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Water chemistry survey of Boulder Basin, Lake Mead

P. R. Tramutt

Bureau of Reclamation

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

WATER CHEMISTRY SURVEY OF BOULDER BASIN
LAKE MEAD

REFERENCE
NOT TO BE TAKEN FROM THIS ROOM

Report No. ChE-46

Chemical Engineering Branch
DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

June 1965

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APPENDIX

ABSTRACT

The survey results indicate that the impoundment of water behind Hoover Dam has not adversely affected the dissolved oxygen (DO) content and that water quality and DO content were uniform regardless of depth. The study made in April-May 1964 will provide water quality data of Lake Mead prior to releases from Lake Powell as a basis for evaluating Lake Powell's effect on water quality and limnology of Lake Mead. The performance of a DO analyzer was tested and found unsatisfactory at depths below 150 ft. Parameters tested by standard chemical analyses of water samples in the Denver Laboratory and by field tests from a boat laboratory at 16 sampling stations on the reservoir were: pH, electrical conductivity, temperature, dissolved oxygen, and dissolved carbon dioxide. Results were: (1) pH at all stations was relatively constant except at Station 1 where the increase was probably due to release of carbon dioxide by decomposition of organic matter. More plant growth was observed here than at any other station. (2) DO content averaged 9.8 ppm at the surface and 8.6 near the bottom. (3) Except at Station 1 no dissolved carbon dioxide was found in the surface water. (4) Regardless of station or water depth, electrical conductivity was uniform throughout the basin. (5) Water temperature to 100 ft varied from 54.8 to 61.5 deg F and below this depth was quite uniform at 52 to 53 deg F.

DESCRIPTORS-- *dissolved oxygen/ reservoirs/ water supplies/ limnology/ pH/ temperature/ salinity/ *water quality/ test procedures/ multiple purpose projects/ chemical engineering/ chemical analysis/ chemistry/ basins/ field laboratories/ field tests/ laboratory tests/ water sampling/ field data/ water management/ *water analysis/ research and development
IDENTIFIERS-- Lake Mead/ Boulder Canyon Project/ *water chemistry/ Winkler method/ polarographic probes/ electrical conductivity/ dissolved carbon dioxide/ Lake Powell/ impoundment

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Office of Chief Engineer
Division of Research
Chemical Engineering Branch
Chemistry Section
Denver, Colorado 80225

Report No. ChE-46
Written by: P. R. Tramutt
Checked and reviewed by: H. M. Hunter
Submitted by: L. O. Timblin, Jr.

Subject: Water Chemistry Survey of Boulder Basin--Lake Mead

Introduction

During FY 1961, the Bureau of Reclamation initiated a research program to determine the effects of irrigation, power, flood control, and other types of water impoundment or regulatory structures upon the oxygen content of streams and reservoirs in the western United States.

Chemical Laboratory Report No. CH-103, dated April 20, 1961, "Progress Report--an Investigation of the Effect of Engineering Structures Upon the Dissolved Oxygen Content of Streams and Reservoirs," and Laboratory Report No. CH-105, dated December 28, 1962, "Progress Report No. 2--an Investigation of the Effect of Engineering Structures Upon the Dissolved Oxygen Content of Streams and Reservoir" described and discussed the objectives of the program and presented results of investigations performed during FY 1961, 1962, and 1963.

During the above period, the program was concerned primarily with (1) laboratory testing to determine the most reliable and practical method for collecting and testing water samples for dissolved oxygen content, (2) field investigations to determine the dissolved oxygen content of water at various locations on the Colorado-Big Thompson Project and, (3) review of technical literature pertaining to instrumentation for measuring dissolved oxygen "in situ" without the necessity of bringing water samples to the surface.

As a result of these investigations it was concluded that (1) the sodium azide modification of the Winkler method (see Appendix) is probably the most reliable available, but that the equipment required to collect and test samples by this method is too heavy, cumbersome, and/or fragile to be used in wide-scale investigations, (2) the engineering structures on the Colorado-Big Thompson Project are not adversely affecting the dissolved oxygen content of water passing through or impounded by them and, (3) further investigations should be made of available commercial instrumentation capable of "in situ" measurement of dissolved oxygen in streams and reservoirs.

As a result of Conclusion No. 3, several industrial instrument companies were contacted for information regarding equipment which they manufacture for "in situ" measurement of dissolved oxygen in waters at depths down to 400 feet. It was found that several instruments were available for measurement of dissolved oxygen in flowing streams of water or other liquids, but that only one of the companies contacted markets equipment especially designed for use in deep water. An oxygen analyzer was subsequently purchased from this company.

Due to the increasing importance given to the quality of municipal and industrial water, the FY 1964 dissolved oxygen program was expanded to include other chemical parameters. Lake Mead was selected for the initial field survey under this expanded program because it would provide (1) water quality data in Lake Mead before the impoundment of water in Lake Powell becomes a significant factor, (2) a basis for evaluating the effect of releases of water from Lake Powell on the quality of Lake Mead water and, (3) an opportunity to evaluate the operation of the dissolved oxygen analyzer at depths down to 400 feet.

The construction of Glen Canyon Dam and the filling of Lake Powell will have pronounced and profound effects on the limnology of Lake Mead. The temperature of the inflow will be radically changed by Glen Canyon Dam and the influence of the spring floods upon the temperature of Lake Mead will also be significantly changed.

Since Lake Powell was filling, it appeared urgent that a water chemistry study be performed in FY64 in Lake Mead. This period provided the last opportunity to obtain such data before the influence of Lake Powell became the overriding factor.

A previous study of the limnology of Lake Mead was performed in 1948-50 cooperatively by the Bureau of Reclamation, Geological Survey, and the U. S. Navy Electronics Laboratory. Since the first survey in 1948-50, continuing monthly measurements have been made of dissolved oxygen and temperature with depth at the intake towers, These measurements are a valuable guide to the water quality released from the reservoir but give no indication of the water quality at other locations in the reservoir basin or the important limnological trends which may be taking place and which may ultimately affect the quality of the water released.

<u>Water Quality Studies, Boulder Basin, Lake Mead</u>

A limited survey of certain limnological factors was undertaken during April and May 1964 to include such parameters as pH, electrical conductivity, temperature, dissolved carbon dioxide, and dissolved oxygen.

These studies were performed to provide basic data regarding the effects of upstream storage upon the quality of the impounded water. Except for monthly samples taken at the intake towers by project personnel, little was known of the quality of the water. For this reason, it was decided that a profile of Boulder Basin would provide a basis for future surveys regarding the effect of upstream storage.

The following program was performed with the assistance of project personnel, the boat operator, and laboratory technician, using the project's 35-foot cabin cruiser as a temperatory laboratory.

1. Sampling stations--16 sites in Boulder Basin of Lake Mead were selected for this program and are shown on the map in the Appendix. The station locations are in the same general area as those of the 1948-50 study.

2. Test program

(a) Temperature and dissolved oxygen determinations were made of the lake water at 10- to 25-foot depth intervals at each station. The readings were obtained "in situ" by lowering the probe of an oxygen analyzer and observing the temperature and percent oxygen saturation on the instrument panel.

(b) Electrical conductivity measurements were made of the lake water at each depth tested, by lowering the conductivity cell of a salinometer.

(c) Water samples were collected at all depths tested by lowering a sampling assembly and bringing samples of water to the surface for the following tests:

(1) pH by a portable pH meter

(2) Dissolved oxygen by the Winkler method (see Appendix)

(3) Dissolved carbon dioxide by chemical methods (see Appendix)

(4) Complete chemical analyses on three samples of water

At each site a minimum of 6 depth locations were tested. During this survey, malfunctions of the oxygen analyzer were encountered. It was then decided that in order to insure reliable dissolved oxygen data, additional analyses should be performed by standard chemical methods (Winkler method).

3. Tabular and graphic results of the survey

Discussion of Test Results

1. pH--The pH at all stations remained relatively constant with the sole exception at Station 1 (see Figure 1). The increase from 7.0 at the 100-foot depth to 7.9 from 150 to 300 feet was probably due to the release of CO_2 by the decomposition of organic matter. More plant growth was observed at this station than at any other.

2. Dissolved Oxygen--The DO content of the surface water (0-5 feet) varied from 9.5 to 10.3 ppm with an average of 9.8, while that from near the bottom of the lake varied from 7.9 to 8.9 ppm, with an average of 8.6 ppm. Most of the decrease occurred in the first 100 feet of depth (see Figure 1). The dissolved oxygen data obtained with the use of the oxygen analyzer (polarographic probe) has been recorded in a separate table (see Table 2).

Due to malfunctions of the instrument, continuous readings were not made at all depths at each station. The data represents only readings taken while the instrument was operable. The failure of the analyzer was due to the ingress of water into the motor compartment of the stirrer assembly. This condition was aggravated each time the stirrer was lowered to depths greater than 150 feet until a sufficient amount of water caused the motor to stop completely. A new stirrer was received from the manufacturer and it also failed when water entered the motor assembly.

3. Dissolved Carbon Dioxide--With one exception, no dissolved CO_2 was found in the surface water. The CO_2 content of the water near the bottom of the lake varied from 0.5 to 3.5 ppm with an average of 1.7 ppm. At Station 1 only did the amount of CO_2 increase sharply. The increase was 0 to 3.5 ppm at depths of 50-400 feet respectively. This increase was probably due to the decomposition of organic matter.

4. Electrical Conductivity--Regardless of the station or the depth of the water, the conductivity of the water was quite uniform throughout the basin. The conductivity of the surface water varied from 1,070 to 1,100 millimhos per cm, with an average of 1,082, and that of the water near the bottom varied from 1,100 to 1,130 millimhos per cm, with an average of 1,114. The greatest variation between surface and bottom water at the same station was 50 millimhos per cm, and the average difference was 30, indicating that the over-all quality of the water was uniform.

5. Temperature--The temperature of the water to depths of 100 feet varied from 54.8 - 61.5° F; however, below this depth the water was quite uniform at 52 - 53° F.

Future Studies

1. Continue surveys of Boulder Basin to determine the seasonal variations in water quality.

2. Continue testing Dissolved Oxygen Probes in order to determine their reliability, accuracy, and usefulness.

3. Expand program to include studies in areas of tourist and recreational densities to ascertain whether these areas are affecting the water quality.

4. Establish one or two stations downstream from Lake Mead for quality of water studies.

Summary and Conclusions

During April-May a water quality survey of Boulder Basin in Lake Mead was completed. Monthly measurements of dissolved oxygen, temperature, and electrical conductivity are continuing to be made at various depths at the intake towers by project personnel. While the data obtained are a valuable guide to the quality of the water released from the reservoir, they give no indication of the water quality trends which may be taking place and which may ultimately affect future releases. This survey included testing at 16 stations with a minimum of 6 depths, for the determination of (1) dissolved oxygen, (2) dissolved carbon dioxide, (3) pH, (4) electrical conductivity, and (5) temperature. Results of the survey indicate both uniform and chemical quality (Table 4) and dissolved oxygen (Table 3), regardless of depth. It therefore does not appear that the impoundment of water behind Hoover Dam has adversely affected the dissolved oxygen content.

Acknowledgments

This report is the result of the combined efforts of many persons including the following Bureau of Reclamation laboratory and field personnel. The assistance of these individuals and all others who participated in the planning and organizing of the program was deeply appreciated.

