THE

VICTORIA BRIDGE,

AT MONTREAL, CANADA,

WHO IS ENTITLED TO THE CREDIT OF ITS CONCEPTION?

OR,

A SHORT HISTORY OF ITS ORIGIN.

BY A CANADIAN.

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THE VICTORIA BRIDGE.

It being at length officially announced that His Royal Highness the Prince of Wales intends to visit Canada in May or June next, in compliance with the invitation of the Legislature and people of the province, with the view of being present at the inauguration of this great undertaking, any information respecting its originators and designers, it must be presumed, will be interesting alike to His Royal Highness and the public at large. The writer of this notice, a Canadian by birth, being desirous that the just pretensions of his countrymen to share in the honor of conceiving the idea and demonstrating the practicability of constructing the bridge which now spans the rapid and mighty St. Lawrence, should not be overlooked by His Royal Highness and the people of England, has taken the trouble to procure all the authentic information extant in the province on this interesting subject. The facts thus collected will be found embodied in the following pamphlet.

The London *Times*, in an article which appeared on the 5th January last, in ignorance no doubt of the true state of the case, has ascribed all the credit of the *conception* as well as the execution of this gigantic effort of engineering skill, to the late lamented Robert Stephenson. The views of the *Times* on the subject will appear by the following extracts from the article in question:—

"A great event has just occurred in Canada. The Victoria Bridge, the greatest work of Robert Stephenson, has been opened for traffic. We believe that seven years and upwards have been consumed in the construction of this wonderful bridge, and at last a train has passed over it, and the St. Lawrence is no longer an obstacle to free communication between the Canadas and the United States. This bridge is the most magnificent work of the kind in existence; for, although within our own island we have the bridge across the Menai Straits, yet in every point the Victoria Bridge is far superior."

"It is, indeed, to be doubted if ever a monument has been raised by human hands which can offer a prouder memorial of the race which reared it than the Victoria Bridge. To Robert Stephenson is due the merit of its conception; to Messrs. Peto and Brassey the praise which belongs to the contractors for such a work when successfully executed."

Had Stephenson lived to have seen the announcement thus made, his high sense of justice and delicacy of feeling would no doubt have prompted him to have set the *Times* right in regard to the source of the *conception* of the Victoria Bridge. Fortunately for the fame of those who are entitled to this credit, Mr. Stephenson has left behind him conclusive evidence in their favor.

Strictly speaking the "conception" of the idea of constructing a Bridge across the St. Lawrence, at Montreal, may fairly be claimed by the Honorable John Young, of that city, a gentleman to whom the province is under great obligations for the development of many grand projects for its commercial improvement. But to Thomas C. Keefer, Esq., civil engineer, a native of Canada, to use the words of the *Times*, "is due the merit" of demonstrating the entire practicability of accomplishing this truly great work.

As His Royal Highness, in order to do justice to all parties, will feel it incumbent on him to obtain full and reliable information on this subject, the writer has compiled the following statement relative to the pretensions of his countryman, Mr. Keefer, from documents recently published in the Canadian papers, and which have thus far remained unchallenged as to their accuracy. He has also appended copious extracts from Mr. Keefer's able report on the Bridge question, which was published early in 1853, before Mr Stephenson had even an intimation that his services would be required in executing the intended work. The writer trusts that the length of these documents and extracts will not deter His Royal Highness from making himself thoroughly familiar with the merits of the question. It will be seen by the letter of Mr. G. R Stephenson, the nephew of the late Mr. Stephenson, written for the purpose of refuting the claims set up by the friends of the resident engineer, Mr. Ross, respecting the conception and design of the Victoria Bridge, that the pretensions of Mr. Keefer are fully admitted. But independent of these admissions, Mr. Keefer may fairly rest his case on the plea of priority, and the great ability displayed in his report, and on the circumstance that this survey and report were made the basis whereon the contractors undertook to perform the work, *as no other survey and report had been made at the time the contracts were let.*

The writer desires to disclaim the existence of a wish or intention to detract one iota from the great merit due to the late Mr. Stephenson for the part which he performed in bringing into existence the work which His Royal Highness the Prince of Wales proposes to inaugurate. But for the name of this great engineer being connected with the enterprise, the capital for its execution could not have been raised, and the time would have passed by and the work have remained without a commencement—a mere idea in the brains of Mr. Young and Mr. Keefer, and those who were convinced by their arguments that a bridge could be thrown across the wide and rapid river. The only claim here advanced is, that justice should be accorded to all parties.

The writer would also remark, that in a compilation like the following there must of necessity be found some repetition of statements, which circumstance, however, will doubtless be overlooked by those who wish to fully investigate the subject. As His Royal Highness, and others taking an interest in the matter, will no doubt be desirous of information respecting the antecedents of a gentleman whose name cannot be overlooked in any impartial history of the Victoria Bridge, the following sketch will not be inappropriate. This allusion to Mr. Keefer's past life will also show that his reputation as an engineer does not rest wholly upon his able report in favor of bridging the St. Lawrence. It will be seen that he had been professionally employed upon many important public works, especially in connection with the improvement of the navigation of the Canadian rivers.

Short Sketch of Mr. Keefer's Professional Life.

Mr. Thomas C. Keefer is a native of Thorold, a township upon the Welland Canal, a few miles from the falls of Niagara. His father was the first President of the Welland Canal Company, and a Director of that Company, and an active co-laborer with the Hon. W. H. Merritt, from the first projection of that undertaking, until its assumption by the Government. This connection made several of his sons engineers. Mr. Keefer's father was born in the British Province of New Jersey, previous to the revolutionary war. His father (the grandfather of the engineer) was a native of France, of German extraction, who spelled his name Kieffer. He joined the Loyalists, and died while serving under Sir William Howe, in New York. His property, which was considerable, was confiscated, and his impoverished family removed to Canada, where all the Loyalist families were invited by the crown.

Mr. Thomas C. Keefer after having had the charge of an important portion of the Welland Canal, was appointed to the Superintendence of the Ottawa Works, works to facilitate the descent of timber on the rapids and falls of the Ottawa. In this school, he acquired that practical knowledge of rapids and the action of ice, which fitted him to deal with the question of bridging the St. Lawrence. In 1849, he published the "Philosophy of Railroads," a pamphlet which ran rapidly through several editions, and led to the railway agitation, which resulted in the formation of the Grand Trunk Railway. A few weeks after this pamphlet appeared, the official *Gazette* announced that Mr. Keefer was the successful competitor for the prize offered by Lord Elgin, for the best essay on the "Influence of the Canals of Canada on her Agriculture." In 1850, Mr. Keefer was appointed to survey the rapids of the St. Lawrence, and also one of the routes of the Inter-Colonial Railway between River Du Loup below Quebec, and the River St. John in New Brunswick. In this survey of the rapids, he, as is mentioned in his report, had an opportunity of forming an opinion upon the Bridge question.

In the following year he was appointed Chief Engineer for both the Canadian Companies, forming the line between Montreal and Toronto, and also of the Bridge Survey. The subsequent organization of the Grand Trunk Company displaced the Canadian Companies, and led to the retirement of Mr. Keefer, and the appointment of the Contractor's Engineer, Mr. A. M. Ross. During the construction of the Grand Trunk Railway, Mr. Keefer has devoted himself to general practice, and has successfully completed two of the finest engineering works in America—the water-works of the cities of Montreal and Hamilton. He has also filled the post of engineer to the Montreal Harbour Commission, while carrying out their extensive Dredging Operations in Lake St. Peter; and has been connected with several of the provincial railways, of one of which he is now acting, and another consulting, engineer.

THE VICTORIA BRIDGE.

[TO THE EDITOR OF THE MONTREAL GAZETTE.]

SIR,—This monument of engineering skill having been completed and now commanding the attention of the world, the question has arisen to whom does the credit of the same belong? Some persons attribute it to the late Robert Stephenson, others to Alex. Ross. The former engineer has authorised a direct claim to be made on his behalf by G. R. Stephenson in a letter published in the *Illustrated News* of the 1st October last. The latter has allowed the credit to be attributed to him publicly in the newspaper above referred to as well as elsewhere, and has by his silence sanctioned the indirect claim thus made on his behalf. The manner in which these rival claims have been placed before the public differs also in this respect, that while Mr. Stephenson does not fail to acknowledge the assistance of others, Mr. Ross allows the inference to be drawn that his genius alone raised the Victoria Bridge.

It may be that his attention has been occupied to the exclusion of this subject, or that other good reasons may have prevented his obviating this position in which he now stands placed before the public.

