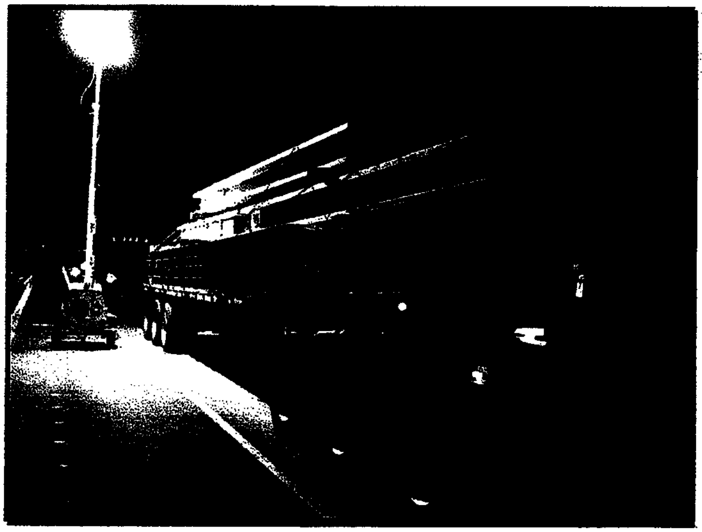
# *Homer Hadley (Interstate 90) Floating Bridge Test Program for Light Rail Transit*

## Draft Test Report

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## 1. EXECUTIVE SUMMARY

In September 2001, KPFF prepared a report titled "Homer Hadley (Interstate 90) Floating Bridge – Draft Structural Feasibility Study Light Rail Conversion". In the report, analytical studies were performed on the floating pontoons and elevated superstructure to determine if the existing bridge structure could support Sound Transit's current LRT loads. Pontoon freeboard loss, rotation, moment, and torsion were obtained and used to evaluate the response of the bridge to the static loads applied at mid-span and at the west end. The results of the study indicated that for LRT live load alone, freeboard loss on the bridge is significant, structure bending-moments appear to be within acceptable levels, torsion stresses are high, and structural retrofit measures are required for the elevated steel superstructures at the east and west ends of the bridge. For rail system dead load added to the bridge, weight mitigation measures were proposed to mitigate freeboard loss. The report also recommended that more global analysis of the bridge be performed to verify these results.

The objective of this report is to perform full-scale load tests to simulate the analytical studies of bridge response to Sound Transit LRT live load included in KPFF's previous report. A test program was selected over a more refined computational analysis because it would eliminate the hydrodynamic modeling and geometric non-linear uncertainties typically associated with floating bridge dynamic analysis.

On September 16, 17, and 18, 2005, KPFF Consulting Engineers performed the full-scale load test of the I-90 Homer Hadley Floating Bridge, simulating light rail transit (LRT) live loading. Both static and dynamic tests were performed and bridge response was measured by instrumentation installed at five (5) stations located on the west half of the bridge. The test vehicles used to simulate the uniform LRT live load consisted of flatbed trucks loaded with weights to approximate the total gross weight of the LRT vehicles.

Test results indicate that:

1. Bridge response correlates well with response predicted using previously developed analytical methods.

2. There appears to be no definitive trend when comparing global bridge response due to static loading to that for dynamic loading. Globally, the bridge responded similarly for static and dynamic loading.

3. The continued use of previously developed analytical methods used to study the response of the bridge to LRT live loading is acceptable.

Additional analysis was performed to assess the global capacity of the bridge at mid-span and near the west expansion joint to support LRT live load in combination with other design loads. The analysis was performed following WSDOT's design criteria document used for design of the bridge. Results indicate that WSDOT's strength and serviceability criteria for pontoon global response are met at mid-span and at the far west end of the bridge for live loading due to two (2) tracks of Sound Transit's LRT system in combination with HS25 traffic on the westbound roadway.

## 2. INTRODUCTION

In September 2001, KPFF prepared a report titled "Homer Hadley (Interstate 90) Floating Bridge – Draft Structural Feasibility Study Light Rail Conversion". In the report, analytical studies were performed on the floating pontoons and elevated superstructure to determine if the existing bridge structure could support Sound Transit's current LRT loads. The analysis of the bridge incorporated a two-dimensional continuous stiffness computer model of the floating structure supported on an elastic foundation and subject to static LRT live loading located in the existing HOV lanes. In the computer model, LRT live loads were placed at mid-span and near the west transition span expansion joint in arrangements that simulated trains bypassing and about-to-bypass, with one train located on each track. Bridge pontoon freeboard loss, rotation, moment, and torsion were obtained, and used to evaluate the response of the bridge to the applied static loads. The results of the study indicated that for LRT live load alone, freeboard loss on the bridge is significant, structure bending-moments appear to be within acceptable levels, and torsion stresses are high. The report also recommended that more global analysis of the bridge be performed to verify these results.