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Table 1

TEST DATA
WATER QUALITY SURVEY
LAKE MEAD--BOULDER BASIN
April-May 1964
16 Stations

Station No.	Determination	Sample depth, feet 5	25	50	100	150	200	250	300	350	400
1	pH	7.4	7.4	7.2	7.0	7.9	7.9		7.9	7.2	7.2
	DO, ppm (Winkler)	9.53	-	9.27	9.08	8.94	8.68	8.50	8.42	8.35	8.27
	Dissolved CO_2, ppm	0.00	0.00	0.00	0.97	1.94	2.13		1.45	2.69	3.54
	Ec x 10^6, micromhos/cm	1,090	1,075	1,050	1,085	1,095	1,110		1,120	1,125	1,125
	Temperature, °F	55.4	55.4	55.4	52.7	52.0	52.0		52.0	52.0	52.0
2	pH	8.2	8.2		8.2		8.2		8.2	8.2	8.2
	DO, ppm (Winkler)	10.1	10.4		9.10		8.64		8.65	8.58	8.18
	Dissolved CO_2, ppm	0.00	0.00		0.48		0.48		0.48	0.48	0.48
	Ec x 10^6, micromhos/cm	1,060	1,070		1,060		1,100		1,120	1,125	1,125
	Temperature, °F	58.5	57.4	56.3	53.4		51.8		51.8	51.8	51.8
3	pH	8.2	8.1		8.1		8.1	8.1	8.1	8.1	
	DO, ppm (Winkler)	10.3	10.2		9.55		9.16	9.1	8.6	8.6	
	Dissolved CO_2, ppm	2.42	0.97		0.97		0.97	1.45	1.45	1.45	
	Ec x 10^6, micromhos/cm	1,060	1,060		1,080		1,110	1,110	1,120	1,120	
	Temperature, °F	58.8	57.4		53.0		51.8	51.8	51.8	51.8	
4	pH	8.2	8.2	8.1	8.0		8.0		8.0	7.9	7.8
	DO, ppm (Winkler)	10.1	9.84	9.45	9.05		8.75		8.87	8.88	8.42
	Dissolved CO_2, ppm	0.00	0.00	0.00	1.45		1.94		1.94	0.97	0.97
	Ec x 10^6, micromhos/cm	1,075	1,080	1,080	1,085		1,115		1,125	1,125	1,130
	Temperature, °F	56.8	55.8	54.7	52.3		51.8		51.6	51.6	51.6

Table 1 (Continued)

Station No.	Determination	5	25	50	100	150	200	250	300	350	375	400
5	pH	7.8	8.0	8.1	8.2		8.1		8.1	8.1	8.1	
	DO, ppm (Winkler)	10.2	10.0	9.79	8.98		8.86		8.87	8.72	8.62	
	Dissolved CO_2, ppm	0.00	0.00	0.00	0.97		1.45		1.45	1.45	1.45	
	Ec x 10^6, micromhos/cm	1,070	1,080	1,080	1,100		1,100		1,120	1,125	1,125	
	Temperature, °F	57.9	57.6	56.1	52.2	52.2	52.8	52.8	52.8	52.8	52.8	
6	pH	8.4	8.4	8.2	8.2		8.2		8.2	8.2		8.2
	DO, ppm (Winkler)	8.98	9.17	9.51	9.41		8.76		8.91	8.85		8.54
	Dissolved CO_2, ppm	0.00	0.00	0.00	0.97		0.97		0.97	0.97		0.97
	Ec x 10^6, micromhos/cm	1,080	1,075	1,080	1,080		1,110		1,115	1,125		1,130
	Temperature, °F	61.2	58.6	54.7	52.5	52.8	51.6	51.6	51.6	51.6		51.6
7	pH	7.8	8.1	8.0	8.1		8.1		8.0		8.0	
	DO, ppm (Winkler)	9.66	9.72	9.69	8.98		8.73		8.73		8.66	
	Dissolved CO_2, ppm	0.00	0.00	0.00	0.97		0.97		0.97		0.97	
	Ec x 10^6, micromhos/cm	1,080	1,080	1,075	1,060		1,105		1,120		1,130	
	Temperature, °F	59.4	58.3	57.9	52.3		51.6		51.6		51.6	
8	pH	8.2	8.2	8.2	8.1	8.1	8.1					
	DO, ppm (Winkler)	9.60	9.68	9.38	9.00	8.55	8.55					
	Dissolved CO_2, ppm	0.00	0.00	0.00	0.97	0.97	1.94					
	Ec x 10^6, micromhos/cm	1,085	1,070	1,060	1,070	-	1,110					
	Temperature, °F	60.8	58.5	55.2	53.1	52.2	51.8					

Table 1 (Continued)

Station No.	Determination	Sample depth, feet 5	25	50	100	150	200	250	300	350	400
9	pH	8.0	8.0	8.2	8.2	8.2	8.1				
	DO, ppm (Winkler)	9.70	9.86	9.10	8.69	8.69	8.42				
	Dissolved CO_2, ppm	0.00	0.00	0.00	1.45	1.45	1.94				
	Ec x 10^6, micromhos/cm	1,090	1,080	1,060	1,085	1,100	1,135				
	Temperature, °F	61.5	59.5	55.0	52.9	52.9	52.3				
10	pH	8.0	8.2	8.2	8.2	8.1	8.1				
	DO, ppm (Winkler)	9.57	9.62	9.67	8.94	8.74	8.75				
	Dissolved CO_2, ppm	0.00	0.00	0.00	0.00	0.97	2.42				
	Ec x 10^6, micromhos/cm	1,080	1,080	1,080	1,070	1,085	1,100				
	Temperature, °F	59.7	59.0	58.8	52.5	52.5	52.0				
11	pH	8.3	8.3	8.3	8.2		8.1		8.0	8.0	
	DO, ppm (Winkler)	9.62	9.62	9.61	8.88		8.81		8.79	8.61	
	Dissolved CO_2, ppm	0.00	0.00	0.00	0.97		2.42		2.42	2.42	
	Ec x 10^6, micromhos/cm	1,075	1,080	1,080	1,080		1,100		1,125	1,125	
	Temperature, °F	59.9	59.5	59.0	53.2		52.0		52.0	52.0	
12	pH	8.0	8.1	8.1	7.8		7.5		7.5		
	DO, ppm (Winkler)	9.51	9.50	9.48	8.93		8.83		8.80		
	Dissolved CO_2, ppm	0.00	0.00	0.00	1.94		2.42		2.42		
	Ec x 10^6, micromhos/cm	1,080	1,080	1,085	1,085		1,100		1,120		
	Temperature, °F	54.8	57.9	57.6	54.3		52.0		52.0		

Table 1 (Continued)

Station No.	Determination	Sample depth, feet 5	25	50	100	150	200	250	300	350	400
13	pH	8.3	8.2	8.2	8.0		7.8	7.8			
	DO, ppm (Winkler)	9.50	9.46	9.46	8.78		8.75	8.81			
	Dissolved CO_2, ppm	0.00	0.00	0.00	0.97		1.94	2.42			
	Ec x 10^6, micromhos/cm	1,075	1,080	1,080	1,070		1,105	1,110			
	Temperature, °F	59.0	58.5	58.5	54.5		53.0	52.5			
14	pH	8.2	8.2	8.3	8.3	8.2	8.1		8.0		
	DO, ppm (Winkler)	9.49	9.49	9.55	8.78	8.87	8.90		8.86		
	Dissolved CO_2, ppm	0.00	0.00	0.00	1.94	1.94	2.42		2.42		
	Ec x 10^6, micromhos/cm	1,080	1,080	1,080	1,080	1,065	1,085	1,100	1,120		
	Temperature, °F	58.5	58.5	58.5	58.0	52.7	52.0	52.0	52.0		
15	pH	8.1	8.1	8.1	7.9	7.9					
	DO, ppm (Winkler)	9.46	9.44	9.45	8.86	8.79					
	Dissolved CO_2, ppm	0.00	0.00	0.00	1.45	1.45					
	Ec x 10^6, micromhos/cm	1,080	1,080	1,080	1,050	1,100					
	Temperature, °F	59.0	58.6	58.8	53.2	52.0					
16	pH	8.0	8.1	8.0	7.9		7.8	7.8			
	DO, ppm (Winkler)	9.46	9.46	9.39	8.94		8.91	8.85			
	Dissolved CO_2, ppm	0.00	0.00	0.00	0.97		0.97	0.97			
	Ec x 10^6, micromhos/cm	1,070	1,080	1,080	1,080		1,120	1,125			
	Temperature, °F	61.0	61.0	59.5	54.0		53.0	53.0			

Table 2

DISSOLVED OXYGEN
POLAROGRAPHIC METHOD
LAKE MEAD--BOULDER BASIN

April-May 1964 Sheet 1 of 2

Sample depth (ft)	Temp deg F	Bar pressure mm Hg	Oxygen solubility ppm	Analyzer reading Percent sat	Analyzer reading Corr ppm	Winkler ppm
5	55.4	694	9.6	105	10.4	10.0
25	55.4		9.6	107	10.6	10.6
50	55.4		9.6	90	8.9	9.8
100	52.7		10.0	89	9.2	9.0
150	52.0		10.0	89	9.3	8.9
200	52.0		10.0	87	9.0	9.0
5	58.8	693	9.2	105	10.6	10.3
25	57.4		9.4	98	10.1	10.2
100	53.0		9.9	90	9.8	9.2
5	59.4	692	9.1	101	9.4	9.7
25	58.3		9.2	101	9.5	9.7
50	57.9		9.3	95	9.0	9.7
100	52.3		9.9	85	8.6	9.0
200	51.6		10.1	83	8.6	8.7
300	51.6		10.1	83	8.6	8.7
375	51.6		10.1	76	7.8 1/	8.7
Readings made with new stirrer						
5	60.8	692	9.0	113	10.4	9.6
25	58.5		9.2	109	10.2	9.7
50	55.2		9.6	97	9.5	9.4
100	53.1		9.9	90	9.1	9.0
150	52.2		10.0	86	8.8	8.6
200	51.8		10.0	85	8.7	8.6
5	61.5	692	9.1	109	10.1	9.7
25	59.5		9.1	105	9.8	9.9
50	55.0		9.6	92	9.0	9.1
100	52.9		9.9	86	8.7	8.7
150	52.9		9.9	86	8.7	8.7
200	52.3		10.0	83	8.5	8.4

1/Original stirrer began to fail.

Table 2 (continued)

Sample depth (ft)	Temp deg F	Bar pressure mm Hg	Oxygen solubility ppm	Analyzer reading Percent sat	Analyzer reading Corr ppm	Winkler ppm
5	59.7	688	9.1	97	9.1	9.6
25	59.0		9.2	98	9.3	9.6
50	58.8		9.2	95	9.0	9.7
100	52.5		9.9	85	8.7	8.9
150	52.5		9.9	84	8.6	8.7
175	52.0		10.0	83	8.6	8.8
5	59.9	688	9.1	100	9.4	9.6
25	59.5		9.1	98	9.2	9.6
50	59.0		9.2	98	9.3	8.9
100	53.2		9.9	88	9.0	8.8
200	52.0		10.0	87	9.0	8.8
300	52.0		10.0	86	8.9	8.8
350	52.0		10.0	86	8.9	8.6
5	58.5	693	9.2	104	10.0	9.5
25	58.5		9.2	100	9.6	9.5
50	58.5		9.2	99	9.5	9.6
100	58.0		9.3	96	9.3	8.8
150	52.7		10.0	89	9.3	8.9
200	52.0	693	10.0	90	9.4	8.9
300	52.0	693	10.0	2/	2/	8.9
5	54.8	695	9.8	103	10.1	9.5
25	57.9		9.3	105	9.8	9.5
50	57.6		9.4	104	9.8	9.5
100	54.3		9.8	91	8.9	8.9
200	52.0		10.1	89	9.0	8.8
300	52.0		10.1	89	-	8.8

2/New stirrer started to fail.

Table 3

DISSOLVED OXYGEN
WINKLER METHOD DETERMINATIONS
LAKE MEAD--BOULDER BASIN
April-May 1964
16 stations

Depth (ft)	Determinations (No.)	Dissolved oxygen, ppm		
		Av	High	Low
5	32	9.8	*10.3	9.5
25	15	9.8	*10.4	9.4
50	28	9.5	9.7	9.4
100	32	9.0	9.4	8.7
150	12	8.8	9.0	8.7
175	2	8.6	8.6	8.6
200	28	8.9	9.2	8.5
250	4	8.7	8.8	8.5
275	2	8.9	8.9	8.9
300	18	8.8	8.9	8.7
350	12	8.7	8.9	8.4
375	4	8.7	8.7	8.6
390	2	8.5	8.5	8.5
400	4	8.3	8.3	8.2

*The high values are probably due to the heavy wave action during testing program.

