CANAL LOCK DESIGN AND CONSTRUCTION:
The Rideau Canal Experience, 1826-1982

by Robert W. Passfield
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Preface:

The Rideau Canal was built as part of a larger effort by the British Army Board of Ordnance to provide a secure military communication between the ocean port of Montreal and Kingston on Lake Ontario, via the St. Lawrence, Ottawa, and Rideau-Cataraqui river systems. In all, three canal systems were constructed: the Lachine Canal (1821-25); the Ottawa Canals (1819-34); and the Rideau Canal, built by the Corps of Royal Engineers under Lt. Colonel John By (1826-32).

On the Rideau Canal project, plans were prepared for three different scales of canal lock and various mechanisms were proposed for operating the lock gates and sluices before the engineers settled on the design details of the 33 by 134 foot locks actually constructed. Thereafter, further design changes had to be made in response to problems encountered during the course of construction and in operating the finished canal.

The present work traces the design evolution of the Rideau Canal locks through all three proposed scales of construction in the context of the contemporary state of canal engineering in the Canadas, the United States, and Britain. The design of the locks actually built is described in detail and deviations made in the basic design during the course of construction are set forth, as well as the method and materials of construction, and the specifications governing the same. Subsequent changes in the operating mechanisms and materials of construction are described and dated through to the present, and the lock structures and operating mechanisms assessed in terms of their operational efficiency and durability in the context of particular problems that necessitated design modifications and/or changes.
In preparing this study, a conscious effort was made to analyse and integrate the vast amount of information conveyed by an extensive collection of Rideau Canal plans, drawings, paintings and photographs held by various public archives and Parks Canada with material extracted from the reports and correspondence of the succession of superintending engineers who were responsible for the operation and maintenance of the Rideau Canal over the years. A selection of drawings, plans, paintings and photographs have been reproduced herein to illustrate the text. For ease of reference, the text has been sub-divided by subject matter into five major sections and numerous sub-sections as indicated in the Table of Contents.
Introduction

On the Rideau Canal, Colonel By did not prepare a plan for the locks until well after construction had commenced. According to the instructions received from the Ordnance, he was to construct a gunboat canal of 5 foot depth from the Ottawa River to Kingston via the Rideau and Cataraqui rivers with locks 20 feet by 108 feet to match the locks of the Lachine Canal. The construction work was to be done by contractors on multi-year contracts. The superintending engineer and the officers on his staff were responsible for preparing plans and specifications detailing how the work was to be performed, and for maintaining, together with the civilian overseers, a strict and constant supervision over the quality of work performed. Although the contract system was to prevail, By was authorized to hire day workers, or use soldiers, where they might be employed to advantage on any part of the work. The Ordnance provided no directions as to the design of the locks, or other canal structures, to be built; but he was directed by Major General James Carmichael Smyth, the framer of his instructions, to examine the Lachine Canal locks which the latter noted were "extremely well executed" and of a much more substantial construction than American canal locks. From the tenor of By's instructions, it is clear that the Ordnance was deeply concerned to ensure that the contract system, adopted to enable the Rideau Canal to
be constructed as rapidly as possible, should not result in
the performance of poor quality work, but was prepared to
entrust the design of the locks, and the other canal
structures, to the superintending engineer.

During the course of construction, By prepared plans
for canal locks on three different scales of canal on
somewhat different design principles: a 20 foot wide gun­
boat lock, a large lake-steamboat lock of 50 foot width, and
the 33 foot wide river-steamboat lock that was actually
built. Initially, he concentrated on working out the layout
of the locks and preparing specifications for the cutting of
the stone for the locks so that some of the excavating and
masonry contracts could be let and work got underway.
However, once By and the Royal Engineers on his staff
returned to their winter quarters in Montreal following the
completion of the first work season on the Rideau, plans
were prepared, dated 1 December 1827, for two different
scales of canal locks for the perusal of the Ordnance. The
first set of plans was for a lock chamber of 20 feet by
108 feet clear of the gates with 5 feet of water on the
sills as was required for the gunboat navigation that By had
been instructed to construct; and the second set of
plans was for a huge lock chamber, on a somewhat different
design, of 50 feet by 150 feet with 5 feet of water on the
sills.

Soon after his arrival in North America, By had become
convinced on both military and commercial grounds that the
Rideau Canal should be constructed as a steamboat navigation
of 10 foot depth with locks 50 feet by 150 feet so as to be
capable of passing the largest of the contemporary river and
Great Lakes steamboats. He therefore attempted to convince
the Ordnance to approve his undertaking the construction of
the large steamboat locks. After encountering strong
opposition to increasing the size of the locks, he scaled down the depth of his proposed large lock steamboat navigation to five feet in an effort to reduce the projected cost and salvage at least some of the benefits that a large lock steamboat navigation would yield. While awaiting the decision of the Ordnance, By proceeded with construction during the 1827 working season on the smaller scale of navigation in keeping with his instructions. He also prepared the 1 December 1827 plan of the 50 by 150 foot lock with a reduced 5 foot depth navigation in a final effort to convince the Ordnance to authorize its construction. Finally, in the spring of 1828 a committee of Royal Engineers, the Kempt Committee, was appointed by the Ordnance to determine the size of lock to be constructed on the Rideau navigation. The committee decided that the locks should be 33 feet by 134 feet with 5 feet of water on the sills to accommodate the smallest of the river steamboats. The locks would not be as large as By would have liked; but the scale of lock did conform to his belief that the Rideau Canal should be constructed as a steamboat navigation rather than a small scale gunboat navigation. The Kempt Committee, however, refused to accept the somewhat unusual lock design that Lt. Col. By had prepared for the large lock in an effort to reduce construction costs, with the result that a more conventional lock design had to be prepared for the newly approved steamboat lock. This plan was completed on 29 June 1828, and received the approval of the Kempt Committee. In all, plans were prepared for three different scales of canal lock, on somewhat different designs, for the Rideau project. Masonry work was commenced, however, only on the first and third lock designs, and only the latter was completed. As construction proceeded, a number of changes
were made in the structural details of several of the approved 33 by 134 foot locks to strengthen them and/or effect a savings in the cost of construction.
The surveying and levelling work, which commenced on the Rideau Canal project on 21 September 1826, continued throughout that fall and winter on the first eight miles of the canal from the newly selected Entrance Valley through to the canal's future junction with the Rideau River at the Hog's Back. While the survey party under the direction of John MacTaggart, the Clerk of Works, carried on their work in the interior, Lt. Col. By and his officers went into winter quarters at Montreal where they prepared plans, sections, and specifications for the canal works required in the Entrance Valley and thereafter, once the survey to the Hog's Back was completed, for the structures required on the rest of the first section of the proposed canal. In May 1827, at the time of By's first trip through the whole of the waterway from the Ottawa River to Kingston, contracts were let for the construction of eight locks in the Entrance Valley and three locks at the Hog's Back (later changed in number) together with contracts for the excavation work and ancillary structures required on that section of the canal. During the spring and summer of 1827, surveying, clearing, and levelling work continued on the interior sections of the Rideau-Cataraqui waterways, while excavations were commenced on the first section of the canal in conjunction with the quarrying of the stone required for the eleven locks already contracted out. As of July 7, 1827, a series of plans and sections were prepared for the first forty-four miles of the canal covering the locksites.
from the Entrance Valley to Long Island inclusive;\(^4\) (Fig. 1) and by the 25th of October 1827, plans and sections had been prepared for the remainder of the canal.\(^5\) As of 2 February 1828, By was able to have all of the excavation and structural work required to construct the canal under contract.\(^6\) Included in this work were contracts for the remaining 36 of the 47 locks to be constructed on the Rideau Canal.

The drawings that By and his engineering staff prepared from the first year's surveys consisted of a series of maps of the existing waterway showing the proposed line of the canal, as well as a drawing of each individual locksite. The latter comprised a plan view of the site setting forth the location of the structures to be built, the depth of the river, and the land to be flooded, a longitudinal section of the locks, and the dam and/or embankments required to raise the water level. An elevation or sketch of the terrain on the line of the canal was also prepared indicating the differences of level to be overcome by the various locks. These drawings were all made to scale, but were not dimensioned in any detail. They did not provide any cut-away views to show interior details, or make use of either geometric or stereometric views. Indeed, strictly speaking they were not engineering drawings so much as architectural drawings. In common with most drawings of structures or machinery previous to the 19th century, they were intended to be illustrations of principles and guidelines to construction rather than working plans from which construction could proceed.\(^7\) In the initial stage of the project, however, this was all that was required to get construction underway. The plans and sections, such as they were, showed the contractors what was to be constructed and the general dimensions and design of the same. The
1 Plan, Elevation & Sections of the Works at Long Island and Black Rapids, Lt. Col. By, 7 July 1827 (PAC, H2/410, Rideau Canal, 1827).

Proposed layout of the overflow dam and locks required to flood the rapids in canalizing the river. Initially, the gunboat locks were to have square end piers, with swing beams on the lock gates, and a guard lock positioned above the lift lock(s).
contractors were to be guided in the progress of the actual work by the specifications prepared by engineering staff. The specifications set forth the minimum dimensions of the stone to be used in the various parts of the lock and detailed how the stone was to be dressed and laid. To ensure that the masonry work was performed in accordance with the plans, sections and specifications, the overseers and engineers on By's staff were responsible for surveying and laying out the work for the contractors, taking levels, fixing up profiles and control posts, and providing templates and bevels to guide the stone masons in the cutting and laying up of the stone. In addition, they supervised the progress of the work and, if necessary, forced the contractors to adhere to the specifications governing the preparation of the materials and the prescribed method of construction. The lock masonry contracts covered only the stonework of the locks, exclusive of the lock gates and the gate and sluice operating mechanisms. These By intended to have constructed by the two companies of Royal Sappers and Miners that the Ordnance had agreed to despatch for service on the Rideau Canal. Here again, the work was to proceed under the direct supervision of By's engineering staff, and the iron work required for the sluices and the lock gates was to be made from patterns furnished by the overseers and engineers rather than made from engineering drawings. In effect, the method of construction adopted made use of immediate on-site direction, with detailed written specifications governing the preparation of materials and the mode of construction, and with wooden templates and patterns serving as guides for the critical detailed work. This system negated any need for the preparation of detailed engineering drawings for the contractors. Nonetheless, Lt. Col. By did
prepare a detailed plan of the 20 by 108 foot lock for the perusal of the Ordnance on 1 December 1827. This comprised two drawings, one of which was a detailed and fully dimensioned plan view, elevation, and cross-section of the lock chamber together with an elevation view of a lower and upper gate.  

13 (Fig. 2) The other was an elevation and longitudinal section of a proposed lower lock gate with in-gate sluices complete with details of the metal hardware of the gate and the sluice mechanism, and dotted lines showing the hidden details of the lock gate framing.  

14 (Fig. 6 & 7) 

Some time after the first series of locksite plans were completed on 25 October 1827 and prior to the June 1828 decision to construct the Rideau Canal with larger locks, more detailed locksite plans were prepared for a number of the locksites where work had been contracted out. The second, incomplete, series of locksite drawings are more detailed than the earlier locksite drawings and incorporate several minor changes in the proposed lock layout and design as well as providing dimensioned cross-sections for the lock chamber walls and the dams indicating their respective height, thickness, and batter, as well as the location and size of their puddle wall.  

15 When taken in conjunction with comments recorded in various progress reports, these drawings of the 20 by 108 foot lock enable an almost full description to be pieced together of the design of the lock that By initially undertook to construct on the Rideau Canal.

From the series of locksite plans, it is evident that the 20 by 108 foot locks on which construction proceeded in 1827 were of a standard design incorporating all of the best features of lock design as it had evolved to that date. The locks were to be built of coursed masonry, with a breastwall
roughly equal to the desired lift of the lock. Double leaf mitre gates operated by swing bars were to be positioned in the lock so as to close against masonry pointed sills constructed on the breastwall (upper gates) and on the floor of the tail of the lock (lower gates). The floor of the locks was to be natural rock where possible with masonry inverted arches being employed where a good rock foundation was not obtainable. The locks were to be filled and emptied by means of tunnel sluices ("ground sluices" or "culverts") built into the lock walls around both the upper and lower gates. As a precaution against water working its way down through the forebay of the lock to the breastwork and possibly heaving the breastwork and upper sill out of alignment, a wall of wood piling was to be driven down to a considerable depth across the rear of the breastwall and the upper sill in all cases where the lock was not situated on bedrock. To facilitate future repairs, vertical stop log grooves were to be formed in the lock masonry walls of the fore and tail bays of single locks, or in the forebay of the upper lock and tailbay of the bottom lock of a flight of locks. A timber sill set into the floor joined the base of the two opposing grooves. In effect, the locks could be sealed off through placing stop logs in the grooves preparatory to their being de-watered. Here again a row of piling was to be driven across the forebay of the lock directly below the stop log sill to prevent the water working its way under the sill and down through the breastwall to the lock chamber.

The locks were to be combined or grouped together at the various locksites in sufficient numbers to overcome the requisite differences of elevation, with the lifts being proportioned equally in the range of the standard 8 to 10 foot lift of contemporary canal locks.¹⁶ In several
instances, such as at Smith's Falls, lifts slightly in excess of 11 feet were contemplated, depending again on the instances, such as at Smith's Falls, lifts slightly in excess of 11 feet were contemplated, depending again on the total lift to be overcome. For the most part the locks were to be grouped in flights of two or three lift locks, but at the Entrance Valley a total of eight locks was required to overcome a difference of elevation of 80 feet. There the locks were grouped in two flights of four locks each with a small basin to be constructed between the fourth and fifth lock. In the 7 July 1827 locksite drawings covering the first forty-four miles of the canal, all of the lift locks on the river, as distinct from the Entrance Valley flight locks which were in an artificial cut far removed from the river, were to have a guard lock positioned at their head to protect the upper gates of the upper lift lock from the full force and fluctuation in level of the water in the river above. The guard lock so positioned was not a lift lock, and consequently had no breastwall. The sills of the upper gates of the guard lock were on the same level as the upper sill of the top lift lock, and the level of the water in the guard lock was always maintained on the same level as the water in the canal above the flight of locks. (Fig. 1)

**Masonry of the Lock Chamber: The Gunboat Lock**

The walls of the 20 by 108 foot locks were to consist of a cut stone facing of coursed masonry backed by a wall of rubble masonry against which a three foot thick puddle wall was placed to form a barrier impervious to water. The masonry of the walls was to be eight feet thick in total at the base and carried up with a batter on both sides so as to form a five foot thick masonry wall at the top (Fig. 2).
FIGURE 2

Plan and Sections of the Eighth Lock, 10 feet lift (PAC, H3/312, Lachine Canal, 1828).

This is actually an 1827 plan of the proposed Rideau Canal gunboat lock at the head of the Entrance Valley flight of eight locks. The design details closely approximate the Lachine Canal locks completed in 1825.
Where the lock walls were free standing above ground, Lt. Col. By proposed that the batter should be eliminated on the exterior of the wall in favour of its being carried straight up to form a 6'-6" thick wall at the top with a rubble masonry wall being built on the outside of the puddle walls to protect it from erosion. The walls of the locks were generally 17 to 18 feet high to allow for the five foot depth of water required for the navigation, plus the lift of the lock (8 to 11 feet) and approximately a two foot guard in the height of the lock wall over the upper water level mark. They were to be strengthened by means of rubble masonry counterforts, 3 feet by 3 feet at the base, built into the rear of the lock wall at roughly 20 foot intervals, and thickened at the lock gates to form piers to contain the tunnel sluices. The outer ends of the lock walls were thickened to form blunt square-ended piers. (Fig. 1) In the course of preparing the 25 October 1827 series of locksite drawings, however, some of the lock chambers were provided with curved wing walls at their ends, and the blunt, square-ended lock wall design was totally discarded thereafter. The interior lock chamber walls were laid in straight courses of varying thicknesses with the only protrusions being two small piers which were situated in pairs on either side of the lock chamber at both lock gates to form a recess for the protection of the gates when open. Both piers were of cut stone to match the face of the lock chamber walls, but were carried straight up rather than battered on the outer face and the side of the pier facing the lock gate. The face of the gate recess piers on the opposite side to the gate, however, was carried up with a concave face to match the lock chamber wall which it met at a right angle. One of the piers of each pair was in the form of a hollow quoin in
which the heel post of the mitre gate leaf was to rest.24 At the gate recesses where tunnel sluices were to be constructed through the masonry, the walls were thickened by adding 8'-6" of solid masonry to the back of the wall for a distance of 30 feet. In effect, the lock wall in the gate recess was to be carried straight up at a thickness of 13'-6" from its foundation to the height of the coping of the lock and was to be 16 feet thick at the gate recess and hollow quoin pier which were 3'-3" and 4'-6" wide, respectively, at the top of the lock.25

The dimensions of the face stone of the Rideau Canal locks, and the manner in which it was to be dressed and laid in the wall, were set forth in the specifications furnished to the masonry contractors by the engineers of the Rideau Canal establishment. They specified that the ashlar stone of the lock chamber walls was to be dressed with chisel drafts and hammer picked between the drafts, and was to measure no less than 2'-6" in length, 20" in breadth of bed, and from 9\(\frac{1}{2}\)" to 16" in thickness. The stone was to be laid alternately header and stretcher in the wall and levelled off the face with bevels provided by the Royal Engineers. The stones of the hollow quoins were to be 3'-8" on the face, 2'-8" in breadth of bed, and from 9\(\frac{1}{2}\)" to 16" thick to match the courses of the lock chamber wall, and they were to be cut according to a template and dressed in keeping with the contract specifications. The ashlar of the lock gate recess between the gate pier and the hollow quoin pier was to be similarly dressed with the stone being at least 2'-0" in length, 2'-8" in breadth of bed, and from 9\(\frac{1}{2}\)" to 16" thick, and laid up vertically in the wall. The coping stone was to be no less than 2'-6" long on the face in keeping with the lock chamber stonework, but was to be somewhat wider, 2'-8", in breadth of bed. No thickness was
specified for the coping stone, but the vertical face was to be cut on a bevel to match the batter of the lock chamber wall. Both the vertical and top face of the coping stone was to be dressed and the front arris rounded off to match a template provided by the Royal Engineers. Lastly, the inverted arch stones of the masonry lock chamber floors, if required, were to be 2 feet long by 2 feet deep and from 9½" to 16" thick and cut to a template furnished by the Royal Engineers.²⁶

No direction was given in the lock masonry contract specifications as to how the stonework of the breastwall and the sills of the lock was to be constructed. However, this was exceptionally demanding work, and By intended to have it performed by the masons of the Corps of Royal Sappers and Miners who were highly skilled in keystone masonry work.²⁷ The plan of the twenty foot wide lock that By prepared for the Ordnance in December 1827 shows a pointed sill consisting of a single course of cut stone masonry keyed together and rendered more rigid through the insertion of cramps to tie together adjacent stones. The breastwork on which the sill rests was to be 10 feet high on its exposed face in keeping with the height of the lifts in the Entrance Valley locks, and was to be constructed of rubble stone masonry with a facing of cut stone sloping back at a steep angle toward the sill. The breastwall so constructed was a solid unit of masonry extending downwards 12 feet from the underside of the sill to the base of the two foot thick floor blocks and back a total distance of approximately 10 feet. At that point a solid row of wood piles was to be driven to a depth of 16 feet across the rear of the breastwall, and a rubble masonry wall several feet thick was to be built against the opposite side of the row of piles. The row of piles passing through the massive unit of masonry
projected downwards as much as three feet below the base of the masonry. It was intended to prevent water working its way down through the breastwall and under the floor of the lock.28 (Fig. 2)

**Lachine Canal Locks Prototype**

The plan of the lock chamber By prepared for the 20 foot by 108 foot Rideau Canal gunboat lock in December 1827 was essentially the same lock as that designed six years earlier by Thomas Burnett, a civil engineer who had been hired to superintend the construction of the Lachine Canal, on the recommendation of Thomas Telford the renowned English civil engineer. The Lachine Canal, constructed in 1821-25 to by-pass the Lachine Rapids at Montreal, had seven locks (6 lift locks and a guard lock) in an 8½ mile long construct with a total lift up 44 feet.29 (Fig. 3)

With the exception of the thickness and configuration of the rear of the lock chamber walls, there was little to distinguish the proposed Rideau locks from the Lachine Canal lock plans. The locks were of the same dimensions, 20 by 108 feet clear of the gates, and varied only slightly in their lifts: a range of from 6 to 9 foot lifts on the Lachine Canal30 and a projected range of from 8 to 11 foot lifts on the Rideau Canal. The Lachine Canal lock walls, as on the projected Rideau Canal, were constructed of rubble stone and faced with large cut stone blocks laid in regular courses, but they were 7½ feet thick at the base and 6 feet thick at the top, with the rear of the wall being laid up perpendicular. In contrast the Rideau lock walls were to be 8 feet thick at the base and sloped inwards on both sides to a thickness of 5 feet at the top. Both lock walls were strengthened in the rear by counterforts, with those on the Lachine Canal being 4 feet by 4 feet and spaced
3 Regulating Lock, La Chine, built upon Rock (PAC, H3/312, Lachine Canal, 1824).

This is the basic plan of the Lachine Canal lock on which the design of the Rideau Canal gunboat lock was based. However the regulating lock, or guard lock, shown here had no lift and hence no breastwork. It was used merely to compensate for fluctuations in the river level. Note the wood sills and the stone arch bridge over the lock chamber.
at 12 foot centers as opposed to the 3 foot by 3 foot counterforts on roughly 20 foot centers to be built on the Rideau locks. The face of the lock chamber walls of both locks was concave in the form of a segment of a circle to better resist lateral pressure on the lock wall and to prevent the boats being lifted in the lock from hitting against the lock wall. Both locks were constructed, or to be constructed, with comparatively large stone blocks which in the case of the Lachine Canal were reputed to be the largest sized blocks of stone used in masonry construction work in Canada to that date. Provision had also been made on the Lachine Canal for the construction of inverted masonry arches to prevent the floor of the chamber from being blown up by ground water where the lock did not rest on bedrock. Indeed, the two lock chambers were almost identical in design including the use of sheet piling in the breastwall to stop the water working its way through, the shape of the gate recess piers, the use of a puddle wall to form a barrier impervious to water on the outside of the lock masonry, and the tunnel sluices which Lt. Col. By proposed to construct in the walls of his Rideau Canal locks.

Sluice System of the Gunboat Lock

The 7 July 1827 series of locksite drawings for the first 44 miles of the Rideau Canal make it clear that Lt. Col. By planned to use tunnel sluices to empty and fill the 20 by 108 foot gunboat locks. Tunnel sluices were to be used at all of the lock gates exclusive only of the upper pair of gates on the guard locks. (Fig. 1) Thereafter, as indicated by the 1 December 1827 lock gate drawing, By decided to use sluices built into the lock gates in place of tunnel sluices at the lower pair of lock gates on the bottom
lock of the Entrance Valley flight of locks,\textsuperscript{36} (Figs. 6 & 7) and he probably decided to do likewise at the lower gates of the bottom lock at the various other locksites.\textsuperscript{37} Gate sluices were far cheaper to construct than tunnel sluices in the walls of the lock, but the latter were much more advantageous in operating a lock. They reduced considerably both the turbulence of the water and the danger of drowning a boat and its cargo when filling a lock. Tunnel sluice outlets were continually below water and situated directly opposite one another below the breastwall. Hence boats in the lock rode above the turbulence, which was greatly reduced through the force of the jets of water issuing from the tunnel sluices being dissipated by striking head on beneath the water surface. In contrast sluices placed in the lock gates were located above the breastwall and in line with the lock chamber. As a result, the jets of water shooting out of the gate sluices were directed down upon the cargoes of the boat/boats about to be raised in the lock. However, this was not a problem at the lower gates of a single lock, or at the lower gates of the bottom lock of a flight of locks, as the boats about to ascend could stay well back in the river/canal while the water in the bottom lock was being lowered by means of the gate sluices to receive them. Once in the lock, it would of course be filled by means of the tunnel sluices passing around the upper gates. Keeping cargoes dry was a serious concern. The Erie Canal, for example, which was built as cheaply as possible to save on construction costs with the intention of its being rebuilt in a more substantial manner at a later date, was equipped with sluices in the lock gates of the majority of its locks. This caused no end of difficulties as the barges ascending in the locks were often sprayed, and sometimes filled, with the water shooting out
of the lock gate sluices up on the breastwall. The Lachine Canal, in contrast, was built with tunnel sluices in the walls of the locks with the result that the water coming out under the boats posed no threat of injury to their cargoes. Indeed, all of the six lift locks on the Lachine Canal had tunnel sluices at both their upper and lower gates of the bottom lock. This was not the case at the upper gates of the uppermost lock of the Lachine Canal, the guard or regulating lock (lock no. 7). Likewise where guard locks were to be placed at the head of either a flight of lift locks or a single lift lock on the Rideau Canal, there was no provision for tunnel sluices in the lock masonry at the upper gates of the guard lock.

Guard locks were not lift locks, and their upper gates were on a level with the lower gates so that sluices in the upper gates would be continually underwater. Guard locks, sometimes called regulating locks, were occasionally used as lift locks to take care of any fluctuations in the level of the river above the mean surface height of the river. The fluctuations would be comparatively small during the navigation season requiring only a minimum displacement of water into the guard lock to raise vessels to the level of the river with little or no danger of injury to their cargoes. Consequently, a savings could be effected through replacing tunnel sluices with gate sluices at the upper gates of the guard locks without posing any operating difficulties as boats ascended through the various guard locks at times of high water (Fig. 1).

**Sluice Value Operating Mechanisms: The Gunboat Lock**

It is not clear from the drawings extant of the 20 foot wide Rideau Canal gunboat lock what mechanism By envisaged using
to operate the tunnel sluice valves. However, the lock masonry drawings do show a man-hole, or more accurately a rectangular slot, passing down through the masonry of the lock wall a short distance in from its face where vertical lift plate valves were presumably to be placed. This was the same type of valve in use on the tunnel sluices of the Lachine Canal locks except that the rectangular slot in the masonry was located farther back from the lock wall face in approximately the middle of the tunnel where it passed through the wall perpendicular to the lock chamber. On the Lachine Canal, a threaded lift rod was set in a wooden frame that descended into the rectangular slot hole in the lock wall masonry. The vertical plate valve was raised or lowered by turning a threaded collar on the shaft against the fixed frame. (Fig. 3) This was a very old mechanism for operating sluice valves which had been used on lock gate sluices of the Canal du Midi in France as early as 1660 (Fig. 4). There the valve operating mechanism, constructed entirely of wood, consisted of a threaded shaft which turned in the top cross member of a sliding frame, the bottom section of which consisted of a vertical plate valve. Both the top of the frame and the valve plate were housed in wooden guides fixed to the lock gate. The sluice valve was operated by inserting a lever through the head or boss of the threaded shaft, to form a capstan of sorts, and by turning the shaft to raise or lower the sliding frame. On English canals of a later date, the threaded shaft or endless screw was used to operate tunnel sluice valves on the large tide locks. Valve plates on the smaller boat locks were generally raised and lowered by means of a rack and pinion arrangement, where the vertical plate valve was located either on the face of the lock wall in the gate recess (Fig. 5) or inside the lock wall a short
Early type of timber lock-gate used on the Canal du Midi, (Rolt, From Sea to Sea: The Canal du Midi, Plate 12).
A 17th century lock gate sluice valve mechanism constructed entirely of wood.
Birmingham & Liverpool Canal (Strickland, Report on Canals, Railways, Roads, etc., 1826, Plate 15).

An English narrow lock, 8 feet by 75 feet, with a single leaf gate swung by a swing beam. The tunnel sluices around the gates are equipped with a sliding vertical valve plate utilizing a rack and pinion mechanism to open and close the valve.
distance in from its face near the entrance to the tunnel sluice as on the proposed 20 foot wide Rideau Canal lock.⁴⁷ (Fig. 2)

The in-gate sluices that By designed for the lower gates of the bottom lock in the Entrance Valley consisted of three separate flat iron valve plates set in a line of sluice openings along the bottom of each gate leaf near the mitre post. The sluice openings were framed with upright timbers set between the two lower cross rails of the gate. The plate valves pivoted on a horizontal axis in gudgeons set in the upright timbers at the mid-point of the opening in the center of the lock gate. The valve plate was operated by means of a vertical rod with one end attached to the bottom edge of the valve plate and the other end to a lift mechanism at the top of the gate. Each lift rod, one per valve, was bolted to a horizontal arm of a 90 degree angle bracket. The vertical arm of the angle bracket was in turn connected to a rack running horizontally along the top of the lock gate. The apex of the angle bracket pivoted in a small metal gudgeon fixed to the top of the lock gate so that when the vertical arm of the angle was pulled by the rack, the whole bracket rotated lifting the horizontal arm which in turn lifted the bottom edge of the pivot plate valve. The horizontal rack was attached to the upright arm of each of the three pivoting angle arms so as to pull all three in unison, and the far end of the rack passed over a roller on an upright support fixed to the top of the lock gate near the heel post. A pinion gear positioned directly above the roller meshed with the teeth on the upper side of the rack. A handle attached to the pinion gear, when turned, moved the rack back and forth to operate the valve plate. In its closed position, the top edge of each valve plate rested against the rear edge of a cross rail of the
lock gate, and the bottom edge was forced tight against the front edge of the bottom cross rail of the gate by the pressure of the water in the lock.48 (Figs. 6 & 7)

The type of valve operating mechanism that By designed for the lower gates of the bottom lock in the Entrance Valley in December 1827 was somewhat unusual, although probably by no means unique as a number of different mechanisms were in use in Britain and the United States.49 Why he chose to use a pivot plate type of valve in his gate sluices is not clear as it required the valve plates, angle arms, and lift rods as well as the rack and pinion to be made of iron, whereas both the flat vertical plate sluice valve and the paddle valves in more common use could be constructed largely of wood. On English canals, the flat vertical lift valve plates, the lift rod, and the guides they travelled in were often constructed in wood with only the short rack fixed to the top of the lift rod, the pinion gear, and the turning handle being made of iron.50 (Fig. 5) The paddle gate or paddle valve commonly used was generally of wood construction with an iron spindle passing up through to the top of the lock gate, where an iron lever (or wrench) was used to turn the spindle and open or close the paddle valve pivoting on that vertical axis.51 (Fig. 8) However, in his initial design, By may have been sacrificing cost savings to durability in opting for metal hardware on the gate sluices. He may also have wished to avoid weakening the lock gate through placing three small sluices in the bottom of the lock gate between the cross rails rather than cutting through one of the cross rails to form a single large sluice. Once he had determined on three small sluices, he had to come up with a means of adopting the customary rack and pinion lift mechanism so as to avoid having to have three separate rack and pinion lift
FIGURE 6

Front Elevation of a Lock Gate, Lt. Col. By, 1 December 1827 (PAC, H2/410, Rideau Canal, 1827).

The plan prepared for the lower gates of Lock No. 1 on the proposed gunboat scale. Here the details of the gate sluice valve mechanism are shown as well as the odd goose neck anchor plate.
mechanisms to operate the three sluice valve plates. Hence the design of the angle bracket/rack and pinion sluice operating mechanism.

**Lock Gates of the Gunboat Lock**

The lock gates of the 20 foot wide Rideau Canal lock were to be of the double-leaf mitre gate type, with the shorter upper gate resting on the masonry breastwall of the lock (Fig. 1). Each leaf was of a standard construction with a heavy wood frame consisting of a vertical heel (or quoin) post and a mitre post into which the heavy wood cross rails were mortised. The frame so formed was reinforced by flat wrought iron "L" and "T" plates bolted at the joints. The use of flat iron reinforcing plates at the joints of the gate frame members made for a far more durable gate and was an innovation adopted from the Lachine Canal gates, where such reinforcing was apparently first introduced in Canadian canal construction. The number of cross rails varied according to the height of the lift. On the 10 foot lifts of the Entrance Valley locks there were three cross rails in addition to the base rail forming the frame of the lock gate, and on the short upper gate, there was one cross rail in addition to the bottom rail. The short upper gate and the long lower gates differed also in the dimensions of their timber members. The mitre post and the heel post of the short upper gates were of squared timber 6 inches by 6 inches and 12 inches by 12 inches respectively while the mitre and heel posts of the long gates were 12 inches by 12 inches and 15 inches by 15 inches respectively. The cross rails also differed as the short upper gate rails were 6 inches by 6 inches, and the long gate rails 12 inches by 12 inches. The vertical heel and mitre posts extended upwards beyond the height of the top
cross rail on each of the gates so that the balance, or swing, beam could extend outwards and upwards over the the coping of the lock wall to facilitate the gate being swung open. To provide leverage, the balance beams were 28 to 30 feet long and tapered downwards uniformly from their outer end to the mitre post.\textsuperscript{55} The tapered swing beam had been employed on the Lachine Canal\textsuperscript{56} and was a common feature of contemporary lock gate design.\textsuperscript{57} Indeed, on a number of canals, the tapered beam was even curved in the horizontal plane so that the extension, which was pushed to swing the gate, would be away from the edge of the lock wall when the gate was swung full open.\textsuperscript{58}

The gate frames on the 20 foot wide Rideau Canal locks were to be planked in a diagonal pattern on their upper face, and the planking was carried up beyond the top cross rail, which was positioned approximately at the level of the water when the lock was full. The planking so extended filled in the triangular area between the top cross rail and the section of the balance beam sloping upwards across the top of the lock gate from the mitre to the heel post. A small rectangular opening was left in the centre of this triangular area so that any excess water let into the lock would overflow the gates rather than the coping of the lock chamber.\textsuperscript{59} The planking was set into the panels formed by the cross rails. The cross rails, as well as the mitre and heel posts, were notched approximately 1\frac{1}{2}" deep on their edges to let in the planking so that it would be flush with the face of the gate frame members once nailed in place.\textsuperscript{60} In this respect, the Rideau Canal lock gates differed from those of the Lachine Canal and American canals where the planking was affixed in a vertical pattern over the whole of the face of the gate frame members.\textsuperscript{61} However, the diagonal planking pattern had been used
previously on the gates of the newly re-built Cascades Canal on the St. Lawrence River above Montreal. It was employed in England as early as 1758, if not before, by John Smeaton in constructing the lock gates of the Calder and Hebble navigation.

Gate Operating Mechanisms: The Gunboat Lock
Each leaf of the mitre gates was to pivot in an iron strap collar which was anchored to the coping of the lock wall and on a gudgeon at the base of the heel post. The gudgeon rested in a metal cup set into the masonry of the gate recess floor at the base of the hollow quoin pier. The gudgeon served not only as a pivot for the gate, but held the gate several inches above the lock floor to provide the clearance required to swing the gate from its closed position - up against the raised mitre sill - to its open position back in the gate recess of the lock wall. The drawings extant of the lock gates of the 20 foot wide Rideau Canal lock do not provide enough detail to determine how the collar strap was to be anchored to the coping of the lock chamber, but the anchor was probably of a design similar to the type of anchor which was in common use on British and American canals: viz. a heavy, relatively flat casting with a raised head through which the collar strap was slipped and pinned (or fixed with a key) and two flared legs through which the anchor bolts, or fox wedged bolts, went to fix the casting securely to the masonry of the lock wall coping. (Fig. 8) Indeed, this was precisely the type of anchor for the collar of the lock gates of the 33 by 134 foot steamboat navigation locks eventually constructed on the Rideau Canal. For the lower gates of the river lock in the Entrance Valley, however, Lt. Col. By designed a different type of heel post anchor to go with a radically different system devised for operating the gates.
Origin of the Floor Chain/Crab System

It is not clear why Lt. Col. By altered the standard collar strap/anchor method of supporting the top of the lock gate heel post or why he rejected the conventional swing beam mode of operation in favour of a different system for the lower gates of the river lock in the Entrance Valley. However, in the latter case it may have been simply a case of there being insufficient room for the men to walk in swinging the balance beams of that set of lock gates. Initially, as the 7 July 1827 locksite plan for the Entrance Valley makes clear, Lt. Col. By planned to employ swing beams on the lower gates of the river lock as elsewhere on on the lock gates of the Rideau system. He also planned to build a curved rubble stone wing wall from the face of the end piers of the river lock, which jutted out into the Ottawa River, across to the sides of the Entrance Valley. Behind this retaining wall, earth was to be dumped to fill up the ground level with the coping of the lock. In this manner, sufficient room was to be provided for the lower gates of the river lock to be swung. But when By submitted his first estimate in November 1827, he proposed to have cut stone steps constructed on each side of the river lock to provide an access to the river below the level of the retaining wall. The two stairwells so situated would have prevented anyone from swinging the balance beams of the lower lock gates, and this change may well account for By’s devising a different system for operating that particular set of gates.

To operate the lower gates of the river lock in the Entrance Valley, By appears to have contemplated employing an endless chain and crab system similar to what he subsequently used to operate the lock gates of the 33 by 134 foot locks constructed on the Rideau Canal in 1828-32.
(Fig. 7) This was the floor chains system whereby one end of an endless chain was attached to the front of the mitre post near the floor of the lock, and passed from there around three flat sheaves (with a vertical axis) fixed in an arc on the lock floor, to the foot of the lock wall where the chain passed under an upright pulley (with an horizontal axis) to the top of the wall and over a second upright pulley to the barrel of a crab or windlass. The chain then wound around the barrel of the crab several times and back over an upright pulley at the top edge of the lock wall (in tandem with the other upright pulley) and down the side of the lock wall and under an upright pulley at its base (again in tandem with the other upright pulley) from which the chain passed around the three flat sheaves set in an arch on the lock floor to the pointed sill where the chain passed through a snub pulley to the back of the mitre post of the lock gate where the chain was attached close to the base of the gate. With this system, it was possible to open the lock gate simply by turning the crab so as to draw in the end of the chain attached to the front of the mitre post and at the same time feed out the end of the chain attached to the back of the mitre post. To close the gate, the crab was simply turned in reverse so as to draw in the end of the chain attached to the back of the mitre post - which was in effect pulled toward the snub pulley fixed to the pointed sill - and to let out at the same time the end of the chain attached to the front of the gate at the base of the mitre post.71 (Fig. 59)

Gate Operating Mechanism on Other Canals
The floor chain/crab system, which eliminated the need for a swing bar on the top of the lock gates, appears to have been devised by By as it differed completely from what had been
FIGURE 7

Rear Elevation and Section of a Lock Gate, Lt. Col. By, 1 December 1827 (PAC, H2/410, Rideau Canal, 1827).

The basic design of the mitre gate leaf intended for the proposed 20 foot wide gunboat lock. This particular gate leaf was to be erected at the lower gates of lock No. 1 where stairwells precluded the use of a swing beam. Hence the roller wheel and the chain on the mitre post, indicating that the floor chain/crab system was to be used in operating the gates.
employed on major American and British canals prior to that date. In the United States, canal lock gates were generally operated by means of swing bars, and only at a later date were different modes of operating lock gates developed which eliminated the need for swing bars. (Fig. 8) In Britain, likewise, swing beams were in general use on contemporary canal gates, although a capstan/drag chains system of a far different design than By's floor chain/crab system had been developed for use in operating the gates of at least three different sets of ship locks on an exceptionally large scale. For example, swing beams were not employed to operate the gates of the 30 by 130 foot tide lock of the Thames and Medway Canal, the 40 foot wide locks of the Prince's Dock Basin at Liverpool, or the 40 foot wide by upwards of 180 feet long locks of the Caledonian Ship Canal in Scotland. The huge size and heavy weight of these gate leafs ruled out their being swung in the conventional manner. Each set of gates on the Thames and Medway tide lock was swung by means of two pairs of capstans positioned at the level of the coping of the lock over manholes descending into piers built into the rear of the lock wall. Each capstan was used to turn a vertical iron shaft which passed down through the manhole to rest in a bearing level with the lock floor. Just above the base of the manhole, a tunnel passed horizontally through the lock wall to provide a passageway for a drag chain, one end of which was attached to the mitre post of a lock gate and the other end of which was wound around the vertical iron shaft. To open the gates, the capstan on the side of the leaf to be opened was turned and the chain attached to the front of the mitre post was drawn in through the tunnel, which was constructed on an angle so as to form a chord to the arc made by the mitre post of the gate as it was pulled open.
FIGURE 8


Mitre gates swung by a balance, or swing, beam with gate sluices consisting of a sluice paddle turned by a lever. Wood sills were constructed on wood floored locks.
To close the gates, each of the capstans below the gates, and on the opposite side of the lock chamber to the leaf to be opened, was turned to draw the chain attached to the back of the mitre post on the gate leaf opposite. Again, the tunnel through the lock chamber wall was angled so as to provide a straight pull from the position of the mitre post of the gate in its open position in the gate recess to the position of the mitre post when the gate leaf was closed up against the pointed sill. In effect, the chains used to close the gates crossed each other in the center of the lock chamber just below the gates, and whether opening or closing the lock gates, the capstan used to pull the chain attached to the opposite side of the mitre post of each leaf had to be turned in unison to play out the chain while its opposite drew the other chain in to move the lock gate.75

(Fig. 9) The Caledonian Canal lock gates were operated in the same manner with the exception that the capstan pits were relatively shallow and the drag chain tunnels were angled downwards in the vertical plane toward the base of the mitre post of the gate leaf, as well as angled horizontally.76 The Prince's Dock Basin lock gates were also probably operated by the capstan/drag chain method rather than by the floor chain/crab system By employed on the lower gates of the river lock in the Entrance Valley of the Rideau Canal.77

Supporting the Lock Gates: The Roller Wheel
In addition to devising a novel method of swinging lock gates, By planned to deviate from conventional lock gate construction practice by placing an iron truck on each leaf of the lower gates of the river lock (Figs. 6 & 7). The truck was to be bolted to the bottom of the base rail of the lock gate frame about one-third of the gate width in from
Plan of the Tide Lock, Thames & Medway Canal (Strickland, Report on Canals, Railways, Roads, etc., 1826, Plate 12).

On this large 30 by 130 foot tide lock, the gates were operated by a capstan/drag chain system with roller wheels supporting the gate leaves. The capstan shaft passed down through the lock wall and the chain passed out through the wall as the level of the base rail of the gate to which the chain was attached at the mitre post. Four capstans were required to operate each pair of gates.
the mitre post. The iron wheel of the truck, which was intended to bear a significant portion of the weight of the gate, was to run on an iron quadrant rail, or roller way, anchored to the floor of the lock. The rail formed an arc to match the arc made by the truck wheel as the gate leaf was swung open from the pointed mitre sill back into the gate recess of the lock wall. Roller wheels were not unknown in lock gate construction, but generally speaking were not employed on the lock gates of contemporary British and American boat or barge canals. In effect, they were not considered necessary for the size of the mitre gates in use on those canals or for the single leaf gates in use on a goodly number of the English narrow locks. In Britain, canal locks were constructed for the most part on one of two different scales: either as broad (or wide) locks roughly 13 feet wide by 65 feet long, or as narrow locks 7 ft. 6 in. wide by 70 feet long in the chamber. The broad lock chambers were commonly constructed on canals connecting river navigations to enable the sailboats employed in the coastal trade to pass through the canals. The inland canals were constructed with narrow locks to serve the long flat-bottomed narrow boats employed on British canals. The major American canals constructed contemporaneously with the Rideau Canal were constructed with locks that corresponded in scale to either the English broad or narrow lock although slightly wider and in some cases somewhat longer in keeping with the slightly different dimensions of American canal boats and barges. For example, the New York Erie Canal, completed in 1825, had broad locks 15 feet wide by 90 feet long, and the New Jersey Morris Canal, completed in 1831, had narrow locks 9 feet wide by 64 feet long. The 20 foot by 108 foot gunboat locks to be constructed on the Rideau Canal were somewhat larger again than the
American barge canal locks, but neither on the Lachine Canal where that scale of lock was first constructed, nor on the Rideau Canal, with the exception of the lower gates on the river lock in the Entrance Valley, were roller wheels employed or intended to be employed. Clearly then, Lt. Col. By's decision to employ roller wheels on the lower gates of the river lock was not dictated by the size of the lock gates so much as it was a product of the earlier decision to eliminate swing bars from the top of the lower gates of the river lock.

Swing beams were commonly referred to as balance beams. As the latter appellation makes evident, they were used not only to swing lock gates, but also to balance the weight of the gate and keep it from sagging at the mitre post and/or exerting a heavy pull away from the anchor collar at the top of the heel post. The extreme length of the balance beam, 28 to 30 feet on each leaf of the mitre gates of the proposed 20 foot wide Rideau Canal locks, and the shape of the beam with its larger outer end tapering down severely toward the mitre post, were such as to provide not only a good leverage for swinging the gate leaf, but a counterbalance to the weight of the gate pivoting on the pintle set in the bottom of the heel post. When the balance beam was removed from the lower gates of the river lock, Lt. Col. By had to provide an alternative means of support for the lock gate to prevent it sagging or from placing too heavy a pull on the collar anchor at the top of the heel post. Thus, he adopted the roller wheel which had already been employed on huge British ship locks. Roller wheels were used on the tide lock of the Thames and Medway Canal to support its heavy cast iron gates and on the large Caledonian Canal lock gates, as well as on the heavy oak framed lock gates of the Prince's Dock lock, each leaf of which was
22 feet wide by 33 feet high. On the lower gates of the river lock in the Entrance Valley of the Rideau Canal, it was the lack of footing to swing the balance beams that resulted in a floor chain/crab system being developed to operate the gates and a roller wheel being added to each leaf to support its weight. On the huge British ship locks, it was the inordinate size and great weight of the lock gates that necessitated the abandonment of balance beams in favour of a drag chain/capstan arrangement for operating the gates as well as the addition of a roller wheel to each leaf of the gates.

The Abortive Goose Neck Anchor Design
The elimination of the swing beams on the top of the gate leafs of the lower gates of the river lock in turn enabled Lt. Col. By to contemplate employing a radically different type of anchor for the top of the heel post. This consisted of a heavy cast iron, gooseneck anchor, the base of which was to be anchored to the coping of the lock. The elevated head was to be attached to the top of the heel post of the lock gate by a pin passing vertically down through the head of the gooseneck into the center of the heel post (Figs. 6 & 7). In effect, the heel post of the gate was not to extend beyond the height of the top rail as on the other lock gates, but was to be cut off level with the bottom of the top cross rail which was to be carried out over the top of the heel post. To strengthen this relatively weak system of framing at the junction of the top rail and heel post, an iron knee bracket was to be bolted into the inside corner. The head of the gooseneck anchor was to be cast with a horizontal slot into which a raised section of a flat iron tongue, bolted to the top of the top cross rail, fitted. Both the head of the gooseneck anchor and the flat iron
tongue were pierced by a hole through which an iron linch pin, approximately 6 in. in diameter by 2 ft. 6 in. long, was inserted vertically down through the coupling so formed and beyond into the center of the heel post. To aid in keeping the pin in its vertical alignment, a flat iron plate, somewhat wider than the pin diameter and pierced through its end, was inserted horizontally into a slot cut into the heel post at a level where the bottom end of the pin would pass through the plate insert and project slightly beyond. The insert was to be held in place in the heel post by the iron knee bracket bolted in the top inside corner of the gate frame.86

It is highly questionable whether the gooseneck type of anchor designed for the lower gates of the river lock in the Entrance Valley would have proved satisfactory in operation had they been actually employed. In the first place, the pin coupling type of pivot on the top of the heel post appears much too rigid to have enabled the mitre gates to function as effectively as they did with the collar strap anchor. Mitre gates were designed so that the pressure of the water acting against the gates would force them tightly together at their point of meeting along the mitre post of each leaf of the gates. This not only rendered them watertight at their junction; but at the same time, forced them back against the hollow quoins of the lock wall, thereby preventing water escaping between the heel post and the hollow quoin surface. With the collar strap type of anchor, the heel post could be positioned so as to leave a small clearance between the heel post and the hollow quoin of the lock wall to enable the gates to swing freely when being opened. Yet the collar strap did not prevent the heel post of the gate leaf being forced back tight against the hollow quoin by the pressure of the height of water being
held back by the gates when closed. With By's pin coupling/gooseneck anchor design, the heel post was to be held in a rigid position so that the pressure of water tending to thrust the gates back into the hollow quoins of the lock wall would have had to have been borne by the linch pin of the coupling. This not only would have put a great strain on the pin, but would have let water spurt through the clearance left between the heel post and the hollow quoin to enable the gate to be swung easily. On the other hand, if the heel post were intended to be positioned tightly against the hollow quoin to bear the thrust of the water pressure and seal off any leakage there, the gates would have been much more difficult to swing and the heel posts would in time have become worn letting water escape between them and the hollow quoin face. Another difficulty with By's projected design was the elevated head of the gooseneck, which required the gate leaf to be several feet higher than the coping of the lock to which the base of the gooseneck was to be anchored. Any surplus water in the lock chamber thus would have overflowed the coping of the lock rather than passing over the lock gates as was the case with the swing beam lock gates that By intended to construct elsewhere on the Rideau Canal system.

Construction Progress
The relative merits or defects of the lock design details incorporated in the plans that By prepared as of December 1827 for the locks under construction in the Entrance Valley of the Rideau Canal must remain a matter of conjecture as the 20 foot wide locks were never completed. Excavation work commenced on the lock pits in the Entrance Valley in the late spring of 1827, and on 16 August 1827 the first stone of the third lock was laid with full masonic honours.
by Sir John Franklin, the arctic explorer, who was then visiting the Rideau site. Several weeks later the Governor General, Lord Dalhousie, laid the foundation stone of the outer pier of the river lock in an appropriate ceremony and was able to report to the Ordnance that he had the masonry of the first (the river lock), second, and third locks in the Entrance Valley underway. By the time construction work was suspended for the winter in the late fall of 1827, the inverted arches of the flooring of the first three locks were nearly completed and the masonry of their side walls laid up to a height of five feet. Some metal hardware had been made for the locks under construction, including the racks and pinions required to operate the sluices for the lower gates of the river lock, and the crabs and chains required to operate the same set of gates. A beginning had been made on laying up the masonry of the retaining walls of the basin situated between the lockpits of the fourth and fifth locks, and the iron work and timber required for the lock gates were on site. A pointed sill for the mitre gates had been constructed of oak timbers framed together with copper bolts and was ready for installation when required.

It was probably intended to use wood sills on the lower gates of the river lock. The lock chamber drawings make clear that the sills on the breastwalls of the lift locks in the Entrance Valley were to have been constructed of stone keywork locked together by means of cramps. On the Lachine Canal, the sills of the regulating or guard lock and of the lower sill of the river lock had been constructed of oak timber rather than of stone masonry as elsewhere on the Lachine Canal locks. This was done at the suggestion of Andrew White, one of the Lachine Canal contractors who with his partner Thomas Phillips had contracted in June 1827.
for the excavation and masonry work at the Long Island and Black Rapids locksites on the Rideau. At the river lock on the Lachine Canal, the substitution of a timber sill in place of a masonry sill for the lower gates of the river lock was credited with saving six feet of excavation in depth and nearly a month's work. Timber sills, if kept continually under water as they would be at the lower gates of river locks, or on the gates of regulating locks, were considered to be equally as durable as stone masonry sills.

During the winter of 1827-28, By planned to have a large portion of the stone required for the eight Entrance Valley locks prepared for use when construction re-commenced in the spring of 1828. However, in January 1828, the Board of Ordnance, which was investigating whether the Rideau Canal should be constructed as a large lock steamboat navigation, forwarded instructions that he was not to undertake any new work beyond what had been contracted out to that date pending a decision on the scale of lock to be constructed and the resolution of several related questions. In consequence, Col. Durnford, the Commanding Royal Engineer for Canada, refused to let masonry work proceed in the spring of 1828, and instructed Lt. Col. By to confine his masonry work strictly to the preparation of stone for the locks until such time as the size of lock to be constructed had been determined.
II The Proposed 50 by 150 foot Steamboat Lock

The Argument
Prior to commencing work on the Rideau Canal project in the fall of 1826, By had submitted two reports to the Master General and Board of Ordnance in London advocating that the Rideau Canal should be constructed as a steamboat navigation. If built with large locks 50 feet by 150 feet having 10 feet of water on the sills, the Rideau Canal would be capable of passing all but several of the very largest steamboats employed on the lower St. Lawrence River and Great Lakes. In effect, By envisaged the Rideau Canal being part of a larger steamboat navigation which he proposed should be formed by enlarging the Ottawa River and Welland canals then under construction, and building short canals on a correspondingly large scale at St. Mary's, to connect lakes Superior and Huron, and at the rear of Montreal Island, to by-pass the small 20 foot wide locks of the Lachine Canal. He argued that were such a transport system constructed to enable the large steam boats to circulate freely from Quebec through to the head of Lake Superior, the trade of the fertile hinterlands of the Great Lakes would come under British control and provide an ever increasing force of steamboats which could be armed for service in time of war. He calculated that there were sufficient steamboats already in service in 1826 on the inland waters and lakes to transport an army of 10,000 men, and if the uninterrupted steamboat navigation were constructed as he proposed, the British forces would be able to marshal in strength at any
point on the frontier with a rapidity of movement that the Americans could not match on land. The Ordnance, after examining By's proposal in detail and receiving a further elaboration from him on several technical points at issue, concurred as to the substantial military advantages to be realized in constructing a large lock steamboat navigation through from Montreal to the Great Lakes; but the cost was judged prohibitive. Fearing that this would be the case, in December 1826 By had proposed that the large 50 by 150 foot locks should be constructed for the present only on the Rideau and the depth of navigation reduced to five feet. Such a scale of lock By maintained would handle all of the trade of the St. Lawrence, including the timber rafts customarily floated down that river, if the latter route should be cut off in time of war. It would also enable the large lake steamboats, with lightened loads, to pass through the canal from Lake Ontario to the upper Ottawa River. The large lake steamboats, of course, would not be able to pass through the Ottawa River or Lachine canals until such time as the locks might be enlarged. In the meantime, steamboats could operate on the long stretches of river above and below the two respective canals to tow the freight barges and Durham boats which were capable of passing the 20 foot wide locks. In this manner, the speed of transit provided by a steamboat navigation could be realized even though the steamboats could not pass through the whole system. The projected cost of constructing the Rideau Canal with large steamboat locks could be reduced appreciably through keeping the five foot depth initially proposed for the smaller canal. Moreover, the enlargement of the Rideau Canal would not entail the heavy expenditures that one would expect where it was proposed to enlarge the width of a canal by 2½ times its former projected width.
The Rideau Canal was being constructed as a slackwater navigation where dams were to be used to flood out the rapids of an existing river system, rather than being constructed as a canal cut independent of the river. Consequently the amount of extra excavation, and hence additional cost, to be incurred in enlarging the width of the canal was relatively insignificant on the Rideau where the canal cuts were few and quite short. So long as the depth remained the same as for the 20 foot wide canal, the major cost of enlarging the canal would be incurred in constructing the larger locks, and even here the projected cost would be reduced by adopting a rather unconventional design for the large 50 by 150 foot lock. As of the winter of 1827-28, By estimated that only £3,000 of work and materials would be lost if the Rideau Canal were to be increased in size beyond the 20 foot width of the locks on which work had commenced in the Entrance Valley. He was convinced that if the depth of navigation were not increased, the construction of the 50 by 150 foot locks would add only £50,000 to the £474,844.1.2½ estimate that he had prepared as of October 1827 for constructing the Rideau Canal with the 20 foot wide gunboat locks. In view of the slight increase in cost and the substantial military benefits to be realized through constructing a large lock steamboat navigation, By was confident that once all of the pertinent information and cost factors were received and reviewed in London, the Ordnance would authorize the construction of the larger scale of canal.

At the end of October 1827, By forwarded the £474,844.1.2½ estimate and a series of locksite plans for the whole of the Rideau Canal to the Ordnance in London with Lt. Pooley, a member of the Rideau project's engineering staff. Pooley was well-versed in all details of the
arguments and considerations in favour of constructing the large lock steamboat navigation locks on the Rideau Canal.\textsuperscript{8} To that point, By had done everything possible to reduce the projected cost of the large lock steamboat navigation, and he could only await the decision of the Master General and Board of Ordnance. Thereafter, By and his staff prepared plans and specifications for the works to be contracted out in the new year.\textsuperscript{9} As of 1 December 1827 he had completed detailed plans of the lock chamber and gates of both the 20 foot wide gunboat lock, on which construction had already proceeded in the Entrance Valley, and the large 50 foot wide steamboat lock that he had proposed should be constructed in its stead.\textsuperscript{10} Whether or not By received permission to construct the large lock depended ultimately on the decision of a committee of Royal Engineers, under the presidency of Sir James Kempt, which was to rendezvous on the Rideau in the late spring of 1828 to examine the Rideau Canal plans and estimate preparatory to deciding what scale of lock should be constructed thereon.\textsuperscript{11}

Lock Chamber Design and Configuration
The plan that By prepared as of 1 December 1827 for the large 50 by 150 foot steamboat lock with 5 feet of water on the sills was an adaptation of the lock design in use on the Welland Canal where, commencing in 1825, a sloop/schooner canal was being constructed to by-pass the falls at Niagara.\textsuperscript{12} The Welland Canal locks were being constructed of wood with chambers 22 feet by 110 feet and 8 feet of water on the sills,\textsuperscript{13} as opposed to the huge masonry locks proposed for the Rideau, but there was a common distinguishing feature. The sills of the upper gates, rather than resting on a breastwall as in
conventional lock construction, were to be placed on the same level as the lower gates with the breastwall being constructed in the forebay a good distance in front of the upper gates. The major advantage of this type of lock configuration in By's view was that since the bottom of all the gates was continually under water, the sluices could be constructed in the gates, thereby effecting a substantial savings through eliminating the need to construct costly sluice tunnels in the walls at the upper gates and at the intermediate gates of flight locks.\textsuperscript{14} (Fig. 11)

There is also a drawing extant of a 50 foot wide lock of a different design that By was apparently considering for construction at one point before deciding to adopt the Welland Canal lock configuration for the proposed large lock steamboat navigation. The lock chamber was basically of the same dimensions and detail, but the lock was of a conventional design with the upper gates on the breastwall. However, the drawing indicates that By was considering having two sluice tunnels in the floor of the lock, just behind the raised mitre sill, with each sluice opening extending 5 feet out from the sill for a width of 8 feet. From there the sluices were to pass down through the breastwall at a steep angle into the lock chamber so that the waters shooting down through the sluice tunnels would strike together in the center of the lock in front of the breastwall, thereby dissipating their force. Such a positioning of the sluices would also have directed the force of the water downwards and through the water in the lock so that any vessels ascending in the lock chamber was not in danger of being flooded.\textsuperscript{15} (Fig. 10) In this sluice layout, By was probably trying to eliminate the need for constructing tunnel sluices in the walls of the large lock. The lack of detail in the single plan view extant of
This abortive plan shows that consideration was given to having the sluice tunnels pass down through the breastwork at the upper gates. The duck foot shaped anchor plates were to be embedded in the lock wall masonry.

this lock, however, makes it impossible to determine how he proposed to operate sluices in such an awkward position where the lock gates had to swing over the floor sluice openings in closing, or if indeed he was ever able to resolve that problem. The sluice tunnels through the breastwall idea was soon abandoned in favour of the Welland Canal lock system.

John MacTaggart, the Clerk of Works on the Rideau project, visited the Welland Canal works in 1827. Although MacTaggart did not approve of the novel configuration of the Welland Canal locks, his report on returning to the Rideau may have given By the idea of adopting such an unconventional configuration of canal lock. It provided a simple way of avoiding the need to construct costly tunnel sluices in the walls of the large 50 foot wide lock. Whatever the case, it was the Welland Canal lock configuration that Lt. Col. By was determined to construct on the Rideau Canal if his large lock canal proposal was accepted by the Ordnance.

**Large Lock: Proposed Wall Details**

The walls of the projected large lock were to be constructed of rubble stone masonry and faced with large cut stone blocks laid in regular horizontal courses. Alternating stretchers and headers were to tie the face stone into the rubble core wall. The walls were to be eight feet thick at bottom and five feet thick at the coping, but in contrast to the twenty foot wide lock, they were to be carried up vertically on the outside and battered only on the inside of the lock chamber. However, as was standard practice in lock construction, the hollow quoin piers and gate recess piers were to be formed on each side of the lock walls at the gates by carrying sections of the wall, 9 feet long and
8 feet long respectively, straight up from the foundation. This provided in conjunction with the elimination of the batter on the 30 foot section of wall in between the piers, a recess for the gates as well as in the case of the hollow quoin pier a vertical surface against which the heel post of the gate could abut.\textsuperscript{18} No specifications for the cut stone work have been found, but a rough scaling from a cross-section drawing of the lock chamber indicates that the face stones were to be approximately 10" to 16" in thickness with the stretchers having roughly a 16" width of bed and the headers going back into the wall from 2 feet to 2 feet 6 inches. This would indicate that By intended to use the same size of cut stone on the large lock as specified previously for the smaller 20 foot wide lock: viz. no less than 2'-6" in length, 20" in breadth of bed, and from 9\frac{1}{2}" to 16" in thickness.\textsuperscript{19} Each lock wall was strengthened by means of two counterforts of rubble masonry, 3 feet by 3 feet, built into the rear of the wall at 30 foot centers, and by widening the walls to a thickness of 11 feet for a distance of 14 feet at the hollow quoins.\textsuperscript{20} The latter was a standard feature of lock design to resist the transverse and longitudinal thrust of the mitre gates against the hollow quoin.\textsuperscript{21} The ends of the lock walls were to curve outwards on a radius of 15 feet in keeping with the wing wall design of the twenty foot wide lock. A puddle wall three feet thick was to be formed against the outer wall of the lock from the foundation of the lock wall to the height of the coping. In the Entrance Valley, where Lt. Col. By intended to substitute seven locks of 11'-6" lift on the scale of the large lock for the eight locks of 10' lift on the twenty foot scale of lock previously planned, the lock chamber walls were to be roughly 18 feet high to allow for a two foot guard over the level of the
water in the lock when full as well as the height of the lift and the five foot depth of water on the sills. At the gate recesses, the walls were to be as high as 29 feet for a distance of 41 feet because of the peculiar positioning of the breastwall.22 (Fig. 11)

Large Lock: Proposed Breastwall and Sill Detail

The breastwall rather than being constructed under the upper gates, or under the intermediate gates in the case of flight locks, was to be positioned in front of the gates so as to cross the lock chamber in line with the gate recess pier. The breastwall was to be constructed of solid masonry 8 feet thick extending upwards from the level of the lock gate recess floor to the underside of the lock chamber floor above. The exposed part of the breastwall between the surface of the lock gate recess floor and the underside of the lock chamber floor above was to be 11'-6" in height, or in effect equal to the lift of the lock as was generally the case with breastwalls whatever their position. The raised mitre sill, which in a conventional lock was positioned on the breastwall, was to be positioned 21 feet away from the breastwall (measured from the face of the breastwall to the point of the mitre sill) with the base of the mitre sill being on a level with the base of the breastwall. The area between the breastwall and the raised mitre sill in effect formed a pit in which the lock gates were swung. The lock gate pit was to be paved with a flat masonry floor consisting of blocks of stone two feet deep laid with their base on a level with the base of the breastwall and the raised mitre sill. The mitre sill was to consist of a solid mass of cut stone masonry 4 feet high and 10 feet thick, extending up 2 feet above the surface of the lock gate pit floor to provide a raised surface against which the mitre
Plan, Elevation and Section of Col. By's proposed Large Lock of 150 feet long by 50 feet wide, the upper and lower gates on the same level and with sluices of Cast Iron in the Gates, Lt. Col. By, 1 December 1827 (PAC, H3/410, Rideau Canal, 1827).

This is the Welland Canal configuration of lock with the upper gates, and the intermediate gates of combined locks, positioned below the breastwall. The novel positioning of the upper gates would have enabled sluices to be constructed in the gates, thereby saving the cost of constructing tunnel sluices at the upper gates.
gates could be closed. The sill, of course, was pointed to match the angle formed by the mitre gates when closed, and the outer edge of the sill was aligned with the edge of the hollow quoin in which the heel post of the gates turned.23

Floor Details of the Large Lock
The floor of the lock chamber was to be constructed of masonry in the form of an inverted arch with a chord of 50 feet, a versed sine of 3 feet and an arc of 50.47 feet.24 The cut stones in the floor were to be two feet deep and laid in a longitudinal pattern breaking joint, with the surface of the floor being level with the top of the raised sill. Indeed, the top row of the masonry on the sill was but a continuation of the floor with the sill surface following the arc of the floor, although the blocks of stone in the sill were to be longer and heavier than the floor stones.25

To prevent water working its way under the floor of the lock, By planned to drive a row of wood piles across the lock chamber just below the gate pit floor commencing at the point of the mitre sill. The piles were to be driven to a depth of 10 feet26 by the two "ringing pile engines" employed at the Entrance Valley during the fall of 1827.27 From the drawings extant of the large lock, it is not clear whether the sheet piling was to pass straight across the lock chamber in line with the point of the mitre sill or whether it was to run parallel and adjacent to the face of the mitre sill out to the hollow quoin to form a V-shaped impediment to water penetrating under the lock gate pit floor.28 To enable repairs to be effected in the lock chamber, stop log grooves were to be built into the lock wall masonry of the forebay of the upper lock and the
tail bay of the lower lock in the Entrance Valley flight of locks, and a timber sill set into the floor in line with each pair of stop log grooves. Generally, sheet piling was driven across the lock bays under the stop log sills; but By did not intend to employ piles there in his large lock. This was even the case at the upper stop log sill which, with the upper gates being removed to their novel position down in a lock gate pit some 21 feet from the breastwall, was to be mounted directly upon the breastwall (Fig. 11).

The lack of a row of piling below the upper stop log sill is surprising, but By may have felt that a solid unit of masonry 8 feet thick was sufficient to prevent water penetrating under the stop log sill and down through the breastwall into the lock gate pit below. If that were the case, it marked a major departure in his thought of this element of lock design. In the smaller twenty foot wide lock By had intended to drive a row of wood piles to a depth of 16 feet across the rear of the breastwall, which was to be a solid unit of masonry 10 foot thick, and a rubble masonry wall several feet thick was to be built up from a depth of 10 feet against the opposite side of the row of piles.29 (Fig. 2)

**Lock Gate Design for the Large Lock**

The lock gates for the large lock were to be of a standard wood frame construction similar to the gates of the proposed twenty foot wide lock although of a far greater size. Each leaf of the gates was approximately 29 feet wide, and on the intermediate gates of the flight locks in the Entrance Valley were to be upwards of 28'-6" high. The gate frame timbers were probably to have been oak and would have been exceptionally heavy. The drawings extant of the large lock do not provide precise measurements as to the dimensions of
the framing timbers of the lock gate, but a rough scaling from the drawings indicates that the heel posts were to be approximately 20" to 22" in thickness, and the mitre posts and top and bottom cross rails about 15" to 18" thick with the intermediate cross rails being 12" thick. The gate frames were to be reinforced at the mortise and tenon corner joints with flat iron T and L plates, and the space between the cross rails was to be covered with planking put on in a diagonal pattern. The extreme width of the gates, of course, was dictated by the 50 foot width of the large steamboat lock, but the extreme height was a function of the configuration of lock adopted with respect to the positioning of the breastwall.

Customarily, as mentioned, the upper lock gates were placed on top of the breastwall with the result that the gates had only to be high enough at the junction of combined locks to hold the height of the lift of the upper lock plus the depth of water in the navigation. In effect, the gates in a lock of 11'-6" lift with 5 feet of water on the sills would be approximately 17 feet high allowing the gate frame to project 6" or more down past the raised sill and with the top of the uppermost cross rail being level with the surface of the water in the lock when full. However, on the Welland Canal type of lock with the gates positioned down behind, and separate from, the breastwall, the gates had to be high enough not only to hold back the lift and depth of navigation in the upper lock chamber, but also to cover the 11'-6" lift of the adjoining lock chamber below and the depth of water on the sills of that lock. In effect, the total height of the gate between the chamber of the Entrance Valley locks would have to be equal to the 11'-6" of the lift in the upper chamber, plus the 11'-6" lift in the lock chamber below (which would encompass the 5 foot depth of
navigation in the lock chamber above the gates), and the 5 feet of water on the sills of the lower lock with perhaps 6" of additional length of gate to project down past the raised sill, or in sum, approximately 28'-6" of gate height. However, By believed that the gates would be relatively easy to operate as the pressure, and level, of water on either side of the gates would be equal whenever the gate had to be swung as was the case with the conventional gate layout. Moreover, the additional head of water immediately in front of the gates would make it possible to fill the lower lock, according to his calculations, in the exceptionally fast time of 3 minutes.

