APRIL, 1911. Report No. 158.

NATIONAL BOARD OF FIRE UNDERWRITERS

COMMITTEE ON FIRE PREVENTION

REPORT

ON THE

CITY OF BOSTON, MASS.

(SUPERSEDING PREVIOUS REPORTS.)

INDEX.

BOSTON, MASS.

REPORT No. 158.

(Superseding Previous Reports.)

CITY IN GENERAL.

Mayor.—Hon. John F. Fitzgerald.

Population estimated to be 678,812; the United States census of 1910 showed 670,585. The city is located on Massachusetts Bay, ranks second as a seaport on the Atlantic Coast and is the principal financial, commercial and distributing point of New England. The more important industries are printing, foundries, machine shops, breweries, the manufacture of clothing, shoes, confectionery, cigars, musical instruments and rubber goods. Excellent shipping facilities are provided by water and three railroad systems.

The city covers an area of 42.68 square miles, of which 4.02 miles are unreclaimed flats and water surface. The surface of the city is undulating, but in general grades are easy. Elevations in the northern part range from tide water to 140; along the water front there is much filled land, with an average elevation of about 35; in the southern and western portions, elevations rise to over 200, with a maximum of 336. There are a few steep grades in each section of the city, the more important being on Beacon Hill, Bunker Hill in Charlestown, and Telegraph Hill in South Boston; the maximum grade is 15 per cent., on Beacon Hill; this may be easily avoided by fire apparatus. Street widths are not uniform; those in the congested value district range from 25 to 100 feet, nearly half being 50 feet or less in width, and in residential sections, generally from 40 to 50 feet, with a few avenues 90 to 200 feet in width. Parks and vacant areas are scattered throughout the city; the most extensive are Boston Common and the Public Gardens, southwest of the high value district.

There are 518.63 miles of streets, generally in good condition, surfaced, in miles, as follows: Asphalt, 21.97, granite block, 98.21, wood block, 2.41, plank on bridges, 3.43, cobble, .29, bitulithic, 6.18, macadam, 350.85, gravel, 31.23, not graded, 4.06. Blocks are mainly of small area and are seldom intersected by alleys except in the southern and western portions of the city proper, where alleys vary from 10 to 20 feet in width. There are 128 bridges crossing railroads and water surfaces, 20 of the latter are over navigable waters and provided with draw; however, these and the few grade crossings seldom cause delays. The passage of fire apparatus between East Boston and the city proper is dependent on ferry service with its attendant delays. The fire department is notified when streets are blocked. Fuel consists of bituminous and anthracite coal, wood, coke and manufactured gas.

Records at the United States Weather Bureau station show an average monthly wind velocity for the past 15 years of 8.0 to 15.6 miles per hour, averaging 11.2; the prevailing direction is from the west. High winds may be expected from any direction and gales of 40 miles per hour occur on an average of about 6 times a year, generally in the cooler months. The wind attains a velocity of 25 or more miles per hour about 74 days per year. Winter temperatures are severe, the minimum monthly mean being 21° F., with 23 consecutive days with the mean temperature below freezing, and three consecutive days with the mean temperature below zero are not uncommon.

The gross fire loss for the past five years, as given in the records of the protective department, amounted to $12,501,701, the annual losses varying from $1,246,110 in 1906 to $3,451,311 in 1910, and the annual number of fires from 2,388 in 1906 to 3,676 in 1907. The average loss per fire was $824, and the average annual number of fires 3,033. The average yearly number of fires per 1,000 population was 4.74, and the annual loss per capita $3.81, the latter a high figure.

FIRE-FIGHTING FACILITIES.

WATER SUPPLY.

OWNERSHIP.—The supply works, including storage reservoirs, conduits, pumping stations, and most of the reservoirs and supply mains, are under the jurisdiction of the Metropolitan Water and Sewerage Board. These works supply also, in whole or in part, 17 other cities and towns in the vicinity. The works were built by the city from 1848 to 1895, and by the Board since that time, at a total expenditure of $41,000,000. Distribution, including all of the distributing mains proper and some of the distributing reservoirs and supply mains, is under the control of the Department of Public Works of the city; the total cost to date has been $15,750,000.

Agreements.—Cities and towns in the Metropolitan Water District are assessed, annually, an amount required to pay interest, sinking fund and maintenance expenses, two-thirds in proportion to their consumption and one-third in proportion to their respective valuation.

ORGANIZATION.—Metropolitan Water and Sewerage Board.—Consists of three members: Henry H. Sprague, Chairman; Henry P. Wolcott and James A. Bailey, Jr., appointed by the Governor of Massachusetts, with the advice and consent of the council, for a term of three years. The present members received their appointment by reason of their knowledge of the legal and sanitary questions involved. All appointments of officers and subordinates of the Board are made by it, most of them under civil service rules.

The consulting engineers of the Board are Joseph P. Davis, Hiram F. Mills and Frederic P. Stearns, the latter chief engineer from 1895 to 1907.

Chief Engineer Dexter Brackett has been connected with the works since their inception, and has held his present position for the past four years; he is in charge of construction, maintenance and operation of the system, being assisted by William E. Foss, assistant to chief engineer; Elliot R. B. Allardice, superintendent Wachusett department; Charles E. Haberstroh, superintendent Sudbury department; Samuel E. Killam, superintendent distribution department; Arthur E. O'Neil, superintendent pumping stations; all experienced men, who direct a permanent force of about 250 men.

Water Department.—On February 1st of the present year, the water department, together with several other city departments, was reorganized and placed under a Commissioner of Public Works, Mr. Louis K. Rourke having been appointed to the position; Mr. F. A. McInnes, who has been connected with the city engineer's office for the past 21 years and is an able and competent water works engineer, was made division engineer in charge of the water and sewer departments. Mr. C. J. Carven is engineer of maintenance.

The works are divided into a central and five suburban maintenance districts, each in charge of a foreman, with headquarters at well stocked yards. The maintenance force consists of 414 men in the distribution division and 137 in the income division, including inspectors and meter readers. Employees are under civil service rules and long tenure of office is general.

Records.—Plans and records of the Metropolitan Water and Sewerage Board are unusually complete, indexed in convenient form and filed safe from fire.

The plans and other records of the city water department are in only fair condition. They include comprehensive general and detail plans of the distribution system, besides gate and service locations in card catalog form; none is up to date and the latter are not complete, for although the data from the original notes is available, sufficient clerical force adapted to the work is lacking. Consumption records are based on Venturi meter measurement.

Quarters.—The main office of the Metropolitan Water and Sewerage Board is at 1 Ashburton place, Boston, with administrative offices at South Framingham and Clinton, as headquarters for the Sudbury and Wachusett departments, respectively. Branch offices are at Glenwood pipe yards in Medford and at Chestnut Hill reservoir. All offices have public telephone connections.

Offices of the city water department are in city hall, School street; main pipe yard with machine and repair shops at 710 Albany street, with other yards in different districts. All have public telephone connections.

Fire Service and Emergency Operation.—Fire alarms are sounded at the pumping stations, office in the city hall and at the Albany street yards, but no provision is made for the response of department employees. Constant watch is maintained at the repair shop and an automobile truck is provided for emergency service.

GENERAL OUTLINE OF SYSTEM.—Supply is from works built by the City of Boston previous to 1895, and from the Nashua river watershed, developed by construction of the Wachusett reservoir by the Metropolitan Water Board since that time. The works formerly owned by the city consist of Lake Cochituate and seven reservoirs on the Sudbury river watershed, from which supply is delivered to the Metropolitan water district through the Cochituate and Sudbury aqueducts. Supply from Wachusett reservoir is conveyed by the Wachusett aqueduct to storage reservoirs on the Sudbury watershed, and thence by the Sudbury and Weston aqueducts to the distribution. From the terminals of the aqueducts, water flows by gravity, or is pumped through cast-iron pipes into distributing reservoirs for the supply of six services, five of which furnish water to parts of the City of Boston. Elevations in this report are above Boston city base.

SOURCES OF SUPPLY.—Drainage Area and Yields.—The following description of the drainage areas which contribute to the supply are given in the order of their development.

Cochituate.—Area of watershed, 17.80 square miles; the yield per square mile is approximately as given below for the Sudbury watershed.

Sudbury.—Area of watershed is 75.2 square miles; average yield for the past 36 years, about 77,175,000 gallons per day. The lowest recorded yields were 1880 and 1883, when the average per day, per square mile, was 578,000 and 583,000 gallons, respectively. The dryest six months of record was in 1910, when the yield for this period was at the rate of 29,000 gallons per square mile per day.

