FOR THE

CITY OF TROY:

A

REPORT MADE TO THE

WATER COMMISSIONERS

BY

HON. WM. J. McALPINE,

TOGETHER WITH

ANALYSES OF THE

WATERS FROM THE DIFFERENT SOURCES

EXAMINED.

WATER COMMISSIONERS' OFFICE,
TROY, N. Y., *February* 13, 1872.

HON. WM. J. MCALPINE, *Pittsfield, Mass.*

DEAR SIR :

You are requested to examine all of the feasible sources for obtaining an increased supply of water for this city, and report upon the cost, maintenance and comparative advantages or disadvantages of each.

The present supply from the Piscawen is an average of nearly two and a half millions of gallons daily. This is generally acknowledged to be an insufficient quantity for our present population of about fifty thousand, one-fifth of which, however, can not be supplied with the present head. A large increase of population is anticipated, causing further and greater demand for water for mechanical and other purposes. You are requested to base your plans and estimates for an ample supply for treble the present population and demands, avoiding, as far as can be done judiciously, present expenditures wherever they can hereafter be made with but little increased cost beyond what would be incurred to make them now.

In looking for this increased supply it is the opinion of our Board that the source should be capable of supplying not less than fifteen million gallons daily, whenever that quantity shall become necessary.

Your attention is particularly called to the highland sources of water to the north, also to the south and east of this city ; also, to the procuring of a supply from the Hudson River. You are also requested to present any considerations in regard to the quality of the water from each of the sources examined.

It is desirable that your report, estimates, &c., shall be presented as soon as can be, having due consideration for all the questions involved.

Respectfully yours,

THOMAS SYMONDS,
RICHARD F. HALL,
Committee in behalf of the Water Com'rs.

To Messrs. Joseph Fales, Thomas Symonds, Lyman R. Avery and Richard F. Hall, Water Commissioners of the City of Troy.

Gentlemen :

The above attached letter of instructions has been received, the necessary surveys have been made, and I now proceed to furnish the estimates of the probable cost of procuring an additional adequate supply of pure and wholesome water from the various sources indicated in the letter referred to, and those which are reasonably accessible or available.

In 1861 I reported, to the then Board of Water Commissioners, at some length, upon the general subjects embraced in your letter, the important portions of which were published in the proceedings of the Board that year.

The growth of the city, or rather of its demand for water, as stated in that report, has been shown to be reasonably accurate by the annual progressive rates of consumption during the subsequent eleven years. It has been found in Troy, as in all other American cities, that the rate of consumption, *per capita*, including the increased demand for household purposes, for machinery, for city uses, but above all, by the leakages from old pipes and wastefulness by the consumers, has considerably increased ; and hence the source of supply then reported upon, the Piscawen, with all of its adjuncts, is now found to be insufficient to meet these demands, including those produced by an increased population, and a more extended use of the water.

In the following report I shall have occasion to quote from my former one, and in some cases to modify the opinions therein expressed, to correspond with the present experience and additional information which twelve years has developed.

THE SOURCES AND THE QUALITY OF WATER.

Water, in its three-fold condition of vapor, liquid, and solid, performs some of the most important functions in the natural and artificial purposes of life.

In the *first*, invisibly associated with the air, it nourishes vegetation, protects the land from the oppressive rays of the sun in hot weather, and warms it in cold weather; in the *second* condition it forms one of the components of almost every substance in nature*; and in the *third*, it protects vegetation, and prevents the injurious effects of the low temperature, which gives to it a solid form, and furnishes man with one of the most agreeable of modern luxuries.

The parent source of all the fresh water upon the earth is the ocean, and the atmosphere is the vehicle by which it is conveyed over, and precipitated upon, the land; from whence, after performing its various functions, it flows back to the sea, to be again exhaled and distributed over

* "The extent with which water mingles with the most solid bodies is wonderful.

"The glittering opal is only flint and water. Of every four tons of earth, one is water. In every plaster of Paris statue there is one pound of water to every four pounds of chalk.

"The air we breathe contains five grains of water to each cubic foot of its bulk, and a healthy man consumes nearly two cubic feet of air per minute. The potato contains seventy-five per cent, and the turnip ninety per cent of water, while the cucumber and melon contain ninety-six per cent.

"The human body is one-half water, or, chemically speaking, is composed of forty-five pounds of carbon, with the nitrogen and a few other elements, diffused through five or six pails full of water."

the land. This system of the circulation of water, in its vaporous and liquid form, has thus continued for ages.

The amount of the watery vapor which can exist in the air is always determined by the temperature of the latter. As this increases the air becomes capable of more absorption of the vapor, and as the temperature is diminished, the air is compelled to discharge its excess in the form of water.

The temperature of the air is constantly changing between summer and winter, between cold and warmer days in each season, between daylight and night, and with the changing direction of the winds from the south or north, from high or low land; all producing periodical, annual, daily, and even hourly changes, which cause the air to discharge its absorbed waters, or renders it thirsty and fitted to re-absorb them.

On one day, the human system finds itself overcharged with moisture, starched linen and paper is limp, and the skin is moist and clammy. On the next, the skin, and especially the lips, are dry or parched. All other animal and vegetable life is affected in like manner. In the latter it produces the growth and ripening of life, and its absence the decay.

The atmosphere is, then, the immediate source to which we must refer for the supply of all water, not alone that which is required for the promotion of animal and vegetable life, but also the vastly larger quantity which irrigates our fields, supplies our mechanical power, and forms the channels of our interior navigation.

The amount of watery precipitation upon any particular district of the land, depends upon its contiguity to large bodies of water, the direction and extent of its elevated grounds, and the direction and temperature of the prevailing winds.

Generally this precipitation is greatest in the tropics, and diminishes towards the poles; but there are some remarkable exceptions, like the rainless districts south and east of the Mediterranean, and those of Western Mexico, and along the western slopes of the Andes.

The winds, apparently so capricious, are governed, in a general way, by certain fixed laws. The increasing temperature, and rate of velocity of the rotation of the surface of the earth, from the poles toward the equator, give the first general direction to the winds. These great currents, encountering the elevated ranges of land, are deflected and produce eddies and irregularities near the surface of the earth; but there will, in all places, be found a general direction to the winds. The warm atmosphere from towards the south, moving over the ocean, absorbs its moisture and discharges it upon the land in the form of dew, rain, or snow; and then, returning to regions of more warm temperature, is again warmed and renews its absorption of watery vapor, which it again discharges upon the land.

The rain fall in the tropics is from one hundred and fifty to three hundred inches per annum, the most of which takes place within a few months; the fall in one week being sometimes equal to the whole annual fall in the temperate zones.

The average rain fall over the State of New York is thirty-five inches, with a range of from twenty-two to forty-two inches, and in the Hudson valley is about thirty-six inches, and upon the adjacent hill slopes, forty inches.

The rain guage which was kept at Troy by the late Dr. Thomas Blatchford, for many years, and subsequently by Mr. J. W. Heimstreet, gives a mean of nearly thirty-nine inches, and a range of thirty to forty-two inches.

The water which is precipitated upon the earth is, in part, absorbed by growing vegetation, and the remainder flows off, through the superficial water courses, to the brooks and rivers, and to the ocean; or it penetrates the porous soil in drops, which unite together beneath the surface in threads, veins and strata, which descend until they meet some impenetrable stratum of earth, or rock, over which they flow subterraneously and reappear in seeping places, springs, and sometimes in streams of considerable size.*

*** In the neighborhood of the ocean, or other large bodies of water, the rain fall on such pervious earth as sand or gravel, flows off sub-**

Springs derive their supply from the aggregation of these rain drops which have penetrated the porous soil; and wells are merely the interception of these underground threads and veins of water; while ponds and lakes are formed, in depressed places, by the same drops collecting in a mass, over a substratum of soil or rock, through which they can not percolate, and then the water rises to the brim of the natural water-tight basin, and flows over in a brook or river.

Water is never found, in nature, in a perfectly pure condition. In its vapory form it has a strong affinity for the gaseous substances with which the air is charged from effete matter; and in its liquid form it is a solvent of almost all substances with which it is brought into contact, upon and beneath the surface of the earth.

