ques

Technical and Bibliographic Notes / Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- [x] Coloured covers/ Couverture de couleur
- [x] Covers damaged/ Couverture endommagée
- [ ] Covers restored and/or laminated/ Couverture restaurée et/ou pelliculée
- [ ] Cover title missing/ Le titre de couverture manque
- [ ] Coloured maps/ Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black)/ Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations/ Planches et/ou illustrations en couleur
- [ ] Bound with other material/ Relié avec d'autres documents
- [ ] Tight binding may cause shadows or distortion along interior margin/ La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure
- [ ] Blank leaves added during restoration may appear within the text. Whenever possible, these have been omitted from filming/ Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.

- [ ] Coloured pages/ Pages de couleur
- [x] Pages damaged/ Pages endommagées
- [ ] Pages restored and/or laminated/ Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed/ Pages décolorées, tachetées ou piquées
- [x] Pages detached/ Pages détachées
- [x] Showthrough/ Transparence
- [x] Quality of print varies/ Qualité inégale de l'impression
- [ ] Continuous pagination/ Pagination continue
- [ ] Includes index(es)/ Comprend un (des) index

Title on header taken from:/ Le titre de l'en-tête provient:

- [x] Title page of issue/ Page de titre de la livraison
- [ ] Caption of issue/ Titre de départ de la livraison
- [ ] Masthead/ Générique (périodiques) de la livraison

- [x] Additional comments:/ Commentaires supplémentaires: Pages wholly or partially obscured by errata slips, tissues, etc. have been refilmed to ensure the best possible image.

This item is filmed at the reduction ratio checked below/
Ce document est filmé au taux de réduction indiqué ci-dessous.

10X, 12X, 14X, 16X, 18X, 20X ✓, 22X, 24X, 26X, 28X, 30X, 32X

The copy filmed here has been reproduced thanks to the generosity of:

Metropolitan Toronto Reference Library
Baldwin Room

The images appearing here are the best quality possible considering the condition and legibility of the original copy and in keeping with the filming contract specifications.

Original copies in printed paper covers are filmed beginning with the front cover and ending on the last page with a printed or illustrated impression, or the back cover when appropriate. All other original copies are filmed beginning on the first page with a printed or illustrated impression, and ending on the last page with a printed or illustrated impression.

The last recorded frame on each microfiche shall contain the symbol —▶ (meaning "CONTINUED"), or the symbol ▼ (meaning "END"), whichever applies.

Maps, plates, charts, etc., may be filmed at different reduction ratios. Those too large to be entirely included in one exposure are filmed beginning in the upper left hand corner, left to right and top to bottom, as many frames as required. The following diagrams illustrate the method:

L'exemplaire filmé fut reproduit grâce à la générosité de:

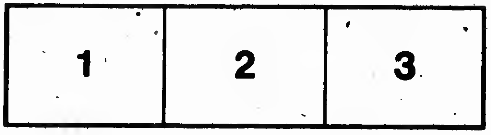
Metropolitan Toronto Reference Library
Baldwin Room

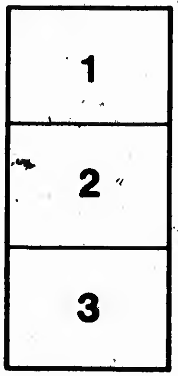
Les images suivantes ont été reproduites avec le plus grand soin, compte tenu de la condition et de la netteté de l'exemplaire filmé, et en conformité avec les conditions du contrat de filmage.

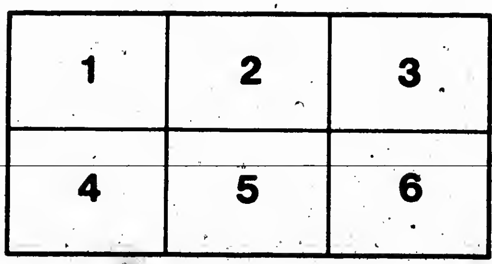
Les exemplaires originaux dont la couverture en papier est imprimée sont filmés en commençant par le premier plat et en terminant soit par la dernière page qui comporte une empreinte d'impression ou d'illustration, soit par le second plat, selon le cas. Tous les autres exemplaires originaux sont filmés en commençant par la première page qui comporte une empreinte d'impression ou d'illustration et en terminant par la dernière page qui comporte une telle empreinte.

Un des symboles suivants apparaîtra sur la dernière image de chaque microfiche, selon le cas: le symbole —▶ signifie "A SUIVRE", le symbole ▼ signifie "FIN".

Les cartes, planches, tableaux, etc., peuvent être filmés à des taux de réduction différents. Lorsque le document est trop grand pour être reproduit en un seul cliché, il est filmé à partir de l'angle supérieur gauche, de gauche à droite, et de haut en bas, en prenant le nombre d'images nécessaire. Les diagrammes suivants illustrent la méthode.

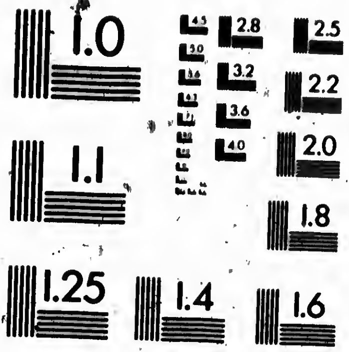






MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



SPECIAL REPORT

OF THE

COMMISSIONERS

OF

Sewerage and Water Supply,

FOR THE

CITY OF SAINT JOHN

AND

TOWN OF PORTLAND,

ON THE FORMATION OF ANCHOR ICE,

BY THE SUPERINTENDENT

GILBERT MURDOCH, ESQ., C. E.

SAINT JOHN, N. B.:
"DAILY NEWS" STEAM JOB PRINT, CANTERBURY STREET,
1881.

With respects
Gilb. Murdoch

SPECIAL REPORT

OF THE

COMMISSIONERS

OF

Sewerage and Water Supply,

FOR THE

CITY OF SAINT JOHN

AND

TOWN OF PORTLAND,

ON THE FORMATION OF ANCHOR ICE,

BY THE SUPERINTENDENT,

GILBERT MURDOCH, ESQ., C. E.

SAINT JOHN, N. B.:
"DAILY NEWS" STEAM JOB PRINT, CANTERBURY STREET,
1881.

Stoppage of Water Supply by Anchor Ice.

November 22nd, 1880.

Engineering Department, Sewerage and Water Works

SAINT JOHN, N. B., Dec. 13th, 1880.

EDWARD E. LOCKHART, Esq.,
Chairman Commissioners Sewerage and Water Supply

DEAR SIR,—On Monday evening the 22nd ultimo, the supply of water to the City and Town of Portland suddenly ceased. I was sitting in my Office at the time (6 P. M.,) and had my attention drawn to the trouble by the ringing of the pressure alarm.

Immediate steps were taken to ascertain the cause. Some of the men had left the pipe yard for home, but not all, and those that remained were sent out in haste to bring back the others at once. As soon as they returned orders were given to have every suspected place searched for leakage, as this was supposed to be the cause of the failure. Parties were sent out almost simultaneously to all the low lying parts of the City and Portland and along the main pipe line; and at 10.15 P. M., Mr. Walker returned with the alarming intelligence that there was no water entering the Gate House at Little River, and that the latter as well as the culvert leading thereto appeared to be choked with ice.

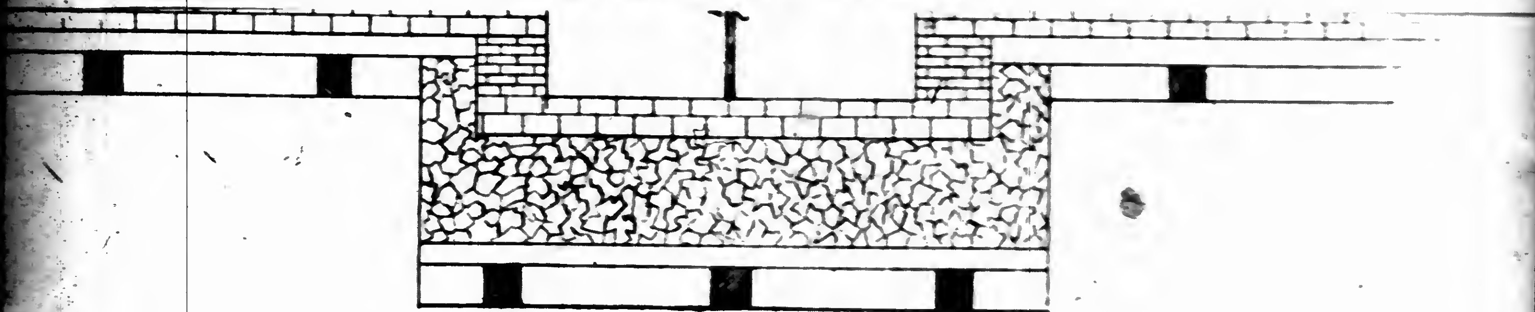
This was a new experience in connection with our works and a greatly more serious one than an ordinary break. The night was intensely cold and a violent gale was blowing from the Northwest. The danger from fire in the City on such a night was great and the result, with no water but such as was held in the Leinster street reservoir, was fearful to contemplate, and there was the additional danger of the soft ice or "frasil" in the Gate House and culvert becoming solidified and cutting off the supply for an indefinite period. Prompt action was imperatively necessary at every risk and cost.

Early in the evening I notified the Chief Engineer of the Fire Department of the failure of the supply and in concert with him arranged to hold the water in the Leinster street reservoir for the protection of the "Block House" summit and a radius of say 1200 to 1500 feet therefrom. The stop cocks to meet this emergency were adjusted while search was being made for the cause of the stoppage. And here I may repeat what I have said on other occasions, that the water held in the reservoir is only valuable as a *supplemental* supply, in its own vicinity, and would not have been adequate to fill the empty pipes and furnish any continuous supply for fire purposes had such been required on the night in question; the requirements of the city have so far outgrown (during the last 43 years) its greatest capacity.

The necessary tools and appliances were collected at once and conveyances found for the men. By midnight the work of cleaning had commenced; and by 2 A. M. the inflow from the culvert had perceptibly increased. This gave encouragement to the men and the work of clearing was prosecuted with renewed vigor. The inflow continued to increase, and by 8 A. M. the greater part of the Gate House ice was gone and the freezing cold water which appeared to fill the culvert and Gate House well, had been displaced by warmer currents from under the ice covered parts of the reservoir.

