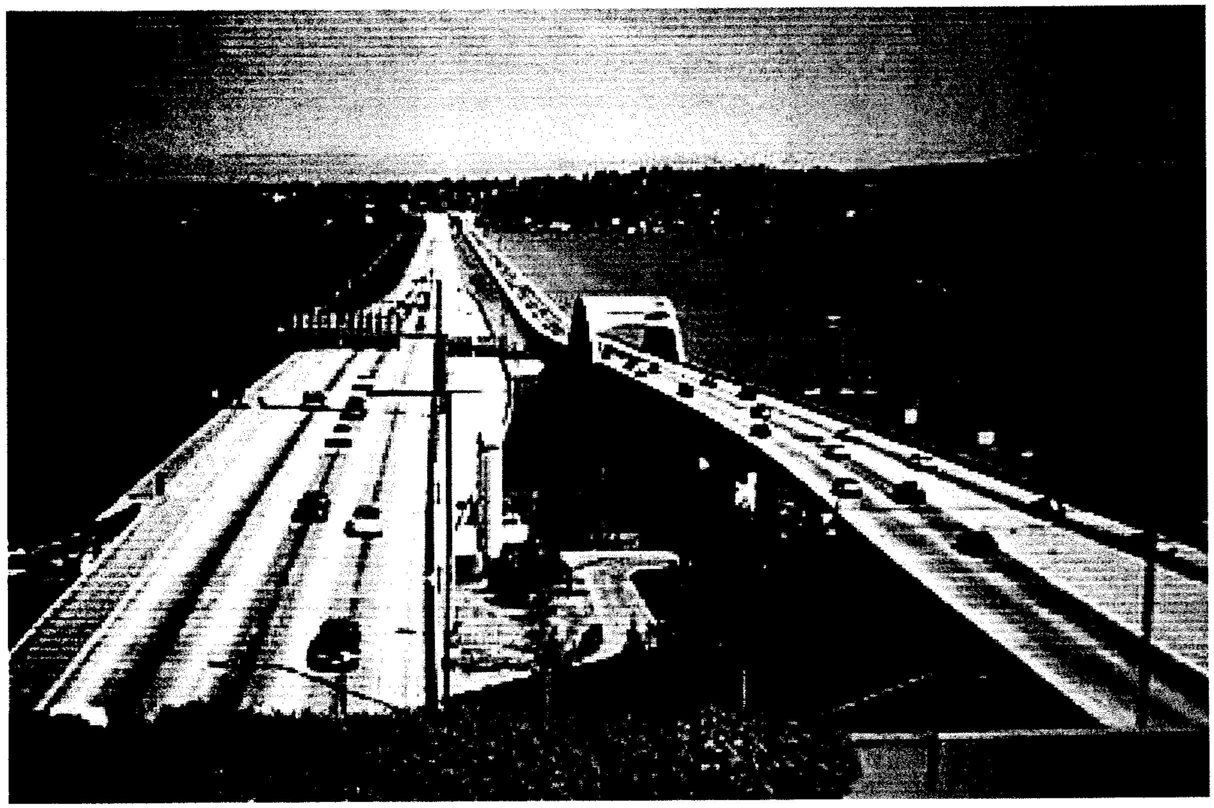
Homer Hadley (Interstate 90) Floating Bridge

Draft Structural Feasibility Study
Light Rail Conversion



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EXECUTIVE SUMMARY

Introduction

The Homer Hadley Floating Bridge was designed and constructed to serve as a safe, reliable link in the Interstate 90 (I-90) transportation corridor across Lake Washington, with an estimated design life of 70 years. The floating bridge is 5,811 feet long and is flanked at each end by a steel bridge transition span that connects the floating structure to the fixed bridge approach spans at each end. A series of prestressed and reinforced concrete pontoons are joined together to complete the floating structure. Over a majority of the floating bridge, the vehicular traffic rides directly on the top deck of the pontoons. However, the roadway is elevated to meet fixed bridge structures at the east and west ends of the floating structure. A 10-foot wide pedestrian/bicycle lane is located on the roadway overhang on the north side of the bridge.

This study evaluates the structural feasibility of converting the two HOV lanes of the Homer Hadley Floating Bridge to light rail. The two existing HOV lanes are located on the south 40-foot wide section of the floating bridge. The 40-foot section is divided into a 12-foot wide shoulder to the north, two 12-foot wide HOV lanes, and a 4-foot shoulder to the south (see Figure 1). The section is bounded by a concrete median barrier to the north and a concrete side barrier to the south, both of which are constructed integral with the floating bridge.

