The Water Supply Of San Francisco, California, Before, During And After The Earthquake Of April 18th, 1906

And The Subsequent Conflagration

HERMANN SCHUSSLER

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The Water Supply Of San Francisco, California, Before, During And After The Earthquake Of April 18th, 1906

Dr. Wm McM. Woodworth
Compliments of J. M. Quay

THE WATER SUPPLY

OF

SAN FRANCISCO, CALIFORNIA

BEFORE, DURING AND AFTER

The Earthquake of
April 18th, 1906,
and the Subsequent
Conflagration . . . .

DEDICATED TO THE

HYDRAULIC ENGINEERS OF AMERICA

BY

HERMANN SCHUSSLER, Chief Engineer

OF THE

SPRING VALLEY WATER COMPANY

JULY 23d, 1906

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THE WATER SUPPLY

OF

SAN FRANCISCO, CALIFORNIA

Before, During and After the Earthquake of April 18th, 1906, and the Subsequent Conflagration

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The earthquake of April 18th, 1906, followed by a general conflagration, destroyed the largest part of the business portion of San Francisco, as well as a considerable part of the adjacent residence district.

The earthquake shock, which occurred about 5.15 A. M. on April 18th, although not injuring our main storage reservoirs in San Mateo County, nor our water sources in Alameda County, practically destroyed the upper thirty-inch conduit line, from Pilarcitos Reservoir, while it broke the lower 44-inch pipe line from Crystal Springs Reservoir for a total distance of about 2,850 feet, and seriously ruptured the 37-inch portion of the middle level San Andres pipe line.

Of the City Distributing Reservoirs. only Lake Honda Reservoir, of about thirty-three million gallons capacity and 365 feet elevation, was seriously injured by the earthquake; but, in spite of this fact, on the morning of April 21st, when the fire in San Francisco was practically under control, it still contained over one-sixth of its capacity.

The most serious injury sustained by the works were the ruptures caused by the earthquake, in hundreds of places, in our city main pipe distributing system, especially where the streets crossed filled ground and, particularly, where such filled ground covered former deep swamps, which swamps, during the earthquake, subsided, tearing off sewers as well as water and gas pipes.

Another as great and fully as fatal damage to the water distributing system was caused by the fact that the service pipes, supplying the many thousands of houses, hotels, factories, etc. (which the conflagration swept away with enormous rapidity, beginning immediately after the earthquake), were torn off, in and by the burning and falling buildings, allowing the water in the main pipe system to flow freely in tens of thousands of uncontrollable and inaccessible jets, large and small, into the accumulated debris of the burning buildings.

The main conduit lines, connecting the large country storage reservoirs with the city distributing reservoirs, were rapidly repaired, the upper level conduit delivering from Lake Merced, within sixteen hours after the earthquake, seven million gallons a day into town, and the middle level, or San Andres conduit, within sixty-two hours after the earthquake, delivering eight million gallons a day into the city.

The water storage on hand in the city reservoirs, at the time of and for several days after the earthquake, coupled with the fresh supplies thus brought in from the outside, enabled us to send water through the unburnt district of the Western Addition towards and to the burning district during the entire duration of the conflagration.

Before I proceed with a detailed description of the effects of the earthquake on the works of the Spring Valley Water Company and of the repairing made necessary thereby, I shall, for the benefit of persons unacquainted with the water supply situation of San Francisco, give a brief description of the works, their past, present and future supply capacity, and a short review of the history of the same.

I.

THE WORKS OF THE SPRING VALLEY WATER COMPANY.

The City of San Francisco does not own a municipal water supply, but is being supplied by a private corporation, viz.: the Spring Valley Water Company.

The State of California has a rainy season, during about five winter months, and a dry season, during the remaining seven summer and fall months.

As the climatic conditions of our State are such that, owing to occasional two or three successive dry and unproductive winter seasons, the streams largely decrease in volume and, in many instances, dry up altogether. it has become an established fact that, in order to maintain a steady and constant supply of water here, either for irrigation or domestic purposes, no matter whether the rainy season is wet or dry, it is absolutely necessary to store in lakes or reservoirs, whether natural or largely artificial, the surplus waters of the wet rainy seasons, in order to tide over the dry seasons, and the effect of so-called "dry winters," which, experience teaches us, are bound to re-occur here from time to time.

The necessity of thus storing the surplus or waste waters of our California rivers and streams has been proven, to my fullest satisfaction, during my hydraulic engineering practice on the Pacific Coast, since 1864. It has been proven, beyond a shadow of a doubt, that, in order to make our State capable of supporting a large agricultural population, commensurate with its marvelous soil and climatic resources, the first and last and most essential condition is to build large storage reservoirs in the watersheds of the many California rivers and streams and in them hold back and store the surplus and waste waters of the same, with a view of supplying a steady flow of water through the succeeding dry season or seasons, and thus build up a commonwealth on this coast, the fertility and constant productiveness of whose resources would draw to our shores and nourish millions of industrious and contented people.

What holds good for a general irrigation scheme, as above outlined, also holds good, only in a greater degree, for supplying our municipality with water for domestic, manufacturing, municipal and other purposes.

Where people are crowded together in our California cities, a constant, reliable and good water supply is still more essential than for the needs of an irrigation system; as, outside of the domestic supply, there exists an urgent necessity for the flushing of house sewers, for manufacturing, shipping and other purposes, and for fire protection, if not otherwise provided for.

In a country like California, where the providing of an abundant supply of fresh and potable water, in large and ever increasing quantities, is and always will be a difficult and very expensive task, owing to the above outlined climatic conditions, the high cost of labor and materials, etc., all cities located near the seashore should provide themselves with an efficient salt-water fire protection system, which, at the same time, could be used for flushing the street sewers.

Thus the fire protection supply would be entirely separate and independent from the domestic water supply by allowing, on the former, no house connections whatever, but only numerous and large fire hydrant connections.

I shall revert hereafter in this report to the fact that our late disastrous conflagration has proven the absolute necessity of entirely separating the domestic water supply from that for fire purposes; as the rapid spread of the fire over such a large area was largely due to the fact that the two systems were combined.

The City of San Francisco derives its water supply from the works of the Spring Valley Water Company, of whose engineering department I have had charge since the fall of 1864. (See Map No. 1.)

The water sources of the Spring Valley Water Company, as at present developed, can be divided into three separate groups:

1. The Peninsular Reservoir supply, in San Mateo County, comprising three storage reservoirs:

   a. The Pilarcitos Reservoir, formed by a clay dam with puddle core, about ninety feet in height, at about 700 feet elevation above tide, and of a capacity of about 950 million gallons. It is connected with the Lake Honda Distributing Reservoir in San Francisco, of 365 feet elevation, by means of a conduit consisting of three tunnels, a 30-inch wrought-iron pipe line, and about one and one-half miles of redwood flume. The 30-inch pipe was practically destroyed by the earthquake between a point about one mile south of San Adres dam and a point west of the village of Baden, by the San Andres earthquake fault following its course for miles. (See Maps 1, 6 and 9.)

b. The San Andres Reservoir is formed by a clay dam, about 90 feet in height, with a puddle core. Its elevation above tide is about 450 feet, and it has a storage capacity of about 5,500 million gallons. This reservoir is connected with the College Hill Distributing Reservoir in San Francisco (at an elevation of about 255 feet) by a pipe line consisting of 44 inch, 37 inch and 30 inch wrought-iron pipes. It is proposed, eventually, to extend the 44-inch pipe the entire distance. (This pipe was badly ruptured by the earthquake in the central portion, near Baden village, where its diameter is 37 inches.) (See Maps 1, 6 and 9.)

c. The Crystal Springs Reservoir is formed by a concrete dam, at present 145 feet in height above its base, its present top being at 280 feet elevation above tide. Its present storage capacity is 19,000 million gallons. It is connected with the University Mound Reservoir in San Francisco, at an elevation of about 165 feet, by a conduit line consisting of three tunnels and a 44-inch wrought-iron pipe line. (See Maps 1, 6 and 9.)

This 44-inch Crystal Springs pipe line crosses the swamp lands on the west side of the Bay of San Francisco, on heavily piled bridges, crossing the San Bruno Swamp at 5, on Map 1, the Guadaloupe Swamp at 6, on Map 1, and the Visitacion Swamp at 7, on Map 1.

By the tremendous lateral vibration of these three swamps, during the earthquake of April 18, the 44-inch pipe was ruptured in a number of places, being torn apart and thrown to the east and to the west of the bridge. In those portions of the three above bridges, located miles apart, which crossed the deepest and softest portions of the respective swamps, the superstructures, on which the pipe rested, were completely destroyed.

The San Bruno fault, which Professor A. C. Lawson, of the University of California, locates as passing diagonally and in a northwesterly direction along the southwesterly slope of the San Bruno Mountains in almost a straight line to the Pacific Ocean (at 9, on Map 1), near Lake Merced, strikes diagonally across our 44-inch Crystal Springs pipe bridge, in or near the above San Bruno Marsh. Judging from the scattered position, after the earthquake, of the various broken fragments of the 44-inch pipe, it would appear that very violent lateral movements had made themselves felt, which were most accentuated in the softer portions of the swamp. (See Map 13, of earthquake fault.)

This is furthermore evidenced by the fact that the earthquake showed great violence on the high shore bluff of the Pacific Ocean, west and southwest from Lake Merced, so that the outlet, or ocean end, of our brick Lake Merced drainage tunnel was completely covered up and closed by a large slide. (See 10, on Map 1.)

By eventually raising the Crystal Springs dam to a height of 165 feet, its storage capacity will increase from 19,000 million to about 30,000 million gallons, while, should the dam be raised to its extreme practical height of 188 feet, which would also require a northerly extension of the main dam, the storage capacity would be increased to about 45,000 million gallons.

The above three reservoirs, viz.: Pilarcitos, San Andres and Crystal Springs, each have side feeders, through which water is brought into them from adjacent watersheds.

As above shown, the water product from these three reservoirs flows by gravitation to and into the respective distributing reservoirs in San Francisco. (The Pilarcitos 30-inch pipe line, owing to the earthquake, being out of commission, the water from the Pilarcitos reservoir now flows through the by-pass (1-2, Map 1) into San Andres reservoir.)

The Pilarcitos water is now being sent along, together with the San Andres water, to San Francisco through the San Andres pipe line, and where the Pilarcitos water, before the earthquake, arrived in Lake Honda reservoir in San Francisco by gravitation, the latter reservoir is now supplied by forcing into it the above waters by the Lake Merced pumps (near San Francisco), which draw it from the San Andres pipe line near Ocean View Station (see Map 1) and force it into the northerly end of the Pilarcitos pipe line.

2. On the Alameda Creek system, no storage reservoirs have, as yet, been constructed, although the Spring Valley Water Company owns, on this fine watershed of about six hundred square miles, three large storage reservoir sites, viz.: The Calaveras, San Antonio and Arroyo Valle sites, of a joint future storage capacity of from 45,000 to 50,000 million gallons. The present average supply, drawn from the Alameda system, consists of about fifteen million gallons a day, drawn from subterranean developed springs and gravel beds and from artesian wells.

By developing, as proposed, the Calaveras portion of the Alameda Creek system, by the construction of a concrete dam, 225 feet in height, we can create a storage capacity of 30,000 million gallons, at an elevation of about 750 feet above tide, which will gather and store the water product of its direct and immediately adjacent watershed of a total area of 139 square miles.

Making full allowance for evaporation, the daily average net product of water of Calaveras Reservoir (as established by many years of rainfall observation and of gauging of the streams) will be, in round figures, about *30 million gallons a day*, year in and year out.

By successively constructing and developing thereafter the proposed San Antonio (31) and Arroyo Valle (3) reservoirs (see Map 1), of a joint capacity of, say, 20,000 million gallons (or more, if required), the two reservoirs having a joint watershed of about 180 square miles, they would produce an additional supply in the neighborhood of 30 million gallons per day.

The Alameda Creek system, when fully developed, as above outlined (which can be done economically and step by step, as the demand for water in San Francisco and around the shores of San Francisco Bay increases), can thus easily be brought up to furnish a total supply of 75 million gallons per day, year in and year out, of water filtered through the company's extensive natural gravel filter beds in the Sunol Valley.

The present water product, of an average of 15 million gallons a day, is conveyed westwardly, through the Sunol aqueduct, consisting of a series of concrete-lined tunnels (having a carrying capacity of from 70 to 75 million gallons daily), and of stretches of heavy redwood flumes from tunnel to tunnel, of a present carrying capacity of 30 million gallons a day.

The Alameda water arrives at the concrete receiving basin, near Niles (No. 4, on Map 1) at an elevation of about 180 feet above tide, and is from here conveyed, in a southwesterly direction, through a 36-inch wrought-iron pipe, buried in the ground, passing the towns of Centerville and Newark, until, about one mile west of Newark, the pipe reaches a strongly piled bridge, on which it is carried, for a distance of fully 16,000 feet, to Dumbarton Point. On this bridge it crosses the swamp lands on the east side of the Bay of San Francisco. (See profile of Alameda pipe line, Map 9.)

At a point about 7,000 feet northeasterly from Dumbarton Point, a navigable slough or stream, 300 feet wide, is crossed by two 16-inch and two 22-inch ball-joint submarine pipes—the former being in service since 1888 and the latter since 1902.

The Bay of San Francisco is crossed by four ball-joint submarine pipes, of the same respective dimensions and age of service as those at the crossing of the slough. The Bay at this point, viz., between Dumbarton Point and Ravenswood, is 6,300 feet in width, which is traversed by the four submarine lines, the two 16-inch lines as well as the two 22-inch lines, being about twelve feet apart from centre to centre; while the 22-inch double line lies northwestwardly from and parallel to the 16-inch line and about 90 feet away from the same (see Maps 1 and 10).

At the Ravenswood, or westerly shore of San Francisco Bay, the four submarine pipe lines again join together into one 36-inch wrought-iron pipe, which, for a distance of about 2,000 feet, is carried on a heavy piled trestle, through the swamp lands, on the west side of the bay, until (at *4 a*, on Map 1) it enters terra firma, being riveted together in a trench about six feet in depth.

In this manner the 36-inch wrought-iron pipe runs along, partly under public roads and partly through private rights of way, to the Receiving Reservoir at the Belmont Pumping Station, which reservoir is about 12 feet above tide (see Map 1). The Belmont Pumping Plant, being in five units, has a capacity of lift 23 million gallons a day to an elevation of 325 feet, into a standpipe erected on a hill to the southwest of the pumping station. From this standpipe the Alameda water, so pumped, again enters a 36-inch wrought-iron pipe, which carries it in a northwesterly direction (see Map 1), through the town of San Mateo, to its junction with the Crystal Springs 44-inch pipe. At this point, near Burlingame, the 36-inch pipe also joins the new 54-inch pipe, which carries the Alameda water to Millbrae Pumping Station. It is proposed to eventually continue this 54-inch wrought-iron pipe northwestwardly from Millbrae to San Francisco and southeasterly from Burlingame to the Belmont Pumping Station. This latter station would then, in turn, be connected with the submarine pipes and the proposed sub-bay tunnel at Ravenswood either by a 54-inch pipe or other large conduit. This will be necessitated when one or more of the proposed Alameda System reservoirs are constructed, which will also require the enlarging of the conduit line to the Bay of San Francisco, its submarine pipes or the construction of the proposed sub-bay tunnel.

The Spring Valley Water Company also owns considerable land or water rights in three of the peninsular streams located south of its present above-described reservoir and watershed properties. On one of these properties (the San Francisquito Creek) a portion of the proposed dam has been already constructed to fulfill certain contract obligations entered into in order to acquire and hold important water rights. The two other streams, viz.: The San Gregorio and the Pescadero, can eventually be brought, by gravitation, into and become feeders of the Crystal Springs Reservoir. This will probably be done by sending the joint waters of the Pescadero and San Gregorio Creeks, by means of a tunnel, into the Portola Reservoir, which is to be raised to 3,000 million gallons capacity. (See Map 1.) From here the waters could be conveyed into the Crystal Springs Reservoir. The conduit, consisting of large redwood flume, iron pipe and concrete-lined tunnel, would, in its northwesterly course, pass within about two miles of Redwood City.

It would enter Crystal Springs Reservoir through a concrete-lined tunnel, located almost on a straight line between Redwood City and the southeasterly end of the Crystal Springs Reservoir (see Map 1). (Through the same tunnel the enlarged Belmont pumping plant will also discharge, in future, the water of the enlarged Alameda supply, which is to be stored in the Crystal Springs Reservoir, on the San Mateo Peninsula.)

The above-mentioned additional peninsular streams, if properly developed and connected with Crystal Springs Reservoir, can easily be counted upon to furnish an average daily supply of from twenty to twenty-five million gallons.

The present three peninsular reservoirs (outside of Lake Merced, in San Francisco County) yield an average supply, over and above evaporation, of eighteen million gallons a day.

Adding hereto the supply that can be developed on the adjacent streams and watersheds, the total daily average supply of the present and adjacent sources on the peninsula and in San Mateo County would be fully 40 million gallons a day.

Adding to this amount the daily supply, which can easily be developed in the company's Alameda system, as above shown, of 75 million gallons per day, including the present 15 million gallons daily, the total daily supply, thus produced, in and from the fine watersheds surrounding the Bay of San Francisco, would be between 110 and 120 million gallons per day, which is in excess of *three times* the daily consumption prior to the earthquake.

Besides the above-mentioned sources of supply, the Spring Valley Water Company owns in the same and adjacent counties water rights, watersheds and reservoir sites capable, when properly developed, of adding largely to the above daily supply.

3. *Lake Merced,* in San Francisco County: Lake Merced is located in the southwesterly corner of San Francisco County. It has an area of about 400 acres, and is fed by innumerable springs in the bottom and around the margin of this lake. The apparent watershed of the lake is between seven and eight square miles, and consists mainly of a sandy hard-pan formation, in the lowest portion of which Lake Merced, consisting of a north and south branch, is located. (See Map 1.)

A very effective system has been constructed, conveying the surface water of two creeks into the Pacific Ocean, and as the intercepting dams, in the respective creeks, go down to the tight hard-pan, the surface waters are not allowed to enter the lake, but are carried towards the ocean.

The average net yield of water of the two lakes combined (over and above evaporation) is somewhat in excess of three million gallons per day.

By having constructed two dams, one between the North and South Lake and one at the old outlet (into the sea) of the North Lake (each dam with gate-well and outlet tunnel), the high-water mark of both lakes can be raised to about twenty-eight feet above tide. Its maximum storage capacity is over 2.000 million gallons.

On the shore of the South Lake (see Map 1), the Lake Merced Pumping Station is located, with two Corliss compound condensing pumping plants, each of a capacity of lifting three and a half million gallons a day, either from Lake Merced or from the San Andres pipe line, into the Pilarcitos pipe line. (See Map 5*a*.)

The Spring Valley Water Company owns about 4 4/10 square miles of land, within which tract both lakes are located.

The San Francisco Distributing Reservoir and Pipe System.

The problem of water distribution in San Francisco is and always will be a very difficult one, owing to the very uneven and broken topography of the inhabited part of the city. The elevations vary from the original fresh and salt water swamp region, in the southeasterly and easterly portion of the city (most of whose present streets are less than twenty feet above tide) to the hilly northerly, northwesterly, westerly, southerly and southeasterly portions of the city—some ridges running up to three hundred feet and over, while isolated hills and slopes that have to be supplied with water reach elevations of over 500 feet. (See Map 4.)

For the highest region, in the southwesterly portion of the city, we have a reservoir at an elevation of 600 feet above tide, into which the water is being pumped.

As it would take too long to describe the city distributing reservoir and pipe system in detail and the very circuitous routes that the pipes have to take to reach and supply the many isolated hills and, by virtue of the topography, peculiarly located and formed supply regions, requiring five separate and distinct reservoir levels, varying in elevation from 135 to 600 feet above city base, I refer, for further information, to Map 5*a*.

In San Francisco City and County we have three pumping plants in operation:

(1). The Lake Merced Pumping Plant, in two units (as briefly described above), lifting seven million gallons daily, either from Lake Merced or from the San Andres conduit line, to the aerator on the Pilarcitos pipe line, from where Lake Honda Reservoir and the Western Addition of San Francisco is supplied (L. H. on Map 5*a*):

(2). The Black Point Pumping Station, in two units (see Map 5*a*), capable of lifting six million gallons daily to the Pacific and Presidio Heights districts (P. H. and P. H. 1, Map 5*a*):

(3). The Clarendon Heights Pumping Station, in two units, capable of lifting three million gallons a day from the College Hill district or from the University Mound district (C. H. or U. M. on Map 5*a*) to and into the Clarendon Heights tank and its district (Cl.-H. on Map 5*a*), at an elevation of 600 feet.

We have constructed (since the earthquake) an emergency pumping plant of a daily capacity of four million gallons (in three units), at the corner of Twenty-sixth and Harrison streets, in the southerly portion of San Francisco, to which plant we may add, if necessary, another unit of three million gallons a day. (U. M. district, Map 5*a*.) This emergency plant has been erected to temporarily take the place of the Pilarcitos pipe line (destroyed by the earthquake). It will lift water from the University Mound (U. M., Map 5*a*) or College Hill district (C. H. on Map 5*a*) to and into the Lake Honda district (L. H. on Map 5*a*), through a special heavy 16-inch cast-iron force pipe, one mile in length, laid for this purpose along Twenty-sixth street to and into the Lake Honda (L. H.) district.

This emergency pumping plant will, in due time, be replaced by a high duty plant of twelve million gallons (in three units) daily capacity, which can be added to, as required.

The City Distributing Reservoirs, with their approximate elevations and capacities, in round figures, are as follows:

Indicated on Map 5A.		Name.	Elevation, Feet.	Capacity, Gallons.
U. M.	1.	University Mound	165	37,000,000
U. M.	2.	Francisco Street Reservoir (Subsidiary to University Mound)	135	3,000,000
C. H.	3.	College Hill	255	14,000,000
L. H.	4.	Lake Honda	365	33,000,000
L. H.	6.	Potrero Heights Reservoir (Subsidiary to Lake Honda).....	315	800,000
L. H.	5.	Lombard Street Reservoir (Subsidiary to Lake Honda).....	305	2,500,000
P. H.	7.	Presidio Heights' Tank..............................	400	700,000
P. H. 1.	8.	Clay Street Tank....................................	375	250,000
Cl. H.	9.	Clarendon Heights' Tank.............................	600	500,000
		City Reservoir in contemplation:		
I. S. R.	10.	Industrial School Reservoir.........................	310	400,000,000

The City Pipe Distributing System.

The City Pipe Distributing System is so arranged that the larger arterial pipes traverse the various pressure or supply districts longitudinally. On Map 5*a* I have only marked them from the respective reservoirs *to* their entrance into the respective districts, as this small photographic reproduction of the supply disticts would have been too confusing, if all these lines had been drawn through the same.

The following list of pipe in our city distributing system gives the pipes laid in the streets of San Francisco, beginning at the outlet gate of each respective distributing reservoir, and does not include the pipes in San Francisco County (shown on Map 5*a*) leading the water from the country reservoirs, nor from Lake Merced, into the respective city reservoirs.

In the following list of pipes, which were in operation in the San Francisco Distributing Pipe System on January 1, 1906, the riveted wrought-iron pipes, from 44 inches diameter down to 13 inches, act as conductors of water to and through the various supply districts, and although connected at street crossings by means of gates with cast-iron laterals, they (the wrought-iron pipe lines) are not allowed to be tapped, neither for house supply nor fire hydrant purposes.