Water is most pure when it is first evaporated in mid-ocean, but as the vapory winds are driven over the land, as before stated, it absorbs the gases which are encountered in the air, and when it falls to the earth and flows over or beneath it, it takes up, in solution, decaying vegetable and animal matter, and the earthy salts and other injurious soluble substances. Rain-water, falling through a pure atmosphere, as outside of towns, upon a clean surface, is the most pure form in which it can be found. That which falls upon a pure sandy soil, free from vegetation, is the next most pure. Vegetation and animal life, while growing, are absorbents of that which is deleterious to animal health in either air or water, but in decay they give out that which is noxious to both. Surface-water is, therefore, the least pure

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terraneously, on precisely that slope which is necessary to give the water a head or descent sufficient to overcome the friction of the particles of earth through which it runs. This subterranean slope is steeper during the rainy season, and flatter at the end of a long, dry spell. In the sand and gravel soil of Long Island, New York, I found it (from a great many measurements), to be from five to eight feet per mile.

Through the Dismal Swamp, in Virginia, and the Pocosin which surrounds it, I found that the water slope was from two to four feet per mile, as carefully determined by the level of the water in the wells and swamps, taken in a dry time, and the rise which occurred in them during the rainy season.

in the autumn, when vegetation begins to decay, and the most so in the winter and spring, when but little decomposition occurs, or when vegetation is growing: while springs and wells, and all of those waters which sink below the surface, and flow subterraneously, derive their principal impurities from earthy solutions, and are nearly equally impure at all seasons of the year, and in the proportion of the presence or absence of soluble materials in the soil or rocks.

Where what is called surface-water passes rapidly over a hard and impenetrable soil, as that of rocks, hardpan, or even frozen ground—that is when the water-shed is steep—it is in contact with these materials for so short a time that it does not absorb much of the organic or inorganic matter on the surface, and hence flows off through the natural streams with but little contamination. But where the rain-water flows slowly over a gently sloping surface, or over loose, cultivated and unprotected soil, it receives much serious contamination. If there are no intercepting pools of still water, it is found very turbid, and unfit for domestic use; and if these pools exist, it receives not only the vegetable contamination of former years, and now in a state of decay, but also its coexistent condition of decayed animal matter. Although the analytical chemists are unable to discover the presence of the latter in any recognized form, the fact remains that they *do* exist in the water, and often in combined forms, some of which are noxious and some are innocuous.

A recent authority on this subject very justly says: "A chemist or an engineer, fairly versed in analyses, can hence tell, from examination of the water of a district, what its geology is, or if he knows its geology he can describe its waters. Even the layman need not long doubt."*

The foregoing description of the natural operations to which water is subjected, is necessary, to enable us, by the exercise of commonsense and ordinary judgment, to deter-

* "Wonders of Water," from the French of Gaston Tissandier. (See appendix.)

mine, among several sources, which is the best for a public water supply to a city.

From high authority it appears that, as in so many other so-called scientific cases, a careful examination of the facts, and good judgment, lead us to safer conclusions than would be derived from mere theory, as this term is usually understood.*

"The characteristics of a good drinking water," says Professor Chandler, "may be enumerated as follows:

"The temperature should be at least ten degrees lower than that of the atmosphere, but should not be much lower than forty-five degrees Fahrenheit.

"It should be free from taste, except perhaps a slight pungency from oxygen and carbonic acid, which is an advantage. Taste is, however, a poor guide. When one becomes accustomed to a certain water, that which is pure tastes flat by comparison. Fifty grains of chloride of sodium (common salt) in a gallon, would hardly affect the taste perceptibly."

A third requirement, is freedom from smell. "This should not be apparent even when a bottle, half filled, is placed in a warm place, for a few hours, and then shaken. It should be transparent, not that it is necessarily *poisonous* if not transparent, but it is preferable to take our solid food in other forms."

"*Sometimes* water may contain peaty matter from swamps, or vegetable matter from new reservoirs, which is not necessarily unwholesome."†

The Professor adds that "the Sanitary Congress of Brussels decided that water, containing *more than thirty-five grains of impurity in one gallon is not wholesome*, and that there should not be *much more than one grain of organic matter*." * * * "The quality of the impurities is more important than the quantity."

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* (See note in the appendix.)

The above stated conditions, with some modifications and additions, may be taken as the absolute requirements of a public water supply.

The eminent author before quoted (Tissandier), says that "water may be considered good when it is fresh, limpid, inodorous, not inclined to become turbid when boiled, when it leaves but little settlement after evaporation, when its taste is sweet and pleasant, and neither salt or insipid, when it dissolves soap easily without forming clots, and when it boils vegetables well."

Purity, softness and limpidity, cover the whole ground.

The sources of fresh water may be examined under the heads of rain water, spring water, the waters of wells, ponds, lakes and rivers.

The three named first are the usual sources of private supply, and the others of a public water supply to towns and cities.

Tissandier says: "Rain water, when first collected, is not, indeed, absolutely pure, but is the purest to be found in nature. It has, however, the defect of not holding any calcareous matter in solution, of not being nutritious, and of not containing sufficient air in solution; hence it is insipid, and of a sickly, sweet taste."

"Cistern water, employed in countries which are deficient in springs and rivers, does not answer these requirements (referring to those above stated of good water), for the rain which trickles down the roofs of houses carries along with it organic and mineral substances. It is true that this matter chiefly sinks to the bottom, and the water becomes, comparatively, pure after resting a few days; but it may be changed again by the decomposition of the organic matter which takes up and carries away the oxygen it contains, and this leaves only an insipid, disagreeable, and highly deleterious liquid."

"Well and spring water, also, is rarely pure, for the pure water of the heavens is itself one of the most eager of drinkers. If there be impure gases in the air through which it passes, it absorbs them. If there be earthy or mineral salts in the earth through which it soaks, it will absorb these also."

"ACCORDING TO THE NATURE OF THE SOIL, THEREFORE, WILL BE THE NATURE OF THE SPRING OR THE STREAM."

"If the water falls upon granite, slate, or the like formations (where it can lie for only a short time, or can pass over quickly, dissolving nothing), it will be pure. * * * Even the laymen can no longer doubt as to the comparative quality of water from such sources."

"The water of ponds and pools, rich in decomposed organic matter, has an odor so disagreeable as to unfit it for table use. Springs, lakes, rivers, wells or cisterns are the only reservoirs of drinkable water; but the ingredients of the water they contain are so different that it is a serious question to which of them the preference should be given." * * * "*The soft water of rivers is the impurest of all, save only the briny flood of the ocean.*"

"They betray, even to the eye, their impurities in bright colors. Streams that pass boggy lakes, or peaty regions, emerge as brown as they are bitter."

"Man, however, has not only become accustomed to these solid additions to his daily beverage, but seems to reward himself, after a while, by a special taste for such waters."*

I have been led to make the above extracts from Tissandier, because the facts and opinions therein expressed are so exactly in accordance with those which I expressed to your Board more than ten years ago, and in subsequent publications, that I preferred to use his words rather than to repeat my own. Nevertheless, I will add a few remarks on points which are not explicitly stated, or which are in addition to the extracts above given.

The atmosphere over a city is always contaminated with the gaseous products of combustion, and those arising from decaying animal and vegetable matter, and garbage which is strewn over vacant places so freely; and from manufac-

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* I have, in a few cases, slightly changed the American translation, to render the author's ideas more clear or more consistent with the same ideas expressed in other parts of the treatise.

tories, slaughter-houses, and sewage matter—all of which are constantly sending upward volumes of noxious gases, which the descending rain water rapidly absorbs, or which are condensed in the upper strata of the air, and are precipitated upon the roofs and surface of the ground, where they will be absorbed by the first fall of water.

The roofs are covered with these substances, and with soot, dust from fœcal matter in the streets, and decaying woody fibre on shingled roofs, and metalic oxides on metalic roofs. The rain water absorbs all of these, and when stored in close cisterns loses its æration and becomes insipid, and unless cooled with ice is repugnant to the taste.

That such water is very impure is evident from the rapid production of animalculæ in it, which shows the abundant presence of the food necessary to maintain that minute but vast quantity of animal life.

Spring water is rarely found in a city, and is the least pure of the waters of the neighborhood, while, outside of a city, it is much more free from impurities.

The temperature of water from deep-seated springs is that of the earth at such depth, which is about the mean temperature of the place for the year. At the point of issue, the temperature of spring water changes a little with that of the season. Spring water is usually highly charged with air, and this, with its low temperature in summer, and high in winter, compared with that of the atmosphere, renders it grateful to the taste. The earthy salts in such water frequently render it more pleasant to the taste, but they are not always healthful.

Water from wells in cities is always unfit for drinking, and in most cases is very deleterious to health. These contaminations are not the less real because they are not usually observed.

The gases of dissolving matter frequently impart a sparkling life to well water, and a small mixture of earthy salts adds a flavor, and, with a temperature lowered by ice, induces many to express a preference for such mixtures over more pure but, to them, less palatable water.

