New Welland Ship Canal Built for Deep-Draft Vessels

Lake Ontario Made Accessible to Large Vessels Used on the Upper Lakes by an Enlarged Canal Across the Niagara Peninsula in Canada—Seven Locks Overcome a Head Requiring 26 Locks in Old Canal

At a cost of more than $120,000,000, the fourth canal to be built between Lake Erie and Lake Ontario to provide slack-water navigation around Niagara Falls is now nearing completion. Much of the new waterway is in use; the remaining portion will be ready for operation at the opening of navigation next spring. After that time there will be available an almost straight canal with only eight locks which will permit the passage of vessels with drafts up to 25 ft., whereas heretofore no vessel drawing more than 14 ft. could pass up or down from lake to lake and then only through a tortuous channel having 26 small locks.

The new Welland ship canal was begun in 1913 as part of a program laid down by the Canadian government, which called for a ship channel of a depth of 25 ft. from Lake Erie down to Lake Ontario and from Lake Ontario down the St. Lawrence River to Montreal. With a channel of that depth, grain moving eastward through the Great Lakes to tidewater would not have to be trans-shipped at the lower end of Lake Erie to smaller vessels capable of navigating the Welland and St. Lawrence canals with their 14-ft. draft limitation, or transferred to railroad cars in order to complete its journey to the sea. International problems stood in the way of building a ship canal down the St. Lawrence River, but none were involved in the reconstruction of the Welland Canal, as it lies wholly within Canadian territory. Increasing congestion of traffic in the Welland Canal made an early start of the work desirable.

Contracts for the construction of a new ship canal were let in the fall of 1913, but within less than a year the World War started and by 1916 it had caused an almost complete cessation of the work. In 1918 the original contracts were canceled. From 1919 to 1921 work was continued on a cost-plus basis with many interruptions due to labor and other troubles. By 1921 conditions in the construction industry had become more stabilized, and new unit price contracts were let in 1921 and the following year. Thus, while 17 years have elapsed since construction was started, actually only about 10 years have been required for the completion of the undertaking.

Engineering studies for the canal were begun long before construction was inaugurated and were continued through the shutdown of the war period.

Earlier Canals—A little more than a century ago, in

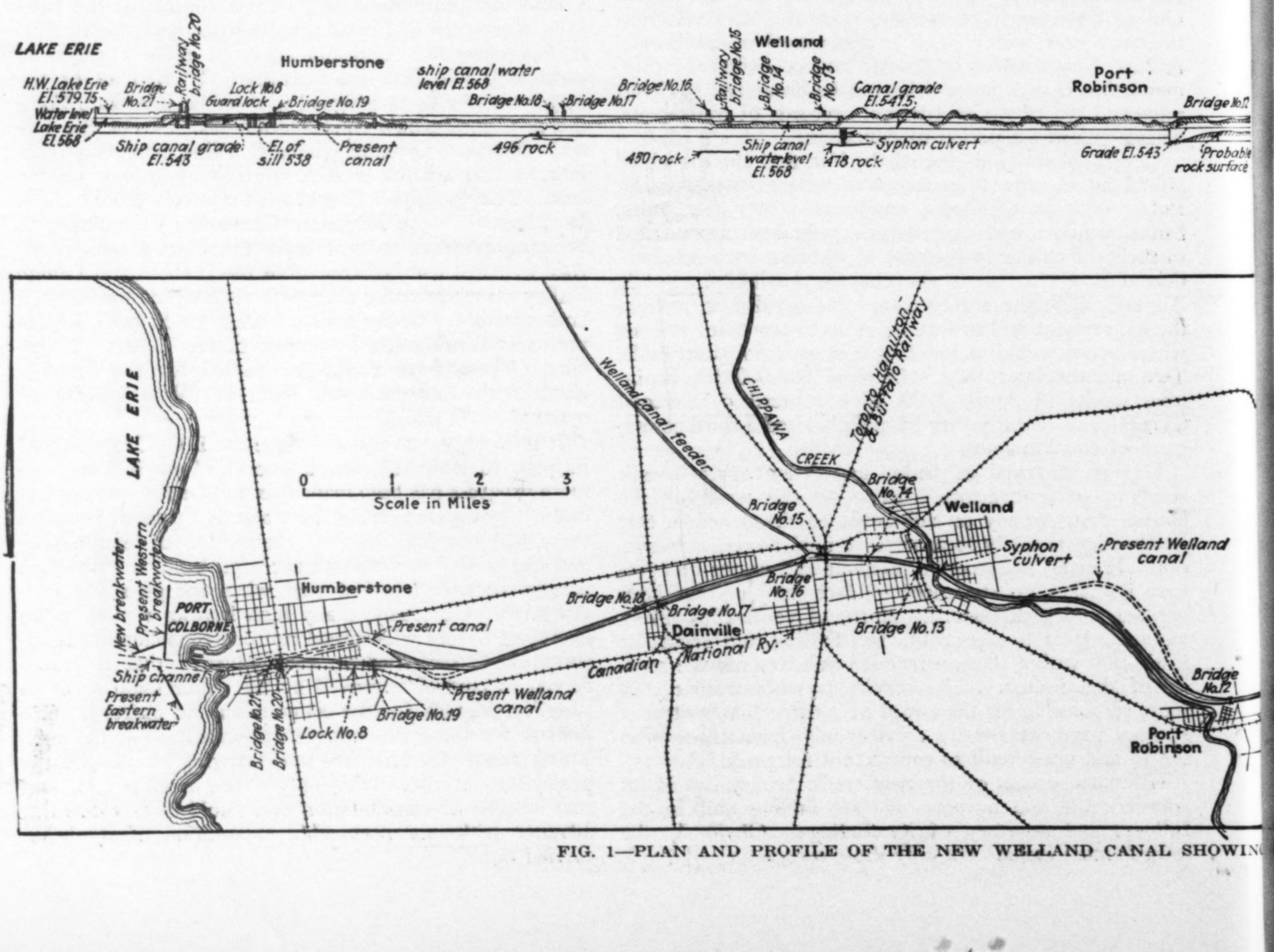


FIG. 1—PLAN AND PROFILE OF THE NEW WELLAND CANAL SHOWIN[G]

