HEAVY MOVABLE STRUCTURES, INC.

NINTH BIENNIAL SYMPOSIUM
"Preserving Traditional Values with New Technologies"

OCTOBER 22 - 25, 2002

THE HISTORY AND FUTURE OF THE CITY WATERWAY LIFT BRIDGE

Duane Stone, PE,
Washington State Department of Transportation
&
Frank Marzella, PE,
Hardesty & Hanover, LLP

OWNERSHIP/PUBLIC USE and MANAGEMENT

Introduction

The City Waterway Bridge, present day.

By modern bridge standards, the City Waterway Vertical Lift Bridge over the Thea Foss Waterway in Tacoma, Washington would be considered common. However, for the early 1900's, the history of its birth including selection of structure type, unique features, construction methods and speed of construction make it most remarkable among movable bridges. Combining all this with the fact that the bridge is now 90 years old makes it even more extraordinary.

The authors of this paper have a special fondness for this structure. As such, we feel that it is important to write and tell the story of an old and beautiful movable bridge in what might very well be one of the last attempts of accurately documenting its history.

In The Beginning

By the 1870's,Tacoma had evolved into a prospering industrial center. In 1873 the Northern Pacific Railroad had reached Tacoma enabling transport of the areas rich natural resources including lumber and coal. Increased profits spurred new financing and other industries including flour processing, a salmon cannery, and numerous machine shops quickly sprouted.

The late 1880's saw a further acceleration of the industrial development of Tacoma. New land was needed to support this development. The City of Tacoma engaged in a massive program to reclaim the land on the eastern side of the city known as the "tideflats". Mills, grain elevators and warehouses quickly developed in the area.

Tacoma became the largest processor and distributor of eastern Washington wheat, overtaking Portland for the title. The lumber industry increased production in response to the huge demand for railroad ties and for general construction. The St. Paul and Tacoma Lumber Company was producing some 87 million board feet of lumber per year. Shipping docks and rail transportation facilities were improved.

At this stage, Tacoma was a major port and was home to several strong industrial sectors. The port was now able to service increasing numbers of steamships and large sailing vessels.

With these goods times, the City of Tacoma initiated the construction of a movable swing bridge across a long narrow arm of Commencement Bay at the line of 11th Street to join the city with the tideflats to the east.

The First Bridge

City of Tacoma Engineers discussed and debated span width and length to the point that progress was impeded. However, one must remember that such an undertaking was pioneering work in the 1890's. A swing span design was finally agreed upon and construction was completed in 1894.

The bridge was a composite iron and steel structure consisting of two fixed truss flanking spans of 185 feet and a swing span of 250 feet. The west approach was an iron viaduct 340 feet long, comprised of plate girder spans. The east approach was a timber pile trestle.

The swing span pivoted about a 34 foot diameter center pier. The center pier was a wrought iron cylinder driven into the stream bottom and filled with concrete.

Other bridge features included a 22 foot deck that also carried two streetcar tracks on a 3'-6" gauge as well and two 6 foot sidewalks. The bridge was powered by local municipal electric power.

The construction contract was awarded to the King Bridge Company of Cleveland, Ohio. The total cost of the original bridge including all approach work was $100,000.

The Problems

Shortly after completion of the swing bridge problems began to develop. As shipping increased in the area the need for bridge openings grew. Owners of steamer and tugboats were experiencing lengthy and dangerous delays while attempting to pass through the narrow channel. The low clearance of the swing bridge necessitated bridge openings for nearly all vessels. Pedestrians, carriage and streetcars also experienced lengthy delays due to the frequent bridge openings required by the ships.

Operation of the swing span quickly became to topic of heated emotional discussion by its users. Exasperated vessel owners filed a formal protest to the City Engineer in December of 1902 incensed by the latest incident of excessive waiting.

The turn of the century brought a steady increase in both vehicular and water traffic volumes, that accompanied Tacoma's port expansion. In 1902 the Corps of Engineers began work on the City Waterway which included massive changes to the areas navigation and docking capabilities. The City Waterway Project transformed the narrow arms of Commencement Bay into six navigable basins having 500 foot wide channels with a minimum depth of 25 feet at low tide.

All of these were the conditions that led the city's decision to replace the original swing bridge. It was simply to low in clearance and already obsolete in size and operational efficiency to meet the traffic requirements and needs of the new era commerce.

