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SESSION WORKSHOP PRESENTATIONS

"NINTH STREET BRIDGE - CONSTRAINTS IN ALL DIRECTIONS"

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Ninth Street Bridge
Constraints in All Directions

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Introduction:

In 1988, Hardesty & Hanover was selected by the New York City Department of Transportation, Bureau of Bridges to prepare a Bridge Reconstruction Project Report and subsequently to prepare the preliminary and final design and provide construction support services for the Ninth Street Bridge over the Gowanus Canal in the Borough of Brooklyn. This paper addresses the myriad design constraints and the evolution of the unique design which fits a new vertical lift bridge directly below an overhead transit structure carrying four subway tracks. The design is now complete and notice to proceed with construction on this three year project was given in September, 1994.

Project History:

The 100 foot wide Gowanus Canal was constructed in the 1840's by dredging and bulkheading the shallow Gowanus Creek thereby allowing sailing vessels to access points further inland in northwestern Brooklyn. At the time, this area was undeveloped swampland. The mile and a half long canal resulted in heavy industrialization of the area it serves. The canal continued to be very busy with navigation until the 1960's when the maritime activities in the New York City area generally declined. The area around the canal is still heavily industrial but the uses are less canal dependent. The Ninth Street has crossed over the Gowanus Canal in Brooklyn, New York for over 100 years. Records indicate that a swing bridge was constructed at this site in the 1800's to tie Ninth Street on the east side of the canal with West Ninth Street on the west side of the canal. It was one of five movable bridges providing continuity of the city street grid across the canal.

By 1903, the swing bridges with their pivot piers in the center of the narrow canal were found to be inadequate for the demands of navigation and a replacement was found necessary. The Third Street, Union Street and Ninth Street bridges were all replaced with Scherzer double leaf rolling lift bridges of similar design. The rolling lift bridge at Ninth Street provides a 45 foot channel centered on the canal. The substructure consists of two unreinforced concrete piers supported on timber piles in the canal and abutments which consist of the swing span abutments reused with minor modifications. In 1960, the entire superstructure on the Ninth Street bridge was replaced in kind but the substructure was retained. The existing Ninth Street Bridge consists of abutments from the 1800's vintage swing span, piers from the 1903 vintage rolling lift bridge and a rolling lift superstructure built in the 1960's.

In the 1930's, the predecessor to the New York City Transit Authority built an elevated structure providing a ninety foot clearance over the Gowanus Canal directly above the Ninth Street Bridge. The structure carries four tracks for use by the "F" and "G" trains as well as the Smith - Ninth Street Station. The structure has large multi-column braced bents on either side of the canal roughly 30 feet from the bulkhead line. The column loads of up to 4000 kips each are supported on footings with timber friction piles.

Several major users of the canal account for 980 openings per year (roughly 3 openings per day). The users include an oil storage facility and a gravel plant. Most users run loaded barges up the canal at high tide due to the shallow canal depths at the north end of the canal. All bridges over the canal are operated by NYCDOT on call with the Ninth Street Bridge being the base of operations.

Study Phase - Scheme Selection:

As part of the study phase, we did an in-depth inspection of the superstructure and substructure. The inspection included a diving inspection of the piers. Cores and borings were also done. The piers were found to be in very deteriorated condition due to weathering, ship impacts and continual exposure to the heavily polluted canal. The piers were found to be progressively tilting and are being monitored. Ship impact has destroyed much of the existing fender system and damaged certain superstructure elements. Other problems noted in the study phase include difficult access to the machinery for maintenance, poor span operation and counterweights that dip into the canal. These deficiencies resulted in the need to reconstruct or replace this bridge. The study included investigation of four primary schemes for on-line bridge replacement as well as a reconstruction scheme. Traffic demands were too high to eliminate the bridge and alternate alignments were not possible due to right of way acquisition problems and the Transit Authority columns in the area. The replacement schemes which were advanced included a single leaf bascule, a double leaf bascule, a vertical lift bridge and a single leaf overhead counterweight bascule. Other schemes including a bobtail swing, retractable bridge, a hydraulic cylinder lift bridge and use of the Transit Authority structure to lift the span were touched on in a value engineering study and eliminated from consideration. Each of the primary schemes was evaluated as to its cost and how well it addressed the site constraints. The schemes are shown in Figures 1 thru 5.

This site offered many very difficult and at times conflicting constraints. The main constraints are as follows:

1) Transit Authority Structure Overhead

   The overhead transit structure limits the height of a vertical lift bridge and the opening angle for a single leaf bascule.

2) Transit Authority Footings

The footings for the elevated Transit Authority structure are very close to the location of footings for the new bridge. The new bridge footings need to be designed to avoid the TA footings both horizontally and vertically. A deep footing adjacent to the existing footings can result in a need to underpin the existing footings.

3) Clearance Above Canal

The new bridge should be high enough above the canal to avoid immersion of bridge elements during periods of high water. When open, the bridge should be high enough to allow passage of current and future canal users.

4) Suitable Roadway Profile

The roadway profile is constrained by the bracing for the TA columns above, tie-in to the existing roadway and various building entrances on either end and vertical geometry which provides adequate stopping sight distance.

The Gowanus Canal is currently used by barge traffic. Frequent ship impacts made a widening of the channel at the bridge desirable. However, the Transit Authority footings limited the amount of widening that could be made. The bridge is very low to the water making raising the profile desirable. However, tie in with the existing roadway system limited raising. Providing adequate vertical clearance for passage of barges with high masts was important. However, the overhead transit structure limited new bridge types and configurations. The close proximity of Transit Authority footings put severe constraints on the substructure construction methods.

The schemes were compared using a matrix identifying the major advantages and disadvantages of each scheme. The matrices are given in Tables 1 and 2. The vertical lift bridge proved to be the recommended scheme primarily because it provided a wider channel and minimized the potential for disturbing the Transit Authority footings.

Preliminary / Final Design:

Once the basic scheme was selected, it was refined to address the needs of NYCDOT, other city agencies and permitting agencies. Initially it was thought that a two counterweight vertical lift span with a central overhead strut would be preferred. However, the barges navigating the canal have high masts. This made a larger vertical clearance, with the span open, desirable and helped obtain Coast Guard approval. The height of lift of a two counterweight vertical lift is limited by the clearance of the counterweights above the roadway with the span in the open position. The tower height was limited by the clearance to the Transit Authority structure above. A maximum of 53 feet vertical clearance above mean high water could be obtained with the two counterweight vertical lift bridge. By using four independent cast iron and lead counterweights located at the corners of the bridge, outside of the roadway, the counterweight travel could be increased thereby increasing the vertical clearance. The counterweight ropes were arranged in a single row, eliminating the need for splaying the ropes and thereby further increasing the height of lift. This resulted in a 60 foot vertical clearance above Mean High Water. The strut with centrally located operating machinery was eliminated primarily due to aesthetic concerns.

