

A CHEMICAL, PHYSICAL, AND BIOLOGICAL INVESTIGATION  
OF THE TOTAL SUSPENDED AND DISSOLVED SUBSTANCES  
IN LAKE DALLAS WITH EMPHASIS ON SANITATION

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IN LAKE DALLAS WITH EMPHASIS ON SANITATION

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## CHAPTER I

### INTRODUCTION

The purpose of this investigation is to determine the suspended organic matter and the total phosphorus in the waters of Lake Dallas and to evaluate these findings. Since organic matter floating in lakes is largely composed of minute plants, animals, and detritus derived from animals and plants, the fertilizing effect of phosphorus must be considered as an integral part of this problem.

A limnological study of Lake Dallas has been conducted for the last five years, and an effort has been made to determine the causal agents which give rise to tastes and odors in the water. The correlation of the organic nitrogen, phosphorus, tastes and odors, and the plankton will possibly show to some extent the reason a partially polluted body of water such as Lake Dallas would likely have high tastes and odors.

A body of water that is apparently polluted with a fertile sewage effluent should have flourishing growths of microscopic plants and animals, since all the necessary food elements are present. Thus, if all other factors, such as oxygen, carbon dioxide, alkalinity, turbidity, and general limnological conditions are constant, the taste and odors may be directly attributed to specific causes. Particular attention

is also given to the organic content of the allochthonous detritus, since various workers have indicated that washed-in organic matter might give rise to more tastes and odors than autochthonous detritus. All natural tastes and odors in reservoirs must arise largely from either living or dead organic matter, so that the scope of this problem is very extensive. Consideration throughout the period of research has been more toward sanitary applications than theoretical limnology.

The limnology of fresh-water reservoirs is a new field in the Southwest and only comparatively new throughout the United States. Weibe (1933-35) (unpublished) made investigations on many of the Texas reservoirs, which were very general in scope and application. Curbo (1935) (unpublished) made an inorganic chemical analysis of Lake Dallas to determine the relative features of this reservoir. Woods<sup>1</sup> (1937) made chemical investigations on Lake Bridgeport with reference to plankton and animal life. Smith<sup>2</sup> (1937-38) worked on Eagle Mountain Lake, investigating the chemical and physical factors with reference to biological productivity. The body of water used in this investigation is a reservoir approximately twelve

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<sup>1</sup>Aletka Woods, "Physical and Chemical Investigation of Eagle Mountain Lake," Unpublished Master's thesis, Department of Chemistry, North Texas State Teachers College, 1937, p. 8.

<sup>2</sup>Burns Ashby Smith, "Chemical Factors Affecting Plankton Growth," Unpublished Master's thesis, Department of Chemistry, North Texas State Teachers College, 1938, p. 7.

years of age. Harris and Silvey<sup>3</sup> (1936-38) made a limnological study of Lake Dallas with regard to factors influencing biological productivity of the lake. Welch<sup>4</sup> (1939) made a seven-months' study of the physical and chemical factors affecting plankton growth. Birge and Juday<sup>5</sup> (1922) have made numerous investigations of mid-western lakes during the past thirty years with regard to factors affecting plankton growth. Actually none of the above-cited investigations tend to show the sanitary effect of either plankton blooms or their organic deposits.

This present work has been in progress during a period of one year in order that all factors such as abnormal rainfall, extreme temperatures, and any other abnormalities that may have arisen could be carefully considered.

It is quite likely that extremely dry periods or exceedingly wet periods might alter the organic and phosphorus content of the lake.

#### Description of the Lake

Lake Dallas is the reservoir which serves as the water

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<sup>3</sup>Benjamin B. Harris and J. K. Gwynn Silvey, "Limnological Investigation on Texas Reservoir Lakes," Ecological Monographs, Vol. X, 1940.

<sup>4</sup>Herschel W. Welch, "Chemical Investigation of Lake Dallas," Unpublished Master's thesis, Department of Chemistry, North Texas State Teachers College, 1939.

<sup>5</sup>Edward Birge and Chancey Juday, The Inland Lakes of Wisconsin, Bulletin No. 64, Published by the State of Wisconsin, pp. 1-220.

supply of the city of Dallas. Clear Creek, Pecan Creek, and Elm Fork of Trinity River serve as source streams for the lake.