Table 4

CHEMICAL ANALYSES
LAKE MEAD--BOULDER BASIN

April-May 1964

Sample No.	B-8531	B-8532	B-8533
Location	Between intake towers at 5-ft depth	Between intake towers at 400-ft depth	Boulder Island Cove at 5-ft depth
K by 10^6 at 25° C	1,060	1,100	1,057
pH	8.1	7.9	7.9
Total dissolved solids, ppm	796	796	796
Calcium, ppm	87	90	95
Magnesium, ppm	28	30	25
Sodium, ppm	91	98	93
Potassium, ppm	5.5	5.5	5.5
Carbonate, ppm	0.0	0.0	0.0
Bicarbonate, ppm	144	151	143
Sulfate, ppm	291	294	291
Chloride, ppm	86	95	85
Nitrate, ppm	0.6	0.0	1.9

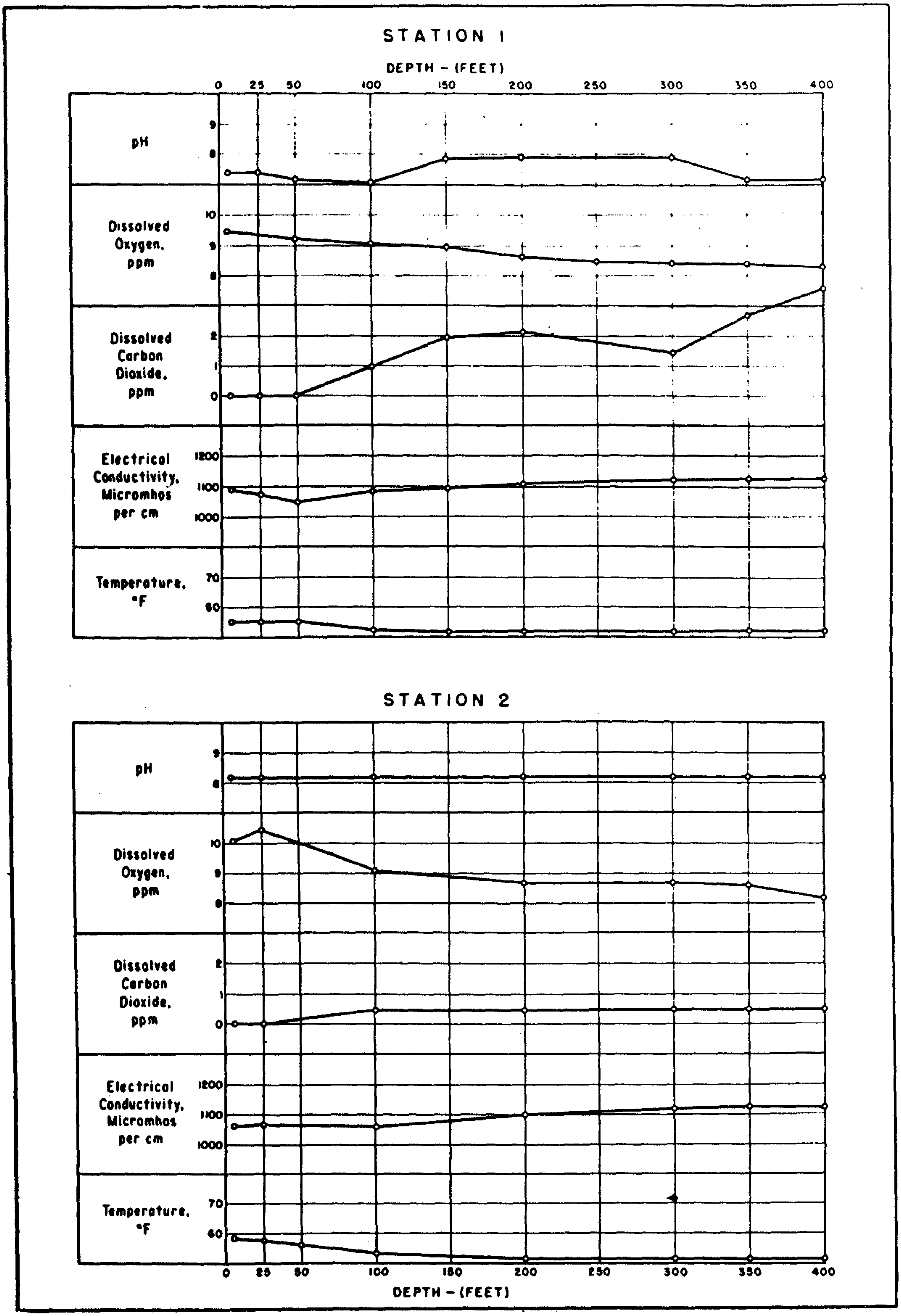
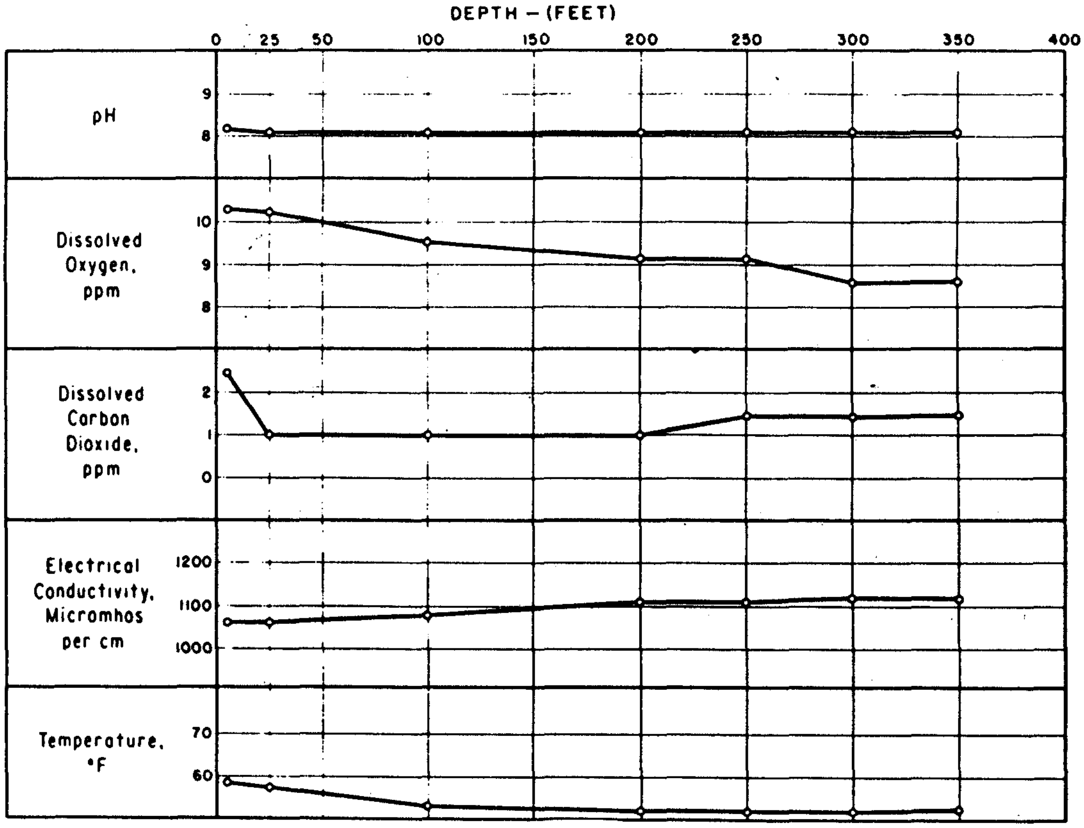
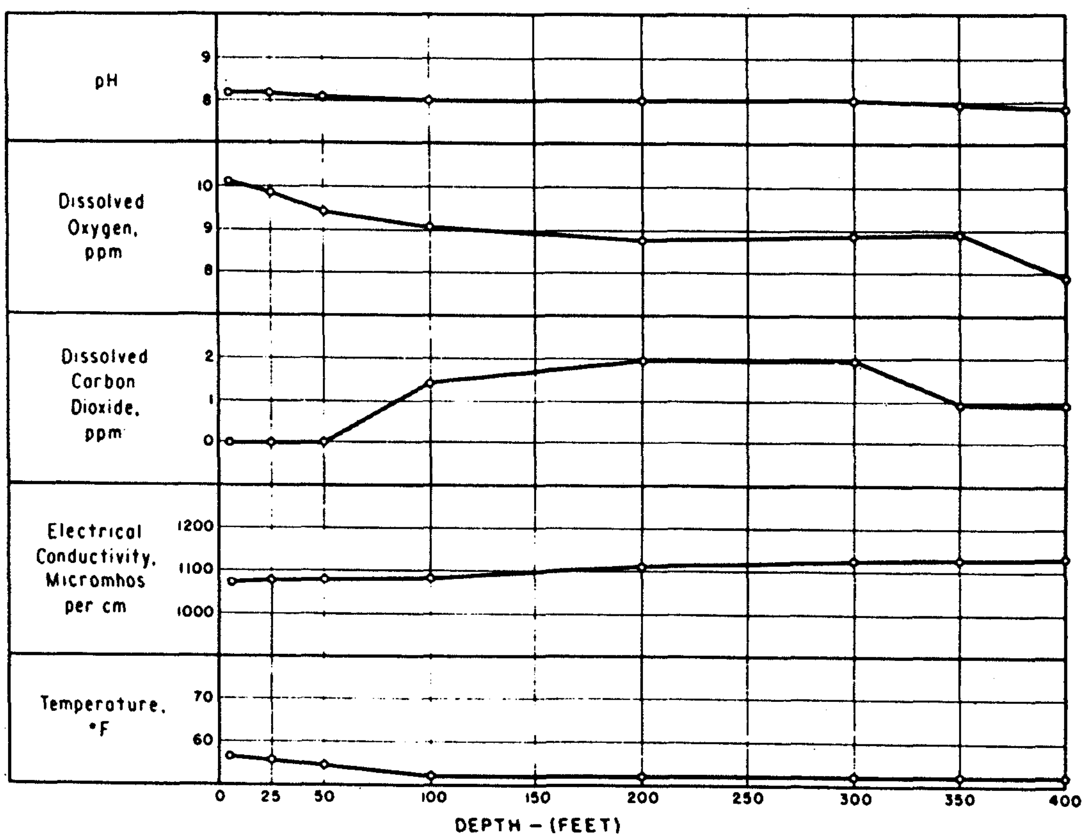

STATION 1
DEPTH - (FEET)
0 25 50 100 150 200 250 300 350 400
pH
9
8
Dissolved Oxygen, ppm
10
9
8
Dissolved Carbon Dioxide, ppm
2
1
0
Electrical Conductivity, Micromhos per cm
1200
1100
1000
Temperature, °F
70
60
STATION 2
pH
9
8
Dissolved Oxygen, ppm
10
9
8
Dissolved Carbon Dioxide, ppm
2
1
0
Electrical Conductivity, Micromhos per cm
1200
1100
1000
Temperature, °F
70
60
0 25 50 100 150 200 250 300 350 400
DEPTH - (FEET)

Figure 1

STATION 3



STATION 4



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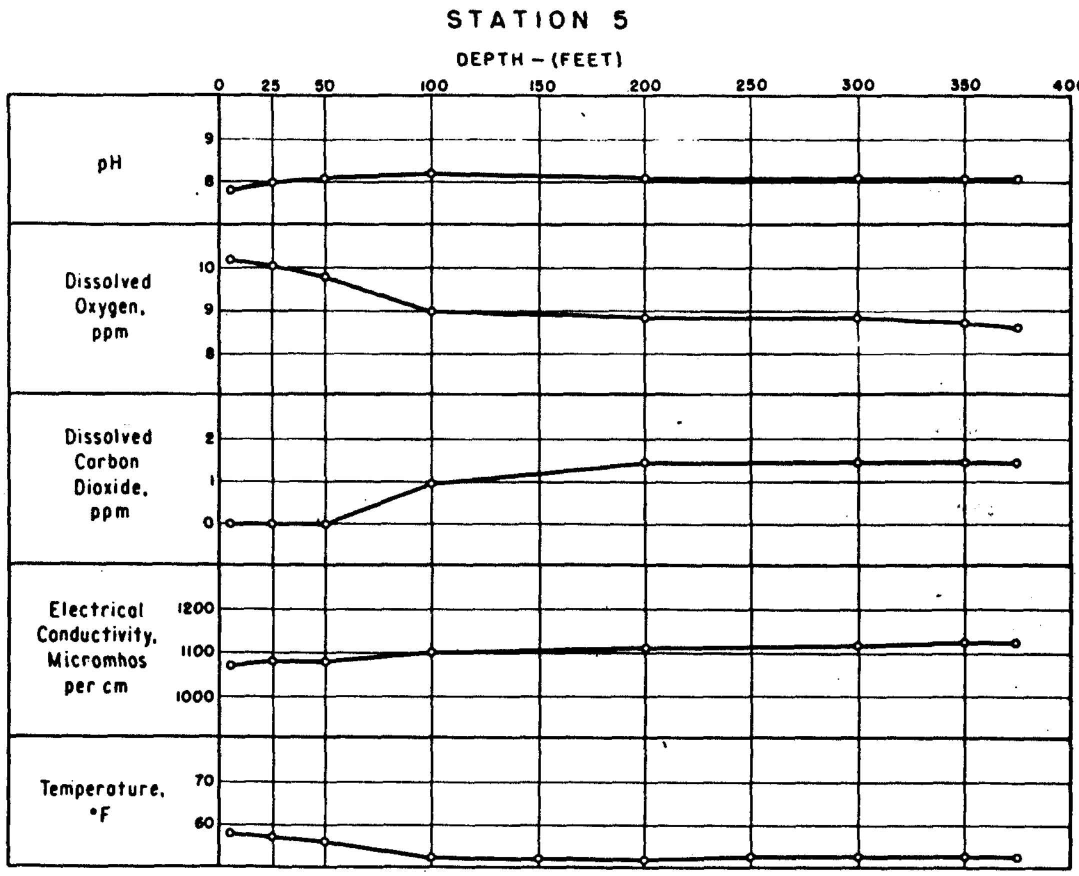

