REPORTS

TO THE

COMMITTEE OF THE COMMON COUNCIL,

ON THE

AQUEDUCTS, &c. FOR SUPPLYING THE CITY OF ALBANY WITH WATER,

FROM THE MOHAWK RIVER;

AND

FROM THE HUDSON RIVER.

BY W. M'CLELLAND CUSHMAN,

CIVIL ENGINEER.

ALBANY:

PRINTED BY W. AND A. WHITE AND VISSCHER.

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1842.

To the Honorable the Common Council of the City of Albany:

THE Committee on Wells and Pumps, to whom was referred the matter of ascertaining the expense of bringing a supply of water to some point on the hill, beg leave to submit the following Reports of the Engineer employed by the Committee for that purpose.

J. I. JONES, ***Chairman.***

January 24, 1842.

TO MESSRS.

JOSHUA I. JONES, THOMAS BLANK, H. STANTON,
J. MERRIFIELD, CHARLES H. OLMSTED,

Committee of the Common Council for introducing supplies of Water into the City of Albany.

GENTLEMEN,

Agreeably to the arrangement investing me with the responsible charge of engineer of the several *projets* for introducing adequate supplies of water into the city, I have now the honor of laying before you my report upon the most eligible plan and location of that route which contemplates taking the supplies from the Mohawk river "at or near the Cohoes," together with a map, profile and plans illustrative of the topography of the district occupied by the aqueduct, of its design and construction, and of the works therewith connected.

One of the first requisites previous to an actual commencement of the business of designating the local position the aqueduct should have, was to determine what height of fountain head at the city would be required for the purposes we have in view, viz. abundant supplies of pure and soft water for the use of the whole city for domestic purposes; for the more expeditious and effectual extinguishment of fires; and for the other incidental purposes usual in cities enjoying advantages and elements of prosperity such as Albany possesses.

In settling this question satisfactorily, I have been materially assisted by levels and fixed marks, of which I was previously possessed; from having been the engineer who conducted the survey for the railroad many years since, over the table upon which the upper part of this city is built. This being the most elevated district, that altitude which would serve for its supply, is of course adequate to every other section of the city.

The highest building upon this table is the store house (commonly known as the "Point Store,") standing on the point formed by the intersection of Washington street and the Schenectady turnpike, and opposite the west end of the Park; of four stories in height, and having been erected expressly for an extensive warehouse, at a time when the bulk of business which now passes north of the city up the canal, passed west, over the turnpike; the elevation of this building is certainly quite as high as any building now occupying the suburb to the west of it, or which may hereafter be erected in that quarter of the city. The eaves of this store were found to be elevated 251.609 feet above common high tide in the Hudson. I am also able to state with confidence, that this elevation is 25 feet higher than the turnpike opposite the cottage of Mr. Van Schaick, situated a few rods east of the "Two mile house."

If then the level of the fountain head is placed at about 250 feet above tide, it will deliver water into the highest chambers of the city, and even upon the roofs of the most elevated buildings of any quarter of the city. All economic purposes would therefore be accommodated perfectly by a fountain head of this elevation.

But for the extinguishment of fires, effectually and expeditiously without other power than that derived from the head of water, it will be necessary to command a greater head than would suffice to deliver water upon the roofs by a hose or conduit pipe reaching to the roof itself. It should be great enough to force upon the roofs a *jet d'eau*, by means of a short hose applied to the hydrant, and without the intervention of ladders, &c. and of course with almost instantaneous effect.

By no manner of contrivance however can fluids be made to issue from such a pipe or any other orifice, with the full theoretic velocity due the head of fluid; and the motion of the jet must inevitably be still further reduced by the resistance of the atmosphere in its ascent after issuing from the orifice or pipe. Both these circumstances modify considerably the height of the jet. But all experience proves that fires may be arrested in their early stages with little trouble or assistance, which would spread devastation in every direction before ladders, lengthy hose and a competent force to manage them, could be provided.

The efficacy of the work in respect to fires, must, it is obvious, be greatly impaired if the plan does not provide more head than would be adequate for economic purposes; and as an additional ten feet at the fountain will enable us to accomplish this most important purpose as perfectly as it is possible by any exertion of power or upon any plan whatever, however expensive, I had no hesitation as to the propriety of establishing this level of the fountain head, and of course in giving other parts of the general design such dimensions, power and capacities as were suited to this view of the objects which it seemed to me obvious should be answered by any work of the kind, of a character intended to ameliorate, to any very essential degree, the present condition of the city.

Location of the aqueduct. The plan and principles upon which the line and profile of the aqueduct proper, were established, are perhaps sufficiently exposed in what follows.

