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**Erie Canal Lift Bridges
Historic Towerless Lift Bridges and How
They Work**

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Erie Canal Lift Bridges- Historic Towerless Lift Bridges and How They Work

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Introduction

The Erie Canal dubbed “Clinton’s Folly” was opened in 1825. The canal connected Lake Erie with New York Harbor and was a major catalyst for the economic development of the State of New York. Almost every major City in New York is located along this major trade route including Buffalo, Rochester, Syracuse, Utica, Schenectady, Albany and last but not least New York City.

Crossing the Erie Canal in Western New York State are sixteen of the earliest examples of towerless vertical lift bridges. These bridges are still operating as important functional elements of the Canal System and are all listed on the National Register of Historic Places.

This paper will discuss the workings of the Erie Canal Towerless Vertical Lift Bridges. The towerless design dates to the beginning of the 20th Century. The design incorporates rigid frame construction and below deck counterweights. In this way the above deck towers and counterweights can be eliminated, and with them the visual markers associated with traditional vertical lift bridges. As far as we know this is the first example of this style of bridge. However, many features were incorporated in the Milwaukee Style Towerless Vertical lift Bridges that were developed in the late 20th Century.

Bergmann Associates has rehabilitated eight of the Canal Lift Bridges in the last sixteen years. The most recent rehabilitations at Ingersol and Washington Street are currently under construction

This paper will discuss some of the unique features of this bridge type as well as the advantages and disadvantages of the towerless bridge design.

The Erie Canal – A Brief History (1)

The Erie Canal was one of the great engineering accomplishments of the early 19th Century extending from Buffalo on the eastern shores of Lake Erie almost 400 miles to Albany on the upper Hudson River. During the initial planning stages it was dubbed “Clinton Folly” after New York’s Governor DeWitt Clinton. Clinton had a grand vision and in 1816 he wrote: “As an organ of communication between the Hudson, the Mississippi, the Saint Lawrence, and the Great Lakes of the north and west and there tributary rivers, it will create the greatest inland trade ever witnessed.” Trade from the west would be funneled straight down the Hudson River to New York City he further wrote: “The city will in course of time, become the granary of the world, the

emporium of commerce, the seat of manufacturers, the focus of great moneyed operations. And before the revolution of a century the whole island of Manhattan, covered with inhabitants and replenished with dense population, will constitute one vast city.”

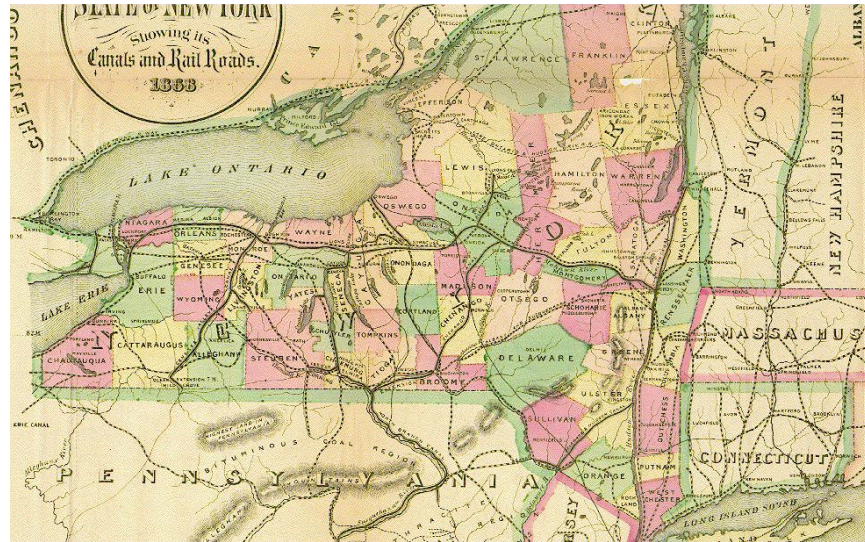


Figure 1: A 19th Century Map of the
Erie Canal from the NY Canal Website.

