard Bay area and in Agency Lake. Even at the Upper Klamath Lake outlet (Y1b) oxygen was less than 6 mg O/ℓ during

January 1968. However, about a week after the ice melted in February a diatom bloom developed and the oxygen quickly increased to 120 - 160 percent saturation.

Nitrogen Compounds -- Ammonia nitrogen decreased from 2 mg N/ℓ under the ice to less than 0.1 mg N/ℓ after melting of the ice. An increase in runoff from the watershed into the lake and an increase in phytoplankton (diatoms) normally occurs upon melting of the ice. In late June 1968 the ammonia concentration increased to about 0.6 mg N/ℓ in both Howard Bay and at the lake outlet (Y1b), the same time that *Oscillatoria* and its attached sediment floated to the surface. The ammonia concentration then decreased at the outlet to 0.1 mg N/ℓ which was much lower in ammonia concentration than at Howard Bay or other locations in the main body of Upper Klamath Lake. Ammonia increased again when the *Oscillatoria* was observed floating in Howard Bay, in September 1968. At this time the ammonia nitrogen in the bay water increased to over 1 mg N/ℓ in contrast to 0.1 mg N/ℓ in the main lake water. The increase of ammonia nitrogen was attributed to sediment-water interchange processes since the sediment lifted to the surface contained 30-45 mg soluble ammonia per liter in the interstitial water.

Nitrate nitrogen increased in Upper Klamath Lake in the late autumn and winter to about 0.3 mg N/ℓ and then decreased to <0.02 mg N/ℓ in April and throughout the summer.

Nitrite nitrogen was detected by field test in the water only once, at station N10b in February 1969. Values of nitrite reported up to 0.02 mg N/ℓ in Table 2 were probably a result of changes taking place in the sample after collection and before determination in the laboratory. An increase in the nitrite concentration was noted in samples collected midday February 6, 1969, and stored in ice 22 hours before analysis.

Total Kjeldahl nitrogen increased in the autumn and decreased in the spring and early summer. A large increase was observed in Howard Bay at the time of *Oscillatoria* and sediment flotation in September. The outlet of the lake system (Y1b) apparently was affected a month later when the total Kjeldahl nitrogen concentration increased from 3.5 to 8.5 mg N/ℓ.

Phosphorus -- Phosphorus (as orthophosphate) increased from 0.03 to 0.05 mg P/ℓ in late autumn to about 0.02 mg P/ℓ in winter. After the ice melted, the orthophosphate decreased to less than 0.03 and frequently less than 0.01 mg P/ℓ depending upon the algal crop. Upon decay of the *Aphanizomenon* the concentration again increased. The algal growth in Agency Lake during 1967 decreased in September and by October had completely disappeared. During this time the ortho and total phosphorus (Table 2) decreased from 0.19 and 0.44 mg P/ℓ to 0.03 and 0.05 mg P/ℓ, respectively. The algae decreased in Agency Lake in August 1968, probably because of unusually cold weather and rain during that period, and by September the ortho and total phosphate concentrations were relatively low. Since Agency Lake is so very shallow (0.3 to 1 meter) by late summer, the algal growth is relatively sensitive to air temperature changes and variations in water flow from the watershed.

Total phosphorus, in general, attained a higher concentration during the winter months (0.3 to 0.5 mg P/ℓ), although it was high in the Howard Bay area in September 1968 when the flotation of Oscillatoria and sediment occurred.

Silicon -- Soluble silicon ranged between 30 and 35 mg SiO_2/ℓ in the autumn and winter of 1967-68 in Upper Klamath Lake and from 35 to 40 mg SiO_2/ℓ in Agency Lake. On March 2, 1968, when the diatom bloom was in progress and consuming silicon, soluble silicon decreased by about one-half and by May was down to 10 mg SiO_2/ℓ. In August it had increased to 45 to 49 mg SiO_2/ℓ as the diatom population decreased.

Sodium -- There were no wide fluctuations in the concentration of sodium at the outlet of Upper Klamath Lake (Y1b). The range was 9 to 14 mg Na/ℓ. Levels in Agency Lake were slightly higher (10 to 20 mg Na/ℓ) than at Y1b.

During both winters, sodium in Howard Bay increased to about 34 mg Na/ℓ in the bottom water, probably from the farm drainage water introduced into the bay (Table 2, A, C).

Potassium -- Potassium remained in the 2 to 3 mg K/ℓ range in both Agency and Upper Klamath Lakes. Howard Bay, however, showed increases during winter particularly in the water near the sediment.

Chloride -- Chloride was always less than 5 mg Cl/ℓ.

Sulfate -- Except for Howard Bay where the concentration was as high as 76 mg SO_4/ℓ in February 1969 in water over the sediment, sulfate throughout the lake was less than 10 mg SO_4/ℓ.

Carbon -- Total carbon at Y1b varied from 20 to 30 mg C/ℓ, whereas the soluble non-volatile organic carbon (SNOC) varied from 7 to 13 mg C/ℓ. The levels for both types of carbon were lower in Agency Lake.

In Howard Bay during winter the carbon was high both in the water over the sediments (60 mg C/ℓ) and in the farm drainage water (37 mg C/ℓ).

Iron and Manganese -- Manganese has been found to be present in only trace amounts in the water (0.004 to 0.2 mg Mn/ℓ) (3). Several analyses from the winter of 1967-68 not listed in the tables indicated that total manganese was usually less than 0.05 mg Mn/ℓ.

Total iron was found to be less than 0.1 to 0.2 mg Fe/ℓ. Field tests for iron (II) were always negative except once at N10b on January 31, 1968, but even then only a very faint color with bathophenanthroline reagent was noted.

Thus, it appears that since the iron and manganese cycle is not influential in this lake system, this mechanism for interchange of phosphorus between sediment and water is of negligible importance.

pH -- pH reached minimum values (6.5 to 7.5) in January and increased rapidly to 8.4 - 9.8 after the ice melted and the diatom bloom developed in February 1968. The values exceeded 10 in the summer of 1968 during heavy algal growths (Tables 2 and 3).

Total Alkalinity -- Total alkalinity decreased from a range of 60 - 70 mg $CaCO_3/\ell$ in the winter to 40 - 50 in the spring and summer. It increased again in late summer. Compared with the main body of Upper Klamath Lake, the general concentration level was lower in Agency Lake and higher in Howard Bay.

Hardness, Ca and Total -- Hardness decreased in the spring and increased slightly in the late summer. The unusually high values at both the outlet (Y1b) and Howard Bay (09d) in August 1968 cannot be explained. The influence of farm drainage water in Howard Bay during the winter months is evidenced by the high concentration levels found there at that time.

Physical Measurements

Temperature -- In the winter the temperature of the lake's surface water, just under the ice, measured approximately 0°C. In summer it reached 26°C at the surface. Apparently as a result of an unusually cold and wet August in 1968, the *Aphanizomenon* growth in Agency deteriorated earlier than normally.

Ice remained until the first week in April 1969 which was abnormally late for ice to be on the lake system.

Water Transparency -- Secchi disc readings were unusually low, ranging from 25 to 115 cm. The lowest transparency occurred in Howard Bay during August and September 1968 when the lake level was very low and Oscillatoria with sediment floated on the surface.

Conductivity -- Conductivity increased during the winter, but after disappearance of the ice it decreased at the outlet from about 140 micromhos/cm to 105-110 and became more homogeneous from surface to bottom. By October the conductivity had increased again to 150.

Conductivity in Howard Bay, as already described, increased during the winter, particularly in the water near the sediment (Table 7).

The high conductivity in Howard Bay in September 1968 was caused by the sediment-water interchange process involving Oscillatoria.

Biological Measurements

Phytoplankton -- A succession of algal blooms occurred throughout the lake during the year with a minimum of activity during the period of ice cover. In Howard Bay, Stephanodiscus was the predominant phytoplankter in December, Cryptomonas in January, and Stephanodiscus again in March 1968. The estimated population of Stephanodiscus at the lake system outlet was 80,000,000 cells per liter in March; the pH of the water was 9.8.

The *Aphanizomenon* blooms started in late May in 1968. In June and July, *Oscillatoria* had floated to the surface throughout the lakes, particularly in the bays and northern areas of the lake system. In 1968 *Aphanizomenon* was not as abundant as in 1967 (Table 3), and other forms of blue-green algae occasionally became predominant.

In autumn the *Aphanizomenon* growth diminished first in Agency Lake. It decreased southward as the season progressed toward winter.