I regarded the plan of a continuous channel of masonry, vaulted and covered with earth, as a protection from our climate—the channel of which is alone occupied by the water, and requiring a very expensive graduation besides, to render it operative, as too disproportionate in point of expense to the cost of supplying the city from the Hudson and other streams, to require any estimate or particular examination; and although my surveys prove beyond a doubt that an open channel or canal might be made at a comparatively moderate expense, between the site of the reservoirs and this city; yet that plan appeared to me too likely to fail in point of efficiency, in this climate, (at least where the volume of water is not far greater than we require,) to risk its construction.

Looking merely to the isolated fact of hydraulics, that water will rise to the level of its fount, an underground conduit, following and undulating with all the inequalities of the surface of the earth, could, I doubt not, be made to answer for a period; but my own experience has convinced me of its liability to become obstructed entirely by sediment, arrested and deposited at the low points—a defect that would, in my opinion render it but an intolerable expedient after a short time, for conveying the supplies from the Mohawk.* The rationale of the deposit

* Some 8 years since the late Judge Buel put down a conduit upon his farm on this principle, the line of which crossed a swale of lower level than either extreme of the pipe. I suggested the application at this point of an apparatus, on a suitable scale, but similar to that designated a "roil chamber" in this report; it was not however appended, and the consequences anticipated ensued, the pipe soon becoming entirely useless.

is obviously this, the friction of the current carries such particles as find their way into the conduit along with it, until meeting with a slope opposed to the current, the gravity of the particles down that slope overcomes the friction of the current, and arrests its progress at the foot of the slope—which of course corresponds with the low point of the valley. Doubtless there is a specific velocity which would propel particles up any given slope; but the subject has never before, I believe, been noticed, and the velocity requisite to force deposited particles up the steep slopes of the series of valleys intersected by a line of conduit, is of course unknown. I am satisfied however from personal experience, that it must be much higher than can be commanded on this or any work of similar extent and capacity.

Every low point might not, and doubtless would not simultaneously become obstructed; but as the place of an obstruction could not be ascertained, it is obvious a single obstruction would be quite sufficient to cut off the supplies of the whole city, beyond the prospect of remedy or relief for weeks, a contingency, the happening of which when most if not all wells would have been dispensed with, can only be contemplated with horror; and which *must*, in my humble judgment, be placed beyond the pale of possibility.

In this dilemma a method occurred to me enabling me to dispense with the great excess of metal usually put in pipes, but which is not usefully employed in sustaining the pressure produced by the head of fluid; and as the expense of conduit pipe laid in conformity with this principle, of sufficient strength and calibre, would not be so formidable as if the usual plan was pursued, the best possible plan applicable to this route which occurred to me, was to employ a conduit of cast iron as the immediate duct for conveying and protecting the water from waste and impurities. To obviate all risk from depositions of sediment in the duct and of interruption to the regularity of the supplies consequent thereon, I further proposed as a first and indispensable condition, to assume absolute control over whatever of sediment the water might contain, after being introduced within the conduit—by forcing it to move onward with the current, continually, till it had reached a convenient point for its detention and removal from the conduit. With this view, vertical bendings and undulation with the surface were excluded as a general thing, and in lieu thereof the conduit was sustained upon a continuous slope or inclined plane, always descending from the reservoirs towards the city, or with the current, until the proper place for its detention occurs; and so on from point to point, descending continually and as uniformly as is consistent with a suitable location in other respects.

Suitable places for arresting the sediment swept along these graded planes of the duct, occur wherever the line crosses the more spacious valleys. At *such* points, instead of sustaining the duct upon high or expensive embankments or works in masonry, it is intended to sink the level of the duct to conform nearly to the surface of the side slopes of the valley across which the route is directed, and again rising upon the opposite side, another plane of gradual descent is projected. The opposition of gravity to the motion of the particles up the latter slope, will produce the deposition of them in the bed or lowest point of the valley.

In order that the flow of water in the conduit may not be impeded by the accumulation of sediment at this point, the size of the pipe is there increased to a degree sufficient to contain the deposition of a given period—until for instance, a decrease of the supplies is observed; it is then expelled from the duct by means of a sluice and wicket attached to the expanded section, which, when opened, allows the water in the pipe to escape with great force and velocity, carrying with it the deposit of sediment.

Besides being absolutely indispensable, for the reasons alleged, to the action of the conduit, these sections become incidentally of much use in purifying the water more perfectly than is otherwise possible. They will therefore be subsequently alluded as *depurating sections* and the enlarged portion of the duct as *roil chambers*.

The wicket is easily manœuvered by an attendant. When again closed after venting, the flow again goes on to its destination at the city and until the time of reopening comes round.