Lake Dallas is located in Denton County, with a drainage area including parts of Cooke, Collin, and Denton Counties. It is in the Upper Cretaceous system, the basin of the lake being in the Woodbine sands.

The watershed of the lake varies greatly from year to year in respect to agriculture and general conditions, so that any present description may be partially altered during any following year. Since, however, the area that makes up the drainage zone for Lake Dallas is vast, adequate supplies of organic matter and minerals should be present for many years to come.

#### Morphometry

Morphometric data on Lake Dallas were obtained from various geological publications and from the volume chart of the city of Dallas Water Supply.

|                                       |        |
|---------------------------------------|--------|
| Maximum Length in Miles . . . . .     | 11.07  |
| Maximum Breadth in Miles . . . . .    | 3.07   |
| Maximum Depth in Feet . . . . .       | 40.00  |
| Major Axis . . . . .                  | N-S    |
| Approximate Latitude . . . . .        | 33°20' |
| Approximate Longitude . . . . .       | 97°    |
| Area (at Spillway) in Acres . . . . . | 10,895 |



|   |         |
|---|---------|
| Length of Shoreline in Miles . . . . .      | 57.4    |
| Volume (at Spillway) in Acre-Feet . . . . . | 195,000 |
| Mean Depth in Feet . . . . .                | 17      |
| Spillway Elevation in Feet. . . . .         | 525     |
| Date Filled (year) . . . . .                | 1927    |
| Drainage Area in Square Miles . . . . .     | 1,111   |

These figures represent conditions as they were at the time the lake was established. Since then the Soil Conservation Service has shown that the silt deposited in Lake Dallas amounts to a fill-in of 13,686 acre-feet or a loss at present date of 7.5 per cent in volume. At the current rate of fill Lake Dallas will be a marsh by 1973.