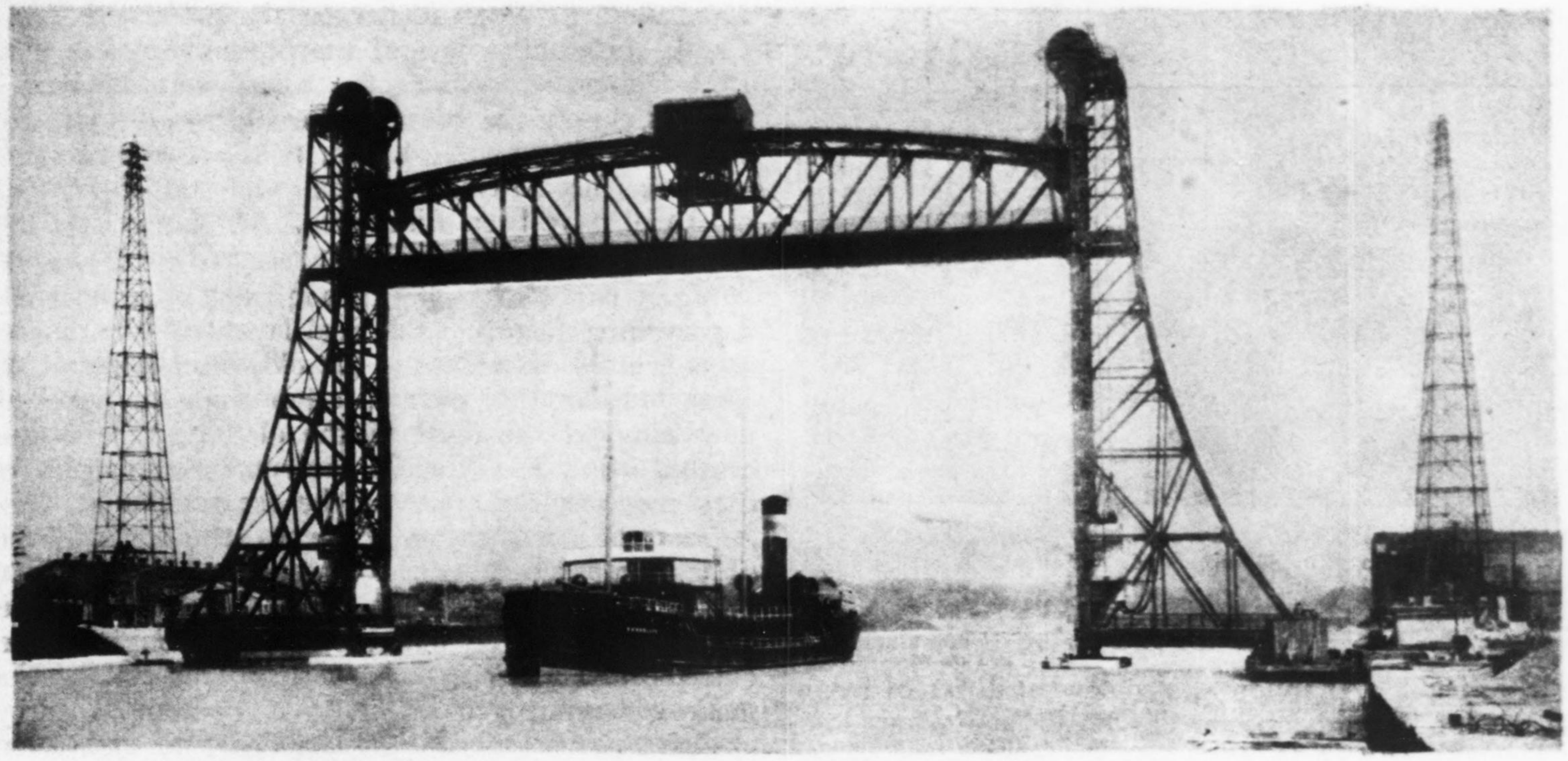
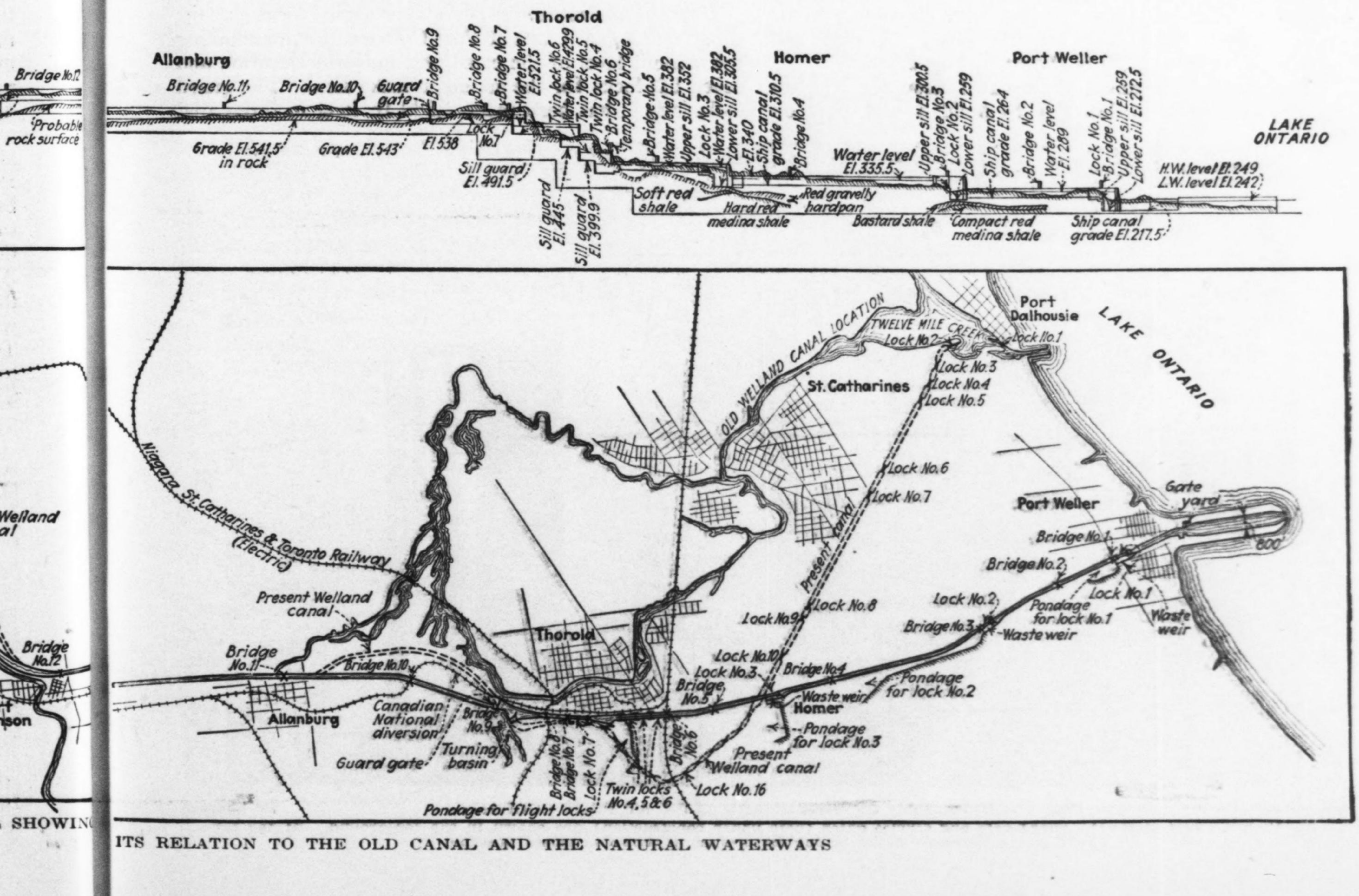


FIG. 2—HIGHWAY BRIDGE OVER A COMPLETED SECTION OF THE CANAL AT PORT ROBINSON

1824, construction of the first canal around Niagara Falls was undertaken as a private enterprise. That channel extended from Port Dalhousie on Lake Ontario to Fort Robinson on Chippawa Creek, from whence small vessels could descend to the Niagara River and up the Niagara River to Lake Erie. It was completed in 1829. The canal had 40 locks 110 ft. long by 22 ft. wide and 8 ft. deep over the sills. Later it was extended to Port Colborne on Lake Erie to save distance and eliminate the difficult navigation of the open channels in Chippawa Creek and the Niagara River. Its length from lake to lake was 27½ miles.

In 1841 the Canadian government bought the canal and built new stone locks 150x26½ ft., 9 ft. deep over the sills, reducing the number of locks to 27. In 1853 the navigable depth of the canal was increased to 10 ft. Much of this canal is still in existence, being used in part for power development. Its cost, including enlargements, was $7,630,000.