Of the cast-iron pipe in the City Distributing System, no house or hydrant connections have been allowed to be placed directly on the 30-inch and 24-inch pipes (they being important main arteries), while on the 22-inch and 20-inch cast-iron pipes (which are also main arteries) but a few house connections have been made, while fire hydrants have generally been set on special 8-inch side branches, with 8-inch gates, between the large pipe and the hydrant connections. A large portion of the 16-inch cast-iron pipe, where it acted as a main artery, has also been kept free from house connections, so that, generally speaking, most of the fire hydrants and nearly all of the domestic supply connections are made on pipes from 12 inches diameter downward.

During about the last decade, none, if any, new fire hydrants have been connected to pipes smaller than 8 inches in diameter; and those that were still connected with pipes of diameters less than 8 inches have been, whenever requested by the Fire Department, cut off from the same and have been, where convenient, placed on larger new pipes; or, frequently, when there was not a larger pipe in the same street, it was laid especially for fire hydrant purposes and the hydrants were placed thereon. During the past two decades a large amount of 6-inch and 4-inch pipe has been taken up and replaced by the company by pipes of larger diameters, on which the San Francisco Fire Department had hydrants placed.

Should the municipal authorities of San Francisco profit by the terrible lesson taught by the earthquake and fire, and entirely separate the fire supply from the domestic supply, in *that* case, a large portion of the 6-inch and 4-inch pipe, now in the distributing system, will be amply sufficient in size, if used for domestic supply alone, as our pressure here, owing to the very hilly topography of San Francisco, is necessarily quite high.

If, on the other hand, the absolutely necessary *independent* salt-water supply is not adopted and inaugurated by the authorities after all, *then* there is no doubt, if the water rates permit it, that most of these 6 and 4 inch pipes will gradually be replaced by larger ones.

In many of the small alleys and in the water-front region and, especially, under the wharves, we still retain and shall probably in the future retain the 4-inch and 3-inch pipes, as convenient and ample sizes for supplying the domestic requirements in these alleys and the ships at the wharves and in the harbor with fresh water for their requirements.

On January 1, 1906, the City Distributing Pipe System consisted of the following sizes and lengths:

A.—Wrought-iron Pipes.

Internal Diameter, in Inches.	Length of Pipe, in Feet.
44	7,213
37½	12,254
33	2,510
30	12,669
22	25,481
13	850

The wrought-iron pipes in the City Distributing Pipe System, as well as those used on the main conduit lines in the country, are made of the best American laminated wrought iron. Their workmanship is southerly and southeasterly portions of the city—some ridges running up to three hundred feet and over, while isolated hills and slopes that have to be supplied with water reach elevations of over 500 feet. (See Map 4.)

For the highest region, in the southwesterly portion of the city, we have a reservoir at an elevation of 600 feet above tide, into which the water is being pumped.

As it would take too long to describe the city distributing reservoir and pipe system in detail and the very circuitous routes that the pipes have to take to reach and supply the many isolated hills and, by virtue of the topography, peculiarly located and formed supply regions, requiring five separate and distinct reservoir levels, varying in elevation from 135 to 600 feet above city base, I refer, for further information, to Map 5*a*.

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This emergency pumping plant will, in due time, be replaced by a high duty plant of twelve million gallons (in three units) daily capacity, which can be added to, as required.

The City Distributing Reservoirs, with their approximate elevations and capacities, in round figures, are as follows:

Indicated on Map 5A.		Name.	Elevation, Feet.	Capacity, Gallons.
U. M.	1.	University Mound	165	37,000,000
U. M.	2.	Francisco Street Reservoir (Subsidiary to University Mound)	135	3,000,000
C. H.	3.	College Hill	255	14,000,000
L. H.	4.	Lake Honda	365	33,000,000
L. H.	6.	Potrero Heights Reservoir (Subsidiary to Lake Honda)	315	800,000
L. H.	5.	Lombard Street Reservoir (Subsidiary to Lake Honda)	305	2,500,000
P. H.	7.	Presidio Heights' Tank	400	700,000
P. H. 1.	8.	Clay Street Tank	375	250,000
Cl. H.	9.	Clarendon Heights' Tank	600	500,000
		City Reservoir in contemplation:		
I. S. R.	10.	Industrial School Reservoir	310	400,000,000

equal to the best boiler work in the country, and they have all been thoroughly immersed and boiled in, and thus coated, in and outside, with the best, most lasting and heavy asphaltum coating, with which process we have had many years of successful experience.

B.—Cast-iron Pipe.

Internal Diameter, in Inches.	Length of Pipe, in Feet.
30	4,494
24	46,363
22	19,183
20	21,840
16	126,153
12	265,037
10	8,489
8	701,453
6	570,977
4	376,114
3	130,755

The metal of which these pipes are made is the best and toughest cast-iron obtainable from American pipe foundries. For years past these pipes are specially made for us under our own specifications and under the eyes of our own experts, who are our regular employees and who have been thoroughly trained for many years for this very purpose.

We also require a heavier thickness of metal in the body of the pipe and a heavier and considerably deeper bell than is generally customary in American city water works. (See the annexed diagram on Map 5*b*, which forms a part of our specifications.) This increase in dimensions proved itself, during the earthquake, a very wise provision, as, in spite of the terrific twisting and wrenching that the city pipe system received all over the city, the breaks in the main pipes (considering our great length of distributing system of 441½ miles) were comparatively few, and these were, in the large majority of cases, principally confined to and caused by the sudden sinking of the streets over the old swamps, which movement (the same as happened to the city's sewers there) tore the pipe over the swamp away from the pipe on terra firma.

In the streets within the main body of the sunken swamp districts, which, during the earthquake, rapidly moved up and down and sideways, back and forward, like jelly in a shaken bowl, there were also, naturally, a number of breaks in the street pipes, caused by the twisting and rapidly undulating motion of ground in which the pipes had to be laid. (See Map 11 and photographs of sunken and twisted streets.)

Furthermore, we had a number of breaks in the main pipes in such streets that were constructed over loosely and poorly filled depressions.

The works of our company in the country (except where they were unavoidably torn up and destroyed by the earthquake faults crossing and recrossing the same) and in the city (where the main pipes, wherever crossing swamps and fills were broken) have withstood the terrific strain to which they were submitted in a most remarkable degree.

This splendid result is largely due to the fact that, ever since my taking charge of the Engineering Department of our company, more than forty years ago, I have established the rigid rule that *only* the very best of materials obtainable, coupled with the very best and most appropriate design and workmanship, should be employed in the construction of our works, as long as the Board of Directors of our company honored me by placing the entire responsibility for the physical success of our works on my shoulders.

In order to recognize and reject inferior or doubtful materials and instead select and accept such materials as would pass *my* individual rigid requirements in every case, whether relating to brick, cement, rock, cast or wrought iron, etc., or to structures, such as foundations, dams, tunnels, reservoirs, pipes, boilers, pumps, etc., etc., it was absolutely necessary to surround myself with men of good character, energy and skill, whom I could gradually discipline and train up into a body of reliable, thoroughly practical and efficient experts, assistants, foremen, mechanics and workmen.

In selecting the men to fill either or all of these positions, I have always placed the *good character* of the men as the first and foremost requirement. After that came energy, adaptability and skill.

Thus I soon found out for what specialty a man was best fitted. If, thereafter, he fully came up to my expectations, he was regularly employed at fair pay and, when his qualifications permitted and the opportunity offered itself, he was advanced in position and salary.

Having steadily followed this method, for fully four decades, of carefully selecting, thoroughly training and properly treating our employees in the Engineering, Construction and Maintenance Departments, I can say, from the bottom of my heart, that the splendid physical condition of our very extensive works, even after the earthquake (which works show an endless variety of constructions best adapted to the climatic, physical and local circumstances), is largely due to the faithful work of every man that has helped me to construct and maintain our works, and which men, since the trying ordeals of earthquake and fire, have done almost superhuman work to, in a very short space of time, rehabilitate our water supply.

II.

SHORT HISTORICAL REVIEW OF THE WATER SUPPLY OF SAN FRANCISCO FROM THE EARLY SIXTIES UNTIL THE EARTHQUAKE OF APRIL 18TH, 1906.

Up to the latter part of the fifties, of the past century, San Francisco received its domestic supply largely from watering carts and from wells and springs. The supply for the hand fire engines was drawn either from the bay or from large cisterns, built at a number of street crossings, and which were kept filled for the use of the volunteer fire department.

The city, during the fifties, having gone through several serious conflagrations, which proved the inefficiency of this fire protection for the rapidly growing city, of mostly wooden houses, and, as at that time, the city's finances, or credit, did not permit the construction of municipal water works, nor were the authorities willing to embark in such enterprise, a law was framed, thereafter called *the law of 1858*, designed to encourage private enterprise to embark in the business of supplying cities and towns in California with water.

Labor was scarce and dear; materials were high, as everything in the shape of metal, cement, etc., had to come around the Horn; money also commanded a high rate of interest.

The above law, while intended to get efficient results as regards domestic supply and fire protection, at the same time proposed to protect the capital invested in such private enterprise, as, without the guarantee of either fair treatment on the part of the authorities or of a fair rate of interest on the money to be invested (most people then believing that as soon as the mines should give out the future growth of the City of San Francisco would be, to say the least, problematical), no capital could have been found to embark in the enterprise.

For the purpose of regulating the price at which water might be sold, the law provided that such rates should be established by a commission of four, two of which were to be appointed by the city and two by the respective water company.

In case that the four could not agree, they should select a fifth commissioner, if they could agree on one.

If not, then the Sheriff was to appoint the fifth commissioner.

The commission was to establish reasonable water rates for one year, or until new rates were adopted.

Before I proceed further with an account of how the water rates were regulated under the law of 1858 and, later on, under the new State Constitution, which supplanted it, when it went into effect on January 1st, 1880, I will give a short account of how the works were gradually and successively developed from the beginning of the year 1865 to the year 1906.

Protected by the law of 1858, a company was organized and brought the water of Lobos Creek (furnishing somewhat over two million gallons daily) through the Presidio, with a tunnel under Fort Mason, and to the Black Point Pumping Station, at the foot of Van Ness Avenue.

From here it was pumped through two sets of heavy double force pipe lines, partly into the Francisco Street Reservoir (at 135 feet elevation), at Hyde and Francisco Streets, and partly into the Lombard Street Reservoir (at 305 feet elevation), at Hyde and Lombard Streets. From these two reservoirs an extensive network of pipes distributed the water of Lobos Creek, under a fair pressure and in a general easterly and southeasterly and southerly direction, to and through what was then San Francisco—the former reservoir taking care of the lower districts of the city, while the latter supplied the higher locations.

In 1860, according to the United States census, San Francisco had a population of 78,000, and, from all appearances, it would continue to grow gradually, as the agricultural interests were being developed in addition to the mining interests.

Encouraged by the law of 1858, which was being justly and fairly interpreted by the Water Commission, and knowing that the supply of the original water company was limited to two million gallons a day from Lobos Creek, a new water company, under the name of the "SPRING VALLEY WATER WORKS," was inaugurated, about that time, by local citizens and with local capital.

This company, having full faith in the city's future growth, and being convinced that the rapidly growing city would, in the near future, need a considerable addition to its water supply, purchased a considerable tract of land, with the water rights appertaining thereto, in the secluded mountain forests of San Mateo County. By constructing the upper Pilarcitos dam or reservoir and, from there, conducting the water of Pilarcitos Creek and tributaries and also that of the upper San Mateo Creek through a tunnel, flume and pipe line of a total length of thirty-two miles, the new company was able to deliver its water, during the fiscal years of 1862-3, into its partly finished Lake Honda Reservoir and its completed Market Street Reservoir, since destroyed by cutting through of Market Street—the former being located near the present Almshouse, at 365 feet elevation, and the latter near Market Street, at its intersection with Buchanan Street, at 200 feet elevation. From these two reservoirs a network of cast-iron pipes distributed the Pilarcitos water supply through the North Mission, Hayes Valley, part of the Western Addition and the main business portion of the city.

Finding it to their mutual interests to join the two supplies together, so that not only one could supplement and assist the other, but also that the operating of both companies under one head would largely simplify and cheapen the management, on the first of the year 1865 the two water companies became one under the name of the "Spring Valley Water Works."

On October 8th, 1864, I had been appointed as engineer of that part of the works of the original Spring Valley Water Works which related to the head waters in San Mateo County and the conduit lines constructed and to be constructed into San Francisco. (See Map 1.)

In the fall of 1864 the foundation of the large Pilarcitos main dam was started and, early in 1865, the second long tunnel on the proposed new Pilarcitos conduit line.

In May, 1866, I was appointed Chief Engineer of the entire Spring Valley Water Works, with headquarters in San Francisco, and have continued in this position from that date up to the present. During this long, continuous period of over four decades, I have designed and constructed all the works necessary to gradually bring the works up to their present capacity of about 35 million gallons a day. I have also advised and insisted upon the timely acquisition of the large, then available, but now enormously valuable watersheds, reservoir sites, water rights and rights of way in and from the mountains and valleys surrounding the bay.

The ownership of these large properties will enable the Spring Valley Water Company to practically, economically, safely and rapidly solve the otherwise serious problem of meeting the fresh water requirements of this city and neighborhood, until the time when we have a population far in excess of one million people. As the population and the demand for water gradually increased during the past four decades, we met such increased and ever increasing demand by a number of timely and appropriate constructions, prominent amongst which are the following:

In the second half of the sixties, building the Pilarcitos Reservoir and its new conduit into San Francisco; and, in the latter part of the sixties and early in the seventies, building the San Andres dam and its independent pipe line. Both of these reservoirs were, some years later, increased in capacity by raising the two dams. (See Map No. 6.)

In the middle of the seventies we constructed the upper Crystal Springs Reservoir and, a few years later, connected the same by a pumping plant, pipe and flume line with the Pilarcitos conduit, thus adding the upper Crystal Springs water to our city water supply.

About the same time we acquired land and water rights at Lake Merced, in San Francisco County, and erected a pumping plant on the north lake and connected the same (which controlled the north lake and the outflow from the south lake), by a pipe line, with our San Andres main conduit line, delivering water into College Hill Reservoir.

In 1885 we constructed the 44-inch wrought-iron Crystal Springs pipe line from the upper Crystal Springs Reservoir to the new University Mound Reservoir, into the city, thus sending a much larger supply from this important source into San Francisco by gravitation, instead of pumping as theretofore.

In 1888 we completed the original Alameda Creek works as far as the 44-inch Crystal Springs pipe, near Burlingame, with double 16-inch submarine pipes crossing the bay.

At this period we also completed the original Belmont pumping plant, thus adding to our works the magnificent Alameda properties, which holdings have since been largely added to and part of their resources developed.

In 1887 we laid the foundation of the concrete Crystal Springs main dam and, by working on the same during 1887, 1888 and 1890, we raised it to its present height of 145 feet above its base, which is 280 feet above tide. The 44-inch Crystal Springs pipe was disconnected from the upper dam and, instead, connected (as originally contemplated) with the lower main dam.

In 1897 the Pilarcitos pumps were constructed, forcing San Andres water into the Pilarcitos pipe line.

In 1898 we completed the Crystal Springs emergency pumping station, with conduit to San Andres Reservoir, and also the Millbrae pumping station, which latter can deliver either Alameda or Crystal Springs water into the higher San Andres pipe line.

In 1900 we completed the Sunol filter beds and Sunol aqueduct, on the Alameda Creek system, largely increasing the capacity of the original Alameda works and also, by filtration, improving the quality of the water. These filter beds also received the water from our extensive artesian lands in Livermore Valley.

During 1902 we constructed the second double line of submarine pipes across the bay, these lines being 22 inches, while the original lines are 16 inches in diameter. Thus we considerably again increased the carrying capacity of the Alameda conduit.

This was followed, in 1903, by our more than doubling the capacity of the Belmont pumping plant and, at the same time, laying the 54-inch Alameda pipe line from the Burlingame junction of the Crystal Springs and Alameda pipe line to the Millbrae Pumping Station.

At the latter place we had also, since 1898, established a large central and effective emergency camp, for the purpose of rapidly repairing any part of the main works, should it become necessary.

This camp stood us in good stead immediately after the earthquake, as without the great variety of almost every kind of repair fittings kept on hand there much more time would have elapsed in repairing the damage done by the earthquake to the San Andres and Crystal Springs main pipe lines.

During the period of forty years, from 1865 to 1905, the population and consumption of water in San Francisco gradually and steadily grew and, naturally, required an enormous extension of the city distributing reservoir and pipe system. Cable roads were constructed, rapidly populating the hilly parts of the city. Water was required and demanded everywhere, and at elevations varying from the sea level up to over 500 feet above tide.

The electric roads came, and spread and scattered the city rapidly over a very large area, and we kept on extending our reservoir, pumps and pipe system.

At the urgent request of, and promise of fair treatment by the city authorities, we not only rapidly extended our distributing system, but also largely increased the sizes of our main pipes, so that, by the end of the year 1905, we had the above detailed list of (pages 13 and 14) distributing pipes, of a total length of 441½ miles, laid and in operation in the City of San Francisco.

The following table shows the population of San Francisco, in round figures, taken, for the even years, from the United States Census and, for the intermediate years, arrived at by a careful estimate made by the writer; and the daily consumption of water, during this period of four decades, taken from five to five years:

Year.	United States Census.	Estimate.	Daily Consumption of Water in Gallons.
1865..................	......	110,000	2,360,000
1870..................	150,000	......	6,040,000
1875..................	......	190,000	11,680,000
1880..................	234,000	......	12,670,000
1885..................	......	265,000	17,050,000
1890..................	300,000	......	20,430,000
1895..................	......	330,000	19,900,000
1900..................	343,000	355,000	25,470,000
1905..................	......	455,000	34,900,000

Spring Valley Water Company's Preparations for Increasing Its Supplies in the Future.

During the last decade railroad facilities to this coast and city have materially increased, and the climatic, agricultural and commercial advantages of our State and city have become much better known and appreciated in America, as well as in Europe. The population of San Francisco, as well as the water consumption, especially during the last five years, began to increase much more rapidly than heretofore, as is shown on the above table.

Taking this increase during these past five years as a basis, in connection with the causes that brought it about, I made, in the year 1904, the following approximate estimate of the probable increase in the population and the minimum water supply that would have to be provided for such increase. (See my testimony in the United States Circuit Court during the latter part of 1904 and the early part of 1905):

Year.	Estimated Population.	Estimated Minimum Supply (in Round Figures).
1910..................	500,000	40 million gallons per day.
1920..................	650,000 (fully)	55 million gallons per day.
1930..................	800,000	72 million gallons per day.
1940..................	950,000 (fully)	90 million gallons per day.
1950..................	1,100,000	110 million gallons per day.

I showed that this estimated rate of increase in population and consumption might be somewhat altered by contributary circumstances, but that the estimate appeared to be rather under than over what we might expect.

Having advised our Board of Directors, in due time, that a material increase in the water supply would have to be provided for, they concluded to erect the Calaveras dam on our watershed in Alameda County, by which a storage reservoir (as above shown) of 30,000 million gallons' capacity would be created and a supply of about 30 million gallons a day would be added to our present supply of about 35 million gallons daily.

This proposed work, which would also include an increase in the conduit and pumping capacity of the Alameda pipe line and Belmont Pumping Works, respectively, and an extension to San Francisco, could be accomplished within a period of from three to five years.

The supply capacity of the works being thus increased from 35 to 65 million gallons per day, the above table shows that this supply would take care of San Francisco until somewhere in the neighborhood of 1925.

Prior to this period additional extensions of the company's works would have been inaugurated on other portions of its extensive watershed and reservoir, or other properties.

Such new work might be the construction of either the San Antonio or Arroyo Valle Reservoirs, or both, which, jointly, would add, say, 20,000 million gallons to the storage capacity and about 30 million gallons to the daily supply.

Or, the company might choose to then first develop and connect with Crystal Springs Reservoir the coast streams, via the Portola Reservoir; or it might prefer to develop other of its extensive water properties.

In short, the probable supply requirements, beyond 1925, as approximately prognosticated in the above table, could be easily met by gradually, successively and economically developing the company's various water properties during the first half of the present century.

The late earthquake has also conclusively shown that a number of short conduit lines, each bringing an independent supply from separate sources and through different localities, is far safer than a long, single pipe line, bringing water from a source from 150 to 200 miles distant. Even if such pipe were duplicated, following about the same route, the cause that would destroy and disable the one is likely to also interrupt the other.

I shall now revert back to the law of 1858 and its interpretation by the Water Commission established under the same (see page 16).

The water rate commission, created under the law of 1858, while regulating the price of water so as to bring a fair and safe revenue on the money invested in this enterprise, most vital to San Francisco's welfare and safety, at the same time established the rates reasonably to the consumers and gradually decreased the same as the demand for water increased.

About the year 1870 promoters of various water schemes, prominent among which was Lake Tahoe, located about 200 miles from San Francisco, appeared before the people, *who*, by continued agitation, both by the interested parties and a part of the press (all promising an abundant supply of cheap mountain water), became considerably enthused on the subject.

As time went on, a number of other additional water schemes were proposed from far and near, also including the Alameda Creek System, which I had recommended to our Board of Directors in my report of

1865 and had strongly urged ever since. Our company then considered the acquisition of the Alameda Creek water proporties, including the Calaveras Reservoir site, as premature and did not buy them. In the early part of the seventies the Oakland and Alameda Water Company purchased sufficient properties there to control the key to the situation.

The city authorities finally took hold of the matter and a water committee was appointed, consisting of the Mayor, City Attorney and Auditor, who engaged an Eastern hydraulic engineer, Mr. Scowden, as expert, to report on the water question and to advise the most feasible and appropriate supply for San Francisco.

After looking into the various schemes proposed he strongly advised the purchase and development of the Alameda Creek properties as the cheapest, safest and simplest solution of the water question.

Finding that my high opinion of the Alameda Creek System, that I had expressed to our Directors in a number of reports during the past ten years, was fully shared by the city's expert, Mr. Scowden, the Spring Valley Water Works concluded to purchase the properties from the Oakland and Alameda Water Company.

By this acquisition, they, in 1875, became the owners of the nucleus of their present magnificent and unique Alameda Creek System, which has ever since been added to by the purchase of watersheds, reservoir sites, natural gravel and filter beds, artesian lands, water rights and rights of way.

This system *alone*, if fully developed, can furnish an abundant supply of naturally filtered water for a population of nearly one million inhabitants, and its nucleus is located within fifty miles of San Francisco.

In 1876, the city authorities, having again brought before them by many various promoters a number of water schemes (although the Spring Valley Water Works had been furnishing right along an abundant supply of good water, and which it was preparing to increase in good faith and protected by the law of 1858, fairly and equitably interpreted), this time appointed a local engineer of the Army, Colonel Mendell, to investigate not only the local but also the various schemes proposed.

He made an exhaustive report in 1877, in which he went into the relative merits of a number of schemes proposed.

No particular scheme was selected by the authorities; but, whether based upon Col. Mendell's report or not, the Board of Water Commissioners entered into negotiations with the Spring Valley Water Works for the purchase of its plant, offering therefor the sum of $11,000,000.

This offer was declined by the Spring Valley Water Works as not being within several million dollars of what they considered to be the true value of the works, particularly when considering the great facility and comparatively light expense (when compared with a distant mountain scheme) with which the daily furnishing capacity of its works (being then fully sixteen million gallons a day) could be largely increased whenever required.

