CITY WATER

Its Amount and Its Availability.

ENOUGH TO SUPPLY 56,000 PEOPLE

The Actual Consumers Should Pay for the Water.

ABLE PAPER BY HYDRAULIC ENGINEER CHARLES L. STEVENSON.

HOW THE CITY COULD MAKE MONEY.

City Creek Can be Made to Produce During the Season of Least Flow from Ten to Twelve Million Gallons Daily—Facts and Figures which Show This to be True.

To the Chamber of Commerce, Salt Lake City:—GENTLEMEN—As a partial response to the published request of Governor Thomas for information on irrigation matters, for use of "Geological Survey," to that of your Secretary that I at the same time send *to your Board like facts concerning* "water supply of Salt Lake City," I present herewith:

First—Maps showing the drainage basins of City Creek, Dry Canon, Red Butte and Emigration creeks.

Second—Data collected from time to time concerning the requirements and supply of Salt Lake City for water for domestic, manufacturing, irrigating and public purposes.

It goes without saying that every effort on our part should be made to point out to the Special Senate Committee, soon to be here, and the Government all available methods for increasing our water supplies, and as one of the best ways to insure that result to induce our Government to reserve and conserve the upper reaches of our creeks and rivers, so that the preservation and cultivation of the timber and forests be kept up and thereby the water flow remain intact and equalized. Nature's methods of storage are among the best, and let us use every endeavor to restore and protect them from constantly increasing inroads.

The "water-shed" maps, drawn to Government scale of two inches to the mile, were made and areas determined from actual surveys, to accompany my report "On additional water supply for portions of Salt Lake City," made to City Council in 1888.

So far as the "water-sheds" of the different basins are concerned, the conditions remain the same to-day, no attempt having been made to store any of the waters therein. Many of the facts in the report then presented to the Council, *are equally pertinent* now, and form the basis of the present statements.

The object of these maps was mainly to ascertain the daily and annual yield of the various creeks in a manner more accurate than could be had from occasional gaugings. To the courtesy of Messrs. Smith and Jacobs of the Water Commission, I am indebted for the facts relative to Parley's Creek, of whose drainage basin no maps have yet been made.

SOURCES OF WATER SUPPLY.

Salt Lake City has within its corporate limits an area of about six *and one half (6.5) square miles exclusive* of streets, all of which sooner or later will require its full quota of water for irrigation, and all the other uses of a great city. It has a population estimated at 40,000, and the supply needed for public purposes is large and constantly increasing. Whatever may be the sources of supply, it has become only too evident that the methods therefor are totally inadequate during the period when most needed. To meet the requirements of furnishing water for all purposes the city has control of the entire flow of City Creek, the bulk of Emigration Creek, one-third of the waters allotable of Utah Lake that may be brought by the Salt Lake City Canal, and recently has secured an 82-100 interest in the flow of Parley's Creek. To acquire this last, a part of the Utah Lake flow has been exchanged therefor. So the amount derivable through the canal is diminished by the volume so obtained.

Let us see what these sources can furnish, separately and collectively.

The greatest amount of water used in the city occurs at a time of year when all the streams are at their least flow; hence it is this smallest yield we should take as representing the water now available from present sources.

These sources are contiguous to the city, and their water-sheds or catchment *basins are all in the adjacent* Wasatch Range, and, with the exception of the City Canal, all have sufficient elevation to flow by gravity to the highest parts of the city.

To ascertain the daily and annual yield of these there are two methods.

First—A direct measurement of the daily flow of the streams, kept up for a series of years, to ensure a knowledge of the greatest yield, the average yield, and that for the years of least rainfall.

Second—By knowing the size of the drainage or catchment basin upon which the rain falls that flows into the streams, and the available *amount of such rainfall thereon for* each year, we attain like results. The first method, unless carefully kept up for several years, so that the flow for the years of greatest drought is obtained, gives practically no more serviceable result than can be had by the second. Correct, or in fact, any statistics of the measured flow of streams are rarely procurable, while, since the establishment of the U. S. Signal Office, reliable tables of the rainfall can be had.

In our case *there are no records of* long continued measurements whatever, but of the

SALT LAKE CITY CANAL

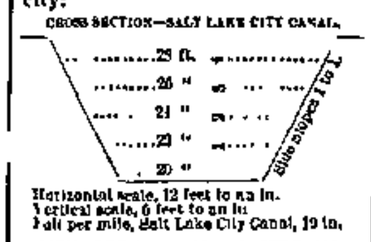
We have absolute data as to size and shape of cross section and rate of fall, so that its capacity and flow can be accurately ascertained for any depth of water it will carry. *From* such data, kindly furnished by the city engineer, this has been definitely determined, and after making allowance of 16 per cent. for evaporation, absorption, &c., we find that its flow capacity between the canal head at Jordan River and city limits, southeasterly, when running

4 feet deep is 24,416,000 gallons daily.
3 " " " 22,890,960 " "
2 " " " 20,069,760 " "
1 " " " 10,069,920 " "

This is the quantity of water it will furnish, if it is delivered to it and allowed to discharge. As the capacity of the source which supplies this canal, when properly utilized, is largely in excess of what it can carry, it is practically unaffected by drought and should furnish any amount less than its greatest flow, *provided always it be kept in repair.* Its winter value is of but little account, and sooner or later a covered conduit must supersede it for all general purposes and for economic reasons. Of this canal and its mode of supply I shall hereinafter make more particular mention.