CONCLUSIONS

Interchange of algal nutrients between sediment and water occurred in June and September 1968 in Upper Klamath Lake when *Oscillatoria* and attached sediment floated to the surface. This mixing of sediment, which contains soluble nutrients, with the water resulted in increases of total phosphorus, ammonia and total Kjeldahl nitrogen, conductivity, soluble silica, and a decrease in dissolved oxygen particularly in September 1968. Experimental pools showed the effect of sediment upon the overlying water: oxygen remained higher under ice in a pool of water not exposed to the sediment, and phytoplankton growth was less intense in spring in this pool.

Chemical analysis did not reveal release processes in winter under the ice. The iron-manganese-phosphate cycle appears to be insignificant in Upper Klamath and Agency Lakes.

Although evaluation of nutrient interchange processes under environmental conditions would be ideal, quantitative measurement by the use of experimental pools as described is difficult because of design and material problems, the high cost and long duration required for the experiment, sidewall effects, and the lack of stirring comparable to that caused by gas evolution, wind, fish, boats, or benthic organisms. In addition, large lakes contain various types of sediment, each of which should be examined, and some lakes are so deep that pools would be impracticable. Often weather conditions may be too severe to permit all-year installation and measurement.

For evaluation of sediments for nutrient interchange (release or uptake) from many lakes, as will be required of the National Eutrophication Research Program in the future, it is necessary that new field methods and suitable laboratory tests be devised to quantitatively determine interchange processes.

Water quality data presented in this report should be useful for future comparisons of lake conditions. These data have proved valuable in laboratory experiments on nutrient interchange and provided basic background for other work on the Upper Klamath Lake system.

Farm drainage water has an adverse effect upon lake water quality as observed in Howard Bay, particularly when ice cover inhibits mixing and circulation of the lake water by wind.

Experience with experimental pools in Upper Klamath Lake will provide NERP with information pertaining to construction of pools for experiments in prevention of nutrient interchange between sediment and water.

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APPENDIX

TABLE 1
METHODS OF ANALYSIS
A. Laboratory Determinations

Determination	Units	Method	Reference
Alkalinity, Total	mg $CaCO_3$/ℓ	Titrimetric with sulfuric acid	SMEWW*
Conductivity	micromhos/cm	Conductimetric measurement	SMEWW
Carbon, Total	mg C/ℓ	Combustion, infrared detection in Beckman Carbonaceous Analyzer	ASTM (D 2579)
Carbon, soluble non-volatile organic	mg C/ℓ	Acidification of sample, volatilization of CO_2 with nitrogen gas, determination in Beckman Carbonaceous Analyzer	
Hardness, Ca	mg $CaCO_3$/ℓ	Titrimetric with EDTA, Hydroxy Naphthol Blue indicator	SMEWW
Hardness, Total	mg $CaCO_3$/ℓ	Titrimetric with EDTA, Calmagite indicator	SMEWW
Nitrogen-Ammonia	mg N/ℓ	Distillation, Spectrophotometric measurement	Technicon Auto analyzer
Nitrogen-Nitrate	mg N/ℓ	Spectrophotometric measurement	Technicon Auto analyzer
Nitrogen-Nitrite	mg N/ℓ	Spectrophotometric measurement	Technicon Auto analyzer, SMEWW
Nitrogen-Total Kjeldahl	mg N/ℓ	Digestion, distillation, spectrophotometric measurement	Aminco digestion, semi-micro distillation apparatus, SMEWW
pH	pH	Beckman Electromate and other portable pH meters	
Phosphorus, ortho	mg P/ℓ	Millipore filtration, spectrophotometric determination	Strickland, FWPCA**
Phosphorus, total	mg P/ℓ	Digestion in acid solution with persulfate, spectrophotometric determination	Strickland, FWPCA
Silica, Soluble	mgSiO_2/ℓ	Spectrophotometric determination	Technicon Auto analyzer, SMEWW
Sodium	mg Na/ℓ	Flame photometric or atomic absorption spectrophotometric determination	SMEWW
Potassium	mg K/ℓ	Flame photometric or atomic absorption spectrophotometric determination	SMEWW
Chloride	mg Cl/ℓ	Titrimetric with mercuric nitrate	SMEWW
Sulfate	mg SO_4/ℓ	Turbidimetric measurement	SMEWW

TABLE 1 (Continued)
METHODS OF ANALYSIS
B. Field Determinations

Determination	Units	Instrument
Conductivity	micromhos/cm	Beckman RB3 - 327 Solu Bridge
Oxygen	mg O/ℓ	Electronic Instruments Limited Model 15A dissolved oxygen meter and probe
pH	pH	Beckman portable pH meters
Transparency	cm	Secchi disc
Temperature	°C	Electronic Instruments Limited

* Standard Methods for the Examination of Water and Waste Water, Twelfth Ed., 1965

** FWPCA Official Interim Methods for Chemical Analysis of Surface Waters, Sept. 1968

TABLE 2
WATER QUALITY OF UPPER KLAMATH
AND AGENCY LAKES
A. Station 09d (Howard Bay)

Date of Collection	Depth	T.Alk.	Cond.	Carbon Total	Carbon SNOC	Hardness Ca	Hardness Total	$N-NH_3$	$N-NO_3$	$N-NO_2$	TKN	P Ortho	P Total	Silica Soluble	Na	K	Cl	SO_4	pH
9-15-67	s	55	109	23	10	33	37	< .1	.05		2.5	.07	.08	27.8	12.0	2.1			8.8
10-12-67	s	61	141	31	10	34	37					.22	.36	31.4	14.0	2.8		<10	7.6
11-16-67	s	59	128	24	8	31	55	1.4	.12		3.0	.05	.15	31.4	11.3	2.6	<5	<10	8.2
	b	58	130	24	6	29	42	2.0	.11		2.9	.05	.16	31.4	10.2	2.4	<5	<10	8.2
12-12-67	s	61	139	22	7	29	39		.02			.02	.15	32.8	11.6	2.2			8.8
12-13-67	s	59	138	22	10	32	38	1.5	.09		8.4	.03	.18	32.8	11.6	2.2			8.1
	b	59	139	22	8	35	40	1.8	.06		2.8	.03	.21	29.3	11.6	2.3			7.6
1-18-68	s	69	181	29	9	43	58	2.3	.13	.01	3.1	.13	.32	30.0	13.0	3.2	<5	15	7.7
	b	84	263	37	13	66	88	2.6	.12	.02	3.5	.25	.49	28.6	15.0	4.4	<5	27	6.5
1-31-68	s	75	169	28	9	42	48	1.8	.06	<.01	3.9	.12	.36	34.0	12.0	2.8		10	7.3
	b	113	367	62	31	110	126	1.7	.05	.02	4.4	.43	.65	32.9	28.0	4.4		32	7.0
3-02-68	s	70	296	43	18	102	106	< .1	.30	.01	3.4	.02	.29	18.3	19.0	3.0	<5	31	8.4
	b	75	355	43	21	128	133	< .1	.35	.01	3.9	.02	.37	15.1	23.0	3.2	<5	20	7.3
4-04-68	s	84	105	19		26	31	< .1	.01	<.01	1.2	<.01	.08	10.3					8.6
	b	78	105	20		22	33	< .1	.02	<.01	1.1	.01	.07	10.7					7.9
5-08-68	s	45	105		8	22	30	< .1	.02		0.8	<.01	.04	9.6	8.8	2.1		<10	7.7
	b	45	115		12	23	32	< .1	.02		0.8	.01	.05	9.6	8.8	1.9		<10	6.8
6-12-68	s	45	112					< .1	<.01		1.0	<.01	.08						8.2
	b	43	105					< .1	<.01		1.4	.03	.08	12.4					8.2
6-25-68	b	50	110			28	61	.59	<.01	<.01				15.2	9.9	2.0			9.2(L)
7-09-68	s	50	120					.24	<.01		1.8	.02	.09	22.0					9.6
	b	51	125					.34	.017		1.7	.04	.10	22.0					9.7
8-14-68	s	58	126	38		67	78	.14	.11	.01	4.6	.05	.53	41.5	9.3	3.2	<5	11	9.4(L)
	b	58	126	36		65	77	.15	.08	<.01	5.8	.01	.34	42.1	9.0	3.1	<5	10	9.4(L)
9-11-68	s	75	185			33	44	1.2	<.01	<.01	4.0	.02	.99	49.0					7.9
	b	75	197			38	47	1.1	<.01	<.01	12.2	.03	1.20	48.0					
10-22-68	s	73	180	30	6	28	39	0.50	<.01	<.01	5.5	.22	.30	37.8	12.0	2.8	<5	<10	6.9

TABLE 2 (Continued)
WATER QUALITY OF UPPER KLAMATH
AND AGENCY LAKES
B. Station Y1b (near outlet
of Upper Klamath Lake)