The water agitation continued unabated and finally culminated in the insertion into the new State Constitution of a clause, intended to replace the new law of 1858 in regard to the regulation or fixing of the price of water, at which private parties or corporations should be compelled to sell their water to cities or towns and their inhabitants.

This new law entirely ignored the fact that many millions of dollars had been expended in good faith by private water companies, invited and encouraged by the authorities and protected, as to fair treatment, by the law of 1858, and, as for the past twenty-two years, fairly interpreted by the umpires appointed under this law.

It goes without saying, that if the new Constitution, with its remarkable water clause, had been the fundamental law governing the price of water in the latter part of the fifties and the early portion of the sixties, it would have been practically impossible to induce private capital, which then brought a high rate of interest, to go into such a hazardous venture as a municipal water supply, where, under the new constitutional provision, the water companies have no voice in the matter, but where the price of water is annually fixed by the Board of Supervisors, and (experience has shown) with very little regard to the cost or true value of the respective enterprises.

But, as the Spring Valley Water Works had a great many million dollars invested in its enterprise at the time the city's offer was made, which investment the company had to protect, and the city refusing to purchase the works at a fair price, there was nothing for the company to do but to proceed in developing and extending its works, as the demand for water increased from year to year, hoping that the new law would be fairly interpreted by the city authorities and a *fair* and *reasonable* rate would be established.

Such rate should, naturally, be based upon a fair valuation of the properties and works of the company, on which value a fair rate of interest, commensurate with the risk incurred in the business should be allowed.

The water rates, or annual revenue, should also include State and county taxes, operating expenses and a fair and equitable allowance for deterioration.

A constant agitation has been kept up before the public, ever since the adoption of the new Constitution, for a municipally owned and managed water supply.

The public was informed, by the promoters of many rival schemes and by politicians, that the San Francisco water rates were much higher than in the East; but they wisely refrained from telling the public that, where in the East, many of the large cities had rivers or large natural lakes to draw from, the climatic conditions on this coast, owing to the absence of such available large rivers and lakes, required the construction of large reservoirs in which to store the water of the rainy or snow-melting season, as in the summer and fall most of the streams were dry, or nearly so.

They neither informed the public that materials, such as wrought-iron and cast-iron, cement, etc., had to be imported here, either by rail or ship, at an expense far in excess of Eastern prices, nor did they tell the people that wages of mechanics and laborers were much higher on this coast than in the Eastern States; that the large Eastern cities are generally located on very much more level ground than the very hilly location of San Francisco, etc., etc., and that for all of these, and other reasons, the cost of water delivered into the homes in San Francisco was and always would be much higher than in the East.

Another and very prominent reason for low prices to the water consumer in the East, which was never understood by the San Francisco public, was, that in many Eastern cities it was customary, and in some it is still in vogue, to have a large part of the cost of water, particularly that pertaining to interest on outstanding water bonds, paid out of the general fund, while the water taker, who was in many or most cases a tenant, paid but a very small annual water rate as such, while, unknown to himself, he paid the larger portion of the annual cost of the water used in his premises in the form of rent to his landlord. The latter, in turn, paid his taxes, which generally included the respective proportion of interest and sinking fund payments made by the city authorities on account of the bonded water debt.

Our company published the comparative facts between the East and the West in a number of reports and pamphlets and also, at many of the meetings of the successive Boards of Supervisors, all these matters were not only fully explained and proven, in order to induce them to treat this company with the same degree of fairness to which they would be compelled by law and by holders of municipal water bonds, if it was a question of fixing water rates for a municipally-owned and managed water works system.

When politicians urged and municipal conventions insisted upon pledges to be made by candidates before nomination for supervisors, or, when nominated, candidates often pledged themselves before election that they would see that water rates should be reduced, provided that they were elected,—the position of the Spring Valley Water Works gradually became almost untenable.

Meanwhile, around San Francisco Bay, while almost all real estate (whether in city or country) constantly increased in value, the water properties of the Spring Valley Water Works, although having increased enormously in value during the past two and one-half decades (being developed, unified and having their most difficult engineering problems successfully solved and their future capacities for large extension proven), were, for *water rate purposes*, continuously largely undervalued.

At the same time, for *taxing purposes*, the value of the company's properties and works was constantly being increased by the assessors of the different counties in which they were located, particularly of San Francisco County, which is the principal place of business of the company.

As before stated (page 20), the City Water Commission, in 1877, offered the company, for its properties and works on the San Francisco peninsula (and exclusive of the Alameda Creek System) the sum of $11,000,000.

As the company considered all of its properties and works, inclusive of its Alameda Creek properties (then undeveloped), to be worth fully $16,000,000, it offered to sell all its holdings and works for this sum; but added, that if the city were unwilling to include the Alameda properties in its proposed purchase, that, in this case, the Water Company would retain the latter properties and reduce the selling price to $13.500,000, as the Water Company considered its holdings on the Alameda Creek System to be worth the balance of $2,500,000. No agreement being reached between the Water Commissioners and the company, the negotiations were discontinued, and the Water Commission concluded to try to acquire some water properties in the Sierra Nevada, which plan was never carried to completion.

I am satisfied that, had the negotiations not been so abruptly broken off by the city at that time, a compromise figure between the city's offer of $11,000,000 and the company's final asking price for the peninsular works of $13,500,000 could have been arrived at; so that the city's purchase might have been then completed at a figure of somewhere between $12,000,000 and $12,500,000.

If the peninsular works had been bought at that time for this figure, this purchase would have given the City of San Francisco a great bargain. This has since been proven by the large increase in values of all real estate and, particularly, of water properties, such as watersheds, reservoir sites and water rights, located in the almost immediate vicinity of San Francisco.

The three San Mateo County reservoirs, Pilarcitos, San Andres and Crystal Springs, now have a joint storage capacity of over 25,000 million gallons; which total storage capacity, by extending and raising the large Crystal Springs Dam (as above shown) can be more than doubled.

In 1877, the population of San Francisco consisted of about 200,000 inhabitants.

In order to meet the constantly growing demand for water since then, the Spring Valley Water Works, although the water rates annually fixed by the Supervisors were not commensurate with the company's financial needs, kept on extending its works and, in order to provide for a more rapid increase in the water consumption in the near future, continued to increase and round off its holdings of water properties up to their present extent of over one hundred square miles, in fee simple, in the counties around the bay, and of large, valuable and necessary reservoir and other properties in San Francisco, City and County. From these properties and works, the Spring Valley Water Company was supplying the City of San Francisco, during 1905, with an average daily supply of nearly 35,000,000 gallons; while the properties acquired since 1877, such as water rights, watersheds, reservoir sites and rights of way, enabled the company not only to meet all of the city's requirements up to date, but also, in the future, to develop, on its fee simple properties, enough water to supply a population considerably in excess of one million inhabitants.

To construct and systematically develop its works (the principal features of which were enumerated on pages 17 and 18) as the population increased, and to acquire the above properties and rights for future extensions, the Spring Valley Water Works expended the following sums of money, segregated by calendar years (see page 24 of Appendix of Municipal Reports of 1899-1900):

1878	*........
1879	*........
1880	$62,627 71
1881	72,148 32
1882	51,687 95
1883	1,050,085 94
1884	932,464 31
1885	881,406 25
1886	652,575 32
1887	1,257,981 75
1888	2,723,251 30
1889	388,215 94
1890	637,454 18
1891	683,196 70
1892	235,337 19
1893	327,342 32
1894	367,781 81
1895	485,910 28
1896	432,378 20
1897	727,957 26
1898	1,174,973 13
1899	708,430 44
1900	†1,079,278 88
Total expenditures for betterments and new construction from 1880 to 1900, both inclusive	$14,932,485 18

*The records of such expenditures, during 1878 and 1879, having been destroyed by the fire of April 18, 1906, they are therefore not here included.

† The expenditures for 1900 are taken from Appendix, page 116, of Municipal Reports of 1900, 1901.

From the year 1880 and up to the year 1900, when the new city Charter of San Francisco went into effect, real estate located around the Bay of San Francisco and in the counties where the Spring Valley Water Works' distributing system, storage reservoirs, watersheds, conduits and water rights were located, viz.: San Francisco, San Mateo, Alameda and Santa Clara Counties,—the values of all kinds of real estate and properties constantly increased, as is shown by the total assessed valuation of real estate (exclusive of improvements and of personal property) in these four counties:

REAL ESTATE ASSESSMENT—IN ROUND FIGURES.

(EXCLUSIVE OF IMPROVEMENTS AND PERSONAL PROPERTY.)

COUNTY.	YEAR.			PERCENTAGE OF INCREASE IN TWO DECADES, FROM 1880 TO 1900.
	1880.	1890.	1900.	
San Francisco..................	$115,000,000	$164,500,000	$190,380,000	65
San Mateo.....................	4,530,000	9,750,000	8,500,000	88
Alameda	31,380,000	49,080,000	47,855,000	52
Santa Clara....................	20,900,000	35,345,000	32,099,000	53

From this showing, it is fair to presume that the magnificent holdings, which the Water Company had acquired and owns in large united bodies in the above four counties, which counties surround the southern half of the Bay of San Francisco, had *also* participated in the above general increase of value during the two decades, from 1880 to 1900, particularly as the very large and unique reservoir sites (with adjacent and tributary watersheds), which cannot be duplicated at any price within such safe distance of San Francisco, lend *a very great additional value* to these properties.

In the following I will assume, for argument's sake, that the City of San Francisco had succeeded in purchasing, in the fall of 1877, the peninsular properties and works of the Spring Valley Water Works for the price which the city then offered, viz.: *A.* $11,000,000. I will further assume that the city (instead of the Spring Valley Water Works) had also purchased then, or prior to that time, the magnificent Alameda Creek properties (also including the larger portion of the Calaveras Reservoir site) for the same price that the Spring Valley Water Works paid for the same in 1875, viz.: *B.* $1,000,000.

I will furthermore assume that thereafter the city had proceeded with the same foresight, judgment and caution as since displayed by the Spring Valley Water Works, and had purchased the same extensive and unique water properties, and had built thereon as good works as this company has since constructed,—and all of this for only the same expenditures as made by the Spring Valley Water Works since 1880, shown in the above table, of $14,932,485.18.

(NOTE.—In this figure, the expenditures during 1878 and 1879, not being available, are not included.)

I will further assume that the city had taken as good care of its works, during these two decades, as the company has, and, finally,—

I will assume that the values of these properties, so acquired, were reckoned only *at cost*, making no allowance, whatever, for the great increase in real estate values, during these two decades, in the above four bay counties (as above shown), nor for the still greater increase, in these counties, in the values of properties specifically adapted for water works purposes:

We would then, at the end of the year 1900, have the following total:—

A.	$11,000,000 00
B.	1,000,000 00
C.	14,932,485 18
Total	$26,932,485 18 or, in round figures: $26,930,000.

(NOTE.—At the beginning of the year 1901, the properties and works of the Spring Valley Water Works were conservatively estimated by competent experts to be work fully *fifty per cent.* more than the above figure.)

In the year 1900, the new Charter of San Francisco went into effect, a very prominent feature of which was the clause providing for the acquisition or construction of a municipal water works system. The city had surveys and preliminary estimates made for various Sierra Nevada supplies, the cost figures of which were *far below* what the actual cost of such works would be.

The city also had some estimates made by its City Engineer, embodying his idea of the value of the properties and works of the Spring Valley Water Works and, in his report of February 23d, 1901, he arrived at the amazingly low valuation of $24,667,800.

The Water Committee of the Board of Supervisors reduced this already low figure by nearly $2,000,-000 more, leaving the estimated value of the works and properties of the Spring Valley Water Works at $22,939,722. This process of arbitrarily placing this low valuation on the properties and works of the Spring Valley Water Company, *regardless of their cost or value*, the Water Committee of the Board of Supervisors, in its report of March 4, 1901, calls "Fixing the Value."

The fact being that, if they had been fair enough to place the real or intrinsic value on these works, the annual water rates, which they were to establish, would have to be raised; while, on the other hand, by arbitrarily assuming the above low value, on which interest was to be allowed to the company, they succeeded in seriously crippling the company's finances.

All of this arbitrary, unfair and unjust action was taken by the city authorities and approved by the Mayor, in spite of our company's solemn protest.

In the appendix, hereto annexed, will be found extracts from my various reports and protests sent to the Supervisors at that time and in subsequent years.

During the year 1901, the Spring Valley Water Works expended for betterments, such as purchases of lands, water rights, rights of way and new construction, the sum of $974,732.67.

(See page 787, Municipal Reports of 1901-1902.)

The City Engineer's valuation of the properties of the Spring Valley Water Works, in his report of January 31st, 1902 (see page 801, Municipal Reports of 1901-2), was $24,468,210.

In other words, although the Spring Valley Water Works had, during 1901, expended for betterments, as above shown, the additional sum of $974,732.67, which sum, added to the City Engineer's valuation of the previous year of $24,667,800, would have made a total valuation of $25,642,532.67 for 1902, he places the valuation of 1902 at $1,174,322.67 *less* than this figure; thus, *not only ignoring the entire year's expenditure of* $974,732.67, but actually reducing the valuation of 1902 by nearly $200,000 *below his valuation of* 1901.

This low valuation, thus adopted by the City Engineer in 1902, of $24,468,210, again did not suit the city authorities, and they concluded to place their valuation at $23,914,454.67 (see page 835, Municipal Reports of 1901-2), on which valuation they "fixed" the water rates for the next fiscal year.

During the year 1902, the Spring Valley Water Works expended for betterments, such as purchases of lands and rights and for new construction, the sum of $735,594.16 (see page 942, Municipal Reports of 1902-3).

The City Engineer's valuation of the properties and works of the Spring Valley Water Works, in his report to the Board of Supervisors of January 30th, 1903, places the value of the same at $28,024,389.00 (see page 957, Municipal Reports of 1902-3).

The Board of Supervisors again disregarded the valuation of their City Engineer and arbitrarily placed their valuation at $24,124,389.00 (see page 1019, Municipal Reports of 1902-3), which is only $209,934.33 more than their valuation of 1902, although the Water Company had expended for betterments, during 1902, the sum of $735,594.16.

These rates, being placed so low that the revenue derived under them would be entirely inadequate to carry on the business of supplying the city and its inhabitants with water, the Spring Valley Water Company began suit against the city, in the United States Circuit Court, enjoining the city from enforcing these rates, which injunction was granted.

The Water Company also brought suit against the city, in the same Court, to annul the above water rates and compel the city to establish *fair* water rates, commensurate with the value of the plant and with the cost of operation.

This suit is still pending.

During the year 1903, the Spring Valley Water Works expended for betterments, such as purchases of lands, rights, etc., and for new construction, the sum of $718,939.48 (see page 515, Municipal Reports of 1903-4).

The City Engineer's valuation of the properties and works of the company, in his report of January 26th, 1904 (see page 499, Municipal Reports of 1903-4), was $24,673,212.00; or, although the Spring Valley Water Works had, during the past year, expended for betterments the sum of $718.939.48, the City Engineer not only entirely ignores this fact but, in addition, *reduces* his valuation of 1904 by $3,351,177.00 below his valuation of 1903.

Not satisfied with this most remarkable estimate by the City Engineer, the Board of Supervisors employed another party, who gave them a valuation of $23,121,502.00 (filed February 29th, 1904,—see page 603, Municipal Reports of 1903-4), on which valuation the water rates of the next fiscal year was based.

During the year 1904, the Spring Valley Water Company expended for betterments, such as purchase of lands and rights, and for new construction, the sum of $462,438.07 (taken from report of Secretary Howard of Spring Valley Water Company, the Municipal Report of that year not being available).

The City Engineer's valuation of the properties and works of the Spring Valley Water Company, in his report of January 26th, 1905, was $25,001,441.00.

The record of what valuation the Supervisors based the water rates on for this year are not available. Suffice it to say that the rates were again cut so low that the Spring Valley Water Company was again compelled to enjoin the city from enforcing the same.

During the year 1905, the Spring Valley Water Company expended for betterments, such as purchase of lands and rights, and for new construction, the sum of $510,751.10 (taken from report of Secretary Howard of the Spring Valley Water Company, the Municipal Report for this year not having been published as yet).

The City Engineer's valuation of the properties and works of the Spring Valley Water Company February, 1906, was $25,450.327.

The arbitrary low water rate adopted by the Supervisors for the year 1906-7 was again far below the needs of the company for operating expenses, taxes and interest. The papers for enjoining the city against enforcing these rates are now in course of preparation.

From the above detailed showing, it will be seen that the position of the Water Company, from a financial point of view, has become practically untenable.

The city is constantly growing and its demand for water is constantly increasing. All of these demands for an increased water supply have been effectively met by the company. It is preparing and fully able, from a physical point of view, to meet any and all demands for an increased supply, drawn from its own fee simple properties lying in close proximity to the city and bay of San Francisco.

But: the cost of labor has largely increased of late, as well as the cost of many of the necessary materials.

The taxes have also enormously increased of late years, as will be hereafter shown.

And as practically the only resource of the company consists in the revenue derived from the sale of water, it is imperative—*at least until such time when the city owns its own municipal supply*—that a sufficient revenue is provided to meet the interest and tax obligations, as well as the operating expenses of the Water Company.

I shall quote, in the Appendix A to this report, extracts from several previous reports to the Supervisors on the *necessity* of providing a fair and adequate water rate,—at the same time showing that *all responsibility* for the consequences of inadequate water rates rests with them.

Assuming that the peninsular properties and works, for which the city offered in 1877 the sum of $11,000,000, and the Alameda Creek properties, then owned by the Spring Valley Water Works,—the company having purchased them two years previous for $1,000,000, had *not* increased in value between that time and the beginning of the year 1901, when the first attempt was made by the city to value our works, under the provisions of the new Charter;

Assuming, furthermore, that the extensive and now enormously valuable lands, water rights and rights of way, purchased by the company during the period between the fall of 1877 and the beginning of 1901, had *not* increased in value over their bare cost, when purchased in separate tracts, until the various properties were united into compact and completed units;

Assuming, finally, that the cost of materials and, especially the cost of labor, employed in the construction of the company's water works plant, had not largely increased during this long period of twenty-three years:

The properties and works of the Spring Valley Water Works, at the beginning of the year 1901, when the first appraisement was attempted by the city authorities under the new Charter, would have a minimum value of:

$11,000,000.00	offered by the city in the fall of 1877 for the peninsular works;
$1,000,000.00	paid in 1875 for all the properties and water rights of the Oakland and Alameda Water Companies on the Alameda Creek System;
$14,932,485.18	expended by the Spring Valley Water Works from the beginning of 1880 to the end of 1900 for betterments, such as purchases of lands, water rights, rights of way and for the construction of its works, up to a supply capacity of 31 million gallons per day in 1900.

Total: $26,932,485.18, or, in round figures, $26,930,000.

In the following table I shall (Sub. A) place this sum of $26,930,000 at the head of the column; also (Sub. B), the annual expenditures for betterments made by the Water Company during the following five years, viz.: 1901, 1902, 1903, 1904 and 1905, are enumerated, as heretofore detailed.

I shall also place in the same table (Sub. C and D) the various valuations of the Spring Valley Water Company's properties and works during and for these five latter years, as made by the City Engineer and the Supervisors.

I shall also place in this table (Sub. E) the taxes annually paid by the Spring Valley Water Company on its properties and works for the respective years; which will show that, although the Supervisors, *for water-rate-fixing purposes,* assumed that the works had not increased in value during this five-year period (although fully $3,400,000 were expended for betterments), the respective City and County Assessors had a full appreciation of their increase of value *for taxing purposes,* which they showed by enormously increasing the company's taxes during that time:

Year.	*A.* (See Page 66) Beginning of Year.	*B.* Expended by Water Co. for Betterments During Year.	Sum of *A.* + *B.* Beginning of Year.	*C.* Valuation by City Engineer at Beginning of Year.	*D.* Valuation by Supervisors at Beginning of Year.	*E.* Taxes Paid by the S. V. W. Co. During the Year.	Remarks.
1901....	$26,930,000 00	....	....	$24,667,800 00	$22,939,722 00	$203,257 61	Page 787, Municipal Rep., 1901-2
"	....	$974,732 67	....	....	....	....	
1902....	....	....	$27,904,732 67	24,468,210 00	23,914,454 67	236,828 97	Page 942, Municipal Rep., 1902-3
"	....	735,594 16	....	....	....	....	
1903....	....	....	28,640,326 83	28,024,389 00	24,124,389 00	321,537 25	Page 509, Municipal Rep., 1903-4
"	....	718,939 48	....	....	....	....	
1904....	....	....	29,359,265 31	24,673,212 00	23,121,502 00	348,222 77	From Secretary Howard of S. V. W. Co., Municipal Report not being available.
"	....	462,438 07	....	....	....	....	
1905 ..	....	....	29,821,704 38	25,001,441 00	....	370,440 21	From Secretary Howard of S. V. W. Co., Municipal Report not yet published.
"	....	510,751 10	....	....	....	....	
1906 ...	....	....	30,332,455 48	25,450,327 00	....	....	

This table shows that, although the Spring Valley Water Company expended for betterments, during the five years from 1901 to 1905 (both inclusive) the sum of $3,402,455.48, which, in turn, increased the value of its works far in excess of this expenditure, the valuation by the City Engineer, during these same five years, increased only from $24,667,800, in the beginning of 1901, to $25,450,327, in the beginning of 1906, or a total increase of only $782,527, or less than one-fourth of the sum actually expended.

The table furthermore shows that, although the City Engineer's *valuation* of the works and properties of the company shows for these five years an increase of only 3 1/10 per cent., the *taxes* paid by the company during 1905 show an increase over the taxes paid during 1901 of 82 2/10 per cent.

Several of the highest authorities in the profession of Hydraulic Engineering in the United States, being thoroughly acquainted with the entire properties and works of the Spring Valley Water Company, as now unified, and with their capabilities for rapid, safe and economical extension in the future, have valued them at fully twice the latest appraisement put upon them by the City Engineer,—especially when compared with the cost and relative merits and demerits of the nearest Sierra Nevada scheme of equal capacity.

Any fair-minded person will be convinced that the actions of the city authorities in connection with the fixing of water rates, especially since the adoption of the New Charter, have been arbitrary, unjust and unfair, the water rates fixed by them being neither based upon the true value of the properties and works nor upon the evidence placed before them by the company; thus making entirely inadequate provision for meeting the annual taxes, operating expenses and interest obligations. While they have succeeded in largely crippling the company's finances, they, the city authorities, are solely to blame if the safety of the city has been imperiled.

These were the existing conditions and circumstances at the time of the earthquake of April 18th, 1906.

III.

THE EARTHQUAKE OF APRIL 18TH, 1906, AND SUBSEQUENT CONFLAGRATION, AND THEIR EFFECT ON THE WORKS OF THE SPRING VALLEY WATER COMPANY.

Immediately after the earthquake occurred, at about 5.15 A. M., April 18th, finding that the telephone service had been interrupted by the earthquake, I started for the Spring Valley Water Company's pipe yard at Bryant street, between Fourth and Fifth streets. I met the head foreman, Mr. Gleeson, with his buggy, who was coming after me, and we found considerable difficulty, owing to the widespread conflagration south of Market street, to get to the pipe yard, where pipes, stores, repair pieces, horses, wagons and men are kept.

Many of the company's men had reported there and were on hand to carry out any orders. The men were at once organized in squads and, under the direction of the several foremen, started out to discover the extent of the damage done by the earthquake to the main street pipe system and, wherever possible, to repair breaks, but, in such manner, as not to interrupt the flow of the water from the respective city distributing reservoirs towards and to the burning districts.