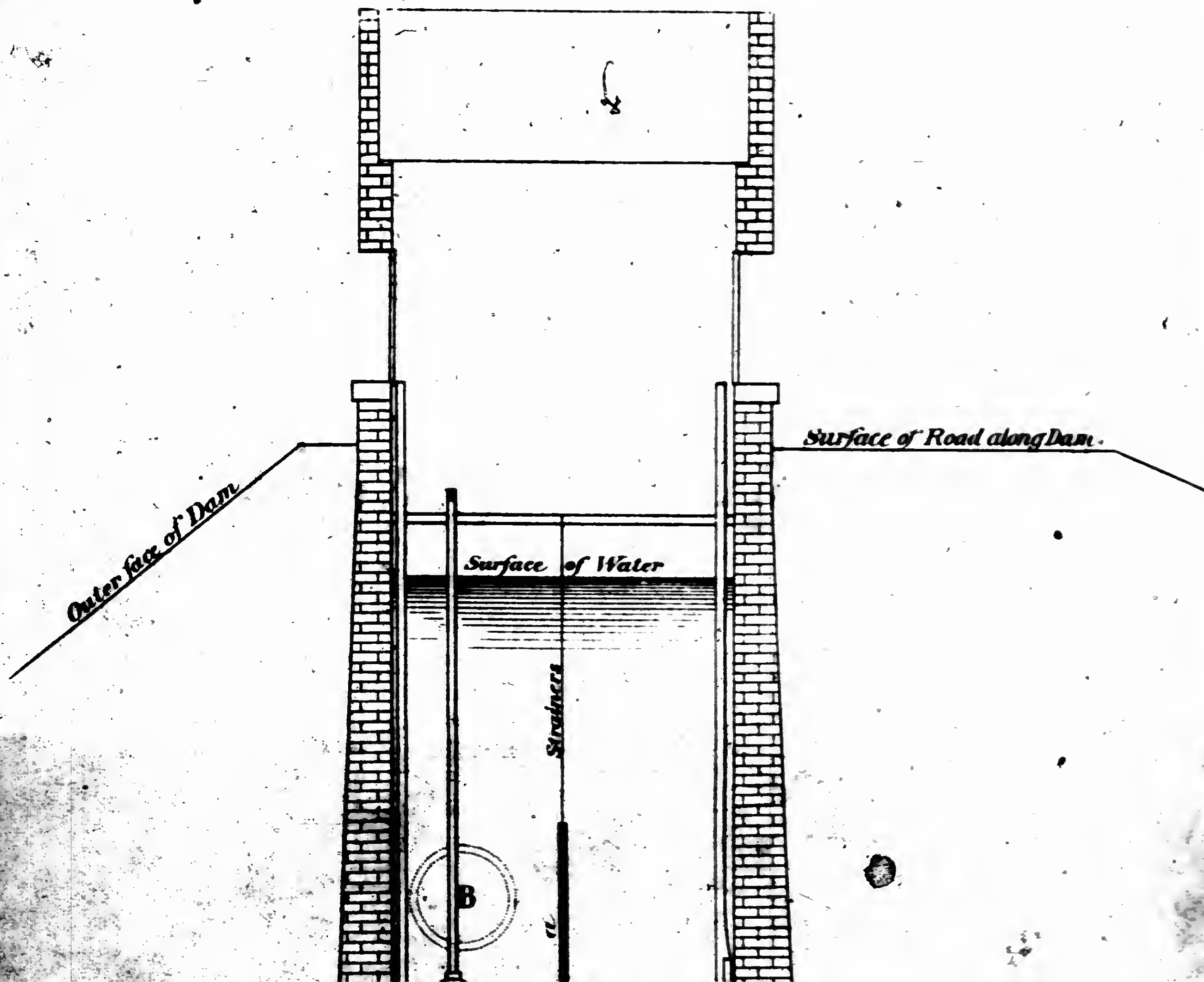
Our City has been supplied with Lake and River water for fully *forty three* years (13 from Lily Lake and 30 from Little River,) and this is the first instance, during the whole of that time, of trouble arising from "*anchor ice.*" The probable physical circumstances or causes which led to the interruption will

SHEET No. 1

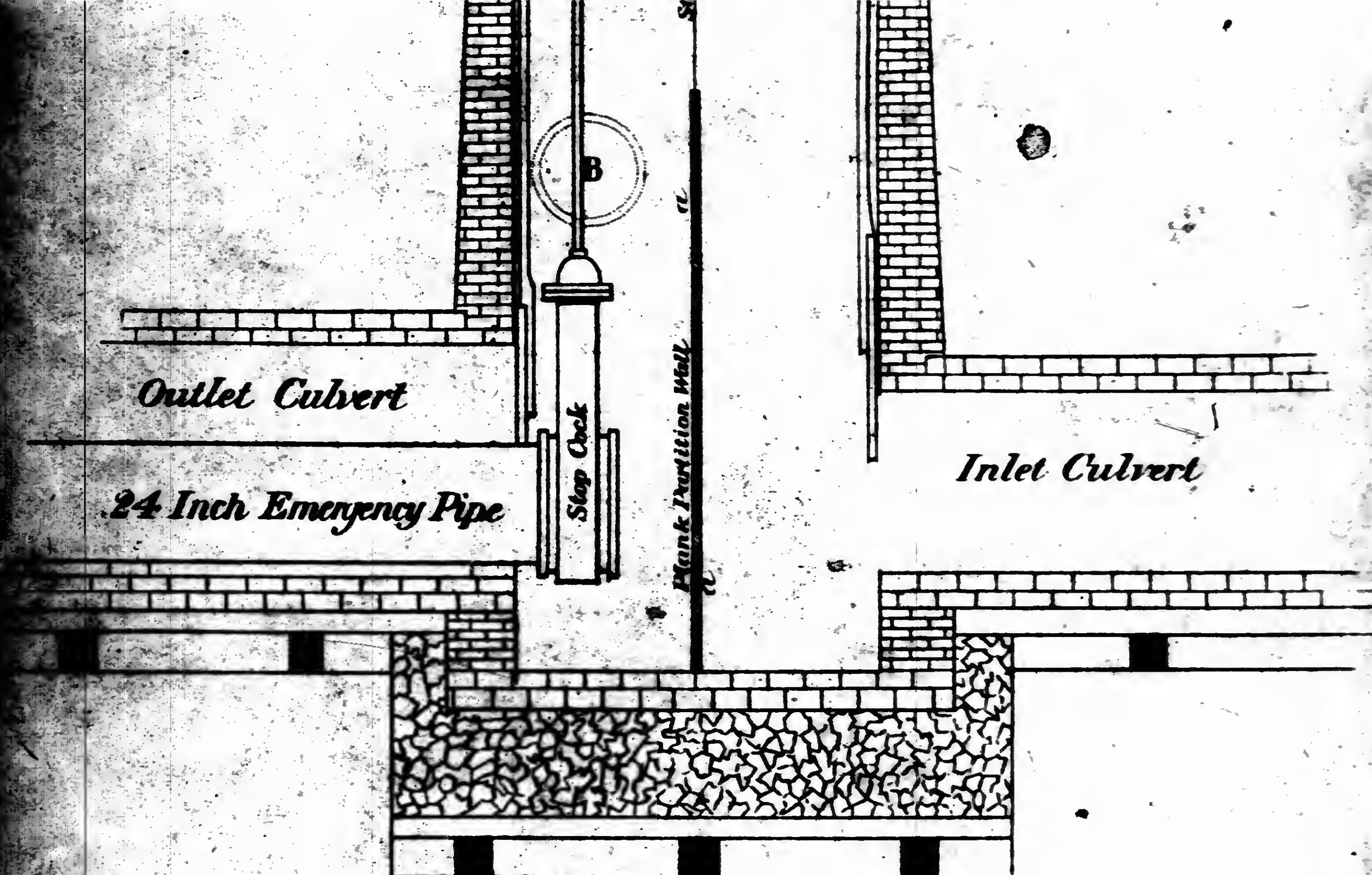


Longitudinal Section of GATE HOUSE

SHEET No. 1



Surface of Road along Dam
Outer face of Dam
Surface of Water
Strainers
B
a



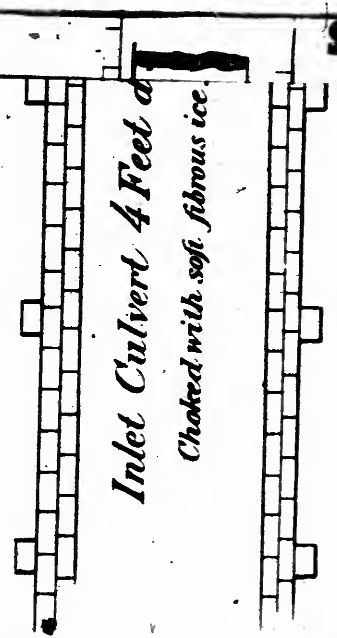
Longitudinal Section of GATE HOUSE

in
Th
the
str
ad
an
in
ev

De
arr
pro
120
em
cau
said
val
not
con
nig
gro
T
con
ing
por
wo
con
Ho
to t
wa
(
full
Lit
tha
phy