Date of Collection	Depth	T.Alk.	Cond.	Carbon Total	Carbon SNOC	Hardness Ca	Hardness Total	$N\text{-}NH_3$	$N\text{-}NO_3$	$N\text{-}NO_2$	TKN	P Ortho	P Total	Silica Soluble	Na	K	Cl	SO_4	pH
10-11-67	s		108	27	13	32	34					.03	.15	32.0	13.5	2.3		<10	9.4
11-16-67	s	58	138	23	7	30	48	2.0	.08		2.9	.07	.13	33.0			<5	<10	7.7
1-18-68	s	63	137	25	8	34	39	1.9	.20	.02	2.7	.12	.18	33.5	11.0	2.7	<5	<10	7.0
	b	65	141	26	6	33	41	2.0	.32	<.01	3.4	.11	.21	34.1	11.0	2.7	<5	<10	7.3
1-31-68	s	64	137	23	7	31	40	1.8	.13	<.01	2.8	.11	.31	35.3	10.0	2.5			7.4
	b	64	139	23	8	32	40	1.8	.13	<.01	2.8	.10	.16	35.4	10.0	2.5			7.7
3-02-68	s	48	110	24	9	30	31	<.1	.13	<.01		<.01	.28	19.4	10.0	1.9	<5	<10	9.8
	b	51	107	22	9	32	32	<.1	.12	<.01	2.1	<.01	.15	20.3	10.0	2.0	<5	<10	9.6
4-04-68	s	43	105	20		18	32	<.1	.02	<.01	1.1	.01	.08	11.7					8.4
	b	42	105	20		19	30	<.1	.02	<.01	1.2	.01	.07	11.7					8.1
5-08-68	s	45	108		9	25	33	<.1	.01		0.9	.02	.06	9.7	8.8	1.9		<10	8.1
	b	46	105		9	23	38	<.1	.01		1.0	.01	.08	10.0	9.3	2.1		<10	8.1
6-12-68	s	47	110					<.1	<.01		1.3	.01	.09						8.6
	b	47	109					<.1	<.01		1.6	.01	.12						8.6
6-25-68	b	50	110			33	51	.56	<.01	<.01				14.7	10.0	2.0			9.9(L)
7-09-68	s		145																
	b		133																
8-14-68	s	54	113	29		64	68	<.1	.03	<.01		.11	.37	40.8	9.8	2.7	<5	<10	9.1(L)
	b	54	114	26		64	76	<.1	.03	<.01	3.6	.07	.27	41.0	9.0	2.7	<5	<10	9.2(L)
9-11-68	s	52	122			34	35	0.1	<.01	<.01	3.5	.09	.24	48.0					9.8
	b	52	123			29	38	<.1	<.01	<.01	3.6	.10	.29	49.0					
10-23-68	s	61	150	26	7	27	38	.55	.06	.01	8.5	.10	.39	39.2	12.0	2.6	<5	<10	
	b		152																
2-06-69	s	53	150	23		24	37	.15	.12	<.01	2.7	.08	.24	29.3	9.9	2.4		<10	8.0(L)

TABLE 2 (Continued)
WATER QUALITY OF UPPER KLAMATH
AND AGENCY LAKES
C. Miscellaneous Locations
in Upper Klamath Lake

Date of Collection	Location	Depth	T.Alk.	Cond.	Carbon Total	Carbon SNOC	Hardness Ca	Hardness Total	$N-NH_3$	$N-NO_3$	$N-NO_2$	TKN	P Ortho	P Total	Silica Soluble	Na	K	Cl	SO_4	pH
9-14-67	U 7a	s	53	114	24	11	32	37		.07			.03	.13	27.5	11.5	2.0			9.5
9-15-67	L20b	s	55	117	26	11	35	40		.10			.06	.18	27.3	12.0	2.6			10.0
10-12-67	O11d	s	60	131	32	11	33	36					.09	.18	35.8	15.5	2.8		<10	7.7
	O13d	s	56	125	28	10	33	35					.09	.15	33.3	13.0	2.6		<10	8.4
	R13a	s	53	128	44	9	33	35					.18	.41	33.3	13.5	2.7		<10	9.5
11-16-67	U 7a	s	60	130	23		31	55	2.1	.07		2.8	.08	.13	33.4	7.0	2.5	<5	<10	7.7
1-31-68	P 9a	s	71	159	25	8	35	44	1.8	.07	.01	2.7	.08	.18	32.3	12.0	2.7			7.8
		b	73	179	27	9	41	53	2.0	.06	.01	3.0	.11	.24	31.8	13.0	2.9			7.9
	N10b	s	68	145	24	7	28	38	2.3	.05	<.01	3.3	.15	.31	34.0	10.0	2.5			7.2
		b	66	139	23	7	27	38	2.3	.05	.03*	2.9	.16	.27	34.0	10.0	2.5			7.2
6-25-68	V 7d	b	49	110			29	54	.51	<.01	<.01				16.4	10.0	2.3			9.2(L)
7-09-68	F29d	b		120					.20	<.01			.03	.09	21.0					10.2(L)
	N24b	b		123					.80	<.01			.01	.13	22.0					10.3(L)
9-11-68	V 7d	s	52	121			27	40	<.1	<.01	<.01	11.1	.08	.23	46.0					9.8
		b	52	122			26	40	<.1	<.01	<.01	4.3	.08	.26	46.0					
9-24-68	V 7d	s	59		22	8	24	34	<.1	.03	<.01	2.2	.08	.20	47.0					
		b	54		20	10	23	34	<.1	.02	<.01	2.5	.09	.21	47.0					
10-23-68	V 7d	s	58	140	26	6	28	37	.38	.05	.01	5.2	.07	.29	39.2	11.0	2.3	<5	<10	8.4
2-06-69	N10b	s	59	150	21		22	41	.37	.02	<.01	4.5	.13	.28	28.0				<10	8.4
		b	146	500	56		140	194	.26	.25	<.01	4.6	.17	.26	26.0	34.0	6.0		76	8.0(L)

*Field test for nitrite was negative. Increase in nitrite probably due to change in sample before laboratory analysis.

TABLE 2 (Continued)
WATER QUALITY OF UPPER KLAMATH
AND AGENCY LAKES
D. Miscellaneous Locations
in Agency Lake

Date of Collection	Location	Depth	T.Alk.	Cond.	Carbon Total	Carbon SNOC	Hardness Ca	Hardness Total	$N-NH_3$	$N-NO_3$	$N-NO_2$	TKN	P Ortho	P Total	Silica Soluble	Na	K	Cl	SO_4	pH
9-15-67	I31d	s	52	123	22		30	32		.20			.19	.44	39.6	18.0	5.0			9.9
	M34a	s	45	109	20	6	28	31		.07			.16	.23	40.0	12.5	1.9			9.7
	M39d	s	43	107	18	5	26	29		.06			.16	.18	38.3	13.5	2.1			9.5
	N35a	s	52	124			29	32		.19			.15	.46	38.5	16.5	3.7			9.5
10-11-67	I31d	s		110	19	8	27	29					.07	.14	35.2	16.5	2.7			9.0
	M34a	s	40	104	17	7	25	26					.03	.07	36.2	16.0	2.4		<10	8.6
	M39d	s	36	99	11	2	18	23					.05	.07	38.3	14.0	2.1		<10	7.4
	N35a	s	41	109	16	5	23	27					.03	.05	40.0	20.0	2.5		<10	7.2
1-31-68	036a	s	52	128	15	3	26	40	0.50	.04	<.01	1.2	.06	.14	40.0	12.0	2.2			7.1
		b	50	129	15	3	24	32	0.60	.05	<.01	1.2	.07	.14	40.0	11.0	2.3			7.4
6-25-68	M35a	b	45	126			28	44	.68	<.01	<.01	2.2			32.9	11.0	2.7			9.9(L)
7-09-68	M35a	s		120																10.4(L)
	M35a	b							2.0	<.01			.35	.51	37.0					
9-11-68	M35a	s	44				25	34	<.1	<.01	<.01	2.5	.04	.18	45.0					8.7(L)
10-22-68	M35a	s	37	110	12	<1	19	25	<.1	.07	.01	0.7	.03	.08	30.6	9.9	2.1	5	<10	7.8

List of Abbreviations used in Table 2

b	- bottom	$N-NO_2$	- nitrogen-nitrite
Cl	- chloride	$N-NO_3$	- nitrogen-nitrate
Cond.	- conductivity	s	- surface
K	- potassium	SNOC	- soluble non-volatile organic carbon
(L)	- laboratory measurement	SO_4	- sulfate
Na	- sodium	T.Alk.	- total alkalinity
$N-NH_3$	- nitrogen-ammonia	TKN	- total Kjeldahl nitrogen