**Lock Gate Sluices**

With the large 50 foot wide lock, all of the sluices were to be constructed in the bottom of the lock gates, and were to be of the same design as on the gate sluices of the twenty foot wide gunboat lock (Fig. 11). As in the earlier design, there were to be three separate flat iron valve plates set in a line of sluice openings along the bottom of each gate leaf adjacent to the mitre post. Each of the three openings was roughly four feet wide by two feet high and framed with upright timbers placed between the two lower cross rails of the gate. The drawings of the large lock do not show any details as to how the valve plates were to pivot. But they were presumably, as with the valve plates in the gates of the twenty foot wide lock, to pivot on a horizontal axis in journal boxes set into the upright frame timbers at the mid-point of the sluice openings. The lifting mechanism was exactly the same as was to have been employed to operate the gate sluices of the smaller lock.

Each valve plate in the three sluices at the base of the gate leaf was operated by means of a vertical iron rod
with one end pinned to the bottom edge of the valve plate and the other end to a lift mechanism at the top of the gate. Each lift rod, one per valve, was bolted to a horizontal arm of a 90 degree angle bracket, the vertical arm of which was connected to a rack running horizontally along the top of the lock gate. The apex or junction of the angle was set in a small metal gudgeon fixed to the top of the lock gate so that when the vertical arm of the angle was pulled by the rack, the whole bracket would rotate lifting the horizontal arm which in turn lifted the bottom edge of the pivot plate valve. The horizontal rack was attached to the upright arm of each of the three pivoting angle brackets so as to pull all three in unison, and the far end of the rack passed over a roller on an upright support fixed to the top of the lock gate near the heel post. A pinion gear was positioned directly above the roller so as to mesh with the teeth on the upper side of the rack. Although it is not apparent from the drawings because of their lack of detail, the roller wheel may well have consisted of two roller wheels between which a tongue, on the bottom side of the rack, would run to keep the teeth of the rack in line with the teeth of the pinion gear in the horizontal plane as well as in the vertical plane. A crank handle was fitted to the shaft of the pinion gear and when turned moved the rack back and forth to operate the three valve plates in unison.32

**Lock Gate Operating System**

Swing bars were to be dispensed with on the large lock gates as was generally the case on large ship locks, but the drawings extant of the proposed 50 foot wide Rideau Canal lock do not show how the gates were to be operated. A truck was to be bolted to the bottom of each lock gate leaf at about one-third of its width measured in from the mitre
post, and the roller wheel of the truck was to run on an iron quadrant rail set into the floor of the lock gate pit. The roller wheel, of course, was required to support the weight of the large gate and keep it from sagging and/or placing a heavy strain on the collar at the top of the heel post. The collar was to be positioned just above the top cross rail of the lock gate, and was probably intended to go over the top of the heel post extension carried up a short distance past the top of the upper rail. The anchor proposed for the heel post was to be made of cast iron in roughly the shape of a duck's foot, 6 feet across and \(8\frac{1}{2}\) feet long with a raised edge around the perimeter forming at one end a collar for the lock gate heel post which was to pass through a circular opening in the heel of the duck foot casting. The base of the collar of the anchor, as indicated, was to rest directly above the upper rail of the lock gate on a level with the water in the lock when full. The lock wall masonry, however, had a two foot high guard over the level of the water in the lock when full so that the collar in effect was to be positioned two feet below the coping of the lock wall. To overcome this difference in elevation, By planned to have the flat duck foot casting anchor built into the masonry of the hollow quoin pier at the required level two feet below the level of the coping on the lock wall, rather than having the anchor positioned on top of the lock wall coping and lagged down in the conventional manner. The heel post was presumably to be mounted on a gudgeon, and as there were no hollow piers and tunnels provided for in the masonry side walls for setting up a capstan and drag chain system to operate the lock gates, By probably planned to employ the floor chain/crab system of operation that he had developed for the lower gates of the 20 foot-wide river lock in the Entrance Valley.
Layout and Lifts on a Slackwater Navigation

In seeking to sway the Ordnance to authorize the construction of a large lock steamboat navigation on the Rideau, By strove always to keep the projected additional costs to be incurred to an absolute minimum. He was aided in this endeavour by an earlier decision, taken on his own responsibility, to construct the Rideau Canal as a slackwater navigation rather than following the original plan proposed by the Ordnance of excavating canal cuts to by-pass the numerous long stretches of rapids found on the Rideau and Cataraqui rivers. On a slackwater navigation, where high dams were constructed to flood out rapids in the river and create large extended bodies of stillwater between locksites, an increase in the proposed scale of navigation, so long as the depth remained the same, did not entail a massive increase in the amount of excavation work as would have been the case on a canal being constructed in a more conventional manner making use of extensive canal cuts. Indeed, through adopting the slackwater system of canal construction, on the Rideau project, By was able to reduce the length of the canal cuts required from a total of 25 miles on the whole of the 123 mile long waterway to no more than 8\(\frac{1}{2}\) miles. The depth to which the excavations had to be carried was also reduced considerably as a result of the water levels being raised by means of the dams. In effect, the major additional expense that would be incurred in increasing the scale of the navigation was in constructing locks 2\(\frac{1}{2}\) times as wide and 1/3 again as long as the 20 foot by 108 foot locks that the Ordnance had initially ordered constructed on the Rideau. By, therefore, focused his cost saving efforts on the locks, and in particular on their design. He also managed to effect a potential savings through reducing the number of locks that would be required to construct the Rideau navigation.
In planning the layout for the large locks in the Entrance Valley and at Jones' Falls during the winter and spring of 1827-28 in anticipation that the Board of Ordnance would authorize him to construct the larger locks, By found that he could reduce the total number of some 47 locks required on the Rideau system by at least two and possibly more. In the Entrance Valley a lock had to be eliminated because of the impossibility of constructing an equal number of the larger locks, with their much greater length, on the same length of gradient as the smaller locks. At the Entrance Valley, eight locks were initially laid out for construction, with a basin 150 feet long between the 4th and 5th locks, on the floor of the valley where the land rose 80 feet in a distance of 1,082 feet. However, where the large lock was concerned, it was impossible even with the elimination of the intermediate basin to place eight locks on that length of gradient. Consequently, By had to eliminate one lock and increase the 10 foot lift formerly proposed for each of the small locks to 11'-6" for each of the large locks. Likewise, at Jones' Falls a similar situation appears to have prevailed. There Lt. Col. By had initially proposed to construct six locks, divided into two equal sets of flight locks separated by an intermediate basin, with each lock having a lift of 10'-2" to overcome a total difference of elevation of 61 feet. However, in the spring of 1828, he was prepared, if authorized to commence construction work on the large locks, to replace at least one flight of three locks, and possibly the other, with two combined large locks of 15 foot lifts each.

Whether these changes were made of necessity or not, they did reduce the potential cost of constructing the large lock steamboat navigation that By favoured. But the major savings he effected were, however, in the design of the large lock.
Masonry Savings attributable to the Lock Configuration

By informed the Ordnance that the adoption of the Welland Canal lock design, which enabled him to place his sluices in the gates and avoid the necessity of constructing tunnel sluices in the lock walls, resulted in a savings in masonry costs to the extent that the large 50 by 150 foot lock could be constructed for only £1,000 more than the smaller 20 by 108 foot lock.42 This was an exceptionally small increase when it is taken into account that the masonry of the smaller locks was estimated as costing from between £6,000 to £8,000 for a lock of 7 foot and 10 foot lift respectively.43 Indeed, the large lock was not only 1/3 longer in the chamber and 2 1/4 times as wide as the small lock, but had to withstand greater pressures which dictated the building of even heavier walls than planned for the 20 foot wide lock. The amount of masonry in the proposed large lock would normally have been increased, in keeping with lock construction design and practice, far beyond what had been calculated for the small lock. But this was definitely not the case as evidenced by the plans that By had prepared for the large steamboat lock based on the Welland Canal lock design.

The elimination of tunnel sluices for the walls of the lock chamber at the upper gates on single locks, and at all of the intermediate gates on flights of locks, enabled Lt. Col. By to reduce substantially the thickness, and consequently the volume, of masonry in the lock walls of the large lock at the gates. On the small lock, the wall at the gates was to be thickened by adding 8'-6" of solid masonry backing for a distance of 30 feet to form a rectangular cross section of wall 16'-6" thick at both the gate recess pier and hollow quoin pier and 13'-6" thick in the gate recess between the two piers. However, on the large lock,
the wall at the gates was to be thickened by only 6 feet of backing for a distance of 14 feet at the rear of the hollow quoin to form a rectangular cross section 14 feet thick. On the remaining stretch of wall between the hollow quoin pier and the gate recess pier, a distance of 35 feet, the wall was to be thickened by 6 feet at the foundation but carried up on a slope to meet the top outside edge of the lock wall, thereby forming a cross section of backing in the form of a right-angled triangle. In this manner, the top of the lock wall of the large lock was to be 5 feet thick in the recess between the hollow quoin pier and the gate recess pier and 8 feet thick where the gate recess pier projected three feet into the lock chamber. In effect, the elimination of the tunnel sluices in the walls of the lock at the gates had enabled Bly to reduce the thickness of the lock wall at the gates from a maximum of 16'-6" on the small lock with tunnel sluices to a maximum of 14 feet on the large lock where the sluices were to be in the gates. Moreover, the additional backing on the small lock had been carried up vertically at the maximum thickness for a distance of 30 feet, whereas on the large lock the maximum thickness of backing was to be carried up vertically for a distance of only 14 feet. For the remaining distance of 35 feet behind the gate recess and gate recess pier, the wall was to be sloped from the maximum thickness of 14 feet at the base to a thickness of 5 feet on the lock wall coping. These savings in the volume of backing required for the lock wall at the gates of the large lock were a direct result of the configuration of the Welland Canal lock where the novel positioning of the gates below, and at a distance from the breastwall, made possible the elimination of tunnel sluices in the wall. But the novel positioning of the lock gates also made possible significant savings in the volume of masonry required in the breastwall of the large lock chamber.
a) Potential Savings in the Breastwork Masonry
In the smaller 20 foot wide lock, By had intended to construct the breastwall on which the gates were to be mounted, as a solid unit of masonry 10 feet thick and 12 feet high (on a lock of 10 feet lift with a 2 foot depth of foundation under the exposed face of the breastwall). A row of wood piling was to be driven to a depth of 16 feet across the rear of the breastwall and a rubble masonry wall several feet thick built up from a depth of 10 feet against the opposite side of the row of piles. In effect, the unit of masonry at the breastwall was to be roughly 13 feet thick (with a row of piles passing down through it), by 12 feet high, and 20 feet in length between the lock walls at the gate recess piers. On the large lock, the breastwall was to be 50 feet long between the lock walls at the gate recess piers and 13'-6" high (on a lock of 11'-6" lift with 2 feet of foundation under the exposed face of the breastwall) but only 8 feet thick. Moreover, the row of piles was to be driven not behind the breastwall as in conventional locks, but in front of the gate sills some 21 feet distant from the face of the breastwall on a level with its foundation. In a comparison of the two locks then, it is clear that the height of the breastwalls was to be approximately equal to the lift of the locks and hence would not change where an equal number of locks were to be constructed to overcome a given difference of elevation regardless of the scale of lock constructed. The breastwall of the large lock was to be roughly 30 feet longer because of the extra width of the lock chamber, but surprisingly, as much as 5 feet less thick than that of the smaller lock. The volume of masonry in the breastwall of the large lock was therefore understandably to be greater than in the breastwall of the small lock (4,000 cu. feet
versus 2,600 cu. feet); but not anywhere near as great as it would have had to have been if the large lock had been of a conventional design with the gates mounted on the breastwall.

The critical consideration which enabled Lt. Col. By to eliminate the piling in the breastwall and reduce its thickness from what he had intended to construct in the smaller 20 foot wide lock, was the altered ratio of water pressure above and below the breastwall of the large lock resulting from the adoption of the Welland Canal lock prototype. In that lock design where the gates were positioned upwards of 21 feet from the breastwall with their bottom rail roughly on a level with its base, there was no impediment to the water filling up the lock gate pit between the breastwall and the gates. The level of water in the lock gate pit was therefore always on a level with that of the water held in the lock chamber by the gates. Moreover, the lock gate pit was upwards of 11'-6" deeper (more or less depending on the height of the breastwall) than the lock chamber floor. Consequently, there would always be a greater head of water, and hence a greater pressure, on the floor of the lock gate pit and against the face of the breastwall, than there would be on the floor of the lock chamber above the breastwall. This, of course, was the exact reverse of the situation in a flight of conventional locks where, with the gates positioned on the breastwall, the head of water and pressure on the floor of the lock chamber above the breastwall when the lock was full were far greater than on the face of the breastwall below. Consequently, there was a real danger in the conventional lock that water under pressure would force its way down through the floor of the upper lock and through the breastwall into the lock below, or penetrate down and under
the floor of the lower lock and blow it up. Such an eventuality had to be guarded against by the construction of massive masonry breastwalls and piling driven to a great depth across the lock chamber at the rear or through the breastwall. This, however, was not a critical factor on the large locks because of the novel arrangement of the breastwall vis.-à-vis. the upper gates. Hence By apparently felt justified in planning to eliminate the row of piling from the breastwall of the large lock and constructing the breastwall only 8 feet thick when he had previously planned to construct the small locks with breastwalls upwards of 13 feet thick, supplemented by a row of piles driven to a great depth. He was also apparently confident that no increase was required in the thickness of the masonry floor inverts of the proposed large lock chamber over what he had planned to construct in the 20 foot wide locks. This appears to have been a function of the decision to maintain a common depth of navigation rather than attributable to the adoption of the Welland Canal lock design for the proposed large lock.

b) Potential Savings in the Masonry of the Floor Inverts
In the 20 foot wide lock, Lt. Col. By had planned to construct his masonry floor inverts of cut stone blocks 2 feet long by 9\(\frac{1}{4}\)" to 16" wide and 2 feet thick (deep), to be laid in a versed sine curvature with a 20 foot chord. In the large lock, masonry floor inverts were to be constructed at the same depth, 2 feet thickness, on a versed sine with a 50 foot chord. (Fig. 11) In locks of a conventional design, masonry floors were generally constructed in the form of an invert to better resist the upward thrust of water penetrating down through the floor
and breastwall of the lock above and up under the floor of the next lock below in a flight of locks. The pressure to be resisted was calculated on the supposition that it would be no more than the equivalent of the pressure of a head of water equal to the total depth of the lock.\(^49\) However, as the depth of water in a lock was commonly proportional to its width, the formula developed for calculating the thickness of a lock floor invert was based on the width of the projected lock. The acceptable thickness of floor depended on the nature of the foundation on which the lock was to be constructed, and as such varied greatly in practice within the accepted range of from 1/15 to 1/3 of the breadth of the lock chamber.\(^50\) In effect, a 20 foot wide lock, according to the accepted formula, would require a minimum thickness of floor invert of 1'-4" and probably more depending on the nature of the soil. Unfortunately, in the absence of any further refinement of the formula as to the nature of the different types of soils to which the respective thickness factors were applicable, such a broad ranging formula provides no effective basis for assessing the efficiency of Lt. Col. By's proposed depth of floor on his 20 foot and 50 foot wide locks. However, it is known that floor inverts on 16 foot wide locks were customarily constructed 2'-8" thick and on 20 foot wide locks 3'-4" thick.\(^51\) From this it would appear that By was planning to construct what was at best a minimally acceptable depth of floor invert in the 20 foot wide locks, and he planned to maintain the same depth of floor invert in the large lock.

At first glance it appears surprising that By did not intend to increase the thickness of the floor invert in the large lock. Especially so as in the Welland Canal lock configuration where the gates were to be positioned below the breastwall in a gate pit, there was a correspondingly
greater depth of water on the upper side of the lock gates. In effect, the depth of water in the large lock, if of an equivalent lift (say 10 feet) and common depth of navigation as the small lock, would be approximately 10 feet deeper in front of the large lock gates than in front of the gates of the smaller lock where they were mounted upon the breastwall. One might suppose this would produce a greater pressure acting down through the floor and under the gate of the large lock to blow up the floor in the lock chamber on the other side than would be the case in the small lock. But this was decidedly not the case. Where the depth of water on the sills was the same for either scale of lock, in this case 5 feet deep, the head of water acting under the floor of the lock below in the small lock by the time it had worked its way down through the masonry breastwall would be equal to the head of water in front of the gates of the large lock where the gates were below and separate from the breastwall. Consequently, a roughly equivalent pressure of water could be expected to act on the underside of the floor of the lock below, should the water work its way through to that point. Therefore, a roughly equal thickness of floor invert was required, in this case 2 feet thick, for both the small and large lock chambers. In sum, it was not a difference in lock design, specifically the different positioning of the breastwall, that enabled Lt. Col. By to maintain the same depth of floor invert in the large lock as in the small lock; but rather the fact that the depth of water on the sills was not to be increased for the large lock.

Ordinarily, larger locks were constructed with a proportionately greater depth of water on the sills to handle vessels of greater dimensions with their correspondingly deeper draughts. But on the Rideau project
to obtain the benefits of a large lock steamboat navigation for military purposes and yet economize on the cost of constructing the same, Lt. Col. By had decided to maintain the same depth of water on the sills as in the smaller 20 foot wide locks. Rather than constructing the 50 by 150 foot locks with 10 feet of water on the sills as was required for the large steamboats when fully loaded; he proposed that such vessels should lighten their loads to reduce their draughts before passing through the canal. The large lock that Lt. Col. By proposed to construct was therefore a bastard or disproportional lock in terms of its breadth to depth ratio, and the formula developed for calculating the depth of floor required in a lock cannot be applied as it was expressed in terms of the projected width of the lock chamber. Nonetheless, it is evident that through maintaining the same depth of water for the proposed large steamboat navigation as was planned for the smaller gunboat canal, By was able to confine the amount of extra masonry required in the large lock floor inverts to solely what was required to meet the increased width of the lock, and thereby again to minimize the extra costs to be incurred.

Through adopting the Welland Canal lock design, Lt. Col. By was able to severely reduce the amount of masonry that would otherwise have been required to construct the large lock steamboat locks proposed for the Rideau navigation, and by maintaining the 5 foot depth of water on the sills he was able to minimize the amount of extra masonry required in the floor inverts, as well, of course, as in the walls in so far as their height was concerned. But in striving to minimize the thickness of the walls of the large lock, he may have carried his desire to effect savings in the amount of additional masonry required to such lengths as to seriously risk endangering the stability
of the walls, or so it would appear according to the accepted lock wall design formulae.

**Lock Wall Design of the Large Lock**

Canal lock walls were generally constructed a minimum of 4 feet thick at the coping and made thicker towards the base in keeping with the height of the particular wall and the pressure to be resisted. To that end, the back of the wall was commonly constructed with an outward talus (slope) or was stepped forward, to provide a progressively thicker wall at increasing depths to better resist the increasing pressure of the water in the lock and to guard against filtration from the lock chamber which, of course, was greater in proportion to the head of water in the lock. (Fig. 25) The greatest pressure to be resisted by the walls, however, was not that of the water in the lock, but the pressure exerted by the clay/earth fill or backing on the outside of the lock. To facilitate the calculation of the thickness of wall required to resist the maximum force that could be exerted against it, the backing was taken to be a semi-fluid denser than water and the mass of the wall was made great enough to resist its momentum. Since the pressure exerted against the wall varied according to the height, or more correctly the depth to which it was taken, a formula had been worked out by canal engineers whereby lock walls were to be constructed with a thickness anywhere from 0.28 to 0.50 of their height. The walls were sometimes given a concave face towards the interior of the lock to place a greater force against the thrust of the earth, as on the Caledonian ship canal and the Lachine Canal, (Fig. 3) or the walls were battered on the inside having a gradual slope from the floor of the lock upwards to the coping. However,
concave lock walls and battered lock walls were of such a shape as to cause a great waste of water during lockage. As a result by the 1830s, if not earlier, canal engineers came to prefer lock walls being constructed perfectly vertical, or at least vertical in the lift portion of the lock chamber with an inward slope below matching the shape of the hull of the boats to be employed on the canal. Provision also had to be made in the wall for a recess to protect the open gates from potential damage as the vessels moved in or out of the lock chamber, but this posed no problem. The gate recess was commonly made 4" deeper than the thickness of the gate and 6" longer than the gate leaf. The wall was thickened behind the gate recess to maintain a common thickness of wall throughout the lock chamber. The height of the wall, however, was determined by the sum of several factors: the proposed depth of water on the sills, the height of the lift, and the height of guard (commonly an additional two feet of wall) that was to be allowed over the level of water in the lock when full. Otherwise, where the design of lock walls was concerned, the only detail requiring further calculation was the length of wall to be constructed beyond the gates at either end of the lock chamber.

Insofar as the forebay of a lock was concerned, the length of wall extending beyond the upper gates was not at all critical. The side walls of the forebay were carried a minimum of 6 or 7 feet beyond the upper end of the gate recess, and were commonly carried further in keeping with a rough rule of thumb that the walls of the forebay should extend beyond the gate recess a distance equal to 1/3 of the width of the lock chamber. Where the tailbay of the lock was concerned, the extension of the side walls was a matter of critical importance. The configuration of mitre
gates was such that the force of the head of water held back by the gates acted to thrust them back into the hollow quoins of the lock chamber wall. The transverse component of that force was commonly guarded against by thickening the side walls of the lock at the gates, but the longitudinal component of the force thrusting the lock gates back against the hollow quoins had to be taken along the length of the side walls. For the upper gates, the lock chamber walls were of sufficient length to bear the force acting along them, but at the lower gates, this force had to be met by extending the side walls of the tailbay a fair distance beyond the gates. The requisite length of the tailbay walls was apparently determined in a number of ways by early 19th century canal engineers. The simplest formula for calculating the proper length for the tailbay walls was governed solely by the width of the lock chamber, with the walls to be extended a distance equal to roughly 4/5 of the width of the lock. In practice, according to this formula, a 15 foot wide lock would be constructed with a 12 foot length of tailbay wall, an 18 foot lock with a 14 feet of tailbay wall, and a 20 foot wide lock with a 16 foot length of tailbay below the hollow quoins. A slightly more complex formula took account of the depth of water in the proposed lock as well as the width of the chamber in calculating the requisite length of the tailbay walls. According to this formula, the length of wall required could be calculated by multiplying the breadth of the lock chamber times the greatest depth of water to be held in the locks and dividing the product by 15. In effect, a 20 foot wide lock containing a maximum of 12 feet of water (a standard 8 foot lift plus 4 feet of water on the sills) would require 16 foot long tailbay walls which accords with the more simple formula based solely on lock width. But if
the 20 foot wide lock were to contain 15 feet of water (a 10 foot lift with 5 feet of water on the sills as was the case with the locks initially proposed for the Entrance Valley), the tailbay walls would have had to be constructed 20 feet long in keeping with the more refined formula.

The plans that Lt. Col. By had prepared for the proposed large lock show that the side walls of the forebay were to be carried beyond the head of the gate recess a distance of 10 feet and thereafter were to turn outwards on a 15 foot radius to form curved wing walls which measured in a straight line to their outer edge made for a 25 foot long forebay wall (Fig. 11). This was an acceptable length of wall, as the customary forebay wall length to lock width ratio of 1 to 3 would indicate that the wall extension should have been a minimum of 16'-9" long. The walls of the tailbay of the proposed large lock were to be carried out 25 feet past the hollow quoin pier at which point curved wing walls turned outwards on a 15 foot radius to form a total length of wall of approximately 40 feet. According to the accepted formula of lock construction, to resist the longitudinal thrust component of the force of water acting against the mitre gates, tailbay while had to be at least equal in length, as indicated, to the product of the width of the lock chamber times the maximum depth of water in the lock divided by 15. In effect, the 50 foot wide Rideau Canal locks with a maximum of 16'-6" of water at the lower gates (a 11'-6" lift plus a minimum of 5 feet of water on the sills) would have required tailbay walls 55 feet long, whereas the tailbay walls of By's large lock were to be 40 feet long. In view of the accepted practice of lock construction elsewhere, the savings in masonry that Lt. Col. By intended to realize by shortening the length of the tailbay walls may have been gained at the risk of
constructing a lock of insufficient strength, or perhaps of barely sufficient strength, to resist the pressures to which it would have been subjected. By way of comparison, on the Caledonian Canal where the locks were 40 feet wide with a minimum depth of 28 feet at the lower gates (20 feet of water on the sills plus an 8 foot lift), the tailbay walls were carried 30 feet outwards in line with the lock chamber walls at which point a counterfort, 8 feet deep by 5 feet wide, was built into the back. The wall from there flared outwards on a slight curve for a further 40 feet and then was carried straight back a further 30 feet perpendicular to the lock chamber to form a wing wall. In effect, exclusive of the 30 foot wing wall perpendicular to the lock, the tailbay walls of the Caledonian Canal locks were upwards of 70 feet long.  

Potential Savings in the Masonry of the Side Walls  
If the large lock were constructed, By planned to make the side walls of the chamber of the same thickness as the side walls of the smaller 20 foot wide lock, 8 feet thick at the base narrowing to 5 feet at the coping, where the height of the walls was roughly equal because of the similar depth of water on the sills and correspondingly high lifts. The walls of the large lock, however, were a good deal longer, 150 feet versus 108 feet in the chamber; and yet, the chamber walls of the large lock were to be less strongly reinforced. Rubble stone masonry counterforts 3 foot by 3 foot were to be built into the rear of the wall at 30 foot centers rather than 20 foot centers as on the smaller lock. At the gate recesses of the large lock, By planned another significant reduction in the amount of masonry. Whereas on the smaller lock the side walls were strengthened by adding 8½ feet of solid masonry backing to the side wall for a
distance of 30 feet to form a gate recess wall 13½ feet thick and gate recess and quoin piers 16½ feet thick, much less backing was to be added to the side walls of the large lock. The quoin pier was to be 11 feet thick from base to coping, and the gate recess pier 11 feet thick at the base sloping inwards on the outside to a thickness of 8 feet at the coping. The approximately 30 feet of side wall in the gate recess between the piers was to be only 8 feet thick at the base, sloping inwards on the outside to 5 feet thick at the coping. In effect, the gate recess wall was to be the same thickness as the side wall of the lock chamber. This was despite the fact that the gate recess walls, which were below the breastwall in the Welland Canal configuration of lock, would be ranging upwards of 30 feet in height as opposed to the maximum height of approximately 18 feet in both the standard 20 foot lock walls and the chamber walls of the proposed large lock. According to the accepted formula for calculating lock wall thickness, a lock wall should be 0.28 to 0.50 as thick as it was high, which in the case of a wall 30 feet high would require it to be between 8½ and 15 feet thick. Clearly in reducing the masonry in the gate recess wall of the large lock to 8 feet thick at the base narrowing to 5 feet at the coping on a wall which was to be upwards of 30 feet high, By was approaching a barely acceptable minimum thickness of wall. On a lock of comparable scale and height of wall, the Prince's Dock lock, Liverpool, where an approximately 36 foot high wall was constructed on a lock 40 feet wide containing upwards of 30 feet of water, the side walls were 8 feet thick at the coping and remained at that thickness down to the mid-point of their height where they were stepped gradually outwards on each side to form a base 20 feet wide, exclusive of the floor invert which carried far up the wall thereby further adding to its thickness.
In designing the proposed large lock, By was clearly attempting to keep the additional costs to be incurred in enlarging the locks to an absolute minimum. To that end, he was prepared to adopt the Welland Canal lock configuration which enabled him to effect substantial savings in the amount of extra masonry that would otherwise have been required in the breastwall and in the side walls of the large lock at the lock gates. He was also prepared to construct the large lock with an absolutely minimum amount of masonry insofar as the thickness of the side walls of the lock chamber, the gate recess walls, and the length of the tailbay walls were concerned. However, whether or not such a lock design would have proved adequate to resist the pressures exerted at the several critical parts of the lock where substantial savings in the volume of masonry were effected remains a moot point, as the large 150 by 50 foot locks were never built.
The Kempt Committee
The Kempt Committee, which was empowered by the Ordnance to decide the scale of lock to be constructed on the Rideau navigation, arrived in Kingston on 15 June 1828. After an intensive investigation of By's plans and estimates, it reported on 23 June 1828. In addressing the main question at issue as to whether the Rideau communication should be constructed as a five foot deep gunboat navigation with locks 20 feet wide by 108 feet long in keeping with the original intention of the Ordnance, or as a five foot deep steamboat navigation with locks 50 feet wide by 150 feet long as then recommended by Lt. Col. By, the Kempt Committee took several factors into account. On the one hand, the committee agreed with By that the nature of the Rideau navigation, where high rocky banks, extensive swamps, and broad lakes precluded the construction of tow paths except at an inordinately great expenditure, would necessitate a more certain means of propulsion for vessels engaged in war operations than could be provided by poles, oars and sail. Steamboats, used for towing and/or transport, appeared to be the only alternative. In these circumstances, the committee was prepared to accept the need to construct a larger scale of lock to accommodate steamboats, but they could see no advantage in constructing a lock as large as 50 feet by 150 feet with only a five foot depth. Moreover, to deepen the navigation was out of the question. Earlier, it had been assumed that the water level could be raised in
the Rideau navigation simply by increasing the height of the
dams and locks at a relatively minimal increase in cost, but
by the spring of 1828, detailed surveys had shown that the
natural banks of the rivers were incapable of holding even
an additional two feet of water without recourse to costly
embanking and excavation work. According to By's
estimate, it would cost an additional £250,000 to deepen the
navigation on a large lock navigation, and this the .
committees found totally unacceptable. This was even
more the case as the Kempt Committee was concerned as to how
the Rideau Canal would fit in with the canals being
constructed on the Ottawa River and the Lachine Canal, and
what changes the construction of larger deeper locks on the
Rideau would necessitate on those canals. To obtain
the full benefit of constructing the large 50 foot locks at
an 8 foot depth or more, the committee believed would
necessitate the enlargement of the Ottawa locks to a similar
scale and even eventually the enlargement of the Lachine
Canal or the construction of a by-pass with large locks to
the rear of Montreal Island. The expenditures that
this would entail were totally out of the question. This
was especially so as the Kempt Committee was acutely
conscious of the fact that the estimate even for the
construction of the Rideau Canal as a 5 foot deep gunboat
canal with locks 20 by 108 was far beyond what the Ordnance
Department had anticipated when the project was initially
approved.

In view of the above considerations, the committee
recommended that the Rideau Canal should be constructed as a
5 foot deep navigation with locks sufficiently large to pass
the sidewheel steamers working on the Ottawa River. These
steamers, which were 30 feet wide over the paddleboxes and
108 feet long, were equal in size to the smallest of the
steamboats employed on the lower St. Lawrence between Quebec and Montreal and had proved to be well adapted to river navigations. A steamer of that size, with a 32 horsepower engine was capable of towing, the committee estimated, at least two fully laden Durham boats at speeds of upwards of 5 miles per hour on the still water formed by the high Rideau Canal dams. The locks would also prove sufficiently large to pass spars intended for the Royal Navy of up to 108 feet. Moreover, the Committee noted that the small steamers would be able to tow the Durham boats passing up from the St. Lawrence through the whole of the Rideau system; and this would provide ample shipping capacity for troop movements and the transport of naval stores.  

Where the configuration of the locks was concerned, the Committee informed Lt. Col. By that they could not authorize any departure from the orthodox lock design with respect to the placing of the sluices and the positioning of the gates on a line of canal as extensive as that of the Rideau. This, of course, meant that By had to abandon the Welland Canal lock design plan embodied in his large lock plan in favour of adopting a design for the new scale of lock more in keeping with the design submitted earlier for the small 20 foot wide locks.

The next day, By submitted a plan for the construction of locks 33 feet wide by 134 feet long in the chamber, with a minimum of 5 feet of water on the sills. A revised estimate set forth that it would cost a total of £576,757.14.9½ to construct the canal with that scale of lock. The plan, mentioned in By's correspondence, was probably only a rough sketch as no drawing of a lock chamber of that date, 29 June 1828, has been found. Indeed, it is highly improbably that By would have been able to produce a detailed drawing overnight as well as a revised cost
estimate. The earliest plan extant of the newly approved scale of steamboat lock, entitled "Plan of the Approved Locks for the Rideau Canal", was prepared by John Burrows, an Overseer of Works, and approved by Lt. Col. By on 8 July 1828. It is probably the first detailed plan prepared following the Kempt Committee report. It shows two combined locks, each of 5 foot depth and 10 foot lift, 33 feet wide in the lock chamber and 133 feet long measured from the face of the breastwall to the point of the lower gates when closed. The width and depth of the proposed lock is in keeping with the overall breadth and draught of the size of steamboat that the canal was intended to accommodate; but the length of the lock chamber bears no relation at all to the corresponding dimension of the steamboat. By, apparently on his own initiative, had decided to make the lock chambers 133 feet long clear of the breastwall and lower gates when closed to enable the longest of the spars then being exported for the Royal Navy, spars some 130 feet long, to pass through the new scale of lock adopted for the Rideau navigation. (The lower gates in opening would have reduced the length of the lock chamber, clear of the gates, by 13 feet thereby reducing the useable length to only 117 feet. But if only one leaf of the lower gates were opened when the spars were floated into (or out of) the lock, then spars as long as 130 feet would be able to pass that size of lock chamber.) The Kempt Committee appears to have approved the lock dimensions suggested by By, as the latter, on his return to By town from Kingston immediately thereafter, laid out the new scale of lock at each of the lock sites in turn. Subsequently, however, the length of the lock chamber was changed. Instead of being 134 feet long, measured from the

The first plan prepared for locks capable of passing sidewheel steamers 30 feet wide across the paddleboxes and 108 feet long. The lock dimensions initially proposed were 33 feet by 143 feet, point of sill to point of sill. The latter dimension was reduced before construction proceeded to 134 feet.
point of the lower sill to the face of the breastwall, the chamber was reduced 10 feet in length. The locks actually constructed on the Rideau Canal, and depicted in all drawings after that of 8 July 1828, were 134 feet long in the chamber measured from the point of the lower sill to the point of the upper sill.\textsuperscript{14} It is evident that the reduced length of the lock chamber was directly in keeping with what the Kempt Committee report had directed it to be.

A lock 124 feet long by 33 feet wide in the chamber actually had a clear length of 111 feet, allowing the 13 foot clearance required for the lower gates to be swung open.\textsuperscript{15} It was calculated years later that the maximum size of vessel capable of passing the Rideau Canal locks was one 110 feet in length by 31\frac{1}{2} feet in width.\textsuperscript{16} This, of course, compares directly with the Kempt Committee decision of 28 June 1828 that the new steamboat lock should be capable of passing a small river steamboat 108 feet long by 30 feet wide over the paddleboxes.\textsuperscript{17} The Kempt Committee must have refused to accept the extra long lock chamber that By proposed once they had time to study the detailed drawings. Then new plans were prepared directly in keeping with the scale of lock that the committee had initially decided should be constructed on the Rideau Canal. As of 1 August 1828, the masonry foundation of the first lock to be constructed on that scale was laid in the Entrance Valley at Bytown, and work proceeded quickly thereafter on the construction of the locks of the newly approved steamboat navigation.\textsuperscript{18}

The plans prepared for the new steamboat canal show a conventional lock configuration with the upper gates placed on a breastwall as in By's original plans for the 20 foot wide gunboat lock, which was in turn in keeping with the
design of the Lachine Canal locks erected earlier. The walls were likewise to be constructed of rubble stone masonry faced with cut stone masonry as on the gunboat lock, but the masonry work was somewhat simplified. In contrast to the concave surface of the proposed gunboat lock, the walls of the steamboat lock were to be carried up with only a slight batter. The breastwall was to be vertical with an indentation along the center section to increase the lock chamber length somewhat; where the breastwalls of the gunboat locks were to be carried straight across the lock and sloped upwards to the upper gates. The curved face of the gate recess and the hollow quoin piers, which on the gunboat lock ran up perpendicular to the concave chamber wall, were eliminated in favour of a vertical face carried straight up the side of the steamboat lock perpendicular to the battered chamber wall. Otherwise, the basic design was the same (Figs. 2 & 13)

In both lock designs, the walls were thickened appreciably at the lock gates, and counterforts were built into the rear of the chamber walls. Tunnel sluices were constructed around the upper gates and intermediate gates of flight locks. Gate sluices were to be used where gates, as at the lower end of a lock, were not positioned upon a breastwall. A provision for piling behind the breastwall was common to both lock designs as was the placing of stop log grooves in the side walls at either end of the lock and the intended use of inverted arch masonry floors where the locks were not positioned on bed rocks. The new Rideau Canal steamboat locks, measuring 33 feet wide by 134 feet long (point of sill to point of sill) were, of course, on a significantly larger scale than the 20 foot wide by 108 foot long (point of sill to point of sill) gunboat locks, and this was reflected in different provisions for operating the gates.
Plan and Sections of a single Lock for the Rideau Canal as approved by Committee of which Sir James Kempt was president, John By, Lt. Col., n.d. (Public Record Office, London, England). R4-000-M-0049

This is the basic design of the locks constructed with masonry floor inverts and a lower sill of wood. However as actually constructed, the breastworks were generally of solid masonry, the sheet piling being eliminated.
The earliest plans of the new steamboat canal lock make it clear that Lt. Col. By planned to dispense with swing bars on the lock gates, and to employ rollers running on iron quadrant tracks to support the weight of the gate leaves when being swung. The rollers, of course, had first been adopted for use when the 20 by 108 foot gunboat lock was under construction in the Entrance Valley to overcome a particular problem experienced at the lower gates of the river lock. There By's plan to construct steps along each side of the lock to provide access to the river below, precluded the operation of swing bars. Hence, he had developed the floor chain/crab system of operation for that set of gates, with a roller to support each leaf in compensation for the lack of a swing beam which would otherwise have supported, or balanced, the weight of the gate. The roller wheels and floor chain/crab system were adopted thereafter for the huge gates of the proposed large 50 by 150 foot steamboat locks; and both the roller wheels and the floor chain/crab system of operation were now to be employed on all of the relatively large gates of the 33 by 134 foot river steamboat lock (Fig. 18)

The Walls of the 33 by 134 Foot Lock
The walls of the steamboat lock were to be constructed of rubble stone masonry faced with cut stone blocks laid in regular horizontal courses, alternating stretchers (which were laid lengthwise in the wall) with headers (which went back into the wall) to tie the face stone into the rubble masonry core wall. The walls were to be eight feet thick at the bottom and five feet thick at the coping with the outside of the wall being carried up vertically and the inside on a batter. Several of the highest lock walls, however, were of a greater thickness, such as the two lower
locks (locks no. 1 and no. 2) in the Entrance Valley where the walls were constructed two feet thicker because of the additional height to which they were raised to prevent the river flooding over them. As was standard practice in lock construction, the hollow quoin piers and the gate recess piers were to be formed on each side of the lock walls at the gates by carrying sections of the facing stone, 11'-6" long and 6 feet long respectively, straight up from the foundation. The batter on the wall between the two piers so formed was also eliminated to form a recess, 21'-6" long with perfectly vertical sides, in which each gate was protected when swung fully open. The lock walls were to be strengthened by means of counterforts of rubble masonry built into their rear at 30 foot centers or less depending on the height of the wall, and by thickening the wall at the lock gates (Fig. 13). The latter was a standard feature of lock design to better resist the transverse and longitudinal thrust on the mitre gates against the hollow quoin. It also provided the additional thickness of masonry required to house sluice tunnels when they were to be constructed in the lock wall around the gates. On the initial lock plans of 8 July 1828 the counterforts were to be constructed 3 feet by 3 feet, but, as indicated by subsequent plans, this was increased to 4 feet by 4 feet on the same spacing to strengthen the lock chamber wall still further. According to the 8th July 1828 plan, the lock walls were to be thickened at the upper gates an additional 6 feet beyond the rear of the rubble masonry for a distance of 33 feet. A sluice tunnel, 3 feet wide by 5 feet high, was to pass through the wall at the upper gates and at intermediate gates on flight locks. A vertical groove, approximately 6" by 6" by 6", was built into each side of the tunnel wall at the mid-point in its
length and the slot so formed, 4 feet long by 6" wide, was to be carried up through the wall masonry to the coping of the lock to enable a vertical plate valve to be raised or lowered to operate the in-wall sluice (Fig. 12). The 6 feet of additional wall thickness at the gates, provided a 3'-6" thickness of wall to the rear of the sluice tunnel, for a total wall thickness of 14 feet from the face of the hollow quoin pier to the outer extremity of the wall. In the drawings of the new lock chamber prepared after 8 July 1828, By eliminated the vertical slot passing up through the wall perpendicular to the sluice tunnel in favour of man holes, 4'-6" square, centered on the sluice tunnel at the mid-point of its length. It appears that By initially planned to thicken the masonry to the rear of the proposed man-hole still further when he became concerned that the masonry there, some 3'-6" thick, "might not prove of sufficient thickness to resist the action of the frost." He therefore planned to add 1/2 feet to the rear of the sluice piers to provide a thickness of 4 1/2 feet between the sluice tunnel and the rear of the pier. Subsequently, as indicated by the lock plans extant, he decided on a different course of action. He left the total thickness of the sluice pier, some 14 feet measured from the face of the hollow quoin pier to the rear of the wall, unchanged while the tunnel sluice was moved one foot closer to the gate recess to provide the 4 1/2 foot thickness of wall desired at the rear of the man-hole. The length of the sluice pier, 33 feet, remained unaltered. On single locks where the sluices were to be placed in the lower gates and the sluice tunnels eliminated, the walls were also to be thickened for a distance of 33 feet, but only to a total thickness of 12 feet measured from the face of the hollow quoin pier. (Fig. 13)
The wing walls of the forebay and tail bay of a single lock were to have stop log grooves to enable coffer dams to be formed in case the lock should have to be dewatered for repairs, and the wing walls were to be curved outwards on a 15 foot radius. The wing walls, in effect, formed a segment of a circle comprising sometimes a semi-circle and at other times a quadrant (Fig. 14). According to the 8 July 1828 plan, they were initially intended to be constructed 12 feet thick at their base sloping inwards on the outside to an 8 foot thickness at the top, and narrowing as the wing walls curved outwards at the point where at its outer end, the wall would have been 3 feet thick from top to bottom. Subsequently, it was decided that the wing walls should be constructed 6 feet thick with vertical sides. In the forebay of the lock, the stop log grooves were situated at the head of the gate recess pier, some 6 feet from the gate recess opening, and from there the wing walls curved outwards. In the tailbay of the lock, the hollow quoin pier continued outwards a distance of 6 feet from the hollow quoin to the stop log groove, and at that point, the wing wall curved outwards. The curved wing walls were to be faced in cut stone to match the lock chamber walls.

No specifications have been found for the cut stone facing of the 33 by 134 lock. The specifications for the ashlar stone of the lock chamber walls of the small 20 foot wide gunboat lock had stated that the dressed stone was to be no less than 2'-6" in length, 20" in breadth of bed, and from 9½" to 16" in height. The stone was to be laid alternately stretcher and header in the wall. No detailed drawings of the masonry of the proposed large 50 foot wide lock were ever prepared, and no specifications for the stone work have been found. However, a rough scaling from a cross section drawing of the large lock chamber
FIGURE 14

indicates that the face stones were to be approximately 10" to 16" in height with the stretchers having a 16" breadth of bed and the headers going back from 2 feet to 2'-6" into the wall. From these rough measurements of the stonework proposed for the large lock, it is evident that By intended to use the same size of cut stone on that lock as specified previously for the smaller 20 foot wide gunboat lock. On the 33 foot wide steamboat lock, however, the earliest drawings indicate that the face stones were to be much larger than those contemplated for use previously. Unfortunately, the exact dimensions are not clearly indicated on the extant drawings.

The first drawing of the new steamboat lock, that of 8 July 1828, shows an elevation view of the coursed masonry stonework where the dressed stone scales at from 6 to 8 feet in length in the face of the wall with each course being either 12 or 20 inches high. A cross-section shows the face stone laid in beds of 24" width with headers going back 3'-6" into the wall. If the dimensions scaled off the plan accurately depict the stonework to be laid, then the stretchers were initially intended to be upwards of 8 feet long, by 24 inches wide, by 12 to 20 inches in height; and the headers were intended to be massive stones 6 feet wide on the wall face, 3'-6" long going back into the wall, and 12" to 21" in height or thickness. The drawing, however, was not to scale where the stonework was concerned, and the masonry detail shown may well not be an accurate depiction of what was intended. Indeed the size of the header stones indicated by the drawing is totally unrealistic. A later drawing of the approved lock, following its reduction in length to conform to the Kempt Committee recommendations, shows stonework details only in a cross-section view of the lock chamber and
a cross-section view of the breastwall. A rough scaling from the lock chamber cross-section yields measurements of 2'-6" and 3'-0" in length for the headers going into the wall, and a roughly 18" to 20" width of bed for the stretchers with the height of the courses varying from 14" to 18". The cross-section through the breastwall, which may well have had larger dimensioned stone than the lock chamber wall, shows headers going back into the breastwall distances of 4'-6", 5'-4", and 5'-6", and stretchers on a 24" wide bed, both of which were in courses from 20" to 22" in height.35 (Fig. 16) In the lock chamber wall, the headers did not extend more than 3 feet back into the wall as indicated in the cross-section view of the chamber (Fig. 13). Putting together the information derived from the two cross-sections, it is evident that as of 1828 By had decided to use in the lock chamber wall, headers of a maximum length of 3 feet, a maximum width of bed in the wall face of 20" and a height of from 14" to 18". The stretchers, judging from the length of stone in the breastwall cross-section, were intended to be as long as 5'-6" on a 24" wide bed, and with a height of from 14" to 18" to match the height of the headers in the walls. In effect, the stretchers in the wall of the 33 foot wide lock chamber were to be twice as long by 4" wider in breadth of bed and upwards of 2" higher than the corresponding stretchers planned for the small 20 foot wide gunboat lock. During the course of construction, however, the size of the cut stone facing blocks appears to have been increased again. A drawing of a Rideau Canal lock completed by Lt. Denison, immediately following his employment on the engineering staff of the Rideau project, shows in an elevation view of the lock chamber wall, stretchers of 4'-6" and 5'-0" in length, with headers 3'-0" wide in the wall
face. The stretchers and headers were laid in a random pattern in straight courses of either 18" or 20" in height, and occasionally 24 inches in height at the base of the wall.36

The only dimensioned drawings extant of the face stone of a Rideau Canal lock chamber wall were made in 1976 following the collapse of the west wall of the Lower Brewer's (Washburn) lock in the spring floods of that year (Fig. 15). Unfortunately, of all the locks constructed on the Rideau system, the Washburn lock was the only one which had had to be totally rebuilt, and on occasion extensively repaired, during the course of the 19th century. The Washburn lock had been built in haste to escape the effects of the dreaded swamp fever which was particularly severe there. In consequence, it had been erected on the first site surveyed despite the unstable nature of the soft clay and sand found in the base of the lockpit. This caused sections of the lock walls to settle and leak as early as 1840, and required the complete rebuilding of the east wall of the lock in 1861. Thereafter, the west wall had had to be completely rebuilt in 1874, and again in 1905-06.37

At each rebuilding and/or interim patching of sections of the lock wall where it bulged or leaked, the original stone which cracked with the settling of the wall, were removed and replaced with new stone. The working out of the quarries along the Rideau route obviously necessitated the later stone work being carried out with smaller dimensioned stone than originally used. Consequently, the as-found drawings show a myriad of different stone dimensions in the wall face laid in random patchy patterns which makes it impossible to determine, with any degree of certainty, the size of the original face stone in the lock chamber wall.38 Nonetheless, the size of the various face stones
Blocks of dressed stone removed from the walls of the Lower Brewers (Washburn) lock (Photo by author, 1977).
in the ashlar of the lock chamber wall can be estimated through examining and applying the rules that had evolved in the trade to guide stone cutters and masons in the preparation of ashlar stone.

As a general rule of thumb, in ashlar stonework, none of the stones were to be less than 2 feet long and 8" thick (wide), and where the height (depth) of a course of ashlar exceeded 10", the breadth of bed of the stone had to be no less than one-third wider than its height.\(^3\) Where the length of the stone was concerned, headers were to extend back into a wall from 3 to 4 times the height of the course, with the shortest headers being at least 18" longer than the breadth of bed of the ashlar.\(^4\) Usually the only difference between headers and stretchers was in the laying pattern. When a stone so dimensioned was laid with its longest dimension in the wall face, it was a stretcher, and when laid with its longest dimension going back into the wall, it was a header.\(^5\) Taking this dimensioning rule of thumb into consideration with respect to the height of the various courses of masonry depicted in a drawing of the 33 by 134 foot lock chamber wall face where the courses were 24", 20" and 18" high as the wall progressed upward,\(^6\) the ashlar stones should have ranged among six basic sizes: viz. on the 24" high courses, 32" wide by 6 feet long, and 32" wide by 8 feet long; on the 20" high courses, 26" wide by 5 feet long, and 26" wide by 6'-8" long; and on the 18" high courses, 24" wide by 4'-6" long, and 24" wide by 6 feet long. The lighter courses, of course, were always placed nearer the top of the wall.\(^7\) Allowing for variations in the dimensions of the stone owing to the nature of the beds in the quarries from which they were cut and drawn, the dimensions of the stone suggested by the stone cutters-masons' rule of thumb for dimensioning ashlar stone accords surprisingly well with the dimensions scaled
off the several drawings of the 33 by 134 foot lock in which the stonework is depicted. This suggests that the work of the stone cutters and masons on the Rideau Canal project was conducted in keeping with the common standards governing the dimensioning of ashlar stone, and that the laying of the stone was in keeping with the accepted practice.

Dressing and Laying the Stonework of the Lock Walls

Although the absence of any specifications for the stonework of the 33 by 134 foot lock makes it impossible to state with certainty how the stone was dressed and laid in the wall, the specifications extant for the stonework that was to be laid in the walls of the 20 foot wide Rideau Canal locks, in conjunction with what is known about how both ashlar and rubble masonry stonework was commonly dressed and laid, enables a fairly complete account to be given of the wall construction details of the locks actually built on the canal.

The specifications for the stonework of the 20 foot wide locks that By was initially ordered to construct on the Rideau Canal set forth the minimum size of the blocks of stone to be prepared for the side walls etc., as well as the method of laying the stone: viz. "the beds to be done in the very best manner with header and stretcher alternately".

The dressing of the blocks of stone was also described in detail where the specifications for dressing the ashlar stone for the small Rideau Canal locks stated that:

The face is to be cut with good fair chissel [sic] draughts arrived and required and hammer-picked between these draughts. The beds are to be levelled off the face with bevells furnished for the purpose by the Royal Engrs, with good chissel draughts all round, and rough hammer picked between, the front draughts to be three inches
Broad, the joint[s] to be squared at least ten inches back, the hollow quoins to be ... done in the same manner as the ashlar only the beds are to be square off the face, and the hollow for receiving the headpost of the Gate, is to be as fair and clean chisselled out as possible, and cut to a mould to be furnished by the Royal Engineers. The beds of the hollow quoins to be square off the face with chissel draughts all round and hammer picked between both beds to have the front draughts three inches broad with the joints to square back full. ...

... The ashlar for the back of the lock Gates etc the gate recess wall ... to be cut in the same manner as the ashlar for the side walls of the locks only the beds to be cut to the square and the joints squared back at least fifteen inches and the face of the stone is not to be hollowed as that mentioned for those for the side walls. The coping stones for the walls ... to be cut, the perpendicular face the same as the ashlar, the horizontal face or upper bed to have good draughts round and picked out between, with the front arris rounded off and made to a bevel furnished by the Royal Engineers, the lower bed with draughts round, and hammer picked between. The whole of the said cut stone to be done after a most workmanlike manner, to the entire satisfaction of the said Commanding Royal Engineer Lieut. Col. By, or other officer appointed to superintend the said works.... 44

Generally in non-decorative or non-ornamental ashlar work, the rough blocks of stone cut in the quarry were given what is called a "quarry dressing" whereby a mash hammer was
used to bring the stone into the required shape by chipping off any large protrusions of stone on the surface of the block. Then the blocks were squared at the edges by dressing the stone back 3 or 4 inches from the face with a pitching tool. The rest of the remaining surfaces of each block were then made true through being picked with a hammer or, for finer work, a point. In this manner, the surfaces of the block were brought roughly even with the squared edges. A block of stone so worked was called "hammer dressed", whereas a surface so finished was referred to as being "picked", "pecked" or "dabbed". This type of work had to be closely supervised to ensure that the upper and lower beds of a stone were not worked hollow because if the surface of the beds was brought below the squared outer edges, the pressure on the stone once laid in the wall would be concentrated on the outer edges, with a consequent danger of their cracking and spalling or splintering off. The squared edges of the blocks were necessary to enable them to be set properly in the wall, as well as to ensure that the stones could be put together with close joints. In stone ashlar masonry work, the backs of the stones were often left rough cut. The beds and the joints of each stone were squared and dressed using the hammer or point, but only for a distance in from the face of up to twice the depth (height) of the course. In effect, stretchers of the dimensions employed in building the Rideau Canal locks would have been fully dressed, but headers going back into the wall to tie in with the rubble masonry backing in the compound wall would have been left rough cut on their back face. For example, a header 18" deep (high) by 24" wide by 6 feet long would have had its sides dressed back just under 3 feet inwards from the face. Nonetheless, the headers had to tie
in with and match the coursing of the rubble masonry backing, and to that end, although their tails could taper slightly in breadth, it was essential that their beds be hammer dressed and true so that the stones would not taper in depth. The proper dressing of the stone blocks was of critical importance in ensuring that the ashlar masonry would be laid with close joints and even beds to minimize settling and prevent unequal pressures being brought to bear on different points of the block which in either case was liable to cause cracking.

As indicated by the specifications drawn up for the ashlar stonework of the 20 foot wide Rideau Canal locks, By was fully aware of how ashlar stone should be dressed and was imposing high standards on his contractors. On the side walls, the stone was to have its face dressed with chisel draughts and be hammer picked in between the draughts to bring it true. The beds were to be levelled by means of a chisel draught all around the edges, with the front draught being at least 3" wide, and the surface area inside the draughts was to be levelled through being picked with a hammer. The joints (ends) of the stone were to be squared back a minimum of 10 inches, as opposed to the 3" to 4" customarily squared back in dressing ashlar stone. In effect, By was concerned to have tight vertical joints in the lock wall masonry. Elsewhere in the lock, this was an even more critical concern. The stone of the gate recess and hollow quoin piers was to be similarly dressed except that the joints were to be squared back full (all the way) for the quoin stones and at least 15 inches for the gate recess stonework. The hollow quoin piers and the gate recess wall and piers were, of course, to be carried straight up from their foundation, and in consequence, the beds of the quoin and recess stones were to be dressed
square off their face so as to sit on a level. Where the dressing of the face of the ashlar in the battered walls of the lock chamber were concerned, it appears that By initially intended to lay the stone on level beds with the face of the stone being sloped to provide the batter desired. None of the drawings extant of the 20 foot wide lock dated prior to December 1827 show enough detail in cross-section of the lock wall to determine if the beds were intended to be level, but the stipulation that the beds were "to be levelled off the face with bevells [sic]" indicates that that was to be the case.54

In laying up vertical ashlar masonry walls in building construction, the beds were always kept square with the face. Where walls were to be built with a batter, the beds were kept level and the face of the stone was cut on a bevel to form the batter.55 However, in lock construction where walls were to be battered, the beds were generally kept square, or perpendicular, with the face of the wall, and hence the beds sloped downwards toward the outer edge of the wall. This, of course, necessitated that either the coping stone or the course of stone directly beneath the coping of such a wall be cut in the cross-section shape of a blunt-nosed wedge with a greater depth in the rear to bring the top of the coping level.56 According to a cross-section drawing of the 20 foot wide Rideau Canal lock prepared ca. December 1827, By intended the beds of the ashlar in the lock chamber walls to be perpendicular to the angle of the face of the lock chamber wall.57 This was also the case in a December 1827 cross-section drawing of the ashlar stonework of the large 50 foot wide lock that he proposed to construct on the Rideau.58 Moreover, all subsequent drawings of the 33 foot wide lock approved by the Kempt Committee for construction on the Rideau Canal show
the beds of the lock chamber masonry being perpendicular to the battered face of the wall. Indeed, both the December 1827 drawing of the proposed large lock, and a later cross-section drawing of the 33 foot wide lock actually constructed, make it clear that the coping stone was to be deeper at its rear than on its face to ensure that the upper surface of the coping would be level when laid on the sloping bed. Clearly either the specifications prepared in the spring of 1827 for the cutting of the ashlar stone for the battered walls of the 20 foot wide lock chamber were written in error in calling for the beds "to be levelled off the face with bevells [sic]", or By thereafter changed the specifications governing the cutting and dressing of the stone for the battered side walls so that the stones could be laid on a slope with their beds perpendicular to the battered face of the lock in keeping with what had been done elsewhere in constructing canal locks.

In laying ashlar masonry, the course immediately below the stone to be set was cleaned off, moistened with water, and covered with a thin layer of mortar before the stone was lowered into place. The block was invariably set so as to break joint with the masonry in the wall below with a minimum overlap of at least 6 inches past the joint of the blocks in the course immediately below it. The headers generally took up about 1/3 of the wall face in each course of ashlar, and in his specifications for the ashlar of the 20 foot wide lock By had stated that the stretchers and headers should alternate in each course. For the most part, headers were placed so as to be centered on the length of the stretcher in the course below. In constructing ashlar walls of sedimentary rocks, such as the limestone and sandstone of which the Rideau Canal locks were
constructed, the stone was always dressed and laid so as to rest in the wall on its natural bed which ensured that any laminations in the stone would be at right angles to the pressure to be exerted on them.64 Once the block was set in place on the mortar bed, it was struck with a wooden mallet to ensure that it was well-settled, and then the stone received its final dressing at the hands of the stone mason to render the upper bed of the stone true and the joints square off the face. In this manner, the joints of the ashlar masonry were kept tight, or close, when the succeeding blocks were laid adjacent to that stone and thereafter in the course above.65 In ashlar masonry work, the vertical joints were not allowed to exceed 3/16" to 1/4" in width;66 and all engineers, including By's staff, were well aware of the need to exercise a continual supervision of the work of the stone cutters and masons to ensure that the ashlar would be constructed with close joints.67

On the Rideau Canal project, even one of the best of the masonry contractors, Thomas McKay who constructed the Entrance Valley locks, had to be carefully supervised by the engineering staff. N.H. Baird who arrived on the Rideau in July 1828 to succeed John Mactaggart as Clerk of the Works, had to do battle with McKay in the early stages of constructing the locks to ensure that the ashlar stonework was properly done. On inspecting the stone work on the newly commenced 33 by 134 foot Entrance Valley locks in September 1828, Baird found that the stones were not well worked, or true, with ½ inch differences in evidence on the surfaces of some of the stone which when laid in the wall made for very rough, open joints. On lock No. 8, one face stone pulled out of the wall for inspection had only 1½" of the joint dressed back square from the face, and in some
places in the side wall Baird counted upwards of eight stretchers in a row without a header. After a voicing of differences, McKay agreed to remedy the problem in keeping with Baird's insistence that the joints be made close and the ashlar properly laid. Baird also found that one of the hollow quoin piers, on the upper end of lock no. 7, was 1/2 inch off true (the vertical), to which McKay replied that he would "dress it off after". Baird in this instance agreed to let McKay proceed, but he did not approve of dressing off the stone after it had been laid in the wall. Once the lock masonry was commenced elsewhere on the canal, Baird was continually travelling to each locksite in turn by horse and canoe on visits which often entailed him spending upwards of 31 days at a time on a round trip from By Town to Kingston and involved him working 7 days a week from 7 a.m. to dusk. During these trips, Baird inspected the joints of the masonry, saw to it that the contractors received the templates required for the cutting of the quoin stones etc., laid out new work, inspected the sand being used in the mortar, and measured the masonry in the walls (with a measurement wheel) so that the contractors could be paid for the work completed to that date.

Where the lock masonry was found to be bad as at Old Sly's, for example, or at Maitlands (Kilmarnock) where the masonry was found to be "very badly jointed" with very few beds square off the face and some joints open as much as 2 inches, the contractors were ordered to take it down and to commence re-laying the wall with better dressed stone. If the stone were of too small a dimension, the contractor was reprimanded, as at Smith's Falls where the contractor was ordered to put larger "tie stones" (headers) in the wall. In addition to Baird's tours of inspection to
ensure that the ashlar masonry was properly dressed and laid, By made periodic trips along the canal to examine the work in progress. The officers of the Royal Engineers on his staff were also assigned permanently, once the masonry work commenced, to stations where the work was considered to be especially critical. Judging from a drawing of the Entrance locks under construction in October 1829, Baird succeeded in getting McKay to dress his stone true on the beds and back from the face of the joints. The drawing shows the ashlar stone in the wall face laid alternately stretcher and header with the joints coming back square off the face for the full width of bed of the stretchers and for an equal distance back on the header. The sides and end of the headers projecting back into the wall beyond the stretchers, however, were left rough dressed as was the custom in building ashlar masonry in a compound wall where the headers tied the ashlar facing to a coursed rubble stone masonry backing.73

Once the stonework was laid, Baird kept men employed in watering the walls while the mortar set. This was done because Baird, who had worked previously on the construction of the Union Canal in Scotland, had remembered that keeping the stone damp while the mortar set "was found of much consequence on the Union".74 Where masonry work was carried on in the late fall, Baird was also very careful to ensure that frost did not get into the mortar. For example, at the Clowes Quarry locksite Hayes, the masonry contractor, was laying up the several lower courses of his lock in late October and early November 1828 to bring the masonry above the ground water level before winter set in so as to eliminate the need to constantly pump the water out.75 Hayes was laying up excellent masonry, but when Baird arrived early one morning in mid-November 1828 and found
masons laying stone after a very severe frost, he insisted that the courses be lifted off and the sections of wall laid earlier be "immediately covered up with Straw and Sand". In England, it was customary by the 1820s if not earlier to grout ashlar masonry lock walls after each course had been laid in mortar, but this was not done initially in constructing the ashlar facing of the Rideau Canal lock walls.

When planning the Rideau Canal works, By had intended to construct his arched key work dams, as well as the masonry of the waste weirs and culverts required, without mortar or cement of any kind being used. Dry stone masonry was less expensive to construct than common masonry, and he was convinced that it would withstand the severe effects of the Canadian climate "better than any other kind of masonry". However, his comments do not make it clear whether he initially intended also to construct the locks in dry stone masonry. John Mactaggart, the first Clerk of Works on the Rideau project, not only shared By's belief where dams, weirs and culverts were concerned, but also was convinced that dry stone locks, if constructed with "the stone laid on edge and well puddled behind", were better suited for construction on North American canals with their severe frost problems. He also was acutely aware that they would be much less costly to construct than locks built of ashlar laid in mortar or cement. In England, it had become common practice to lay ashlar stonework (where, as on the Rideau, all of the stones were cut straight and true, gauged and squared over their whole width) close together in the lock wall face with only "a thin even bed of fine soft pouring mortar to be poured over the bed, but not to be trowelled". There the frosts of winter were not a serious problem where lock masonry was concerned. Any
potential frost problem was negated by laying the dressed stones "perfectly flat and out of winding", with the result that only a thin liquid mortar, grout, poured into the vertical joints was necessary to seal and render them watertight. On the Rideau Canal, however, it was decided that the first locks constructed should have their ashlar face stones laid in common mortar and be pointed thereafter with hydraulic cement. There was apparently no grouting used initially in laying up the ashlar.

The Coursed Rubble Masonry Backing of the Lock Walls
The rubble masonry backing of the Rideau Canal lock walls was constructed of stones which were roughly squared with a hammer in the process of which particular attention was given to hammer dressing the beds on parallel planes and bringing the ends roughly vertical, or perpendicular, to the beds. Most of the stones, however, were left in their natural irregular shape with regard to their width of bed, as was the custom in this type of masonry work. With the exception of the beds, which had to be level, the sides of stones used in laying up coursed rubble masonry were merely hammer dressed to form a roughly vertical surface or at least a surface that formed an angle of greater than 60 degrees with the bed of the stone. Otherwise the stones selected had to be good and sound, and seldom exceeded a foot in height. However, on the Rideau Canal locks, most of the rubble stones in the side wall backing and in the breastwork were equal in height to the corresponding course of stone in the ashlar stone facing. Where smaller sized rubble stones were set between the larger stones, the smaller stones were of such a height that generally only two stones were required to bring the upper bed level with that of the larger stones in the ashlar course. (Figs. 16 & 74)
In laying coursed rubble masonry, each course was set and levelled before the next course was laid up, and the stones were positioned so as to break joint and laid on their natural beds as was the case with the ashlar stonework. In compound walls of coursed rubble masonry faced with ashlar, the rubble masonry was carried up at the same time as the ashlar. The two walls were tied together by means of throughs (headers that passed through the whole thickness of the wall) and binders (headers that passed a distance into the backing but not completely through). To that end, although the rubble masonry courses were constructed with different sized stones necessitating occasionally two or more stone being placed in the depth of a course, the upper bed of each course of rubble masonry was always brought level with the corresponding bed of the ashlar facing to which it was to be interlocked, or bounded, by means of the throughs and binders. On the Rideau, as evidenced by a drawing of the Entrance Valley locks under construction in October 1829, the coursed rubble masonry backing was brought up level with the beds of each course of the ashlar facing as it was raised, and the two were bonded together in the proper manner.

In a compound wall such as on the Rideau Canal locks, it was essential that any settling in the rubble backing be minimized to prevent the joints being forced open and/or the headers being cracked. To that end, the joints, which in a simple rubble masonry wall might well be upwards of 2" thick with the stones imbedded in a mass of mortar, were kept as thin as possible. Moreover, gaps caused by the poor fitting of the roughly cut rubble stone were filled in with smaller stones or quarry chips imbedded in mortar, rather than pure mortar, to minimize any settling. The stones were carefully placed flush in mortar and well bonded both to one
another and to the ashlar facing stone. It was essential that no hollows or spaces be left in the wall. As a further precaution, it was customary to thoroughly grout the rubble masonry as it was brought up level with the respective courses of the ashlar facing. Lastly, once the rubble masonry was laid up, the joints at the back of the wall were generally raked and rough pointed.90

On the Rideau project, N.H. Baird inspected the rubble masonry backing in the side walls of the locks under construction as carefully as the joints of the ashlar facing. Where the rubble backing appeared to be badly constructed, he did not hesitate to have stones pulled for a closer inspection. In several instances when he found hollows without mortar in the wall and/or dirty stone used, as in the lock walls under construction at Merrick's Mills and Old Sly's, he gave the contractor strict orders to grout the walls thoroughly and lay up the rest in a better manner under threat that if the backing were not better constructed on his return, he "would certainly pull up every stone".91 Otherwise, the rubble stone in the backing of the lock walls appeared to have been well laid so as to break joints horizontally as well as vertically in the wall. The variety of stones of different sizes and shapes used were fitted and set tightly one against the other in mortar to form a solid mass of rubble masonry incorporating the stonework of the counterforts as well as the additional thickness of the backing at the lock gates.92 The mortar joints at the back of the rubble wall were probably raked and pointed in keeping with the practice of stone masons elsewhere. To keep ground water out of the lock wall masonry, a puddle wall was constructed against the outside of the rubble backing.93
Clay Puddle Walls
In canal construction work, puddled clay had long been used to render canal beds and banks watertight where canal cuts had to be taken through sand, gravel or any other permeable ground. It was used in constructing the beds and banks of sections of the Canal du Midi in France as early as 1667-81, and it came into widespread use in English canal construction following James Brindley's use of clay puddle in constructing the Bridgewater Canal in 1760-61. In North America, it was used in the construction of the Lachine Canal, 1820-25, and on at least several contemporary American canal construction projects. On the Delaware and Hudson Canal, for example, a thick layer of puddle lining was constructed on the summit level to prevent the water seeping down through the light gravelly soil of the canal bed and on the Union Canal, Pennsylvania, a puddling compound composed of clay and lime was used to seal off leakage through a porous limestone bedrock. In addition as late as 1850 clay puddle was the standard core wall built into English earthen dams to render them watertight, but by that time, concrete made from hydraulic lime had all but superseded clay puddle as the preferred material for stopping filtrations through canal beds and banks.

