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February, 1917

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

A COMPARATIVE BACTERIOLOGICAL
STUDY OF THE WATER SUPPLY OF
THE CITY AND COUNTY OF
DENVER, COLORADO

—
BY

WALTER G. SACKETT

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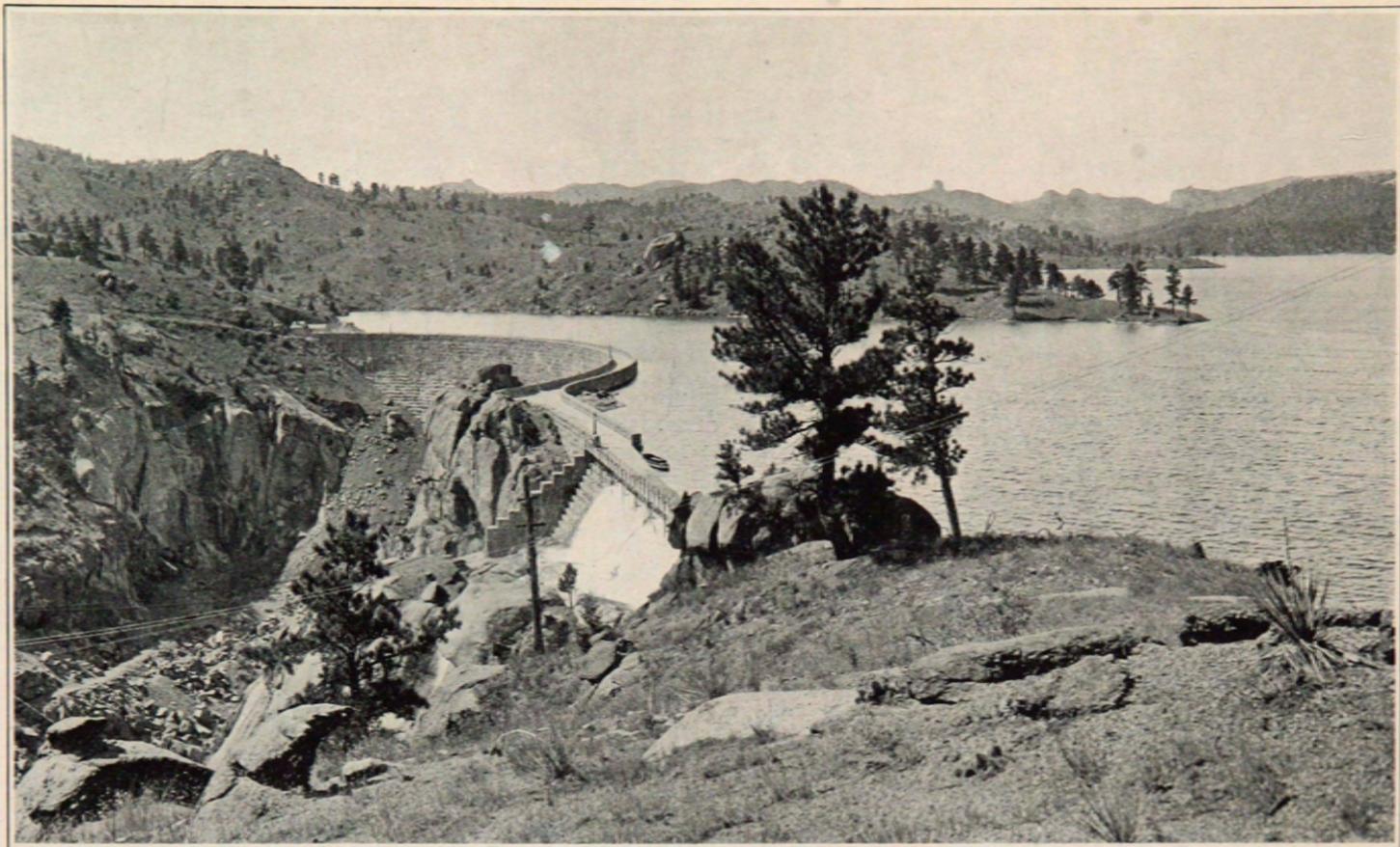
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Denver's Water Supply--Lake Cheesman, Showing Dam and Water Flowing Over Spillway

A Comparative Bacteriological Study of the Water Supply of the City and County of Denver, Colorado

By WALTER G. SACKETT

There is, perhaps, no city in the United States where an abundant supply of pure, wholesome drinking water is more important to the health of the public at large than Denver, Colorado. This is very apparent to any one who has traveled in the West during the summer time and has observed the thousands of tourists who visit the Capitol City each season. Even with her magnificent climate, cloudless skies, and her other natural advantages, Denver could never have attained to her present enviable position among the cities of the world as a health resort and a most desirable place to live, were it not for her splendid supply of pure, mountain water.

Pure as such a water is believed to be in the popular mind, yet a supply of this character may become the source of much grief from a health standpoint and may prove extremely dangerous to the community unless it is under the constant supervision of experts who watch its chemical and bacteriological character from day to day.