This popular fallacy often forms one of the strongest objections to any scheme of public water supply. Investigations have been made, all over the country, which show that some of the most serious diseases arise from the use of well water in cities.

In times of cholera the progress and fatality of this disease has been traced, in a vast number of cases, directly to the use of impure water from certain wells, and their analyses, compared with that of other waters in the same cities, often show why this frightful disease is promoted and rendered more fatal by the use of such impure water.

From what has been said before, it will be seen that well water becomes charged, during its precipitation in the form of rain, with all of the dissolving gases in the city atmosphere; and on the surface, with the solutions of decayed animal and vegetable matter, and mingled with the drainage of stables and privies which have entered the soil, all of which combine to render such water a most disgusting solution.

Several analyses which I have had made of water taken from wells where the soil and other circumstances were similar to those of your city wells, show impurities of twenty-five to thirty-five grains to the gallon (equal to the half of one per cent), of which one-half is from organic animal matter, exactly similar to that derived from sewers and cess-pools.

Analyses of cistern-waters, in other places, have shown them also to be very impure, and when not well ventilated they frequently become exceedingly offensive.

The cause of this offensiveness is well known. It is nature's method of purification. The vegetable and animal matter which water has absorbed is dissolved, and all of its lighter portions are thrown off in the gases which are so evident to our senses.

Hence I am warranted in the assertion that stored cistern water is certainly unwholesome, and generally loathsome and unfit for use.

Water from wells is rarely found soft enough for washing, and resort is, therefore, had to cisterns of rain water. It has been ascertained that in the use of soap the difference between well water and tolerably pure brook water, is equal to one dollar per annum for each inhabitant, and a saving equally great will be made in the wear and tear of the clothes.

It will follow, from this discussion, that all of the water which is obtained from wells is that which the excavation intercepts as it flows subterraneously through the soil. The quantity which any well will furnish depends merely upon the area of the land which drains into it, and the porosity of the soil to receive and store it.*

The waters of rapid brooks, and rivers, become highly charged with air; but their currents abrade the banks and bottom, and take up, in suspension, the alluvial matter, which renders them turbid, and, in that condition, unfit for domestic uses. When such water is discharged into a lake, or artificial reservoir, and allowed to stand quiet, it precipitates all the heavy portions of such suspended matter and becomes clear and limpid.

These rapid streams also gather and carry forward with them a considerable amount of vegetable matter, the specific gravity of which is the same as or less than that of the water; when the water becomes quiet, these matters float on the surface, and a warm atmosphere dissolves them into gases, which arise and are driven off by the winds, and a process of self-purification goes on which greatly improves the water thus stored.

It is often asserted that the impurities of water may be removed by filtering. In most of the filters in use the operation is merely to separate such matter as is held in mechanical suspension, or where the molecules are larger than those of the water; but they will not remove that which is chemically united with it. Turbid waters may be

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* The available rain fall, over the well occupied portions of the city of Troy, is about equal to an average of a million of gallons a day. A continuous well or trench along the river, would not intercept the whole of this quantity, and any other system of wells would not obtain one-fourth of it. After a long period of dry weather such wells would only furnish an insignificant amount of water.

rendered clear by filtering, but the best filter is quiesence, such as in a natural lake, or the engineer's imitation thereof, a reservoir.

The reservoir, or lake, also performs another important service in purification which artificial filters can not do. When the water is kept quiet, all foreign matter which is heavier than it is precipitated to the bottom, and if the water is deep enough it is no longer subject to decomposition; and all that which is lighter floats, and, in warm weather, is dissolved into gases, which the wind drives away, leaving the water in its most pure condition.

Filters to separate the matter chemically united with the water are expensive, and must be changed with the constantly changing condition of the water, and, practically, are never kept in use for any long period of time.

Carbon filters are used to absorb the impurities, but their capacity of absorption is, comparatively, very small, when providing for a household which consumes a hundred gallons of water daily. English experiments show that this quantity of impure water will fill up such filters in a few days, and thereafter they will be useless until the charcoal has been deprived of these absorbed impurities.

Objections have been made to water which has been stored for use in reservoirs in some of our cities, because, at intervals of several years, it has become defiled for a few days during the warmest weather.

This defilement is generally produced by the rapid production, either of animalculæ or of aquatic vegetation, the seeds of which, perhaps, lie dormant within the body of the water, or are carried to it by the air, and are generated when the water has remained stagnant, at a high temperature, for a considerable time, and, probably, when the atmosphere is in a certain electric condition. The conjunction of all the causes necessary to generate this minute life occurs only at long intervals of years, and then only exists for a few days.

The first fall of the temperature, or the first brisk breeze, destroys the conditions necessary to maintain this ephemeral life, and following a general law of nature, it dies, and dissolves into gases as quickly as it was generated, and in a few days the water is as pure as before.

This class of aquatic vegetation, and also animalculæ, are brought into life and propagate with astonishing rapidity.*

The original purity of water is no protection against this contamination, though it doubtless lessens its extent and frequency.

It has been stated, with some degree of probability, that the appearance of such excessive quantities of these animalculæ, or of the minute aquatic vegetation which is sometimes found in water, is due to the sudden destruction of either one or the other; that all water is full of minute seeds, or spores of both animal and vegetable matter; and that nature has provided that exquisite adjustment by which animal life is produced sufficient to consume the vegetable matter, by which means the water is kept pure; and whenever, from any cause, there is a sudden destruction of animalculæ, the vegetation becomes excessive and decays in large quantities so as to defile the water. These creatures are, therefore, nature's aquatic scavengers.

Again, if from any cause there is a sudden destruction of this minute aquatic vegetation, the animalculæ die suddenly, for want of food, and their decaying bodies poison the water.

Stored water, however, always carries on a system of self-purification.

Water does not receive or part with caloric freely, and, when stored in large and deep bodies, maintains nearly an equal temperature at all seasons of the year.

The fierce rays of the noon-day sun, and currents of hot air in contact with the large body of water in a reservoir,

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* Rain water, which one day shows no evidence of animal life, will the next be found teeming with animalculæ. In hot weather the body of a dead animal will, in a few days, become a mass of living matter; and the shallow, stagnant pools of water by the way side, under the influence of great heat for a few days, will be covered with "frog spittle," a species of vegetation. Another of this class

would be tempered by that of the cooler nights and less warm days, so as to give a lower temperature in summer and a higher one in winter; and this water, conveyed in pipes below the surface of the earth, will be delivered at the houses at a very pleasant and equable temperature.

Professor Silliman says that decomposition does not take place to a depth of more than ten feet below the surface of the water.

Whenever water is collected in lakes or reservoirs, and especially when these lakes are large, compared with the water shed, the coloring matter will be mainly removed by the bleaching effect of sun-light—the only practical method of removing color from water.

I regret that I have been compelled to devote so much space to this branch of the subject. It has been necessary to meet certain prejudices, and popular, but incorrect, opinions, which are commonly met with in discussions of this character.

NOTE.—The appendix to this report contains extracts from authoritative writers on the subject of water. These are too voluminous to print, but they will be useful to the Board for reference.

Some of these extracts are, however, so pertinent to a proper consideration of the question that I have marked them specially, so that you may publish them if you deem proper.

THE QUANTITY OF WATER REQUIRED.

Among the Romans, who imported their customs from the East, water was considered one of the greatest luxuries of life, but it was confined to the rich. In the twelfth century, in Paris, the Court and the rich merchants only could indulge in its free use.

As late as the sixteenth century this city only furnished its inhabitants with an average of a *pint and a half a day;* and this was entirely drawn from the River Seine, into which was discharged all of the sewage of what was then a populous city the size of Troy. Although the Roman Emperor, Justin, more than ten centuries earlier, had built an aqueduct for good water, from Arcueil, it had, in the year fifteen hundred and fifty, gone into decay and disuse.

Nearly a century later, the whole supply of water to the citizens of Paris was but five pints a day to each inhabitant. For half a century the Government were discussing the question whether the Roman aqueduct should be rebuilt or the water pumped from the Seine. The latter plan prevailed, and the pumps were located *below the discharge of all the city sewers.*

In the eighteenth century, during the French revolution, the water supply was increased to *twenty pints a day* for each of half a million of people.

At the beginning of the nineteenth century the aqueduct of Ourcq was commenced, and completed in eighteen hundred and thirty-seven, and it, until very lately, furnished more than half of the water used in Paris. Five years ago I examined the plans and route of a new aqueduct of greater size, which was to bring water from a distance of over sixty miles. This work is also now completed.