The details of the substructure and the associated construction methods were carefully designed to minimize impacts on the adjacent Transit Authority footings. The process of evaluating appropriate substructure construction and protective measures for the Transit Authority Structure started with an analysis of the Transit Authority structure column bents adjacent to the canal. Each bent consisted of two rows of concrete encased steel columns braced at various levels to form a very rigid structure. The east bent has nine columns while the west bent has seven columns. Two of the columns are supported on a common footing. All other columns are supported on independent footings. Each footing is supported on timber piles of unknown length. It was assumed that the footings adjacent to the canal could move horizontally or vertically due to construction activity. The sensitivity to these movements was evaluated for various combinations of horizontal and vertical movement. It was found that movements on the order of 1/4 inch would overstress the columns. Since movements of this magnitude could not be precluded, installation of repositioning apparatus which can relocate the columns horizontally or vertically was called for. A rigorous monitoring and repositioning program will be carried out throughout construction. Substructure details were selected to minimize the impacts on the Transit Authority structure as well as provide durable construction. Soil conditions and the potential for differential movement possibly causing a misalignment of the span guides lead to selection of caissons installed to rock roughly 160 foot below grade. The upper layers of soil were unsuitable for foundations of the type required for this bridge. Since potential obstructions exist in the area of the existing bulkhead which will be straddled by the new piers, the pier footings were raised as high as possible above potential obstructions and the number of caissons reduced to a minimum. Each tower pier will consist of a precast concrete box type footing filled with concrete supported on five 30 inch diameter caissons. The caissons will have saw toothed tips and be rotated into position. The caisson installation techniques were selected to minimize the potential for vibrations and loss of ground during installation.

The vertical lift bridge has four towers, each with four columns. The two towers on each side of the canal are connected together at the top with a machinery room. The entire bridge including the superstructure and substructure was analyzed using a multimodal spectral analysis for seismic design in accordance with the latest New York State requirements. The tower bases are enclosed in concrete walls and the upper portion of the towers and machinery rooms are enclosed in stainless steel panels. The architectural details were reviewed and approved by the City Arts Commission.

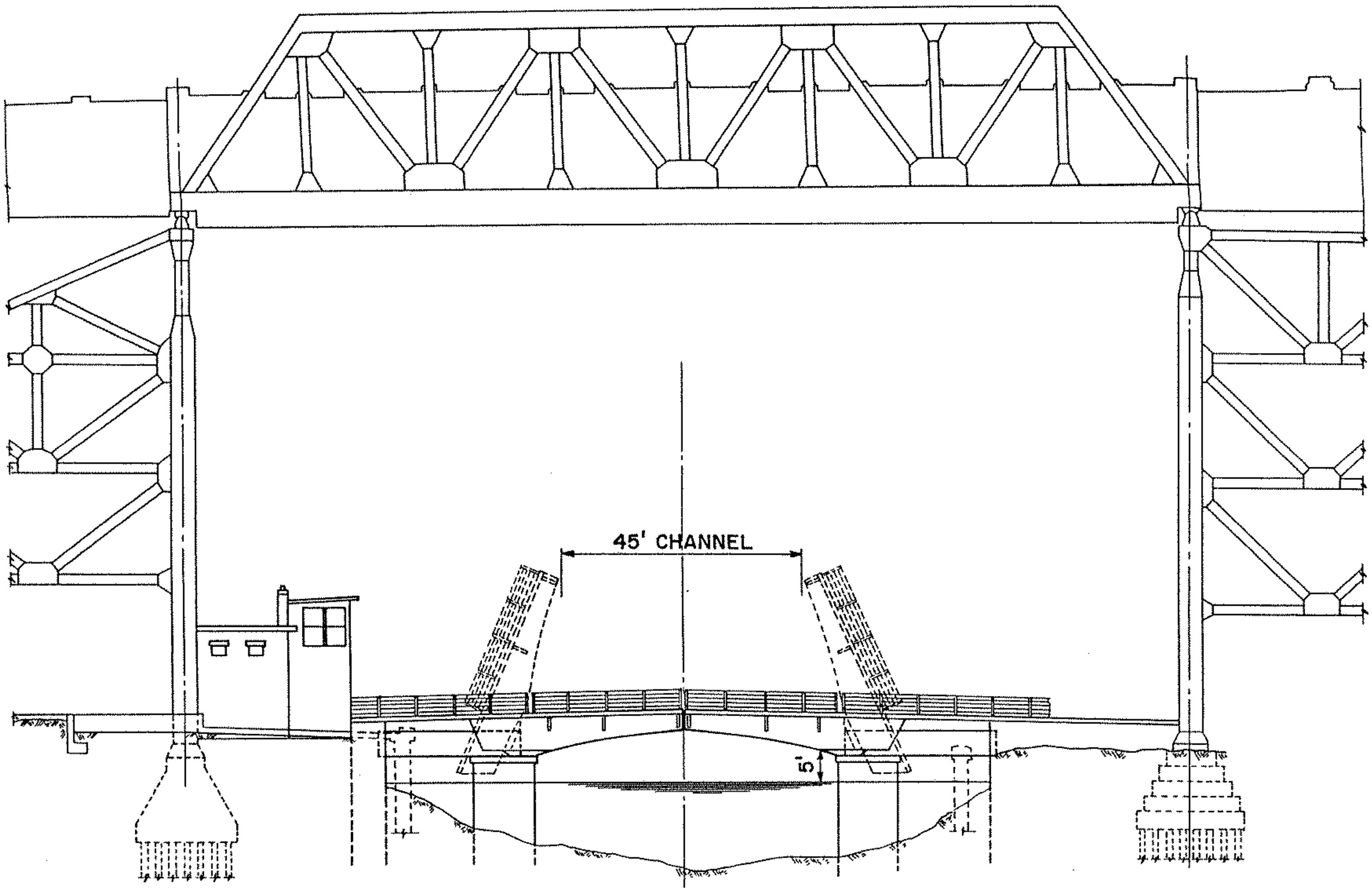
The lift span consists of a half depth filled steel grating supported on nine longitudinal girders and two transverse lifting girders. The span carries two westbound and one eastbound lane as well as two 7'-6" wide sidewalks over a 60 foot wide channel. The pier protection system was designed for the latest AASHTO vessel impact criteria and consists of circular sheet pile cells with granular fill and concrete caps along with timber dolphins and wales.

The operator's room had to be carefully positioned to give the optimal view of the roadway and canal. Due to the maze of Transit Authority bracing above the roadway, locating a suitable position for the operator's room proved to be quite difficult. In the end, a location was selected by bringing a bucket truck to the site and positioning the bucket at potential operator's room locations until the best combination of view to the east and west down Ninth Street as well as the view of the canal was obtained. The best position of the operator's room was found to be high above the roadway at the southwest corner of the bridge. Supporting the operator's room using a cantilever arrangement rather than spanning completely across the roadway was found to give an improved view of the area below the operator's room. This view was particularly important as it gave a better view of pedestrian traffic in the urban area of the Ninth Street Bridge. A two story control house will be built at grade with stairs leading up to the operator's room. The control house footings were configured to fit around the TA footings and will be supported on minipiles designed to minimize disturbance to the TA footings.

The operating machinery includes four 13'-4" diameter counterweight sheaves. Provisions for lifting the sheaves for installation directly below the TA structure were incorporated in the tower design. There are four 2" diameter wire ropes per sheave. Pairs of sheaves are driven from a central set of operating machinery. Because of space limitations, the lock machinery is located on the span. Four sets of crank type lock machinery are provided, one per corner. This tower drive vertical lift bridge has AC SCR drives and PLC skew controls.