The flow of water from the country reservoir, viz., Pilarcitos, San Andres and Crystal Springs, into the respective city reservoirs, stopped soon after the earthquake, showing that each of the three independent conduit lines had been ruptured.

As the telephone service between the city office and country reservoirs had also been interrupted by the earthquake, I started out at once to examine where and to what extent these main country conduit lines were ruptured. On the road I met my assistant, Mr. Lawrence, coming towards town to report to me what the various pipe walkers (one for each line) had reported to him. (See Map 9, showing profiles of the four wrought-iron pipe lines conducting water to San Francisco.)

The sum and substance of their reports was that:

1. The earthquake, having torn a crack or fault, several miles in length, along and across the upper or 30-inch Pilarcitos pipe line, had either completely destroyed it, tearing and telescoping it in a number of places, or *at least* had so injured it, that it would be many months, to say the least, before it could be put into service again, if at all. At the large Frawley Canon the Pilarcitos 30-inch pipe was thrown some 60 feet to one side. It was torn in two for over 100 feet and thrown bodily, in two parts, and about at right angles to its original line; so that, no matter what construction could have been put there, it could not have been maintained there, owing to the evidently great violence of the shock. Other portions of the Pilarcitos 30-inch pipe were destroyed by the earthquake, pulling the pipe apart in many places, while, at other places, it was telescoped. (See Map 13 and photographs, from 1 to 19 inclusive.)

2. The San Andres pipe line, which consists of 44-inch, 37-inch and 30-inch pipe, was badly ruptured near Baden Station (about in the middle of the line) and suffered some other minor damage.

3. The 44-inch Crystal Springs pipe line was badly ruptured in seven places between the Crystal Springs dam and Millbrae Station, and also where, on a substantial pipe trestle, it had to cross the three swamps or marshes in the three respective valleys, viz.: the San Bruno, Guadaloupe and Visitacion Valleys. Those portions of these long pipe crossings that crossed over the softer portion of these marshes in an almost northerly direction, having been subjected by the earthquake to a number of violent shakings from southwest to northeast and vice versa, were completely demolished down to the pile and cap foundation, which latter, in almost every case, were left uninjured. In some cases, where the 44-inch pipe had been thrown straight up in the air first, it had, in its downward course, not only destroyed the strong superstructure but had, in several instances, crushed the heavy timber caps bolted down to the tops of the piles.

In no case was one of the piles injured.

I at once determined that it would take about two weeks (provided all repair pieces were at hand and the necessary large amount of heavy lumber was at once available which would be required for the rebuilding of a total (in the three valleys) of about three thousand feet of bridge and relaying and re-riveting thereon the large 44-inch wrought-iron pipe. This total distance of destroyed bridges and broken pipes, in the three valleys, afterwards turned out to be 2,850 feet.

The southern, or San Mateo County, portion of the 30-inch Pilarcites pipe line being destroyed, but the northerly portion, near San Francisco, being but slightly damaged, the latter was immediately repaired, and, by starting the Lake Merced Pumping Station to pumping from Lake Merced Reservoir, in San Francisco County, where there was over a thousand million gallons of water on hand at the time of the earthquake, we were able, at nine o'clock on the evening of April 18, or sixteen hours after the earthquake, to send a stream of between six and seven million gallons of water per twenty-four hours past Lake Honda Reservoir (at 365 feet elevation) into and through the Western Addition. This regular daily supply, added to the 31,000,000 gallons stored in Lake Honda Reservoir, at 7 A. M. of April 18, largely assisted in keeping a water supply passing through the Western Addition during the entire progress of the fire and thereafter.

Before noon of April 18, all orders for materials, tools, fittings and men were given for the immediate repair of the 37-inch San Andres pipe at Baden, and also for the reconstruction, in as short a space as possible, of the badly ruptured 44-inch Crystal Springs pipe and bridge.

The San Andres 37-inch pipe, having four large lugs torn off by the earthquake near an expansion joint on the bridge at Baden, which could not be repaired with bands and lead joint (and boiler-makers and tools not being immediately available), I had four large iron patches made by some of the engineers of the Belmont and Millbrae pumps, and had them securely bolted, with rubber gaskets and a number of tap-bolts, over the torn openings of the pipe. The 37-inch pipe was then securely wired and bandaged with galvanized No. 9 wire and cables twisted out of the same and, on the morning of April 20, the water from San Andres Reservoir was then slowly and carefully turned again into this long line of wrought-iron pipe. (See photographs 24 and 25.)

By 7 o'clock on the evening of April 20, or sixty-two hours after the earthquake, a second stream of water was pouring into its respective city reservoir, the College Hill Reservoir. This reservoir had been emptied of its contents of 11,400,000 gallons, which it contained at 7 A. M. April 18, by its main arterial pipe, 22-inch diameter, and its companion pipe, 16-inch diameter, both on Valencia street, having both been torn off and destroyed between Eighteenth and Nineteenth streets by the sinking of Valencia street of from one to five feet.

This new supply, thus brought into the empty reservoir on Friday evening, while portions of San Francisco were still burning, was very welcome to a large portion of the unburnt South Mission and to the larger part of the Potrero, and to the large factories there. This additional volume of water, thus brought into and through College Hill Reservoir (at 255 feet elevation) was gradually increased to 8,000,000 gallons a day, which, with the supply of from six to seven million gallons daily sent in from the Lake Merced Pumping Station, made a total supply of from fourteen to fifteen million gallons daily flowing into the city.

The following table gives the state of the three largest city reservoirs from April 18, at 7 A. M., to 7 A. M. April 22:

Time.	Elevation 365 Feet. Stored in Lake Honda Reservoir, Gallons.	Elevation 165 Feet. Stored in University Mound Reservoir, Gallons.	Elevation 255 Feet. Stored in College Hill Reservoir, Gallons.	Total Water Stored in 3 Reservoirs, Gallons.
Wednesday, April 18th, 7 A. M.	31,100,000	30,000,000	11,400,000	72,500,000
Thursday, April 19th, 7 A. M.	13,700,000	12,200,000	....	25,900,000
Friday, April 20th, 7 A. M.	8,500,000	6,500,000	....	15,000,000
Saturday, April 21st, 7 A. M.	5,400,000	5,600,000	....	11,000,000
Sunday, April 22d, 7 A. M.	1,500,000	5,200,000	....	6,700,000

The above table shows that at no time during the fire were all the city reservoirs empty. Besides, in addition to the water thus stored, a gradully increasing supply was sent through the repaired Lake Merced and San Andres conduits into the city during April 19th, 20th, 21st, 22d and thereafter.

The seven breaks on the 44-inch Crystal Springs' main pipe, between Crystal Springs and Millbrae, where the pipe was in the ditch, were soon repaired. But the repairing of that portion of this pipe, between San Bruno and San Francisco, which was carried on the three widely separated piled bridges across the three separate swamps, met with considerable delay, owing to the scarcity of the properly sized lumber and heavy timber, and also on account of the lack of proper transportation facilities for the same.

Finally, about ten days after the earthquake, having meanwhile lost no time in quickly dismantling, segregating and preparing the pipe for relaying by cutting off the torn edges, and other work, some 2-inch by 12-inch redwood and pine planks were secured, and I at once started a force of carpenters to construct, on the original pile foundation, a substantial system of blocking, spiked together. On this blocking, stringers were placed, from block to block, made of 2-inch by 12 inch pine planks, spiked together into two continuous girders. Across these two girders, 3-inch by 12-inch planks were laid, and on this cross-planking the torn-off sections of the 44-inch pipe were placed and riveted together, care being taken to place lead-jointed bands around the new joints (straddled by heavy galvanized wire cables, made on the spot), at such points in the bridge crossing, where the softer portions of the marsh joined the firmer parts and also near the central points of the softer portions of the same. (See photographs 20, 21, 22 and 23.) Thus, in case of a recurrence of the earthquake, there was provided, at the proper places, a number of strong but flexible joints in the 44-inch pipe, that would have enough give, so as, if possible, not to allow the pipe to be ruptured again in these critical places.

One feature of the destruction of the bridge and pipe across the San Bruno marsh was that some of the pipe was thrown to the west and some to the east as much as four or five feet.

Most of the broken 44-inch pipe was ruptured in the round seams and in lengths from thirty to fifty feet. There was one piece, though, about 800 feet long, of this 44-inch pipe, which was mostly lying on the west side, but so curved that it made quite a snake-like appearance, and that pipe we examined carefully, as to the strain received by the round seams, and we did not find even the slightest appearance of a strain in the rivet seam or a crack in the asphaltum coating. I attribute this remarkable flexibility of this 44-inch pipe to the high elastic limit and the great degree of ductility of the laminated iron used in its construction. We re-established, by careful survey, the straight line and grade of the pipe, and found that neither the original straight line of the piles nor the grade of their tops had been disturbed by the earthquake. Meanwhile, with a lot of jack-screws, we worked the long 800-foot piece of pipe carefully, until the survey showed it was straight in line and grade and in place, on the newly completed trestle.

After the 44-inch Crystal Springs pipe had been so repaired, it was again covered by a redwood casing, on the bridge, for the entire length that had been broken.

The seven serious breaks in the 44-inch line between Crystal Springs Dam and Millbrae, having been also repaired, we were able to turn the water into the now repaired and fully rehabilitated long Crystal Springs pipe line, slowly filling the same with water, while driving out the air through the air-valves on the high places in the pipe line.

The water arrived at the University Mound Reservoir, in San Francisco, at the rate of 125,000 gallons per hour, at 2:10 A. M., on May 16th. Gradually, by 1 o'clock P. M. of the same day, the flow of water had been increased to 270,000 gallons per hour, or about six and a half million gallons a day. By 6 P. M., May 16th, it had been increased to 440,000 gallons per hour, or at the rate of about 10,600,000 gallons per day. Thereafter, it has been steadily increased, so that the supply filled the University Mound Reservoir, although a large amount of water was being wasted from the same in San Francisco, through breaks in the street pipes, through thousands of house and other service pipes, still broken, and through the very lavish and wasteful use of water by the people.

The same San Andres earthquake fault, as Professor Lawson has named it, that destroyed the Pilarcitos 30-inch pipe line, also passed through the original brick and cement gate well at the inlet of San Andres Reservoir outlet tunnel, fracturing it. The new concrete gate-well, that also stood in the line of the fault, and within about ten feet of the above brick gate well, was apparently left uninjured. (See Map 13 and Photographs from 38 to 45 and 102.)

The brick tunnel, connecting the concrete gate-well with the main San Andres tunnel, was somewhat damaged by the earthquake, but not so as to interfere with the flow of the water through the same. As manhole C (Photograph 38) gives ready access to this tunnel, the fissures will be easily closed by cement grouting.

The San Andres dam, built of selected clay, with a first-class clay puddle core through the entire length of the center of the dam and from the bedrock up to near the top, was left uninjured, only showing a few small cracks in the macadam pavement on the top of the dam and above the puddle core. (See Maps 13 and 6 and Photographs Nos. 28 and 32.)

The large, heavy brick and cement tunnel, from the waste or overflow weir, was cut in two by the earthquake fault passing right through it, and was badly crushed near its outlet end. The heavy timber chute connected with the same was also partly destroyed. (See Map 13 and Photographs from 29 to 37 and 103.)

The Lock's Creek aqueduct, one of the main feeders of the San Andres Reservoir, having been damaged by the earthquake and the nearness of the fault has since been repaired and is now in normal condition. (See Map 13, and Photographs from 46 to 53, and from 14 to 19.)

The San Andres waste-weir tunnel, as well as the brick gate-well, above mentioned, will be repaired this summer by either using first-class re-enforced concrete or by constructing a heavy timber chute.

The Crystal Springs main concrete dam, 145 feet in height, which forms the large Crystal Springs Reservoir, of a present capacity of 19,000 million gallons, was left uninjured by the earthquake. (See Maps 13, 6, 7 and 8 and Photos 26, 98, 100 and 101.)

The upper Crystal Springs Dam received a severe blow near its extreme east end and near the top. The earthquake fault passed through the serpentine bluff, against which the east end of the dam is built. Its original lower portion, that has a puddle core, was apparently uninjured, as the earthquake fault ran through the upper and eastern part of the road-fill, which has been made over the top of the original clay core dam. (See Maps 13 and 6, and Photos 27 and 99.)

As the water, on both sides of the dam, is practically on the same level, communicating through the lower tunnel and through the two upper waste-weir tunnels, no practical injury is done to the dam.

Neither the Sunol filter beds, on the Alameda Creek System, nor the Sunol Aqueduct and 36-inch pipe line, on the east side of the bay, nor the four submarine pipe lines were injured; only a slip-joint, on one of the two 16-inch shore connections, was pulled apart several inches, on the east side of the bay; and two 8-inch blow-offs, at the west shore connection of one of the 16-inch pipes, were broken off by the shock. (See Maps 1 and 10.) These minor injuries were quickly repaired, and Alameda Creek water has since been crossing under the Bay of San Francisco and pumped at Belmont Pumping Station. We now receive from there about fourteen and a half million gallons a day, no more being required from there at present.

The Alameda pipe line, on the east side of the Bay of San Francisco, gives one of the best illustrations of the suddenness of the earthquake shocks. The submarine pipes bring water from the Sunol filter beds through an aqueduct, consisting of concrete tunnels and heavy redwood flume, along Niles Canon, to a point near Niles. Here the 36-inch pipe starts, descending gradually, for about eight miles, in a southwesterly direction, through Centerville and Newark, to a bridge passing over the Newark marsh for fully 9,000 feet, to a navigable slough, which is about 30 feet deep and 300 feet wide. Through this slough four submarine pipes (two 16-inch and two 22-inch) run—the former laid in 1887 and the latter in 1901. These submarine pipes are connected at both ends to the 36-inch wrought-iron pipe, each submarine pipe being controlled by two gates. At the westerly side of the above slough those four submarine pipes are connected together, each one with a shut-off gate and each one with a blow-off. The 36-inch pipe then proceeds southwesterly, on the same kind of additional trestle, for over 7,000 feet, to Dumbarton Point, which is located on the easterly shore of the narrow neck of the Bay of San Francisco. At this point the 36-inch pipe again divides into two 16-inch and two 22-inch ball-joint submarine pipes, each one with gates and blow-offs, which pipes run parallel to each other and underneath the bay—the two 16-inch being to the south and 90 feet from the 22-inch pipes. These pipes again join at the San Mateo shore, at Ravenswood, into one 36-inch pipe, with exactly the same construction as at the above described slough; and thereafter the 36-inch goes southwestwardly through the marsh on a pile trestle for nearly 2,000 feet, and from there, for fully nine miles, in a ditch underground, through Menlo Park and Redwood City to Belmont Pumping Station, where the same discharges the water into a reservoir. From this reservoir the water is pumped into a standpipe and runs to San Francisco.

At the time when we built the first submarine lines and the 36-inch pipe, during 1887 and 1888, fearing that the watchman might shut the submarine gates down too suddenly, with a strong current of water flowing from Niles tank towards the submarine pipes, I put on an automatic safety valve at the east side of the slough and the bay, in order to lessen or avoid all shock danger to the eight or nine miles of 36-inch pipe that might be caused by the sudden shutting off of the submarine pipe gates. These automatic safety valves had a number of large rubber disks, which were regulated carefully to open automatically at the slightest shocks above the normal pressure. East of this shock valve I had a tall air chamber, where any air in the 36-inch pipe would collect and could be let out. I knew that the bottom of the bay and the bottom of the slough were not perfectly level, and that there might be high places in the pipe where any air getting into the same might accumulate. I therefore put up these air chambers to prevent any air from entering the submarine pipes. Eastwardly from the air chamber and close to the same was placed a vacuum valve, on top of the 36-inch pipe, which valve would open instantly and automatically, the moment the pressure was taken off the pipe by a break, or whenever it was emptied, for repair purposes, by opening a blow-off gate.

At the time of the earthquake, on the morning of April 18th, the water was coming westwardly, at the rate of fully 16 million gallons daily, through the 36-inch pipe, having a mean velocity of fully 3½ feet per second. The water was flowing towards the bay with that velocity, going through the submarine pipe and towards and to the reservoir at Belmont. When the shock came the vacuum valve instantly dropped and let air into the pipe, showing that at that point east of San Francisco Bay the first shock observed came in a southwestwardly direction. It further showed that this shock was much more rapid than the velocity with which the water flowed in the same direction. The vacuum valve fell down, and when the reaction shock came, from southwest to northeast, the valve closed suddenly, throwing up a stream of water into the air while closing. At the same instant the safety valve nearby opened automatically, closing when the shock was passed, and thus by discharging quite a quantity of water relieved the long 36-inch pipe to the east from the effect of the shock, which might have been disastrous.

All the three large pumping plants in San Francisco, viz.: Black Point, Lake Merced and Seventeenth Street Station, were not injured by the earthquake, as well as the ones at Millbrae and Crystal Springs. At Belmont Pumping Station the only slight damage done was the breaking of a flange on a steam valve on one of the five pumps, which has since been repaired; the other four independent plants there received no injury whatever.

Lake Honda Reservoir, in San Francisco County, which was constructed by Engineer Von Schmidt and, later, added to by an architect named Jordan, was turned over to me in 1866. It was injured by the earthquake cracking the heavy western wall, the shock coming from the west and shaking up a sandy mountain, about 100 feet high, causing the slope to slide down towards the wall. By the free use of pure cement grout the large cracks and fissures in the west wall were successfully filled and closed, and the reservoir, having since been full, appears to be practically tight. (See Photos 54, 55 and 56.)

Lombard Street Reservoir and Clay Street Tank, both in San Francisco, had their wooden roofs burnt off. The former has been cleaned and the brick bottom and sides, where necessary, covered with a new asphaltum coating; and the latter tank, after having been cleaned and painted, will soon be in commission again.

All the other city distributing reservoirs were uninjured, both by earthquake and fire.

The city pipe distributing system was broken and in many instances torn and twisted off, especially in places where the ground, over which the streets had been constructed, had been poorly and loosely filled over old deep swamps and soft marshes. There were also a number of breaks in the streets that passed with deep loose fills over former ravines. (See Map 11 and Photos from 57 to 81.)

In solid ground there was very little trouble and but very few breaks. A number of the breaks noted on the accompanying Map No. 11 as being on solid ground were caused by the use of dynamite and other explosives, employed in blowing down buildings.

In the above sunken streets the city sewers, as well as other conduits, such as gas pipes, electric light conduits, etc., suffered the same as the water pipes, in that they were also similarly ruptured by the sinking and violent oscillations of the ground.

On July 18th there had been discovered and repaired 300 breaks in the street pipe system, of which number 276 were in and immediately adjoining the burnt district, while in the entire balance of the city, viz., in the unburnt district, only 24 breaks have been found and repaired.

But the most serious problem that we have had to meet in rehabilitating the city distributing system has been the work of shutting off the thousands of broken service pipes and house supply pipes that were torn off by the burning and falling buildings during the conflagration at the average rate of between about 6,000 and 7,000 service pipes a day, ranging from ⅝ of an inch to 4 inches in diameter and sometimes over, which service pipes were thus torn off and left running wide open during the entire conflagration, discharging uselessly into the accumulated debris.

The total number of the house, hotel, elevator, standpipe and factory connections and of automatic-sprinkler pipes, thus torn off and left open by and during the entire conflagration, amount to over 23,200 separate pipes in the burnt district. The breaking, tearing and twisting off of the main street pipes in over three hundred places and the opening of these many thousands of service pipes left but little pressure in the main pipes in the unburnt district and for the Fire Department along the burning margin of the same.

I shall here quote from my letter of June 20th to the Chief Engineer of the San Francisco Fire Department on this subject and on the difficulties being encountered by our city repair forces in rehabilitating the city distributing system in the burnt district:

"4. As you know, the principal breaks caused by the earthquake in our City Distributing Pipe System occurred in those regions where the streets crossed old swamps and deep fills, while on the solid ground the main pipes suffered but very little. The city sewer system was also badly hurt in these identical sunken streets, particularly south of Market street.

"But with the exception of the tearing off by the earthquake of the 22-inch and 16-inch pipes, on Valencia street (by Valencia street sinking about five feet between Eighteenth and Nineteenth streets), which, within a comparatively short time, emptied the College Hill Reservoir, the damage done by the breaks in the balance of our pipe system was not any more serious than, as the conflagration progressed, the gradual tearing off, by the burning and falling buildings, of over 23,200 service connections, such as house services, factory supply pipes, standpipes for hose reels, large elevator pipes, automatic sprinkler pipes, etc. The immediate effect of, first, the tearing and twisting off, by the earthquake of the main street pipes (especially in swampy and filled ground) and, second, the conflagration, lasting from three to four days, successively and irresistibly tearing off and opening, on an average, over six thousand a day of the above service connections during the prevalence of the fire, or, by actual count, a total of 23,200 service pipes, large and small (having a total area of about seven thousand square inches) was to take away the pressure in the burning region.

"Is there a better argument in favor of a municipal independent fire protection system? With a number of large salt water reservoirs on the hills, in the city squares and an entirely independent fire-pipe and fire hydrant system (especially if swamps and loose fills were avoided), such a disastrous conflagration could be entirely avoided in the future. Foreseeing a calamity, such as has just visited us, I outlined an independent salt water plan some eight or ten years ago, in a report to the Board of Supervisors, so as to separate the domestic from the fire service, but neither my report nor the urgent advice of the late Chief Sullivan was ever heeded by the authorities. I am now engaged in the preparation of a similar plan for a salt water municipal fire protection, with the hope that either it or some other similarly effective plan will be adopted by the city in the near future.

"I have gone into some detail in this letter to you, so as to reiterate my views on the subject of an independent salt water supply and also as I wish to show you the great difficulty we are meeting in the indifference on the part of the property owners in the burnt district in regard to removing the large piles of debris piled on sidewalks and streets, particularly in the regions of the former brick buildings.

"We are importuned by hundreds of people, who want to rebuild in those districts, to furnish them with water. As all the water supplied in that part of the burnt district, where brick buildings prevailed, comes from the south and, of necessity, has to pass northwardly through the low, level burnt regions between Valencia street, on the west, and Potrero avenue, on the east, and then in a northeasterly direction and between Market street, on the north, and Berry street, on the south—all of the main pipe lines within these regions—and paralleling either Valencia or Market street (with the exception of the Market street mains) pass through the regions where the streets have sunken all the way from one to five feet and the sewers and main pipes have been torn off and have sunk with the streets.

"The burnt district contains over one hundred miles of main street pipes, over which the above 23,200 open service pipes are scattered. Most of the large and vital main pipes, especially those feeding or leading the water to the shipping and former business districts, have been repaired, and more than one-half of the total of 23,200 open service pipes have been closed, thus not only preventing the water from escaping from the repaired main pipes, but, *above all*, succeeding in carrying a good fire pressure along said main pipe lines and into the old business districts. As the main pipes generally lie within from three to five feet of the curb, and, as the stop-cocks are under the sidewalks and also the taps are near the main pipe, we have encountered tremendous difficulties, also causing much delay in getting at these stop-cocks, which were all left wide open by the fire and which all have to be shut off before we can send the water under pressure to the next adjoining block.

"Frequently, single lot owners, or even a group of adjoining lot owners, clear their piles of debris from the streets and sidewalks and then demand water from us. Meanwhile, the blocks, *through which* the water *has to come* to reach the above applicants for water, remain littered and covered with high piles of brick, iron and other debris, which the owner or owners of the respective lot or lots refuse to move. (See Photos 83 to 88.) The work, therefore, of rehabilitating the water supply, particularly in the former brick building districts, is very costly to our company and, under the circumstances, where we have to remove the debris ourselves, in order to get at the main pipes and the stop-cocks, although we have a large force working, *is very much retarded* by the indifference or unwillingness of the respective lot owners.