Without pretending to decide on the comparative value of the professional labors of these gentlemen, it appears right at the present time to put on record such facts relating to this work as may prove that, although a Stephenson or a Ross, or both of them, were instrumental in erecting the superstructure of the Victoria Bridge, a Canadian engineer was the first to remove the almost universal impression of the impracticability of a bridge; to demonstrate the safety and propriety of the present site after it had been condemned by his only predecessor, and to lay down the engineering principles on which a bridge has since been constructed.

In this lies the gist of the question, Stephenson's great idea of the tubular principal having been already embodied at the Menai Strait and there patented by him for after ages.

It is within the memory of many persons that about the year 1846 Mr. Young and Mr. Galt obtained a survey of the St. Lawrence, with the view of ascertaining the engineering practicability of building a railway bridge across the river opposite to this city, which could resist the pressure of the ice without interrupting the navigable channel. This survey was entrusted to Edward F. Gay, an American Engineer, then in the employ of the Columbia and Philadelphia Railway Company, who reported that the difficulties in the site selected were insurmountable and a railway bridge impracticable, at the same time suggesting a line across the Nuns' Island. It may also be remembered that at the time referred to the difficulty of resisting the "*ice shove*," as it is termed, in the St. Lawrence appeared to justify the doubt whether a bridge could be made to withstand this pressure, aud if it could, whether the vast body of water dammed back might not be turned over the city, to its certain destruction. Not forgetting the difficulty of avoiding an interruption to the navigation, a point of some importance to a people who had expended 10,000,000 dollars to make the St. Lawrence navigable, which also stared them in the face. At this gloomy juncture, Mr. Young (be it said to his honor), with the zeal and peseverance of a Clinton, again obtained a survey, which was commenced in 1851 and completed in 1852, by Thomas C. Keefer, a Canadian Engineer, when a plan of the bridge was made and in the following spring published in a "Report on the survey for the railway bridge over the St. Lawrence at Montreal, surveyed 1851-'52, by order of the committee of the Montreal and Kingston Railway Company,—Hon. John Young, Esq., Chairman, T. C. Keefer, Esq., Engineer."

The professional responsibility of this report and plan was assumed by Mr. Keefer, and if there be any professional credit attached to it he is clearly entitled thereto.

In this report Mr. Keefer states his theory as to the effect of a bridge in preventing the sudden packing of the ice and consequent rise in the water of the river; the means to be taken to render it secure and useful as a railway bridge, aud the means of maintaining and improving the navigable channel. The superstructure is also detailed and the comparative value of iron and wood stated, preference being given to the former, but the latter recommended, "if the project is to be taken up as a self-sustaining commercial speculation."

All which points, and the peculiarities of the present bridge as to solid approaches, to curtail the channel, as to distances between the piers, to allow the passage of vessels and rafts, and as to a gradual rise in level, to avoid the necessity of a draw-bridge, are so plainly stated, that it makes the use to which Mr. Keefer's report was subsequently applied, apparent even to an unprofessional observer, and leaves the details of stone and iron work alone for Mr. Keefer's successors.

In 1852, after Mr. Keefer's plans were made, Mr. Ross appeared in Canada, driving the locomotive of the Grand Trunk Company, and claiming the right of way and sway for it and its engineers. He then availed himself of the plans, knowledge, and brain-work of Mr. Keefer, and submitted the result of his observations to Mr. Stephenson. This gentleman in 1853 visited, professionally, the proposed site of the bridge, and with a slight deviation adopted Mr. Keefer's surveyed line, his approaches, spans and theory as to resisting the ice-pack, candidly stating the name of the person in whose data he chiefly relied to be that of *Keefer*, and admitting the value of those labors, and the advantages which local knowledge, combined with professional skill, gave this Canadian engineer.

It was not until 1856 that Mr. Keefer stated his intercourse with Mr. Ross, or made public his claim for professional credit. This he did only in self-defence, whilst urging against the Grand Trunk Company, his demand of compensation for the survey above referred to, made on account of the Montreal and Kingston Railway Company, and assumed by the Grand Trunk Railway. This obligation, be it remarked, was admitted, and paid by the Grand Trunk Company, and his claim of professional credit now stands unchallenged.

The great and noble Stephenson did raise the superstructure that spans the St. Lawrence. His hand is there as over the Menai Strait. He, without the weight of whose name, the bridge had not been built, assumed the responsibility of work, which Mr. Ross and his assistants have so ably executed.

But Mr. Stephenson did not forget to ascribe honor to whom honor is due, and is it for us Canadians to ignore, or to allow to be ignored, a fellow countryman, who stands forth to the world as worthy of an honor that might well add lustre even to the brow of England's favored son? Such conduct would make us worthy of the charge of shining only by a reflected light, and deserving of having our candle stuck under a bushel.

Public opinion is always right, and must prevail. It did justice to the demonstrator of the egg problem, although Amerigo for a time wore his master's honors, and I doubt not that hereafter, when this subject has been winnowed, public opinion will do justice to this Canadian Engineer, in attributing to him the credit of being the founder of the Victoria Bridge, a work worthy of its architect, its builders, and of the honored name which it bears of our beloved sovereign.

Without making this communication longer by apologies for its not being shorter, which I found impracticable, believe me to remain, truly yours,

W. B. L.

Montreal, Dec. 22, 1859.

Letter of Mr. GEORGE ROBERT STEPHENSON.

[TO THE EDITOR OF THE MORNING POST.]

Sir,—In your impression of the 8th instant there appeared a letter, under the signature of "Veritas," claiming for Mr. Alexander M. Ross, an engineer in Canada, "the entire credit of the plan by which this bridge has been accomplished," and designating that gentleman as "the man to whom Canada and the world is indebted for conceiving the Victoria Bridge, maturing it, providing for and successfully overcoming all its difficulties, and carrying out all the details of the plan."

The writer adds that "the position which Mr. Robert Stephenson occupies in relation to the undertaking is a very secondary one," and he appears to desire that the same inference should be drawn with regard to the construction of the tubular bridges on the Chester and Holyhead Railway, with which he describes Mr. Ross as having been "associated."

Referring to the original prospectus of the Grand Trunk Railway, he also states—" As at this date Mr. Stephenson had no connection with the Grand Trunk Railway, his name, of course, does not appear in the prospectus."

Knowing, as I do, the extreme reluctance of Mr. Robert Stephenson to make any personal statement upon any question, however nearly it may touch his reputation, I did not consider myself authorised to notice the letter in question until an opportunity offered of personally consulting him. I now, however, request you to record the following simple facts:

1. The Mr. Alexander Ross referred to in the letter was an assistant to Mr. Stephenson in the construction of one division of the works on the Chester and Holyhead Railway.

He had a subordinate share in the construction of the masonry of the bridge at Conway, but no share whatever in the construction of the Britannia-bridge, nor was he concerned in any way in the construction of the tubes for either structure.

2. Mr. Ross went out to Canada in 1852 as agent for the contractors for the construction of the Grand Trunk Railway of Canada. At a subsequent period he became chief engineer of the Grand Trunk Railway, a position, however, from which he was discharged by the directors before the completion of their line.

3. The original prospectus of the Grand Trunk Railway described the line "as forming 964 miles of railway (including a bridge over the St. Lawrence at Montreal) which will be constructed under the superintendence of Robt. Stephenson, Esq., M. P., and A. M. Ross, Esq." Mr. Stephenson has at no time had any connection with the railway; but as regards the bridge, although its importance was specially pressed on the directors by the Hon. Mr. Young, yet so great were felt to be the difficulties of carrying the railway over the St. Lawrence, that no bridge was really determined upon until Mr. Stephenson visited Canada in 1853. Mr. Stephenson having then reported that a bridge was practicable, it was ordered to be constructed on his plans, which adapted the principle of the Britannia-bridge to the peculiar conditions of the river St. Lawrence.

4. Upon the adoption of Mr. Stephenson's plan for the construction of the bridge, Mr. Stephenson became chief engineer, and Mr. Ross resident engineer of the bridge works. After Mr. Ross's dismissal by the directors of the railway, Mr. Stephenson, as chief engineer, nevertheless continued Mr. Ross in his office at the bridge.

5. Mr. Stephenson, although he has, no doubt, relied frequently and largely upon Mr. Ross, is by no means mainly indebted to that gentleman, as the letter would imply, even for "the data" on which his calculations were made. Those data were chiefly collected by Mr. T. Keefer, before Mr. Ross visited Canada, and Mr. Keefer handed over his material to Mr. Ross on leaving the service of the company.