The objective of this report is to perform full-scale load tests to simulate the analytical studies of bridge response to Sound Transit LRT live load included in KPFF's previous report. A test program was selected over a more refined computational analysis because it would eliminate the hydrodynamic modeling and geometric non-linear uncertainties typically associated with floating bridge dynamic analysis.

On September 16, 17, and 18, 2005, KPFF Consulting Engineers performed the full-scale load test of the I-90 Homer Hadley Floating Bridge, simulating light rail transit (LRT) live loading. The intent of this report is to:

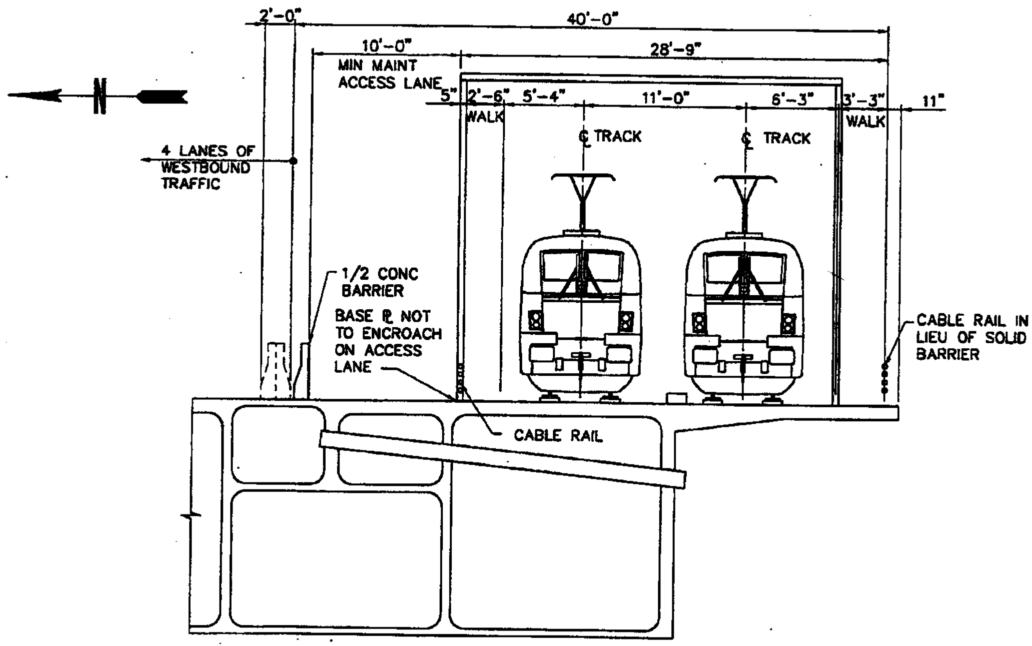
- Present test program description and purpose.
- Present the results of the test program.
- Present comparisons of test results to bridge response predictions made by analytical methods.
- Present conclusions on the applicability of previously used analytical methods.
- Incorporate predicted bridge response to LRT loading into the original design criteria used by WSDOT to design the floating bridge.
- Conclude on the structural effects of LRT on the floating bridge.

## 3. TEST PROGRAM OVERVIEW

The test program involved performing full-scale load tests on the floating bridge and comparing measured bridge response to that predicted by the analytical studies. Global bridge response under both static and dynamic load conditions was measured. Response parameters measured include:

- Freeboard loss
- Bridge rotation
- Cantilever tip deflections along the south edge
- Horizontal and vertical deflections at the expansion joint
- Vertical and horizontal accelerations
- Global pontoon strain due to combined moment, torsion, and shear

Static load conditions were simulated by placing fully-loaded test vehicles at specific locations within the existing HOV lanes of the bridge at mid-span and near the west transition span expansion joint. Test vehicle location within the existing HOV lanes corresponded to track location 3 identified in the previous analytical study, which accommodates the addition of a fourth westbound traffic lane.