To ensure that entire certainty of effect which is considered requisite, the roil chambers must be raised upon light embankments high enough at least to elevate the wicket just above the bed of the valley crossed, and thereby give full liberty to the rush of water for clearing the chamber from its incumbrances.

The projections accompanying this report will afford all satisfactory illustration of the plan and mode of action of the roil chambers.

The grading of the route in conformity with the plan and views which have just in a general way been indicated, will consist, over a great majority of the distance, simply of a trench—upon the bottom of which, the conduit will be laid, at a depth sufficient at every point at least to prevent any interruption from the influence of frost. Light embankments will maintain the gradual slope of the conduit at such other points as it is deemed preferable to cross the valleys of lesser extent in that way, to increasing the length of line to too great an extent, or to incurring the expense of roil chambers, &c. necessary, as already fully explained, at every point where the level of the conduit is allowed to sink below the gradual slope or inclined plane.

The result of a particular course of examination with instruments, fully confirmed impressions formed on a preliminary reconnoisance, as to the practicability of building the aqueduct on this plan in every essential particular. It has been deemed expedient however, since the location of the route was effected, to sink the level of the conduit at one point between the banks of the Patroon's creek and the northern extreme of the line, and to locate a depurating section there in preference to embanking; and also to relieve the grade by varying from the plane of uniform slope at one or two points of an extra depth of trench work.

The route may be described as pursuing the valley of the Hudson, running as high up on the west slope of the river as practicable, with the object of securing a better and less expensive position in regard to ease of graduation, as to make as directly for the northern terminus and curtail the length of conduit pipe as much as a judicious location in other respects would warrant. It is borne but once out of generally a very direct course, by a spur protruding itself from the main ridge somewhat across the line, which is met with about one mile above the Patroon's creek, and immediately after crossing the brook which at present supplies the lower section of the city with water. The length of line would be reduced to some extent if it were practicable to conduct it up this brook to near its source, and thence to strike northerly 'till a reunion with the present line could be effected. An attempt was made to effect this object, and was abandoned only when the levels demonstrated its impracticability conclusively.

Having found it advisable to begin the location upon the north bank of the Patroon's creek, nearly opposite the head of the factory pond, and to trace the line northward before locating within the city, I shall follow the same order in the few descriptive notices which I have yet to offer to your observation.

The bed of the conduit has at this place an elevation of 204 feet above tide; and the line passes through a depression of the spur putting out from the main ridge, and terminating near the Van Rensselaer manor house. The location through the neck of this spur incurs an increase of trench-work; but it is deemed preferable to circuiting around the face of the point in question, or to restricting the location of the line within the city limits, which would be the effect of the change. Within a mile from the creek, some light pieces of embankment are required, but none worthy of notice till the line crosses the Water-works brook already mentioned. Here an embankment of 16,009 cubic yards occurs, which, however, will neither be difficult or expensive to form. After crossing this brook, the line doubles round the face of the prominent spur which has already been the subject of remark; and for several miles intervening between this spur and the brook crossed a little southerly of Esq. Mitchel's on the Niskeuna road, which is 5½ miles from the actual terminus within the city, but three pieces of embankment are noticeable, and those light and readily formed. A pretty extensive stretch of trench-work, of extra depth, becomes requisite in passing a summit on the mile south of Mitchel's brook; the length of extra cutting is 3400 feet at this place, and the estimated expense of its execution 15 cents per cubic yard.

Although the character of the northern division of the line is essentially different from the city division, and more broken by gullies and ravines, but one embankment approaching 20,000 cubic yards is required, with some four others of much less extent, upon the entire distance.

At station 25, on the north bank of Water-works brook, the level of the bed of the conduit is 207.925 feet above tide; and ascends thence to station 119, a distance of 6⅓ miles, uniformly, (with the single exception already specified,) at the rate of 3.696 feet per mile—where it has an elevation of 231.547 feet above tide level.

For about a mile immediately south of the point at which I crossed the Troy and Schenectady railroad—which is near the northern terminus—an extra depth of trench-work is requisite. This is the only remaining earth-work of consequence required to complete the grading, if I except 427 cubic yards of rock excavation north of the reservoirs; which material, though approaching in several instances near to the line, I am happy to say it is unnecessary to encounter in any other instance, except where highly advantageous, as in establishing the wheel for elevating the supplies from the river.

From the station last noted, the bed of the pipe slopes more abruptly than at any other place, for a short distance, with the view previously stated, of relieving the trench-work. Thence it rises by a very gentle slope to station 131, just north of the railroad, where it has an elevation

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of 236 feet. From this place rising with the surface to the site of the reservoirs, which it enters at a level of 244 feet above tide, and 16 feet below the level of the fountain head, and at a distance of just $9\frac{3}{4}$ miles from the terminus in the city of Albany.