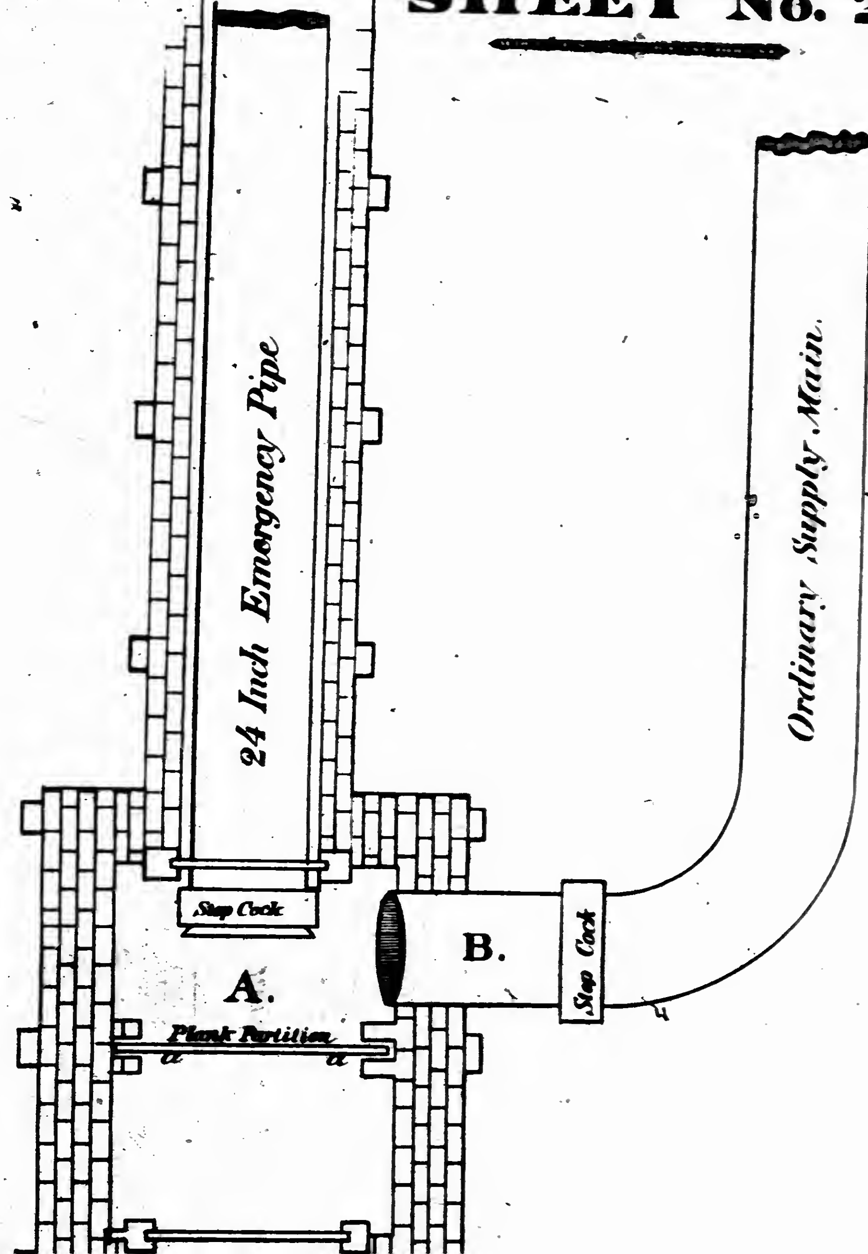
SHEET No. 2

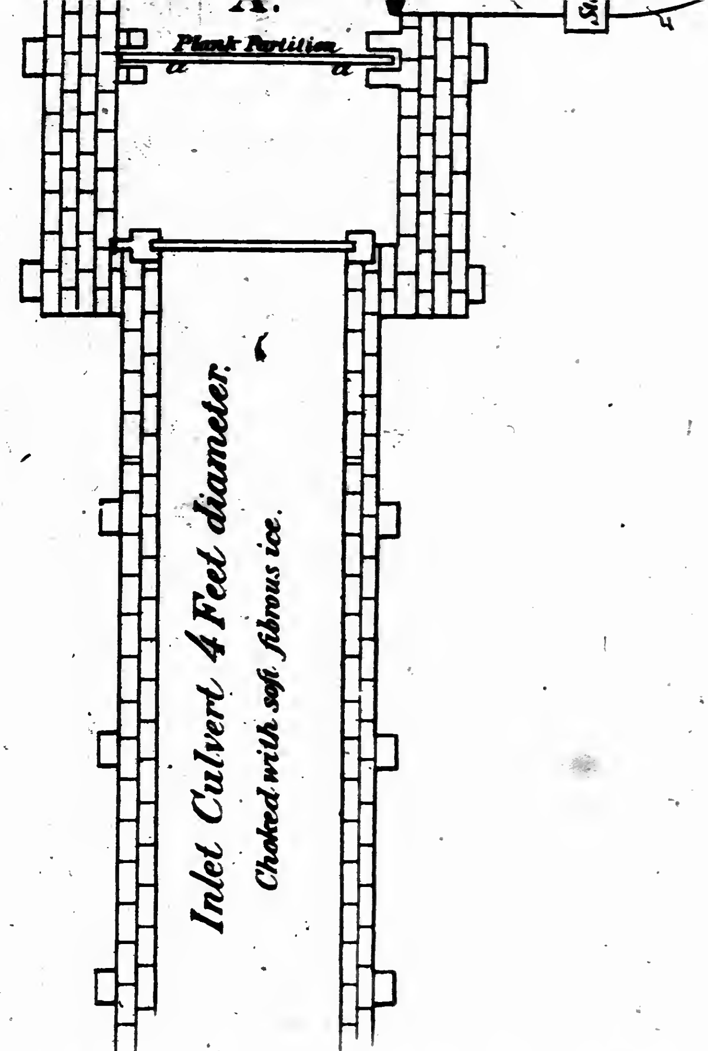
SHEET No. 2



Plan of Gate House

SHEET No. 2


24 Inch Emergency Pipe
Ordinary Supply Main.
Stop Cock
Stop Cock
B.
A.
Plank Partition
a
a



Plan of Gate House

in
Th
the
str
ad
an
in
ev

De
ar
pr
12
en
ca
sa
va
nc
co
ni
gr

cc
in
pe
w
cc
H
te
w

fr
L
th
p

be noticed more fully, hereafter, but in the mean time it may be well to place on record the measures taken to overcome the difficulty and keep the masses of soft fibrous ice, in the culvert and Gate House, from solidifying.

The first step taken was to open the gate on the inlet end of the culvert to its fullest capacity; next to remove the strainers from their places, in the centre of the Gate House, and lastly to open the gates or stop cocks on the 24 inch emergency or flushing pipe, which leads from the bottom of the receiving chamber. This pipe it may be remarked was placed in 1858—twenty two years ago—with a view to empty the Gate House well, or the reservoir itself if need were, and to meet any other emergency which might arise, requiring for safety a speedy withdrawal of the water or a quickening of the current for flushing purposes. The effect was not apparent for some time, but ultimately it began to show, and by 2 A. M. (23rd) the greater part of the softer ice in the western division, or outlet side of the Gate House, (marked A on accompanying plans, sheet 1 and 2), had disappeared and the water had gained sufficient strength and volume to rise to the City supply main (B) which is placed about 9 feet above the bottom of the well.

There was still, however, a large quantity of ice in both chambers. In the western or outlet one, it clung tenaciously to the walls and gate rods and floated in soft spongy masses in the inlet or eastern chamber, making the water thick and slushy. After an hour's trial it became apparent that something more had to be done to quicken the velocity and restore the works to their normal condition.

The flushing gates were again opened and all the inflowing water allowed to run off as quickly as it came. This of course had a wearing action on the soft ice and the inflow began again to increase. While this was going on a stage was made and a man lowered into the western or lower well (A) of the Gate House to cut an opening in the planking (*aa*) which held the frame work of the strainers and divided the Gate House into two compartments. This was a work of some difficulty and danger, but it was accomplished without an accident of any kind occuring, and the result was satisfactory in every particular. As the aperture was enlarged the inflow increased, and finding ready egress from the bottom of the well the velocity became sufficiently rapid to destroy or carry out the ice from the upper chamber, where it had lingered longest, as well as from the culvert: and ultimately bring, as already noticed, a warmer body of water to the Gate House. This latter result was manifested by a thin vapor which rose from the water and from the man engaged in cutting the hole returning to the surface in a lather of sweat, as if he had been working in a summer temperature.

As the danger was now (7 A. M.) past, the stop cocks on the emergency pipe were sufficiently closed to allow the water to rise to its usual height in the Gate House, and the work of refilling the mains begun. This was a work that required time and care. By 9 A. M. the leading and distributing pipes were filled to the contour of Elliott Row, and by midday the greater part of the City and Town of Portland was supplied. It took a considerable time, however, to get the air fully expelled from the mains, and in consequence of this and the heavy drafts made in the lower districts for flushing and other purposes, the supply did not reach the summits with its usual force until late in the night, say 24 to 30 hours from the time it was cut off.

I have been particular in relating minutely all the circumstances of our experience on this occasion, that they may become matter of record and possibly assist in showing how to deal with a like occurence again, should such another trial unfortunately come to us. In discovering it, if possible, in its incipiency and in leading to the adoption of measures fitted to mitigate, as far as practicable, the evils which spring from such visitations—to avert the danger altogether or reduce it to a minimum.

To do this some knowledge is required of the nature of "*frasil*," "ground" or "anchor ice"—it is known by all the three names—and the conditions under which it is formed. It is well known to millmen and others, through its frequent interference with gates and flumes, and in rarer instances to managers of water works through the sudden interruptions it causes at times to their daily supply. Among scientists, however, there is a wide difference of opinion as to the causes or natural laws which call it into being and place it often where it is least expected, as happened in our own experience.

The only Water Works that I know of on this continent that have been subject hitherto to serious visitations from anchor ice are those of Chicago, Cleveland, Detroit. and Montreal—the two last especially, but in different forms.

In the winter of 1868-69 two interruptions occurred to the water supply of Chicago from this cause, by the last of which the "entire gateways were obstructed by 'anchor ice.'" The supply was cut off from the tunnel, and before the ice could be removed and matters restored to their usual condition the reservoirs were emptied and the whole city was out of water for nearly three (3) hours. For several days in January 1878 similar trouble was experienced at the crib, which forms the inlet to both tunnels; and so serious have these interruptions become that plans are being devised to ensure a supply for fire purposes chiefly, should both tunnels fail to furnish their usual daily supply. And so imminent and constant is the danger supposed to be that *two* men and sometimes *three* are engaged during the winter season in keeping the gateways clear of ice: and "besides this a tug is kept all winter long" near the mouth of the river ready to start (for the crib) in very short notice with whatever may be needed."

Cleveland, Ohio, had in 1873, a similar experience to ours, but on a larger and more protracted scale. During a heavy westerly gale which prevailed, while ice was forming rapidly in the vicinity of the inlet to the aqueduct which supplied the pump wells, the water was observed to be unusually low, but as this had been observed on several occasions before no particular notice was taken of the fact until the following night, when it had fallen away to such an extent that one pump only could be kept going at one fourth of its speed. This led to inquiry.

An examination was made of the aqueduct "and it was discovered that from the inlet for the distance of eight hundred (800) feet inland it was *filled* with fine particles of ice, which when taken out had the appearance of coarse snow." And about *thirty* hours elapsed before the ice was removed and the supply restored.

This was the only time there had been trouble from ice at the inlet aqueduct since the establishment of the works 20 years before, and as in our case was a new experience and a great surprise to all concerned. Shortly after this their new lake tunnel was completed and I do not know that any further trouble has been experienced since.

DETROIT has had equal if not greater trouble than Chicago, and is not sure yet of being wholly free from it. There as in other places the visitations have been intermittent and irregular—depending largely on the thermal character of the season and the force and direction of the winds. The water for the supply of this city is taken from Detroit River, and was led to the settling reservoir (previous to 1875) by 290 feet of 36 inch wrought iron pipe, the inlet orifice of which was *twenty-five* (25) feet below the surface of the water. Since 1875 the point of intake has been changed, for sanitary reasons, and the water is now conveyed to the settling basins through *eleven hundred* (1100) feet of 60 inch wrought iron pipe. I am not aware of any trouble having been experienced as yet with this new pipe, but with the old 36 inch one the interruptions were frequent and serious, though earnest efforts had been made to prevent the formation or rather the aggregation and adhesion of the ice to the inlet strainers and frame work by which they were sustained and protected.

As far back as 1866 the water commissioners of Detroit applied to Professor Douglas, of Michigan University, to see if science could devise a cure, or rather a preventive of this winter trouble, and after a patient investigation of the physical conditions that usually accompany the formation of the anchor ice he came to the conclusion that it was chiefly due to radiation, and advised accordingly, with a view to test the accuracy of his theory, the mooring of a raft above the inlet end of the pipe. This he supposed would arrest the radiant heat and prevent its escape in the same way as plants and flowers are protected by thin coverings from the effects of early frosts.

In the following year the committee in charge of the works had a line of booms placed, as advised by Professor Douglas and firmly held *in situ* over the inlet pipe until the ice formed; but the hoped for results did not follow. By the aid of divers a submerged platform was then placed over the strainers in the hope of stopping the supposed radiation, but this too failed and instead of abating the evil the stoppages took place at a higher temperature than ever.

During one of the frequent interruptions which took place the committee induced one of their divers to go down to the inlet pipe and examine its condition and surroundings. The intense cold prevented him from remaining long, but he was there long enough to discover that the inlet pipes and strainers, with their surrounding spiles was one mass of ice particles, collected into a mound some *ten* feet high and about fifteen feet in diameter; and that large quantities of minute crystal of ice were rapidly passing and adding to the mass already collected. Specimens of the ice were brought to the surface in a bag. It was in sheets and particles thin as paper, translucent with sharp pointed edges.

A further examination revealed the fact that the small amount of water the pump was receiving at the time the search was being made came through the lower or down stream side of the strainer, this being the only point at which the pipe could be reached. Here there was but little ice. When these facts were ascertained the committee thought they had solved the problem and could apply a remedy. It was to enclose the strainers except a part of the down stream side so as to prevent these floating particles from collecting on and around it. To do this a large piece of can-vas was prepared of suitable size and firmly fasten[illegible] diver around the spiles which, with the platform, comp[illegible] and encircled the strainers, except on the down [illegible] side. This was but completed when the weather [illegible] colder. During the night the thermometer indicated [illegible] degrees below the freezing point, and before daylight the engine stopped for want of water.