In 1887 the third canal, now being replaced, was



ITS RELATION TO THE OLD CANAL AND THE NATURAL WATERWAYS

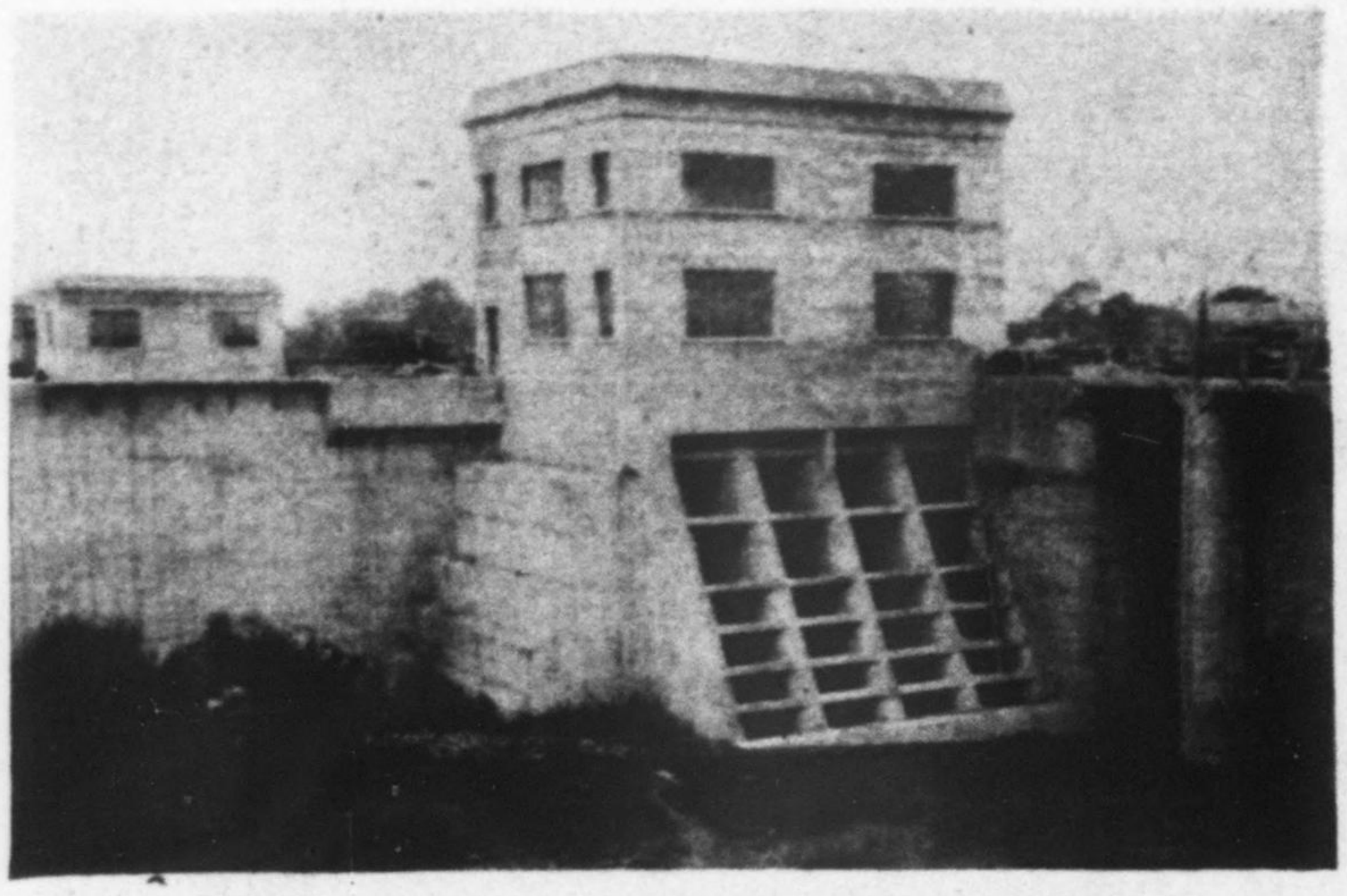


FIG. 3—LOCK CONTROL TOWER AND SUPPLY INTAKE
The control room is in the upper part of the building housing the intake gate mechanism. Below is the water intake with trash-rack supports in place. At the right is the waste wier and at the extreme left two buildings on opposite walls of the lock to house the gate-operating machinery.

opened to traffic. It followed a somewhat different route from that of the previous canal, was 26¾ miles long and had 26 locks 270x45 ft. with lifts of from 12 to 14 ft. and a depth over the sills of 14 ft. That canal cost $25,375,000.

New Ship Canal—The canal now nearing completion is a radical departure from its predecessors and shows in a striking way the progress made in canal design in recent years. In the first place, the adoption of an unusually high lift of 46½ ft. for the locks made it possible to reduce the number of lift locks from 26 to 7 and also made possible a considerable shortening of the length of the canal through a direct ascent of the Niagara escarpment—the same rock outcrop through which the Niagara River cuts its gorge a few miles east—rather than by a side-hill route, as had been necessary in the earlier canals with their low-lift locks. A plan and profile of the new canal is shown in Fig. 1.

The changed alignment of the canal below the Niagara escarpment made it desirable to build a new port on Lake Ontario, Port Weller, at the mouth of Ten Mile Creek, three miles east of the present canal terminal at Port Dalhousie. Above the escarpment the new canal follows closely the route of the old one but on a much straighter alignment. In all, nearly two miles of distance has been saved and the dangerous curves of the old canal have been eliminated. On Lake Erie the existing harbor at Port Colborne is used.

Maintenance of traffic through the present canal was a governing factor in the final layout of the new canal, as it crosses or intersects the old one at several places. That consideration dictated establishing the level of the new canal at the level of the old one where the two crossed below the Niagara escarpment and again where they cross near the top of the escarpment at Thorold. Beyond the top of the escarpment the matter of level was of less importance as the water level in the old canal fluctuated with the fluctuation of Lake Erie, while the new canal is to be maintained at a constant level of extreme low water in Lake Erie. This stabilization of the long summit level of the canal is accomplished by the use of a guard lock at Port Colborne, the eighth lock in the canal. Normally this lock will overcome a head of 3 or 4 ft., but during storms the head may increase to as much as 12 ft.

The canal runs almost due north from Lake Erie to Lake Ontario. The drop of 326½ ft. between mean water level in the two lakes is concentrated near the north end in descending the steep slope of the Niagara escarpment. The drop below the guard lock is overcome in seven locks of 46½-ft. lift each. This lift is about 14 ft. greater than that of the Panama Canal locks and 6 ft. more than the maximum lift in the locks of the New York state barge canal.

Operating Program—There are eight locks in the canal, one a guard lock at Port Colborne for maintaining the summit level of the canal at a uniform elevation and seven lift locks for the ascent to Lake Erie. The guard lock, lock 8, has been made 1,380 ft. long in order that

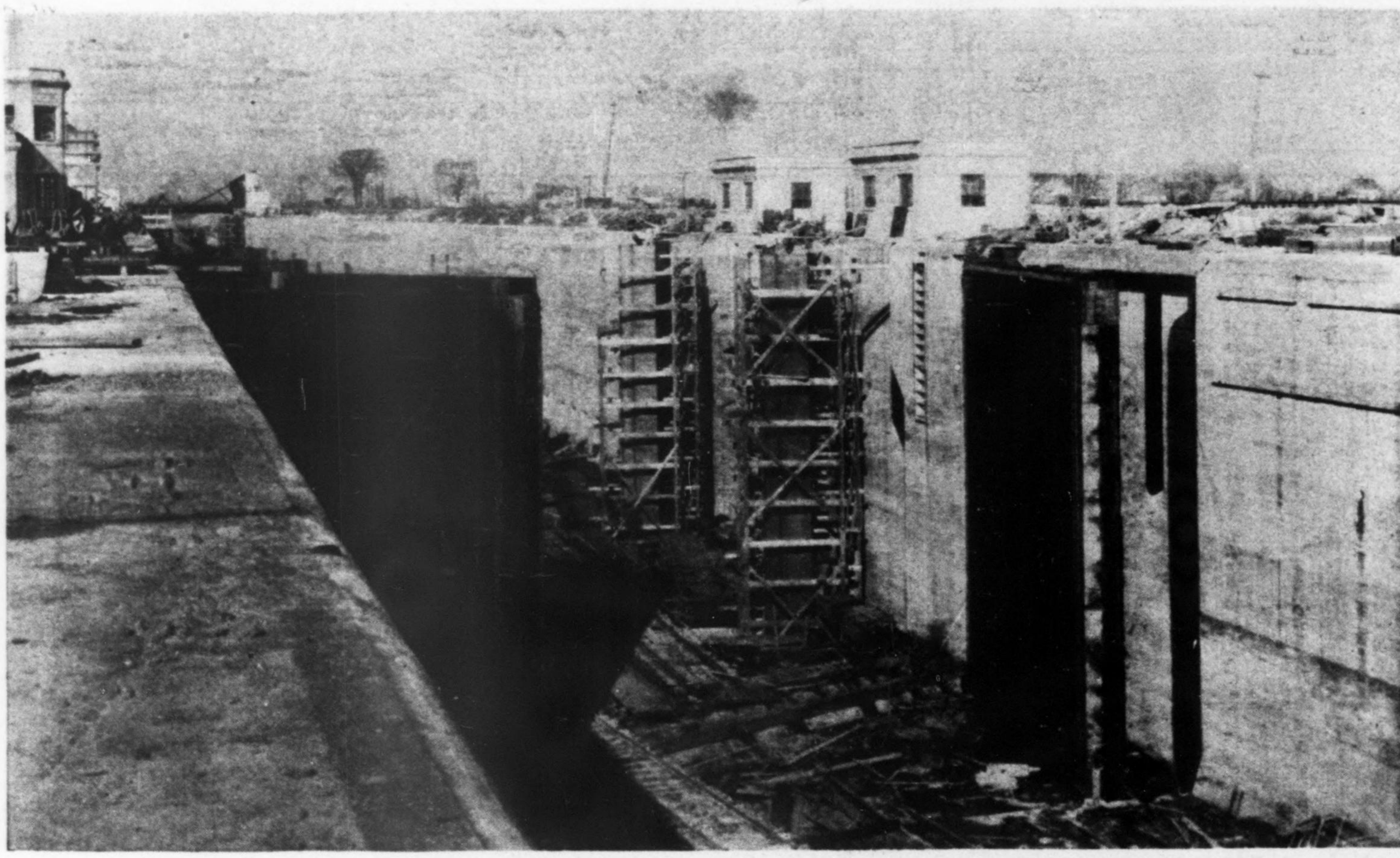


FIG. 4—OUTER END OF THE GUARD LOCK AT PORT COLBORNE
The timber unwatering gate, guard gate and service gates (both under construction) are shown in the foreground. At the far end of the lock one of the rolling-lift bridges is shown in closed position.

more than one vessel may be passed through it in one operation. Seldom will there be any great variation between the summit level and that of Lake Erie, and consequently the quantity of water required for the operation of lock 8 will not be large. What water is used will be taken from Lake Erie and discharged into the canal for use in the lower locks. Additional water for the lower locks also will be drawn from Lake Erie through a supply weir in the channel of the present canal which now bypasses lock 8.