The line within the city. From the station on the north bank of the Patroon's creek, previously mentioned as the point of commencing the surveys, the route strikes southerly across the head of the factory pond; and thence makes almost a direct course across the table, till it strikes the turnpike in Knox-street, opposite the north end of the Park, where the line of surveys terminates.

A few remarks in explanation of this part of the routes are required. Besides offering no single advantage of which I can perceive the force, had the line been run lower down towards the river, it must have traversed the numerous ravines scooped from the table, and indenting it at various points between Fox creek and the factory pond; an idea of which may be obtained from a glance at their delineations upon the map. Such a line would besides be attended with further difficulty, in its extension southerly of Washington-street; which has appeared to me to be the best method for furnishing the immediate supplies to all parts of the city, as branches of the main duct may then be taken out at right angles, and be led down the streets parallel with Washington-street, to every quarter of the city. On the easterly line there would be some difficulty in disposing of the water vented from the depurating section, which would become necessary in crossing the valley intervening between State and Lydius-streets. None of these impediments occur upon the line pursued, which also permits me to extend the main duct southerly along Knox-street, flanking Washington square on the west, as far as Lydius-street, upon a perfect level; and, of course, without requiring any provision of the kind required upon a more easterly location.

The valleys of the Patroon's creek and Fox creek are passed by means of depurating sections.

The map and profile will present, better than words, the details of descriptive minutiæ relating to the direction, local position and connection of the routes; and the foregoing remarks should rather be viewed as glancing at the extent and local character of the work at a few points, noticeable not from intrinsic difficulty of execution, but chiefly from their comparatively superior extent over the great majority of work required. The estimates of the cubical quantity and expense of the earth-works and masonry required for the support and protection of the conduit will alone exhibit with proper fullness, the actual extent of the local difficulties to be encountered, or give a fair and palpable view of the feasibility of the work as a whole.

I found it convenient to divide the line into mile sections for the purposes of estimation; and I submit the results at this place, preserving the same division—which appeared to me better to illustrate the subject than any other—with confidence, as giving all requisite information upon this important branch of the duty with which I have been charged.

DETAILED ESTIMATES *of the cubical quantities of work required, with estimates of the expense of performing it, etc.*

SECTION I.

EARTH-WORK.		MASONRY.	GRUBBING.	PRICES.	TOTAL COST.	
No. c. yards trenching.	No. c. yards embanking.	No. of perches.	No. of rods.			
----	1108	----	----	$0.12	$132.96	
2044	----	----	----	0.13	265.72	Extra depth.
----	1740	----	----	0.11	191.40	
2911	----	----	----	0.12	349.32	Common depth.
----	----	133.0	----	4.25	565.25	
----	----	26.8	----	5.25	140.70	

Total cost of the Section, $1645.35.

SECTION II.

----	16286	----	----	0.12	1954.32	
2696	----	----	----	0.17½	471.80	Extra depth.
1804	----	----	----	0.12	216.48	Common depth.
----	----	180.0	----	4.25	890.00	Includes piling founda-
----	----	58.8	----	5.25	308.70	[tions, coffer dam, &c.
----	----	----	240	1.00	240.00	[at factory pond culv.

Total cost of the Section, $4081.30.

SECTION III.

----	19174	----	----	0.11	2109.14	
2870	----	----	----	0.12	344.40	Common depth.
----	----	172.2	----	4.25	731.85	
----	----	40.3	----	5.25	211.57½	
----	----	----	93	1.00	93.00	

Total cost of the Section, $3489.96½.

SECTION IV.

----	7277	----	----	0.10	727.70	
----	2490	----	----	0.11	273.90	
3315	----	----	----	0.12	397.80	Common depth.
----	----	248.0	----	4.25	1054.00	
----	----	56.0	----	5.25	294.00	
----	----	----	178	1.00	178.00	

Total cost of the Section, $2925.40.

SECTION V.

----	7820	----	----	0.12	938.40	
5440	----	----	----	0.15	816.00	Extra depth.
1031	----	----	----	0.12	123.72	Common depth.
----	----	149.0	----	4.25	633.25	
----	----	48.7	----	5.25	255.67½	
----	----	----	42	1.00	42.00	

Total cost of the Section, $2809.04½.

SECTION VI.