"An early resumption of normal conditions in regard to the domestic supply and, particularly, to the hydrant supply, is to the interest not alone of our company and the Fire Department, but also to the entire city. Anything that you and your department can do to facilitate this matter will be highly appreciated by our company, and, particularly, by

Yours respectfully,

" H. SCHUSSLER,

" *Chief Engineer of the Spring Valley Water Company.*

P.S. I enclose sample of the notices which have been sent around, in large numbers, but so far they have had but a very slight effect.

The following is a copy of the notice above referred to:

" OFFICE OF SPRING VALLEY WATER COMPANY.
" San Francisco, Cal., June 1, 1906.

" *Notice.*

" The streets, sidewalks and basements, through the burned district, especially in that part within the old fire limits, are encumbered with debris, the removal of which is now one of the greatest problems which confront the city. In every one of the basements within this burned district are old connections with the water mains, varying from three-fourths of an inch to four inches in diameter, which have been left open by the fire, and which cannot possibly be wholly closed before the street and lots have been cleared. The Water Company has a large force of men now engaged in closing these leaks as far as possible, but in spite of these efforts many must remain open until the work of clearing away the debris from the streets, sidewalks and basements has been well advanced toward completion. We are now bringing daily into the city fully twice its present legitimate consumption, one-half of which is wasted by passing to the sewer through concealed openings in the burned district. The waste of water in itself is not being considered by the Company, but it is its first duty to keep the reservoirs within the city limits full as a protection against fire. Under these conditions, which we believe have not been fully understood, we trust that people desiring water through the burned district will rely upon our using our best efforts to supply them at the earliest possible moment, and that they will excuse delays which result from causes entirely beyond the Company's control.

" SPRING VALLEY WATER COMPANY.

The foregoing extracts from my letter of June 20th are self-explanatory.

Since the writing to the Chief of the San Francisco Fire Department of the above letter, fully one month has passed, and still many of the streets in the former business district, through all of which our water pipes pass, are littered and filled with debris to this day, the same as before.

In spite of the above-described condition of the streets, our various squads of repair forces, working under a systematic and methodically devised plan of rehabilitation, have so far succeeded in putting nearly 75 per cent. of our distributing system in the burnt district into normal condition. By doing so, we have used every possible effort and spared no expense to not only supply water for domestic purposes to those who wanted to rebuild in the burnt district, but we are also maintaining a good pressure on the fire hydrants there, thereby assisting in protecting the newly constructed buildings against fire.

One of the most serious breaks in the main pipe lines was caused by the earthquake shaking and settling down, by from one to five feet, the region between Eighteenth and Nineteenth streets, on Valencia street. (See Photos 57, 58, 59, 63, 64 and 65.) Here an old swamp had been loosely filled in, many years ago, by any and all kinds of material and rubbish obtainable, the fill being twenty feet or more in depth. Our pipes, which had to be below the pavement of the street, had to cross this region. Being aware of this state of affairs regarding the character of the foundation and fill (I constructed the pipe in 1876), I remembered the location of this swamp, and made our 22-inch pipe of wrought-iron. I put in a number of cast-iron bell joints, with lead joints, which would give or yield somewhat in case of a slight settlement. This pipe is to-day in a perfect condition, except at the points where the swamp dropped down suddenly, during the earthquake, from four to five feet, which naturally tore off the pipe both at the north and south boundary of the swamp. This serious break was quickly repaired by laying across the swamp and over the top of the pavement and well into terra firma on each side of the sink; a long stretch of 24-inch cast-iron pipe. This gave us a chance to drive a supply of water along Market to Sansome street, to Montgomery avenue, etc., to and into the Francisco Street Reservoir.

As the high and isolated Pacific and Presidio Heights regions are supplied by the Black Point Station, which in turn draws its water from the Francisco Street Reservoir, it was of the greatest importance to send a sufficient supply of water as rapidly as possible via Valencia, Market and Sansome streets and Montgomery avenue to and into the Francisco Street Reservoir.

The Crystal Springs System, from which, in normal times, this reservoir receives its supply, being at that time interrupted by the breaks on the 44-inch pipe line, could therefore not be called upon; thus, by the above rapidly completed repairs of the Valencia street mains, the object was accomplished.

In order to supply the unburnt region of the Mission District, we quickly also laid over the Valencia street swamp, and on top of the pavement, a 16-inch cast-iron pipe; thus making the supply of the unburnt portion of the College Hill, or middle city supply district, independent of the supply sent to the Francisco Street Reservoir.

More than ten years ago I pointed out to the company the wisdom of establishing a very large storage reservoir in San Francisco, to hold from three to four hundred million gallons, at fully three hundred feet elevation. The company thereupon purchased a tract of land of forty-two acres back of the Industrial School, for the purpose of constructing thereon the above reservoir. From this reservoir, a conduit consisting of a series of large concrete-lined tunnels were to be constructed in a general direction of northeast by north towards the southwesterly head of Market street in San Francisco, where, from a gate-house at the northeast end of this tunnel, at an elevation of about 265 feet above tide, a system of large distributing mains would radiate in southeasterly, easterly, northeasterly and northerly directions. All of the city reservoirs and districts below the level of this main gate-house were to be supplied by gravitation from the same. The hilly part of the West Mission was to be supplied from the same main tunnel, through side adits, which in turn would supply the large proposed north and south main on Dolores street.

But the continuous cutting down, by the Supervisors, of the price of water during the last decade prevented our company from undertaking this important work, as the company's revenue was thereby reduced below its bare requirements for its obligations, consisting of taxes, operating expenses and interest.

We had also projected a 16,000,000 gallon reservoir on our Market street block, near Buchanan street, at 150 feet elevation. This reservoir would be supplied from the University Mound Reservoir and also from the above proposed Industrial School Reservoir. It would have a large independent pipe line, down Market street, studded with many hydrants, and was intended to give to this important, broad thoroughfare an entirely independent system of fire protection. I knew at that time that the foundation of Market street, with the exception of its filled easterly end, was solid and reliable throughout, as was also proven during the earthquake. A strong plea was made by our company with the Board of Supervisors, in June, 1893, against destroying this fine isolated rocky hill, made and placed there by nature, apparently, for the purpose of a commanding reservoir at the head of this great thoroughfare. If this hill were saved, we agreed to at once construct this reservoir. But all our arguments and warnings were of no avail, and the Supervisors ordered Ridley street to be cut through this fine reservoir site with a deep and long excavation. There is no doubt, whatever, that this large volume of water stored therein, at 150 feet elevation, coupled with an independent large pipe *for fire purposes* only, down Market street, would in all probability have prevented the late fire from crossing over to the north side of the same.

APPENDIX A.

(See Page 25 of Report.)

I shall here quote from several of my printed reports, made and handed to the Supervisors, pleading for fair treatment, in order to show that the attention of the city authorities had been fully and plainly called to the tremendous responsibility they were assuming by trying to cripple the finances and, consequently, the resources of the Spring Valley Water Company.

Page 9 of my report to the Board of Supervisors, made January 28th, 1904:

"NECESSITY OF AN AMPLE WATER SUPPLY.

"Your predecessors in office were, and no doubt your Honorable Board is fully aware, that it is an absolute necessity that this city *must* have an ample supply of water at all times, both for domestic and fire purposes, no matter whether such water is supplied by the municipality or by private enterprise, or by both.

"That the city authorities have heretofore been and are now desirous of providing water for the city's future growth is proven by the various steps taken by them, from time to time, to procure a municipal supply.

"That the Spring Valley Water Works and its successor, the Spring Valley Water Company, has been and is *emphatically* of the same opinion, that the necessity for an increase of the supply has existed and does exist, has been proven not only by its systematically acquiring additional properties, necessary in the near future, and by constantly extending its works, but also by many *urgent*, but *vain* appeals to your predecessors in office: *not to reduce and cripple* the necessary revenues of the company, as by such reduction the proper and timely extensions of the works would be prevented,—extensions that were and are *absolutely essential* to meet the rapidly growing demands of the community.

"The Spring Valley Water Company, which now supplies this city with water, has, for more than forty years past, given to this city and its inhabitants as good a service as was obtainable with the physical and financial means at its disposal; and, but for such good service, this wind exposed and largely inflammable city might have been swept by conflagrations, as the best fire department in the world, without such a water supply, would be powerless.

"NECESSITY FOR FIRST-CLASS WORK.

"It pays neither the municipality nor a private corporation to use cheap and inferior materials and to employ poor workmanship in the construction of water works or other utilities.

"This fundamental principle has guided the Spring Valley Water Company and its predecessor in the past and will continue to do so in the future, as our experience has taught us that to build after *first-class design* and with the *best of materials* and *workmanship*, but without extravagance, is *true economy*.

"Appropriateness of design, best quality of materials, and the high-class workmanship employed, have given our works reputation and standing all over the United States, which we intend to maintain.

"Good works, like ours, cost money, as the city will find out when it embarks into municipal ownership of the proposed public utilities.

CAPITAL INVESTED AND INTEREST THEREON MUST BE SAFE.

"In such event, the city will have to pledge its faith and credit, in order to induce capital (which is naturally timid) to invest in the city's proposed bond issues.

"If a necessary utility is *not* undertaken by the city, but instead is left to private enterprise, capital, in order to be induced to invest in the stock and bonds of such private corporation, *must*, of necessity, have not only the fullest confidence in the ability of the management, but also, and primarily, in the financial stability of the corporation, which means an assurance of absolute safety of the investment and interest, not only in the present but also in the future.

"RESPONSIBILITY OF THE CITY AUTHORITIES.

"Subject to the approval of the voters, the new Charter vests in the Board of Supervisors the power to acquire municipal water works, either by purchase or construction.

"If this course is adopted and approved, the entire responsibility for an adequate and constant supply of good water for the future will rest with the Board of Supervisors. With them will also rest the responsibility of establishing and maintaining, without a shadow of a doubt and to the fullest satisfaction of capital, the desirability of the investment and of the absolute security of principal and interest until the final redemption of the bonds.

"Should, on the other hand, the city authorities neglect or fail to carry out the above Charter provision, but should *instead* leave such utility to private enterprise, they are, in this case, no less responsible for a constant and abundant supply of water and also for the security, safety, and financial stability of such private enterprise. For the latter case, the new Constitution provides that the Board of Supervisors must annually fix a fair water rate, which means, that not only should *operating expenses* and *taxes* be provided for, but also a fair interest should be returned to the owners of the enterprise, and enough *additional revenue* should be provided to pay interest on the cost of such new extensions of the works as are necessitated by the increasing consumption, not to mention a fund to provide for *deterioration*.

"If the city authorities, in their annual rate fixing *fail* to provide the proper and necessary amount of revenue, thereby preventing the expenditure of additional capital for constructing such new works as are made necessary by the constant growth of the consumption, *the responsibility for such failure to have the works extended in due time*, falls directly upon them.

"Assuming that all of the legal difficulties were now removed that will be encountered by the city in acquiring all of the lands, water-rights and rights of way necessary to bring an independent municipal supply of water from the Sierra Nevada to this city; *even* if the works were commenced at once, it would take about six years, or until the year 1910, before such municipal water could be distributed in San Francisco.

"*During this interim*, that is from *now until* 1910, the city will be constantly growing in population and, as my above estimate shows, the water consumption will, by that time, have grown to at least *forty million gallons a day*.

"It is *imperative*, therefore, that the works now supplying the city with water *must* have their capacity increased, and that, *ahead of time*, so as to keep fully ahead of the growing consumption.

"To provide for such additional supply requires *time* and *money*, the interest on which the city authorities will also have to safeguard, in addition to all taxes, operating expenses and interest on the stock and bonds.

"The attention of the various Boards of Supervisors has heretofore been frequently called to *their responsibility* in the matter, as the following extracts from my former reports will show.

"In my report of February, 1901, page 7, I say:

"'This splendid result, of meeting the ever-growing demands for water *gradually* and *successively*, as the city grew, and in spite of the frequency of single and successive dry and unproductive rainy seasons, could *never* have been accomplished if it had not been for the *timely* acquisition of water rights and lands and the construction of the magnificent storage reservoirs and the development of other additional resources which the company had provided *in time* to meet just such emergencies. And *as sure* as this city is bound to grow, calling upon whoever may be supplying it with water hereafter, whether it is a corporation or the municipality itself, or both, *additional water facilities have to be provided at no matter what cost*.'

"On page 8 of the same report, I say:

"'Whether a corporation or the municipality supplies the water to this city, it is absolutely essential to *look ahead* and acquire the water-rights, lands, reservoir sites, etc., *ahead of the time* when they are absolutely needed; our experience having shown that once the fact is established that properties, as above described, will be needed in the reasonably near future (which means for a large and rapidly growing community like ours within the next ten or twenty years), *it is always true economy* to buy them as they are offered for sale from time to time, so as not to excite the seller and raise the price unnecessarily. Many of our large water-right and other properties have taken *from ten to twenty years to complete the entire purchase*.'

On pages 10 and 11 of the same report, I say:

"'This corporation has been for about forty years supplying this city with water, and, unless other water works are built hereafter either by the city or some one else, this company will be called upon for some years to come to meet the ever-increasing demand for water in this city. Water works, under our climatic conditions, as well as on account of the high price of labor and materials, cost a great deal of money. As for an increasing supply for the future, and an improved and extended distributing and reservoir system in this city, a great deal of money will be required, and as money is proverbially timid (especially as to water-supply enterprises in California, where the purchaser of water demands a supply at such price as the purchaser or his municipal representative fixes), it is difficult to sell either stock or bonds of this corporation at a *fair price* which anywhere near approaches the *value* of the property, on account of the insecurity of the interest to be paid on the same,—particularly where, *so far*, the city authorities have been constantly cutting the rates, and make no allowance whatever for a sinking fund for the redemption of the bonds.'

"In the same report, page 28, I say:

"'As one of the direct results of the repeated reductions (against our protest) of the water rates, particularly since the beginning of the year 1897, by which reductions the financial resources of the Spring Valley Water Works were *seriously interfered with*, also working to the detriment of the city and the Fire Department, I wish to state, that while we laid (in round numbers) in the streets of San Francisco in

1896	32	miles of pipe,
We laid in		
1897	16	miles of pipe,
1898	15½	miles of pipe,
1899	14	miles of pipe,
1900 only	4	miles of pipe.

"On page 171 of the same report to the Supervisors, I say:

"'As the Spring Valley Water Works is the main source from which the city is supplied, it appears to be a very short-sighted policy and almost suicidal on the part of the city authorities to cripple the company's financial resources, by adopting water rates which will not permit a sufficient income to allow for taxes, running expenses, and interest on present and necessary additional obligations. *At least*, until such time as the city of San Francisco has constructed, owns and manages its own municipal water works, the policy of the city authorities should be to co-operate with the present works, so that by fair and impartial treatment the company would be able to properly develop the works, and with money obtained at reasonable rates of interest. Such policy, if adopted by the city, would soon allow a gradual fair reduction of the water rates in the future, as the works expanded, as has been plainly shown in my report on the value of the Spring Valley Water Works. If, on the other hand, the city authorities persist and succeed in crippling the company's finances, they alone will be to blame for making the works as well as the water supplied not only more costly, but they will also be *solely responsible* if the final result of their short-sighted policy is to decrease or paralyze the efficiency of the water works for fire as well as domestic purposes.'

"In my report made two years later to the Board of Supervisors, in February, 1903, I say on this subject, on page 10:

"'As long as the Spring Valley Water Works is practically the only source from which the city gets its supply of water, it is but fair to ask for it fair treatment at your hands, and to give it every encouragement in your power to properly enlarge the works and keep pace with the growing demands of the city,—*at least* until the city has acquired and constructed its own municipal water works.'

"In the same report of 1903, page 18, I say:

"'As near as can be estimated, the population of our city has of late years grown at the following ratio:

"'At the beginning of 1900, the population was 355,000 inhabitants; at the beginning of 1901, the population was 365,000 inhabitants; at the beginning of 1902, the population was 385,000 inhabitants; at the beginning of 1903, the population was 410,000 inhabitants.

"'This growth, if continued, will require in the near future *large expenditures of money* and a *corresponding* and *assured revenue* to meet the increasing *cost of interest, operating expense* and *taxes*. *Without* such revenue, the improvements now under way and which are necessary to meet the increasing requirements for water in our rapidly growing city *cannot be made*.'"

APPENDIX B.

During the first days of May, Professor Charles Gilman Hyde and Professor Charles Derleth, Jr., both of the Department of Civil Engineering of the University of California, made an exhaustive examination of the works of the Spring Valley Water Company and the repairs then in progress.

The following are extracts from the report of Professor Derleth, which appeared in the Engineering News of May 17th, 1906, published in New York:

(NOTE.—In the following extracts, Professor Derleth's photographs and references to them have not been reproduced.)

"The writer has visited Pilarcitos, San Andreas and Crystal Springs reservoirs, also all of the important flumes and conduits connecting these reservoirs with San Francisco. He has had no opportunity to examine the Alameda conduit south of Burlingame, but is informed that all of the works along this part of the conduit and at its source of supply are intact and feels confident that such is the case, since all of that work lies in a region of lesser disturbance. The water supply of Oakland, Alameda and Berkeley, as I have already reported, is practically uninjured, and it is likely that the Alameda conduit south of Burligame has been subjected to very nearly the same degree of shock as the works of the Contra Costa Company of Oakland.

"The Pilarcitos reservoir is to the west of the main fault line and is separated therefrom by by a range of hills known as the Sawyer Ridge. That reservoir is thoroughly intact and its earth dam (95 feet high) is unaffected. The waste-way conduit connecting it with San Andres Lake is also intact. The reservoir is full of water.

"The main fault line runs through Crystal Springs Lake, but in no way appears to have affected the imperviousness of its bottom, since the reservoir on May 3 was full of water. It is interesting to note that the fault line passes through the older dam, which separates the lake into two halves, but that dam is not seriously affected, and even if it were ruptured, there would be no danger, so far as it individually is concerned, to the impounding capacity of the whole reservoir.

"All observations of the effect of the earthquake along the fault line convince the writer that there was an oscillating, shearing action of the surface materials, so that the material to the east of the fault line rubbed against that at the west. This shearing oscillation was not wholly horizontal, but must have had some vertical component. At this time, however, it is not possible to state the exact direction of action. Of course these surface movements must be due to a rupture in the hard materials beneath, but just what has occurred in the firm crust below is not entirely evident. From Crystal Springs Reservoir to Lake Merced the surface ground usually is what is known as black adobe land. In places it is yellow adobe and sometimes it is a mixture of the two. This ground along the fault line has been subjected to tensions and compressions, and the earthquake has left permanent distortions and offsets.

"The Pilarcitos conduit for a considerable distance practically coincides with the main fault line; indeed, one might almost imagine that the break in the ground was purposely staked out along the pipe line, or vice versa, from San Andreas dam to Frawley Gulch, a distance of about six miles. In this length the conduit is a 30-inch laminated wrought-iron pipe of about 3-16-inch metal, with transverse circular riveted joints. The rivets are ⅜-inch in diameter. The center line of the pipe is usually about 3 to 4 feet beneath the ground. In these six miles of length the pipe is ruptured in a great many places. At one point it is ruptured at a riveted joint by tension; at another by compression. The writer counted 19 such ruptures from a point near the northern end of San Andreas Lake to Frawley Gulch. "All ruptures occur at transverse riveted joints. There are some places where the pipe has collapsed; in one instance for a length of about 50 feet. There are no doubt many more ruptures that have not as yet been unearthed. Where the ground has been subject to resultant tension the pipe is pulled apart by amounts varying from almost nothing to as much as 5 or 6 feet. At compensating places where the resultant effect has been compression, the pipes are collapsed and telescoped by similar amounts.

"A property fence crossing the pipe line is offset 7 feet along the fault line, the two pieces of fence remaining straight and parallel to their original direction. This decidedly shows that, in the vicinity, the surface ground to the west has been moved bodily to the north northwest relative to the surface material to the east of the fault line. Fence distortions are common along the fault line. At Frawley Gulch the conduit crossed a timber trestle, heavily built, about 100 feet in length and some 25 feet in maximum height. This trestle is about one-quarter of a mile to the east of the fault line and the ground is firm adobe land, nevertheless the shock was so severe that it entirely demolished the trestle and pipe which it carried. The trestle seems to have vibrated in a vertical plane normal to its length and has been thrown down-stream to the southeast.

"I cannot speak of the Pilarcitos pipe line from this point to the city, as I have not examined that part of the line, but ruptures, if they occur, are probably not so numerous nor so serious. I might make the same remarks for that portion of the pipe near Pilarcitos Reservoir. The Pilarcitos conduit will no doubt be abandoned."

At another place, "the pipe was telescoped 49 inches and thrown out of alignment. This rupture strikingly shows that the pipe metal was of high quality.

"Since the earthquake, because of damage to the conduits, no water has reached the city from Pilarcitos, Crystal Springs or Alameda, and San Andreas Lake has temporarily become the distributing reservoir for the city; and probably will so continue in the future. The waters from Pilarcitos Lake, however, can flow to San Andreas through the waste-pipe connecting them. This pipe is unharmed, but Pilarcitos water has not been needed. The San Andreas pipe line is now delivering water to the city. Relatively speaking, its injuries were very slight; only one important rupture has come to my notice. It was quickly repaired by putting a temporary band on the pipe.

"The fault line touches the eastern edge of the San Andreas dam, which dam is an excellent construction of earth and clay nearly 100 feet (93 feet) in height above the original surface of the ground. As an eye witness I am convinced that this dam was subject to a most severe earthquake shock, and since it retains the water of San Andreas Lake apparently just as well as before the earthquake, it should be a source of great satisfaction to its designer and builder. The ground is considerably scarred by cracks running north northwest on the eastern bank of the dam where the nose of a hill naturally projects to form its abutment. These cracks, which are quite pronounced, are in the abutment and not in the dam itself. There are a few smaller cracks running in the same direction at the extreme westerly end of the dam. On the roadway of the dam there are some small longitudinal cracks, apparently due to the unequal settling of the triangular masses with respect to the core, but they are not serious. The writer is convinced that an earth dam properly constructed will stand a very violent shock, and he cannot praise too highly the construction of this one. A very careful study of this dam may throw some light upon the situation and problems to be solved at Panama, but there is no reason for discussing the subject now.

"The flume from the Crystal Springs pumping station, which enters the San Andreas reservoir at the east end of its earth dam, has entirely collapsed just below that dam, where the main fault line intersects the flume. At this point the flume rests on a wood trestle of considerable height. As soon as this flume is repaired the waters from Crystal Springs reservoir could reach San Andreas and thus be sent to the city.

"The huge concrete dam at Crystal Springs (115 feet above the natural surface), it will be at once seen, was subject to a series of thrusts and pulls in vertical planes along its length, since it is parallel to the fault line. It is the writer's judgment that the predominating effect has been a thrust. The dam has been very generously designed and is of great strength. Its inner face has a much heavier batter than the Rankine formulas require. So far as the writer could see, and he observed the dam carefully, there is not the slightest crack. The intake works, Crystal Springs Pumping Station and all accessory construction in the neighborhood of the dam are intact.