Lock 7, at the northern end of the long summit section of the canal, is a single lock to let boats down to the pool above the flight locks at Thorold. Just above it is a guard gate which is kept closed at all times except during passage of vessels, as a precaution against draining the whole summit canal through the failure of the gates of lock 7. An added precaution is provided by having duplicate gates at the upper and lower end of lock 7 and of the twin lock No. 6 at the head of the flight of three locks down the Niagara escarpment.

The flight locks, Nos. 6, 5, and 4, each have double chambers, one for upbound traffic and the other for downbound. Otherwise a vessel might be delayed as long as two hours if another vessel, coming in the opposite direction, had entered the flight. These locks have a supply basin above lock 6 with a waste weir which discharges into an artificial channel along the route of the old canal some distance from the new canal. The water so disposed of is returned to the canal in the pond above lock 3.

Locks 3, 2 and 1 are on a gentle slope toward Lake Ontario and are separated from each other by sections of open canal. Each is provided with a pond for water storage and a waste weir and channel parallel to the locks, as shown in Fig. 5. The emergency sluices under the waste weirs will open automatically if the pond water rises much above its normal level and threatens to overtop the banks and flood the surrounding farm lands. Such an abnormal rise might be occasioned by the failure of a gate or any similar accident in the reaches above. The spillway channels are concrete-lined and have a secondary weir at the lower end for checking the velocity of the water and destroying its energy. The lower weirs also are intended to back up the water in the raceway and thus submerge the sluice gates during the frosty season.

In a number of instances there are bridges across the lock-approach channels which will serve as a guard for the gate against ramming by a vessel out of control, sacrificing the bridge for the gates. At other points where protection is needed, fender cables are provided. These cables are $3\frac{1}{2}$ in. in diameter and are mounted on an arm which operates like a rolling-lift bridge. The cable is wrapped around a stationary bollard and is arranged to unwind from another spring-drum bollard which provides sufficient tension to check any vessel before it strikes the gate.

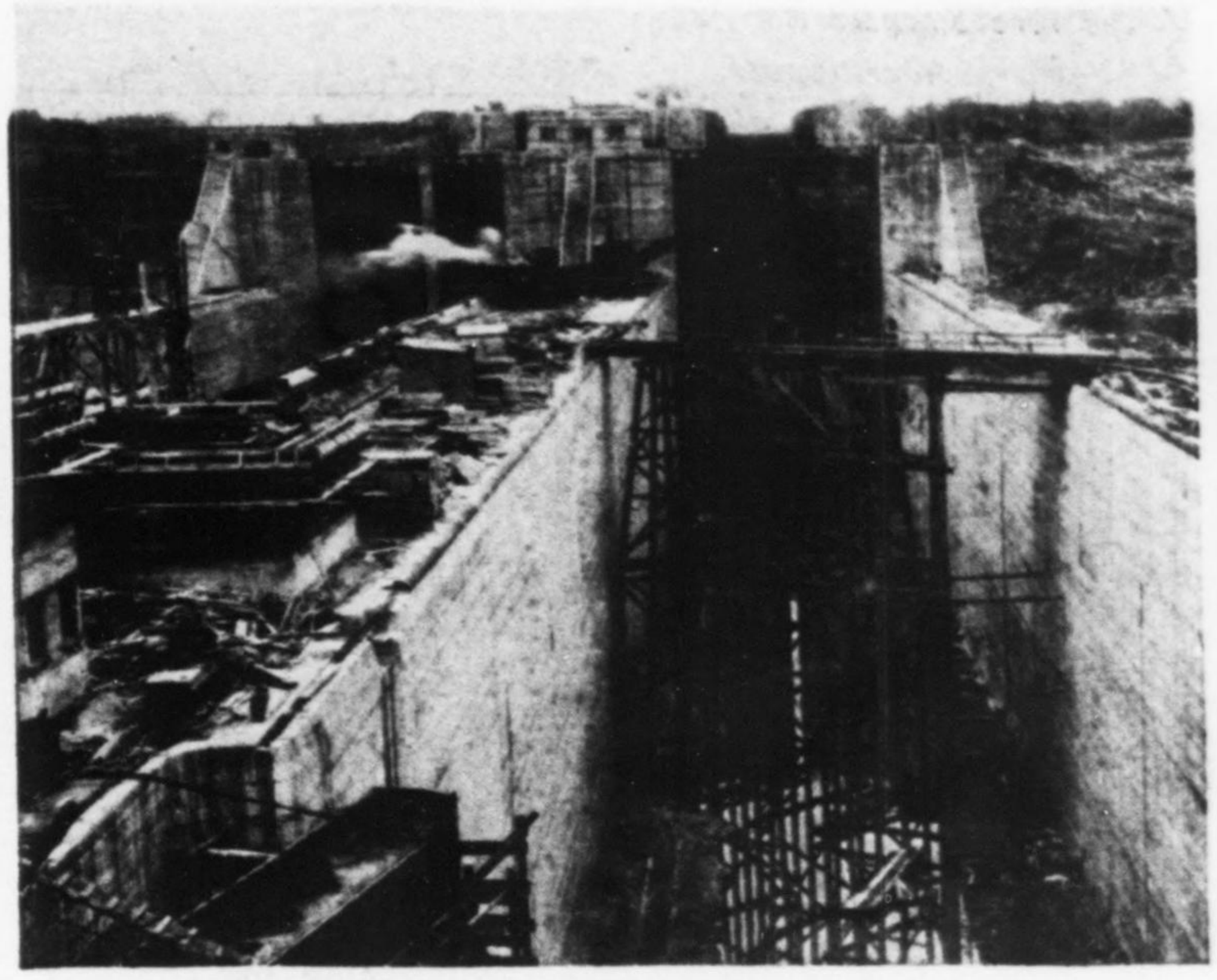


FIG. 6—TWIN FLIGHT LOCKS AT THOROLD
Looking up the flight of three twin locks at Thorold from the C. N. Ry. bridge. The lock chambers are 80 ft. wide and 82 ft. deep. The three locks give a total lift of 139.5 ft. (The C. N. Ry. bridge shown above the lower of these locks on the cover of this issue has been replaced by a rolling lift bridge.)

Water for filling the single locks is drawn through an intake located back of the approach wall in the pond above the lock, instead of from the channel directly above the gate, as is the more common practice. This arrangement does away with the objectionable currents created in drawing directly from the navigable channel. All intakes are provided with frames to support trash racks, but no racks will be installed unless found necessary. Both the intake and discharge valves are tainter or segment gates arranged so that they are under complete control at all times.

From the intake gates the water passes down into the filling culverts in the canal wall, the water for the far side passing beneath the lock floor, and from these large culverts it is discharged at short intervals through smaller lateral openings at the floor level of the lock. In unwatering the locks, the water passes out through the same ducts to discharge openings having rectangular bell mouths at opposite sides of the lock chamber below the lower gate. The energy of the discharged water is dissipated in the surge created by these two opposing streams.