Another descent was made immediately and the important fact ascertained that with the temperature of the atmosphere at 29° the water at the surface was 33° and at the bottom of the river 35°. At this descent much less ice was found on the strainer and its surroundings than the first time. The lower side was clean but on the upper side the action of the current had worn the ice into elongated cones pointing up stream. About three hours after, the diver again descended (thermometer 33°) and found the ice entirely gone. The submerged platform was removed, and no further trouble was experienced until the river ice began to move, when it was again repeated with the thermometer at 16°, and the committee concluding their valuable Report, say that "by the aid of "the submarine diver they have ascertained the fact that, at certain temperatures, these *ice particles are ever present in the river* "and are continuously [illegible] down by the action of the current, "and whatever obst[illegible]ey meet with, in their passage, "they collect upon. [illegible] the case we recommend the coming summer, the entire removal of all spiles and other substances "adjacent to the strainers believing that with nothing but the "smooth dome for these particles to lodge upon the quantity that "will accumulate cannot very seriously affect the flow of water to "the inlet pipe."

I am not sure that the recommendation of the committee was carried out, yet I have reason to believe that it was, and also that the removing of the "spiles," &c., did not secure complete exemption from interruption, as I find in subsequent reports descriptions given of further efforts and devices for overcoming their ice difficulties, chief among which was the extension of the inlet main in a direction parallel with the bed of the river. This extension reached 20 feet above and 20 feet below (to right and left as it were) of the principal 36 inch inlet pipe, and was perforated throughout its entire length, as far as its surfaces were exposed, with closely set three-quarter inch holes—the diameter of the holes in the original strainers having been half inch.

In addition to this lateral extension of the strainers a gate was also placed at the end of the direct inlet main to be opened when the holes in the laterals were choked and admit the water without straining. This gate was worked from the shore end by a chain or wire rope placed inside the inlet pipe, and its dimensions were 3 x 4 or twelve square feet. It appears to have answered fairly well, but did not admit the quantity of water it should have done in consequence of its area having been reduced by ice adhering to its frame work, and an additional gate was recommended as a remedy for this reduction of area. I have written to Mr. Edward, the engineer in charge of the Detroit works, for further information which will be submitted as soon as received.

MONTREAL has suffered more from anchor ice—or *frasil* as it is called there—than either of the places named, but not in the same way and her experience for this reason had no warning value to ourselves nor any of the cities named, as will appear by the following brief statement of facts.

The Montreal Water Works, as they now exist were planned by Thomas C. Keefer, Esq., C. E., and went into operation in the fall of 1856. Water power is used to force the water into a reservoir placed on the "slope of the mountain" about 204 feet above City datum or 166 feet above the level of the water at the pumping station.

The water for City use and to work the pumps is taken from the St. Lawrence above the Lachine rapids, and is brought to the wheel house by an open canal or aqueduct which is about 5 miles long, 8 feet deep, and 40 feet wide, at the water line, with an inclination or fall of about 2¾ inches per mile.

The maximum capacity of the works as originally designed was 5,000,000 gallons daily, and so long as the aqueduct was *free from ice* they were fully able for this duty. In the winter season, however, their capacity was reduced to about 3,000,000 gallons, through the contraction of the channel by anchor ice washed from the St. Lawrence into the aqueduct.

This ice trouble began with the new works and was an annual one but was not always equally severe. Various expedients were tried to overcome it but without beneficial effect. Piers were built at the entrance to the aqueduct to stop its insidious approach, and afterwards removed, when found to be useless, and men and gunpowder had to be employed every winter at the entrance to keep it open and serviceable.

So long as the demand for water did not exceed 3,000,000 gallons per day the supply was maintained; but in 1859 (3 years after the works had been opened) the supply to the reservoir had to be cut off and the water sent directly into the mains for City use. This was done that the water in the reservoir might be retained for fire purposes which could be done by shutting off only, as the daily draft exceeded the diminished capacity of the pumps.

"These troubles," says the superintending engineer (Mr. Lasage) "went on increasing every winter, so much so that in the year "1862, 1863 and 1866 water puncheons had to be resorted to in "order to supply the citizens." In 1868 a steam engine was erected to "save the City from another water famine," and in 1872 a second one was put up for winter use, the consumption having risen to 6,615,000 gallons per day. But as the cost of pumping by water power is greatly less than by steam the rates in Montreal being as $3.41 to $25.00 for each million of gallons placed in the reservoir, a contract was made in 1873 for a new and much larger aqueduct at an estimate cost of about $1,850,193.60.

The action of the ice and frazil on the old aqueduct is thus described by Mr. Keefer in a report made to the water works committee in 1869: "The difficulties," he says, "arise from two causes "viz.: rapid fluctuations in the winter level of the St. Lawrence, "and that peculiar form of ice known as frazil, which is derived "from the bottom instead of the surface, and therefore floats under-"neath instead of upon the same level with other ice. The fluc-"tuations increase the thickness of the aqueduct ice, from *above*,—"the frazil from *below*. The former cause the ice-cold currents of "the river to rise suddenly and flow over the frozen surface of the "aqueduct immediately thickening and weighing down the ice in "the latter, then by as sudden a fall to still further depress this "ice, so that by mid-winter (with the steady reduction of the "average surface of the river in addition) the water way under "the aqueduct ice is so diminished that, in order to supply the "wheels a rapid under current sets in, bringing in frazil "in great abundance until the passage is nearly or quite choked "up. When this result takes place, if the wheels continue run-"ning they rapidly empty the aqueduct below the obstruction, "letting down the ice almost or quite to the bottom, thus bringing "about a state of things irremediable so long as the cold weather "lasts. Difficulties have increased as the demand for additional "pumping power increased and the remedy has been too long de-"layed."

From the foregoing brief description of the ice troubles of Montreal it will be seen that they differ materially from those of Chicago, Cleveland and Detroit—though much the same in principle; and show that the insidious influence of the anchor ice or frazil was underestimated by the unquestionably able engineer who planned and executed the works and by the still more eminent gentlemen who were consulted professionally before their construction was begun by the City of Montreal.

It was believed that more or less ice trouble would be met with, as must necessarily be the case in all northern latitudes but no one anticipated what really did take place. The formation of "frazil" as well as its subsequent movements and aggregations appear still to be involved in some degree of mystery and do not seem to follow the ordinary laws of freezing as generally understood.

Having noticed at some length the troublesome and treacherous character of this form of ice, and the efforts that have been made in various ways to overcome it, a few remarks in relation to the

Views held by Scientists

in relation to its formation, may not be out of place nor altogether void of interest.

It almost seems incredible that ice should be found at *twenty-five* (25) feet below the surface of open water, and that it should be aggregated and massed, at that depth, into a mound or pyramid *ten* feet high and *fifteen* feet wide at the base; that it should be found lining with great uniformity the interior surface of subterranean water courses, raising suddenly the levels of lakes and rivers and causing them to overflow more rapidly than in ordinary floods—stopping the inflow to large culverts, placed 20 feet or more below the water level, and blocking an open canal with a constant current flowing through it (as at Montreal,) but the evidence is complete and irresistible.

Scientists are divided in opinion as to the *modus operandi* of nature in making and working with anchor ice. The conditions under which it is found appear to be wonderfully uniform, wherever it is met with, and agree exactly with those that prevailed here on the night of the 22nd ult., viz.: open water, clouded by day, clear by night, high wind and thermometer ranging from 5° to 18° or 20 degrees above zero. Under these conditions anchor ice has interrupted again and again, as we have seen, some of the noblest water supplies of America, and engineering skill and scientific research have failed, as yet to find a perfect cure.

Professor Douglas, of Michigan University, when applied to by the water authorities of Detroit attempted to explain the phenomena "upon the principle of Wells' well known" and acknowledged theory of the formation of dew, viz.: by radiation" clear water he said "being to a great extent transcalent (permitting "the passage of heat) would not interrupt the caloric from below "from rising and passing into the air above, when the surface water "is open and *below the freezing* point. Nor would the depth (25 "feet) affect it, for it is well known (said the Professor) that caloric "that has been transmitted through one layer of a transcalent "medium will be transmitted through any number of layers; the "rays of the sun would also convey heat through the water to the "pipe (a good absorber of caloric) and these would dissipate the "ice. As soon as the ice forms on the river all radiation and trans- "mission of caloric would be stopped by the interscalency of the "ice," and from this reasoning he advised the placing of "three or "four large scows or timber rafts directly over the pipe to intercept "the heat radiated therefrom as well as from the surrounding "water" and send it back again to the source from whence it came.

This opinion was endorsed by Professor John F. Frazer and the Journal of the Franklin Institute, (Philadelphia) but it was not satisfactory to the late Professor Henry, the Superintendent and scientific head of the Smithsonian Institute, (Washington.) Ground or anchor ice he said in a letter addressed to Professor Douglas was a "puzzle to physicists." The radiation explanation was one which readily suggested itself to such as were familiar with the experiments of Dr. Wells, and was generally adopted previous to the researches of Malloni, (an Italian savant) who had shown intensity *was interrupted by the thinnest sheet of water*. This it will be observed is in direct opposition to the view held by Professor Douglas that clear water was a transcalent medium and would transmit heat through any number of layers. Professor Henry inclined to the theory of Arago, who held that *anchor ice was formed when the water at the surface was cooled below the point of congellation and by the motion of the stream was brought into contact with a solid body at the bottom which acting as a nucleus of crystalization immediately determined its solidification:* but yet he thought the whole subject required further elucidation.

James B. Francis the celebrated hydraulic engineer and Superintendent of the locks and canals at Lowell, Mass., holds similar views to Henry and Arago in regard to the formation of this description of ice and in a deeply interesting paper published on this subject a few years ago, gave an array of facts, in his own experience, which seemed to put the matter beyond discussion and shew conclusively that the radiation theory of Prof. Douglas was untenable. A few extracts from this paper may be worthy of perusal.

"Anchor ice," Mr. Francis says, "is an aggregation of small "crystals or needles of ice, forming in water a spongy mass easily "penetrated with any hard substance. It is frequently found "adhering in large quantities to the bottom and sides of water "channels both open and covered. In clear weather, as the sun "approaches the meridian masses of anchor ice often rise from the "bottom of the open channels and float off, sometimes with earth "and small stones adhering. It is *produced in the greatest abun-* "*dance in cold, clear, windy* nights. It unquestionably *originates* "*at the surface of the water*, the necessary conditions being that "the *water should be at the freezing temperature*, the *air below* that "point and the surface of the water agitated, either by a current "or by the wind. In its first stages the ice is in small detached "needles or crystals; if there is little or no current this ice ac-"cumulates at the surface and finally consolidates into a sheet; "if the current is too strong to permit this, portions of it accumu-"late at the surface and finally consolidates into a sheet; if the "current is too strong to permit this, portions of it accumulates, "in the spongy masses and float along at or below the surface, "their specific gravity differing but little from that of water. In "a current of water there is a constant intermixture of the water "at different depths producing a uniform temperature all depths "and tending to distribute uniformly foreign matter held in sus-"pension. The small crystals of anchor ice found at the surface "come down by means of this intermixture and distribute through-"out the whole depth of the stream much in the same manner as "earthy matters are carried along in suspension by currents. "These crystals have a strong tendency to adhere to each other or "to any other solid body they may come in contact with. The "adherence can only take place by freezing, and here" says Mr. "Francis, "lies the mystery of anchor ice. How can water be-"come ice without a loss of heat?