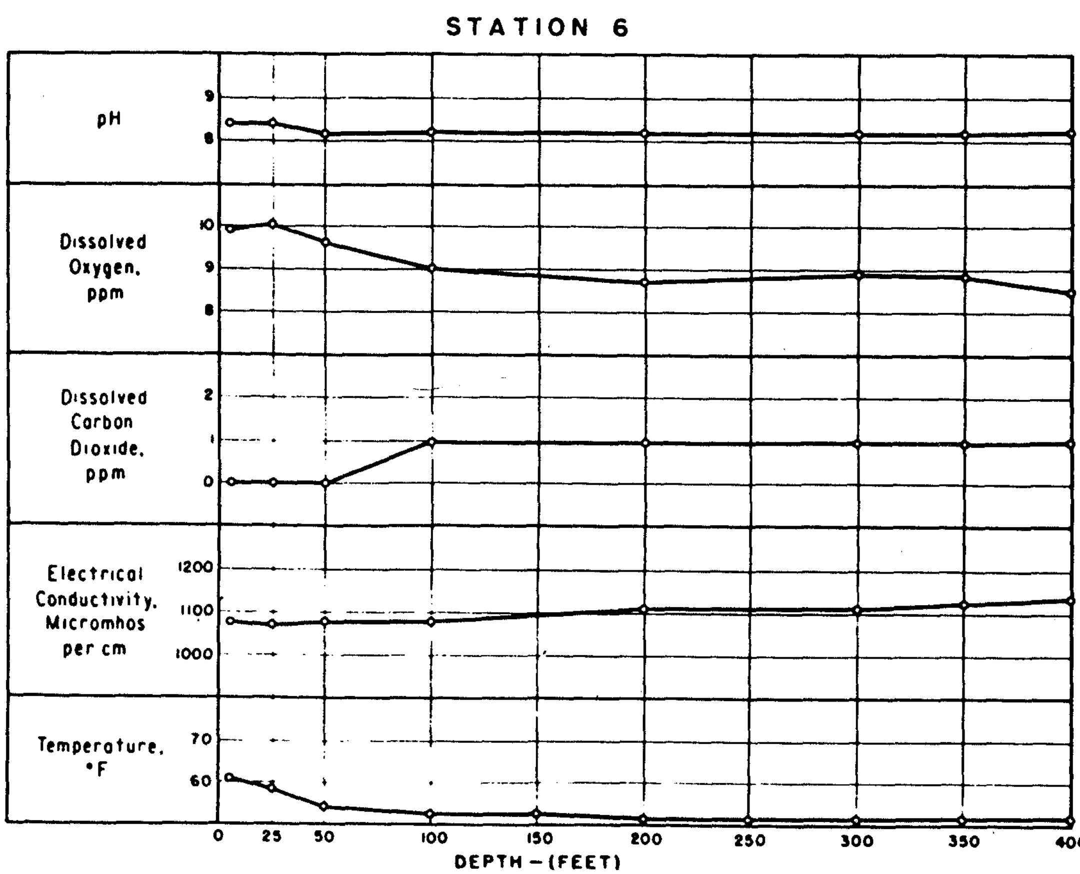

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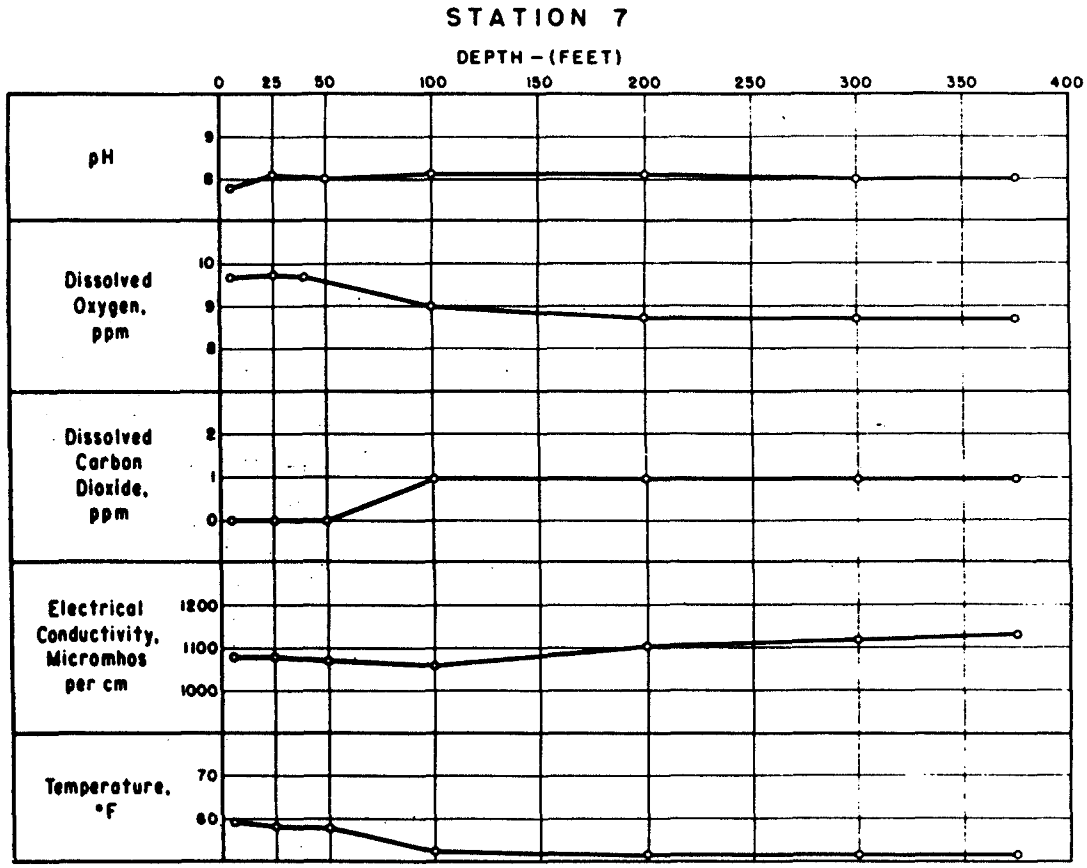


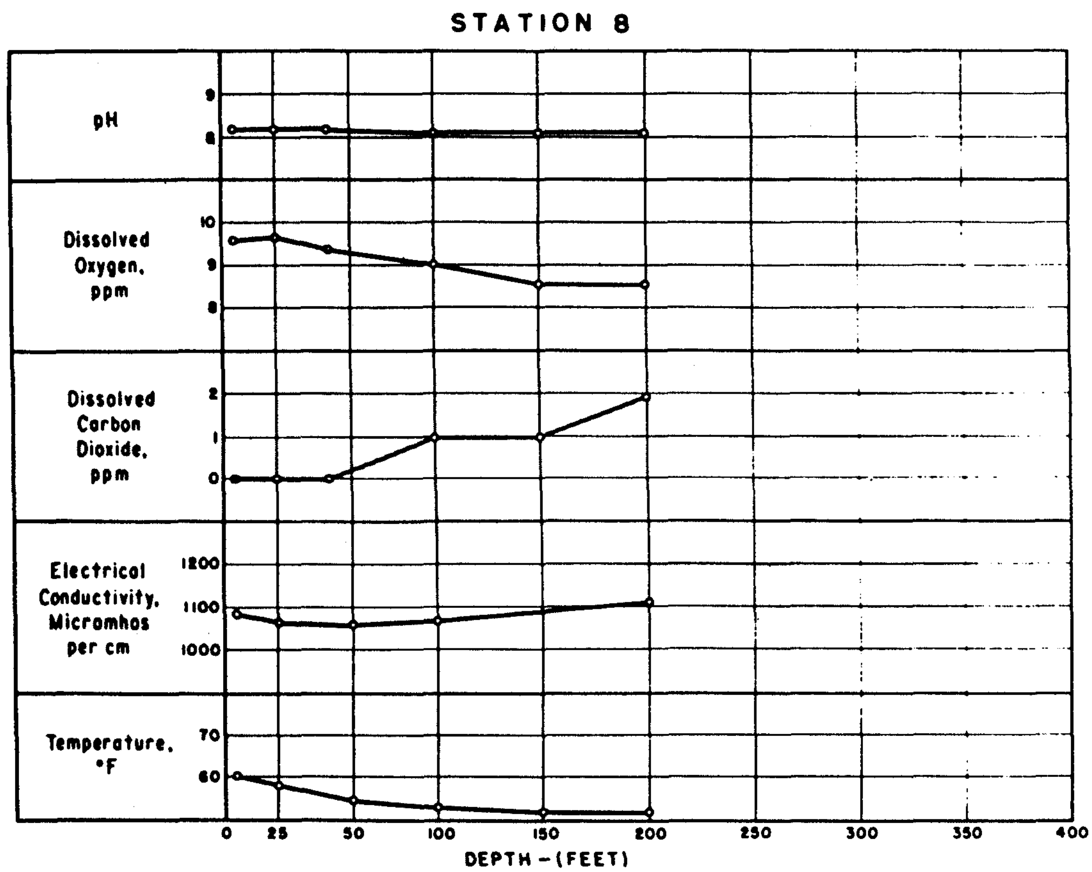
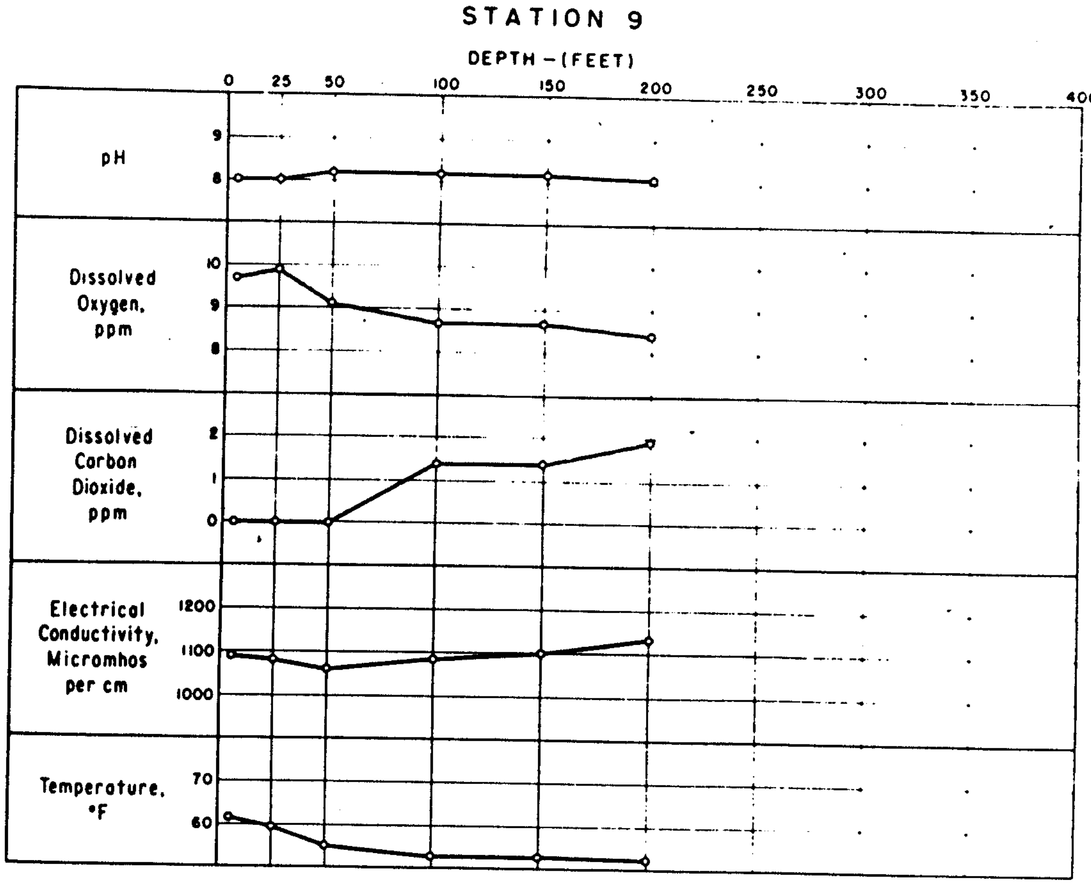
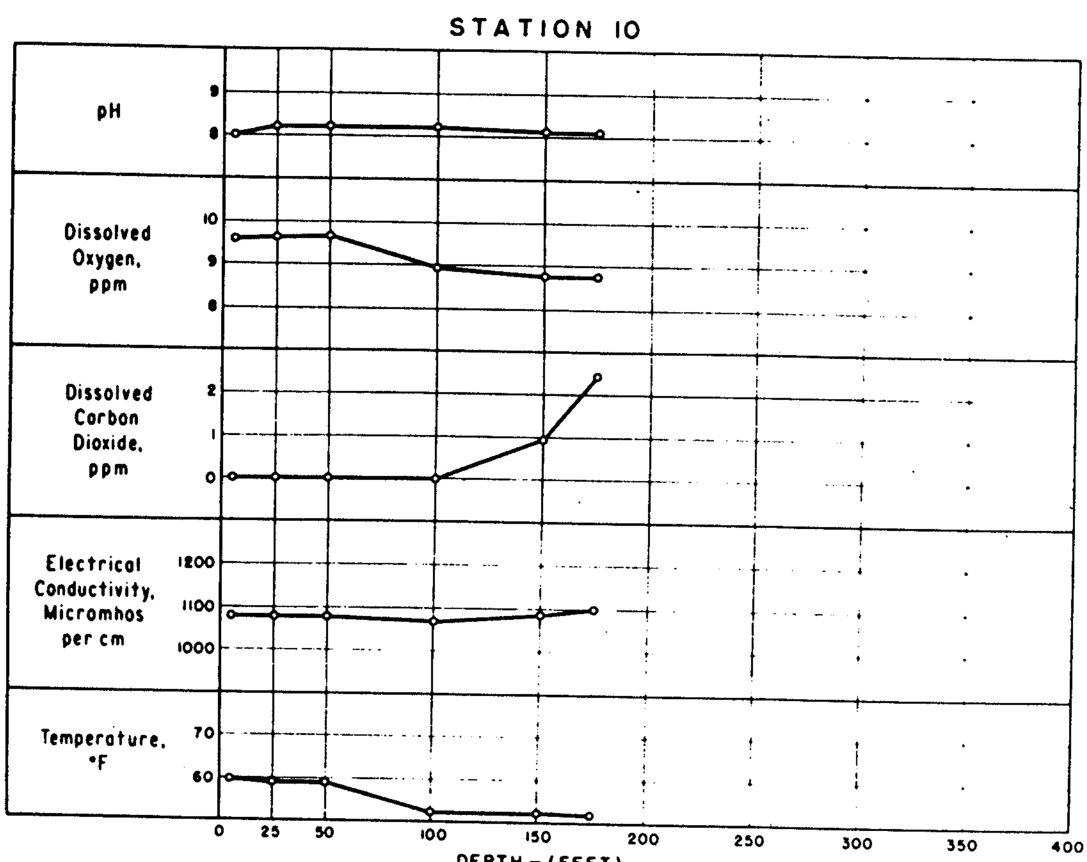