The following diagram shows the cross section of the canal from its head to the southeastern limits of the city:

CROSS SECTION—SALT LAKE CITY CANAL.



Horizontal scale, 12 feet to an in.
Vertical scale, 6 feet to an in.
Fall per mile, Salt Lake City Canal, 19 in.

CITY CREEK AND OTHER STREAMS.

As City Creek was the first to be appropriated to the use of our citizens, so has the impression grown upon them that somehow none of the other waters can well take its place. Yet analysis made by Prof. Kingsbury of the Deseret University and by Prof. Albert R. Leeds of the Stevens Institute of Technology show that many of the streams flowing into Salt Lake Valley contain less of the insoluble sulphates of lime and magnesia and are otherwise equally pure, while the waters of Utah Lake are still purer and softer and thereby better suited to all purposes of manufacturing and irrigation, and especially is the higher temperature thereof more beneficial for the latter purpose. It should be had in practically unlimited quantity at all points below canal level.

But City Creek, whether its waters be as good or not, is nevertheless, with or without storage, a magnificent source of supply. To ascertain its yield, the second method before mentioned (rainfall upon drainage area) has *perforce* been adopted, and *the same may be said with reference* to Red Butte and Emigration creeks, which constitute the remaining water feeders. It is to be sincerely hoped that like measurements will be had of all the streams flowing into Salt Lake Valley.

RAINFALL.

The following table of rainfall is compiled from the records kept at Fort Douglas from 1865 to 1875 and from that date to January 1st, 1889, *from U. S. Signal Office in this city:*

TABLE NO. 1.

Years.	Inches Rain.	Years.	Inches Rain.
1865	16.61	1877	11.63
1866	22.23	1878	17.86
1867	26.14	1879	13.11
1868	17.25	1880	10.91
1869	22.32	1881	16.85
1870	20.96	1882	15.00
1871	23.12	1883	14.24
1872	15.12	1884	17.52
1873	17.37	1885	19.60
1874	19.55	1886	18.50
1875	21.07	1887	11.66
1876	16.31	1888	13.62

Mean of 23 years, 17.79.

From this table we learn that for twenty-three years past the average annual rainfall in this valley has been 17.79 inches, and the smallest amount recorded, 10.91 inches in the year 1880. From the same source it *is also ascertained that the average* summer rainfall, or rather that which occurs between the middle of May and the middle of September, has been 3.31 inches. Since we cannot predicate the available water upon any other than the delivery of a very dry season, that of 1880, the dryest known for twenty years, has been adopted as the basis for obtaining the least fall of rain upon the various drainage basins. The present season having been preceded by two years of extremely light precipitation has caused a drought probably equal to that of 1880, and quite as little water is derivable from the basins.

To arrive at the rainfall that obtains along and upon such basins, the California ratio of increase be*tween the valleys and the mountains* has been adopted.

[See Report United States Commission, Irrigation of Sacramento and San Joaquin Valleys, California, 1877.]

That the condensation of moisture in the shape of snow and rainfall, during the year, is far greater along the mountain summits, than is ever found in our valley is too well known to require comment, while the analogy that exists between the Sierra Nevada and the Wasatch is such that this California ratio is manifestly a safe one to adopt as it is probably below the true amount.

CITY CREEK WATER-SHED AND YIELD THEREFROM.

Upon the water-shed maps herewith presented, is also given the elevation of the mountain summits above sea level. If now we take the elevation of Salt Lake Valley, as found at Temple Block, S. E. corner, to be 4350 feet above that level, and that of the summits as shown on the map, we are enabled to arrive at the mean elevation of the basins, and upon the basis mentioned ascertain *the rainfall and probable* yield therefrom. Upon the City Creek basin we find that in the year of least precipitation there was obtained about twenty inches of available rain; that is, allowing one-half to have been lost to us through evaporation and absorption. The area of the water-shed being 12,908 acres, and one inch of rain per acre equaling 3630 cubic feet, a very simple calculation shows that if these waters *could* be stored, a daily yield of 19,255,905 gallons can be had during a very dry year.

How much of the waters of City Creek it is practicable to store requires more extended surveys and examinations than I have been able to make. In 1880 the minimum flow was 7,000,000 gallons during a part of August.

This season Mr. Ottinger finds it about the same during the month of July.