"The Crystal Springs conduit at the time of writing is not supplying water to the City. It is mainly a 44-inch laminated wrought-iron pipe, about ¼-inch in thickness with riveted joints, rivets ½-inch in diameter. This pipe is ruptured in a number of places, but mainly where it crosses the marshes. The worst destruction has occurred in a distance of about 1,600 feet, where the pipe crosses a marsh between San Bruno and South San Francisco. In this place the pipe rests upon a wooden floor, supported by pile bents. These piles on the average penetrate the mud to a depth of about 40 feet. It appears to the writer that this marsh shook like a bowl of jelly, the vibrations being mainly in a south southeasterly direction, or nearly at right angles to the length of the trestle. It appears that during the vibrations of the earthquake the trestle moved with mother earth, the pipe due to its inertia tending to remain quiet. As a result the pipe was alternately thrown from one side to the other of the trestle floor and its box covering was generally smashed. The pipe broke along transverse circular joints, sometimes by tension, sometimes by crushing. On May 2, when the writer visited this pipe line, the work of repair had been already considerably carried out, and within a surprisingly short time the city will be receiving water through this large conduit.

"During the inspection of these works Professor Hyde and the writer made their headquarters at the Millbrae pumping station. At this station the company can command and direct the flow in all its conduits. Under normal conditions, by eight valves, housed four each in two small gate houses, one can command almost any combination of flow to the city from the four main sources of supply. The Millbrae pumping station is really an emergency plant, but at present it is a scene of the greatest activity. The region about Millbrae has been subjected to a very severe shock, but the Millbrae pumping station has been absolutely unharmed by the 'temblor.' I should observe that it is a practice of the Spring Valley engineers to use cement mortar for their brickwork, with selected brick, and to use careful proportions of cement, sand and stone of the highest qualities for their concrete. The brickwork and concrete of the Millbrae pumping station exhibit no cracks whatever. In striking contrast thereto one may see near the Millbrae station of the Southern Pacific Company the power-house for the trolley lines which run cars from Fifth and Market streets in San Francisco to San Mateo. This building is of cheap brick construction and has been almost utterly destroyed. Its north and south walls have entirely collapsed and the east and west walls seem to be held in place by the roof girders.

"It is plain that the water-works of the city of San Francisco have been subjected to a test more severe than the hand of man could devise. The water supply of a city is a most important matter, and ever since the earthquake the water problem has been the greatest one of the many problems which have confronted the citizens of San Francisco. It is not surprising, therefore, that much concern should be expressed about the water situation, and it is easy to believe that the present task of the Spring Valley Water Company is no small one from the engineering standpoint, and no enviable one from the municipal and political side. Having carefully examined the works, I feel it my duty to speak of the situation as I find it, and this I can certainly do without bias. The destruction to the Spring Valley Water Company's plant, as outlined above, has been produced by nothing less than a cataclysm; something which the mind of man could not foresee and whose effects no engineering structure, no matter how good, could resist. The Crystal Springs conduit to me seems excellent, but it was doomed on the marshes. The Pilarcitos pipe line had to succumb. It was right on the line of fault for a length of six miles, and the city should be thankful that its waterworks' engineers provided it with so complex and varied a system of conduits. It seems to me that the city has been saved from a terrible water famine simply because the San Andreas conduit survived the general destruction. Perhaps in the future it will be wise to avoid the marshes and made ground for important pipe lines. It seems to me also that the small reservoirs within the confines of the city should be connected with the main conduits by pipes of considerable size in no way connected with nor dependent upon the gridiron system of the streets. Had the city reservoirs of San Francisco tapped the large conduits independently of the street mains, some of the present delay in obtaining water and fire pressure might have been eliminated.

"Earthquakes are not uncommon in California, and they will naturally occur again. There has been much talk of tapping the water sources of the Sierra Nevada Mountains and bringing the water to San Francisco by conduits and water courses which must be nearly 200 miles in length. In the light of our present catastrophe how much more danger must there be of earthquake destruction upon a line of so extended a length? Conduits in duplicate would be of no avail; if one breaks so will the other. The only safeguard would be two distinct conduits, running in widely separated districts, but such a proposition would entail great cost.

"For safety the city needs a number of sources of water and a number of conduits so arranged that they will not tend to be destroyed all at the same time. The Spring Valley conduits have at least answered these requirements to such an extent that the San Andreas conduit survived. Buildings and other structures in San Francisco to a great extent have been notoriously poor and the time is ripe for the people of the Western metropolis to realize that they must enforce proper building laws and a proper attitude toward healthy construction, both in municipal circles and in private works. It is my opinion that the works of the Spring Valley Water Company are relatively of an exceptionally high type of construction. Its wrought-iron conduits after 30 years of use, even in their present demolished condition, exhibit surprising preservation. Its pumping stations have already been alluded to; they have survived where nearby structures have collapsed. The Crystal Springs dam needs no praise—it speaks for itself. The earth dam at San Andreas appears to fulfill its functions as well as ever, although it is directly on the line of the main fault, and has been greatly scarred. It should be carefully examined.

"Within the city's boundaries, main branch pipes and in general the pipes of the gridiron system have been much destroyed. In the softer and made ground this is especially true. Moreover, the great extent of the fire destruction has left innumerable taps and service pipes to hundreds of burned buildings in a most dilapidated condition. Again, explosions of gas mains in many places have added further rupture to the streets and the pipes beneath them. With this general demoralization of the gridiron system within the city and the loss of the Pilarcitos and Crystal Springs conduits, the situation on the morning after the earthquake may be understood; there was little water in the city and no water pressure.

"In the two weeks that have elapsed since the earthquake, the engineers of the Spring Valley Water Company have been using San Andreas Lake as a distributing reservoir, and water has been forced with gradually increasing pressure into the city through the San Andreas conduit. The Crystal Springs conduit is also being repaired as fast as human energy can do so. To protect the western addition of the city from fire it was necessary to insure as quickly as possible a proper fire pressure. At Valencia street, between Eighteenth and Nineteenth, where everything was ruptured, a 16-inch cast-iron main was laid on the west side of the street to give pressure to the western addition at the same time that a 24-inch main was laid on the east side of the same street to repair the break in the pipe and force water into Market street. With much difficulty, by gradually increasing the pressure, water was forced down Market street and along other streets of the business section, where numerous breaks were found, so that by May 1 water reached the Black Point pumping station at Fort Mason, situated at the northerly end of Van Ness avenue. Since that time work has rapidly progressed so that at this writing water has reached most, if not all, of the city's distributing reservoirs, and the great danger from further fire is past. During the first week after the earthquake, however, the city was in a very precarious condition. During the first fortnight it was found necessary to deprive the people of the use of much water, naturally to their great inconvenience. It was necessary to adopt such measures to produce sufficient pressure in the crippled lines to discover important leaks. The Spring Valley engineers were much criticised in those earlier and trying days. As the exact situation becomes more clearly understood the stand of the Water Company will be more and more appreciated.

"During the past week many rumors have been afloat regarding loss of water from the main reservoirs. These rumors, I believe, are now exploded. All of the reservoirs are full and the city practically has an unlimited supply of water."

APPENDIX C.

Extract from an article in relation to the effects of the earthquake on the water supply of San Francisco from "The New York Times" of Monday, July 9th, 1906:

"That no system of underground mains now employed for water distribution could remain intact through such a disturbance as that which wrecked the city in April no engineer needs to be told. Even slight disturbances induce large leakage, and severe ones destroy a water-main system so completely as to render it temporarily useless for fire protection. The same is true in equal degree of gas mains, and in almost equal degree of electrical conductors. If we imagine a condition in which the water mains are broken and useless, the gas mains fractured and pouring their inflammable and explosive contents into vaults and cellars in great volume, and electric wires torn from their fastenings, short circuited and establishing arcs with every conductor within reach, we have about the worst combination from the fire underwriting point of view. Exactly this disastrous situation was brought about by the last great earthquake in San Francisco. It is one against which the underwriters must protect themselves—but how?

"Perhaps the problem is one which admits of satisfactory solution, but it is obviously one of great difficulty, and its solution will not be found by experimentation along the lines of establishel engineering practice."

APPENDIX D.

The following are extracts from the report of City Engineer Woodward on the breaks in the San Francisco sewer system caused by the earthquake as published in the "San Francisco Chronicle" of June 17th, 1906:

"The vicinity of Van Ness avenue and Vallejo street is one of the prominent points of interest. It was found that Van Ness avenue had been more or less affected from a point 150 feet south of Vallejo street to Union street, the greatest subsidence being two feet at the crossing of Vallejo street. There was also subsidence of Vallejo street for 150 feet on each side of Van Ness avenue. There was a lateral movement to the north on Van Ness avenue of about three feet on Vallejo street, decreasing to about one foot at Green street, the ground and buildings upon it having been moved bodily so that now the buildings encroach upon the neighboring lots or upon the street. As a result of the subsidence and lateral movement the sewers extending east, south and west of the crossing of Van Ness avenue and Vallejo street were broken for about 150 feet. The scene of the disturbance was an old fill of about forty feet which had been made years ago in the ravine leading to the northwest to the lagoon formerly called Washerwoman's bay. * * *

"On Valencia street, between Eighteenth and Nineteenth streets, there was a lateral movement to the east, with a maximum of six feet and a subsidence with a maximum of five feet. This occurred in made ground over the old Willows marsh, one of the tributaries of Mission creek.

"The Fourth and Sixth street sewers were also greatly damaged, some of them showing a vertical and horizontal movement of as much as five or six feet."

He further summarizes the following breaks in the sewers:

"On Fourteenth street, between Valencia and Harrison streets; on Harrison street, between Twelfth and Thirteenth streets; on Eleventh street, between Harrison and Bryant streets; on Ninth street, between Bryant and Brannan streets; on Dore street, between Bryant and Brannan streets; on Laguna street, between Greenwich and Lombard streets; on Shotwell street, between Seventeenth and Eighteenth streets; on Seventeenth street, between Folsom and Harrison streets; on Howard street, between Seventeenth and Eighteenth streets."

(MEM.—The above reported list of breaks in the San Francisco sewers (caused by the earthquake) generally coincide with breaks in the street pipe system of the Spring Valley Water Company.)

APPENDIX E.

1. Brickwork.

Standard Employed in the Construction of the Works of the Spring Valley Water Company.

Brick to be straight and even-sized; to be hard-burnt and of a dark cherry color; to give a clear ringing sound when two bricks are struck together.

Mortar to be made of one barrel of *A1* Portland cement to be mixed with two barrels of clean, sharp sand and the proper proportion of water. This amount of mortar to be made up and (immediately) used for the laying of every 500 brick;

So that every 1,000 brick laid require two barrels of Portland cement and four barrels of sand.

The Portland cement to be at least six months' old and to have been thoroughly aerated, after being manufactured, by systematically shoveling it over a number of times.

Besides, the cement must show the proper tensile strength and must otherwise be thoroughly tested in all respects before use.

No lime is allowed to be used in the mixing of mortar.

The brick, before being laid, to be properly moistened with water so that they will not absorb any part of the water contained in the mortar, which water is essential for properly completing the chemical process of hardening of the cement mortar.

All brickwork, while being laid, must be well bonded, so that the headers are not separated by more than four rows of stretchers in buildings; while in chimneys every three stretchers are to be followed by a layer of header bricks.

All horizontal and vertical joints must be completely filled with mortar. The upper surface of each completed course of bricks must be left clean, no flushing over the same of any surplus mortar being allowed, thus giving a perfect bond between this course and the next.

In very particular hydraulic work, where the brickwork is to be under water and subject to water pressure, I frequently allow only two stretcher courses between two header courses.

The only exception to this rule is made in our tunnel arching, where the top arch is usually laid in two, three, four or more consecutive rings, all consisting of stretchers, but bonded together by first-class joints of cement mortar. A good example of this character of brickwork is shown in photographs of San Andres brick gate-well, from 40 to 45, and also in photographs 33, 36 and 103, showing the brick outlet tunnel of the San Andres waste-weir.

Both of these structures received the full force of the irresistible blow of the earthquake, the San Andres fault passing right through them. Still, although the brickwork was crushed by the blow, all bricks and joints of cement mortar were sheared through together, and no bricks or fragments of the same were broken away or torn from their respective mortar joints, showing the excellence of the materials and the superior workmanship.

The brick chimney of our Black Point Pumping Station, as well as the brick building and chimney of our Seventeenth Street Pumping Station, both in San Francisco, though not struck by the fault that passed through the above San Andres structures, were subjected to the same severe shock as felt by the same and other portions of the peninsula.

The main reason that the brickwork in these two structures of the Spring Valley Water Company in San Francisco withstood the shock, showing no injury whatever, while other similar structures on the peninsula, built with poor mortar and inferior workmanship, were damaged or partly demolished by the earthquake, is to be found in the careful selection of the materials used, the superior workmanship employed and the careful and minute inspection during the entire construction.

If the same high class of materials and workmanship, as used in the brickwork of the Spring Valley Water Company's Engineering Department, had been employed in the construction of brick buildings generally on the peninsula, it is very likely that most of those injured by the earthquake would have also escaped.

2. Concrete.

Standard Employed in the Construction of the Works of the Spring Valley Water Company.

One barrel of A1 Portland cement (cement same as described for our brickwork), two barrels of clean, sharp sand and about two-thirds of a barrel of water, thoroughly mixed with 22 cubic feet of hard, clean washed rock, broken into sharp-edged fragments of all sizes (the largest pieces to go through a two and one-fourth (2¼) inch ring).

This amount of material, with the proper workmanship, makes fully 22 cubic feet of first-class concrete, in place.

The broken rock, before being put into the mixer, to be thoroughly washed in order to make a perfect bond with the mortar and saturated with clean water (for the same reason, as above described, for the wetting of the brick before laying).

The concrete, after being thoroughly mixed, to be transported at once to and put into its place in the work under construction, within fifteen minutes after mixing. Here it is to be rapidly spread in layers, not exceeding three inches in thickness, and to be thoroughly rammed by hand until the new layer is completely consolidated with the former one and all the interstices between the rock fragments are completely filled by the cement mortar.

The next day's work to make a close, tight junction with the work of the previous day.

New work is not to be exposed to the sun, but kept covered with planks and sprinkled with water until completely hardened.

In the construction of the Crystal Springs concrete dam and all our other concrete work, the above proportions and methods were strictly adhered to; only in the Crystal Springs Dam (being of very massive dimensions) the alternate block system was adopted, as shown in Plan 6 and 7.

That the above-described method of carefully selecting the materials for all our concrete, and employing the very best care and workmanship in the execution of the same, was the proper method, is shown not only in the most perfect condition (after the earthquake) of the concrete foundations of all our pumping plants, but also and particularly by the fine condition of the concrete at San Andres Reservoir and the Crystal Springs concrete dam, the former being practically *on* the fault, while the latter was located less than one-third of a mile northeast of the same.

Concrete made of a poorer quality of materials, or of a poorer mixture, or made with less care, or with inferior workmanship, would have succumbed to the terrific strain put on the same by the earthquake, especially in the neighborhood of, or on the fault.

3. Clay Embankments.

Standard Employed in the Construction of Reservoir Dams of the Spring Valley Water Company.

Topsoil removed from surface of the proposed base of the dam and the slopes of the hills until firm bed of good clay material is reached. A trench is then cut along centre line of proposed dam, of proper width down to and into the tight bedrock, and clear up at each end and above the high-water mark; or, if bedrock cannot be found, to a thoroughly tested and perfectly tight and reliable and continuous clay substratum.

(See Plan 6.) This trench is carefully filled with the best of puddle clay, in thin layers (not exceeding three inches), thoroughly spaded, slightly watered, and tightly rammed, until the surface of the prepared base of main dam is reached. Puddle being kept so stiff that a horse's hoof walking over the same will not sink more than two inches into the same.

First-class bank clay is then spread in layers, not exceeding ten inches in thickness, over the entire base of the dam, excepting the puddle pit, these layers pitching about one foot in forty towards the centre line of the dam. Carts and wagons hauling the material on to the dam travel longitudinally with the same, while still loaded, cutting with their wheels through the slightly watered face of the dump, thus thoroughly consolidating the new layer with the former one.

Over the completed layer a three-ton roller, having a face of not over three feet, is hauled continually over the same, so that every point is reached, the principal direction in which the roller travels being also longitudinally with the dam.

Near the junction with the natural slope of the hill, against which both ends of the dam abut, where the roller cannot reach (and which slopes have first been properly benched), first-class hand-ramming is to be employed, with the proper amount of watering; thus consolidating the embankment material with the slopes of the hill at each end.

The placing of puddle clay, of the kind and in the manner above mentioned for filling the trench, is continued upwards at the same ratio as the raising of the main embankment on each side of this puddle core progresses, until the puddle core reaches a level of about three feet above the high-water mark of the proposed reservoir.

Thereafter a layer, from 12 to 16 inches thick, of first class, tightly packed, hard stone rip-rap, is placed on the water slope to prevent wash; while on the dry slope a layer of loam is placed, on which a proper grass sod can be raised, to prevent the washing or gullying out of this slope during rain storms. The top of the dam is then macadamized, the level of the finished top being from five to six feet above the highest water mark.

It goes without saying that proper waste or overflow weirs are provided of the best of brickwork or concrete.

Outlet conduits are not allowed to pass through the body of the dam, but are constructed in the form of brick or concrete-lined tunnels through the adjoining mountains.

4. Wrought Iron.

Wrought Iron Used for the Construction of the Main Conduit Pipe Lines of the Spring Valley Water Company.

Plates to be manufactured of the best and most pliable American iron obtainable (charcoal iron preferred).

Piles to be built up with one (1) inch plate below and above, with first-class scrap of same quality carefully packed in between, thus making the body of the plate laminated or stratified, as this largely increases its resistance against rust.

Rivets to be manufactured of iron, fully equal in quality to the plates.

Workmanship in manufacturing and laying the pipe equal to the best of boiler work.

All pipe thoroughly coated in and outside with a heavy, tough and pliable coat of best asphaltum, firmly and closely adhering to the iron.

All materials, during manufacture, and all workmanship on pipe being constantly subject to close inspection, with strict enforcement of the specifications.

The following data are taken from the actual tests made of the iron used in the manufacture of the plates and in our 54-inch Alameda pipe line:

Thickness of iron, 0.275 inch.

Tensile strength, longitudinally with the plate, varied from 48,275 pounds to 52, 790 pounds per square inch.

Transverse tensile strength, from 46,540 pounds to 49.950 pounds per square inch.

Elastic limit, longitudinally, from 32,430 pounds to 34,800 pounds per square inch.

Elongation, longitudinally, from 20 per cent. to 24 per cent.

Reduction in area, longitudinally, from 31.7 per cent. to 41.8 per cent.

Longitudinal bending test, cold: Strip of iron two (2) inches wide, bent over and beaten down upon itself and squeezed or hammered flat; did not show crack on outside of bend.

Transverse bending test, cold: Iron bent closely around two (2) inch round rod without cracking.

(Note.—For dimensions and specifications of cast-iron pipe employed by the S. V. W. Co., see Map 5B and Sheet 5B1.)

APPENDIX F.

Short Outline of the Most Important Section of a Salt-water Fire-protection System for San Francisco.

1. Duplicate electrically-driven pumping plant on terra firma, at North Beach (perhaps at or near foot of Van Ness avenue, or Polk street, or Larkin street), each of the two units being in two halves, and each half being of a capacity of delivering sixty (60) gallons per second (each), or 3,600 gallons per minute, or 216,000 gallons per hour, or fully 5 *million gallons a day*, against a pressure of 165 pounds (including 25 pounds for friction in suction pipe and in one and one-half miles of 24-inch double force pipe, leading along

Polk and Larkin streets to Washington and Jackson streets respectively, and to the proposed Lafayette Square Reservoir).

North Beach electrically-driven pumping plant to have a complete relay of the same power and delivering capacity, but driven by turbine steam engines.

Thus, in case of a failure of the electric current, the turbine engines could be started up, on short notice, pumping the water from the bay into the Lafayette Square Reservoir.

2. From this pumping station a double line of either heavy galvanized, lap-welded, laminated wrought-iron 24-inch force pipes, with double-faced deep lead joints at every 20 feet; or 24-inch heavy cast-iron pipe, in lengths of twelve (12) feet, to be laid, with deep lead joints, along the two above-mentioned separate routes to the above proposed reservoir.

3. The four (4) pumps being so connected by a system of gates with the two (2) separate 24-inch force pipes that each of the four 5 million gallon units can send its water into and through either one of the two force pipes.

4. The reservoir, to be constructed on Lafayette Square at an elevation of about 340 feet above city base, to have a capacity of about 20 million gallons, constantly stored therein.

In case of a serious conflagration, although the full contents of the reservoir may be available, one, two or more of the North Beach pump units could be set in motion at once, thus keeping the reservoir practically full during the greatest period of draft on the same.

5. From this reservoir two independent 24-inch outlet pipes, of similar quality and construction as outlined for the force pipes, should start, each one from an independent first-class concrete gate-house, with brass-faced gates; one pipe line to follow down the north side of Clay street to the east side of Van Ness avenue, and the other one along the south line of Clay street to the west line of Van Ness avenue; the former one then to turn down in an easterly direction along Pine street to Montgomery, while the other one would go along Bush street to Sansome.

These two independent pipe lines should be interconnected on safe and solid cross streets, but with their connection gates ordinarily shut; these cross connections to be put on north and south streets that have no electric car lines.

The above main east and west streets, viz., Clay, Pine and Bush streets, also to be kept free from electric car lines, to avoid electrolysis.

At every street crossing on Van Ness avenue and on Bush and on Pine streets, from Van Ness avenue east, crosses with proper gates can be placed for eventual north and south extensions of these branch pipes.

No hydrants should be placed directly on the 24-inch pipes, but always on specially-provided branch pipes, with extra gate near the main, thus having the security of two water gates between each hydrant and the 24-inch main pipes.

6. *Each one* of the two independent 24-inch Pine and Bush street pipe lines could, at a moment's notice, deliver, at or near Montgomery street, and through the hydrants connected with them 120 gallons per second; or, with *both* 24-inch pipes in full operation 240 gallons per second; or at the rate of fully 20,000,000 gallons per day, under a net acting direct head of 120 pounds per square inch, or about 275 feet pressure, at the outlet of the hydrants there, *and without the aid of a steam fire-engine.*

OR, in other words, if a large fire supply should be suddenly needed somewhere along the lines of the Bush or Pine street pipes, and west of Montgomery street, then, in that case, a number of hydrants could draw at one and the same time up to a total of 120 gallons per second, from any one of the two 24-inch pipe lines, while maintaining a good gravitation pressure at the various hydrants.

As a matter of course, on such portions of the respective 24-inch pipes, where the ground is more elevated than in the Montgomery street flat, the net acting gravitation pressure would be correspondingly less.

Still, owing to the great elevation of the Lafayette Square reservoir, a good fire-pressure could be maintained in the entire region traversed by these two 24-inch pipe lines, with their branches.

By thus bisecting the city from east to west by a belt or tier of independently protected blocks, which can and should also be repeated from north to south, the city could be divided up into large protected squares, each square comprising a number of blocks across which it would be difficult for a fire to make headway.

The Lafayette Square Rerservoir, being located on a very high and isolated peak, could eventually be made to feed (either by gravitation or pumping), other salt-water reservoirs, to be located on independent heights, each one, in turn, having its special district to protect.

In selecting the proposed routes for the force mains, as well as for the fire mains, I was guided not only by the fact that the streets mentioned are built on solid and consequently practically safe ground, but also by the fact that on neither of the streets nor in the blocks mentioned did any break occur in our street mains during the late earthquake.

The plan for an effective salt-water fire protection, as above outlined, is substantially the same as proposed by me to the Board of Supervisors about ten years ago.