Figure 1 (continued) Sheet 4 of 8





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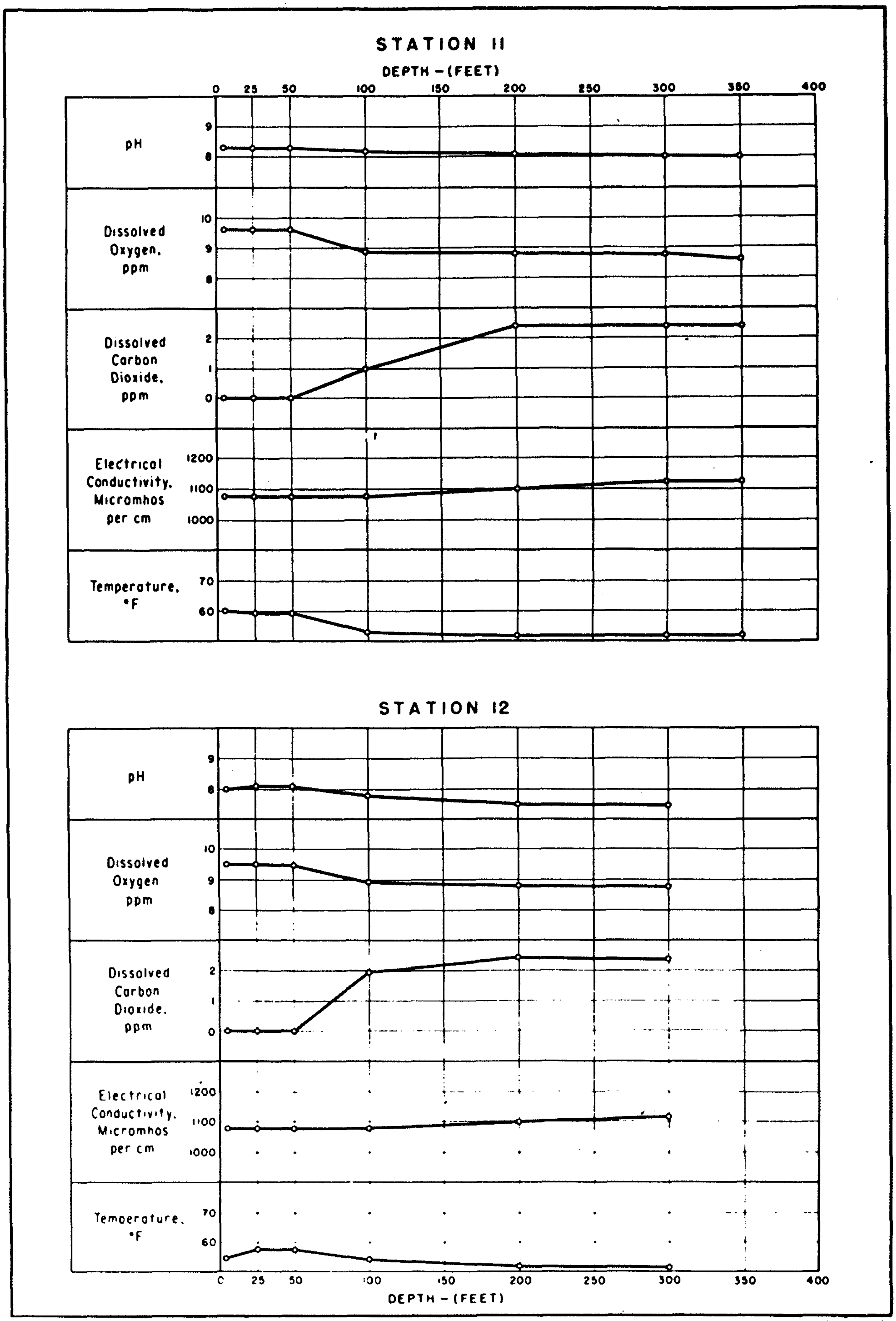
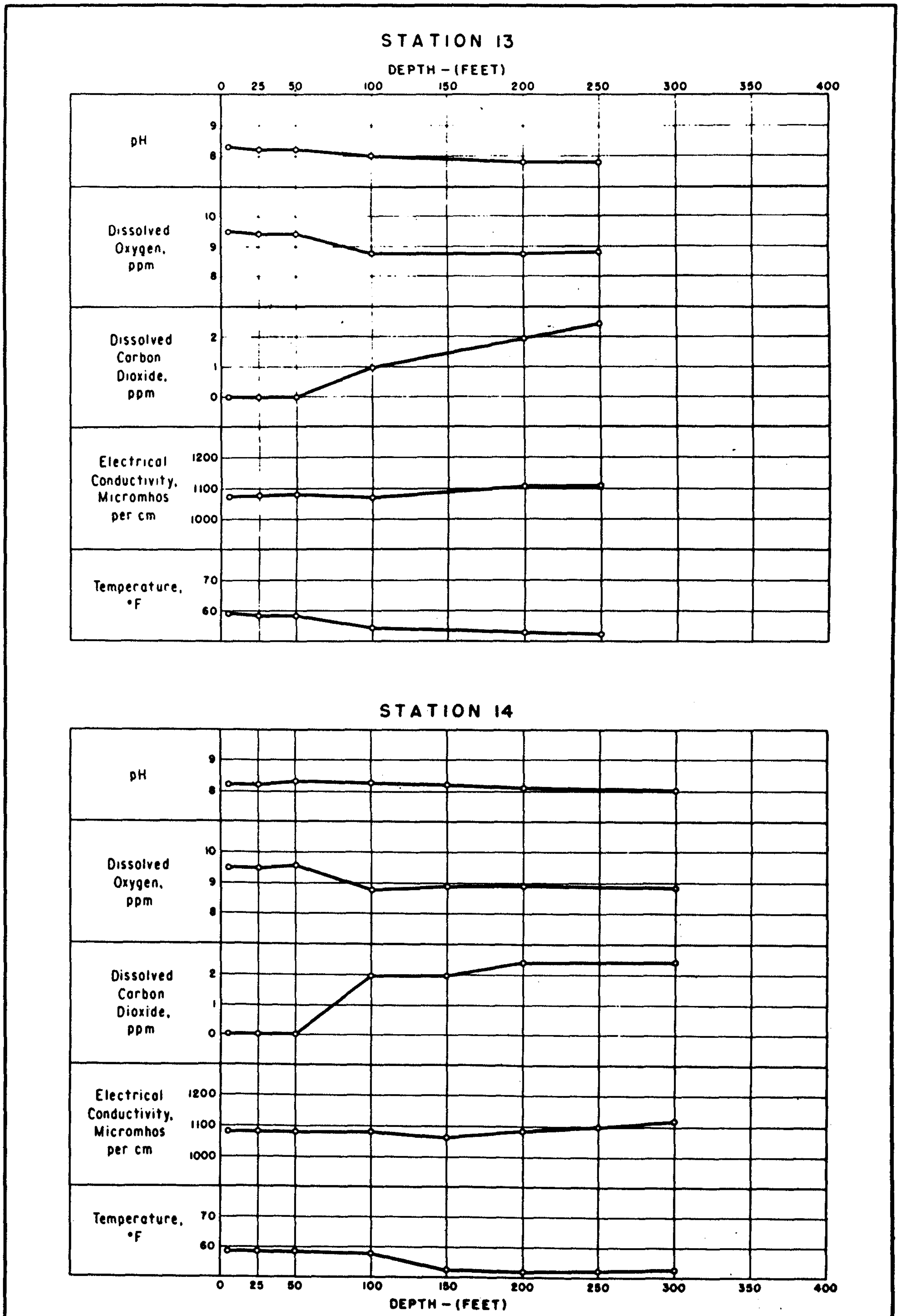