6. All the details connected with the bridge have from first to last been under Mr. Stephenson's supervision, and many of them have been worked out in his office in London under my sole superintendence. The whole of the iron work has been designed in this office. It has been constructed, and some of the tubes put together temporarily, in England, and it has all been shipped to Canada, with detailed drawings and instructions, approved by Mr. Stephenson himself, so as to leave the parties on the other side little more than the duty of putting the pieces together as desired.

7. Mr. Ross, from his first connection with the Victoria Bridge, has been, together with the rest of the engineering staff, under the pay of Mr. Stephenson, the chief engineer.—Mr. Ross has not ventured at any time on any important work connected with the bridge; except upon instructions or after consultation with Mr. Stephenson; nor has Mr. Ross had to bring any originality of conception or ingenuity of adaptation to bear upon either the designs or the details since the work commenced.

8. The construction of the bridge was from the very first, placed in the hands of Mr. Stephenson by the directors of the railway, with full powers to appoint whomsoever he thought proper to assist him. The directors have placed their reliance on his design and reports, and have held him responsible for the works. Mr. Stephenson would not have shrunk from his responsibility had any unforeseen failure or accident occurred, nor has he shrunk from defending both the principles and details of his plan from the various attacks to which they have been subject.

Under such circumstances, you will probably be of opinion that justice to Mr. Stephenson requires that the public should be set right as to the claim made on behalf of another, not only to have "conceived but to have matured, overcome the difficulties, and carried out all the details, of this bridge." Allow me to add, however, that it is with great reluctance, and only as an act of justice to other parties concerned, that Mr. Stephenson authorizes, and that I feel myself compelled to make this statement. Mr. Stephenson has always been, and always will be ready to do ample justice to Mr. Ross, who has never himself advanced the extraordinary pretensions claimed for him by his injudicious friend in England.

I am, &c.,

GEO. ROBT. STEPHENSON.

24, Gt. George street,
Westminster, Sept. 22.

[From the Hamilton *Spectator*, Dec. 6.]

WHO IS ENTITLED TO THE HONOR OF BEING THE ORIGINATOR OF THE VICTORIA BRIDGE?—Two letters have appeared in the Montreal *Gazette*, claiming for T. C. Keefer, Esq., presently of Hamilton, the honor of originating the ideas which have resulted in the building of the Victoria Bridge. It is said that Mr. Keefer's report, published in 1853, showed that the bridge should be built precisely where it now stands; that it should be constructed at the present high level; that causeways should be run out into the St. Lawrence as they actually have been; that the distance between the piers should be within a few feet of that finally determined upon; and that the bridge should be used for Railway purposes only. Mr. Keefer's design was indeed for a wooden superstructure, with a centre span of iron. But this was only on the score of economy, for this report says that "if, as he conceived it should be, it be made to partake of the character of a national work, it should be built for all time; the expense limited only to the means to be attained. As a connection of the two sections of the Grand Trunk Railway, its cost should be distributed over the whole line, and however unprofitable it might then appear as an independent stock, it would in a thousand direct and indirect ways be cheap at any cost." The writers in the *Gazette* are unwilling that a Canadian, entitled to the credit of virtually designing the bridge, should have his name less prominently associated with the great work than those who merely carried out his ideas, however celebrated they may be as Engineers.

[TO THE EDITOR OF THE SPECTATOR.]

SIR,—In your notice of the Victoria Bridge in to-day's paper, some of the statements respecting my connection with that work, are more unqualified than I would wish them to be. My location of the Bridge was not "precisely where it now stands," but a little lower down. The subsequent alteration, which did not involve any principle, was made by another Canadian Engineer—Mr. Samuel Keefer, after the contract had been executed. Point St. Charles, being the nearest point above the harbour, and the most convenient to the city, is the site which would, at first, naturally suggest itself to any engineer as the place for the Bridge: and but little importance would have been attached to the question of location, had it not been for the fact that two American Engineers of high standing had previously located Bridge lines higher up the river, upon Nun's Island; and one of them had expressed the opinion that any attempt to bridge the river at Point St. Charles would, in consequence of the action of the ice, "be attended with great risk, if not prove a total failure." I took a different view, and a great part of my report is taken up in demonstrating that the danger was more apparent than real—and in endeavouring to prove that a bridge at Point St. Charles could sucessfully resist the ice. My reasoning was sustained by Mr. Stephenson, and the Bridge was placed upon the forbidden territory.

I did not fix the bridge "at the present high level," (which is about fifty-five feet above high water over a part of the channel,) but at a higher one; because I did not suppose any encroachment upon the navigation would be permitted. This was before the Grand Trunk era, and I had underestimated the strength of Railway influence in our Parliament and Executive. The other specifications of my plan in your article—as to the solid approaches; exclusion of common travel; and distance between piers—are correct.

In addition to these four distinctive features of my plan, which, with the site, were adopted by Mr. Stephenson, my report also shewed the inapplicability of the suspension principle to this place. There was at that time a strong but indiscriminate feeling in favor of suspension bridges, as (by affording wider spans) offering less obstruction to the ice; and this principle was then about to go into operation for railway purposes at Niagara. To this day opinions are divided upon this point, many believing, after the successful working at Niagara, that greater safety for the structure and greater economy would have been attained by adopting the suspension principle for the Victoria Bridge, without reflecting that while this plan is on all grounds the most suitable for the peculiar conditions at Niagara, it would have been the most unsuitable and expensive, even if practicable—at Montreal.

The lamented death of Stephenson has deprived me of that final and explicit acknowledgment of my labors which would have been given had he lived. In a letter, the publication of which was authorised by him, it is stated that the "data on which his calculations were made" were "chiefly" supplied by me. On more than one occasion since 1853, in his reports and speeches, he has alluded to my report in flattering terms. Upon this testimony, and the text of my report, which speaks for itself, I am content my claims should rest.

HAMILTON, Dec. 26, 1859. THOS. C. KEEFER.

Letter from MR. KEEFER'S ASSISTANT in the Survey.

[TO THE EDITOR OF THE TORONTO GLOBE.]

SIR,—A discussion upon the "authorship" of the Victoria Bridge, has recently been carried on in the Montreal and Quebec papers, and occasionally noticed by the press of Upper Canada, in course of which the claims of Mr. T. C. KEEFER have been warmly advocated by his friends, and, singularly enough, have passed unchallenged by those of Mr. A. M. Ross, with the single "per contra" of a Mr. Doyle, who, in the Quebec *Chronicle* attempts to summarily dispose of Mr. Keefer's pretensions. The gist of his argument is, that because that gentleman was set aside to make room for the English engineers who carried out the principles of his design, and because he was not actually engaged upon the construction of the bridge, that, therefore, it is not *his* bridge, and his name should not appear thereon. By this species of logic Mr. Doyle sets the manufacturer above the patentee or originator, a conclusion more remarkable for its convenience than for its truth. He also appears as the champion of the late Mr. Robert Stephenson, a superfluous task at all times, and rendered doubly so on this occasion, from the fact that Mr. Keefer constantly admitted that the name and aid of the great engineer were material in the accomplishment of the magnificent work in question.

Having been employed upon the surveys for this bridge in 1851-2, I feel called upon at this conjuncture to state briefly facts known to me concerning Mr. Keefer's claims to the merit of having designed its leading features, and projected its present site, but I must premise that the recent statements in that gentleman's favour are by no means the first or most important which have been published, and I beg to draw attention to the following extracts from a letter which appeared over the signature of Mr. Keefer in the *Globe* of the 6th of June, 1856—and which was induced by a series of personal attacks upon the subject in question. In reply to the assertion of the *Leader* that Mr. Keefer affected to treat it as his own work, he says:—

"I have as yet made but one claim with reference to the Victoria Bridge (which is to be found in my petition to the Legislature), viz.: that "the contract of it was based upon my svrvey." This was forced upon me by the refusal of the Grand Trunk Company to pay for what they had made use of; and not until I made this public did that Company consent to arbitration.

"What I now, at the challenge of the *Leader*, will claim, is as follows:—

"1st. That I placed the bridge on the Point St. Charles shoals, after that site had been condemned by the American engineers, from whom the *Leader* says I borrowed my idea, and that upon these shoals it has been placed.

"2nd. That I designed it with solid approaches, not only as necessary to its own safety, but for the purpose of retaining *in situ* the bordage ice; and that I demonstrated that the obstruction formed by these approaches should have the effect of deminishing, instead of increasing the rise of water above the bridge. The feature is also retained in Mr. Stephenson's plan.

"3rd. That notwithstanding the low banks of either shore, I elevated it so as to go over the navigation and avoid a draw-bridge, which would have been impracticable. This feature has been followed, although upon a considerably reduced scale.

"4th. That I gave a clear water-way of 250 feet, while that in the present bridge is 242 feet, or only eight feet less.