"It adheres to surfaces of stone and wood over which water is "running with a considerable velocity, in some cases exceeding 20 "feet per second and growing up under this rapid current at the "rate of an inch an hour. It is clearly not dependent upon "radiation in the manner Dr. Wells has shown dew to be formed "for we find the piers of bridges and the *interior* surfaces of sub-"terranean water courses, *where there can be no loss of heat* by "radiation, covered with anchor ice."

Respecting the formation of this ice Mr. F. remarks, by way of suggestion, that it "commences to form at the surface of water "agitated either by a current or by the wind. The water being "at the temperature of 32° Fah., and the air at a lower tempera-"ture heat passes from the water to the air equivalent to the "formation of a certain amount of ice; the water being agitated "and the ice in minute crystals, the latter become mixed with the "water before all the ice due to the loss of heat is formed; and "although the crystals are removed from the further loss of heat "they will continue to enlarge until an equilibrium is attained. "The amount of ice formed after the crystals leave the surface "may be very small but still be sufficient to cause them to adhere, "when by means of the current they are brought in contact with "each other or with any other solid at the freezing temperature."

He also notes the fact that on drawing the water out of a subterranean water course he had found the interior surface of the channel coated with anchor ice, with great uniformity and symmetry and several inches in thickness and says it must have formed before it entered the subterranean channel and subsequently adhered.

Again as an instance of the sudden trouble which may arise from anchor ice and of the exceptional circumstances under which it is found at times, he relates an experience he had in December, 1863, when the ice which covered the river was carried out by a heavy rain. The rain storm occurred on the 13th and 14th of the month named, (December) and in the night between the 15th and 16th the wind was high from the Northwest; anchor ice making freely with the thermometer at 30°. At 6 A. M. of the 16th the wind was fresh and the thermometer at 26°, the anchor ice forming very freely. The water *wheel for moving the sluice gates of the Northern Canal could not be started on account of anchor ice having* choked up the outfall through which the water is drawn. No anchor ice is ever found at this wheel when the river is frozen over.

The unusual amount of anchor ice at this time forming at such a high temperature was attributed to the high wind and rapid current in the river and the great extent of open water above the dams, on which anchor ice could form. Part of the ice thus formed *passed* into the canals when it adhered to the sides of the water courses and orifices greatly obstructing the flow of the water. And Mr. Francis concludes his exceedingly interesting and valuable paper by remarking that the circumstances attending the formation of ice at Detroit do not appear to differ in any essential particular from that attending the formation of anchor ice at Lowell. The depth of 25 feet at which the ice was formed at Detroit is greater than it is found at Lowell, where none of the Canals exceed 20 feet in depth and are generally 10 feet or less. If however they were 25 feet deep we should expect anchor ice to gather at the bottom of them pretty much as it does now *if the surface remained unfrozen.*

But it may not be necessary to dwell longer on this point as the scientific aspects of the question are of less direct importance, to us than the facts themselves which may be briefly summarized as follows, viz.: (1) That ice will and does form in *open* water under certain meteorological conditions; (2) that at such times it is found floating in fine particles at various depths from the surface; (3) that it adheres readily to all solid bodies with which it comes in contact; (4) that it grows or aggregates rapidly when once it has secured a centre of crystalization; (5) that it not infrequently closes submerged culverts and water courses as well as open canals and aqueducts; (6) that the conditions most favorable to its rapid formation are open water at or below freezing, a sky clouded by day and clear by night, a high wind and an air temperature ranging from about five degrees to 20 degrees above zero; (7) that it seldom forms in bright sunshine, but on the contrary is often loosened by this influence and is seen to rise in masses to the surface; (8) that it is less troublesome when the mercury is at or below zero than at higher temperature, and (9) that the trouble ceases as soon as the *surface of the water is firmly frozen over.*

As the surface of our reservoir is now firmly frozen over there is no likelihood of a recurrence of the trouble during the present winter, unless, indeed a sudden thaw and freshet should reopen the pond and carry away the ice, which is not at all probable. It becomes us however to look to the future, to consider well our position in the light and danger of this new experience, and see what can be done, in reason, to overcome or reduce to a minimum the inconvenience and risk that come of such untimely interruptions as we had in November. It is true the like may not happen again for another forty (40) years and more, but of this we have no assurance; and it should be no matter of surprise if the same thing occurred again in less than twelve months. Some suggestions have been made with a view to this which are more or less worthy of consideration.

It has been said that the care-taker at the reservoir should be placed in communication with the engineer's office by means of *telephone* or *telegraph*. Such an arrangement might be useful on many occasions when work was being done or immediate information required, as in freshet times, of the state of the reservoir and waste way, but I do not think it would have averted the recent accident; as the care-taker had no reason to believe that anchor ice was being formed, and found at 5 p. m.,—an hour only before the stoppage took place—the usual height or depth of water in the Gate House well.

Such a line of communication would have been of great service however, had it existed when the interruption occured and would have saved some *three or four hours* of valuable time, which was spent in searching for the cause. This in itself is a weighty point in favor of the suggestion and should commend it strongly to your approval.

As there are no telegraphic wires on either of the Loch Lomond roads, the whole cost of construction as well as of maintaining and working would have to be borne, for the present at least, by the Water Department. Mr. Robinson, of the Western Union Telegraph Co., estimates the first outlay at about $500.00 and the annual working and maintaining at about $50.00, exclusive of labor, but both estimates, the last especially, are only approximate.

A Second Gate House

has also been suggested; and this, no doubt, would have been a valuable auxiliary had it existed and *been free from ice*. The last named condition would have depended, however, on its position and whether it was exempt from the physical influences which destroyed for a time the usefulness of the present one. Had they been near one another, that is to say placed anywhere in the dam or in the cove that leads to the waste way, there is reason to believe that both would have been affected alike—as the open, agitated water extended along the whole front of the dam as well as into the waste way cove.

To understand this properly it may be necessary to explain, that there was first, immediately outside of the dam, a strip of thin shell ice which adhered to the face of the embankment and followed the shore line into the cove as shown on the accompanying sketch; (*see Sheet No. 3*) next a body of open water about 100 feet or more wide, and beyond this again ice or frozen water, which covered the greater part of the reservoir. The open water was kept from freezing, though its temperature was doubtlessly below 32°, by the gusty gale which had been blowing from the night of the 20th, and remained open until the wind began to subside on the 23rd.

A Gate House placed at a point protected from this fierce wind and fed from ice covered water, would probably have remained open, and proved of great service in restoring the supply, but I r

d
d
o
o-
o
of
e.

a
st
n
h
y
n
o-
n,
ll

at
n
ol-
ng
00
r,
er
ly
he
to

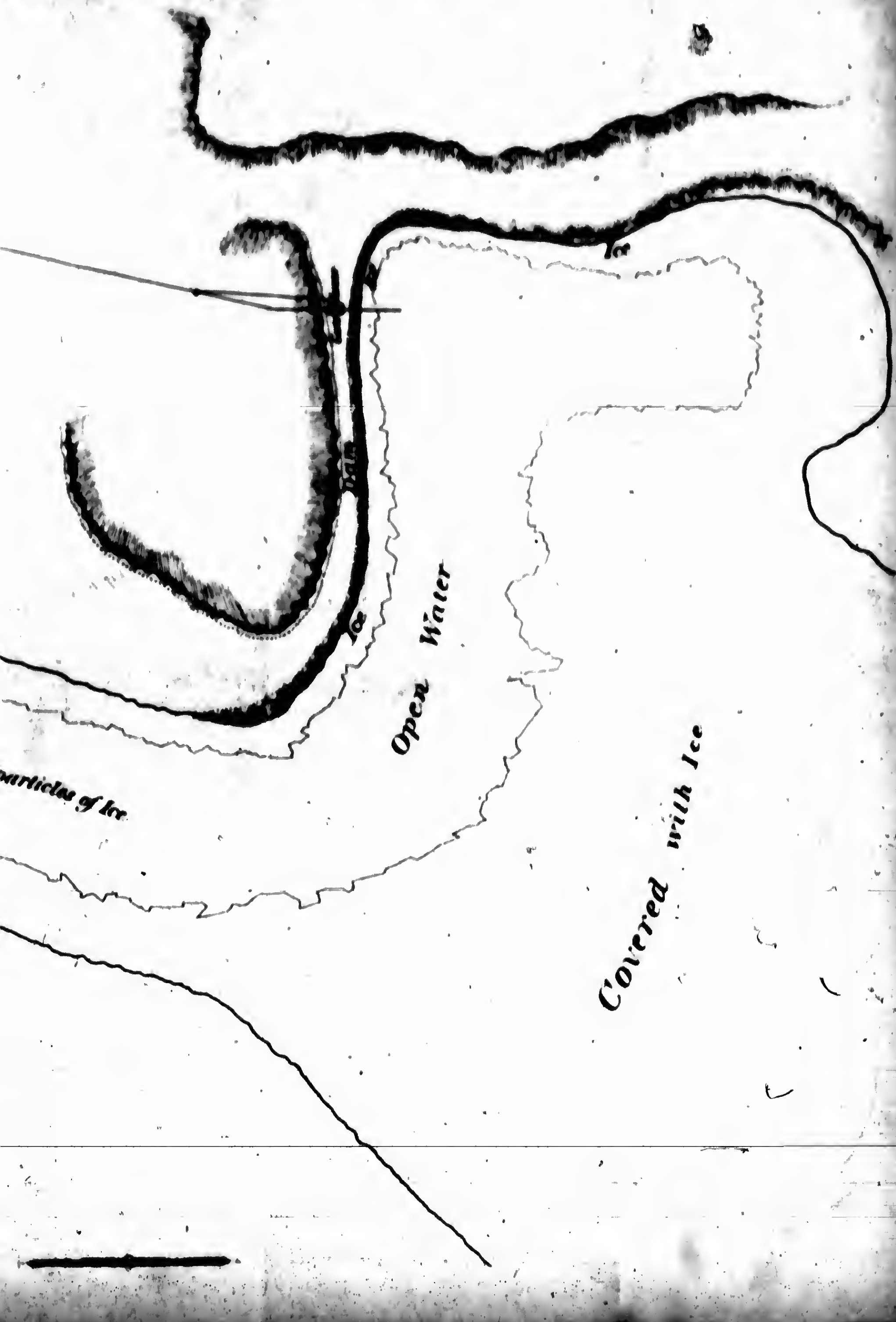
nd
ed
I

B

SHEET N[illegible]

Sketch, shewing the appearance of the Little River Reservoir at the evening of the 22nd day of November A.D. 1880.

SHEET No. 3



in favor of t
approval.

As there
roads, the w
working wo
Water Dep
graph Co., o
annual work
labor, but be

has also bee
valuable au
named cond
and whethe
destroyed fo
been near on
or in the co
lieve that
agitated wat
as into the w

To under
there was fi
shell ice whi
lowed the sl
sketch; (*see*
feet or mo
which cover
was kept fr
below 32°,
night of the
subside on t

A Gate H
and fed from
open, and pr

do not know where it could have been placed on such a night to have guaranteed its usefulness. Nor is it customary to have more than one main inflow from a service reservoir to a Gate House even where anchor ice is almost an annual visitant, as the physical influences which would destroy the one would be almost certain to destroy the other at the same time.

From the foregoing considerations and the further facts that the construction of a new Gate House—with inflow and outflow culverts—would be a work of no small difficulty and danger, and cause probably, some considerable interruption to the water supply of the City and Portland, I could not advise its being undertaken at present, nor until there is, at least, a reasonable prospect of its being a substantial improvement when completed. And I might also add that, from an engineering standpoint, it is always considered prudent to have as few openings as possible in reservoir embankments like ours; as every such opening made for pipe or culvert is more or less a point of weakness.