Clay puddle was first used in Canadian canal construction on the Lachine Canal project where particular attention had been paid to rendering the lock walls impervious to water, whether seeking to penetrate the masonry from within the chamber or from the exterior. To that end, all of the stonework had been laid in mortar of the best quality made with lime slacked on the spot and mixed with sharp clean sand, and the joints were pointed with Roman (hydraulic) cement. As a further precaution, as
each of course was laid up, it was grouted "by pouring into the interstices a mortar made of quick lime, sand and gravel intermixed", and a puddle wall was built up along the whole length of the back of the lock wall. In retrospect, the Canal Commissioners who oversaw the construction of the Lachine Canal were convinced that its well executed masonry was "a model for other public works". They credited the use of clay puddle and grouting in the construction of the lock walls for the fact that their locks were watertight in contrast to the masonry of the Erie Canal locks which leaked "like a Sieve" where such precautions had not been taken. Whatever the case, British canal engineers such as Thomas Burnett, who had designed and superintended the construction of the Lachine Canal locks, were convinced of the efficacy of clay puddle. In Britain Thomas Telford, who had recommended Burnett to the Lachine Canal Commissioners, and his colleagues had long since made a serious study of clay puddle to determine the best materials of composition and method of application for use in canal construction.

To make puddle, clay had to be worked, chopped and beaten with a spade and a small amount of water added to render it homogeneous and plastic. From experience, the best puddling had been found to be a lightish loam containing a mixture of coarse sand or fine gravel in its natural state. Solid clay was not suited for puddling because of the great quantity of water it would absorb, and its disposition to shrink and crack when its water content decreased. Unworked clay was not impervious to water, but if properly mixed with sand or a fine gravel and wetted, worked, and kneaded, it could be made so condensed, or consolidated, as to be completely watertight if used in a situation, such as canal construction, where it could be kept wet.
that end, where a natural puddle clay could not be found, a sharp sand or small rough gravel stones no longer than musket-balls (5/8" in diameter) were mixed with a lightish loam in the prescribed manner. When properly chopped and worked, clay puddle consolidated to approximately 2/3 of its original bulk. It was essential that all vegetable mould, top soil and/or roots were removed from the mix to prevent cavities being left in the puddle wall or lining by their decay and/or worms and moles working their way into the puddle in search of food.

To puddle the bed of a canal cut, the clay puddle was usually laid down or packed in a succession of layers or courses of from 10" to 12" thick, and built up to a total thickness of three feet. Once the top layer was set, from 18" to 24" of soil was spread evenly over it and levelled. For side walls, the puddle was usually built up to a thickness of only 18 inches, but again was covered on the slopes with a layer of common soil "to prevent the slipping of the puddle". In the first instances where puddle was used in English canal construction, it had been held that one layer of puddle had to dry before succeeding layers could be built up on it, but Telford subsequently discredited that theory. Where a puddle wall was to be built in conjunction with masonry walls, it was carried up "in successive layers of two or three feet at a time" as the stonework progressed. This was presumably the method of construction adopted in forming the puddle walls on the outside of the Lachine Canal lock masonry.

On the Rideau Canal project, By planned to construct puddle walls on the outside of his lock wall masonry from the very commencement of construction. Both the plans for the 20 foot wide lock that he was initially ordered to construct, and the plans prepared for the proposed 50 foot
wide lock that he wished to build, show that a puddle wall three feet thick was to be erected all along the outside of the lock walls and was to rise from the base of the lock masonry wall to the coping. In the case of the 20 foot wide lock on which the lock walls were to be battered on both sides, the puddle wall was to have been carried up parallel to the batter of the wall at a uniform thickness of three feet. The first drawing for the 33 foot wide lock which the Kempt Committee approved for construction shows a puddle wall of three foot thickness on the outside of each lock wall. However, all subsequent drawings of the 33 foot wide lock show a puddle wall two feet thick and that was the thickness of puddle constructed. The puddle wall on the Rideau locks extended from the outer end of the curved wing wall along the whole side of the lock passing in an unbroken band around the piers and counterforts projecting at the rear of the wall from one end of the lock to the other. Cross-section views indicate that the base of the puddle wall was on the same level as the base of the lock masonry wall, and that it was carried up to the same level as the coping. In practice, however, the puddle wall may well have stopped just short of the coping level to enable a layer of earth to be spread over its top surface as was the custom in all puddle bed or wall construction. Where the side walls of a lock projected above the ground level, as on the west side of the Long Island combined locks, a coursed rubble masonry wall had to be constructed on the outside of the puddle wall to retain and protect it. Otherwise, the earth was backfilled into the lockpit and tamped down to form a packed surface against the puddle wall. Where springs were encountered, as in the lockpits of the Entrance Valley locks, drains were constructed adjacent to the base of the
puddle wall. They consisted of two vertical flat stones with a third flat stone placed across their tops with little or no mortar being used so that the drain so formed could function as a weeping tile. In the Entrance Valley, the puddle wall was carried up on the outside of the lock wall at the same time as the masonry was raised.

On the Rideau project, the cost of puddling proved much higher than anticipated as the puddle clay had in many instances to be procured a fair distance from the respective locksites. This was reflected in the contract prices that By had to pay, which were in several instances as much as 1s.6d. per cubic yard more than the initial estimate he had prepared for the work. The dearth of suitable puddle clay close at hand, and/or the materials required for making the same, may well account for the fact that on some sections of the canal, the so-called puddle used in constructing the locks was not strictly speaking clay puddle at all. It was "merely clay well rammed while moist", and as such it was not impervious to water as a well-worked, and properly mixed, clay puddle would have been when erected in a wall. In consequence, where drains were not constructed at the base of the puddle wall to carry off the ground water, the water gradually worked its way through the clay wall and during the course of construction materially injured the mortar in the masonry of some of the lock walls. This was even more so on the masonry of the breastworks of the Rideau Canal locks wherein a clay puddle wall was also to be constructed to prevent the water working its way down through the breastwork and into the lock below.
The Breastwork of the 33 by 134 Foot Lock

The breastwall of the 33 by 134 foot lock was to be constructed under the upper sill as in conventional lock designs. It was to be constructed of solid rubble masonry faced with cut stone to match the mode of masonry construction elsewhere in the lock. In the 8 July 1828 lock drawing, the breastwall was to have an almost concave face (Fig. 12). It was formed by carrying the wall inwards on an angle from its outer edge, next to the sluice tunnel opening in the hollow quoin pier, to meet a center section some 12 feet wide. The center section was perpendicular to the lock walls but set back some 2 feet from the face of the outer edge of the breastwall at its junction with the lock chamber wall. This was in keeping with the latest development in lock design where breastwalls were being made concave instead of perfectly straight to accommodate the prows of boats, and hence enable longer boats to pass through the lock chamber than would otherwise be the case.

The breastwall in the 8 July 1828 design was to be 20 feet thick at its base and 13 feet high with an exposed face of 10 foot height to match the lift of the lock. The top 2'-9" of the breastwall consisted of the upper sill, which was to be 4'-6" wide at the hollow quoin piers and 10 feet wide at its pointed center. The sill was to be constructed of cut stone to match the face stone on the breastwall with which it formed an integral unit. Against the inner face of the rubble unit masonry of the breastwall, By planned to build a puddle wall one foot wide which would extend down along the whole inner face of the breastwall and as much as 2 feet below it to prevent water working its way below the foundation. To the same end, a row of wooden sheet piling 22 feet long was to be driven down through the clay puddle wall to a depth some 10 feet.
below the foundation of the breastwall. On the opposite side of the clay puddle wall, a second mass of unit rubble masonry was to be formed approximately 10 feet thick and of the same height as the inner face of the breastwall. This second wall extended a short distance beyond the gate recess piers to form a foundation for the masonry of the lock floor invert which ended at the gate recess piers.  

In a drawing prepared shortly after the 8 July 1828 drawing, By greatly reduced the amount of masonry that he planned to put in the breastwall of the 33 by 134 foot lock. The configuration of the breastwall remained the same, but it was reduced to a unit of masonry 10 feet thick, measured on the center line of the lock, by 13 feet high. That height included the masonry sill, which continued to be an integral part of the breastwall, and an exposed face on the breastwall of 10 feet to match the lift of the lock. The sill was to be 10 feet wide at the center to match the thickness of the breastwall on which it rested, but the width of the sill was increased to 5 feet (from 4'-6" on the 8 July drawing) where it met the hollow quoin piers at either side of the lock. A puddle wall 12" thick was to be formed across the inner face of the breastwall unit, in effect crossing the lock in a direct line with the point of the mitre sill. A row of sheet piling 3" wide (3" planks?) by 15 feet or more long was to be driven down through the puddle wall so as to extend a good 8 feet below the foundation of the breastwall. On the opposite side of the puddle wall, a second wall of rubble masonry was to be constructed across the lock. It was to be approximately 10 feet high, starting on the same foundation level as the breastwall, and 3½ feet thick with the result that its outer edge lined up with the nearest edge of the tunnel sluice in the gate recess (Fig. 16). A single course of rubble stone
FIGURE 16

16 Sections of lines A - B of a Pointed Cill & recess as approved of by the Committee of which Sir James Kempt was president, John By, Lt. Col., n.d. (Public Record Office, London, England). R4-000-M-0051
masonry was also to be laid so as to extend outwards an additional 10 feet to the gate recess piers where the lock floor invert commenced. This single course of rubble masonry, in effect, formed a sub-floor for the course of cut stone masonry forming the floor of the gate recess pit between the raised mitre sill and the gate recess piers where the raised floor invert commenced. The floor invert was to be stepped up 1'-6" above the surface of the gate recess pit floor, and the mitre sill was to be raised the same height above, rather than 2'-9" above as was the intention in the first plan prepared. The dressed stone floor of the gate recess pit provided a cap for the back up wall of rubble masonry as well as for the puddle wall in back of the breastwall and for the breastwall itself where it extended out past the raised mitre sill. A trench 3 feet wide by 1 foot deep was also to be formed across the gate recess floor in line with the tunnel sluices in the gate recess wall on either side of the lock, as was the case in the first lock design. In effect, in the second plan prepared for the 33 by 134 foot lock, By planned to reduce the thickness of the breastwall from 20 feet thick at its base to 10 feet and the back up wall of rubble masonry from a thickness of 10 feet to 3½ feet. The gate recess pit, which was to be 2'-9" below the top of the sill, was to be stepped down only 1'-6" in the new plan. Otherwise, the plan of the breastwall remained the same. Thereafter further changes were made.

In the opening days of August 1828, work commenced in the Entrance Valley on the first of the 33 by 134 foot locks to be constructed on the Rideau Canal. In a progress report at the close of the work season, By reported that the masonry of the three upper locks was nearly finished. Included in the details of the progress report was the comment that sheeting piles had been driven in the three
upper breastworks and the lower pointed sill. But thereafter, By found that the huge boulders suspended in the blue clay of the Entrance Valley prevented the successful driving of sheet piles. In consequence, he directed that both the sheet piling and the puddle wall should be eliminated from the breastwork. In the absence of sheet piling, By considered the puddle wall to be a liability rather than an asset as it broke up what would otherwise have been a solid unit of masonry, which he believed was of sufficient thickness to prevent water penetrating through even if it succeeded in forcing its way down through the floor invert of the lock above to the breastwall.

The breastwall, as indicated, was planned to consist of a 10 foot thick breastwall and 3½ foot thick back up wall, separated by a 12" thick puddle wall through which the sheet piling was to be driven. Removing the puddle wall and replacing it with rubble masonry would result, in effect, in a single unit of masonry some 14½ feet thick. Initially, By intended to do away with the sheet piling and puddle wall in the breastwork only where piles could not be successfully driven, but thereafter, no sheet piling or puddle wall was placed in the breastworks or lower sills unless a particular problem was encountered which dictated its use. For example, at Jones Falls it was reported that a poor foundation made it indispensably necessary to secure a sill of the lower lock by piling, and at Long Island, a puddle wall had to be placed in front of the upper breastwall "to prevent the possibility of its blowing" under the pressure of the water backed up by the Long Island Dam. Once the sheet piling and puddle wall had been eliminated of necessity from the breastworks of several of the Entrance Valley locks, By became convinced that a solid unit of masonry, if constructed of sufficient thickness, was
superior to a breastwork constructed in the more conventional manner with a puddle wall and sheet piling wall passing through it. Thereafter, piles were hardly ever used in the locks or if used, were employed "only partially in front of the breastwork."\textsuperscript{135} A plan of the standard lock actually built on the Rideau Canal shows that the breastwork was constructed as a solid mass of masonry 13 feet high on its face, measured from the foundation to the top of the sill. It extended back 23'-6" on the base level to the gate recess piers, at which point the masonry was stepped up roughly 6 feet and continued out a further 8 feet so as to extend beyond the stop log grooves in the wing walls of the forebay.\textsuperscript{136} In effect, the main mass of the breastwork masonry was maintained at the same height, or depth, but extended almost 10 feet in thickness to compensate for the elimination of the sheet piling and puddle wall.\textsuperscript{137} (Fig. 17) As it turned out, however, this new breastwork design was defective.

The breastwork was constructed of rubble masonry faced with heavy dressed stone.\textsuperscript{138} The mitre sill, which was raised 1'-6" above the floor of the gate recess pit, consisted of blocks of cut stone 2'-8" thick, with a 29" breadth of bed, laid parallel to the lock chamber in 4 or 5 foot lengths. The largest stone, forming the point of the mitre sill, was 7 feet long, measured from its point to the end joint, 3'-0" wide and 2'-8" deep.\textsuperscript{139} The heavy sill stones were laid with arched joints\textsuperscript{140} to conform with the pointed shape of the sill and the almost concave shape of the breastwall face. The sill stretched back 10 feet from its point to the breastwall face in the centre of the lock, and 5 feet back where it connected with the hollow quoin pier on either side of the lock chamber. On the breastwall face the top course of ashlar, in effect the back
of the sill, was 20" high (or deep) with the courses beneath
being 18" deep. The stretchers had a 16" width of bed, with
the headers going back only 24" into the breastwork.141
All of the breastwork ashlar stonework below the sill
stones, however, were merely square jointed and laid in
common mortar.142(Figs. 16 & 17) Whether or not
breastworks so constructed of solid masonry would be able to
withstand the water pressures to which they would be
subjected in the absence of puddle walls and sheet piling
walls remained to be proven. However, in Britain narrow
locks had been constructed, and successfully operated, with
solid masonry breastworks unprotected by sheet
piling.143 (Fig. 5)

In May 1831, the first section of canal comprising the
Entrance Valley locks was raised to its operating level to
test the locks. The head of water raised against the upper
lock, lock no. 8, immediately forced its way down through
the masonry apron in the forebay of the lock and penetrated
through the solid masonry breastwall.144 There sheet
piling had apparently been dispensed with on account of a
ridge of limestone passing under the upper end of the
lock.145 The force of the water was so great that it
moved a number of the large stone blocks forming the upper
sill out of their alignment as well as several of the ashlar
stones in the face of the breastwall. Accounts vary as to
the extent of the damage caused to the Entrance Valley locks
by the raising of water on that section of canal. Lt.
Denison, one of the Royal Engineers on By's engineering
staff wrote, in 1839, an account of the problem strictly in
terms of the water forcing its way down through the apron in
the forebay of the upper lock, lock no. 8, and displacing
the sill and ashlar stones in the breastwork of that lock
alone.146 Lt. Frome, another Royal Engineer on By's
staff, however, wrote in February 1837 an account of the
damage in which he stated that "the water forced its way through the breastworks, in many instances moving the large stones which formed the sills". Whatever the case, whether the damage was caused by water working its way through only the apron in the forebay of the upper lock, or whether the water also worked its way through the floors of the lock chambers in the flight locks, it presented a serious problem and called into question the design of the breastwork of the 33 by 134 foot lock.

Remedying Defects in the Breastwork Design and the Use of Hydraulic Cement

After assessing the damage caused to the breastwork(s) in the Entrance Valley by the raising of the canal waters, the engineering staff and the masonry contractors consulted, principally McKay and Redpath, were convinced that the problem was caused by: 1) a design flaw where the sills were of too light a construction for the water pressures experienced, and 2) the laying of the stonework of the breastwork in common mortar which had enabled the water to penetrate through the mass of masonry. On the Entrance Valley locks, the first locks to be constructed, the frost of winter had subsequently caused a good deal of injury to the mortar in the lock masonry, and one officer of the Royal Engineers on By's engineering staff, Lt. Denison, was convinced that the works were injured because of the lack of a properly constituted clay puddle wall on the outside of the masonry. In a later report, Dension stated that the puddle walls on some of the Rideau Canal locks were constructed of well rammed moist clay rather than a proper clay puddle. He believed that water working its way through this improperly constituted 'puddle' wall had injured the mortar in the masonry either, one would
presume, directly by preventing the mortar from hardening or indirectly through the actions of the frost.\textsuperscript{150} However, where the breastwork masonry was concerned, By was convinced that it was not inadequate puddle walls (or the absence thereof in the case of some of the breastworks) which was responsible for water working its way through the masonry, but rather the failure to use hydraulic cement in the laying of the stonework.\textsuperscript{151}

In England, John Smeaton had used hydraulic cement in laying the lock walls of the Calder and Hebble Navigation as early as 1760-1764.\textsuperscript{152} He had subsequently conducted a number of experiments which proved that masonry exposed to the action of water had to be laid in hydraulic cement, or at least common mortar mixed with an hydraulic lime, if it were to set properly.\textsuperscript{153} In 1796, a natural water lime, Parker's Roman Cement, had been discovered in England,\textsuperscript{154} and it thereafter came into widespread use for constructing basins, docks and canal locks.\textsuperscript{155} Indeed, a number of deposits of the natural Roman cement were found in various localities such as on the coast near Harwich, at Southend, the Isle of Sheppy, and the Isle of Wight, and marketed under the name of their source of origin: i.e. Harwich cement.\textsuperscript{156} On the Rideau project, the junior officers of the Corps of Royal Engineers on the engineering staff and the artificers of the two companies of Royal Sappers and Miners, all of whom had studied field engineering under Colonel Pasley at the Royal Engineer Establishment, Chatham, would have been quite familiar with the properties and proven utility of hydraulic cement in constructing masonry works that would be exposed to the action of water.\textsuperscript{157} Colonel By also could not but have been aware of its use in canal construction work.\textsuperscript{158}
Lt. Col. By apparently would have preferred to have used hydraulic cement in laying the stonework of the Rideau locks, but none was available locally when the masonry of the Entrance Valley locks was commenced in August 1828. Thereafter, a quantity of Harwich cement, a dark brownish coloured natural Roman cement, was ordered from England. However, the high cost and the difficulties of obtaining a ready supply from England, probably account for By's decision to use common mortar, made on the spot from local limestone, for laying the stonework of the locks while reserving the imported Harwich cement for pointing the masonry. Hydraulic cement could have been procured from the United States, and some was. It is not clear why it was not imported in sufficient quantities to enable all of the stonework of the locks to be laid in hydraulic cement. When construction commenced on the Erie Canal in 1817, one of the assistant engineers, Canvass White, was sent to England to ascertain how canals were constructed. While there, he had become highly impressed with the British use of waterproof or hydraulic cement in constructing canals. Following his return to America, he discovered, at Chittenango, New York, on a branch of the Erie Canal, limestone rock suitable for making hydraulic cement. His so-called "waterproof lime" was used in constructing the stone masonry of the Erie Canal locks and aqueducts. The hydraulic cement had made possible much stronger, durable, and more watertight locks and aqueducts on that canal, and John Mactaggart, who apparently visited the Erie Canal and inquired into the building of the staircase locks at Lockport, could not but have been unaware of the use of hydraulic cement there.
When work commenced on the Erie Canal project, it was assumed that any hydraulic cement to be used in the construction of the canal works would have to be imported from Europe at a substantial cost. In view of the cost factor, it was decided to forego constructing the lock masonry with hydraulic cement in favour of laying the stone in common mortar and merely pointing the joints with imported hydraulic cement. Following White's discovery of "water lime" in 1818, that decision was reversed and the lock masonry was apparently laid in hydraulic cement. No mention has been found of any puddle wall being constructed in back of the lock wall masonry on the Erie Canal, and historians writing about the Erie Canal have credited the use of hydraulic cement "for the excellence of the canal's stonework" and for its having "more durable and watertight locks" than would otherwise have been the case. However, at least some contemporary observers did not perceive the Erie Canal lock masonry as being worthy of emulation. It was reported as early as 1828 by the Commissioners of the Lachine Canal that the masonry of many of the Erie locks leaked "like a Sieve". In contrast, the Lachine Canal lock masonry, which had been laid in common mortar with Roman (hydraulic) cement being used only to point the joints in conjunction with a thorough grouting of the rubble masonry backing and the construction of puddle walls, had been rendered completely watertight.

By may well have decided on the basis of the Lachine Canal experience that it would be more convenient and less costly to dispense with the use of hydraulic cement for the laying of the lock masonry of the Rideau Canal. The laying of the stones in common mortar in conjunction with a pointing of the joints with hydraulic cement, a thorough
grouting of the rubble masonry backing, and the construction of puddle walls would more than suffice to render the Rideau Canal lock masonry impervious to water. Once convinced of the feasibility of laying the locks in common mortar, By apparently was not concerned to employ hydraulic cement in any quantity, and initially did not even take full advantage of a "water lime" discovered during the early period of the canal's construction.

The properties and advantages of hydraulic cement were well known to Ruggles Wright, one of the contractors on the Rideau Canal project, who on his own initiative had conducted a search which resulted in June 1829 in his discovering in the vicinity of Hull, a type of limestone from which an hydraulic cement could be made. The Hull cement was manufactured by Philemon Wright & Sons and when tested proved to be of an excellent quality, superior to the Harwich or Roman cement which "was nearly spoilt before it reached the canal". By had immediately entered into a contract with Philemon Wright & Sons who agreed to supply all of the hydraulic cement required on the Rideau project beyond the quantity of Harwich cement already ordered from England. Again, however, the hydraulic cement was used only for pointing the masonry of the locks after the stonework had been laid in common mortar. In this instance, it appears that cost considerations alone were responsible for the decision to confine the use of hydraulic cement exclusively to the pointing of the masonry. Common mortar could be manufactured on the spot using limestone and cordwood found along the canal route. The hydraulic cement had to be purchased from Philemon Wright & Sons at a cost of 5s.6d. per bushel where upwards of 2,000 bushels of hydraulic cement had to be ordered at one time just to carry on the
pointing of the lock masonry. Whatever the reason for By's decision to confine the use of hydraulic cement to pointing work, only common mortar was used to lay the stonework of the locks until the spring of 1831 when, after the problems experienced with the breastwork(s) in the Entrance Valley, it was realized that a mistake had been made in constructing the locks in common mortar.

When the breastwork(s) in the Entrance Valley were damaged in May 1831 by the first raising of the waters in that section of the canal, By had consulted with Thomas McKay, the masonry contractor for the Entrance Valley locks, as to what could be done to make the breastwork watertight and capable of withstanding the water pressures in evidence. McKay proposed that the masonry sills be taken up together with the first two courses of masonry on the face of the breastwall and across its top to the inverted arch of the lock chamber floor (in effect, across the whole of the lock gate pit floor between the gate recesses) (Fig. 17). The whole of that masonry to then be relaid "with well squared stones bedded and grouted with [hydraulic] cement of the best quality that can be found." When John Redpath, the Jones Falls contractor, was consulted, he was of the same opinion as McKay: that it was essential to re-lay the dressed stonework of the breastwork in hydraulic cement and thoroughly grout it. Redpath made it clear that he had long held this to be necessary as he had:

observed that the common mortar takes such a long time to set where it is exposed to damp, which must always be the case with works of this nature.

Redpath, however, had several additional comments to offer with respect to how the breastwork might be strengthened and rendered impervious to water.
17 Sketch shewing in Red the proposed new masonry of Cills, in yellow the Masonry to be taken up and rebuilt, n.d. (Rideau Canal Office, Smiths Falls).
R4-026-F-0052
The breastwork is shown here as actually constructed without any sheet piling or clay puddle wall through it.
Redpath was convinced, as a result of the information received from Bytown regarding the trials of the locks, that the sills were too lightly constructed for the water pressures bearing on them. At Jones' Falls where the lifts were exceptionally high - 15 feet as opposed to 10 feet on the Entrance Valley locks - this was a matter of serious concern. It was essential that the masonry sills be firmly fixed in place for if the stones shifted only an eighth of an inch, it would be impossible to keep the gates watertight. To that end, Redpath recommended that the stonework, to be re-laid and grouted in hydraulic cement, also should be bolted together to form a compact solid unit by means of fox wedge bolts and screw bolts passing down through at least the top three courses of the stonework. Redpath suggested for the officers on the engineering staff to consider,

whether a bar of Iron bedded into the surface of the sill about 2 feet more or less on a parallel line from the Gates, with holes through it to admit the bolts, this is to be sunk to such a depth as to admit a covering of lead, might not have a tendency of better strengthening and uniting them together and of preventing a jar of the gates from shaking a single stone.\textsuperscript{182}

If his suggestions were followed, Redpath estimated that it would require at least 150 barrels of hydraulic cement to complete the new work required in re-laying the breastworks of the four Jones' Falls locks, as well as to point the inverted arch floors and the sluices that he had not yet commenced pointing in keeping with the original mode of masonry construction: viz. laying the stonework in common mortar and pointing it thereafter with hydraulic cement.\textsuperscript{183}
To protect the breastwork against excessive water pressures, Redpath recommended that the puddle ditch which he had placed in the breastwork of his locks, crossing the lock chamber in line with the point of the mitre sill, should be sheet piled to a depth of four feet below the pavement of the lock gate pit floor to relieve pressure on the breastwall by preventing the water working its way down through from the lock above. Redpath had apparently been informed of By's earlier decision to eliminate sheet piling from the breastwork of the locks and had complied at Jones' Falls, but he obviously was unaware of By's concomitant decision to eliminate the puddle wall entirely from the breastwork to form a large solid unit of stone masonry. What Redpath was advocating, with his suggestion that sheet piling be driven down through the puddle wall in the breastwork of the Jones' Falls locks, was a return to the original design of the breastwork set forth in the first plans prepared by By for constructing the 33 by 134 foot locks.

In an effort to strengthen the breastworks and render them watertight, the recommendations of McKay and Redpath were acted upon. On the locks already constructed on the Entrance Valley to Long Island section of the canal and at Jones Falls where the work was far advanced, the masonry sills and top courses of the breastwalls were taken up and relaid in hydraulic cement. Heavy iron straps were then set into the stones of the sill a distance back and parallel to its two front edges, and fox wedge bolts from 5 to 6 feet long were put down through the masonry to hold the sill stones firmly in place. Later when the water was raised at Jones Falls, this expedient proved itself as no problems were experienced on the "dangerously high lifts" constructed there. At the locksites where the
construction of the breastworks and sills had not yet been commenced, which included most of the locks from Burritts Rapids to Kingston Mills inclusive, the sill stones were notched to the course below, and all of the stonework was laid in hydraulic cement with joggled joints to form an interlocking mass of stone which was then made a solid watertight unit by grouting. This enabled the contractors to dispense with the long fox-wedge bolts and iron straps that had had to be added to the sills constructed previously,\textsuperscript{188} where the breastwall ashlar in the courses below the sill had been merely square jointed and laid in common mortar.\textsuperscript{189} However constructed, grouting was henceforth forced into all of the breastworks.\textsuperscript{190}

No mention has been found as to whether sheet piling was driven in the breastworks still under construction. Redpath and the other masonry contractors may well have taken it upon themselves to drive the sheet piles in keeping with the original lock construction plan prepared by By, or they may have come to share By's view that changes made in the breastwork and sill construction were sufficient to overcome any potential water problems. As far as the Royal Engineers were concerned, it was the use of hydraulic cement and grouting that rendered the breastworks and sills "perfectly secure."\textsuperscript{191} In describing the construction of the canal, Lt. Frome, one of the Royal Engineers on By's staff, commented that piles were hardly ever used "and then only partially in front of the breastwork."\textsuperscript{192}

**Grouting and Jointing the Lock Masonry**

Following the problems experienced in rendering the breastwalls and masonry sills of the Rideau Canal locks watertight, it was decided to grout all of the lock masonry previously laid including the side walls, inverted arch
floors, and the aprons (forebay and tailbay floors). The locks on which the masonry work had not yet commenced had their stonework laid in hydraulic cement. These locks also were then grouted, with particular care being taken to thoroughly grout the inverted arch masonry floors of the locks not founded on bedrock. This was done, for example, at Hartwell's where the two combined locks were built on a clay foundation filled with large boulders and numerous springs. At that locksite, piling was dispensed with as on most of the other locks, and rough blocks of stone were tossed in between the boulders to form a secure base for the lock floor inverts which were laid in hydraulic cement and then heavily grouted. The grout was made from the hydraulic cement which Philemon Wright & Sons manufactured from the limestone quarried near Hull which when burnt and ground very fine made an excellent hydraulic cement. The cement was packed in barrels lined with paper in keeping with the instructions received from By, and each barrel contained 300 lbs. or 5 bushels of cement. As of August 1830, the Wrights were capable of producing 500 bushels of hydraulic cement within 10 days of an order being received, and when operating on a large order were capable of manufacturing anywhere from 500 to 1,000 bushels in a span of 16 days.

It is not known what mix was used to make the liquid grout, but the Wrights are known to have recommended, where the laying of stone masonry was concerned, that their hydraulic cement should be mixed with fine river-washed sand free of all dirt, in a 4 to 1 ratio (4 cement to 1 of sand, a terribly rich mixture almost the reverse of modern practice). The cement was to be mixed in cold water and prepared in small quantities for immediate use. The 4:1 mix was further recommended for all masonry work that would be
under water, with the works to be left to stand for 8 hours before being submerged in water. For pointing masonry with hydraulic cement, the Wrights recommended a 5:1 mix (5 cement to 1 of clean river sand).\textsuperscript{197} As these cement mixes were recommended to Montreal merchants who commenced marketing Philemon Wright & Sons Hull cement in 1831, and the first works on which the Wrights' new hydraulic cement was used were the locks of the Rideau Canal, it appears certain that these were the mixes that had proved most satisfactory in constructing the Rideau Canal locks masonry.\textsuperscript{198} The sand mixed with the cement was taken from the Ottawa, Rideau and Cataraqui rivers. Mactaggart noted that the sand found in the large fresh water rivers of the Canadas, was remarkably clean and well suited for cement work.\textsuperscript{199} The Hull cement "set rapidly under water," and after May 1831, large quantities of it were used in laying new stonework and grouting the lock masonry that had been laid previously in common mortar and merely pointed with hydraulic cement.\textsuperscript{200}

To grout the masonry of the locks already constructed, holes slightly larger than 1½" in diameter were drilled horizontally into the vertical mortar joints, and all of the joints were thoroughly pointed with hydraulic cement. To force the grout, or liquid hydraulic cement, into the joints, tin tubes were made about 1½" in diameter and approximately 6 to 8 feet long,\textsuperscript{201} or occasionally 12 to 15 feet long.\textsuperscript{202} The tubes were formed with a right angled leg about 8" from the bottom end, and a tin flange, in the shape of a cup, was soldered on the tube at about 6" from the bottom leg so as to project 3" all round. The tube was inserted in the hole drilled in the vertical joint of the lock wall (or breastwall, etc.) masonry, and seamed with clay all round the hole. Then the tube was pushed into the
hole a distance of approximately 6" so that the flange cup acted to compress the clay seam around the hole to form a tight seal. The grout, was then poured into the top of the tube by means of a funnel, and the pressure of the head of liquid in the length of tube was sufficient to force the grout into all of the openings and cavities in the interior of the wall. Large quantities of hydraulic cement grout were by this means forced into the side walls, breasts, floors, and aprons of the Rideau Canal locks previously constructed, and especially so in the case of the locks which were not founded on bedrock. On the new masonry constructed after the decision was taken to grout the ashlar masonry with hydraulic cement, a much more conventional method of grouting the masonry was probably followed.

In lock construction work where the ashlar face was to be grouted, it was customary to cut a small vertical v-shaped channel with a hammer and punch in each end of the blocks of stone 15 inches back from their face to receive the grout. A thin layer of "fine soft pouring mortar" was then poured thinly over the bed on which the stone was to be laid and left untrowelled. The mortar used in jointing the blocks was spread on the end of the block against which the new block was to be set. Generally, the mortar was spread on the end of the block so as to form a 2" wide vertical strip just back of its face, and the new block was then set up against it and the back of the close joint (of 1/4 inch or less), was filled with Roman cement. Once the back of the joint was pointed, the grout was simply poured down the diamond shaped hole formed by the grooves of the adjacent blocks of stone (Fig. 18). The grout not only filled up any gaps in the joint, but once it hardened, the diamond shaped core of grout formed a "joggle"
FIGURE 18

Plan of Pointed Cill and recess of Combined locks as approved by the Committee of which Sir James Kempt was president, John By, Lt. Col., n.d. (Public Record Office, London, England).

In this drawing, the joggle joints of the sill masonry are shown, as well as the iron quadrant track supporting the roller wheel of the gate leaf, and the sheave blocks of the floor chain/crab system for operating the lock gates.
joint, which prevented movement of the ends of the stone under pressure.\textsuperscript{207} It also served to seal the joint and prevent any leakage through it.\textsuperscript{208} Each course of the lock wall, of course, was thoroughly grouted before the next course of stone was laid up.\textsuperscript{209}

On the Rideau Canal, the lock masonry from the Entrance Valley to Long Island inclusive and at Jones Falls had been constructed by the spring of 1831, and the masonry on the rest of the system was well advanced.\textsuperscript{210} In consequence, most of the lock masonry was laid with butt joints and grouted by means of the drilling and gravity tube method. The stone of the sills and breastwalls of some of the last locks to be constructed, and/or of the last sills to be taken up and re-laid, were grooved, set in hydraulic cement, and grouted to form joggle joints interlocking the mass of stone and making it a solid watertight unit.\textsuperscript{211} It is not clear where the idea for grouting the masonry by means of the drilling and gravity tube method originated, or how thoroughly the existing lock masonry was grouted during the last year of construction work on the project 1831-1832.\textsuperscript{212} Following the completion of the canal, however, By recommended to the Ordnance Department that:

\textit{The pointing of the Masonry with Philemon Wright's cement, and the forcing in grout made of the same cement wherever the work will take it, should be constantly attended to during the Spring and summer of each year; ....}\textsuperscript{213}

This, he suggested, could be carried on at a trifling expense if the artificers employed thereafter as lockmasters or locklabourers were to be moved from station to station to assist the less skilled locklabourers in doing the work.\textsuperscript{214} In practice, the work had to be done in the fall or spring of the year while the water level in the
canal was down and the waste weirs fully open in keeping with the method of flood control devised by Lt. Col. By in 1829.215 Thereafter on the Rideau Canal, the pointing and grouting of the lock masonry, in conjunction with the replacing of any badly weathered ashlar with new stone, was regularly attended to each spring by the lockmen until well into the 20th century.216

In the construction of stone masonry walls, there were several methods, other than joggling, by which joints could be strengthened and the stones prevented from being displaced. The wall coping stone, for example, was commonly dowelled together with the stone in the course beneath.217 The dowels, which were made of slate or gunmetal (a copper/tin alloy), were 1" to 2" square and had a length of from two to three times the thickness. The dowels so formed were set in cement mortar in corresponding holes made in adjacent stones.218 The extant drawings of the Rideau Canal locks, however, do not indicate whether dowels were used to fix the coping stone to the lock wall beneath. Another method of jointing stone masonry - cramping - was definitely used on the Rideau Canal locks in the same manner as it was used elsewhere. In canal construction, cramps were commonly used to bind together the coping stone around the gates and the coping stone from the upper gates to the head of the lock.219 The stones around the gates, of course, were most liable to be displaced because of the force of the water in the lock thrusting the gates back against the quoin pier, and the pull, in the opposite direction, of the gates on the anchor when they were being swung open. The cramps were made of a non-corrosive metal, such as gunmetal, in the shape of a staple from one to two inches wide by nine to 18 inches long and 1/4 to 1/2 inch thick, with the ends turned down 3/4 to
1½ inches. In making the joint, a hole of the required depth and dimensions was made in each stone a distance back from the joint to match the length of the cramp, and then a shallow groove was cut to connect the holes so that the cramp could be set into the stone slightly below the level of the upper bed. The cramped joint, so formed, was then commonly sealed with cement mortar, or as was the case on the Rideau locks, with molten lead.\(^{220}\) (Fig. 19)

In lock construction, iron bolts were also used to bind together the coping stone on the quoin pier around the gates.\(^ {221}\) On the Rideau locks, this took the form of the long fox-wedge bolts used to fix the lock gate anchor to the coping of the quoin pier. The bolts were of such a length as to pass completely through the coping stone and the course of stone directly beneath to anchor themselves in the third course of masonry (Fig. 74). The fox-wedge bolts were basically iron rods threaded on the upper end so as to take a square nut, and with a groove cut in the bottom end in which a wedge of flat iron was set. When the fox wedge bolt was inserted down into a hole drilled through the masonry and driven, the ends of the bolt were splayed out by the wedge and forced into the stone thereby anchoring the bolt securely in the stone. The holes were drilled just slightly larger than the bolt diameter, and the bolts were seated with molten lead.\(^ {222}\) Fox-wedge bolts, of course, were also used to anchor the sill stones at Jones Falls and several other locksites on the Rideau Canal where the lock masonry had been completed prior to the spring of 1831 when problems were experienced with the breastworks of the Entrance Valley locks on the first raising of the water in that section of the canal.
FIGURE 19

19 Cramps leaded into the lock wall coping masonry, Ottawa locks (Photo by author, 1978).
Deviations in the Sill Construction: Wood Sills

In keeping with the practice followed in constructing the Lachine Canal locks as well as British and American locks, By decided soon after the commencement of work on the Rideau Canal to construct the lower sills of single locks and the lower sill of the bottom lock of each flight of locks in wood. As he explained to the Ordnance, wood sills could be constructed much more quickly than stone masonry sills with a subsequently great saving in costs where the pumping out of the lower end of the locks was concerned, and wood sills if kept constantly under water, as they would be at the lower gates of a lock, were equally durable. Initially, By envisaged having to construct the wood sills, as well as the lock gates, with copper bolts and nails, but he soon discovered that in the Canadian climate iron, which was far cheaper, was just as durable as copper. Indeed, John Mactaggart, the Clerk of Works, noted that in the Canadas in contrast to England, "iron does not corrode by rust in the twentieth part of the extent, the atmosphere seems to contain no salt vapours." This fact had long since, in 1820, been discovered by the Admiralty which in consequence had substituted wrought iron nails for the copper fastenings used previously in planking vessels intended for service on the Great Lakes. But By and his staff were unaware of these earlier findings and made the discovery over again on the basis of their own observations.

As the construction of the sills was by far the most critical work in constructing a lock, that work was closely supervised and carried out by the civilian artificers employed directly by the engineering establishment. When the lock contractor was ready to have a sill installed, the Clerk of Works together with the Master Carpenter, Mr.
Fitzgibbon, and his men were dispatched to frame the sill and put it in place.\textsuperscript{229} The levels for the floor and sills, of course, were provided to the contractor at an earlier date by the Clerk of Works so that the floor of the lock could be brought to the proper level to receive the sill.\textsuperscript{230}

Each of the wood sills was constructed of oak timber framed together in a triangle (Fig. 13). The base of the triangle was formed by two massive timbers 21" thick by 18" wide by some 34 or more feet long. The two arms, forming the front edge of the sill each consisted of an oak timber 21" thick by 15" wide notched into a pointed center post which was 21" thick by 16" wide. To strengthen the frame so formed, two braces 18" deep by 9" wide were notched into each half of the sill frame, and three iron tie rods were used to draw the members tightly together: a through bolt at each base angle of the frame, and a long tie rod passing down the center line of the sill frame. The latter tie rod had angled arms which projected out over the timbers forming the front edge of the sill and served to tie them together with the longitudinal center post and the two base timbers. Where the wood sills were to be positioned on bedrock, the rock was levelled off and the frame anchored by means of fox-wedge bolts. The sill frame was then in-filled with random rubble masonry, rough dressed and close jointed.\textsuperscript{231} A second large timber, 21 inches square, was also placed across the lock in line with the stop log grooves in the lock wall masonry to form a sill for the stop logs.\textsuperscript{232} The short gap or distance between the base of the sill frame and the stop log sill, approximately 16" in width, was in-filled with clay puddle. Lastly, 3" plank was used to cover in the sill frame and the clay puddle gap, with the planks being set down flush with the surface of the
frame members into grooves cut along their top inner edge. The floor of the gate recess in front of the wood sill was also covered in with 3 inch plank so that the sill, in effect, projected 18" above the gate recess floor. (Fig. 20)

On the locks constructed with masonry floor inverts as well as the locks with wood floors, the wood sills on the lower end of the lock were framed together in the same fashion as the wood sills anchored on bedrock. However, the tie rods at the base angles of the sill frame were eliminated and the oak frame was anchored to a solid platform of cross timbers. The timber sub-floor consisted of 15" by 15" squared timbers extending across the whole width of the lock and into the base of the quoin pier. They covered in solidly the whole floor from the stop log sill to the gate recess pier where the cross timbers formed a base for the end of the lock chamber floor. This cross timber platform in turn rested upon seven evenly spaced longitudinal sleepers, 15" by 15", extending the whole distance from the stop log sill to the lock chamber floor. The oak sill frame was anchored by means of long heavy spikes driven down through the sill members and the timber platform and into the longitudinal sleepers. The frame was in-filled with rubble stone and covered in with 3" planks in the same manner as the sills in the rock floor locks. The gate recess floor in front of the sill was also planked with 3" planks nailed longitudinally across the top of the timber platform sub-floor. Here again, the sill projected 18" above the gate recess floor. The sluice channel, or ditch, crossing the gate recess floor in line with the sluice openings in the wall masonry, was formed by leaving a 36 foot gap in the cross timbers forming the sub-floor platform, and nailing 4" plank directly across the
FIGURE 20

Plan of Pointed Sill on Rock, Rideau Canal, J. Burrows, 23 October 1840 (Rideau Canal Office, Smiths Falls). R4-026-F0046

This half-plan of a pointed sill shows how the sill triangle was framed and in-filled, as well as the fox-wedge bolts anchoring it to the bedrock.
longitudinal sleepers beneath. In the wood floor locks, a row of sheet piling consisting of 3" planks was also driven across the lock between the base of the sill frame and the stop log sill adjacent to the latter.235 (Fig. 21) On the Rideau Canal, wood sills were constructed not only at the lower gates of the single locks, and at the lower gates of the bottom lock in each flight of locks, but also at the upper gates on the several locks where the breastwork was eliminated.236

Deviations in the Breastwork

During the course of construction, By decided to dispense with breastworks on a number of the single locks to effect a saving in the cost of construction. Breastworks were eliminated on four of the locks constructed on bedrock: viz. at Clowes Quarry, Maitlands Rapids (Kilmarnock), the Narrows, and the Isthmus (Newboro). There the upper sills were constructed on the same level as the lower sills of the respective locks, with the upper gates being of the same length as the lower gates.237 At Clowes Quarry, which appears to have been the first lock so constructed, the rock excavated for the lock pit formed a natural breastwork just in advance of the intended position of the upper gates of the lock. In view of this, By decided that he could with perfect security throw the whole of the 9'-6" lift directly on the upper gates, thereby saving the cost of constructing a breastwork which would have contained some 9,308 cubic feet of masonry.238 This was done by constructing the head of the lock up against the natural rock ledge intended to serve as an advanced breastwork. Stop logs were placed in the stop log grooves of the upper wing walls to a height equal to that of the advanced breastwork so there would be, in effect, 5 or 6 feet of water over them at the upper end.
FIGURE 21

Half Plan and Section of a Wooden pointed Sill & Apron for a Lower Gate when laid on Clay or Earth with the connexion with a wooden floor in the Lock, n.d. (Rideau Canal Office, Smiths Falls).
R4-026-F-0037

Initially, masonry floor inverts were planned for locks erected in clay or earth, but as a cost saving measure wood floors were often substituted.
of the lock. The gap of several inches between the rough face of the natural rock ledge and the stop log wall was then in-filled with small stones laid in hydraulic cement. The oak sill for the upper gates was then anchored to the bedrock comprising the lock chamber floor down in front of the stop log breastwall in the same manner as the lower wood sills were anchored to bedrock.

What By constructed at Clowes Quarry was a lock that conformed with respect to the positioning of the upper gates, to the Welland Canal lock design adopted previously in the plan of construction proposed for his large 50 by 150 foot steamboat lock. The use of this design also enabled By to save on the cost of constructing sluice tunnels in the masonry of the quoin piers at the upper gates. With the upper gates being on the same level as the lower gates and consequently continually under water, the lock could be filled directly through sluice valves on the gates without fear of damaging the cargoes of vessels being locked up. The fact that the upper sills in this configuration of lock would be continually under water, of course, enabled By to effect a further saving by substituting a wood sill for a masonry sill at the upper gates. Similar savings were at Maitlands Rapids (Kilmarnock), the Narrows, and the Isthmus (Newboro).

At Maitlands Rapids, where the lift of the lock was only 2'-3", By did not hesitate to dispense with a masonry breastwork in favour of throwing the whole of the lift upon the upper gates. At the Narrows and the Isthmus where locks were constructed to raise the level of Rideau Lake (the summit level of the canal) four feet ten inches to save an equivalent depth of hard rock excavation on the 1½ mile long cut through the isthmus, the low lift of the two locks, 4'-10" and 8'-0" respectively, was again thrown upon
the upper gates and the breastworks eliminated to effect a further savings. Stop logs were presumably also wedged in the stop log grooves of the upper wing walls of the three locks up to a level 5 or 6 feet below the surface of the water above the locks as was the case at the Clowes Quarry lock.

**Lock Chamber Floors**

At the commencement of the Rideau Canal project, Lt. Col. By had intended to construct his locks with two types of floor, either of natural rock where the bedrock in the lock pit excavations was sufficiently solid to serve that purpose, or with masonry arch inverts in porous rock, clay or gravel bottoms. Thereafter, the early surveys indicated that most of the locks would be constructed in rock with probably a small number of inverted arches being required. However in the absence of boring tools, the exact number of masonry floor inverts required could not be determined until the lock pit excavations were completed. In the first estimate prepared in November 1827 for the construction of the smaller 20 by 108 foot gunboat locks, By had calculated on constructing 17 locks with masonry floor inverts. However, by June 1828 when the scale of lock was increased by the Kempt Committee decision, the progress of excavation had revealed that much of the rock being excavated was not sufficiently sound to serve as a lock chamber floor. This necessitated the potential construction of a greater number of masonry floor inverts than had been calculated upon. Thereafter in an effort to keep construction costs in line with the estimate insofar as the lock floors were concerned, a decision was made to substitute wood floors for masonry inverts wherever practicable in the locks being constructed on soft bottoms. As a result, in addition to
the 23 locks which were eventually constructed with natural rock floors, 8 locks were constructed with wood floors and a total of 16 locks were constructed with masonry floor inverts.\textsuperscript{248} (These figures do not, of course, include the two locks that the Department of Railways and Canals constructed at Beveridges lockstation on the Tay Canal branch in 1883-86. There the upper lock was constructed with a wood floor and the lower lock with a natural rock floor.)\textsuperscript{249}

\textbf{a) Inverted Arch Masonry Floors}

Masonry floor inverts were constructed where there was any doubt as to the stability of the ground\textsuperscript{250} as at Hartwell's and the Hog's Back, which were adjudged to be two of the potentially worst foundations on the whole line of the canal. There numerous large boulders were found suspended in a blue clay full of springs, and similar soil conditions, in addition to running sand, were also found in the Entrance Valley.\textsuperscript{251} As a result, it was decided to construct the eight flight locks at By Town as well as the two combined locks at Hartwell's and the Hog's Back with masonry floor inverts (Fig. 22). Elsewhere, masonry floor inverts were constructed on the four locks at Jones Falls because of the succession of exceptionally high lifts there, and the fact that the rock excavation undertaken for the 20 foot wide locks had been carried somewhat deeper in places than required later when the size of locks was increased.\textsuperscript{252}

Where masonry floors were required on canal locks, they were usually constructed in the form of an inverted arch to provide a greater resistance to any upward pressure that might result from water filtering down under the breastwork from the higher level of water above the lock.\textsuperscript{253} They also served a structural function by distributing the
22 Masonry floor inverts, Ottawa Locks (Photo by author, 1978).
weight and lateral pressure of the side walls more evenly, thereby preventing any partial settlement.\textsuperscript{254} On the Rideau Canal, By had planned to construct the arched masonry floor inverts of the small gunboat locks on a versed sine with a 20 foot chord\textsuperscript{255} and the proposed large steamboat lock on a versed sine with a 50 foot chord.\textsuperscript{256} He presumably followed through and constructed the inverted arches of the 33 foot wide lock on a versed sine with a 33 foot chord. A drawing of the masonry floor inverts on the Jones Falls locks indicates that the inverts there were built on a 50 foot radius forming, in effect, a segmental arch.\textsuperscript{257} According to the lock plans prepared by By's engineering staff, the stones of the floor inverts were to be 18 inches wide, by anywhere from 3 to 4\frac{1}{2} to 6 feet long, and were to be laid so as to break joint.\textsuperscript{258} An extant drawing of the Rideau Canal locks shows the depth of the dressed stone blocks in the masonry floor inverts varying from a depth (or thickness) of 3 feet in the center of the lock to 5 feet at the springing of the arch at the base of the side walls. In effect, the extrados, or back, of the inverted arch is depicted as being flat, with all of the stones cut accordingly to set on a level across the bottom of the lock pit.\textsuperscript{259} This form of inverted arch, however, was constructed only at the bottom end of the lock floor, where the floor met the sunken gate recess floor (Fig. 23). On the rest of the floor the stones of the inverted arches were all cut to a uniform depth, 2 feet thick, with the extrados of the arch paralleling the intrados, or inner surface of the arch, as was customary in arched masonry bridge construction.\textsuperscript{260} Indeed, the voussoir stones were cut to varying depths to provide a straight back (or level bottom) to the floor arch only at the bottom end of the lock floor because the last row of
FIGURE 23

Detail of the bottom end of a masonry floor invert at the gate-pit, Ottawa Locks (Photo by author, 1982).
arch stone projected above the gate recess floor 1'-6" on the longitudinal axis of the lock chamber and as much as 4'-6" at its junction with the face of the gate recess pier on either side.\textsuperscript{251}

The stones of the lock floor inverts were cut and laid with arched joints in conformity with the voussoir stones in a conventional masonry arch bridge (Fig. 13), but if the stones were to act in the manner of a true arch, or in this case a true inverted arch, it was essential that the individual stones be dressed full back from the face to form close joints.\textsuperscript{262} This critical concern is reflected in the terms of the masonry contracts for the small 20 foot wide lock that By was initially ordered to construct, wherein it is specified with respect to the floor inverts that "the joints are to be squared full back, the whole breadth of the stone."\textsuperscript{263} However, the inverted arch stones in the 33 foot wide locks actually constructed on the Rideau Canal were only dressed back a few inches from the face with the result that the joints were not as tight as they ought to have been. In view of this fact, Lt. Frome questioned whether the inverted arches were capable of acting as a proper structural component of the lock if any settling should occur in the side walls.\textsuperscript{264} After the difficulties experienced with the breastworks in the spring of 1831, however, immense quantities of hydraulic cement grout were forced into the masonry floor inverts of several of the locks to render them thoroughly watertight.\textsuperscript{265} This no doubt strengthened the arches sufficiently to rectify any potential structural problem.

To form a foundation for the stones of the invert arch floor, various methods were adopted. For example, at the Entrance Valley locks where a "shaky clay", filled with large boulders, was encountered a foundation of packed
broken stone, or what N.H. Baird called "MacAdam," was built up to form an even base for the inverted arches. In effect, the gaps left in the floor of the lock pit excavation, where portions of "shaky clay" and boulders were removed, were filled up with small broken stones similar to those used in constructing macadamized roads, but in contrast to road construction practice, the macadamized stones in the lock floor invert foundations were bonded with a hot lime mortar. Otherwise, the foundations were probably constructed in the same manner as a macadamized road where hard impact limestone would be broken down with hammers into small cubes roughly 1½" per side and then spread evenly over the levelled up natural ground in several layers 3 to 4 inches thick. Each layer would be compacted thoroughly before the next layer was added; and the resultant base of angular stone fragments upwards of 9 to 10 inches thick was all but impervious to water. This was even more so with respect to the foundation of the lock floor inverts where hot lime mortar was poured over the broken stones to further bond together the various layers of the road metal. Elsewhere on the Rideau locks, as for example at Hartwell's, where similar problems were experienced in excavating the lock pits, a foundation was formed simply by throwing blocks of rough stone into the gaps in the lock pit floors and constructing the floor inverts and lock wall masonry upon that base. No piles were used in either case. The foundation upon which the inverted arch stones were laid elsewhere on the canal was constructed, as at the Entrance Valley locks, of macadamized stone bonded with hot lime mortar. Where inverted arches were required, the cut stones were "two feet in depth, with 12 inches of small stone or rubble masonry for the inverts to rest upon." (Fig. 13)
b) **Bare Rock Floors**

Where the rock excavated for the lock was sufficiently solid, the lock walls and the breastworks were laid up on the bedrock which was levelled to form the floor of the lock (Fig. 24). The wood sills at the lower end of the lock, of course, were anchored directly to the bedrock floor (Fig. 20). The gate recesses were also planked at the lower sills on the locks with bare rock floors.²⁷²

However, at Old Slys, where the rock floor of the upper lock was heavily damaged by blasting during the excavation of the lock pit, timbers had to be cut to fit the uneven surface of the bedrock between the gate piers. The timbers anchored to bedrock were then planked to form a level lock gate recess floor to support the wooden sill.²⁷³

On the Rideau Canal, twenty-three locks were constructed with bare rock floors which included the lock at Black Rapids, the three combined locks at Long Island, the two locks at Nicholsons, the lock at Clowes Quarry, the three locks at Merrickville, the lock at Maitlands (Kilmarnock), the two locks at Old Slys, the three combined locks and the detached lock at Smith's Falls, the lock at the Narrows, the lock at the Isthmus (Newboro), the lock at Chaffey's Mills, and the detached lock and the two upper locks of the combined locks at Kingston Mills.²⁷⁴ (The lower lock constructed at Beveridges lockstation on the Tay Canal branch of the Rideau Canal by the Department of Railways and Canals in 1883-86 has a bare rock floor, but has not, of course, been counted in the above computation.)

With the exception of the floor of the upper lock at Old Slys, the bare rock floors have lasted without any maintenance down to the present. Today a number of the stone floors are fissured, and there has been some undercutting of the lockwalls and piers through wear.²⁷⁵
24 Levelled bedrock lock chamber floor, Long Island Locks (Photo by author, 1978).
(Fig. 24) At Old Sly's, the rock floor apparently caused some problems as there is a report to the effect that erosion necessitated the construction of a timber floor during the winter of 1867-68, or at least the renewal of the timber floor in the gate recess. Years later, the wooden gate recess floor again had to be replaced, but this time was re-built with a concrete slab.276

c) Wood Floors
Sometime between June 1828 and January 1829, as the progress of the lock pit excavations revealed that a far greater number of masonry lock floor inverts would have to be constructed than originally estimated, By decided to substitute wood floors for inverted arch masonry floors.277 Consequently, the last of the locks constructed on the Rideau Canal were built with either bare rock floors or, in clay and gravel, wood floors.278 As By explained to the Ordnance Board, it was necessary to floor locks constructed on soft bottoms to prevent the rush of water from the sluices undermining the chamber walls and breastworks, and since wood floors, if kept constantly under water were nearly as durable as stone as well as far less expensive to construct, he had decided to construct wood floors wherever an inverted arch would otherwise be required.279 (Fig. 21) In all, eight locks were constructed with wood floors, including the lock at Burritts Rapids, the lock at Edmund's, the lock at First Rapids (Poonamalie), the lock at Davis, the two combined locks at Upper Brewer's Mills, the lock at Lower Brewer's Mill (Washburn), and the river lock of the Kingston Mills flight of locks.280 (An additional wood floor lock, the upper detached lock at Beveridges lockstation, was constructed by the Department of Railways and Canals in 1883-86 on the Tay Canal Branch of the Rideau Canal.)
The decision to construct some of the single locks with wood floors is readily understandable as a cost saving measure. The lock chamber would always be covered in a depth of water at least equal to the level of the water in the navigation below the lock; indeed, that is why it had been possible to construct the lower sills of single locks and of the bottom lock of flight locks in wood. However, the decision to construct the upper lock of the two combined locks at Upper Brewer's Mills with a wood floor involved slightly different considerations. During the navigation season, the floor of the upper lock would always be covered with water to a depth at least equal to that of the navigation, and much more when the lock was full, in contrast to the upper sills and breastworks, which would be exposed to the air during the locking process. Hence, it was possible to contemplate constructing the upper lock chamber floor of wood, even though the upper sills and breastworks had to be constructed of masonry regardless of the type of lock chamber floor. During the off-season, however, the intermediate gates on the combined locks at Upper Brewer's Mills would have to be kept closed to protect the wood floor by maintaining a depth of water in the upper chamber.

In canal lock construction, wood floors were by no means a new feature. Both in England and the United States locks were commonly constructed with wood floors. In England wood floors were even used in conjunction with inverted arch floors of stone or brick. In soft, or alluvial, bottoms where piling was necessary to support the lock structure, masonry inverted arch floors were invariably constructed, and occasionally the inverted arch, as well as the side walls, was raised upon a wooden floor (Figs. 9 & 25). In effect, the heads of the vertical piles were cut
Sections of Lock & Basin Walls, Brick (Strickland, Report on Canals, Railways, Roads, 1826, Plate 16).

Where timber sleepers were used to support British or American locks, the sleepers and a plank sub-flooring invariably extended completely under the lock chamber walls.
off level and heavy wood, transverse sleepers were laid across the tops of the piles, which were driven in spaced rows across the whole width of the lock, with the outer piles of each row in line with the outer face of the side walls or in line with the outer face of the counterforts constructed in back of the lock walls. The transverse sleepers, which could measure upwards of 14" by 14" on large ship locks, were then covered over with 4" planking laid in a longitudinal direction, with butt joints, so as to form a solid level platform. The masonry lock walls, including the counterforts where applicable, as well as the inverted arch masonry floor were then raised up on the wood platform, or sub-floor so formed. In locks constructed on a clay or gravel base, the floors were commonly built in a similar fashion but without piles (Fig. 25). The heavy transverse sleepers were laid on the levelled bottom of the lock pit excavation and planked longitudinally, with the masonry side walls being again raised upon the planks which also served as a floor for the lock chamber.\textsuperscript{282} In this case, however, the construction of the wood floor was a much more critical concern, as is evidenced in the specifications governing the construction of wood floors in American canal lock construction.

\textbf{Structural Details of American Wood Floored Locks}

In the United States when locks had to be constructed in the absence of a solid, durable rock base, a wood foundation was generally constructed in a manner which varied only slightly from canal to canal. Once the lock pit was excavated in clay or gravel, two heavy range timbers were positioned, one on each side of the lock pit bottom, in a longitudinal direction in line with the inner face of the lock walls and were set down into trenches dug for that purpose.\textsuperscript{283} A
bed of good gravel puddle of whatever depth the engineer should think sufficient was spread over the levelled bottom of the lock pit. Heavy sleepers were then positioned across that base, into which they were driven or sunk at least one inch, with the longitudinal range timbers being notched slightly if required to provide a level support for the sleepers at the requisite depth. The transverse sleepers consisted of hewn timbers of white oak or pine, anywhere from 10" to 12" square. They were generally laid about 6 inches apart except for the area under the lower sill (or both sills if the lock was to be constructed without breastworks) where the sleepers were laid adjacent to one another. The sleepers invariably passed across the whole width of the lock and extended roughly from 3 to 5 inches beyond the outer edge of the lock walls. The spaces between the sleepers were in-filled with gravel puddle, well-rammed and packed up to their upper surface which was levelled off, probably with an adze, to form an even surface for the planking to be erected upon them. To prevent water working its way down along and under this foundation, four rows of sheet piling were driven across the whole width of the lock in puddle trenches excavated at each end of the lock and below the two sills, adjacent in each instance to a transverse sleeper. The sheet piling usually consisted of 2½ inch white oak or pine plank cut with square edges and driven close together to a depth of 6 feet or more below the upper surface of the transverse timbers. On this foundation, two layers of plank flooring were then constructed.

The planking used in constructing the wood floors of American canal locks was generally 2 or 2½ inch white oak or pine plank free from shakes and with square edges laid close to make water tight joints. The first layer of planking, or
sub-floor, was put down in a longitudinal direction over the whole width of the foundation formed by the transverse sleepers and thoroughly fixed in place by means of treenails (trunnels), 9 inches long by 1½ inches square driven through each plank where it crossed over a sleeper, and 6 inch iron spikes. The lock wall masonry was then constructed on this sub-floor, and the white oak timber frame of the lower sill (and upper sill in locks constructed without a breastwork) was anchored directly on it by means of treenails and long iron bolts passing through the sub-floor into the transverse sleepers below. A second layer of planking was laid between the masonry of the lock walls. This floor, the actual floor of the lock chamber, was constructed of the same sized planks laid again in a longitudinal direction and secured with treenails and 6 inch spikes in the same manner as the sub-floor, but with the planks being off-set to break joint with the parallel planks below. To secure a tight fit against the battered or curved face of the side walls, the bottom 2 to 2½ inches of the first course of masonry, depending on the thickness of the planking, was generally dressed off vertically. The planks forming the outer edge of the wood floor were scribed and planed to obtain a close watertight joint. Such was the standard method of constructing wood floored locks on contemporary American canals, but on the Rideau the wood floored locks were constructed somewhat differently.

Initial Plan for Constructing Wood Floored Locks
On the Rideau Canal, By had decided by January 1829, to substitute wood floors where inverted masonry arch floors would otherwise be required on the locks remaining to be constructed. However he apparently had not worked out the design details of a wood floor at that date. During the
winter of 1829-30, a series of plans (dated 18 March 1830) was prepared for the canal works under construction at the various lock sites. Three plans in that series show wood floors on locks where Lt. Col. By anticipated that the lock pit excavations would not encounter rock, or rock sufficiently sound to serve as a lock chamber floor. These drawings show only the general details and layout of the wood lock chamber proposed for construction. There is no detail at all of the gate recess floor, lower sill, or the tailbay and forebay aprons. However, he may well have planned to construct them in the same manner as on the single locks with masonry floor inverts where the lower gate recess floor and lower sill were constructed of wood and the tail bay and forebay aprons of stone paving. Whatever the case, the design of the wood lock chamber floor that By initially planned to construct can be readily described from the drawings in the March 1830 series of locksite plans, and from an undated plan and section of the wooden gate recess floor and lower sill layout on a wood floored Rideau Canal lock which shows clearly the floor support system devised initially by By and his engineering staff.

From the drawings extant, it is obvious that By did not plan initially to place longitudinal range timbers in the base of his lock pit excavations in the area of the lock chamber floor. The transverse timbers were to be laid directly on the clay or gravel base of the lock pit excavation, or perhaps set into a compact layer of macadamized stone built up, as was the case with the masonry inverts, to form an even base for the lock floors. The transverse sleepers were to consist of logs upwards of 24 inches in diameter, and 35 feet or more long, hewn level on two sides at a uniform thickness of 12 inches, to form a
flat surface in contact with the base of the lock pit (or macadamized stone layer). The plank floor was to be erected upon them. The sleepers were to be evenly spaced on roughly four foot centers, leaving a gap of approximately two feet between them, except in the area of the masonry breastwork and the lower sill where the sleepers were laid side by side to form a solid platform. However, in contrast to the practice of British and American canal engineers in constructing wood floored locks, the sleepers did not pass all of the way under the masonry side walls. Indeed, in By’s lock design, the transverse sleepers were to penetrate only one foot, or at most 18 inches, beyond the face of the masonry side walls and gate recess walls. The only exception to this was the sleeper at the junction of the lock chamber floor and the gate recess floor (and possibly the several sleepers directly beneath the position of the lower sill frame) which penetrated 3½ to 4 feet into the base of the lower gate recess and quoin pier, respectively. The side walls of the Rideau Canal locks with wood floors were not to rest fully upon the transverse sleepers and plank sub-floor as in British and American lock construction practice, but were to be built upon the bottom of the lock pit excavation. Only the front of the wall, approximately one half of the breadth of bed or slightly less of the stretchers in the ashlar stone facing, supported upon the ends of the sleepers (Fig. 29). In effect, By appears to have concluded that the clay foundations found in the lock pit excavations would be stable and hard packed enough to support the weight of the masonry side walls without settling. He therefore designed his lock floor foundation, the transverse sleepers, to serve as a structural component, a strut, to strengthen the lock walls against any sliding movement inwards. The masonry
breastwork likewise was to be constructed upon the natural lock pit floor with only the front of the breastwork (approximately 1½ feet measured in from the concave face of the breastwall in the center of the lock, and 4½ feet measured at its intersection with the gate recess pier) being supported upon two adjacent sleepers passing under it.  According to the March 1830 series of plans of the works to be constructed at the various locksites, By did not plan to drive sheet piling across the bottom of the chamber in his wood floored locks.  Nor as mentioned, was he planning to place longitudinal range timbers in line with the inner face of the side walls in the bottom of the lock to aid in levelling up the transverse sleepers as was the practice in American wood floored locks.  However, elsewhere in the locks, By was prepared to construct sheet pile walls, and he soon came to utilize longitudinal range timbers in a limited way.

**Wood Gate-Recess Floors in the Locks with Masonry Floor Invert**

Drawings prepared for the construction of single locks with masonry floor inverts and lower sills of wood show clearly that at a very early date By was planning to drive sheet pile walls across the lower end of such locks (Fig. 13).  The wood floors constructed in the lower gate recess area of the single locks with masonry floor inverts and lower sills of wood were to consist simply of a foundation of transverse sleepers laid across the gate recess floor area with a small gap between them.  The innermost sleeper butted up against the masonry of the inverted arch floor of the lock chamber which was approximately a foot above the top surface of the sleepers measured in the longitudinal center of the lock.  This timber foundation was to be planked over with a single
layer of planking laid in a longitudinal direction to form a floor for the gate recess pit some 13'-6" wide between the end of the lock chamber floor invert and the point of the lower mitre sill. The foundation for the lower sill frame and the tail bay apron was to consist likewise of heavy transverse sleepers slightly raised, with their bottom surface on a level with the top surface of the transverse sleepers in the gate recess area. These sleepers were again equally spaced with small gaps between them and were to be carried out as far as the outer curve of the wing walls to form a foundation for the stone paving to be laid in the tail bay of the lock. All of these sleepers were to be rough hewn and were to extend a short distance into the base of the lock wall masonry. Provision was made for a row of sheet piling to be driven across the lock between the oak sill frame base, anchored to the transverse sleeper foundation, and the acting as a sleeper. In effect, the sheet piling was to prevent water working its way back into the lock under the stop log sill if the lock chamber should ever have to be de-watered to effect repairs. Similarly, Lt. Col. By probably intended to drive sheet piles across the base of the lower sill in his wood floored locks. However, when By and his engineering staff got to the point of designing the lower sill area of the new wood floored locks, (Fig. 21) the subfloor system was altered from what had initially been adopted for the wooden floor system in the gate recess/lower sill area of the single locks being constructed with masonry floor inverts in their chambers.