I have given this history of the water supply of Paris, as it has been the pioneer city of Europe in the questions of modern water supply and sewerage. The history of the water supply of London, would be merely a repetition of that of Paris, except that its improvements have been made at later dates.

At present, London is chiefly supplied with water from the Thames and New River, and the experts (often in the interest of the monopolizing water companies), insist upon the purity of the waters from these rivers, into which flows as much sewage as there is into the Hudson River. Schemes for a supply of pure water from Wales and Cumberland, more than two hundred miles distant from London, *are now being discussed*, and they will, doubtless, ultimately be carried out.

The following table shows the present supply, in gallons per day for each inhabitant, from several of the European cities:

Imperial Rome, in the first century,	300 to 340	gallons.
Modern Rome,	207	"
Carcassonne,	88	"
Manchester,	50	"
Marseilles,	41	"
Genoa,	31	"
Liverpool,	30	"
Edinburgh,	30	"
Glasgow,	22	"
Geneva,	16	"
Madrid,	16	"

In American cities of large size, like New York and Boston, the distribution exceeds an equivalent of one hundred gallons per day to each inhabitant; that is, this amount, *per capita*, gives the whole consumption of water for domestic and mechanical purposes, for shipping, for the extinguishment of fires, cleansing of sewers, sprinkling of streets, leakage of pipes, etc., etc., and this rate is applied to the whole of the population, whether they be consumers, or beyond the area of distribution.

In eighteen hundred and sixty-one I stated that, "The population of Troy, now furnished with water, is estimated at twenty-five thousand, and the amount of water distributed at from one and a quarter to one and a half millions of gallons daily, which gives from fifty to sixty gallons to each person, including the items of expenditure above named."

If the consumption above stated, had been applied in the usual way, to the whole of the inhabitants, and not merely to the consumers, the daily average would have been from thirty-two to forty gallons *per capita*.

This rate of consumption, ten years ago, would have fairly represented that of other Northern American cities, situated as Troy is. Meanwhile it has been found that the distribution has had to be increased one-half more than was then required.

In many cities the managers have attributed the excess to the wasteful use by consumers, while if they had sought for the true source of the evil, it would, at least in great part, be found in the continuance of old and leaky pipes.

It is only necessary, for one acquainted with the manufacture of iron, and of pipes, to understand the miserable quality of the former, and the bad character of the latter, to show that water pipes which were laid many years ago (and even some of those now used), have rusted and actually worn through, and with the innumerable leaky joints, which have been caused by neglect in the first laying, or by disturbances from excavations, etc., for sewers, gas pipes, and drains, to show where ten times as much water is wasted as that which is caused by unnecessarily opened faucets.

I further stated, in the report of eighteen hundred and sixty-one, that whenever the whole of the then present population of thirty-eight thousand six hundred and ninety-three became water consumers, they "would require two millions of gallons daily; and when it increased as estimated (to seventy-five thousand consumers), it would require three and three-quarter millions; about one-fourth of which tions were intended to furnish fifty gallons a day, supplied to the consumers.

In making similar estimates now, the Engineer is compelled to use a larger co-efficient of consumption, and for safety to apply it to the whole of the estimated population, because he has to provide not only for a more generous use of water for closets, baths, etc., but also for more wastefulness in domestic consumption, for more uses for mechanical purposes, but, above all, for the leakage from old pipes of bad metal, and leaky joints, none of which, by the best present system of police supervision and management can be avoided.

If the present population be taken at sixty thousand, and a supply of sixty gallons *per capita* be applied, it would require three millions six hundred thousand gallons to be distributed daily, on the average, and on some days during the year perhaps one-fourth more.

It is usual, in such cases, to ascertain a source which will supply at least twice the present population, which would be, for Troy, a little over seven millions of gallons daily.

The present supply from the Piscawen, with the aid of the several retaining reservoirs, is now furnishing an average of from two to two and a half millions; but, in the seasons of the least rain-fall, it can not be counted upon for more than two millions, and therefore we must look to sources which can supply at least five or six millions more.

By your instructions I am required to seek for a supply of at least ten millions of gallons, with the means of increasing it to fifteen millions if it shall be hereafter required.

THE PROPOSED SOURCES OF SUPPLY.

Accompanying this report, is a map showing the drainage areas of each one of the streams, north of the city, to the Hoosick River, and south to and including Wynantskill.

On this map is given the number of acres of land, which shed their waters into each of the intervening streams, and the *average* number of gallons daily, which each would furnish above the level of the several places, where these streams would be intercepted.

These averages are made up upon the plan of storing all of the available rain-fall, and allowing none of it to run to waste during the seasons of the greatest fall of water.

In none of these valleys (except the Piscawen, and that not to its full extent) is it possible to store up any considerable quantity, compared with the whole volume of the stream, of what would otherwise be waste or surplus water.

It is, therefore, necessary to make some assumptions, to ascertain the approximate quantity which these streams, unaided by artificial retaining reservoirs, will furnish during the seasons of low water.

In this argument it may be safely considered, that comparatively small natural or artificial reservoirs, on either of the streams in question, will be sufficient to cover the cases of extreme low water or drought which usually continue only for a month or so.

There is a general rule that the low water of small streams (excluding that of very extreme low water) is equal to one-third of the mean annual flow. This rule must, however, be judiciously applied. Where the water-shed is over porous soil, and with flat slopes, the proportion is considerably greater; and when the water-shed is over impervious soil or rock, the extreme low water is comparatively less than in the case just stated.

While there is a general similarity in the water-sheds of all of the streams in question, yet there is a difference between those north and those south of the city. At near the sources of the latter, there is a table land on which there are many small natural lakes, which act as retaining reservoirs, and tend to equalize the flow of the water in the stream below, so that in seasons of drought they furnish a daily supply comparatively greater than the streams north of the city. The steeper water-sheds of the latter, send down the floods more quickly, and the impervious soil prevents the subterranean reservoirs, which elsewhere furnish a supply of water so much more abundant during the dry seasons.

After considering the circumstances of the case, I am of the opinion that the minimum flow of the streams north of the city (in the sense above stated) may be taken at one-fifth, and of those south, at one-fourth of the average flow of the year.

The following table shows the areas of the drainages and the average estimated flow daily from each of the streams referred to:

TABLE.

Name of stream.	Water-shed. Acres.	Average daily flow. Gallons.
Piscawenkill,	1,363	2,028,169
Deepkill,	4,461	6,636,778
Tomhannock,	35,565	52,913,311
Poestenkill,	43,692	65,006,147
Wynantskill,	18,257	26,948,628

Upon each of the streams in question, there are several sites where retaining reservoirs may be built, by the aid of which any amount of water can be provided for, nearly up to the maxima averages above stated.

With the reservoirs now built on the Piscawen, and the proposed new distributing reservoir, the times of extreme low water of the other streams may be bridged over, and a supply of eight or ten millions be assured, beyond all question, even in the dryest times.

The Tomhannock, Poestenkill, or Wynantskill, will, therefore, each furnish the largest possible supply that can reasonably be anticipated for the city.

It will also be seen, from the above table, that Deepkill would, for many years, furnish the additional quantity desired, by the aid of such storing reservoirs, as can be easily and cheaply made.

This creek would be intercepted by the conduit proposed for bringing the waters of the Tomhannock to the Piscawen and the high distributing reservoirs, and its present use will not prevent an extension of the same work to the Tomhannock, whenever it is required, without the loss of any considerable sum, which may be at first expended in bringing it into use.

Leaving this question for the present, we have before us the three streams—the Tomhannock, Poestenkill and Wynantskill. The latter has not been instrumentally examined, because its water-power is exceedingly valuable, and rendered more so by the large retaining reservoirs which the parties interested have constructed.

The annual mean quantity of water which the Tomhannock and Poestenkill will furnish, is so nearly alike that they may be so considered, and as each of them exceed by twice the highest estimates of supply asked for, the question of their sufficiency in the driest times (above referred to) need not enter into the present examination, especially as there are means of correcting the low water deficiencies (if they should ever occur) by some inexpensive retaining reservoirs.

The works required to bring in the waters of the Poestenkill would be nearly three miles of brick conduit of three feet diameter, and with a slope of three feet per mile.

Those for the Tomhannock would be combinations of brick conduits, iron pipes, and uncovered but lined and paved canals, altogether making a distance of nearly thirteen and a half miles.

If these works are only extended to Deepkill the length will be eight miles.

The length of the covered parts of the work will be about the same on each of the plans, so that it is evident that the cost of the outlay to build the work to the Tomhannock must exceed that of the Poestenkill by a sum nearly equal to the cost of the ten and a half miles of uncovered work on the former.