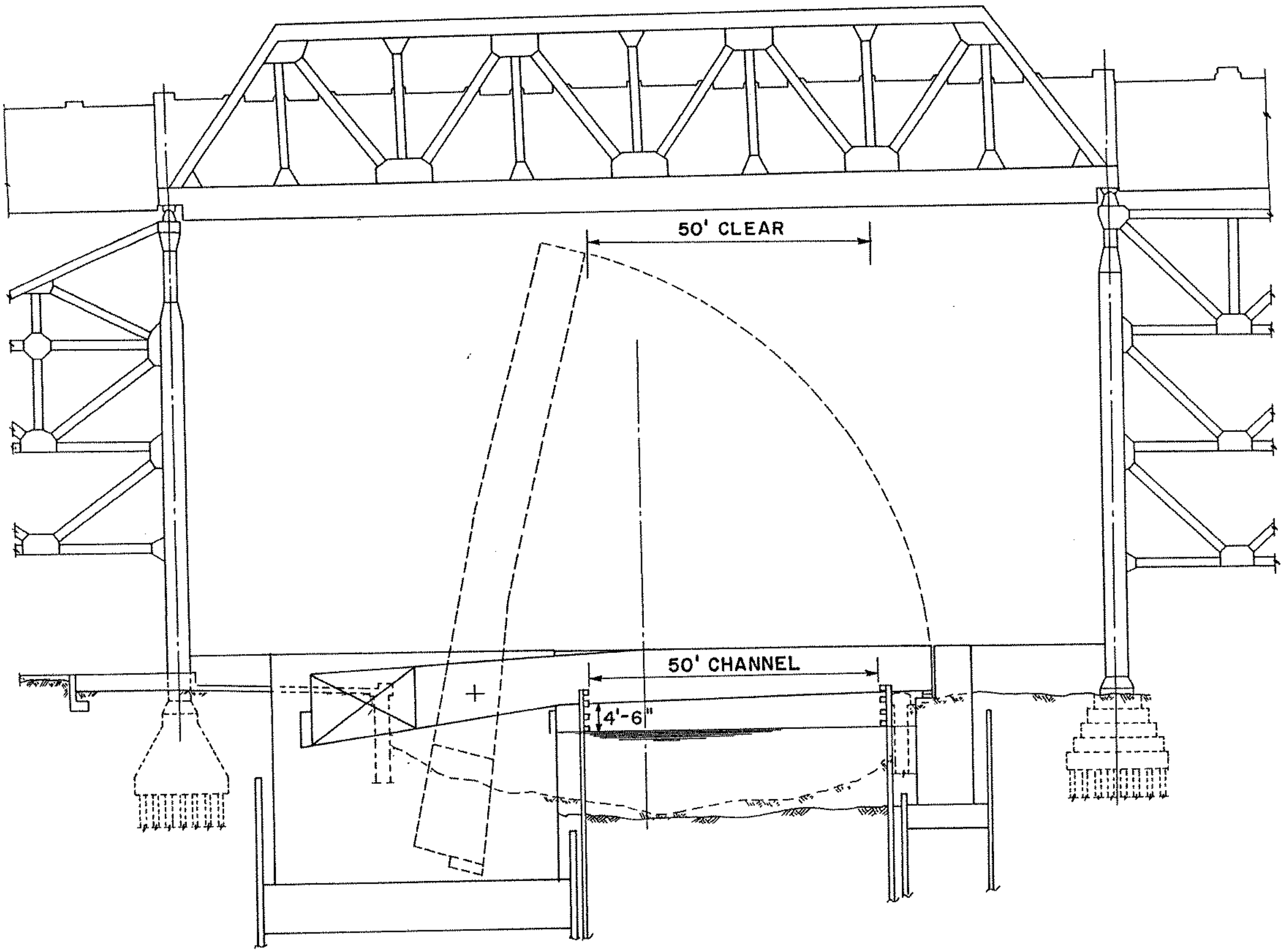
Construction

The project was bid in February 1994. The low bid of $33 million was received from Schiavone Construction Co./August C. Lozano - Joint Venture. The project start date for this three year project was September 19, 1994.