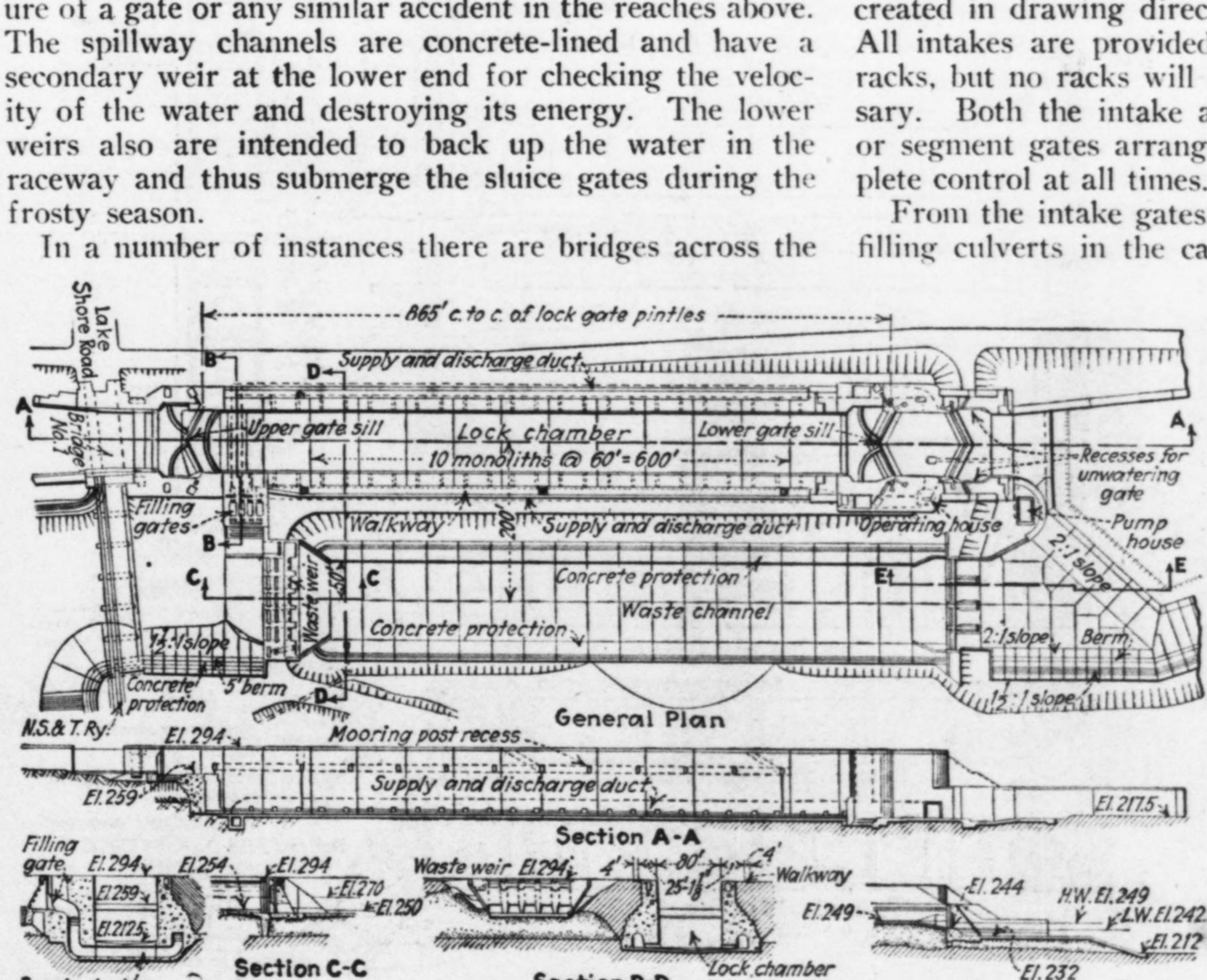


FIG. 5—DETAILS OF A TYPICAL LOCK

Lock Construction — The limitations placed by the necessity of maintaining an open channel for traffic through the old canal and the character of the underlying rock largely

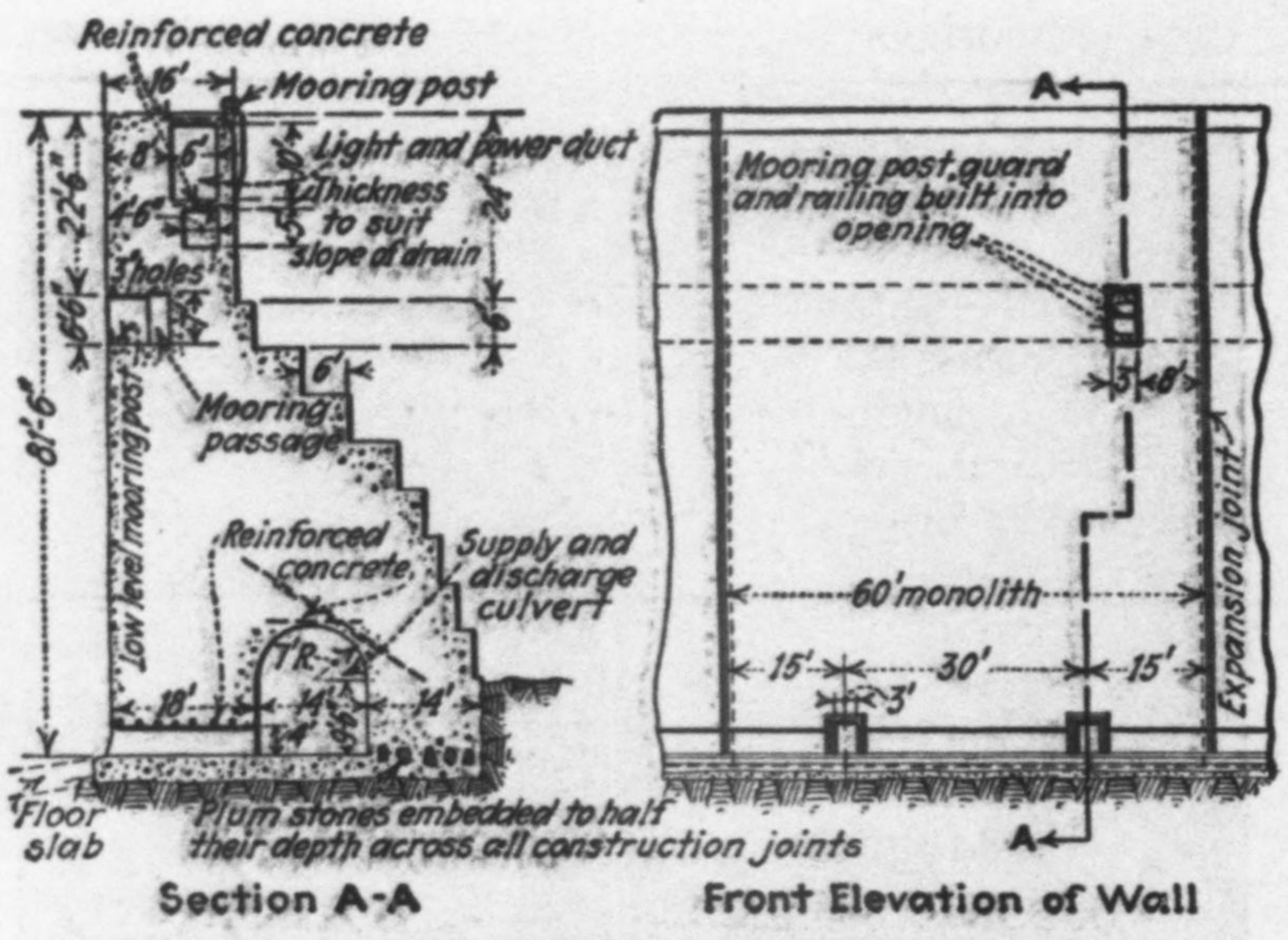


FIG. 7—DETAILS OF THE LOCK WALLS

On account of the great height of the walls two levels of mooring posts are provided at two levels. The lower level, in recesses in the walls, is reached by stair wells from the surface. Here the snubbing posts are designed to slip the mooring line when the boat raises above them.

determined the final location of the locks after their approximate location had been fixed. Generally, rock is not far below the surface at the northern end. In the final location of the locks they were so placed as to bring their walls upon firm rock at points where the total amount of rock to be removed would not be excessive.

The rock at the north end of the canal is a red shale which decomposes rapidly upon exposure to the air and is easily eroded, yet sound if protected from exposure. Consequently, in excavating for the lock structures the preliminary excavation was carried to about 1 ft. above grade, and then just before the contractor was ready to start the concrete work, the last foot of rock was excavated, leaving a fresh surface upon which to found the walls. Upon completion of the locks the underlying rock was fully grouted as a precaution against underflow and uplift.

The lock walls are of monolithic concrete, reinforced in a few places, principally over the top of the main filling culverts where tension may occur, also over the small lateral outlets where experience in the first lock showed that shrinkage cracks may develop. Where the filling culvert passes under the lock floor, the floor is heavily reinforced. In the flight locks at Thorold the center wall between the twin locks is reinforced against shear. Anchor rods are used under the lock floors as a precaution against uplift.

The usable length of the lift locks is 820 ft., the width 80 ft. and the depth over the sills 30 ft. Details are shown in Fig. 5.

Lock Gates—All lock gates, except the unwatering gates, are of steel. The lower gates at each lift lock are 82 ft. high by 45 ft. wide and weigh 980 tons, or 490 tons per leaf. Some of the principal details are shown in Fig. 8. The gates are of the ordinary mitering type, but the method of operation is novel. It is by a system of cables actuated by motor-driven winches, as shown in Fig. 11. With this system the gates are fully controlled in all positions. Limit switches prevent any overrun.

A novel feature of the gate is the use of safety horns on the mitering faces to minimize the danger if a gate is unmitered by a vessel nosing against it.