Since the earthquake and subsequent conflagration, I am convinced more than ever that in a city subject to earthquakes, where many miles of the distributing domestic supply pipe system *must* cross and supply swampy as well as hilly regions, that the fire protection of this city should, *under no circumstances,* entirely depend upon hydrants placed on the net-work of pipes used for domestic purposes.

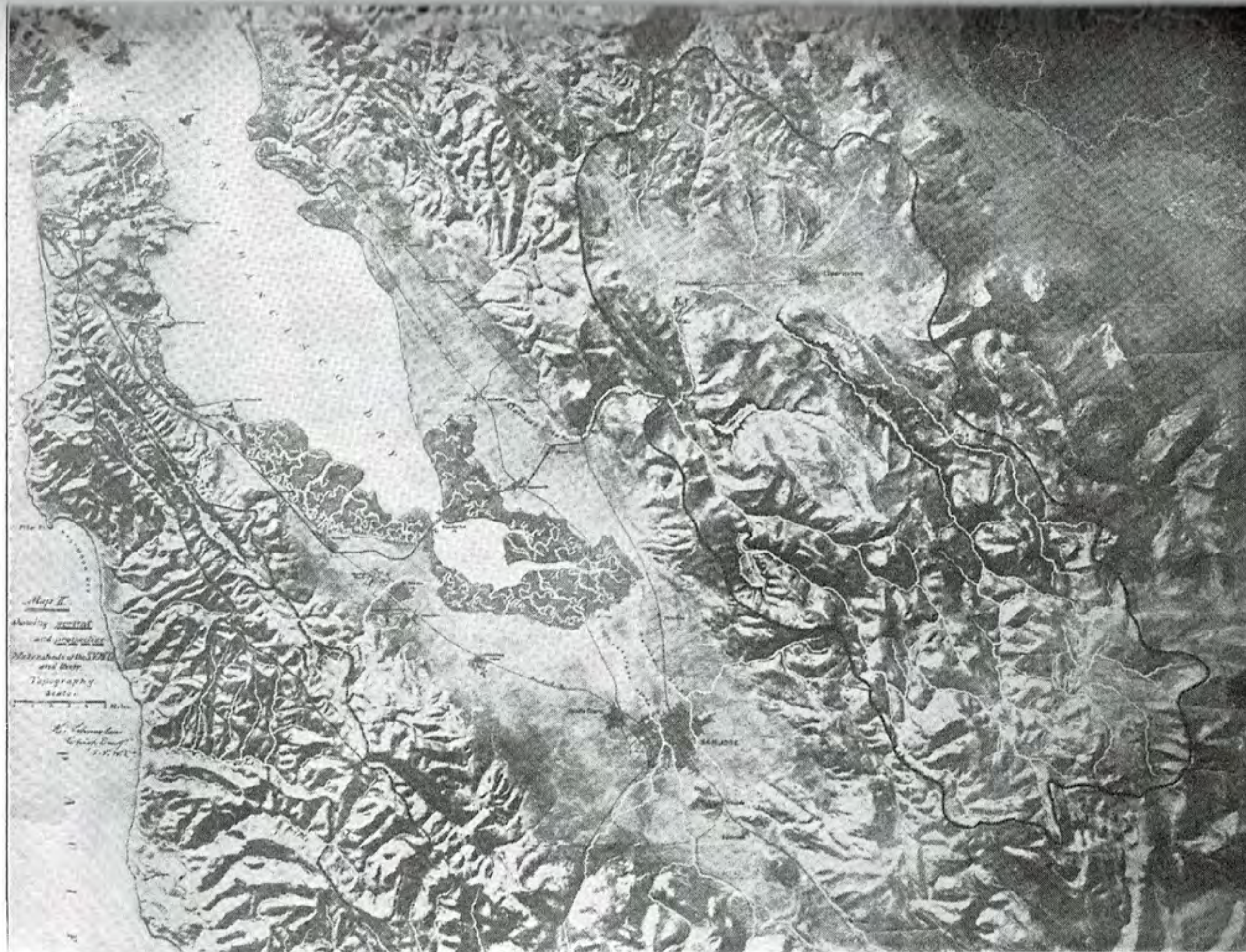
With an independent fire protection system, as above outlined, the routes for the main artery pipes can be carefully selected, entirely avoiding swampy regions, only entering the same by smaller and easily controlled branch pipes.

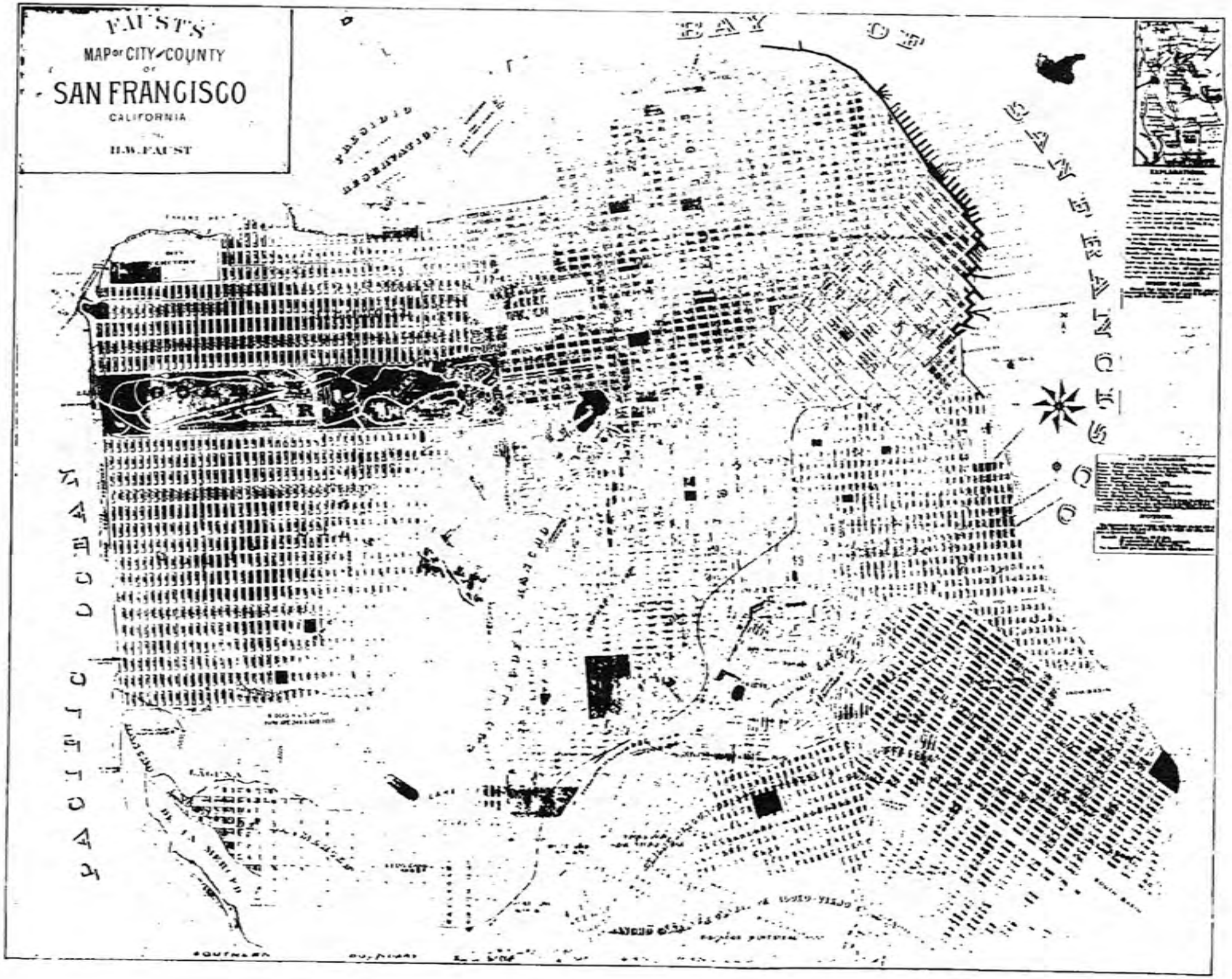
The conflagration, which started immediately after the earthquake, in about a hundred separate places, quickly assumed such dimensions that hundreds and thousands of structures, largely of wood, were in a short period consumed by the flames. As the conflagration rapidly progressed, the burning and burnt houses fell, and thousands of the service pipes that had been supplying the dwellings, hotels, boarding-houses, stables, factories, etc., with domestic water, were torn off.

These pipes, according to their uses, varied in diameter from five-eighths of an inch to four inches and over. They broke or tore off near the level of the ground, or of the basements, and there they continued to discharge the water from the street mains in thousands of inaccessible, and therefore uncontrollable, jets, large and small, thus taking the water out of the street mains and away from the fire hydrants, generally at points located at a lower level than the respective street fire hydrants.

If this city would profit by this severe lesson and would construct either a salt or fresh water fire protection system of pumps, reservoirs, pipes and hydrants, *but entirely independent of and disconnected from the domestic supply system,* with its many tens of thousands of house taps, allowing *no connections except street fire hydrants* to be made with its pipe system, constructed as above outlined, there is no doubt that a conflagration, starting like the late one, could be confined to comparatively small limits.

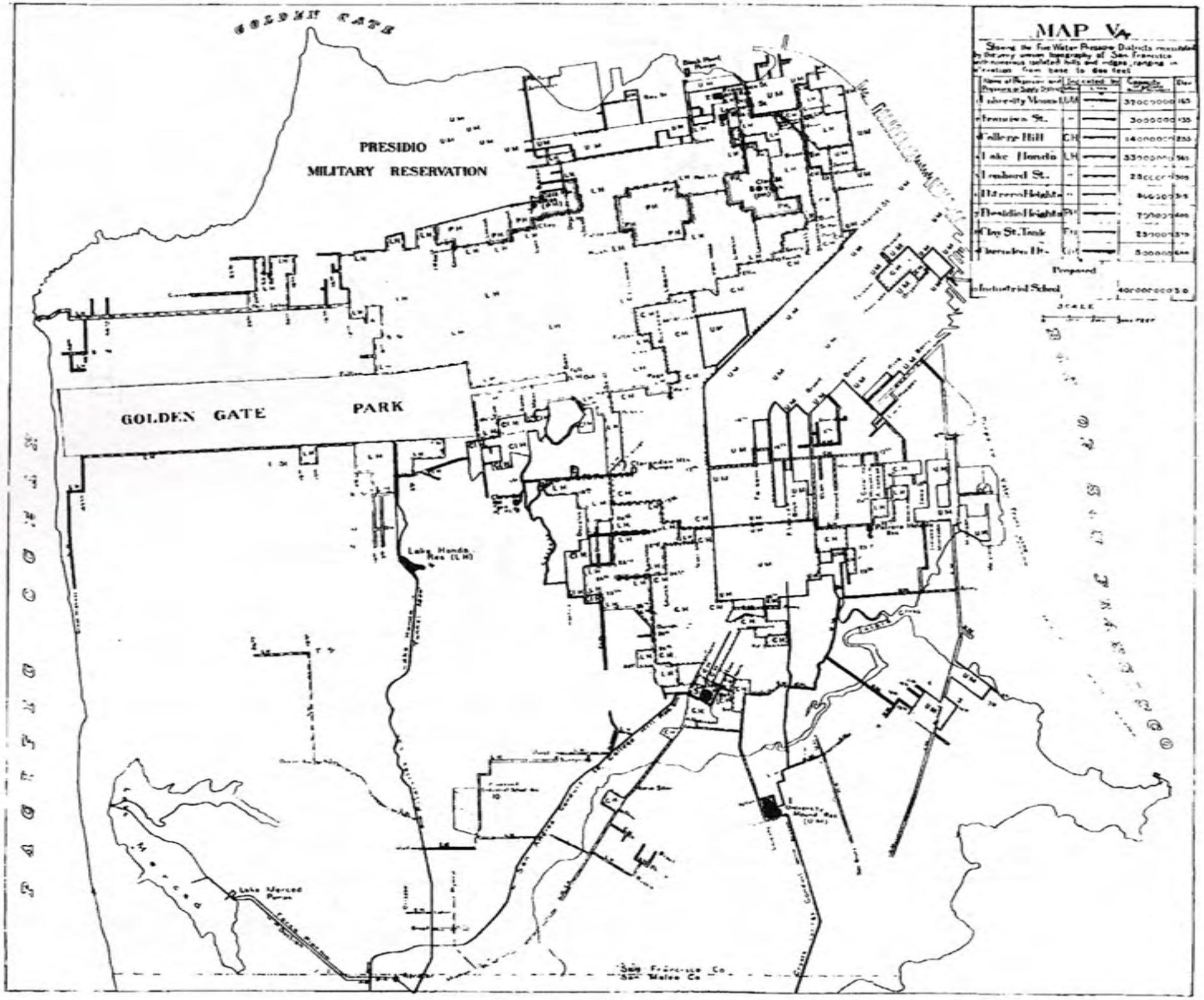
Owing to the great pressure that such independent system would carry on its mains and hydrants, the many hose companies that would then be scattered all over the city, in case of a recurrence of a similarly severe earthquake (immediately followed by perhaps half a hundred of separate simultaneous fires), would be able to control the fire by attaching their hose to the nearest fire hydrant of the independent system.


Map II
Topography
Scale


FAUST'S
MAP OF CITY & COUNTY OF
SAN FRANCISCO
CALIFORNIA
H.W. FAUST
BAY OF
SAN FRANCISCO
PACIFIC OCEAN

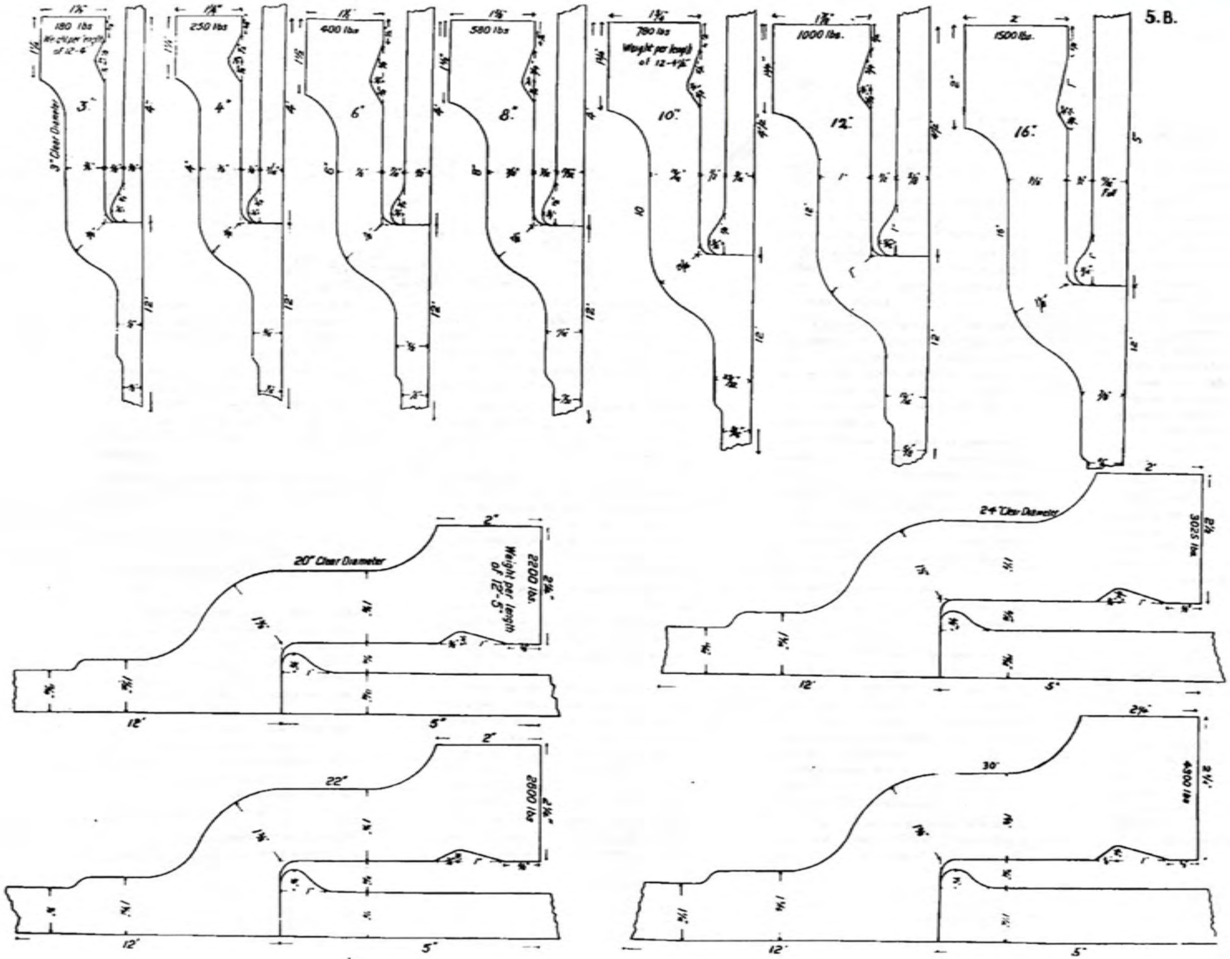

MAP
OF
SAN FRANCISCO
GOLDEN GATE
PRESIDIO
MILITARY RESERVATION
GOLDEN GATE PARK
PACIFIC OCEAN
BAY OF SAN FRANCISCO


MAP
SHOWING STREETS COVERED BY
THE CITY DISTRIBUTING PIPE
SYSTEM OF THE SPRING VALLEY
WATER CO.
GOLDEN GATE
Britton & Rey's
MAP
OF THE CITY AND COUNTY OF
SAN FRANCISCO
Compiled from the latest Official Data
PRESIDIO
MILITARY RESERVATION
GOLDEN GATE PARK
PACIFIC OCEAN
RANCHO SAN MIGUEL
LAGUNA DE LA MERCED
BAY OF SAN FRANCISCO


MAP V
College Hill
Lake Honda
Lombard St.
Clay St. Tank
Proposed
Industrial School
SCALE
GOLDEN GATE
PRESIDIO
MILITARY RESERVATION
GOLDEN GATE PARK
Lake Honda Res. (L H)
Lake Merced Pumps
San Francisco Co.
San Mateo Co.

STANDARD DIMENSIONS USED BY THE SPRING VALLEY WATER COMPANY

5.B.



SPECIFICATIONS

—FOR—

CAST IRON PIPE

—FOR THE—

SPRING VALLEY WATER WORKS

H. Schussler
Chief Eng'r S.V.W.W.

All pipes shall be of first-class quality of tough cast iron, close grained and homogeneous through the entire thickness of the metal, and of a tensile strength of not less than 15,000 nor more than 18,000 pounds per square inch; to be entirely free from blow-holes, porousness, flaws, cracks, splits, or any other defect, and free from cinders, slag, or any other impurities, the metal, when broken, to present a uniform gray surface, and not a white and vitreous one.

The granulation of the iron being uniform throughout and the grain being neither too fine nor too coarse.

The degree of hardness to be such that the iron shows no brittleness, but has a degree of softness that admits of being chipped, drilled, tapped, or cut with ease.

In cutting the pipe with a hardy, under ordinary blows, delivered by a workman with a suitable sledge, the cut must extend not less than twice around the entire circumference of the pipe, and to a depth of not less than one-fifth of the thickness of the metal, before breaking; and the pipe must then break, with a square break, along the groove made by the hardy, without any lateral or longitudinal splits or cracks or jagged projections. After the nipple end has been thus cut off, a second similar hardy cut around the pipe, to cut off a piece of the pipe, equal in length to one-half the diameter of the pipe, without splitting the pipe nor the ring.

In pipe of 12 inches diameter or over, the ring so cut off shall not be more than 6 inches in width

The groove made by the hardy to show the toughness of the metal by the burring up of the edges, as the cut is being made, like this ‾‾\/‾‾ instead of small chips and splinters flying off from the edges of the groove during the cutting, which would indicate brittleness.

A test with the diamond-point chisel by cutting a groove, either straight or curved, must show the same tough characteristics as required by the above hardy test, and under no circumstances to show any incipient cracks or splits caused by such cutting, no matter if the cutting extends through the entire thickness of the pipe. The diamond-point chisel tests to be as follows: A longitudinal V cut with the diamond-point chisel, is to be made, starting 8 inches from the cut end of the pipe and running towards the same, at right angles. The depth of this cut is to be two-thirds the thickness of the pipe, not exceeding ½ inch. The pipe must not crush through towards the inside, while the cut is being made to its full depth, nor must it crack through to the end, until the chisel cut has approached the same within 2½ inches.

At a distance of 12 inches from the cut end of the pipe a circular, diamond-point chisel V cut is to be made to a depth of two-thirds the thickness of the pipe, and of a diameter equal to half the diameter of the pipe, but not to exceed 4 inches in diameter. The piece so surrounded by this circular V cut to be driven through to the inside of the pipe, by one or more hard blows from a sledge, delivered on top of a drift bar set on the center of the outside of this piece. And after it has been thus driven in, the edges must show a clean break, without any splits or cracks running from said hole, either to or towards the cut end of the pipe, or in any other direction.

All of the above tests to be made subject to the direction of the S. V. W. W., and at the expense of the contractor.

The pipes shall be cast vertically in dry sand moulds, without the use of core nails, chaplets, thickness-pieces, or any substitute therefor.

The pipes shall have smooth and perfect surfaces in pipe and bell inside and outside, and to be free from damage by handling in the transportation to the point of delivery.

The pipes shall be straight throughout their length and truly cylindrical in bore, to which the outside of the pipe shall be concentric, and the metal of the shell must be of a uniform thickness, as hereafter specified for their respective diameters from bell to nipple, while the internal diameter shall be of the full size specified.

The bells and nipples of all pipes shall be smooth and shall conform to the dimensions shown on diagram for their respective diameters in every respect. The nipples shall freely enter to the bottom of the bells, to their full depth, and shall make a close, fair fit against the inside shoulder of the bell all around, the bells shall receive the nipples to their full depth and allow the free turning of the inserted pipe around the full circle, and the space for the lead joints shall be as specified on diagram.

Every pipe shall be of the length of 12 feet net, and of a standard weight as specified for its respective diameter on the diagram.

The S. V. W. W. reserve the right to reject, free of expense to it, any pipe weighing less than four (4%) per cent. below the standard weight, and any pipe weighing more than four (4%) per cent above the standard weight, but if accepted, no extra weight above the four (4%) per cent extra will be allowed for in the payments.

The pipes shall be in all their parts of the dimensions and the bells and nipples to be of the proportions as shown in the accompanying diagram.

All pipes shall be subjected to a test by hydraulic pressure of 300 pounds per square inch by and at the expense of the contractor. The pipes shall be absolutely tight and impervious to water under the above pressure, and show no weakness in any part.

All the pipes shall be thoroughly cleaned and prepared to receive their asphaltum coating, without the use of acid or other liquid, and shall be protected from rain, fog, moisture, and exposure to the weather prior to dipping, and coated, before there is time for them to become rusted, with a first-class coating of asphaltum and tar, firmly adhering to the pipe. The pipes to be free from rust and strictly clean when they are immersed in the bath.

Pipes shall be first heated to 20 degrees above the temperature of the boiling coating, then immersed in a proper mixture of pure asphaltum and refined coal tar maintained at a boiling heat.

Pipes, after a sufficient time in the bath, to be withdrawn slowly in a nearly vertical position, and dripped so as to have a coating of uniform thickness, and to remain suspended in that position until the surface be sufficiently hard to resist injury in being rolled outside.