Wachusett.—Area of watershed, 118.90 square miles; average yield for the past 14 years, about 134,362,000 gallons per day. Lowest recorded yield for a year was in 1910, when the average was 820,000 gallons per day per square mile. The dryest six months of record occurred in 1910, the yield being at the average rate of 193,000 gallons per day per square mile.

TABLE No. 1.—STORAGE RESERVOIRS.

Watershed.	Name of Reservoir.	Elevation of High Water.	Maximum Depth.	Available Capacity, Million Gallons.	Supplies.
Cochituate	Lake Cochituate	144.36	70	2,242	Cochituate aqueduct.
Sudbury	Ashland	225.23	49	1,416	Natural channel to Framingham No. 2.
	Hopkinton	305	55	1,520	Natural channel to Framingham No. 2.
	Whitehall Pond	337 91	18	1 256	Natural channel to Framingham No. 2.
	Framingham No. 2	177.12	17	529	Framingham No. 1 or 48-inch pipe to Sudbury aqueduct.
	Framingham No. 3	186.50	21	1,180	Two 48-inch pipes to Sudbury aqueduct or directly into Framingham No. 1.
	Framingham No. 1	169.27	14	287	Sudbury aqueduct.
	Sudbury	259.97	67	7,253	Weston aqueduct or Framingham No. 3.
	Farm Pond*	159.25	12	167	Sudbury aqueduct.
Wachusett	Wachusett	395	129	64,698	Wachusett aqueduct to Sudbury reservoir.

* Not now used as a part of the system.

Storage Reservoirs.—There are ten storage reservoirs on the three watersheds, with combined storage capacity of about 81,000,000,000 gallons. Details of reservoirs are given in Table No. 1. All have well constructed dams, provided with waste ways and other appurtenances. They are maintained in excellent condition. Framingham No. 1 has a muddy bottom and is not much used; about 1,500,000 gallons per day are wasted to the river to meet power demands. Farm pond is not now an integral part of the system. The water from the Wachusett reservoir is used when possible to the exclusion of other sources, as it is considered of better quality; this reservoir was first filled in May, 1908, when the water level was raised 0.31 of a foot by flash boards; in June, 1909, the water level rose to within one foot of the spillway.

Supply Conduits.—*General.*—All conduits are well designed and substantially built, for the greater part of the distance of masonry or concrete in open trench, with well compacted foundation embankments where necessary; usual earth cover is 4 feet. Well maintained and reasonably secure against interruption or breakage. River or stream crossings are well designed and maintained and are either by masonry bridges or inverted siphons of two or more lines of pipe. On each is one or more appliances for measuring the flow of water, either gaging chambers, weirs or Venturi meters.

Cochituate Aqueduct.—Built in 1848 from Lake Cochituate to Chestnut Hill reservoir, 13.3 miles; of egg-shaped section, 5 feet in width and 6 feet 4 inches in height. Capacity under ordinary conditions is 18,000,000 gallons in 24 hours; maximum capacity under head, 23,000,000 gallons. At the lower end the aqueduct has connections through two gate chambers to Chestnut Hill reservoir, a pipe connection from the Sudbury aqueduct, and connections to the pump wells of both the High and the Low service pumping stations.

Sudbury Aqueduct.—Finished in 1878; consists of two portions, the Sudbury supply aqueduct from Dam No. 1 to Farm pond gate house, a distance of 1½ miles, and of the Sudbury aqueduct proper, from the latter point to Chestnut Hill reservoir, 15.9 miles. Both portions are of horseshoe-shape section, the Sudbury supply aqueduct, 6 feet 10 inches high and 7 feet 6 inches wide; the Sudbury aqueduct, 7 feet 8 inches high and 9 feet wide. Maximum capacity of the aqueduct, 109,000,000 gallons per day. The terminal chamber at Chestnut Hill reservoir has four cast-iron pipes leading from it, one into each basin of the reservoir, one into the Cochituate aqueduct, and one to the effluent gate house of the reservoir, with connections to pump wells of both pumping stations.

Wachusett Aqueduct.—Finished in 1897, leads from Wachusett dam in Clinton to head of Sudbury reservoir in Southborough, 12 miles. Masonry portion is of horseshoe section, 10 feet 6 inches high and 11 feet 6 inches wide. Maximum capacity, 320,000,000 gallons per day, when clean.

Weston Aqueduct.—Placed in service in 1903. Conveys water from Sudbury reservoir to a terminal chamber on high land a short distance west of the Charles river in Weston, 13.4 miles. This aqueduct is of the same general shaped section as the Sudbury and the Wachusett aqueducts. Maximum capacity, about 320,000,000 gallons per day. At the Sudbury river and Happy Hollow valleys are single lines of riveted steel siphon pipe, 7½ feet in diameter. There will ultimately be three parallel lines of pipe at each siphon, but one can be made to convey more than half the capacity of the aqueduct.

PUMPING STATIONS.—General.—Of the five stations maintained by the Board, four supply water to the City of Boston. Complete records of the performance of each station are maintained. Coal is purchased either in boat-load lots or, for the

smaller stations, from local dealers, and the supply is assured by the proximity of the stations to tide water. All stations are operated continually. For equipment see Table No. 2.

Chestnut Hill Low Service Station.—*General.*—Located about 5 miles west of the centre of the city, near Chestnut Hill reservoir. The station, supplemented by the gravity flow from the Weston aqueduct, supplies by direct pumpage the Southern Low service and Spot pond and Mystic reservoir, both distributing reservoirs of the Northern Low Service. Suction is taken from a well fed through two 60-inch pipes from the reservoir, a 48-inch from the Cochituate aqueduct, or a 48-inch from the effluent gate house.

Equipment.—Consists of three pumps with a combined rated capacity of 105,000,000 gallons per day. The three units serving the Southern Low service are connected to an equalizing tank in the station, with top at elevation 192; one is generally in reserve. A 40,000,000-gallon High service pump is being installed. The three boilers in service aggregate 525 h.-p., which provides for a proper reserve; two 300 h.-p. boilers are being installed. Steam piping in duplicate.

Construction.—Built in 1900; three connecting stone buildings separated by brick division walls; openings unprotected between pump and boiler room; between boiler room and coal house, protected by single, tin-clad doors. Flat composition roofs on sheathing on steel girders with several large skylights of heavy glass in pump and boiler room roofs. Pump room, 8,100 square feet in area, 44 feet to eaves; floor, brick arched on structural steel with slate finish. Boiler room, 3,200 square feet in area; floor of brick on level with pump room basement floor. Coal house of 4,300 square feet area, floor of cement.

Hazards.—A small frame wagon shed and a moderate-area brick stable are located about midway between the Low and High service stations, but these offer very slight exposure to either station. Lighting electric from station dynamo in alcove of pump room; wiring in good condition. Hazard from oils well guarded.

Protection.—Five hydrants on High service mains on grounds of this and adjacent High service station. Two standpipe risers on pump room floor with 50 feet of 2½-inch linen hose with nozzles attached for each riser. One hundred feet of serviceable 2½-inch cotton, rubber-lined hose for hydrant are stored in cart, and two hand chemical extinguishers in the barn. Nearest fire station one mile distant.

Chestnut Hill High Service Station.—*General.*—This station, located about 350 feet southwest of the Low service station, supplies by direct pumpage the Southern High service with equalizing reservoirs, and the water repumped at the West Roxbury station to the Southern Extra High service.

Equipment.—Four pumps with a combined rated capacity of 66,000,000 gallons per day. The larger unit is usually in use and the three smaller held in reserve; these latter are so connected that they can discharge in the Southern Low service. The seven boilers, aggregating 1,050 h.-p., allow a safe reserve. A single steam line feeds the two smaller units and each of the other units is fed by a single line; these three lines are well cross-connected in the boiler room.

Construction.—Three connecting stone buildings, separated by brick division walls having unprotected openings. Slate-covered roofs on sheathing on steel trusses. Station built in 1887, with addition to pump room for additional unit built in 1897.

Pump room covers 9,100 square feet and is 56 feet to the eaves; heavy joisted floors on iron stringers, except the addition, which has tile floor on iron beams; basement floor concrete. Boiler room of 4,300 square feet, and coal house of 3,800 square feet, each 50 feet to the eaves; floors of brick and cement.