Both the upper and lower gates of all the locks, with one exception, are similar and interchangeable. Spare gates are provided for emergency use and a dry dock for their storage has been built adjoining the pool above lock 1. Normally, the spare gates are to be stored for painting and repair upon a shelf, from which they may be floated by raising the pond level 5 ft. A floating crane is used for replacing gates which may be damaged or need repairs. During the operating season it will lie in the harbor below lock 1.

Timber unwatering gates are located in the lock walls just below lock 1, lock 4 and at both ends of lock 8. These gates, when closed, will exclude the lake water from the outer gates at locks 1 and 8, so that the gate chamber may be pumped out for repair work. Similarly, below lock 8 and lock 4 their use will avoid emptying long sections of the channel for repair work at the lock. As the unwatering gates are almost entirely submerged at all times, and therefore inaccessible for maintenance, they have been made of timber instead of steel.

Canal Prism—Outside of the lock chambers the canal prism normally has a bottom width of 200 ft. and a surface width of 310 ft. At curves and at other points where operating requirements dictate the normal width is increased. Where the canal is excavated in earth, the depth of channel has been made a minimum of 25 ft., but in rock a depth of 27½ ft. was excavated to reduce the

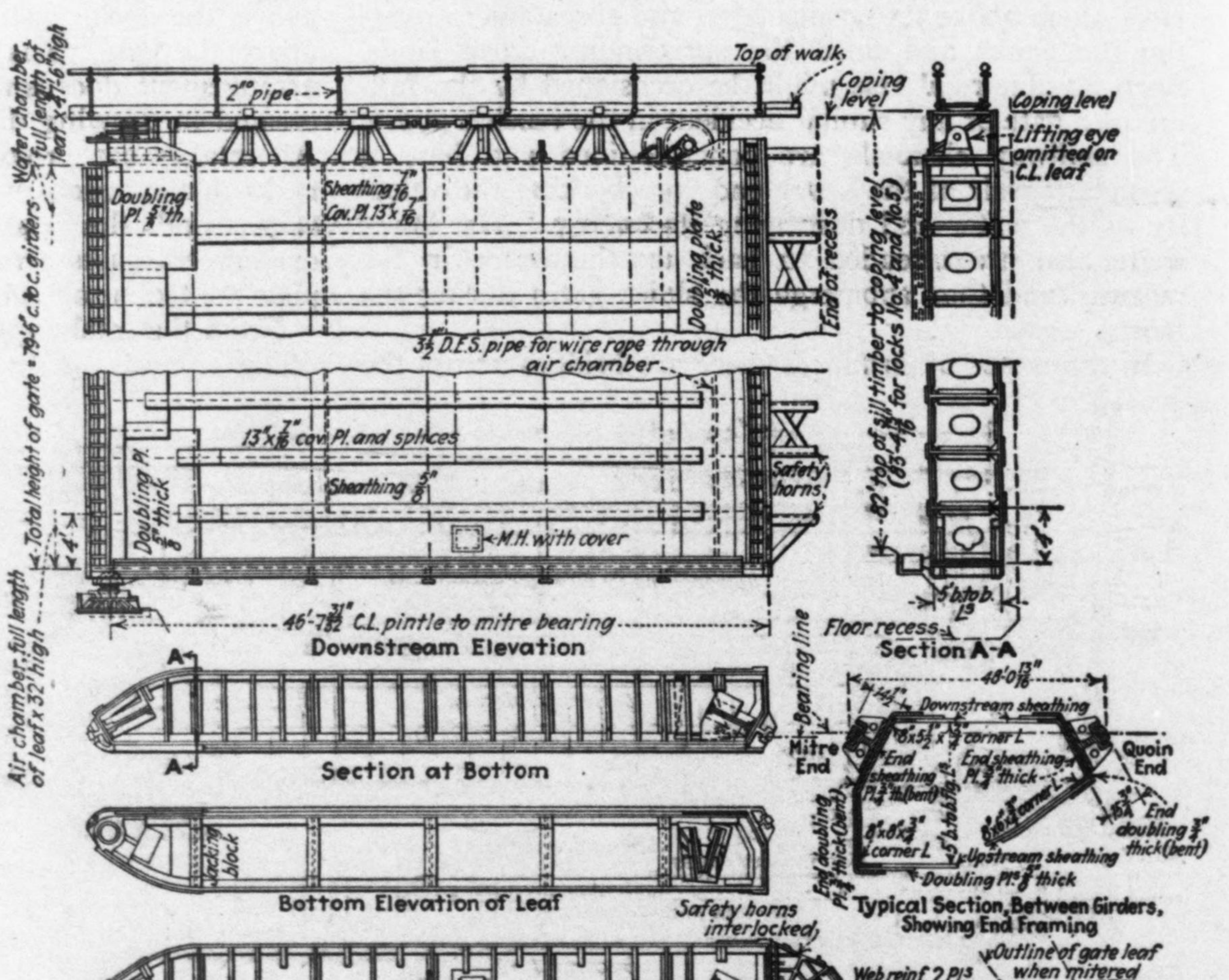


FIG. 8—DETAILS OF THE LOWER LOCK GATES

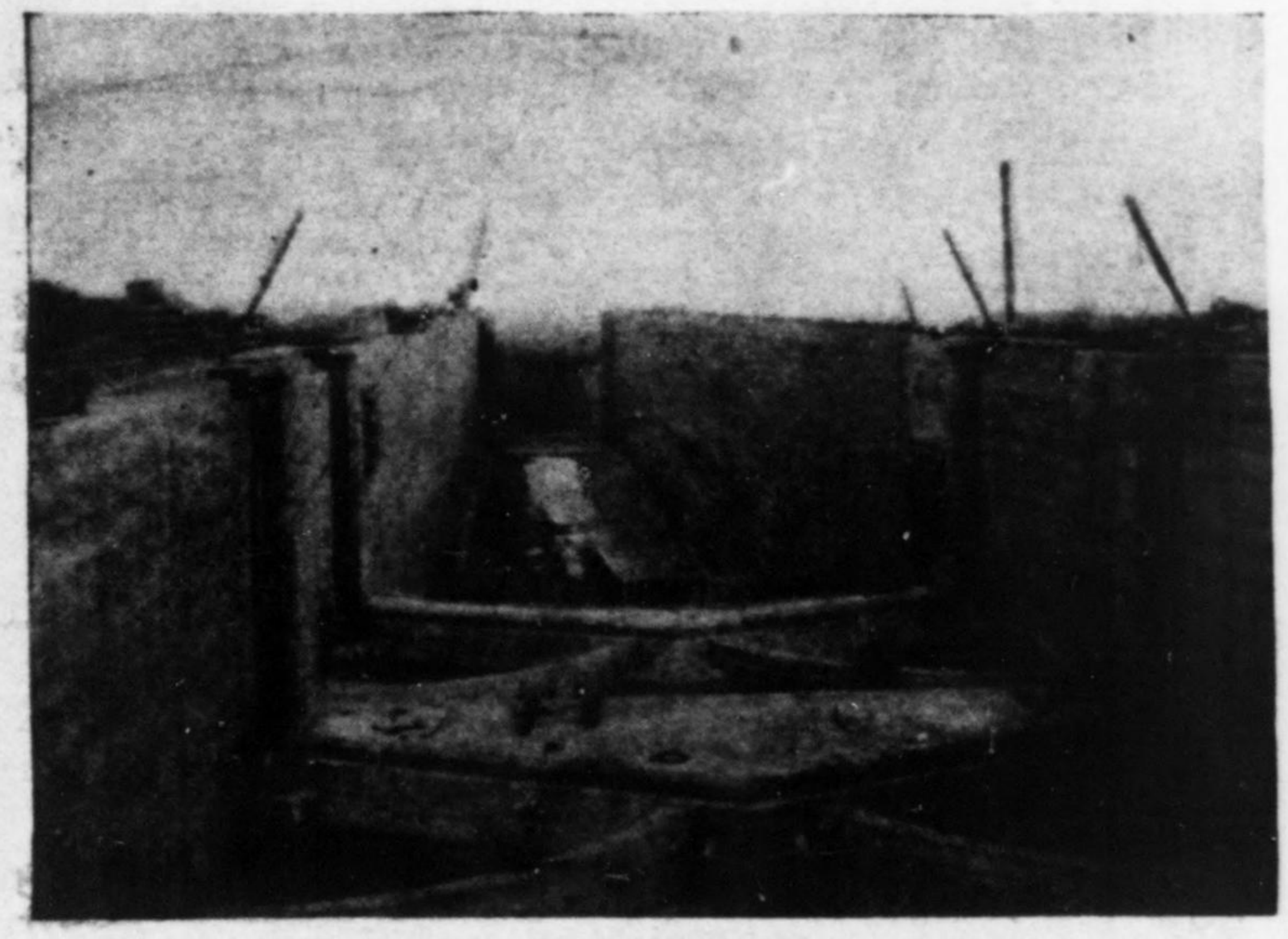


FIG. 9—UPPER LOCK CHAMBER OF ONE OF THE FLIGHT LOCKS

Sills and curved toe walls for the guard gate and service gate in the foreground and beyond the curved breastwall at the upper end of the chamber. The toe walls act as guides for the gate-operating cables. In the distance a crane is erecting one of the 82-ft. high service gates at the lower end of the lock. There is a guard gate at that end also.

amount of underwater rock excavation necessary in deepening the canal at some future date. As noted previously, a depth of 30 ft. over the lock sills has been provided, in order that the canal may be excavated to that depth without altering the locks.