In 1817 Governor Clinton convinced the legislature to authorize \$7 million to fund his vision, and his vision was right on the money. The canal opened a gateway to the Midwest and transformed the fortunes of not just New York City but much of New York State. Albany Schenectady, Utica, Syracuse, Rochester and Buffalo all lie along the Erie Canal and boomed as the result of canal traffic. In addition several lateral canals opened in the 1820's including the Champlain, the Oswego and the Cayuga-Seneca Canals.

The Erie Canal was opened October 26, 1825 when Governor Clinton set out from Buffalo in the canal boat "Seneca Chief" along with two other boats. They arrived in New York Harbor nine days later. Governor Clinton emptied two barrels of water from Lake Erie into the ocean at New York in a ceremony known as the "Marriage of the Waters"

Before the Canal was opened farm goods, timber and minerals had to be hauled over rough roads for weeks at a cost of about \$100 a ton. After the canal opened the goods could be transported in days at a cost of \$10 per ton. As the volume of goods increased on the canal the Port of New York grew from the 5th largest port to the busiest in America in just 15 years. In the first nine years, the tolls on the canal recouped the entire cost of construction.

Between 1835 and the turn of the Century the entire network of canals was enlarged twice to accommodate heavier traffic. The canals were again enlarged and several areas were realigned between 1905 and 1918 to accommodate much larger barges. When it was reopened in 1918 the system was renamed the New York State Barge Canal.

By the mid- 20th Century the commercial traffic on the canals had declined due to railroads and highways. Now the Canal is used mainly for recreational traffic.

Canal Lift Bridges

The Erie Canal as constructed in 1825 was 363 miles long, 40 feet wide, 4 feet deep and rose from tide water on the Hudson through a series of locks to an elevation of 565.5 feet at the Niagara River. The Barge Canal opened in 1918 has a minimum bottom width of 74 feet and depth of 12 feet. There are 306 railroad and highway bridges that cross the canal most of which are fixed type bridges. However, there are sixteen movable bridges mostly in the western reaches of the canal with a minimum clearance of 15 ½ feet. These bridges are vertical lift bridges that were built in the 1910's as part of the Barge Canal construction. The following is a list of the Canal Lift Bridges:

	LIFT BRIDGE	LOCATION
1	Main Street Lift Bridge	Fairport
2	Union Street Lift Bridge	Spencerport
3	Washington St. Lift Bridge	Adams Basin
4	Park Avenue Lift Bridge	Brockport
5	North Main Street Lift Bridge	Brockport
6	East Avenue Lift Bridge	Holley
7	Hulberton Road Lift Bridge	Hulberton
8	Ingersoll Lift Bridge	Albion
9	Main Street Lift Bridge	Albion
10	Eagle Harbor Road Lift Bridge	Eagle Harbor
11	Knowlesville Lift Bridge	Knowlesville
12	Prospect Street Lift Bridge	Medina
13	Main Street Lift Bridge	Middleport
14	Gasport Road Lift Bridge	Gasport
15	Adams Street Lift Bridge	Lockport
16	Exchange Street Lift Bridge	Lockport

What makes these bridges of interest is that they are all Towerless Vertical Lift Bridges. Vertical lift bridges date to early 19th Century in Europe; and were mainly used over canals where short span and small lifts were required. We are not aware of any towerless vertical lift bridges constructed prior to these structures.

Squire Whipple developed a vertical lift bridge design and obtained the first patent for a lift bridge in the United States for use over the Erie Canal in 1872. These bridges appeared to have functioned adequately but were removed to accommodate the construction of Barge Canal. The Towerless Vertical Lift bridges along the Erie Canal were designed in the in the 1910's as part of the widening of the canal that was taking place between 1905 and 1918. It is interesting to note that in an era where the contributions to movable bridge design of well known engineers such as Whipple, Waddell, Harrington, Strauss and Scherzer's are known and well documented

the designer's of these innovative structures appears to be a team of State employees with no single engineer documented as the creative force behind the design.