Hazards.—Only mild exposure from stable above mentioned. Oils in metal tanks in basement of pump room and on boiler room floor; reserve supply in coal house. Lighting electric, from dynamo in Low service station; a small frame building connecting with boiler room houses dynamo for emergency lighting use; wiring is old, but in fair condition.

Protection.—Outside fire service as noted above for Low service station. Six standpipe connections in pump room basement with 50 or 100 feet of 2½-inch linen hose with nozzles, attached to each. Several connections for hose in boiler room.

West Roxbury Station.—Located at Washington street and Metropolitan avenue; pumps take suction from the Southern High service under a head of 80 feet and discharge against a head of 220 feet, supplying the Southern Extra High service by direct pumpage with an equalizing standpipe. Three pumps, with an aggregate capacity of 3,750,000 gallons per day, and three boilers aggregating 180 h.-p. The large unit is operated in the summer and one of the smaller in the winter; one steam line supplies the larger and another the two smaller.

The building is a low, small-area, joisted brick, divided by brick partition walls into pump, boiler and coal rooms; wall openings unprotected. A small addition to the south was built in 1910 to house additional pump; this has flat composition roof. Peaked roof, slate-covered, on sheathing on wooden rafters. Wood floor in pump room and brick floors in boiler and coal storage rooms. Loft for storage over pump room.

No exposures. Oils in cabinet in frame shed connecting boiler rooms. Lighting by gas from city mains.

There are 1½-inch connections for hose on the discharge end of each of the smaller pumps, and one connection has a 50-foot length of 1½-inch linen hose, with nozzle. Hand chemical extinguisher in pump room. The nearest hydrant is about 100 feet from the station.

TABLE No. 2.—PUMPING STATIONS—EQUIPMENT.

PUMPS.

Station.	Number and Make.	Class.	Date of Manufacture.	Diameter, in Inches.		Stroke, Inches.	Rev. per Min.	Pressure, Lbs.		Pipe Conn., Diam., Ins.		Rated Capacity Each, Gals. per Day.	Slip, per Cent.	Condition.	No. of Shifts.	Least No. of Men on Shift.
				Steam Cylinders.	Water Plunger,			Steam.	Water.	Suction.	Discharge.					
Chestnut Hill, Low Service.	3. Holly	Vertical, triple-expansion, condensing, crank and fly-wheel triplex, single-acting	1899	17 & 31¼ & 48	37	60	30	150	30	2–36	2–36	35,000,000	2	Good.	3	4
	1.* Holly	Ditto	1911	32 & 60 & 90	43¼	60	25	150	55	2–36	2–36	40,000,000	..	*		
	2. Holly	Horizontal, twin-compound condensing, crank and fly-wheel, duplex, double-acting	1887	21 & 42	25	36	18½	80	50	24	24	8,000,000	3	Fair.		
Chestnut Hill, High Service.	1. E. D. Leavitt, Built by Quintard Iron Works	Vertical, triple-expansion, condensing, crank and fly-wheel, triplex, double-acting	1895	14 & 24½ & 39	17½	48	50	180	55	36	36	20,000,000	4	Good.	3	4
	1. Allis	Vertical, triple-expansion, condensing, crank and fly-wheel, triplex, single-acting	1898	30 & 56 & 87	42	66	18	180	55	48	48	30,000,000	2	Good.		
West Roxbury.	2. Worthington	Horizontal, twin-tandem, compound, condensing, duplex, double-acting	....	8 & 12	10⅝	10	50	90	97	8	8	1,000,000	3	Fair.	3	1
	1. Knowles	Ditto	....	8 & 16	11¾	18	36	90	97	12	12	1,750,000	4	Good.		

* Being installed.

BOILERS.

Station.	Number and Make.	Type.	Date of Manufacture.	Grate Surface, Sq. Ft.	Heating Surface, Sq. Ft.	Rated Horse Power, Each.	Steam Pressure.		Fuel.	Insurance.	Inspection.	Condition.
							Max. Allowed.	Average.				
Chestnut Hill, Low Service.	3. Atlantic	Vertical Tubular	1899	60	2,146	175	166	150	Bituminous Coal and Anthracite Screenings.	None.	State Boiler Inspector, Annually.	Good.
	2. Robb-Mumford	Vertical Tubular	1911	....	....	300	166	150				Good.
Chestnut Hill, High Service.	1. Lake Erie	Belpaire Locomotive	1898	64	3,000	200	185	180				Good.
	2. Lake Erie	Horizontal Return Tubular	1899	33	1,475	150	185	180				Good.
	1. I. P. Morris	Vertical Tubular	1903	38	2,989	200	185	180				Good.
	1. I. P. Morris	Vertical Tubular	1903	48	2,989	200	185	180				Good.
	1. Hodge	Horizontal Return Tubular	1908	33	1,475	150	185	180				Good.
West Roxbury.	2. Hodge	Vertical Tubular	1901	12	472	50	103	90	Anthracite Coal.			Good.
	1. Hodge	Vertical Tubular	1908	....	....	....	...	90				Good.

TABLE No. 3.—DISTRIBUTING RESERVOIRS.

Name of Reservoir.	Constructed.	Elevation of High Water.	Area, Acres.	Available Capacity, Million Gallons.	Supplied From	Supplies
Weston	1903	200	66.6	200.0	Weston Aqueduct	Southern Low Service.
Chestnut Hill	1868	134	122.7	300.0	Sudbury & Cochituate Aqueducts	Pumping Stations.
Spot Pond	1901	163	308.7	1,791.7	Low Service Pumping Station and Weston Aqueduct	Northern Low Service.
Mystic	....	157	4.5	26.2		
Fisher Hill	1888	251	3.1	15.4	High Service Pumping Station	Southern High Service.
Waban Hill	1877	264.5	2.8	13.5	High Service Pumping Station	Watertown and Belmont, outside city limits.
Bellevue Standpipe	1886	376.3	24′ Diam. and 40′ High.	0.135	West Roxbury Station	Southern Extra High Service.
Orient Heights Standpipe	1889	204.4		0.135	Fells Reservoir*	Northern High Service.

* Capacity of Fells Reservoir, 41,400,000 gallons; supplied from the Spot Pond Pumping Station.

Spot Pond Pumping Station.—Located at Spot Pond and pumps water to the Northern High service, which includes in the city a small residential district in Breed's Island in East Boston. This station is a fireproof building with no exposures and is equipped with a 20,000,000-gallon and a 10,000,000-gallon pump; average daily pumpage about 8,000,000 gallons.

DISTRIBUTING RESERVOIRS.—General.—Of the ten distributing reservoirs controlled by the Board, there are five on services supplying some parts of the City of Boston, besides Fisher Hill reservoir and the standpipes on Bellevue Hill and Orient Heights, owned and maintained by the city. Stages of water are determined by self-registering devices either at the reservoirs or transmitted by cable to electric gage at the pumping stations. Keeper lives near each of the reservoirs and all are maintained in good condition. The larger reservoirs occupy natural basins, with earth dams, usually rip-rapped and paved; the smaller are in excavation and embankment. All are in good condition and kept full. Chestnut Hill reservoir, in addition to supplying the pumping station of the same name, can feed the Southern Low service by gravity.

PRINCIPAL SUPPLY MAINS.—The distribution system of the Metropolitan Water Works which contribute to the supply of Boston comprises the following mains:

From the terminal chamber of the Weston aqueduct a 60-inch main extends across the Charles river, there reducing to a 48-inch, which is laid to the Chestnut Hill reservoir; the portion east of the river is being paralleled by a 60-inch, about two-thirds of which is laid, but only a short length near the reservoir is in service; at the Chestnut Hill reservoir, this line and the discharge mains from the Low service pumps connect to three mains of the Southern Low service.

Two 48-inch mains from the Low service pumping station, supplied also from the Weston aqueduct, feed Spot pond, each connected by a 24- and 30-inch pipe to Mystic reservoir; the two latter extend easterly to Charlestown, supplying the Northern Low service; a 48-inch branch from the easterly 48-inch runs through Everett to Chelsea, where it divides into a 20-, 24- and 36-inch, which cross Chelsea creek, supplying the Northern Low service in East Boston, and a 24-inch connects to a 30-inch, which crosses the Mystic river into Charlestown.

From the High service pumping station, a 30- and a 36-inch force main feeds Fisher Hill reservoir; a 48-inch runs through West Roxbury, reduces to 36-inch and continues through Dorchester; a 36-inch feeds Waban reservoir; these mains are connected at numerous points to the city distribution system.