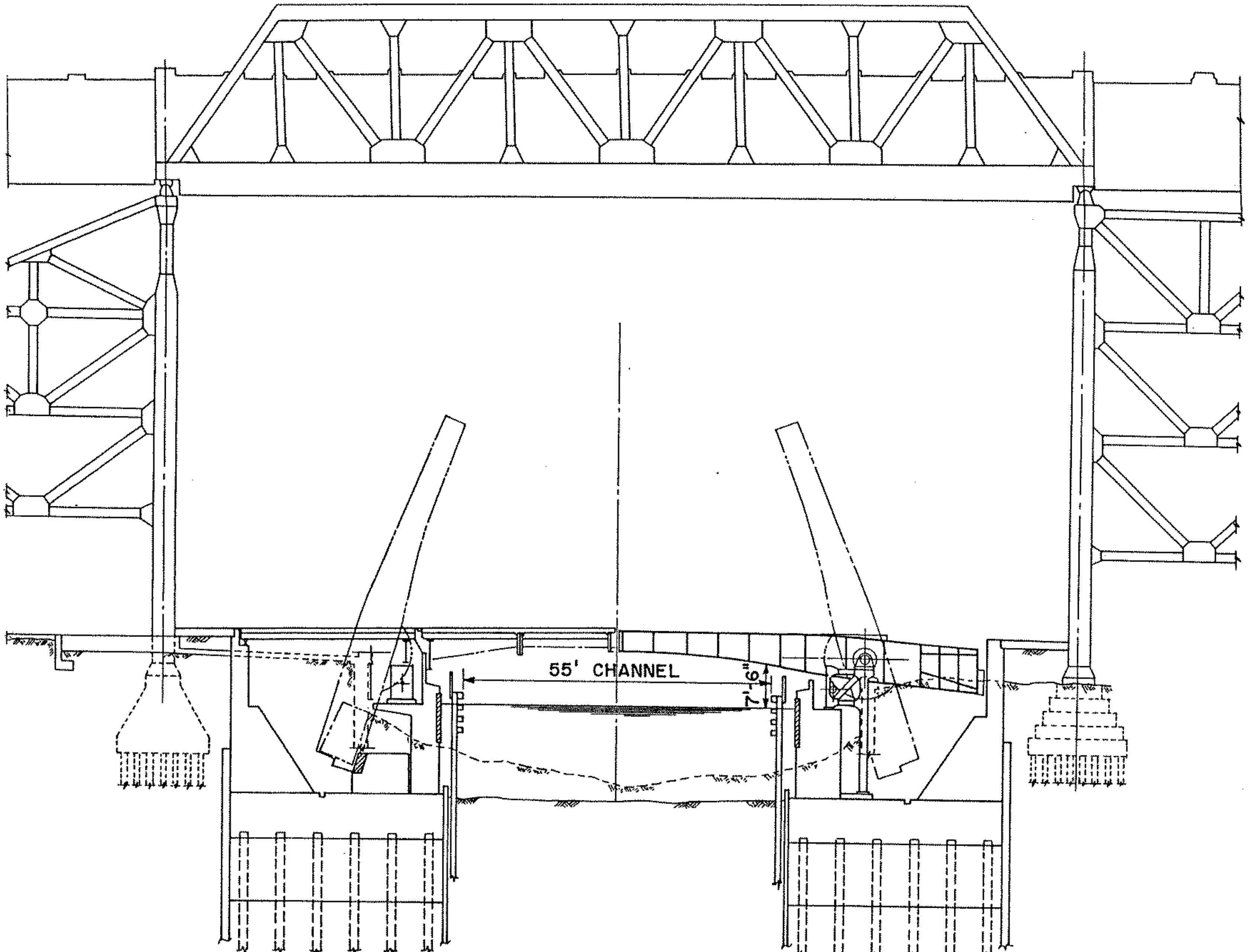
SCHEME I - REHABILITATION

FIGURE 1



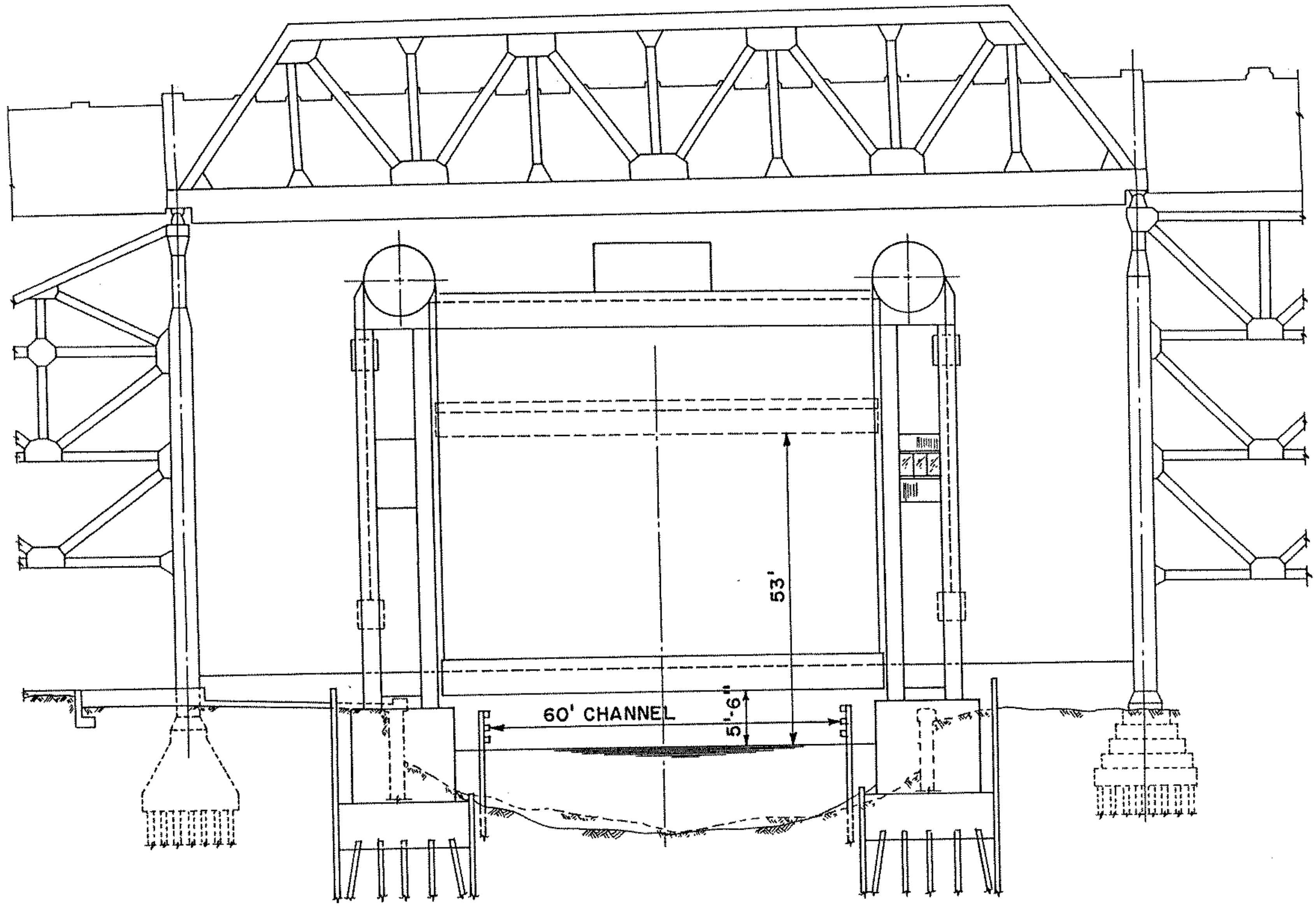
SCHEME II - SINGLE LEAF BASCULE

FIGURE 2



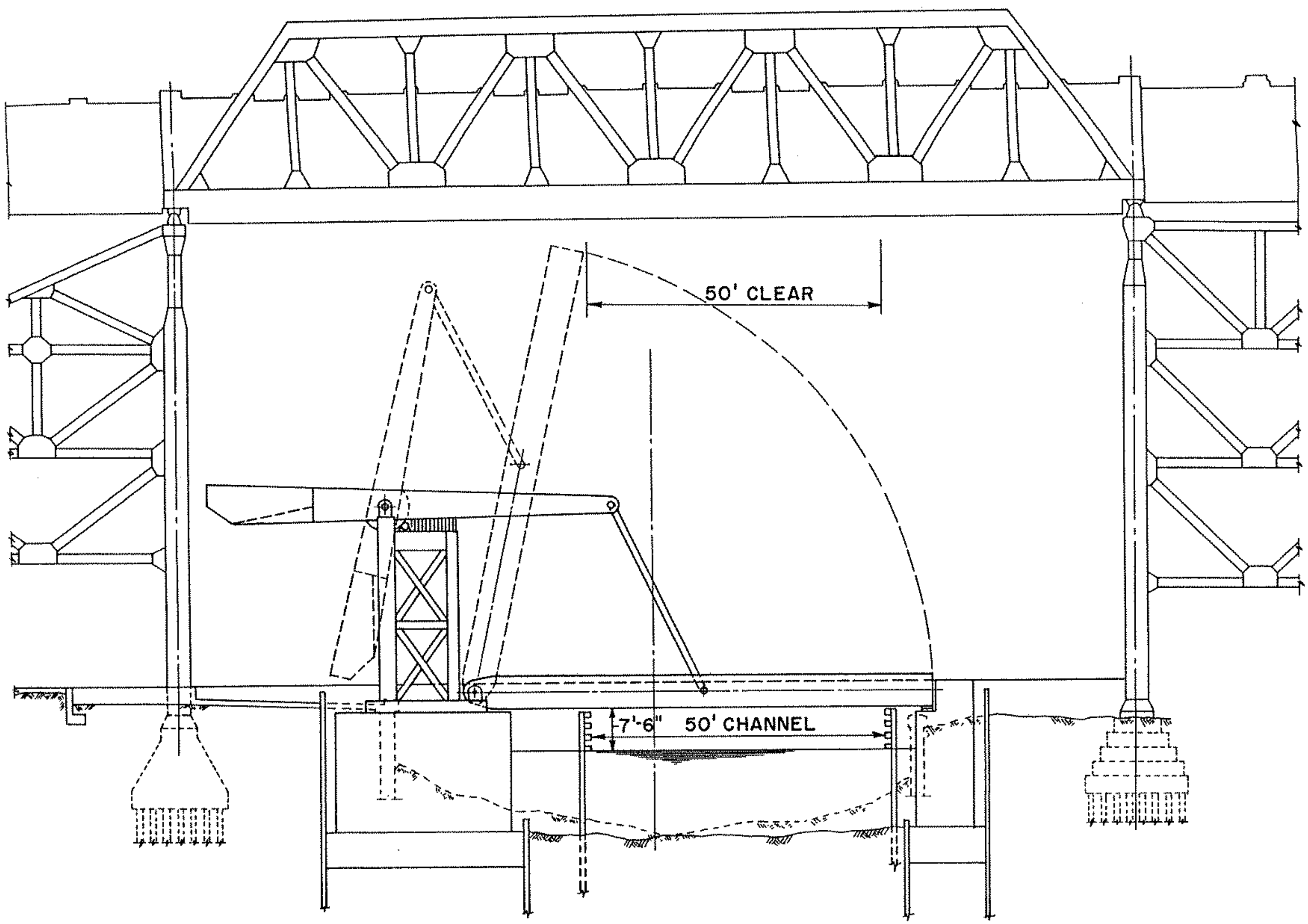
SCHEME III - DOUBLE LEAF BASCULE

FIGURE 3



SCHEME IV - VERTICAL LIFT BRIDGE

FIGURE 4



SCHEME V - OVERHEAD COUNTERWEIGHT BASCULE

FIGURE 5

Description / Scheme	I Rehabilitation	II Single Leaf Bascule	III Double Leaf Bascule	IV Vertical Lift	V Single Leaf Bascule Overhead Ctwt.
Channel Width	45'	50'	55'	60'	50'
Total Cost Est. (1991 mil$) (Including R.O.W. Acquistion)	10.3	18.6	22.0	16.8	15.0
Design Life (Years)	30	50	50	50	50
Maintenance / Operation Costs	Most	Moderate	Moderate	Least	Moderate +
Construction Time	24 Mo.	30 Mo.	30 Mo.	24 Mo.	24 Mo.
Roadway Closure Time	12 Mo.	24 - 30 Mo.	30 Mo.	24 Mo.	24 Mo.
Minimum Channel During Construction	40'	45'	45'	45'	45'
Channel Offset	None	10' West - Scheme IIa 17' East - Scheme IIb	None	None	14'
Vertical Clearance Open	90'	90'	90'	53'	90'
Vertical Clearance Closed - At Fender - At Center	 5' - 0" 8' - 4"	 4' - 6" 6' - 0"	 5' - 6" 7' - 6"	 5' - 6" 5' - 6"	 7' - 0" 7' - 0"
Elevation Of Lowest Point Of Pier Wall	N/A	8" Above Record High 2' Below Estimated High	20" Above Record High 1' Below Est. High	N/A	N/A
Degree Of Agency Permit Action	Minimal	Coast Guard Permit Required To Offset Channel	Moderate	USCG Permit Req'd Vertical Clearance	USCG Permit Req'd To Offset Channel
Impact On Transit Structure	Minor	Major, Underpinning Req'd	Major, Underpinning Required	Minor	Minor
Impact On Adjacent Properties	Minor	Adjust Entrance Elevations	Adj. Entrance Elevations	Minor	Minor