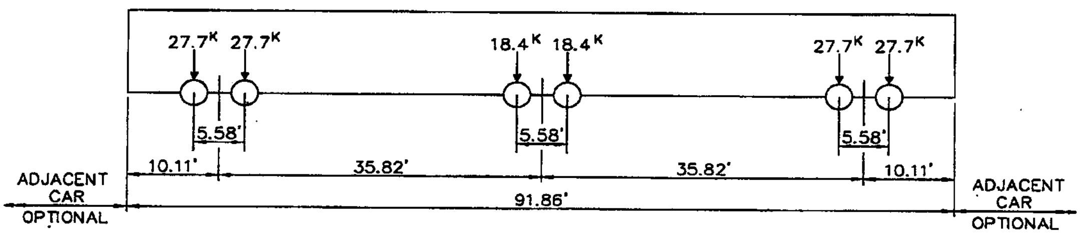

Alternative LR (MOD) - 3

Dynamic load conditions were simulated by driving fully-loaded test vehicles in train formation at 30-miles-per-hour within the existing HOV lanes of the bridge. Tests were conducted for single trains traveling in both directions along the entire length of the bridge and for trains bypassing at mid-span and near the west transition span expansion joint.

Response data for the static and dynamic test was collected in real-time as the test vehicles moved along the bridge. Baseline readings for the empty bridge condition and for the condition with traffic in the westbound lanes were also taken.

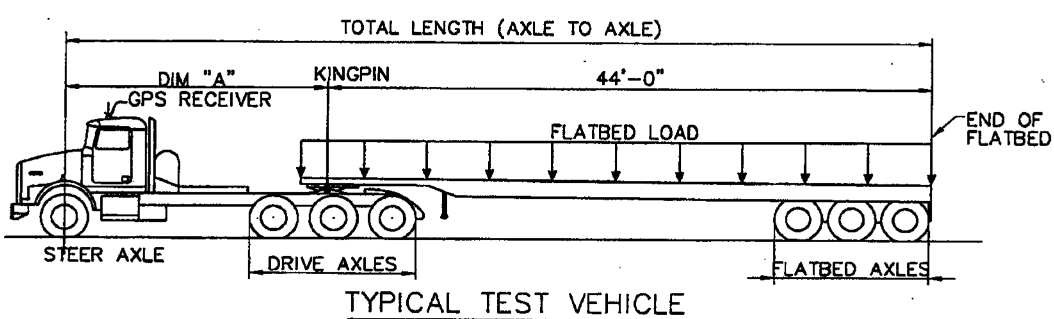
***a. Simulated LRT Vehicle***

The test program simulated the uniform LRT live load applied to the bridge for a 4-car train. One car of the simulated Sound Transit LRT train is shown below:




LRT VEHICLE LIVE LOADING

The uniform load applied to the bridge for the vehicle shown above is approximately 1600 pounds per lineal foot (plf). This live load is applied over a distance of 370-feet for a 4-car train. The test vehicles used to simulate the uniform LRT live load consisted of flatbed trucks loaded with weights to approximate the total gross weight of the LRT vehicles. Axle spacing and axle load for the loaded flatbeds trucks did not match those of the simulated LRT vehicle. Shaughnessy and Co. provided, loaded, and operated the test vehicles. The general arrangement of the typical test vehicle is shown below:




TYPICAL TEST VEHICLE
NOT TO SCALE

A "train" of test vehicles consisted of four (4) trucks spaced evenly apart to approximate the total 370-foot length of the simulated 4-car train. The simulated trains were placed on the bridge at mid-span and near the west transition span expansion joint to replicate the loading applied in the analytical study. The trains were arranged to simulate the bypass and about-to-bypass condition, with one train located in each HOV lane. Train "A" was located in the north HOV lane and Train "B" was located in the south HOV lane. Load added to the flatbed of each truck consisted primarily of steel and concrete material. The target gross vehicle weight (GVW) for each truck was 148,000-lbs to approximate the weight of one LRT car. The tables below summarizes the actual weight of each test vehicle as documented by Shaughnessy and Co.