The Denver Union Water Company, a Colorado corporation organized in 1894, which supplies Denver with its water, has recognized the great importance of bacteriological and chemical examinations of the water, as well as the necessity for the accurate control of its filters and sterilizing plants. To this end it maintains a modern chemical and bacteriological laboratory in Denver in charge of Dr. H. I. de Berard. The laboratory is finished throughout in white enamel, has cement floors, and in every respect presents a most pleasing and sanitary appearance. Its equipment, including electrically heated and regulated incubators, sterilizing and distilling apparatus, is of the very latest design.

Daily analyses of the water from each source of supply, as well as from different taps over the city, are made in the Company's laboratory to test the condition before it enters the filters and after it is treated. An accurate check is thus kept on the work done each day by each unit of the system. Any trace of im-

purity in the raw water is at once discovered and remedied by proper treatment.

In addition to its resident chemist and regular assistants in the laboratory and at the filtration plants, the Company employs as consulting chemists and bacteriologists a number of the best known and most skilled water experts in the country. These experts visit Denver frequently for the purpose of checking the work done by the filter plants and offering suggestions for keeping the purification system fully abreast of the times.

SOURCE OF SUPPLY

The principal source of supply is Lake Cheesman, located fifty miles from Denver, and formed by impounding the waters of the South Fork of the South Platte River and Goose Creek. The surface area of this reservoir is 879 acres, and it has a storage capacity of 26,000,000,000 gallons—enough to supply Denver for two years without replenishment or assistance from any other source. From Cheesman Lake the water is carried down South Platte Canon in the channel of the South Platte River to the intake of the water system, 25 miles below, and 25 miles from Denver. A 60-inch pipeline conveys the water from the intake works to Marston Lake, which can accommodate 6,400,000,000 gallons and to Platte Canon reservoir, with a storage capacity of 300,000,000 gallons.

Besides the Platte River water, Marston Lake receives an additional supply from Bear Creek taken out above Morrison.

Cherry Creek, thru a system of infiltration galleries, contributes a limited amount to the city supply.

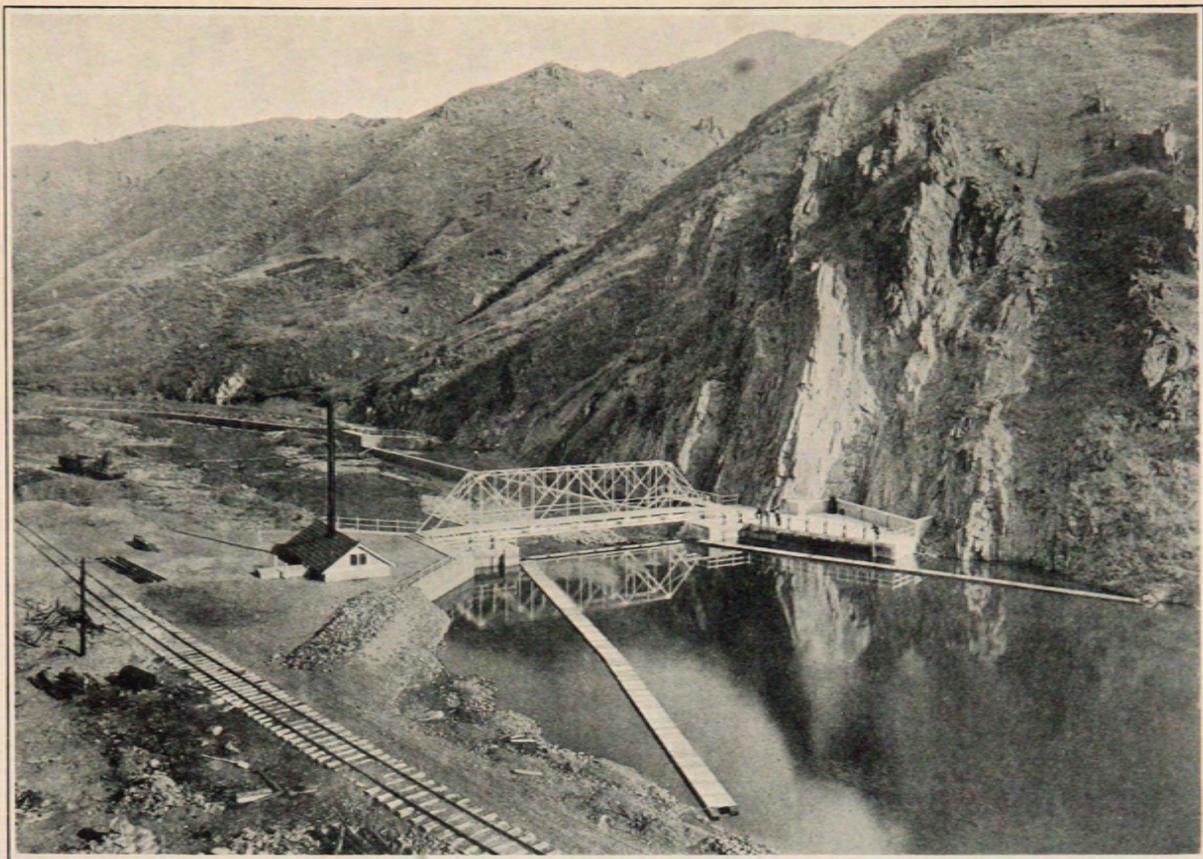
FILTRATION AND TREATMENT

Three methods of purification by filtration are employed in connection with the Denver supply:

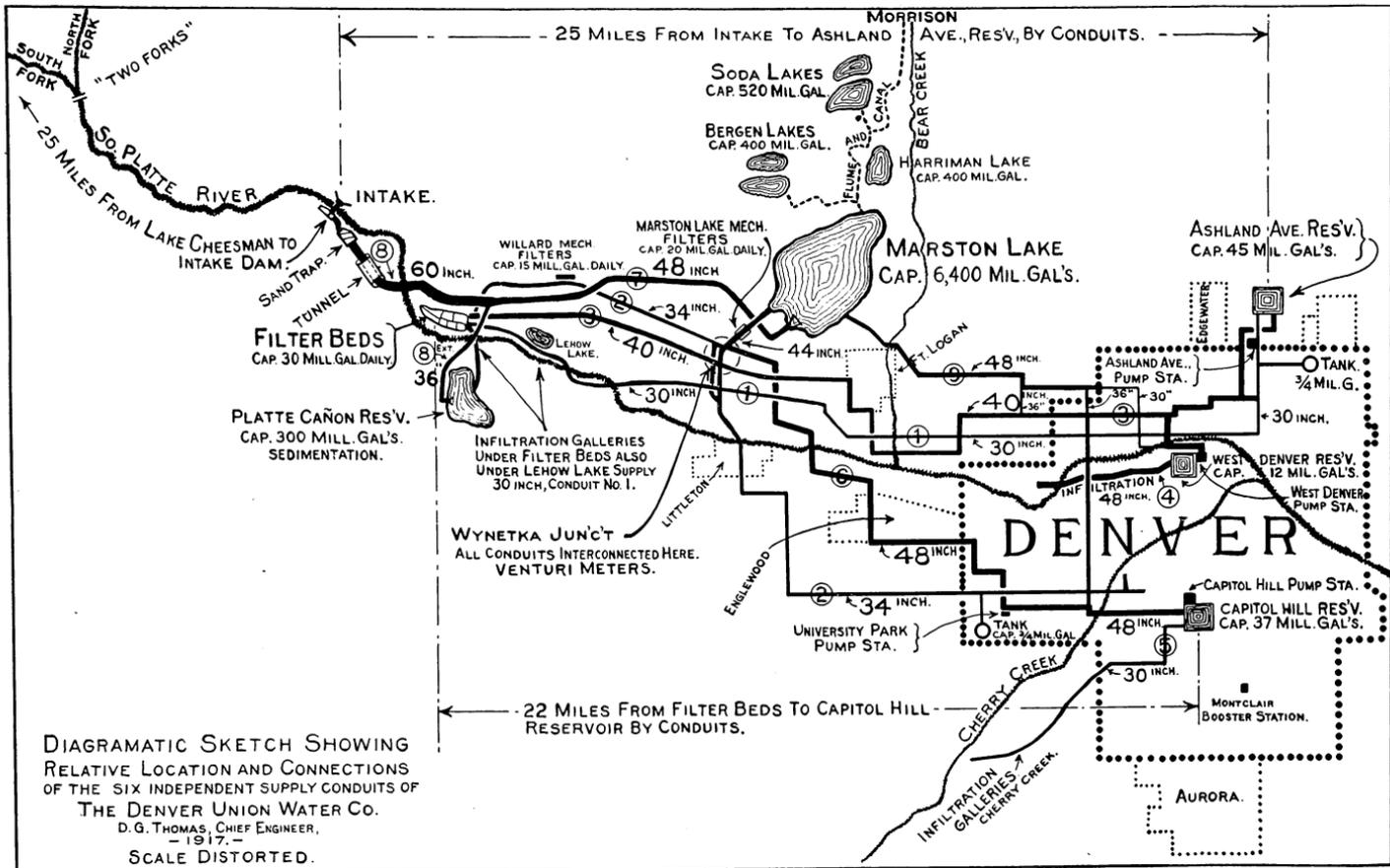
1. Mechanical filtration is practiced at the Willard plant, which has a daily capacity of 15,000,000 gallons, and at the two Marston Lake plants with a combined daily capacity of 25,000,000 gallons. The filtered water from the Willard plant is subsequently treated with hypochlorite. Chlorine gas and hypochlorite are used at the two Marston Lake plants, respectively.

2. An English slow sand plant located at Platte Canon with six filter beds having a total filtering area of 10½ acres is capable of furnishing 30,000,000 gallons of filtered water daily. Preliminary sedimentation is accomplished in Platte Canon Reservoir. Hypochlorite is added to the filtered water as needed.