EMIGRATION AND RED BUTTE CREEKS WATER-SHED AND YIELD.

In a similar manner we find that Emigration Creek will, during a year of greatest known *drought, furnish* a flow equivalent to 10,105,000 gallons could it be stored. In 1880, during August, I gauged the flow of this *stream* at a point opposite Wagener's brewery and found its flow to be at the rate of 3,200,000 gallons daily. April 26th of this year Messrs. Smith and Jacobs found but 1,013,236 gallons; a week later, after the spring rains, it was running at the rate of more than 7,000,000 gallons. This goes to show the fallacy of casual measurements of flow and the necessity of rating boxes, as suggested recently by Mr. Newell of the Geological Survey. Its minimum summer delivery may be safely *estimated* at 1,500,000 gallons.

Moreover, there is no good engineering reason why the summer flow may not be equalized and increased in all the creeks and streams.

Both Emigration and City Creek canons are favorable basins for a high rather than a low ratio of available rainfall, owing to the numerous springs, which, as underground reservoirs, serve to keep up the summer supply. On the other hand in Red Butte Canon, as in Dry Canon, a very large part of the rainfall sinks and does not re-appear on the surface as springs, and so is permanently lost to us; *moreover, the claims of the* Government upon the creek are such that it should I think be eliminated from the list of available sources of the city.

PARLEY'S CREEK.

The acquirement of 82-100 of the volume of this stream has been quite recent and I have made no personal examination thereof. Its flow, as near as can now be estimated, is about the same as that of City Creek; so under the most extraordinary periods of drought its minimum supply belonging to the city may be taken as being 5,750,000 gallons daily.

One of the best features in connection with this supply is the construction of a small distributing reservoir near the mouth of the canon. *This reservoir when filled* sixteen feet deep holds 7,000,000 gallons, and its elevation is such that it will operate in connection with City Creek water to equalize the supply through the city pipes. This is one move, at least, in the right direction. It is still unfinished, and it is to be hoped that it will be properly lined with hard brick laid in cement, so as to be always water tight. The expense of so doing is certainly extremely small by comparison with the advantage gained. It should be borne in mind that this is also a winter source of supply, and should in every way be made first-class.

The following table, showing the capacity of the sources for water supply and irrigation, adjacent to and controled by Salt Lake City, prepared with considerable care, from what I believe to be reliable data, gives in detail many facts that would seem to be applicable and needed for a *proper study of our water question.*

TABLE NO. 2.

Table Showing Capacity of Some of the Sources of Water Supply, Adjacent to Salt Lake City.

Name of Source.	Area of Watershed Sq. miles.	Area of Watershed Acres.	Average Daily Yield as delivered from Radials of Street hose sprengs Cubic Ft.	Average Daily Yield as delivered from Radials of Street hose sprengs Gallons.	Maximum Daily Yield Gallons.	Av. yield per second, during Six Months Cubic Ft.	Av. yield per second, during Six Months Gallons.	Velocity, Ft. per sec.	Velocity, Miles per hr.
City Creek,	20.17	12,908	2,967,154	19,255,905	185,000,000	29.71	192,66		
Emigration Creek,	15.26	9,766	1,554,918	10,105,000	7,200,000	15.03	97,62		
			From Measurement		1,500,000				
					Six Months.				
Dry Canon Springs,	1.86	539	10,707	80,300	150,000	0.120	0.968		
Parley's Creek 82-100,					5,750,000				
Salt Lake City Canal,			16,888,000	121,416,000		195.00	1,260.00	2.00	1.36
Running 4 ft. deep,			9,715,000	72,890,960		112.47	848.60	1.32	1.11
" 3 " "			4,656,000	33,069,760		54.12	409.60	1.33	0.90
" 2 " "			1,342,000	10,069,920		13.64	101.89	0.71	0.48
" 1 " "			1,213,000	9,097,920		14.04	104.80	1.17	0.79
Large Flume 6 x 2 "			678,107	6,220,840		8.06	60.00	1.01	0.69
Small " 4 x 2 "			16,000	120,000		0.185	1.39		
Artesian Well by pumping 2nd foot,									
Unknown but supply of water therefrom great, by no means of capacity of Canal.									

AMOUNT OF WATER OBTAINABLE FROM PRESENT SOURCES AND THAT REQUIRED BY SALT LAKE CITY.

As the result of the examinations of our present sources of water supply, we find that practically there are but four belonging to or controlled by the city to be relied upon, viz: One-third of Utah Lake waters via the city canal, Emigration and City creeks and 82-100 of Parley's creek. Without here going into the question *of storing the waters of any of the* streams, let us examine the matter of amounts of water needed for present and future distribution.

The summer flow of City, Emigration and 82-100 of Parley's creeks is respectively 7,000,000, 1,500,000 and 5,750,000 gallons per day, while the city canal should have, *or can be made to have*, at all times of the irrigating season, a capacity, if needed, of 121,416,000 gallons.