The results of this study indicate that WSDOT's strength and serviceability criteria for pontoon global response are met at mid-span and at the far west end of the bridge for live loading due to two (2) tracks of Sound Transit's LRT system in combination with HS25 traffic on the westbound roadway. A comprehensive analysis of all remaining pontoons of the bridge should be done during final design. Also, as concluded in the previous analytical study, response of the bridge to LRT live loading must be evaluated by Sound Transit's rail designers for conformance to light rail system tolerances.

## 6. MOTION ANALYSIS AT WEST TRANSITION SPAN

Motion analyses were performed for the west transition span due to combined LRT live load, HS25 traffic load, and 1-year storm loading. Motions due to LRT and traffic loads were obtained from the 2-dimensional computer model used for the global analysis of the floating bridge. Motions due to storm loading were obtained from the 1983 hydrodynamic study performed by the Glosten Associates. All motions were translated to the elevation at the top of roadway. A summary of the results is shown below. Additional information is contained in Table 21 and Figures 29 & 29.1 .

Transition Span Rotation:

| | |
|---|---|
| Horizontal rotation of transition span due to transverse displacement of floating bridge, $\theta_H$ | 0.12 degrees |
| Vertical rotation of transition span due to vertical displacement of floating bridge, $\theta_V$ | 0.26 degrees |

Movement at joint between fixed approach structure and transition span at Pier 7:

| | |
|---|---|
| Max. longitudinal expansion/contraction of joint, $\Delta_{x7}$ | ±0.8 inches |
| Max. transverse displacement of deck | 0 inches |
| Max. vertical displacement of deck | 0 inches |

Movement at joint between transition span and floating bridge at Pier A-1:

| | |
|---|---|
| Max. longitudinal expansion/contraction of joint, $\Delta_{x\,A\text{-}1}$ | ±1.2 inches |
| Max. transverse displacement of deck, $\Delta_y$ | 4.7 inches |
| Max. vertical displacement of deck, $\Delta_Z$ | 10.0 inches |

Transition span motion due to changes in lake level is not included above. The design criteria for the bridge indicates a maximum rise of 0.8-feet and a maximum fall of 3.8-feet from the normal water elevation of 8.02-feet. Sound Transit's rail designers should include this component of motion in the design of the rail system.