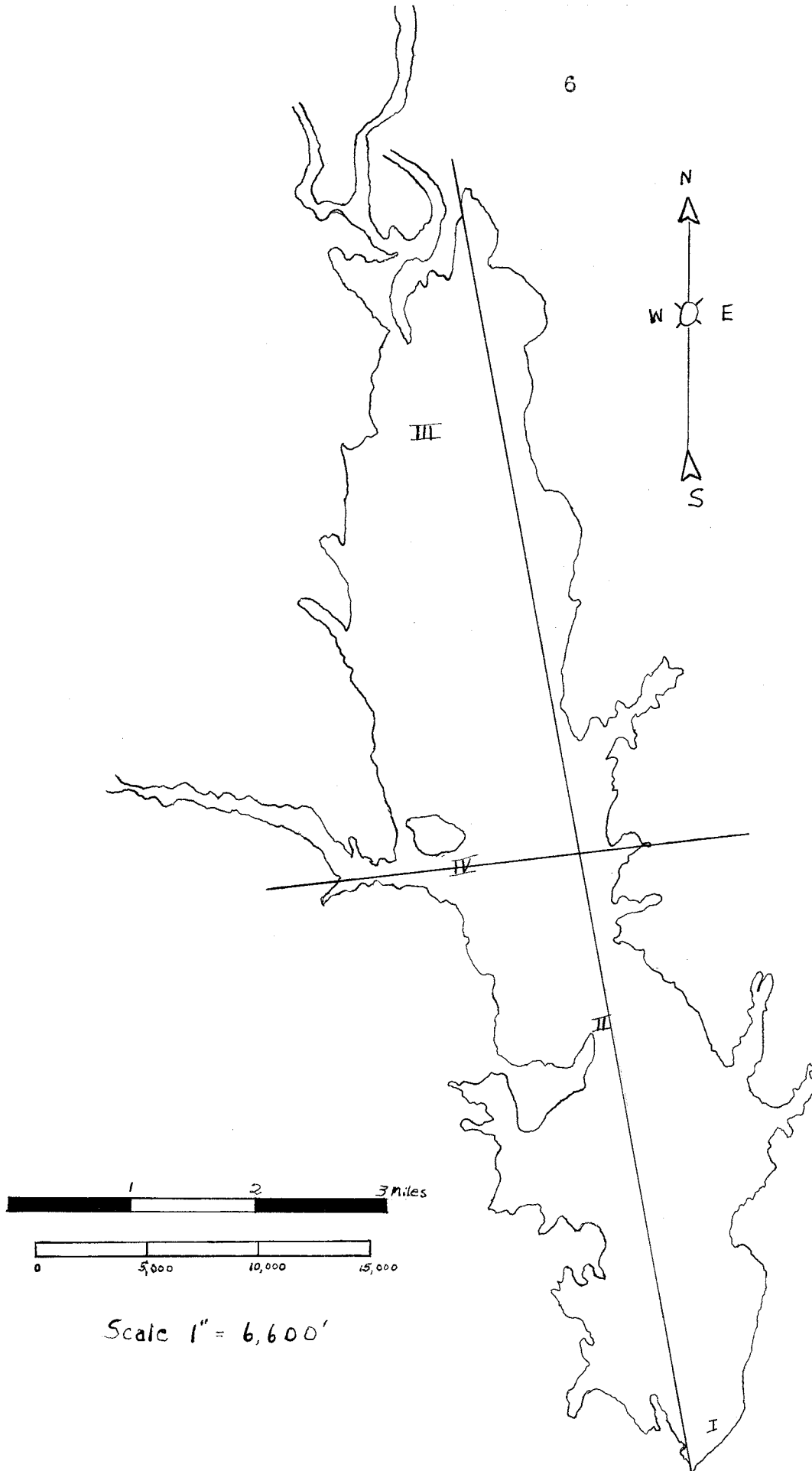


Fig. 1.--Map of Lake Dallas

## CHAPTER II

### METHODS

#### Physical

The determination of temperature at each depth was made by means of a Negretti and Zambra reversing thermometer mounted in a special case, corrected for pressures of three tons, and sealed in an outer glass tube. Tropical thermometers were used in this work.<sup>1</sup>

Turbidity was determined in the field by use of the United States Geological Survey Turbidimeter Scale. The Jackson Turbidimeter was used in cases where the waters were disturbed by winds or currents.

The color of the water was determined by a United States Survey Comparator. Samples of the lake water were compared with standards of the same turbidity; then filtered samples of the lake water were compared with standards of distilled water, and checking these readings made an accurate color determination possible.

#### Chemical

Samples for chemical determination were collected by means of Juday samplers attached to calibrated ropes.

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<sup>1</sup>Harris and Silvey, op. cit.

Determinations were made each week from September, 1940, through August, 1941. Samples were obtained from three stations; namely, Station I, at the Dam; Station II, at Shahan's Point; and Station IV, on Pecan Creek, as represented on the map (Figure 1). One complete set was run each week. Each determination was run in duplicate to insure accuracy.

Inorganic.---Oxygen was determined by adding .7 ml. of concentrated sulfuric acid and 1 ml. of potassium permanganate to the sample and following in 20 minutes by 1 ml. of potassium oxalate. Upon disappearance of color, 1 ml. of manganous sulfate and 3 ml. of alkaline potassium iodide were added. The solution was stirred and 100 ml. of it were titrated with standard sodium thiosulfate, using starch as an indicator.

The equation used was:

Ml.  $.025N Na_2S_2O_3 \times 2 =$  p.p.m. dissolved oxygen.

Carbon dioxide was determined by the titration of 100 ml. of the sample in a Nessler tube with N/44 sodium hydroxide, using phenolphthalein as indicator.

Since the alkalinity is due largely to soluble bicarbonates, it was determined by titrating the sample with .02N sulfuric acid, using methyl orange and phenolphthalein as indicators. The phenolphthalein indicates the presence of the carbonates.

Hydrogen-ion concentrations were determined colorimetrically with the La Motte comparator, using phenol red as indicator. Hydrogen-ion concentrations were also measured in

the laboratory, using a Beckman pH Meter.

Nitrites were determined by adding 2 ml. of alpha-naphthylamine acetate and 2 ml. sulfanilic acid to 100 ml. of sample, and the standard was made up to 100 ml. in Nessler tubes. The depths of color of the sample and standard were compared and matched. The equation used was:

$$\frac{\text{ml. standard NaNO}_2 \times .5}{\text{ml. of sample}} = \text{p.p.m. NO}_2 \text{ nitrogen as N.}$$

Chlorides were determined by titrating 50 ml. of sample with standard silver nitrate, using 1 ml. of potassium chromate as indicator until the first brownish precipitate persisted.