Figure 1 (continued) Sheet 6 of 8



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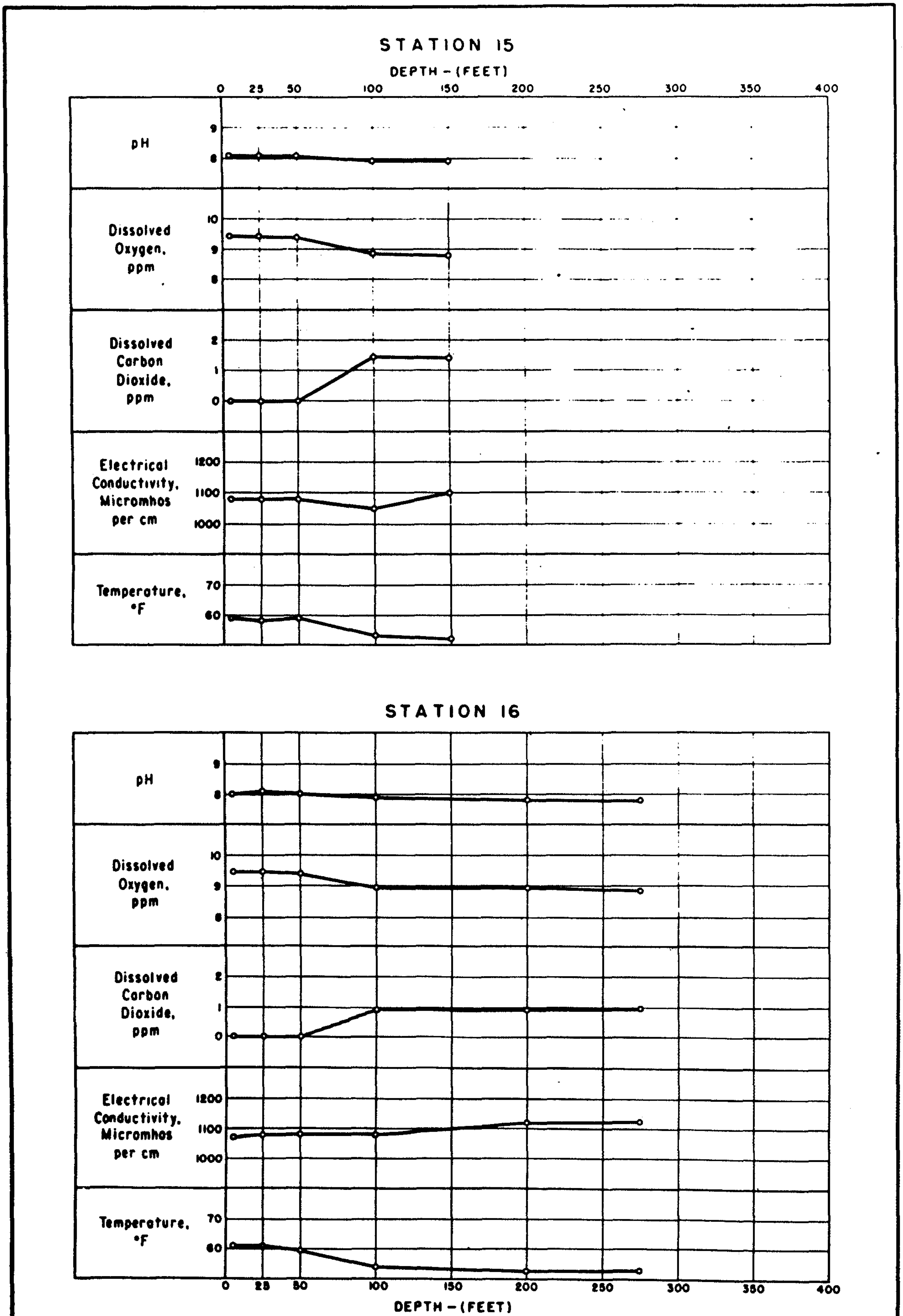
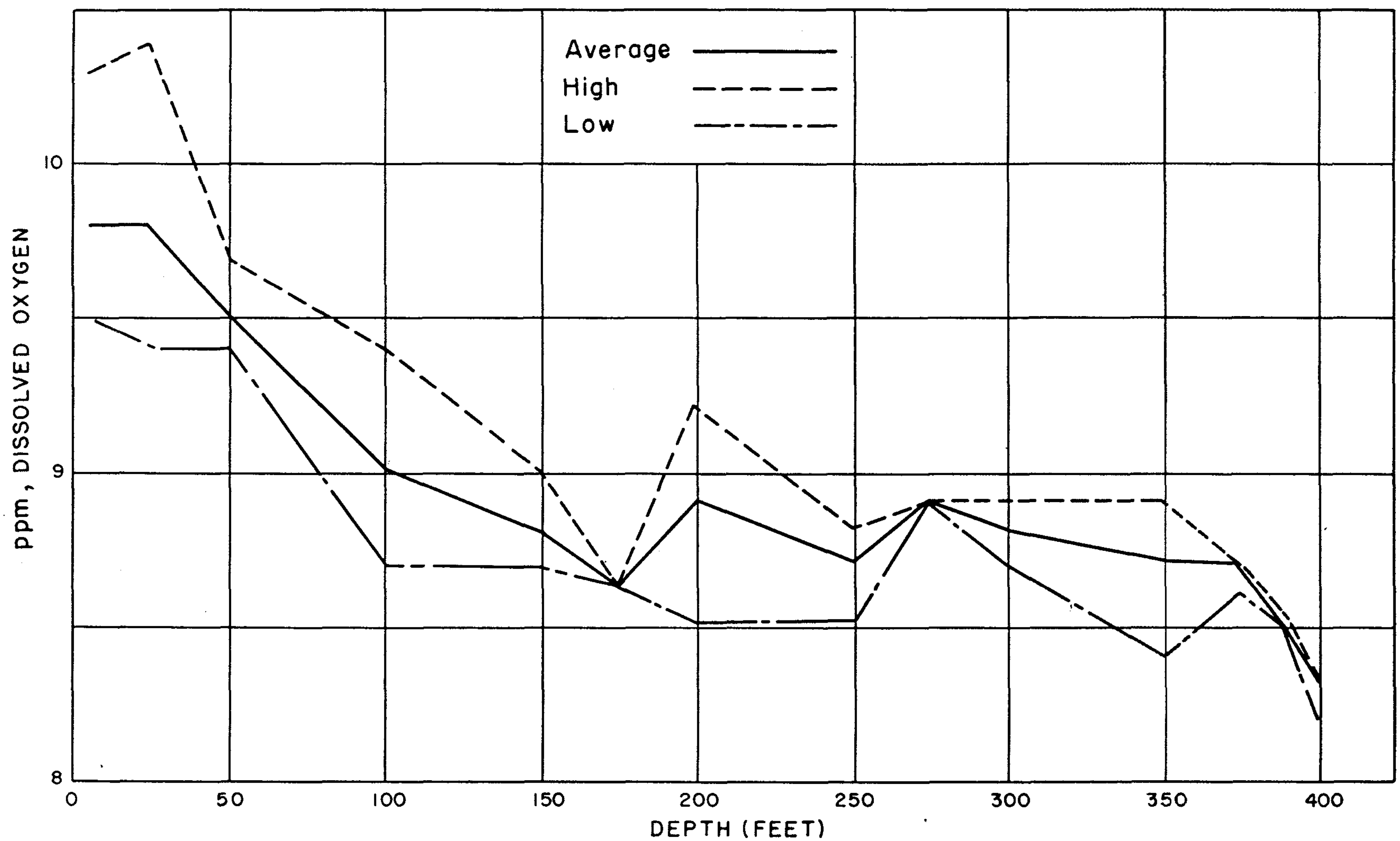


Figure 1 (continued)

Sheet 8 of 8



DISSOLVED OXYGEN CONTENT
WINKLER METHOD -- 16 STATIONS
LAKE MEAD -- BOULDER BASIN
APRIL - MAY 1964

FIGURE 2

WINKLER METHOD FOR DETERMINATION OF DISSOLVED OXYGEN*
(SODIUM AZIDE MODIFICATION)

Reagents

1. Manganous sulfate--Dissolve 480 grams of $MnSO_4.4H_2O$, 400 grams of $MnSO_4 \cdot 2H_2O$, or 364 grams of $MnSO_4 \cdot H_2O$ in distilled water, filter and dilute to 1 liter.

2. Alkali-iodide-azide--Dissolve 500 grams of NaOH (or 700 grams KOH) and 135 grams of NaI (or 150 grams KI) in distilled water and dilute to 1 liter. To this solution add 10 grams of NaN_3 dissolved in 40 milliliters of distilled water.

3. Concentrated sulfuric acid.

4. Starch solution--Prepare a thin paste of about 2 grams of soluble starch in cold water. Pour into 200 milliliters of boiling water and boil for a few minutes. When cool, add a few drops of chloroform, toluene, or about 0.25 gram of salicylic acid as a preservative.

5. Standard sodium thiosulfate stock solution--Dissolve 24.82 grams of $Na_2S_2O_3 \cdot 5H_2O$ in boiled and cooled distilled water and dilute to 1 liter. Preserve by adding 5 milliliters of chloroform or 1 gram NaOH.

6. Standard sodium thiosulfate solution, 0.025N--Prepare either by diluting 250.0 milliliters of stock sodium thiosulfate solution to 1 liter, or by dissolving 6.205 grams of $Na_2S_2O_3 \cdot 5H_2O$ in freshly boiled and cooled distilled water and diluting to 1 liter. Add 5 milliliters of chloroform or 0.4 gram of NaOH for a preservative. Standardize with biniodate.

7. Standard potassium biniodate solution, 0.025N--Dissolve 3.249 grams of $KH(IO_3)_2$ in distilled water and dilute to 1 liter. Dilute 250 milliliters of this solution to 1 liter.

8. Standardization--Dissolve approximately 2 grams of KI free from iodate in an Erlenmeyer flask with 100-150 milliliters of distilled water. Add 10 milliliters of H_2SO_4 (1:9) followed by exactly 20.00 milliliters of standard biniodate solution. Dilute to about 200 milliliters and titrate the liberated iodine with 0.025N thiosulfate solution until the solution is a pale straw color. Add 5 milliliters of starch solution and titrate to a colorless end point. Normality of the

$$\text{thiosulfate solution} = \frac{0.5000}{\text{ml. of thiosulfate solution required}} .$$

*Standard Method for the Examination of Water and Waste Water, pp. 309-12, 11th Edition, 1960, American Public Health Association, 1790 Broadway, New York 19, New York.

Procedure

To the sample in a 250- 300-milliliter D.O. bottle add 2 milliliters of the $MnSO_4$ solution followed by 2 milliliters of alkali-iodid-azide reagent well below the surface of the water. Stopper with care to avoid entrapping air bubbles and mix by inverting several times. When the precipitate (manganic basic oxide) settles, invert the bottle several times again. After the precipitate settles, carefully remove the stopper and immediately add 2 milliliters of concentrated H_2SO_4, allowing the acid to run down the neck of the bottle, restopper carefully and mix gently until solution of the precipitate is complete, and the released iodine is uniformly distributed throughout the solution. Titrate 203 milliliters* of the solution with 0.025 N sodium thiosulfate solution as in the standardization procedure.

Calculation

One milliliter of 0.025 N $Na_2S_2O_3$ is equivalent to 0.2 milligram of dissolved oxygen. Therefore, each milliliter of sodium thiosulfate used is equivalent to 1 milligram per liter of dissolved oxygen if a volume equal to 200 milliliters of original sample is titrated.

Determination of Dissolved Carbon Dioxide**

Reagents

1. Phenolphthalein indicator--Dissolve 5.0 grams of phenolphthalein in 1 liter of 50 percent alcohol. Neutralize the solution with 0.02N sodium hydroxide.

2. Standard sodium hydroxide stock solution

   (a) Dissolve 21 grams of NaOH in about 100 ml of distilled water and let stand for 48 hours in a wax-lined or polyethylene container protected from atmospheric CO_2 with a soda lime tube.

   (b) Pour off the supernatant liquid and transfer to a liter volumetric flask and dilute to a liter with freshly boiled and cooled distilled water. This solution should be approximately 0.5N.

   (c) Standardize against potassium biphthalate or sulfuric acid standards.

   (d) Store in a bottle as described in (a).

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*Equivalent to 200 milliliters of original sample corrected for addition of reagents.