EARTH-WORK.		MASONRY.	GRUBBING.	PRICES.	TOTAL COST	
No. c. yards trenching.	No. c. yards embanking.	No. of perches.	No. of rods.			
----	3038	----	----	0.12	364.56	
4085	----	----	----	0.13	531.45	Common depth.
----	----	95.0	----	4.25	403.75	
----	----	19.6	----	5.25	102.90	
----	----	----	64	1.00	64.00	
				Total cost of the Section,	$1466.26.	
SECTION VII.						
3888	----	----	----	0.14⅓	557.36	Extra depth.
----	12630	----	----	0.11	1389.30	
----	3944	----	----	0.12	473.28	
919	----	----	----	0.13	119.47	Common depth.
----	----	174.6	----	4.25	742.05	
----	----	35.9	----	5.25	188.47½	
----	----	----	192	1.00	192.00	
				Total cost of the Section,	$3661.93½.	
SECTION VIII.						
----	10230	----	----	0.10	1023.00	
3162	----	----	----	0.13	411.06	
----	----	136.0	----	4.25	578.00	
----	----	27.1	----	5.25	142.27½	
----	----	----	95	1.00	95.00	
				Total cost of the Section,	$2249.33½.	
SECTION IX.						
2600	----	----	----	0.16¼	422.50	Extra depth.
----	19580	----	----	0.14	2741.20	
----	10510	----	----	0.12	1261.20	
1773	----	----	----	0.13	230.49	Common depth.
----	----	387.0	----	4.25	1644.75	
----	----	102.6	----	5.25	538.65	
----	----	----	116	1.00	116.00	
				Total cost of the Section,	$6954.79.	
SECTION X.						
4490	----	----	----	0.16¼	729.62	Extra depth.
1873	----	----	----	0.13	243.49	Common depth.
----	12664	----	----	0.11	1393.04	
427	----	----	----	1.00	427.00	Rock.
----	----	794.0	----	4.25	3374.50	Includes aqueduct
----	----	37.3	----	5.25	195.82½	[bridge at Troy
----	----	----	36	1.00	36.00	[railroad.
				Total cost of the Section,	$6399.47½.	
Aggregate cost of grading, etc.					$35,682.85½.	

The constructions in masonry connected with the graduation, consists with a single exception, of culverts for a majority of which but very limited dimensions are required. All the common roads are passable without any other provision than the trench-work necessary at other parts of the line. The excepted work is an aqueduct bridge required to sustain the duct in the passage of the Troy railroad. The bridge consists of a single arch of 40 feet span, and it is intended to construct it entirely of rubble masonry.

It has appeared to me the best, if not the only policy, to impart a character of permanency to every part and member of the aqueduct. All the culverts are therefore to be constructed in masonry; and as undressed rubble work, carefully executed, possesses the requisite strength and durability, in making up my estimates I have calculated upon employing this species of work for the bulk of the masonry required in culverts. Many of them may be simple trunks composed of side walls of masonry, with what may be called the plat-arch—constituted simply of flat stones laid across the water way, and resting upon the side walls. Where it has been thought necessary to arch the culverts, it is intended to employ brick work in the arches. In all cases, the prices set down in the estimates are sufficient to put up, at this time, work of the best quality.

It has not been thought necessary or proper to put in the estimates any considerable item for land or damages, because, for three fourths of the entire line of aqueduct, the conduit must lie beneath the present surface of the soil; where, of course, after refilling the trench, the surface will be just as suitable for the purposes of cultivation as it was previous to occupation for these purposes. For the remaining distance, the streams and valleys crossed have generally steep banks, with little or no bottom or tillable land; and but little inconvenience can be experienced in other respects by the erection of embankments, where necessary for the effective operation of the aqueduct. It did not consequently appear probable that owners of the soil, under such circumstances, will charge more than perhaps a nominal sum for these privileges, and the brief interruption from occupying the land during construction.

The next question refers to the quantum of water required daily for the use of the city.

The quantity necessary to supply the wants of any given number of people may be easily arrived at with all satisfactory precision; for we have positive data furnished by the experience of other cities, which establishes the quantity of water daily consumed by their inhabitants. But the engineer entrusted with the execution of a plan for bringing from a distant point, supplies of water adequate to the permanent wants of a city, must give an attentive glance at the future, in order that his plans may accommodate, or be made to accommodate at reasonable expense, the then wants of the city. It is difficult, in the first place, to settle with certainty the future number of inhabitants of a city; and it is physically impossible for any plan to be equally well adapted to the present and future demands of a city not entirely stationary.

However, as from the nature of the present plan, the supply may be augmented to almost any desirable extent, at future periods, at an expense certainly much within the ratio of increase in numbers, it is unnecessary, as it seems injudicious, to construct an aqueduct of much greater size than is required to furnish an abundant present supply. If the size of the conduit is made, in the first instance, sufficient to deliver a competent supply for the city at a period of, say fourteen years hence, I think it will be going quite as far as prudence dictates.