The greater part of the canal is excavated through clay or other glacial residue in which hydraulic dredges were used to advantage, but at the southern or upper end, where the canal crosses the height of land near Port Colborne, much rock was encountered. The total amount of rock excavated for the entire canal was in the neighborhood of 9,000,000 cu.yd., and the earth excavation exceeded 50,000,000 cubic yards.

All earth slopes are protected by a concrete revetment extending from below the water line to well above the limit of possible wave action.

Bridges—In all there are 21 railway and highway bridges across the canal. They are of four general types, direct lift, single-leaf rolling bascule, double-leaf rolling bascule, and swing—the type depending upon the location of the bridge and the character of the traffic. The single-leaf rolling type is used for crossings which come at the narrow lock-approach channels, and the longer spans are used for the open-channel crossing.

Chippawa Creek Siphon—The most difficult problem of the whole undertaking was the construction of a siphon under the canal to carry Chippawa Creek. In the construction of the two earlier canals the canal was carried over the creek in an aqueduct of stone masonry but such a plan was not feasible with the deeper canal Consequently, it was decided to carry the creek under the canal in an inverted siphon culvert.

At the site chosen for the new culvert, just north of the old aqueducts, rock lies at a depth of 100 ft. below the ground level. It is covered with a glacial clay. The first scheme called for carrying the culvert under the canal through this solid rock, but, as that would have required placing the bottom of the culvert 170 ft. below the surface, the scheme was abandoned in favor of a monolithic concrete culvert carried on piles in the clay at a depth just sufficient to clear the bottom of the canal. Details of the culvert are shown in Fig. 10, as is the method of maintaining traffic in the old canal. Steel sheetpiles 70 and 55 ft. long were used for the outer and inner walls of the cellular cofferdam, respectively.

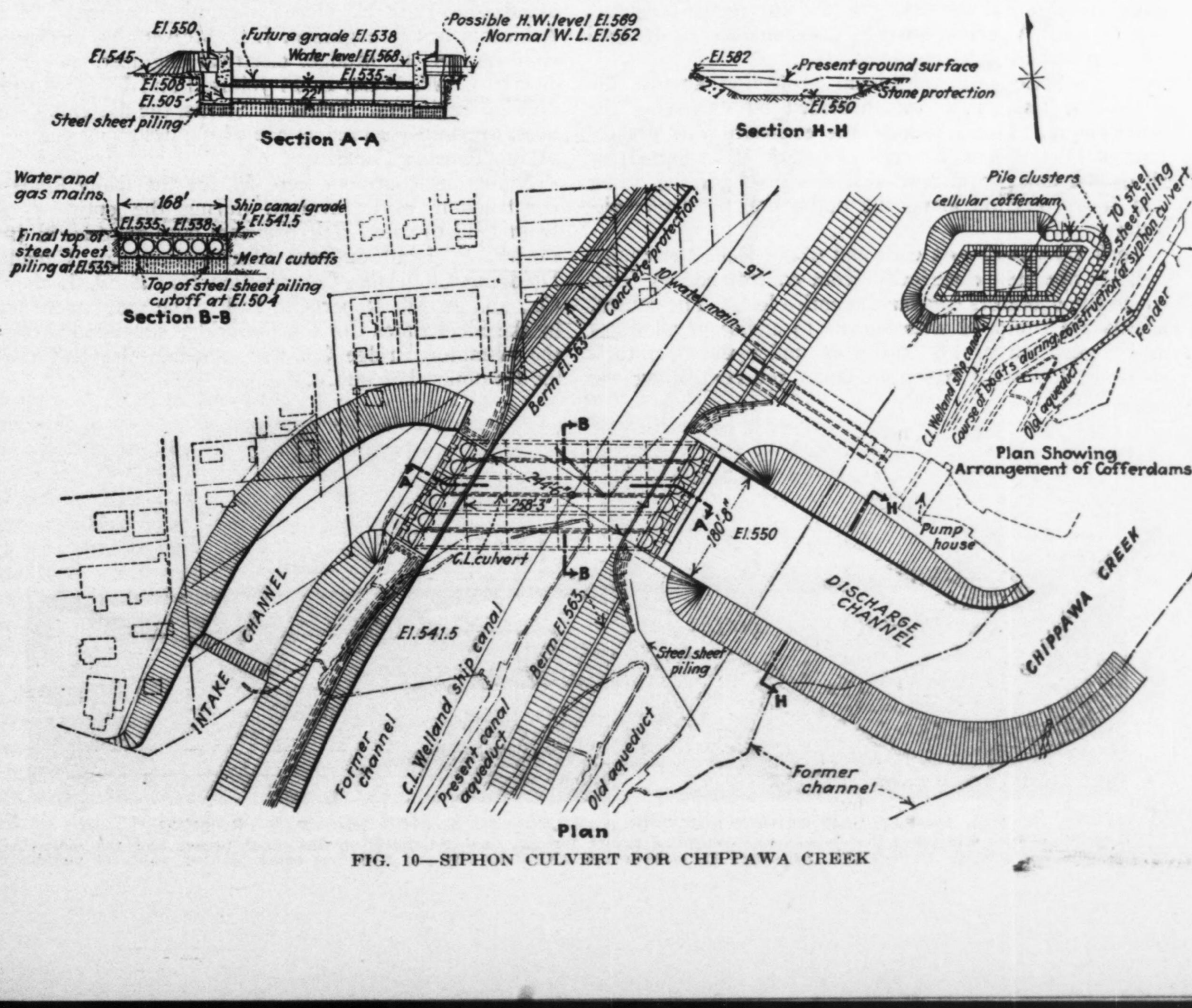


FIG. 10—SIPHON CULVERT FOR CHIPPAWA CREEK

Early in the operation it was realized that the greatest difficulty would be encountered in controlling the saturated clay through which the excavation had to be carried, and consequently the area was subdivided into pits, which were carried down to subgrade successively in such a way as to permit the construction of the vertical shafts and horizontal sections of the culvert in large units. An elaborate system of bracing for the walls of the pit was developed in the hope of taking care of the thrust of the surrounding clay, but even so, much difficulty was encountered in maintaining the cofferdam at the northeast corner where it projected out into the present canal, and in several instances 18x18-in. timbers failed under the great pressure which developed.

Harbors—The new harbor at Port Weller extends a mile and a half out into Lake Ontario between breakwaters which form a roadstead 800 ft. wide, except at the entrance, where it is narrowed down to 400 ft. The two breakwaters consist of earth embankments 200 ft. wide on top, with the outer ends protected by rock-filled reinforced-concrete cribs. The same type of crib also is used at the inner end of the harbor to provide dockage facilities. The cribs were built on wooden pontoons and towed to the site, where they were floated off the pontoons and sunk by opening seacocks in the concrete bottoms of the cribs.

The cribs were sunk to a prepared bed as close as possible to proper alignment, and then a true alignment for the top of the wall was obtained by capping them with poured-concrete coping blocks. This arrangement produced a true top for the wall and added to its strength.

The two embankments were made of excavated material brought down from the canal excavation on a railroad which the Department of Railways and Canals built along the route of the canal for use during the construction period. A certain quantity also consisted of dredged material from the harbor excavation.

At Port Colborne additional protection against the storms of Lake Erie was provided by extending the breakwaters. Here, because the exposure was greater than at Port Weller, concrete cribwork was adopted for all of the new work, and rock was used for the filling and for protection along the outer side of the breakwater.

Lock Operation—At each end of all locks the equipment is operated electrically from control houses from which the operators can see the entire lock. The control boards are equipped with signals to advise at all times as to condition of all apparatus under the operator's control. Provision has been made for controlling the operations locally in an emergency and for manual operation. Alternating current at 550 volts is used for the motor equipment.