CONSUMPTION.—The average daily consumption for the past 6 years, within the area served by the whole works and in the City of Boston, together with the estimated population, the average per capita consumption and the percentage of the services metered, is shown in Table No. 4.

TABLE No. 4—CONSUMPTION.

Year Ending Dec. 31st.	Average Daily Consumption, Gallons.	Estimated Population.	Gallons Per Capita Supplied.	Per Cent. of Services Metered.
Metropolitan District.				
1905	118,398,000	902,090	131	.....
1906	117,542,000	930, 40	126	.....
1907	124,145,000	955,760	130	.....
1908	125,441,000	973,320	129	21.50
1909	119,386,000	977,760	119	28.35
1910	112,092,000	1,022,230	110	36.32
City of Boston.				
1905	89,743,900	595,380	151	5.3
1906	90,951,800	613,220	148	5.4
1907	96,422,800	628,520	153	5.5
1908	98,379,300	643,810	153	5.7
1909	94,029,900	659,110	143	12.4
1910	87,346,700	674,400	130	18.7

Consumption in each service in all of the cities and towns supplied is determined by meters, 73 of which are in use. The City of Boston uses an average of 77.9 per cent. of the water supplied in the Metropolitan district.

Table No. 5 shows the average and maximum daily consumption in the more important services in the district; the maximum occurred on February 10, 1910. The amount pumped is 74 per cent. of the total used; upon the completion of the 60-inch line from the terminus of the Weston aqueduct, this quantity will be reduced.

TABLE No. 5.—CONSUMPTION BY SERVICES, METROPOLITAN WORKS, 1910.

Service.	Average Daily Gallons.	Maximum Daily Gallons.
Southern Low	44,667,600	65,690,000
Northern Low	26,032,400	41,440,000
Southern High	32,644,400	77.120,000
Northern Extra High	681,000	.....

The average daily rate of consumption in the year 1907 far exceeded that estimated for this period at the time of the construction of the works, and the rate between the hours of 1 A. M. and 4 A. M. was about 70 per cent. of the average daily rate. In order to check this enormous waste an act was passed in 1907, requiring all cities and towns supplied by the Metropolitan Water and Sewerage Board to meter all new services and 5 per cent. yearly of all old services, except those used for fire or public purposes; another act, in 1909, placed a penalty upon the non-observance of the law. As an immediate result the average daily consumption in 1909 was reduced 6,305,100 gallons, or 5.03 per cent. less than the preceding year, and the per capita was less than in any other year since 1903. Again, in 1910, a slightly larger reduction was effected.

Maximum.—Maximum consumption occurs in the winter months, when fixtures are left open to prevent freezing. The maximum daily consumption for the City of Boston occurred on February 10, 1910, and was 123,690,000 gallons, or 183 gallons per capita; on that day 65,350,000 gallons was used from the Southern Low service, 21,890,000 gallons from the Northern Low service, and 36,450,000 from the Southern High service.

Meters and Connections.—The city is installing over 6,000 meters each year and considerably reducing the per capita consumption thereby. There are 98,203 service taps, about 1,400 of which are 4 inches or larger in diameter; of these, 580 serve elevators, 115 motors and 171 private fire-fighting equipments, including 254 sprinkler equipments; those 6 inches and larger, about 200 in number, supply isolated plants and the department does not make any connections larger than 4-inch in closely built-up districts where pipes immediately enter buildings, but does not restrict the number of such connections.

PRESSURES.—There are 19 recording pressure gages maintained on the Metropolitan Works and the charts show that there are no wide variations in pressure.

On the city's distribution system, there are 20 recording pressure gages; the location and average pressure at each is shown in Table No. 6.

TABLE No. 6—RECORDING GAGE PRESSURES.

Location.	Service.	Elevation.	Average Pressure.	
			3 A. M.	9 A. M.
Chestnut Hill Pumping Station	S. Low.	127.5	6	17
Boston Common	S. Low.	48.4	40	36
Salem St., Engine No. 8	S. Low.	27.2	45	41
East St., Engine No. 7	S. Low.	22.7	48	44
Milk St., Post Office Building	S. Low.	20.9	48	48
Congress St., Engine No. 38	S. Low.	21.1	46	41
Fourth St., at O St., Engine No. 2	S. Low.	51.8	33	30
710 Albany St	S. Low.	24.0	50	42
Gibson St., Water Dept. Yard	S. Low.	29.3	46	40
Western Ave., Engine No. 34	S. Low.	27.5	49	48
Bunker Hill St., Engine No. 32	N. Low.	36.0	56	54
Marion St., Engine No. 5	N. Low.	64.3	39	34
City Hall	S. High.	105.1	62	56
Quincy St., Engine No. 24	S. High.	98.3	64	58
Walnut St., Engine No. 20	S. High.	20.8	97	90
Norfolk St., Engine No. 19	S. High.	79.1	72	70
Chestnut Hill Ave., Engine No. 29	S. High.	111.5	60	57
Centre St., Engine No. 28	S. High.	82.9	72	68
Centre St., Engine No. 30	S. High.	172.0	33	30
Washington St., Engine No. 45	S. High.	84.4	71	68

The above records show that there are no excessive variations of pressure and that in general the same pressures are maintained as were observed 6 years ago when pressure readings were taken at 829 hydrants with the results shown in Table No. 7. The drop in pressure at times of maximum consumption between the Low service pumping station to Boston Common has been reduced from 18 pounds to 11 pounds. To compensate for the greater loss by friction, caused by the larger consumption, the pressure at the Low service pumping station is increased during the day over that maintained at night and also upon the receipt of third alarms.

TABLE No. 7.—PRESSURES.

Service.	Average.	Maximum.	Minimum.
Southern Low:			
Whole Area	47	60	30
Congested Value District	47	54	42
Southern High:			
Whole Area	66	95	23
Congested Value District	82	90	64
Southern Extra High	80	110	50
Northern Low	52	61	33
Northern High	44	58	21

DISTRIBUTION SYSTEM.—General.—Distribution is in five services; Southern Low and Northern Low, both supplied mainly by pumpage supplemented by gravity, Southern High, Northern High and Southern Extra High, all supplied by pumpage, the two former to reservoirs and the latter with an equalizing standpipe. Elevations throughout the area served range from tide water to 336.

Southern Low Service.—*General.*—Supplies about one-third of the area south of the Charles river, serving the greater part of the city proper, including over one-half of the congested value district, the principal lumber, warehouse and shipping districts, besides numerous important minor mercantile sections. It also supplies most of South Boston, two-thirds of Brighton and small sections in the northeasterly part of Roxbury and Dorchester, in all covering an area of about 9 square miles, in which elevations range from tide water to 65.

Main Arteries.—Three 48-inch mains extend easterly from the Low service pumping station, for distances of from 1 to 3½ miles, where they divide into pipes of smaller size; two 30-inch and a 40-inch enter the congested value district, which is girdled by a 16-, 24-, 30- and 36-inch loop; a 24- and a 30-inch pass easterly through Roxbury and Dorchester, two 20-inch and two 30-inch mains supply South Boston and a 16- and 20-inch feed part of Brighton, which further receives a supply from a 16-inch connection to the 48-inch Metropolitan main which passes through this section. These feeders are well looped and are cross-connected when opportunity affords. The supply to this service can be re-inforced from the Northern Low service through pipes 20 and 30 inches in diameter extending across the Warren street bridge from Charlestown. The entire area is well sub-divided by secondary feeders, 10, 12 and 16 inches in diameter, well looped and connected to larger mains.

Minor Distributers.—In the congested value district, 65 per cent. of the mains are 10 inches or larger in diameter; they are well cross-connected at street intersections and the block lengths are short.

In the remainder of the city proper and in Roxbury there are about equal parts of 6- and 8-inch, with a fair proportion of 10-inch; and in South Boston and Brighton 6-inch predominates, with a small percentage of 8- and 10-inch; much of the pipe in the former district is over 50 years old. The system is generally well cross-connected, with few dead ends, except in Brighton and the eastern part of Dorchester.

TABLE No. 8.—MAINS IN CONGESTED VALUE DISTRICT.