**Analysis of Water and Sewage, pp. 9, 107, Theroux, Eldredge and Mallmann, Third Edition, McGraw-Hill Book Company

3. Standard N/44 sodium hydroxide--Dilute to 1 liter with freshly boiled and cooled distilled water the exact quantity of stock standard sodium hydroxide (2) as determined by the following formula:

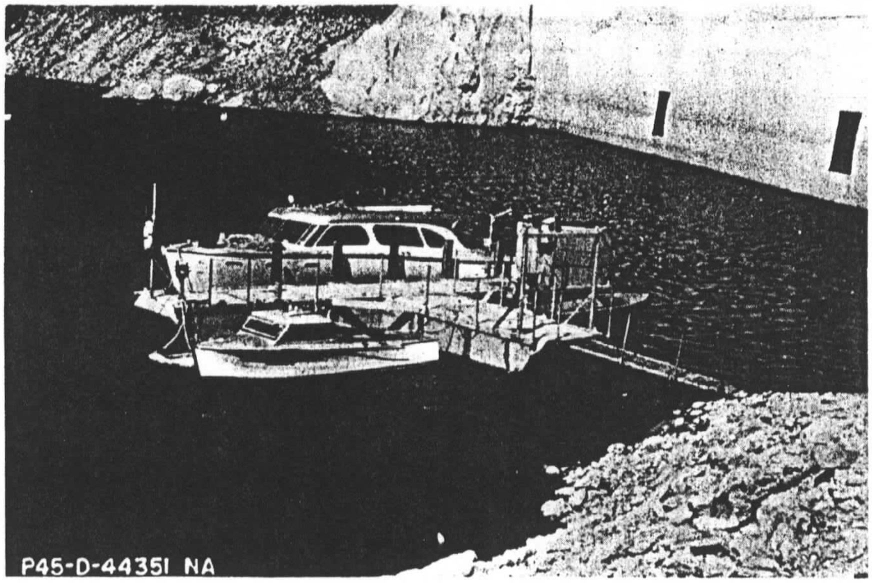
$$\frac{22.73}{\text{Normality of stock NaOH}} = \text{ml of stock NaOH to make 1 liter of N/44 NaOH}$$

Procedure

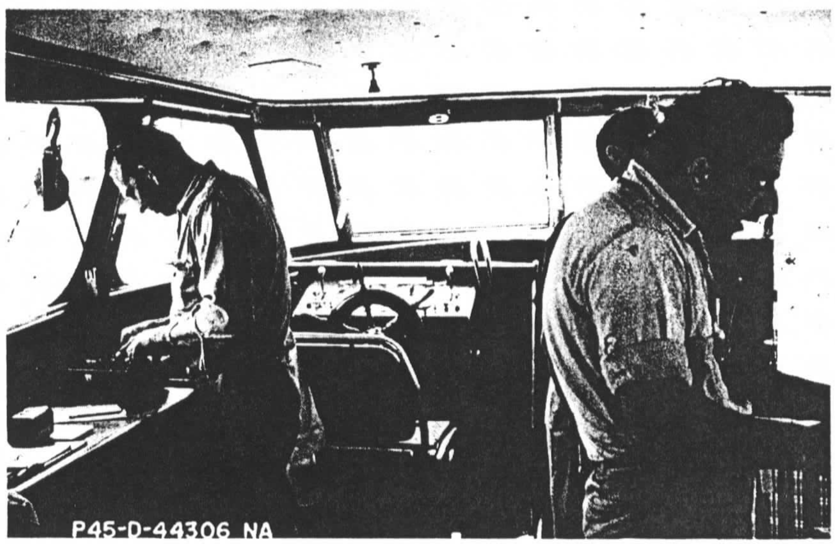
1. Collect sample by means of a rubber tube from water sample discharging into a 100-ml graduated cylinder. Allow the cylinder to overflow for a few minutes and withdraw the tubing while the sample is flowing. Adjust sample to 100 ml mark. Add five drops of phenolphthalein indicator. (Always use same amount of indicator for sample as for the standardization procedure.) If the sample turns red, free carbon dioxide is absent. If colorless, titrate rapidly into the cylinder with N/44 standard alkali solution, stirring gently with stirring rod until a definite pink color persists for 30 seconds. This color change is the end point.

Calculations:

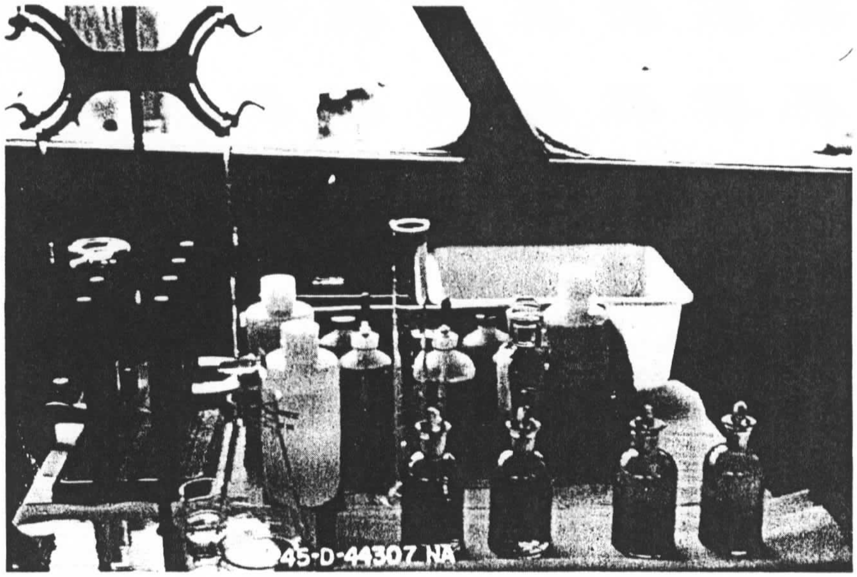
$$\text{mg/1 } CO_2 = \frac{\text{mlNaOHx N of NaOH x 44,000}}{\text{ml sample}}$$



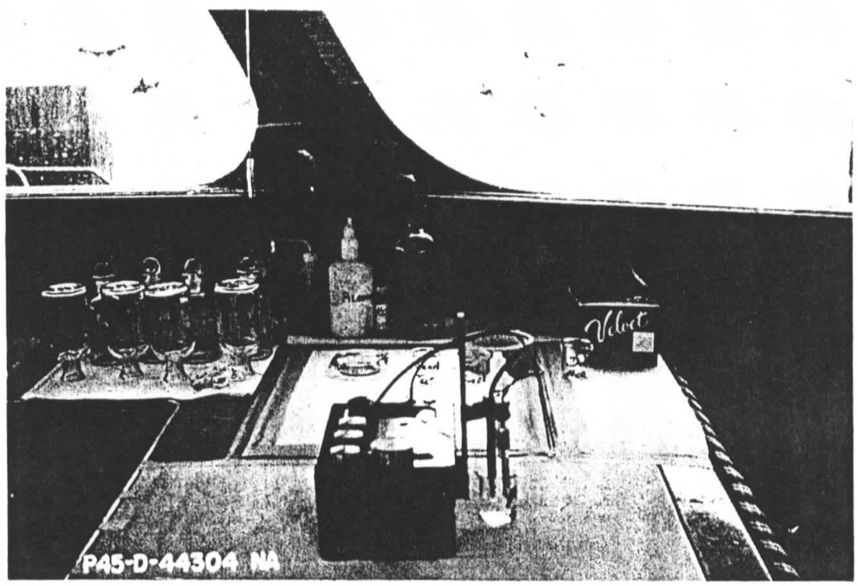
Project 35-foot cruiser used for Boulder Basin Water Quality studies



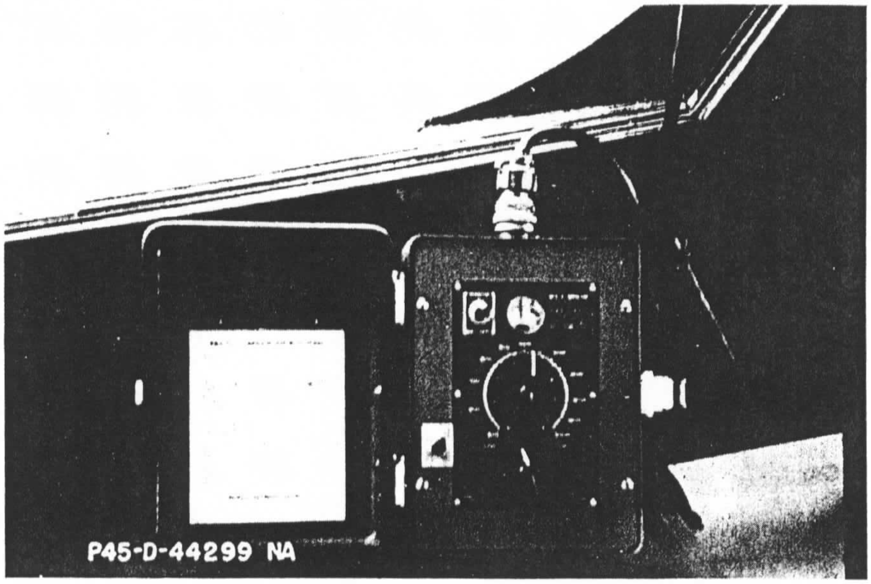
Personnel in laboratory area of cruiser



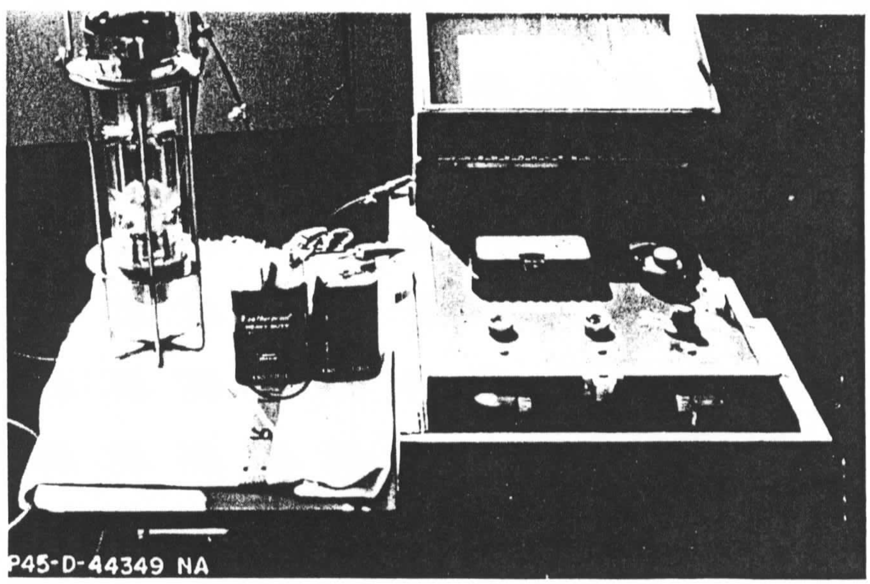
Laboratory area aboard cruiser for volumetric titrations of dissolved oxygen and carbon dioxide