It appears, then, that with *existing arrangements* all those portions of the city lying above the level of the city canal, exclusive of the First, Tenth and Eleventh Wards, would be *required to get* its water from City and Parley's creeks, whose least joint flow as measured is now limited during August to 12,750,000 gallons daily, and which are still permitted to flow for irrigating purposes on to a very considerable acreage *below* canal level.

From information derived from Mr. Winder, late City Watermaster, I have been enabled to compile a table of areas within city limits, showing the sources of supply therefor, as now apportioned and computed the amounts of water required for irrigation thereon.

Table of Areas within Salt Lake City Limits and Sources of Irrigation Supply as at Present Apportioned.*

Locality.	No. of Blocks.	No. of Acres.	Name of Source.	Water required daily for Irrigation when entire City is watered. Gallons.
Parts of 1st, 10th and 11th Wards, above Canal level	82	820	Emigration Creek	3,369,000
North of City Creek Aqueduct	184	2840	Salt Lake City Canal and City Creek	18,168,200
Parts of 12th and 19th Wards above Canal level	100	1000		902,000
Parts of 16th, 24th and 21st Wards below Wall St. Water Sect.	11	110	City Creek	510,000
Part of 12th Ward above Canal level	15	115	City Creek	194,400
Parts of 15th, 20th and 21st Wards above Wall St. Sect and below new ditch	30	30	City Creek	1,111,500
Parts of 18th, 20th and 21st Wards above new ditch	84	222.5	Surplus water from Emigration and Red Butte Creeks	1,822,500
Cemeteries	34	235	No supply at all	820,300
	34	60	No supply at all	
Area of Salt Lake City, exclusive of Streets, 4,725 acres, or 6.82 sq. miles.				27,057,800

*Utilizing Parley's Creek will materially change apportionment, but volumes required will remain the same.

From this we learn that, above city canal level 295 acres are now supplied from City creek and the balance goes to the lower wards, by ditch or *through the city water pipes, leaving* 517 acres, including city cemetery, of the lands through which City creek flows practically without water for irrigation.

The ditches from Parley creek are so crude and unfinished, and with no pipe service yet, that this valuable source cuts no figure in the present supply to the city.

AMOUNT OF WATER SUPPLY REQUIRED FOR IRRIGATION.

The *amount* of water which Salt Lake City requires, and will hereafter require for irrigation during the period of about 120 days, from the middle of May to the middle of September, is so enormous that the quantities required for domestic and other purposes sink into insignificance by comparison. Fast becoming a city, filled with lawns and shrubbery in place of gardens and ordinary crops, with abnormally wide streets, the requirements are *simply immense. Long* experience has demonstrated that watering in our climate for city lots should be as often as at least once a *week*, and such is the custom here. During the "season" from seventeen to twenty waterings are had, and we find from the tables of rainfall that only an *average* of 3.31 inches of rain can be had during this period, while in seasons of drought it falls much below this amount. Experience has also demonstrated that the *best results* are obtained when at each watering as much water is used as would be equal to covering the ground one inch deep. At *least* this amount is generally *required. Lawns should* be daily sprinkled and consume probably even more than this *watering* average.

This, therefore, means that during the "season" from 20 to 23 inches are flowed over the whole surface of the lands, the rainfall being counted in, and practically amounts to the same as though that number of inches of rain had fallen between the middle of May and middle of September. It also means an equable distribution of this fall with corresponding or rather more favorable results. For the waters of irrigation bring with them elements of fertilization from the wash of the mountains, that *the* most eminent scientists agree, fully equal the losses due to cropping. Mr. Hollister has so frequently brought this to our *notice* and *cited* authorities that further comment is unnecessary.

To those not familiar with the *needs of irrigation*, this may seem an unusually large allowance, and very few appreciate how large an amount of moisture they put on an acre of ground when they cover it an inch deep. It means 0.63 gallons, or 5¼ pounds per square foot, or 113 tons per acre at each watering, or 2260 tons of water in a season. Yet, large as this looks, it is not as great as the original founders of the city deemed necessary to provide.

In a conversation had with Mr. Orson Pratt, one of the very *best informed* men among the early pioneers, some eighteen years ago, on the subject of the amount of water *required for irrigation here*, that gentleman said to the writer: "It was our expectation that a flow of seven and a half gallons, or one cubic foot of water per second should suffice for 100 acres of land for about that same number of days, and at the onset that amount or perhaps more was used; since we have got the ground saturated and cultivated, our crops don't probably require, in ordinary seasons, more than three-fourths that."

Since the general public do not seem to be clearly informed in regard to the amount used for different purposes for irrigation, a few words here concerning the duty one cubic foot of water per second is expected to do, may not be amiss and becomes a proper digression from the immediate *subject* matter.

IRRIGATING DUTY OF WATER.