The equation used was:

$$\frac{(\text{ml. of AgNO}_3 - 0.2) \times 500}{\text{ml. of sample}} = \text{p.p.m. chloride}$$

The foregoing analyses were followed as outlined in Laboratory Manual for Chemical and Bacterial Analysis of Water and Sewage (Theroux, Eldridge, and Mallman, 1936).

Silica was determined by adding 2 ml. of 10 per cent ammonium molybdate solution and 4 drops of 50 per cent by volume sulfuric acid to 100 ml. of sample in Nessler tubes. The color developed was compared with an artificial standard of picric acid solution.<sup>2</sup>

Ammonia was determined by adding 1 ml. of sodium hydroxide, 4 drops of copper sulfate, and 4 drops of lead acetate to 50 ml. of sample. The precipitate was allowed to settle,

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<sup>2</sup>Foster Dee Snell and Cornelia T. Snell, Colorimetric Methods of Analysis, Vol. I, p. 518.

and an aliquot part was pipetted off and the ammonia content determined by direct Nesslerization.<sup>3</sup>

Nitrate determinations were made by adding .5 ml. of pyrogallol sulfonic acid and 20 ml. of concentrated sulfuric acid to 10 ml. of samples and standards in 50 ml. evaporating dishes and allowed to stand for one hour. The color varies from rose to olive-green to black, depending upon the concentration.<sup>4</sup>

Phosphates were determined by adding 10 ml. of highly acid ammonium molybdate solution and 5 drops of stannous chloride solution to 100 ml. of sample and standard phosphate solution diluted to 100 ml. Each was well mixed and the intense blue colors compared. One milliliter of standard diluted 100 ml. is equivalent to 1 p.p.m. of phosphate radical. The blue color is due to the hydrogel  $\text{Mo}_3\text{O}_8 \cdot \text{H}_2\text{O}$ .<sup>5</sup>

Centrifuged material.--Through the twelve months, 36 liters of water per week from each station were collected and centrifuged in a Sharples-Super centrifuge at 45,000 r.p.m., which was sufficient to rid the water of all floating material. The centrifuge was drained, and the water was evaporated in an oven along with the centrifuged sample, thus assuring no loss of centrifuged material by mechanical drainage.

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<sup>3</sup>Ibid., p. 650.

<sup>4</sup>Ibid., p. 508.

<sup>5</sup>Industrial Engineering Chemistry, Analytical Edition 4, 1932, pp. 107-9.

The solid thus obtained was removed, dried in an oven at 60° C., weighed, and reported in parts per million as dry weight.

Fats were determined from the dry weight by using a Soxhlet continuous extractor with ether as a solvent. The extractions were continued over a period of not less than twenty-four hours to insure complete extraction.

Organic nitrogen was determined by adding 5 ml. of concentrated sulfuric acid to the sample, which was digested to a colorless liquid. After cooling, 300 ml. of distilled water and enough 10 per cent sodium hydroxide were added to make the solution neutral to litmus. Two hundred milliliters were distilled over and the organic nitrogen determined as ammonia by Nesslerization.<sup>6</sup>

Threshold odors.---The samples were collected in odor-free, glass-stoppered, 250 ml. bottles. A known sample of the water collected was diluted to 250 ml. in a 600 ml. odor flask and heated to 65° C. The sample was smelled. The dilution at which the odor could be described was the threshold odor. The equation used was:

$$\frac{250}{\text{ml. of sample}} = \text{threshold odor}$$

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<sup>6</sup>F. R. Theroux, E. F. Eldridge, and W. L. Mallman, Laboratory Methods of Chemical and Bacterial Analysis of Sewage, p. 33.

## CHAPTER III

### PHYSICAL AND CHEMICAL FEATURES

#### Physical

##### Temperature

Temperature is one of the most important factors in an aquatic environment. Probably no other single factor has so many direct and indirect effects.<sup>1</sup> Water in nature is a great storehouse of heat without, at the same time becoming a menace to the adjustments of life to temperature as they now exist.