"I made the ice-breaker detached, and of crib-work, and proposed, for economy, to use wood for the superstructure of all but the central span. In the work in progess, the ice-breakers are of stone, attached to the piers, and a superstructure wholly of iron is proposed.

"The above, I submit, are all the leading features of the bridge; and I invite the *Leader* to show when and where, and from whom I derived any of them, and also, what there is of originality in the design as now being carried out or in what respect it differs essentially (save only in a reduction of the quantity of the work) from the plan proposed by me All these contributions to the original design of the Victoria Bridge. which Mr. Ross put into Mr. Setphenson's hands, and for which he, claims to be associated with him as engineer, were taken without acknowledgment from my office."

The statements made here in 1856, are corroborated in 1859 by Mr G. R. Stephenson, writing under the sanction of his illustrious relative where he says:—

"5th. Mr. Stephenson, although he has, no doubt, relied frequently and largely upon Mr. Ross, is by no means mainly indebted to that gentleman, as the letter would imply, even for 'the data' on which his calculations were made. These data were chiefly collected by Mr. T. Keefer before Mr. Ross visited Canada, and Mr. Keefer handed over his material to Mr. Ross, on leaving the service of the Company."

These claims, so boldly put forth in the *Globe* of 1856, have never been called in question, although they were made while Mr. Ross was in Canada, and three years before Mr. Stephenson's death. The journal which had attacked Mr. Keefer, whilst replying to his previous communications, was silent as to these.

In the autumn of 1851, a hydrographical chart of the St. Lawrence, in the neighbourhood of Montreal, was prepared under Mr. T. C. Keefer's direction, upon which the outline of both shores and the navigable channel,—between the head of Nun's Island and the foot of the current St. Mary were delineated. In the winters of 1851-2, however, a more accurate examination of the river bed was completed over the same area, and a thorough investigation of that part of it was perfected upon which the Victoria Bridge has since been built. All the sinuosities of the deep water line in and about the harbour were shown upon the chart referred to; the line of the Point St. Charles shoals was clearly marked thereon, and the peculiar "*retrecisement*" of the channel, together with the bar near Moffat's Island, were exactly fixed. In fact, all the information material in definitely locating the bridge was then obtained. The site of the present bridge and its immediate vicinity received particular attention, as Mr. Keefer's predecessor had condemned this position, and he was therefore anxious that no requisite detail should be wanting in support of his reversal of that decision. When this preliminary information had been obtained, I assisted in preparing the plans for a railway bridge upon the combined arc and truss principle, the clear spans to be 250 feet, with stone piers and solid abutments projecting for some distance from either river bank towards its centre, and an ascending grade line from each shore to the point of crossing of the navigable channel, which was about midway; the lower chords to be 100 feet above summer level of water. I also drew the "general elevation," showing all these particulars, and bearing a marked resemblance to the outline of the present bridge. Mr. Keefer declared that the wooden trusses should be changed for iron tubes, were the work made a provincial undertaking.

When these plans were prepared, Mr. A. M. Ross, subsequently the Chief Engineer of the Grand Trunk Railway, visited the office, accompanied by Mr. T. C. Keefer, who explained to him his opinions and conclusions, the fruit of several months' previous labour and investigation, and showed him, in my presence, all the plans upon which his designs were exhibited. As no further examination of the river was then made, even if it could have been accurately effected in the rapid open water of the summer of 1852, I presume that the wisdom of adopting Mr. Keefer's plans was at once recognized, and subsequently paid for by the Grand Trunk Company, upon the decision of the late Mr. Robert Stephenson. When it is considered that the phenomena of the packing and shoving of ice in the narrow parts of Canadian rivers, consequent upon the annual descent of ice fields formed in the basins lying above these points, have furnished an interesting topic of discussion for the most scientific minds in this Province, and that Mr. T. C. Keefer brought to the consideration of this part of the subject (upon which the proper location of the bridge mainly depended) 14 years' professional experience, chiefly gained in hydraulic engineering, and attended by the most marked originality and success in combating with the ice jams and rapids of the Ottawa, it will not be so much a matter of surprise to find him completely refuting the arguments of his predecessor, Mr. Guy, whose experience, though not so large, was gained in the same school as his own. But it cannot fail to excite indignation when the attempt is made by his former successor to quietly absorb his well grounded claims; and although it is yet a matter of dispute as to whom the honor is due for the admirable manner in which Mr. Keefer's ideas were elaborated and carried into effect, there can be no doubt of the fact that when he quitted the discussion of this subject, he precluded the possibility of any leading feature of the present noble structure being ascribed to any other origin than his own.

I am, Sir,
Your obedient servant,
THOMAS MONRO.

Toronto, Feb. 8th, 1860.

Extract from a letter addressed to the Compiler from Canada, under date of 28th January, 1859.

But Mr. Keefer's position does not rest upon hear-say and the mere fact of the claims made by him having been unchallenged. His report published before Mr. Stephenson visited Canada, and before he had given any serious attention to the Bridge question, shews clearly what his views were, and the Bridge now shows how many of them have been adopted. Mr. Stephenson, in his speech at Montreal, and in his report, has not failed to acknowledge his obligations to Mr. Keefer, and has not feared to characterise his report, as an "admirable one," or to speak of Mr. Keefer, as an engineer whose opinions are entitled to confidence. Mr. Ross, who was under far greater obligations to Mr. Keefer (for Mr. Keefer's previous labours enabled Mr. Ross to bring over a bridge scheme ready for contract), has not mentioned his name at all. Probably Mr. Ross supposed that as Mr. Keefer was only a colonist, the discovery of his piracy would never be made in London; but strange to say, that revelation has come from the highest quarter, the undoubted authority of Mr. Stephenson himself. Even the *Toronto Leader*, which in 1856 attacked Mr. Keefer most savagely,—in 1859, in writing the history of the Victoria Bridge makes the following admissions:—"Mr. Keefer dealt both "boldly and ably with the subject; he laid down the principle that the "bridge should pass over the navigation, that it should rest upon piers "which should be as few in number as practicable, and although admitting "the advantages of iron over wood, yet owing to the increase of cost of "the former, his preference was evidently in favor of the timber bridge. "Mr. Keefer likewise argued against constructing the bridge for a "general, as well as for railway traffic, because the ferries in summer, "and the ice in winter, would successfully compete with it."

Mr. Keefer's *preference* was not, as stated by the *Leader*, in favor of wood, but he was employed by Canadian Companies, and saw no hope of an iron structure being obtained. He had not that capital to depend upon which the Barings and Glyns were ready to furnish upon the recommendation of Stephenson.

In a letter written to correct some statements made in his behalf by the *Hamilton Spectator* in December last, (published herewith) Mr. Keefer mentions that in addition to the four *distinct* features of his plan specified in the extract from the *Globe*, there were two others—one of which, the exclusion of common travel, is mentioned in the extract from the *Leader*—the remaining one was that the bridge should be a solid tubular one, whether the tubes were all made of wood or iron; and his report shows how inapplicable the suspension principle would be, although that principle was then being applied to railway purposes at Niagara.

The main features of Mr. Keefer's plan are three, although the five mentioned in Mr. Monro's letter (already given,) have been incorpora ed into the bridge, as built. The deviations from his plan are altogether mechanical ones, such as the form of a pier, the substitution of iron for wood, the alteration of a gradient, or the slight shifting of the line of crossing. These three main features were—First. The placing of the bridge upon the Point St. Charles Shoals after that site had been condemned by distinguished American engineers. Second. The elevation of the centre of the bridge by uniform gradients from the low banks of each side, and thus passing over the navigation, whereas in the plans of his American predecessor, it was proposed to stop the navigation altogether by a level bridge. Thirdly. The solid approaches of several hundred yards upon each shore, thus blocking up so much of the water way of the river in addition to the obstruction caused by the piers. This was a bold proposition, for when Mr. Keefer commenced the survey in 1851, there were not ten men in Montreal who believed that a bridge upon the Point St. Charles Shoals could be made to stand at all, and nine engineers out of ten might have been disposed to continue the piers and arches to the shore, and thus have given the greatest freedom to the river. Bu Mr. Keefer shewed that the danger was to be apprehended from the grounding of the icebergs, by the two great width and shallowness of the water, and that the bordage ice should be prevented from descending by the solid causeways on each shore. He argued the ice question so successfully, that after the publication of his report, public opinion was changed upon the question, and when Mr. Stephenson arrived in Canada, the nnmber of doubters was inconsiderable.