Impact On Navigation	Minor	Increased Horizontal Clearance, Channel Offset	Increased Horizontal Clearance	Less Vert Clearance More Horiz Clearance	Increased Horizontal Clearance, Channel Offset
Hazardous Waste Disposal (Not Including Dredging)	None	5000 C.Y.	4000 C.Y.	2100 C.Y.	1600 C.Y.

Table 1

Scheme I - Rehabilitation

Key Advantages

- Lower Cost
- Shortest Roadway Closure

Key Disadvantages

- Relatively High Cost For 30 Year Reconstruction Life
- Horizontal Clearance For Marine Traffic Is Not Improved
- The Scheme Does Not Provide For Reduced Maintenance Costs
- Reconstruction Of Rest Pier Restricts Channel To 40 Feet During Construction
- The Counterweight Will Continue To Dip Into The Water
- The Operating Machinery Will Continue To Be Difficult To Access And Maintain
- Stopping Sight Distance Will Continue To Be Substandard

Scheme II - Single Leaf Bascule

Key Advantages

- Increased Channel (50' Channel)
- Improved Fendering
- Reduced Maintenance

Key Disadvantages

- Channel Offset
- Dredging Required
- Pit Type Pier Required
- Possible Flooding
- Underpinning Required
- Raised Profile Impacts Adjacent Properties
- Barrier Gates Required

Scheme III - Double Leaf Bascule

Key Advantages

- Increased Channel (55' Channel)
- Improved Fendering
- Reduced Maintenance

Key Disadvantages

- Pit Type Pier Required
- Possible Flooding
- Underpinning Required
- Raised Profile Impacts Adjacent Properties
- Highest Cost

Scheme IV - Vertical Lift

Key Advantages

- Large Increase In Channel (60' Channel)
- Improved Fendering
- Reduced Maintenance
- Machinery Kept High And Dry
- Minimum Impact On Transit Structure