Most vertical lift bridges at the time were the span drive vertical lift type pioneered by Doctor Waddel. The lift spans were typically flanked by towers. The lift span was balanced by counterweights that were hung at either tower. The operating system was driven by winch and a system of wire ropes attached to the top and bottom of the towers at the four corners of the span. The span was pulled up and down by winding up the uphaul and downhaul ropes. Since the ropes at the four corners of the span are driven by a central motor the four corners move at the same rate eliminating any skew concerns. The drive machinery was centrally located on the lift span over the roadway. The towers, over head counterweights, and drive machinery located over the roadway combine to make the span drive vertical lift bridges some of the most visually obtrusive movable bridges.

The Towerless Vertical Lift Bridges eliminate the towers and centrally located drive machinery over the roadway. Therefore with the exception of the stair towers and control house (see photo 1) the towerless vertical lift bridges would look like any other simple span truss over a small non-navigable waterway.

The typical Towerless Vertical Lift Bridge along the Erie Canal is approximately 120' feet center to center of lifting post. The bridge cross sections are typically 21'-6" center to center of truss with two 6'-9" sidewalks. The span typically weighed about 213,000 pounds and the lift varied from about 12'-0" to 14'-3" providing a maximum vertical clearance of 15'-6" above high water. Several of the bridges were constructed on a skew to the canal opening and one was constructed with a skew as well sloped profile.



Photo 1: Elevation View of a Canal Lift Bridge
in the down position.

Workings of the Erie Canal Vertical Lift Bridges

There are several design features that are unique to the Erie Canal Vertical Lift Bridges. The unique features include:

- Counterweight and operating systems that are contained below the roadway..
- A direct drive rack and pinion operating system
- A drive system that is located only on one end of the lift span.
- The uphaul and downhaul rope systems are used for skew control.
- The barrier gates are integral with the bridge.
- The span is open to pedestrians while in the up position.

Counterweight and Machinery Pits

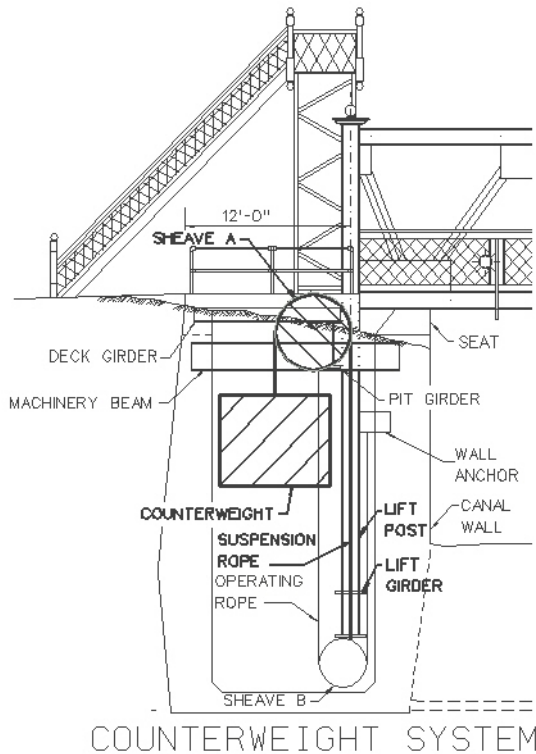


Figure 2: Section through the Counterweight Pit

The workings of the towerless vertical lift bridges are contained below the roadway in the pits at either side of the channel. The span is balanced similarly to other vertical lift bridges in that the span is connect by wire ropes that run from a lift girder over a counterweight sheave to a counterweight. In a typical vertical lift span the counterweight sheave and counterweight would be located in a tower above the roadway. and the lifting girder spans between the ends of the top chord.

In towerless construction the Counterweight Sheaves (Sheave A) are located just below the roadway in the machinery pits at either side of the canal. The end posts for the lift span trusses extend down below the roadway into the machinery pits as well. The counterweight ropes are attached to the bottom of the end post or lifting legs as they are called. In essence the lift span is like a table with the counterweights attached to the bottom of the table legs. The ropes pass over the top of the sheaves and are attached to the counterweights. The counterweights are located just below the sheave when the bridge is

down. As the span moves up the counterweight moves down and the counterweight is located in the bottom of the machinery pit when the bridge is fully opened.