3. Infiltration galleries located near the slow sand filter beds and Lehow Lake, along the South Platte River above Mississipp



Intake on South Platte River in Platte Canon



DIAGRAMATIC SKETCH SHOWING
 RELATIVE LOCATION AND CONNECTIONS
 OF THE SIX INDEPENDENT SUPPLY CONDUITS
 OF THE DENVER UNION WATER CO.
 D. G. THOMAS, CHIEF ENGINEER,
 - 1917. -
 SCALE DISTORTED.

Avenue, and Cherry Creek near Sullivan complete the filtration system.

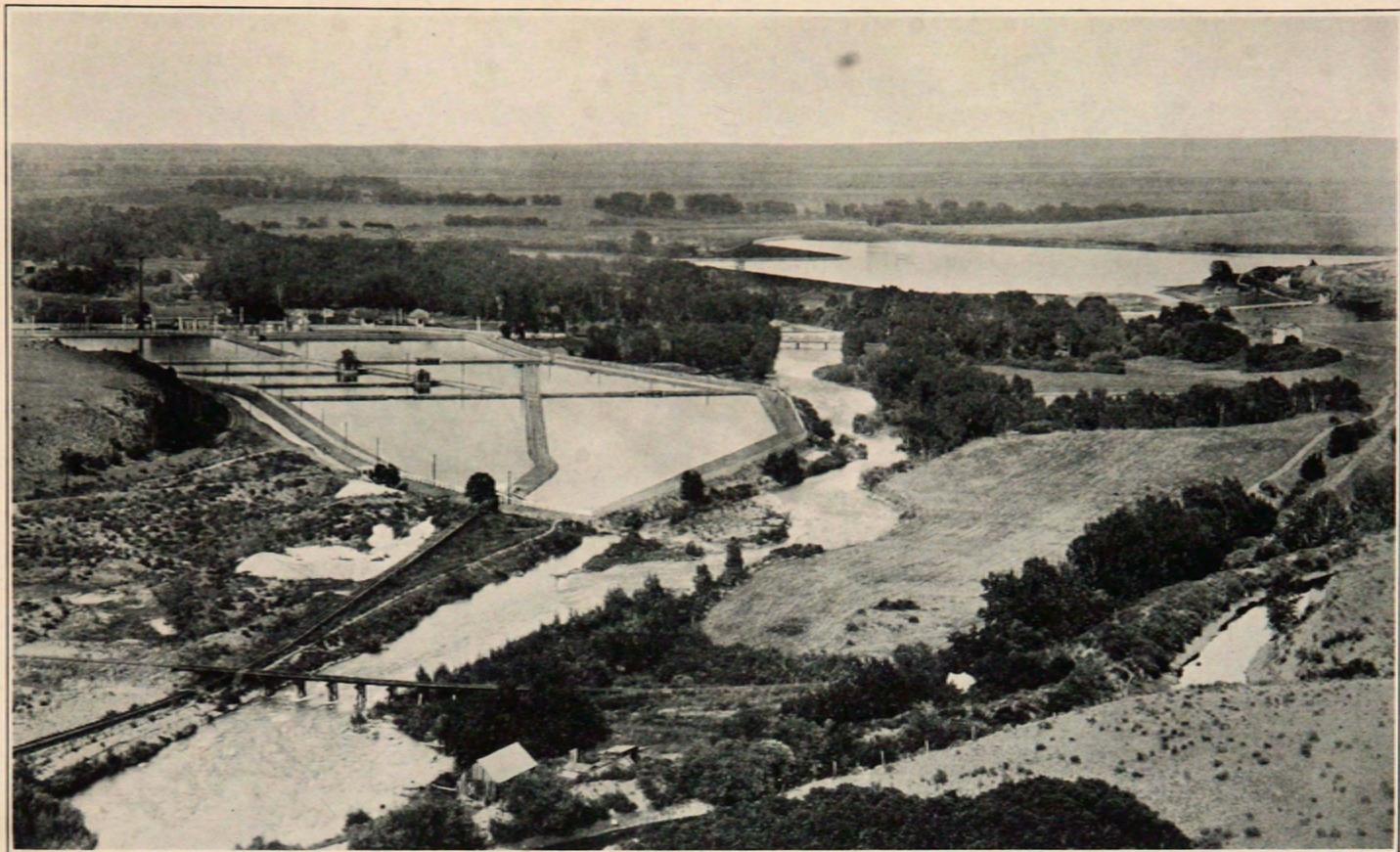
All of these waters, with the exception of that from Cherry Creek, are treated with either chlorine gas or hypochlorite. The total capacity of the combined plants approximates 81,000,000 gallons of filtered water daily. The population of Denver is, in round numbers, 250,000; the daily water consumption varies from 250 to 350 gallons per capita.

A diagrammatic representation of the entire system is shown on page 5.