Units for the various parameters are listed in Table 1

TABLE 3

TEMPERATURE, TRANSPARENCY, pH AND SPECIAL LIMNOLOGICAL OBSERVATIONS IN UPPER KLAMATH AND AGENCY LAKES

Date	Location	Secchi Disc (cm)	Temp°C		pH		Special Limnological Observations
			Surface	Bottom	Surface	Bottom	
7-20-67	0 9d*		20		9.5		No Aphanizomenon bloom in Upper Klamath Lake
	I24b*		23.6		9.3		
	H20a*		21				
	L20b*		21		9.2		
	I31d*		21.5	21.1	9.5		
	M34a*		23	20.5	9.5		
	M35a*		23.2	20.7	9.4		Aphanizomenon bloom in Agency Lake
	M39d*		21.5	19	9.3		
9-14-67	0 9d		18	17	9.6		Aphanizomenon bloom over entire lake system
	Q11d		18	17	9.2		
9-15-67	0 9d	155	19	18	8.8		
	U 7a	80	19	16	9.5		
	P19c	85	20	17.5			Many gas bubbles on surface of water
	L20b	85	20.5	18	10.0		
	I24b	125	20.5	16.5	9.8		
	H20a	70	19	17.5	9.8		
	I31d	65	16.5	15.5	9.9		
	M34a	110	15.5	15.5	9.7		
	N35a	55	16	16	9.5		
	M39d	95	14	14	9.5		
10-10-67	0 9d	114	15	12.5	8.5	8.2	
	O13d	124	16.5	14	8.2		
	P12d	120	18	13	9.5		
	R11a	42	17	13	10.0		

TABLE 3 (Continued)

TEMPERATURE, TRANSPARENCY, pH AND SPECIAL LIMNOLOGICAL OBSERVATIONS IN UPPER KLAMATH AND AGENCY LAKES

Date	Location	Secchi Disc	Temp °C		pH		Lake Conditions
			Surface	Bottom	Surface	Bottom	
10-11-67	Y 1b	90	13.5	13.5	9.7		Cold front passed over lake system during morning
	I24b	100	12	12	8.9		
	H20a	110	13	12	9.0		
	L20b	160	14	13	8.9		
	P19c	155	13	12	8.1		
	I31d	160	12	11	9.0		
	M39d	>60	11	10.8	7.2		
	N35a	157	12	12	7.4		
	M34a	>60	12.5	12.5	8.6		
10-12-67	O 9d	90	13	13	7.6		
	U 7a	60	12.5	12.2	9.2		
	W 3b	72	12	12	9.2		
	O11d	114	12	12.5	7.7		
	Y 1b	56	12.5	12.5	9.4		
	O13d	110	13	12.5	8.4		
	P12d	110	12.5	12	8.9		
	R13a	58	13.5	13	9.5		
	R11a	50	13.5	13	9.1		
11-14-67	O 9d	70	8	8	7.5		
11-16-67	O 9d	75	6.5	6.5	8.2	8.2	
	Y 1b	65	7.5	7.5	7.7		
	N10b	65	8	8	8.9		
	O13d	50	8	8	8.7		
	O11d	105	8	8	7.8		
	R13a	50	7.5	7.5	9.0		

TABLE 3 (Continued)

TEMPERATURE, TRANSPARENCY, pH
AND SPECIAL LIMNOLOGICAL
OBSERVATIONS IN UPPER KLAMATH
AND AGENCY LAKES

Date	Location	Secchi Disc	Temp °C		pH		Lake Conditions
			Surface	Bottom	Surface	Bottom	
	012d	95	8.0	7.5	7.9		
	R11a	85	7.0	7.0	7.8		
	U 7a	85	8.0	7.5	7.7		*Aphanizomenon* bloom nearly gone at this station.
12-12-67	0 9d		0.5	1.0	8.8		Ice about 6 cm. thick at station; coldest Dec. 12 at Klamath Falls, Oregon, on record (min. temp. 1°F)
12-13-67	0 9d*				8.1	7.6	*Stephanodiscus* predominant.
1-17-68	0 9d	65	0	1.0	7.7	6.5	Ice 15 cm. thick at station; *Cryptomonas* predominant algae.
1-18-69	Y 1b		1.0	2.0	7.0	7.3	A few diatoms present.
1-30-68	0 9d		1.0	2.0			Ice 23 cm. thick; 2 cm. snow over ice.
	Y 1b		2.5	2.5			No ice at station, but ice within 300 ft. Ice covered remainder of lake.
	P 9a		1.0	1.5			
1-31-68	0 9d	50	1.0	1.5	7.3	7.0	*Cryptomonas* predominant algae.
	Y 1b		2.0	2.5	7.4	7.7	Very few algae present.
	P 9a	65	0.5	1.5	7.8	7.9	
	N10b		1.5	3.5	7.2	7.2	Ice 30 cm. thick; 25 cm. snow cover over ice.
2-01-68	0 9d	45	0	1.0	7.2(L)	7.0(L)	Ice 30 cm. thick; 7 cm. snow cover.
	036a	87	0	2.0	7.1	7.4	Ice at least 30 cm. thick; 7 to 10 cm. snow cover.
	0 9b		0	0.5			

TABLE 3 (Continued)

TEMPERATURE, TRANSPARENCY, pH AND SPECIAL LIMNOLOGICAL OBSERVATIONS IN UPPER KLAMATH AND AGENCY LAKES

Date	Location	Secchi Disc	Temp °C		pH		Lake Conditions
			Surface	Bottom	Surface	Bottom	
2-29-68	0 9d*		6.5	5.0			No trace of ice on lake; ice melted about Feb. 24, 1968. Lake level over 0.75 meter higher than when ice on lake.
3-02-68	0 9d	45	5.5	6.0	8.4	7.3	_Stephanodiscus_ present at both locations in large numbers.
	Y 1b	38	8.5	7.5	9.8	9.6	
4-03-68	0 9d*					9.2	Much zooplankton activity near surface of water.
4-04-68	0 9d	65	9.5	9.0	8.6	7.9	Predominant phytoplankton: _Cyclotella-Stephanodiscus_. Some unidentified green coccoids.
	Y 1b	70	9.0	9.5	8.4	8.1	
5-08-68	0 9d	115	14.5	14.3	7.7	6.8	_Anacystis_ (_Microcystis_), _Fragilaria_, and _Ankistrodesmus_.
5-09-68	Y 1b	105	13.3	12.5	8.1	8.1	
6-11-68	0 9d	95	18.3	18.3	8.2	8.2	_Anacystis_ at 09d. _Aphanizomenon_ bloom started during late May.
6-12-68	Y 1b	65	16.0	15.3	8.6	8.6	Clumps of _Oscillatoria_ with sediment floating on surface throughout both lakes particularly in bays. Also, _Anacystis_ at Y1b.
6-13-68	036a*				9.2		
6-25-68	V 7d*				9.2(L)		
	0 9d*				9.2(L)		
	M35a*				9.9(L)		
	Y 1b*				9.9(L)		

TABLE 3 (Continued)

TEMPERATURE, TRANSPARENCY, pH
AND SPECIAL LIMNOLOGICAL
OBSERVATIONS IN UPPER KLAMATH
AND AGENCY LAKES

Date	Location	Secchi Disc	Temp °C		pH		Lake Conditions
			Surface	Bottom	Surface	Bottom	
7-09-68	O 9d	105	23.7	23.4	9.6	9.7	_Oscillatoria_ floating on surface.
	Y 1b	55	26.0	24.6			
	F29b*				10.2(L)		_Oscillatoria_ floating on surface.
	N24b*				10.3(L)		
	M35a*				10.4(L)		
8-13-68	See 24-hr. measurement of temp. and oxygen, Table V.						
8-14-68	O 9d	25	18.0	18.2			_Aphanizomenon_ and _Rivularia_.
	Y 1b	55	18.4	18.4			_Anabaenopsis_
8-20-68	V 7d	60	14.3	14.3	9.5		
	M35a*		16.0		7.5		Appreciable rain and cold weather for a usually dry month.
9-10-68	O 9d		24.3	20.0	8.7		
9-11-68	Y 1b	70	20.5	19.4	9.8		
	V 7d	57	19.5	19.2	9.8		
	O 9d	25	21.5	19.5	7.9		Dead fish 5 to 8 cm. long on surface of water along with sediment and _Oscillatoria_. Agency Lake had green fibrous mass floating near east shore. Lake very shallow; boat churned sediment.
9-23-68	V 7d		13.2	13.1	9.5		_Aphanizomenon_ bloom still intense.
	M35a		16.4	13.5	7.8		_Aphanizomenon_ bloom decreasing.
9-24-68	O 9d		16.9	13.0	8.4		_Oscillatoria_ floating around this area.
	O36a*						Only traces of _Aphanizomenon_.
10-02-68	Y 1b						Intense bloom in progress.
3-24-69							Ice remains throughout lakes.