That Messrs. Stephenson and Ross had Mr. Keefer's views fully before anything was done, is evident from the 22nd paragraph of Mr. Stephenson's report of 3rd of November, 1855, where he says, "In the *first* design for the Victoria Bridge, ice breakers very similar to those described in Mr. Keefer's report were introduced, &c."

EXTRACTS FROM REPORT OF THOS. C. KEEFER Esq.,

I will first state what I conceive to be the conditions of bridging the St. Lawrence, and then proceed to a description of the characteristics and phenomena of the river above and below Montreal, before alluding to the details of the bridge and the principles of its construction.

First. The bridge must be so arranged as not to obstruct the navigation. The navigation of the section of the St. Lawrence which it is proposed to bridge is in one direction (downward) only—the ascending craft going by canal; also it is confined to daylight, as no craft will attempt to descend the rapids in the night. In so far, therefore, as any bridge may be considered an impediment to a navigation, it is evident, from the considerations above mentioned, that the site proposed would offer the minimum of obstruction. The current being such as to render a drawbridge inadmissible, there is no other means of providing for the navigation than by elevating that portion of the bridge which spans the navigable channel, *above* the limits required for the passage of craft.

This height, in the case of the Menai Bridge, in Britain, and the Harlaem Bridge, (for the Croton Aqueduct) in America, has been established at one hundred feet.

The bridge site being above the "sea navigation" of the St. Lawrence, I applied at Oswego for information as to the headway required for lake and river craft, and submit the following reply from a most competent quarter. From this it will be seen that with the topmasts struck, the main spars of the largest lake craft stand 86 feet above the water line, so that the provision I have made of 100 feet above low water and 91 feet above highest water at any navigable period, must be considered ample.

To shew the impracticability of accommodating the navigation by means of a "draw-bridge," I would state that the Supreme Court of the United States have decided in the Wheeling Bridge case, that for the current of the Ohio (which is less than that of the St. Lawrence opposite Montreal) a "draw" of *two hundred* feet in width is the least which can be accepted.

Even if it were practicable to meet the requirements of the navigation by a "draw-bridge," it is questionable whether the "high level" bridge would not be preferable. The highest known ice floods have risen to a point 25 feet above extreme low water mark. It would not be prudent to place the superstructure of a bridge within at least 20 feet of this point, so that *any* bridge over the St. Lawrence at Montreal must be elevated about 45 feet over low water mark. Fixing the abutments, therefore, at this height, the additional cost of elevating the whole bridge gradually from either shore to the height required to pass *over* the navigable channel will not be much greater than the cost of a draw-bridge, and the necessary approaches and expense attendant upon it. The fact that there is but *one* navigable channel, and this so narrow that it can be spanned by a single arch, has enabled me, by elevating to the extreme height *this arch only*, to make an arrangement of the bridge which while it admits of the greatest economy in the construction, enhances the architectural effect, and offers an unmistakeable guide to lead the river craft into the proper channel.

By increasing the centre span the channel may be crossed higher up and the bridge shortened,—the width of the other spans and the length of the approaches may be increased or diminished and the outline of the structure may be varied, but I am of opinion that the plan now proposed for bridging the St. Lawrence will, in all essential features, be found the most secure, effective, and economical.

The second condition is, that the bridge must be a *solid* one adapted to the passage of railway trains.

Suspension bridges in this country have of late been adopted for large bridges, and are now about to be applied to railway purposes. Where a channel is too wide to be spanned by beams or arches, or where the depth of water or narrow chasms make piers or towers impracticable, the suspension bridge is the only and most economical resource. For railway purposes a single span may be made available, but for a long bridge where a succession of spans are required, if constructed in the ordinary manner the vibration would be destructive to the work, and if constructed on any other principle their economical advantages disappear. From the vastly increased quantity of masonry required a suspension bridge would be more expensive in the site proposed than any other class of structure.

The third condition is that the bays or distance between the piers should be as wide as practicable. From economical considerations only the great cost of every pier would dictate the employment of the least possible number; but as the "conditions" proposed have no reference to the *cost* of the structure, I would state that it is on account of the requirements of the timber navigation and the safety and efficiency of the structure itself that I have left a clear water way of about 250 feet for each bay. The usual length of a "dram" of timber floating down the river ranges from 200 to 240 feet, and as rafts are not under the same control as boats but are liable to be driven from one side of the river to the other by wind, the raftsmen cannot select a particular arch for shooting the bridge, nor are they able to prevent its "swinging" and passing broad side through.

The importance of the solid approaches upon the shoals at either end of the bridge (which will be explained in another place) renders it desirable that this arrangement should be maintained, and as thereby a considerable portion of the water way of the stream is occupied—forcing the passage of the river toward mid-channel—it is clear that, unless the number of piers are kept within certain bounds, too much of the area of discharge may be taken up, particularly if the large "shoes" of crib work surrounding the base of each pier,—which I consider indispensable, are adopted.

But the most important argument in favor of wide bays is that all risk of an "ice jam" between the piers is thereby reduced if not wholly removed. The greater the distance between the points of support the weaker will be the resistance of any solid sheet of ice arrested by the piers, and the more rapidly it will be borne down, broken, and driven through by the current and following ice. Although there might be little or no risk to an elevated bridge from the jamming of ice, yet a greater evil, that of a temporary stoppage and overflow of the adjacent bank above the bridge, is incurred by planting the piers too close to each other.

Having stated, first, that the bridge should pass *over* the navigation; second, that it should be a solid railway bridge resting upon piers, and thirdly, that these piers should be as few in number as practicable, I will add, that it is greatly to be desired that so extensive and important a structure could be constructed of some more durable and less inflammable material than wood. The length of superstructure required is above 7000 feet, the cost of which, if constructed of iron, would be about six times greater per lineal foot than if built of wood. The *extra* cost of iron over wood would be about £500,000, or much more than the whole estimate for a wooden bridge. A wooden bridge properly constructed and protected will last at least half a century, and if it were not for the contingency of fire would be all that is needed.

This risk of fire should not, however, operate against the construction of the bridge in wood—if the more expensive structure be unattainable, because it is slight, considering the vast number of wooden railway bridges in America,—and would be reduced in the present instance to a very remote contingency. Cut off by the solid approaches from either shore, and elevated where the wooden structure would necessarily commence from 50 to 100 feet above the water, it is exposed to fire only from the passing of engines. The rails being laid *upon the top* of the bridge—with the exception of the centre span which would be iron—by casing in the sides, top and bottom, no accidental fire could be communicated to it, and as the bridge would be under constant surveillance I consider the risk of fire should be no barrier to its early construction. The width of the spans have been established at nearly the limits of a wooden structure for railway traffic, both for reasons already given, and with a view of replacing, at some future date, the remainder of the hollow wooden beams by similar ones of iron.

It has been proposed to arrange the bridge for ordinary traffic as well as for railway trains. This I have not done, considering it unnecessary and objectionable if a wooden structure be adopted. In winter the carriage way underneath the rail, being covered, would be impassible for lack of snow; but, if by any arrangement made passable, it would not be used (except for a few days while the ice is forming or leaving) because of the *detour* made by the bridge. For the same reason, ferries, in summer, by running directly to the Bonsecour Market or other desired points, would compete successfully with the bridge for the local traffic. The revenue to be anticipated from this source would not pay the collector, and it would be manifestly imprudent to expose a wooden bridge to the ever active pipes of passing *habitants*.

A path for foot passengers can, however, be projected from the sides of the bridge, which would be profitable, as it must become a favourite resort.

The disturbance of the river level by the action of the ice is peculiar to Cornwall and points below the Lachine rapids, the current between

Caughnawaga and the head of the Lachine rapids, that at the head and foot of all the rapids above these, except the Longue Sault, viz: the Coteau, Cedars and Cascades, and those of the Ottawa, is not checked and frozen over during the winter as is that of Current St. Mary and of the Sault Normand. There is no doubt that if the level of the river opposite Montreal harbour were undisturbed by the action of the ice, the Current St. Mary, the Sault Normand, and the Laprairie basin would remain unfrozen.

Lakes St. Louis and St. Francis freeze over, and although vast quantities of ice descend and are formed in the rapids above them during the whole winter, the ice does not pass on *under* the frozen surface of the lake or produce any permanent or important effect on the level of the river. It piles at the foot of the rapids, where it is destroyed gradually on the approach of spring—without passing through the lakes. Also, after the Laprairie basin becomes frozen over, large quantities of ice are still brought down and piled at the foot of the Lachine rapids, which remain there.

All destructive effects of the ice are incidental to the elevation of the river and the sudden "slipping" of some of the ice dams, and it becomes important therefore to consider *where* and *how* these are formed—and whether they can be ameliorated or guarded against.