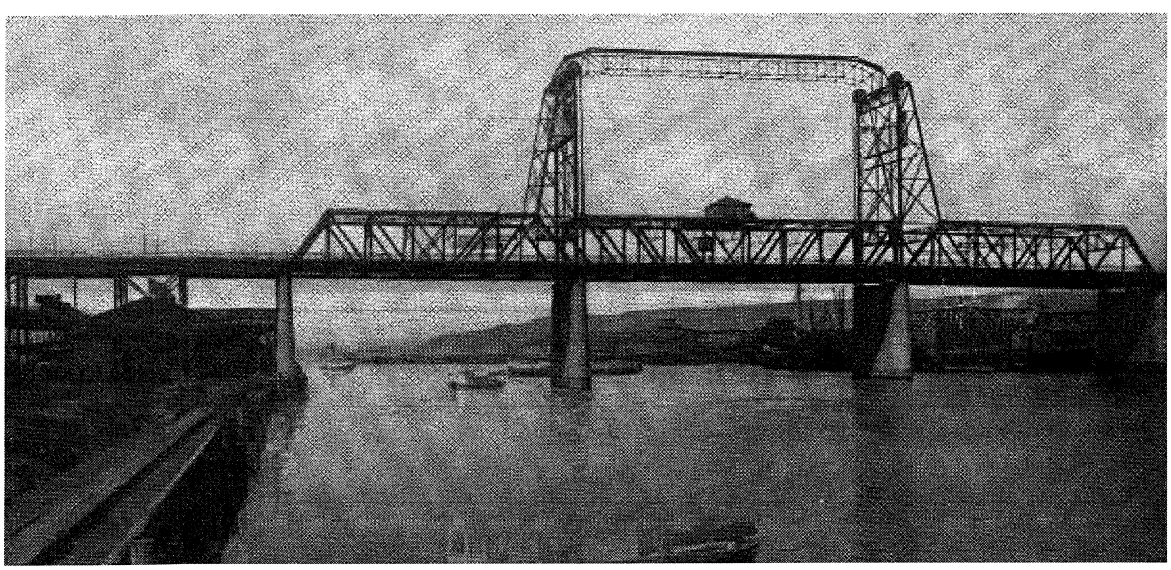
The Vertical Lift Bridge

The engineering firm of Waddell and Harrington (founders of the present day Hardesty & Hanover) of Kansas City, Missouri, was selected to prepare the plans and specifications for the new bridge. After only five years in partnership, the firm had already established itself as the leading design firm of vertical lift bridges.

Various design options were evaluated including a single leaf bascule span comprised of a 286 foot riveted Pratt truss draw span. Waddell and Harrington's decision to opt for a vertical lift as opposed to a bascule was almost certainly dictated by the economic superiority of the vertical lift bridge given the site conditions and design constraints. Clearly a vertical lift (certainly a high level one) would not require as many operations as a bascule would for the passage of low masted vessels. Vertical lift bridges are more suitable for larger horizontal clearances, and certainly at the time a 200 foot channel was considered large. But perhaps the most significant feature was the need to accommodate a 16 inch iron municipal water main from the city to the tideflats. Although considered by many to be unsightly, this was easily accomplished by spanning the opening between the two towers with a light truss. With the bascule option this would have required costly special towers (as laying the pipe on the river bottom was deemed impractical) in addition to the laying of submarine cables.

Thus a vertical lift bridge design was selected. The general original design features included the following:

Lift Span:	221 foot Pratt Through Truss
Flanking Spans:	2 – 190 foot Pratt Through Trusses with Integral Towers
Truss Depth:	47 feet
Foundations:	Concrete Piers on Timber Piles
Roadway Width:	50 feet
Roadway Deck	Timber Stringer with Timber Paving Blocks
Tracks:	2 Street Car Tracks Embedded in the Deck
Sidewalk Width:	2-10 foot sidewalks
Vertical Clearance:	135 feet Raised, 60 feet Lowered
Horizontal Clearance:	200 foot Clear Channel



City Waterway Bridge, circa 1913, span closed.

Notable Design and Construction Features

Construction of the bridge utilized every material and construction technique available at the time. State of the art engineering and planning played into every detail. The specification called for bridge completion in one year. That is 365 days to build 1750 feet of bridge! Waddell and Harrington personally oversaw the construction of the entire bridge. Remember it is 1911!

Traffic Control

The contract for construction of the bridge was let in the summer of 1911 to the International Contract Company of Seattle. The first notable feature of the construction was the requirement to maintain maritime and vehicular traffic during construction, yet replace the existing bridge on the same general alignment. An ingenious plan was developed. A timber trestle was built parallel to the existing alignment. The existing swing span was then positioned to meet the temporary alignment. The geometry of the temporary bridge was such that the swing bridge could swing into the work area in such a manner as not too interfere with installation of the tower piers while maintaining full passage of marine vessels.

The original pivot pier was left in place to be used later for the erection of the lift span. This arrangement elicited the wonder of thousands of local beholders. The only traffic interruptions were during the relocation of the swing span and the lift span erection. The swing bridge and temporary trestles were demolished after the lift span was completed.

Foundations

Foundation work for the bridge substructure began immediately following demolition of the original swing bridge's approaches. The contractor worked continuously throughout the day and night. The foundations for the four main piers were constructed by first sinking cribs made up of 12 x 12 inch fir timber with an opening of 21' x 81' to a depth of 54' below high water. The material inside was excavated by open dredging. Piles were then driven by jetting (200 for each central pier and 150 for the end piers). These piles were special select large diameter fir piles of lengths up to 125 feet.

Of course, several pile locations proved troublesome, especially at Pier No.3. Once the pile driving was completed the cribs were dewatered, cleaned and the piles trimmed to the correct elevation. Plain concrete was then poured to a depth of 30 feet.

The four Fowler type piers were then built up from the 30 foot bases. Plain concrete of Portland Cement and local Vashon sand was poured in 4 to 5 foot layers into the self-supporting forms of the conical Fowler piers. The shaft heights vary in height from 72 to 90 feet. Over 12,000 cubic yards of concrete was used in the four main piers.

Towers and Lift Span

In October 1912 construction of the falsework for construction of the towers began. The tower legs were fabricated in two pieces and were spliced together in the field. Erection of the towers went swiftly and with their completion the erection of the lift span was started.

A system of cantilevered brackets were erected from the two main piers at an elevation of 120 feet. These brackets were made of three wooden bents that were corbelled outward from the pier caps and tied back to their adjacent lift tower. This allowed for erection of the lift span (in-place) without any interference with navigation or operation of the swing span below.

These bents were used to erect one panel point of the lift span from each tower. Utilizing the original center pier of the swing span for support, falsework was erected upon which the two central panel points of the lift span were erected. The remaining two panels on each side of the lift span truss were erected from horizontally strung wire cables. Turnbuckles were used to adjust the positions of the remaining truss members for their fit up and completion of the lift span in the up position. Once completed the lift span was freed from its falsework.

The final lift span proper was an eight panel riveted steel Pratt truss. The tower spans were similar seven panel Pratt trusses.