PATROL OF THE WATER SHED

While the Denver Union Water Company is exercising every precaution to make the water safe for domestic purposes, it does not depend entirely upon the purification plants to accomplish this. It goes without saying that, all things being equal, the purer the raw water the more easily can the impurities be removed and the purer will be the filtered water.

Altho the water-shed in the vicinity of Cheesman Lake is so sparsely settled that it will average little more than one person to the square mile, the Denver Union Water Company recognized the possible danger of pollution from this source, as well as from Platte Canon, and secured the passage of an ordinance which provides for the protection and preservation of the purity of the water supply of the City and County of Denver and for the patrol of the water-shed, and the arrest and punishment of all persons who violate the provisions of the act. The ordinance covering this point follows:—



View Showing Filter Beds and Subsidence Reservoir at Platte Canon

BY AUTHORITY
Ordinance No. 102.
Series 1909
Supervisor's Bill No. 32,
Introduced by Sup. Robertson

A BILL FOR

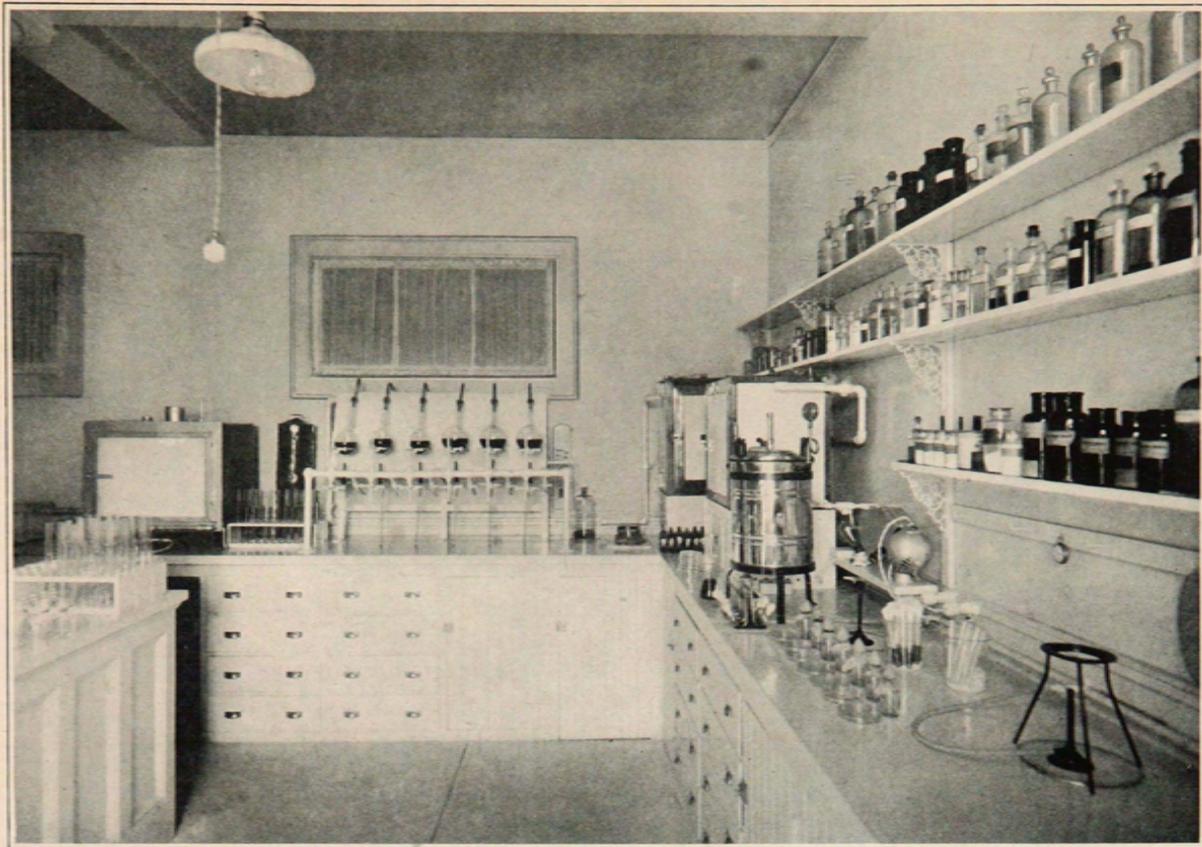
AN ORDINANCE TO PROTECT AND PRESERVE THE PURITY OF THE WATER SUPPLY OF THE CITY AND COUNTY OF DENVER, AND PROVIDING FOR THE PATROL OF THE SOUTH PLATTE RIVER AND BEAR CREEK AND ANY OF THEIR TRIBUTARIES FROM THE FIFTEENTH STREET BRIDGE OVER SAID RIVER IN THE CITY AND COUNTY OF DENVER TO THE HEADWATERS OF SAID STREAMS AND FOR THE ARREST AND PUNISHMENT OF ALL PERSONS VIOLATING THE PROVISIONS OF THIS ORDINANCE.