TABLE 3 (Continued)

TEMPERATURE, TRANSPARENCY, pH
AND SPECIAL LIMNOLOGICAL
OBSERVATIONS IN UPPER KLAMATH
AND AGENCY LAKES

Date	Location	Secchi Disc	Temp °C		pH		Lake Conditions
			Surface	Bottom	Surface	Bottom	
10-22-68	M35a	35	8.7	8.7	6.9		
	V 7d	50	10.5	9.8	8.4		
	Y 1b	55	10.8	9.5	7.8		_Aphanizomenon_ bloom greatly diminished in intensity.
10-23-68	O 9d	105	9.0	9.0	6.9		
11-06-68	V 7d		7.0	7.0			No bloom of _Aphanizomenon_.
2-06-69	N10b		0	2.0	7.0	7.0	7 inches of snow over ice. About 45 cm. ice
	Y 1b		1.0	0.5	7.1		Snow and ice over entire lake except at outlet and few small pools on the east side of the lake.
3-24-69							Ice still over most of lake.
4-02-69							Ice in part of lake.

*Data for these stations will not be found in the tables. Profile temperature and oxygen data for locations not marked with an asterisk can be found in Table IV.

TABLE 4

TEMPERATURE AND OXYGEN VARIATION
WITH DEPTH IN AGENCY
AND UPPER KLAMATH LAKES

Date	9-14-67		9-14-67		9-15-67		9-15-67		9-15-67		9-15-67		9-15-67		9-15-67		9-15-67		9-15-67		9-15-67		9-15-67	
Time	1515		1600		1503		1437		1540		1408		1245		1345		1325		-		1020		0955	
Station	09d		Q11d		09d		R13a		U7a		P19c		L20b		I24b		H20a		I22d		M34a		N35a	
Depth	Temp	Oxygen	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O
0	18.0	6.4	18.0	11.0	19.0	2.2	21.0	16.5	19.0	14.4	20.0	13.8	20.5	14.8	20.5	7.0	19.0	13.8	19.5	6.8	15.5	7.6	16.0	6.7
0.9	18.0	5.7	18.0	11.0	19.0	2.3	20.0	14.2	18.0	8.3	19.0	7.7	20.0	7.3	19.0	7.2	18.0	8.3	19.0	3.6	15.5	7.3	16.0	6.8
1.8	17.0	5.9	18.0	9.8	18.0	1.3	17.0	8.4	16.0	7.6	17.5	5.5	18.0	3.1	17.0	7.2	17.5	1.5	17.0	3.2	15.5	7.0	16.0	6.5
2.7			17.0	1.0											16.5	2.2			17.0	3.4	15.5	5.8	16.0	6.2

Date	9-15-67		9-15-67	
Time	0910		1040	
Station	M39d		I31d	
Depth	Temp	Oxygen	T	O
0	14.0	7.2	16.5	8.0
0.9	14.0	7.2	16.5	8.0
1.8	14.0	7.2	16.0	7.2
2.7			16.0	6.2
3.6			15.5	6.0
4.5			15.5	4.0
5.4			15.5	3.7
6.3			15.5	3.3

Depth - meter

Temperature - ^{o}C

Oxygen Concentration - mg/ℓ

TABLE 4 (Continued)

TEMPERATURE AND OXYGEN VARIATION
WITH DEPTH IN AGENCY
AND UPPER KLAMATH LAKE

Date	10-10-67		10-10-67		10-10-67		10-10-67		10-11-67		10-11-67		10-11-67		10-11-67		10-11-67		10-11-67		10-11-67		10-11-67	
Time	1455		1540		1555		1605		0855		0917		1015		1000		1035		1205		1225		1355	
Station	09d		013d		P12d		R11a		I24b		I31d		N35a		M39d		M34a		H20a		L20b		Y1b	
Depth	T	0	T	0	T	0	T	0	T	0	T	0	T	0	T	0	T	0	T	0	T	0	T	0
0	15.0	6.8	16.5	4.5	18.0	10.2	17.0	16.4	12.0	8.8	12.0	8.5	12.0	5.1	11.0	8.0	12.5	8.9	13.0	8.6	14.0	9.0	13.5	12.4
0.3	15.0	6.8	16.0	4.5	17.0	11.0	16.5	14.3	12.0	9.5			12.0	5.2			12.5	9.1	12.5	8.7	13.0	9.6		
0.6	15.0	6.8	15.0	3.8	15.0	11.1	14.0	14.6	12.0	9.8	12.5	8.2	12.0	5.2	10.8	8.4	12.5	6.2	12.5	8.7	13.0	9.6	13.5	12.4
0.9	14.0	4.3	14.0	2.9	13.0	11.6	13.0	15.0	12.0	9.8			12.0	5.3					12.5	8.7	13.0	9.6		
1.2	13.0	4.1					13.0	10.5	12.0	9.8	12.5	8.2	12.0	5.1					12.0	6.3	13.0	6.0	13.5	12.4
1.53	13.0	3.5							12.0	8.6														
1.83	12.5	1.3							12.0	8.8	12.3	8.3											13.5	12.4
2.4											11.8	5.8											13.5	12.4
3.1											11.5	5.7											13.5	12.4
3.7											11.3	5.0											13.5	12.4
4.3											11.0	1.3												

Date	10-11-67		10-11-67		10-12-67		10-12-67		10-12-67		10-12-67		10-12-67		10-12-67		10-12-67		10-12-67		10-12-67		10-12-67	
Time	0730		1255		0830		0910		0945		1010		1030		1045		0755		1120		1100		1115	
Station	Y1b		P19c		09d		011d		013d		P12d		R13a		R11a		Y1b		Y1b		U7a		W3b	
Depth	T	0	T	0	T	0	T	0	T	0	T	0	T	0	T	0	T	0	T	0	T	0	T	0
0	13.0	11.4	13.0	7.7	13.0	4.7	12.0	2.3	13.0	6.0	12.5	7.4	13.5	11.0	13.5	8.6	11.0	10.4	12.5	11.4	12.5	9.7	12.0	11.6
0.3			12.5	7.8	13.0	4.5																		
0.6			12.5	7.8	13.0	4.5	12.5	3.3	12.5	6.3	12.0	7.6	13.0	11.3	13.0	8.7			12.5	11.4	12.5	9.8	12.0	11.6
0.9			12.5	7.8	13.0	4.5	12.5	2.0	12.5	5.7														
1.2			12.5	7.8	13.0	4.5					12.0	7.6	13.0	11.2	13.0	8.7	12.0	10.3	12.5	11.4	12.5	9.8	12.0	11.6
1.5			12.5	7.6																				
1.8			12.0	7.5											13.0	8.7	12.5	10.3	12.5	11.4	12.2	9.7	12.0	11.4
2.1			12.0	7.3																				
2.4															13.0	8.7	12.5	10.2	12.5	11.4	12.2	9.2		
3.7	13.0	10.0																						

TABLE 4 (Continued)

TEMPERATURE AND OXYGEN VARIATION
WITH DEPTH IN AGENCY
AND UPPER KLAMATH LAKES

Date	11-14-67		11-16-67		11-16-67		11-16-67		11-16-67		11-16-67		11-16-67		11-16-67		11-16-67		11-16-67		12-12-67		1-17-68	
Time	1350		1100		1400		1340		1320		1425		1415		1430		1450		1505		1350		1600	
Station	09d		09d		013d		N10b		011d		012d		R13a		R11a		U7a		Y1b		09d		09d	
Depth	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O
																					ice-6cm		ice-15cm	
0	8.0	9.8	6.5	11.6	8.0	8.9	8.0	9.3	8.0	6.9	8.0	8.5	7.5	9.3	7.0	8.4	8.0	8.3	7.5	8.4	0.5	16.0	0	8.0
0.25	8.0	9.6	6.5	11.6	8.0	9.1	8.0	9.3	8.0	6.9	8.0	8.5	7.5	9.3	7.0	8.4	8.0	8.3	Uniform		1.0		0	8.0
0.50	8.0	9.6	6.5	11.6	8.0	9.1	8.0	9.4	8.0	7.0	8.0	8.5	7.5	9.3	7.0	8.4	8.0	8.3	down to		1.0		0	4.5
0.75	8.0	9.6	6.5	11.4	8.0	9.1	8.0	9.4	8.0	7.0	8.0	8.5	7.5	9.3	7.0	8.4	8.0	8.3	6 meters		1.0		0	2.0
1.00	8.0	9.6	6.5	11.4	8.0	9.2	8.0	9.6	8.0	7.0	8.0	8.5	7.5	9.3	7.0	8.4	8.0	8.3			1.0		0	0.5
1.25	8.0	9.6	6.5	11.4	8.0	9.2					7.5	8.4	7.5	9.3	7.0	8.2	8.0	8.3			1.0		0	0.5
1.5	8.0	9.6	6.5	11.6							7.5	8.3	7.5	9.4	7.0	8.2	8.0	8.3			1.0		1.0	0.4
1.75	8.0	9.6	6.5	11.6							7.5	8.3	7.5	9.4	7.0	8.2	7.5	8.3			1.0		1.0	0.4
2.0	8.0	9.5	6.5	11.6											7.0	8.2	7.5	8.3						
2.25																	7.5	8.3						
2.50																	7.5	8.3						