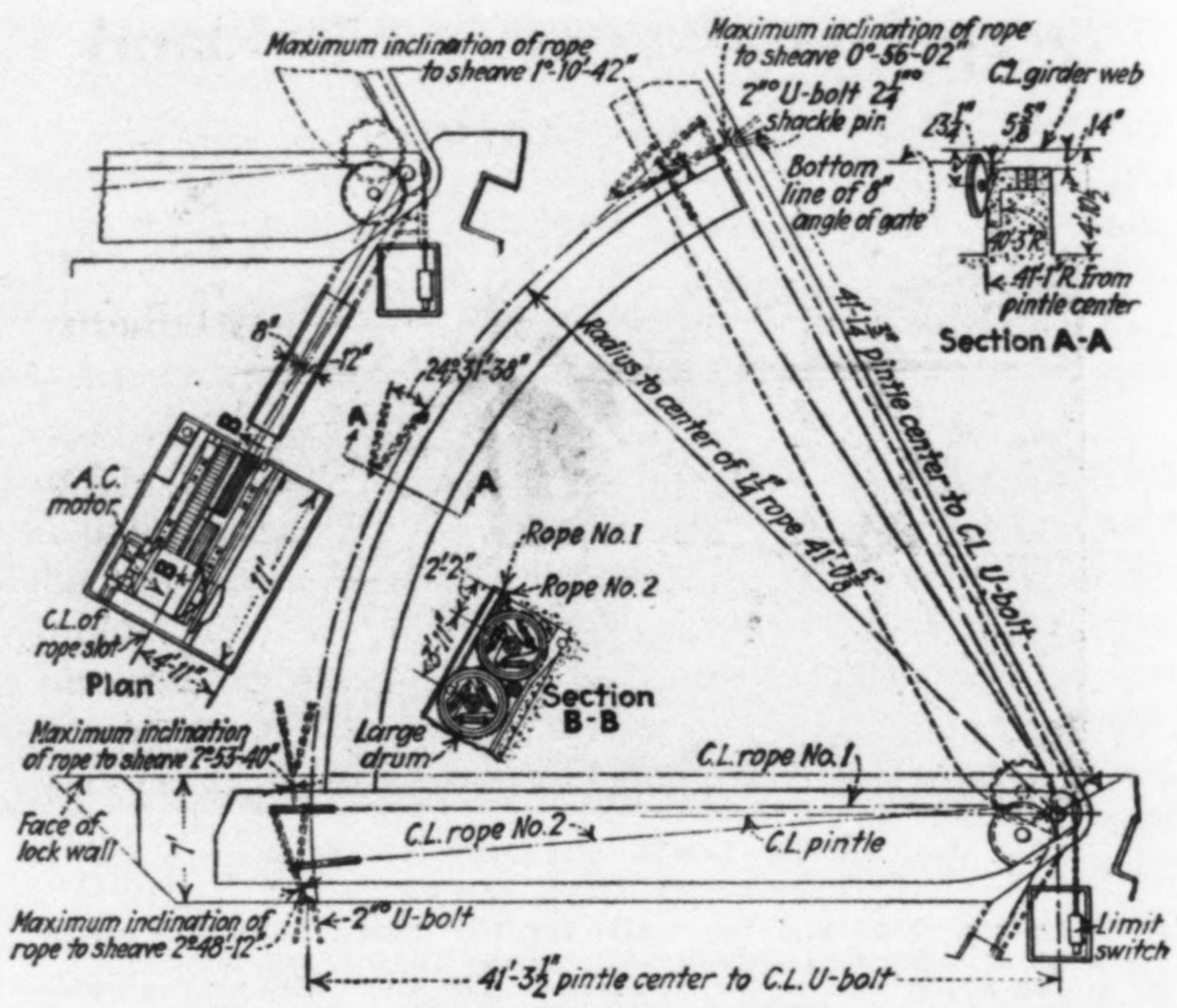


FIG. 11—GATE-OPERATING MECHANISM

Engineers and Contractors—Construction of the canal has been carried on by the Department of Railways and Canals of the Dominion of Canada, of which A. E. Dubuc is chief engineer. When the work was first started, J. L. Weller was placed in direct supervision of the work as engineer-in-charge. In 1919 he was succeeded by Alex J. Grant as engineer in charge and Mr. Grant has carried the work through to the present time. Assisting Mr. Grant are E. G. Cameron as his principal assistant; Frank E. Sterns, designing engineer; M. B. Atkinson, bridge engineer; J. B. McAndrew, mechanical engineer; A. L. Mudge, electrical engineer, and F. C. Jewett, C. W. West, E. P. Johnson and E. P. Murphy, division engineers. Frank E. Sterns, the designing engineer, previously served as one of the designing engineers of the Panama Canal.

Numerous contracts were let for the many kinds of construction work involved during the entire period from 1913 to date. The principal ones were let to J. P. Porter, P. Lyall & Sons Construction Co., Canadian Dredging Co., Atlas Construction Co., E. O. Leahey & Co., and A. W. Robertson, Ltd. The gates were built by the Steel Gates Co. and the bridge superstructures by the Hamilton Bridge Co., the Canadian Bridge Co. and the Dominion Bridge Co.

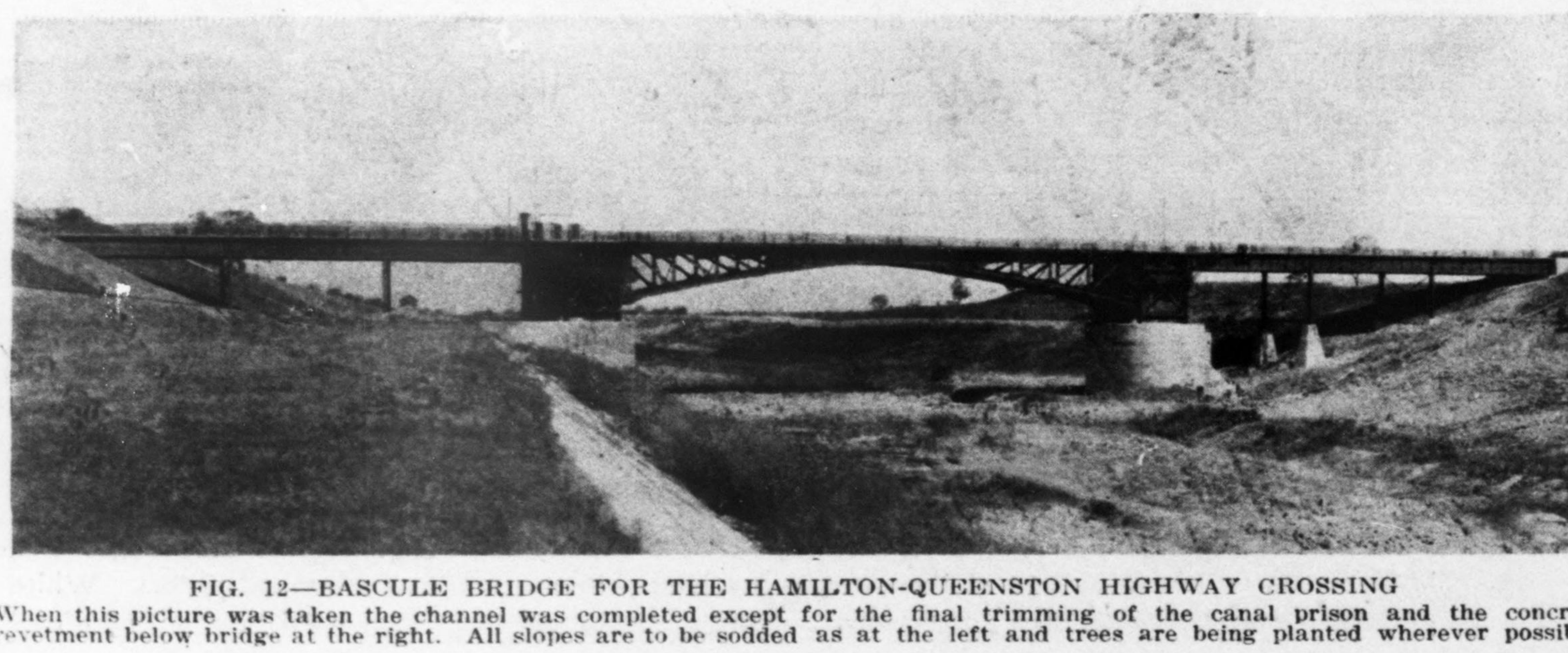


FIG. 12—BASCULE BRIDGE FOR THE HAMILTON-QUEENSTON HIGHWAY CROSSING

When this picture was taken the channel was completed except for the final trimming of the canal prison and the concrete revetment below bridge at the right. All slopes are to be sodded as at the left and trees are being planted wherever possible.