All of the water-power of the Poestenkill is now occupied by valuable factories, upon which much of the present and future prosperity of the city depends, and an abstraction of so large a part of the water from this stream, as must ultimately take place, would seriously injure one of the most large reparation which must be made to the owners of water property.

This abstraction will be attended with far less expense upon the Tomhannock, and the difference in this item becomes a proper charge to be added to the cost of the Poestenkill plan.

This subject, as well as that of the actual outlay required to construct the two plans, will be presented in another place in this report.

It remains to speak of a third source of supply referred to in your instructions, viz., from the Hudson River.

I have received no specific instructions or opinions from the Board as to the place where the water should be taken from the River, but there can be no doubt but that it should be taken at least as high up as above the State dam, and above the sewage discharges from Troy, and almost as little doubt that it should be taken from the more pure waters above the sewage of Lansingburgh, Waterford and Cohoes, and the less pure waters of the Mohawk and canals.

I have accordingly arranged the plans and estimates to bring the Hudson River water from near Waterford, by a conduit along the river bank to a convenient place to locate forcing pumps, which could deliver the water into the proposed high distributing reservoir, at the same elevation as has been calculated for the Tomhannock and Poestenkill plans.

As will presently appear, the estimates show that the additional supply demanded, will cost as much or more present outlay of money from the Hudson River plan as either of the other plans named, and if to this is added a sum, the interest of which will keep the engines in operation and repair, and renew them when worn out, the whole cost of this plan becomes actually more than twice the cost of either of the others.

From the discussion in a preceding part of this paper, it must be evident that the quality of the water even above Waterford, must be greatly inferior to that which the mountain streams contiguous to the city will afford.

The Water Commissioners of Albany, under the advice of Professor Chandler, have recommended the use of the Hudson River water, even after it has had the pollution of the contiguous populous cities of Troy, West Troy, Lansingburgh, Waterford, and Cohoes, and of the Erie and Champlain canals, all of which discharge their sewage and other impurities directly into the Hudson.

They have chosen this source in preference to that which can be obtained from the elevated contiguous sand regions where nature has formed just such filter beds, upon the grandest scale, as are artificially made to render the Thames and other European waters fit for domestic use.

This decision in Albany has rendered it necessary to examine, somewhat critically, the character of the Hudson River water, as without such authority in its favor, public sentiment alone would be sufficient to decide against its use, at least upon this part of the Hudson.

In the appendix will be found voluminous extracts from foreign and domestic authorities, and even from Professor Chandler, showing not only the impure but even dangerous character of such river water as that of the Hudson at this place. The citations of the use of the Thames water for London; the Seine for Paris; the Connecticut for Hartford; the Schuylkill for Philadelphia, and the cities along the Ohio and Mississippi rivers, are all met and answered by the fact that at each of the cities named, new inland sources have been obtained, or are now being sought for, to escape the pollutions which must necessarily exist in river waters, bordered by their usual dense populations.

Even on theoretical grounds it is found to be impossible to prove, or at any rate to convince the commonsense of the public, that such waters are fit for domestic uses. The analytical chemists themselves admit that their science does not enable them to detect the presence of some very poisonous matters in water, among which are portions of sewage and other matter, which have carried the impregnations of that frightful disease, cholera, with diarrhœa, dysentery, and fevers, to all those who have used such

These facts are so well known, not only to physicians, but to the intelligent public, that it seems to be almost unnecessary to argue the question further.

The water companies of London, Paris, and some other places, where arbitrary power has conferred a monopoly of this most necessary element, water, have for centuries succeeded in producing such an effect upon those who control, as to disguise almost plain facts, and to obtain certificates from really scientific men. In this country we are more free from such influences, and the man of science is forced to meet the man of judgment on the fair field of argument. Hence there are here but few of the dangers to be apprehended that prevail in the older countries.

It is sufficient, however, to refer this question of the comparative quality of the waters of the Hudson and the highland streams to the judgment of the citizens of Troy, even without the additional argument of its extra cost.

These reasons seem to settle the question that the proper source of supply should be from the highland streams.

THE DISTRIBUTION TO THE CITY.

In eighteen hundred and sixty-one, one-fourth of the population resided above the level which the pipes and plans then in operation could furnish.

Since that time the population in this unsupplied district, has largely increased, and from its healthy locality, beautiful views, and convenient building grounds, it will doubtless become a favorite place for the residences of the citizens, especially as the lower portions of the town are now over-crowded with stores, workshops and buildings required for workmen. The continued extension of these must compel the removal of other residences, northward, across the river or upon the beautiful plateau in the rear of the University.

From these considerations I am inclined to believe that the early future demand for water above the level of the present supply, will be nearly or quite equal to that which is now furnished below that level, and that this proportion will hold good for many years to come.

The plans proposed for the highland streams supplies, are arranged to deliver the water at an elevation of three hundred and thirty feet above tide, into a reservoir which will contain sixty-six millions of gallons.

This elevation will supply all of the houses now built upon this plateau, and those which may be built on Burdett Avenue with from 30 to 40 feet head, and of course those upon the lower grounds of the plateau with a corresponding increased head.

Where the conduit from the Tomhannock crosses the Piscawen, the surplus water, or any other amount that may be desired, can be conveniently delivered into it, to supply any present or future demand on the lower service.

The present service starts with a head of 110 feet above tide at the Piscawen, and furnishes water under 62 feet head above the level of the street at the Water Commissioners' office. The pipes from this service should be extended up the Piscawen to the lower Oakwood reservoir, which would increase the head, throughout the city, by 142 feet. This extra head would, doubtless, burst many of the old, rotten, decayed pipes, but it would, probably, result in as much good as harm, by necessitating the removal of a great number of leaky pipes and joints, the waste from which, in a few years, would be equal to the cost of replacing them.

The Poestenkill plan contemplates a conduit to enter the proposed high distributing reservoir at the same elevation as the Tomhannock plan.

In each plan there are two services contemplated; the Upper, which will furnish water to a level somewhere about one hundred and seventy-five feet above tide, and the Lower service will furnish all that part of the city below the above mentioned level, or rather where it will give to all of the houses a head not less than the one hundred and seventy-five feet.

The Oakwood reservoir, connected with the pipes as before suggested, will furnish a large body of water which can quickly be distributed to all portions of the city where the lower service-pipes are laid down, if it should ever be needed during large conflagrations. In like manner the proposed high distributing reservoir will contain a still larger body of water which may be quickly distributed by the upper service-pipes.

The two services may at any time, in case of emergency, be connected in the same manner as I arranged at Albany, so that the large volume of water in the high distributing reservoir, with its very great head, may be applied almost instantly to all of the pipes and fire hydrants in the city, whether they are in the upper, or lower service.

This arrangement might possibly save immense losses of private property. It will bring a strong pressure upon the house service-pipes in the lowest parts of the city, and endanger any that are weak, yet there may be some extraordinary exigency where this risk would become justifiable.

DESCRIPTION OF THE PLANS.

I. FROM THE TOMHANNOCK.

The water will be taken out of the creek just east of the covered bridge, in the town of Pittstown, and conveyed by brick conduits, iron pipes and an open canal, lined and paved with stone, to the high distributing reservoir, on the high lands east of the city.

At the creek there will be built a "Beaver dam" (of trees, brush, stone and gravel, with hydraulic stone-masonry abutments and bulkhead), provided with screens and gates, from which a brick conduit, of five hundred feet length, will be extended.

There is an excellent site for a stone dam, about five hundred feet further up the stream, where the bottom is rock. This dam would cost about the same as the Beaver dam.

To avoid unnecessary injury to the fine meadow lands above the dam, the water will only be raised two feet higher than the low water of the creek.

As a protection against the great floods the abutments will be built three feet higher than any previous known height of water, and from them will be extended guard-banks to where the highest ground is above the highest floods.

The conduit and canal, for half a mile below the dam, will have a guard-bank, raised three feet higher than the highest known floods.

Wherever the canals are introduced all surface-water will be excluded from them by ample side ditches connected with a series of culvert passages under the canal, and, in most cases, similar ditches and culverts will be made along and under the brick conduits.

The open canal will be fenced, throughout, with gates for the use of the farmers.

Bridges, of ample and convenient size, will also be made for their use.

The aqueduct water will be conveyed under all of the highways in brick conduits.

The brick conduits, of an aggregate length of eight thousand feet, will be used through all of the long, deep cuttings, over the minor ravines, and in other places where there is danger of injury, or too much exposure in the canal.

The deep ravines will be crossed by iron pipes of an aggregate length of four thousand feet.