The ice first "takes" in Lake St. Peter, fifty miles below this city, *after* the St. Lawrence has received the main branch of the Ottawa, and several large streams from the north and south shores. The stopping of the ice on the shoals in and at the entrance to this lake, gradually raises the level of the St. Lawrence as far up as Bout de l'Isle and Point Aux-Trembles, but seldom to a height greater than five feet, which therefore is for this portion of the river the excess of the winter level over that which obtained before the commencement of frost. This amount of elevation would on account of the current be but slightly felt in Montreal harbour, where the average excess of the winter over the autumnal level of the water is three times as great. We thus find the water standing at a winter elevation in our harbour of fifteen or twenty feet, while twelve miles below us at the same moment of time, the elevation does not exceed five feet. Similar investigations will shew that the principal obstructions are found between Montreal and Longue Pointe. The "longitudinal opening" in the Current St. Mary, described by Mr. Logan, proves that the greatest encroachment on the discharge of the stream takes place at this point.

The ice also takes at the head of Isle Bourdon or Porteous' Island, (at Bout de l'Isle,) among the first points: no drift ice therefore comes out of the Ottawa to block up the main channel of the St. Lawrence and set the waters back upon Montreal: and since there are no streams coming into the St. Lawrence between Montreal and Bout de l'Isle the materials of the ice dams must be derived from points adjacent to and *above* the city,

It is therefore certain that the inundations are to be attributed to dams formed by ice floated *past* the city, that they are not the result of operations going on *below* us, and which cannot be influenced by improvements here. Having established the point were the ice dams are made, it is important next to examine the area from which they draw their supplies.

The length of river which sends down ice for the formation of these dams is about fifty miles—extending from Montreal to lake St. Francis.

This lake being comparatively deep becomes frozen over early, and arrests the ice which descends from Prescott and the intermediate islands—another stretch of about fifty miles of river. Cornwall therefore presents phenomena similar to Montreal. The great distance, numerous islands, the strong currents and rapids between Prescott and Cornwall, send down inordinate quantities of ice, which being arrested by the solid crust over the lake St. Francis, "flashes" the river opposite Cornwall. In like manner the current, the rapids of the Coteau, Cedars, Cascades, and the Sault St. Louis and Normand, bring down the manufacture of fifty miles of river to be arrested principally between Montreal and Longue Pointe. The shallow expanses of Lake St. Louis and the Laprairie basin are of no value in arresting the ice on account of their strong currents. If Lake St. Louis were frozen over at the same time with Lake St. Francis—the winter inundations at Montreal would be diminished about 50 per cent; but as it does not present a barrier to the ice descending from the rapids above it until about the same time that the river is closed opposite Montreal—it affords no protection. It is worthy of remark, however, that the causes which produce the closing of Lake St. Louis and the river opposite Montreal at about the same time, have no connection with each other. The river takes *here* because by the rise of water the current is slackened; and the floating ice from above is arrested against the "bridge" below, without current enough to force it under—like logs in a boom: whereas the level of Lake St. Louis is not altered, but a certain time and degree of cold are necessary to enable the opposite bordages to encroach upon its strong current. If the early part of the winter be mild or changeable and accompanied by much wind, these bordages may be broken off repeatedlv by the swell before they are closed; but if the winter sets in, as in December last, (1851) with uninterrupted severity, this lake is closed sooner—less ice descends and a dimiminished rise of water is the result at Montreal. This explains the apparent anomaly of greater inundations in "open" winters and less in severe ones.

The Laprairie basin is so extremely shallow that it is not frozen over until its depth is increased about ten feet by the action of the ice dams below. While this lake-like expanse is of no more value than Lake St. Louis in arresting the early ice,—its extensive shoals and margins furnish proportionally the largest in quantity and the most formidable in character of the *material* of which the ice dams are composed. The ice which descends from points above the Lachine rapids, is composed of "fragments of the glacial fringe broken off by the wind, and enlarged in their descent by the cold;" but in the Laprairie basin the strong clear ice which forms round the islands, rocks, and upon the shore and shoals with the first frosts, is forced up and broken off from its attachment to the sides and bottom by the hydraulic lift of the subsequent rise of water, and—from the peculiar bend of the coast between Longue Pointe and the Lachine rapids—there exist no projecting "jetties" of land to retain this formidable bordage in the place of its formation. With the rise of water the current "in shore" increases and sets the whole field, sometimes half a mile in width and two or three miles in length, in motion. These form the "league after league" mentioned by Mr. Logan, and by their momentum these masses break up the resisting "bridge," and force under with such violence the blocks which form the dam. This process may be repeated—a new bordage being broken off by a second rise of the water and sent down to aid in a still further elevation of the river. When a sufficient quantity has thus been sent down to raise the level of Laprairie basin about ten feet the current therein is so diminished that it becomes frozen over, and then all further supply is cut off.

The natural inference from the foregoing is, that if the bordage ice can be retained *in situ*, and the "taking over" of Laprairie basin thereby be expedited, a very great portion of the supply furnished for the ice dams would be cut off and the intensity of these be correspondingly diminished. This hypothesis is confirmed by the fact that in severe winters when the ice takes rapidly there is a lighter inundation than in milder ones. In the former case the *time* required to close the river (and therefore the quantity of ice which can pass down in a given time) is a minimum, while in the latter the stopping and starting, the freezing and "slipping" extend over a long period of time,—and a greater quantity of ice passing down, a greater dam is formed and a greater inundation takes place. A most important effect of a protracted closing over of the open water is the greatly increased quantity of snow which, falling in this water, is converted into "*frasil*" or "anchor ice, " and having about the same specific gravity as water is carried *under* the sheet-ice, and "banks" upon the shoals, reducing the waterway of the stream.

For the foregoing reasons I am led to the conclusion that the intensity of the ice phenomena at Montreal is due to the great area of open water which exists until January above the city, the absence of natural features above us for arresting or retaining the ice formed within this area, and to the existence of such features immediately below and opposite to the city.

Inasmuch as the natural bridges of ice wherever formed, have the effect of arresting its further descent—which descent is the sole cause of the winter inundations—I am of opinion that an artificial bridge, in so far as it will aid in arresting descending ice, retain *in situ* the bordages, elevate the level of the water—thereby diminishing the current,—and expedite the closing over of the river above us—will unquestionably tend to diminish rather than to increase the intensity of the winter inundations at Montreal.

SITE OF BRIDGE.

While the selection of the site has been governed by the accidental conditions of the river, it possesses a variety of advantages which under such circumstances could hardly have been anticipated.

1st. The location is on the most direct line of connection for the Grand Trunk Railway. This road, without reference to the bridge, would on approaching the city cross the canal at the only convenient point (which is near Gregory's and above all the basins) and proceed down to Point St. Charles for its freight terminus and for a connection with the harbour independent of the canal. The bridge line is a continuation of the main track coming down to Point St. Charles.

2nd. The line in the river runs upon a rock bottom and in more shallow water than can be found upon any other direct line crossing the St. Lawrence. It is a remarkable fact that the shoalest water to be found in the St. Lawrence below Lake Ontario is on the *last* rapid—the Sault Normand opposite Montreal.

The width of the river, and consequent length of the bridge is not only counteracted by this shoal water (fully half of the whole distance being less than five feet deep,) but this width involves little disadvantage, because the distance between the only navigable channel and the shores admits of a gradient, which passing *over* the limits required for the navigation, yet descends at once so as to strike the business level at both of these shores.

3rd. The ice seldom lodges *above* the line of the bridge although it always does to a greater or less degree immediately below it. Nun's Island gives a direction to the current which throws the ice against Moffat's Island, where it piles with great force. The shoal which is suspended from the lower end of Nun's Island to the centre channel, will act as a breakwater to the western half of the bridge against the effect of "bergs" of ice. The average depth of water on this shoal not exceeding seven feet, detached ice breakers can be constructed upon it at a moderate cost, which will break the momentum of large descending fields,—while accumulations of ice having too great a draught of water to pass under the arches will be "picked up" by this shoal before reaching the piers of the bridge. On the eastern half of the bridge, the greater portion of the work will derive much protection against the effects of descending ice, by the works of the Champlain and St. Lawrence Railway and by the natural breast work of Moffat's Island.

4th. The site, while it possesses all the advantages of a line in the rapids where there is but one navigable channel, not only has that channel narrower than any available one in the rapids above, but this rapid is so moderate as not to offer any great impediment to the work of erection and construction, and for three months in the year is frozen over and accessible at every point upon strong ice.