Key Disadvantages

- Reduced Vertical Clearance In Open Position
- Barrier Gates Required

Scheme V - Single Leaf Overhead Counterweight Bascule

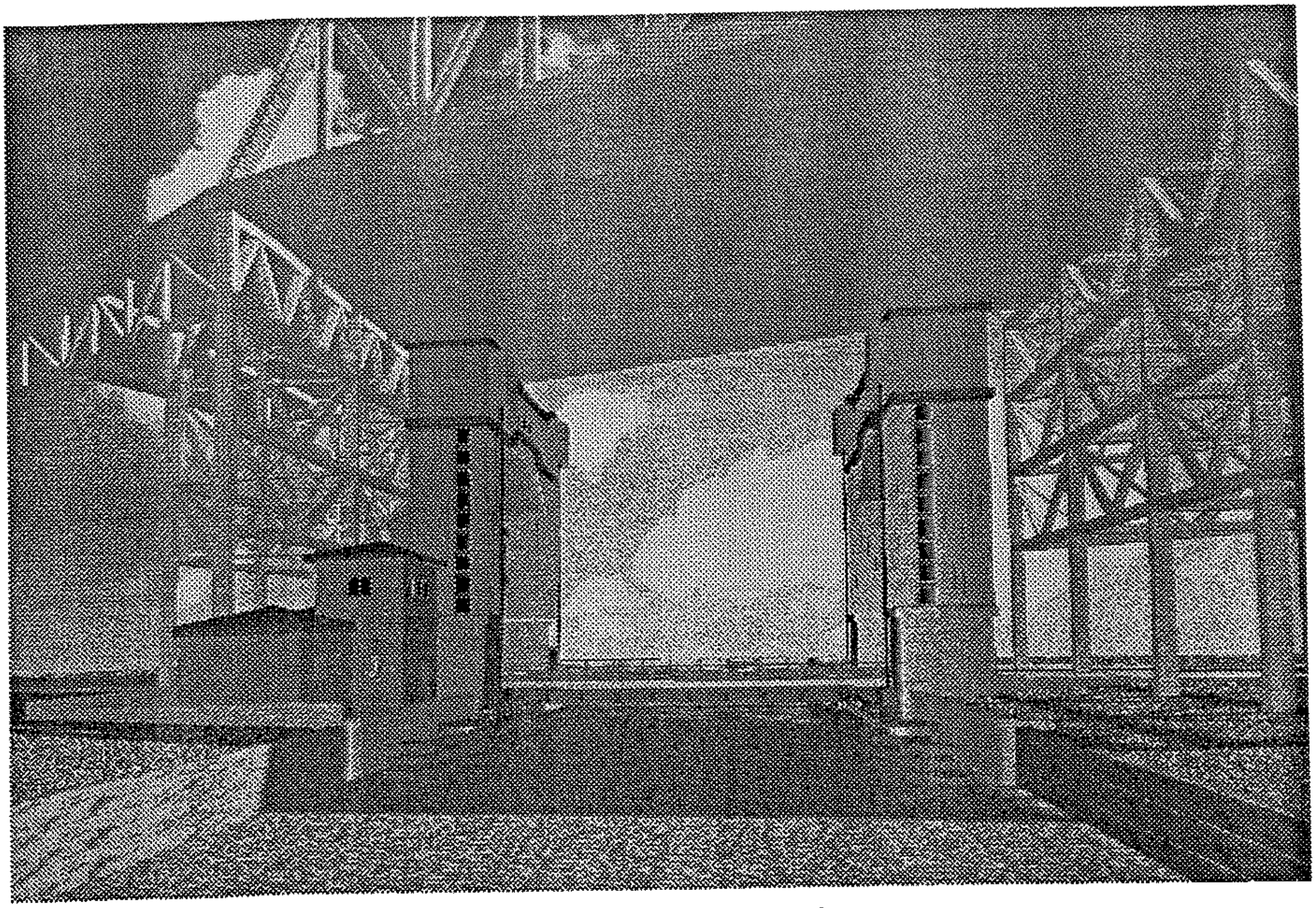
Key Advantages

- Increased Channel (50' Channel)
- Improved Fendering
- Reduced Maintenance
- Machinery Kept High And Dry
- Minimum Impact On Transit Structure

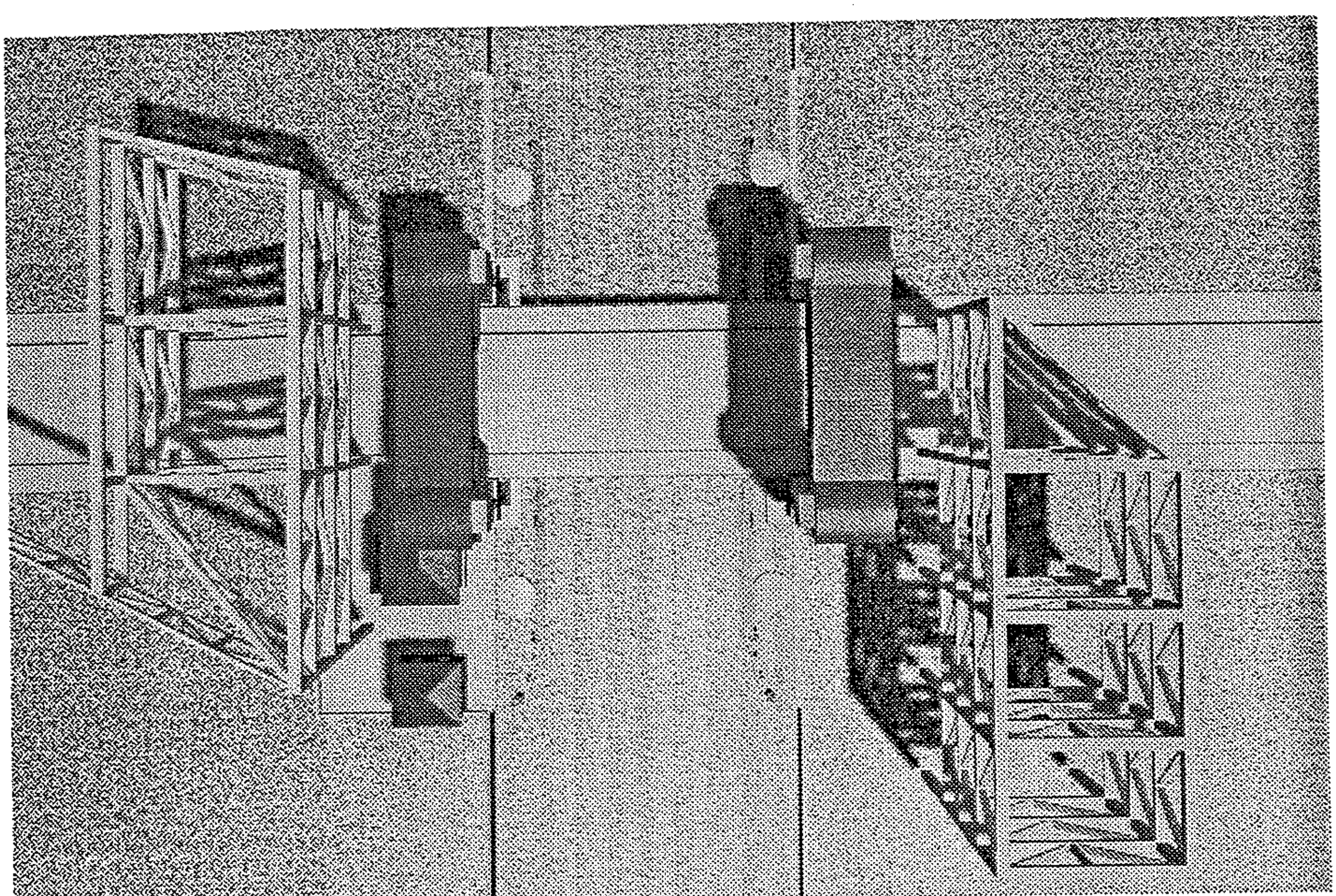
Key Disadvantages

- Channel Offset
- Dredging Required
- Fracture Critical CTWT Links Prone To Vehicle Impact - CTWT Could Drop
- Complex Design Prone To Maintenance Problems
- Barrier Gates Required