The present Gate House is greatly smaller than it should be and inconvenient in many ways, but its inlet culvert is large and capacious. It was built by the Water Company in the fall of 1849, when the present works were established on Little River—from plans furnished by George H. Bailley, Civil Engineer, Boston—and has been allowed to remain as originally built, from the difficulties which stood in the way of its reconstruction or enlargement. This question was fully considered by the able engineers Messrs. Slade and McKean, who were consulted in 1856 on the best means of improving our then water supply; and the reasons which then prevailed against doing anything still exist, viz.: the lengthy interruption it would probably occasion to the water supply, and the unforeseen difficulties and dangers that would arise from opening and closing the old embankment—now so strongly and thoroughly consolidated. Had we, however, a connection with Loch Lomond I would strongly urge an enlargement of the present Gate House or the construction of a new one altogether; but until this long anticipated and much required extension is made it would not be prudent to attempt any radical change in connection with the present Gate House arrangement on Little River.

Another suggested security against a total deprivation of water as took place so suddenly on the 22nd ultimo, is an additional

Service Reservoir

capable of containing not less than one week's supply, and as much more as possible. This is certainly a most desirable thing, could a suitable site for the same be obtained in the immediate neighborhood of the City, and the cost of construction not too great, as it scarcely could be, measured by the magnitude of the inconvenience, of the loss and of the danger that follow a day's suspension, even, of our ordinary water supply. This I have recommended in former reports and when doing so on one occasion summarised the advantages that would accrue as follows, viz.:—

"Before quitting this division of my report, I consider it my "duty to press earnestly on your attention the necessity of having "an *intermediate reservoir* constructed at an early day, the site "suitable for which is known to you. It may be true that at "present it is not much wanted and that if no accident happen to "Little River reservoir, or the mains that lead from thence to the "City, it may not be required for some years; but without one "the City supply is not as safe nor as perfect as it should be. "We have no guarantee of immunity from accident any more "than others, and, in the meantime, did any serious casualty be-"fall, or circumstances necessitate the emptying and cleaning of our "present reservoir the City would be at once deprived of water "until the defect was repaired, whether it took a day, a week, or a "month.

"In the water supply of a City nothing should be left to hazard. "Everything should be perfect and if possible duplicated to such "an extent as to render interruption for any lengthened period "impossible. What is done, is well done, but not extensive "enough. A reservoir of the kind proposed, capable of contain-

"ing *three or four* weeks' supply, is still wanted and is a necessary "appendage to works like ours, without which they are not com- "plete ; as there is a daily risk which it is not prudent to continue "only for the shortest time possible.

"The consequences involved in a lengthened interruption to the "usual water supply of the City are serious to contemplate ; and "without regard to domestic and manufacturing convenience, "might entail a direct loss by fire, in a few hours upon the City, "far beyond the whole cost of the work contemplated.

"But without regard to accident an intermediate reservoir must "sooner or later be built. Without it our present reservoir can "never be properly cleaned ; and it is to be expected from the "uncleared, peaty nature of the collecting ground that a time is "coming when it will be absolutely necessary for the purity of the "water to empty this reservoir and remove the accumulated "vegetable matter which is brought down in great quantity by "every flood.

"No doubt from the grade adopted in laying the 24 inch main, "water would find its way into the City although the greater part "of the present head was removed ; but it should be borne in "mind, that were it necessary, for any cause, to empty the reser- "voir and clean it, the discharging and supplying water must be "conveyed to the Gate House, through the same culvert and it "would become so riled and contaminated with vegetable and "other organic substances, washed up and carried about by the "effluent current, that in all probability it would be quite unfit "for use.

"An intermediate reservoir would, it must be readily perceived, "not only give great additional safety to the City, but allow the "mains and stop cocks to be properly flushed and leisurely ex- "amined and repaired whenever necessary ; it would also allow "the reservoir to be emptied and cleaned as often as occasion re- "quired ; and when the time came, as come it must, that the "draft on the mains by day was more than they could furnish, "this reservoir would be an equalizer and regulator of the flow, "storing the surplus by night to meet the extra demand by day, "and by this means securing a better general head than other- "wise could be had.

"From these considerations, I think it very desirable that some "initiatory steps should be taken before long for the promotion of "this most desirable object." *(Report 1862, 1864 and 1867.)*

The site referred to above as suitable for an intermediate reservoir in connection with our Little River system of supply, is on the Wilson farm, near the upper end of what is called by some the "Trafton Valley," to the eastward of the old Westmorland road. *(See sheet No. 4.)*. By the erection of an embankment across the lower end of this valley, a reservoir could be constructed which would have a water surface when full of about *eighteen* acres, and an average dapth of about ten feet.

The bottom of this reservoir would be on about the same level as that of our present Leinster Street reservoir and its capacity would be equal to about one week's supply at our present rate of consumption. The maximum surface level would be about 140 feet above City datum, or 20 feet below that of Little River reservoir. To bring the water to the City a main or mains of suitable size would have to be laid between its outlet and the aboidean. I have not made any estimate of the probable cest, but it would exceed considerably that of an extra gate house and pipe chamber. It would, however, be a much more valuable auxiliary in case of accident and greatly more so in case of fire. But the pressure at best would be low and diminish with the draft, when the latter was taken from the impounded water alone; as it would necessarily be when the supply was cut off as on the 22nd ultimo. But allowing for this defect it would still be of incalulable value as a supplementay supply when other sources failed.

In view of a probable extension to Loch Lomond at an early day it may not be thought immediately necessary to construct this reservoir, but in reference to this, it may be said that although we had our mains extended to Loch Lomond, and had a high and low service supply in full operation, this reservoir would still be a

y,
or-

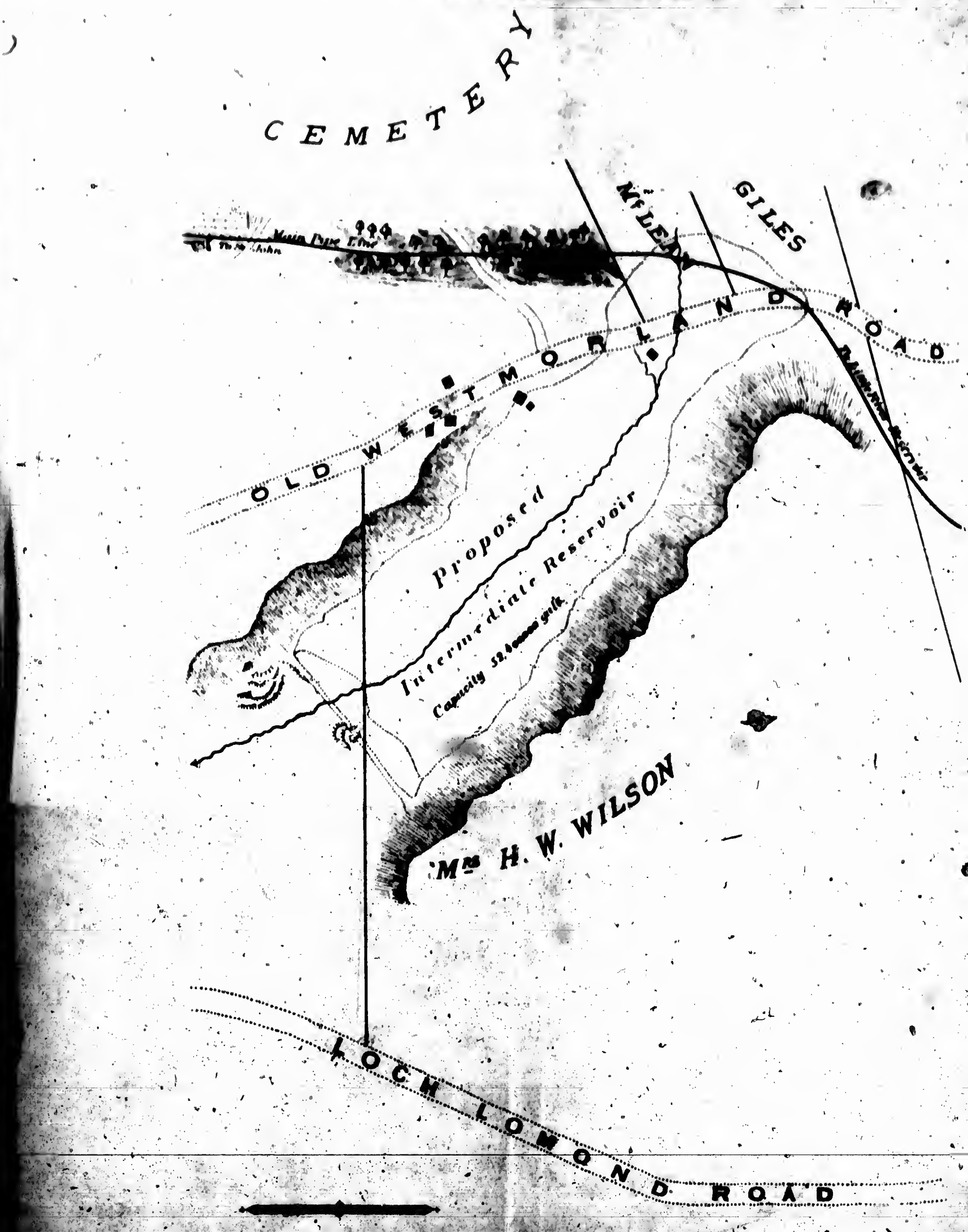
ne
of

or-
on
ne
d.
ne
ch
nd

ol
ty
of
0
r-
de
n.
d,
r.
of
at
or
s-
at
a

y
s
o
w
a

SHEET No.4


CEMETERY
McLEOD
GILES
OLD WESTMORLAND ROAD
Proposed
Intermediate Reservoir
Mrs H. W. WILSON
LOCH LOMOND ROAD

"storing the sur
"and by this me
"wise could be h
"From these c
"initiatory steps
"this most desira

The site referre
voir in connection
the Wilson farm,
"Trafton Valley,
(See sheet No. 4.)
lower end of this
would have a wa
an average depth

The bottom of
as that of our p
would be equal t
consumption. T
feet above City d
voir. To bring
size would have
I have not mad
exceed considera
It would, howeve
accident and gre
best would be l
was taken from
sarily be when th
allowing for thi
supplementay su

In view of a
day it may not b
reservoir, but in
had our mains e
service supply in

aluable appendage to our water supply, and particularly to the ow service, to which it would really belong.

Before leaving this subject it may be proper to remark that ome of the advantages claimed for an intermediate reservoir, in he extracts given above, such as the flushing and repairing of nains and stop cocks, were secured in 1873 when the 24 inch pipe vas laid from the aboideau to Little River.

Besides the foregoing the connecting of

Lily Lake

with our present reservoir has been suggested for fire and other purposes.

The value of this lake for city use was fully tested by the old water company previous to removing their works to Little River, n 1850—the water supply of the City having been drawn from this source for upwards of thirteen (13) years.

It is deficient in elevation as well as in storage capacity and drainage area, and its water is greatly inferior to that of Little River for domestic and manufacturing purposes.

The surface water of this lake is about eighty (80) feet above City datum, while the bottom of our Leinster street reservoir is one hundred and twenty-three (123) or *forty-three* (43) feet *higher* than the surface water of the lake.