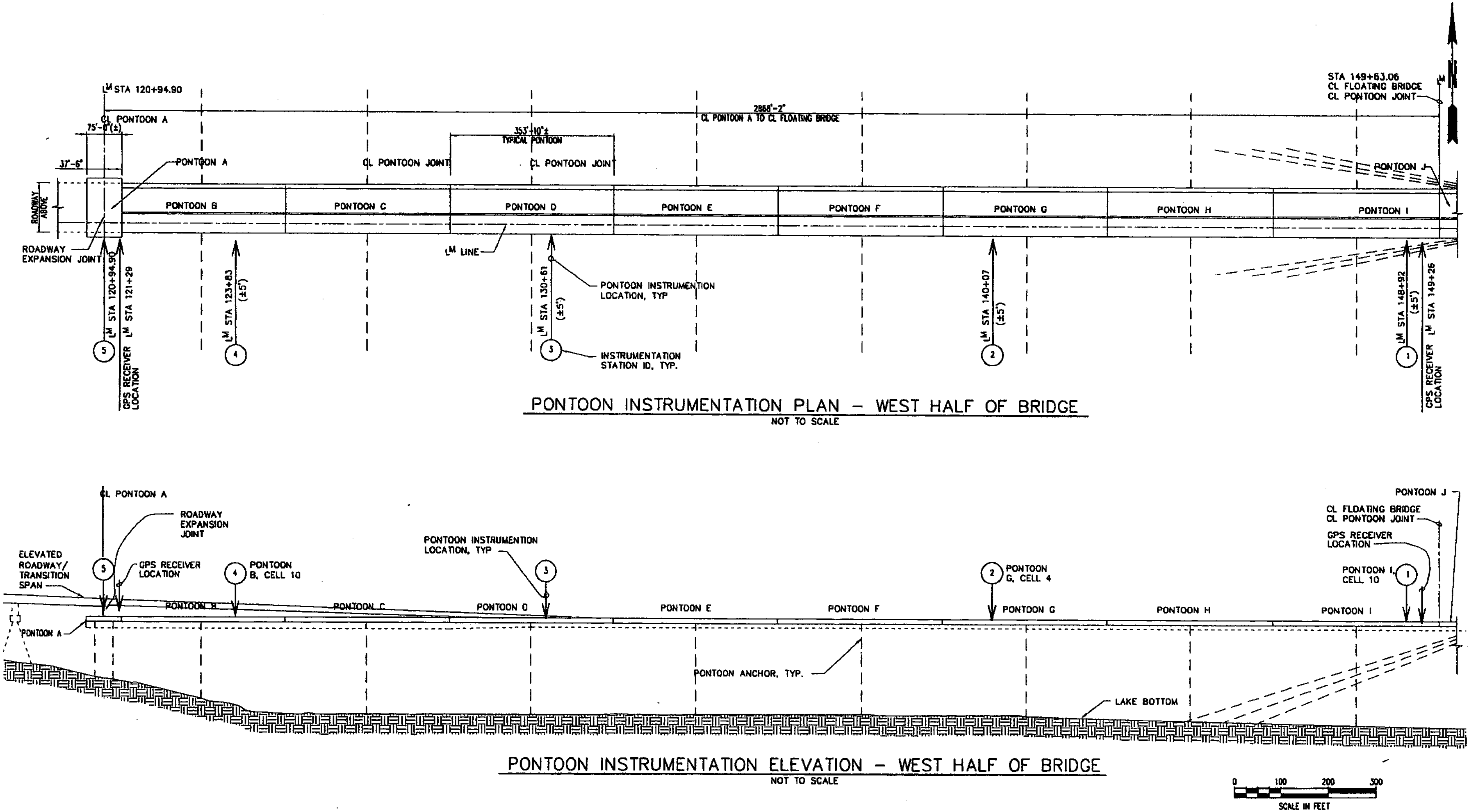



**FIGURE 1 - INSTRUMENTATION LOCATIONS**

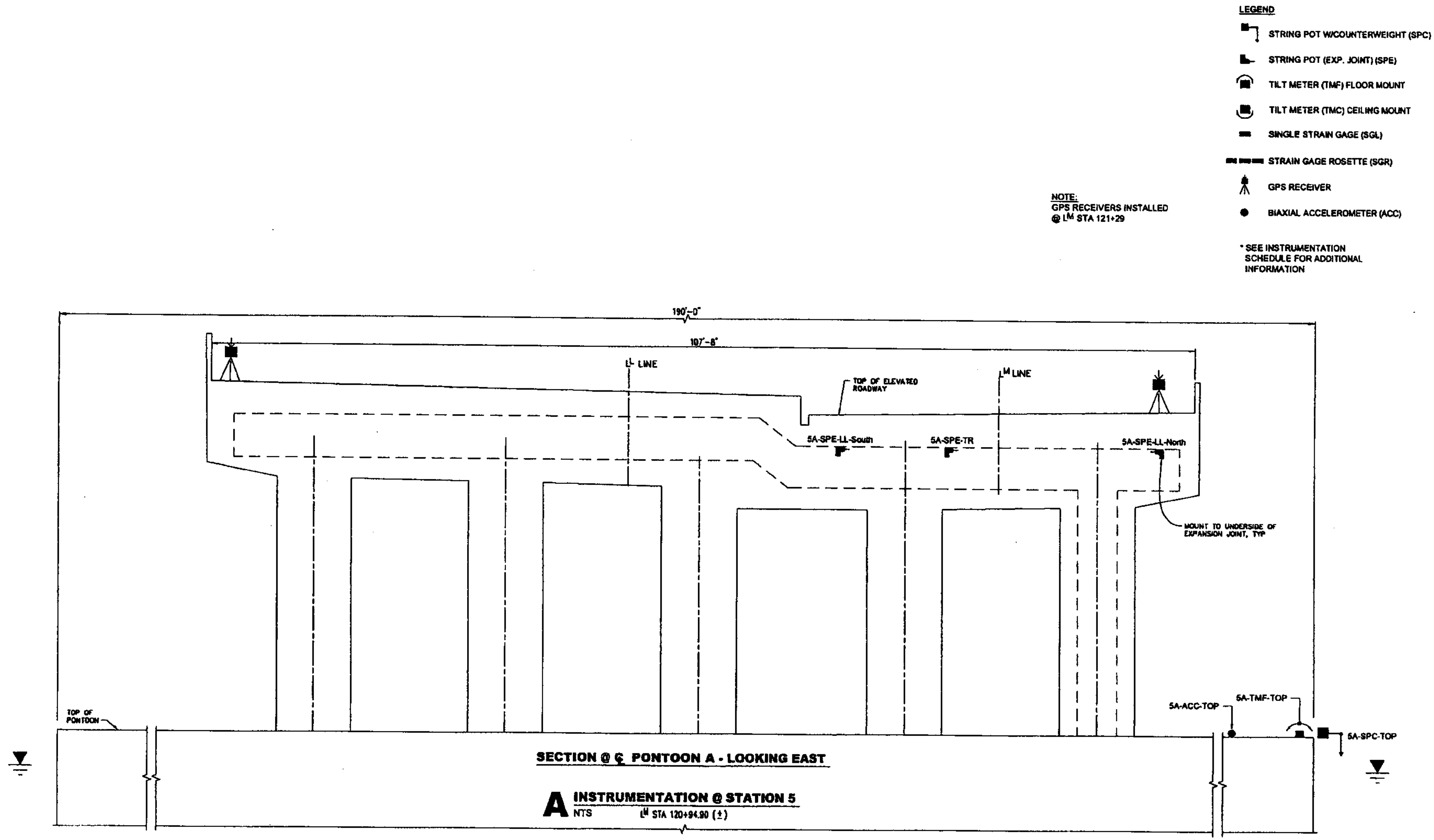



FIGURE 6 - INSTRUMENTATION SECTION

# Expansion Joint Displacements Due to Traffic, LRT, and 1- Year Storm

Third Lake Washington Bridge - Homer Hadley