The time of stratification is governed by the temperature, rainfall, and wind action. Since the major axis of Lake Dallas is north-south, it is expected that spring winds, since their general direction is south, southeast, or southwest, will disturb the surface water to such an extent that stratification may be delayed. Observations have been made in which stratification in progress for two weeks was suddenly disturbed by high winds.<sup>2</sup> Heavy summer rains often produce various types of density currents which may completely upset stratification or induce stratification.

Thermal stratification occurs during the summer seasons

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<sup>1</sup>Paul S. Welch, Limnology, p. 43.

<sup>2</sup>Harris and Silvey, op. cit.



in Lake Dallas. The temperature of the water under investigation varied from 00.0 to 32.0°C., the mean temperature being 16.5°C. (Figure 2)

### Turbidity

Turbidity is a condition of water resulting from the presence of suspended matter. Prominent among these materials are plankton organisms, finely divided substances of organic origin, and silt. From 15 to 30 per cent of this turbidity is due to organic material and from 70 to 85 per cent to inorganic matter.

Lake Dallas has an annual average turbidity of around 70 p.p.m.<sup>3</sup> The samples studied came from localities varying in turbidity from 10 to 2,800 p.p.m. The turbidity is highest during periods of greatest rains and varies with locality. (Figure 2)

### Color

Color in water is due to those hues which are inherent within the water itself and resulting from colloidal substances or substances in solution. This rules out the apparent hue (1) to living or non-living organisms in suspension and (2) color due to extrinsic conditions.<sup>4</sup> Most of the color in water, consequently, is due to iron, calcium carbonate,

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<sup>3</sup>Ibid.

<sup>4</sup>P. S. Welch, op. cit., p. 79.

carbon, and manganese. The color in Lake Dallas varies from 15 to 40 p.p.m. This absence of excessive staining indicates an absence of large amounts of iron and decaying organic matter in the region of the watershed.

### Chemical

The temperature changes have little effect on the chemical substances other than dissolved gases. The effect on the chemical condition of the lake seems to be one of mixing the water during cooler months and stratification during warmer months. The warmer water will tend to dissolve more solids and less gases, with the reverse being true of cooler water.

### Dissolved Oxygen

There was an equal distribution of dissolved oxygen from October through May. The variation during this period was only 2.00 p.p.m., that being from 10.0 to 12.0 p.p.m. in May. The average from October through May was 11.5 p.p.m.

During June, however, and as the summer progressed, the amount of dissolved oxygen decreased. The low point was reached in July when dissolved oxygen was zero at Station IV. The other locations, however, did not show such a sharp decrease. These showed a variation of 5.0 to 9.0 p.p.m., depending upon the location.

During the fall turnover, bottom waters became as well supplied with oxygen as surface waters. Advanced stagnation

exhausts the oxygen at the bottom; consequently, anaerobic conditions did prevail.

There are various theories as to the source of the oxygen supply, but none are free from objections. The source of the oxygen is still unsolved.<sup>5</sup>

#### Hydrogen-ion Concentration

The pH ranged from 7.4 to 8.4. The peak was reached in July and remained fairly constant through the fall, winter, and spring months, the variation being only 1.0 at any time. The bottom waters were more acid during the summer months. Station IV had the highest pH, which was 8.4.

The variety of conditions determining hydrogen-ion concentration are as yet not specifically known, however, it is known to possess a significance of sufficient importance to require attention.

#### Alkalinity

Free carbon dioxide varied from 1.0 p.p.m. to 65.5 p.p.m. during 1940-41. The highest was found in Pecan Creek in May, and the range of variation was 1 p.p.m. in the months preceding June. The average for the period was 10.3 p.p.m.

The alkalinity determined as bicarbonate varied from 80.0 p.p.m. to 475 p.p.m. These two extremes were found on the same day but from different stations in the lake.

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<sup>5</sup>Ibid., p. 173.

Since the alkalinity represents bound and half-bound carbon dioxide, it is expressed as calcium carbonate. The carbonates of magnesium and calcium are the chief forms in which the carbon dioxide is combined or bound. The bicarbonate represents an intermediate stage between free and bound carbon dioxide. Hence, on considering the bicarbonate as being attacked and utilized by various agencies to precipitate the carbonates, an index of the potential formation of insoluble carbonates is obtained.