Be it Enacted by the Council of the City and County of Denver:

Section 1. It shall be unlawful for any person to deposit into the channel of the South Platte river or Bear creek, or any of their tributaries above the Fifteenth street bridge over said river in the City and County of Denver or between or upon the banks of said streams, any unwholesome matter or substance whatever tending to the defilement or pollution of the water of said streams, or to allow the drainage from any sewer, drain or cesspool to drain into or percolate into said streams, or their tributaries, or any of them, or to permit any dead animal or decaying vegetable matter to be placed or left within a distance of three hundred (300) feet of the banks of any said streams, or their tributaries, or to do any other act or thing whereby the water of said streams might become polluted or unfit or unwholesome for human consumption; Provided, That the disturbances of water by placer mining or tailings from ore reduction mills flowing into any of said streams or tributaries shall not be construed as defilement or pollution of the water thereof.

Section 2. The Health Department of the City and County of Denver shall appoint one or more special officer or officers as shall be determined by the Health Department and the Mayor, to be approved by the Mayor, to patrol the South Platte river and Bear creek and their tributaries from the Fifteenth street bridge over said South Platte river in the City and County of Denver to the headwaters of said South Platte river and Bear creek and their tributaries, to enforce the provisions of Section one of this

ordinance, which officer or officers shall have power to cause the arrest of any person or persons who shall violate the provisions of Section one of this ordinance, or who shall omit, neglect or refuse to obey said officer or officers or shall resist the same, or shall refuse, omit or neglect to obey any special regulations of the said Health Department of Mayor adopted or made to carry out and fulfill provisions of Section one of this ordinance, and to transport the parties so offending to the City and County of Denver to be tried before the Justice of the Peace of the City and County of Denver having exclusive original jurisdiction under the charter of said City and County of all cases arising under the charter and the ordinances of said City and County, and upon a conviction of the said party or parties, shall be fined in a sum not less than twenty-five dollars (\$25.00), nor more than two hundred dollars (\$200.00), and every omission, neglect or continuance of the thing commanded or prohibited by this ordinance for a period of twenty-four (24) hours shall constitute a separate and distinct offense, and shall be fined accordingly."



Laboratory of The Denver Union Water Company

BACTERIOLOGICAL EXAMINATION OF DENVER CITY
WATER SUPPLIED BY THE DENVER UNION
WATER COMPANY—COMPARATIVE RESULTS
FROM FOUR LABORATORIES.

At the request of Mr. D. G. Thomas, Chief Engineer of the Denver Union Water Company, a comparative study of the raw and treated waters furnished by the Company was undertaken November 11, 1916, by four different laboratories working separately and independently. Those co-operating in this investigation were Dr. Wm. C. Mitchell, Bacteriologist for the City and County of Denver, Denver, Colorado, Dr. John B. Ekeley, State Chemist, University of Colorado, Boulder, Colorado, Dr. H. I. de Berard, Chemist, Denver Union Water Company, Denver, Colorado, and Professor W. G. Sackett, Bacteriologist, Colorado Experiment Station, Fort Collins, Colorado.

On November 11th, representatives from the four above laboratories met in Denver and were taken by automobile on an inspection trip over practically the entire system. Each had his own sterilized sample bottles and took samples according to his own particular practice from twelve different points over the system. These included the following:—

1. Mississippi Avenue, infiltration galleries, inlet West Denver reservoir; treated.
2. Platte River, intake to Marston Lake, 48-inch conduit; raw.
3. Bear Creek; intake to Marston Lake, flume; raw.
4. Marston Lake; outlet to North Side Marston Lake plant; raw.
5. North Side Marston Lake plant; treated.
6. Platte Canon infiltration galleries, 30-inch conduit, Wynetka; treated.
7. Slow sand filters, 40-inch conduit, Wynetka; treated.
8. Willard rapid filters, 34-inch conduit, Wynetka; treated.
9. South Side Marston Lake plant, 48-inch conduit, Wynetka; treated.
10. Drinking fountain, City, First and Broadway.
11. Cherry Creek infiltration galleries, Capitol Hill reservoir; not treated.
12. Tap in City chemical laboratory.

All samples were iced immediately upon collection and kept in this condition during transit and until arrival at destination.

Samples examined by Dr. Ekeley, University of Colorado at Boulder, were about one hour in transit, and those sent to the Experiment Station, Fort Collins, were approximately three hours on the way. All samples were plated inside of twelve hours after collection.

Duplicate plates were made for the agar and gelatin counts, and in testing the waters for the presence of *Bacillus coli*, one 1/10 c. c. portion, one 1 c. c. portion and five 10 c. c. portions were used on all waters, and for the raw waters additional higher dilutions of 1/100 and 1/1000 c. c. were employed.

Each laboratory carried out the examinations according to its own particular routine, which was essentially the same thruout except for the medium used in the fermentation tubes for the *B. coli* tests. On this point the four laboratories differed: One used lactose broth; another, fresh ox bile; another "Bacto-bile"; and still another, dried ox gall. In spite of this lack of uniformity in methods, the results of the examination are strikingly uniform.