Diameter, in Inches.	Southern Low Service.		Southern High Service.		Both Services.	
	Length, in Feet.	Per Cent. of Total.	Length, in Feet.	Per Cent. of Total.	Length, in Feet.	Per Cent. of Total.
4	1,800	1.4	2,350	3	4,150	3
6	17,300	13.9	10,000	14	27,300	14
8	23,300	18.7	12,300	18	35,600	18
10	5,350	4.3	6,900	10	12,250	6
12	43,000	34.6	26,300	38	69,300	36
16	16,300	13.1	11,800	17	28,150	14
20	1,550	1.2	.....	.....	1,550	1
24	4,650	3.7	.....	.....	4,650	2
30	8,200	6.6	.....	.....	8,200	4
36	3,100	2.5	.....	.....	3,100	2
Total	124,600	100.0	69,650	100	194,250	100

Northern Low Service.—*General.*—Supplies, by gravity from Spot pond and Mystic reservoir, East Boston and the greater part of Charlestown and Breed's Island, comprising a total area of about 2.5 square miles, in which elevation ranges from tide water to 75; generally compactly built up and mostly residential in character, although there are dock and warehouses sections of considerable importance, besides scattered minor mercantiles and manufactories.

Main Arteries.—A loop of 16-, 20- and 24-inch pipe extends about the area served in Charlestown and is fed by three Metropolitan mains, two, a 24- and a 30-inch, entering from the west and a 30-inch from the north. Secondary feeders, 12 and 16 inches in diameter, are fairly well arranged. Three Metropolitan mains, a 20-, a 24- and a 36-inch, supply well arranged loops of 12-, 16-, 20- and 30-inch pipes in East Boston which in turn supply Breed's Island through two 12-inch lines. Secondary feeders are generally installed where needed.

Minor Distributers.—About equally divided between 6- and 8-inch, with 12-inch in the more important streets; mains well gridironed, with few dead ends.

Southern High Service.—*General.*—Supplies Beacon Hill in the city proper, including a portion of the congested value district, and by extension of mains furnishes sprinkler and standpipe supply to buildings in a considerable portion of the congested value district where supply for other purposes is from mains of the Southern Low service. Also supplies sections in the higher parts of

Charlestown and South Boston, mainly of thickly built-up frame residences, about one-third of Brighton and nearly all of Roxbury, West Roxbury and Dorchester, the last four mainly frame residential sections with occasional areas compactly built up. Supply pumped at Chestnut Hill High service station into the distribution system, with Fisher Hill reservoir, holding about 6 hours' supply when filled, as an equalizer. Elevations range from 20 to 180 throughout the area served, which is about 12.5 square miles.

Main Arteries.—From the pumping station, two mains, a 30- and 36-inch, extend to Fisher Hill reservoir and continue easterly to the city limits as a 30- and 48-inch. They are cross-connected near the reservoir to a 48-inch Metropolitan supply main which extends from the High service station southeasterly through the city for the supply of territory beyond its limits, and three other similar connections are made to the city distribution system along its route. The supply to the city proper is furnished by one 42-inch and two 20-inch mains which unite on the Common and branch into five 16-inch mains. Roxbury, West Roxbury and Dorchester are served by 24-, 30- and 36-inch mains, which, considering the connections with the Metropolitan supply mains, are ample for the service required. The areas in Brighton, South Boston and Charlestown are each supplied by a single 16-inch main. Secondary feeders in the Jamaica Plain section of Roxbury and in West Roxbury are incomplete; in other sections fairly well arranged.

Minor Distributers.—Mainly 6-inch with a fair proportion of 8- and 12-inch; the gridiron is generally complete in the more thickly built-up sections, but dead ends are numerous, particularly in the outlying and newly developed areas.

Southern Extra High Service.—Supplies the higher portion of West Roxbury, a scattered residential section covering an area of about 1.8 square miles in which elevations range from 125 to 336. Supplied from West Roxbury pumping station, with Bellevue standpipe as an equalizer.

A 12-inch main from the pumping station to the standpipe feeds other 12-inch mains which in turn supply an incomplete gridiron of 6-, 8- and 10-inch pipes.

Northern High Service.—Supplies a small residential section of the higher part of Breed's Island, covering an area of about one-half square mile in which elevations range from 35 to 160.

A single 12-inch main leading from a 12-inch Metropolitan main connects to the standpipe and supplies a few 6- and 8-inch distributers which serve this unimportant section.

PIPES.—Length and Age.—Table No. 9, compiled from the records of the water department, gives the length of the various sizes of pipes 4 inches and larger in diameter, in the distribution system on January 1, 1911, and the net increase since January 1, 1905. Over 40 miles of the pipe, mainly of the larger sizes, which was in use in 1850, are now in service. The department lays little pipe less than 8 inches in diameter and no 4-inch, to furnish hydrant supply, and has replaced 22.2 miles of old pipes of small diameter with larger sizes during the past six years.

TABLE No. 9.—PIPES AND VALVES IN SERVICE IN THE DISTRIBUTION SYSTEM.

Diameter, in Inches.	Length of Pipe, in Miles.	Per Cent. of Total.	Net Increase in Miles Since Jan. 1, 1905.	No. of Gate Valves.
4	12.14	1.6	—4.27	492
6	237.54	31.1	—13.95	3,873
8	124.16	16.2	13.18	1,902
10	37.14	4.8	11.47	640
12	238.22	31.2	15.40	2,689
16	41.11	5.4	4.20	435
20	18.00	2.3	.04	74
24	14.67	1.9	—.12	67
28	.05	.....	.00	0
30	18.74	2.4	1.87	57
36	8.49	1.1	.30	20
40	4.38	.6	.01	11
42	3.18	.4	.00	6
48	7.42	1.0	1.08	12
Total..	765.24	100.0	29.21	10,278

Of about 94.5 miles of Metropolitan supply mains from 12 to 60 inches in diameter, about 44 miles, mostly 48- and 36-inch mains, contribute in whole or in part to supply Boston. These mains, with the exception of some short lengths acquired from municipalities, are less than 15 years old; about 10 miles have been laid during the past six years.

Condition and Cover.—With the exception of about two miles of 20- and 30-inch wrought iron, cement lined pipe, all pipes are cast iron. Those laid in the original works were uncoated and the metal appears from examination to be in a good state of preservation, although the tubercular formation ranges from 1 to 2 inches in thickness. Pipes laid in marshy ground are frequently so corroded as to fail. Many of the smaller, old pipes have been replaced by new pipes of larger size. Dead ends are frequently flushed, during the summer, through flush hydrants or special hydrant blow-offs. Mains are laid with the axis of the pipe 5 feet below street grade. Average frost penetration, from 3 to 4 feet; maximum, about 5 feet. Many lines cross the rivers, channels and railroads either in tunnels or beneath ground, but there are a large number crossing on bridges; these are well protected from mechanical injury and securely supported, but considerable trouble has been experienced near the bridge abutments; three lines, a 16-, a 20- and a 30-inch, are carried from Charlestown into the city proper on the Warren street bridge. No trouble has been experienced in recent years from frozen mains.

Seven serious ruptures have occurred on Tremont street, between Boylston and Common streets, on the two 30-inch Low service mains, since the construction of the subway. The last one, early in 1910, necessitated shutting out both mains because of their close proximity. This operation required about one and one-half hours, during which period the pressure and quantity of water available was materially reduced. This section of pipe has been examined and supported in a proper manner, so that the recurrence of such accidents should be less frequent.

Distributing mains of the Metropolitan system are laid with sufficient cover, and, as they have been recently laid, their carrying capacity has only slightly decreased.

Specifications.—The Metropolitan Water and Sewerage Board and the city water department both have well drawn specifications governing the purchase of pipe which conform in general with the American and New England water works specifications. Pipes are subjected to rigid inspection during manufacture and installation, but hydrostatic pressure is not generally applied before backfilling. Special attention is given to the effect of the chemical composition of the iron upon the reliability of the pipe.

Electrolysis.—See Electricity, page 42.

GATE VALVES.—Number and Kind.—There were 10,278 gate valves in service on the distribution system on January 1, 1911, as shown by the records of the water department and given in Table No. 9. All are of special design and operate in a uniform direction; those 24 inches and smaller in diameter are made in the department shops, and the larger ones are manufactured by contract, all from patterns owned by the city. All 20 inches and larger are geared. The wooden boxes with iron manholes which provided access to the operating nuts are being replaced by permanent concrete boxes; the larger gates are set horizontally and inclosed in brick vaults. Valves are set at or near property lines at street intersections and their location is indicated on some fixed object.