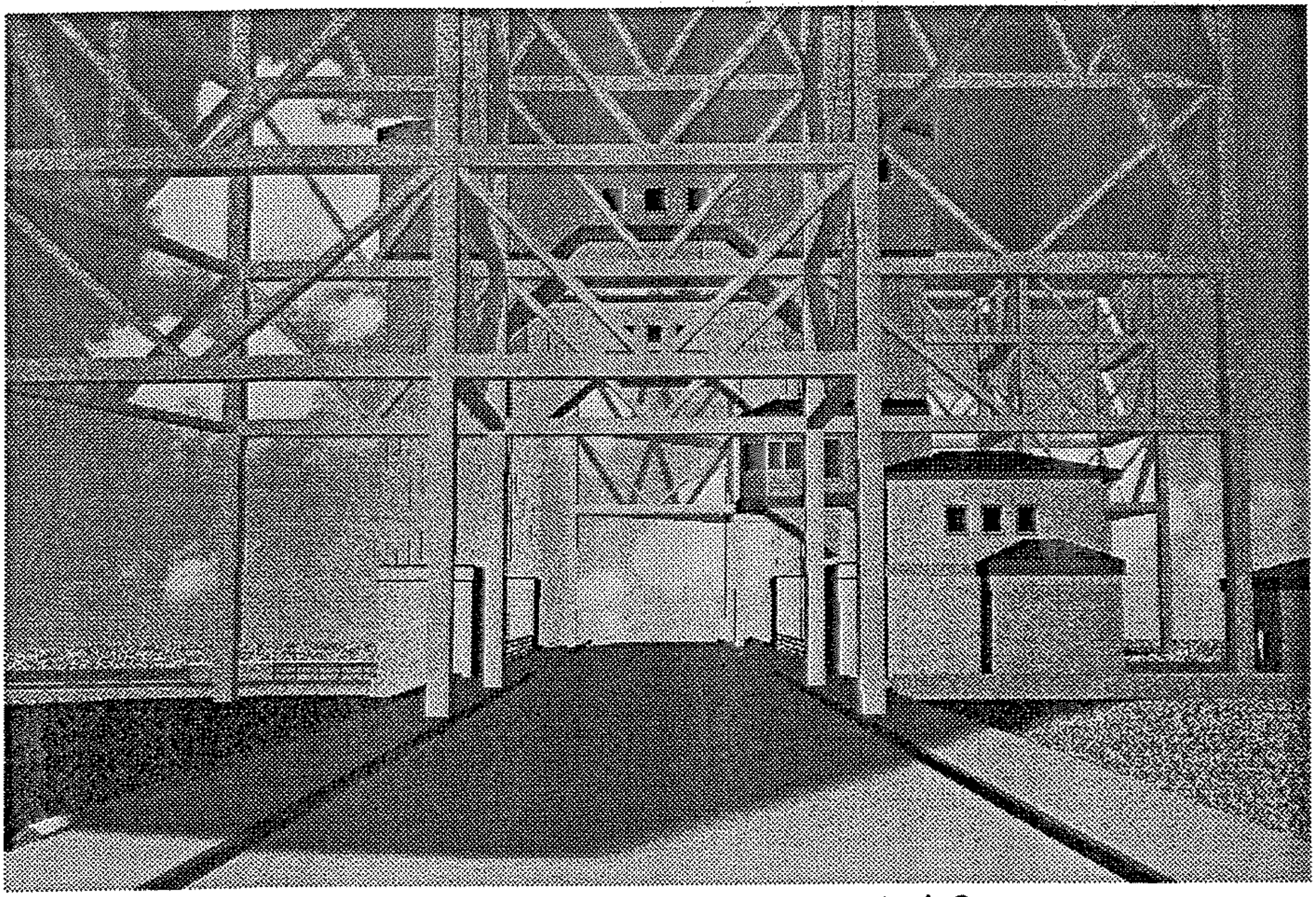
Table 2



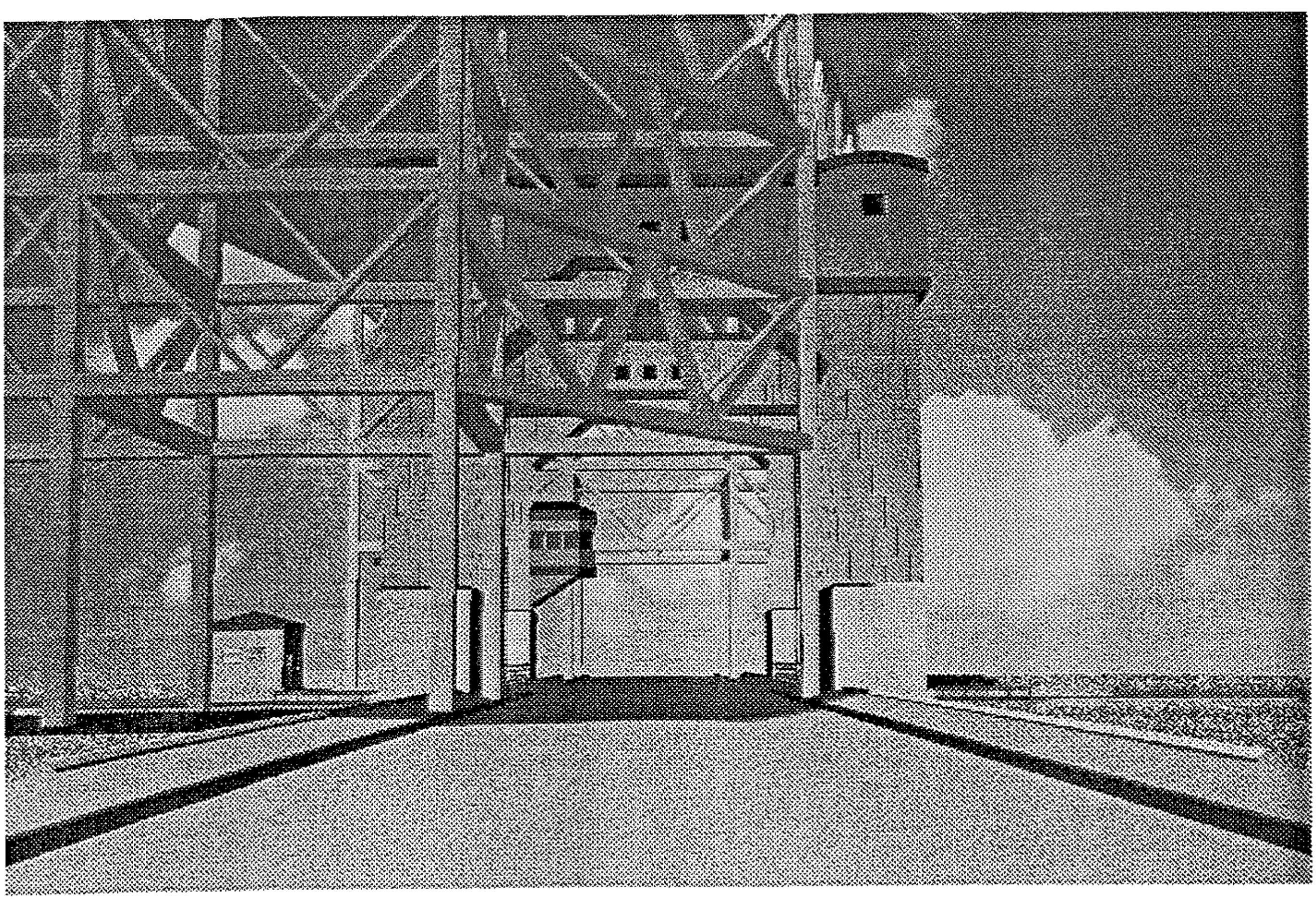
Ninth Street Bridge - South Elevation



Ninth Street Bridge - Plan View



Ninth Street Bridge - Looking East Along Ninth Street



Ninth Street Bridge - Looking West Along Ninth Street impracticable. Inspection wells should be utilized in the grounding system for future inspection of the ground electrode and the connection of conductors to the electrode. The inspection wells also allow the annual or semi-annual resistance testing recommended for these critical grounding systems.