A recent writer from Colorado, name unknown, says: "This subject, as a matter of argument, offers a range hardly inferior to the celebrated case of the elephant examined by the three blind men. Each writer, or speaker *draws from his own* experience, ignoring that of his opponent, and while each may be measurably correct in his deductions, the aggregate result is somewhat confusing to the collector of statistics."

In fact, the infinite variety of soils, the different climatic conditions, the peculiar requirements of different crops, the intelligence of the farmer, and the skill with which he arranges his system of distributing laterals, are factors capable of such numberless conditions that no formula could be based on them. The increase of shade, as in fruit culture, and the repeated stirring of the *surface soil* have worked wonders in the economy of use of water.

In Colorado, in the devising of new *works, to insure full capacity*, as wide a margin as allowing but 50 to 55 acres to the one cubic foot per second has been the previous practice, but as every year shows marked improvement in the methods of application, the "duty" is largely on the increase.

In this immediate section of Utah forty years experience has demonstrated the "cubic foot per second" as sufficing for 100 acres.

The evident necessity for a system which should accurately measure a given *quantity* of water, gave rise to the adoption of this "cubic foot per second" as the unit of measure among engineers and is incorporated into the *irrigation laws of some of* the States and Territories. It is now almost universally used in gauging the streams and in apportioning the waters drawn from them for the canals and to the consumer, in place of the old square inch or "miner's inch" of the Pacific Coast.

The actual amount of water used must also, sooner or later, become the measure of cost to the consumer, instead of areas or acreages supplied.

One party along a line of works needs for his crops, say of cereals, even less than one-third that of another who has a market garden, or whose fruit culture requires the additional amounts. Another, adjacent to the same line, desires, for power purposes, mills, manufactories, electrical works, or any other industrial *process*, a certain amount of water outside of any of the uses thus cited.

The applications of water under pressure have become so multifarious, that whether it be driving a cable railway, hoisting machinery, a dynamo, an air compressor, a sewing machine, a candy or soap factory, or produce the hot and cold blasts that temper the halls of legislation, or the force that controls the fires of cities, its value in this direction cannot be overestimated. Enough has been stated even, to show the great difference in the irrigable duty of the "cubic foot per second," and its values in the other directions indicated, must be measured by stated quantities in a given time.

IRRIGATION NEEDS IN SALT LAKE CITY.

Experience having taught us that the irrigable duty of one cubic foot of water per second is in this city enough for 100 acres, it has been that adopted in the computations and given in the *accompanying table*, No. 3.

This water duty allows nearly 21 inches for a season of 100 days, practically equal to about *one-quarter inch per day* over the surface; but gardens, lawns, etc., require water during at least 120 days, or with 20 waterings, say 1¾ inches to a watering. This means 4537 cubic feet, or 34,030 gallons per acre.

During parts of July and August the least flow of City Creek is 7,000,000 gallons daily; that *from* 82-100 Parley's Creek is 5,750,000 gallons daily, and that from Emigration Creek is 1,500,000, gallons daily, or a *total minimum* flow of 14,250,000 gallons daily.

From table No. 3 we find that *above* canal level there is an area, within present city limits, of 1332 acres, which, when it is all brought under irrigation will require 8,031,360 gallons daily during 120 days of the year. The three creeks owned or controlled by the city during the same period furnish 14,250,000 gallons, leaving for domestic supply 6,618,640 gallons daily that can be utilized.

With a city like Salt Lake, which has no large manufactories, a supply of twenty gallons per capita, exclusive of hose service, is generally conceded by all hydraulicians ample for domestic purposes solely. Thus for these purposes alone the least supply of the three creeks after allowing for *irrigation, during the dryest years* known, is sufficient for a population of 281,000 people. Now it is only during the period of 120 days that this minimum quantity of 5,618,640 is left to us, and there are no good engineering reasons why this amount may not be doubled and that at reasonable cost. During the balance of the year the least joint supply from the three creeks, *for domestic uses solely*, will suffice for over 700,000 people if utilized, and this without *storage. Assuming* the same amounts of water used as in New York city, or 100 gallons per head and we have enough for over 110,000 inhabitants.

The use of the creek waters for irrigating the areas *above* City Canal level, leaves 2640 acres in the city *below* its level. Should this canal be drawn upon for its full capacity, it would admit of flooding this entire area of 2640 acres 1 6-8 inches deep every day, or 11 3-8 inches at each watering, or 16 feet deep during the "season."

But the canal, for the *necessary irrigation only* of all the lands within city limits below its level, need furnish but 18,400,200 *gallons daily, or* but little more than one-seventh its full capacity. Two-thirds of the whole area of the city would thus seem to be pretty well provided for in the way of irrigation waters.

SALT LAKE CITY CANAL.