Spacing.—Gate valve spacing is generally good. In the congested value district, the average length of main in both High and Low service that it would be necessary to cut out in case of repairs is about 420 feet, with 10 lengths out of 420 over 1,000 feet and a maximum of about 1,600 feet. In a representative residential section, the average was found to be 690 feet, with maximum lengths of 1,400 and 2,400 feet.

Inspection.—Seven men and two teams are assigned to this work during the open season. About 5,000 inspections are made each year; the box is cleaned, its location recorded and checked on the plans, and the valve operated, oiled and repaired. Records of inspections are kept on history cards, but these are not up to date or filed, owing to the lack of clerical help. The necessity and importance of this work is shown by the records, which state that of 7,095 inspections, 29 High service and 20 Low service valves, ranging from 4 to 20 inches in diameter, were found closed and 300 partially closed, one division gate was open, 12 valves required replacing, 100 were either not on plans or not in ground, 2 gate vaults were filled up and 1,952 boxes required cleaning.

Closing of Valves.—All valves are normally open, except those at service limits; these latter are indicated on the plans and an up-to-date list is in the hands of responsible employees. When valves are operated which affect hydrant supply, work is generally continued until completion, and water is turned on in case of fire in the area; if hydrants are left out of service, fire department headquarters is notified by telephone. Although considered advisable by the department, no records are kept of the operation of valves and many of the closed valves are attributed to the operations of the waste detection crews.

Valves on Services.—Many of the older services are not equipped with valves at the curb, and the street has to be opened to make a shut-off; further records of the location of the piping are lacking in many instances. The locations of services laid during the past 30 years are recorded in card catalog form and the older ones are rapidly being located and recorded.

HYDRANTS.—There were in service on January 1, 1911, 8,103 public and 307 private hydrants. Table No. 10, compiled from records of the water department, gives classification, dimensions and number of each make.

TABLE No. 10.—HYDRANT DATA.

Kind.	Connection to Main.	Inside Diameter of Barrel.	Diameter of Valve.	Number and Diameter of Outlets	Number.
Lowry.....	Directly over main.	9	6½	Chuck	2,029
Boston Lowry	6 & 8*	5½	4	Chuck	786
Post (Ordinary)	6 & 8*	6	5	1-4½ & 2-2½	2,964
Boston Post.	6 & 8*	7¼	6	2-4½ & 1-2½	2,096
Boston.....	4	3	2½	Chuck	228
Total.....	....	....	....	.....	8,103

* 6-inch if less than 15 feet in length.

Hydrants are made in the department shops. The Lowry, Boston Lowry and Boston hydrants are of the flush type. The Lowry is set directly over the main, frequently at the intersection of mains, and the Boston Lowry on the sidewalk; the Boston is an old type used for flushing dead ends and gradually being replaced. The Boston Post

hydrant is of excellent design, having valve opening and barrel of ample dimension, and is equipped with independent valves on each outlet; the drip, however, is not positively operated but is dependent upon a spring. Most of the hydrants are enclosed below the sidewalk or street level in wooden or concrete boxes with iron covers. Very few have the connection to the main equipped with a gate.

How Located.—Hydrant locations are determined by the water department at positions recommended by the fire department, if such seem feasible upon examination. The locations of flush hydrants are designated by offsets in white paint from one or more points.

Drainage.—Hydrants have automatic valves which discharge directly into the ground, although a few are either connected to sewers or plugged. Drainage is generally poor, due to type of drip.

Inspection.—A general inspection of all hydrants is made in the fall and thereafter the frequency depends upon the temperature. About 35 men are employed in the city proper and from 3 to 7 in each of the several suburban maintenance districts. Out of about 35,000 inspections, only 20 hydrants were found frozen during the past season. Those which are below ground-water level are pumped out daily and the boxes of others in exposed places are packed with hay. After hydrants have been operated by the fire department they are immediately put in serviceable condition.

Distribution.—The average linear spacing of hydrants in the congested value district is 125 feet, and the area served by each hydrant is 40,000 square feet. In a representative residential district the spacing was found to be 296 feet and the area served by each hydrant, 78,000 square feet.

Use by Street Department and Others.—Although 516 water posts are distributed throughout the city, the sewer, street cleaning, street watering and highway divisions operate hydrants indiscriminately, and contractors on city work are also permitted to use them. The damage reported from this cause is considerable.

TABLE NO. 11.—HYDRANTS IN CONGESTED VALUE DISTRICT.

Make.	High Service.	Low Service.	Total.
Lowry	64	254	318
Boston Lowry	5	6	11
Boston	8	10	18
Boston Post	10	57	67
Ordinary Post	5	6	11
Total	92	333	425

FIRE FLOW TESTS.—The flow from 76 hydrants in 14 groups, located within congested frame areas, was measured by engineers of the National Board in March, 1911, to determine the probable fire engine supply available. Five or six hydrants were opened simultaneously and the discharge measured by means of Pitot tubes. Results are classified in Table No. 12, and the locations of the groups are shown on the accompanying map. The quantities obtained were in general sufficient for the protection of the surrounding areas. Nine hydrants, or 12 per cent. of those opened, failed to deliver 600 gallons per minute, a fair supply for a second size fire engine. These small discharges were due to the condition of the old 6-inch mains, which predominated in Tests Nos. 3, 6, 7 and 9, as in all cases the residual pressure observed on the adjacent large mains showed that their ultimate carrying capacity had not been reached.

TABLE NO. 12.—FIRE FLOW TESTS IN CONGESTED FRAME AREAS.

Number and Location of Group.*	Discharge, Gallons per Minute.								Pressure, Pounds per Square Inch.	
	Individual Hydrants.						Total of Group.	Average per Hydrant.	Hydrants Closed.	Hydrants Open.
1. Rutherford Ave. and Chapman St. *nl*	†270	600	1,080	1,440	1,700	1,820	6,910	1,150	60	38
2. Vine and Tufts Sts. *nl*	750	940	2,340	2,370	2,870	.....	9,270	1,850	59	37
3. Prescott and Princeton Sts. *nt*	350	500	580	1,020	1,070	1,120	4,640	770	40	12
4. Chelsea and Marion Sts. *nl*	1,300	1,400	1,600	1,780	2,310	.....	8,390	1,680	56	22
5. Everett and Cottage Sts, *nl*	730	1,030	1,060	1,080	1,600	.....	5,500	1,100	54	27
6. M and 7th Sts. *sl*	†180	800	820	850	1,010	.....	3,660	730	42	33
7. I and 2nd Sts. *sl*	480	540	540	750	930	1,490	4,730	790	42	30
8. 6th and E Sts. *sl*	†180	710	910	1,050	1,140	1,380	5,370	900	44	37
9. Leonard and Duncan Sts. *sl*	450	570	730	910	970	1,020	4,650	780	48	21
10. Wrentham St. and Dorchester Ave. *sh*	600	810	870	1,180	1,300	.....	4,760	950	63	22
11. Rockland St. and Walnut Ave. *sh*	700	870	1,220	1,410	2,300	.....	6,500	1,300	63	42
12. Whitney and Smith Sts. *sl*	920	1,260	1,360	1,640	2,070	2,110	9,360	1,560	42	28
13. Minden and Posen Sts. *sh*	710	850	860	1,130	1,910	.....	5,460	1,090	85	77
14. Weld Hill and Wenham Sts. *sh*	580	1,000	1,100	1,680	2,850	.....	7,210	1,440	65	20

* Location of groups shown on accompanying plan by corresponding numbers. † Hydrant Throttled.
sl Southern Low Service. *nl* Northern Low Service. *sh* Southern High Service.

That the carrying capacity of the supply lines to the congested value district is ample was shown by the break in the 30-inch main on Tremont street, when the consumption rate on the Southern Low service reached 100,000,000 gallons per day, which was 45,000,000 gallons in excess of the rate previous to the break; during this high rate of flow, the recording gage on the Common showed a drop from 42 pounds to 5 pounds and that at Engine House No. 38, on Congress street, a drop from 49 pounds to 25 pounds.

During the progress of the simultaneous fires on Albany and Purchase streets in August, 1910, the maximum hourly fire draft showed a fire flow of 20,000 gallons per minute, 4,000 gallons of which was used on the latter fire.