The machinery pit at the near side adjacent to the control house contains the drive system along with one counterweight. The drive systems, as originally designed, contained two 11 horsepower motors and a series of open gears. The output shaft extended across the full width of the machinery pit with two 9.6" pinions mounted to the shaft. The pinions were used to drive linear racks that were mounted on the end post / lifting posts at either truss (or on an adjacent drive post on skewed bridges). Both trusses were driven on a common shaft ensuring that the rate of lift would be the same for each truss and preventing any transverse skew as the bridge opened and closed.



Photo 2: Rack and Pinion Engagement

The open gearing and bearings for the output shafts were supported from the framing for the counterweight span that covered the counterweight or machinery pit. At the near side pit the drive machinery was supported on an independent machinery frame that could be accessed through hatch doors in the sidewalk area.



Photo 3: Open gearing and output shaft supported from the counterweight span framing.

The rehabilitated Canal Lift Bridges have new enclosed gear reducers to replace the existing open gearing. A new rack and pinion gear was installed as part of the rehabilitation. Sample machinery plans showing the demolition of existing machinery and the layout of new machinery for the rehabilitated of the Ingersol and Washington Street Bridges have been provided in the appendix.

Equalizing Rope System

Probably the single most interesting aspect of the Canal Lift Bridge design is the equalizing rope system. The Canal Lift Bridges have operating machinery on the near side of the bridge only. The far side of the bridge is lifted by uphaul and downhaul ropes connected to the near side. The uphaul and down haul ropes are similar to the ropes from a span drive bridge except that they are driven passively.

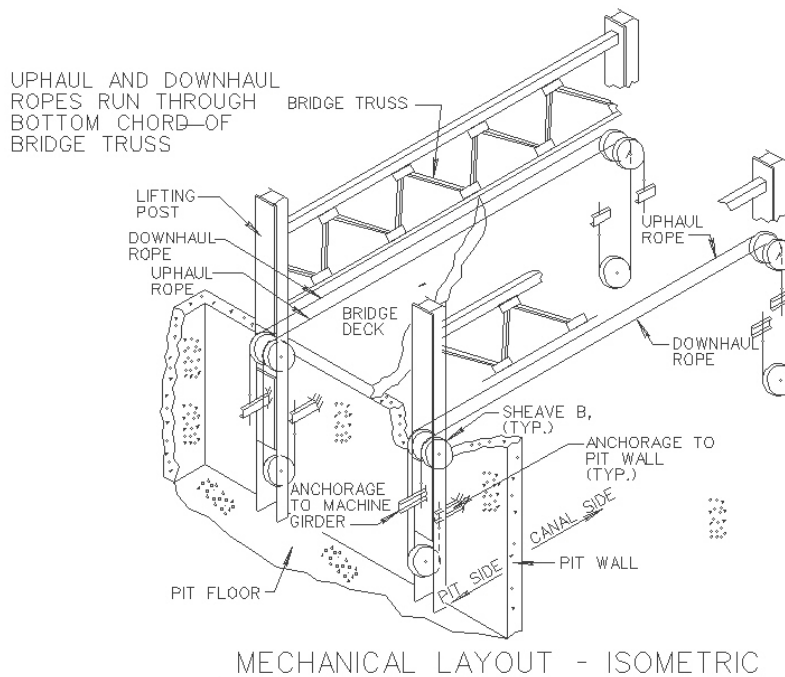


Figure 3: Isometric View of Uphaul / Downhaul Ropes

Figure 3 shows an Isometric View of the Equalizing Rope System as viewed from the far side counterweight pit. Note there is no gear drive at the far side pit. The uphaul and downhaul ropes are mirror images. The Uphaul ropes have one deflector sheave mounted to the lifting post in the machinery pit (at the gear driven end), and two sheaves mounted to the lifting post at the counterweight pit (at the free end). The downhaul ropes are arranged in opposite fashion with one sheave at the free end of the span and two sheaves at the gear driven end of the span. The ends of the uphaul and downhaul ropes are attached to anchorage beams that are embedded in the concrete piers.