Floating bridges are unique bridge structures in that they not only have to carry traditional vehicular traffic loads, but they also must remain watertight. Unique design solutions are used to enhance the watertight integrity, such as the use of prestressed concrete members, installation of watertight access hatches and doors, and rigorous adherence to regular inspection and maintenance procedures. In essence, the Homer Hadley Floating Bridge is a permanently moored marine structure rather than a conventional fixed bridge. The importance of embracing these concepts was discussed in detail in the document titled "Report of the Governor's Blue Ribbon Panel Investigation into the Sinking of the I-90 Lacey V. Murrow Bridge," dated May 2, 1991. This report contains numerous recommendations for the need to apply sound marine engineering practice when designing, constructing, maintaining, and modifying floating bridges.

Similarly, the design alternatives, which were studied within this report, were evaluated so as to assure structural and operational feasibility while drawing heavily on the concept of applying sound marine engineering practice to any modifications that would be required of the Homer Hadley Floating Bridge.

Study Alternatives and Analysis

Converting the existing HOV lanes to light rail requires the evaluation of rail system dead load and location. The dead load of the rail system will reduce the bridge freeboard and, as the rail system is located further from the center of buoyancy of the bridge, its dead load causes the bridge to lose additional freeboard and list. Since any bridge list must be leveled or trimmed with offsetting ballast, the added ballast necessary to trim the bridge further reduces the freeboard. As a result of this, several rail systems, BR, LR, and LR (mod) were evaluated. The characteristics of these systems are described in the following table:

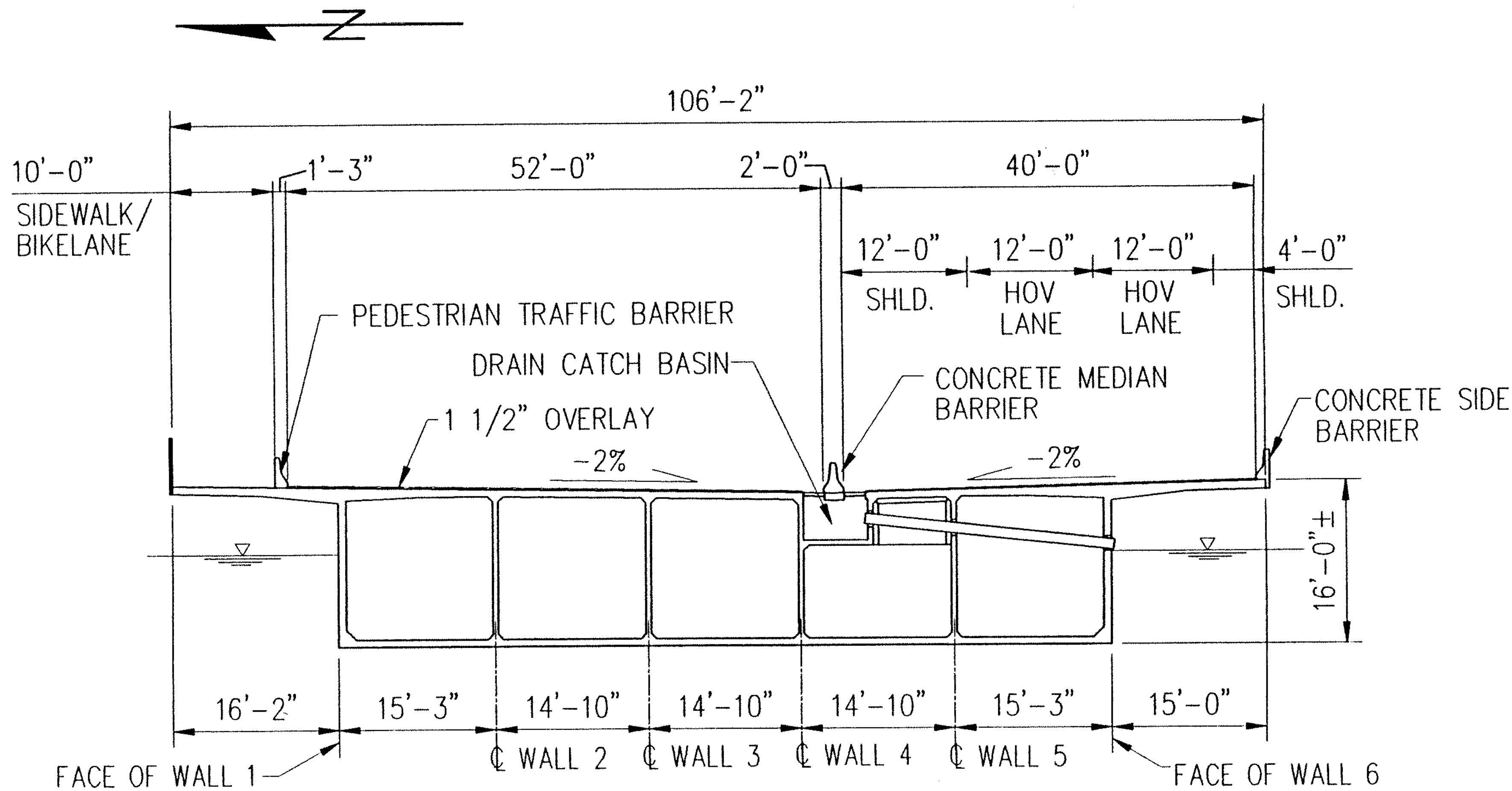


FIGURE 1
TYPICAL SECTION AT FLOATING PONTOON

Rail System Designation	*Rail System Description*
BR	The "basic rail" system consists of the typical superimposed dead loading for the two-track Sound Transit LRT, with a loading per route foot of 1,470 pounds.
LR	The "light rail" system consists of a minimum superimposed dead loading for the two-track Sound Transit LRT, with a loading per route foot of 800 pounds. The system was weight optimized by reducing the concrete plinth weights and eliminating the restraining rails.
LR (mod)	As the project progressed, it became clear that it would be necessary to remove the existing south concrete side barrier in order to meet the project criteria. Therefore, the LR scenario above had to be revisited and revised to include two restraining rails to preclude possibilities of derailment. These added safety features result in a new lower bound LRT superimposed dead load, LR (mod), with a loading per route foot of 920 pounds.

All rail systems are located eccentric to the centerline of the bridge; consequently, they all will result in bridge freeboard loss due to placement of trim ballast. Four track locations/configurations were developed for the study in order to capture a range of impacts to the bridge. These are discussed in the table below:

Location/Configuration	*Description*
1	Location 1 positions the LRT tracks as close as possible to the concrete median barrier within the existing 40'-0" wide designated HOV lanes of the bridge, while still providing the minimum 10'-0" maintenance access lane.
2	Location 2 positions the LRT tracks as far as possible to the south within the existing designated HOV lanes of the bridge.
3	Location 3, which was included at a late stage of the study, is similar to Location 1 with respect to the position of the exterior outboard LRT track on the south cantilever; however, the remainder of the configuration was significantly revised to accommodate a 2'-0" median barrier movement to the south. The medium barrier movement is associated with a preferred westbound lane addition configuration from the westbound lane addition study. Other modifications to the configuration include the relocation of the walkway and inboard LRT track, as well as modification of the OCS pole system.
4	Location 4, which was also included at a late stage in the study, is identical to Location 1, but with the median barrier relocated 8'-0" to the south and the maintenance access road separated entirely from the LRT operational area.

For the purpose of this study, eight separate combinations of rail types, locations and configurations were considered, and are shown in the table below. As the study progressed, it became clear that the LR (mod) system had significant advantages over the BR and LR systems; therefore, it was the only rail system type which was combined with all of the locations and configurations.

Rail System	*Location/Configuration*	*Design Combination*	*Figure No.*
BR	1	BR-1	2
BR	2	BR-2	2
LR	1	LR-1	3
LR	2	LR-2	3
LR (mod)	1	LR (mod) 1	3 (sim)
LR (mod)	2	LR (mod) 2	3 (sim)
LR (mod)	3	LR (mod) 3	4
LR (mod)	4	LR (mod) 4	4

Hydrostatic analyses were performed on the floating bridge to determine the loss of bridge freeboard (height above waterline) associated with the location of the different rail configurations. Freeboard loss was based on the new rail dead loads and the corresponding ballast required to trim the bridge back to a level condition. Trim ballast was assumed to be gravel and was assumed to be placed in the center of the northernmost cells of the floating bridge.

A structural analysis was performed on the floating pontoons and elevated superstructure to determine if the existing floating bridge structure could support Sound Transit's current light rail loads, meet Sound Transit's structural performance criteria for light rail vehicles, and WSDOT's performance criteria for floating bridges.