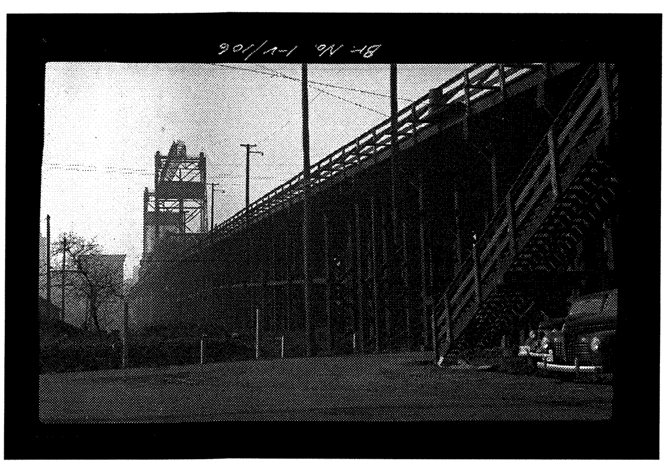
Bridge machinery, counterweights and the wood roadway deck were all erected in the raised position.

The last structural component to be erected was the overhead truss span connecting the two towers and the water main. This was erected by a wooden traveler moving along the top chords of the lift span (with the lift span in the fully raise position).

West side viaduct.

Approaches and Grades

The west approach consisted of a 7 span steel plate girder viaduct. This included approximately 100 feet of retaining wall and 650 feet of plate girder spans. A lower roadway and sidewalk provided access for workers to the west side municipal docks. The lower roadway provided a 19'-4" width with a 10' sidewalk. It sloped downward drastically to the dock area at 8% grade.



Original east timber approach.

The east approach originally consisted of approximately 500 feet of timber trestle.

The entire bridge was built on grade. From the start of the western approach to the main tower pier on the east side, the roadway slopes downward at 2.57%. From that point to the fourth main pier the grade continues at 4%. Then the entire east side timber trestle structure sloped downward at 5% to the tideflats.

Operating Machinery

The bridge machinery is an example of Waddell and Harrington's span drive machinery system patented by the firm in 1908. It consists of a machinery room located on the lift span itself centrally located above the upper truss chords.

A pair of 75 horse power direct current Westinghouse railway car motors drive an open gear train. There are three sets of reduction gears that drive four uphaul/downhaul operating drums (one drum for each corner of the lift span). Each drum houses two operating ropes, the ends of which are attached to the upper and lower portions of the towers. As the operating drums are rotated by the machinery, the operating ropes are paid in and paid out, and the movable span is raised or lowered accordingly.

Each drive motor has one electrically operated brake. A hand brake was also provided for additional operator control. All rotating shafts are supported by plain bronze bushing type shaft bearings.

The lift span is connected to the counterweights by 64 –1 ½ inch diameter fiber core wire ropes of 6 x 19 Warrington construction (16 ropes in each corner). Each main counterweight sheave is cast steel and has a pitch diameter of 9'-4". The main sheaves are supported by 16 inch diameter trunnion shafts and plain bronze bearings. The counterweights are concrete poured around a steel frame and weight 400 tons each. The ropes are connected to the counterweights by a system of pinned equalizing plates, designed to properly distribute the load to the counterweight ropes.

There are vertical guide rollers in the longitudinal direction and vertical guide slots in the transverse direction to aid in the movement of the lift span. The longitudinal guide rollers are spring loaded on the east side be to self adjusting for expansion and to accommodate the thrust load created by the grade.

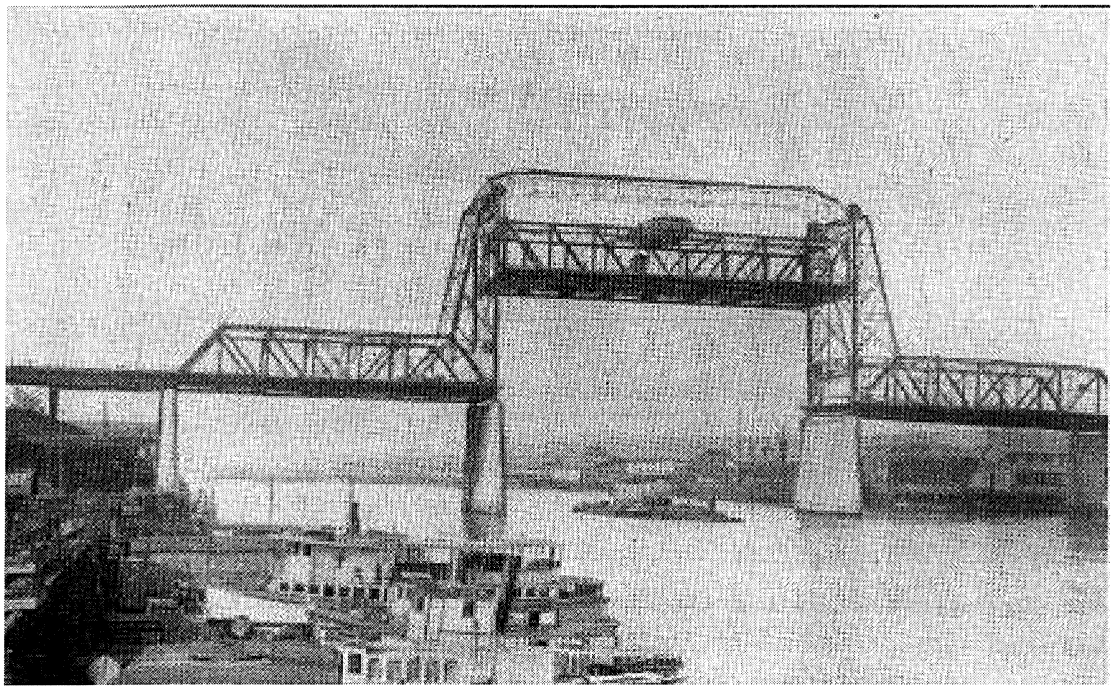
The operational sophistication of this design can be attributed to the mechanical engineering skills of John L. Harrington. So successful was Harrington in developing and refining the span drive concept that, at the time, it came to replace the bascule where larger horizontal clearances were required.