Wood Gate-Recess Floors in the Wood Floored Locks

In the plans developed subsequently for the construction of the lower gate recess/sill area of the new wooden floored
lock, the junction between the lock chamber floor and the
gate recess floor on a lower level was to be made by placing
a large transverse sleeper, 16 inches deep by 24 inches wide
with squared edges, across the lock at the gate recess pier
where the lock chamber floor ended. The top front edge of
this heavy timber, which was 4 inches above the level of the
top of the other transverse sleepers supporting the lock
chamber floor because of its greater thickness or depth, was
then notched. This let the end of the 4" thick plank
flooring, when nailed to the notched sleeper, a level
surface with its top. In this manner, the heavy sleeper was
made to form the end of the lock chamber floor while at the
same time protecting the end of the floor planking. The
lower gate recess/sill area of the lock was stepped down a
full 2'-4" below the level of the clay bottom of the pit
beneath the transverse sleepers in the lock chamber floor.
This difference was made up, however, by the laying of
longitudinal range timbers, 12 inches in depth, along the
center line of the lock and along each side. They were of
such a length as to extend from the sheet pile wall (to be
driven across the lock at the base of the lower gate sill
frame adjacent to the stop log sill) under the whole of the
gate recess/sill area and beyond some four feet under the
end of the lock chamber floor timbers. In effect, the
longitudinal range timbers were to be some 30 feet long.
Transverse sleepers, well dressed with squared edges, in
contrast to the sleepers under the lock chamber floor, were
then laid tight against one another to form a solid platform
under the lower gate recess/sill area. These transverse
sleepers, 16 inches in depth by anywhere from 16 to 18
inches in width, were of such a depth that the end two
sleepers formed a base for the heavy transverse sleeper
forming the end of the lock chamber floor. The only gap in
the platform of adjacent sleepers was in the area of the gate recess ditch crossing the lock where the tunnel openings of the sluices would normally be located if sluice tunnels were constructed around lower gates. There a gap was left between the transverse sleepers, and 4 inch planks were laid across the lock directly on the longitudinal range timbers to form a floor for the ditch. The ditch so formed was 1 foot deep by 3 feet wide with the plank flooring being notched into the bottom of the dressed sleepers on either side to form watertight joints (Bog, 21).

The oak frame of the lower sill was to be anchored directly to the solid platform of transverse sleepers. In front of the mitre sill, the transverse sleepers were covered over in the gate recess area with a layer of four inch planks laid in a longitudinal direction. On the other side of the ditch, the planking was laid across the lock for the short distance between the gate recess ditch and the end of the raised lock chamber floor. This arrangement of the timber substructure under the lower gate recess/sill area of a wood floored lock was typical of American wood floored locks, except in American construction practice the gate recess floor was generally not stepped down below the lock chamber floor but rather was a continuation of it, and gate recess ditches were also atypical. The gate recess ditches, it appears, functioned primarily to trap any loose rocks or objects that might wash into the lock chamber and to prevent their jamming the lock gates being swung over the gate recess pit floor. On American locks this precaution was probably dispensed with to simplify the construction of the gate recess floor.
Proposed Variation in the Wood Floor Structural Design

At some point during the progress of construction, consideration appears to have been given to changing the design of the wood floors in the lock chamber area. Two extant drawings show a wood lock chamber floor in cross section wherein the floor is supported upon six longitudinal sleepers laid directly on the bottom of the lock pit excavation between the side walls. The latter were to be totally self supporting on the bottom of the excavation and structurally independent of the foundation of the floor. The base of the side walls was to be constructed with a perpendicular leg or footing 18 inches deep jutting out into the lock chamber approximately the same distance, to form a ledge all along the inner base of the wall. The longitudinal sleepers, consisting of squared timbers 15" by 15", were to be laid in the lock chamber with their top surface level with that of the masonry ledge. The 3 inch difference in depth was to be made up by a layer of in-fill, probably gravel puddle or macadamized stone, under the sleepers to build up the lock pit floor between the base of the side walls. The longitudinal sleepers were to be positioned one on each side of the lock chamber against the masonry ledge of the side walls with the other four being equally spaced across the lock at 5'-6" centers. This timber foundation was then to be in-filled in the same manner as the foundation and covered with two layers of planking each approximately 4 inches thick. The ends of the sub-floor planking, which was laid across the longitudinal sleepers, rested upon the masonry ledge at the base of the side walls as was the case with the planking flooring laid at right angles to the sub-floor over the whole width of the lock chamber. Both layers of planking were constructed tight up against the masonry side walls. The face of the
bottom course of ashlar stone in the lock chamber walls was laid so as to overlap the outer edge of the plank floor by several inches provide a watertight joint between the wood floor and the masonry side walls.\(^\text{302}\)

It is highly unlikely that this second type of wood floor was ever constructed on any of the Rideau Canal locks. On the one hand, it is a very poor design. The longitudinal sleepers would not provide any resistance to the upward thrust or pressure exerted by any filtrations that might penetrate under the chamber floor from the higher level of water above the lock, and the longitudinal direction of the timbers would not inhibit, but actually facilitate, the penetration of water along under the lock chamber floor.\(^\text{303}\) The very fact that By and his engineering staff even considered constructing such a floor, indicates that they were not all that familiar with wood lock floor designs or the basic principles governing their construction. Nonetheless, they appear to have learned quickly. All of the evidence gathered during the carrying out of repairs on the wood floored locks, such as when floors were replanked or parts of the lock wall masonry replaced just above the floor level, indicates that the wood floors were constructed on transverse sleepers as initially planned, rather than on longitudinal sleepers as indicated by the two drawings purporting to show how the wood floors were constructed.\(^\text{304}\) (Fig. 27) This is not to say, however, that the wooden lock floors were constructed exactly as planned in March 1830. To the contrary, where wood floors have been subsequently exposed, a slightly different floor support structure has been found than Lt. Col. By initially planned to construct.
Structural Details of a Wood Floored Lock as Constructed

From information gathered to date during the carrying out of various repairs to the Lower Brewer's (Washburn) lock, it is evident that the initial plan of construction devised for the wood chamber floors was altered during the construction of this lock, if not also the other wood floored locks. In the Lower Brewer's lock, the transverse sleepers were laid on heavy longitudinal range timbers. The laying pattern of the range timbers is not known for certain, but it appears that they ran the whole length of the lock chamber floor from a point under the masonry breastwork to the end of the chamber floor. There were five such timbers in the floor spaced irregularly on from 5 to 7 foot centers. In effect, they would appear to have been laid one along each side of the chamber near the face of the side walls, one on the longitudinal center line of the lock, and one on each side of the center timber at roughly equal spacings (Fig. 29). The range timbers were probably rough hewn on the bottom to form a level surface but were left with their natural rounded top surface which was notched to match notches cut 7 to 8 inches deep into the bottom of the transverse sleepers. The width of the saddles cut into the bottom of the sleepers indicated that the longitudinal range timbers, which were set down into trenches dug in the clay floor of the lock pit excavation, were approximately 24 inches in diameter (Fig. 26).

The transverse sleepers crossed the whole of the lock chamber and extended approximately one foot into the face of the masonry side walls. The sleepers were rough peeled logs anywhere from 15 to 20 inches in diameter. They were, as mentioned, notched on the bottom to fit down on the range timbers, and hewn level on the top to a uniform depth of 10 inches. The sleepers were irregularly spaced at about 30
Truncated and broken sleepers removed from the Lower Brewers Lock. The sleepers shown are inverted. The saddle notches rested down on the longitudinal range timbers, and the top of the sleepers was hewn level with an adze to take the plank sheeting. (Photo by author, 1976).
inch centers, and the 9 to 12 inch gaps between them were filled up with clay puddle and probably macadamized stone. (Fig. 27) Each sleeper was pinned to the longitudinal range timbers underneath by means of 1\frac{3}{8}\" diameter treenails passing through them, but not all intersections were so pinned.

The floor of the lock chamber which consisted of 4 inch thick planks laid longitudinally between the side walls was also pinned to the sleepers with wooden treenails spaced some 13 to 15 inches apart on the sleepers in zig-zag lines. Iron spikes were probably used to supplement the treenails in holding down the planking as was customary elsewhere in constructing wood floors. To ensure a tight fit of the planking against the masonry side walls, the bottom edge of the first course of ashlar was cut vertical to a height equal to the thickness of the planking.

At Lower Brewer's, both the planking and sleepers were of hemlock with the odd sleeper of ash. Initially, it was intended to construct the sleepers and planking of the wood floored locks of either elm or oak. But the area along the Cataraqui River where most of the wood bottomed locks were constructed abounded in hemlock trees, which were adjudged to be very durable under water. As a result, most of the sleepers in the wood floored locks on the Rideau Canal were of hemlock and the planking either of hemlock or oak, with the odd sleeper of pine.

The rubble masonry backing of the side walls was laid directly on the clay floor of the lock pit excavation, with the first course of the ashlar masonry facing being laid with its face roughly one foot in on the ends of the transverse sleepers. In effect, only the front of the side walls was to be supported by the timber floor.
27 Timber sleepers exposed during lock repair work, Poonamalie Lock (J. Tulloch Photo, Winter of 1974-75).
foundation. On at least one section of the Lower Brewer's lock chamber, the side wall was not even constructed with a level base. There the clay of the excavation, which sloped inwards towards the bottom edge of the ends of the transverse sleepers laid on the lock pit floor, was hard packed. The contractor, rather than excavating the clay down to the level of the base of the sleepers, merely constructed the base of the rubble masonry backing of the lock wall on the slope of the excavated clay, building up and out from the ends of the sleepers until he reached the required width. It is questionable whether By and his engineering staff would have approved of this method of construction for the side walls, as all of their drawings show the side walls being raised with the full base width of the rubble masonry backing on a level with the base of the transverse sleepers. However, the Lower Brewer's Mills lock walls were otherwise constructed in By's prescribed manner with the ashlar facing, the first course of which rested on the ends of the transverse sleepers, being tied back into the rubble wall backing with headers laid in the customary way.

The Wood Floored Lock at Beveridges Lockstation
To date, no drawings have been found that show all of the structural details of the wood floored Rideau Canal locks as constructed by By and his engineering staff. As a result the description of this type of floor structure has had to be based on comments in engineering reports, drawings showing partial views, and evidence gathered over the years while repairs were being carried out. However, an undated drawing in Parks Canada's collection of Old Rideau Canal drawings entitled "General Plan of Locks," shows a plan view, longitudinal section, and cross section of a 33 foot
by 134 foot lock.\textsuperscript{322} (Fig. 28) This is definitely not a plan for any of the wood floored locks constructed by the Royal Engineers in 1830-32. In the first place, the lock shown has both sills on the same level with an advanced breastwork so that all of the lift would be thrown on the upper gates. This, of course, was the configuration of lock built at four sites on the Rideau Canal: viz. on the single locks at Clowes Quarry, Maitlands Rapids (Kilmarmock), the Narrows, and the Isthmus (Newboro), but all four of these locks where the breastwork was eliminated had bare rock floors. On the other hand, of the eight locks constructed by the Royal Engineers on the Rideau Canal with wood floors, all had masonry breastworks and upper sills, which is not the case with the wood floored lock in the drawing in question. Moreover, the transverse sleepers on By's wood floored lock extended only about a foot into the side walls with the back of the wall masonry resting on the ground, whereas the transverse sleepers in the undated drawing pass completely under the side walls. The side walls of the unidentified lock drawing also do not have any counterforts in their rear in contrast to the lock walls constructed by the Royal Engineers. However, it is known that one of the two single locks constructed at Beveridges lockstation by the Department of Railways and Canals during the construction of the Tay Canal Branch of the Rideau Canal in 1883-86 had a wood floor.\textsuperscript{323}

At Beveridges lockstation on the Tay Canal Branch, the upper lock (lock #34) was built with a wood floor and the lower lock (lock #33) with a natural bedrock floor. Moreover, neither of the Beveridges locks was constructed with tunnel sluices at their upper gates,\textsuperscript{324} which indicates that the upper gate sills were probably constructed on the same level as the lower gate sills, with
General Plan of Locks (Beveridges, ca. 1883), Engineering & Architecture Branch, Parks Canada, Canals Engineering plan R - 20 - 185.

This is the plan of the upper lock at Beveridges lockstation, Rideau Canal. It is typical of an American wood floored lock design with the sleepers passing completely under the lock walls, both sills on the same level, and a floor consisting of two layers of sheet planking with the joints overlapping. Note the breastwall in advance of the upper gates, and both the sills on the same level.
an advanced breastwork, thereby enabling the upper sluices to be built in the gates. In effect, the configuration and type of floor of the upper lock constructed at Beveridge's lockstation in 1883-86 conforms directly to that of the lock in the undated drawing in question. Indeed, the drawing entitled "General Plan of Locks" may well be the general plan of construction prepared ca. 1882-83 for the two detached locks to be constructed at Beveridge's Bay in anticipation of the two locks being constructed on a clay foundation. The fact that one of these locks, the lower lock, was actually constructed with a rock bottom, can readily be accounted for by the fact that the lock pit excavation, once carried out, uncovered a rock base sufficiently sound to serve as a floor for that lock, thereby dispensing with the need to construct a wood floor there. The other differences in the structural details of the locks in the "General Plan of Locks" drawing and the wood floored locks constructed by the Royal Engineers on the Rideau Canal proper can be accounted for simply as modifications made in the basic lock design fifty years after the original wood floored locks were constructed on the Rideau Canal proper. In sum, the evidence appears all out conclusive that the "General Plan of Locks" drawing is a plan of construction prepared ca. 1882-83 for two wood floored locks which were intended to be built at Beveridge's lockstation on the Tay Canal Branch of the Rideau Canal, and as such depicts the structural details of the wood floor actually constructed in the upper lock (lock #34).

On the lock depicted in this "General Plan of Locks," longitudinal range timbers were dispensed with and the transverse sleepers were laid directly on the clay floor of the lock pit excavation. The sleepers were 12" by 12" squared timbers, approximately 49 feet long, which passed
completely under the masonry side walls of the lock with their ends flush with the back of the wall. The sleepers, which were spaced about 12 inches apart, were probably in-filled with clay puddle or gravel, and then a sub-floor of 3 inch plank was laid in a longitudinal direction across the whole surface of the sleepers, and the masonry side walls constructed upon that platform. The floor of the lock chamber between the side walls was planked with a second layer of 2 inch planking laid likewise in a longitudinal direction but off-set so as to break joint with the plank sub-floor. The structural details of this wood floor lock, in effect, were in keeping with British and American construction practice rather than with the floor design that By had developed for his wood floored locks. The transverse sleepers directly under the wood sill frames were placed side by side to form a solid platform for the mitre sills. Two rows of sheet piling were driven across the lock at each sill, one in line with the base of the sill frame and the other in line with the point of the mitre sill. The sleepers of both sill platforms were constructed on the same level as the sleepers in the lock chamber as again was the American practice, rather than stepped down to form a sunken gate recess floor at the lower gates as was the case on the original Rideau Canal wood floored locks. The sleepers in the forebay and tailbay of the lock were carried out to the end of the wing walls and were spaced the same as the sleepers in the lock chamber.325

At the head of the lock, a breastwall was to be formed by permanently fixing stop logs in the stop log grooves of the upper wing walls up to the level of the bottom of the water in the navigation above the lock. Surprisingly, no sheet piling was to be driven under the upper stop log sill to prevent water working its way under should the lock be
dewatered. There is also no detail as to how the natural advanced breastwall of the excavation was to be protected, or how the gap between the stop log advanced breastwall and the natural breastwall was to be filled up. There is, however, an indication that a second set of stop log grooves was to have been constructed in the upper wing walls with a second stop log sill beneath, at the natural advanced breastwall formed by the lock pit excavation. At some later date, as indicated by additional markings on the drawing, the stop log breastwall was probably replaced with a concrete breastwall in the same position in advance of the upper gates.326 The fact that a new wood floored lock was constructed on the Rideau Canal system as late as 1883-86 indicates that wood floored locks were not adjudged to be inherently, or greatly, inferior to locks with masonry floor inverts so long as the floor of the wood floored lock was kept continually under water.

Design Defects and Durability of the Wood Floored Locks
From the record of repairs carried out on the locks of the Rideau Canal in the 150 years since their construction, it is evident that with the sole exception of the Lower Brewer's (Washburn) lock, the wood floored locks have proved as durable as the locks with bare rock and masonry invert floors, with comparatively infrequent repairs being required.327 This is not to say, however, that the wood floor design devised by By and his engineering staff was without defect. To the contrary, the problems that have been experienced with the walls of the Washburn lock, and past leakage problems with the floors and side walls of at least three additional locks out of the eight wood floored locks, are all attributable to structural defects in the wood floors constructed in the Rideau Canal locks.
In constructing his wood floored locks, By, as mentioned, deviated from the standard practice of American and British canal engineers by having his transverse sleepers extend only a foot into the masonry side walls instead of completely under them (Fig. 29). Thus, rather than the whole weight of the side walls being supported on a timber raft (formed by the transverse sleepers and plank sub-floor) as in Britain and the United States, in By's design only the front of the wall (the ashlar facing) rested on the transverse sleepers while the rubble masonry backing rested on the clay base of the lock pit excavation. In effect, By appears to have tried to improve on the conventional design of a wood floored lock, where the side walls were totally dependent on their own dead weight to resist lateral pressure, by having his transverse sleepers act as struts to keep the walls from sliding inward at the bottom. Yet at the same time, in common with the more conventional design, his sleepers were still able to resist any upward pressure exerted by water working its way down under the lock floor from the canal above. The potential defect of By's design, however, was that it was totally dependent upon the clay at the foundation of the rubble wall being sufficiently hard packed to support the wall masonry without any appreciable settling. If the clay were not sufficiently hard packed to resist settling, a number of obvious problems (at least in hindsight) would develop:

1) the weight of the back of the walls in settling would put undue pressure on the ends of the transverse sleepers causing them to arch slightly in the middle, thereby opening up the floor joints and letting water leak down through with a consequent danger of undermining the structure;
29 Wood floor details exposed following the partial collapse of a lock chamber wall at Lower Brewers. The transverse sleepers, resting on a longitudinal range timber, extend only a foot or so into the face of the lock wall. The plank flooring had long since been replaced with a concrete cap. (Parks Canada photo, May 1976).

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2) the settling of the back of the walls would open up the joints in the ashlar facing, through exercising a downward leverage on the headers, thereby letting water leak into and through the side walls; and

3) the settling of the back of the walls might cause the rubble masonry backing erected on the clay foundation to separate from the ashlar facing supported on the stable transverse sleepers, with the unanchored ashlar eventually bulging out into the lock chamber.

Unfortunately, the repair record of four out of the eight wood floored locks provides ample evidence of the development of one or another of these problems, which all are attributable to the settling of the clay foundation acting in conjunction with By's particular floor/wall support system. One of these wood floored locks, that at Lower Brewer's (Washburn), has displayed evidence of all three problems.

With the exception of the Lower Brewer's lock, the most common problem with the wood floored locks has been leakage through the floor caused by the floor joints opening up. Indeed, only two locks - those at Burritts Rapids and Edmunds - have escaped this problem. Leakage through the floor serious enough to require either major repairs, or the renewal of the whole plank floor, was experienced at Davis lock in 1843, 1869, 1907 and 1914, at the lower Kingston Mills lock in 1833, and 1872, at Poonamalie in 1913, and the two Upper Brewer's locks in 1873. At Lower Brewer's leakage through the wood floor joints was a problem in 1840 and 1861 in conjunction with other problems which continued to recur thereafter on that lock. It would appear that a slight settling of the side walls was responsible for the recurring
problems at the Davis and lower Kingston Mills lock. Elsewhere the floor leakage problem was confined to the area between the sluices and may well have been caused by the force of the water wearing the planking. The floor leakage problem may also have been attributable in part to By's decision to use only one layer of planking rather than the conventional two layers. For example, once the wood floors on the two Upper Brewer's locks and the lower Kingston Mills lock were renewed with two layers of planking - a 3" plank sub-floor with a 2" plank floor covering - in 1872 and 1873 respectively, the floor leakage problems there ceased. In effect, with two layers of planking overlapped so as to break joint, even if the joints opened up slightly because of an all but imperceptible settling of the lock walls, the floor could still remain watertight.

Only at the Lower Brewer's lock has settling occurred in the rubble wall backing sufficient to open up the mortar joints in the ashlar facing of the lock chamber of a wood floored lock. There as early as 1840 the lock walls were reported to be leaking badly, and thereafter the walls had to be continually grouted and pointed to enable the lock to function. Despite all such efforts, in 1861 the east wall was so badly undermined by water leaking through the wall that it dropped down, and the west wall bulged, indicating that the ashlar facing had separated from the rubble backing settling into the clay foundation. At that time, the east wall was totally rebuilt on a concrete foundation and the west wall braced and tied back. However, by 1874 the west wall had totally separated from its rubble backing, and the whole wall had to be rebuilt. Twenty years later, in 1904, the west wall again bulged inwards and had to be rebuilt. Elsewhere, partial settling occurred in back of one of the side walls of the Edmunds lock, which
resulted in sections of the wall bulging inwards in 1905. In effect, where the clay foundation under the back of the side walls was sufficiently hard packed to resist settling, the wood floored locks have required few repairs, but where the backing has settled to a greater or lesser degree into the clay, the structural defects in By's floor design have produced concomitant problems. Had the transverse sleepers in the wood floored locks extended under the whole base of the side walls, the settling of the rubble backing, which opened up the joints in the ashlar masonry and/or caused the ashlar to separate from the rubble backing, could not have occurred. This indeed appears to have been the conclusion of the canal engineers working on the Rideau Canal. In constructing the Beveridges wood floored lock in 1883-86, the transverse sleepers were carried completely under the lock walls (Fig. 28). Nonetheless, despite the problems experienced, to date only two wood floored locks - that at Lower Brewer's and at Davis - have had to be totally replaced by a new lock structure, and the demolition of the Lower Brewer's lock has provided further evidence as to the potential durability of wood floored locks if properly constructed.

At Lower Brewer's a concrete cap was previously poured over the wood floor of the lock to combat leakage in keeping with what had been done at First Rapids (Poonamalie) in 1913-14, Davis in 1914-15, and probably elsewhere on the wood floored Rideau Canal locks. But the concrete cap proved no more capable of withstanding the stresses produced by the on-going settling of the side wall backing at Lower Brewer's than the plank floor. The concrete cap in that lock developed cracks, and as a result when flood waters were sluiced through the Lower Brewer's lock chamber during the construction of a new waste water control
system/dam in the spring of 1976, the water penetrated down through the floor and totally undermined the mid-section of the west wall. The washing out of the clay foundation left a large section of the wall supported solely on the ends of the transverse sleepers which were themselves undermined so that the ends were unsupported. Several of the unsupported sleepers thereupon cracked, letting the bottom courses of ashlar over a distance of about 50 feet drop into the gaping hole in the clay foundation. The lock was temporarily repaired with a concrete wall section in May-June 1976, and then following the completion of the navigation was totally demolished and rebuilt in the form of a concrete box faced with ashlar stone taken from the original lock. In the course of the initial repair work, 15 transverse sleepers were cut out of the lock floor and shipped to the Rideau Canal Office, Smith's Falls Yard, where they were measured and stored. (Fig. 26) Subsequently, tests on several wood samples revealed that the sleepers, although a part of the lock structure for upwards of 145 years, were still sound and capable of serving their initial purpose. Sapwood deterioration was found to exist to some degree in all of the samples, but the heartwood was completely sound. In sum, the good condition of the transverse sleepers taken from the Lower Brewer's lock substantiates By's view that wood if kept continually under water would prove as durable as stone. If the ends of the sleepers had not been undermined and left unsupported, there is every reason to expect that they would have continued to function as intended in the Lower Brewer's lock as they have in the other wood floored lock structures up to the present day. The Davis lock was reconstructed in the winter of 1981-82 in the same manner as the Lower Brewer's lock. However, the wood from the old lock was not tested.
Tailbay and Forebay Floor Aprons

In the plan of construction adopted for the 33 by 134 foot lock, stone paving was to be laid (probably in mortar) in both the tailbay and forebay of the lock. The paving in both cases was to cover the whole of the area between the side walls commencing at the stop log grooves sill and extending out even with the outer radius of the wing walls. It was to consist of rubble stone, quarry dressed into blocks roughly 18 to 24 inches long by 8 to 10 inches square in cross-section, laid in a longitudinal direction with the stone off-set so as to break joint. Following the difficulties with the breastworks of the Entrance Valley locks in the spring of 1831, all of the stone pavement in the aprons was laid in hydraulic cement and well grouted. This was deemed essential in the case of the forebay aprons to prevent water working its way down under the upper sill and breastwork and a wise precaution to prevent the tailbay apron being undermined.

On the wood floored locks, stone paving was dispensed with in favour of a wood apron. In both the tail and forebay of the wood floored locks, the transverse sleepers were continued out beyond the sill of the stop log grooves, but at a closer spacing (approximately 10 inches apart) than in the lock chamber (Fig. 21). Unlike the sleepers in the lock chamber, the sleepers in the fore and tailbays of the lock were to be square hewn, roughly 14 inches per side. The sleepers were to be carried out as far as the outer radius of the wing walls, a distance of 16 feet past the stop log grooves sill, and then covered over with a layer of longitudinal planking 4 inches thick. To protect the ends of the plank flooring, the outer sleeper was to be 4 inches thicker (or higher) as was the stop log grooves sill, so that the planks could be notched down into the upper inner...
Both banks of the canal, and the canal bed, were paved with stone for a distance below each lock to prevent erosion on the water shooting out of the lock gate sluices.
edge of the respective sleepers to form a flush surface.338

Once a number of the Rideau Canal locks were put in operation, it was found that the aprons in the tailbay of the locks constructed on soft ground or clay, did not extend out far enough as the turbulence of the water shooting out of the sluices in the lower gates caused the banks to slide into the canal. To combat this, the stone paving was continued out on a line with the inner face of the lock walls for a further distance of from 12 to 15 feet and carried back, on a slope to match the natural floor of the canal, a distance of about 8 to 10 feet to form two wing aprons. In addition, the slopes of the banks above the wing aprons were covered with rubble stone where required to prevent them eroding.339 (Fig. 30) This extension of the tailbay apron, however, did not prove sufficient to combat erosion and undermining of the natural floor of the canal. By 1834, after two years of operation, the clay floor of the canal directly below both the Upper Brewer's and the Lower Brewer's locks was badly eroded.340 To guard against further erosion caused by the force of the water coming out of the lower gate sluices, a wood apron was constructed below the locks extending out upwards of 60 to 70 feet from the tailbay of the respective locks (Fig. 31). It was constructed on a foundation of longitudinal range timbers laid in trenches cut in the clay bottom of the canal, with approximately 6 timbers being spaced across an area slightly wider than the width of the lock. Long, heavy transverse sleepers, extending in length from the outer edge of one wing wall to the outer edge of the other, were laid upon the range timbers and fixed to them with treenails at their intersections. Piles were driven at the corners to anchor the heavy timbers securely in place, and the open
Where locks were constructed in clay, water shooting through the lower gate sluices caused severe erosion necessitating the construction of extensive aprons below the locks.
space between them was filled in with a stiff clay. This sub-structure was then floored over with a layer of planking; and rock filled timber cribs were constructed upon either end of that platform in line with the wing walls of the lock. The timber crib retaining walls were constructed so as to slope outwards. The area behind the base of the crib on its shoreward side was filled up with large rocks and gravel as the crib was raised to the required height several feet above the navigation level of the water below the lock. The area behind the upper part of the timber crib retaining wall, between the crib and the eroded canal bank, was simply filled in with earth. The top of the crib wall was stabilized by being anchored into the natural bank of the river by means of a row of heavy long timber ties fixed to the crib and extending back 15 feet or so into the bank where they intersected and were fixed to a horizontal timber firmly set into the ground. Today, little evidence remains of the timber aprons constructed below a number of the Rideau Canal wood floored locks during the first years of the canal's operation. Salvage archaeology, which was carried out in the lower gate recess and tail bay area of the Lower Brewer's (Washburn) lock in the fall of 1976, provided confirmation that the gate recess and tailbay floors were constructed in keeping with the plans prepared by Lt. Col. By and his engineering staff for the Rideau Canal wood floored locks. However, no evidence was found of the extensive wood apron constructed directly below the tailbay of the Lower Brewer's lock ca. 1835.
IV Lock Operating Mechanisms

The Locking Process: Lock Lifts and Sluices
When canals were to be constructed over any great distance, differences of elevation had to be overcome by means of the lifts of locks. The operation of locks in turn required the employment of sluices of one type or another to raise and lower the level of water in the lock chamber. Each lock, in effect, operated as an hydraulic machine to lift and lower boats from one level of water in the canal to another as water was let in or let out of the lock chamber by means of the valves on the sluices at either end of the lock. Gates, of course, were placed on either end of the lock to enable the boat or boats to enter the lock chamber prior to the locking process and to exit thereafter. To lower a boat from the upper reach of the canal to a lower reach, the sluices at the upper gates of the lock were opened to enable water to flow in and bring the level of the water in the chamber up level with that in the upper reach of the canal. Then, with the water pressure on either side of the upper gates equalized, the upper gates were swung open to enable the boat to enter the lock chamber. Once the boat was in the chamber, the upper gates and sluices were closed, and the sluices at the lower gates were opened letting the level of water in the chamber drop slowly until it reached its natural level with the water in the navigation below the lock. At that point, with the water pressure on the lower gates equalized, the lower gates were swung open and the boat proceeded out onto the lower reach of the canal. To
proceed in the other direction from the lower to the upper reach of the canal, it was only necessary for the next boat to enter the lock chamber through the open lower gates, after which the lower gates and sluices were closed. Then the upper sluices of the lock were opened letting the water in the upper reach of the canal flow into the chamber with the result that as the level of the water in the chamber rose, the boat was lifted up until the rising water reached the level of the water in the upper reach. Once the lock chamber was full, with the water pressure equalized on both sides of the upper gates, then the upper gates were opened enabling the boat to proceed out on the upper reach of the canal. These operations were called respectively, "locking down" and "locking up."  

The difference of elevation to be overcome in ascending and descending from one level of the canal to another at any given point, determined the number of locks to be constructed where each lock was generally given a "lift" (or "fall") anywhere from five to ten feet with an 8 foot lift being the most common on navigations upwards of six feet deep. The difference of elevation to be overcome was commonly divided evenly among the number of locks required so as to economize on the amount of water used in passing a boat, and to facilitate the operation of a flight of locks. On the Rideau Canal, By followed the common practice in laying out his locks, and tried whenever possible to have equal lifts of approximately eight feet. (For example, at Long Island a 25'-3" difference of elevation was overcome by three combined locks of equal lifts, at Nicholson's a 14'-10" fall by two detached locks, at Merrickville a 25 foot fall by three detached locks, at Old Slys a 16'-6" fall by two combined locks, and at Smith's Falls a 33 foot elevation was surmounted by a detached lock.
and three combined locks of equal lifts.) It also proved necessary in view of the configuration of the ground and the amount of fall to be overcome, to construct a number of locks with lifts greater than eight feet, but still within the common range of canal lock lifts. (For example, in the Entrance Valley an 80 foot difference of elevation was surmounted by a flight of eight locks each of 10 foot lift, at Hartwell's a 21 foot difference of elevation by two combined locks of equal lifts, and a number of the single locks had lifts as follows: Black Rapids a 9 foot lift, Burritts Rapids a 10 foot lift, Clowes a 9'-6" lift, Edmunds an 8'-8" lift, Chaffey's a 10'-2" lift, and Davis lock a 9'-9" lift.) However, the configuration of the ground where a fall had to be overcome was not always such as to enable By to construct lifts in keeping with limits generally accepted in canal lock construction. In several instances, he had to construct locks with exceptionally low lifts (viz. the 2'-3" lift on the Maitlands [Kilmarnock] lock, the 5'-9" lift on the First Rapids [Poonamalie] lock, and the roughly four foot lift on the Narrows lock). Occasionally, he constructed locks with lifts much higher than was considered prudent by at least one member of his engineering staff.\(^3\) This latter was the case at Jones Falls where By had initially planned to overcome a total rise of 61 feet by means of six locks with 10'-2" lifts; but the layout had to be changed when it was discovered that the first lock would rest on a soft marshy bottom and the positioning of the other locks would necessitate a good deal of hard marble rock excavation. To reduce the amount of rock excavation required and secure a sound foundation for all of the locks, it was decided to construct four locks (three combined locks and a detached lock) with approximately 15 foot lifts each, to overcome the difference in elevation at that lock-
site.\(^4\) Thereafter, for similar reasons, exceptionally high lifts were constructed elsewhere on the Rideau Canal (viz. a 13'-6" lift on the lower lock at the Hog's Back, a 13'-2" lift on the Lower Brewer's [Washburn] lock, and an 11'-8" lift on the detached lock and each of the three combined locks at Kingston Mills).

Although By and his engineering staff always strove to construct the combined locks with equal lifts, this did not prove possible in at least one case. At Brewer's Upper Mills a total fall of 17'-6" was overcome by two combined locks; but the upper lock was given a lift of only six feet and the lower lock a high lift of 11'-6". This was done to take advantage of the ground and avoid expensive rock excavation where the upper lock, which was partially positioned on rock and partly on clay, was concerned. Nonetheless, this expedient was not without its drawbacks. Some time after the canal was completed and in operation, Lt. Frome of the Royal Engineers made a general comment to the effect that where the lifts of the combined locks on the Rideau Canal were unequal, "some trouble is experienced in managing the supply of water from one to another, as a lock of five foot lift naturally will not supply sufficient water for one of ten."\(^5\)

The lifts of locks in the early 19th century were generally operated by means of sluice culverts, or tunnels, passing in through the lock walls around the upper gates of the lock chamber and sluices positioned directly on the lower gates. Although culverts were much more expensive to construct and required a major augmentation in the amount of masonry in the upper quoin piers, they were deemed necessary so as to avoid having water shooting out directly into the lock chamber from the upper gates up on the breastwork. In effect, if sluices were positioned directly on the upper
gates, the water shooting through the sluices in filling the lock chamber would cascade directly down on the vessel being locked up with a consequent danger of flooding its cargo. Where the discharge of the water in the chamber was concerned, the positioning of the sluices directly on the lower gates posed no problem. The bottom of the lower gates was continually under water, and any boat waiting to enter the lock chamber to lock up could stay well clear of the water shooting out of the sluices in the lower gates on the water in the lock chamber being lowered to receive the vessel. Consequently, the sluices for lowering the water in the lock chamber were commonly positioned directly on the lower gates. On the Rideau Canal, the 33 by 134 foot locks were constructed with culvert sluices at the upper gates of the single locks and on the intermediate gates of all combined locks, while gate sluices were built into the lower gates of the single locks and of the bottom lock in the combined locks. In this respect then, By was merely following the conventional arrangement of culvert and gate sluices. Indeed, he really had little choice following the Kempt Committee's rejection of the Welland Canal configuration of lock which, if constructed, would have enabled him to have had sluices in the upper gates as well as in the lower gates. The only deviation from the conventional positioning of the sluices on the Rideau Canal, was with respect to the four locks constructed without breastworks. On the single locks at Clowes Quarry, Maitlands Rapids (Kilmarnock), the Narrows, and the Isthmus (Newboro), where the sills of the upper gates were down on the same level as the sills of the lower gates, culvert sluices were dispensed with at the upper gates in favour of sluices positioned in the gates. (The two detached locks constructed on the Tay Canal Branch of the Rideau Canal in
1883-86, also have sluices in the upper gates, as well as the lower gates, to take advantage of a similar elimination of the breastwork.)

The Culvert Sluices
At the commencement of the Rideau Canal project, By had planned to use sliding vertical plate valves on the culvert sluices of the 20 by 108 foot locks that he was initially instructed to construct (Fig. 2). In keeping with the type of valve in use on the Lachine Canal, the valve plate was to be constructed of wood, and operate in a wooden frame passing down through a slot in the quoin pier masonry to the culvert. The only difference between the Lachine Canal culvert sluice valve system and that which By proposed to employ on the Rideau Canal locks was in the positioning of the valve. On the Rideau locks, it was to be positioned only about a foot or more back from the face of the gate recess wall near the upper end of the culvert, whereas on the Lachine Canal locks, the valve was positioned at the mid-point of the length of the culvert approximately opposite the upper gates (Fig. 3). The early Rideau Canal drawings do not show the type of mechanism to be employed to work the vertical sliding plate valve. By may well have intended to follow the Lachine Canal system where a threaded iron shaft, which passed down through the wooden frame to the plate valve, was turned to open and close the culvert sluice. No culvert sluices were to be constructed on the 50 by 150 foot large steamboat lock proposed for the Rideau. On the first drawing prepared for the newly approved 33 foot wide lock on 8 July 1828, Lt. Col. By planned to again use a sliding vertical plate valve on his culvert sluices at the upper gates only now the valves were to be positioned at the mid-point of the culvert as on the
Lachine Canal locks (Fig. 12). To that end slots, approximately one foot wide by 5 feet long, were to be constructed in the masonry of the quoin pier opposite the upper gates and pass down through the pier so as to bisect the culvert. In effect, where the slots bisected the culvert, grooves would be constructed in the side walls 12 inches wide by 12 inches deep to hold the frame timbers of the sliding valve plate which had to be large enough to close off the three foot wide by five foot high sluice.10

Sometime in the late summer of 1828, By decided to replace the proposed sliding vertical plate valve with a pivot plate valve system apparently of his own devising. To house the pivot valve mechanism, which required a great deal more room to operate than a vertical lift valve, as well as to provide access so that routine maintenance and repairs could be carried out, By was forced to have manholes constructed in the masonry of the quoin piers directly over the mid-point of the culvert sluices roughly in line with the upper gates. The manholes were to be 4'-6" square with a level bottom set down some 1'-10" below the upper inclined floor of the culvert and, of course, somewhat less on the lower side of the inclined culvert floor.11 (Fig. 32)

The wooden plate valve was to pivot on a horizontal axis at its mid-point in a timber frame. It was initially to be operated by means of a lift rod with one end attached to the lower edge of the pivot valve plate and the other end to an iron rack and pinion mechanism at the coping of the pier directly on the edge of the manhole. However, sometime prior to December 1829, By decided to substitute a crab and endless chain arrangement in place of the rack and pinion, for operating the pivot plate.12 (Fig. 33) During the following year, 1830, the new pivot plate valve system was
FIGURE 32

R4-026-F-0043

Details of the manhole constructed to house, and provide access to, the pivot valve mechanism placed in the sluice tunnels.
installed in the culverts of several of the locks and tested. It was found that the valve plates constructed of oak were "unequal to the pressure." This in turn necessitated their replacement with cast iron pivot plates.  

The Original In-Culvert Sluice Valves

The in-culvert sluice valves constructed on the Rideau Canal locks as of the opening of the canal in May 1832, consisted of a wood frame, built of heavy 10" by 10" and 10" by 11" squared oak timbers wedged into the base of each manhole, and an iron plate valve which pivoted horizontally at its mid-point in that frame (Fig. 33). The valve plate was solid cast iron, 5'-3" long by approximately 3 feet wide and 3/4" thick. The plate, however, was cast so as to have ribs 5" or 5½" wide, passing across its back near each outer edge and the horizontal axis, as well as in the form of an "X" in each of the two panels so formed. The ribs increased the thickness of the casting to 2 inches where they were located, with the exception of the center rib which increased the thickness of the valve plate on its axis to 2½ inches. A trunnion, 1½ inches in diameter, extended out an inch on either side of the valve plate on its horizontal axis. The two trunnions fitted into cast iron sockets. The sockets, which were 5½ inches long by 3 inches wide and 1½" inches deep, each had a 1½ inch diameter hole one inch deep in its face to receive the trunnion of the pivot plate. The sockets, or journal boxes, in turn were set into notches, or mortises, cut in the side members of the timber frame in the manhole.  

The valve plate was operated by means of a 3/8 inch diameter endless chain, one end of which was fastened to the mid-point of the bottom edge of the plate, and the other end

Along the bottom of the drawing, the tunnel sluice valve mechanism and operating crab are shown together with the reinforced plate valve. The original pivot plate valve, socket, and the improved clevis-shaped journal box are shown at the upper right. In the top center are views of the lock gate sluice valve plates. The remaining sketches pertain to the wall-face sluice system.

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to the mid-point of the top edge. From these two points, the chain passed up the manhole and wound around the barrel of a crab positioned directly above on the coping of the quoin pier. The crab was constructed of iron and consisted of a barrel, 7½ inches in diameter, fixed on a horizontal axle mounted in a rigidly connected double A-frame (Fig. 33). A large wheel gear on one end of the barrel was turned by a pinion gear on top, which in turn was driven by a manual crank. By turning the crank handle one way, the bottom edge of the pivot plate was pulled up opening the valve, and by turning the crank handle in the opposite direction, the top of the pivot plate was pulled back into a closed position.15 The top of the manhole opening directly below the crab was covered in solid with wood planking with the exception of two holes about 1½ inches in diameter where the two ends of the endless chain passed down through into the manhole.16 (Fig. 42)

Improvements Made to the In-Culvert Sluice Valves, 1833-34
During the first season of navigation, problems were experienced with the in-culvert sluice valves which did not prove strong enough to resist the great water pressure acting on them. In several instances, the pivot plate actually exploded causing fatal injuries to the lockmen working the operating crabs above, and problems were experienced with the iron sockets (journal boxes) in which the valve plates pivoted. The sockets, which in conjunction with the lower sill of the timber frame bore the whole pressure of the water in the culvert, had merely been let into the frame members. This proved insufficient to withstand the pressure of the water which on occasion drove the sockets right out through the wood.17 To rectify these problems, Captain Daniel Bolton who had succeeded Lt.
Col. By as Commanding Royal Engineer on the Rideau Canal in August 1832, made three changes in the design details of the in-culvert pivot valve sluice system to strengthen it. As of March 1833, he decided to reinforce the cast iron plate valve with bars of wrought iron, 5 inches wide by 3/4 inches thick which were to be rivetted to both sides of the existing pivot plate. Two bars were placed on the face of the valve plate so as to run its whole length along either edge. On the back of the valve plate, two bars were placed in an identical position with the rivets passing through to tie the reinforcing bars tightly together with the valve plate sandwiched between them. On the back of the valve plate, the longitudinal bars had to be heated and bent slightly to conform to the raised ribs of the original casting. Two additional 5 inch by 3/4 inch wrought iron bars were placed across the ends of the longitudinal reinforcing bars at the top and bottom edge of the valve plate. The cross bars were also held in place by means of rivets fixing them to the valve plate, and by a single eye bolt at each corner of the valve plate. (Fig. 34)

While these modifications were being made to the valve plate, Bolton did away with the original mode of attaching the crab chains to the mid-point of the top and bottom edge of the valve plate in favour of attaching chains to its four corners to provide greater support when being opened or closed. This, indeed, was why he bolted the corners of the improved valve plate together with eye bolts to each of which a short length of chain was forged. The two chains on the upper end of the valve plate were then forged together on the bottom link of one of the crab chains, while the two chains on the lower end of the valve plate were forged onto the other crab chain. This enabled the valve operating system comprising an endless chain and crab to continue to
Sketch A, Captain D. Bolton, 22 March 1833 (Rideau Canal Office, Smiths Falls).
R4-004-F-0009

Showing the reinforcing added to the In-tunnel sluice valve plates, the details of the improved clevis-shaped journal box, and the ratchet and pawl proposed to be added to the rack and pinion of the wall-face and lock gate sluice systems, as well as an iron grating proposed for covering the manholes at Black Rapids.
function as it had previously. The third change made by Bolton was in the design of the iron sockets.

To provide a stronger connection with the wood frame of the in-culvert sluice valve, the iron socket was replaced by an iron journal box cast in the form of a clevis. The head of the new journal box was of the same width as the old socket (3 inches) and somewhat longer (13 1/2" as opposed to 5 1/2"), and the hole in the face for receiving the trunnion of the pivot plate was the same, 1 1/2" in diameter by 1 1/2 inches deep. But the new journal box as distinct from the old, had arms 7 inches long by 3 inches wide and 1 1/2 inches thick which extended back perpendicular from each end. The arms fitted snugly over the 11 inch width of the 11" by 10" timber frame members, and had a single hole near their outer end to receive a bolt which was to pass completely through the timber member and fix the journal box securely to it. These modifications strengthened the in-culvert sluice mechanism sufficiently to withstand the great water pressures acting against the pivot plate valves; and all but eliminated the leakage problems experienced with the valve plate and journal boxes of the in-culvert sluice valves initially constructed on the Rideau Canal locks.

Out of the 47 masonry locks constructed on the Rideau Canal by Lt. Col. By, forty-three were provided with culvert sluices at their upper gates, or on the intermediate gates if they were flight locks, and of these all but a handful were equipped with the in-culvert sluice valve system devised by the Rideau Canal engineering staff. The only exceptions were the several locks with exceptionally high lifts, such as the locks at Jones Falls, where it was "thought advisable" to substitute wall face sluice valves for the in-culvert valve system.
The Original Wall-Face Culvert Sluice Valves

On the handful of locks with exceptionally high lifts, By dispensed with the construction of manholes for housing the in-culvert valves in favour of constructing wall-face valves in the upper end of the culvert openings, with small air holes or vents passing up through the lock wall masonry behind the valves (Fig. 33). These air vents, 14 inches square, were constructed back 2'-5" from the face of the gate recess wall (measured to the near face of the air vent shaft) and passed from the roof of the inclined culvert straight up to the coping of the quoin pier. There the coping stone reduced the air vent to an opening 12 inches square or 12 inches in diameter, depending it appears on the preference of the stone mason cutting the quoin coping stone.24

Otherwise, the masonry details of the culvert sluices were the same regardless of whether the lock was constructed for in-culvert sluices or wall-face sluices with the possible exception of the size of the culvert face opening at its upper end. The openings on the culverts of the Rideau Canal locks according to the standard plan of construction were to be exactly 3 feet wide by 5 feet high;25 but a drawing of the valve frame for the Jones Falls and Kingston Mills locks, where wall face sluice valves were constructed, shows that the culvert openings were 3'-5½" wide by somewhat more than 5 feet high.26 (Fig. 38) This would appear to indicate that where By planned to construct wall-face sluice valves, the culvert openings were constructed somewhat larger so that the framing of the sluice valves would not constrict the area of the opening too much less than the desired 15 square feet. Whatever the case, the masonry of the upper opening of the culvert sluices was carried straight back perpendicular to
the gate recess wall a distance of 18 inches at which point the culvert began its incline downwards and around the upper gate. It was in that square sided rectangular opening that By positioned the frame for his wall face sluice valves.\(^27\)

The wood frame for the wall face sluices was constructed of heavy oak planks, the two upright sides of which were 3 inches thick by 18 inches wide with three horizontal members 5 inches thick by 18 inches wide. These latter members were positioned one at the top and at the bottom of the frame and the other at its mid-point so as to divide the culvert face into two openings of equal height and approximately 35\(\frac{1}{2}\) inches wide (or a fraction of an inch more or less depending on the exact width of the opening in the masonry).\(^28\) Each of the openings was to be closed by a pivot valve on a horizontal axis (Fig. 35). To that end, the underside of the top cross member of the frame and of the middle cross member, were notched inwards to about their mid-point to form a sill against which the upper edge of the respective valve plates would rest when closed. The top outer edge of the middle cross member and of the bottom member were also cut on a bevel to match the slope of the back of the valve plate when in the closed position. The bottom end of each valve plate, in effect, extended out beyond the face of the sluice frame in its open position, and when closed rested down against the bevelled top edge of the middle and bottom frame members respectively.\(^29\)

The valve plate consisted of a 7/8" thick flat plate of cast iron, rectangularly shaped and approximately 35 inches wide by somewhat less in height with two arms projecting from its rear along either side. The arms were 1\(\frac{1}{2}\) inches thick and stood out 8\(\frac{1}{2}\) inches at their deepest point on a line about one-third of the distance from the top of the
Figure 35

On the far right is shown the original wall-face sluice valve operating system with the dual goose neck brackets, and to the left the chains proposed to be substituted on the upper valve plate in 1835.

Descriptive Sketch No. 2, Annual Estimate for 1835, Captain D. Bolton, 16 August 1834, (Rideau Canal Office, Smiths Falls).
R4-026-F-0034
valve plate. From that point the back edge of each arm curved inwards towards the valve plate and swept into a concave curve to the outer edges of the arm where it again curved inwards to the top and bottom of the valve plate. Each arm also had a hole, approximately 1 inch in diameter, passing through its deepest section, some 7 inches back from the rear face of the valve plate on a line about 1/3 of the distance down from its top. The pivot valve plates were positioned in the wood sluice frame by means of an iron gudgeon fixed on either side of the sluice opening in line with the holes in the valve plate arms. The pivot point, where the gudgeons were fixed, was back toward the middle of the sluice frame and about 8 inches below the underside of the timber cross member above the sluice opening, so that the valve plate, when pivoted open, would rest flat up against the frame leaving the whole of the sluice opening below free for the water to shoot through.

The pivot plates were operated by means of a lift rod, or connecting bar, worked by a rack and pinion positioned on the edge of the coping of the lock wall directly above the wall face sluices (Figs. 33 & 36). Each valve plate had a short goose neck bracket positioned at the mid-point of its bottom edge with the flattened base of the bracket being bolted with a single bolt through the plate. The other end of the goose neck, which had an eye in its center, was bolted to the lift rod to form a pin coupling. When the crank handle on the rack and pinion was turned to raise the lift rod, both sluice valves were opened simultaneously. They were closed in the same fashion merely by cranking the rack and pinion gearing system in the opposite direction. The goose neck bracket and the lift rod, were all made of iron (Fig. 35). A counterweight was positioned on a second
The original rack and pinion mechanism adopted for operating the wall-face sluice valves.
rack acting on the opposite side of the pinion gear to facilitate the opening and closing of the wall face sluice valves. The rack and pinion lift system was worked by means of a secondary pinion gear mounted on a separate axle turned by a crank handle. That gear in turn meshed with a large tooth wheel mounted on the same axle as the primary pinion gear that acted in the racks of both the lift rod and the counterweight. To hold the two racks in position on either side of the primary pinion gear during their travel, the backs of the racks had a raised tongue down their center which rode in the groove of roller wheels mounted on separate axles on either side of the primary gear at a distance removed sufficient to keep the travelling racks tight up against the teeth of the pinion gear as it turned. (Figs. 36 & 37) Wall sluice valves so formed were constructed, as mentioned, on the Rideau Canal locks with exceptionally high lifts which included in addition to the locks at Jones Falls and Kingston mills, the Lower Brewer's (Washburn) lock, the lower lock at Upper Brewer's, and the lower lock at the Hog's Back, if not several locks elsewhere on the Rideau system.

Modifications in the Wall-Face Sluice Valves, 1834-35

The wall sluice valves apparently worked well in conjunction with the rack and pinion operating system. Nonetheless, a problem was experienced which made it essential that the system be modified to make it easier and safer to operate. It was found that even with the counterweight rack acting on the primary pinion gear, it was difficult to open both sluice valves simultaneously against the pressure of the water acting on the valve plates. As soon as the valves were partially opened, the rush of water entering the sluice openings often forced the valves violently closed again and
FIGURE 37

R4-000-F-0015

Frame and gearing details of the rack and pinion mechanism used to operate the original wall-face sluice valves on the locks with high lifts.
in so doing tore the crank handle out of the hands of the lock labourers several of whom incurred injuries when struck by the spinning crank. In 1833, Captain Bolton planned to rectify the problem by mounting a ratchet wheel on the axle turned by the crank handle, with a pawl mounted the frame so as to ride on the teeth of the ratchet wheel (Fig. 34). The pawl, in effect, would let the ratchet wheel turn forward as the crank was turned to open the sluice valves. If the force of the water rushing through the partially opened sluices should suddenly strike the valve plates with a sufficient force to kick the crank handle back in the opposite direction, the pawl would catch on the ratchet wheel thereby preventing the sluice valves from being driven violently closed with a resultant spinning of the crank handle in reverse. To close the sluice valves, it would only be necessary to lift the pawl, and crank the pinion gear back in the reverse direction.\textsuperscript{35} In closing the valves, however, there are nothing to prevent the water from again driving the valve plates closed with a resultant dangerous spinning of the crank handle. This may well be why Bolton did not proceed with placing ratchet wheels and pawls on the rack and pinion lift system of the wall face sluice valves. This persistent problem apparently received a good deal of thought, as in the following year during the winter of 1834-35, Bolton made changes in the hook-up of the wall-face sluice valves with the lift rod. The new arrangement remedied the crank handle kick problem experienced both in opening and closing the sluice valves.\textsuperscript{36}

At that time, the rigid goose neck bracket connecting the upper valve plate of each wall face sluice with the lift rod, was removed and replaced with two slack chains, one end of which was fixed to the lift rod and the other end to the
bottom edge of the valve plate at either side (Figs. 35 & 38). In this new hook-up, the lower sluice valve plate was partially opened by the raising of the lift rod, before the slack chains became taut and commenced pulling open the upper valve. The lift rod, of course, would reach the height of its travel on the bottom sluice valve reaching its full open position, but presumably the force of the water shooting through the as yet but partially opened upper sluiceway would act so as to force the upper valve plate fully open. In closing the sluices, a similar factor was at work. The cranking down of the lift rod would, of course, force the lower sluice closed, while the chains on the upper sluice would merely go slack. However, the bottom of the valve plate, as originally designed, projected out several inches past the face of the sluice frame and the pivot point of the plate was set back about two-thirds distant from its bottom edge so as to give it a natural tendency to close. In effect, once the chains went slack, the force of the water shooting down past the upper pivot plate would force its bottom edge down thereby closing the valve automatically. At the same time as the chains were substituted on the upper pivot valve plate of the wall face sluices, it was proposed to cut a groove into the bottom of the upper valve plate at its mid-point slightly wider than the lift rod to provide an additional clearance for the now independently acting valve plate in its movement past the lift rod when closing. To prevent leakage through this vertical slot, it was also proposed to place a wood stop or bracket, somewhat higher than the length of the slot, on the middle sill of the sluice frame so as to form a tight seal against the back of the valve plate in its closed position (Fig. 35). This proposed secondary alteration in the wall face sluice valve plates, however, was not carried
The chains on the upper valve plate were added in 1835 at which time the shape of the valve plate and the goose neck bracket base were modified.
Bolton did make several additional changes by way of strengthening the wall sluices and reducing leakage between the sides of the valve plates and the wood frame.

On the lower valve plate, the original goose neck bracket which had been bolted to the mid-point of the lower edge of the plate by a single bolt, was replaced by a goose neck bracket with a much wider, and hence stronger, base. The base of the new bracket was 24½ inches long by 3½ inches wide, and extended backwards to a width of 5 inches for a distance of 1½ inches in from either end. Five bolts, one in each end tab and three equally spaced along the main band, were used to fix the bracket securely along the bottom edge of the valve plate. The goose neck of the bracket extended outwards a distance of 5 inches and curved upwards 2½ inches (measured from the surface of the valve plate to the center of the connecting pin hole). This extension was slotted (7/8 inch slot) so as to form a coupling end to fit onto the lift rod to which it was pin connected as was the case with the original goose neck bracket. Not all of the new brackets, however, were made exactly the same. The new goose neck brackets installed on the lower sluice valves of the Jones Falls and Kingston Mills locks, for example, had a slightly different base. There the extended base of the new brackets was rectangularly shaped, 13 inches long by 3 inches wide, and was bolted to the valve plate by means of four, rather than five, equally spaced bolts. The slot in the goose neck head was also somewhat wider, some 1½ inches in width. (Fig. 38) In all other respects, the new brackets were identical to those installed on the other locks with wall-face sluice valves over their culverts.

To accommodate the new chain and goose neck connections on the upper and lower valves, respectively, of the wall-face sluices, it was necessary to make new valve plates
which Bolton redesigned to give them additional strength and reduce leakage through the sluices. The new valve plates were cast with raised ribs on their rear face crossing in the form of an X between the side arms, and the top end was widened 3/4 inches on each side for a distance of 10½ inches.\textsuperscript{41} (Fig. 39) This latter was the part of the valve plate which pivoted up and back away from its closed position on being opened, as opposed to the bottom part of the plate which swung forward and upwards through the sluice frame. As the top part of the valve plate swung backwards, Bolton took advantage of this to widen that section of the plate, and to notch the wood frames on either side, approximately one inch deep, in the area covered by the wider section of the valve plate in being pivoted open. The notch, in effect, served as a stop against which the wider part of the valve plate closed, and thereby rendered the top sides of the valve plate watertight in the sluice frame.\textsuperscript{42} The new valve plates substituted in the wall face sluices by Bolton in 1834-35, were 36 1/8 inches wide at their widened top end, by 18 1/8 inches long. The bottom 17½ inches of that length consisting of the narrower part of the valve plate, that swung forward through the 34 5/8 inches wide sluice frame opening. In other respects, the new plates were formed in the same manner as the original sluice valve plates.\textsuperscript{43}

Where the sluice frame was concerned, a stop was added across the top of the middle and lower sills to raise the bottom edge of the valve plates with the result that the plates, when closed, were at a far less steep angle than had hitherto been the case. This change, of course, reduced the amount of travel required to open the pivoting valve plate, and presumably made them easier to open. According to a drawing of the sluice frame and changes made in the wall
Plan of Sluice Valves for Face Sluices, John Burrows, Clerk of Works, 29 August 1837 (Rideau Canal Office, Smiths Falls).

R4-026-F-0035.

The sluice valve plate and goose neck bracket as re-designed in 1834-35.
face sluice valves at this time, the culvert openings at Jones Falls and Kingston Mills were 3 feet 5½ inches wide. This indicates that the planks of the sluice frame, on either side of the 34 5/8 inch wide valve plate, must have been 3 inches thick allowing for a 7/16 inch clearance on either side of the valve plate. The rest of the wood frame appears the same as originally constructed with the exception of the center sill between the two valve plates, which now was shortened so that it did not go through to the back of the frame. Where previously the middle sill plank had been 18 inches deep to match the depth of the other frame planks, it was now made only about a foot in depth and tapered on both sides toward the back. In effect, the shortening of the middle sill depth, resulted in the water passing through the upper sluice striking against the top of the lower sluice valve plate when both sluices were open so that the force of the water would aid in keeping the bottom sluice full open.44 (Fig. 38)

Following the 1834-35 modifications in the original wall face-sluice valves, very few changes appear to have been made, and these were only of a very minor nature. In December 1836, Captain Bolton prepared plans for perforated cast iron covers, one inch thick, which were to be fitted over the air vent shafts on the locks at Jones Falls and Kingston Mills (Fig. 40). There, of course, the air shafts passing up through the quoin pier above the culvert sluices were only 12 inches square, and 12 inches round respectively. The air shaft covers were to be made one inch wider than the air shaft so as to rest in a ledge ½ inch wide by one inch deep cut into the coping of the stone edges of the shafts.45 These air shaft covers were probably cast during the winter of 1836-37, and installed the following spring. During the 1838 navigation season, a
problem was experienced with the new goose neck brackets installed on the lower valve plates of the wall face sluices in 1834-35. These brackets after four years of use apparently developed a tendency to crack and break off together with the adjacent portion of the valve plate casting around the base of the goose neck. To remedy this defect, the then Major Bolton redesigned the goose neck bracket on the lower sluice valve plates. The new bracket was made narrower, only 5\(\frac{1}{2}\) inches in width as opposed to 24\(\frac{1}{2}\) inches wide, but longer so that it extended more than a third of the way up the face of the valve plate. The three bolts fixing the new goose neck bracket to the valve plate were also placed farther back from its bottom edge than had been the case with the bolts of the former bracket.\(^{46}\) (Fig. 41) In this manner, the whole thrust of the water on the valve plate when being opened or closed, was not borne by its bottom edge as was the case previously, but was spread over the interior of the valve plate. With the exception of the change which had to be made in the design of the goose neck bracket of the lower valve plate in 1838, Major Bolton appears to have been reasonably pleased with the performance of the wall-face valves following the improvements made in 1834-35. Indeed, his actions during the period 1837-39, indicate that this was decidedly the case.

Elimination of the In-Culvert Sluice Valves, 1839

The improvements made to the in-culvert sluice valves in 1833-34, strengthened them sufficiently to overcome the dangerous breakage problem experienced during the first two years of the canal's operation; but the true cause of that problem, which was inherent in the very operation of a pivot plate valve, remained to beget a further problem. It
The old plan shows the problem being experienced with the goose neck bracket design adopted in 1834-35. The new plan is a proposed improvement adopted in 1839.
appears that initially By opted for a pivot valve system in the culverts of the Rideau Canal locks because of his belief that a pivot plate valve if properly balanced would be far easier to open and close than a vertical slide valve (or guillotine gate) which would be held tight against the back side of its slide frame by the pressure of the water in the culvert. To that end, By constructed a pivot plate valve system at the mid-point of the culverts (the only place where sufficient room could be made to operate such a valve), and designed his valve plate so that the horizontal axis on which it was to pivot about its mid-point was one inch closer to the top than the bottom. In this manner, the valve plate was suspended almost in equilibrium, but would rest with a slightly greater pressure of water against its lower than its upper half thereby ensuring that the valve would be kept closed by the force of the water acting against it. At the same time, the valve plate in being almost in equilibrium, the slightest pull of the crab chain fixed to its bottom edge would be sufficient to open it. This was likewise the case in closing the valve. Once fully open, only the slightest lifting of the upper end of the valve plate by the crab chains would cause the bottom half of the plate to pivot downwards to the point where the greater pressure of water acting against the bottom half of the pivot plate would hold it tightly closed. It was recognized that the positioning of the sluice valve in the mid-point of the culvert, which was far below the level of the upper culvert opening in the lock chamber, would result in a far greater water pressure acting against the sluice valve than if it had been positioned on the wall face. But what By apparently failed to take into account was the impact force of the water that would be shooting through the open culvert sluice valves.
The force of the water striking against the valve plate, on the operator commencing to close the valve, placed a great strain on the valve plate and journal boxes and was occasionally of such a force as to tear the crab handle out of the hands of the lock labourers. The strengthening of the valve plates and journal boxes in 1833-34, enabled the in-culvert valves to withstand the great strains to which they were subjected in opening and closing. But the other aspect of the problem remained with the spinning crab handle occasionally inflicting injuries on the lock labourers similar to those that had been received in operating the wall-face sluice valves prior to their improvement in 1834-35.50

In an attempt to remove the safety hazard posed by the existing mode of operating the in-culvert sluice valves, Captain Bolton in May 1836 devised a braking system to be installed on the crabs. As an experiment, he sweated a band of iron on an old gear wheel and mounted it on a crab at the opposite end of the drum from the turning gear wheel. A brake shoe band was then positioned above the new wheel band with a lever attached which could be moved, by means of a turn handle operating on a threaded shaft, to tighten down the brake shoe (Fig. 42). The intention here was to put a brake on the crab while the valve plate was being closed so that the force of the water shooting through the culvert would not drive the partially closed plate violently shut with a resultant spinning of the crab handle. To the same end, Bolton also planned to mount a ratchet wheel and pawl on the crab axle next to the brake wheel.51 This attempt to resolve problem, however, could not have been all that successful or encouraging as in the spring of 1837, Captain Bolton proposed to his superiors a totally different solution to the problem.
FIGURE 42

42 Views of the Crab now in use on the Sluice Valves in the masonry of the Locks on the Rideau Canal shewing the Strap, Pinion and Pawl proposed to be added to prevent accidents to the men employed working the Locks, Capt. D. Bolton, 30 May 1836.
R4-026-F-0028
FIGURE 43

Elevation and Plan of the proposed new Sluices showing same open, Captain D. Bolton, 29 April 1837 (Rideau Canal Office, Smiths Falls).

Proposed wood valve plates moved in a vertical plane by means of a screw lift consisting of a threaded shaft and rotating nut similar to a screw jack.
In this proposal, the threaded shaft passed through the square-headed nut which was turned by a double headed lever. The nut rotated in a fixed base so that turning the nut in one direction raised the threaded shaft, and hence the sluice valve plates, and in the opposite direction would lower them.
In the spring of 1837, Captain Bolton began to think seriously of converting the in-culvert sluice valves at the upper gates on the Rideau Canal locks to wall-face sluices. To that end, he prepared plans of several different proposals for the Ordnance Board. Initially, he proposed a plan which would have had two wood valve plates sliding in a vertical wood frame built over the culvert sluice openings in the face of the gate recess wall. The valve plates were joined together by metal straps, and were to be operated by means of a screw lift rod threaded on its top end so that when a threaded horizontal cross arm was turned against the solid lift rod frame on the coping of the lock wall, it would raise and lower both valves simultaneously.\(^5\) (Figs. 43 & 44) Thereafter, in the fall of 1837, Bolton decided to modify the screw lift design slightly, and to discard the sliding wood valve plates system in favour of adopting the iron pivot plate valves in use at Jones Falls, Kingston Mills and elsewhere on the existing wall-face culvert sluices.\(^5\)

In an effort to improve the existing wall-face sluice valves, Bolton re-designed the arms of the pivot plates to move the center of the pivot down in line with the mid-point of the plate face from its former position about one-third of the way down from the top of the valve plate. The pivot point otherwise remained as it had been about 7 inches back from the rear face of the valve plate.\(^5\) The original position of the pivot had been such that when the valve plate was full open, it would rest up against the top of the sluice opening thereby letting all of the water pass under it.\(^5\) Now, by moving the pivot point downwards, the water would flow both above and below the valve plate when fully open; and the valve plate was brought even closer to being in equilibrium.\(^5\)
Proposed wall-face sluice system having a screw lift, a re-designed valve plate with its pivot axis lowered, and the goose neck bracket re-established on the upper valve plate. The screw lift was not adopted.
Bolton must have concluded that the change in the pivot of the valve plates, in conjunction with the rigid screw lift system, would make the pivot valves less difficult and dangerous to operate where the force of water against the top and bottom face of the valve plates when closed, and against their face and back when opened, would be almost equal. In any case, he proposed to do away with the chain hook-up adopted on the upper pivot plate of the existing wall face sluice valves in 1834-35, in favour of returning to the solid goose neck connection on the upper plate matching that retained on the lower plate.\textsuperscript{57} (Fig. 45) Bolton also contemplated doing away with the center sill in the wall face sluice frame. To accommodate this change, he planned to place the valves so that the bottom edge of the top plate would overlap the front upper edge of the bottom plate when closed. In this new arrangement, the sluice frame was also to be set in the lock wall at an angle with its base projecting out from the wall.\textsuperscript{58} (Fig. 46) When it came to converting the Rideau Canal in-culvert sluice valves to wall-face sluice valves, however, only a few of these proposed modifications were actually adopted.

After two years of planning, it was decided as of the spring of 1839 to proceed with the replacement of the dangerous in-culvert sluice valves with wall face valves. By this time, Major Bolton was convinced that the change over could best be accomplished by adopting the existing crab and endless chain system to operate pivot plate valves of a design made similar to those already in service on the original wall-face valves following the 1834-35 improvements. Only two changes were incorporated into the design of the wall face valve plates in keeping with the changes that Bolton had had in contemplation during the fall of 1837. The pivot point of the valve plates was moved
46 Proposed Wall-Face Sluice, Sketch No. 2, Captain D. Bolton, 9 September 1837 (Rideau Canal Office, Smiths Falls).