$\theta_H$ = 0.002113474 rad = 0.12 deg - Horizontal Rotation about Bearings at Pier 7

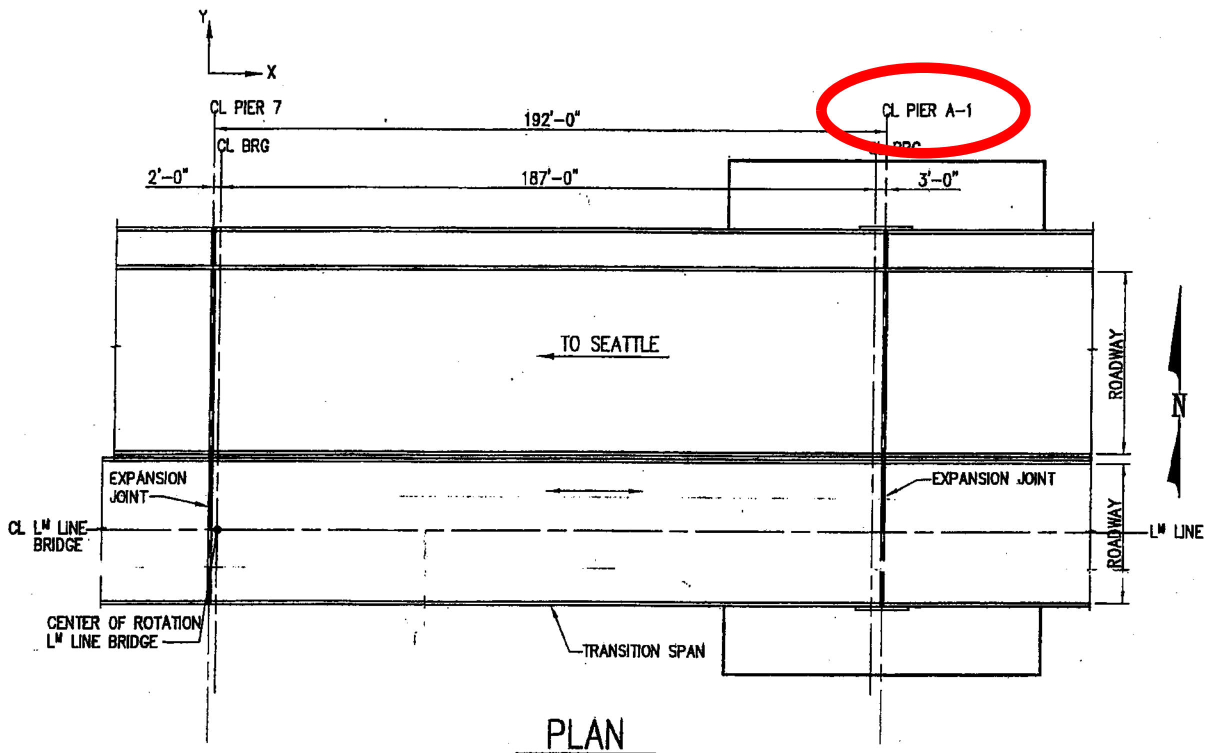
$\theta_V$ = 0.00445844 rad = 0.26 deg - Vertical Rotation about Bearings at Pier 7