#### Chlorides

The chlorides varied from 15 p.p.m. to 80 p.p.m. The highest was in January and the lowest in September. The chlorides did not vary greatly during the first four months, but in May and thereafter fluctuations occurred.

Chlorides arise from the action of the lake water on the underlying sands, from inflowing waters, and from decomposition of organic matter.

#### Inorganic Nitrogen

The inorganic compounds of nitrogen are present in water as nitrites, nitrates, ammonia, and free nitrogen. These arise from rainfall, ammonia in the air, inflow waters, and the decomposition of organic matter.

Nitrates varied from a total absence in February to 0.2 p.p.m. in August. The nitrate content is rarely ever high in uncontaminated waters, but will reach a high level in

contaminated waters. It is possible that nitrates can serve the same function in water as on land, that is, as a fertilizer for the plant life.

Nitrites varied from a total absence to 0.1 p.p.m. at different stations. Nitrites are present either from the action of nitrifying bacteria on ammonia or the action of nitrogen reducing factors upon the nitrates; for example, algae, weeds, and nitrate reducing bacteria. The nitrite content is somewhat higher in contaminated waters. (Figure 3)

In the lake proper nitrites were somewhat lower than in the mouth of Pecan Creek and near Pecan Creek.

Ammonia ranged from a trace to 4.2 p.p.m. The high points were in the fall, winter, and summer, with a drop in the spring. (Figure 3)

#### Silicon

Silicon determined as silica ranged from .5 p.p.m. to 4.5 p.p.m. throughout the months. There was a fairly constant supply of silicon. Sources of silicon are silt and the re-dissolving of the silicon from such organisms as diatoms and other plants. The silicon content probably offers an index for healthy plant growth. (Figure 6)

#### Phosphorus

The soluble phosphorus content of the water varied from none to 12.0 p.p.m. Sources of phosphorus are from inflow waters rich in phosphates and from dead phytoplankton. It is

supposed that the phytoplankton requires an adequate supply of phosphorus, as do land plants. Station IV had the highest phosphate content because sewage effluent from Denton's sewage disposal plant is allowed to flow into Pecan Creek. (Figure 4)

#### Organic Matter

The presence of organisms, both within a lake and about its margins, insures the more or less continued addition of organic materials to the water. Contaminated waters often show a higher content than do uncontaminated waters. The organic matter concerned in this paper is organic nitrogen and ether extracts (crude fats).

Organic nitrogen.--The organic nitrogen varied from 1.25 p.p.m. to 0.02 p.p.m. It was assumed that this nitrogen was originally present as crude protein in a complex structure. Sources are plant and animal organisms, debris, and possibly sewage which has not undergone decomposition.

The organic content of Station IV, the mouth of Pecan Creek, was found to be the highest of the three stations at all times. This can be directly attributed to the fact that sewage effluent from the Denton sewage disposal plant empties into the lake at this point. The fertile effluent gives rise to enormous plankton "blooms" in the creek, and possibly in the lake proper. These blooms inevitably give rise to taste and odor in the water. The organic content of the lake was found to be the greatest at the peak of the plankton blooms,

and, likewise, the organic content was the least when plankton counts were lowest. (Figures 3,4,5, and 6)

Fats.--Fats varied from 0.09 p.p.m. to .004 p.p.m. This crude ether extract contained all ether soluble oils and chlorophyll. Hence, the principal source of fats was plants. Further sources were probably oil from animal organisms, fish, decomposition of fish and other aquatic animals, and sewage effluent. The greatest amounts of fats were found at Station IV, and the least amounts of fats were found at Station I.

Threshold odors.--The threshold odors varied from 10 in June, 1941, to 245, in July, 1941. The principal source of odors and tastes in the water were from organic materials which were undergoing decomposition; namely, dead phytoplankton, sewage and debris that was washed in off the watershed. Therefore, the threshold odor is an index to the amount of pollution that is contained by a body of water. (Figures 2 and 5)

## CHAPTER IV

### CORRELATION OF PHYSICAL, CHEMICAL, AND BIOLOGICAL FACTORS

The chemical, physical, and biological factors of a lake are closely related. It is illogical to represent one without the other. The values of the physical, chemical, and biological factors shown in the following figures are averages. For each station, the weekly readings were averaged to give a monthly value. Then the monthly values for the three stations were averaged.