R4-026-F-0026

Proposed wall-face sluice system with an angled sluice frame, the centre cross-piece of the frame removed, and overlapping valve plates.
downwards towards the mid-point of the valve plate, and a
gooseneck bracket was now used to connect the upper valve
plate to the lift rod rather than the chains adopted on the
existing wall face sluices in 1833-34.59 (Fig. 45)

To operate the new wall-face culvert sluice valves,
Bolton removed the crabs and endless chains from their
former position directly over the manholes of the culverts.
He re-positioned each crab on the coping of the gate recess
wall directly in line with the culvert sluice openings
below, and a short distance back from the edge, with the
barrel of the crab parallel to the lock.60 (Fig. 47)
The endless chain wound around the barrel passing out from
there to the edge of the coping where it was carried over on
two 7½ inch diameter sheaves mounted side by side in iron
frames bolted to a piece of flat iron. The flat iron, one
inch thick by 5½ inches wide by 24 inches long,61 was in
turn anchored to the outer edge, or arris, of the gate
recess wall coping where the stone was cut on a bevel to
receive it.62 (Fig. 48) To this point, Bolton had
really not devised anything new as the design and
positioning of the sheave frames plate and the positioning
of the crab for working the endless chain passing over the
sheaves was but a copy of a part of the floor chain/crab
system that Lt. Col. By had devised for operating the lock
gates on the Rideau Canal.63 Once the endless chain
passed over the sheaves on the coping in Bolton's wall face
sluice valve operating system, one end of the chain was
attached directly to the top of the lift rod a short
distance below the coping of the wall. The other end of the
chain passed down the recess wall and around a snub pulley
(mounted on the wall at the mid-point of its height) before
passing back up the wall where it was attached to the lift
rod.64 (Fig. 47) To open the new wall-face sluices, it
The crab/chain system adopted for operating the wall-face sluice valves that replaced the in-tunnel valves in 1839.
Plan of the Plates, Frames, and Sheaves required for the Sluice, Rideau Canal, 16 May 1839 (Rideau Canal Office, Smiths Falls).

The coping sheaves unit adopted for use in the new wall-face sluice valves system in 1839 is of the same design as the coping sheaves unit used in the original crab/floor chain gate operating system.
was necessary only to turn the crab so as to wind up the chain attached to the top of the suspended lift rod. To close the sluice valves, the crab had only to be turned in the opposite direction winding in the other end of the chain which, acting around the snub pulley, would pull the connecting (lift) rod downwards thereby forcing the sluice valve plates closed.

It is not clear where Major Bolton got the idea for the sluice operating system adopted in 1839. He may have worked it out for himself in an effort to re-use as much as possible of the existing in-culvert sluice valve operating equipment, or he may have seen such a system in use elsewhere. In Scotland, a similar sluice operating system insofar as the arrangement of the endless chain, lift rod, and snub pulley are concerned, was employed on the lock gate sluices of the Edinburgh and Glasgow Union Canal as early as 1817. Since the engineer of that canal, Hugh Baird was the father of Noah H. Baird the former Clerk of the Works on the Rideau Canal construction project, it is even possible that Bolton was made aware at one time or another of the arrangement of the gate sluice operating chains on the Union Canal. If so, he merely adopted it for operating the new Rideau Canal wall-face sluices in conjunction with a crab rather than the geared winch used on the Union Canal gates.

Following the 1839 changeover from in-culvert sluice valves to wall-face culvert sluice valves at the upper gates and intermediate gates on the Rideau Canal locks, no major changes appear to have been made in the design of the sluice valves or sluice valve operating mechanisms with the exception of the sluices at the upper gates of lock no. 8 in the Entrance Valley. There the in-culvert sluice valves were converted to wall-face sluice valves operated by a crab
and chains as part of the 1839 changeover; but fifty years later, debris generated by heavy shipping activity in the Ottawa basin, began to accumulate in the upper set of wall-face valves on lock no. 8. The debris accumulated to the point where it periodically jammed up the valves necessitating the employment of a diver to free them up. To avoid this recurrent trouble, that set of sluice valves in 1894-95 was removed and replaced by "sliding vertical flanges."67 (Fig. 49) With respect to the culvert sluices, the only other major change was in the manhole covers.

At the time of the canal's construction, the manholes housing the in-culvert sluice valves, were merely covered over with planks through which holes were drilled for the crab chains and to vent the culverts.68 (Fig. 42) This was regarded, however, as being only a temporary expedient, and Captain Bolton as early as 1833 made plans to replace the plank manhole covers with iron grates made of 7/8 inch round bars (rods). By way of experiment, he had iron grates made up for the manholes on the in-culvert sluice valves of the Black Rapids lock;69 (Fig. 34) but wood manhole covers remained in use elsewhere. At the time the in-culvert sluice valves were converted to wall-face sluice valves, the wood plank manhole covers were replaced by a wood grating.70 These remained in service, with periodic replacements in kind, until the year 1900 when a programme was instituted to replace all of the wood grating manhole covers with flat iron strap gratings. This changeover was undertaken as a safety precaution in response to an August 1899 accident involving the superintending engineer of the Rideau Canal, Arthur Phillips. While Phillips was observing the operation of one of the combined locks at Long Island, the wood grating on which he was
FIGURE 49

Vertical Sliding Valve plate over Tunnel Sluice at upper gates of Lock No. 8, Ottawa Locks (Photo by author, 1982).
standing gave way dropping him down into the rushing water which shot him through the sluice culvert and out into the lock chamber. Fortunately, Phillips was not seriously hurt, but the experience did convince him of the need to replace the wood manhole covers with gratings of iron. The iron strap gratings which Phillips had installed over the Rideau Canal lock manholes in 1900, have remained in place up to the present day. (Fig. 50)

Today, all of the manually operated culvert sluice valves on the Rideau Canal locks are of the wall-face type, and all but one of these sluice valves (the vertical sliding plate valves on the sluices at the upper gates of lock no. 8) are of the pivot plate type (Fig. 51). The only other valve systems in use on the sluice culverts of the Rideau Canal locks are hydraulically operated valves installed in the base of the manholes at the upper gates of the Black Rapids lock in 1968, and the hydraulic, vertical movement valves installed to operate the new sluice system constructed in the floor of the high lift lock built at Smith's Falls in 1973-74. No field work has been undertaken in the preparation of the present report to determine how many of the Rideau Canal culvert sluice valves are operated by the rack and pinion system installed on the high lift locks at the time of the canal's construction, or how many by the crab and endless chain system adopted by Bolton in 1839 for the new wall-face sluice valves. It is even possible that some of the rack and pinion operating mechanisms installed on the original wall face valves have been replaced by a crab and chains. These questions, however, could be answered by a systematic field survey taking note of the type of operating mechanism in use on each of the culvert sluices in conjunction with a notation as to whether or not there is a vertical groove in the gate
This iron strap grating was installed over the tunnel sluice manholes of the Rideau Canal locks as of 1900.
Wall-face sluice valve, Poonamalie (J. Tulloch photo, winter of 1974-75).
A typical wall-face sluice valve of today with goose neck brackets on both valve plates.
recess wall above the sluice opening. To accommodate the wall face sluices installed at the time of the canal's construction, a vertical groove was built into the face of the gate recess wall as it was laid up to house the lift rod and counterweight rack of the original rack and pinion operating mechanism.\textsuperscript{73} (Fig. 36) When the new wall-face sluice valves were installed on the rest of the locks in 1839, with a crab and endless chain operating system, the lift rod and chains merely passed down the face of the existing gate recess wall.\textsuperscript{74} Hence the presence of a vertical groove in the gate recess wall directly above the culvert opening indicates that that culvert sluice initially had one of the original wall face valves with a rack and pinion operating system, regardless of whatever system is now employed to operate the valves. The absence of a groove, on the other hand, would indicate a wall face sluice valve system installed by Bolton in the 1839 changeover unless, of course, the gate recess wall has had to be totally rebuilt as with the Lower Brewer's (Washburn) lock reconstructed in 1976-77, and the Davis lock in 1981-82.
V The Lock Gates: Design Evolution

The Lock Gates built in 1830-32
The first gates for the approved 33 by 134 foot locks were constructed in the workshops at Bytown as early as May 1830, but thereafter lock gates were framed on the locksites using timber culled from the surrounding forest. Some lock gates, as at Bytown, were built by carpenters employed directly by the Royal Engineers on the day work system; but most were built by contractors for £100 per pair, with a single contract for the gates at each locksite. The timber and ironwork was furnished by the Royal Engineers Department. The contractors were responsible for the fitting and hanging of the gates, but the work proceeded under the direct supervision of Mr. Fitzgibbon, the Master Carpenter, who travelled from site to site as required. The lock gates designed for the 33 by 134 foot Rideau Canal locks were of a conventional double-leaf mitre gate type then in widespread use on canals. Overall, 75 pairs of lock gates were built on 47 masonry locks grouped at 22 locksites.

Each gate leaf was framed with heavy oak timber, with the frame consisting of two upright posts joined by numerous horizontal cross rails. The vertical posts were the heel post, commonly called a quoin post because it pivoted in the hollow quoin pier of the lock masonry, and the mitre post, which closed against the mitre post of the other gate leaf. As its name implies, the outer edge of the mitre post was cut on an angle, or mitred, so as to form a broad bearing surface where the gate leaves pressed one against the other.
on being closed. The heel post was a massive timber 16" square, but rounded on its outer extremity to fit the approximately 8" radius of the hollow quoin pier masonry. The mitre post was 13½" square, with the outer edge bevelled to the angle formed by the closed gates with the longitudinal centre of the lock. The horizontal cross rails of the gate frame differed in their dimensions, but all were tapered in plan across the back of the gate to compensate for the smaller dimension of the mitre post (Fig. 52).

The heaviest horizontal rail, the base rail, was a timber 15" thick by 16" wide. It was tapered in the gate from 16" in width at the heel post down to 13½" in width at the mitre post. The top rail was of somewhat smaller dimensions, a 13½" thick by 16" wide timber. It was tapered in width (or depth in the gate) from 16" down to 13½". The intermediate horizontal cross rails on the first Rideau Canal gates constructed were all of the same dimensions, and uniformly tapered. Timbers 9" thick by 13" wide were tapered from 13" at the heel post to 10½" wide at the mitre post, and framed flush with the front surface of the gate frame. The intermediate cross rails were, in effect, 3" less in depth than the top and base rails, to enable the planking to be set into the gate face.

The number of cross rails varied with the height of the lock lift. On a short upper gate for a lock of 10 foot lift, for example, there were three intermediate cross rails spaced so as to be closer together at greater depths below the surface of the water in the lock. From top to bottom, the gaps between the rails were 3' - 6", 3' - 4", 3' - 2½", and 3' - 0". On higher lifts, a gate might have as many as five intermediate cross rails with even closer spacing, ranging progressively downwards from 2' - 7½" at the top of the gate to a 2' - 0" gap at the bottom.
52 8th Gate of the 1st 8 Locks, By Town, Rideau Canal, Lt. Col. By, n.d. (Rideau Canal Office, Smiths Falls). R4-001-F-0285

Framing and construction details of the first lock gates erected on the Rideau Canal. The fox-wedge bolts anchoring the anchor plate/collar strap are also clearly depicted.
The cross rails were framed into the vertical posts with mortise and tenon joints, with the end of the rail at the shoulder of the tenon set about 1/4" into the vertical posts. None of the drawings extant of the lock gates first constructed on the Rideau Canal in 1830-32, show the mortise and tenon details. However, carpenters generally worked from practice, or custom, in deciding on the proportions of the mortise and tenon, and no precise rules were laid down for the trade. In British canal construction practice, the tenons were usually one-third the width of the rail, and passed halfway into the post. The tenons on the Rideau Canal lock gate cross rails, however, apparently passed all of the way through the quoin and mitre posts.

There is one Rideau Canal drawing extant from the canal construction period that does show the mortise and tenon details of a lock gate: a 1 December 1827 drawing of the lock gate proposed for the 20 foot wide gunboat lock that Col. By was initially ordered to construct. In the December 1827 drawing, the tenons are the full thickness, or height, of the cross rails, and about one-third the width of the rail in the gate. (The only exception is the base rail where the tenon on each end is just over half the thickness of the base rail, and carried out flush from the upper surface. This, however, was probably done to increase the cheek of the mortise at the base of the heel and mitre posts to keep them from any danger of splitting. In that proposed gate design, the bottom end of both the heel post and mitre post projected only 3" or 4" below the underside of the base rail.) The tenons, and hence the mortise, passed all of the way through the mitre and heel posts. (Fig. 7)

The proportions of the mortises and tenons of the lock gates actually constructed for the 33 foot wide lock were
probably the same as that planned for the smaller 20 foot wide lock. In which case, the tenons were about one-third the width of the cross rail, and its full thickness, passing completely through the vertical posts. The rectangular mortises may well have been tapered slightly narrower near the shoulder of the tenon to form a tight joint when wedges were driven in to expand the tenon. This was a common practice in joinery.\(^6\) The lock gate joints, as indeed all mortise and tenon joints, were pinned to fix the tenon permanently in the mortise. In joinery, the pins were usually of hard wood,\(^7\) but the Rideau Canal lock gate joints were pinned by means of one of the bolts passing through wrought iron reinforcing plates placed at each framing joint.\(^8\) The hole, or draw-bore, drilled through the mortise and tenon acted, on the bolt being driven through, to force the shoulders of the tenon tight against the cheeks of each mortise in the heel and mitre posts.\(^9\) (Fig. 52) The manner in which the tenons were wedged in the mortise has probably not changed over the years. The details of the saw cuts, and the two \(\frac{1}{2}\)" hardwood wedges inserted in the end of each tenon, are shown on an April 1982 Parks Canada drawing.\(^10\) (Fig. 85)

Both the heel post and the mitre post projected about 2' - 8" above the top of the upper rail (roughly 8" above the coping of the lock wall masonry). A step board, or foot board, consisting of a 4" by 20" plank, was fixed across the top of the vertical posts. A hand rail of iron rods crossed the top of the gate leaf. On lower gates with sluices, the iron railing was of a heavier construction to provide support for the rack and pinion sluice operating machinery. Both the heel and mitre posts projected down below the bottom of the base rail, but unequally. The mitre post projected only 6" below the base rail, so as to allow a 6"
clearance when swung over the masonry floor of the lock gate pit. The heel post extended 11" below the base rail, leaving only a 1" clearance between the foot of the heel post and the gate recess floor in the masonry lock wall.

The gate leaves were about 19' - 6" in overall width, but varied greatly in height. Upper gates had to resist a head of water equal to the depth of navigation, approximately a six foot head, but lower and intermediate gates on the high lift locks, such as the 15 foot lifts at Jones Falls, had to withstand a 21 foot head of water. The precise height of the gates was determined by the sum of several factors: the depth of the navigation, the lock lift, the bearing surface required against the raised sill of the lock, and the height of guard desired above the level of the raised water in the lock. In Colonel By's lock design, the sills were raised 1' - 6" above the lock gate pit floor, and the base rail of the gate when closed overlapped the sill by 6". (This bearing surface was increased by the quoin and mitre posts which extended a further 6" and 11" respectively below the top of the sill).

The upper cross rail was positioned so as to provide a one foot guard, or height, above the raised water level in the lock chamber. Taking these several factors into account, a lock gate on a lock of 10 foot lift was 17' - 6" high, measured from the bottom of the base rail to the top of the upper rail. The quoin and mitre posts on that size of gate were 21' - 1" and 20' - 6" long respectively. The largest gates, on locks of 15 foot lifts, were 22' - 6" high, measured from the bottom of the base rail to the top of the upper rail, with quoin and mitre posts 26' - 1" and 25' - 6" long respectively.

To strengthen the framework of the gates, munnions and braces were inserted between the cross rails of each gate
leaf. The munnions consisted of short pieces of vertical bridging positioned in a line about 7' - 10" in from the outer edge of the mitre post, directly over the roller wheel supporting the gate. Each munnion was 7" wide and about 14" in depth, to match the depth of the tapered cross rails at that position in the gate. The ends of the munnions were set into the cross rails about \( \frac{1}{4} \)" and probably framed into the cross rails with simply a housed brace joint. The munnions ran in a vertical line from the base rail through to the upper rail.\(^{11}\) (Fig. 52)

On the long lower gates, the munnion between the base rail and the cross rail directly above, served to separate and help frame the two sluice openings in the bottom of the gate. The first recorded use of the term "munnions" on the Rideau Canal project is on a Royal Engineers drawing showing the framing of the centre piece between the sluice openings. The term "munnions" was used to describe the center frame member, and the term was obviously extended thereafter to cover any vertical bridging between the cross rails of the lock gate. The munnion, forming the centre member of the sluice opening frames, was definitely framed into the cross rails with housed brace joints, leading one to suspect that all of the munnions and braces were jointed into the cross rails in the same manner.\(^{12}\) (Fig. 59)

The braces were placed in a line between the cross rails, but on diagonals passing upwards and outwards in the gate leaf. A long brace ran from the base rail near the heel post outward and upward to the upper rail, near the vertical line of munnions. The smaller outer section of the gate, between the munnions and the mitre post, was strengthened by two short braces on a diagonal line parallel to the long brace: one in the upper part of the gate, and one in the lower part of the gate. Each brace was 6" wide,
wide, and of varying depth depending on the corresponding depth of the tapered cross rails in each panel of the gate.\textsuperscript{13}

The back of the lock gate frame was angled in plan, tapered on its back (or downstream) side to compensate for the heel post being 2½" thicker than the mitre post. The frame was sheathed on its upstream face with 3" oak or red pine planking. The planks were spiked on in a vertical pattern over the intermediate cross rails, and let into the top and base rail, as well as the heel and mitre posts, to form a flush surface. The planks were about 10" wide, squared on their edges,\textsuperscript{14} and spliced together with a spline. Both edges of each plank were grooved or ploughed to form, with the adjacent plank, a slot into which a 1½" by ½" iron spline or tongue was inserted.\textsuperscript{15} This not only strengthened the planking, but formed a joint that could withstand any contraction or expansion caused by the swelling or shrinking of the wood.

On contemporary British canals the joints of the planking were caulked,\textsuperscript{16} and this may have been the case with the Rideau Canal lock gates. Large quantities of oakum were ordered from the Ordnance stores in Montreal for the Rideau project: some 6 cwt. of oakum in December 1823, as well as 20 barrels of pitch.\textsuperscript{17} Generally, oakum was either soaked in pitch before being driven into planking joints, or the oakum was driven as was, with the pitch being used as a sealer.\textsuperscript{18} The face of the lock gate leaf was perfectly flat in plan, and the timber framework was finished by cutting chamfers on all exposed edges.\textsuperscript{19}

Gate Ironwork: a) The reinforcing plates

The lock gate framework was reinforced at all joints with flat iron T and L plates bolted through the timbers
(Fig. 52). An L plate was positioned at each bottom corner where the base rail and vertical posts joined, and T plates were placed at the junction of each cross rail with the vertical posts. The number of T plates on a gate leaf depended on the number of cross rails, which in turn depended on the height of the lock lift. The plates were 2½" to 3" wide, with their base and leg each about 24" long. They were made at the smith's forge in Bytown from English flat iron imported via Montreal where the Commissary General's Office let government contracts to local merchants/importers. The flat iron forwarded to the Rideau project was of unspecified lengths, but the iron ordered in widths of 2½" and 3" ranged from ¼" to 5/8" to ½" in thickness.

The reinforcing plates were positioned on both sides of the gate, and were fixed to the timber frame with clinch bolts (often referred to as "clench bolts"). The bolts were equally spaced in a standard pattern of five bolts per plate, with the centre bolt in each case passing through the draw-bore of the cross rail tenon. The bolts appear to have been about ¼" in diameter. Holes were drilled through the timber framework, and the bolts driven until their heads were tight against the reinforcing plate. Then the protruding ends were bent over and flattened against the opposite reinforcing plate, clenching the two plates in place. In this manner, the bolts and reinforcing plates acted not only to pin the cross rail tenons into the vertical posts of the gate frame, but also made the frame more rigid.

Gate Ironwork: b) The Gudgeon and Foot Box

Each gate leaf pivoted on an iron gudgeon in the base of the heel post. The gudgeon projected down into an iron socket
set into the masonry floor. Extant early drawings do not show how the gudgeon was fixed to the base of the heel post, or the dimensions of the gudgeon. Even the terminology used is inconsistent. The pivot in the base of the heel post was variously referred to as a "gudgeon" and a "pintle", and the socket set in the masonry floor of the gate recess at the hollow quoin pier was called either a "tail socket", a "foot box", or a "heel post box". The early drawings, however, do indicate that there was a wrought iron band around the base of the heel post, and the configuration of the gudgeon depicted does closely approximate the gudgeon shown in detailed drawings of the Rideau Canal lock gates made in January 1918. Indeed, the gudgeon design may well have remained unchanged down through the years. Today on historic British canals, the two components of this standard ball and socket joint at the base of the heel post, are called a "pivot" and a "box".

On the Rideau Canal, the pivot depicted in latter-day drawings comprises two cast-iron parts: the gudgeon and the crosstail. The crosstail, consisting of two cross arms with a hexagonal socket in the centre of the casting, is set into the base of the quoin post and a wrought iron band, of the same outside diameter as the quoin post, is fitted over its bottom end of the post. Earlier as shown in a drawing dating from 1918, wedges were driven in between the outer ends of the crosstail arms and the iron band to hold the crosstail and band firmly in place (Fig. 53). More recently saw cuts, about eight in total, have been made in the bottom surface of the quoin post and wooden wedges driven in on a random pattern to bind the crosstail and iron heel band in place (Fig. 54). The cast iron gudgeon, consisting of a ball pivot with a tapered hexagonal tail 8½" long, fits into the hexagonal socket of the crosstail with the ball protruding below the base of the quoin post (Fig. 55).

In this drawing various views are shown of the foot box, the gudgeon, the cross tail and the wrought iron band, as well as the manner in which the tenon of the bottom rail is wedged.
FIGURE 54

Base of quoin post, new lock gate Smiths Falls yard (Photo by author, 1983).

The crosstail, with its hexagonal socket, is set into the quoin post to hold the gudgeon. Wood wedges, driven into saw cuts, hold the crosstail and heel band in place. Note the wedges driven into the end of the base rail tenon.
Lock gate gudgeon, Smiths Falls Yard (Photo by author, 1983).

When the gudgeon is set into the crosstail, the ball of the gudgeon protrudes from the base of the quoin post as shown.
The foot box to receive the gudgeon has always been set down into a block of stone in the floor of the lock at the base of the hollow quoin pier. Wood wedges are used to align the foot box in the stone before seating it permanently with a pour of molten lead (Fig. 53).

Gate Ironwork: c) The Roller Wheel
To prevent the gate leaf sagging and putting an undue strain on the anchor collar, a roller wheel or truck was bolted to the bottom of the base rail. The truck was positioned directly below the vertical brace in the lock gate leaf (Fig. 52). In effect, it was centred about 11' - 9" from the outer extremity of the heel post, and about 7' - 10½" from the mitre post measured from the mitred edge at the rear of the gate leaf. The roller wheel was 11½" in diameter with a 3½" wide convex running surface. It was mounted on a 1½" diameter axle in a cast iron truck wheel frame. The base of the frame was shaped like a channel beam 14½" wide overall, and was bolted to the base rail with four 5/8" diameter screw bolts.29 (Fig. 64) As originally planned and constructed, the channel shaped base of the truck, with its 13½" wide web between the two ½" thick channel flanges, was wide enough to fit snugly over the base rail at its position on the gate leaf.30 However, when the dimensions of the base rail were later increased to strengthen the lock gates, the channel frame of the truck, both the flanges and the channel web were set into the base rail flush with its bottom surface.31 (Fig. 60) The truck wheel ran on an iron quadrant rail anchored to the masonry gate-recess floor of the lock.32 (Figs. 18 & 59)

Today, the roller wheel trucks have been eliminated from the Rideau Canal lock gates, although the iron quadrant rails are still in place on the gate-pit floor of a number
of the locks. It is not clear, however, when or why the roller wheels were eliminated.

Roller wheels were placed on the original lock gates to compensate for the lack of a swing beam on gates operated by means of the floor chain/crab system developed by Colonel By (Fig. 59). On conventional canals of much lesser width swing beams, or balance beams as they were often called, served not only as levers to swing the gates, but also as counterweights to balance the weight of the gate leaf on the ball and socket pivot at the base of the heel post. In effect, the heavy extension of the swing beam helped to keep the gate leaf from sagging at the mitre post, and also acted to prevent the gate leaf from exerting a heavy pull on the anchor collar at the top of the heel post. However, conventional English barge canals in the early 19th century had either narrow locks (7'-6" wide by 70 feet long) or broad locks (13 feet wide by 65 feet long). The largest locks constructed in the Canadas to that date, the Lachine Canal built in 1821-1825, had locks somewhat larger: 20 feet wide by 108 feet long. In contrast, the new Rideau steamboat locks under construction in 1828-1832, were 33 feet wide by 134 feet in length, and the Royal Engineers were concerned that the extreme width of the Rideau locks would preclude the use of the swing beam employed on lock gates elsewhere.

Although the Royal Engineers did not elaborate on their specific reasons for rejecting the swing beam for the large Rideau Canal locks, the factors involved in the evolution of their lock gate design can be deduced from their ultimate decision to adopt the roller wheel for supporting the lock gate and the floor chain/crab mechanism for operating the gates. The factors considered were probably the following:

1) That it would be difficult to swing such large mitre
gates (19' - 6" wide) with a swing beam as there were limits to the size of lever that could be erected on a lock gate; 2) that on such large gates the swing beam could never be of a sufficiently large size to act as a counterweight for the weight of the gate; and 3) that if in the absence of a balance beam the weight of the gate were not support in some other fashion, it would hang on the collar strap raising the danger of opening up the joints of the new masonry on the coping of the quoin pier.

These factors were all embraced in the lock gate design adopted. The addition of the roller wheel on the bottom of the gate leaf near the mitre post, prevented the gate from sagging at its outer end, and also prevented the gate from hanging on the collar strap at the top of the heel post. In this fashion, the counterweight function of the swing beam was realized in another manner. The lever function of the swing beam was compensated for by the floor chain/crab system which provided a mechanical means of operating the lock gates. Hence, although the conventional balance beam was eliminated from the Rideau Canal lock gate design of the Royal Engineers, other devices were incorporated into that design to compensate for its loss.

On the Rideau Canal, long curved swing beams were introduced on the lock gates commencing in 1835. These swing beams which were replaced thereafter by a somewhat straighter beam, were massive timbers of the same basic design as on conventional canal gates: heavy on their outer end, tapering down in size toward the mitre post. Indeed, in 1850 the swing beams, by then passing straight across the top of the gates, were 18" square on their outer end, tapering to 15" square at the mitre post, and were 40 feet long. In effect, the swing beam extended 20' - 6" out beyond the heel post of the gate.
Nonetheless, even that size of swing beam must have been judged insufficient to counterbalance the weight of the lock gate leaf. The roller wheel was retained, and re-mounted on new replacement gates throughout the 1850's and 1860's, and probably long thereafter. The first drawing showing a Rideau lock gate without the roller wheel is dated 1918, but a second drawing of the same year shows the roller wheel in use. In the early 1950's, there were still several lock gates with the roller wheel running on the iron quadrant rail. However, the roller wheels have long since been eliminated from the Rideau Canal lock gates.

The roller wheel has never been restored to the lock gates despite the fact that the long swing beams were done away with on a number of lock gates being converted to the push-bar system of operation over the first decades of the 20th century. The swing beams, or swing bars, on these gates are straight beams 10" by 24", extending only 4'-6" out past the heel post, and are totally incapable of serving the counterbalancing function of the traditional swing beam. To compensate for the lack of the roller wheel, the design of the gates was modified somewhat. A bridle, consisting of mild steel strapping, was added. The open end of the bridle was bolted on the mitre post, at about the third cross rail down, and the neck of the bridle took the threaded end of a modified eye-bolt, or collar loop, hooked around the collar strap at the heel post. (Fig. 83) By adjusting the nut on the threaded shaft of the collar loop, the bridle could be tightened to keep the mitre post from sagging; but the design modification did nothing to take the weight of the outer end of the gate off the collar strap. Indeed, depending on the tension in the bridle, it may even increase the pull on the collar strap. Viewed from the perspective of lock gate design practice, the
elimination of the roller wheel from the gates is highly questionable. It leaves the whole weight of the outer end of the gate leaf hanging on the collar strap, increases wear on the collar brasses, no doubt makes the gate harder to open, and puts a heavy strain on the masonry of the quoin pier coping.

**Gate Ironwork: d) The Anchor Plate (Spider) and Collar Strap**

The gate leaf, supported by the gudgeon in the base of the heel post and the roller wheel, was held in position by an anchor collar placed around the upper extension of the heel post. This extension of the 16" by 16" heel post was turned, or rounded, on an 8" radius. Bushings were set into the wood to provide a wearing surface for the post turning in the anchor collar. The anchor collar was in turn keyed to a massive anchor plate bolted to the coping of the lock wall masonry.43 (Fig. 56)

The anchor plate, or spider as it has come to be called, was a heavy almost flat iron casting with three splayed legs and an elevated head. The head, 3" thick by 5" high, ran the full width of the anchor plate, 2' - 2½". It had a concave surface on its vertical face about 3" deep on an 8" radius, to match the heel post radius. Each shoulder of the raised anchor plate head was pierced by a horizontal opening 2" square, through which the ends of the anchor plate collar strap passed. The three splayed legs of the anchor plate were each about 4' - 2" long, measured from the face of the raised head, and 4½" wide by about 2½" thick. They were further strengthened by raised ribs running along the bottom of the casting along the outside of the outer legs and down the middle of the centre leg. The anchor plate was also thicker and wider at the end of each leg, as
56 "Plan of the Anchor and Strap fixed on Coping", detail of "Elevation of a Lower Lock Gate in perspective", Captain D. Bolton, 14 March 1833 (Rideau Canal Office, Smiths Falls).

Note the brass bushings set into the circumference of the quoin post.
well as at the mid-point in the length of the centre leg. At each of these points, bolt holes of about 1½" diameter were provided for a total of four anchor bolts. The centre bolt was on a 32" radius, centred on the centre of the concave face radius of the anchor plate head, and the arc of three bolt holes at the end of the legs was on a 4'-6" radius from the same centre.

The anchor plate was set into the surface of the hollow quoin pier masonry, with the concave face of the elevated anchor head flush with the radius of the hollow quoin masonry. The anchor plate was leaded in, and fixed in place with four fox-wedge bolts, each 1½" in diameter and about 52 inches long, with about two inches of thread extending above the anchor plate to take a large square-headed nut. (Fig. 56) In canal construction practice, the quoin pier coping stone was always a massive slab of a half ton or more in weight. On the Rideau Canal locks, the quoin pier coping stone was a 4' - 0" by 4' - 0" slab, either 1' - 4" or 1' - 6" thick. The length of the fox-wedge bolts was such that they passed down through the coping stone of the quoin pier, through the first course of stone below, and into the centre of the next course (Fig. 52). The fox-wedge bolts, of course, were anchored by driving the bolt down on a flat iron wedge inserted in a slot at the bottom end of the bolt. This action caused the bolt end to splay into the stone, thereby locking the bolt in place. Lead was then poured down around the anchor bolts, and the anchor plate was bedded in lead when set into the coping of the quoin pier masonry. (Fig. 58)

The anchor collar strap was a U-shaped band of wrought iron, 1" thick by 5" wide, with an 8" inside radius forming a semi-circle. The extended arms of the collar strap were just under 2" square, with a horizontal slot near the outer
just under 2" square, with a horizontal slot near the outer end of each arm. Once the gate was in place, the collar arms passing through the square holes in the elevated head of the anchor plate. Then a key was slipped through the slot in the protruding end of each collar arm to lock them in place. The two keys were made out of 3/8" flat iron, and were 7½" long by 2½" wide. One end was cut on a bevel narrowing down to ½" wide, to facilitate the wedge being driven into the collar arm slot. When the gate leaf required replacement, or repair, it could be easily removed by driving out the two keys and pulling out the collar. Once released from the collar strap, the gate could then be hoisted up out of the foot box socket in which the gudgeon on the base of the heel post, pivoted.

To provide a wearing surface, and prevent the iron collar strap cutting into the wood of the heel post, brass castings were used. Each casting was a brass bar about ½" thick by ½" wide, and 5" or more long. The bars were positioned vertically in a band around the circumference of the heel post at the height of the collar strap, there being eight bars per post equally spaced. The castings or brasses were set into the wood so that only the slightly raised surface of brass came in contact with the collar strap, and the concave surface of the anchor plate head. The brass castings, which acted as a bushing on the heel post turning with the opening and closing of the lock gate, were held in place by means of a 2" screw at either end of each bar.

Over the years, only minor modifications have been made in the anchor plate and collar strap details. Today, fewer brass castings are used to form a bushing, 5 instead of 8, and the bars or rods are somewhat smaller, approximately ½" square. Moreover, the five rods are equally spaced only
"Underside of Cast Iron Anchor Plate", detail of "Typical Upper Lock Gate or Dry Gate", 2 April 1982 (Rideau Canal Office, Smiths Falls).
R4-026-F-074
over the semi-circle of the heel post circumference that comes in contact with the collar strap. The collar strap has been increased in width from 5" to 6", but the extension arms of the collar strap have been reduced to 1 - 5/8" wide by 1" thick, possibly to facilitate the collar arms slipping through the 2" by 2" openings in the anchor plate head.\(^2\) (Fig. 57) The collar straps have been replaced from time to time;\(^3\) but the cast iron anchor plates are for the most part the originals. They have been re-used whenever the quoin pier coping stone has needed replacement; but where the castings have broken in being removed, new iron castings were obtained from the Alloy Foundry, Merrickville.\(^4\) However, a major change has been made in the way the anchor bolts are seated or bedded in the quoin pier coping stone.

On the several lock reconstructions recently undertaken --- the Washburn lock in 1976-77 and the Davis lock in 1981-82 --- a new practice was introduced for bedding the anchor bolts of the anchor plate. Hardened steel bolts, 40" long by 1 1/2" in diameter, have replaced the iron fox-bolts which ranged up to 52" long,\(^5\) and instead of being bedded in lead, the anchor bolts of the reconstructed locks were bedded in a non-shrink grout. The square-headed nuts on the original anchor bolts were replaced with modern hexagonal nuts.\(^6\) Why hexagonal nuts were substituted for the more historic square-headed nuts is not known.

The substitution of grout for lead in seating the anchor bolts, is also highly questionable on both policy grounds as well as the potential durability of the work. On the one hand, lead is the historic material used originally to seat the anchor bolts/anchor plates on the Rideau Canal, and the leading is highly visible around the anchor plates. In keeping with Parks Canada policy with respect to the
FIGURE 58

58 Ottawa Locks, Anchor plate and Collar strap (Photo by author, 1978). The lead seating for the anchor plate is visible around its edges. When the coping stone on this lock was renewed, hexagonal nuts replaced the original square headed nuts on the fox-wedge bolts.
Rideau Canal, the historic material ought to be used in this case where the material of construction is visible. Secondly, leading is still the better method for seating metal anchor bolts in stone masonry. Grout is porous, and there is a danger that corrosion, once started on the steel anchor bolts, will cause oxide jacking eventually splitting the coping stone of the quoin pier as well as the courses penetrated by the anchor bolts.

**Gate Ironwork: e) The Sluices in the Lower Gates**

On the Rideau Canal, sluice tunnels or culverts were built into the quoin pier masonry around the upper gates and around the intermediate gates of combined locks. Consequently, the upper gates, and intermediate gates of combined locks, were constructed solid without any openings in them. However, the lower gates on single locks and the bottom set of gates on combined locks were constructed with sluices passing through them. The only exception to this arrangement of tunnel sluices and gate sluices was with respect to the four locks built without breastworks. The upper gates on these locks, at Clowes Quarry, Maitlands (Kilmarnock), the Narrows, and the Isthmus (Newboro), were also constructed with sluices. There, of course, the upper gate sills were on the same level as the lower gate sills, and constantly under water. Thus, there was no danger of flooding the cargoes of vessels ascending the locks on the upper gate sluices being opened.

The design of the lower gates with sluices in them, differed only slightly from the upper gates in framing details. The cross-rails were more closely spaced on the long lower gates, but the bracing pattern was the same. The vertical munnions were framed in line directly above the roller wheel as on the upper gates, dividing the gate into
two panels. The long diagonal brace, framed between the cross rails, passed upwards and outwards from the top of the base rail near the heel post to the underside of the top rail at the line of munnions. The other panel of the gate leaf contained two diagonal braces, one in the top half and one in the lower half, running parallel to the main diagonal brace as on the upper gates. The only difference was that the lower brace commenced at the top of the next rail above the base rail, leaving the space between the two bottom rails free for the sluice openings.57 (Figs. 59 & 75)

There were two sluice openings in the base of the lock gate, set in a horizontal line near the mitre post. Each opening was 5' - 0" wide by 1' - 6" high, and framed between the cross rails by three vertical munnions, with the centre munnion positioned directly over the roller wheel.1 All of the munnions were 1' - 6" long, by 9" thick and from 15½" to 16-7/8" in depth, depending on the depth or thickness of the gate at their respective positions. The munnions had a tenon on each end, which was framed into the cross rails with a simple housed-brace joint. The cross rails were held tight against the shoulders of the tenons by means of flat iron straps, one on each side of the gate centred on the respective munnion. The straps 5/8" thick by 4" wide and about 36" long, were each pierced by three bolt holes passing through the full thickness of the gate: one through the base rail, a second through the top of the munnion; and a third through the cross rail above. The plates were tightened together against the munnion by means of a nut on the threaded end of 5/8" diameter bolts some 21" long. Part of the opening so framed was enlarged somewhat by cutting the top of the base rail on a bevel downwards toward the rear of the gate, and cutting the top front edge of the bases rail on a sharp bevel to match the slope of the valve plate face when closed.58 (Fig. 60)
59 Elevation of a Lower gate in Perspective and plan of Part of the flooring in front of the sill, Captain D. Bolton, 14 March 1833 (Rideau Canal Office, Smiths Falls).

The framing details of a lower gate are shown as well as the original crab/floor chain system of operating the lock gates.
60 Details of the Sluices in the lower lock gates, n.d. (Rideau Canal Office, Smiths Falls).
R4-026-F-0038

The framing details of the sluice openings in the gate and the munnion between the sluice openings are shown here, as well as the journal bolts and iron reinforcing plates supporting the two pivot valve plates.
The arrangement of the sluices in the bottom of the lower gates on the Rideau Canal locks was in keeping with conventional design practice. Generally, gate sluices were positioned in between the two bottom cross rails of the gate-leaf and as close to the mitre post as possible. This ensured that the sluices would be well under water, and that the jets of water shooting out of the mitre gates would strike against each other, thereby reducing turbulence. Canal engineers were always concerned to make the sluice openings as large as practicable to expedite the filling and emptying of the lock chamber, and this appears to have been the case on the Rideau. On British canals, the total area of the sluice openings for emptying, or filling, a lock chamber bore a proportion of between 0.002 and 0.013 to the surface area of the water in the lock.59 While the 33 foot by 134 foot Rideau Canal locks, this would have necessitated sluices having a total opening of somewhere between a minimum of 8.8 square feet and 57.5 square feet. The actual total opening of the 5 foot by 1.5 foot Rideau gate sluices, with two sluices in each of two gate leaves, was 30 square feet. (The two tunnel sluices for filling the lock chamber were each 3' by 5', for a total opening of 30 square feet as well.) There were, of course, limits imposed on the size of the gate sluices by the need to keep water turbulence in the lock chamber to a minimum on the water being discharged, and to avoid a major weakening of the lock gate.

The sluice valves in the Rideau gates were rectangular cast iron plates pivoting on a horizontal axis. In their design and mode of operation, the valves plates were very similar to those in the wall-face sluices over the tunnels at the upper gates of a number of the Rideau Canal locks with high lifts. The valve plate was 1' - 10½" high by 5' -
1\(\frac{1}{2}\)" wide, and 7/8" thick. The top 14\(\frac{1}{2}\)" of the plate was somewhat wider, with about a 1" wide shoulder on either side. The casting was strengthened by raised ribs in a diagonal pattern across its rear between two arms that projected back perpendicularly on either side. Each of the projecting arms was about 1\(\frac{1}{4}\)" thick, and was pierced by a single hole of about 1" in diameter, centred 5\(\frac{1}{4}\)" back from the face of the valve plate.60 (Fig. 33)

The pivot for the valve plate was to the rear of the sluice opening at about 1/2 its height, and was positioned so that the valve plate when closed would slope downwards and outwards toward the front of the gate. In that manner, the force of the water in the lock would hold the valve closed. The journals for the valve plate were constructed simply by drilling a hole, about 1" in diameter, horizontally through the vertical munnions of the sluice frame at the required position. A piece of flat iron, 3\(\frac{3}{4}\)" by 8\(\frac{1}{2}\)" with a 1" diameter hole through it, was then set into the munion and held in place with four screws. The sluice plates were slipped into the sluice opening from the front of the gate, one valve plate to each sluice opening, and a journal bolt inserted through the hole in the arm of the sluice valve plate and the journals formed in the munnions. The journal bolts were forelock bolts, about 14" long, and slotted on one end to receive a cotter or key to facilitate the valve plate being removed if necessary. There were three journal bolts for each gate leaf, with the centre bolt serving as a pivot for both valve plates. There were no bushings in the valve plate journal boxes. The journal bolt simply turned in the hole through the arm at one or other end of the valve plate and in the corresponding hole through the munion, with the shoulder of the latter being reinforced with the flat iron insert on both sides.61 (Fig. 60)
As initially designed and built, the sluice valve plates were joined by an iron bar bolted across the bottom edge of the sluice valve plates. A bracket in the centre of the bar, between the valve plates, was in turn pinned to a connecting or lift rod that was operated by a single rack and pinion gear at the top of the lock gate. In effect, both valves were opened simultaneously by a single mechanism. This system, however, did not work as well as expected and in the fall of 1838 a conversion program was commenced to provide each sluice valve with a separate operating mechanism. The bar connecting the valve plates was replaced by a separate bracket bolted along the bottom of each valve plate. This bracket, called a goose-neck, had a central arm curving outwards with a clevis end in which the lift rod was pinned. (Fig. 61)

The original valve plate system remained in service until the early 1860's when the valve plates were repaired and modified somewhat. One of the changes was the introduction of brass bushings for the journal bolts. This was done to increase the life-span of the valve mechanism, and was apparently carried out by machining the existing journal bolts down, and adding the bushings. During the 1860's, the sluice openings on new gates were moved away from the mitre post toward the centre of the individual gate leaves. The sluice openings were framed in the same manner, but the munnion between them was on the centreline of the gate leaf rather than directly over the roller wheel as previously. (Fig. 78) This was not a good design feature as it would have increased turbulence in the water below the lock chamber. By 1918, if not sooner, the sluice openings were again positioned as close as possible to the mitre post in keeping with the original design and traditional design practice. (Fig. 81)
Plan for Proposed Alteration for Opening Sluices of Lower Gates, 1838 (Rideau Canal Office, Smiths Falls). R4-001-F-0280

Showing the original system for operating the gate sluices and the modified system introduced in 1838. The reinforcing rails added to the front of the original lock gates are shown on the left gate.
The sluice valve plates in the bottom of the lower gates were operated by means of a lift rod, or connecting rod. It was an iron bar 1\(\frac{1}{4}\)" square, and extended up the face of the lock gate to a rack and pinion gear mechanism mounted on an iron railing at the top of the gate. The connecting rod was pinned to a toothed rack which ran against a pinion gear, on the opposite side of which was a similar rack with a counterweight attached. Each rack had a tongue along its back which ran in a grooved roller positioned so as to hold the respective racks up against the pinion gear. The pinion gear, which controlled the travel of the racks, was turned by a large toothed gear wheel keyed on the same shaft. The large toothed gear wheel, about 25" in diameter, was in turn driven by a second pinion gear keyed on a crank shaft. A crank handle fitted on the other end of the crank shaft, which when turned in one direction opened the valve plates in the bottom of the gates, and when cranked in reverse, closed them.68

The gearing system, as well as the counterweight, made for ease of operation in opening the valves against the head of water in the lock chamber. Also, the gears were kept well lubricated by the locklabourers using oil and tallow. For example, in 1870 the Rideau Canal required 80 gallons of lard oil for lubricating crabs and machinery, 66 gallons of sweet or machinery oil, and 326 lbs. of tallow for the machinery.69 The tallow was probably used for lubricating the valve machinery that was constantly under water. It is not clear why lard oil was used in addition to the machinery oil. At that time, however, various animal and/or vegetable lubricants were in general use, and were considered superior to the early petroleum lubricants available.70 The shafts of the two pinion gears, and of the two grooved rollers, were all mounted in a cast iron frame and bushed with brass.71 (Fig. 62)
Details of the rack and pinion mechanism assembly for operating the gate sluices. The design of the original mechanism for operating the wall-face sluices was identical (see Fig. 37).
The rack and pinion gear system mounted on the lock gates was a facsimile of the rack and pinion gear that was mounted on the coping of several locks to operate the wall-face sluice valves on the culverts at the upper gates. Over the years, few changes have been made in the gate sluice operating mechanism. Initially, some trouble must have been experienced in closing the gate valves. In 1833 Captain Bolton, the superintending engineer, prepared a plan for adding a ratchet mechanism to the rack and pinion gear system. A ratchet wheel was to be mounted on the crank shaft, beside the pinion gear, with a pawl bolted to the frame of the gear system. It acted so that the crank handle could be freely turned in closing the gate valves, but was prevented by the pawl from being driven back open by the force of the water acting against the valve plates on their being closed. This was an experiment, and must not have worked well. The ratchet mechanism was not added to the gate sluice operating machinery; but rather each sluice valve plate was provided after 1838 with a separate rack and pinion operating mechanism (Fig. 61). This halved the water pressure acting against the operating gears, and may well have solved the problem of the crank handle being kicked back by the force of the water striking the valve plates on their being closed. Subsequently, the rack and pinion/lift rod mechanism remained as originally designed, and has been replaced in kind down through the years. (Fig. 63)

Painting the Lock Gates:
The lock gates were painted in keeping with the conventional military practice followed by the Royal Engineers in finishing gun carriages and barracks buildings. The ingredients of the putty, primer and paint required for
Figure 63 - Rideau Canal, Merrickville, View of Lock Gate (W.D. Naftel photo, 1973).

View of the rack and pinion mechanism retained on the lock gates for operating the sluices. The gate bridle added to the lock gates sometime in the 1940's is also partially shown.
finishing the lock gates were ordered from the Ordnance stores in Montreal, and were mixed on the worksites for immediate application. The ingredients were ordered in large quantities, for example, in December 1828 the Ordnance store was ordered to forward to Bytown: 60 gallons of boiled Linseed Oil; 336 lbs. of Whiting; 500 lbs. of dry Red Lead; 560 lbs. of White Lead ground in oil; 280 lbs. of Spanish Brown ground in oil; 10 lbs. of crude Litharge, and 10 lbs. of livigated Litharge; and 28 lbs. of dry Lampblack. Most of the paint ingredients were shipped in kegs of 28 lbs. each.  

During the construction of the lock gates, the iron tongues or splines inserted in the planking joints, the wrought iron reinforcing plates, and the tenons of the cross rails, as well as the munnions and braces, were all seated in a thick coat of white lead mixed with linseed oil. In keeping with the conventional practice in the building trade, the wood work of the gates was then probably rubbed with sandpaper or pumice stone to remove any roughness. Putty was used to fill in the countersunk heads of the spikes, and the caulked planking joints. The putty was made by beating whiting (a chalk — calcium carbonate) with linseed oil to form a thick dough. The putty might also have been mixed with white lead to form a very plastic or pliable sealant, used extensively in shipbuilding. This mixture, about 50% white lead and 50% putty, yielded a sealant that would not crack with the expansion and contraction of the wood planks.

Efforts were made to obtain planks that were well sawed and free from sap and wane, for the lock gates. But knots could not have been avoided. It is not known how knots were treated. In civilian practice, painters burnt out the knots by placing fresh slaked lime on them for
24 hours. Then the slaked lime was scrapped off and the indentations filled with "size knotting", a mixture of red and white lead. This filling was then covered with a priming coat consisting of a mixture of red and white lead thinned with linseed oil, and smoothed off with a pumice stone. This process may well have been followed in preparing the Rideau Canal lock gate planks for priming and painting.

The lock gates having been sealed and prepared, the woodwork was treated with a very thin coat of linseed oil mixed with Spanish brown. This coat of primer was applied heavily until the wood ceased to soak it up. Linseed oil, obtained by crushing flax seeds and filtering and boiling the residue, was the basic ingredient of all early 19th century primers and paints. In civilian house painting, it was generally mixed with white and red lead for priming. However, the military preferred to mix Spanish brown with linseed oil for the priming coat as it was cheaper. Spanish brown was a red ochre, or red iron oxide, that had at one time been imported into England from Spain, hence its name. It made a coarse primer suitable only for rough work such as the painting of barracks buildings or lock gates, and was manufactured cheaply in large quantities. Paint was then added over the primer coat.

In the early 19th century, paint consisted of linseed oil mixed with white lead and turpentine, to which drying and colouring agents were added. The drying agent was almost invariably litharge, a powdery residue formed by the oxidation of lead, which caused paint to dry quickly. Numerous colouring agents were used depending on the colour desired. The British army, however, used white lead, lampblack, and Spanish brown as colouring agents to produce
the white, black and brown paint most commonly used on military buildings in the Canadas following the War of 1812. This colour preference was reflected in the colouring agents ordered for the Rideau project: white lead, lampblack, and Spanish brown.

White lead was a basic ingredient of paint as well as a colouring agent. It consisted of flakes of white lead oxide ground into a powder, bleached, and saturated with linseed oil. Lampblack was a bluish-black pigment, or soot, obtained by burning mineral oil, turpentine, or tar in the absence of much oxygen, producing a smoky flame and soot residue. In addition to its use in producing black paint, lampblack could be mixed in lesser quantities with white lead to produce a "common colour" of grey, or lead grey, widely used by the military.

In civilian painting practice, Spanish brown was simply a colouring agent. However, the military used it both as a stiffening agent when mixed with linseed oil for priming rough woodwork, and as a colouring agent when mixed with linseed oil, white lead, and litharge for painting wood brown. This procedure was followed in finishing the Rideau Canal lock gates which were probably given three coats of paint in keeping with the military practice of the day. The resultant dark reddish-brown colour of the lock gates can be seen in the military artists' watercolour paintings of the Rideau Canal locksites during the 1830's and 1840's.

The iron work on the Rideau Canal lock gates was painted black. In civilian painting practice, all iron work was customarily given a priming coat of linseed oil, followed by two coats of red lead paint. The finishing coats of paint were invariably black. The Royal Engineers also customarily painted all iron work and guns
black. The ingredients of their black paint in the early 19th century were linseed oil, red lead, lampblack and Cumberland black lead. In the Rideau Canal project correspondence, there is no mention of Cumberland black lead, but linseed oil, dry red lead, and lampblack, as well as ground white lead, were ordered from the Ordnance store in Montreal. All things considered, the iron work on the lock gates was probably given a priming coat of linseed oil, followed by two coats of red lead paint, and finished with several coats of black paint. The black paint could well have been made by mixing linseed oil, dry red lead, and lampblack with white lead.

The Stone Coloured Lock Gates:
About the mid-19th century, a decision was taken to paint the lock gate woodwork a stone grey colour rather than continuing with the original Spanish brown colour. The iron work, however, remained black. By 1861, if not several years before, the lock gate specifications called for new lock gates to receive three coats of white lead paint, with the last coat a stone colour, and the iron work was to be painted black. It is not known whether the change in paint colour was made prior to the military giving up the canal in 1856, or thereafter on the Board of Works for Upper and Lower Canada taking over. However, it is clear that the existing gates were not immediately painted the new colour. In the early years following the Board of Works take over, expenditures were made only on what was considered "absolutely necessary to maintain the navigation", and by 1864, the Superintending Engineer was asking for funds to improve the appearance of the canal by painting its buildings, making minor repairs to them, and generally tidying up the locksites. Consequently, with 75
pairs of lock gates on the canal and a replacement rate of about five pairs of new gates per year, the transition in colour from Spanish brown to stone coloured lock gates would have taken place over a number of years. The colour chosen for the lock gates was one commonly used by the military in painting woodwork.

During the late 18th and 19th centuries, the British military painted the woodwork of its gun carriages, platforms, and stores buildings variously either a lead colour or a stone colour. Spanish brown, mixed with linseed oil, was used as a primer, and the wood received three coats of white lead paint, with a colouring agent added to the last coat to obtain either the lead grey or stone grey colour as desired. Periodically, circulars were issued prescribing the paint mix and colours required — generally black for iron guns, lead grey for wooden gun carriages and platforms, and a stone colour for the canvas of carriages. Military buildings were painted either the lead grey or stone colour, or a combination of both. The stone colour, such as was applied to the Rideau Canal gates, was obtained by adding a small quantity of manganese sulphate and English umber — an iron oxide containing manganese dioxide — to white lead paint. In civilian painting practice, a stone colour was obtained simply by adding stone ochre — an iron oxide — to white lead paint.

Prior to the year 1865, lock gates were built by private contractors on competitive bid, and the specifications covered how the new gates were to be painted. Any routine repairs that the existing lock gates required, including the replacing of damaged or rotted timbers and planking, was done by the Rideau Canal staff who then painted the new members. However, in the winter of
1864-65, two of the lock gates being repaired by the Rideau Canal staff proved unsound, and new gates had to be constructed. These proved cheaper to construct than the gates let on contract, and the Superintending Engineer requested permission to have his staff construct lock gates.\textsuperscript{109} The following winter, five pairs of lock gates were built by Robert Driscoll of Smiths Falls on contract;\textsuperscript{110} but by September 1866, permission was obtained to employ four carpenters of the Rideau Canal staff over the winter in constructing the lock gates required for the next year.\textsuperscript{111} Thereafter, all lock gates were constructed by the Rideau Canal staff; and separate appropriations were made for a number of years to cover the cost of painting the new lock gates.\textsuperscript{112}

The existing gates were apparently also re-painted each year. The Annual Reports of the Department of Railways and Canals during the 1890's comment to the effect that the customary spring repairs carried out by the lockmasters and locklabourers consisted of "pointing and grouting the lock walls, and painting the gates".\textsuperscript{113}

Today, lock gates are built by Parks Canada staff at the Centre Street Yard, Smiths Falls, where three carpenters and four labourers are employed year round. The gates are renewed at a rate of six pairs per year, and replaced with gates framed similarly to those first erected on the canal. The planking is still put on with splines in the joints, but no caulking is used. Prior to constructing the lock gates, the wood is pressure treated with chromated copper arsenate (C.C.A.). This procedure was commenced in 1974 on four pairs of gates, and used on all gates after 1977. It is expected to increase the life-span of the gates from the 12 year average of the previously untreated gates, to a life-span of 20 to 24 years.
The iron reinforcing plates have now given way to hot-dipped galvanized steel plates which are covered with a fast drying white primer. The iron castings are coated with a red oxide primer, and all of the metal work is then given a single coat of black marine enamel. The treated woodwork of the lock gates is given a single coat of exterior grey enamel, with the gates being repainted every year above the water level.114

Gate-Operating Mechanisms: a) The Floor Chain Crab System
Once a plan had been developed for the lock gates as construction proceeded on the Rideau Canal in 1826-32, the next problem was to devise a system for operating the gates. The simplest, and most common, system for operating lock gates was by means of a balance, or swing, beam mounted across the top of each gate leaf. However, on the Rideau project the Royal Engineers were of the opinion that the extreme width, some 19' - 6", and consequent great weight of each gate leaf exceeded what could be properly swung by a balance beam. In devising a system for operating large lock gates, the Rideau Canal engineers had two aims in mind: 1) to use a single crab for both opening and closing the gate leaf; and 2) to keep the machinery as simple as possible.115 Guided by these aims, they developed a system that may well have been unique to the Rideau Canal: the floor chain/crab system (Fig. 59). This system, apparently of Colonel By's own devising, had been intended for use on the large 50 by 150 foot steamboat locks that he proposed to build on the Rideau Canal; but was adopted for the lock gates of the 33 by 134 foot river steamboat locks actually constructed.

In the floor-chain system, one end of an endless chain was attached to the front of the gate at the base of the
mitre post in the lock chamber. From there the chain passed around an arc of three sheave blocks anchored to the masonry floor of the gate-pit, under a sheave of a set of pulleys at the base of the gate-recess wall, and up the wall and over a sheave of a second set of pulleys mounted on the edge of the wall coping. From there the chain passed to a crab mounted on the coping with its barrel parallel to the lock chamber. The chain then wound round the barrel several times, and passed back over the other sheave of the pulleys on the edge of the coping, down the lock wall and under the second sheave of the set of pulleys at the base of the gate-recess wall. From there the chain passed around the arc of the three sheave blocks in the direction of the lock gate when closed. At the gate, the chain passed under the mitre post, around a pulley anchored to the front of the masonry sill below the gate, and returned to the mitre post. That end of the chain was then attached to an eye fixed to an iron band around the base of the mitre post. Turning the crab in one direction drew the gate open, and turning it in the opposite direction pulled the chain around the mitre sill pulley drawing the gate leaf closed against the mitre sill.\textsuperscript{116}

There are a number of drawings extant of the sheave blocks, pulleys, and the crab used in opening and closing a gate leaf in the floor-chain system. They may be described as follows:

The pulleys on the edge of the lock wall coping consisted of two sheaves mounted side by side with a horizontal axis, on a 1" thick, 3\footnotesize{1/2}" by 24" flat iron base. The edge of the coping was chamfered to receive the plate which was anchored to the masonry with two fox-bolts. The coping pulleys were of the same design as the twin pulleys mounted on the lock wall coping at a later date when crabs were employed to operate the new wall-face valves which were
installed to replace the in-tunnel sluice valves at the upper gates. The latter set of coping pulleys was probably based on the same design plans, or patterns for the castings (Fig. 48).

The gate-recess pulleys, at the base of the gate recess wall, had two sheaves mounted side by side on a horizontal axis in a frame of angle iron 8" by 8" by 1" thick. The frame was anchored to the gate recess floor with two fox-bolts. (Fig. 64)

The three sheave blocks on the gate-recess floor, each consisted of a cast iron housing containing two sheaves mounted on a vertical axis. The cast iron blocks were equally spaced along the arc described by the mitre post on the gate being opened. The middle of the three sheave blocks, called a "Tail Block" by the Royal Engineers, differed from the other two in its base configuration. The tail block was held to the masonry floor by three anchor bolts passing through a horizontal tail plate which formed was an extension of the base of the sheave block. The other two sheave blocks had no tail plate, and were anchored to the floor by a single bolt of ¼" diameter that acted as a pin in passing through the axis of the sheaves (Figs. 64 & 59). The housing of all three sheave blocks was about 9" in diameter and 7" high. A separate tab of flat iron, 1½" wide by ¼" thick, with an eye formed in one end, was held in place on the top of the sheave block by the sheave pin/anchor bolt, and the tab was bent down across the two sheaves, a section of which protruded from openings in the casting (Fig. 65). Extant drawings indicate that the tab kept both lines of chain in place against the groove of their respective sheave, but this is questionable. The chain affixed to the front of the mitre post had to be free to drop off the sheave block, or otherwise the gate leaf
On the upper left are views of the roller wheel for supporting the lock gate, below and to the far right the crab/curved swing beam system adopted in 1835 with reinforcing rails on the gate. Across the bottom are the sheave block, gate recess pulley and mitre sill pulley of the crab/floor chain system shown in the centre.
FIGURE 65


R4-026-F-0031

Sheave block and Tail sheave block of the original crab/floor chain gate operating system.
could not have been swung open. It would have been stopped at the first sheave block. Indeed, during the 1830's when swing beams were added to the lock gates and the endless chain and sheave blocks were re-positioned in an arc on the lock wall coping, only one chain was confined to the sheave blocks. In the new system of similar layout to the floor-chain system, one chain passed straight across the chord of the arc of sheave blocks directly to the crab. (Fig. 64) This agreement was probably adopted in response to problems experienced in trying to run both chains around the arc of sheave blocks, as was attempted in the original floor-chain system.

Today, on the lock gates operated by the crab/swing beam system, there are two sheave blocks on an arc quadrant with a single pulley on a horizontal axis (Fig. 69). The single pulley is positioned on the edge of the lock chamber coping, with the crab at the other end of the quadrant, much farther back. The two sheave blocks in between on the arc are of the same design as the original floor-chain sheave blocks, except that the tab confines only the bottom chain to its sheave groove. The upper chain on its sheave is left free to lift off as the outer end of the swing beam swings across overhead (Fig. 66). On swinging the gate leaf open, the outer end of the swing beam passes back over the arc of sheave blocks and the chain attached to the end of the swing beam drops back down into the grooves of the upper sheave. This is probably the way in which the original sheave blocks of the floor-chain system worked. The early drawings showing the tab confining both chains are either a misrepresentation, or the sheave blocks were modified during installation to make them work. Several early watercolours of the Rideau Canal locks, dating from ca. 1840, also show the two lines of chain passing around
66 Swing Beam Sheave Block (Photo by author, 1978). On the existing sheave blocks, contrary to the early drawings, the bottom chain is confined by the tab and the upper chain is free to lift off.
the arc of sheave blocks on the coping of the lock (Fig. 68). This shows that the original system could be made to work with the swing beam on the gate leaf, as well as with the floor chain system of operation.\textsuperscript{122}

The single mitre sill sheave of the original crab/floor chain system was mounted in an angle iron frame, and had a vertical axis. It was anchored by two fox-bolts passing horizontally into the raised face of the mitre sill masonry (Figs. 64 & 59). The chain passing round this pulley was let out in one direction on the gate being cranked open, and drawn in around the pulley in the other direction to pull the gate closed against the mitre sill on the crab being cranked in the opposite direction. In opening the gate, the crab might also have been turned back quickly in the opposite direction on the gate leaf nearing its full open position, using the mitre sill pulley as a snub pulley to stop the gate movement. A wooden block was also positioned in the gate-recess against the wall to act as a stopper for the gate leaf at the end of its travel in opening.\textsuperscript{123} (Fig. 59)

The crab in the floor-chain gate operating system was of the same general design as the crab used for operating the in-tunnel sluice valves on the Rideau Canal locks. The only difference of note was that the drum, or barrel, in the gate operating crab was of a greater diameter. There may also have been a difference in the gearing of the two crabs. The crab for operating the sluices was of a conventional design with a large gear-wheel keyed on the shaft of the drum. The gear-wheel and drum were rotated by a pinion gear on a crank shaft positioned directly above and parallel to the drum shaft. A crank handle was keyed to each end of the crank shaft for turning.\textsuperscript{124} Several early rough sketches show the gate-operating crab without any gearing.
The crank handles are mounted directly on the ends of the drum shaft as in a simple winch. However, these rough sketches may well be inaccurate. Where the floor-chain system has survived, at one of the Ottawa locks and one of the Kingston Mills locks, the gate-operating crab is geared in the same manner as the sluice crabs. The only difference in design being that the sluice crabs still have a smaller diameter drum.

The Royal Engineers referred to the crab used in the floor-chain system of operating the locks gates variously as a "crab", a "crab windlass", and a "capstan". The term "crab", however, is the correct appellation. Crabs were mechanical devices with a horizontal drum rotated by a gearing system consisting of a large spur-gear mounted on one end of the drum shaft and a pinion gear mounted on a parallel crank shaft with turning handles. "Windlass" is a nautical term for a winding device with a horizontal drum, used for weighing anchor on small vessels. It often was rotated by means of hand spikes slipped into pigeon-holes on the extension of the drum. The windlass was equipped with a pawl and ratchet gear to prevent the drum rotating backwards on the spikes being removed for re-insertion. The term "capstan" is totally inappropriate when applied to the Rideau Canal mechanisms. Capstans always have a vertical axis/drum, and generally were rotated by means of capstan bars inserted into square pigeon holes in the drumhead at the top of the capstan.

Provenance of the Iron Work: The Castings

The heavy castings for the lock gates, as well as the chains for the gate operating system, were supplied to the contractors by the Royal Engineers of the Rideau Canal
staff. The 3/8" patent chains were of English manufacture, and it appears that they were procured from the Naval Dock Yard stores at Kingston.\textsuperscript{133} All of the heavy castings --- such as the heel post boxes, the anchors, the trucks, the sluice valve plates, gudgeons, sheave blocks, sheaves, pulleys, and crabs, --- were purchased by the Commissariat Department in Montreal from the Bell foundry (Les Forges du St. Maurice), eight miles up river from Trois Rivières at the junction of the St. Maurice and St. Lawrence rivers in Lower Canada.\textsuperscript{134}

In the spring of 1829, the Bell foundry had contracted to supply some castings for the Rideau Canal locks,\textsuperscript{135} and on the castings being forwarded by Bytown, Colonel By was highly impressed with the malleable nature and toughness of the iron. Up to 40 tons of heavy iron castings would be required on the Rideau project, and for some time By had been concerned to ascertain the quality of castings obtainable in the Canadas. A poor or brittle casting could cause a serious accident, for example, if an anchor plate gave way. Not only was the Bell foundry metal reputed to be the best produced in the Canadas; but By had observed that Canadian castings in general were far superior to what was produced in England.\textsuperscript{136} As he explained to his superior, Colonel Durnford:

> the metal in this Country being melted with Charcoal, and absorbing a portion of Carbon, renders it tough and more malleable than the English Iron which is melted with Sea Coal.\textsuperscript{137}

The iron castings for the Rideau Canal could have been obtained in Upper Canada from the Marmora Iron Works;\textsuperscript{138} but By insisted that the Commissariat Department purchase the castings from the Bell foundry. Indeed, he recommended that the castings not be advertised for competitive tenders on the grounds that:
it is better for Government to pay a fair price for an acknowledged good Article, than to risk having an inferior article at a lower price.\(^{139}\)

As it turned out, as was often the case with By insisting on quality materials, the price ultimately obtained was reasonable. The castings were purchased at a discount from the Bell foundry for £22.10 per ton;\(^{140}\) whereas the price of the Marmora castings was 25 shillings per cwt. (£22.6 per ton), and imported English castings would have cost £21 per ton, including transportation.\(^{141}\)

At Bytown, fully dimensioned free-hand sketches were made by N.H. Baird, the Clerk of Works, setting forth the design details of the castings required for operating the lock gates. The sketches, once approved by Colonel By, were then taken to the Carpentry shop.\(^{142}\) There patterns, or what the Royal Engineers variously referred to as "moulds" or "mouls", were made.\(^{143}\) The wood patterns were made to the exact scale required and fully duplicated the particular casting required, complete with moving parts that could be disassembled in the same manner as the finished casting. The sheave blocks, for example, had wooden sheaves inserted on a wooden pin. The patterns were then forwarded to St. Maurice where the sand moulds were made to receive the pour of metal.\(^{144}\)

**Gate-Operating Mechanisms: b) The Swing Beam/Crab System, 1834-35**

During the first three seasons of operation, all of the Rideau Canal lock gates were operated by the floor-chain/crab system. The system worked well; but difficulties were experienced as the floor-chain system proved susceptible to jamming from chips of wood and/or pebbles lodging in the sheave blocks on the floor of the lock. This was a particularly severe problem at a time when the timber trade
was being carried on along the waterway and its tributaries, and saw mills were being established. Occasionally long delays were experienced on the floor-chain system jamming. This was particularly so when the jammed sheave blocks were at lock gates, other than intermediate gates of combined locks, where the floor-chains were continually under water, necessitating the employment of divers to clear the system. Faced with this problem, the Royal Engineers decided during the 1834 navigation season to make a trial of the more conventional balance beam system for operating the lock gates.\textsuperscript{145}

The swing beam designed by Captain Bolton, the superintending engineer for the Rideau Canal, was an oak timber 41' - 2'' long and 13'' square, tapering downwards toward the mitre post end of the gate. The beam was curved both in the vertical and horizontal plane, and was bolted along the back of the lock gate at the quoin post and mitre post. The outer end of the swing beam extended 21 feet out beyond the top of the quoin post, and the opposite end curved downwards across the back of the lock gate leaf to the mitre post at the level of the first rail below the top rail (Fig. 64). The curved section between the quoin and mitre posts was made by sawing five longitudinal cuts into the end of the timber parallel to one another for a distance of 10 feet, and then steaming the wood in a steaming box. Once bent, two keys were inserted on the bent section consisting of, in each case, a small metal plate held in place by means of two bolts passing through the whole thickness of the swing beam in the same manner as in "kerfing" timber (Fig. 67). The outer extension of the swing beam beyond the quoin post was also curved, in this case in the horizontal plane, but it appears to have been bent solely through steaming the wood.\textsuperscript{146} (Fig. 64)
Plan of Swing Bar with method of working the same, Ottawa Canals, D. Bolton, 10 December 1839.