It has been stated, that owing to *its faulty location* and leaky condition, the canal cannot be made *at present* to flow to its capacity. Neither will it at present be required to, for anything within city limits. As a matter of fact and as I am credibly informed it is within these limits entirely dry, while furnishing an abundant supply to the farmers south of the City. It is but a very few years ago when after passing through the city its overflow was running north emptying into City Creek aqueduct and so wasting into Jordon River.

Whatever may be the reasons which have permitted this great *work to get into its present* ruinous condition, the fact goes far to show a negligence that may properly be called criminal; and because a new portion is being constructed, it is no reason for letting the old become useless meanwhile. Repairs will certainly remedy the leakages of the canal, and rebuilding, where necessary, the errors due to faulty construction. Repairs, like repentance are always in order, and another year of neglect like the previous one will create damage equal to the financial outlay therefor.

Whatever may be said about the faulty location and construction of *this great waterway*, or the *excessive* damage from *muckrake* yearly, which has done so much to bring it into disrepute, the wisdom displayed in its *adoption was of the highest order. Nor has* it been built any too soon to meet our rapidly increasing wants. The waters of Utah Lake, which it can bring us, for irrigating and manufacturing purposes, are superior in quality to those from all other sources. We are, however, frequently told that the construction of a canal at all was a terrible mistake; that a pipe should have been laid to prevent any chance for damage to lands along its route, etc. Doubtless one of these days, when population is sufficient to warrant the cost and to insure greater purity, something of this kind will be necessary. But even now, while a pipe, or its more practicable *equivalent*, a masonry conduit, would be a first rate thing to have, yet to bring the same amount of waters from the *same starting point on the Jordan*, will require that conduit to be 11 feet in diameter, or if iron pipes were used, 14 of them 3 feet in diameter will be required, and carry the cost away up into the imposing millions. The canal *has* heretofore brought the water into and through the city, and can be made to do it again. Surely the $225,000 the canal is said to have cost was a judicious expenditure.

COMPARISON BETWEEN DOMESTIC AND IRRIGATION SUPPLY.

A purely domestic supply of 20 gallons per capita means 7,300 gallons per annum to an individual. Now an acre of land requiring irrigation during the same period, though distributed generally during 120 days, requires not less than 613,000 gallons, or nearly 90 times as much. During the 120 days, however, the acre consumes 270 times as much as the individual. Following out the calculation we find that the water ultimately required for our irrigation, with no allowance for entailed or other waste, would suffice for the domestic purposes of a population of 1,350,000 people.

I give these figures to show the cause which necessitates such immense volumes of water. The probabilities are that during the irrigating season 30,000,000 or more gallons daily will in the future be used and rightfully wasted. By rightful waste I mean that quantity of water left to flow along our streets, not only for irrigation of foliage and grassplots thereon, but that which cannot well be controlled, as also that quantity which so flowing will always be an important factor from a hygienic point of view.

In all the preceding estimates the quantities given are for a supply to the *entire* acreage of the city as at present bounded, while the least capacity of the streams has been taken as the basis *from* which *such supply* is to be had. This is not entirely a just way of estimating, since it is fairly presumable that whenever required in the future a portion of the flow of all the creeks, now wasted, will be stored and utilized.

As will also be noticed no deduction has been made for buildings, the whole area having been computed as requiring irrigation. The needs of the streets and for hydrants and public purposes will however, quite offset this amount, and it is sincerely to be hoped that no diminution of the flow along any of our streets will ever be required, and below the city canal level there would seem to be no excuse for any such diminution.

The foregoing statements are applicable to Salt Lake City within its present boundaries, but the time must come when 1280 acres of the Fort Douglas reservation will be within its limits. It will extend south and ere long reach across the Jordan, so whatever systems of supply are adopted they must be designed with reference to sooner or later conveying all the waters attainable.

In the presentation of the facts that have come mainly within my *own cognizance*, it has been the endeavor to show how and where the city of Salt Lake has a supply of water within its ownership or control amply sufficient *for irrigation forever* of the entire acreage of the present town, as well as for domestic and all other purposes, based on a per capita supply equaling that of New York City, for a population of over 110,000 persons.

Without going at all into the *methods of supply* it will suffice to say that a reasonable utilization of the means at our command will prevent any recurrence of the present disgraceful condition of our *irrigation system. By this, do not* let me be understood as not favoring the search for, and examinations of, all other available sources; quite the contrary, since the fullest information on these points will be of utmost value. Especially should we find out all we can about the subterranean waters underlying us, and the present boring therefor is a move in the right direction.

In a future paper some suggestions on the subject of storage in the upper reaches of our streams, in the line indicated in my previous communication, will be presented.

SUGGESTIONS CONCERNING AN INCREASE OF WATER SUPPLY, FOR IRRIGATION DURING THE SUMMER MONTHS, IN THE STREAMS ADJACENT TO SALT LAKE CITY, WITH AND WITHOUT PONDAGE.