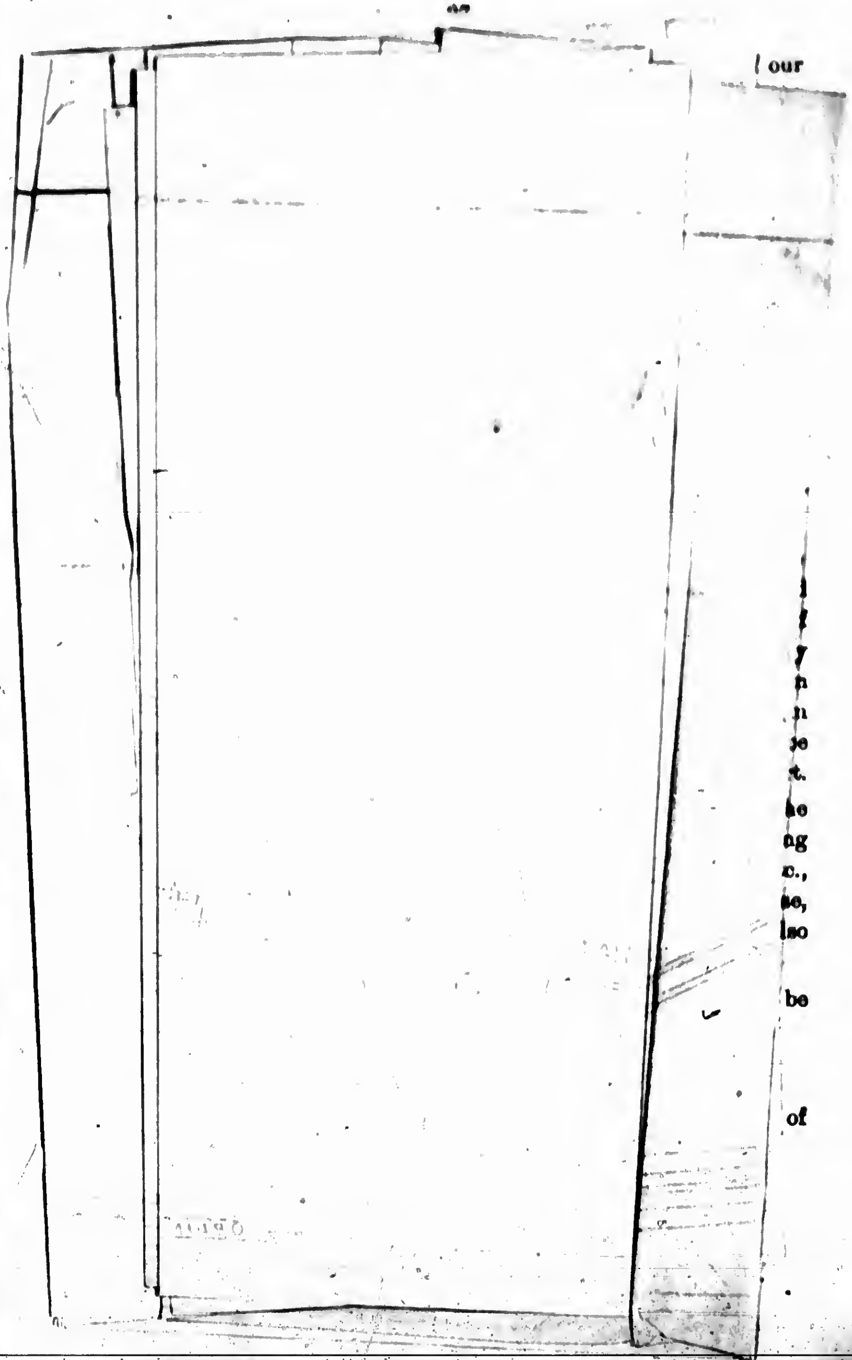
When this lake was used by the old water company, the supply of water for the City, was pumped into the Leinster street reservoir three or four times a week, and doled out daily between the hours of 6 and 8 A. M. For 22 hours out of the 24 the water was shut off, unless an alarm of fire was given, when the reservoir had to be opened and the pipes filled before any could be got for its suppression from the City fire plugs. The daily demand was then about 25,000 gallons, now it is more than *two hundred* times that quantity—and even then in dry seasons this lake was barely able to furnish the small supply required of it. Its capacity and elevation could be raised to some extent by raising the dam at its outlet, but not sufficiently so to put any part of its water into the Leinster street reservoir by gravitation.

To make the water of this lake useful therefore, as a short time supply, in fire seasons, or when other sources failed, extensive pumping works would have to be erected and maintained in a constant state of readiness; and such mechanical arrangements made as would shut off, entirely, the ordinary supply from Little River, when the water of this lake was being used by pumping directly into the distributing mains, as in the Holly and Waterous systems; or a return be made to the old practice of pumping into and distributing from this old reservoir.

In the first named (that is pumping directly into the mains) the pressure in case of fire could be run up to any desired point, with Little River and Leinster street reservoir shut off, but the sudden jerky strain which would be hurriedly placed on house fittings as well as main and service pipes would be very destructive to such as were weak and worn and cause no small inconvenience and expense to water takers. This would be avoided of course by pumping as of old into the Leinster street reservoir, but in that case the general pressure would be less than it now is.

The water of this lake would be a valuable acquisition to our present system, on special occasions, could it be pumped into a *large reservoir*, as has been proposed, in opposition to direct pumping, elevated 200 feet or more above City datum, or say from 120 to 140 feet higher than its present surface level.

A reserve reservoir in a position of this kind, kept constantly full and capable of containing a week's supply or more would be a nice thing to have and be a great additional security in times of fire and in other exigencies, but an appendage of this kind built of stone or cut out of the solid rock would involve a very large outlay in addition to what would be required for pumps and engines; mains and gates and pressure regulators, &c., much more probably than the ratepayers of Saint John and Portland would be disposed to bear at the present time; with an extension to Loch Lomond still in abeyance.