To the authors of this paper, who joined the industry some seventy years later, the brilliance of the operational simplicity of this design stands clear. To us, the phrase "keep it simple" is a phrase we all should live by and we appreciate this outstanding example.

The Bridge Opens

The bridge was ready for traffic and officially opened on Saturday February 15, 1913 (only some six months behind schedule). From a raised platform on the west side, local dignitaries and project officials gave speeches to more than 10,000 onlookers. The City Mayor, W.W. Seymour opened his address by remarking on the significance of this bridge stating:

> "We of Tacoma should be proud of this grand structure. It is widest of its type,
> one of the highest and the only one in America built on grade."



City Waterway Bridge, circa 1913, span open.

At the conclusion of the address, the lift span was raised to its full height, lowered and christened with a bottle of champagne. It was a grand event with flowers being thrown from the upper heights and the distribution of free cigars from C.E. Fowler, President of the International Contract Company. Fowler claimed it to be "the greatest bridge opening ceremony [he] ever saw."

The total cost of the project was $480,000. Of this amount, $275,000 covered all the bridge machinery and superstructure steelwork.

This was five times the cost of the original swing bridge. This roughly equates to $4 per square foot for elevated movable bridge. It would take considerable thought to estimate the cost of such a bridge today. One could easily say that to build a similar modern bridge today would cost at least 75 times this amount, and could never be built in 18 months.

The importance of the bridge in providing access to the tidelands remained strong until the late 1940's. Through those years the area continued to develop in the chemical industry while forest product industry remained strong. The bridge was used daily by thousands of vehicle and pedestrians. The lower deck on the west side provide access for hundreds daily to the municipal docks and the steam ships to Seattle.

Rehabilitation and Maintenance

During the early 1940's, the bridge carried the burden of traffic to and from the extensive was industries that had developed in the tideflats. The heavy traffic caused extensive wear to the lift span and two flanking span wood decks.

In 1945 the lift span deck and tower decks were replaced with a concrete deck. Tacoma city engineers were opposed to open steel gratings on the lift span. A design was developed by the State Toll Bridge

Authority utilizing "Haydite" lightweight aggregate in the concrete mix. While the "Haydite" proved adequate, the mix was somewhat heavier than anticipated due to the fact that it was necessary to add natural sand to the mix to provide better workability. The old deck was much lighter than had been estimated by the Authority, so it was necessary to add weight to the counterweights. A total of 74 cubic yards of concrete was added to the tops of the counterweights to counterbalance the span side weight change (which also included approximately 71,000 pound structural steel cover plates used to strengthen the floorbeams to accommodate the new deck).

The lift span became stuck in an intermediate position (or was completely inoperable) several times during the deck replacement. This was due to the removal of too much deck and the drive system's inability to power through the resulting imbalance condition. On several occasions, the span was raised to a point where the top of the counterweights were level with the deck. Then sufficient blocks were removed from the counterweights and placed on the deck to enable the lift span to be fully lowered.

The job was performed by the Cascade Contractors of Seattle for $148,000.

In 1949 the bridge's electrical drive and control system were converted from the original direct current system to an alternating current system. The equipment was purchased from Westinghouse.

The replacement electrical system consisted of a 3 phase, 480 volt, open delta electrical service to operate the bridge and a separate 120/240 volt service to provide lighting and controls. An open delta circuit is one in which two single phase transformers are connected to achieve 3 phase power.

A unique element of this electrical service is that power is transmitted to the lift deck across six copper bus bars mounted on insulators. The bus bars run vertically the height of the bridge and graphite collector shoes mounted on the lift span run along them to pick up the power similar to the way an electric bus or trolley car gets it's power.

The bridge's prime mover is a pair of 75 HP wound rotor motors with secondary resistance speed control utilizing a drum controller with five speeds in each direction. It is equipped with stop lights, but not with warning lights. The traffic gates are manually operated. The traffic gates are not interlocked to prevent bridge operation, therefore there are no bypass switches. There are two thrustor type motor brakes but no service brakes. The motor brakes are interlocked to prevent bridge operation if the brakes are not released. There is a nearly open and a nearly closed limit switch, which limits the operation of the bridge to the lowest speed.

This AC drive system is still in use today.

Also, in April of 1949, a severe earthquake shook Tacoma and broke the counterweights from their guides. The City's bridge crew replaced the angle iron guide steel in two days No other significant damage was reported.

In 1951 the timber deck and posts on the east approach were severely deteriorated and were replaced. Then in 1954, the entire east side trestle structure was replaced with a 9 span pre-stressed concrete girder structure with reinforced concrete decks and a earth filled retaining wall abutment. This undertaking was the first large pre-stressed concrete bridge structure to be built in the State of Washington. The

Original east approach replaced with prestressed beams.

Roadway looking east, late 1950's.

construction was performed in stages, maintaining traffic through the reconstruction period. The street car tracks were removed.

Also in 1954, an off ramp was built on the west side to funnel westbound traffic off the bridge directly to Tenth Street where traffic bottle necks could be more efficiently distributed.

By the early 1960's the water main was no longer in use. In 1963, the City of Tacoma Department of Public Work let a contract for the removal of the deteriorating iron span connecting the two lift towers and complete removal of the water main.

In 1969 the overhead tower span was replaced with a lightweight aluminum version designed to carry electrical power transmission and telecommunication lines. It still stands today.

The operating ropes of the span drive machinery were replaced several times. Fifty eight of the original sixty four counterweight ropes are still in service.