| Point | Location | | | Coordinates | | | Traffic and LRT Displacements | | | 1 Year Storm Displacements | | | Total Displacement | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (X) | (Y) | (Z) | X - Location ($L^M$ Line) (ft) | Dist. From $L^M$ Line - Y (ft) | Elevation - Z (ft) | ΔX (in) | ΔY (in) | ΔZ (in) | ΔX (in) | ΔY (in) | ΔZ (in) | ΔX (in) | ΔY (in) | ΔZ (in) |
| S1 | Pier 7 - CenterLine of Bearings | LM - Line | Top of Overlay | 11904.9 | 0 | 54.49 | 0.22 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | **0.26** | 0.00 | 0.00 |
| S2 | Pier 7 - CenterLine of Bearings | Centerline Rail | Top of Overlay | 11904.9 | -10.5 | 54.7 | 0.42 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | **0.53** | 0.00 | 0.00 |
| S3 | Pier 7 - CenterLine of Bearings | South Edge of Deck | Top of Overlay | 11904.9 | -20.92 | 54.91 | 0.61 | 0.00 | 0.00 | 0.18 | 0.00 | 0.00 | **0.79** | 0.00 | 0.00 |
| S4 | Pier A -1 -- CenterLine of Bearings | LM - Line | Top of Overlay | 12091.9 | 0 | 51.15 | 0.62 | 3.36 | 7.20 | 0.02 | 1.36 | 1.02 | **0.65** | 4.71 | 8.22 |
| S5 | Pier A -1 -- CenterLine of Bearings | Centerline Rail | Top of Overlay | 12091.9 | -10.5 | 51.36 | 0.81 | 3.37 | 8.02 | 0.10 | 1.36 | 1.12 | **0.91** | 4.73 | 9.14 |
| S6 | Pier A -1 -- CenterLine of Bearings | South Edge of Deck | Top of Overlay | 12091.9 | -20.92 | 51.57 | 1.01 | 3.38 | 8.80 | 0.17 | 1.36 | 1.21 | **1.18** | 4.74 | 10.00 |

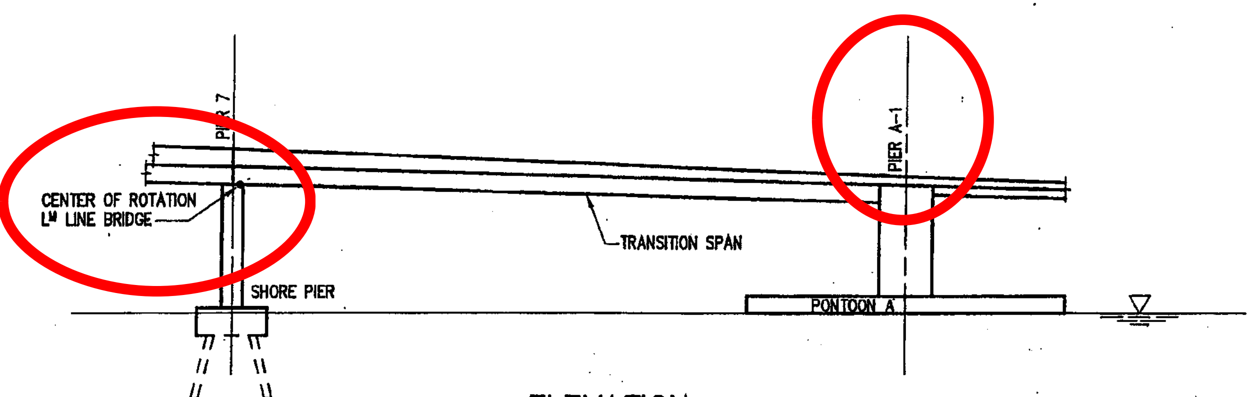
Notes:

1. Displacements and accelerations of Pontoon A are taken from the report titled, "Wave Loading Analysis of Lake Washington Bridges, and Results, New I-90 Floating Bridge" as prepared by The Glosten Associates, Inc. and dated May 1983
2. Displacements and accelerationsare based on expected Maxima for the 90% confidence interval
3. Elevations are taken from the as-built plans and are based on Lake Washington Normal Water Level of 8.02 ft

## TABLE 21
## EXPANSION JOINT DISPLACEMENT DUE TO LRT, TRAFFIC AND 1-YEAR STORM



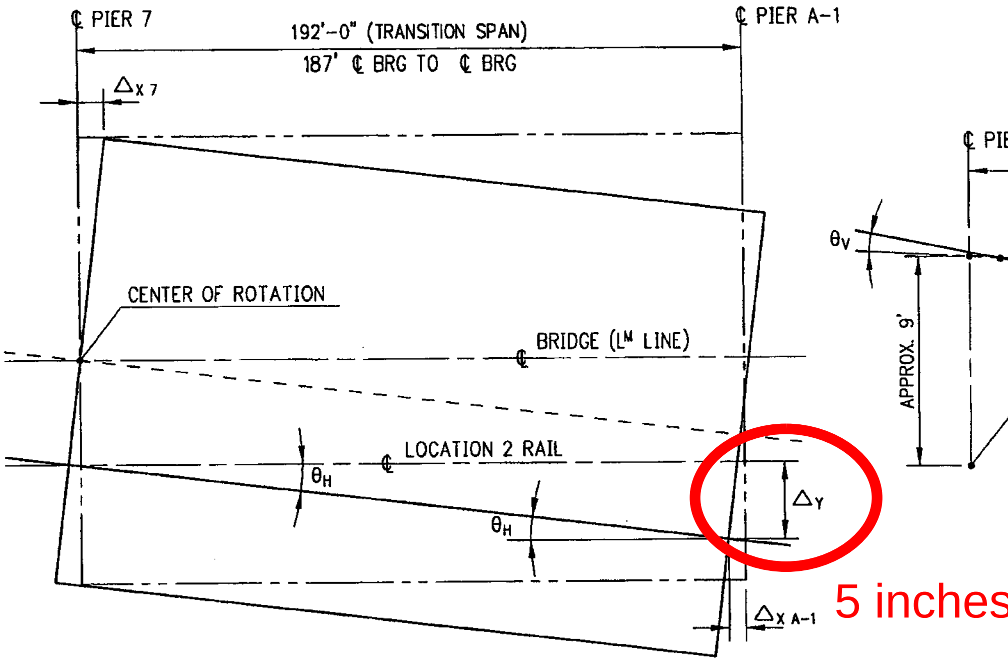

PLAN




ELEVATION

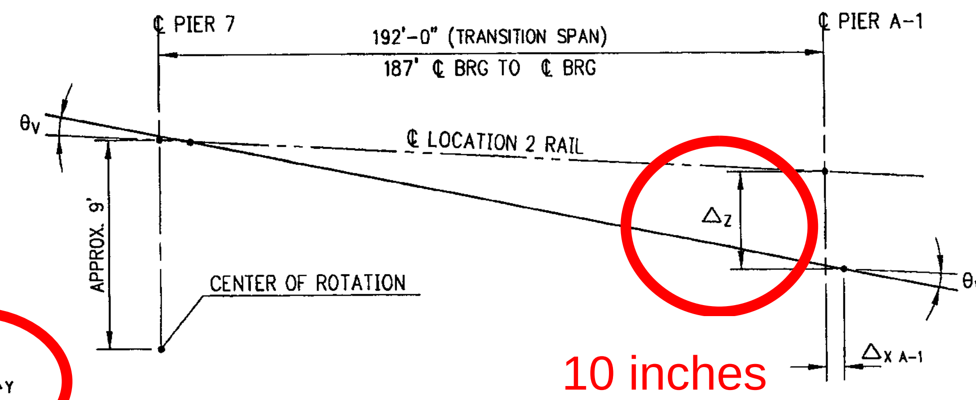
# FIGURE 29

# TRANSITION SPAN




PLAN

HORIZONTAL RAIL MOVEMENT AT CENTERLINE PIER A-1




ELEVATION

VERTICAL LRT RAIL MOVEMENT AT CENTERLINE PIER A-1

## FIGURE 29.1

## TYPES OF MOTION OF THE RAIL AT THE TRANSITION SPAN EXPANSION JOINT