It is true there always are some circumstances in one city which do not obtain in another, and that these may be fairly allowed to influence, in some degree at least, the individual consumption of water ; but any disparity which may exist in the necessary consumption in cities very disproportionate in size, will obviously become less with an increase in bulk of population, and may be assumed wholly to disappear in all the larger commercial cities, in whatever part of the world situated.

I therefore set it down as certain, that the quantum necessary for each inhabitant of the city of Albany, is or will be as great as that which experience has shown to be necessary for an inhabitant of London, for instance; where the quantity daily supplied on an averago to each house has been ascertained to be exactly 162½ gallons (imperial), which is equivalent to 21 gallons to each inhabitant of the city.

If we allow the same rate of increase in population which obtained for the ten years preceding the last census, the city of Albany may be assumed to contain, at the period above fixed, 49,372 inhabitants ; and the calibre of the conduit must, of course, be at least adequate to deliver 1,036,812 gallons of water daily within the limits of the city.

Consumption does not, however, go on during the sleeping hours of the night—an intermission of, say eight hours ; and the conduit must, moreover, be capable of delivering this quantity within a lapse of sixteen consecutive hours, the day of actual consumption or occupation.

A conduit-pipe of the length of the Cohoes aqueduct, actuated by the head of fluid at command within the city limits, viz. 55 feet, must then, agreeably to the relations subsisting between the length, head and diameter of pipe, have a calibre of 17.09 inches.

The weight of metal required depends, at least in the first instance, upon the pressure within the pipe, which of course is governed exclusively by the head of fluid it sustains. It is easy, therefore, to determine experimentally the strength or thickness of metal, by applying to a section of the pipe, of the required calibre, a force equivalent to the pressure exerted within the tube by the actual head of water it will have to sustain when laid down. It is never safe in practice, however, to provide barely that thickness of metal which would withstand the pressure for the brief period of a trial of this kind; and it is always necessary to allow a large excess of strength where, as for this purpose, the strain is permanent in its action. All things considered, however, $\frac{1}{20}$ of an inch is amply sufficient permanently to sustain the pressure resulting from a head of 55 feet; that is, it would do so, provided the thickness of the metal itself was not liable to be changed, and the strength consequently impaired, by other causes than the pressure of fluid—by the oxidation of the metal, for instance.

When excess of metal alone is relied upon to meet the gradual corrosion of the pipe by rust, it is of course impossible to assign any thickness which can, with reason or propriety, be said to be permanent. Nor has experience yet furnished sufficient grounds upon which that excess which would produce any certain number of years of duration, can be predicated, and consequently we are unable to asssign with any probable accuracy, the period when the conduit would be gone to decay and require relaying with new pipe. But the method I have to propose, cuts off all debate upon this point—instead of making any provision for relaying the pipes at stated periods, at great expense, or of laying down an excessively heavy pipe in the first instance; it is proposed to obviate the necessity of either expedient by a provision designed to *arrest* the *corrosion* of the material.

The joints of conduit pipes have usually been sealed with lead. It has occurred to me however, that if zinc were used for this purpose—(a well known property of which metal is to exert a powerful preservative influence against the tendency of iron to oxidate, wherever exposed to the air or immersed in water,) the oxidation of the metal could be arrested, and the useless excess of metal usually given pipes might be dispensed with.

Lest, however, it should not be found practicable *perfectly* to prevent the formation of rust* (and I only calculate upon cutting off the material portion of the destroying influence without anticipating literal extinction,) to meet contingencies, I propose to increase the thickness

* The interior of the pipe may be lined with a coating of hydraulic cement, a remedy against accretions of oxide upon the inner surface, which has been tried with success by the French engineers.

assigned above fivefold, or to five-twentieths or one quarter of an inch. With so large a surplus of substance, we certainly may rely upon the efficacy and durability of the conduit.

The weight of metal per lineal inch of pipe, will then be 3.547 lbs. amounting to $103\frac{1}{3}$ tons per mile of conduit.

So far as experience has gone in this country in the business of casting pipe for this express purpose, I believe none exceeding nine feet in length have been cast; but very obvious and important advantages will attend the use of longer links; although less convenient to handle, it is believed there can be no difficulty in casting links of 15 feet—at least none which a more extended experience in this particular branch will not very soon surmount, especially as there are some compensating drawbacks to the founder in casting long links.

With double thickness for the lap at the joint, and a lap of 5 inches, the weight of castings per mile of finished conduit, will amount to $109\frac{1}{7}$ tons.