In Tables I, II and III, on pages 11, 12 and 13, the data from the four laboratories are given in detail.

Little comment is necessary on these results other than to call attention to the excellent and safe condition of the filtered and treated waters as shown by the low gelatin and agar counts and by the total absence of *B. coli* from the main supply, complying in all respects with the standard adopted by the Public Health Service of the U. S. Treasury Department.

Additional evidence of the excellent quality of the Denver water is to be had in the low death rate from typhoid fever, particularly during the past few years, amounting to only 8.57 per 100,000 population for 1914, and 6.72 for 1915. A diagramatic representation of the decrease in typhoid death rate for the past ten years is shown on page 14.

Denver is peculiarly fortunate in having at its service a corporation like the Denver Union Water Company, which unquestionably has the health of her citizens at heart as is clearly manifested by the minute precautions that are taken to insure the purity of the water; furthermore, in visiting the different plants and grounds of the Company, one cannot fail to be impressed with the business-like methods of operation and the splendid condition of the property—lawns beautifully kept, unsightly ditch banks in flowers, buildings, bridges, pipelines and equipment well painted, ditch banks and drives free from weeds and rubbish, and last but not least, the interior of the filter houses clean and sanitary.

COMPARATIVE RESULTS OF CO-OPERATIVE INVESTIGATION
Samples Collected November 11, 1916.

Table No. I.—Number of Bacteria per c. c. on Gelatin at 20° C.
 after 48 hours.

Sample No.	Source	Jno. B. Ekeley State Chemist U. of C.	W. G. Sackett Bact. Colo. Ag. Exp. Sta.	Dr. W. C. Mitchell Bact. City & Co. of Denver	H. I. de Berard Chemist D. U. W. Company	Average
1.	Mississippi Av. Infiltration Galleries Inlet W. D. Res.	6	14	16	7	11
2.	Platt Riv. Raw—Intake Marston Lake—48" Cond.	165	2080	1400	1325	1240
3.	Bear Cr. Raw—Intake Marston Lake—Flume ...	1400	5400	Liq	4850	3880
4.	Marston Lake—Outlet N. S. Plant—Raw	435	750	300	600	520
5.	Marston Lake N. S. Plant—Treated	6	19	16	16	14
6.	P. C. Infiltration Galleries—30" Cond.	58	96	8	74	59
7.	Slow Sand Filters, Treated—40" Cond. Wynetka	54	12	53	75	49
8.	Willard Rapid Filters, Treated—34" Cond. Wynetka	6	43	9	62	30
9.	Marston Lake So. Side Plant—Treated—48" Cond. Wynetka	8	20	12	23	16
10.	Drinking Fountain in City—Cor. 1st & Bdwy.	18	41	20	57	34
11.	Cherry Cr. Infiltration Galleries—Cap. Hill Res.	(Bottle Broken)	1	5	1	2
12.	Tap in City Chemical Laboratory	51	25	21	69	42

COMPARATIVE RESULTS OF CO-OPERATIVE INVESTIGATION
Samples Collected November 11, 1916.

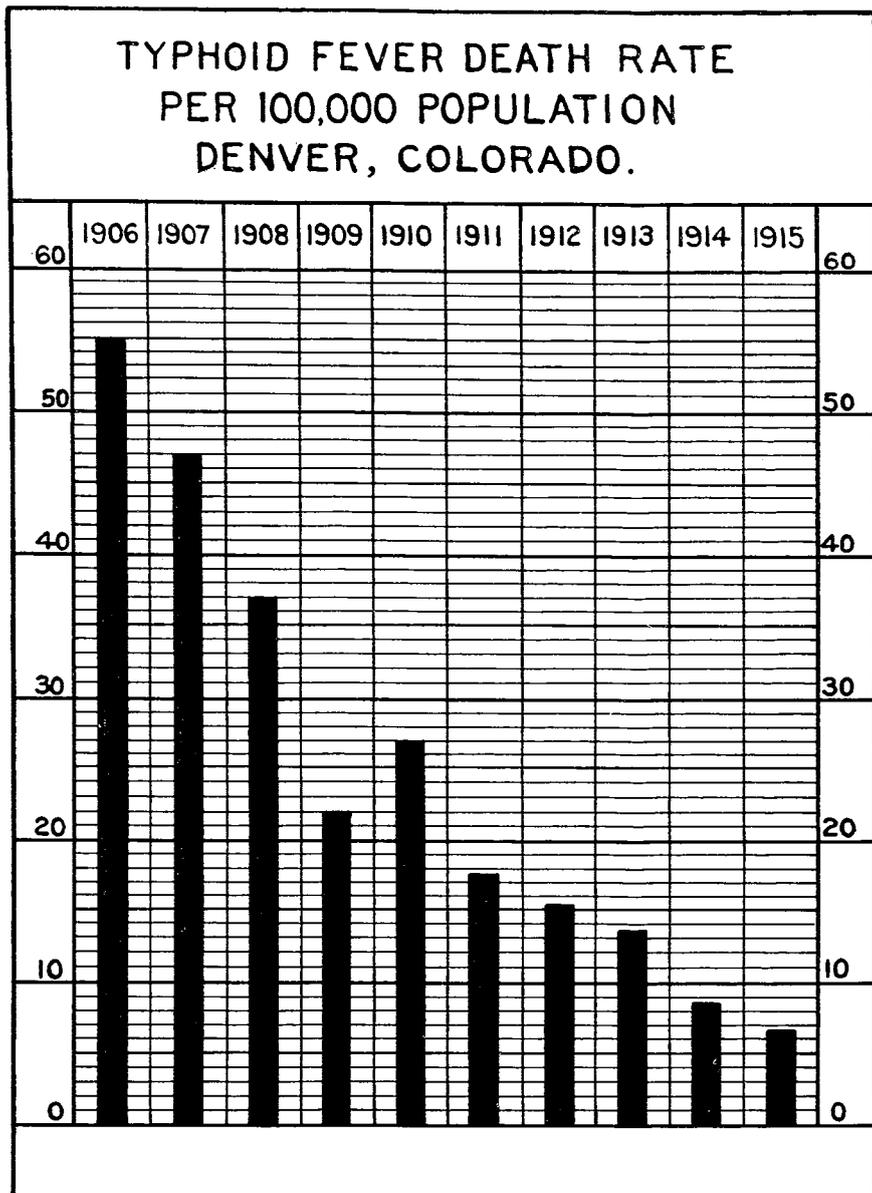
Table No. II.—Number of Bacteria per c. c. on Agar at 37° C.
 after 24 hours.