Date	1-18-68		1-30-68		1-30-68		1-30-68		1-30-68		1-31-68		1-31-68		1-31-68		1-31-68		2-1-68		2-1-68		2-1-68	
Time	1130		1530		1300		1415		1445		1430		1600		0910		1300		0855		0910		1045	
Station	Y1b		Y1b		09d		P9a		N10b		N10b		Y1b		09d		P9a		09d		09b		036a	
Depth	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O
					ice-23cm		ice-25cm		ice-30cm		ice-30cm				ice-23cm		ice-25cm		ice-23cm		ice-30cm		ice-30cm	
0	1.0	5.8	2.5	5.4	1.0	8.2	1.0	10.0	1.0	2.0	1.5	1.3	2.0	6.2	1.0	8.3	0.5	10.3	0	7.7	0	8.0	0	2.7
0.25			2.5	5.3	1.0	8.3	1.0	10.3	1.0	1.6	1.5	1.2	2.0	6.1	1.0	8.2	.5	10.3	0	7.2	0	8.2	0.5	2.3
0.50			2.0	5.3	1.0	8.3	1.5	9.4	1.0	1.7	1.5	1.1	2.0	6.0	1.0	8.2	.5	10.3	0	7.1	0	8.2	0.5	2.0
0.75			2.0	5.3	1.0	3.4	1.5	7.5	1.0	1.2	2.0	.8	2.0	6.0	1.0	2.1	1.0	7.6	0	3.6	0	7.6	1.0	1.9
1.00	1.0	5.7	2.0	5.3	1.0	1.6	1.5	5.5	1.5	0.9	2.5	.6	2.5	5.9	1.0	1.8	1.0	7.5	.5	2.7	0.5	2.1	1.5	1.4
1.25			2.0	5.3	1.5	1.0	1.5	1.4	2.0	0.7	3.0	.4	2.5	5.7	1.0	1.4	1.0	2.1	.5	1.4			1.5	1.0
1.50			2.0	5.3	1.5	0.7			2.5	0.7	3.5	.4	2.5	5.7	1.0	1.0	1.5	1.9	1.0	1.3			2.0	0.6
1.75			2.0	5.3	2.0	0.4			3.0	.5	3.5	.4	2.5	5.7	1.5	0.7			1.0	1.0				
2.0	1.0	5.7	2.0	5.3					3.5	.4	3.5	.4	2.5	5.7										
2.25			2.0	5.3					3.5	.4	3.5	.4	2.5	5.7										
2.50			2.0	5.3					3.5	.4	3.5	.4	2.5	5.7										
2.75			2.0	5.3					4.0	.5	3.5	.4	2.5	5.7										
3	1.5	4.5	2.0	5.3									2.5	5.7										
4	1.5	4.0	2.0	5.5									2.5	5.7										
5	2.0	3.5	2.5	5.5									2.5	5.7										

TABLE 4 (Continued)

TEMPERATURE AND OXYGEN VARIATION
WITH DEPTH IN AGENCY
AND UPPER KLAMATH LAKE

Date	2-29-68		3-2-68		3-2-68		4-4-68		4-4-68		5-8-68		5-9-68		6-11-68		6-12-68		7-9-68		7-9-68	
Time	1635		0920		1445		1430		0925		1615		1100		1530		1100		1500		1000	
Station	09d		09d		Y1b		Y1b		09d		09d		Y1b		09d		Y1b		Y1b		09d	
Depth	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O
0	6.5	18.0	5.5	14.4	8.5	15.2	9.0	10.1	9.5	8.7	14.5	12.0	13.2	12.2	18.3	12.4	16.0	12.1	26.0	11.8	23.7	6.7
0.25	6.5	18.0	5.5	14.4	9.0	15.0	9.0	10.1	9.5	8.7	14.5	12.0			18.2	12.4	16.0	12.1			23.8	6.4
0.50	6.5	18.0	5.5	13.1	9.0	15.0	9.5	10.1	9.5	8.7	14.5	12.0	13.3	12.2	18.3	12.3	16.0	11.4			23.9	6.4
0.75	6.5	18.0	5.5	13.0	8.5	15.0	9.5	10.0	9.5	8.6	14.5	12.0			18.3	12.4	15.8	11.4			23.9	6.2
1.00	6.5	18.4	6.0	12.4	8.5	15.0	9.5	10.0	9.5	8.6	14.5	11.9	13.3	12.1	18.3	12.4	15.8	11.4	25.8	11.4	23.9	6.4
1.25	6.0	18.4	6.0	12.1	8.0	15.0	9.5	9.9	9.5	8.6	14.5	11.9			18.3	12.4	15.8	11.4			23.9	5.0
1.50	6.0	18.5	6.0	11.9	8.0	15.0	9.5	9.9	9.5	8.6	14.5	11.9	13.3	12.0	18.3	12.4	15.6	11.2			23.5	5.1
1.75	6.0	18.3	6.0	11.6	8.0	15.0			9.5	8.6	14.5	11.9			18.3	12.4	15.6	11.2			23.4	4.8
2.00	6.0	16.5	6.0	11.6	8.0	15.0	9.5	9.9	9.5	8.6	14.4	11.9	13.2	12.0	18.3	12.4	15.5	11.2	25.0	11.0		
2.25	5.5	14.3	6.0	11.6	8.0	15.0			9.5	8.6	14.3	11.8			18.3	12.3	15.5	11.1				
2.50	5.0	3.0	6.0	<2.5	7.5	15.4	9.5	9.9	9.0	8.6			13.2	12.0			15.5	10.8				
2.75					7.5	15.4			9.0	2.1							15.5	10.8				
3.00					7.5	15.4	9.5	9.9					13.2	12.0			15.5	10.8	24.8	10.5		
4.00					7.5	15.5	9.5	10.1					13.0	11.9			15.4	10.4	24.6	9.7		
5.00					7.5	15.8	9.5	9.9					12.7	11.3			15.3	10.4	24.6	9.7		
5.50					7.5	15.4							12.5	10.3			15.3	10.4				
5.75					7.5	15.4											15.3	7.4				
6.00							9.5	9.9														

TABLE 4 (Continued)

TEMPERATURE AND OXYGEN VARIATION
WITH DEPTH IN AGENCY
AND UPPER KLAMATH LAKE

Date	8-20-68		9-10-68		9-11-68		9-11-68		9-11-68		9-23-68		9-23-68		9-24-68		10-22-68		10-22-68		10-22-68		10-23-68	
Time	1130		1650		0845		1100		1300								1530		1700		1200		1000	
Station	V7d		09d		V7d		Y1b		09d		V7d		M35a		09d		V7d		Y1b		M35a		09d	
Depth	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O
0	14.3	10.7	24.3	2.7	19.5	7.2	20.5	8.1	21.5	3.3	13.2	10.8	16.4	10.9	16.9	9.0	10.5	9.6	10.8	8.1	8.7	10.1	9.0	5.6
0.25			24.0	2.0	19.2	7.3	20.5	8.1	21.5	3.3							10.3	9.5	10.8	8.1			9.0	5.2
0.50	14.3	10.6	23.0	1.3	19.2	7.3	20.2	8.0	21.5	2.9							10.3	9.3	10.7	8.1			9.0	4.6
0.75			21.0	1.1	19.2	7.3	20.1	8.0	20.5	1.4							10	9.0	10.6	8.0			9.0	4.4
1.00	14.3	10.6	20.5	1.0	19.1	7.2	20.1	8.0	20.0	1.3			13.5	9.0			10	9.0	10.4	7.7	8.7	9.9	9.0	4.0
1.25			20.0	1.0	19.2	7.2	19.8	7.6	19.6	1.2							9.8	8.3					9.0	3.7
1.50			20.0	1.0	19.2	7.2	19.5	7.5	19.5	1.2	13.1	10.1			13.0	9.6			10.3	7.6			9.0	3.5
1.75					19.2	7.2	19.5	7.5																
2.0							19.4	7.3											10.1	7.4				
2.25							19.4	7.3																
3																			10	7.4				
4																			9.6	7.5				
4.5																			9.5	6.9				

TABLE 4 (Continued)