Counterweight Ropes

American Cable & Wire supplied the original wire ropes in 1911. They are 1 ½ inch diameter 6X19 plow steel, with a documented original ultimate strength of 161,000 pounds (S.F.~6.44). The original design weight of each counterweight was 800,000. In 1945 the timber deck was removed and replaced with a concrete deck. The deck replacement theoretically increased the weight of the counter weights by 10 percent, to 880,000 pounds. Currently, the estimated weight of each counterweight is approximately 1,200,000 pounds. The increase weight is largely due to resurfacing of the deck and sidewalk modifications.

After 90 years since the wire ropes were installed, all but 6 of the original ropes remain in service today. Correspondence in inspection files, dated 1945, recommends that consideration be given to replacing the wire ropes soon, based on the years they have been in service. This was also the year when the timber deck was replaced with concrete. In 1949 another inspection was conducted on the counterweight wire ropes and the conclusion of this inspection was not to replace the ropes at this time due to their good condition. However, it was recommended during the same inspection report that their replacement be included in the budget for 1951-1953 biennium. There is no further correspondence in the letter files until 1972, at that time factor of safety calculations were performed (S.F.~5.85), and the conclusion was to consider replacement of the ropes as soon as possible. In the same document, a possible alternative was suggested to replacing all of the ropes, "remove one rope and perform an in-depth inspection and destructive test to determine the remaining capacity". A rope was removed in 1974 and United States Steel Corporation tested a 5-foot section including one of the original sockets in 1975. The test revealed an actual breaking strength of 179,000 pounds and the fiber core was dried out and crumbling. With little documentation, a hand written note in the letter file states; "replacement of the counterweight ropes not recommended at this time". In 1987 Stafford Engineering performed an inspection, including the counterweight ropes. The results of this inspection were clear; "The integrity of the ropes is highly questionable. Plans should be made immediately to replace the ropes". A follow up letter to this inspection suggest that another rope should be removed and a new test performed, more comprehensive then the one in 1975. Three more ropes were removed and pulled tested to ultimate strength in February 1988. All three ropes were full length with original sockets. The ropes failed between 170,000 and 175,000 pounds (S.F.~4.53). The conclusion from this inspection, including the ultimate strength, core analysis and individual wire analysis it was concluded that the ropes should definitely be replaced. It was also concluded from this inspection that the complete lift system should be analyzed to meet the current standards.

With the concern of the lift system integrity coupled with the decaying structural components, a Rehabilitation Study of City Waterway was initiated in 1988. This study was complete in January of 1989. The cost estimate for a Rehabilitation of the two approach spans and the lift span was near $10 million. In 1990 it was pointed out that a seismic retrofit would also be required. By 1995 the cost estimate for rehabilitation was approaching $15 million. Again in 1997 a Recommendation for Rehabilitation surfaced. As in 1989, the 1997 rehabilitation was not done due to scope creep.

In 2001 two more counterweight ropes were removed for examination and testing by Hardesty & Hanover and N.W. Duke Co. Both ropes were tested using an electromagnetic testing device to determine the presence and location of any broken or cracked strand wires. Selected areas identified by the electromagnetic testing were internally examined. The ultimate strength for each rope was determined using full-length ropes including the original sockets. Both cables failed at approximately 175,000 pounds of tension. The failures were in the areas that were identified by the electromagnetic test. Visual inspection of the failed cables indicated advanced fatigue of the wires.

The Bridge Today and Its Future

Today, other than the repairs mentioned above, the bridge proper remains mostly original.

The span drive machinery and electrical systems are fully operational. The electrical system is functionally obsolete, with the stores of spare components essentially exhausted.

Over the past several years, the Washington State Department of Transportation has performed several inspections, destructive and non-destructive tests on the counterweight ropes. As stated previously, the counterweight ropes are mostly original and their remaining useful life is highly questionable. The counterweight sheave trunnion shaft's remaining useful life is also questionable due to fatigue concerns.

The remainder of the span drive machinery is in good to fair condition due mainly to its robust design and good maintenance.

Corrosion is starting to take its toll on the bridge steel. Both upper and lower chords of the lift span and side span trusses exhibit section loss, resulting in the need reduce the load rating of the bridge to a maximum vehicle weight of 10 tons. There is heavy section loss of the side walk support bracket steel on the steel approach trusses on both sides of the bridge. Currently, both sidewalks are closed and the bridge is restricted to only one lane of traffic in each direction. The two closed lanes are now being utilized as sidewalks.

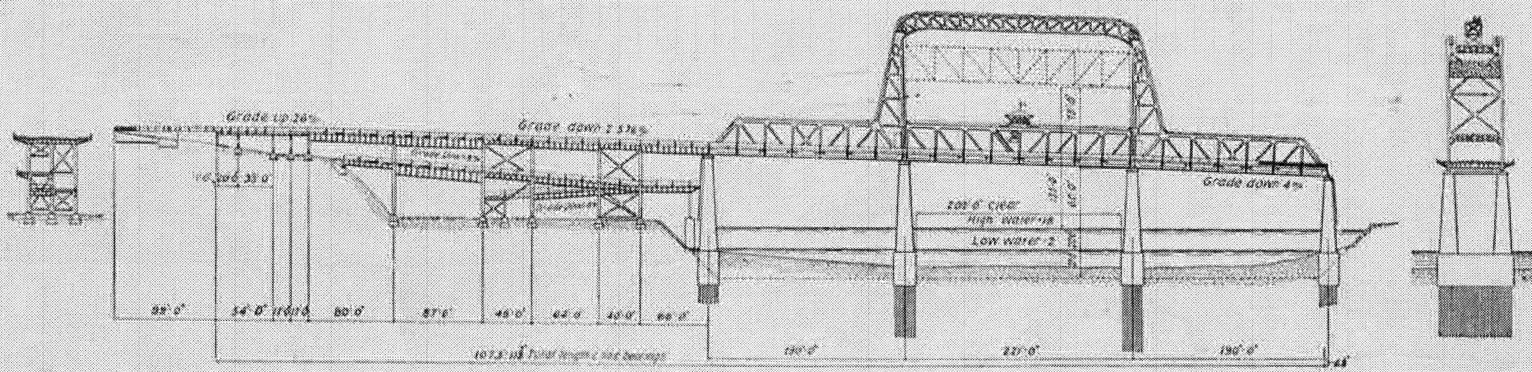
Present day. Sidewalks closed due to heavy deterioration.