TRANSIENT VOLTAGE SURGE SUPPRESSION (TVSS)

TVSS is required with a lightning protection system on each incoming electrical service, telephone service, radio and TV cables that enter the structure. TVSS is essential in the protection scheme for the structure. When a direct lightning strike occurs or when a strike is only close to the structure, induced voltages occur on all of these systems. These induced voltages are damage causing "spikes" which in turn damage the electronics within the structure. Lightning strikes that hit electrical or telephone lines have an excellent conductor into the heart of the structure and the computers and controllers that operate the structure. TVSS takes these over voltages to ground at a preset level, taking the over voltage off the line.

Selection of the right TVSS product can be quite perplexing. Each of the electrical, telephone, radio and TV services have different requirements to evaluate.

The electrical service TVSS should be designed to withstand the common lightning discharge intensity in the area of the structure with a 50% safety factor for the above average strike. A 240 KA per phase rated TVSS is recommended for each of the main electrical services on movable structures. Because of the amount of internally generated "spikes" on the electrical systems caused by the extensive use of motors common in these structures, secondary TVSS protection is recommended for critical operation panels. A 80 KA per phase rated TVSS is recommended for this application. Lower KA per phase ratings on secondary panels may be required to insure that the clamping voltage of the TVSS is below the deterioration voltage of the equipment it is to protect.

Electrical TVSS products have two basic types, parallel and series. The series products are installed in series with the electrical service. They are typically the best in performance, because of the factory installed wiring versus the field installed wiring of the parallel product. A consideration of the series suppression technique is that the price can be up to 10 times that of the parallel suppressors and that the electrical system has to be shut down to service the series suppressor. The series suppressor has not been as successful in the market place as the parallel suppressor because of these two factors.

The parallel electrical suppressors have the same KA per phase rating as the series but the primary difference is that they are installed in parallel with the electrical service. Parallel suppressors are normally installed with a disconnect, which can be factory installed. If the product requires service, the complete electrical service does not need to be shut down. Only the use of the disconnect to separate the product from the electrical service need be utilized.

Care must be taken in the field installation of the parallel suppression equipment. Manufacturer's installation instructions must be followed very closely. The length of the wires from the panel to the parallel TVSS determines the performance of the product. If the manufacturer's length requirements are not followed, the product will not perform up to the specifications of the product. Added conductor length results in longer reaction time and therefore greater let through voltage before the parallel TVSS is set into action. This added time and added voltage can be the factor for damage or possible failure to critical equipment. If in doubt call the manufacturer for recommendations.

Both the series and the parallel suppressors come with options, such as audible alarms, remote monitoring, and surge counters. Standard equipment for either of these electrical surge suppressors should be indication lights that monitor the suppression modules for each phase, not just show that power is supplied to the unit. Bus bar internal connections are recommended in lieu of small electrical wiring used in some products. Either product should also offer a five (5) year full warranty on the suppression units. For the parallel units, spare modules may be ordered for continuous protection if modular failure occurs.

Many claims of performance have been stated in the industry. The main factor should be the performance rating, making sure that all comparisons are based on equal terms. The warranties and the guarantees should be submitted for evaluation before purchasing.

The telephone and data line TVSS is becoming more and more important as an increasing amount of information is conveyed across these lines. If these lines are fiber-optic, no suppression is required. If the telephone lines are the standard copper, then suppression must be included on each line. The types of suppression techniques vary, but most critical is the reaction time which should be less than one nanosecond and the voltages of the suppression must match the voltages used in the telephone system and the deterioration voltage of your equipment. The deterioration voltage of your equipment can be obtained from the manufacturer of the telephone equipment. Other information that must be made available is the type of connectors utilized in the telephone system so that the TVSS connectors will match the system.

Radio and TV lead wires will probably be coax conductors. The operating power of the system, the connector types used, and the model number of the cable must be obtained to insure a proper match of the TVSS product to the system. The clamping voltage of the TVSS must match the system to insure that the clamp is below the deterioration point of the equipment the TVSS is to protect.

ESE LIGHTNING PROTECTION SYSTEM

An ESE lightning protection system uses many of the same principals of the Franklin/Faraday cage system with substantial improvements in performance. To further explain some of the basic circumstances surrounding a lightning discharge, its relationship to objects on the earth and its relationship to a lightning protection system, the following is offered for consideration:

When a storm approaches a structure and finally reaches what is referred to as the "zone of influence" of that structure, electrical charges start to migrate up the outer skin of that structure. These electrical charges accumulate on sharp edges of the roof or roof top equipment. As these charges build on these sharp or pointed objects on the roof area, they are referred to as corona. If the storm is intense enough and if it is not moving too quickly across the structure, the corona build up can become strong enough to break down the atmosphere and create an "upward streamer". This upward streamer seeks to complete the circuit from the discharge of the cloud. The downward leader from the cloud seeks the least path of resistance or conductive path typically from the highest object nearest to the downward leader. The upward streamer is an attractive path to the downward leader and when the two meet the circuit is completed. If a lightning protection system is installed on the structure and has created the successful upward streamer, the lightning strike should be directed to ground through the ground conductors of the lightning protection system. When the successful upward streamer is created strong enough to capture the downward leader, it is referred to as a "hot strike".

If the storm is weak or too fast and the formation of the upward streamer is weak or too late, the downward leader sees the whole structure as equal and may strike anywhere on the structure. This is referred to as a cold strike. The cold strike is typically when most damage occurs to structures with installed Franklin/Faraday lightning protection systems. Franklin/Faraday systems are approximately 50-60% effective because of this situation.

The ESE lightning protection system insures the formation of the upward streamer, and that the formation will be earlier and stronger than the Franklin/Faraday systems. This is accomplished via various techniques depending upon the manufacturer of the ESE product. By having the formation of the upward streamer earlier and stronger from the ESE terminal, the capture of the downward leader is greatly increased. ESE terminals are approximately 85-96% effective, a 35% minimum improvement over the Franklin/Faraday systems.

ESE terminals do not "pull" lightning from the neighboring property, the systems are designed to cover the areas required for the structure. Most designed ESE systems for draw bridges only require a terminal on the top of each control house of the bridge. With only two ESE terminals, the installed cost, maintenance, and roof and roof top equipment penetrations are minimal compared to the Franklin/Faraday systems.

ESE lightning protection systems should be designed with the manufacturer of the ESE product to insure that the cones of protection fully cover the areas required and that all requirements of the warranty (five years) and $6,000,000.00 product and general liability insurance coverage is designed into the project (offered by some manufacturers).

Methods of designing lightning protection for moveable structures are more diverse when utilizing ESE terminals. ESE terminals because of their larger radius of protection can be installed upon masts not on the structure and protect adjacent structures that are within the designed cones of protection. This means that ESE lightning protection may not necessarily be required to be installed upon a structure and therefor lessen the amount of induced voltages cast upon the structure during a lightning discharge. When the structure has a moveable section, it may not be a requirement to have ESE lightning protection equipment attached to the moveable section. Therefore eliminating the concerns of jointed lightning protection fittings, which can be a weak link of the system, and conductor fatigue caused by continual bending of the conductor and eventual conductor failure.

The detailed design of all three of these parts of a lightning protection system will help to eliminate damage caused by lightning, but 100% protection from lightning has not been achieved. Careful Design, installation, and maintenance are the key to success of a lightning protection system.