TEMPERATURE AND OXYGEN VARIATION
WITH DEPTH IN AGENCY
AND UPPER KLAMATH LAKES

Date	2-6-69		2-6-69	
Time	0950		1345	
Station	N10b		Y1b	
Depth	T	O	T	O
Surf	Ice -45 cm		1.0	11.0
0.50	0	2.9		
1.00	1.0	3.9	0.5	11.1
1.25	1.0	3.9		
1.50	1.5	2.7		
1.75	1.8	2.6		
2.00	1.8	2.6	0.5	11.6
2.25				
2.50	2.0	2.6		
2.75	2.0	1.8		
3.00			0.5	11.6
4.00			0.5	8.9

TABLE 5

OXYGEN AND TEMPERATURE VARIATION
THROUGH A 24-HR PERIOD
IN UPPER KLAMATH LAKE

Date	8-13-68		8-13-68		8-13-68		8-13-68		8-13-68		8-14-68		8-14-68		8-14-68		8-14-68		8-14-68		8-14-68	
Time	1530		1700		1730		1800		2400		0400		0445		0530		0610		1500		1630	
Station	Y1b		09d		V7d		Y1b		Y1b		Y1b		V7d		09d		Y1b		09d		Y1b	
Depth	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O	T	O
0	20.0	9.4	22.0	15.1	20.7	7.9	20.0	8.7	18.7	9.6	18.5	8.1	18.0	5.7	18.0	9.0	18.0	7.2	20.0	12.8	18.4	9.5
.25					20.8	7.9							18.5	5.7	18.3	7.7						
.50			21.5	15.1	20.6	7.9							18.5	5.4	18.3	7.7			20.0	12.7		
.75					20.6	7.9							18.5	5.5	18.3	7.4			20.0	12.7		
1.0	20.0	9.4	21.2	11.8	20.6	7.9	20.5	8.7	19.0	9.0	18.5	7.7	18.5	5.7	18.2	7.4	18.3	7.1	20.0	12.7	18.4	9.4
1.25	20.0	9.4	21.0	10.2	20.6	7.9							18.5	5.6			18.3	7.1	20.0	12.3		
1.50	20.0	9.3															18.3	7.0				
1.75	20.0	9.3															18.4	7.0				
2.0	20.0	9.2					20.2	8.8	19.1	7.9	18.5	7.1					18.4	6.9			18.4	9.5
2.25	20.0	9.0															18.4	6.9				
2.50	20.0	9.0															18.4	6.9				
2.75	20.0	8.8															18.4	6.8				
3.0	20.0	8.6					20.0	8.7	19.1	7.8	18.5	7.1					18.3	6.7			18.4	9.5
4.0							19.8	8.4	19.0	6.8	18.5	6.1									18.4	8.9
4.5							19.4	8.3	19.0	6.2	18.5	5.7									18.4	8.9

TABLE 6

PHYTOPLANKTON OF UPPER KLAMATH LAKE(a)

Date	Dec. 13, 1967			Jan. 17, 1968		Jan. 17, 1968		
Station	09d		Predominant	09d		Y1b		Predominant
Phytoplankton	Surface	Bottom	Phytoplankton	Surface	Bottom	Surface	Bottom	Phytoplankton
Centric Diatoms	10,700	16,500	Stephanodiscus		70	150	20	
Pennate Diatoms						200		
Green Coccoid	20							
Blue-green Coccoid	200	40						
Blue-green Filamentous								
Green Flagellates	1,430	290		40	90	20		
Other Flagellates				3,540	2,160	20		Cryptomonas
Total, No/ml.	12,370	16,830		3,590	2,300	390	20	

Date	Jan. 31, 1968		Jan. 31, 1968		Jan. 31, 1968		Jan. 31, 1968		Jan. 31, 1968		Predominant
Station	09d		Y1b		P9a		N10b		N35a		Phytoplankton
Phytoplankton	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	
Centric Diatoms		40	90	30	70	70	90		20	40	
Pennate Diatoms										20	
Green Coccoid			10			20					
Blue-green Coccoid											
Blue-green Filamentous					70			20		110	
Green Flagellates	480	400		10	70	180	420	180		200	
Other Flagellates	4,800	1,700			790	480	440				Cryptomonas
Total, No/ml.	5,280	2,180	100	40	1,000	750	950	200	20	370	

a. Additional qualitative data on phytoplankton also listed in Table 3.

TABLE 6 (Continued)

PHYTOPLANKTON OF UPPER
KLAMATH LAKE

Date	March 3, 1968		March 3, 1968			April 4, 1968		
Station	09d		Y1b		Predominant	09d		Predominant
Phytoplankton	Surface	Bottom	Surface	Bottom	Phytoplankton	Surface	Bottom	Phytoplankton
Centric Diatoms	30,270	26,360	82,200	73,960	Stephanodiscus	8,200	920	Cyclotella-Stephanodiscus
Pennate Diatoms	220	570	130	130		130	220	
Green Coccoid	350	220	260	260		970	1,200	
Blue-green Coccoid				80		180	350	
Blue-green Filamentous	310	130	40					
Green Flagellates	4,050	2,200	2,550	1,860	Unidentified	1,100	660	Unidentified
Other Flagellates	11,100	1,890	1,010	180	Cryptomonas	40	40	
Total, No/ml.	46,300	31,390	86,190	76,390		11,000	3,400	

TABLE 6 (Continued)

PHYTOPLANKTON OF UPPER KLAMATH LAKE

Date	May 8, 1968		May 8, 1968		
Station	09d		Y1b		
Phytoplankton	Surface	Bottom	Surface	Bottom	Predominant Phytoplankton
Centric Diatoms	150	200	40	90	
Pennate Diatoms	480	370	1,900	3,100	Fragilaria
Green Coccoid	530	440	440	570	
Blue-green Coccoid	480	750	1,100	350	Anacystis (Microcystis)
Blue-green Filamentous					
Green Flaellates	260	300	350	400	
Other Flagellates					
Total, No/ml.	1,900	2,100	3,800	4,500	

Date	June 12, 1968		June 12, 1968		
Station	09d		Y1b		Predominant
Phytoplankton	Surface	Bottom	Surface	Bottom	Phytoplankton
Centric Diatoms		1,100	40	260	
Pennate Diatoms	130	220		180	
Green Coccoid	400	220	180	180	
Blue-green Coccoid	6,600	2,900	8,700	7,100	Anacystis (Microcystis)
Blue-green Filamentous	20	350	350	180	Aphanizomenon*
Green Flagellates	260	970	970	620	
Other Flagellates					
Total, No/ml.	8,300	4,700	10,000	8,500	

* Aphanizomenon bloom began during last of May; difficult to count by Sedgwick-Rafter method.

TABLE 7

CONDUCTIVITY MEASUREMENTS
IN HOWARD BAY, UPPER KLAMATH LAKE*

Station Date	09d 1/30/68	P9a 1/30/68	N10b 1/30/68	SBE(a) 1/30/68	SBW(b) 1/30/68	PBE(c) 1/30/68	Y1b 1/30/68	N10b 1/31/68	09d 1/31/68	09d (10' north) 2/01/68	09d (100' north) 2/01/68
Depth(m)											
Surface	170	170	160	190	200	200	170	150	185	120	120
0.5	200	190	165	195	200	200	170	150	200	130	120
1.0	500	280	170	210	210	200	170	155	500	380	370
1.25		400									
1.75	550			220	220	230		160	525	400	
2.75			180					160			
5.0							170				

Station Date	N10b (200' east) 2/06/69
Depth(m)	
Surface	150
1.0	180
1.5	200
2.0	400
2.5	500

Conductivity of water from farm drainage water-flow pipe.

1/30/68 - 500
3/02/68 - 255

*See Table 2 for other conductivity data.

Notes: All measurements made under about 45 cm. of ice.
Values are in micromhos/cm.

a. SBE - Experimental pool with water column exposed to the sediment (east position)
b. SBW - Experimental pool with water column exposed to the sediment (west position)
c. PBE - Experimental pool with plastic bottom. Water not exposed to sediment (east position)

Experimental pools 10 ft. long by 10 ft. wide extending to bottom of lake. Location at 09d.
Plastic pools were filled with water in Nov. 1967, the conductivity of which was about 185 micromhos/cm.