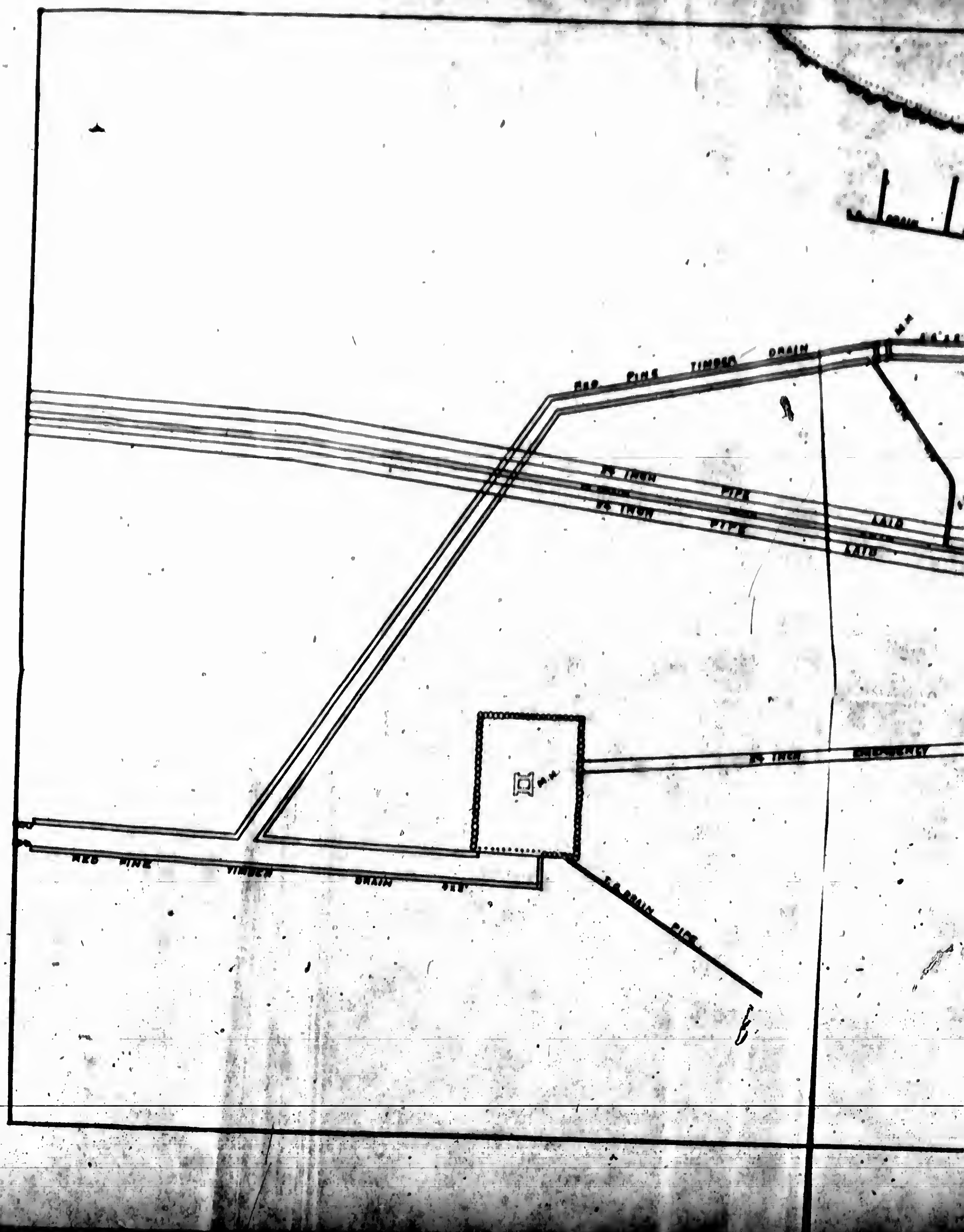


our

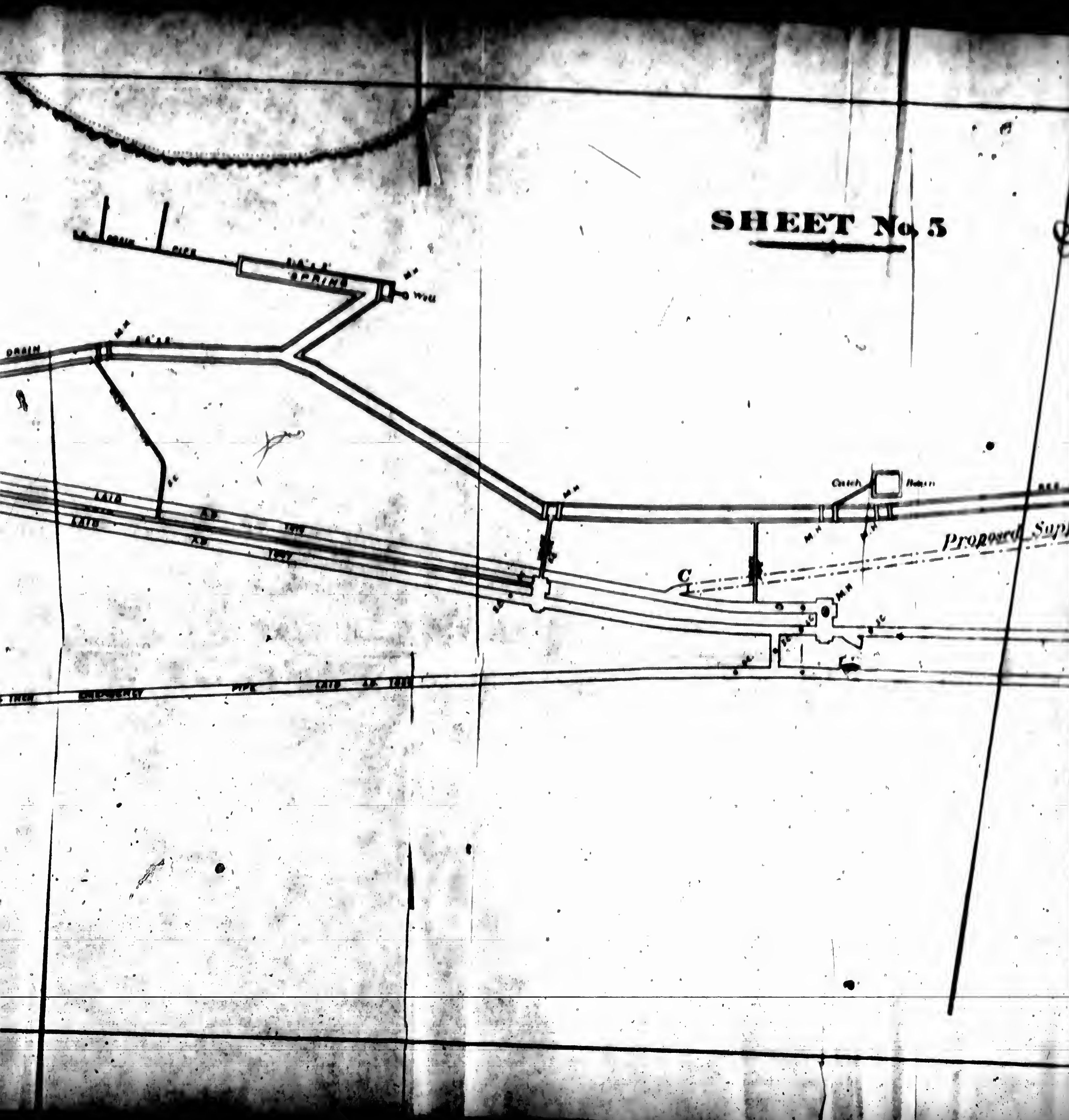
y
n
n
e
t.
he
ng
c.,
se,
lso

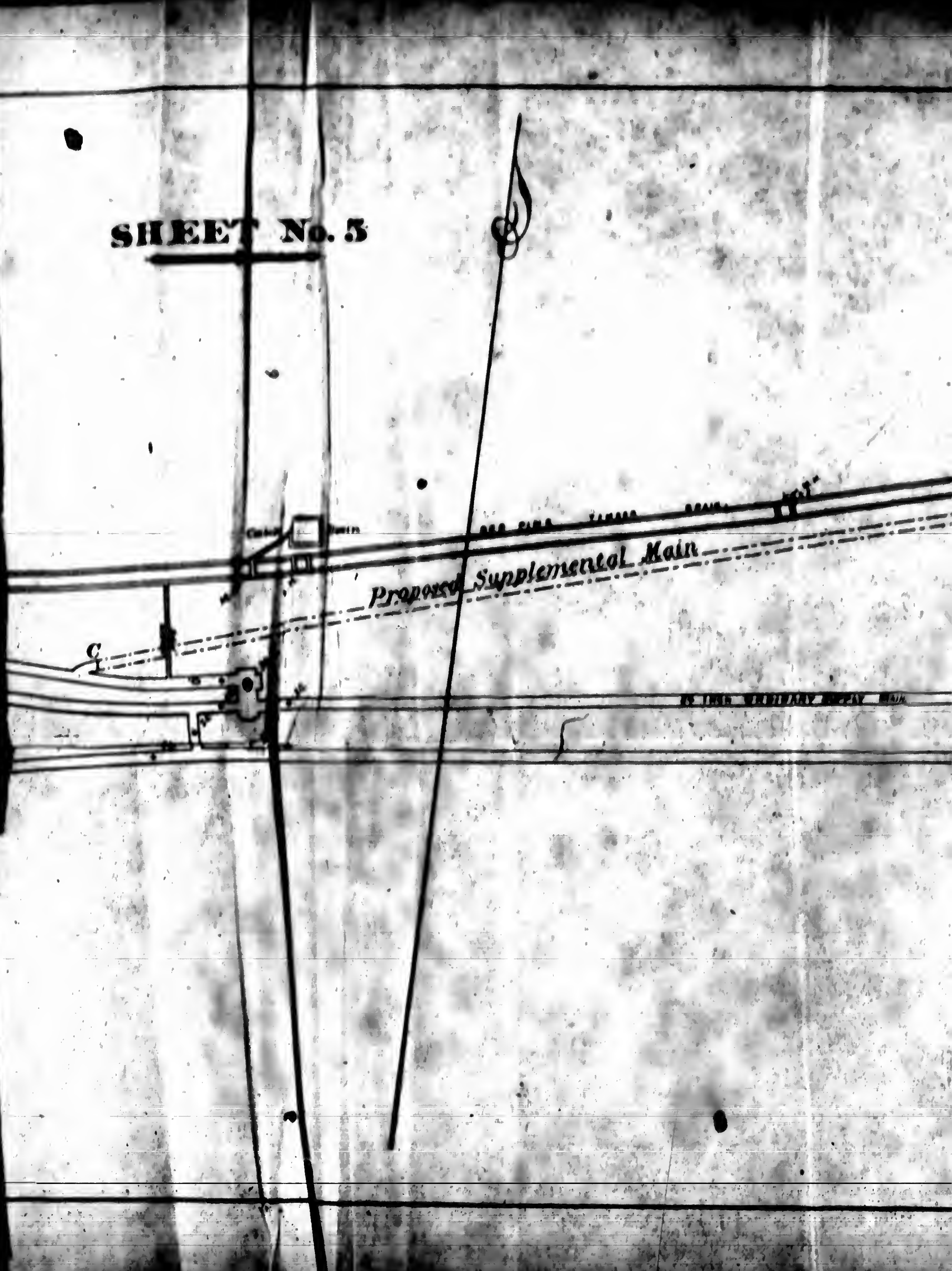
be

of



PINE TIMBER DRAIN
IRON PIPE LAID
IRON PIPE LAID
RED PINE TIMBER DRAIN
M.H.
S.G. DRAIN PIPE


SHEET No. 5
SPRING
DRAIN
Catch Basin
C
Proposed Supp


SHEET No. 5
Proposed Supplemental Main
C

Before conc
ent experi
1st. That
anch C, o
old paper
may be ne

case of o
he water w
nd contain,
rawn from
ectionable,
ard, as it n
here would
he water o

A conne
house so lo
the surface
its usefulne
the last na
the night c
for makin
yielded to o

This wo
year, nor
time, if po
sent out a
that they
advise

(2). Th
made at s

in the Ga

Before concluding this Report, I would advise in view of our ent experience,

1st. That one or more pipes be laid, as soon as practicable, from anch C, on the new 24 inch main, *(See Plan, Sheet No, 5)*, to old paper mill sluice (marked D), and such arrangements made may be necessary to secure a

Supplementary Supply

case of other interruptions. By an arrangement of this kind he water would be taken, of course, from the surface of the pond nd contain, probably, more suspended matter than it does when rawn from a lower point; but not to an extent to make it objectionable, nor to cause uneasiness, as when the ground is frozen ard, as it necessarily would be under the conditions contemplated, here would be little chance of much impurity being absorbed by he water on its way to the reservoir.

A connection of this sort would answer practically for a gate house so long as the inlet end of the sluice was free from ice and the surface level of the reservoir maintained; but the extent of its usefulness would be measured and limited to large extent by the last named circumstance. Both conditions were favorable on the night of the 22nd ultimo, and arrangements had been begun for making this connection with all possible speed when the ice yielded to our efforts and disappeared from Gate House and culvert.

This work cannot be well done, however, at this season of the year, nor would it be advisable to attempt it before the spring time, if possible; but I propose to have the necessary pipes, &c., sent out as soon as the going is sufficiently good for this purpose, that they may be on hand and ready when wanted. I would also advise

(2). That a careful and continued series of observations be made at stated hours daily on the

Temperature of the Water

in the Gate House at and below its surface level—on the air of the Gate House and on the open air outside of the same; also on the sky noting its degree of clouding and the general force and direction of the wind.

Such observations may not amount to much, practically, but if it be as stated by authorities on this subject that when anchor ice begins to form the water is at or below 32° Fah., the thermometer in observant hands will shew when this point is being approached, or reached, by the water in the gate house well and to this extent give notice of approaching danger; unless indeed the change, from the one state to the other, be extremely sudden, as th[illegible] good reasons for believing it is, at times, when the condi[illegible] eminently favorable.

Observations of the kind suggested were commenced on the 23rd ultimo and have been continued since, but they are not as full nor as frequent as they should be when reliable stationary instruments are received and placed, ready for use. The thermometer used in this work should be accurate and trustworty in every way, as without this the observations would be absolutely useless. I have failed, so far, to find self-registering instruments of this character in the City and think they will have to be ordered from some maker of standing; such as Negrette and Zambra, or Cassela of London, England.

(3). In addition to the thermal observations just noted I would recommend another class of observations having for their object the

Early Detection of Ice

when it begins to form and float about in the water waiting as it were for something to cling to. The Detroit divers you will recollect saw in their winter descent "large quantities of minute crystals of ice" float in the water far below its surfact, and Mr. Francis says that these crystals have a strong tendency to adhere to each other and to any other solid body they may come in contact with."

Now what I propose to do is to immerse in the gate house well a box fitted with iron shelves inside and pierced on the outside for the admission of water as a nucleus or artificial centre of accretion to which the ice may adhere, if present, and by the withdrawal of which it may be brought to the surface and discovered.

This box, or ice detector as it may be called, I would have examined three or four times a day during the winter season, and hourly or oftener when the conditions under which the anchor ice is known to form prevailed.

I do not know that this or the thermal observations suggested will prove of much practical value, but as the responsibilities are great and our opportunities ample for putting to proof the tests proposed, they are worthy, at least, of a trial whether they succeed or not. Both are but experiments; the success or failure of which it may take years to determine should succeeding seasons prove unfavorable to the formation of anchor ice, as I sincerely hope they will.

(4). The only other suggestion I have now to make in reference to the future is that a

Raft of Suitable Size

be made and moored early next winter over the outlet end of the inlet culvert, not so much with a view to stop radiation and prevent the making of anchor ice as to give a means of access to it, should it exist, and an opportunity of starting it with bars or such other tools as may be found best fitted for the work of loosening. During the recent stoppage a raft had to be made and launched for this purpose which necessarily occupied considerable time.

Another subject which is worty of consideration—not only in relation to total suspensions of supply—but also with reference to a more efficient protection of the higher parts of the City is that of

Street Tanks for Fire Service

placed at such points as in the judgment of the fire department of Saint John and Portland they would be most serviceable. Arrangements of this kind exist in New York, in Boston, in Chicago, in Detroit and in many other places in addition to fire hydrants and are maintained with as much care.

Their usefulness would be measured of course by the quantity of water they contained but in the case of a total suspension as on the night of the 22nd ultimo, an hour's supply even might prove of incalculable value in arresting the progress of a newly discovered fire.

Some of the old wells that formerly existed in the City—such as that on the northern side of King Square—should be cleaned out and reserved for work of this kind. This is a matter of no small importance and should not be overlooked by the proper authorities.

The above recommendations it may be remarked are substantially the same as were made in my Reports of 1864 and 1865.

Respectfully submitted,

GILBERT MURDOCH,

Supt. S. and W. Works.