This drawing of the crab/curved swing beam system introduced on the Ottawa Canals in 1840, shows how the swing beam was bent by making five longitudinal saw cuts in one end and steaming the wood. The swing beam introduced earlier, in 1835, on the Rideau Canal was bent in the same fashion, but also curved in the horizontal plane.
To swing the beam, Captain Bolton moved the arc of sheave blocks and endless chain up on the coping of the lock wall and re-positioned the crab.\textsuperscript{147} (Fig. 68) The working parts of the new system were readily accessible for inspection or repair and performed so well under trial, that it was decided to begin converting the floor-chain/crab gate operating system over to the swing beam/crab system during the fall of 1835.\textsuperscript{148} The change-over to the swing beam/crab system, however, proceeded slowly in a piecemeal fashion and the conversion was never totally completed. During the 1860's, for example, there were still a large number of locks being operated by the original floor chain/crab system, and conversion to the newer system was made only as the chains and sheaves blocks wore out and required replacement at a particular lock station. The replacements were then mounted on the lock wall coping in conjunction with the addition of a balance beam to the top of the gate leaves.\textsuperscript{149} The relatively slow transition to the swing beam/crab system on the Rideau system as a whole suggests that the original floor-chain/crab mechanism probably functioned quite well at locksites not immediately downstream of saw mills. The debris from saw mills caused innumerable problems at certain locks throughout the better part of the 19th century.

By 1850, if not earlier, the swing beam variously referred to as a "swing bar" and/or "Swing beam", was simplified, strengthened, and incorporated into the lock gate structure.\textsuperscript{150} The modified swing beam was made much heavier than previously, 18" square at its outer end tapering down to 15" by 15" at the mitre post end. It was also straight in the vertical plane, and positioned directly across the top of the lock gate leaf, rather than bolted across the back of the gate frame as previously. Indeed,
Figure 68

View from the upper end of the Guard Lock at Hog's Back - looking towards Bytown, Thomas Burrowes, n.d. (PAO).
R4-003-A-009

Showing the curved swing beam, crab and double line of chain around the arc of sheave blocks on the lock wall coping of the Rideau Canal locks.
the modified swing beam replaced the foot board plank of the original lock gate design, and was mortised down onto the top of the quoin and mitre posts. Metal strapping, bolted to the quoin and mitre posts, held the swing beam firmly in place. A slight curve was retained at the outer end of the swing beam in the horizontal plane. Starting 11' - 3" back from its outer end, the beam curved 24" outwards. This curve outwards from the front of the gate was probably intended to keep the end of the swing beam from being struck by large vessels passing through on the gates being fully open (Fig. 77)

Drawings of the lock gates from the 1860's show that pine swing beams were substituted for oak in conversions carried on after that date; but the outer end of the swing beam is not shown making it impossible to determine how long the curve in the horizontal plane was retained. A photograph taken of a Kingston Mills lock ca. 1880, makes it clear that a perfectly straight swing beam was being installed on the lock gates by that date. The swing beams varied in length, ranging between 33 feet and 40 feet long. Today, twelve sets of the crab/swing beam system remain in use, and all have a straight swing beam. (Fig. 69)

A photograph taken of Locks #7 and #8 at Ottawa ca. 1860-63, shows that the arc of sheave blocks was not always used in conjunction with the swing beam/crab system of operating the lock gates. Where a stairwell, passing along the side of a flight of locks at the lock gates, prevented the deployment of the sheave blocks, a single vertical pulley was used with the endless chain and crab. One end of the chain was attached to a pin under the outer end of the swing beam. From there the chain passed directly to the sheave of the pulley on the edge of the lock coping,
Ottawa Locks, Swing Beam System (Photo by author, 1978).

Twelve sets of the crab/swing beam system have been retained in use on the Rideau Canal. All have the straight swing beam as shown.
went around the pulley, and back straight across under the swing beam to the drum of the crab set a distance back on the coping. The chain then wound round the drum several times, and passed back in a straight line to the pin on the swing beam where it too was attached. Turning the crab in one direction drew the gate leaf open, and in the other direction pulled it closed. This modification of the swing beam/crab system, in which the arc of sheave blocks was dispensed with, had been given a trial at a much earlier date as is evidenced by an 1841 Thomas Burrowes' watercolour of the Narrows lock and lock gates. However, the modified system must not have worked as well as the system did with the arc of sheave blocks as they continued to be employed wherever possible. Indeed, sheave blocks were replaced in kind throughout the 19th century as required, despite the additional expense they represented, and the few lock gates where the arc of sheave blocks could not be deployed were among the first converted to a newer push-bar system of operation.

There are a small number of artists' sketches of Rideau Canal locks dating from ca. 1840-50, and one as late as 1896, that depict swing beams in place on the Rideau lock gates without the operating mechanism. In effect, there is no hint or trace of the crab, endless chain, or arc of sheave blocks. These drawings, however, are invariably distant general vistas of the lock sites, the allowance must be made for artistic license. The artists either ignored such minor details, or they may well have been influenced in what they saw through eyes accustomed to viewing British and/or American locks. British and American locks were invariably smaller than those on the Rideau, and were generally operated by means of a simple swing beam pushed manually without the aid of any mechanical device or system.
Gate Operating Mechanisms: c) The Push-Bar/ Crab System, 1900-1901

A major change in the gate operating system of the Rideau Canal locks was inaugurated during the winter of 1900-1901. During the off-season, several of the lock gates at the Ottawa locks previously worked by the swing beam/crab system were converted to a new system employing a push-bar and crab (Fig. 70). At the same time, the push-bar/crab system was tried on new upper gates being installed on the Poonamalie and Chaffeys Mills locks.

In the new arrangement, a push bar 5" by 8" in cross-section and 30 feet long of Douglas fir, was attached to the front of the gate leaf by means of a pintle-hinge connection that enabled the push bar to pivot slightly on the gate being swung. The extended arm of the pintle shoulder was bolted along the top of the push bar, with the pintle fitting down into the socket or eye of a horizontal strap hinge bolted to the top of the mitre post just below the foot board crossing the top of the gate leaf. A cotter pin held the pintle in the hinge. The opposite end of the push bar passed directly beneath the barrel (or drum) of the crab which was re-positioned on the lock wall coping perpendicular to the push bar. To operate the push bar, the endless chain was again employed with the crab. One end of the chain was fastened to a hook on the push bar at the mitre post end, and from there the chain passed along the top of the push bar to the barrel of the crab. The chain wound round the barrel about 8 times, then passed out along the push-bar, and was fastened to a second hook at the outer end of the push bar. Turning the crab in one direction drew the chain attached to the mitre post end of the push bar toward the crab, pulling the gate open. Turning the crab in the opposite direction drew in the chain fastened to the
The push-bar system adopted in 1900-1901 showing the arrangement of the crab, push bar and chain.
outer end of the push bar, which extended far out beyond the crab on the gate being at its full open position. This pull exerted on the outer end of the push bar drew it back toward the crab, pushing the gate leaf closed.158 (Fig. 71)

In the new system, the long swing beam extending out beyond the quoin post across the top of the gate was eliminated and replaced by a gate member of equal cross-section but extending only across the top of the gate leaf. The arc of sheave blocks on the lock wall coping was also discarded. The crab and endless chain, of course, were retained and re-positioned for continued use. A great deal of care had to be taken in positioning the crab to prevent the push bar binding between the legs of the crab on the gate leaf being swung. Greased wooden blocks, and occasionally wooden rollers, were positioned six to ten feet to the rear of the crab to keep the extended end of the push bar from dragging on the ground during the working of the gates.159

It is not known why the push bar/crab system was tried in 1900-1901, or where the idea of employing such a system originated. Much earlier in 1829, a similar system had been designed for operating the lock gates of the Ottawa River canals --- the Grenville, Chute-a-Blondeau and Carillon canals --- then being constructed under the direction of the Royal Staff Corps. To work the lock gates, a long bar was hooked on a pin fixed to the top of the mitre post at the front of the gate leaf. The bar then passed through the legs of a small crab positioned on the coping of the lock wall, perpendicular to the bar. The only extant description of the crab is rather vague, but it appears that cogs on the drum of the crab, or perhaps a large gear wheel substituted for the drum, meshed with the teeth of a rack fixed to the travelling bar.
71 Push bar system, detail of drawing "Face of West Gate No. 5", n.d. (Rideau Canal Office, Smiths Falls). Assembly details of the push bar system for operating the lock gates.
Turning the crank handle of the crab in one direction caused the rack or toothed bar to draw the gate leaf open, and turning the crank handle in the opposite direction pushed the gate leaf closed. As initially designed, the cogs were to be either of iron or oak construction, and it is not known which material was actually used. A roller at the rear of the crab, kept the rack-bar in line during its travel.

The rack-bar/crab system of operating the lock gates on the Ottawa River canals was designed by Major Henry DuVernet, the superintending engineer of the Royal Staff Corps on that project. The design was based on a system he had seen in use on a lock in the dock at Antwerp and at Ostend in the Netherlands. A similar device was in use on a number of American barge canals locks in the mid-19th century; but there the crab and toothed rack were mounted on a platform directly above and in line with the centre of the lock chamber just clear of the lower gates where headroom was not a problem for barges.

The rack-bar/crab system used on the Ottawa locks closely approximated the layout of the push bar/crab system adopted in 1900-1901 for operating the Rideau Canal lock gates. The only major difference was that the endless chain, wrapped round the barrel of the crab, was used to operate the new Rideau system rather than a cog wheel/toothed rack drive system driven by a crab. However, the Rideau Canal system was not based on the Ottawa lock gate operating system as it had been abandoned years before, and was probably forgotten by 1900. Indeed, had it not been forgotten, the experience with the Ottawa canals gate operating system would probably have discouraged any later experimentation with a similar system on the Rideau Canal.
As early as 1839, Major Bolton the superintending engineer for the Rideau and Ottawa canals, stated that the rack-bar/crab system in use on the Ottawa canals was placing a great strain on the gates in opening and closing, and was continually breaking down. From Bolton's viewpoint, the gate operating mechanism was poorly designed as in lock gate construction it was always considered imperative that the pull on the lock gate leaf in opening and closing should be as close to the bottom of the mitre post as possible to minimize any wracking strain on the gate being swung against the water pressure. On the Ottawa locks, the problems experienced suggest that the gates may well also have been poorly designed or fitted --- either not sufficiently rigid to withstand the wracking strain or such that they worked heavy. Whatever the case, during the winter of 1839-40 Bolton had the rack-bar/crab system of the Ottawa lock gates replaced with the same curved swing beam/crab system that he had introduced on the Rideau Canal as early as 1834.162 (Fig. 67)

On the Rideau Canal, the experimentation with the push bar/crab system on several lock gates in 1900-1901 proved satisfactory, and thereafter there appears to have been an effort to convert to the new system as lock gates needed replacing. However for the next few years, 1901 through 1905, the swing beams continued to be placed on a number of new lock gates constructed. This was probably done to use up the swing beam timber on hand, and what had already been contracted for from Messrs. Cameron and Company of Ottawa and a Mr. Ryan of Smiths Falls.163

Over the years, few changes have been made in the push bar/crab system. Sometime between 1900 and 1920, white and red pine were substituted for Douglas fir push bars, and the dimensions of the 30 foot long push bar were reduced from 5"
by 8" to 5" by 7". The wood rollers positioned to the rear of the crab were replaced in most cases with a single steel roller, although at some locksites the greased wooden block continued to be used to support the push bar when extended out through the crab. At one point prior to 1920, wire cables were substituted for the endless chain by way of experiment, but the wire cable did not work as well as the 3/8" chain, and the experiment was discontinued.

When initially introduced on the Rideau Canal in 1900-1901, the push bar was often called a "draw bar". However, this was a misnomer as in working the gates the bar itself does not draw the gate leaf open. The gate is pulled open by the chain hooked to the mitre post end of the bar as the chain is wound up by the crab. On the other hand, the bar does push the gate leaf closed on the crab winding in the chain attached to the outer end of the bar. Hence the more proper terminology is "push bar", and that is the term that came to be used on the Rideau Canal by 1920.

Gate Operating Mechanisms: d) The 1982 Systems

The conversion from the swing beam/crab to the push bar/crab system of operating the Rideau Canal lock gates was not carried out at all of the locks. Today, there are 61 sets of push bar/crab gate operating mechanisms and 12 sets of the older swing beam/crab operating mechanisms in use on the Rideau Canal, inclusive of the two locks built on the re-constructed Tay Canal branch in 1885-1891. In addition, the original floor chain/crab system designed by Colonel By is still in use on one lock gate leaf of an Ottawa Entrance Valley lock (Figs. 72 & 73) and on one gate leaf of a Kingston Mills lock. In both cases obstructions near the lock gate, a building and a vertical rock cliff
FIGURE 72

72 Lock No. 8, Floor Chain System (Photo by author, 1978). One of two lock gate leaves on the Rideau Canal still operated by the crab/floor chain system. The original cast iron sheave blocks have been replaced by flat sheaves on a quadrant of concrete.
73 Lock No. 8, Floor Chain System / Wall-face Sluice and Crab (Photo by author, 1978).

Here the difference in size is evident between the lock gate operating crab used in the floor chain system and the crab used to work the wall-face sluices.
respectively, prevented the deployment of either the swing beam/crab system or the more recent push bar/crab system. The opposite gate leaf in each case, however, was converted to the push bar/crab system.167 ..

Prior to Parks Canada taking over the Rideau Canal from the Department of Transport, a program of modernization was undertaken with respect to the gate operating mechanisms. Hydraulic cylinders were installed to operate new steel lock gates on the Newboro lock in 1966-67, and in 1969 hydraulic cylinders were installed to operate the gates of the Black Rapids lock. In the latter case, the wood lock gates were retained. Thereafter, the modernization program was aborted. This was a result of a growing interest in the Rideau Canal as an historic waterway which in 1967 saw the Historic Sites and Monuments Board of Canada recommend that the Rideau Canal and its structures be declared of national historic significance and preserved. This recommendation culminated ultimately in the canal being transferred to Parks Canada in 1972 with a mandate to maintain and operate the waterway while preserving its historical integrity.

During the course of the changeover from the Department of Transport to Parks Canada in 1972-73, a large concrete lock of 26 foot lift was constructed alongside the three flight locks at Smiths Falls, and that new lock too was equipped with hydraulically operated gates.

Today, Parks Canada is committed to a policy of replacement in kind where the lock gate mechanisms are concerned,168 thereby ensuring that examples of all three manually operated lock gate mechanisms will be preserved on the Rideau Canal: the floor chain/crab system designed by Colonel By during the canal's construction; the swing beam/crab system developed in 1834; and the push bar/crab system introduced in 1900-1901.
Testing the Lock Gates: 1831-1832

As of October 1831, the water was raised in the new Rideau Canal system from the Ottawa locks as far as Merricks Mills, and the steamer Union was put in service. At that time, the iron work and machinery of the gates, as well as the strength of the gates, was tested under actual working conditions. The design of the Rideau Canal lock gates and operating machinery was based for the most part on experience elsewhere in canal construction work with which the Royal Engineers and their support staff were familiar. However, the 33 foot wide Rideau Canal locks were much larger than any locks constructed previously in the Canadas, and their lifts in several instances were higher than any known to have been constructed to that date. This posed a serious design problem as to the strength required. The actual design of the Rideau lock gates, and their metal work, was relatively standard; but the actual dimensions of the timbers and castings were arrived at by a rough rule of thumb. In effect, the size of the members of the lock gate were augmented to what the Royal Engineers thought would compensate for the greater pressures to which the larger gates would be subjected. For example, the dimensions of the first Rideau Canal lock gates, for the 20 foot wide lock initially proposed for construction, were based on the Lachine Canal lock gates of similar size with lifts of 6 to 9 feet. There the quoin post of the gates was roughly 15" square, the mitre post 12" square, and the cross rails about 12" wide in the vertical plane (and probably square). The dimensions of the lock gate timbers on the 33 foot wide Rideau locks with lifts from 8 to 15 feet, were increased to 16" square for the quoin post, 13½" square for the mitre post, with cross rails 13" by 9", and the top rail being 13½" by 16" and the base rail 15" by 16". The spacing of
the rails was about the same for the proposed 20 foot wide
gunboat lock gates as it was for the larger 33 foot wide
steamboat lock gates actually constructed. At that
date stress calculations were unknown, and the adequacy or
inadequacy of the lock gate design could only be established
through testing after the water was raised in the canal.

On the water being raised in the Rideau Canal, it was
found that the scantling of the lock gates was
insufficiently strong to resist the water pressures to which
it was subjected on the locks of higher lift. In effect,
the 13" by 9" cross rails were too light for the lifts from
10 to 15 feet, and there was apparently some evidence that
the rails were in danger of buckling. To strengthen the
gates an additional cross rail was placed across the
planking on the front of each gate leaf in line with each
cross rail (Fig. 74).

The strengthening rail passed across the whole width of
the gate leaf, and was 10" thick in the middle curving
inwards and feathering out to nothing at each extremity.
The width, in the vertical plane, of the strengthening rails
varied. On the Jones Falls lock gates of 15 foot lift, for
example, the bottom strengthening rail on the lower gates
just above the sluice openings, was 14" wide, the next above
12" wide, and the next three above that 10" wide. To
stiffen the strengthening rail still further, a 1" by 5"
iron bar was let into the upper and under side of the rail,
and bolted together. Five long horizontal bolts passed
completely through the strengthening rail, the lock gate
planking, and the respective cross rail to bind the
strengthening rail and cross rail together as a unit. The
two outer bolts were centred on the head of the T-plate set
into the lock gate frame at all joints between the cross
rails and the mitre, or quoin, post. (Fig. 64) On the
A drawing of the original lock gate showing the reinforcing rail added to the front of the upper gates in 1831-32, and the bolt pattern of the reinforcing rails as seen on the rear elevation of the gate.
locks of lower lift, and on upper gates, a somewhat simpler strengthening rail was added which apparently did not have the iron bar reinforcing.\textsuperscript{174} (Fig. 74)

The addition of strengthening rails was the first change made in so far as the framing of the original lock gates was concerned. Thereafter, the gate design continued to evolve empirically in response to problems experienced under actual working conditions and the desire to improve the design of the gates through making minor modifications.

**Lock Gate Design Modifications: 1840**

In 1840 when new lock gates had to be constructed for the Hogs Back lock station, the lock gate design was re-examined by the Royal Engineers and two sketches were prepared providing for structural changes in the gates. Both sketches called for one dimension of the cross rails to be increased and for a closer spacing of the rails, within the gate frame. The changes were no doubt motivated by the inadequate strength of the existing lock gate design, and a desire to avoid adding strengthening rails to new gates erected on the canal.

In both of the 1840 sketches, the thickness of the cross rails in the vertical plane was increased substantially over the 9" uniform thickness of the cross rails in the original lock gate design. In the lower gates, the first cross rail above the sluice openings was increased to 15" thick, the next rail above to 13\(\frac{1}{2}\)" thick, and the next three rails above that to 12" thick. This represented an increase of 6", 4\(\frac{1}{2}\)" and 3" respectively in the cross-section measurement of the cross rails. Two members of the gate leaf frame were also increased in dimension. The quoin post remained 16" square and the base rail remained 15" thick by 16" wide tapering downwards toward the
mitre post. However, the mitre post was increased by \( \frac{1}{2} \)" in both dimensions to 14" square, and the top rail was increased from 13\( \frac{1}{2} \)" thick in the vertical plane to 14" thick. The gate planking remained 3" thick (Figs. 75 & 76).

Within the gate frame, the spacing of the cross rails was reduced by the increased thickness of the cross rails, thereby in effect further strengthening the lock gate leaf. Consideration was apparently given to halving the spacing between cross rails at the bottom of the gate and reducing the spacing by lesser amounts toward the top of the gate. This spacing, if adopted, would have also necessitated the insertion of an additional cross rail; but the final spacing adopted, which ranged from 1' - 10\( \frac{1}{2} \)" just above the sluice openings, through 1' - 11\( \frac{1}{2} \), 2' - 0\( \frac{3}{4} \), 2' - 1\( \frac{1}{4} \), to 2' - 8\( \frac{1}{2} \)" at the top of the gate, virtually maintained each cross rail on the same centre line as in the original design for locks comparable lifts.\(^{175}\) The obvious uncertainty over whether the cross rails should be even more closely spaced to further strengthen the lock gates probably reflects the state of engineering at the time. Stress calculations were unknown where wood lock gates were concerned.

With the closer spacing of the cross rails, attention focused on the bracing between the rails. In one October 1840 sketch, Sketch No. 1, the pattern of the bracing in the original lock gate was to be retained with the vertical line of munnions between the cross rails directly over the roller wheel, and the diagonal bracing in each panel.\(^{176}\) (Fig. 75) However, in Sketch No. 2, of the same date, the wood diagonal bracing was totally eliminated, and the munnions were to be replaced with iron brackets bolted between the cross rails on the same alignment as the munnions.\(^{177}\) (Fig. 76)
In the 1840 lock gate plan, the size of the timbers was increased and the spacing between the cross rails reduced to eliminate the need for adding strengthening rails across the face of the gate.
In this proposed 1840 design, the diagonal bracing was to be removed and metal brackets or spacers positioned in line above the roller wheel between the more closely spaced heavier cross rails of the new lock gate design.
Lock Gate Design Modifications: 1850

In 1850, the design of the Rideau Canal lock gates was further modified in detail by the Clerk of Works, Mr. Harvey. The dimensions of the timber members in the gate leaf and the spacing of the cross rails remained virtually the same as in the strengthened 1840 lock gate design; but the gate leaf was made more rigid. In addition, changes were made in the joinery of the gate and in the reinforcing plates at the framing joints.

To render the lock gate leaf more rigid, iron tension bolts were added on alternate sides of a line of munnions positioned near the centre of the gate. Where previously the individual munnions or brackets were positioned in a line between the cross rails to maintain a rigid spacing, now each bolt passed through two rails and served to draw them together against the munion between the rails. The bolts were off-set one from another, alternately to either side of the respective munion. In effect, the bolts overlapped so that each rail was tied to the rail directly above and directly below, and all of the rails were tied together as a unit. The bolts were of varying lengths to take account of the variations in spacing between the rails and the differing thickness of the rails. Overall, the bolts ranged from 4 feet to 6 feet in length, were about 1" in diameter, and were threaded to take a nut (Fig. 77).

The rigidity of the gate leaf frame in the 1850 design was increased further, and the frame strengthened against sagging, through the introduction of a metal tie bar. It passed on a diagonal from the base of the mitre post across the back of the gate to the top of the quoin post just below the anchor collar. The tie bar was bolted to the mitre post and quoin post at each extremity, and a turn buckle near the upper end enabled the tension to be adjusted. In the 1850
The 1850 lock gate design with the tie bar/turnbuckle, the swing beam curved only in the horizontal plane, and the tension bolts on either side of the vertical munions. The planking splines and tenon details are also shown, as well as the curvilinear face of the gate.
design, the swing beam then being employed to operate new lock gates, passed directly across the top of the gate leaf. It was mortised down on the top of the heel and quoin posts and held rigidly in place by means of metal straps bolted to the posts, thereby further stiffening the lock gate frame. The dimensions of the mitre post were also increased from the 14" x 14" of the 1840 plan to 15" x 15", and the rails were increased in width through the gate to 15". The thickness of the rails in the vertical plane remained almost the same as strengthened 1840 rails, varying according to their position in the gate. In effect, the cross-rails were 15" x 15", 14" x 15" and 13" x 15" in dimension.

Where the framing of the gate was concerned, the major change involved the mortise and tenon joints. In all previous Rideau lock gate designs, the tenons had passed all of the way through the quoin and mitre posts; but in the new design, the tenons of the rails were made to pass only half-way into the quoin and mitre posts. The reinforcing plates were also modified. Previously the head of the T plates at each joint had contained only three bolts, one on the centre line of the rail, and one to either side. In 1850, the heads of the T plates were lengthened and several were forged together with an additional strip of metal so that the reinforcing plate extended for a much greater length along the quoin and mitre posts. Indeed, at the top and bottom of the gate leaf, the reinforcing plates and bolts through them, extended unbroken in a line across two sets of rails.

In the 1850 lock gate design, the face of the lock gate is shown for the first time as being curvilinear in plan, somewhat wider in the centre and tapering toward the quoin and mitre posts. This was a standard feature on large lock gates constructed in England by the mid-19th century, if not
earlier, and was a good design feature as the curvilinear section in plan possessed greater strength to resist water pressure than a comparable lock gate of straight section.\textsuperscript{180} It appears that this feature was adopted in 1850 as none of the drawings of the earlier lock gates show that particular detail. The original lock gates were definitely tapered downwards from the quoin post to the mitre post straight across the back of the gate leaf to compensate for the fact that the quoin post was 16" square and the mitre post only 13\textfrac{1}{2}" square. The 1850 lock gate plan is also the first to show the 1\textfrac{1}{2}" by 1" iron spline or tongue inserted between the planking joints. The splines, however, were a feature of the original lock gate design that was retained.\textsuperscript{181}

**The Jones Falls Lock Gate Collapse, July 1869**

Lock gates requiring replacement on the Rideau Canal were constructed in keeping with the 1850 design of Mr. Harvey, the Clerk of Works, from 1850 through 1864 when the gates were again re-designed. However, a number of gates of the 1850 design continued in use long thereafter, and supposed deficiencies in that design were blamed initially for a lock gate collapse at Jones Falls.

At 7:30 P.M. on Friday, July 16th 1869, a barge loaded with fire wood entered into the upper chamber of the three combined locks at Jones Falls from the intermediate basin. Almost immediately the lower gates of the upper lock burst, and the force of the flash of water and debris carried away the other gates in succession, leaving only the bottom pair of gates on the river lock, and the top pair of gates on the upper lock, extant. A local farmer Michael Timblin, who had just stepped onto the barge, was drowned and Michael Kelly a barge hand was badly injured. Kelly was rushed immediately
to Bytown by steamer to obtain medical attention, but died of his injuries. Navigation on the canal at Jones Falls was interrupted for a month while new lock gates were constructed, and an investigation held into the collapse of the lock gates in conjunction with a coroner's inquest into the deaths of the men.182

On examining the burst lock gates, it was found in every case that the quoin posts had split from the bottom to the top along the line of the bolts through the reinforcing plates with half of the quoin post left standing in the quoins. These gates were all eleven to twelve years old, dating from 1857 and 1858, and were built in keeping with the 1850 lock gate design with the tenons framed only half way into the quoin and mitre posts and the reinforcing plates extending further along the posts than previously. The wood was still sound, and under normal conditions the gates would not have been replaced for another five or six years. On the other hand, the lower pair of gates, which had withstood the onrushing water and debris, were about 4 years old and framed differently in keeping with a new lock gate design of 1864. In that newer design, the tenons were made to pass all of the way through the quoin and mitre posts, and were wedged. In view of this obvious difference in the framing of the gates and the nature of the injury suffered by the collapsing gates, the Rideau Canal staff including the superintending engineer J.D. Slater, the Clerk of Works Francis Abott, and the Lockmaster Peter Sweeney, was convinced that the Jones Falls accident was caused by the "faulty" framing system adopted for the lock gates in 1850.183

In view of the fact that it was the quoin posts that had split, it was concluded initially that this failure was owing to a specific fault in the 1850 lock gate design:
that the tenon passed only half-way through the quoin post, and each cross rail had two draw bar holes through the tenon in line with three bolt holes in the elongated head of the reinforcing plates. On the long gates at Jones Falls, where there were eight cross rails on the locks of 15 foot lift, this meant that there were 40 holes in a line over the length of the quoin post. In contrast, in the older lock gate design there were only three holes relatively closely spaced at each junction of the cross rail with the quoin post: single draw bar hole through the tenon, and a bolt hole to either side through the reinforcing plate. Hence it was concluded that the extended line of bolt holes up the quoin post had seriously weakened it, causing the collapse of the gates.\textsuperscript{184}

It was further speculated that the water pressure alone had not caused the accident at that particular moment in time, but rather that a piece of firewood or waterlogged debris must have lodged between the mitre sill and the base rail of the gate, preventing it from closing tightly against the sill. The pressure of the water would then have forced the top of one gate past the other, twisting the gate leaf, and in that manner would have precipitated the accident. All of the gates struck by the onrushing water, the barge, and debris, would then have split at their weakest point, viz. along the line of the bolt holes in the quoin post. This explanation as to what had precipitated the lock gate collapse was suggested by a similar accident at Kingston Mills in 1860. There a piece of wood jammed against the mitre sill had caused a pair of gates to collapse in the same manner.\textsuperscript{185} The initial explanation, blaming a fault in the 1850 lock gate design for the Jones Falls tragedy, was quite plausible; but a further investigation revealed the true cause of the lock gate collapse.
On more closely examining the Jones Falls locks and interviewing the lockmaster and lock labourers, it was determined that the cause of the gates bursting was not a design fault, but rather the result of developments over time caused by poorly constructed lock gates. The first pair of gates to give way, the lower gates on the upper lock, were constructed on contract by a Mr. Edward Dufton in the spring of 1858. These gates had been poorly built, and over time had settled at the toe. This sagging in turn caused the gates to overhang at the top, with the result that the top of the two gate leaves closed together first, leaving the pressure of the water to force the bottom of the gates in against the sill. The force of the water against the partially open bottom of the gates acted not only to twist the frame, but exerted a lifting force against the mitre sill. Over time, small sections along the edge of the sandstone mitre sill had been split or cleaved off, and the bearing surface of the gate against the sill had been further reduced by wear on the base of the mitre post. When new, the mitre post had overlapped the sill by 5", but after eleven years the bottom had become rounded reducing the overlap to three or four inches. With the reduced bearing surface against the sill and the great pressure being exerted against it by the water acting on the poorly fitting gates, on July 16th 1869 the sill and gates had given way.

Investigation showed that the top edge of the mitre sill had been cleaved off to a depth of 5" at the centre petering out to nothing at a distance of 9 and 10 feet respectively on either side. Once the mitre sill had cleaved, the water pressure on the gate had immediately crushed the bottom of the mitre posts against the broken sill. At the same time, the gates were driven up over the
sill and the quoin posts split from bottom to top as the gates were torn away. The force of the water released by the first pair of gates giving way had then carried away the next two pairs of gates in succession.

The splitting of the quoin posts was not attributed to the large number of holes drilled through it in keeping with the 1850 lock gate design. Rather it was concluded that the anchor collar and gudgeon/foot box had held the quoin posts firmly in place causing the posts to split on the gates being torn away. Something had to give. Had the quoin post not been held firmly in place at its base, experience on the St. Lawrence Canals suggested that the bursting gates would have broken off the anchor collar, or would have torn away the anchor collar. In effect, it was the poor construction of the Jones Falls lock gates, and their subsequent sagging, that had caused their ultimate destruction in July 1869. No fault was found with the 1850 lock gate design. However, whether the 1850 plan of construction was weaker or not than the previous design was a purely academic question. The superintending engineer of the Rideau Canal, James Slater believed it was, and had developed a modified design several years earlier in 1864. All new gates constructed after that date had been built to the newer design, and after 1866 all gates were being built by the Rideau Canal staff, thereby improving quality control where the actual construction of the gates was concerned.

At the time of the Rideau Canal's construction, careful attention had been paid to the lock gates with Mr. Fitzgibbon, the Master Carpenter, overseeing both their construction and fitting into the lock. Once the water was raised and the gates in operation, a careful attention was again paid to ensure that each pair of gate leaves remained perfectly perpendicular at their junction. In addition to
any potential sagging of the gate leaf, wood shrinkage was a problem that had to be taken into account both in constructing the lock gates and in inspecting them in situ. Shrinkage could cause problems as it had on the Hartwell's lock gates in September 1831. There, Colonel By observed that:

the swelling of the lower part of the Gates from being constantly Wet and Damp, and the shrinking of the upper part of the Gates exposed to the action of Wind & Sun, ... although unperceptible to the eye has caused a sufficient alteration in the Square of the Gates to throw them out of the perpendicular when the full pressure of the Water is thrown on them.

This shrinking of the upper part of the lock gates at Hartwell's had placed a great strain on the anchor collar, and opened up a fine crack in the joint between the masonry block to which the anchor plate was fixed and the adjoining coping stone. To rectify this, the keys of the collar were slackened off, and a piece of iron shim was set into the facing mitre post surfaces. This made for a perfectly perpendicular joint which kept the lock gate straight, free of any twisting, and took any undue strain off the collar.

The Royal Engineers were obviously well aware of the critical importance of keeping the lock gates adjusted to the perpendicular, and constantly inspected them for any shrinkage or sagging that would bring undue pressure to bear on either the anchor collar/anchor plate, the gate frame, and/or the mitre sill. However, their successors were not as attentive to such details. The Jones Falls lock gates which had settled at the toe, were out of perpendicular at their junction for years, and had worked heavy for years yet no adjustments were made. Ultimately, undue pressure being exerted against the mitre sill over a period of time, brought disastrous consequences.
Lock Gate Design Modifications: 1864

The 1864 lock gate plan made remarkably few changes from the 1850 design. The dimensions of the framing timber remained the same, with the exception of the quoin post which was increased from 16" square to 16" by 17". The curvilinear shape of the gate face was retained, as well as the splines of iron in the joints of the 3" by 10" planks. The pattern of the munnions and overlapping tension bolts down the centre of the gate leaf remained unchanged; but the tension bar across the back of the gate was discarded. At least, the tension bar or tie is not shown on any of the several lock gates plans extant from ca. 1864-1865. Why it would be discarded is a mystery. Tension bars were regularly employed on British canal lock gates of any size to prevent sagging, and were considered a good design feature. Otherwise, the only design changes of note were in the positioning of the sluice openings in the lower gates, and in the joinery of the gates.

In the 1864 lock gate plan, the sluices in the bottom of the lower gates were moved. Previously the two sluice openings had been positioned in line as close as possible to the mitre post. In the new plan, they are still positioned between the base rail and the cross rail next above, but the munnion separating the two sluice openings is in the exact centre of the gate leaf (Fig. 78).

The major change in the lock gate design, however, was with respect to the mortise and tenon joints. In the 1864 design, the tenons of the rails once again passed all of the way through the quoin and mitre posts, marking a reversion back to Colonel By's original lock gate design. The tenons were also increased in size from the 3" width of the 1850 design to 5" in width. This latter width was in keeping with the practice in British canal lock construction.
The cross rail tenons now pass through the posts and the sluices are in the centre of the gate. The elongated T-plates have been retained and the tie bar discarded.
Here, diagonal planking was experimented with further strengthen the lock gate leaf. The sluice still positioned in the centre of the gate. The T-plates are not shown, but were retained.
in so far as the tenon to timber width ratio (1:3) was concerned; but on British lock gates the tenons customarily were mortised only half way into the quoin and mitre posts. Nonetheless the two changes in the joinery details were in response to what James Slater, the Rideau Canal superintending engineer, perceived as a weakness in the 1850 lock gate design. Indeed, lock gate specifications extant indicate that the joinery changes were made as early as 1861, and they may well date from Slater's becoming superintending engineer in 1858.

What was perceived later, following the July 1869 Jones Falls lock gate disaster, as the major weakness of the 1850 lock gate design was apparently not seen as such previously. In the 1864 design, the elongated reinforcing plates at the junction of the cross rails with the quoin and mitre posts were still retained with their long line of bolt holes running up the posts. At some time between 1864 and 1918, a reversion was made to the older type of T and L reinforcing plates with less elongated heads. As of 1918 only three bolt holes were made in each head. The T-plates as in Colonel By's original design, had a draw bore in the centre, passing through the centre of the cross rail tenon, and a single bolt hole just to either side. This change probably dates from directly after the Jones Falls lock gate collapse of 1869.

Just previously in 1865, consideration was given to planking the lock gates in a diagonal pattern so that the planks could act as a brace (Fig. 79). Whether this was done by way of experiment is not known as later drawings of the lock gates continue to show the planks in a vertical pattern, as they were in all previous Rideau Canal lock gates.
Lock Gate Design Modifications: 1918

Detailed lock gate plans from the year 1918 indicate that the only major changes in the Rideau Canal lock gate design over the late 19th century was in the positioning of the gate sluices and in the dimensions of the gate frame members. The mortise and tenon details were the same as in the 1864 gate, and between the cross rails the pattern of munnions and off-set tension bolts introduced into the middle of the gate leaf in 1850 was retained. The 3" by 10" vertical pine planks also had 1½" by ¼" metal splines inserted between them as in the original lock gate design. The T and L reinforcing plates are of the same pattern as originally used on the Rideau Canal lock gates in 1830-32, marking a rejection of the elongated T plates introduced in 1850 with their extended line of bolt holes passing up the mitre and quoin posts (Figs. 80 & 81). This design feature was retained in the 1864 lock gate design and, as mentioned previously, the change back to the older pattern of T and L reinforcing plates was probably made immediately following the Jones Falls disaster of July 1869.

In the 1918 lock gate plan the sluice openings in the bottom of the lower gates were moved away from the centre of the gate leaf. Down through the years, the sluice openings remained of the same size, approximately 5 feet wide by 1½ feet high, and were always framed between the base rail and the first cross rail above by means of munnions held in place with metal strapping bolted to the rails. In the 1864 lock gate design, the sluice openings were moved for the first time and positioned in the exact centre of the bottom of the gate. Sometime thereafter, as indicated by the 1918 plan, the sluice openings were re-positioned back adjacent to the mitre post. This older positioning of the sluices was more in keeping with traditional practice on
\textbf{FIGURE 80}


R4-026-F-0075

With the exception of the roller wheel now long since discarded, the lock gates constructed on the Rideau Canal today are a replica of the 1918 gate design shown here.
In the 1918 plan, the sluices have been moved back adjacent to the mitre post, and the elongated T-plates of the 1850's and 1860's have been discarded. The planking splines are shown below.
The basic design of the gate sluice valve mechanisms has remained unchanged since the construction of the canal. Compare this drawing and figure 81, for example, with figures 60 and 61.
canals elsewhere and good design practice. Placing the gate sluices as close to the mitre post as possible ensured that the jets of water shooting out from the pair of mitre gates would strike one against the other, reducing turbulence directly below the lock.¹⁹⁹ (Figs. 81 & 82)

The strength of the gates was again a concern in the late 19th century as indicated by the increase in the dimensions of the lock gate frame members. In the 1918 plan, the gate members are far heavier than in any previous gate design and their augmentation in size continues a trend towards strengthening the lock gates that started on the water first being raised in the canal in 1831. As of 1918, the quoin post was made 16" by 18", the mitre post 16" square, the top and bottom rails 15" by 19", and the intermediate cross rails a uniform 14" by 16". Compared to the 1865 lock gate plan, this represents a gain in thickness of 2" in one dimension of the quoin post, and 1" in both dimensions for the mitre post. Both the top and base rails, now 15" by 19", were in effect increased 1" in width at their centre, though continuing to taper downwards towards the mitre and quoin posts in keeping with the curvilinear form of the gate face seen for the first time in the 1850 lock gate design. The 14" by 16" intermediate cross rails were 1" wider than the 1865 cross rails. However, the thickness of the cross rails in the vertical plane was no greater than for most of the cross rails in the 1865 gate plan, and the spacing between the rails was approximately the same as in the first strengthened lock gates of 1840 and all subsequent lock gates.²⁰⁰ This last major increase in the dimensions of the gate frame timbers may well have been related to the concurrent introduction of Douglas fir in place of the oak, a heavier and stronger wood, used previously for framing the Rideau Canal lock gates.
Longevity of the Lock Gates:
During the construction of the Rideau Canal in 1826-32, there was no difficulty in obtaining locally oak trees that would yield the massive timbers required for constructing the lock gates, such as for the original quoin posts which were 16" square by some 26 feet long and the mitre posts 13½" square by 25' - 6" long. Some small scale lumbering had been carried out on the lower Cataraqui and Rideau rivers as early as 1800 and 1810 respectively, but lumbering did not penetrate into the interior forest until the canal was opened in 1832. Initially, the virgin forest of the Rideau corridor yielded excellent quality oak highly suitable for constructing lock gates, but this did not long remain the case.

During the 1840's a small number of lock gates had to be replaced through accident or deterioration in the wood, and at that early date the dwindling supply of local large dimensioned square oak timber had to be supplemented with "western Oak" brought from the western districts of Canada West (Ontario). However, by 1860 there was only one place where large-dimensioned oak timber could be purchased --- the Calvin and Buck shipyards at Garden Island near Kingston --- and a high price was demanded for it. This resulted in consideration being given to substituting rock elm or pine for the upper rails of lock gates, which were subjected to less water pressure than the lower rails. This proposal was not acted on; but in 1863, pine was substituted for oak in the case of the large swing beams, which rough cut were 13" square and up to 41½ feet long. With the opening of the Canadian Pacific Railway access was gained to the Douglas Fir of British Columbia, and by 1900 if not earlier Douglas Fir was substituted for oak timbers in constructing the Rideau Canal.
lock gates. At that time, the swing beams were also constructed of Douglas Fir.\textsuperscript{203}

The early substitution of oak from a different area of Ontario for local oak timber, and the later substitution of Douglas Fir had a marked impact in both instances on the longevity of the lock gates, despite all of the gates being painted to the same standards. The early lock gates constructed of local oak lasted on an average anywhere from 20 to 22 years, and there is one gate, erected on the low lift lock at Maitlands in 1847 that lasted for 27 years. The lock gates constructed of "western oak", from the western districts of Ontario, had a life span of one-quarter to one-third less,\textsuperscript{204} lasting no more than 15 years.\textsuperscript{205} The Douglas fir lock gates had an even shorter life span of about 12 years on an average.

Commencing in 1974, several gates were treated with a preservative, chromated copper arsenate, as were all new gates after 1977. This treatment is expected to yield a life-span of 20 to 24 years,\textsuperscript{206} thereby marking a return to the life-span achieved by the first gates erected on the Rideau Canal.

\textbf{Lock Gate Design Modifications: 1982}

The lock gates presently being constructed on the Rideau Canal are a replica of the 1918 lock gate. Since that time only one change of note was made in the gate leaf and one new design feature added: the gate bridle.

The gate bridle, of $\frac{1}{2}$" by 3\frac{1}{2} metal strapping, has its open end bolted to the mitre post at the second cross rail from the top. The closed end of the bridle slips over the threaded end of a closed collar loop placed around the lock gate collar at the quoin post. An adjusting nut on the threaded end of the collar loop enables the tension in the
bridle to be adjusted (Fig. 83). The bridle keeps the gate from sagging, and may well have been intended to compensate for the absence of the roller wheel on the modern Rideau Canal gate leaf. The gate bridle fulfills somewhat the same function as the metal tie bar. However, it was bolted directly to the bottom of the mitre post and the top of the quoin post across the back of the gate leaf. In the new design, the gate bridle under tension puts a strain directly on the lock gate/anchor collar --- a questionable design feature. Besides the gate bridle, the other new feature of the present gates is in the dimensions of the frame members.

In the 1982 design, the dimensions of the gate frame timber have once again been increased over their predecessors. The top and bottom rails are now 15" by 20", as opposed to 15" by 19" in the 1918 design, and the intermediate cross rails are 14" by 17", whereas in 1918 they were 14" by 16". The quoin post has remained the same size as in the previous gate design, 16" by 18". The increased width in cross-section of the lock gates, however, does not effect the vertical spacing of the cross rails which is approximately the same as it has been on all lock gates since 1840.

In appearance, the 1982 lock gate differs surprisingly little from the original Rideau Canal lock gates erected in 1830-32, but it does incorporate several design changes adopted during the course of the 19th century in addition to the new gate bridle feature. With the exception of the missing diagonal braces of wood and the narrow cross rails of the under-designed original gate, the gate frame today bears a strong resemblance to that originally constructed. The dimensions of the frame members have been increased gradually over the years, but the number of rails on locks
Figure 83

Front Elevation of Lower Gate, detail of "Typical Lower Lock Gate or Wet Gate", 16 April 1982 (Rideau Canal Office, Smiths Falls).

The gate bridle added sometime in the 1940's is shown. The sluice system has been modified somewhat. The rack and pinion gearing, the valve plates and counterweights are all of a slightly modified design than hitherto.
of comparable lifts has remained unchanged and the spacing is still close enough to the original to escape detection. The pattern of the framing of the quoin post, mitre post, and cross rails also remains as it was.

The pattern of munnions between the cross rails in the centre of the gate leaf today, is the same as adopted in 1850 and maintained on all of the lock gates ever since. The vertical tension bolts, introduced at the same time to tie the cross rails together, are still employed for that purpose. However, from the plans in hand it appears that the tension bolts are now placed on only one side of the munnions, and no longer overlap to tie all of the cross rails one to another. The tension bolts also are now of 7/8" diameter, rather than of 1" diameter as previously (Fig. 84).

The joinery of the gates, with the tenon being mortised all of the way through the quoin and mitre post and wedged, is the same as on all the Rideau Canal lock gates except the 1850 design. The present T and L reinforcing plates are of the original design and bolt pattern, differing only from the ill-fated 1850 gates with their long line of bolt holes passing up the quoin and mitre posts (Fig. 85). Oddly enough, the L reinforcing plate at the bottom corners of the gate leaf and the T plate directly above have been elongated and joined in the 1982 design. This is a partial throw back to the 1850 design of the reinforcing plates in that area of the gate leaf, but in the new design no additional bolt holes have been drilled in the posts. Otherwise, the framing details are exactly the same as on the original gates.

The vertical pine planking on the Rideau Canal lock gates has been retained down through the years. Although diagonal planking may have been experimented with during the
FIGURE 84

Rear Elevation of a Lock Gate, detail of "Typical Upper Lock Gate or Dry Gate", 2 April 1982 (Rideau Canal Office, Smiths Falls).

The dimensions of the gate frame timbers are shown, as well as the truncated swing beam put on gates intended to be operated by a push-bar. Note the absence of the roller wheel, the function of which is only partially compensated for by the gate bridle.
FIGURE 85

"Framing of Gaterails into Heel or Mitre Post", detail of "Typical Upper Lock Gate or Dry Gate", 2 April 1982 (Rideau Canal Office, Smiths Falls).

R4-026-F-0073

The mortise and tenon framing details shown here, probably have remained unchanged, with the exception of the 1850 lock gate design, since the construction of the first Rideau Canal lock gates in 1830-32.
1860's, it was not adopted. Metal splines are still inserted between the planks as on the original lock gates, but the splines or tongue irons are now 1" by 3/8" rather than 1½" by ½" as on all previous lock gates.

It is not known how the plank sheeting was set into the frame of the early lock gates; but the practice followed today may well represent an unbroken tradition where the mechanics of erection are concerned.

Whether framed at the locksite as previously, or at the Smiths Falls Yard shop as is the practice today, the construction process has remained the same as long as anyone can remember. The mortises are cut through the quoin and mitre posts, grooves cut to let in the head of the T-plates flush with the surface of the respective posts. The posts are then driven onto the cross rail tenons to form the gate leaf framework which is then squared up before the wedges are driven into the tenons (Figs. 86 & 87).

Today in planking the lock gates, splines are driven into the grooves along the edges of the planks, and the three outer planks on each side are painted on their edges preparatory to being driven against the quoin and mitre posts respectively. These planks are spiked, and the T-plates bolted into place. A rebate, or rabbet, cut along the inner edge of the posts, as well as on the top and base rails, lets the 3" by 12" planks in so that their face is flush with the surface of the gate leaf frame timbers. Then the splines are driven into the remaining planks, their edges painted, and they are in turn driven into place, each tight against the adjacent plank until only a small gap about 8" or so wide remains between the two converging sheets of planking near the centre of the gate leaf (Fig. 88).
FIGURE 86

Mortised mitre and quoin posts awaiting painting and framing, Smiths Falls Yard (Photo by author, 1983).

To the right are the cross rails with the tenon cut on each end and the face cut in its curvilinear shape. The indentations covering the surface of the wood indicate that it has been pressure treated with the preservative chromated copper arsenate.
A wood beam ram is being swung to drive the mitre post onto the tenon of the cross rails. In the centre of the gate, grooves have been cut in the rails to receive the munnions, and the tension bolts are in place for later tightening on the frame members being squared up, bolted and wedged.
88 Planking a lock gate on site, Ottawa Locks (Ashton Dale photo, n.d.)

Here the gate frame has been squared, the tenons wedged, the three outer planks on each side spiked down, and the T-plates bolted through at the cross rail joints. The splines are being driven into the planks and paint spread over the rails and plank edges preparatory to planking the centre of the gate.
The gap is measured, as well as any gap between planks that were not driven as tightly together as required. A plank, the "key plank", is then ripped to the required width, both edges grooved, and the edges painted. To enable the key plank to be inserted in the gap, together with the splines required on either side of the key plank, the tightly wedged plank sheeting on either side of the gap is jacked up about eleven inches and the key plank driven into the gap. In the raised position, the splines are also driven in, clear of the top rail, along either side of the key plank. Then the jacks are eased off and weights put on the sheeting to force the planks back down tight together against the rabbets of the gate frame members. Once forced back into place, the planks across the middle of the gate are spiked down completing the sheeting of the lock gate leaf.

The present swing beam along the top of the gate leaf is of a dimension and design intermediate between the original foot board and the 19th century swing beam. The original foot board, or step board, extended only across the top of the gate leaf and consisted of a 4" by 20" plank fixed to the top of the quoin and mitre posts. It did not extend beyond the posts. The swing beam adopted in 1834 was much larger, being 13" square by 41 feet long and extending out a good 21 feet beyond the quoin post. The original curved swing beam, of course, was replaced about 1850 by a straight swing beam of even greater dimensions: 18" square at its outer end tapering down to 15" by 15" at the mitre post. Commencing in 1900-1901 with the introduction of the push bar/crab system of operating the lock gates, the long heavy swing beams were gradually replaced by smaller beams. The 1918 plan, for example, shows a beam of Douglas fir that is 10" by 24", and indicates that the beam was sometimes constructed of two pieces 10" by 12".
On the push-bar gates, the so-called "swing bars" are only 24 feet long, extending about 4 feet out past the quoin post (Fig. 70). On the gates where the swing beam/crab system of operating the gates has been retained, the swing beam is a solid piece, somewhat larger, 15" by 16" and 29 feet long. Cleats, 5" by 8" and 3" by 5", are bolted alongside the swing bar on the section over the lock gate to provide a wider foot path and a base for the pipe railings crossing the gate leaf (Fig. 69). In appearance, the swing bar on the top of the gate leaves operated by the push-bar/crab system more closely approximate the foot board of the original gate leaf than any other since the introduction of the curved swing beam in 1834. The resemblance, however, is slight.\textsuperscript{207}
Appendix A: Cements

"Experiments tried at Quebec as to the properties and adhesive qualities of the following Cements, by order of Colonel Nicolls, Commanding Royal Engineer, dated 17th November 1834", Papers on Subjects Connected with the Duties of the Corps of Royal Engineers, vol. III, London: John Weale, 1839, pp. 184-185.

Name of Cements: English or Harwich; Canadian or Hull, on the Ottawa, generally used on the Rideau Canal; and Quebec, made from the Black Rock, by Lieut. Baddeley.

Nature of Experiments: 1) Pointing

Description of Experiments:

On the 1st October 1834, one-third of thirty-four square feet of the left angle of the flank of the interior of the parapet of St. Ursule bastion was pointed with the three cements enumerated. The cements were applied by three masons at the same time to the raked out joints. In working, the Harwich set first of the three; the Quebec (or Lieut. Baddeley's) set within the half hour; but the Hull (Mr. Wright's) took an hour to set. The latter kept its colour like the Harwich, but the Quebec changed from a rich freestone colour to that of a bluish grey.

Results of Experiments: after 7 months winter, the coldest day 29°F. below zero.

Harwich best! Next best, Hull.

Nature of Experiments: 2) Building
Description of Experiments:
On the 2nd October 1834, a trial of these cements was made in building a stone wall of four courses, with coping of the same materials laid on edge, the site of which was in an embrasure of the left flank of St. Ursule bastion, N.B. The first two courses were commenced in dry weather, but the third in a heavy shower of rain (which continued for the remainder of the day), which made the Quebec and Hull run out of the joints ere they could set, but the Harwich set nearly as fast in as out of the rain; a most decided advantage over its rivals. It was thought advisable to withdraw the workmen for this day, taking the precaution to cover the work until the next morning, when the dryness of the weather enabled the masons to complete the work.

Result of Experiments: after 7 months winter, the coldest day 29°F. below zero
Harwich best! The two others have stood very well indeed, and to all appearances will remain so for years.

Nature of Experiments: 3) Plastering, in water

Description of Experiments:
On 17th October 1834, an experiment was tried in building a triangular well, sunk in the ditch under the left flank of the same bastion, which was plastered with the three cements, and the water raised in it as high as the top of the fifth course, which remained in that state during the winter.

Result of Experiments: after 7 months winter, the coldest day 29°F. below zero
Harwich the only one that stood the test.
These above were inspected by Colonel Nicolls on 25th May 1835.

Nature of Experiments: 4) Adhesive qualities of the cements.

Description of Experiments:

On the 19th November 1834, two bricks were cemented together with Harwich cement, two with Hull cement, and two with Quebec cement: on the 24th of February 1835, in the presence of Colonel Nicolls, Lieut. Baddeley, Lieut. Gordon, Mr. Masson, the Master Mason, and Mr. Houston, the Acting Overseer of Works, the following experiments were tried, viz.:

Results: 1st. The two bricks cemented together with Harwich cement sustained 5½ cwts.; and were separated with 6 cwts.

2nd. The two bricks cemented together with Hull cements, 3½ cwts.; the time occupied in placing the weights upon the scale until the separation took place was only about four minutes. They were separated with 4 cwts.

3rd. The two bricks cemented together with Quebec cement sustained 9½ cwts. This experiment took ten minutes, when the iron hook of the scales gave way. Separated with 10-32/112 cwts.
Another experiment on the adhesive qualities of Quebec cement

The adhesive surface was a rectangle of iron of 18 x 3 inches, and consequently contained 54 square inches. The cement was 3/16 in. in thickness, and the surface had been cemented together twenty-one days.

Results: Sustained .......... 406 lbs.
Broke with .......... 420 lbs.

N.B. Method of mixing the cements into a working state, viz.

Harwich Cement .......... 6 measures of cement.
                        2 measures of sand.
                        4 measures of water.

Hull Cement .......... 6 measures of cement.
                        2 measures of sand.
                        3 measures of water.

Quebec Cement .......... 6 measures of cement.
                        2 measures of sand.
                        2½ measures of water.

The measure used for the cement, as well as the water, was a common tin of 1 pint.

Alex Gordon,
Lieutenant Royal Engineers.
Appendix B: Tools and Building Materials

To Francis Sisson, Ordnance Storekeeper, Montreal,
"List of Stores requires for the Service of the Rideau Canal for the year 1829" (Public Archives of Canada, RG8, Series C, vol. 47, reel C-2619, pp. 98a - 98h.)

Royal Engineers Office
Rideau Canal
11 December 1828

Required to be supplied for the Service of the Rideau Canal, the undermentioned articles, viz.

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adzes, Carpenters</td>
<td>24</td>
<td>with pences or hammer heads, weight 3 1/2 lbs. each,</td>
</tr>
<tr>
<td>Axes, Pick American</td>
<td>24</td>
<td>form &amp; make</td>
</tr>
<tr>
<td>Axes, Pick Common</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Axes, Pick Common</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Anvils for Smiths Large</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Augers, screw, polished</td>
<td>150</td>
<td>1/2 inch-20, 1 1/8 inch-10, 1 inch-20, 1 1/2 inch-30,</td>
</tr>
<tr>
<td>Bars, Tamping Miners</td>
<td>150</td>
<td>2 inch-30</td>
</tr>
<tr>
<td>Bellows, Large for Smiths</td>
<td>3</td>
<td>with Metal Backs &amp; [&amp;] Irons complete</td>
</tr>
<tr>
<td>Buchards for Masons</td>
<td>150</td>
<td>faces 2-1/8 in. X 2-1/8 in., 36 points on each face,</td>
</tr>
<tr>
<td>Brushes for Painters, Sash Tools</td>
<td>18</td>
<td>Sizes No. 5 - 8, of No. 6 - 4, No. 7 - 3, of No. 8 - 3,</td>
</tr>
<tr>
<td>Brushes for Painters, Camel Hair</td>
<td>24</td>
<td>pencils for Lettering or writing in oil</td>
</tr>
<tr>
<td>Brushes, Whitewash</td>
<td>12</td>
<td>Stock or flat, 6 inches wide, Leather bound</td>
</tr>
<tr>
<td>Brushes, Tar Common</td>
<td>24</td>
<td>Common, round heads, Iron bound with handles</td>
</tr>
<tr>
<td>Chisels, Firmer Cast steel, polished</td>
<td>12</td>
<td>(in sets or dozens, from 1/8 to 1 inch)</td>
</tr>
</tbody>
</table>
Chisels, Firmer, Cast Steel polished, 1\(\frac{1}{4}\) inch, 1\(\frac{1}{2}\) inch, 1\(\frac{3}{4}\) inch,
2 inch, .... 3 dozen of each ....................... dozen 12

Chisels, Socket ... 1 inch, 1\(\frac{3}{4}\) inch, 1\(\frac{1}{2}\) inch, 2 inch,
2\(\frac{1}{4}\) inch, ..... 3 dozen of each ....................... dozen 15

Chisels, Masons, best Cast Steel, \(\frac{1}{4}\) inch, 1 inch, 1\(\frac{1}{2}\) inch,
1\(\frac{3}{4}\) inch, 25 of each ........................................ 100

Chisels, Mortice, from 1/8 to 3/4 inch, in sets of 8 each ....... sets 8

Chisels, Masons, best Cast Steel, 1\(\frac{1}{4}\) inch-25, 2 in.-25,
2\(\frac{1}{4}\) inch - 30, 2\(\frac{1}{2}\) inch - 50 .................. dozen 130

Chisels, Points, best Cast Steel, 1\(\frac{1}{4}\) lbs. wt. - 50,
1\(\frac{1}{2}\) lbs. wt. - 50 ..................................... 100

Crow Bars, Middling Size, well steeled, 5\(\frac{1}{2}\) feet long, wt. 35 lbs. each, 200

Crow Bars, Small Size, well steeled, 4 feet long, wt. 35 lbs. each .... 200

Drills, Hand, Miners, Six feet long, double ends & bulb in the
middle, well steeled, weight 23 lbs. .................... 100

Drills, Hand, Miners, Five feet long, double ends and bulb in the
middle, well steeled, weight 18 lbs. ............... 100

Files, Hand, Saw, best Cast Steel, six inches long (three square) ...... 576

Files, Whip Saw, " " " , seven inches long (half round) ...... 200

Files, Tenon Saw, " " " , four inches long (three square) ..... 144

Files, flat, coarse, four Smiths, 9 inches long - 72, 12 in. - 96,
14 in. - 144, 16 in. - 144, 18 in. - 144 ............ 600

Files, Bastard, Cut for Smiths, 9 inch - 48, 12 in. - 72,
14 in. - 144, 16 in. - 144 ........................... 408

Files, Smooth, for Smiths, 9 inch - 48, 12 inch - 72, 15 in. - 96 ...... 216

Files, half round, for Smiths, 9 inch - 48, 12 inch - 72,
15 inch - 96 (fine and coarse, of each an equal
number) ...................................................... 216

Files, Rat Tail, for Smiths, 9 inch - 72, 12 inch - 96, 16 inch - 96 ... 264

Files, Harding, for Smiths, 3 inch - 48, 4 inch - 72, 6 inch - 72 ...... 192

Files, Slitting, for Smiths, 9 inch - 48, 12 inch - 72 ...................... 120

Files, Rubbers, large, for Smiths, 14 inch - 96, 18 inch - 120 ...... 216
Files, Flat (Rasps) for Smiths, 14 inch - 72, 16 inch - 48 .......... 120
Files, Half round (Rasps) for Smiths, 14 inch - 72, 16 inch - 48 ...... 120
Files, Three Square, for Smiths, 14 inch - 72, 16 inch - 96 .......... 168
Gouges, Scribing, in sets of 12 each from 1/8 to 1 inch ............ Sets 8
Hammers, Sledge, for Smiths, wt. 9 lbs., wt. 11 lbs.,
    wt. 12 lbs., 4 of each .................................. 12
Hammers, Sledge for Masons or blocking hammers, 8 lbs. .......... 12
    24 lbs. .............................................. 12
Jumpers, Miners, 1 inch round, Iron,
    2 feet long - 50, 2½ feet long - 50,
    3 feet long - 50, (well steeled) ...................... 150
Lathe, Turning, Large, with chucks, rests & tools complete for
turning wood and iron on a large scale say the
greatest diameter to be turned will not exceed
    3 feet ........................................... 1
Lines, Mackarel for Masons .................................. 96
Mattocks, Common with the cutting parts (?) or reversed,
    weight 8 lbs. each ..................................... 250
Needels, Miners, Swedish Iron with eyes or bows from ½ inch thick to
    a point 4 feet long each. ............................. 250
Needels, Miners, Composition with eyes or bows .. 2 feet 6 in. long each 50
Picks, Miners, with two points 1½ feet long,
    8 lbs., 9 lbs., 10 lbs., 11 lbs., 50 of each ............. 200
Picks, Masons, with two points 9 inches long from point to point,
    100 of 9 lbs. each, 100 of 12 lbs. each ............... 200
Rules, 2 feet, Carpenters with Brass 1/2 moon joints ............... 36
Rules, " " " " " " " & Brass Slides ................. 12
Rules, " " " " Six inch joints ............................. 36
Rules, 3 feet ..........., Eight joints or parts ..................... 12
Shovels, Irish or long handles, pointed mouths ..................... 300
Shovels, English, Short handles with Bow Heads,
    100 of square mouthed, 200 round mouthed ............... 300
Spades, Common, Short handles with Bow Heads, square mouthed .......... 150
Spades, Common, Short handles with Bow heads,

Grafting tools ½ moon mouthed (for clay) 20 inches long 100
Scrapers, Miners, ¼ inch wide & 7 inches long in the mouth or hollow
part with iron handle 3 feet long ......................... 150
Stones, Grinding, Large (from Dunn, Newcastle) 4 feet diameter,

6 inches wide, good coarse grit - 6 fine grit - 6 ..... 12
Stones, Grinding, Small (from Dunn, Newcastle) 4 feet diameter,

6 inches wide, good coarse grit - 6, fine grit - 6 .... 12
Squares, Iron, figures, 1 foot & 2 foot long in the Blades ............... 48
Trowels, Masons, Large, 9 inches long - 20, 7 inches long - 30,
6 inches long for pointing - 24 .......................... 74
Trowels, Plastering, Square mouthed 10 inches long .................... 24
Vices, Large Iron for Smiths ..................................... 3
Vices, Hand .................................................................. 12

Materials
Bolts for Windows, Canadian Sash, one long pane & one short in each
pair (Iron with springs) ......................... Pairs 150
Blocks, Large for four inch rope, Treble - 6, Double - 6,

Single - 6, Snatch - 6 .................. 24
" " for three inch rope, ditto ..................... 24
" " for 2½ inch rope, ditto ..................... 24
" " for 2 inch rope, ditto ..................... 24
" " for 1½ inch rope, ditto ..................... 24
Chalk, White ........................................................ lbs. 224
Cement, Parker's Roman, in barrels of 3 bushels each ............ Barrels 150
Copper sheathing, 1/8 of an inch thick .......................... Sheets 50
Coals, Newcastle, for Smiths use, one hundred Chaldrons,
equal to ................................................. Bushels 3600
Gunpowder, large grained, for Miners use, (not more than 100 Barrels
to be forwarded at one time) Barrels 100 lbs.
each .................................................. Barrels 400
Glass (4th crown) boxes to contain 100 feet each 7½ by 8½ ..... Boxes 10
Hambro, Lines .................................................. Hanks 36
Hemp, Thread ..................................................... lbs. 12

<table>
<thead>
<tr>
<th>Iron, Flat, Swedish</th>
<th>in.</th>
<th>in.</th>
<th>Cwt.</th>
<th>No.</th>
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<tr>
<td>6 x 1¼</td>
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<td></td>
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<tr>
<td>5½ x 7/8</td>
<td></td>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>5 x ½</td>
<td></td>
<td></td>
<td>35</td>
<td>2½ x ½</td>
</tr>
<tr>
<td>4 x ½</td>
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<td>25</td>
<td>2 x ½</td>
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<td>3 x ¼</td>
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<td>60</td>
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<td>3 x 1</td>
<td></td>
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<td>40</td>
<td>1 x ½</td>
</tr>
<tr>
<td>3 x 5/8</td>
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<td></td>
<td>30</td>
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365 Cwt.