The State of Washington is now faced with the choice of investing millions of dollars to restore the structure to its original grandness or to demolish a true piece of American movable bridge engineering history. The construction cost of complete rehabilitation of the bridge is now estimated to be $34 million.

The fact the State Road 509 has been re-routed across a new cable stayed bridge to the south has lessened the importance of the City Waterway Bridge. Daily vehicular usage has been declining since the late 1950's. Currently, the lift span is opened approximately 1 to 6 times per month for the passage of marine vessels and for maintenance.

Although not completely official, the City Waterway Bridge is scheduled for demolition in 2006. The estimated cost of demolition is $6 million.

The Washington State DOT Bridge Preservation Section and their engineering consultants are tasked with maintaining the operational status as well as the overall safety of the structure until that time.

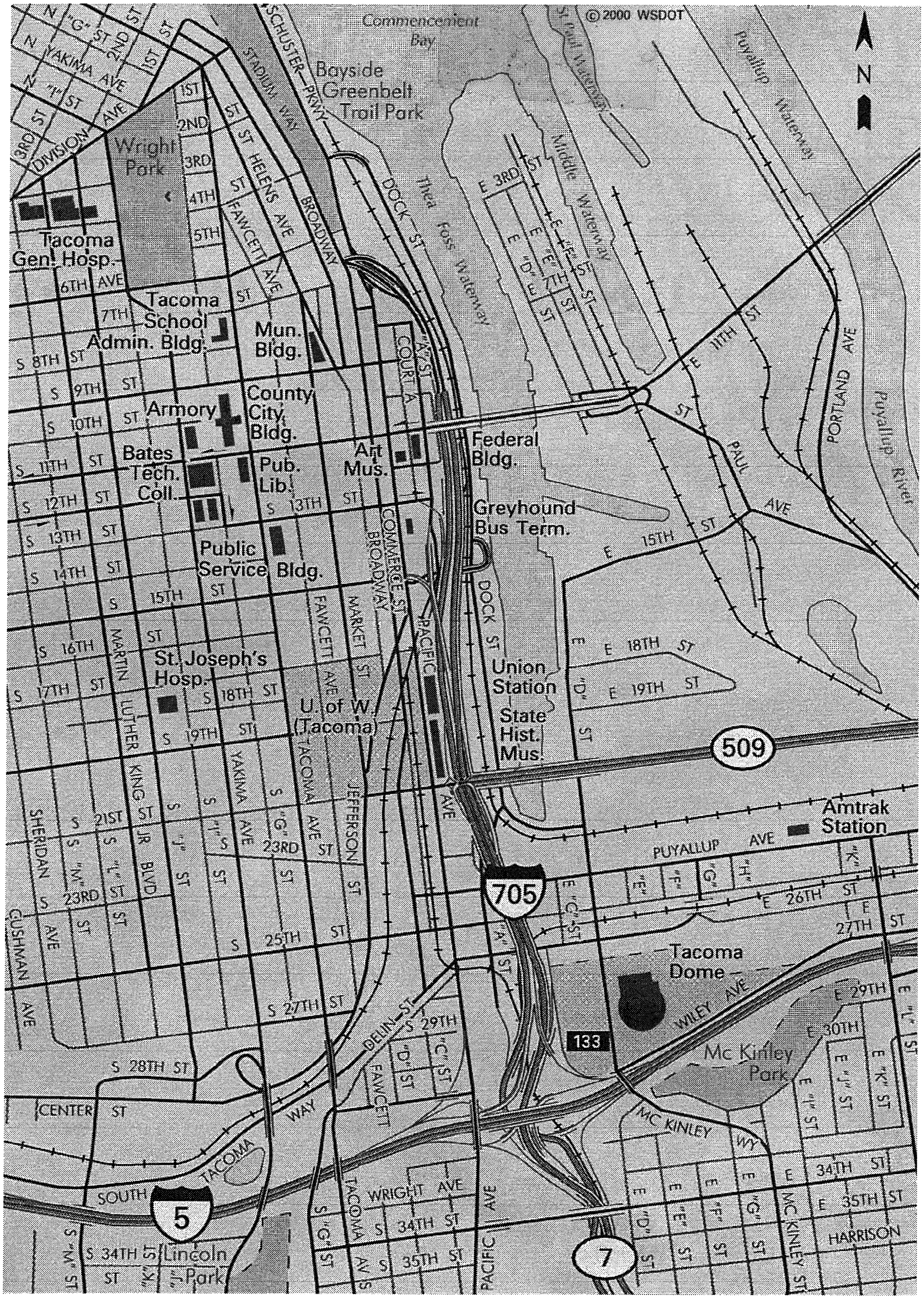


Vertical Lift Bridge Over City Waterway, Tacoma, Wash.