Where the pipes are used there will be covered chambers of stone masonry, into which the canal or conduit will enter or leave upon one side, and the pipes from or to on the other side, and regulating gates, and waste weirs, and pipes introduced in the chambers.

These chambers will each have three pipes of eighteen inches diameter inserted, but two of them will be plugged up, and but one pipe carried across the ravines at present. Whenever a greater demand for water is made, the second pipe can be put in, and finally the third one.

The canal will be made with a cross section equivalent to four feet width of bottom, five feet depth, and slopes of one and a half to one: the water being calculated for three and a half feet depth though another foot of depth can be put in if ever required.

The fall of the canal will be six inches per mile, giving a mean velocity of one and three-tenths feet per second, which is not sufficient to move fine gravel.

The canal prism will be first excavated to receive a puddle lining of six inches thickness, and when it and the paving are put in they will give the sectional area above stated.

In some places where suitable gravel can easily be procured, the canal slopes and top will be lined with clean screened gravel, instead of the stone pavement.

The canal and ditch prisms will be finished off on concave lines, and the top banks on convex lines, being the outline form of prism which an unprotected canal of this kind would take by long use.

These canals, with the water three and a half feet deep, will discharge twenty-seven millions of gallons of water per day.

With the velocity which the water will have, ice will not, in the coldest weather, form more than one foot thick, and the canal reduced even to two feet depth (that is, with the ice one and a half feet thick) will still discharge ten millions of gallons.

As before stated, the surface of the water can be safely raised from six to twelve inches, and thus increase the capacity of the canal to twelve or fifteen millions.

The brick conduits will be circular and made of two concentric rings, each of four inches thickness, laid in hydraulic cement mortar, plastered on the outside, and on the inside with nice pointing of the joints, and cement washing.

Where the conduit joins the canals, protecting wings of masonry and puddling will be put in, and where the conduits pass under the highways a third ring of brick will be laid on the upper semicircle.

These conduits will slope at the rate of three feet per mile, and will discharge, when full, ten millions of gallons of water a day. An extra head of one to one and a half feet can be given to each one, and its discharge increased to twelve or fifteen millions.

The pipes will have a head of two and a half feet in one thousand, or at the rate of thirteen and a quarter feet to the mile, and the three will then discharge ten millions of gallons daily. In the same manner as with the conduits the head of water may be increased one or two feet, and thus increase the discharge to twelve or fifteen millions.

One pipe will deliver three and a third millions, with a fall of two and a half feet in one thousand, but this may be increased, as above stated, to five millions.

The pipes will be laid down in the ordinary way, but with check-guards to prevent them from sliding on the steep side hills, and a blow-off water gate placed at the bottom to scour out any sediment which may be collected at the lowest place.

At the pipe chambers screens will be placed to intercept leaves in autumn, and floating objects, and a waste weir and discharge pipe to carry off these things and prevent overflow.

The whole length of the canals is..................	12.04 miles.
The whole length of brick conduits is..............	1.51 "
The whole length of iron pipes is..................	.75 "
Total distance from the high distributing reservoir to the Tomhannock,..............................	14.30 miles.

II. FROM THE POESTENKILL.

The water would be conveyed from the Poestenkill to the high distributing reservoir by a brick conduit of three feet in diameter, fourteen thousand three hundred feet long, and on a slope of three feet per mile, and in passing the cemetery, by iron pipes of eighteen inches diameter, eight hundred feet long, and on a slope or head at the rate of two and a half feet per one thousand feet, the total distance being two and eight-tenths miles.

The conduits, pipes, and chambers will be arranged as before described for the Tomhannock plan.

The dam to divert and control the water which is let into the conduit, will be of stone masonry laid in hydraulic cement mortar, and with guard-gates, and screens, as before described.

The dam will be placed just above the toll-house bridge where there is a foundation and sides of rock.

For half a mile below the dam it will be expensive to build and maintain the conduit against the floods, as the valley is only wide enough for the passage of the creek, and the banks are rocky and precipitous.

III. THE HUDSON RIVER PLAN.

As before stated, the water would be taken from the river above Waterford, and conveyed in a conduit to the skiff ferry, a short distance above the State dam, where the well and pumping works would be placed.

The force main would be a mile in length and two feet in diameter, and would deliver the water into a small reservoir, from which it would be conveyed to the high distributing reservoir by a canal and pipes, as described in the Tomhannock plan.

The pumping machinery would consist of a compound cylinder condensing steam engine, the largest cylinder being fifty-two, and the smaller one thirty inches diameter, designed for steam at fifty pounds.

The diameter of the pump piston would be twenty-eight inches.

This is the cheapest form of pumping machinery, and would deliver six million gallons of water in twenty-four hours, into the reservoir, situated three hundred and thirty feet above the level of the tide, requiring a perpendicular lift of three hundred and ten feet, and a representative frictional head of ten and a half feet.

The engine, when working steam as above stated, would be equal to four hundred horse-power.

The duplicate steam engine would be non-condensing, of one-half the above power.

The duration of such machinery would be about twenty-five years, and would require a present investment equal to eighteen and four-tenths per cent of its cost, at seven per cent per annum, compound interest, to renew it.

IV. DEEPKILL PLAN.

No instrumental surveys have been made of the last mile of this line, or of the dam and reservoir, but an approximate estimate can be arrived at, which, added to the cost of the Tomhannock line south of the place of the departure of the Deepkill line, will furnish sufficient information to determine whether this plan is worth further examination.

The whole lenth of the line would be about eight and a half miles, including seven and a half miles of the Tomhannock line. The upper mile will be more costly, as it generally follows along the steep banks of the kill, where, comparatively, more length of condnit must be employed. But as the canals and conduits will be required to discharge but two-thirds as much water, they may be made of less size.

The cost of a storing reservoir must also be added to this plan. If the plan should be determined upon the land for this reservoir should now be procured, but it would not be necessary, for several years, to build the dam to its full height.

THE ESTIMATED COST.

I. THE TOMHANNOCK PLAN.

The conduit, pipes, and canals from the Piscawen to the Tomhannock creek.

CONDUIT,

Of brick, 3 feet interior diameter; two rings of 4 inches each; fall 3 feet per mile, 7,700 feet long:

Brick masonry, laid in hydraulic cement mortar, will cost 75 cents per cubic foot, or $20.25 per cubic yard:

7.68 cubic feet brick masonry, 75cts......	$5.76		
35 cubic ft. excavation at 1c. per cub. foot,	.35		
25 cubic ft. back-filling at 1c. per cub. foot,	.25		
Add extra,............................	.14		
7,700 feet of conduit at..................	$6.50	$50,050	
Head walls at the ends of Conduits:			
23 cubic yards of masonry, $10,...........	$230		
600 feet foundation, $50,...............	30		
Paving, etc.,.............................	10		
14 end connections at....................	$270	$3,780	$53,830
PIPES CROSSING RAVINES,			
Of cast-iron, 18 inches diameter; chambers at each end, arranged for three pipes, waste, etc.			
4,000 feet of iron pipe, laid,..............	$5.60	22,400	
Pipe-Chambers:			
16 cubic yards of masonry, $10,..........	$160		
500 feet of foundation, $50,..............	25		
Covering 22.5 sq. feet, 40c.,...............	9		
Excavation, screens, gates, etc.,...........	46		
8 pipe-chambers,.........................	$240	1,920	
4 blow-offs,..............................	50	200	
Steps on side-hills,......................		280	24,800
Amount carried forward, ...			$78,630

Amount brought forward,..........................			$78,630
CANAL.			
187,000 cubic yards of excavation and embankment,..............................	30c.	56,100	
5,000 cub. y'ds of rock excavation,........	$2.00	10,000	
22,500 " " " puddling,..............	70c.	15,700	
25,000 sq. " " paving, ...	40c.	10,000	
6,250 bub. " " gravel lining,..........	50c.	3,125	
6,000 " " " excavation, side ditches,.	25c.	1,500	
50 cross drains of 40 ft.=2,000 feet of 8 in. pipe,..................................	$1.00	2,000	
50 farm bridges,..........................	$75	3,750	
15 road bridges,.........	$150	2,250	$104,475

NOTE.—A covered conduit at each of these bridges would cost almost exactly the same as the bridges, and would never require renewal.

NOTE.—The cost of this canal is $1.81 per foot.