<table>
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<th>in.</th>
<th>Cwt.</th>
<th>in.</th>
<th>in.</th>
<th>Cwt.</th>
<th>No.</th>
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<tbody>
<tr>
<td>4 x 4</td>
<td></td>
<td></td>
<td>40</td>
<td>1½</td>
<td>x 1½</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>3 x 3</td>
<td></td>
<td></td>
<td>50</td>
<td>1¾</td>
<td>x 1¾</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>2½ x 2½</td>
<td></td>
<td></td>
<td>30</td>
<td>1-1/8</td>
<td>x 1-1/8</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>2 x 2</td>
<td></td>
<td></td>
<td>60</td>
<td>1</td>
<td>x 1</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

Iron, Square, Swedish, Scrap for ragged bolts for the Lock Gates
½ x ½ 40

410 Cwt.

[Law moor?] charcoal, bolt, scrap ½ inch iron, eight pined or
sided for rivets of iron work of Lock Gates ..... 60
ditto ... 7/8 inch iron ......................... 40
ditto ... 1½ inch iron ......................... 40

140 Cwt.
<table>
<thead>
<tr>
<th>Iron, Flat, English,</th>
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<th>in.</th>
<th>Cwt.</th>
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</thead>
<tbody>
<tr>
<td>6 x 1</td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>5 x ½</td>
<td></td>
<td></td>
<td>432</td>
</tr>
<tr>
<td>4 x 5/8</td>
<td></td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>3 x ½</td>
<td></td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>2½ x ½</td>
<td></td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>2 x ½</td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>712  Cwt.</td>
</tr>
</tbody>
</table>

| Flat sheet, Double |                           | 5 Cwt. |
| Flat Hoop, one inch wide |                           | 5 Cwt. |

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<thead>
<tr>
<th>Steel Flat, Shear, best quality</th>
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<th>in.</th>
<th>Cwt.</th>
</tr>
</thead>
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<tr>
<td>2½ x 5/8</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>2 x ½</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>1½ x ½</td>
<td></td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steel, Flat, Crawley,</th>
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<th>in.</th>
<th>Cwt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 x 7/8</td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>2½ x ½</td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>2 x ½</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>1½ x ½</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>1 x ½</td>
<td></td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steel, Flat, Blister,</th>
<th>in.</th>
<th>in.</th>
<th>Cwt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 x ½</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>2½ x 5/8</td>
<td></td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steel, Flat, Hoop L.</th>
<th>in.</th>
<th>in.</th>
<th>Cwt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 x ½</td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>2½ x 5/8</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>2 x ½</td>
<td></td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>
Steel, Cast, Square

<table>
<thead>
<tr>
<th>in.</th>
<th>in.</th>
<th>Cwt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1\frac{1}{2}$ x $1\frac{1}{2}$</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>1 x 1</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>$\frac{3}{4}$ x $\frac{3}{4}$</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Steel, Cast, Flat

<table>
<thead>
<tr>
<th>in.</th>
<th>in.</th>
<th>Cwt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2\frac{1}{4}$ x $\frac{1}{2}$</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>2 x $\frac{1}{2}$</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>$1\frac{1}{4}$ x $\frac{1}{2}$</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1 x $\frac{1}{4}$</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Steel, Spring, Flat

| 2\frac{1}{2} | 3/8 | 4 |
| 2 x $\frac{1}{2}$ | 4 |

Steel Buttress or Silver for Jumpers (to be had of the Monkland Steel Company) .................................. Cwt. 10

Leather Basil skin for aprons for Carpenters 25, for Masons 25, for Smiths 25 ........................................... 12

Leather, for Pumps (Kendal Blue Pen) best quality ................................ lbs. 100

Ladles, Iron, to hold one quart .................................................. 6

Lead, Pig ........................................................................... Cwt. 20

Lines, Cod ........................................................................... hanks 24

Mineral Tar, or coal gas, residence ........................................ Barrels 80

Nails, Spikes, 7 inch long, Common .............. 2,000

6 inch long, Common .............. 12,000

5 inch long, Common .............. 5,000

4 inch long, Common .............. 5,000

3 inch long, Common .............. 5,000

2\frac{1}{2} inch long, Common .............. 5,000

Nails, Shingle, best cut, .......................................................... 200,000

Nails, Clasp, Assorted Sizes and of each an equal number .... 36,000

Nails, Brad, Assorted Sizes, viz. $\frac{1}{2}$ inch, $\frac{1}{4}$ inch, $\frac{1}{2}$ inch,

1 inch, $1\frac{1}{2}$ inch, $1\frac{1}{2}$ inch, of each 5,000 .... 30,000
<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nails, 28 dy [penny nail, 4-3/8&quot;] Wrought, best quality</td>
<td>40,000</td>
<td>20 dy [penny nail, 4&quot;] Wrought, best quality</td>
</tr>
<tr>
<td>16 dy [penny nail, 3-5/8&quot;] Wrought, best quality</td>
<td>24,000</td>
<td>12 dy [penny nail, 3&quot;] Wrought, best quality</td>
</tr>
<tr>
<td>10 dy [penny nail, 3&quot;]* Wrought, best quality</td>
<td>50,000</td>
<td></td>
</tr>
<tr>
<td>Nails, Tacks, on inch long</td>
<td>40,000</td>
<td>1/4 inch long</td>
</tr>
<tr>
<td>1/2 inch long</td>
<td>30,000</td>
<td>for Pumps, of Copper, 1/2 inch long</td>
</tr>
<tr>
<td>Oakum</td>
<td>Cwt. 6</td>
<td>6 inch long</td>
</tr>
<tr>
<td>Oil, Linseed, Boiled</td>
<td>Gallons 10</td>
<td>Oil, Sweet</td>
</tr>
<tr>
<td>Oil, [raw ?]</td>
<td>Gallons</td>
<td>Portfires or Tubes for Miners</td>
</tr>
<tr>
<td>Putty, best quality, made with Linseed Oil in</td>
<td>Bladders of 14 lbs. each</td>
<td>lbs. 448</td>
</tr>
<tr>
<td>Paint, Red Lead Dry</td>
<td>lbs. 500,</td>
<td>White Lead, ground in Oil, in Kegs 28 lbs. each</td>
</tr>
<tr>
<td>Paint, Spanish Brown, ground in oil, Kegs 28 lbs. each</td>
<td>Kegs 10</td>
<td>Litharge, Crude and Levigated, of each 10 lbs.</td>
</tr>
<tr>
<td>Lampblack, Dry</td>
<td>lbs. 28</td>
<td>Pitch</td>
</tr>
<tr>
<td>Rope, 6 inch Tar, Hawser laid</td>
<td>fathoms 300</td>
<td>6 inch white</td>
</tr>
<tr>
<td>4 inch white</td>
<td>fathoms 300</td>
<td>4 inch Tarred, Hawser laid</td>
</tr>
<tr>
<td>3 inch, 2 1/2 inch, 2 inch, 1 1/2 inch, 1 inch, 1/4 inch, tarred, Hawser laid, 300 fathoms of each</td>
<td>lbs. 28</td>
<td></td>
</tr>
</tbody>
</table>

*The penny nail sizes are taken from Fig. 1, "Builders' Hardware, Staple Hardware", International Library of Technology, 1909 ed.*
<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spun Yarn</td>
<td>2 Cwt.</td>
</tr>
<tr>
<td>Sand Paper, No. 1 - 2 quires, No. 2 - 2 quires, No. 3 - 2 quires</td>
<td>6 Qires</td>
</tr>
<tr>
<td>Turpentine, Spirits of</td>
<td>10 Gallons</td>
</tr>
<tr>
<td>Tar</td>
<td>20 Barrels</td>
</tr>
<tr>
<td>Wire-Brass for Miners</td>
<td>10 lbs.</td>
</tr>
<tr>
<td>Whiting</td>
<td>336 lbs.</td>
</tr>
</tbody>
</table>

800 Pieces of Red Pine Plank, 16 feet long/3 in. thick, from 9 to 10 inches wide to be well sawed & to be free from Sap and Wane*

Castings, of Iron & Brass for Lock Gates and Sluice gearing, from 40 to 50 tons of iron & about 500 lbs of Brass**

Chains, for Capstans [sic] of Lock Gates, 1/8 inch, studded, proven, patent

Chain, with 20 swivels and Hooks ............... fathoms 532

*The Red Pine Timber can be purchased on the spot at from 3d. to 9d. per Cubic foot; the sawing will cost about 5d. per 100 Superficial feet.

**The Castings of Iron will be generally of a heavy description, such as Heel Post boxes, Anchors, Trucks, Crabs & c. for the Gates of the Locks. Those of Brass will be smaller, as Journals, Bouches & c. for the Lock Gate Sluice gearings, the Moulds for which will be furnished and directions given from time to time by the Royal Engineers Department.

John By, Lt. Col. Royal Engineers
Commanding, Rideau Canal
**Appendix C: Lock Gate Ironwork, 1832**

(Public Archives of Canada, MG13, W044, vol. 26, reel B-1299, p. 152. The materials listed were furnished to the Tay Canal Company, and consist of what was used on the gates of a single Rideau Canal lock, for two pairs of mitre gates.)

Statement of Wrought and Cast Iron work forwarded from the Royal Engineers Store, Bytown, for the Lower Lock on the River Tay, vizt.

<table>
<thead>
<tr>
<th>Date</th>
<th>Item Description</th>
<th>Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct. 8th</td>
<td>19 Pair T Plates for Lock Gates</td>
<td></td>
<td>.6 3s. 4d.</td>
</tr>
<tr>
<td></td>
<td>8 Pair L Plates for Lock Gates</td>
<td></td>
<td>2 2 0</td>
</tr>
<tr>
<td></td>
<td>140 Clinch Bolts for Lock Gates</td>
<td></td>
<td>2 2 0</td>
</tr>
<tr>
<td>Nov. 17th</td>
<td>4 Anchor Straps for Lock Gates</td>
<td></td>
<td>7 0 0</td>
</tr>
<tr>
<td></td>
<td>4 Gudgeons &amp; Tail Sockets</td>
<td></td>
<td>1 3 0</td>
</tr>
<tr>
<td></td>
<td>4 Bands for Heel Posts, Gates</td>
<td></td>
<td>1 0 20</td>
</tr>
<tr>
<td></td>
<td>4 Bands for Mitre Posts</td>
<td></td>
<td>0 2 18</td>
</tr>
<tr>
<td></td>
<td>20 Rag Bolts for Anchors</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>32 Brass Castings for Collars</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gates</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>68 - 2 inch Screw Nails for</td>
<td></td>
<td>1 1 4</td>
</tr>
<tr>
<td></td>
<td>Collars of Gates</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14 Spike Nails made in</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Smith Shop</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Pair T Plates for Lock Gates</td>
<td></td>
<td>1 1 20</td>
</tr>
<tr>
<td></td>
<td>21 Bolts for plates for Lock</td>
<td></td>
<td>0 1 22</td>
</tr>
<tr>
<td></td>
<td>Gates</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>25 2 4</td>
</tr>
</tbody>
</table>

Royal Engineers Store
Rideau Canal
15 Feby. 1832

Angus McGillvary
Clerk of Stores

William Tormay
Master Smith

Received the above in good order at the Tay Locks.
For the Tay Company, John Jackson
Civil Engineer
Appendix D: Constructing Swing Bars, 1839


Item 1: The present mode of Working the Lock Gates on the Ottawa Canals experience has fully proved is extremely defective, so much so as not only to endanger the safety of the Gates from the great strain and force required to open and shut them, but also constantly rendering the Navigation liable to serious interruption, every month during the navigable season adds to the evil, and the Gates cannot stand much longer, the strain and force now required to Work them. Under such circumstances some change appears to be imperatively called for, it is proposed therefore in the first instance to substitute Swing Bars on the highest gates, for the present [push/draw bar] mode of Working them, as shewn in the accompanying Sketch A to be Worked by an endless chain round a Crab, the same as on the Rideau Canal, and should this plan as anticipated, fully answer the other Gates can be also altered. (Fig. 67)

The Oak Timber can only be got out of the Woods during the Winter, and the expense could be charged to the Tolls.

Carillon Canal Lower Entrance,
Constructing 1 pair of Swing Bars & c. on the Lower Lock Gates

<table>
<thead>
<tr>
<th>Item Description</th>
<th>L</th>
<th>S</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>160 Cub feet of best White Oak timber,</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>1s.6d. per ft.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Cast Iron blocks &amp; 2 Plates &amp; Sheaves, with frames, Weight 380 lbs.,</td>
<td></td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>3d. per lb.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Straps and 2 Stays of 3½ x 5/8 inch Iron, Weight 100 lbs., 2d. per lb.</td>
<td></td>
<td></td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Item</td>
<td>Units</td>
<td>Weight</td>
<td>Price</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>-------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>2 Eye Straps for fastening ends of Chains</td>
<td></td>
<td>40 lbs.</td>
<td>6d. 8p.</td>
</tr>
<tr>
<td>of 2½ x 5/8 Iron, Wt. 40 lbs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2d. per lb.</td>
<td></td>
<td>2d. lb.</td>
<td>6 8</td>
</tr>
<tr>
<td>16 Plates of 2½ x 1/4 inch Iron, Wt. 70 lbs., 2d. per lb.</td>
<td></td>
<td>70 lbs.</td>
<td>11 8</td>
</tr>
<tr>
<td>28 Screw bolts and 10 Rag Spikes of 5/8 inch round Iron, Weight 72 lbs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2d. per lb.</td>
<td></td>
<td>2d. lb.</td>
<td>12</td>
</tr>
<tr>
<td>16 bolts of 1 inch round Iron with washers</td>
<td></td>
<td>130 lbs.</td>
<td>1 1 8</td>
</tr>
<tr>
<td>&amp;c. Weight 130 lbs., 2d. per lb.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44 lbs. of 7 inch Spike Nails No. 3, 5d. per lb.</td>
<td></td>
<td>44 lbs.</td>
<td>18 4</td>
</tr>
<tr>
<td>100 Bushels of Charcoal</td>
<td></td>
<td>100 lbs.</td>
<td>1 6</td>
</tr>
<tr>
<td>1142 lbs. of Cast Iron for 2 Crab Windlasses, 3d. per lb.</td>
<td></td>
<td>1142 lbs.</td>
<td>14 5 6</td>
</tr>
<tr>
<td>168 lbs. of Wrought Iron for Crab Windlasses, Workmanship included,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1s.6d. per lb.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Crab Stones 4 feet by 3 ft. 6 in.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20s. each</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>160 lbs. of 3/8 inch patent Chain, 6d. per lb.</td>
<td></td>
<td>160 lbs.</td>
<td>4</td>
</tr>
<tr>
<td>34 days of a Carpenter making &amp; fixing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the Swing Bars &amp; c. on the Gates, 5s. per day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 days of a Smith making &amp; altering the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>above, 5s. 3d. per day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 days of a Helper, 3s.3d. per day</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 363 -
Making a large Box for Steaming Swining Bars

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 Supl. feet of 3 inch pine Plank, 2d. per ft.</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>40 lbs. of 7 inch Spike Nails No. 3, 5d. per lb.</td>
<td></td>
<td>16 8</td>
</tr>
<tr>
<td>4 days of a Carpenter, 5s. per day</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>73 9 8</td>
</tr>
<tr>
<td>10% for Contingencies</td>
<td></td>
<td>7 6 10</td>
</tr>
</tbody>
</table>

**Total:** £ 80 16 7½

D. Bolton, Major  
Senior R. Engineer  
Rideau & Ottawa Canals  
10 December 1839
Appendix E: Lock Gate Specifications, 1861

Ottawa, 21st August 1861

Dear Sir:

I have the honour to transmit a schedule of tenders received for the renewal of the woodwork of three pairs of lock gates, a pair for Hartwells, Hogsback & Edmunds respectively, the work was authorized by your letter of 8th of Feby. last.

The specifications include furnishing all materials removing & replacing the iron & machinery, painting three coats & hanging the new gates in working order on the same plan as the present gates (which have lasted upwards of twenty years) -- my estimate for the work is as follows, --

2,200 cubic feet white oak timber .... $ 660
5,000 ft. B.M., 3 inch pine plank .... 100
500 lbs. spikes ....................... 50.
Framing, Hanging & c. ................... 900.
Carriage of Materials ................. 200.

$2,000.

The above is about as low as the Work can be done for. The oak timber will probably have to be got at Garden Island or French Creek, 30 cents per foot is what they charge for selected timber.

Mr. Richardson could not do this work for his bid & he has no means of his own that I am aware of. He has since sent me a letter, a copy of which I enclose, but it cannot be entertained as the amounts of the several tenders were then known. Mr. Neilson of [?] is the next. He offers as
securities John Bell & James Brown of the same place. All the parties are said to be responsible.

Before entering into agreement, I will await your instructions which please send as soon as convenient as this work must be done before navigation closes.

James D. Slater
Supt. R. Canal

Rideau Canal

Schedule of tenders for Lock Gates at Hartwells, Hogsback & Edmunds -- 3 pairs, opened 19 Aug. 1861.

James D. Slater

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wm. A. Richardson</td>
<td>$1350.</td>
</tr>
<tr>
<td>Michael Kelly</td>
<td>$3510.</td>
</tr>
<tr>
<td>P. Killduff &amp; C.</td>
<td>$2844.</td>
</tr>
<tr>
<td>Porter &amp; C.</td>
<td>$2050.</td>
</tr>
<tr>
<td>Wm. Davis</td>
<td>$1946.</td>
</tr>
<tr>
<td>Gibson &amp; Geddes</td>
<td>$2610.</td>
</tr>
<tr>
<td>Geo. Neilson</td>
<td>$1590.</td>
</tr>
<tr>
<td>McGuigan &amp; Carroll</td>
<td>$2740.</td>
</tr>
<tr>
<td>Edward Dufton</td>
<td>$2600.</td>
</tr>
<tr>
<td>Alva A. Clothem</td>
<td>$3250.</td>
</tr>
<tr>
<td>Jervis Goodwin</td>
<td>$2600.</td>
</tr>
</tbody>
</table>

(Rideau Canal Office, Smiths Falls)
Rideau Canal

Specification for Lock Gates [August 1861]

Stations  All the wood work except swing beams of three pairs of Lock Gates is required to be renewed, one pair at Edmonds, one pair at Hogsback, and one pair at Hartwells stations respectively.

Timber and Framing  The timber for these gates to be of the best quality of white oak, and of the same dimensions, and framed in the same manner and according to the plan of the present gates, the tenons to be 5 inches wide, the depth of the bar, and long enough to extend thro the mitre and heel posts, and to be strongly wedged.

Sheeting  The sheeting to be of three inch pine planks, single lengths not over 10 inches in width, seasoned and free from all imperfections, to be dressed and grooved suitable to receive the iron tounsg of the old gates, to be well spiked with six inch spikes about 5 to the [lb. ?] 2 at each crossing.

Iron and Hanging  The old gates are to be taken down and all the machinery and iron work carefully removed, and fitted to the new gates, to be embedded in a good thick coat of the best white lead and oil, as well as all joints, tenons, touns &c, the new gates are to be properly hung in their places and put in good working order, --- The new gates are to receive three coats of white lead paint, the outside or last coat to be a stone color.
Stipulations  The materials of every description to be of the best quality, and the work done in a tradesmanlike manner under the direction and to the acceptance of the superintendent, and according to the stipulations and provisions of the printed form of Contract hereinto annexed.

Time  The gates to be framed and delivered at the several stations within two months after the acceptance of the tender, the old gates to be taken down during the winter, and the new gates put in their place before the 15th day of April next, unless it may be considered necessary to put any one pair or the whole of the gates in their places sooner, in that case the contractor must agree to make the change in the shortest possible time, so as not to delay the navigation of the canal longer than necessary.

Tender  A bulk sum must be stated in the tender for each pair of gates, or for the whole the price to cover all cost of tools, materials, staging, labour and all contingencies of every nature which may be necessary for the proper construction, completion and hanging of the gates.

Tools  There are blocks suitable for taking down and hanging the gates at Ottawa and Edmonds stations, which the contractor may have the use of free of charge by returning them in as good order as received.

The actual signatures of two responsible persons will be required who are willing to become security for the due performance of the contract.
Appendix F: Lock Gate Specifications, 1864

Rideau Canal

Specifications (See Fig. 78, the 1864 lock gate plan)

For the renewal of the wood work of six pairs of Lock Gates on the Rideau Canal namely, three pairs at Ottawa, one pair at Hartwells, and two pairs at Jones Falls Lock Station.

The timber for these Lock Gates to be of the best quality of white oak, except the swing beams which may be of good white pine, the Gates to be framed the size of the present ones, and constructed in like manner, with the exception of an additional bar or rail inserted in each Gate, as shewn on the plans, the tenons to be five inches wide, the depth of the rail, and long enough to extend through the mitre and heel posts, and to be well and strongly wedged. The muntins to be six inches thick and the depth of the rail, and strengthened by one inch round Iron bolts, with nuts & screws as shewn on the plans, the bottom or lower muntins which carries the flanges are to be at least nine inches thick with Iron plates of suitable size and thickness sunk in on each side where the journal bolts go thro and to be fastened on with 5/8 inch Iron round rivetted, additional plates two feet 6 inches long 4 5/8 will also be bolted on to the lower muntins on the front and back of the Gates with 1" bolts & nuts, 3 in each, as shewn on the plan. These Irons together with the one inch round bolts going through the centre of the Gates up and down, are to be furnished by the contractor, also the one inch round Iron bolts for the additional T plates on the extra rails above named.
The white pine swing bars must be of the same size as the old ones, and have the required curve in the solid, the foot boards are to be of white oak 5 x 7 strongly bolt on with sufficient number of white oak brackets to carry the machinery.

The sheathing to be of three inch pine plank, single lengths ten inches in width or under, seasoned and free from all imperfections, to be dressed and grooved suitable to receive the Iron tongues of the present Gates, to be well spiked on with six inch wrought spikes about 5 to the pound, two at each crossing, the Iron tongueing to be carefully removed from the planking of the old Gates straightened and put into the new planking.

The old Gates are to be taken down and all the Iron work carefully removed, as well as all machinery &c. any part broken by the contractor is to be repaired at his expense, any other repairs required to the Iron work or Machinery will be done by Government unless a special subsequent agreement be made in writing with the Contractor to perform these repairs so soon as the amount of work required can be ascertained. All the Iron work to be well bedded in a thick coat of the best white lead, and oil, as well as all tenons, joints, tongues, and planking.

The new Gates are to be properly hung in their places, and put in good working order, the material from the old Gates to be deposited as directed, the new Gates are to receive three coats of white lead paint, the outside or last coat to be a stone color. The Iron work to be painted black.

The material of every description to be of best quality, and the work done in a traditional manner under the direction and to the satisfaction of the superintendent or other officer who may be appointed to take charge of the
work, and also according to the stipulations and provisions of the printed forms of contract hitherto annexed.

The old Gates are to be removed and the new ones in their places, and the whole of the work fully completed before the fourteenth day of April next 1865, a bulk sum to be stated in the tender for the whole of the work described in this specification which is to cover all cost of tools and labor, material of all kind, stageing and every other contingency which may be necessary for the proper construction, completion and hanging of the Gates.

The portion of repairs mentioned to be performed by the Department are repairs to Iron work and machinery under water, the amount of which cannot at present be ascertained. The repairs to the existing work to be done by the contractor will be to make good the bolts, nuts & screws, fixing T plates and also make good the Iron tongues which are inserted in the joints of the sheeting, any Iron work that may be injured or broken by the contractor is to be repaired at his expense, the new Iron to be furnished by the contractor as stated in the bill of Iron.

James D. Slater
## Rideau Canal

**Bill of Materials for Locks Gates**

**Jones Falls, Lower Gates**

<table>
<thead>
<tr>
<th>Description</th>
<th>No. of pieces</th>
<th>length</th>
<th>size</th>
<th>quantity</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swing bars, pine</td>
<td>2</td>
<td>40</td>
<td>15 x 16</td>
<td>134</td>
<td>*Upper high gate</td>
</tr>
<tr>
<td>Heel posts, oak</td>
<td>2</td>
<td>26</td>
<td>16 x 17</td>
<td>98</td>
<td>28' - 6&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>27' - 6&quot;</td>
</tr>
<tr>
<td>Mitre posts, oak</td>
<td>2</td>
<td>25</td>
<td>15 x 15</td>
<td>90</td>
<td>All the rest the same.</td>
</tr>
<tr>
<td>Rails, oak</td>
<td>6</td>
<td>20</td>
<td>15 x 18</td>
<td>222</td>
<td></td>
</tr>
<tr>
<td>Rails, oak</td>
<td>2</td>
<td>20</td>
<td>15 x 15</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Rails, oak</td>
<td>4</td>
<td>20</td>
<td>14 x 15</td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>Rails, oak</td>
<td>4</td>
<td>20</td>
<td>13 x 15</td>
<td>108</td>
<td></td>
</tr>
<tr>
<td>Muntons, oak</td>
<td>12</td>
<td>2</td>
<td>6 x 15</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Muntons, oak</td>
<td>8</td>
<td>2</td>
<td>9 x 18</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Planking, pine</td>
<td>-</td>
<td>-</td>
<td>10 x 3</td>
<td>1840 B.M.</td>
<td></td>
</tr>
<tr>
<td>Bolts through Muntins</td>
<td>12</td>
<td>1' - 2&quot;</td>
<td>1&quot; dia.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolts perpendicular</td>
<td>12</td>
<td>5' - 6&quot;</td>
<td>1&quot; dia.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolts perpendicular</td>
<td>10</td>
<td>4' - 6&quot;</td>
<td>1&quot; dia.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolts for Extra T plates</td>
<td>20</td>
<td>1' - 5&quot;</td>
<td>1&quot; dia.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Tongue Iron</td>
<td>24</td>
<td>-</td>
<td>1½ x ½</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plates on Muntins</td>
<td>16</td>
<td>2' - 6&quot;</td>
<td>4 x 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washers for Journals</td>
<td>16</td>
<td>8&quot;</td>
<td>4&quot; x 1&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rivets on Muntins</td>
<td>24</td>
<td>9&quot;</td>
<td>5/8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The above bill of Materials will answer for the two pairs at Jones Falls, except the length of the Heel and Mitre posts which are noted in the margin.*
Endnotes

1 PAC, MG13, WO44, reel B-1294, Vol. 18, pp. 69-74, Major General J. Carmichael Smyth to General Mann, Inspector General of Fortifications, Memorandum as to the formation of the Rideau Canal between the Ottawa River & Kingston upon Lake Ontario, 14 March 1826; and ibid., pp. 94-95, Wellington, General Minute, 15 June 1826.

2 Ibid., p. 95, Wellington, General Minute, 15 June 1826.

3 Ibid., Major General Smyth to General Mann, Memorandum, p. 72, 14 March 1826.

4 PAC, Lock Gate, Rideau Canal, 1827, John By, Lt. Col., Royal Engineer Commanding Rideau Canal, 1 December 1827; and PAC, Map Division, H3/312, [Lachine Canal, 1828], "Plan and Sections of the Eighth lock, 10 foot lift," stamped Inspector General of Fortifications. n.d. The latter drawing is definitely a drawing of the Eighth lock of the Rideau Canal rather than of a Lachine Canal lock as attributed in the Archives reference. The Lachine Canal had only seven lift locks, and none of them exceeded nine feet in lift. The drawing shows the 20 by 108 foot lock with a ten foot lift and indicates the same lift for the seventh lock; and the details of the lock are very similar to the details that can be discerned on the locksite plan for the Entrance Valley. (See PAC, Map Division, H11/410, Rideau Canal, 1827, "Plan, Elevation and Sections of the Works in Canal Valley and Entrance Bay,
Ottawa River as proposed by Lt. Col. By, Commanding Royal Engineer," John By, Lt. Col., 7 July 1827.) No other plan of the details of the proposed 20 foot wide Rideau Canal lock has been found; yet the Bryce Committee in their 22 January 1828 report refers to having carefully examined the design of the locks that Lt. Col. By had under construction (PAC, MG13, W044, Vol. 19, Reel B-1294, p. 132, Report of the Committee on Rideau Canal to General Mann, Major General Bryce, President, 22 January 1928). It would appear that Lt. Col. By prepared the drawing of the eighth lock of the Entrance Valley locks on 1 December 1827 at the same date as he prepared the lock gate drawing, and the plan for the proposed 50 by 150 foot lock that he was recommending should be recommended in place of the 20 foot wide lock for the perusal of the Ordnance (see below).

5 PAC, Map Division, Vl/410, Rideau Canal, 1827, Plan and Sections of the Large Lock Proposed by Lieut. Col. By, Royal Engineers, Commanding Rideau Canal; length 150 feet, Breadth (in the clear) 50 feet, with the Sluices in the Gates, N.B. These show the upper part of the Series of Seven Locks proposed for the Entrance Valley, Ottawa River, John By, R.E., 1 December 1827. (Note: By planned to reduce the number of locks in the Entrance Valley to seven if the large lock were authorized, and to do this he planned to increase the lifts of the individual locks to as much as 11'-6".)


Ibid.

I. The 20 by 108 Foot Gunboat Lock

Planning and Layout
4 PAC, RG8, Series C, Vol. 44, Reel C-2618, p. 89, Lt. Col. By to General Mann, 6 July 1827. The six sheets of plans are in the Map Division of the Public Archives of Canada (Map Division, V1/410, Rideau Canal, 1827); and all bear the date 7 July 1827 and are numbered AA12, through AA17, inclusive.
5 Ibid. The plans completed in the 25 October 1827 series, appear to be numbered AA19, Plan of Lock on Hurd's Shallows [Burritts Rapids] through to AA32, Plan of Locks and Dam at Jones Falls. The plans are not numbered in sequence in order of their location along the canal, and may well have been assigned "AA" numbers as soon as the survey work at a particular site had been completed and the layout of the structures determined, regardless of the relative positions of the locksite vis-à-vis the others.
I


7 I am indebted to Leslie Maitland, Architectural Historian, Parks Canada, for pointing out that the early drawings prepared by Lt. Col. By and his staff were strictly speaking architectural, rather than engineering, drawings. See Leslie Maitland, "Works both durable and ornamental: The Rideau Canal," unpublished manuscript, Ottawa, 1977.


12 Patterns were used throughout the construction period for the iron works, see for example, Public Archives of Ontario, Baird Diary, Reel No. 1, entry for Wednesday, 24 September 1828.

13 PAC, Map Division, H3/312, [Lachine, 1828], "Plan and Sections of the Eighth lock, 10 foot lift," stamped Board of Ordnance, n.d. [Rideau Canal, 1 December 1827].

14 PAC, Rideau Canal Lock Gate, 1827, scale 2 feet to 1 inch, signed John By, Lt. Col., R.E., 1 December 1827.

15 The second set of locksites drawings are intermixed with the first set in the PAC, Map Division, V1/410, Rideau.
Canal 1827. The second set may date from 1 December 1827, the date of the lock gate and lock drawings forwarded to the ordnance (see F.N. 17 above) or at least prior to May 1828 by which time Lt. Col. By had contracted out the work at the lock sites in the interior. None of the plans located of this second set are dated, but all appear to bear the title "Plan of the Dam and Locks to be constructed at ....". See for example, "Plan of the Dam and Locks to be constructed at the Black Rapids being a Part of the Rideau Canal"; "Plan of the Dam & Locks to be constructed at Long Island Rapids for the Rideau Canal"; and "Plan of the Dam & Locks to be constructed at Old Sly's Rapids, Rapids of Smith's Falls being a part of the Rideau Canal". (Note: the second set of locksite plans may well have not been completed for every locsite on the Rideau Canal before the decision was made to construct the canal with larger locks).

16 PAC, Map Division, VI/410, Rideau Canal, 1827, Series of Rideau Canal locksite plans, dated 7 July 1827 and 25 October 1827, Entrance Valley to Kingston Mills inclusive. John Mactaggart, the Clerk of Works on the Rideau project, who was experienced in British canal construction stated that lock lifts varied but averaged about 10 feet (John Mactaggart, Three Years in Canada: An Account of the Actual State of the Country in 1826-27-28 comprehending its resources productions, Improvements, and Capabilities and including Sketches of the State of Society, Advice to Emigrants, etc., London: Henry Colburn, 1829, Vol. 1, p. 163). Loammi Baldwin, an experienced American canal engineer, noted that lock lifts were generally eight feet (Loammi Baldwin, Engineer, "Report to Hon. Nathan Willis, Hon.

17 The three combined locks proposed for Smith's Falls had lifts of 11'-2" each to overcome a total difference of elevation at that site of 33'-6" (PAC, Map Division, V1/410, Rideau Canal, 1827, Locks and Dam at Smith's Falls, Rideau River, Plan AA27, John By, Lt. Col., R.E., 25 October 1827.

18 PAC, Map Division, V1/410, Rideau Canal, 1827, Plan, Elevation and Sections of the Works in the Canal Valley and Entrance Bay, Ottawa River, as proposed by Lt. Col. By, Commanding Royal Engineer, Plan AA12, John By, Lt. Col., R.E., 7 July 1827.

19 On the first section of the canal, for example, a guard lock was to be placed at the head of the lift locks at Hog's Back, Black Rapids and Long Island. At Black Rapids a difference of elevation of 10 feet was to be overcome by a lock of 10 foot lift, with a guard lock at its head (PAC, Map Division, V1/410, Rideau Canal, 1827, Plan, Elevation and Sections of the Works of the Rideau Canal at Black Rapids proposed by Lt. Col. By, Royal Engineer Commanding, Plan AA13, John By, Lt. Col., R.E., 7 July 1827). At Long Island, a difference of elevation of 24 feet was to be overcome by three combined locks of eight foot lift each with a guard lock at their head (Ibid., Plan, Elevation and Sections of the works for the Rideau Canal at the foot of Long Island as proposed by Lt. Col. By, Commanding Royal Engineer, [7 July 1827]. At the Hog's Back, a 30 foot difference of elevation was to be overcome by three lift locks of 10 foot lift each, with a guard lock at
their head (Ibid., Plan, Elevation & Sections of Works of the Rideau Canal as proposed to be performed at the Hog's Back by Lt. Col. By, Royal Engineer Commanding, Plan AA14, John By, Lt. Col., R.E., 7 July 1827. Guard locks were later eliminated everywhere except at the Hog's Back. There, a guard lock and a single lift lock were eventually constructed, with the rest of the lift being carried by the addition of two lift locks at Hartwells.

20 See, for example, PAC, Map Division, V1/410, Rideau Canal, 1827, "Plan of the Dam and Lock to be constructed at the Black Rapids being a part of the Rideau Canal", Drawing AA5, John By, Lt. Col., R.E., [winter 1827-28]; and Ibid., "Plan of the Dam and Locks to be constructed at Long Island Rapids for the Rideau Canal", Drawing AA3, John By, Lt. Col., R.E., [winter 1827-28].

21 See, for example, PAC, Map Division, V1/410, Rideau Canal, 1827, "Plan, Elevation and Sections of the Works in Canal Valley and Entrance Bay, Ottawa River as proposed by Lt. Col. By Commanding Royal Engineer", Drawing AA12, John By, Lt. Col., R.E., 7 July 1827.

22 All of the locks depicted in the 7 July 1827 series of locksite drawings which covered the Entrance Valley to Long Island inclusive had blunt square ended piers at their ends. The locksite drawings in the rest of the series, prepared on 25 October 1827, show rounded wing walls at the ends of the locks commencing with the first locksite plan prepared on that date: viz. Ibid., "Plan of Lock on Hurd's Shallows head of Barret's [sic] still water with a part of the Oxford Snie" Burritt's Rapids locksite, Drawing AA19, John By, Lt. Col., R.E., 25 October 1827. The second drawing in the 25 October
1827 series, that of the Nicholson's and the Clowe's locksites, shows square-ended piers on the lower end of the Nicholson's lock; but otherwise all of the other wing walls are rounded as they are in the rest of the lock drawings. Clearly, it was at the time of the preparation of the 25 October 1827 drawings that By decided to construct all of the locks on the canal with rounded wing walls.

23 See the second series of locksite drawings for the first section of the canal, where the blunt square ended end piers of the 7 July 1827 drawings have been replaced by rounded wing walls, as for example in PAC, Map Division, V1/410, Rideau Canal, 1827, "Plan of the Dam and Lock to be constructed at Long Island Rapids for the Rideau Canal", Drawing AA3, John By, Lt. Col., R.E., [winter 1827-28].

24 PAC, Map Division, V1/410, Rideau Canal, 1827, "Plan, Elevation & Sections of the Works of the Rideau Canal as proposed to be constructed at the Hog's Back by Lt. Col. By, Commanding Royal Engineer", Drawing AA14, John By, Lt. Col., R.E., 7 July 1827.

25 PAC, Map Division, H3/312, (Lachine Canal, 1828), "Plan and Sections of the Eighth lock, 10 foot lift", [Rideau Canal, 1 December 1827].


27 Lt. Col. By had originally intended to have the Royal Sappers and Miners lay up the stonework of the locks to ensure that it was properly done (PAC, MG13, W044, Vol. 18, Reel B-1294, pp. 10-11, Lt. Col. By to General Mann, 1 October 1826). However, the Ordnance did not comply with Lt. Col. By's request that four Companies of Royal Sappers and Miners be despatched to the Rideau project. By was forced to rely on the masonry contractors to lay up the stonework of the lock chambers under the strict supervision of his engineering staff. As indicated, By may still in 1827-28 have been counting on the masons of the two Companies of Royal Sappers and Miners that the Ordnance had agreed to send, being employed in laying the masonry sills and breastwalls which were a critical part of a lock.

28 PAC, Map Division, H3/312, [Lachine Canal, 1828] "Plan and Sections of the Eighth lock, 10 foot lift", stamped Board of Ordnance, n.d. [Rideau Canal, 1 December 1827].

29 PAC, RG11, Series I, Committee Reports, Lachine Canal, 1821-41; and Ibid., n.p., The Committee of Management report, 20 April 1821; and Ibid., n.p., Copy of the Agreement made with the Engineer, 28 March 1820.

I


32 Ibid., 22 December 1828.


34 See PAC, Map Division, H3/312, Lachine, 1828, Rideau Canal, 1 December 1827, Plan and Sections of the Eighth lock, 10 foot lift; and the references cited in endnote 28c.

35 See for example, PAC, Map Division, V1/410, Rideau Canal, 1827, "Plan, Elevation and Sections of the works for the Rideau Canal at the foot of Long Island as proposed by Lt. Col. By", [7 July 1827]. The sluice opening in the masonry was to be 5'-3" high by 2'-3" wide; but there is no evidence as to the type of sluice valve mechanism Lt. Col. By intended to use on the 20 foot wide lock.

36 PAC, Lock Gate, Rideau Canal, 1827, ['Plan of a lock gate for the 20 by 108 foot lock proposed for the Rideau Canal'], John By, Lt. Col., Royal Engineers, 1 December 1827.

37 The series of locksite drawings dated 25 October 1827 were prepared under severe time constraints in order to enable Lt. Col. By to forward the plans to the Ordnance together with his estimate for the Rideau Canal project in December 1827. Consequently the plans show only a
plan view sketch of the outline of the lock masonry and the position of the respective dams. There are no details indicating the type of sluice to be used on any of the locks depicted.

38 PAC, MG24, A12, Section 3, Reel A534, John Richardson and C.W. Grant, Late Commissioners, Lachine Canal, Quebec, to John Neilson, 22 December 1828.

39 There were seven locks with lifts of 6 to 9 feet and a guard lock on the Lachine Canal to overcome a descent of about 45 feet (PAC, RG1, E12, Vol. 3, p. 107, Captain Phillpotts, First Report on the Inland Navigation of the Canada's called for by Lord Glenelg's Dispatch to the Earl Durham, London, 23 August 1828.

40 PAC, Map Division, Lachine Canal, [1824], "Regulating Lock, La Chine, built upon Rock copied by Geo. C.D. Lewis, Lieut., R.E., Dec. 1, [illegible] from a drawing done in the year 1824 by Mr. John [Burnett].

41 PAC, Map Division, V1/410, Rideau Canal, 1827, Plan and Elevation and Sections of the Works on the Rideau Canal proposed to be performed at the Hogs Back, Lt. Col. By, 7 July 1827.

42 PAC, Map Division, H3/312, Lachine Canal, (1828), [Rideau Canal, December 1827], "Plan and Sections of the Eight Lock, 10 foot lift".

43 PAC, Map Division, H3/312, Lachine Canal, [1824], "Regulating Lock, La Chine, built upon Rock".


45 William Stickland, Report on Canals, Railways, Roads and other subjects made to "the Pennsylvania Society for the Promotion of Internal Improvement",
Philadelphia: H.C. Carey and I. Lea, 1826, p. 10 and Plate 13, "Double Valve, with One foot lift, Tide Lock, Thames and Medway Canal".


48 PAC, Lock Gate, Rideau Canal, 1827, [R4-026-F-0056]; and PAC, Map Division, Vl/410, Front and Rear Elevation and Cross section of a lock gate, Lt. Col. John By, 1 December 1827.

49 See for example, the drawing of a "lever valve" used on the lock gates of the Rochdale Canal, Great Britain, Plate XIV, William Strickland, Report on Canals, Railways, Roads and other subjects made to "The Pennsylvania Society for the Promotion of Internal Improvements" Philadelphia: H.C. Carey and I. Lea, 1826.


52 PAC, Map Division, H3/312, Lachine, (1828), [Rideau Canal, December 1827], "Plan and Sections of the Eighth Lock, 10 foot lift".

53 PAC, MG24, A12, Section No. 3, Reel A534, n.p., Richardson and Grant to John Neilson, 22 December 1828.

54 The lock gates of the St. Lawrence military canals constructed at an earlier date do not appear to have had flat iron plate reinforcing at their joints. See for example, PAC, Map Division, F/312, Cascades, 1825, "Plan and Elevations of the Lower Lock Gate of the Canal at the Cascades, to accompany Lt. Robe's report of the 19th November 1825".

55 PAC, Map Division, H3/312, Lachine, (1828), [Rideau Canal, December 1827], "Plan and Sections of the Eighth Lock, 10 foot lift".

56 PAC, Map Division, H3/312, Lachine Canal, [1824], "Regulating Lock, La Chine, built upon Rock".

57 See for example, Andrist, The Erie Canal, p. 62, "The Lock Gates for the Erie Canal"; and Gladwin, The Canals of Britain, p. 229, Fig. 13, "A 'top-end' gate to suit any lock from No. 3 to No. 58 inclusive, Worchester & Birmingham Canal".

58 Ibid., p. 229.

59 PAC, Map Division, H3/312, Lachine, (1828), [Rideau Canal, December 1827], Plan and Sections of the Eighth lock, 10 foot lift".

60 PAC, Map Division, "Lock Gate, Rideau Canal, 1827"; and ibid., Vl/410, Front and Rear Elevation and cross section of a lock gate, Lt. Col. John By, 1 December 1827.

61 PAC, Map Division, Lachine Canal, [1824], Regulating Lock, La Chine, built upon Rock; Andrist, Erie Canal,

62 PAC, Map Division, F/312, Cascades, 1825, Plan and Elevations of the Lower Lock Gates of the Canal at the Cascades, 19 November 1825.


64 PAC, Map Division, H3/312, Lachine, (1828), [Rideau Canal, December 1827], Plan and Sections of the Eighth lock, 10 foot lift".

65 PAC, Map Division, "Lock Gate, Rideau Canal, 1827"


67 Rideau Canal Historic Prints and Drawings Collection, Parks Canada, Drawing No. R4-026-F-0036, "Lower Side View of the Anchor and Strap of the Heel Post", [1832].

68 PAC, Map Division, V1/410, Rideau Canal, 1827, Plan, Elevation and Sections of the Works in the Canal Valley and Entrance Bay, Ottawa River, as proposed by Lt. Col. By, Commanding Royal Engineer, Plan AA12, John By, 7 July 1827.

There is no drawing extant that shows precisely how Lt. Col. By planned to use the floor chain/crab system on the lower gates of the 20 foot wide lock. But the lock gate drawing of 1 December 1827 (PAC, National Map Collection, "Lock Gate, Rideau Canal, 1827") shows a chain attached to the back of the gate at the base of the mitre post, and there is no balance beam on the gate leaf. The existence of the chain and its particular positions on the lock gate, however, would indicate that By planned to use the floor chain/crab system on the gates in question.

For the layout of the floor chain system used later on the 33 by 134 foot locks, see Public Record Office, London, England, "Plan of a pointed cill [sic] and recess of combined locks", John By, Lt. Col., C.R.E., (1832) and/or print copy in National Historic Parks and Sites Branch, Parks Canada, Historic Prints and Drawings Collection, R4-000-M-0050.

See for example, the system employed to swing the lock gates on the Delaware and Hudson Canal ca. 1850 making use of a horizontal rack, mounted over the center of the lock just above and to the back of the mitre gates. The rack was moved backwards and forwards to close and open the gates by means of a main gear wheel turned by a pinion gear worked by a handle (Wakefield, Delaware and Hudson Canal, p. 40, "Canal Lock Gate, 1850-1899"). The drop gate, on a horizontal axis at its base, was introduced at the upper end of the locks on several


Stevenson, Sketch of the Civil Engineering of North America, 1838, p. 201.
American canals, including the Delaware and Hudson, the Morris Canal in New Jersey, and the Erie Canal in the 1860s. The Canal Museum, Weighlock Building, Syracuse, New York, has in its possession an excellent engineering drawing of a drop (or tumble) gate of the type erected at the upper gate of numerous American canal locks during the 1860s and thereafter: viz. "Plan of Tumble Gate, Lock No. 39, Erie Canal, 1865".

74 See Strickland, Report on Canals, 1826, Plate No. 12, "Plan of the Tide lock at the Frindsburg entrance into the Canal and Tunnel of the Thames to the Medway"; Ibid., Plate 19, "Plan View of One Half of the Lock Gate, Prince's Dock, Liverpool"; and Samuel Smiles, Lives of the Engineers, with an account of their principal works; comprising also a history of inland communication in Britain, London: J. Murray, Vol. II, 1862, p. 414; "Lock, Caledonian Canal".

75 Strickland, Report on Canals, 1826, Plate No. 12, "Plan of the Tide lock at the Frindsburg entrance into the Canal and Tunnel from the Thames to the Medway" and "Section of the Tide Lock".


77 Two drawings in Strickland, Report on Canals, 1826, make it clear that swing beams were not used on the lock gates of the Prince's Dock Basin, Liverpool: viz. Plate No. 19, "Plan View of One Half of the Lock Gate, Prince's Dock, Liverpool" and Plate No. 20, "Side View of the Gate Valves and Counterweight"; but do not show the method used to swing the gates. However, had the gates been swung by a system radically different than the capstan/drag chain method of operation used on the tide lock of the Thames and Medway Canal which
Strickland depicted in detail in his work, he would no doubt have provided a drawing of the same as he was actively engaged in recording the details of British lock design and construction in all its varieties.

78 PAC, Map Division, "Lock Gate, Rideau Canal, 1827;" and Ibid., V1/410, Front and Rear Elevation and cross section of a lock gate, Lt. Col. By, 1 December 1827.

79 This is evident from a perusal of lock gate illustrations in numerous books and articles on the subject of early British and American canal construction.


81 Stevenson, Sketch of the Civil Engineering of North America, 1838, p. 202; Strickland, Report on Canals, 1826, pp. 55f. Elsewhere, the Chesapeake and Ohio Canal was constructed with broad locks 15 feet wide by 100 feet long on a 6 foot deep navigation; and the Delaware and Hudson Canal had narrow locks 9 ft. 6 in. wide by 75 feet long.

82 See the 7 July 1827 and 25 October 1827 series of Rideau Canal locksite plans in PAC, Map Division, H3/312, Lachine Canal, 1825, "Regulating Lock; La Chine, built upon Rock".

83 Strickland, Report on Canals, 1826, p. 9 and Plate No. 12, "Plan of the Tide lock, Thames and Medway Canal".


85 Strickland, Report on Canals, 1826, Plate No. 19, "Plan View of One Half of the Lock Gate, Prince's Dock, Liverpool".
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86 PAC, Map Division, "Lock Gate, Rideau Canal, 1827"; [R4-026-F-0056]; and Ibid., Vol. 410, Front and Rear Elevation and cross section of a lock gate, Lt. Col. By, 1 December 1827.


91 PAC, Map Division, H3/312, Lachine, 1828, Rideau Canal, December 1827, "Plan and Sections of the Eighth Lock, 10 foot lift".


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96 PAC, MG13, WO44, Vol. 19, Reel B-1294, p. 70, General Outline of the Works to be performed on the Rideau Canal from its commencement, 15 December 1827.

97 The work restraint order was issued by General Mann, the Inspector General of Fortifications on 5 January 1828 (See RG8, Series C, Reel C-2618, Vol. 45, p. 71, Lt. Col. By to General Mann, 15 March 1828).


II Lt. Col. By's 50 by 150 Foot Steamboat Lock


4 PAC, RG8, Series C, Vol. 45, Reel C-2618, pp. 210-11, Lt. Col. By to General Mann, 10 June 1828.


8 PAC, MG13, WO44, Vol. 19, Reel B-1295, pp. 197-98, Lt. Col. By to Col. Durnford, 1827. The locksite plans were the 7 July 1827 and 25 October 1827 series which covered the whole of the proposed canal (See PAC, Map Division, V1/410, Rideau Canal, 1827).

9 Hudson's Bay Company Archives, D.5/2, Governor George Simpson's Inward Correspondence, Reel 3M56, Lt. Col. By to G. Simpson, 28 October 1827, pp. 309-10; and Montreal Gazette, Vol. IV, No. 90, 10 December 1827.

10 PAC, Map Division, "Lock Gate, Rideau Canal, 1827", signed John By, Lt. Col., R.E., 1 December 1827; PAC, Map Division, H3/312, Lachine (1828) [Rideau Canal, 1 December 1827], "Plan and Sections of the Eighth lock, 10 foot lift".


15 PAC, Map Division, At/410, Rideau Canal, John By Atlas, p. 26, Proposed plan of a Lock for the Rideau Canal, 150 feet long by 50 feet broad, n.d. [1827].


18 There are three distinct sets of plans extant of the large 50 foot wide steamboat lock including the Welland Canal design that Lt. Col. By proposed to construct on the Rideau Canal: viz. PAC, Map Division, V1/410, Rideau Canal, 1827, Plan and Sections of the Large lock Proposed by Lieut. Col. John By, Royal Engineer, Commanding Rideau Canal; Length 150 feet, breadth (in the clear) 50 feet, with Sluices in the Gates, John By, Lt. Col., 1 December 1817; Ibid., Plan, Elevation & Section, of Col. By's proposed Large lock of 150 feet long by 50 feet wide the upper & lower Gates on the same level with Sluices of Cast Iron in the Gates, John By, Lt. Col., R.E., 1 December 1827; and, Ibid., No title, (4.sections), [Plan and Sections of the large locks to be constructed in the Entrance Valley, Rideau Canal], signed John By, Lt. Col., R.E., 1 December 1827.

19 For the masonry specifications of the twenty foot wide lock, see PAC, RG8, Series C, Vol. 48, Reel C-2619, pp. 104-9, Masonry contract of Walter Fenelon, 7 May 1827, or present text, section entitled "The 20 foot by 108 foot Gunboat Lock".

20 PAC, Map Division, V1/410, Rideau Canal, 1827, Plan and Sections of the Large Lock, Lt. Col. By, 1 December 1827.

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22 PAC, Map Division, V1/410, Rideau Canal, 1827, Plan and Sections of the Large Lock, Lt. Col. By, 1 December 1827.
23 Ibid.
24 Ross, Ottawa: Past and Present, p. 57, quoting from Thomas Burrowes notebook.
25 PAC, Map Division, V1/410, Rideau Canal, 1827, Plan and Sections of the Large Lock, Lt. Col. By, 1 December 1827.
26 Ibid.
28 PAC, Map Division, V1/410, Rideau Canal, 1827, Plan and Sections of the Large Lock, Lt. Col. By, R.E., 1 December 1827. Generally sheet piling was driven in a straight line across the chamber in front of the upper sill and behind the lower sill of a lock. The single extant drawing of the proposed large lock with the upper gates mounted on the breastwall in the conventional manner, shows clearly a row of sheet piling running straight across the lock chamber just in front of the upper sill on the breastwall. Rather curiously, it shows that the sheet piling below the lower gates was to be driven across the tailbay of the lock in the configuration of a gothic arch with its arcs roughly paralleling the angle made by the closed lock gates. A note on the drawing states with respect to the piling below the lower gates, and presumably with respect to the piling above the upper gates, that "Puddling 1 foot broad [was to be placed in a trench crossing the chamber] under the masonry, thro' the Centre of which a row of Buck Piles is driven." (PAC,
Map Division, At/410, Rideau Canal, Proposed Plan of a lock for the Rideau Canal. 150 feet long by 50 feet broad, [Lt. Col. By, R.E., 1827]).

29 PAC, Map Division, Vl/410, Rideau Canal, 1827, Plan and Sections of the Large Lock, Lt. Col. By, R.E., 1 December 1827.

30 Ibid.

31 PAC, RG8, Series C, Vol. 45, C-2618, p. 211, Lt. Col. By to General Mann, 10 June 1828.

32 PAC, Map Division, Vl/410, Rideau Canal, Plan and Sections of the Large Lock, Lt. Col. By, 1 December 1827; and Ibid., Plan, Elevation & Section of Col. By's proposed Large Lock, Lt. Col. By, 1 December 1827.

33 PAC, Map Division, Vl/410, Rideau Canal, 1827, Plan and Sections of the Large Lock, Lt. Col. By, R.E., 1 December 1827.

34 The position of the collar on the lock gates is evident on all of the large lock drawings, but only one drawing shows clearly the type of anchor that Lt. Col. By envisaged employing for the lock gates: viz. PAC, Map Division, At/410, Rideau Canal, Proposed Plan of a Lock for the Rideau Canal, 150 feet long by 50 feet broad, [Lt. Col. By, 1827].

35 See for example, the lock masonry details in PAC, Map Division, Vl/410, Rideau Canal, 1827, Plan and Sections of the Large Lock, Lt. Col. By, R.E., 1 December 1827.

36 Samuel Clowes, a civil engineer, had undertaken a preliminary survey of the Rideau-Cataraqui waterways in 1824-25 at the behest of the Legislature of Upper Canada. In his report, Clowes recommended that the canal be constructed by excavating canal cuts around the lengthy stretches of rapids on the rivers (See PAC, RG5, Al, Vol. 70, Reel C-4614, pp. D37269-D37326, Civil
Secretary's Correspondence, "Third General Report to His Excellency Major General, Sir Peregrine Maitland, Lt. Governor of Upper Canada", [Clowes' report], York, 5 February 1825). Lt. Col. By was instructed to follow Clowes' plan insofar as possible (PAC, MG13, W044, Vol. 18, B-1294, pp. 70-72, Major General, Sir J. Carmichael Smyth, Memorandum as to the formation of the Rideau Canal between the Ottawa River & Kingston upon Lake Ontario, addressed to General Mann, [By's instructions], 14 March 1826.


38 PAC, Map Division, H11/410, Rideau Canal, 1827, "Plan, Elevation and Sections of the Works in Canal Valley and Entrance Bay, Ottawa River, as proposed by Lt. Col. By, Commanding Royal Engineer", John By, Lt. Col., R.E., 7 July 1827. See also Ross, Ottawa: Past and Present, p. 59; and MacTaggart, Three Years in Canada, Vol. I, p. 105.

39 PAC, Map Division, V1/410, Rideau Canal, 1827, "Plan and Section of the Large Lock, Proposed by Lieut. Col. John By, Royal Engineer Commanding: N.B. These shew the upper part of the Series of Seven Locks proposed for the Entrance Valley," John By, Lt. Col., R.E., 1 December 1827.

40 PAC, Map Division, V1/410, Rideau Canal, 1827, "Lock and Dam at Jones' Falls, Section No. 17", John By, Lt. Col., R.E., 25 October 1827.


44 PAC, H3/312, Lachine Canal, 1828 (Rideau Canal, 1827), Plan and Sections of the Eighth Lock, 10 feet lift, n.d.

45 PAC, VI/410, Rideau Canal, 1827, Plan and Section of the Large Lock, Proposed by Lieut. Col. John By, 1 December 1827.


47 PAC, RG8, Series C, Vol. 48, Reel C-2619, p. 106, Masonry contract of Walter Fenelon for the Hog's Back, 7 May 1827; and PAC, Map Division, H3/312, (Lachine Canal, 1828) [Rideau Canal, 1827], Plan and Sections of the Eighth lock, 10 foot lift.

48 Ross, Ottawa: Past and Present, p. 57; and PAC, Map Division, VI/410, Rideau Canal, 1827, Plan and Sections of the Large Lock, Lt. Col. By, 1 December 1827.


54 Rolt, Navigable Waterways, p. 24, "Calder & Hebble Navigation, Sections of a typical lock, 1758, John Smeaton".
57 Ibid., p. 283. Gladwin, Canals of Britain, quotes Crecy (History of Engineering, 1833) to the effect that the thickness of the side walls should be equal to half their height. Spons, (Dictionary of Engineering, 1874) states that the greatest thickness of the side walls at their base should be from 1/4 to 1/2 of their height.
60 Gladwin, Canals of Britain, p. 24, quoting Crecy (History of Engineering, 1833) to the effect that lock walls should be perpendicular towards the interior of the lock; and Burnell, "River and Inland Navigation", Aide-Mémoire, III, 1851, p. 282, states that "it has become the practice to make side-walls vertical".
63 See, for example, Smiles, Lives of the Engineers, II, p. 414, "Lock, Caledonian Canal".
64 Great Britain, Aide-Mémoire, III, Part P-R, p. 283, Burnell, "River and Inland Navigation".
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73 Strickland, Reports on Canals, 1826, "Sections of Locks and Basin Walls", Plate #17, Prince's Dock, Liverpool.

III The Approved 33 by 134 Foot Steamboat Lock


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9 Ibid., p. 29, Kempt Committee, Kingston, to Lt. Col. By, 28 June 1828.


11 PAC, Map Division, V1/410, Rideau Canal, 1828, Plan of the Approved Locks for the Rideau Canal, John Burrowes, Overseer of Works, signed John By, Lt. Col., R.E., Commanding Rideau Canal, 8 July 1828.


14 See for example, Great Britain, Corps of Royal Engineers, Papers on Subjects connected with the Duties of the Corps of Royal Engineers, London: John Weale, 1839, Vol. III, Plate 19, "Rideau Canal"; and PAC, MG13, W044, Vol. 20, Reel B-1295, p. 459, "Plan and Section of a Single Lock for the Rideau Canal as approved by the Committee of which Sir J. Kemp was president", n.d.

15 Ibid.

16 Canada, Department of Public Works, General Report of the Commissioner of Public Works, 1867, Queen's Printer: Ottawa, 1868, p. 64.


18 U.E. Loyalist (York, Upper Canada), 7 August 1828.
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19 Compare, for example, PAC, Map Division, H3/312, Lachine, 1828, Rideau Canal, December 1827, Plan and Sections of the Eighth lock, 10 foot lift, and Ibid., Vl/410, Rideau Canal, 1828, John Burrows, "Plan of the Approved Locks for the Rideau Canal", 8 July 1828.

20 PAC, MG13, W044, Reel B-1295, "Plan and Section of a Single Lock for the Rideau Canal", n.d.; and PAO, Baird Papers, Reel #1, Baird Diary, entry for Friday, 12 September 1828.

21 Dalhousie Muniments, Scottish Record Office, "Remarks on the Works at the Entrance Valley," Lt. Col. By, 5 May 1828, reproduced in Rideau Canal, Historic Prints and Drawings Collection, R4-000-M-0008.

22 PAC, Map Division, Vl/410, Rideau Canal 1828, John Burrows, "Plan of the approved locks for the Rideau Canal", 8 July 1828. Counterforts are projections of masonry at the back of a wall, and they act through their weight increasing the stability of the wall. Buttresses, in contradistinction, project from the front of a wall, and they act by increasing the leverage of a wall (Spons' Dictionary of Engineering, III, pp. 2746, 2748).


26 PAC, Map Division, Vl/410, Rideau Canal, 1828, "Plan of the approved lock for the Rideau Canal", 8 July 1828.

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29 Great Britain, Papers on Subjects connected with the Duties of the Corps of Royal Engineers, Vol. III, Plate 19, "Rideau Canal."


33 PAC, Map Division, V1/410, Rideau Canal, 1827, Plan and Sections of the Large Lock proposed by Lieut. Col. John By, R.E., 1 December 1827.


35 PAC, MG13, W044, Reel B-1295, "Plan and Section of a Single lock for the Rideau Canal," n.d. Note: this drawing is the same as the views shown in the drawings no. R4-000-M-0049, R4-000-M-0050, and R4-000-M-0051 in Historic Prints and Drawings Collection of Research Division, Parks Canada.

36 Lt. Denison, 'Descriptions of Works on Rideau,' Papers, Vol. III, Figure 1.


38 Personal Communication, Ted Macdonald, Engineering and Architecture, Ontario Region, Parks Canada, to Robert
W. Passfield, 29 October 1980: "Copy of field notes giving dimensions of stones, west wall, Lower Brewers" (Washburn), 13-29 April 1976, 26 pages; "Diagram showing location of stones in West Wall, Lower Brewers lock, December 1976"; and "List of Stones to be replaced or acceptably repaired."


40 Ibid., pp. 2375-76.

41 Ibid., p. 2374.

42 Lt. Denison, 'Works on Rideau Canal,' *Papers of the Royal Engineers*, Vol. III, Figure 1.

43 Byrne and Spon, eds., *Spons' Dictionary of Engineering*, Vol. III, p. 2376. When two new masonry locks were constructed in 1884-86 at Beveridges lockstation during the rebuilding of the Tay Canal branch of the Rideau navigation, the superintending engineer specified that each of the coping stones on the quoin piers where the crabs were to be seated, should be 4'-0" by 4'-0" by 1'-6" or 1'-4" deep (PAC, RG43, B49, Vol. 213, F.S. Wise to Manning and Macdonald, 15 June 1886). Presumably this was the same size of stone as was used in the coping of the quoin piers of the locks constructed on the Rideau Canal in 1828-32.


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46 McKay, Building Construction, p. 36.
47 Ibid., p. 47.
49 McKay, Building Construction, p. 36.
50 Byrne and Spon, Spons' Dictionary of Engineering, III, p. 2375.
51 Parks Canada, Historic Prints & Drawings Collection, R4-000-M-0041, "8th Gate of the 1st 8 Locks, By Town, Rideau Canal", John By, n.d. [ca. 1832], masonry details.
52 Byrne and Spon, Spons' Dictionary of Engineering, III, p. 2375.
53 Ibid., p. 2373.
55 McKay, Building Construction, pp. 52-53, and Figure 28-A.
57 PAC, Map Division, H3/312, (Lachine Canal, 1828), [Rideau Canal, December 1827], "Plan and Sections of the Eighth Lock, 10 foot lift," Inspector General of Fortifications.
58 PAC, Map Division, V1/410, Rideau Canal, 1827, Plan and Sections of the Large Lock proposed by Lieut. Col. John By, R.E., 1 December 1827.
59 See, for example, PAC, Map Division, M/410, Rideau Canal, n.d., Plan and Section of a Single Lock for the Rideau Canal as approved by Committee of which Sir J. Kempt was president, John By, Lt. Col., R.E.

60 Op. cit., Plan and Sections of the Eighth Lock, [December 1827]; and op. cit., Plan and Sections of the Large Lock, 1 December 1827.

61 Byrne and Spon, Spons' Dictionary of Engineering, III, pp. 2374-2375.


63 Byrne and Spon, Spons' Dictionary of Engineering, III, p. 2374.

64 McKay, Building Construction, p. 38.

65 Byrne and Spon, Spons' Dictionary of Engineering, III, pp. 2373-75.

66 Ibid., p. 2376.

67 Ibid., p. 2373 and below.

68 Provincial Archives of Ontario, Baird Papers, Reel #1, N.H. Baird Diary, entries for Saturday, 6 September 1828; Monday, 8 September 1828; and Friday, 12 September 1828.

69 PAO, Baird Diary, entry for Thursday, 13 September 1828. Years later when two new locks were constructed on the Rideau Canal, at Beveridges lockstation during the Tay Canal branch reconstruction 1884-1886, F.A. Wise the superintending engineer also was very strict with regard to the ashlar masonry work. He instructed his man to see to it that all of the stones were "thoroughly washed off" before being laid, that "no face stones which have any dry seams or checks are allowed to go into the walls - that the beds & joints
are properly cut before being laid, no stone should be
dressed after once being laid" (PAC, RG43, B4a, Vol.
213, p. 41, F.A. Wise to J.D. Taylor, 11 September
1885). Wise also instructed the contractors that the
top bed of cream coloured stone being quarried at
Portland for the locks was "of too soft a nature, and
would not be permitted to go into the walls below the
six foot line": viz. the water line. However, the
harder stone, streaked with yellow or purple, could be
used in the lower portions of the wall (Ibid.,
F.A. Wise to Messrs. Macdonald and Manning,
contractors, 2 July 1884).

PAO, Baird Diary, entries for Saturday, 18 October 1828
and following. When in Bytown working in the Royal
Engineers' Office, Baird had Sundays off; and this was
probably the case with all of the men working on the
Rideau project stationed at the various sites. For
example, on Sunday, 7 September 1828, Baird rested at
home; and then he and MacTaggart, who was about to
depart for England, went for a walk to the Rideau
Falls.

PAO, Baird Diary, entries for Wednesday, 1 October
1828, Monday, 13 October 1828, Tuesday, 14 October
1828, Saturday, 18 October 1828, and Thursday, 14
November 1828.

Ibid., entry for Saturday, 18 October 1828.

PAC, Map Division, H1/410, Rideau Canal, 1829/30,
Present State of the First 8 Locks, Entrance Valley,
Lt. Col. John By, R.E., 24 October 1829.

PAO, Baird Diary, entry for Tuesday, 9 September 1828.
Noah Baird worked in the construction of the Union
Canal which connected Edinburgh with the Forth and
Clyde Canal constructed earlier. Nicol Baird was the
resident engineer on the Union construction project, completed in 1822 (Jean Lindsay, *The Canals of Scotland*, David & Charles: Newton Abbot, 1968, pp. 26, 37, & 40). He was Noah Baird's father; and young Baird probably started work as a surveyor or surveyor's assistant as was customary on canal engineering projects at that time.

75 PAO, Baird Diary, entry for Monday, 20 October 1828.
76 Ibid., entries for Tuesday, 14 October 1828 and Friday, 15 November 1828. During the construction of the two new masonry locks at Beveridges lockstation on the Tay Canal branch in 1884-86, the superintending engineer stipulated that: "no masonry to be laid until the frost is out of the stone" (PAC, RG43, B4a, Vol. 213, p. 66, F.A. Wise to Mr. Cunningham, Inspector of Masonry, 14 April 1885).

78 PAC, MG13, W044, Vol. 19, B-1294, p. 89, Lt. Col. By to General Mann, 7 July 1827.

81 Ibid., p. 3.
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86 Public Record Office, Plan and Section of a pointed cill, [R4-000-M-0051]; Map Division, M/410, Rideau Canal, "8th Gate of the 1st 8 Locks, By Town, Rideau Canal," Lt. Col. By, Commanding Royal Engineers, n.d. [Wall construction detail shown adjacent to the gate].

87 Byrne and Spon, Spons' Dictionary of Engineering, III, pp. 2373-2375.


89 McKay, Building Construction, pp. 47-52.

90 Byrne and Spon, Spons' Dictionary of Engineering, III, pp. 2377 and 2375.

91 PAO, Baird Diary, entries for Monday, 13 October, Tuesday 14 October, Saturday, 18 October and Monday, 20 October 1828.


93 Lt. Denison, 'Works on the Rideau Canal,' Papers of the Royal Engineers, III, Plate 19, Rideau Canal Lock.


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97 Wakefield, Delaware and Hudson Canal, p. 35.


101 Plans in the Public Archives of Canada, Map Division, of the locks constructed earlier on the St. Lawrence Military Canals do not indicate any use of puddle. These locks were constructed either in rock cuts in the banks of the river or in the river itself near the bank, and with an abundance of water, leakage was not a matter of concern.


103 PAC, MG24, A12, Section No. 3, Reel A534, n.d., John Richardson and C.W. Grant, Late Commissioners, Lachine Canal, to John Neilson, 22 December 1828.

104 PAC, RG11, Series I, Vol. 1, Reel C-4243, Copy of the Agreement made with the Engineer, Mr. Thomas Burnett, 28 March 1820.


107 Smith, A History of Dams, p. 266.
108 Burnell, River and Inland Navigation, p. 270, Aide-Mémoire, Vol. III. The calibre of the standard musket at this time was 0.75"; and musket balls were of a somewhat smaller diameter: viz. 0.68" (Ralph Willet Adge, Captain, Royal Regiment of Artillery, The Bombardier and Pocket Gunner, 7th ed., revised, London: T. Egerton Military Library, 1813, p. 53. Reference furnished by David McConnell, Research Division, Parks Canada).


111 Ibid., p. 270.

112 Strickland, Report on Canals, p. 3.

113 PAC, Map Division, V1/410, Rideau Canal, 1827, Plan of the Dam and Lock to be constructed at the Black Rapids, [1827]; and Ibid., Plan and Sections of the Large Lock proposed by Lieut. Col. John By, R.E., 1 December 1827.