Sample No.	Source	Jno. B. Ekeley State Chemist U. of C.	W. G. Sackett Bact. Colo. Ag. Exp. Sta.	Dr. W. C. Mitchell Bact. City & Co. of Denver	H. I. de Berard Chemist D. U. W. Company	Average
1.	Mississippi Av. filtration Galleries, Inlet W. D. Res.	2	1	Cont.	1	1
2.	Platt Riv. Raw —Intake Marston Lake—48" Cond.	17	51	73	68	52
3.	Bear Cr. Raw—Intake Marston Lake—Flume ..	61	76	68	280	121
4.	Marston Lake—Outlet N. S. Plant—Raw ...	27	36	25	104	48
5.	Marston Lake N. S. Plant—Treated	6	5	11	12	8
6.	P. C. Infiltration Galleries—30" Cond. Wynetka .	1	1	6	2	2
7.	Slow Sand Filters, Treated —40" Cond. Wynetka	2	0	7	7	4
8.	Willard Rapid Filters, Treated —34" Cond. Wynetka	4	2	5	2	3
9.	Marston Lake So. Side Plant —Treated—48" Cond. Wynetka .	2	0	3	3	2
10.	Drinking Fountain in City—Cor. 1st & Bdwy.	3	3	17	11	8
11.	Cherry Cr. Infiltration Galleries—Cap. Hill Res.		1	5	1	2
12.	Tap in City Chemical Laboratory	4	0	6	7	4

COMPARATIVE RESULTS OF CO-OPERATIVE INVESTIGATION
 Samples Collected November 11, 1916.

Table No. III.—Number of Bacillus coli per 100 c. c.

Sample No.	Source	Jno. B. Ekeley State Chemist U. of C.	W. G. Sackett Bact. Colo. Ag. Exp. Sta.	Dr. W. C. Mitchell Bact. City & Co. of Denver	H. I. de Berard Chemist D. U. W. Company	Average
1.	Mississippi Av. filtration Galleries, Inlet W. D. Res.	0	0	0	0	0
2.	Platt Riv. Raw—Intake Marston Lake—48" Cond.	10	10	6	10	9
3.	Bear Cr. Raw—Intake Marston Lake—Flume ..	10	10	6	100	32
4.	Marston Lake—Outlet N. S. Plant—Raw	6	0	6	6	4.5
5.	Marston Lake N. S. Plant—Treated	0	0	0	0	0
6.	P. C. Infiltration Galleries—30" Cond. Wynetka .	0	4	2	2	2
7.	Slow Sand Filters, Treated—40" Cond. Wynetka	0	0	0	0	0
8.	Willard Rapid Filters, Treated—34" Cond. Wynetka	0	0	0	0	0
9.	Marston Lake So. Side Plant—Treated—48" Cond. Wynetka .	0	0	0	0	0
10.	Drinking Fountain in City—Cor. 1st & Bdwy.	0	0	0	0	0
11.	Cherry Cr. Infiltration Galleries—Cap. Hill Res.		0	0	0	0
12.	Tap in City Chemical Laboratory	2	0	0	0	0.5



THE ABOVE CHART PLOTTED FROM STATISTICS OBTAINED FROM THE HEALTH DEPARTMENT OF THE CITY AND COUNTY OF DENVER.