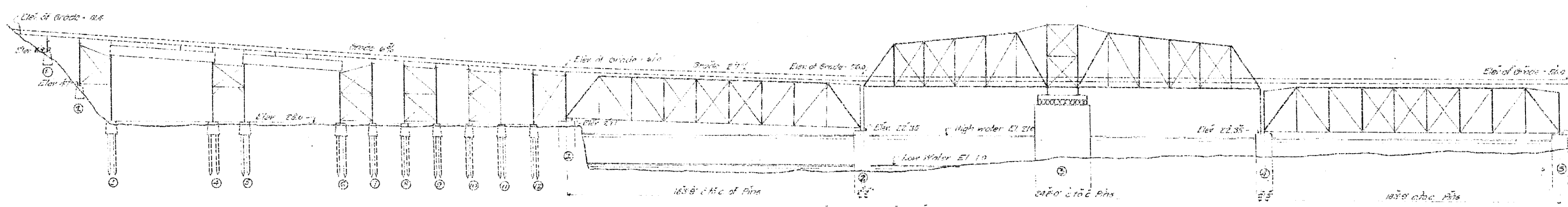
OWNER................	City of Tacoma, Wash.
TRAFFIC...............	Two street railway tracks and highway traffic on paved roadway 50 feet wide; two 10-foot sidewalks.
SUPERSTRUCTURE.......	Two 190-foot truss spans and one 221-foot lift span, over river, with 650-foot steel viaduct. Total length roadways provided 1750 feet. Water pipes are carried across the opening by a small truss span at top of the towers.
MOVEMENT OF SPAN.	Total movement of 75 feet in one minute giving clear vertical opening above high water of 135 feet. Operated by electric power.
SUBSTRUCTURE.........	Concrete piers supported on piles and sunk by the open dredging process.
APPROACHES...........	On the east end wooden trestle. On the west end 650 feet of steel viaduct providing on upper deck for same traffic as the spans, on lower deck for highway traffic on 20-foot roadway and one 10-foot sidewalk.
COST.................	$480,000.00.
COMPLETION.....	1913.

LIFT BRIDGE PATENTS BY WADDELL & HARRINGTON.
August 22, 1909. March 22, 1910. March 29, 1910. May 31, 1911.
Other patents pending.

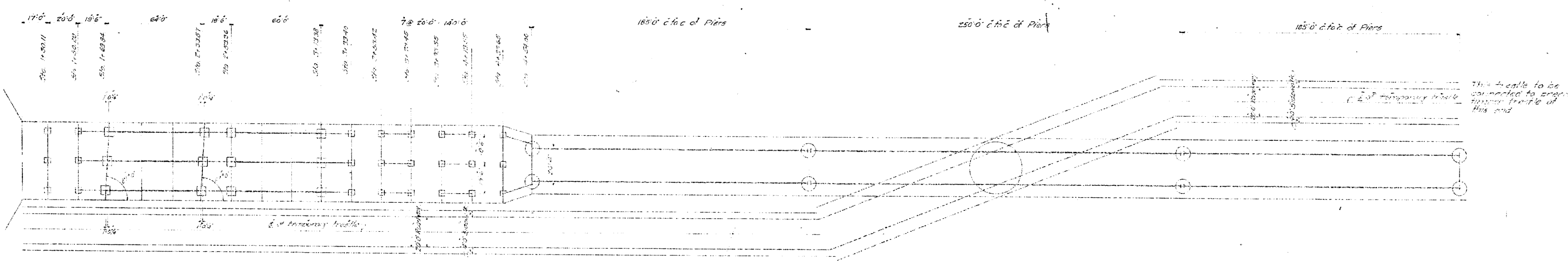
WADDELL & HARRINGTON,
CONSULTING ENGINEERS,
KANSAS CITY, MISSOURI.



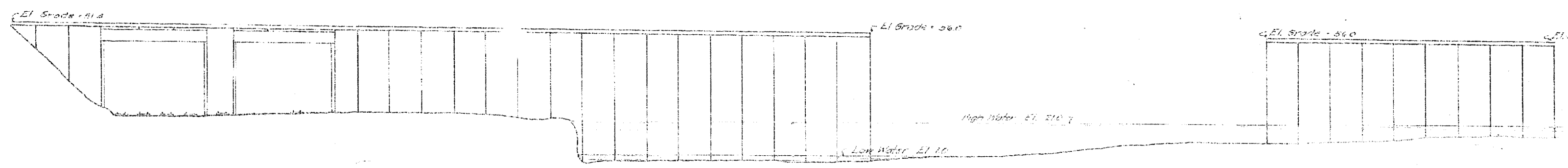
Map of Downtown Tacoma.



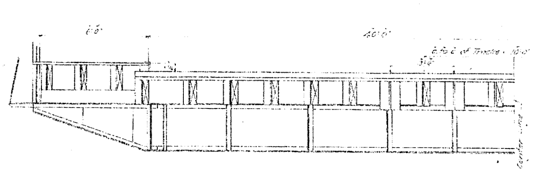
ELEVATION OF OLD BRIDGE



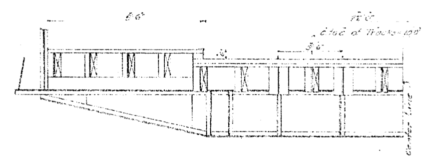
PLAN OF OLD BRIDGE AND TEMPORARY TRESTLE