RECENT IMPROVEMENTS AND ACTION ON PREVIOUS RECOMMENDATIONS.—Since the inspection of the city in 1905 by engineers of the National Board, the Metropolitan Water and Sewerage Board has completed and filled the Wachusett reservoir and has paralleled the Weston Aqueduct for about two-thirds the distance between the terminal chamber and Chestnut Hill reservoir. The supply to the Northern Low service in East Boston has been materially increased and doubly assured by laying a 36-inch main through Chelsea and beneath Chelsea creek in a tunnel. The supply to the Southern Low service has been augmented by the construction of a 48-inch line from the terminus of the Weston Aqueduct through Brookline to the Fenway on Longwood avenue. The capacity of the High service pumping equipment at Chestnut Hill reservoir is being increased by the installation of a unit of 40,000,000 gallons capacity, which will be ready for service within three months. A pump of 1,750,000 gallons capacity has been installed in the West Roxbury station, thus partially complying with recommendation No. 3.

The city water department has constructed a tunnel and laid a 24-inch line beneath Fort Point Channel from the city proper to South Boston; this line is fed by 30-inch pipe laid from the junction of the large arteries in the congested value district southerly to the channel, thus fulfilling recommendation No. 1*d*. Little work has been done in compliance with 1*a* and but few mains of the Southern High service have been extended in the congested value district. The Fells reservoir has not been connected to the Southern High service as was suggested in recommendation No. 2, the additional High service pump in the Chestnut Hill Low service pumping station making it less necessary at the present time. Although a large number of new mains have been laid, not all the recommendations embodied in No. 5 have been complied with. The policy of replacing the small old mains by pipes of larger size has been continued by the department along the lines outlined in Nos. 7, 8 and 9, and a fair portion of work has been done toward accomplishing No. 6, and a few secondary feeders have been laid in residential sections according to recommendation No. 10. Little has been done in compliance with Nos. 11 and 12; the number of dead ends remains about the same and those along service limits have not been looped. The per capita rate of consumption is being reduced both by the use of the Deacon meter and by the installation of service meters, the latter being compulsory under a legislative act. Although in general the gate spacing throughout the system is fair, there are numerous long lengths of pipe which could be advantageously subdivided by gates as recommended in No. 14. The department has made considerable progress in complying with No. 15 and has established a gate inspection crew and a card catalog system for recording the location and condition of gates. The fire department is notified by telephone when gates affecting the hydrant supply are operated, but no further records are kept, thus disregarding No. 16. Hydrants are not inspected as frequently as suggested in No. 17, and the threads of the hydrant outlets have not been made to conform with the National standard as stated in No. 18. No. 19 has not been complied with, although an automobile emergency wagon and a crew are on duty and prepared to respond at all times.

SEPARATE SALT WATER FIRE MAINS.—A pipe line of extra-heavy 12-inch cast-iron pipe, as shown on the accompanying map No. 2, was installed in 1898. Hydrants are set every 300 feet along the route; these have 8-inch barrels and three 3-inch independently gated hose connections; in a recess in the barrel, connections can be made by portable Morse sets carried on the chiefs' wagons, with the telegraph circuit used to signal orders to the fire boat. The fire boat connection is at Central Wharf and Engine 44 does not have to move from its present berth to make connections, and can furnish water in ten minutes, provided it is at the dock, although it does not connect to the system except on orders. The pipe is kept filled with fresh water; tests have been made and the pipes flushed once a year. Engineers of the National Board were present at a test of the system made on July 29th, 1908. The hydrants used were the three farthest from the fire-boat connection. Engine 44 (the fire-boat) supplied the pipe line through six 3½-inch hose lines, 35 feet long, and maintained 190 pounds water pressure at the pumps throughout the tests. It started on signal over the telegraph circuit for each test when preparations had been completed. The signalling system worked admirably; the pumps started and stopped promptly as desired.

The first test was with 6 lines, 3 from each hydrant, of 100 feet each of 3-inch hose, and one 1½-inch, five 1⅜-inch and three 1¾-inch smooth nozzles were used. The total discharge was 4,230 gallons per minute, with nozzle pressure of 36½ to 55½ pounds; this developed the full capacity of the pipe line for the pressure carried at the pumps

for moderately effective streams. The second test was with 4 lines of 100 feet of 3-inch hose from one hydrant siamesed into a deluge set with 3-inch nozzle; 2,280 gallons per minute were delivered at 72 pounds nozzle pressure. Another test was with 4 lines from one hydrant of 100 feet of 3-inch hose, each with 1⅜-inch smooth nozzle. The pressure at the nozzle ranged from 92 to 104 pounds and the discharge was 2,210 gallons per minute. The system has a capacity equivalent to 5 first size engines.

SEPARATE HIGH PRESSURE FIRE MAIN SYSTEM.—For several years past the question of constructing a separate high pressure fire main system has been advocated by the city authorities and a bill was recently passed by the State legislature empowering the city to construct works at an expense of $1,000,000. The proposed system covers practically the same area as the congested value district.

CONCLUSIONS.—Organization.—The organization of the Metropolitan Water and Sewerage Board is excellent and is removed from harmful political influence. The recent reorganization of several of the municipal departments should result in a material increase of efficiency of the water department, as the present officials are well qualified for their positions.

Records.—The records of the Metropolitan Water Works are exceptionally complete; those of the water department are fairly complete, but are not up to date nor sufficiently in detail, on account of lack of clerical force adapted to the work.

Supply Works.—Sources now developed are ample for the Metropolitan district for several years. Present supply works are part of a comprehensive plan providing for the incorporation as needed of predetermined additional sources. The past able performance of the Metropolitan Water Board gives assurance that the increasing needs of the district will be properly anticipated.

Existing works are well designed, carefully built and well maintained. The main conduits are ample in size and so arranged that interruption of service in any one would not seriously interfere with a continuous supply at the present rate of consumption. With increasing demands upon the supply works, Weston aqueduct will grow in relative importance and eventually become the main dependence of the district. However, accident to a well designed and substantially built masonry structure of this kind is unlikely. The large amount of water stored within the limits of the Metropolitan district makes it improbable that trouble serious enough to curtail full supply to the city would ever arise.

Pumping Stations.—Capacity of pumps in each of the stations at Chestnut Hill reservoir is well in excess of present requirements, and the large High service unit now being installed will provide for sufficient reserve on this service, although only about 5 hours' supply is available by gravity from the equalizing reservoir. The equipment of the West Roxbury station is sufficient in capacity to assure moderate protection to the district. The pumping stations, except that at Spot pond, are non-fireproof; however, the possibility of serving the two Low services by gravity, of using some of the pumps on either High or Low service, and the installation of an additional High service unit in the Low service station, preclude the possibility of interruption of supply to either of these services by destruction of a station by fire; the Southern Extra High service supply is, however, menaced by such a possibility.

Distributing Reservoirs.—The Low service reservoirs are of sufficient capacity to furnish uninterrupted supply to their distribution systems should their own supply be cut off by accident. Distributing reservoirs and standpipes of the High service are of value only as equalizers and could not maintain an uninterrupted supply if their own supply failed. All are at sufficient elevation to give satisfactory pressures in the districts served by them.

Supply Mains.—The mains of the Metropolitan Works supplying the Southern Low service and Northern Low service, both in Charlestown and East Boston, are ample in capacity and so arranged that interruption of supply is improbable.

The Southern High service is also supplied by mains of sufficient size, which can be fed from either of two pumping stations. There is danger of interruption of the supply at West Roxbury in the Southern Extra High service and on Breed's Island in the Northern High service, as both their areas are served by single lines of pipe and the available supply in storage is small.

Consumption.—Since the passage of a legislative act, which compels the metering of a certain number of services each year, the average daily consumption has been reduced by over 10,000,000 gallons, and the per capita rate, which is still in excess of reasonable requirements, will probably be further reduced by the continuation of this policy and the proper enforcement of waste restriction measures. Such reduction in the consumption rate defers the time when additional supply will have to be developed, and at the same time enables larger quantities to be drawn from the distribution system for fire protection purposes.

Pressures.—Pressures are fairly well maintained and do not show undue friction loss at times of maximum draft; they are adequate to furnish ample fire engine supply, and the combination of High and Low services in the congested value and other important mercantile and manufacturing districts enables the former service to supply sprinkler and other private fire-fighting equipments in a most reliable and satisfactory manner. The High service should be extended across Fort Point channel into an important manufacturing district, as has been outlined by the water department.

Protection in the Congested Value and Other Districts.—The adequacy and reliability of the water supply for fire protection in the congested value district is sufficient to meet almost any condition that may arise; however, the values involved in the city are very high, and it is probably impracticable to maintain in a city of this size a fire department dependent entirely on fire engine service and able to properly cope with two serious simultaneous fires. The early installation and equipping of a separate high pressure fire system is the best method of offsetting the serious structural conditions in parts of the district, and preventing fire protection from being reduced to a dangerous minimum when fighting fires in other parts of the city.