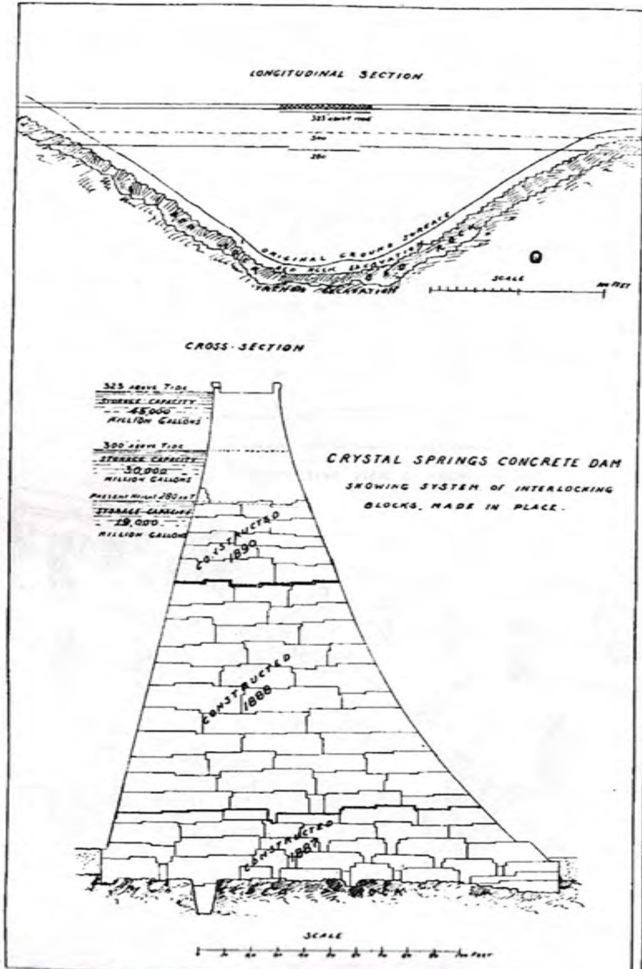
Coating, when cold, to be smooth, tough, without brittleness and blisters, tenaciously attached to the castings, and not liable to abrasion with ordinary handling.

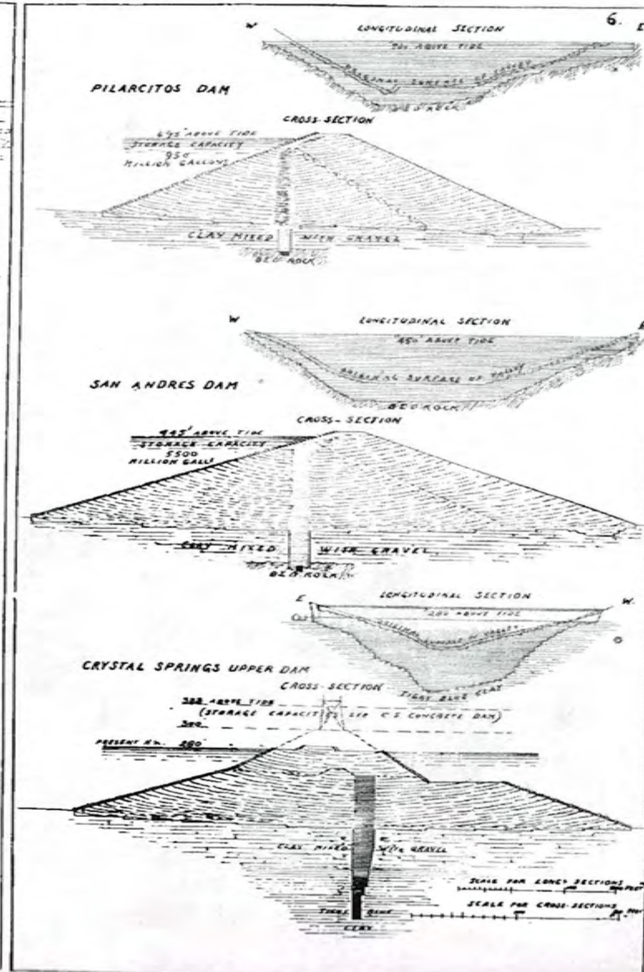
The S. V. W. W. to have the privilege of rejecting all pipes that do not come up to the above specifications. The preliminary acceptance at ____ not constituting the final acceptance by the S. V. W. W., but the tests for final acceptance by the same party to be made at ____

The S. V. W. W. reserves the right and privilege, without any charge or expense of any kind to them, to reject the whole lot or shipment, or any part thereof, if in the opinion of their agent, or his representative, the above specified tests show that there are a sufficient number of pipes, in his judgment, or in the judgment of his substitute, defective or not up to the specifications causing him to make such rejection.

Bids to be made for tons of 2000 pounds, net weight, of iron.

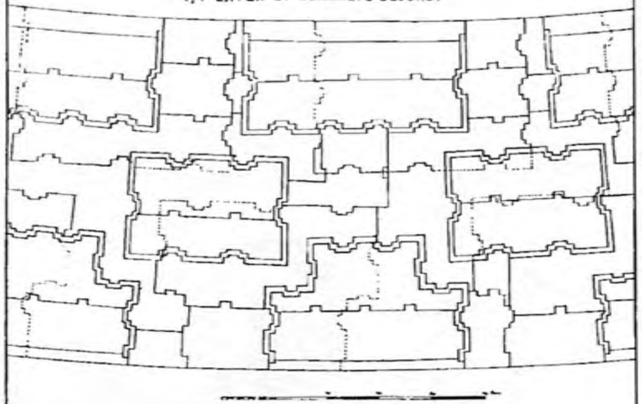
For dimensions and weights, see other side of this sheet.


LONGITUDINAL SECTION
ORIGINAL GROUND SURFACE
BED ROCK
TRENCH EXCAVATION
SCALE
CROSS-SECTION
325 ABOVE TIDE
STORAGE CAPACITY
45,000
MILLION GALLONS
300' ABOVE TIDE
STORAGE CAPACITY
30,000
MILLION GALLONS
STORAGE CAPACITY
19,000
MILLION GALLONS
CRYSTAL SPRINGS CONCRETE DAM
SHOWING SYSTEM OF INTERLOCKING
BLOCKS, MADE IN PLACE.
CONSTRUCTED 1890
CONSTRUCTED 1888
CONSTRUCTED 1887
BED ROCK
SCALE

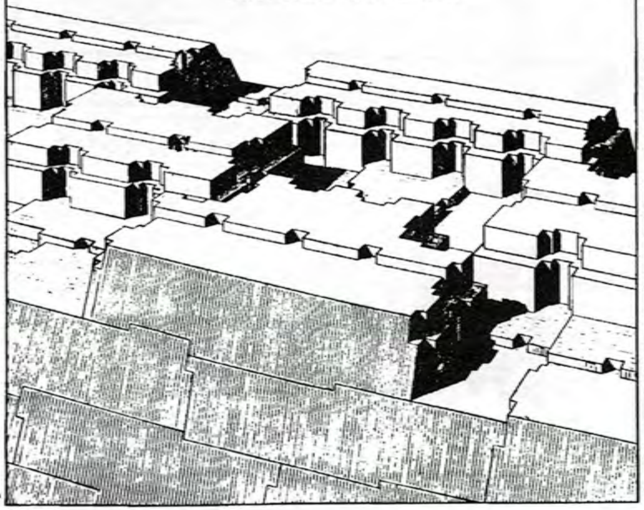

6.
W
LONGITUDINAL SECTION
E
PILARCITOS DAM
CROSS-SECTION
CLAY MIXED WITH GRAVEL
BED ROCK
W
LONGITUDINAL SECTION
E
SAN ANDRES DAM
BED ROCK
CROSS-SECTION
STORAGE CAPACITY
5500
CLAY MIXED WITH GRAVEL
BED ROCK
E
LONGITUDINAL SECTION
W
CRYSTAL SPRINGS UPPER DAM
CROSS-SECTION
CLAY MIXED WITH GRAVEL
SCALE FOR LONG. SECTIONS
SCALE FOR CROSS-SECTIONS

7.

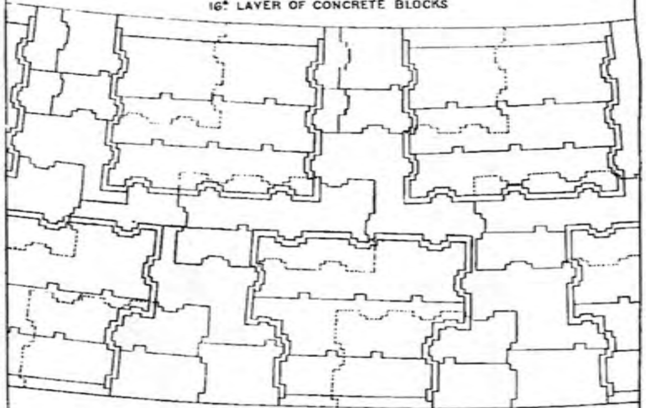
CRYSTAL SPRINGS DAM DETAILS
17th LAYER OF CONCRETE BLOCKS.



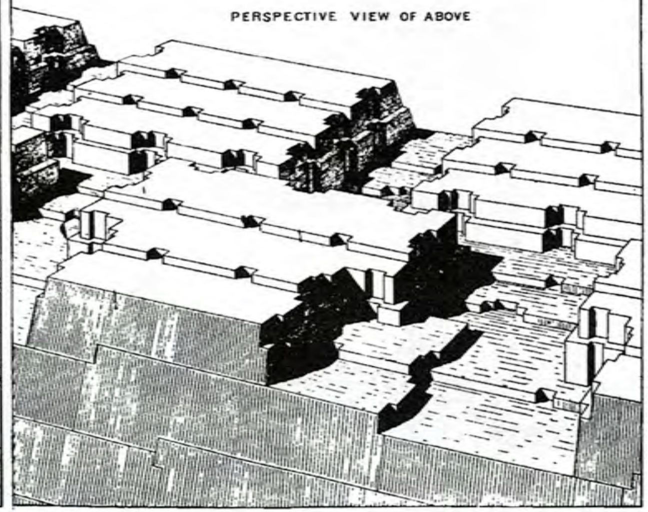
PERSPECTIVE VIEW OF ABOVE

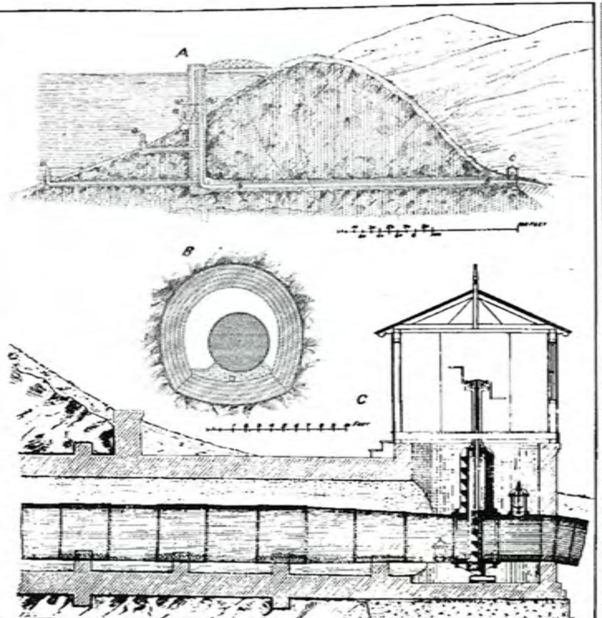


CRYSTAL SPRINGS DAM - DETAILS
16th LAYER OF CONCRETE BLOCKS



PERSPECTIVE VIEW OF ABOVE





DETAILS OF OUTLET TOWER & GATE SYSTEM OF THE CRYSTAL SPRINGS MAIN DAM.

A. Long Sect of Outlet Gate Tower & Tunnels.

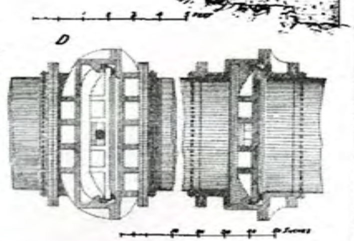
B. Cross Section of Main Outlet Tunnel b-b

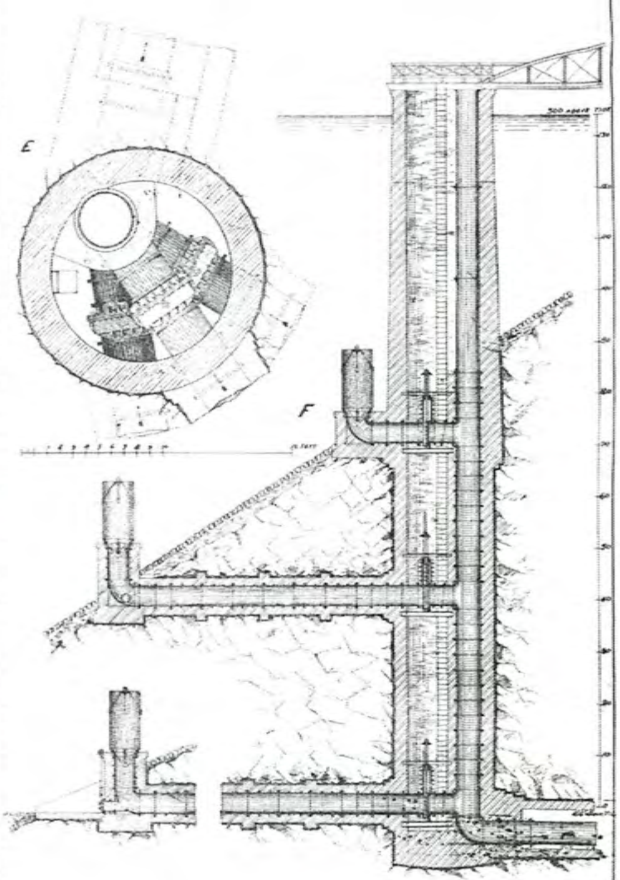
C. Detail of Main Regulating Gate at C.

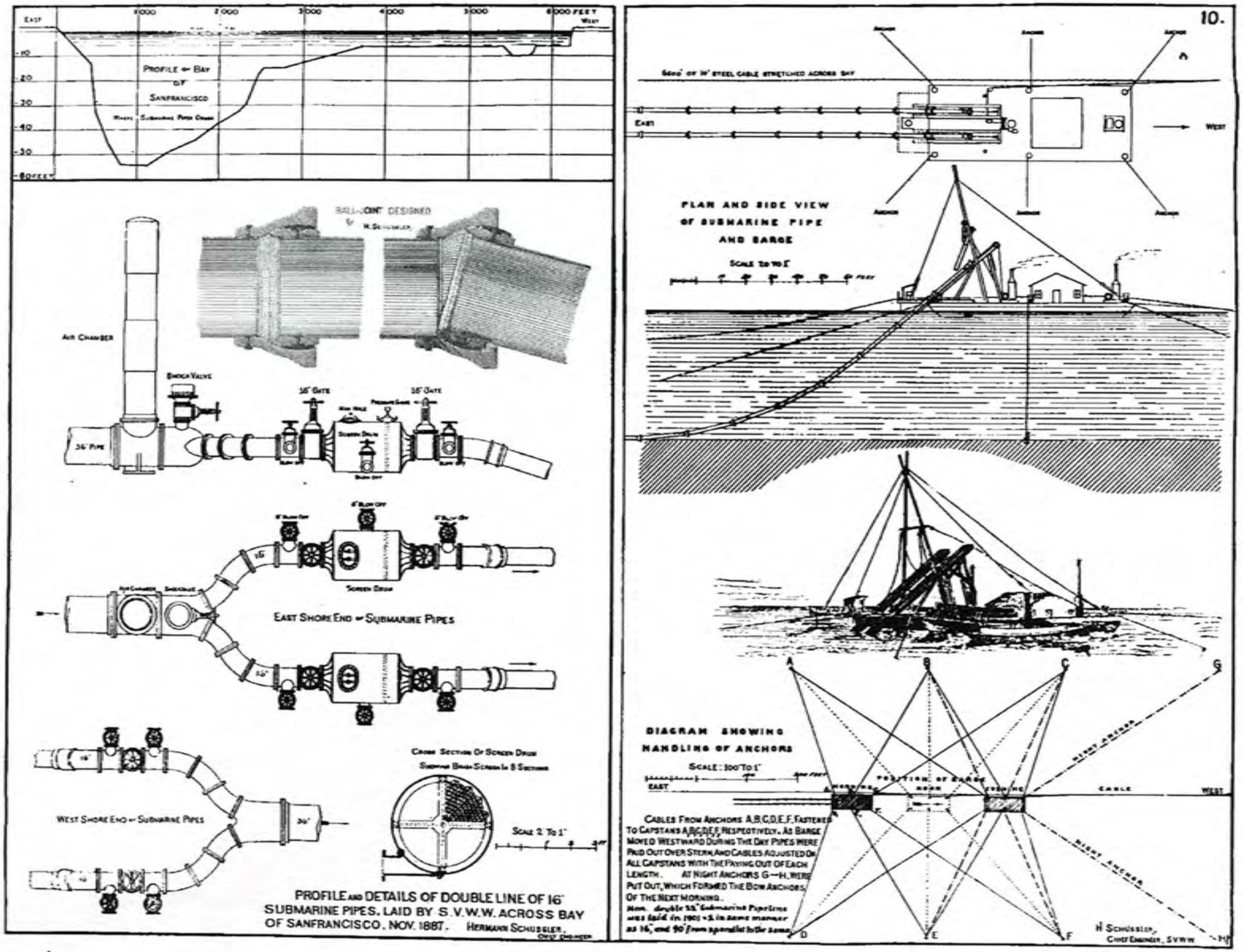
D. Horizontal Sections of Main Regulating Gate & Casing at C.

E. Horizontal Section of Gate Tower A (at a'-a')

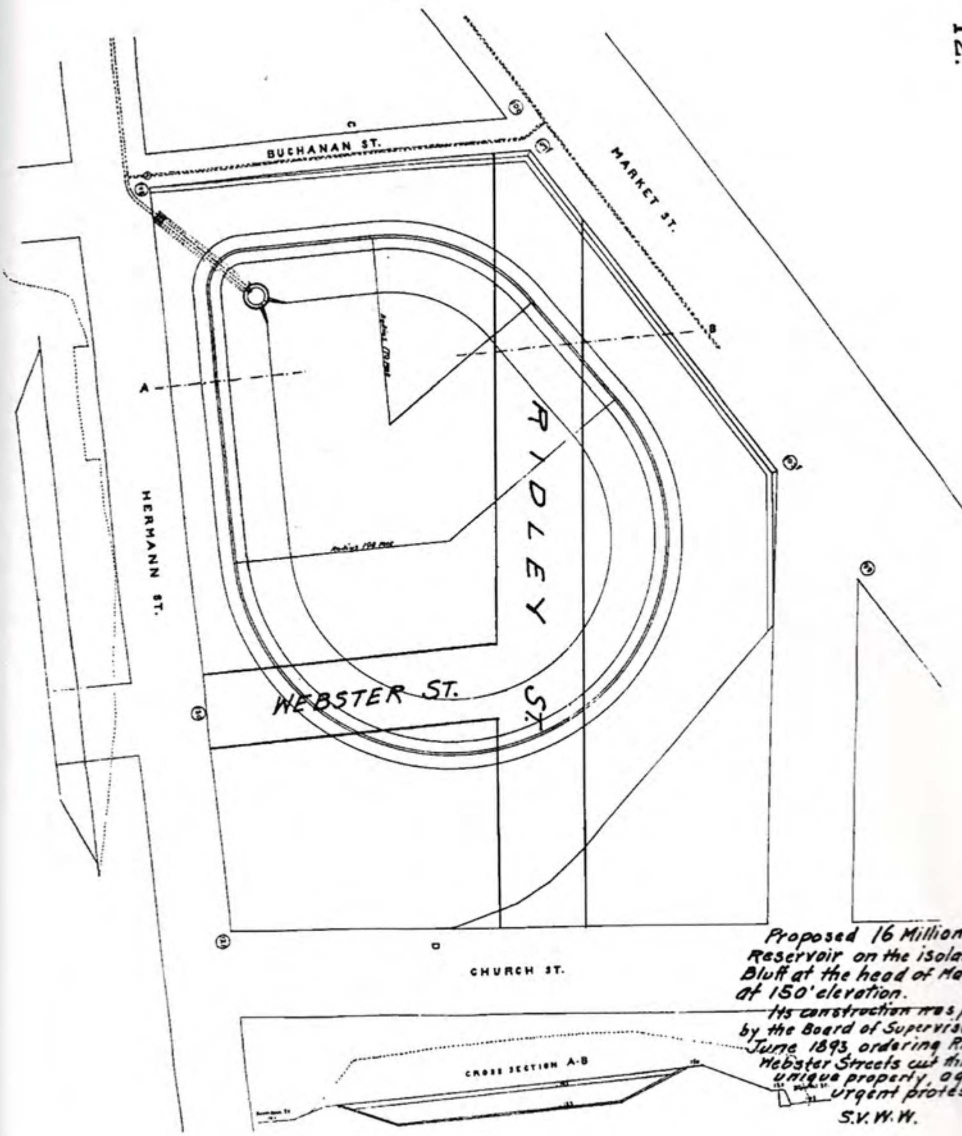
F. Vertical Section through Gate Tower A and its three Feed Tunnels, Gates, Fishscreens etc.






10.
EAST
WEST
1000
2000
3000
4000
5000
6000 FEET
PROFILE OF BAY OF SANFRANCISCO
WHERE SUBMARINE PIPES CROSS
BALL-JOINT DESIGNED BY H. SCHUSSLER.
AIR CHAMBER
SHOCK VALVE
16" GATE
16" GATE
36" PIPE
SCREEN DRUM
BLOW OFF
EAST SHORE END OF SUBMARINE PIPES
6" BLOW OFF
WEST SHORE END OF SUBMARINE PIPES
CROSS SECTION OF SCREEN DRUM
SCALE 2" TO 1"
PROFILE AND DETAILS OF DOUBLE LINE OF 16" SUBMARINE PIPES, LAID BY S.V.W.W. ACROSS BAY OF SANFRANCISCO. NOV. 1887. HERMANN SCHUSSLER, CHIEF ENGINEER
ANCHOR
PLAN AND SIDE VIEW OF SUBMARINE PIPE AND BARGE
SCALE 20 TO 1"
DIAGRAM SHOWING HANDLING OF ANCHORS
SCALE: 300' TO 1"
CABLE
NIGHT ANCHOR
CABLES FROM ANCHORS A,B,C,D,E,F, FASTENED TO CAPSTANS A,B,C,D,E,F, RESPECTIVELY. AS BARGE MOVED WESTWARD DURING THE DAY PIPES WERE PAID OUT OVER STERN AND CABLES ADJUSTED ON ALL CAPSTANS WITH THE PAYING OUT OF EACH LENGTH. AT NIGHT ANCHORS G—H, WERE PUT OUT, WHICH FORMED THE BOW ANCHORS OF THE NEXT MORNING.
A
B
C
D
E
F
G
H
H. SCHUSSLER, CHIEF ENGINEER, S.V.W.W.

12.



Proposed 16 Million Gallon Reservoir on the isolated rocky Bluff at the head of Market Street at 150' elevation.
Its construction was prevented by the Board of Supervisors in June 1893 ordering Ridley and Webster Streets cut through this unique property, against the urgent protests of the S.V.W.W.

CPSIA information can be obtained
at www.ICGtesting.com
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