CONCLUSIONS

1. The hydrostatic analysis resulted in eliminating the BR system as a feasible LRT system.

2. The hydrostatic analysis indicated that the added weight from both LR and LR (mod) systems could be mitigated using reasonable approaches.

3. The hydrostatic analysis estimated the bridge responses during LRT loading at both midspan and at the expansion joint locations. These bridge responses need to be verified by a more rigorous hydrodynamic analysis and Sound Transit should verify that the deflections are compatible with the LRT tolerances.

4. The structural analysis concluded that Location/Configuration Option 2 is not feasible. This is because this location placed LRT loads too far out on the south end of the floating bridge cantilever and overstressed the floating pontoon top deck.

5. The structural analysis showed that Location/Configuration Options 1, 3, and 4 can be utilized without overstressing the floating pontoon top deck; however, in order to accomplish this, the south concrete side barrier must be removed and replaced with a cable railing.

6. When considering the above conclusions, it becomes clear that the Alternatives LR (mod) 1, 3, and 4 are the only alternatives which could be further considered without strengthening the existing floating bridge pontoons. Because of this, all three of these options were identified as the preferred alternatives.

7. Weight mitigation requirements for the preferred alternatives involve 3 main elements:

   - Removal of the existing south concrete side barrier and replacement with a cable railing.

   - Removal of existing ballast within the floating bridge pontoon cells.

   - Removal of 1 inch of the existing concrete overlay on the south side of the concrete median barrier and replacement with 1/4-inch of polymer concrete overlay.

   In addition to the above alternatives, LR (mod) 4 required that the relocated median barrier to be constructed using lightweight concrete.

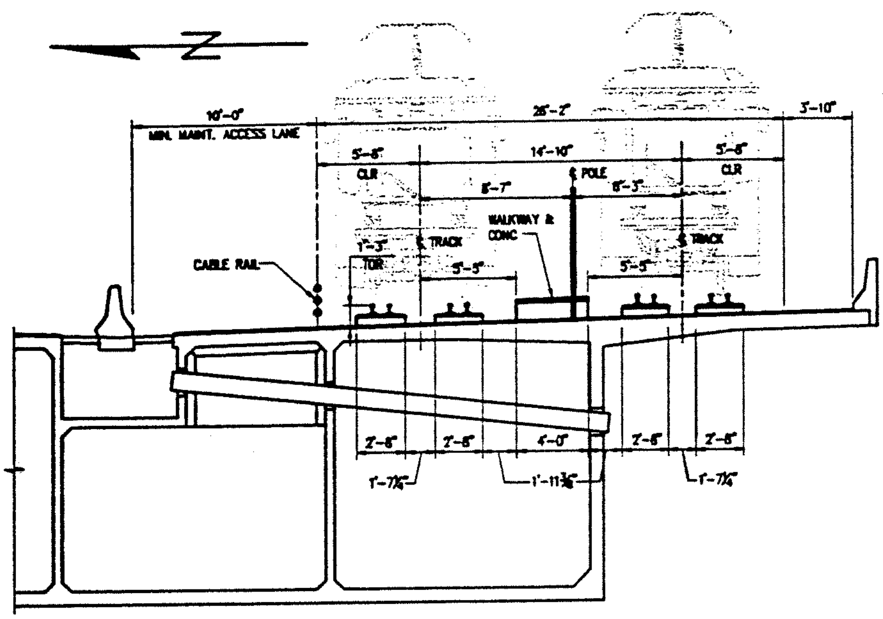
8. The structural analysis of the elevated superstructure for all options identified very few problems. However, the steel box girders did not meet Sound Transit's criteria for deflection. A steel cover plate retrofit for the box girder is proposed to mitigate the excessive deflections. The weight of the steel cover plates can be completely mitigated by removing additional existing gravel ballast from locations directly under the retrofitted box girders.