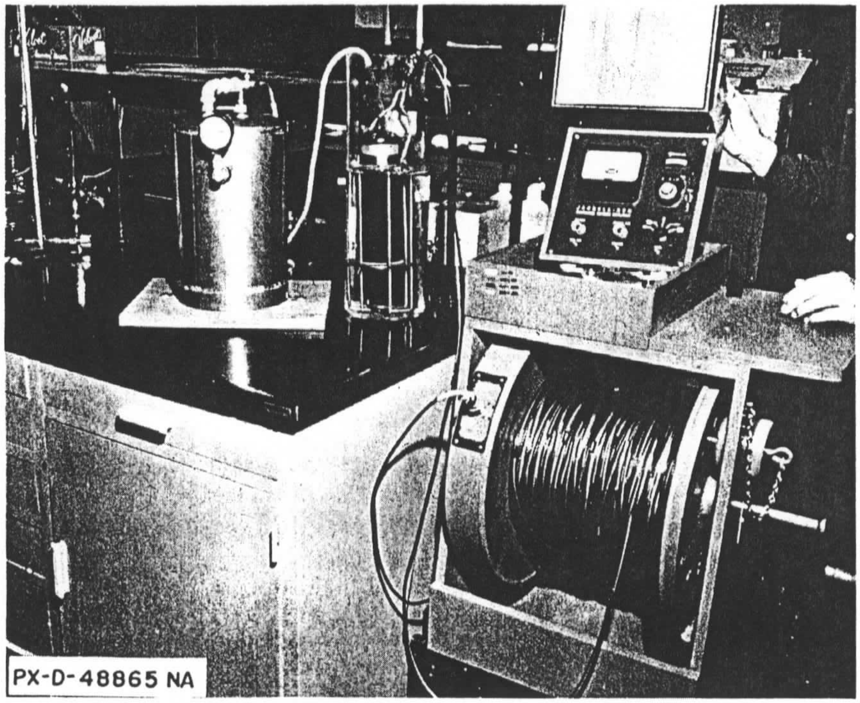
Portable pH meter



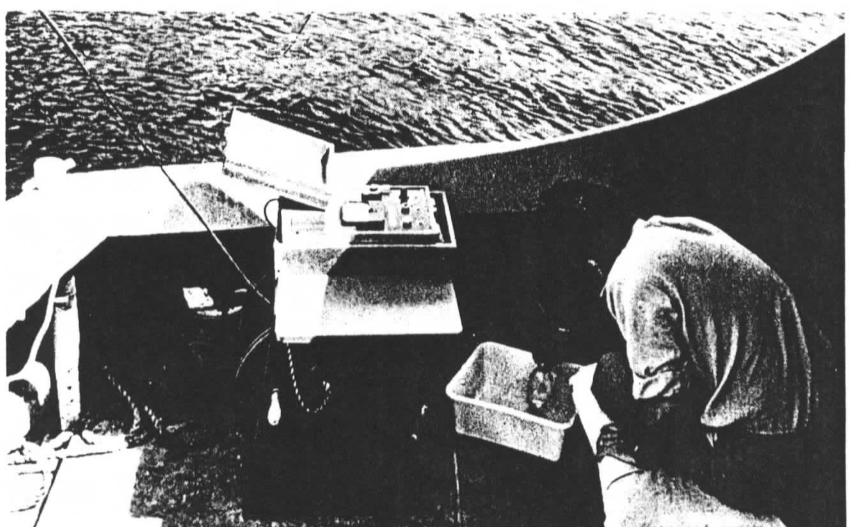
Salinometer for determining the electrical conductivity of water



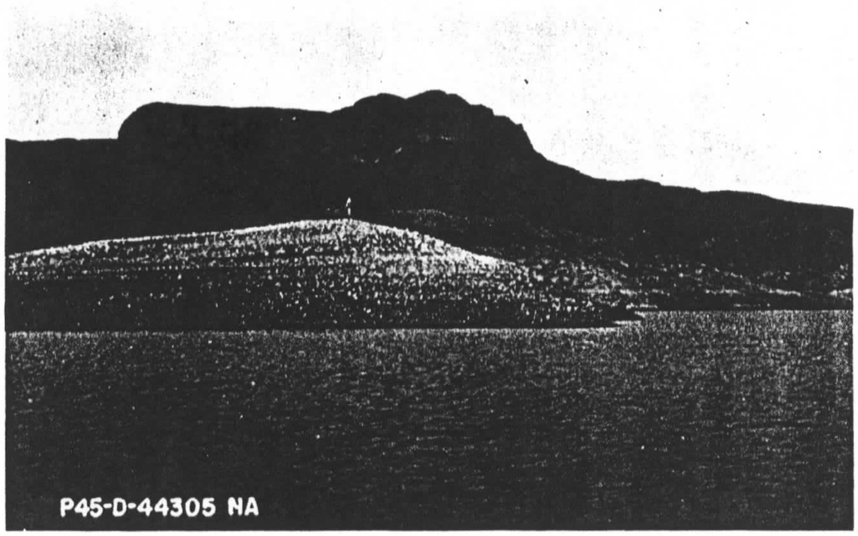
Dissolved oxygen analyzer and deep immersion stirrer assembly



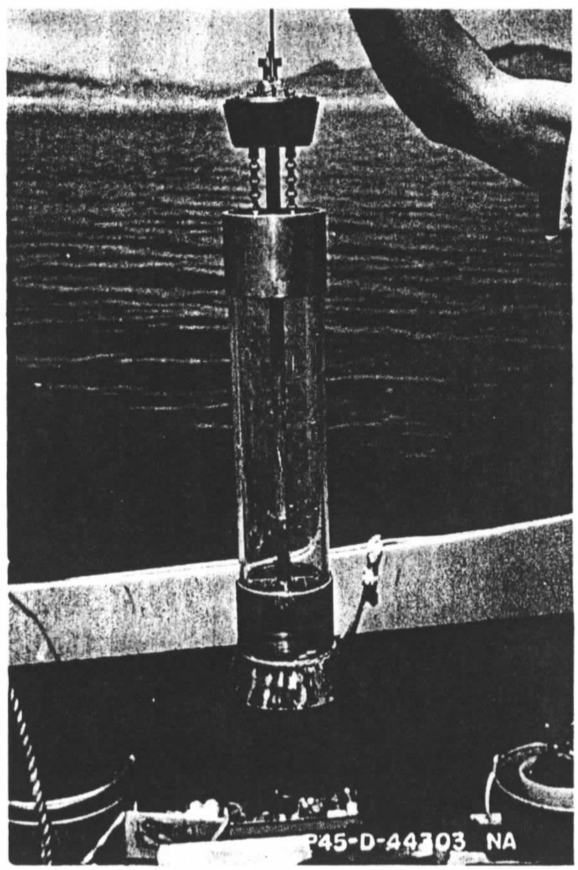
Dissolved oxygen apparatus showing meter, reel with 400-foot cable, stirrer and air tank



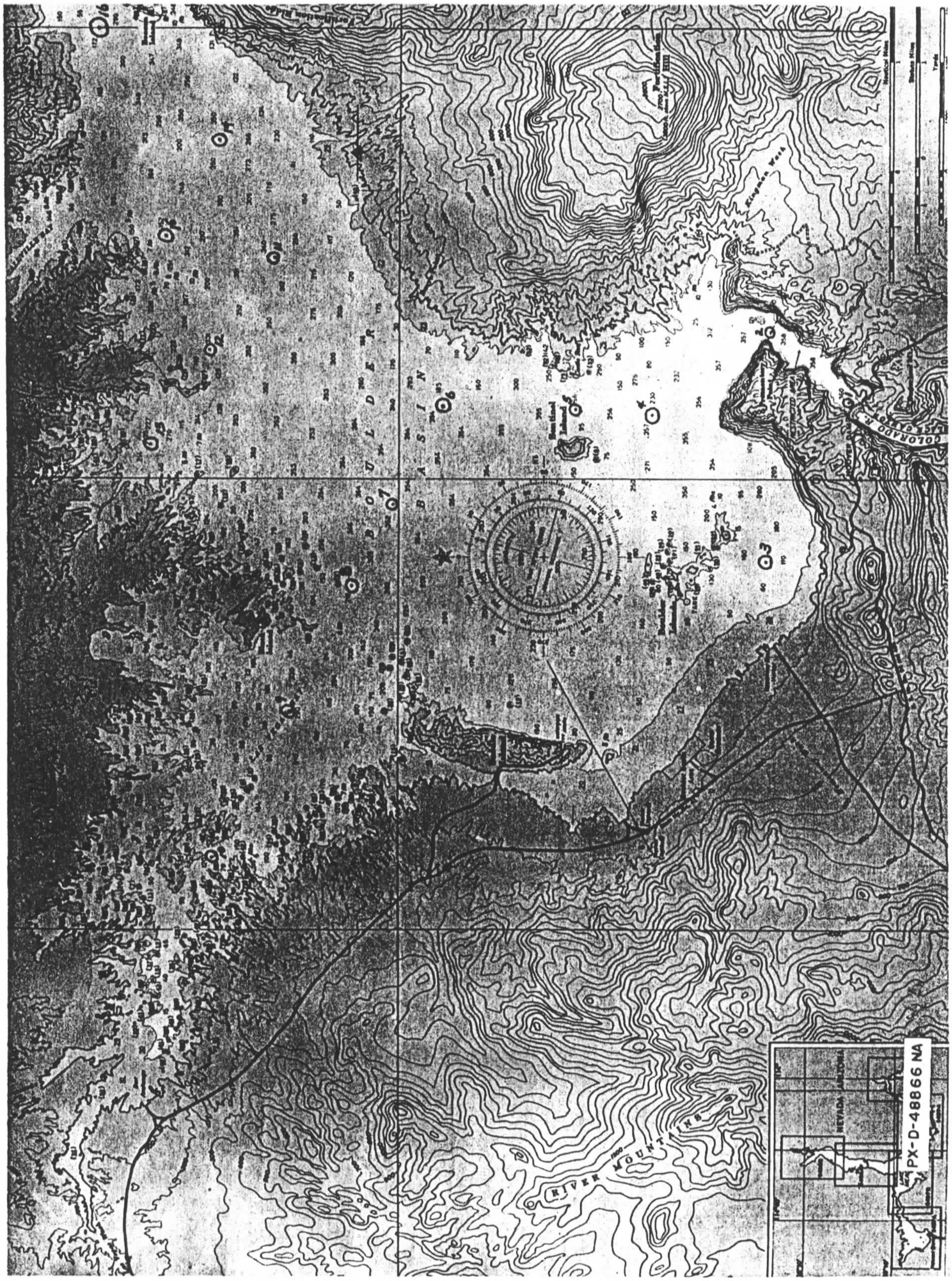
Oxygen saturated water sample for calibration of instrument



Typical marker used to locate sampling points



Water sampler



Sampling Stations

APPENDIX

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
	1.12985×10^6	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582×10^7	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
	0.3048 (exactly)*	Meters per second
Feet per year	0.965873×10^{-6}*	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	0.3048*	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	0.028317*	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
FORCE*		
Pounds	0.453592*	Kilograms
	4.4482*	Newtons
	4.4482×10^{-5}*	Dynes
WORK AND ENERGY*		
British thermal units (Btu)	0.252*	Kilogram calories
	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	1.35582*	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	0.09290*	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	304.8*	Liters per square meter per day
Pound-seconds per square foot (viscosity)	4.8824*	Kilogram second per square meter
Square feet per second (viscosity)	0.02903* (exactly)	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	35.3147*	Millicuries per cubic meter
Milliamps per square foot	10.7639*	Milliamps per square meter
Gallons per square yard	4.527219*	Liters per square meter
Pounds per inch	0.17858*	Kilograms per centimeter

GPO 845-237

CONVERSION FACTORS--BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, January 1964) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given on pages 10-11 of the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg; that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Table 1

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03 (exactly)*	Square centimeters
	0.092903 (exactly)	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	0.0040469*	Square kilometers
Square miles	2.58999	Square kilometers
	VOLUME	
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
	CAPACITY	
Fluid ounces (U.S.)	29.5737	Cubic centimeters
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	9,463.58	Cubic centimeters
	0.946358	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	1,233,500*	Liters

ABSTRACT

The survey results indicate that the impoundment of water behind Hoover Dam has not adversely affected the dissolved oxygen (DO) content and that water quality and DO content were uniform regardless of depth. The study made in April-May 1964 will provide water quality data of Lake Mead prior to releases from Lake Powell as a basis for evaluating Lake Powell's effect on water quality and limnology of Lake Mead. The performance of a DO analyzer was tested and found unsatisfactory at depths below 150 ft. Parameters tested by standard chemical analyses of water samples in the Denver Laboratory and by field tests from a boat laboratory at 16 sampling stations on the reservoir were: pH, electrical conductivity, temperature, dissolved oxygen, and dissolved carbon dioxide. Results were: (1) pH at all stations was relatively constant except at Station 1 where the increase was probably due to release of carbon dioxide by decomposition of organic matter. More plant growth was observed here than at any other station. (2) DO content averaged 9.8 ppm at the surface and 8.6 near the bottom. (3) Except at Station 1 no dissolved carbon dioxide was found in the surface water. (4) Regardless of station or water depth, electrical conductivity was uniform throughout the basin. (5) Water temperature to 100 ft varied from 54.8 to 61.5 deg F and below this depth was quite uniform at 52 to 53 deg F.

ABSTRACT

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