In the preceding papers I have shown that by actual measurements the City of Salt Lake owns or controls water sources ample during periods of greatest known drouth to fully irrigate the *entire acreage* of the city, and still have enough water for all other purposes for a population of 50,150 persons. This last being based upon the extreme supply of 100 gallons daily to each inhabitant, a per capita amount only equalled by the very large cities like new York.

Examination has shown that this minimum supply can be readily doubled so as to provide for twice this number or say 110,000 people.

It must be borne in mind however, that, at present, but about one-third of the city's area is irrigated, so that many years may elapse before we arrive at the necessity of using anything like the least flow during the *dryest seasons. Hence storage of the* water is not an essential merely to *increase* the supply either now or for some years to come. There are, however, other and economic reasons why impounding a portion of the flow may be advisable, as permitting a better and more complete utilization for distributive purposes, and thereby obtain a better return financially from the system that may be adopted.

Let us begin with City Creek as that which has had the most complete examination. This creek, as shown by table No. 3 furnishes a large supply of water for irrigation below the level of the City Canal. In any *future attainment of waters from* other sources it is proposed that all points below canal level shall take their irrigation supply from that source. In fact any other arrangement would seem absurd except for such water as flow through the city mains. This leaves the three creeks, City, Parley, and Irrigation for watering the areas above canal level and for pipe distribution from the first two named. In other words it releases some 3,000,000 gallons of City Creek water which can be utilized economically in the watering of 517 acres which now have no waters of irrigation and only a small part of *which has any water for even domestic purposes*

Of this area about 60 acres is devoted to cemetery purposes as I was *informed at time of making the* field examination of 118 acres of unsold lots (192) belonging to the city. In round numbers there are 295 acres within city limits which can not obtain water from any source whatever as they lie above the upper line of the present pipe service. Should an adequate supply be obtained for the city, Catholic and Hebrew cemeteries it would prove a very profitable investment for the city from the annual income obtainable from the lots. At "Mount Olivet" cemetery, where a good supply is had from Red Butte and Emigration Creek, the yearly water rate is $3.50 per lot. In 1885 Mr. Taylor, *city sexton informed* me that 1550 lots were then sold and occupied and that the new addition would contain 2000 more. At this date the lots sold are about 2000 and on *these* he thought an annual rate averaging $1.50 per lot could be readily obtained. The Hebrew and Catholic burial grounds adjoining, contain upward of 600 lots and a like or perhaps greater average may be had thereupon.

To this region of 517 acres City Creek is, or should be, immediately tributary, since it can be brought out upon the very highest points within the limits mentioned. Nor can this work any hardship to those who receive other waters in lieu of City Creek, since they get a vastly greater supply, a supply which the whole of City Creek cannot alone furnish and such increased flow would soon settle the vexed question of *original* water rights.

To best carry out this redistribution of the waters of City Creek it would doubtless be *advisable* to impound a portion thereof and they *should be taken out sufficiently high* up the stream to make available the natural advantages afforded by "Little Valley." This valley occurs on the east side of the creek, one and three fourth miles due north from Brigham street, at its junction with Seventh East street. It is a singularly well adapted nook in the mountains for reservoir purposes having a slight fall to the north so that its outlet is *up stream* with reference to the main channel of City Creek. A natural wall of rock and cement forms its west bank and a short distance below its present earth bottom the solid rock is found.

As this depression lies in the direct line of any flume or conduit, for bringing out the water, it can with but little expense be converted into a *storage basin to hold* 80,000,000 gallons and will have a surface of about 12 acres. From this surface an ice crop of 10,000 tons can be annually harvested and a royalty of at least 75c per ton therefore. The itemized estimates of cost including bringing out the water from the creek together with that of the storage basin work and iron supply main, will be about $11,500.

The elevation of Little Valley is *such that if the waters be brought* therefrom in an iron pipe to the point from which it will be distributed to the upper wards, a water power equal to 320 H. P. can be had *so that practically the waters from* this basin can be *utilized twice.* For certain kinds of manufacture, when location is not a material feature, and especially for electric light and power works, such a force as this would create, becomes extremely valuable. Given for instance near the north line of the city such a "power plant" as indicated and we can distribute electrically at any point in the city, at least 300 horse power and this also without interfering with the ultimate uses of the water, for, having fulfilled its duty in creating an electric force, or been used directly, it proceeds to fill its mission for domestic and irrigation purposes.

So much attention is now being paid in all the great cities of this and foreign countries to the making use of the right and flow of water for running machinery, that we should be very remiss in devising any *system did we not avail ourselves of the* great head possible to be obtained from our surrounding water courses. This form of usage certainly possesses the merit of creating no nuisance from smoke, while the income desirable and other economic features make it desirable.