The water front, including the lumber yards in the city proper, Charlestown, East Boston and South Boston, requires 15,000 gallons per minute, in addition to that available from the fire boats, and the proper protection of the several important mercantile sections and the garage district demands 10,000 gallons per minute, and other closely built-up sections from 4,000 to 8,000 gallons, depending upon the hazard. The above quantities are generally available at pressure sufficient for engine supply throughout the city.

Main Arteries.—Arteries in the Low service are of ample size, sufficient in number and well distributed throughout the area served; the same is true in the principal area of the Southern High service, but in remaining portions of the High service, arteries are frequently deficient and sometimes lacking, generally in the outlying sections.

Minor Distributers.—Over 32 per cent. of the pipe in the distribution system is 6 inches or less in diameter, and some 6-inch pipes are old, tuberculated and unable to furnish a satisfactory hydrant supply; however, these latter are being rapidly replaced by mains of larger size according to a well outlined policy of the department, and there is about 14 miles less of 6-inch pipe in service than there was 6 years ago, which, together with the fact that little pipe less than 8 inches in diameter is laid, assures a gradual strengthening of the distribution system.

Condition of Mains.—Tubercular formation grows with considerable rapidity, and the carrying capacity of the older mains, many of which are of the larger sizes, is considerably reduced. Inasmuch as many of these are without service connection, the cleaning of them is feasible and desirable. Exposed lengths are well installed and protected. Electrolytic conditions are carefully watched and the traction company co-operates with the department in providing the most approved preventive measures; the strength of pipes, even the oldest, except where laid in unfavorable ground, is good.

Gate Valves.—In general, the system is well equipped with gate valves, but there are occasional sections of pipe, particularly of larger size, which could be advantageously subdivided by the installation of additional gates. That a systematic inspection of gates, as adopted, was necessary, is shown by the inspection records. The failure to confirm, in writing, telephone notices to the fire department when hydrants are out of service is liable to cause a conflict of responsibility, and record of the operation of all gates should be kept for the same reason.

Hydrants.—Hydrants are of ample dimensions, and in most districts there are enough post hydrants available, thus obviating the delay in placing the chuck on flush hydrants. Distribution is generally good, and particularly so in all high value and congested districts. Inspections are fairly frequent and efficient, but the records of repairs show that the indiscriminate use of hydrants causes considerable damage.

Recent and Contemplated Improvements.—The Metropolitan Water and Sewerage Board has made several additions to the system which greatly improve the reliability of the supply and provide for future growth. The city water department has complied with many recommendations embodied in the 1906 report of the National Board of Fire Underwriters, including the laying of large mains and, most important, the reduction of the per capita consumption by the installation of meters.

FIRE DEPARTMENT.

ORGANIZATION. — Basis. — Full paid; the services of call numbers were dispensed with in 1909.

Supervision.—The department consists of the headquarters or commissioner's office, the fire force, the fire alarm, the repair shop and the veterinary hospital.

A Fire Commissioner is the administrative head and controls the promotion and retirement of members, the selection of candidates for appointment, the enforcement of discipline and the expenditure of appropriations. He co-operates with the State police to regulate the handling and use of explosives and the storage of gasolene, and assists, through the officers of the fire force, in the inspection of moving picture theatres. The fire appliances in theatres and public halls must be approved by him before licenses are issued. He is appointed by the Mayor for a 4-year term; the approval of the State Civil Service Commission is required under the present city charter. He may be removed by the Mayor for cause. Fire Commissioner Charles D. Daly was appointed for a full term in 1910.

The Chief is the executive officer of the fire force and has full control at fires. He is responsible to the Commissioner for the efficiency and operation of the force. Chief officers and heads of branch departments are appointed, under civil service regulations, by the Commissioner with the approval of the Mayor, and may be removed only for disability or incompetence; they report to the Commissioner.

Districts.—The force is organized on a division and district basis. Each division consists of 7 dis-

tricts and is under the direct supervision of a deputy chief. The senior deputy chief is acting chief as occasion requires.

The city is divided into one marine and 13 land districts with a district chief assigned to each, who is held responsible for the condition and operation of the companies in the district; each takes charge at fires in his own district until relieved by a superior officer.

There are 6 to 8 companies in each closely built-up district and from 5 to 9 in outlying districts.

Membership.—Total, 1,006. Fire force, 897.

FIRE FORCE:	Oct., 1905.	Jan., 1911.
Chief	1	1
Deputy Chiefs (formerly Assistant Chiefs)	2	2
District Chiefs	11	14
Supervisor of Engines	1	1
Captains	54	55
Lieutenants	73	89
Engineers	45	48
Assistant Engineers	48	44
Hosemen and Laddermen	572	637
Chiefs' Drivers	13	6
Call Members	68	0
Total	888	897
STAFF AND OFFICE	8	10
REPAIR SHOP	28	55
VETERINARY HOSPITAL	6	6
FIRE ALARM FORCE	29	38

Officers.—

	Age.	Appointed to Present Position.	Years in Service.
Chief, John A. Mullen	60	1906	36
Senior Deputy Chief, John Grady	56	1909	36
Junior Deputy Chief, Peter F. McDonough	53	1909	27

Expenses.—The expenses of the department, exclusive of the fire alarm branch, have been as follows during the past three fiscal years:

Year Ending Jan. 31st.	Salaries and Pensions.	General Expenses.	Maintenance, Total.	New Apparatus and Houses.
1909	$1,142,352	$292,074	$1,434,427	$62,064
1910	1,138,231	289 392	1,427,623	100,900
1911	1,230,265	278,297	1,508,763	106,818

The average annual per capital expense for maintenance for this period is $2.17, based on an average population of 671,000. For the 3-year period, 1900 to 1902, inclusive, the annual per capita expense for maintenance was $2.08, based on an estimated averaged population of 572,000. In both cases the cost of new apparatus and houses and the expense of the fire alarm are not included.

Enlistment and Appointments.—Original appointments are made by the commissioner from certified lists furnished by the State Civil Service Commission. Applicants must be between 22 and 30 years of age, except that men who have served as call members are eligible until 35 years of age, must weigh not less than 135 pounds, be at least 5 feet and 7 inches tall, and pass physical and mental examinations. New members are on probation for six months, during which time they attend the drill school and must pass an examination by the department physician. Promotions are made by the commissioner, with the approval of the mayor, under limited civil service regulations; selections are based on merit and recognize efficient service, as well as seniority and experience; the men selected are subjected to non-competitive examinations. Engineers are promoted from the rank of assistant engineer, usually after several years' service and on the recommendation of the supervisor of engines. Assistant engineers are promoted from the ranks after taking a course in the school of instruction and an examination given by the supervisor of engines. They must also be examined and licensed by the State boiler inspection department before appointment. Pilots and engineers on the fire boats have to hold the usual government licenses.

Retirement and Pensions.—No age limit is set for retirement; 5 members are over 62 years of age, and 32 are between 55 and 61 years old. Members of the fire force who have served 15 years may be retired on half pay at the discretion of the commissioner; those permanently disabled in service are retired on two-thirds pay. Injured members receive full pay, and two relief associations, to which membership is voluntary, provide sick and death benefits. The Firemen's Mutual Relief Association, to which all members of the uniformed force belong, pays $2,000 death benefit. The State pays $1,000 to dependent relatives of a member killed in the service, and the city provides a pension in such cases.

Companies.—*Organization.*—There are 44 engine, 2 fire-boat, 27 ladder, 3 water tower and 13 chemical companies. See Table No. 13. Four of the engine companies are in two stations, forming double companies. Each double company has 3 officers, 2 engineers, 2 assistant engineers and 15 or 20 firemen, each of the other engine companies in the closely built-up districts has 2 officers, an engineer and assistant engineer and 8 to 10 hosemen, and in the suburban districts from 5 to 8 hosemen. Each fire-boat has 2 officers, 5 pilots, 5 engineers and 4 hosemen. The aerial and ordinary ladder trucks, except No. 14, have companies of 11 to 14 members, including 2 officers; the combination ladder trucks have 7 to 9 men, including a lieutenant. The chemical engines are manned by 3 to 6 and the water towers by 3 to 5 men, including in each case a lieutenant.