The expense of conduit pipe has some reference to weight of metal with a given size; and the very reduced quantity of metal required on the present plan, I had calculated would enhance the difficulty of execution, or at least the amount of labor in proportion to weight. After consulting with men of skill and experience in the business of founding, I am satisfied however, that there is no difficulty of a practical nature in executing the castings which can not be overcome by skill and caution. Thin castings do however require a greater amount of mechanical labor as well as fuel, in proportion to the weight of metal. But it is believed that an allowance of $33\frac{1}{3}$ upon the actual price paid for the execution of the heavier pipes, will pay the founder liberally for their execution, particularly where the quantity required is so unprecedently large.*

The actual price paid for executing the castings for the Croton aqueduct, is a very small fraction less than three cents per lb.—increasing this to four cents, would give the cost of our pipe a little less than $90 per ton, and for the entire length of conduit $9\frac{3}{4}$ miles, $1064\frac{1}{7}$ tons at $90 per ton is $95,772.85.

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* It is worthy of mention that thin castings have always superior consistency, and that there is no difficulty of detecting flaws and defects in such, which would escape close observation in thicker ones.

The Reservoirs: Where the supplies are to be drawn from a river at all times more or less roily, but especially so during the continuance of heavy rains and freshets, a reservoir for receiving and holding the water till a partial subsidence takes place, seems to be absolutely necessary. This reservoir should be placed as near the pumps as possible. The commanding head land or point just west of the (new) Harmony factory, has been selected as the most advantageous position, as well in reference to economy of construction, as for its proximity to the elevating apparatus.

As the water must be maintained at as high a level in this reservoir as is required for the fountain head, it is possible to employ it for both purposes. But as the continual additions to the supply forced up by the pumps, naturally tend to prevent the roil from subsiding, I think the top stratums may alone be found of sufficient purity for use. This stratum must, however, be passed into another reservoir, which will form the immediate fountain of supplies. It is also proposed to build the reservoirs immediately contiguous upon the point where the receiving reservoir has been established.

In a work constructed exclusively by the city, it would certainly be proper and extremely desirable (other things being equal,) to locate important accessory works within the city limits; but the advantages possessed by the site chosen over every other, is deemed sufficient to justify the extra-urban location. Aside however from economy in construction and security, the other location would require double the head to deliver an equal supply of water at the city.

There does not appear to be any circumstance limiting the capacity of the receiving reservoir; but the fountain of supplies must, at a minimum, always keep one third of a day's supply in reserve. But even were contingencies out of the question, it appears to me true policy to adopt the size of the reservoirs in the first instance, to the probable demands of the city at a much more distant period than would be prudent in the case of the conduit pipe. In my judgment, if they are made sufficient for holding, (exclusive of the volume of water in the conduit itself,) the supplies of three days, there will at all times be reserved sufficient to meet any casualty which can happen to the elevating machinery; and it is obvious that such an excess will be adequate to meet the ordinary demands of as distant a period as it is expedient in the first instance to provide for.

It is proposed to give the fountain $\frac{2}{3}$ the capacity necessary for this purpose; and to open a communication between the two, by means of

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a wicket gate placed low down in the division wall, in order that the two may be thrown together into one, on the happening of any exigency requiring more than the reserve of the fountain reservoir. We shall have accordingly 3 × 1036812 = 3110436 gallons for the capacity of the two reservoirs.

The circular form, on many accounts, seems to me the best plan for these works. The depth of water may be $3\frac{1}{3}$ fathoms ; and the frustum of a cone, inverted, with a battre of 1 foot in 4 of height, will, I think, be the best disposition for the body of the work. The superficial diameter of the pools of the reservoirs will of course be 150.46 feet and 107.86 feet respectively.

Brick work in hydraulic mortar, may be used with advantage for the bulk of the lining walls of the pool, which is needed to prevent the filtration of the water, and as a defence against contamination and "hardness," from dissolving and holding in solution soluble portions of the soil. The walls to be built upon inverted domes of brick work—serving as well for secure foundations for the side walls, as for a bottom lining and receptacle for sediment—the cavity of the domes being placed below the level from which the water will be drawn off, in order to meet the latter purpose. The upper wing of the pool walls, for, say 5 feet in height, should be backed with concrete, to guard the lining walls effectually from disruption whenever the surface of the water may be incrusted with ice.

Estimate of the expense of erecting the Reservoirs.