To give some idea of its value, it should be understood that it now costs our manufacturers, Electric Light Works, machine shops, etc., who use steam at the rate of from $80 to $100 per horse power per annum. At one half or two-thirds this rate it would seem as though the water power thus created, would soon be *sought after. It is the more reasonable* to make this supposition since its application requires much less machinery and the power can be utilized at less cost for original plant than by any other known motor. When, moreover, we consider that the advantages thus gained do not take from the present supply one extra gallon of water, but by simple use of the head obtained from Little Valley basin we make the water do double duty, some idea of the economic value of proper impounding may be had. In this instance a *storage* in City Creek basin is not a *necessity* but as a means of distribution the construction of such a reservoir becomes extremely *advisable.*

At the present time, and for some years past, no charge has been made to the consumer for water used in irrigation except such as flowed through the city pipes. So irrational a proceeding grew out of fancied difficulties liable to arise between the city as a whole and the individuals who claimed prior rights to the waters of the streams. Now for the acquired rights of the city may obtain *is not to be here discussed. Certain* it is that it has controlled all the waters flowing into and through the same for very many years and annually taxed its citizens to pay for new ducts, reservoirs and sources of supply. Had a proper and sufficient water service for irrigation and other purposes been *kept up* and furnished to the earliest appropriators as should have been done by the city even with charge therefore, I opine that this question of ownership or *prior rights would long since* have sunk into "inocuous desuetude."

It is however as illogical as absurd to tax the individual who use no water for irrigation equally with the one who daily requires 6180 gals. for each acre. The time must come, and that ere long, when this water shall be paid for by the actual consumer in direct proportion to amount used and the city derive the income therefor to which it is justly entitled.

As a reservoir of *advisability* rather than *necessity*, let us see what financial advantages it would give us as well as distributive ones. Exchanging canal and a portion of Parley's Creek water for City Creek, we have shown, leaves available to the latter 3,000,000 gallons for irrigation and other purposes. The Little Valley Reservoir while not a storage *basin*, in the strict acceptation of the term, nevertheless would increase, by its holding of 80,000,000 gallons, the *daily available supply*, for 120 days, by 667,000 gallons each day. If this 3,667,000 gallons were flowing through city pipes, as in course of time much of it will, it would yield a revenue equal to three sevenths of the present income or say $12,100 per annum. Throwing out of the question all revenue from irrigation to individuals, we find that the Little Valley pond would bring to the city annually something like the following:

Rent from 10,000 tons ice at 75c per ton,	$7,500
Water power, 300 h. p., at $10	3,000
City Cemetery 2,000 lots at $1.50	3,000
Catholic Cemetery and	
Hebrew Cemetery 600 lots at $2.	1,200
Total annual revenue	$26,700

This means a gross income of six per cent on $445,000 or 60 per cent on the real outlay.

There are, however, certain incidental advantages that also accrue, that possess a positive money value. The city of Salt Lake in its corporate capacity *is the owner of 193 lots* in the unwatered region, lots which at present have but a nominal value. With water these lots will have a *positive average value of $800 each* or a total of $150,000.

Following up City Creek, and above Little Valley, are several sites where storage basins of reasonable size can be made in the side valleys. In fact a total bondage giving delivery of about 3½ to 4 million gallons per day during four months can thus be saved up, and these can at any time be made when the wants of our city *necessitate* them. Making storage basins in the main channel of mountain streams is not to be advocated when such can be avoided. While proper construction will doubtless admit of avoiding serious accidents, locations in side canons reduces such chances to a minimum.

There is also another source of annoyance in reservoirs through which the main stream flows, and that is the tendency to "silt up" which is much lessened when the water is led from the main stream into basins located similarly to Little Valley.

Another method recently and successfully adopted in City Creek to increase the yield has been aiding the flow of springs by more thoroughly opening them and clearing away the accumulations of years. Not fully satisfied with even this increase, Superintendent Ottinger has made use of a system of what he *terms "mining"* for water, and this is to drift into the side formation, where indications of water existed, and by "smiting of the rocks" he has brought forth such volumes as Moses of old might well envy. During this our season of unprecedented drouth, the surface yield has been increased by not less than 2,000,000 gallons daily. As a conclusion it will be here safe to state that City Creek can be made to produce during the season of least flow, from 10 to 12 million gallons per day with comparatively light expenditure for storage. Its waters should however be more effectively distributed.

A recent reconnoissance of Emigration Creek leads me to infer that similarly good results would occur *from like methods of "mining"* and "sluicing" the springs. Along the creeks are also apparently good sites for light storage. I regret not being able to obtain even an approximation of the quantity that this creek may be made to flow. The same reasons which dictate the *advisability* of a distribution reservoir in Little valley apply to this creek though in a lesser degree, but the period for its construction near the mouth of the canon may be left for some years to come.

All that has been said concerning City Creek and increase of flow, appertains in the fullest measure to Parley's Creek. It is truly a splendid *source of supply and no time should* be wasted in getting its waters into the new receiving reservoir at the canon, and into the pipe distribution of the city. One *spring*, near Mountain Dell Fork, recently barely seeping above the