116 Ibid., Plate 19.


118 PAO, Baird Diary, entry for Friday, 19 September 1828.
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119 PAC, Map Division, H1/410, Rideau Canal, 1829/30, Sections of the First Eight Locks, Rideau Canal, Lt. Col. By, 24 October 1829.
120 Ibid., Sections across 4th and 5th lock.
122 Denison, 'Works on the Rideau Canal,' Papers of the Royal Engineers, III, p. 133. The back fill placed against the clay puddle wall was, however, thoroughly pounded down and solidified by means of a pounder (PAO, Baird Diary, Wednesday, 10 September 1828).
123 PAC, Map Division, V1/410, Rideau Canal, 1828, "Plan of the Approved lock for the Rideau Canal," 8 July 1828.
125 PAC, Map Division, V1/410, Rideau Canal, 1828, "Plan of the approved lock for the Rideau Canal," 8 July 1828.
127 The U.E. Loyalist, 7 August 1828.
128 PAC, MG13, W044, Reel B-1294, p. 64, Progress Report for 1829, extract printed in Karen Price, Construction History of the Rideau Canal, Manuscript Report No. 193, p. 69. See also PAO, Baird Diary, entry for Wednesday, 10 September 1828, to the effect that workmen were commencing to drive 12 foot long piles in the breastwork of lock no. 6.
Occasionally the mass of the solid unit masonry breastworks was increased substantially such as on one of the Hartwell's lockstation locks (PAC, Map Division, Rideau Canal 1829/30, Plan and Section of the Locke at Hartwell's, 18 March 1830). Likewise on the Jones Falls locks where the change in the size of lock from 20 by 108 feet to 33 by 134 feet, after the lock pits had been cut out of the rock, necessitated the
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construction of exceptionally large unit masonry
breastworks to in-fill parts of the rock cut (Ibid.,
Plan and Section of the Locks at Jones Falls, 18 March
1830).

138 Lt. Denison, 'Works on the Rideau Canal,' Papers of
Royal Engineers, III, p. 134.

139 Parks Canada, Historic Prints, Drawings and Photographs
Collection, "Rideau Canal," Sketch Shewing in yellow
the proposed new Masonry of Sill," n.d. [1831]
[R4-026-F-0044]; and Ibid., "Sketch Shewing in Red the
proposed new masonry of Sills, in yellow the masonry to
be taken up and rebuilt," n.d. [1831] [R4-026-F-0052].
Note: these drawings were probably prepared after May
1831 when problems with the breastworks necessitated
the upper courses of ashlar, including the masonry
sills, being lifted and replaced with stonework of a
stronger construction (see below in text). Whatever
the case, the masonry of the sill and breastwork shown
in these drawings are such as was constructed on the
Rideau Canal locks prior to May 1831.

141 Parks Canada, Historic Prints, "Sketch Shewing in
yellow the proposed new Masonry of Sill,"
R4-026-F-0044.
134.
143 William Strickland, Report on Canals, Railways, Roads
and Other Subjects made to "The Pennsylvania Society
for the Promotion of Internal Improvements,"
15, Birmingham and Liverpool Canal.
144 Lt. Denison, 'Works on the Rideau Canal,' Papers of
Royal Engineers, III, p. 134.
It is unclear whether the breastwork at the upper sill of lock no. 8 had a sheet piling and puddle wall or not. By stated that he had dispensed with the sheet piling and puddle wall, as related, where he could not drive piles, and the limestone ridge under the upper end of lock no. 8 would have prevented the piles being driven. On the other hand, a progress report of 1829, states that sheet piling was driven "in the three upper breastworks" which would have included the breastwork under the upper sill of lock no. 8 (PAC, MG13, W044, Reel B-1294, Progress Report for 1829, extract printed in Price, Construction History of the Rideau Canal, p. 69.

Denison, op. cit.

Edward Frome, Lt., Royal Engineers, "Account of the Causes which led to the Construction of the Rideau Canal, connecting the Waters of Lake Ontario and the Ottawa; the nature of the Communication prior to 1827; and a Description of the Works by means of which it is converted into a Steam-boat navigation." [February 1837], p. 80, in Great Britain, Corps of Royal Engineers, Papers on Subjects Connected with the Duties of the Corps of Royal Engineers, Vol. I, London: John Weale, 2nd. ed., 1844.


Ibid., p. 133.

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155 Ibid., pp. 20-22; and Drago, Canal Days in America, p. 11. Previously, tarras or puzzolana had to be imported and mixed with quick lime to make hydraulic cement. In France, the lock masonry of the Canal du Midi, constructed 1666-1681, was laid in mortar made by mixing lime with puzzolana brought from Civita Vecchia, Italy (Rolt, Canal du Midi, p. 75).


158 Lt. Col. By was a close friend of John Rennie, the English canal engineer, and no doubt would have closely examined English canal works prior to embarking for Canada to undertake the construction of the Rideau
Canal. Moreover, Lt. Col. By was an engineer who was always abreast of, if not in the forefront of, new developments in the field of civil engineering (See R.W. Passfield, Engineering the Defence of the Canadas: Lt. Col. John By and the Rideau Canal, Manuscript Report No. 425, Parks Canada, 1980, Preface. Lastly, By examined closely the plans and lock masonry of the Lachine Canal following his arrival in Lower Canada; and the locks of that canal had been pointed with hydraulic cement (see text below).

161 PAC, RG1, E12, Vol. 3, Captain Phillpotts Second Report, p. 201, Note 'C'.
165 MacTaggart, Three Years in Canada, Vol. II, p. 239.
166 Drago, *Canal Days in America*, p. 177. The engineers in charge of the Erie Canal project were apparently unaware that William Weston, an English canal engineer, who superintended the construction of the Middlesex Canal in Massachusetts from 1794 to 1804, had discovered near the route of that canal in 1797 a deposit of trass suitable for making hydraulic cement. It was subsequently used in constructing that canal (Ibid., pp. 11 and 178).

167 Ibid., pp. 177-78.

168 Ibid., p. 178.


170 PAC, MG24, A12, Section 3, Reel A534, n.p., John Richardson and C.W. Grant, Late Commissioners, Lachine Canal, to John Neilson, 22 December 1828.


172 PAC, MG24, D8, Wright Papers, Vol. 33, p. D14893, Ruggles Wright, Hull, to Col. Durnford, Commanding Royal Engineer, Canada, at Quebec, 8 June 1829. The properties, colouration, and comparative advantages of impure lime or hydraulic cement, as distinct from the quick lime used in common mortar, are set forth and explained in Byrne and Spon, eds., *Spons' Dictionary of Engineering*, Vol. III, p. 2279.


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177 See for example, PAC, MGl3, W044, Vol. 866, Reel B-2811, p. 170, Section No. 17, Jones' Falls entry; and the lime kilns shown on PAC, Map Division, H1/410, Rideau Canal, 1829/30, Present State of the First 8 Locks, Entrance Valley, Rideau Canal, 24 October 1829.


180 McCord Museum, Montreal, Redpath Papers, Item No. 20, 30 May 1831. Note: the words quoted are those of Redpath; but he is stating that his view "coincides exactly" with the idea McKay had expressed in a letter just received from Bytown.

181 Ibid., John Redpath to Lt. Col. Boteler, 30 May 1831. Lt. Col. Boteler was an Officer of the Corps of Royal Engineers whom By had placed in charge of supervising the construction of the southern section of the canal.

182 Ibid., Redpath to Boteler, 30 May 1831.

183 Ibid.

184 Ibid. It is curious that Redpath should state that he had constructed a puddle wall in the breastwork of his locks at Jones Falls; and that piles ought to be driven through the puddle to a depth of 4 feet below the lock gate floor. Sectional drawings of the Jones Falls locks, dated 18 March 1830, show the breastworks constructed of uninterrupted masonry resting on bedrock with the exception of the lower sill of the bottom lock where sheet piling was driven (PAC, Map Division,
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Rideau Canal, 1829/30, Plan and Section of the Locks at Jones Falls, Lt. Col. By, R.E., 18 March 1830). One possible explanation is that Redpath deviated from the plan of construction that By had wanted and depicted in the drawing; and that the bedrock did not underlay all of the lockpits.


Lt. Frome, ibid., pp. 94-95, 87, and 89.


Lt. Frome, op. cit., p. 89.


Lt. Frome, op. cit., p. 95.


Lt. Frome, op. cit., pp. 80-81.

PAC, MG24, D8, Wright Papers, Vol. 33, P. DL4903, P. Wright & Sons to Lt. Col. By, 20 July 1829; and Ibid., Vol. 34, p. DL4998, P. Wright & Sons to D. McMartin, [1831]. Wright originally intended to sell the cement for 5s.6d. per French Minot, but the agreement concluded with N.H. Baird, the Clerk of Works on the
Rideau project, in August 1830 specified that the price was to be 5s.6d. per bushel. (PAC, MG24, D8, Wright Papers, Vol. 34, pp. D14963-D14964, P. Wright & Sons to N.H. Baird, 30 August 1830, draft agreement). There are also references to the cement being sold in "puncheons" and/or "casks" (Ibid., p. D14996, P. Wright & Sons to Lt. Col. By, 29 October 1830; Ibid., p. D15138, P. Wright & Sons, to C.S. Forbes, Deputy Commissary General, 23 March 1832; Ibid., p. D15034, Jno. B. Ward to J. Craighton, 7 August 1831; and Ibid., p. D15042, Ruggles Wright to B. Bruster, 11 August 1831). It was essential that cement powder be kept in air tight casks or barrels as exposure to air over a period of time would injure the quality of the cement (Pasley, Course of Practical Architecture, p. 23).

In 1834, Wright's Hull Cement was tested against the English Harwich Cement, and another hydraulic cement manufactured at Quebec, with respect to setting time in pointing work, and setting properties when used during a rain, plastering qualities under water and adhesive qualities. The results of the tests may be found in Lt. Alex. Gordon, R.E., "Experiments tried at Quebec as to the properties and adhesive qualities of the following Cements, by order of Colonel Nicolls, Commanding Royal Engineer, dated 17 November 1834," Papers of the Royal Engineers, Vol. III, pp. 184-85 (Appendix A).

When the Wrights first submitted their new hydraulic cement to Lt. Col. By for testing, they recommended
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that "it should be mixed with clean white washed sand, in the proportion of one third of sand to the quantity of cement" (Ibid., Vol. 33, p. D14453, P. Wright & Sons to Col. By, July 1829. However, in 1831-32 when the Wrights were commencing the marketing of their hydraulic cement in Montreal, they recommended as indicated above in the text, a 1 sand to 4 cement and a 1 to 5 mix depending on the use to which the cement was to be put. This was most probably the mix that was arrived at for use on the Rideau Canal locks.


204 Ibid.; and Lt. Frome, op. cit., p. 80.


207 McKay, Building Construction, p. 47.


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210 PAC, MG24, A12, Vol. 36, Lt. Col. Couper to Earl Dalhousie, 1 August 1830; and Great Britain, House of Commons, Canada Canals, [London: King's Printer], 1832, p. 6, C.G.E. [Ellicombe], Memorandum, 10 February 1832.

211 Lt. Frome, 'Construction Account of the Rideau Canal,' Papers of the Royal Engineers, Vol. III, pp. 89 and 134. See also, Public Record Office, London, "Plan and Sections of a pointed cill and recess of a combined lock," John By, Lt. Col., n.d. [R4-000-M-0050]. This plan view shows clearly how the masonry of the sills was joggled.

212 The grouting method used on the Rideau Canal masonry is commented on in Lt. Frome, Ibid.; and Ibid., Lt. Denison, 'Works on the Rideau Canal,' Vol. III. See also Ibid., Vol. IV, pp. 208-9, Lt. Denison, "Notes on Injecting Cement or Hydraulic Lime into leaky joints of masonry." During 1831-32, the grouting operation on the locks previously constructed may well have been confined to the masonry that was leaking.


214 Ibid., p. 231.


216 See for example, Department of Railways and Canals, Annual Report, 1902-03, p. 185; and Ibid., 1909-10, p. 275. As of 1921, a concrete block plant was established on the Rideau Canal at Brook's Bay, Lake Opinicon. Thereafter concrete blocks of the same dimensions as the stone work were used to replace badly weathered blocks of stone and/or to rebuilt the facing of the locks where required (see Ibid., 1921-22, Rideau Canal maintenance report).
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218 McKay, Building Construction, p. 52. A third method of jointing heavy stone masonry, plugged joints, is described in Ibid., pp. 51-52.


220 McKay, Building Construction, pp. 51-52.

221 Strickland, Reports on Public Works, p. 141.

222 PAC, Map Division, M/410, Rideau Canal, "8th Gate of the 1st 8 Locks, By Town, Rideau Canal," Lt. Col. By, R.E., n.d.


226 Ibid., p. 220.

227 MacTaggart, Three Years in Canada, Vol. II, pp. 346-47.

228 Judith A. Beattie, Gunboats on the St. Lawrence River (1763-1839), Manuscript Report Series, No. 15, Parks Canada, Ottawa, 1967, pp. 126-27. In October 1820, a report from the Canadas advised the Admiralty that "the expense of copper fastenings to ships employed on the Lakes is quite unnecessary, as the iron does not appear to be corroded in any degree as we have been accustomed
to see it" (Ibid., pp. 127 and 102). This assessment originated with the Surveyors of the Navy at Kingston who informed their commander, Commissioner Barrie, on 19 April 1820, "that Copper is not necessary in the construction of Ships which are not exposed to the corroding effect of salt water, and that Iron fastenings would be found to be as durable as the Timber with which they would be repaired, taking care that the Bolts in the flat of the Bottom be carefully guarded from the wash of the Bilgewater (Ibid., p. 101).


230 Ibid., Thursday, 14 November 1828. Although the Rideau navigation was to have a minimum depth of 5 feet, the upper and lower sills were actually constructed with an additional foot of water on them so vessels drawing 6 feet of water could in fact pass all of the locks (PAC, MG13, WO44, Vol. 15, Reel B-217, p. 246, Lt. Col. By to Col. Ellicombe, 26 June 1834. See also, Ibid., p. 250, Captain D. Bolton to Col. Nicolls, 7 April 1834).

231 Parks Canada, Historic Photographs, Prints and Drawings Collection, R4-026-F-0046, "Plan of a Pointed Sill on Rock, Rideau Canal," T. Burrowes, 23 November 1840. Wood sills constructed at a later date on the Rideau Canal were modified somewhat in detail and more elaborately constructed with mortise and tenon jointing used to frame the sill (Ibid., R4-026-G-0051, Section of a Wood Sill, Rideau Canal, n.d.) as well as an increased number of tie rods and iron straps (Ibid., R4-026-F-0047, Plan and Elevation of a Wood Sill, n.d.).

Ibid.

Lt. Frome, Construction Account of the Rideau Canal, Papers of Royal Engineers, I, p. 95; and Lt. Denison, Works on the Rideau Canal, Ibid., III, Plate 19, Fig. 5, "Plan of a Wooden Sill adopted in some of the Lower Locks on the Rideau Canal."

Parks Canada, Historic Photographs, Prints and Drawings Collection, R4-026-F-0037, Half Plan and Section of a Wooden Pointed Sill laid on Clay or Earth, n.d.; and Lt. Denison, "Works on Rideau Canal," Papers of Royal Engineers, Plate 19.

Lt. Frome, Construction Account of the Rideau Canal, Papers of Royal Engineers, I, p. 94.


Lt. Frome, Construction Account of the Rideau Canal, Papers of Royal Engineers, I, pp. 84-85.


See text, section on 'Design Details of the large 50 by 150 foot Lock.'


Lt. Frome, Construction Account of Rideau Canal, Papers of Royal Engineers, I, p. 86.
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245 PAC, RG8, Series C, Vol. 45, Reel C-2618, p. 208, Lt. Col. By to General Mann, 10 June 1828; and MacTaggart, Three Years in Canada, Vol. I, p. 137.


248 The calculations of the number of floors constructed on each type is based on information contained in Lt. Frome, Construction Account of the Rideau Canal, (Papers of Royal Engineers, Vol. I) and various entries in the Baird Diaries (PAO, Baird Papers, Reel #1).


251 Lt. Frome, Construction Account of Rideau Canal, Ibid., I, pp. 78-81, 96.

252 Ibid., p. 92; and PAC, Map Division, H1/410, Rideau Canal, 1829-30, Plan and Section of the Locks at Jones Falls, Lt. Col. By, R.E., 18 March 1830.


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256 Ross, Ottawa: Past and Present, p. 57.
260 For example, PAC, Map Division, H1/410, Rideau Canal, 1829/30, Plan and Section of the Locks at Hartwell's, John By, Lt. Col., R.E., 18 March 1830; Parks Canada, Canal Engineering microfilm plans, R-20-101, "Plan and Sections of the Locks at Jones Falls showing the progress at the end of the year 1830," n.d.; and PAO, Baird Diaries, Reel #1, entry of 25 September 1828, rough sketch of inverted arch on Entrance Valley locks.
261 See Parks Canada, R4-000-M-0051, Plans and section of a pointed sill and recess of combined locks, (Breastwork Section); and Parks Canada, Rideau Canal Photo Survey 1974, Ottawa Locks, Photographs No. 27 and 36.
264 Lt. Frome, Construction Account of the Rideau Canal, Papers of Royal Engineers, I, p. 96.
265 Ibid., pp. 80-81.
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266 PAO, Baird Diary, entry of Thursday, 25 September 1828 and accompanying sketch.


270 Only one drawing of the Rideau Canal locks shows the foundation that was placed under the inverted arch stonework in any detail, but it is impossible to determine whether the foundation under the masonry inverted arch was constructed of macadamized stone bonded with hot lime mortar or of small rubble masonry stone laid in cement. [See Public Record Office, London, "Plan and sections of a single lock," n.d. (Parks Canada, R4-000-M-0049), the "Cross Section" view.]


272 Lt. Frome, Construction Account of the Rideau Canal, Papers of the Royal Engineers, I, 94-95; and Lt. Denison, Works on the Rideau Canal, Ibid., III, Plate 19, Fig. 5, "Plan of a Wooden Sill adopted in some of the Lower Locks on the Rideau Canal."

273 Frome, op. cit., p. 87.

274 These calculations as to the number of locks with bare rock floors are based on information in Frome, op. cit., and PAC, MG13, W044, Vol. 18, Reel B-1294, pp. 235f., Lt. Col. By to Col. Durnford, Document K, [14 January 1831].

276 Judith Tulloch, *The Rideau Canal, 1832-1914*, Parks Canada, Manuscript Report Number 177, Structural Changes: Old Slys, p. 120. Tulloch states that a new timber floor was constructed in the upper lock at Old Slys during the winter of 1867-68. However, the Acres report, op. cit., states that there is still a bare rock floor in the upper lock at Old Slys (lock no. 27). Therefore, it was probably only the wooden gate recess floor that had to be re-laid in 1867-68.

277 At the time of the Kempt Committee Report of June 1828, Lt. Col. By was still thinking in terms of constructing his locks with either bare rock or masonry inverted arch floors. However, as early as January 1829, N.H. Baird was planning to construct a wood floored lock at Burritts Rapids, thereby indicating that the decision had been made prior to that date (See Baird Diary, Thursday, 29 January 1829).


280 Computation based on information in Ibid., and Lt. Frome, *Construction Account of the Rideau Canal*.


282 Strickland, *Report on Canals*, pp. 8-9; and Ibid., Plate 16, "Sections of Lock and Basin Walls."


284 Ibid., pp. 135-37; and Ibid., pp. 124-25, E.H. Gill, Chief Engineer, "Specifications for a Lock, Sandy and Beaver Canal."


288 The series of locksite plans, which is not complete for all of the locksites, can be found in PAC, Map Division, H2/410, Rideau Canal 1829/30, NMC 0012892.

289 The three plans showing wood floors in the locks are Ibid., "Plan of the Ground at Chaffey's Mills shewing the Lock and Waste-Water Way," 18 March 1830; Ibid., "Section at Brewer's Upper Mill," 18 March 1830; and Ibid., "Plan and Sections of the Works at Brewer's Lower Mills," n.d. 18 March 1830. Subsequently, it was determined that the rock being excavated for the Chaffey's lock was sufficiently sound to serve as a rock floor for the lock.


291 See Parks Canada, Historic Prints, Maps and Photographs Collection, R4-026-F-0037, "Half Plan and Section of a Wooden Pointed Sill & Apron for a Lower Gate when laid on Clay or Earth with the connexion with a wooden floor in the lock," n.d.
292 PAC, Map Division, H1/410, Rideau Canal 1829/30, Plan and Section of the Works at Brewer's Lower Mills, [18 March 1830].

293 There is a watercolour by Thomas Burrowes, dated May 1830, of the upper lock at Upper Brewer's Mills under construction which shows clearly the transverse timber of the lock floor. The timbers are resting, however, on a uniformly light layer of fill which matches the colour of the side wall masonry and differs greatly from the colour of the clay in the lock pit excavation. The light coloured layer beneath the transverse sleepers may well be macadamized stone (See PAO, Burrowes Sketch No. 65, "Brewer's Upper Mills: Upper Lock partly built, Excavations, Embankments & in Progress," May 1830, [Parks Canada, R4-023-A-0003].

294 Parks Canada, R4-023-F-0037, Half Plan and Section of a Wooden Pointed Sill and Apron for a Lower Gate," n.d.

295 Ibid.; and PAC, H1/410, Rideau Canal 1829/30, Plan and Section of the Works at Brewer's Lower Mills, [18 March 1830].

296 Ibid., Chaffey's Mills Lock, Transverse section of lock; Ibid., Section at Brewer's Upper Mills, 18 March 1830; and Parks Canada, R4-026-F-0037, Half Plan and Section of a Wooden Pointed Sill and Apron for a Lower Gate, n.d.

297 PAC, H1/410, Rideau Canal 1829-30, Plan and Section of the Works at Brewer's Lower Mills, 18 March 1830. The drawing of the wood floor lock proposed for Chaffey's Mills, but never built, shows only a single transverse sleeper under the front of the masonry breastwork (Ibid., Plan of the Ground at Chaffey's Mills, 18 March 1830).
298 See for example, PAC, Map Division, H2/410, Rideau Canal 1829-30, Plan of the Ground at Chaffey's Mills shewing the Lock and Waste-Water Way, 18 March 1830.

299 Parks Canada, R4-000-M-0049, Plan and Section of a Single Lock for the Rideau Canal, Lt. Col. By, n.d.

300 As mentioned, the March 1830 series of locksite drawings of the projected wood floored locks show only the proposed floor construction details in the lock chambers, with just straight lines indicating the outline of the lower gate recesses and sills. (See for example, PAC, H1/410, Rideau Canal 1829/30, Plan and Section of the Works at Brewer's Lower Mills, Lt. Col. By, [18 March 1830]).

301 Parks Canada, R4-026-F-0037, Half Plan and Section of a Wooden Pointed Sill & Apron for a Lower Gate when laid on Clay or Earth with the Connexion with a wooden floor in the lock, n.d.

302 PAC, MG29, B6, Vol. 3, "Plan and Sections of the Rideau Canal Locks;" and Lt. Denison, Works on the Rideau Canal, Papers of Royal Engineers, Vol. III, Plate 19, Fig. 4, "Transverse Section of a Lock with a Wooden Floor."

303 On the importance of these two considerations in lock floor construction, see Burnell, River and Inland Navigation, Aide-Mémoire, III, Part P-R, p. 283.

304 Interestingly enough, the finished drawings of Plate 19, in Denison's Works on the Rideau, Papers of Royal Engineers, Vol. III, published in 1839, appears to have been based directly on the other odd drawing in question, (MG29, B6, Vol. 3, "Plan and Sections of the Rideau Canal Locks") which shows a wooden lock floor constructed in the same peculiar manner. Even the titles and figure numbers on the sections depicted in
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both drawings are exactly the same. The explanation may well be that the MG29, B6, drawing (undated) was a preliminary plan for a wooden lock floor which was never constructed. Denison, in selecting a drawing to be reproduced by a lithographer to illustrate his article several years later, failed to notice the discrepancy between the wood floors depicted in this particular drawing and the wood floors actually constructed on the Rideau Canal locks.

305 PAC, RG11, Vol. 183, J.D. Slater, Superintending Engineer, to T. Trudeau, Secretary, Board of Works, Annual Report of 1861, January 1862, Rideau Canal, entry for Washburn lock. Slater says that the longitudinal timbers were "running the length of the lock;" but he must have meant the length of the lock chamber as the stepped down lower gate recess floor would have prevented the continuation of the longitudinal timbers past the end of the lock chamber floor.

306 In making repairs to the floor of the Lower Brewer's lock in 1861, it was found that the longitudinal timbers were "about 7 feet apart" (PAC, RG11, Vol. 183, File #55208, John Page, Chief Engineer, to Secretary, Board of Works, 28 September 1861). The author found, by measuring the sleepers removed from the Lower Brewer's lock floor in 1976, that the notches on the bottom of several were about 5 feet apart center to center (R. Passfield, Random measurements of Lower Brewer's lock sleepers, Smith's Falls Yard, July 1976).

307 Ibid. Also Personal Files, Washburn Lock, W.D. Bennett, Superintendent, Rideau Canal, to R. Passfield, History Research Section, 22 June 1976, Memorandum
giving dimensions of two of the sleepers removed from the Lower Brewer's lock and noting the notches found on the same.


310 PAC, RG11, Vol. 183, File #55208, John Page to Secretary, Board of Works, 28 September 1861.


313 Parks Canada, Canals Engineering, [slide].

314 Lt. Col. By stated that the Lower Brewer's Mills lock floor and sleepers were of hemlock (PAC, MG13, W044, Vol. 18, Reel B-1294, p. 330, By to Durnford, Document K, 14 January 1831). This was confirmed by J.D. Slater, Superintending Engineer, Rideau Canal, during repairs carried out in 1861 (PAC, RG11, Vol. 183, Slater to Trudeau, Annual Report for 1861, Washburn lock). However, of three random samples cut from the Lower Brewer's lock sleepers and sent for testing in 1976, two were found to be Eastern Hemlock and one, Ash (Personal Files, Washburn Lock, Conservation Division, Parks Canada, to Martin E. Weaver, Restoration Services Division, Parks Canada, 23 November 1977.)

315 PAO, Baird Diary, Friday, 30 January 1829.

316 PAC, MG24, 19, Vol. 7, p. 2048, Memorandum of a Journey from Kingston to Bytown made along the Route of the


320 Parks Canada, Canals Engineering, Lower Brewer's lock Slide Collection, Slide No. 2, July 1976.

321 Ibid.

322 Parks Canada, Canals Engineering, Rideau Canal microfilmed plans, R-20-139, "General Plan of Locks."


324 Parks Canada, Rideau Canal Photo Survey, 1974, Beveridges Lockstation, Photo No. 28, Lock 34 and Photo No. 16, Lock 33.

325 Parks Canada, Canals Engineering, Rideau Canal microfilmed plans, R-20-139, "General Plan of Locks."

326 Ibid.

327 See Judith Tulloch, The Rideau Canal, 1832-1914, Manuscript Report Number 177, "Structural Changes, 1832-1914," pp. 79-143, as well as the Department of Railways and Canals, Annual Reports and those of the Department of Transport after 1935, on Rideau Canal repairs.

328 The structural details of a wood floored lock as recorded during the demolition of the Lower Brewer's (Washburn) lock in 1976 can be found in Parks Canada,
Historic Prints, Drawings and Photographs Collection, Lower Brewer's Lock, Photographs R4-024-F-0007, and R4-024-F-0019 to R4-024-F-0035 inclusive.

Tulloch, The Rideau Canal, 1832-1914, pp. 79-143.

Ibid., "Washburn (Brewer Lower Mills)", pp. 136-40.


Tulloch, ibid., pp. 127 and 132.

Personal Files, Washburn Lock, Copy of D.A.H. Farmer, Acting Director, ARC Branch to J.I. Nicol, Director General, Parks Canada, 14 April 1976. See also photograph on page 5, The Citizen, Ottawa, 14 April 1976.

Random measurements of several of the truncated sleepers in the Smith's Falls Yard were made by the author in July 1976; as well as earlier by the Rideau Canal Office (Personal Files, Washburn Lock, W.D. Bennett, Superintendent, Rideau Canal, to R.W. Passfield, 22 June 1976).

Personal Files, Washburn Lock, Copy of L. Lafleche, Conservation Technician et al., Conservation Division, Parks Canada, to Martin E. Weaver, Head, Preservation Training and Technical Services, Restoration Services Division, Parks Canada, 23 November 1977.


Parks Canada, R4-026-F-0037, Half Plan and Section of a Wooden pointed Sill and Apron for a Lower Gate, Rideau Canal, n.d.

Lt. Denison, Works on the Rideau Canal, Papers of Royal Engineers, III, p. 134, and Plate 19, Fig. 1.
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341 Ibid., p. 391, Captain D. Bolton, R.E., Sketch shewing the proposed mode of extending the present aprons below the locks at Brewer's Upper and Lower Mills, 25 August 1835.


IV Lock Operating Mechanisms
2 Ibid., p. 281.
3 Lt. Frome, Construction Account of the Rideau Canal, Papers of Royal Engineers, Vol. I, p. 95. The figures for the various lifts are taken from the Frome article.
4 PAO, Baird Papers, Reel #1, Baird Diary, entry for Sunday, 12 October 1828.
5 Lt. Frome, op. cit., pp. 95-96. Again, the figures for the various lock lifts are taken from the Frome article. With respect to the lifts cited for the locks, it should be noted that although two combined locks were constructed at the Hog's Back the upper lock was a guard lock with no lift so that the whole lift of 13'-2" was carried on the lower lock.
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9 See text, "Design Details of the Large 50 by 150 foot lock".

10 PAC, Map Division, V1/410, Rideau Canal, 1828, Plan of the Approved Locks for the Rideau Canal, Lt. Col. By, 8 July 1828.

11 Parks Canada, R4-026-F-0043, Sections and Plan of the Sluice & Man hole for a 10 foot lift, Rideau Canal, Lt. Col. By, Royal Engineers, n.d. Work first commenced on the newly approved 33 foot wide locks in the Entrance Valley early in August 1828 (The U.E. Loyalist, 7 August 1828, p. 71). By 1 March 1829, it was reported that the three upper locks in the Entrance Valley were almost finished (PAC, MG13, WO55, Vol. 866, Reel B-2811, p. 168, Lt. Col. By, Abridged Statement of the Progress of the Works, 1 March 1829). As these locks were constructed with manholes, it is clear that the decision to use a pivot valve must have been taken sometime between the 8th July 1828 and the commencement of the 33 foot locks in the Entrance Valley early in August 1828, or at least very shortly thereafter.


13 Lt. Frome, Construction Account of the Rideau Canal, Papers of Royal Engineers, Vol. I, p. 95. Remarks to the effect that crabs and chains were being substituted
for rack and pinions, and cast iron for wood valves on all of the culvert sluices, can be found in PAC, MG13, WO44, Vol. 18, Reel B-1294, p. 226ff., Lt. Col. By to Col. Durhford, Document K, [14 January 1831].


15 Ibid., Figures 13, 7, 8, and 25. Note: Figures 7 and 8 show the valve plate as it was reinforced after the canal had been in operation for a year or more. Figure 6 shows the chains attached to the four corners of the valve plate, which is a form of hook-up adopted in 1834. See also, Parks Canada, R4-026-F-0028, Views of the Crab now in use to raise the Sluice Valves in the Masonry of the Locks on the Rideau Canal, shewing the Strap, Pinion and pawl proposed to be added, Captain D. Bolton, Senior Royal Engineer, Rideau Canal, 30 May 1836.

16 Parks Canada, Historic Prints & Drawings Collection, R4-026-F-0028, "Crab, with Proposal of Additional Features for Accident Prevention", D. Bolton, 30 May 1836.


18 Ibid.; and Parks Canada, R4-004-F-0009, Sketch A, Journal Plates and Journal Box Figures, D. Bolton, Senior Royal Engineer, 22 March 1833.


21 Ibid., pp. 137-38, and Plate 21, Figures 16, 17 and 18. See also, Parks Canada, R4-004-F-009, Sketch A, Journal Box Figure, D. Bolton, 22 March 1833.

22 Denison, op. cit., p. 138.


24 Denison, Ibid., Plate 21, Fig. 2, Note: The air vent passing through the coping stone was approximately 12 inches in diameter on the Jones Falls locks and 12 inches square on the Kingston Mills locks (Parks Canada, R4-025-F-0047, Plan & Sections of the Cast Iron Covers for the Air Holes of the Sluices in the Walls of the locks at Kingston Mills & Jones Falls, Rideau Canal, Capt. D. Bolton, 1 December 1836.


26 Parks Canada, R4-025-F-0046, Detail of the Sluice Valves at Kingston Mills and Jones Falls, n.d.

27 Denison, op. cit., Plate 21, Figures 2 and 5. Denison's drawing and several others to the contrary, it is also possible that all of the culverts were constructed slightly larger than the 3'-0" by 5'-0" openings that By planned to construct.

28 Parks Canada, R4-026-F-0034, Descriptive Sketch No. 2, [Wall face Sluice Valve modification], Capt. D. Bolton, 11 August 1834. Denison, op. cit., Plate 21, Figures 1 and 2, gives different dimensions for the sluice frame members. His drawing shows two upright members 6 inches thick, which in a three foot wide masonry opening would leave a sluice opening only two feet wide; but the valve plates were 34 and 5/8ths inches wide (Parks Canada, R4-026-F-0035, Sluice Valves for
the Face Sluice, John Burrowes, 29 September 1837). Clearly, the sluice culverts at Jones Falls and Kingston Mills, if not everywhere on the Rideau Canal locks, were somewhat larger than 3 feet by 5 feet, and the side members of the wall face sluice frames were probably 3 inches thick and not 6 inches thick as indicated by Denison's drawing.

29 Parks Canada, R4-026-F-0034, Descriptive Sketch No. 2, [Wall Face Sluice Valve modification], Capt. D. Bolton, 11 August 1834.

30 Parks Canada, R4-026-F-0034, Descriptive Sketch No. 2, [Wall Face Sluice Valve modification], Capt. D. Bolton, 11 August 1834. This drawing, which shows the original wall-face sluice valve system with but one later modification - the substitution of chains on the upper plate valve - is not dimensioned and does not show enough detail to determine the type of journal used for the valve plate. The several key dimensions given have been taken off drawings of the improved pivot valve sluice plates that were substituted for the original plate valves during the first few years of the canal's operation.

31 Ibid.; and Denison, op. cit., p. 137.

32 Parks Canada, R4-026-F-0034, Descriptive Sketch No. 2, [Wall Face Sluice Valve modification], Capt. Bolton, 11 August 1834; and Denison, op. cit., Plate 21, Figures 1, 2, 3, 19, 20, 21, 22, and 23. Note: Figures 1 and 2 show chains on the upper sluice valve plate, a modification that was adopted after the canal was in operation. Otherwise, the machinery depicted in the Denison drawings are of the sluice machinery placed on the wall face sluice valves at the time of the canal's construction.
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33 Denison, Ibid., Figures 19, 20, 21, 22 and 23. See also Parks Canada, R4-004-F-0009, Sketch A, Figure 4, [Rack and Pinion Lift], Captain D. Bolton, 22 March 1833.

34 Manuscript sources consulted to date do not note, other than the Jones Falls and Kingston Mills locks, which locks actually had wall face sluices constructed on them. In the absence of a survey of the locks, the above list had been prepared solely on the basis of what the author has observed during random visits to various locksites on the canal.


36 Parks Canada, R4-004-F-0009, Sketch A, Figure 4, [Rack and Pinion Lift], Captain Bolton, 22 March 1833.

37 Parks Canada, R4-026-F-0034, Descriptive Sketch No. 2, [Wall Face Sluice Valve modification], D. Bolton, 11 August 1834; and Denison, op. cit., p. 137 and Plate 21, Figures 1, 2 and 5. See also, Parks Canada, R4-025-F-0046, Detail of the Sluice Valves at Kingston Mills and Jones Falls, [1835].

38 Parks Canada, R4-026-F-0034, Descriptive Sketch No. 2, [Wall Face Sluice modification], D. Bolton, 11 August 1834; and Denison, op. cit., Plate 21, Figure 1.

39 Parks Canada, R4-026-F-0033, Plan Shewing the Alteration of the Goose Neck of the Sluice Valves, Rideau Canal, Old Plan figure, Major D. Bolton, 10 December 1838.

40 Parks Canada, R4-025-F-0046, Detail of the Sluice Valves at Kingston Mills and Jones Falls, [1835]. See also, Parks Canada, R4-026-F-0035, Sluice Valves for Face Sluices, Rideau Canal, John Burrows, Clerk of Works, 29 August 1837.
41 Ibid.
42 Parks Canada, R4-025-F-0046, Detail of the Sluice Valves at Kingston Mills and Jones Falls, [1835].
43 Parks Canada, R4-026-F-0035, Sluice Valves for Face Sluices, Rideau Canal, John Burrows, Clerk of Works, 29 August 1837.
44 Parks Canada, R4-025-F-0046, Detail of the Sluice Valves at Kingston Mills and Jones Falls, [1835].
45 Parks Canada, R4-025-F-0047, Plan and Sections of the Cast Iron Covers for the Air Holes of the Sluices in the side Walls of the Locks at Kingston Mills & Jones Falls, Rideau Canal, D. Bolton, 1 December 1836.
46 Parks Canada, R4-026-F-0033, Plan Shewing the Alteration to the Goose Neck of the Sluice Valves, Rideau Canal, Major D. Bolton, 10 December 1838.
47 Lt. Denison, Works on the Rideau Canal, Papers of Royal Engineers, Vol. III, Plate 21, Figure 7.
49 Lt. Frome, Construction Account of the Rideau Canal, Papers of Royal Engineers, Vol. I, p. 95; and Lt. Denison, Works on the Rideau Canal, Papers of Royal Engineers, Vol. III, p. 137. The floor of the culverts where the in-culverts sluice valves were positioned, is about five feet below the level of the floor of the culvert opening in the gate recess wall (Parks Canada, R4-026-F-0043, Section & Plan of the Sluice & Manhole for a 10 foot lift, Rideau Canal, Lt. Col. By, n.d.). As Lt. Denison (op. cit.) points out, the positioning of the valves at the mid-point of the culvert increased the head of water against the valves by an addition of half the height of the lift.
50 PAC, RG8, Series C, Vol. 59, Reel C-2637, p. 229, Lt. Col. W.R. Wright, Commanding Royal Engineer, Quebec, to
IV

Sir, 9 April 1839; and Parks Canada, R4-026-F-0028, Views of the Crab now in use to raise the Sluice Valves in the Masonry of the Locks on the Rideau Canal, Shewing the Strap, Pinion and Pawl proposed to be added to prevent accidents to the men employed working the locks, Captain D. Bolton, Senior Royal Engineer, Rideau & Ottawa Canals, 30 May 1836.

51 Ibid.
52 Parks Canada, R4-026-F-0024, Elevation and Plan of the proposed new Sluices showing the same open, Captain D. Bolton, 29 April 1837.
53 Parks Canada, R4-026-F-0025, Proposed Wall Face Sluice, Sketch No. 1, Captain D. Bolton, 9 September 1837; and Parks Canada, R4-026-F-0026, Proposed Wall Face Sluice, Sketch No. 2, Captain D. Bolton, 9 September 1837.
54 The change in the pivot point of the wall face sluice valve plates can be seen clearly by contrasting a drawing showing the improved valve plates installed in the existing wall face sluices in 1833-34 (R4-026-F-0035, Sluice Valves for the Face Sluices, Rideau Canal, J. Burrows, Clerk of Works, 29 August 1837), and a drawing of the proposed new valve plate (R4-026-F-0039, Sluice Valves for Face Sluices, Rideau Canal, Sketch No. 5, J. Burrows, 4 September 1837, signed D. Bolton, 9 September 1837).
56 See Parks Canada, R4-026-F-0025, Proposed Wall Face Sluice, Sketch No. 1, Captain D. Bolton, 9 September 1837; and Parks Canada, R4-0026-F-0026, Proposed Wall Face Sluice, Sketch No. 2, Captain D. Bolton, 9 September 1837.
57 Ibid., See also Parks Canada, R4-026-F-0027, Proposed Screw and Nut to raise the Sluice Valves, Rideau Canal, Sketch No. 4, J. Burrows, 21 August 1837, signed Captain D. Bolton, 9 September 1837.

58 Parks Canada, R4-0026-F-0026, Proposed Wall Face Sluice, Sketch No. 2, Captain D. Bolton, 9 September 1837.

59 PAC, RG8, Series C, Vol. 59, Reel C-2637, pp. 229-30, Lt. Col. J.R. Wright, Commanding Royal Engineer to Sir, 9 April 1839; Ibid., p. 237, Lt. Col. Oldfield to Sir, 24 June 1839. The sluices valve arrangement was that depicted in Parks Canada, R4-026-F-0025, Proposed Wall Face Sluice, Sketch No. 1, Captain D. Bolton, Senior Royal Engineer, Rideau and Ottawa Canals, 9 September 1837.

60 See foreground detail in Provincial Archives of Ontario, Thomas Burrowes Watercolours, Slide No. 14, North Entrance of the Rideau Canal from the Ottawa River taken from the Royal Engineering Office, Bytown - sketched May 1845.

61 Parks Canada, R4-026-F-0055, Plan of the Plate Frames & Sheaves required for the Sluices, Rideau Canal, 16 May 1839. The plate frames, sheaves, and the sluice valve plates were cast at the Three Rivers Foundry, the forges of St. Maurice, Lower Canada (PAC, RG8, Series C, Vol. 59, Reel C-2637, pp. 229-30, J.R. Wright to Sir, 9 April 1839).

62 Parks Canada, W.D. Naftel Photo Collection, R4-000-F-0037, 1973 Photo, Wall Face Sluice Crab, Chains and Sheaves.

63 See for example, a photograph of the crab, chains and sheaves of one of the two surviving examples of a floor chain/crab gate operating mechanism on the Rideau Canal.
(Parks Canada, W.D. Naftel Photo Collection, R4-000-F-0021, 1973 Photo, Crab and chains of the original floor chain/crab gate operating system on a lock at Kingston Mills).

64 See for example, Parks Canada, W.D. Naftel Collection, R4-000-F-0007, 1973 Photo, View of Crab and Lock Wall Sluice Control, Old Slys.

65 Provincial Archives of Ontario, N.H. Baird Papers, MS 293, A-1-C, Copy of Plan and Specifications prepared by H. Baird for the lock gates of the Edinburgh and Glasgow Union Canal, 7 January 1817. This drawing shows a geared winch on top of a lock gate operating an endless chain one end of which is attached directly to the top of a suspended lift rod and the other end of which passes around a snub pulley and back up the gate to attach to the top of the lift rod. The Union Canal chain arrangement also had a counterweight hanging on the side of the chain that went down around the snub pulley. It is not known whether Bolton put a counterweight on his sluice operating chain system in 1839. None of the photographs consulted of the crab/endless chain operating mechanism now in existence shows a counterweight; but they may have been removed over the years.

66 N.H. Baird was the Clerk of Works on the Rideau Canal project from 1828 to 1832 after which he was employed for a number of years as an engineer in preparing plans for the enlargement of the Welland Canal. Baird would have had the copies of his father's canal engineering drawings in his possession from the time of his arrival from Scotland in 1828. Thus Bolton could have seen the sketches during the construction of the Rideau Canal, or could have communicated with Baird on the subject at
any time between 1837 and 1839 when the former was planning to change the in-culvert sluice valves over to wall face sluice valves.

67 Judith Tulloch, The Rideau Canal, 1832-1914, Parks Canada, Manuscript Report No. 77, Structural Changes 1832-1914, pp. 81-82; and Department of Railways and Canals, Annual Report for the Fiscal Year 1 July 1894 to 30 June 1895, Ottawa: Queen's Printer, 1896, p. 150.

68 Parks Canada, R4-026-F-0028, Views of the Crab now in use, Captain D. Bolton, 30 May 1836.

69 Parks Canada, R4-004-F-0009, Sketch A, Figure 6, Grating for upper Sluices at Black Rapids, Captain D. Bolton, 22 March 1833.

70 See detail in PAO, Thomas Burrowes Watercolours, Slide No. 14, North Entrance of the Rideau Canal from the Ottawa River taken from the Royal Engineers' Office, Bytown, May 1845.

71 Department of Railways and Canals, Annual Report for Fiscal Year 1 July 1899 to 30 June 1900, Ottawa: Queen's Printer, 1901, Part I, p. 205.

72 Parks Canada, W.D. Naftel Photo Collection, 1973, R4-000-F-0043, background detail. Initially in the spring of 1900, twenty-eight of the new iron gratings were installed as follows: at the Ottawa locks (10), at Black Rapids (2), at Long Island (4), at Merrickville (2), at Old Slys (4) and Smith's (4). The rest of the wood gratings were replaced shortly thereafter.

73 See Parks Canada, W.D. Naftel Photo Collection 1973, R4-000-F-0008, Original Design of Rack and Pinion on Wall.

74 See Ibid., R4-000-F-0007, View of Crab and Lock Wall Sluice Control.
V The Lock Gates: Design Evolution


5. Parks Canada, Historic Prints and Drawings Collection, R4-026-F-0056, "Lock Gate Rideau Canal", 1827.


8. Parks Canada, Historic Prints & Drawings Collection, R4-000-M-0041, "Drawing of the 8th Gate of the 1st 8 Locks, By Town, Rideau Canal".

9. The action of a draw-bore hole and pin are described in the "Draw-bore" entry, Chambers Dictionary of Science and Technology, p. 365.
"Framing of Gate rails into Heel or Mitre Post", detail of "Typical Upper Lock Gate or Dry Gate", J.R. Sanders drawing, Engineering & Architecture Branch, Parks Canada, 2 April 1982, Sheet 1.


Parks Canada, Historic Prints and Drawings Collection, R4-026-F-0038, "Details of the Sluices in Lock Gates", n.d. [ca. 1832].

Parks Canada, Historic Prints and Drawings Collection, R4-000-M-0041, "Drawings of the 8th Gate of the 1st 8 Locks, By Town, Rideau Canal, n.d. [ca. 1832].


The early Rideau Canal lock gate drawings of 1832 and 1840 do not show cross sections, or consequently the iron tongues joining the planking. The first drawing to show the iron tongues is dated April 1850. (Parks Canada, Historic Prints and Drawings Collection, R4-001-F-0288, Rideau Canal, Bytown, Sketch of Lock Gate No. 4, 25 April 1850). However, the Rideau Canal lock gate specifications of 1861 and 1864 state that
the iron tongues of the gates being replaced were to be re-used. (PAC, RG 11, Bla, vol. 183, reel T - 209, p. 000031, Rideau Canal, Specifications for Lock Gates, 21 August 1861; and RG 11, Bla, vol. 184, reel T - 209, p. 000608, Rideau Canal, Specifications for the Lock Gates, 15 October 1864). Since the gates being replaced had lasted anywhere from 15 to 20 years, it is evident that iron tongues were placed in the several lock gates built in the 1840's, if not the original lock gates. Moreover, the lack of any detail in the 1840 lock gate plans concerning the iron tongues, and the same lack of detail in the 1850 lock gate plan which actually shows the iron tongues, indicates that the iron splines were nothing new. Had the iron splines not been present in the original lock gates, their introduction at a later date would surely have been commented on.

18 Personal Communication from Richard Fairweather, Marine Works & Transportation Division, Engineering & Architecture Branch, Parks Canada.
19 Parks Canada, Historic Prints and Drawings Collection, R4-001-F-0285, Eighth Gate of the First Eight Locks, Bytown", ca. 1832.
20 Parks Canada, Historic Prints & Drawings Collection, '8th Gate of the 1st 8 Locks, Bytown, Rideau Canal', Lt. Col. By, n.d., R4-001-F-0285 and R4-000-M-0041. It is impossible to scale the thickness of the reinforcing plates off existing drawings. One drawing (ibid,
R4-026-F-0038) shows a 5/8" by 3" plate acting as a munnion between the two valve plates in the gate sluices of a lower gate.


24 Parks Canada, Historic Prints & Drawings Collection, R4-000-M00041, '1st Gate of the 1st 8 Locks', Lt. Col. By, n.d. The drawing does not show the bolt details, only the bolt hole pattern on the reinforcing plates.

25 See for example, Parks Canada, Historic Prints and Drawings Collection, R4-000-M-0041, '1st Gate of the 1st 8 Locks, Bytown, Lt. Col. By', n.d.; and ibid, R4-026-F-0045, Recess of combined locks as approved by Committee of which Sir James Kempt was President. The details of the gudgeon that Col. By designed initially for use on the lock gates of the 20 foot wide gunboat lock, can be seen in "Lock Gate, Rideau Canal", Lt. Col. By, 1 December 1827 (Parks Canada, Historic Prints and Drawings Collection, R4-026-F-0056). This gudgeon design, however, was clearly modified in detail, and particularly with respect to its seat in the case of the heel post, before being used on the larger lock gates actually constructed in 1830-32.


Parks Canada, Historic Prints and Drawings Collection, R4-001-F-0285, '8th Gate of the 1st 8 Locks, Bytown, Rideau Canal', Lt. Col. By, n.d.


Parks Canada, Historic Prints and Drawings Collection, R4-000-M-0041, '8th Gate of the 1st 8 Locks, By Town, Rideau Canal, Lt. Col. By, n.d.

Parks Canada, Historic Prints and Drawings Collection, R4-026-F-0038, Details of the Sluices in Lock Gates, n.d.

Ibid, R4-000-M-0050, Plans and Sections of a pointed sill and recess of Combined Locks, Lt. Col. By, n.d. [ca. 1832].


PAC, Map Division, H3/312, Lachine Canal, 1828 [Rideau Canal], Plan and Sections of the Eighth Lock, 10 Foot lift, Inspector General of Fortifications.


Parks Canada, Historic Prints & Drawings Collection, R4-001-F-0288, "Rideau Canal, Bytown, Sketch of Lock Gates No. 4", 25 April 1850.


40 Several employees of the Rideau Canal Office who were working on the canal in the early 1950's can remember the roller wheels still being in use on several of the gates at the Ottawa Locks and at Kingston Mills at that time. (Phone communication, Ian Fraser to R. Passfield, 20 December 1982).

41 The push-bar, often mistakenly referred to as a draw-bar, was first employed on the Rideau Canal gates in 1900-1901. (See P.A.C., RG54, B4a, vol. 216, pp. 219-220, A.T. Phillips, Annual Report, 4 July 1901).

42 "Typical Upper Lock Gate or Dry Gate", Rideau Canal Office, Smiths Falls, 2 April 1982. The gate bridle appears to have been added to the Rideau gates commencing in the 1940's. (See R4-017-F-0062, "A View into Newboro Lake from the lock at Newboro", ca. 1940). Later photographs show the gate bridle, but the 1920's and 1930's photographs and those of earlier dates do not. The only exception is a 1925 photograph of lock gates at Kingston Mills. It shows a gate bridle somewhat similar to the present design: the collar loop around the collar strap; the threaded collar loop shaft through the head of a bridle; and the bridle bolted to the gate frame. However, the bridle is just a simple U-shaped device bolted to the top rail at the mid-point between the quoin and mitre posts. (R4-025-A-0040,
Kingston Mills, Lower Lock and Channel, 1925). It may mark an early experiment that was discarded thereafter, to be revived in the present design more than a decade later.

43 Parks Canada, Historic Prints & Drawings Collection, R4-000-M-0041, "8th Gate of the 1st 8 Locks, By Town, Rideau Canal", Col. By, n.d. [ca. 1832]; and ibid, R4-026-F-0036, "Lower Side View of the Anchor & Strap for the Heel Post", n.d., [ca. 1830's].


45 Parks Canada, Historic Prints & Drawings Collection, R4-000-M-0041, "8th Gate of the 1st 8 Locks, By Town, Rideau Canal", Col. By, n.d., [ca. 1832].


48 Parks Canada, Historic Prints & Drawings Collection, R4-000-M-0041, "8th Gate of the 1st 8 Locks, By Town, Rideau Canal", Col. By, n.d., [ca. 1832].

49 It has been observed, on the several locks reconstructed to date, that the lead did not in all cases penetrate down to the bottom of the fox-bolt. This has been attributed to the molten lead cooling,
and solidifying, before reaching the bottom (Phone communication from Ian Fraser, Technical Officer, Rideau Canal Office, Smiths Falls, December 13, 1982).

"Plan Shewing Under Side of Anchor to Heel Post, and Details", detail of "Plan Shewing Method of Framing Lock Gates on the Rideau Canal", Rideau Canal Office, Ottawa, 1 January 1918; and "Lock Gate Collar", detail of "Typical Upper Lock Gate or Dry Gate", Rideau Canal Office, Smiths Falls, 2 April 1982.


Detail on "Typical Upper Lock Gate or Dry Gate", Rideau Canal Office, Smiths Falls, 2 April 1982.

For example, at Hartwell's the collar straps of the upper gates were replaced in 1871, on that pair of gates being replaced (PAC, RG 11, vol. 440, p. 001555, Rideau Canal, Annual Report, 19 October 1871). However, there is insufficient data to determine the life-span of the anchor collar straps.


"Typical Upper Lock Gate or Dry Gate", Rideau Canal Office, Smiths Falls, 2 April 1982. The original fox-bolt anchor bolts are shown in Parks Canada, Historic Prints & Drawings Collection, R4-000-M-0041, "8th Gate of the 1st 8 Locks, By Town, Rideau Canal", Lt. Col. By, n.d. [ca. 1832].

Phone communication from Ian Fraser, Technical Officer, Rideau Canal Office, Smiths Falls, 13 December 1982.
One of the earliest drawing extant that shows the framing details of the lower gates is dated November 26, 1840. (Parks Canada, Historic Prints & Drawings Collection, R4-003-F-0037, "Plan & of Lock Gates, Hogs Back, Rideau Canal, Sketch No. 1", November 26, 1840).

Parks Canada, Historic Prints & Drawings Collection, R4-026-F-0038, "Details of the Sluices in Lock Gates", n.d. [ca. late 1830's].


Parks Canada, Historic Prints & Drawings Collection, R4-026-F-0038, "Details of the Sluices in Lock Gates", n.d. [ca. 1830's]; and Denison, 'Works on the Rideau Canal', Papers of Royal Engineers, III, 1839, Plate 21, Figs. 9, 10, 11 & 12.

Parks Canada, Historic prints & Drawings Collection, R4-026-F-0038, "Details of the Sluices in Lock Gates", n.d. [ca. 1830's].

Parks Canada, Historic Prints & Drawings Collection, R4-001-F-0280, "Plan proposed for additional machinery for Opening the Sluices of the Lower Gates Separately", Major D. Bolton, 3 September 1838; and Denison, 'Works on the Rideau Canal', Papers of Royal Engineers, III, 1839, p. 137.

Ibid, Plate 21, Figs. 11 & 12.


Parks Canada, Historic Prints & Drawings Collection, R4-009-F-0044, "Lower Gate, Merrickville Station, Rideau Canal", 1864.

Denison, 'Works on the Rideau Canal', Papers of Royal Engineers, III, 1839, Plate 20, Figs. 1 & 2 and Plate 21, Fig. 19. See also Parks Canada, Historic Prints & Drawings Collection, R4-026-F-0032, "Crab Fixed on Gate to Open Gate Sluices", n.d. [ca. 1830's].

PAC, RG 11, vol. 185, p. 001132, Rideau Canal, Repairs ending 30 June 1870.


Parks Canada, Historic Prints and Drawings Collection, R4-026-F-0032, "Crab fixed on Gate to Open the Gate Sluices", n.d. [ca. 1830's].

Parks Canada, Historic Prints & Drawings Collection, R4-004-F-0009, Sketch A, Figure 4, Captain Bolton, 22 March 1833.


Specifications for the first lock gates have not been found; but all the later specifications called for the
wood members and the iron work of the gates to be "well bedded in a thick coat of the best white lead, and oil". See PAC, RG 11, Bla, vol. 184, Reel T - 209, p. 000607, Specifications for the Lock Gates, 15 October 1864; and ibid, vol. 183, p. 000031, Rideau Canal, Specifications for Lock Gates, 21 August 1861.


78 I am indebted to Richard Fairweather, Marine Works & Transportation Division, Engineering & Architecture Branch, Parks Canada, for this information.


80 The Builder's Practical Director, n.d., p. 231.


82 The Builder's Practical Director, p. 231.


84 Harley, Artist's Pigments, pp. 108-111.


90 Whitfield, "Paint for British Ordnance", p. 3.
91 The Builder's Practical Director, p. 231.
93 Parks Canada, Historic Prints & Drawings Collection, Thomas Burrowes' Rideau Canal watercolours.
94 Early engineering drawing watercolours by the Royal Engineers invariably show the iron work on the gates in a natural grey colour, indicating an absence of paint. However, these engineering drawings were intended to show the gates as constructed. The watercolour paintings of the locksites, produced by military topographers during the 1830's and 1840's show that the iron work was definitely painted black, and this practice has been continued ever since on the Rideau Canal.
95 The Builder's Practical Director, p. 231.
97 PAC, RG 8, Series C, vol. 47, C-2619, p. 98f, List of Stores required for the Service of the Rideau Canal for the year 1829, 11 December 1828. (See Appendix B)
98 On the Rideau Canal project, the painters no doubt used the common paint ingredients and colouring agents. The Ordnance Department, however, had developed a special black paint for iron ordnance by the 1820's. It consisted of a mixture of Grant's black ground in oil, dry red lead, linseed oil, spirits of turpentine, and anticorrosion. (Ralph Willett Adye, The Bombardier and Pocket Gunner, 8th ed., Revised and Corrected according
V

Anticorrosion consisted of powered glass and white lead with lampblack added as the colouring agent.
(Charles H. Owen, Rough Notes on the Manufacture of Ordnance, Carriages, and Ammunition, Prepared for the Use of the Gentlemen Cadets of the R.M. Academy, Woolwich: Printed at Royal Artillery Institution, 1867, p. 35). I am indebted to David McConnell, Historian, Historical Research Division, Parks Canada, for this information and the reference above to Wilkinson-Lathan, British Artillery.


100 PAC, RG 11, Bla, T - 209, vol. 184, p. 000049, James Slater, Rideau Canal, Report from 1st January to 1st July 1864.

101 PAC, RG 11, Bla, T - 209, p. 000718, Rideau Canal, James Slater, Rideau Canal, Report from 1st January to 1st July 1865, 9 July 1865. The only watercolour painting showing the stone grey gates is Thomas Burrowes, "Another View of Brewers Upper", Sketch No. 66. Unfortunately, it is undated. However, the painting was made sometime between 1850, the date of erection of the swing bridge shown in the painting, and the 21 May 1866, the day Burrowes died.

V

Britain, National Army Museum, "War Office Circular No. 930, Painting Ordnance, Artillery, Engineer, and Military Train Carriages", 21 October 1865, p. 5. I am indebted to David McConnell, Historical Research Division, Parks Canada; for these references.

104 Great Britain, National Army Museum, War Office Circular No. 859, Painting Ordnance, Artillery, Engineer, and Military Train Carriages, 30 April 1864; and ibid, Circular No. 930, Painting Ordnance, Artillery, Engineer, and Military Train Carriages, 21 October 1865. Again, I am indebted to David McConnell for these references.
106 Great Britain, National Army Museum, Circular No. 930, Painting Ordnance, 21 October 1865, p. 5.
111 Ibid, James Slater, Superintending Engineer, to F. Braun, Secretary, Public Works Department, Letter No. 82256, 18 September 1866.
112 Ibid, Slater to Braun, Letter No. 84084, 17 January 1867. On the painting of the new gates see, for example, ibid, vol. 185, p. 001121, Schedule of Repairs

113 See, for example, Dominion of Canada, Annual Report of the Department of Railways and Canals for the fiscal year 1 July 1894 to 30 June 1895, Ottawa: Queen's Printer, 1896, p. 153.


116 Frome, 'Construction of the Rideau Canal', Papers of the Royal Engineers, I, p. 95; and Denison, 'Works on the Rideau Canal', ibid, III, pp. 135-136, and plate 20, Fig. 4.


118 Denison, 'Works on the Rideau Canal', Papers of the Royal Engineers, III, pp. 134, and plate 20, Figs. 9 and 10.

119 Drawings showing the sheave block casting details are in Parks Canada, Historic Prints & Drawings Collection: R4-026-F-0029, "Plans, Sections and Elevations of the
Cast Iron Blocks through which the chains pass for working the Lock Gates", D. Bolton, 14 March 1833; and R4-026-F-0030, and R4-026-F-0031, both of the same title, n.d.; and Denison, 'Works on the Rideau Canal', Papers of the Royal Engineers, III, Plate 20, Figs. 6, 7 and 8. For the layout of the sheave blocks, see Denison, *ibid*, Plate 20, Fig. 4.

By the late 19th century, what the Royal Engineers had called "cast iron blocks", or "blocks and sheaves" were being referred to by the Rideau Canal engineers as "chain blocks", when ordering replacements. (See for example, PAC, RG 43, B4a, vol. 2012 (new) A.T. Phillips, Acting Superintending Engineer, to C. Schreiber, Chief Engineer; pp. 141-147, 2 July 1896, and *ibid*, p. 572, 12 July 1897). The latter terminology is a misnomer as "chain blocks" are technically a lifting device.

Many of the original sheave blocks were replaced by new castings commencing during the 1890's. See for example, Annual Reports of the Department of Railways and Canals for 1895 through 1910.

The crab for the in-tunnel sluices is shown in Denison, 'Works on the Rideau Canal', Plate 21, Figs. 24 & 25.

Denison, 'Works on the Rideau Canal', Plate 20, Figs. 4 & 5; and Parks Canada, Rideau Canal Office, "Elevation of a Lock Gate and Recess Wall Shewing the Machinery to open the gates, Jones Falls, Rideau Canal", D. Bolton, 14 March 1833.


Frome, 'Construction of the Rideau Canal', Papers of the Royal Engineers, I, p. 97; PAC, RG 8, Series C, vol. 50, reel C-2619, p. 52, Alexander Strachan, A.C.G., Commissariat, Bytown, to General Routh, Quebec, 26 December 1829; and ibid, pp. 59-60, Durnford to Couper, 11 February 1830.

PAC, MG 13, W055, reel B-1299, vol. 26, p. 151, John By to Colonel Nichol, 22 February 1832.


137 PAC, RG 13, W055, vol. 867, B-2812, p. 155, Durnford to the Ordnance Department, 11 February 1830, quoting By to Durnford, 4 February 1830.


139 PAC, RG 8, Series C, vol. 50, reel C-2619, p. 53, By to Commissary General Routh, 9 January 1830.

140 Ibid, p. 55, Edward Grieve, Agent for the St. Maurice & Three Rivers Iron Works, to Commissariat Department, Montreal, 22 January 1830.


142 Provincial Archives of Ontario, N.H. Baird Diary, reel #1, diary entry for Monday, 15 September 1828.

143 PAC, RG 8, Series C, vol. 47, C-2619, p. 98h, Colonel By, List of Stores required for the Service of the Rideau Canal for 1829, 11 December 1828; and P.A.O., Baird Diary, reel #1, diary entry for Wednesday, 24 September 1828.


147 Denison, 'Works on the Rideau Canal', Papers of the Royal Engineers, III, p. 136 and Plate 20, Fig. 5; and PAO, Thomas Burrowes, Sketch #16, "View from the Upper end of the Guard Lock at Hog's Back", n.d.


151 Parks Canada, Historic Prints & Drawings Collection, R4-001-F-0288, "Rideau Canal, Bytown, Sketch of Lock Gates No. 4", 25 April 1850.

152 See, for example, Parks Canada, Historic Prints & Drawings Collection, R4-009-F-0044, "Lower Gate, Merrickville Station, Rideau Canal, 1864".


154 PAC, RG 11, vol. 183, pp. 000173-000174, Rideau Canal, Annual Report for 1861, January 1862; and ibid,
vol. 184, p. 000548, Rideau Canal, Summary of Repairs for 1864.


156 PAO, Thomas Burrowes, Sketch #27, "Lock, Blockhouse & c. at the Narrows, Rideau Lake --- the first descent from Summit towards Bytown, 1841".

157 Among the general vistas inaccurately depicting the lock gate operating system on the Rideau Canal are: P.J. Bainbrigge, "Kingston Mills, Rideau Canal, Ontario", August 1841; W.H. Bartlett, "Locks on the Rideau Canal (near Bytown)", ca. 1841; E. Whitfield, "Ottawa City, Canada West, shewing the locks of the Rideau Canal", 1855; and F.H. Taylor, "Jones Falls Locks from the Kenny Hotel", 1896. (Parks Canada, Historic Prints & Drawings Collection, R4-025-A-0015; R4-001-A-0010; R4-001-A-0015; and R4-020-A-0015, respectively).

159 PAC, RG 43, B4a, Letterbooks, vol. 164, A.T. Phillips, Superintending Engineer, Rideau Canal, to D.E. Eason, Superintending Engineer, Trent Canal, 15 July 1920. As of 1920, consideration was being given to adopting the push bar system for the Trent Canal lock gates.

160 PAC, RG 8, Series C, vol. 47, C-2619, pp. 89-90, Henry DuVernet, Major, Royal Staff Corps, Grenville, n.d. [January 1829].


169 PAC, MG 24, A12, Dalhousie Muniments, Section #3, reel A534, n.p., By to Lord Dalhousie, 8 June 1832.


171 PAC, Map Division, H3/312 Lachine Canal 1828, Plan & Sections of the 8th Lock 10 foot lift. This is actually a plan of the first proposed Rideau Canal lock, the design of which was based on the Lachine Canal lock design.


174 Parks Canada, Historic Prints & Drawings Collection, R4-000-M-0041, "8th Gate of the 1st 8 Locks, By Town, Rideau Canal", Colonel John By, n.d. [ca. 1832].

175 Parks Canada, Historic Prints & Drawings Collection, R4-003-F-0037, Plan &c. of Lock Gate for Hogs Back, Rideau Canal, Sketch No. 1, 26 October 1840; and ibid, R4-003-F-0036, Plan of Lock Gate, Hogs Back, Rideau Canal, Sketch No. 2, 26 October 1840.

176 Parks Canada, Historic Prints & Drawings Collection, R4-003-F-0037, Plan &c. of Lock Gate for Hogs Back, Rideau Canal, Sketch No. 1, 26 October 1840.

177 Parks Canada, Historic Prints & Drawings Collection, R4-003-F-0036, Plan of Lock Gate, Hogs Back, Rideau Canal, Sketch No. 2, 26 October 1840.
178 Ibid, R4-001-F-0288, Rideau Canal, Bytown, Sketch of Lock Gate No. 4, 25 April 1850; and PAC, RG 43, B4a, vol. 206, p. 122, J.D. Slater to F. Braun, 20 July 1869.

179 Parks Canada, Historic Prints & Drawings Collection, R4-001-F-0088, "Rideau Canal, Bytown, Sketch of Lock Gate No. 4", 25 April 1850.


181 Parks Canada, Historic Prints & Drawings Collection, R4-001-F-0288, "Rideau Canal, Bytown, Sketch of Lock Gates No. 4", 25 April 1850.


183 PAC, RG 11, vol. 185, file #7439, J.D. Slater to F. Braun, 20 July 1869; and ibid, file #9184, Statements of Lockmen and Others who were at Jones Falls, 26 July 1869.

184 PAC, RG 11, vol. 185, file #7439, Slater to Braun, 20 July 1869.

185 PAC, RG 11, vol. 185, file #9184, Statements of Lockmen and others at Jones Falls, 26 July 1869, statement by Francis Abbott.

186 PAC, RG 11, vol. 185, file #9184, John Seppell, Montreal, to F. Braun, 13 January 1870.


188 PAC, RG 8, Series C, vol. 441, pp. 279-280, Colonel By to Colonel Durnford, 14 September 1831, quoted by

189 PAC, RG 11, vol. 185, file #9184, Statements of Lockmen & others who were at Jones Falls, 26 July 1869.

190 Parks Canada, Historic Parks & Drawings Collection, R4-009-F-0044, "Lower Gates, Mirrickville Station, Rideau Canal", 1864; ibid, R4-013-F-0048, "Lower Centre Gates, Smiths Falls, Rideau Canal", 1865; ibid, R4-008-F-0013, "Lower Gate, Clowes Quarry", 1865; ibid, R4-009-F-0045, "Lower Gates Mirrickville, Rideau Canal", 1865; and ibid, R4-009-F-0043, "Basin Lower Gates, Mirrickville", 1865.


193 Burnell, "River and Inland Navigation", *Aide-Mémoire*, III, 1851, p. 286. In British lock gate construction, the tenons were customarily made one-third the width of the cross rails.


195 Parks Canada, Historic Prints & Drawings Collection, R4-009-F-0044, "Lower Gates Mirrickville Station, Rideau Canal", 1864.

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