5th. Terminating at Point St. Charles in immediate contiguity with the canal basins, the water level of which, aided if necessary by an additional supply from the head of the Lachine rapids, can be conducted over hundreds of acres both on land and in the river,—the bridge will lead all the railroads from the southern shore to the only point where they can be placed in immediate connection with the navigation and receive supplies "ex-warehouse," or direct from inland or sea craft for distribution to every part of New England or the Lower Provinces. In connection with this subject I have projected a scheme of docks around Point St. Charles, which shews the capabilites of the place in point of extent to be at least equal to that of Liverpool, Glasgow, or London, and which may be taken up in sections and extended as required for the increasing wants of commerce.

The importance of this point, its fitness for a general railway terminus in connection with the sea and inland navigation, is explained at large in the appendix in an extract from my unpublished Report on the Montreal and Kingston Railway, and also an extract from a lecture before the Mechanics' Institute of this city.

It will be at once seen on reference to a map, that *the whole* of the channel between Nuns' and Montreal Islands may be filled with water and made available for the navigation. Also by obtaining (upon top of the embankment) permanent access to Nuns' Island, the outer coast of that island presents an extensive frontage and deep water where barges and lake and river craft not drawing over nine feet water may load for ports below.

It is only by an artificial harbor accommodation like this that Montreal can ever hope to share with Quebec any portion of the export trade in deals. Bright deals brought by railway to Point St. Charles and Nuns'

Island, could afford this transportation on account of the higher price these command over those which have been floated. This trade by attracting a larger marine to this port could not fail to give an important impulse to our commerce.

PRINCIPLES OF CONSTRUCTION.

The importance of retaining the "bordage" ice *in situ* has been explained, and for this purpose, that part of the bridge extending from the shores over the shoals, to the depth of five feet water, being a distance of 450 yards on one side and 570 on the other, is designed to be a solid causeway or embankment carried above the level of the highest winter flood; from which point to the level of the rails it may be carried up by a viaduct of arches—an embankment, or trestle work for the present. On the south eastern shore the great width and dead shoal water around the Laprairie basin, form square miles of ice which, so soon as it is freed from its attachment to the shore, is carried by the throw of the current directly down through the *now* important channel between Moffatt's Island and the St. Lambert side. The works of the Champlain and St. Lawrence Railroad Company, although incomplete and not high enough, retained this bordage *in situ* during last winter, (1851—1852) and this in connection with the fact that the winter set in with great severity, was one cause why the inundation at Montreal was less than usual,—was unacccompanied either on the formation or departure of the ice with any " shoves"— and that the surface of the river opposite Montreal presented the evenness of a mill pond instead of the ragged quarry aspect of broken ice usually seen.

The solid approaches will be cheaper and more substantial than any other portion of the bridge of equal length; and, in fact, no substitute which will bring the rails down to the level of Point St. Charles can be devised for them, exeept that of extending the piers and bays to the shore and carrying the masonry up to the level of the rails. A system of masonry arches giving free passage to the water would be exposed to the risk of being blocked up and overthrown by the "shoves" of the ice.

To carry out the arrangement of descending from the central arch to each shore on the top of the tubes, it is evident (since the depth of these is 30 feet under the rails) that as the shore is approached the lower side of the tubes would be brought within the reach of the winter flood. Before this point is reached, therefore, the arrangement and character of the structure must be changed, and as it would destroy the effect of the bridge again to elevate the tubes and run *through* them—the solid causeway is necessary. It is true that by abandoning the proposed arrangement of running on top of the tubes, raising the masonry of all the piers to the level of the rails, and continuing the piers and tubes to the shores—the solid approaches can be dispensed with; but I consider that there are objections to such an arrangement exclusive of economical considerations and the loss of the effect of the solid approach in retaining the bordage. If the spans are such that tubes whether of iron or wood are required,—passengers would be confined in a tunnel two miles in length with all its disagreeable connections, and if the spans are so narrow as to admit of an iron bridge open at the top—the side trusses would yet be necessarily so high that it would become a long trough which unless open at the bottom would fill with snow, while it would effectually deprive the passengers in summer of that view from the windows of the train which will constitute one of the great attractions of the bridge. On the other hand by the arrangement proposed the appearance of the bridge with passing trains is improved—the snow is avoided—the monotony of the outline is broken by the single elevated tube in the centre, and the channel is thereby clearly displayed to the navigation. The pleasure and comfort of the passengers is enhanced—economy and safety to the structure are secured—and, if built of wood, the risk of fire is greatly diminished.

THE PIERS.

The most important question in connection with the structure is that of the piers. The superstructure and approaches are simple matters, and so would the piers be were it not for the ice phenomena. Many persons (astounded by the commotion when a "shove" takes place) entertain the belief that piers cannot be made to stand in the river below the Lachine rapids, or at least below Nuns' Island; but the simple contrivance described by Mr. Logan shows how easy it is to *elude* the effects of the ice, however difficult it may be to *oppose* them. That the ice is not, as is often remarked, "irresistible," may be proved from the fact that the islands, rocks, wooden wharves and stone quays have not been removed by it. Probably there is no point where the ice strikes with greater force than against the long wharf at the Bonsecour Market—but this cribwork has resisted the shock, and forced into the air a broken heap of fragments. The power required to crush a cubic inch or foot of ice is very much less than that required to crush stone, iron or wood. If therefore there is mass enough or support enough, as is annually proved by the stone quays of Montreal, the ice is broken into fragments or ground into powder;—but the simpler, more economical, and effective method is that universally employed where ice is to be encountered, of *turning the ice back upon itself* and leaving the first arrivals to take the shock of all that follows after. By sloping the up-stream face of a pier or ice breaker so that the ice will ride up upon it, the stability of the pier is increased by the additional weight piled upon it and a heavy rampart of ice receives all future assaults.

But it is to be expected that the violence of the ice shocks will be diminished rather than increased by the erection of a bridge. At present when a dam slips and the ice begins to move, it is carried on with increasing momentum until it strikes the shore. But if sustained at intervals of 100 yards or less across the stream by piers, the initial velocity would be checked and the ice would rise and fall *in situ* with the variations of the water level.

The plan I have proposed contemplates the planting of very large "cribs" or wooden "shoes" covering an area of about one-fourth of an acre each, and leaving a clear passage between them of about 240 feet —a width which will allow ordinary rafts to float broad-side between them. These "islands" of timber and stone will have a rectangular *well* left open in the middle of their width toward their lower ends, out of which will rise the solid masonry towers supporting the weight of the superstructure, and resting on the rocky bed of the river. This enclosure of solid crib work, all round the masonry yet detached from it, will receive the shock, pressure, and "grinding" of the ice, and yield to a certain extent by its elasticity without communicating the shock to the masonry piers. These cribs, if damaged, can be repaired with facility, and from their cohesive powers will resist the action of ice better than ordinary masonry. During construction they will serve as coffer dams, and—being formed of the cheapest materials—their value as service ground or platforms for the use of machinery, the mooring of scows, &c., during the erection of the works will be at once appreciated. Their application to the sides of the piers is with particular reference to preventing the ice from reaching the spring of the arches which will be the lowest and most exposed part of the superstructure if wood be used.

The class of superstructure proposed for these wide spans, if of wood, would be a strong rectangular open built hollow beam, assisted by a deep open built arch. The two systems of arc and truss, however objectionable in iron bridges, have been proved to be susceptible of advantageous combination in the numerous and excellent bridges built on what is known as the "Burr" or Pennsylvanian principle—decidedly the best class of wooden railway bridges in existence The elasticity of timber permits both systems to come into play without injury to either when a strain is upon them, (which is not the case with iron) while the too great elasticity of the wooden arch is counteracted by the rigidity of the truss to which it is attached.

Experiment at Menai proved the superiority of the rectangular form for hollow beams in iron. It is somewhat singular, that the best form of wooden bridge in America for wide spans was, long previous to the Menai experiment, a type in wood of the celebrated tube. The strength of both bridges is collected near the four angles; the sides top and bottom, in the iron wonder, serving chiefly to maintain the relative position of the vital parts. The strength of the wooden tube must be wholly in the top and bottom chords—the inferior capacity of wood for the connection of its parts being in some measure compensated for by the practicability of employing the auxiliary arch.

EFFECT OF THE BRIDGE ON THE RIVER AND ICE.

The area of the water section of the river at the site of the bridge is in ordinary winters more than double that in summer, although the flow of water remains the same—the velocity only being diminished. The effect of a bridge by preventing the descent of a large portion of the materials which now aid in forming the ice dams, and by concentrating the current in the main channels, would, in my judgment, prevent the grounding of the ice at many points where from the great breadth of the river, the distribution of the current over its whole surface (and therefore its reduced power) it now grounds; and, particularly, by restoring to Current St. Mary that portion of the flow which the ice dams now drive through the channel east of St. Helen's—would aid in keeping the former channel clear and thus diminish the packing which is here so formidable.