DAM AT TOMHANNOCK :			
225 cubic yards of brush and gravel,.......	$3.00	$675	
4,500 feet of apron,.............	$50	225	
150 cubic yards gravel on slopes of dam,...	$1.00	150	
Stone protection at foot of apron,...... ...		25	
100 cubic yards of masonry,...............	$10	1,000	
Foundations, etc.,........................		525	2,600
Bulkhead :			
36 cubic yards of masonry,......	$10	360	
700 feet of foundation,.	$50	35	
Excavation and embankment,.............		75	
75 cubic yards revetment walls,............	$3.00	225	
Screens, gates, &c.,.......................		105	800
Guard-banks, etc., to high land, say........			500
			$187,005

NOTE.—A stone dam would cost nearly the same as above estimated for a Beaver dam.

The line from the Piscawen to the High Distributing Reservoir :			
6,200 feet long, including 200 feet pipe at Hoosick road.			
6,000 feet of canal,..	$2.00	12,000	
500 feet of pipe crossing Piscawen and Hoosick road,..............................	$5.60	2,800	
4 pipe-chambers,.........................	$240	960	
2 blow-offs, ...	$50	100	
Adjustment to discharge the Tomhannock water into the Piscawen,...............		140	$16,000
Amount carried forward,........................			$203,005

Amount brought forward, ...			$203,005

THE HIGH DISTRIBUTING RESERVOIR,

and inlet and outlet pipes, ...			65,000
72,000 cubic yards of embankment, ...	30c.	$21,600	
8,000 " " " puddling, ...	30c.	2,400	
6,000 " " " clean gravel on bottom, ...	$1.00	6,000	
5,000 cubic yards of slope wall, ...	$2.50	12,500	
Inlet and outlet passages, ...		6,000	
Land, 27 acres, ...	$500	13,500	
Fencing, 4,200 feet, ...	50c.	2,100	
Seeding banks, etc., ...		900	
		$65,000	
Land and right of way, ...		$24,120	
11.4 miles of fencing, both sides, ...	$1,000	11,400	35,520
			$303,525
Add for the superintendence and contingencies, ...			30,352
			$333,877

II. THE POESTENKILL PLAN.

A brick conduit of three feet diameter, 14,300 feet long from the dam to the high distributing reservoir, with pipe of 800 feet length in passing the Cemetery.

14,300 feet of conduit, as before, ...	$6.50	$92,950	
1,000 feet of side-hill rock excavation, extra,	$3.00	3,000	
5,000 feet of other excavation, extra, ...	$1.00	5,000	
			$100,950

Dam and Bulkhead:

150 cubic yards of excavation, including rock, ...	$1.00	150	
700 cubic yards of masonry, ...	$15.00	10,500	
2,000 " " " gravel on slope of dam,	75c.	1,500	
Bulkhead, gates, screens, etc., ...		850	
			$13,000
Land and right of way, ...			3,600
2.65 miles of fencing (one-half), ...	$500		1,325
			$118,875
The high distributing reservoir, ...			65,000
Amount carried forward, ...			$183,875

Amount brought forward,		$183,875
The connecting pipes, with the present distribution at Eighth street.		
4,000 feet of pipe, 24 inches diameter,	$9.00	36,000
		$219,875
Superintendence and contingencies,		21,987
		$241,862

III. THE HUDSON RIVER PLAN.

A wing dam in the Hudson, near Waterford, to divert the water into a conduit of three feet diameter and two miles long, to a pump-well directly west of the Piscawen, crossing by the Tomhannock line; an engine and pumps at the river, and a force main of two feet diameter, one mile long, to a small reservoir, and a canal and pipe to the high distributing reservoir.

RIVER CONDUIT :

Wing dam in Hudson,		$10,000	
10,560 feet of conduit,	$6.00	63,360	
Pump-well,		10,000	
Houses for engine, boiler and coal,		21,000	
Chimney,		4,000	
Engine, pumps, boiler and duplicates,		100,000	
Small reservoir, near the Piscawen,		10.000	
5,280 feet of force main, 2 feet diameter,	$9.00	47,520	
3 check-valves, 2 gates, connecting pipes,		4,000	
			$269,880
Canal and pipe from the Piscawen to the high distributing reservoir,			14,500
Land, right of way, etc.,			25,000
			$309,380
The high distributing reservoir,			65,000
			$374,380
Superintendence and contingencies,			37,438
			$411,818

The annual cost of running this engine, to deliver six millions of gallons of water per day, would be as follows :

4,380 tons of coal,	$5.00	$21,900	
Oil, tallow, and waste,		1,000	
Engineer and assistant,		2,200	
Two firemen,		1,500	
Two laborers,		1,000	
Repairs,		1,000	
			$28,600

This sum, capitalized at 7 per cent, is	$408,571
The sum which, compounded at 7 per cent for twenty-five years, would be necessary to renew the machinery, would be,	$18,400
These two sums, added to the first outlay,	411,818
Shows the whole representative cost of pumping from the Hudson, as compared with the Gravity plans, to be	$838,789

To the cost of the Gravity plans is to be added the damages to the existing mills, and to the water-power upon the several streams.

It is not considered judicious to present these estimates in detail, and it may be considered as sufficiently accurate, for the present purpose, to state that these damages will be more than half a million of dollars greater upon the Poestenkill than they will be upon the Tomhannock plan, and if the whole of the water of these streams should be taken for the city, this difference will be increased two or three times.

A comparison of the estimates will then be—

I.	The Tomhannock Plan,	$333,877
II.	The Poestenkill Plan,	741,862
III.	The Hudson River Plan,	838,789
IV.	The Deepkill Plan,	300,000
V.	The Wynantskill Plan,	590,000

In conclusion I have to report that the Tomhannock plan possesses advantages over all of the others in the economy of its cost, and the purity of its water, and is equal to any of the others in the abundance of water.

I take this opportunity of stating that all of the field-work has been made under the direction of Professor D. M. GREENE, who has either made or aided me in making all of the calculations and estimates, and has materially assisted in the preparation of this report.

His knowledge and skill in his profession has been given to these duties, and I have never been more usefully or agreeably associated with another Engineer than I have been with him.

MR. GREENE deservedly stands very high in his profession, and has an honorable and high career before him, and I hope that, when you determine to build the works, they may be intrusted to his hands.

Respectfully submitted,

WM. J. McALPINE.

TROY, September 26, 1872.

ANALYSES OF THE WATERS.

WINSLOW LABORATORY R. P. INSTITUTE,
November 13, 1872.

To the Board of Water Commissioners of the City of Troy.

GENTLEMEN:

I have, as requested by you, made a careful quantitative analysis of the four following waters:

1st. A sample taken from the city reservoir near Oakwood Avenue;

2d. A sample taken from the Tomhannock at "Chase's," a point about twelves miles from this city;

3d. A sample taken from the "Rifts," on the Hudson river, near the Waterford bridge; and

4th. A sample taken from the Poestenkill near the toll bridge on the Brunswick road.

These waters were collected by Mr. Chapin, the superintendent of the Waterworks, on the 2d and 3d of October last. Their analysis was immediately commenced and continued until they were finished. They all contained but a trifling amount of suspended matter, which was allowed to subside, and the determinations made in the settled waters.

The following table shows the result of the analyses of these waters.

The weights given are in grains and decimals of a grain to the imperial gallon of 277.2 cubic inches.

TABLE.

	Reservoir.	Tomhannock.	Hudson river.	Poestenkill.
Color in one foot tube,	Slight yellow.	Slight yellow.	Gre'nish yellow.	Reddish yellow.
Taste at 30° C. (86° F.),	None.	None.	Boggy.	Boggy.
Oxygen absorbed by organic matter from Permanganate of Potash,	.0784	.0742	.2884	.2128
Hardness on Clark's scale,	7°.4	2°.37	3°.16	2°.42
Total solid contents,	8.4560	4.4160	5.1968	3.6260
Inorganic matter,	6.6080	4.2560	3.7128	2.940
Organic matter,	1.8480	0.1600	1.4840	0.6860
The inorganic matter contains the following:				
Chlorine,	.0490	.0791	.0749	.0847
Sulphuric acic, SO_3,	.2686	.3268	.2398	.1425
Silica,	.5278	.5684	.5684	.4144
Lime,	2.9801	1.1489	1.1409	.7522
Magnesia,	.1551	.3231	3.594	.1859
Oxide of iron, alumina and phosphates,	.0210	.0361	.0266	.0267
Potassa,	.1414	.0875	.0546	.0644
Soda,	.2079	.2114	.1204	.1659

It will be seen from the table that the constituents are given as found, without combining the bases with the acids, as the chemist may hypothetically consider them to exist in solution in the water. They are, undoubtedly, combined and exist as chlorides, sulphates and bicarbonates in the waters. From the small quantity of inorganic matter present in all these waters it can be seen that nothing but the lime and magnesia present will exercise any effect on their character as regards their economic use.