867 perches of brickwork in side walls, at $5.25,	$4,551 75
675 " " in inverted domes, at $5.25,	3,543 75
301 " concrete in guard wall, at $4.40,	1,324 40
57 " brick work in parapet, at $4.75,	270 75
Piling the foundations of the guard wall,	350 00
Total cost of the reservoirs,	$10,040 65

A reservoir located within the city would have one peculiar advantage not yet alluded to. In the event of any accident happening to the aqueduct itself, cutting off the supplies, a reservoir located at this end of the line would be capable of mitigating the force of the accident till the water it held in reserve should be exhausted ; and if our aqueduct were one of a complicated order, which, when injured, could not be quickly or easily repaired, this circumstance would have much force. I am of course speaking on the supposition of an equal head of water serving wherever this reservoir should be placed ; which, however, as has been previously shown, is inconsistent with a city location.

It is difficult however to perceive, how, in cases of accidents or failure of the conduit, an interruption exceeding a few hours of time could possibly take place—since the point of failure would certainly manifest itself—and the worst that could happen would be the rupture of a single link of the conduit—which could be replaced in a few hours in as perfect style as when the pipe was first laid down, and at trifling expense. The security of an abundant supply on the happening of any casualty to the elevating apparatus and machinery, is made doubly sure by the size of the reservoirs—but of this I have already spoken.

The force pump and elevating machinery: It is contemplated to draw the supplies of water from the main race of the Cohoes Company. Several plans may be resorted to for raising the water from the river or from this race. Steam and water power are both here applicable with as many advantages as perhaps are attainable at almost any other locality. But the great fall in the river at the Cohoes, takes place just above the site chosen for the pumps, and the remarkable facilities for an application of the latter species of power afforded by that circumstance, has left no hesitation in my mind which species of power ought to be employed for our purposes in the present instance.

At present there is a clear fall of 82 feet from the level of the water in the race to the river bed, and 70 feet of this, in ordinary seasons, may be considered available head. In other words, we are at liberty to use a wheel of any diameter, up to 70 feet. After due consideration, however, I have settled upon 65 feet as the best size for the wheel, it being perfectly secure at all times and seasons from being influenced or impeded by floods in the river.

The grand proportions of this wheel may startle the imagination, but for myself, I am satisfied there are no real grounds for apprehension in any practical point of view. That a wheel of this size may be erected without difficulty, and be as easily kept in order and made to perform its office, as one of much less size, I have become thoroughly convinced from personal examinations, made expressly with the view of determining if we could prudently avail of all the head afforded by the locality—for other things being equal, the larger the size, the less will be the expense of power required—and economy of power is very important in regard to the work here required to be performed.

It is proposed to erect the wheel on the plan invented by H. Burden, Esq. one of which is now in successful operation at the Bloomery and nail factory of Messrs. Corning & Co. where, recently, by the politeness of the inventor, I had an excellent opportunity to witness the efficiency of the plan and to form a judgment of its special adaptation to the purposes I wished to affect.

The cost of erecting a wheel on this plan is estimated at $7,000. The wheel to be established in a prismatic shaft excavated from the solid rock bluff forming the bank of the river; and the tail water discharged by means of a short tunnel excavated from the same material—of about 125 feet in length. The cost of excavating the site and erecting the buildings necessary for the protection of the pumps, is estimated at $6,000. A wheel of this description, having its sheathing and shroud properly impregnated with an antiseptic, as estimated for, may be considered as durable as the conduit itself.

The force pump consists of a cylinder with four valves—two opening inward, and connecting with the race from which the supplies are to be drawn; and two outward, into tubes at each end of the cylinder, which are made to unite and discharge into a force tube reaching thence to the reservoir. The stroke of the pump to be effective each way; diameter of the cylinder, 18 inches, with a stroke of 26 inches—making thirty single strokes per minute.

The force tube will be passed under the bed of the old and new canals, and up the face of the point occupied by the reservoirs. I do not perceive any insuperable difficulty in the way to prevent this disposition. If this part of the work is done during the winter—as it may be—the trench through the banks of the canal may be cut and the tube laid without any difficulty or interruption to the navigation. The passage of the canal may thus be affected without any work in masonry or other expensive provision. The calibre of this tube is 18 inches, and its thickness $\frac{1}{3}$ of an inch.

The pump will deliver 24 gallons of water into the reservoir per stroke of the piston. The expense of erecting it, with the requisite gearing to connect with the power, is estimated at a gross sum of $2,500. The force tube is 720 feet long—and the weight consequently $20\frac{1}{5}$ tons inclusive of the lap at the joint. At $90 per ton its cost amounts to $1,818.

The mechanical effect of 2.66 gallons of water on the wheel will be required for the elevation of one gallon 110. feet high, or to the level of the water in the reservoirs.

The joints, it has already been mentioned, are to be sealed with zinc; each joint will require about 60 lbs. of this metal to make it secure—amounting to $93\frac{1}{3}$ tons of metal for the entire work.

The quota of metal required for this purpose becomes a material item