There are but two ways in which the bridge can produce an effect upon the river—and in either case the result will be the same—viz.: the Laprairie basin will "take" at an earlier date and at a lower level than it now does. Taking the most alarming view of the case, viz: that the first ice which descends in December is arrested and chokes up a portion of the water way between the piers. A rise of water is the consequence which, if maintained, so deadens the current in the Laprairie Basin that it is frozen over—the further descent of ice, and of course the further elevation of the water, is arrested. If this first rise is not maintained it will be because the additional head of water acquired will cut out the obstruction and avert the inundation.

In the event of the early ice being arrested as above the consequence will be that the river would remain open during the winter opposite Montreal as it now is opposite Caughnawaga.

But if, (as is most probable), the first coming ice passes under the arches and descends to form the ice dams below,—the water rises and breaks off the bordages—the current slackens, and before the Laprairie basin has reached the point at which it now generally freezes, the bridge by its piers and approaches will have arrested the now slowly moving bordage and close the river. Thus Laprairie basin is the guage of the inundations—and although the level at which it now closes varies with the severity of the season—it is manifest that any bridge must tend to expedite rather than retard this consummation.

It may still be feared that the bridge will increase the inundation when the ice breaks up in spring. The worst case is when the ice gives way in Lake St. Louis, and descends into the Laprairie basin upon the top of the local ice there—before the latter has started. But as the bridge will retain the ice in the Laprairie basin longer than usual, (although being above it will not delay the opening of navigation in Montreal harbour,) the result will be that the Lake St. Louis ice will be received by the solid crust of the Laprairie basin at the foot of the Lachine rapids—and any temporary "flashing" will be confined to these rapids, where it can do no harm.

The "longitudinal opening" in the current St. Mary will probably be regularly extended up to the bridge as the concentration of the current caused by the latter, will tend to cut through the surface ice—keeping an open channel opposite Montreal, and ensuring the quiet and gradual departure of the ice without shoves.

To bear out the assumption that "obstructions" in the St. Lawrence at Montreal would diminish the winter inundations, it may be remarked that these last have certainly not been increased by the canal and harbour improvements. It is a well established fact that the water has not stood so high by at least four feet since the wharves were constructed as before.

It is an encouraging reflection that the progress of improvement which follows the demands of commerce may have the same ameliorating effect upon the character of our river as that of cultivation on the soil. If this were not probable, the prospects of the future commerce of Montreal would be gloomy indeed. The new wharves at Caughnawaga and Lachine will aid in retaining the bordages, and future improvements— when the Board of Works make permanent instead of floating Light-Houses—will still further aid in arresting the descent of ice from L. St. Louis. There is very little doubt but that a line of piers across this lake near Isle Dorval would very much diminish the annual inundations at Montreal.

The real difficulty with the St. Lawrence opposite Point St. Charles —the point where a "jam" is most feared—seems to be a superabundance of room. The great breadth of the river and the diminished current here when the water is high permit the ice to ground on these shoals—whereas if the channel were confined somewhat as it is in summer, the water would maintain its passage—as it does *at the head* of every rapid in the St. Lawrence and Ottawa.

But assuming that the bridge fails to diminish the winter floods, and that it should increase them, the extra inundation will be confined to the shores above Point St. Charles, and it is important to consider what can be done.

It would be but a slight expense to run a dyke or levée at the few low points where the river would overflow its banks and to turn the course of the River St. Pierre so that it may discharge *below* the bridge.

ESTIMATE AND REVENUE.

The cost of bridging the St. Lawrence, from Point St. Charles across Moffatt's Island to the St. Lambert shore, will of course depend upon the plan and material employed; but as the financial obstacles have hitherto been the barrier to its commencement it is necessary to present estimates shewing the least amount for which a serviceable structure can be attained, as well as estimates for a completed and durable work worthy of the great interests which it affects.

Recognizing the principle that it is the duty of an engineer to shape his plans according to the wants and necessities of the case, it will be evident that the class of structure undertaken will be governed by the prospective revenue—if it be viewed in the light of an *independent* commercial speculation. But if, as I conceive it should be, it be made to partake of the character of a national work, it should be built for all time—the expense limited only to the means to be attained. As a connection of the two sections of the Grand Trunk Railway, its cost should be distributed over the whole line; and however unprofitable it may now appear as an independent stock, it will, in a thousand direct and indirect ways, pay almost any cost.

I will not attempt to estimate the average tonnage and rate of toll which may be charged for the next twenty years, and thus determine the amount which may now be expended on a bridge, but with the rate of return which it is usual to anticipate from such structures in this country, and in view of the fact that the broad guage has been adopted for the trunk line, I have come to the conclusion to recommend a superstructure chiefly of wood, if the project is to be taken up as a self-sustaining commercial speculation.

The cost of an efficient railway bridge upon the site proposed, with a superstructure of wood for the side arches and a wrought iron tube for the centre one—the whole resting upon abutments and piers of substantial masonry, and having approaches formed by solid embankments of earth, will be £400,000 Currency. With an iron superstructure in the side arches, the cost would be increased to £900,000. Cy.

My instructions having in view the connection of the Canada Grand Trunk Railway I did not deem it necessary to examine sites for the bridge above Nuns' Island, as the *detour* would be objectionable, the cost at least as great, and facilities for construction less. The arguments in favor of sites above Point St. Charles are, a supposed greater immunity from the action of ice, and less risk of inundating the city by reason of the "obstruction" which it is presumed by some the bridge will cause. As I do not entertain any apprehensions on either score, I have selected the present site as the most convenient, and in every respect the most eligible one.

EXTRACT FROM THE REPORT OF EDWARD F. GRAY, ENGINEER OF THE COLUMBIA AND PHILADELPHIA RAILROAD, UPON BRIDGING THE ST. LAWRENCE AT MONTREAL, MADE IN 1846.

It may be remarked that Mr. Gay is the only Engineer preceding Mr. Keefer who made a report, plans, and estimates. Mr. Morton took a line of soundings for a site, which, like Mr. Gay's, was across Nun's Island, considerably above where the Victoria Bridge now stands.

"The data thus obtained, confirmed as it is by impressions derived from a personal examination of the river, and by my familiarity with the operations of large bodies of ice on streams somewhat similar, enables me to express the opinion, that any attempt to construct a permanent bridge across the St. Lawrence, below Nun's Island, or between it, and the lower end of St. Helen's Island, would be attended with great risk, if not prove a total failure. This is inferred from the fact, that the river is so much contracted in its width at St. Helen's Island as to form a natural dam, sufficient to obstruct the free passage of the ice, during its formation, and breaking up, and thus cause an accumulation of both ice and water opposite the city, which would endanger and probably destroy any structure of the kind, that might be attempted at that point.

"Another line has been examined across the river, under the direction of Mr. Morton, chief engineer of the Atlantic and St. Lawrence Railway, to whose kindness I am under obligations for a copy of the soundings taken upon it, which is the more valuable, as affording comparative evidence of the accuracy of our measurement.

"This line, which may be denominated the "railroad line," crosses the west channel, about one-fourth of a mile below the site which I have selected, and being near the foot of the Island, is considered objectionable, as a bridge upon it would be exposed to the re-action of the ice from the main channel.

"It has been suggested that the construction of a "draw" in the bridge would be required. If so, it is to be regretted, as the shallowness of the water near the shores, would require the location of the "draw" to be made in the channel, at considerable distance from the shore, in order to accommodate the river trade, or rather masted vessels descending the river.

"And as a "draw," exceeding sixty feet in length, cannot well be made sufficiently strong for the purpose of railway travel, it must be evident that the erection of two piers in the river channel, within sixty feet of each other, would be calculated to obstruct the passage of the ice, and perhaps jeopardise the safety of the bridge, more especially, as the superstructure of one hundred and twenty feet, of one span, next the "draw," would have to be constructed three feet nearer the surface of the water than would otherwise be required, in order to allow the "draw" to be moved back within it. It is to be hoped, therefore, that the construction of a draw may not be found necessary.

"The vast importance of a permanent bridge across the St. Lawrence, at Montreal, and its tendency when finished, (by the facilities for intercourse which it will offer, to develop the resources, and promote the prosperity of the province generally,) must be obvious to any one who is familiar with the river in that vicinity, and has reflected on the subject. And it certainly would afford cause of great regret, if the authority for building the bridge should be coupled with conditions calculated to impair its safety or its usefulness when done."