Nitrites and nitrates were present in small amounts, and their range of variation over a long period was small (Figure 3). The plankton ranged from 945,000 to 3,000 organisms per liter during the period. Consequently, since the nitrites and nitrates were practically constant, their effect upon plankton and plankton growth seems to be negligible. (Figures 4 and 5.)

The true relationship of ammonia is doubtful. It is believed by some authorities that 8.00 p.p.m. of ammonia produce fatal results to organisms. Ammonia was found to be as high as 12.0 p.p.m. at Station IV, but no fatal results to organisms were noticed. It is possible that ammonia





might be utilized by plant and animal organisms as a source of energy in the absence of normal energy stores in order to continue their existence for an indefinite period. This assumption is made on the basis that the formation of ammonia from its elements is an exothermic reaction in which 24,000 calories of heat are given off. However, it must be remembered that ammonia formed here is not formed from its elements, and the energy evolved by ammonia formation in water may or may not approximate 24,000 calories per mole. (Figure 3)

The chlorides seem to have no specific bearing, as their concentration in the water fell within narrow limits.

The silicon content was higher in those regions which showed fewer plankton, indicating that silicon content varied inversely as the plankton organisms. Any results to the contrary are the outgrowth of abnormalities. (Figure 6)

There is a correlation between soluble phosphorus and plankton growth, as evidenced by great decreases in the phosphate content in the regions of high plankton growth. This phosphorus is probably utilized by the organisms, such as the phosphates of the soil are utilized by land plants. These results are at variance with the investigations of Juday<sup>1</sup> (1922) in Wisconsin. (Figure 4)

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<sup>1</sup>Chancey Juday, Transactions of Wisconsin Academy of Sciences, Arts, and Letters, Vol. XIX, Madison, Wisconsin, State of Wisconsin, 1922.



Alkalinity and hydrogen-ion concentration were confined within limits suitable for the existence of the plankton, since any variation in the two did not hinder growth.

It was at first thought that turbidity would show a definite correlation with plankton; however, the results obtained did not bear out this assumption.

Organic nitrogen and fats were positively correlated with the number of plankton organisms. The very definite correlation of organic nitrogen and plankton growth is very clearly illustrated in plotting the curves of each against the months and locations. The resulting curves show that with a rise in plankton organisms a corresponding rise in organic nitrogen resulted. At Station IV organic nitrogen and fats were positively correlated with plankton. However, throughout the entire period fats did not show a definite correlation with organic nitrogen and plankton to enable us to use fats as an index of the presence of plankton and organic nitrogen. (Figure 5)

Threshold odors were found to vary inversely with the plankton and organic nitrogen, and directly with the phosphate content. These facts would tend to prove that plankton utilize organic matter in the presence of phosphorus, as a stimulating or catalyzing agent. The plankton die, putrefy, decay, and in turn give rise to marked increases in threshold odors. Therefore, where threshold odors are high, the organic content of the water is likely to be exceedingly high. (Figure 5)







## CHAPTER V

### SUMMARY

Chemical, physical, and biological investigation of the water show several interesting facts:

1. Only one stratification occurs each year, and that is in the summer.
2. There is a correlation between temperature, turbidity, and odor. With an increase in temperature, the odor of the water increases simultaneously, and, with an increase in turbidity due to excessive rainfall washing in detritus, there is a decrease in odors. This decrease may be attributed to dilution and to the lowering of the temperature of the water, as shown by Figure 2.
3. There is no definite correlation between ammonia, nitrites, nitrates, and organic nitrogen, as shown by Figure 3.
4. There is a marked correlation between phosphates, organic nitrogen, and plankton. It is believed by some authorities that phosphorus is utilized by plants to aid in the utilization of organic material, as shown by Figure 4.
5. There is a definite correlation between the plankton, organic nitrogen, and odor. The plankton varied inversely with the odor, and the organic nitrogen varied directly with the odor, as shown by Figure 5.



6. Silicon and organic nitrogen show no definite correlation, as illustrated by Figure 6.

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