When the bridge is opened, the top sheave at the driven end pushes up on the uphaul rope system which pulls up the lower sheave at the free end at an equal rate. When the bridge closes, the lower sheave at the driven end of the bridge pushes down on the downhaul rope which pulls down the upper sheave at the free end at an equal rate. As the bridge moves up or down the length of uphaul and downhaul ropes gets taken up at one end of the bridge and let out at the other.

3/4 inch wire ropes were used for the uphaul and downhaul ropes on the Canal Lift Bridges. For the long horizontal run over the canal 1 inch diameter threaded rod was used. Intermediate deflector sheaves were provided along the bottom chords of the truss to take up sag in the rods.

Integral Crash Gates and Stair Towers

Most movable bridges at the time had manually operated barrier gates. Before the bridge could be opened operators had to run out to the far ends of the bridge in order to close the gates and prevent vehicles from entering the channel or the pit. By providing 3-inch diameter wrought iron pipe between the lifting posts at 2'-0" on center, a barrier was provided automatically. Similar gates are provided in the sidewalk areas.



Another feature unique to the Canal Lift Bridges is the stair towers. By providing stair towers adjacent to a sidewalk at either approach to the bridge, pedestrians would be able to use the bridge in the raised position. Photo 4 shows a view of the bridge in the up position taken from one of the approaches. This view shows the integral crash gate and the pedestrian stair tower.

Photo 4: Barrier Gate Integral with Lifting Posts. Note Staircase to Raised Bridge Sidewalk

Advantages and Disadvantages of the Canal Lift Bridge Design

The Canal Lift Bridges provide a less obtrusive structure than the typical span drive or tower drive vertical lift bridge. Except for the control houses and the pedestrian staircases, the Canal Lift Bridges look like any other pony truss bridge of the time. Similar construction has been used more recently in the Milwaukee Style Towerless Vertical Lift Bridges. The Milwaukee Bridges use multi-girder construction, and in some cases the control houses are located along the river bank. In such cases, all visual clues to a movable bridge are removed when the bridge is in the down position.

The Canal Lift Bridges are controlled by operating machinery on the near side of the bridge, and the barrier gates are integral with the lifting posts. As such, there is no need to provide submarine cables for communication with equipment at the far side. At the time of construction this may not have been such a significant issue. Construction on the Canal Lift Bridges would have been done in the dry in the off season. However, today the expenses of

submarine cables and the environmental permitting issues are a major concern in movable bridge design. The canal lift bridges don't have warning gates in advance of the bridge. If there were warning gates then communication across the channel would be required. The communication link with gates at the far side could be made with a cat track type festooned cable system in the piers or wireless communication to avoid the cost and environmental issues with submarine cables.

The equalizing system of uphaul and down haul ropes guarantee that the near and far sides of the span move at the same rate of speed without the need for complex feedback controls. Transversely the near side lifting posts are lifted by pinions on a common shaft therefore transverse skew is controlled as well.

The main disadvantage to the towerless design is tight spacing in the pit. In particular at the near side where the operating machinery, including motors, reducers, racks and pinions have to fit around the counterweight, the counterweight ropes and counterweight sheaves as well as the equalizing ropes and the 6 deflector sheaves in each pier. Fitting these components and providing access for maintenance is a challenge. For larger bridges the pit needs to get larger as well. Larger bridges require larger counterweights, larger ropes and larger diameter sheaves. This is true for both counterweight sheaves and deflector sheaves. Also the size of the counterweight pit limits the lift height. For every foot of lift height the counterweight must move down an equal distance.

The counterweight pits for the Canal Lift Bridges are wet and steel and machinery in these areas are subject to corrosion due to road salts. This issue can be improved by better location of the road breaks and improved drainage details.

The sixteen canal lift bridges functioned efficiently and reliably with only routine maintenance for over 85 years. All of the bridges have been rehabilitated over the last 15 years. Typical rehabilitation project have included:

- Rehabilitation of the trusses and pits.
- Replacement of the bridge deck system.
- Replacement of the approach spans.
- New drives and controls.
- New machinery.
- Rehabilitation of the control houses.
- Highway approach reconstruction.

REFERENCES:

(1) New York State Canal Corporation Website)

APPENDIX