ELEVATION OF TEMPORARY TRESTLE



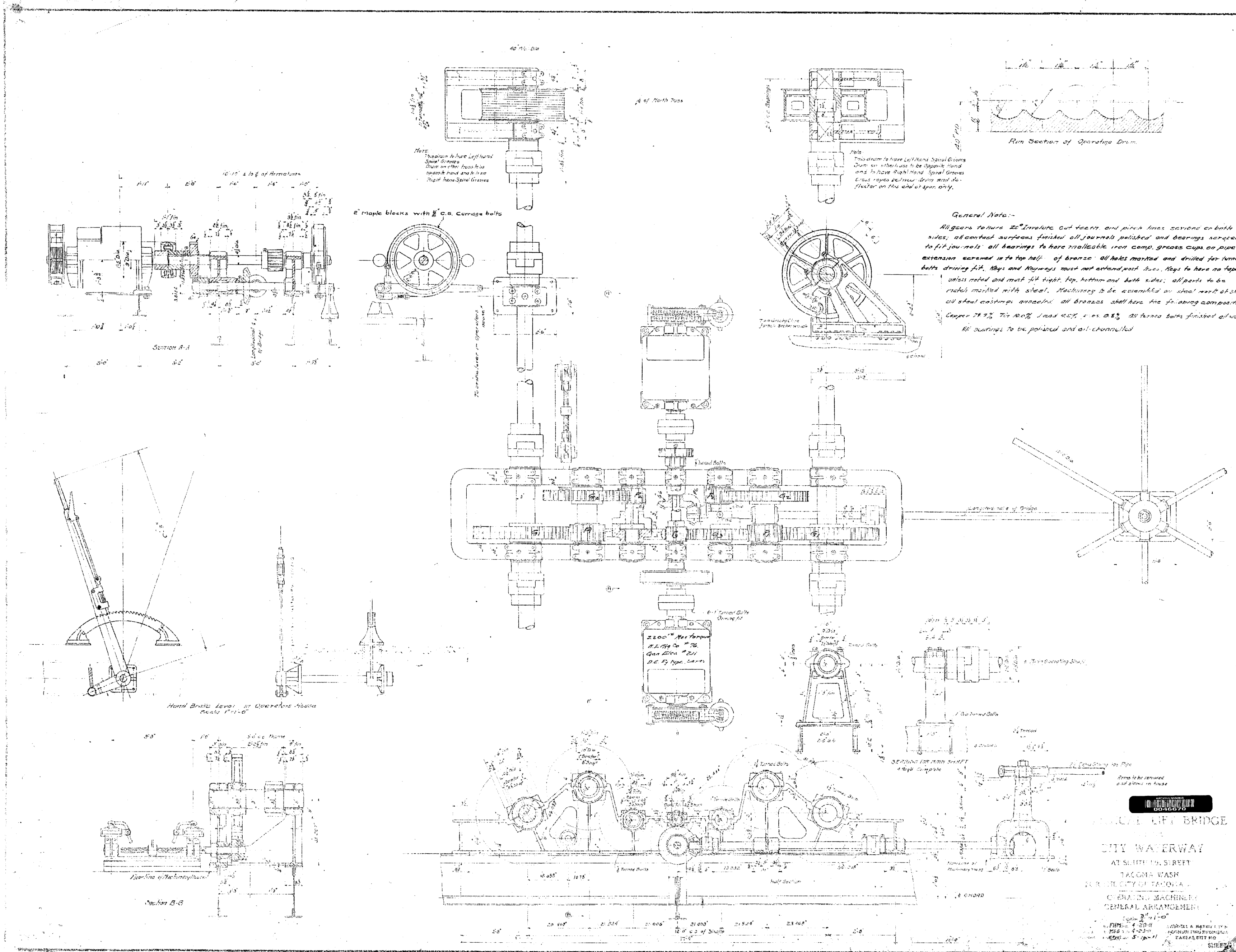
CROSS SECTION OF ROADWAY
ON OLD APPROACH



CROSS SECTION OF ROADWAY
OF OLD TRUSS

Note–
Temporary trestle to be built in a workmanlike manner to the satisfaction of the engineers.
The construction as shown above must be modified to meet the following conditions
Entrance to present Municipal Dock must always be maintained, either from present structure or temporary structure.
Temporary bents must not be placed closer to railroad track than present bents, and present tracks between stations 1+70 and 2+33 must be spanned, contractor being allowed to use girders of present structure.
Contractor may if he choose, maintain traffic by using present west approach to a point at or near station 3+40, thence connecting with temporary trestle on angle of 45° and protecting traffic on present structure during his operations

BRIDGE [illegible] CITY WATERWAY
[illegible] SOUTH [illegible] STREET
TACOMA, WASH.
FOR THE CITY OF TACOMA, WASH –
GENERAL LAYOUT OF [illegible] STRUCTURE
& TEMPORARY TRESTLE
Scale [illegible]



40" Pit. Dia
Note
This drum to have Left Hand Spiral Grooves
Drum on other truss to be Opposite Hand
and to have Right Hand Spiral Grooves
Run Section of Operating Drum
8" Maple blocks with ⅞" C.S. Carriage bolts
Section A-A
General Note:-
All gears to have 20° Involute cut teeth and pitch lines scribed on both sides; all contact surfaces finished all journals polished and bearings scraped to fit journals all bearings to have malleable iron comp. grease cups on pipe extension screwed in to top half of bronze all holes marked and drilled for turned bolts driving fit. Keys and Keyways must not extend past hubs. Keys to have no taper unless noted and must fit tight, top, bottom and both sides; all parts to be match marked with steel. Machinery to be assembled on steel work at shop. all steel castings annealed all bronzes shall have the following composition
Copper 79.7% Tin 10.0% Lead 9.5% Zinc 0.8% All turned bolts finished all over
All bearings to be polished and oil-channelled
Centre line of Bridge
Hand Brake Lever in Operators House
Scale 1"=1'-0"
Section B-B
Half Section
12'-0" c. to c. of Shafts
Arms to be removed and stored in house
0046670
VERTICAL LIFT BRIDGE
CITY WATERWAY
AT SOUTH 11th STREET
TACOMA WASH
FOR THE CITY OF TACOMA
OPERATING MACHINERY
GENERAL ARRANGEMENT
Scale ¾" = 1'-0"
FHM 4-20-11
MSG 4-23-11
5-16-11
WADDELL & HARRINGTON
CONSULTING ENGINEERS
KANSAS CITY MO
SHEET