Experience proves that these two substances act beneficially on the human system when found in as small or even larger proportions than as are found in these waters. Their most important bearing is, however, as regards their effect when the waters are used for washing and cooking purposes, and in steam boilers. It will be seen from the table that the water now in use by the city is much harder than that obtained from the other sources. This fact is due to the greater quantity of lime contained when compared with the others, the hardness of water being almost directly proportional to the quantity it contains of lime and magnesia. A somewhat larger quantity of soap or bicarbonate of soda will be necessary to render the reservoir water soft than with the other waters, as each degree of Clark's test corresponds with a grain of carbonate of lime in the gallon, and which requires about ten grains of soap to combine with it and form an insoluble precipitate. A smaller quantity of bicarbonate of soda will produce the same effect. The presence of this soap lime precipitate, in any quantity, is found to interfere with the easy cleansing of clothes by water so contaminated. As most of the lime and magnesia probably exist as carbonates in these waters the hardness will be much lessened by boiling them, which will cause a precipitation of some of the lime and magnesia. For culinary purposes the best waters are those that are quite soft, as the presence of lime salts, particularly sulphates, prevent edibles from becoming soft when boiled.

The presence of a considerable portion of lime is, however, beneficial in tea-making, as the lime prevents too much of the bitter principle of the leaf from being dissolved. The amount of lime present in each of these waters shows them to be suitable for cooking purposes. For use in steam boilers these waters will, undoubtedly, cause incrustations of carbonate and sulphate of lime and magnesia, but not in as large quantities as from waters obtained from such sources as springs and wells in this vicinity. The silica, alumina, oxide of iron, soda and potassa, found in these waters, are not in sufficient quantity to exercise any influence on their quality.

THE ORGANIC CONSTITUENTS.

The organic matter found in river waters, in many cases, determine their qualifications for drinking purposes. In these waters the total amount of organic matter has been determined, and also a determination of the oxydizable matter contained in the organic matter. The total amount of organic matter was determined by evaporating a measured quantity of the water to dryness, heating the residue which remained to 160° C. and weighing; then igniting this residue, by which means the organic matter was burned off, with a slight amount of the carbonic acid in the inorganic matter which was restored, by moistening the residue with a saturated solution of carbonic acid in water and drying at 160° C. The difference between the weight found in this case and that obtained by the first weighing gave the weight of organic matter. As is customary, owing to the small amount of organic matter, and also its complex nature, no systematic analysis of it has been made. To determine the quantity of oxydizable or putrescent organic matter contained, a dilute solution of permanganate of potash was added to a slightly acidulated portion of these waters, and allowed to stand for three hours without heating.

Owing to the property of giving up oxygen to produce oxydation which this permanganate has, if there be any organic matter brought in contact with it which is in a decomposing state, it will be oxydized by the permanganate and its nature rendered harmless. This decomposing portion of the organic matter contains many of those substances which render it injurious for drinking purposes. It will be seen from the table that, although the reservoir water contains the largest quantity of organic matter, the oxydizable amount is much smaller than in the Hudson river or the Poestenkill. The Tomhannock, as will be seen, contains the least organic matter of all, and also the smallest oxydizable amount. In evaporating large quantities of these waters, in the course of analysis, some things were noticed in reference to the organic matter present which it may be well to mention here. The waters taken from the reservoir and Tomhannock had, in their natural state, but little color, and by the concentration of several gallons to a small bulk but a slight yellow color was observable in either, and a slightly peaty odor. The Hudson river and the Poestenkill, however, when treated in the same manner, became of a dark reddish color, resembling, in many respects, a solution of tan bark. For laundrying purposes these colors, in the last mentioned waters, might prove objectionable. The superior quality of laundry work done in this city is considered, by several scientific observers, as due, in a great measure, to the clear quality of the water used. A second specimen of water, taken from the Tomhannock on the 9th of October, was quite different, in appearance, when compared with the first. It had a slightly turbid appearance, and seemed to have considerable organic matter in solution. No determinations of organic matter were made in this specimen, as they had already been completed in that first taken. The different appearance of this second specimen is, probably, due to the fact that there had been rain on the day previous to which it was collected, and was what would naturally result from such a cause.

MICROSCOPIC EXAMINATION.

In order to make the examination of these waters as complete as possible a microscopic analysis was deemed necessary, and at my request Dr. R. H. Ward, the distinguished microscopist of this city, has made such examination, from whose report I quote as follows:

"The practical and not inconsiderable value of a microscopic examination in such cases is to determine what portion of the organic and inorganic constituents exist in a solid form, and to determine the nature of such constituents * * * * I have examined the four waters above mentioned, both in the samples submitted to me by you, and in other samples from the same sources directly obtained by myself.

"They all appear, under ordinary circumstances, reasonably pure and clear, and, like all other waters that are fit to drink, when examined in small quantities reveal, only occasionally, the presence of living inhabitants, or of other solid bodies. There is scarcely a greater folly than the nearly universal belief that good drinking water swarms with living things." * * * * "The living organisms in these waters are both vegetable and animal forms." "The plants are chiefly, if not exclusively, protophytes, volvocineæ, desmids, pediastræ, diatoms, palmallaceæ, and a variety of zoöspores and confervoid growths." * * * * "Nearly all of these are so minute as to be invisible to the naked eye." * * * "Many of these plants, especially the diatoms and desmids, are free from any suspicion of hurtfulness, and the general absence of oscillatoriæ is a favorable indication. The abundance of zoöspores and confervacea, however, and the prevalence, in smaller quantities, of nearly every kind of protophyte is not above suspicion, and is certainly bad as far as it goes." "The minute animals exist in almost equal variety of forms." "Of those familiarly called animalcules we have both the ciliated and flagellate infusoria, and wheel animalcules, as well as the lower and simpler forms." * * * * "The cyclops is quite abundantly represented, and is the most conspicuous inhabitant of the reservoir water." * * * "Most of the animals mentioned are harmless, and only in the case of one of these families is there an awkward uncertainty as to the effect of using food or drinks containing them."

"The visible particles other than living, in these waters, are of less importance. They are what makes the water 'riley,' as it is called. They consist, chiefly, of disintegrated wood, leaves, and of still more finely comminuted particles of rock, especially slate and limestone. They are utterly inconsiderable at most seasons, but after rains, or in freshets, render the waters muddy and disgusting. Such impurities, if not entirely harmless in food, are certainly of far less significance than would be inferred from the appearance of the water. If frequently confined to water abounding in them, however, it is a serious question what effect would be produced on the city's reputation for good laundry work." * * * * "Microscopical study shows these waters intermediate in position between the clear, hard water of springs and wells, which has but little visible impurities, and stagnant and decidedly unwholesome water which abounds in far different objects. Water from the four sources under consideration is, evidently, water of brooks and ponds, surface water, but not bad water. Such water is often more unwholesome than the clearer waters of springs and wells on account of the comparative absence of soluble and invisible impurities. As far as my observations have yet gone, the waters of the Hudson (above Lansingburgh), and of our present distributing reservoir, are about equally supplied with the impurities above discussed. The Poestenkill water is, measurably, better than these, and the Tomhannock seems to be the least objectionable of all both in respect to suspended mineral and organic impurities."

CONCLUSION.

The sources from which these waters are derived are such as preclude, with but one exception, the presence of effete animal matter, such as is contained in the sewage of cities, and which includes, undoubtedly, much that is injurious to the human system. These causes could not, if present, be detected by the chemist, as their nature is, at present, a matter of considerable dispute. A knowledge, however, that the presence of these substances is injurious is sufficient to give warning against the use of waters so contaminated. The microscopic examination of these waters does not seem to show any decidedly objectionable qualities in the suspended matter. The organisms mentioned as being found are not of a character which would render the waters objectionable for drinking and cooking purposes.

A consideration of the relative effect produced on these waters, by rains, in respect to their turbidity, seems to be a matter of considerable importance. In respect to the general qualities of these waters it would seem that the Hudson river, from its situation, would be the one most liable to contaminations of sewage matter from growing towns on its banks at points above this city. It is possible, however, that the purifying power contained in the water itself would render these constituents harmless before reaching this point. The Tomhannock seems least open to these objections both from its situation, and as the result of analysis shows that there is but a small quantity of oxydizable organic matter present. The Poestenkill water, owing to its slight taste and decided color, does not seem to present as good characteristics as the others. The Reservoir water, but for its considerable hardness, is of a good quality for technical and domestic uses.

Respectfully yours,

EDWARD NICHOLS,
Assistant in Analytical Chemistry.