TABLE 8

COMPARISON OF SURFACE AND BOTTOM
LAKE WATER QUALITY
WITH EXPERIMENTAL POOLS

	11-16-67		11-16-67		11-16-67		12-13-67		12-13-67		1-18-68		1-18-68		1-18-68	
	09d		SBW		PBE		09d		PBE		09d		SBW		PBE	
	s	b	s	b	s	b	s	b	s	b	s	b	s	b	s	b
Alkalinity	59	58	64	65	60	60	59	59	60	49	69	84	70	74	70	73
Conductivity	128	130	185	185	160	160	138	139	151	139	181	263	169	189	189	194
Carbon, Total	24	24	27	27	25	25	22	22	22		29	37	28	30	30	30
Carbon, SNOC	8	6	10	10	11	10	10	8	8		9	13	12	11	10	10
Hardness, Ca	31	29	47	47	44	42	32	35	42	42	43	66	38	49	42	46
Hardness, Total	55	42	65	62	52	64	38	40	44	43	58	88	52	58	56	60
N-NH_3	1.35	2.0	1.7	1.7	1.3	1.1	1.5	1.8	1.5	1.5	2.3	2.6	2.2	2.5	3.0	2.4
N-NO_3	.12	.11	.11	.12	.12	.12	.09	.06	.09	.09	.13	.12	.13	.14	.18	.19
N-T. Kjeld.	3.0	2.9	2.8	2.7	5.6	2.3	8.4	2.8	2.6	1.8	3.1	3.5	2.8	3.4	3.7	3.5
pH	8.2	8.2	7.3	7.3	7.9	7.6	8.1	7.6	7.6	7.2	7.7	6.5	7.0	7.0	7.2	7.4
P, Ortho	.05	.05	.09	.11	.04	.04	.03	.03	.07	.07	.13	.25	.12	.16	.11	.15
P, Total	.15	.16	.17	.20	.11	.11	.18	.21	.17	.13	.32	.49	.25	.30	.45	.34
Silica, Sol.	31.4	31.4	29.3	29.3	30.0	30.0	32.8	29.3	28.0	28.0	30.0	28.6	30.9	31.8	31.1	31.0
Sodium	11.3	10.2	13.0	10	13.6	11.8	11.6	11.6	11.6	11.8	13.0	15.0	13.0	13.0	13.0	14.0
Potassium	2.6	2.4	3.5	3.2	3.0	3.0	2.2	2.3	2.5	2.5	3.2	4.4	3.2	3.4	4.2	3.4
Chloride	<5		<5	<5	<5	<5					<5	<5	<5	<5	<5	<5
Sulfate	<10		11	18	13	14					15	<10	11	14	14	16
Secchi Disc Reading	75		70		95						65		65		55	

s - surface sample
b - bottom water sample
SBW - sediment bottom pool (west position)
PBE - plastic bottom pool (east position)

TABLE 8 (Continued)

COMPARISON OF SURFACE AND BOTTOM
LAKE WATER QUALITY
WITH EXPERIMENTAL POOLS

	1-31-68		1-31-68		1-31-68		3-02-68*		3-02-68		3-02-68		4-04-68		4-04-68		4-04-68	
	09d		SBW		PBE		09d		SBW		PBE		09d		SBW		PBE	
	s	b	s	b	s	b	s	b	s	b	s	b	s	b	s	b	s	b
Alkalinity	75	113	75	74	75	76	70	75	59	60	64	67						
Conductivity	169	367	181	189	179	219	296	355	222	223	225	284	105	105	165	165	130	130
Carbon, Total	28	62	28	28	30	28	43	43	33	35	37	37	19	20	24	24	21	23
Carbon, SNOC	9	31	10	10	14	14	18	24	14	13		18						
Hardness, Ca	42	110	37	45	37	61	102	128	72	72	73	94	26	19	48	51	33	31
Hardness, Total	48	126	52	55	50	65	106	133	74	76	74	98	31	30	54	55	41	42
$N-NH_3$	1.8	1.7	2.0	2.0	1.8	1.9	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
$N-NO_3$	.06	.05	.07	.08	.08	.13	.30	.30	.26	.27	.27	.33	.01	.02	.02	.02	.01	.02
N-T. Kjeld.	3.9	4.4	3.9	3.6	4.0	3.7	3.4	3.9	2.2	2.7	3.0	2.8	1.2	1.1	1.5	1.4	1.1	1.7
pH	7.3	7.0	7.2	7.0	7.3	7.3	8.4	7.3	8.5	8.4	8.6	7.4	8.6	7.9	8.7	9.1	8.4	8.1
P, Ortho	.12	.43	.14	.18	.11	.19	.017	.017	.009	.010	.013	.012	.008	.01	.006	.006	.008	.013
P, Total	.36	.65	.37	.32	.37	.37	.29	.29	.17	.20	.21	.24	.075	.071	.058	.073	.063	.131
Silica, Sol.	34.0	32.9	33.0	33.1	34.0	33.0	18.3	18.1	18.5	18.5	18.8	18.8	10.3	11.7	6.9	7.1	8.3	8.4
Sodium	12	28	12	13	12	14	19	23	16	16	16	18						
Potassium	2.8	4.4	2.9	3.0	2.9	3.3	3.0	3.2	2.5	2.5	2.4	2.8						
Chloride							<5	<5	<5	<5	<5	<5						
Sulfate	10	32		-			31	20	21	21								
Secchi Disc Reading	50		55		55		45		49		49		65		65		65	

* All pools flooded with lake water last week in February when ice melted.

TABLE 9

PROFILE DATA FOR TEMPERATURE
AND OXYGEN OF THE EXPERIMENTAL
POOLS AND LAKE

	11-16-67 0830 09d		11-16-67 0850 PBE		11-16-67 0915 SBW		1-17-68 1600 09d		1-17-68 1620 PBE		1-17-68 1430 SBW		1-31-68 0910 09d		1-31-68 0925 PBE		1-31-68 0855 SBW		2-01-68 0845 PBE	
Depth	Temp.	0	Temp.	0	Temp.	0	Temp.	0	Temp.	0	Temp.	0	Temp.	0	Temp.	0	Temp.	0	Temp.	0
Surf	6.5	9.5	6.5	9.2	7.0	7.5	0	8.0	0	7.4	0	7.2	1	8.3	0	9.5	0	8.4	0	7.2
0.25	6.5	9.5	6.5	9.1	7.0	7.5	0	8.0	0	7.4	0	7.2	1	8.2	0	9.3	0	8.1	0	7.2
0.50	6.5	9.5	6.5	9.1	6.5	7.5	0	4.5	0	7.4	0	7.2	1	8.2	0	9.2	0.5	6.3	0	7.2
0.75	6.5	9.5	7.0	8.9	6.5	7.5	0	2.0	0	7.4	.5	4.9	1	2.1	.5	8.5	1	5.7	0	7.2
1.00	6.5	9.5	7.0	8.7	6.5	7.5	0	0.5	0	6.0	.5	4.8	1	1.8	.5	8.3	1	5.5	0	7.2
1.25	6.5	9.5	7.0	8.7	6.5	7.5	0	0.5	.5	6.0	.5	4.7	1	1.4	.5	8.1	1	5.5	0.5	7.1
1.50	6.5	9.5	7.0	8.7	6.5	7.5	1	0.4	.5	5.8	1.0	3.5	1	1.0	1.0	4.2	1.5	1.7	1	3.4
1.75	6.5	9.5	7.0	8.7	6.5	7.5	1	0.4	.5	5.3	1.0	1.5	1.5	0.7			1.5	1.3	1	2.1

	2-29-68 1635 09d		2-29-68 1620 PBE		2-29-68 1645 SBW		3-02-68 0920 09d		3-02-68 0900 PBE		3-02-68 0935 SBW	
Depth	Temp.	0	Temp.	0	Temp.	0	Temp.	0	Temp.	0	Temp.	0
Surf	6.5	18.0	6.5	18.6	6.5	20.0	5.5	14.4	5.5	15.3	5.5	15.2
0.25	6.5	18.0	6.5	19.0	7.0	19.2	5.5	14.4	5.0	15.6	5.5	15.3
0.50	6.5	18.0	6.0	18.8	6.5	18.6	5.5	13.1	5.0	15.6	5.5	15.3
0.75	6.5	18.0	6.0	18.8	6.0	18.0	5.5	13.0	5.0	15.7	5.5	15.2
1.00	6.5	18.4	5.5	17.8	5.5	17.2	6.0	12.4	5.0	15.7	5.5	15.2
1.25	6.0	18.4	5.5	17.8	5.5	16.4	6.0	12.1	5.0	15.8	5.0	15.2
1.50	6.0	18.5	5.5	17.8	5.5	15.8	6.0	11.9	5.0	15.8	5.0	15.2
1.75	6.0	18.3	5.0	17.6	5.5	15.0	6.0	11.6	5.0	16.0	5.0	15.2
2.00	6.0	16.5	5.0	17.6	5.0	14.6	6.0	11.6	5.0	13.5	5.0	15.2
2.25	5.5	14.3	5.0	12.2	5.0	14.4	6.0	11.6	5.5	12.5	5.0	15.2
2.50	5.0	3.0	5.0	3.1	5.0	3.2	6.0	<2.5	5.5	11.8	5.0	7.4