Preferred Alternatives and Costs

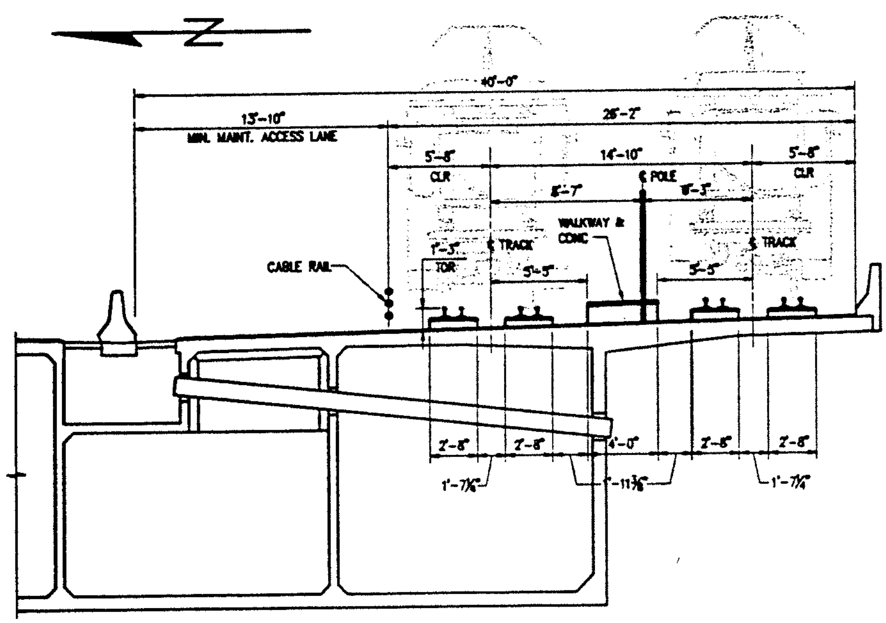
The study preferred Alternatives LR (mod) 1, 3, and 4, which are shown in Figures 12 through 15 at the end of this report. LR (mod) 3 was shown in two versions (A and B) to identify two separate approaches to achieve the 10'-0" maintenance lane and LRT walkway. All options are shown with the full width of the bridge to illustrate how they can integrate with potential modifications to the westbound lane configurations. Costs for the preferred alternatives are shown below:

Preferred Alternative	***LRT Conversion Cost***	***Added Westbound Lane Cost***	***Total Cost***
LR (mod) 1	$12,296,000	$ 0	$12,296,000
LR (mod) 3A & 3B	$12,070,000	$15,826,000	$27,896,000
LR (mod) 4	$10,852,000	$12,001,000	$22,853,000

The above costs do not include sales tax, engineering or construction management, electrical modifications or temporary services, mitigation of traffic impacts due to the elimination of the existing HOV lanes, and LRT system installation costs.

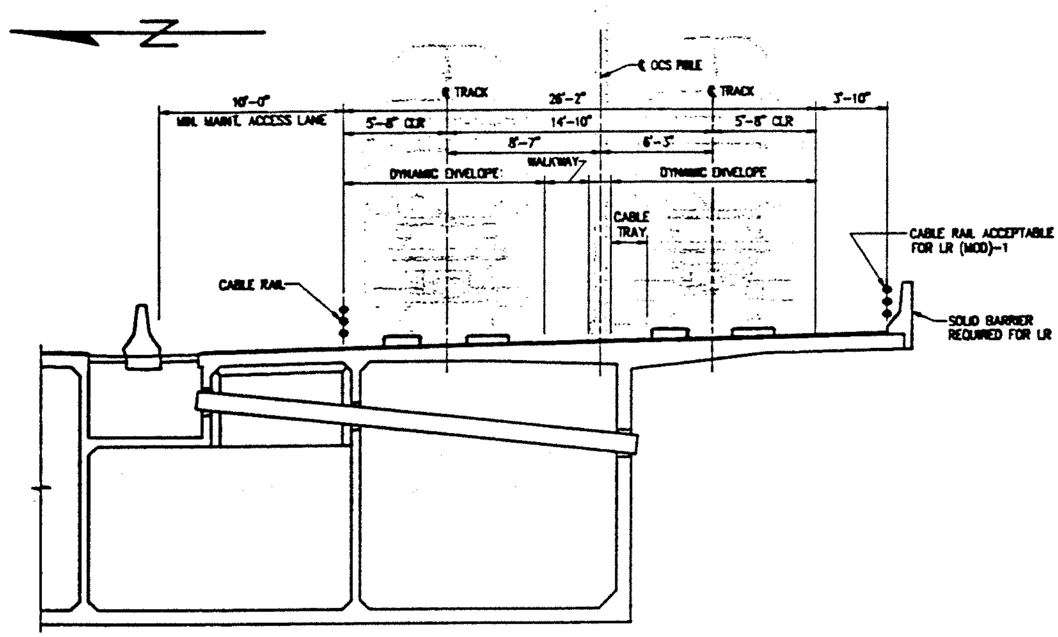


ALTERNATIVE BR-1

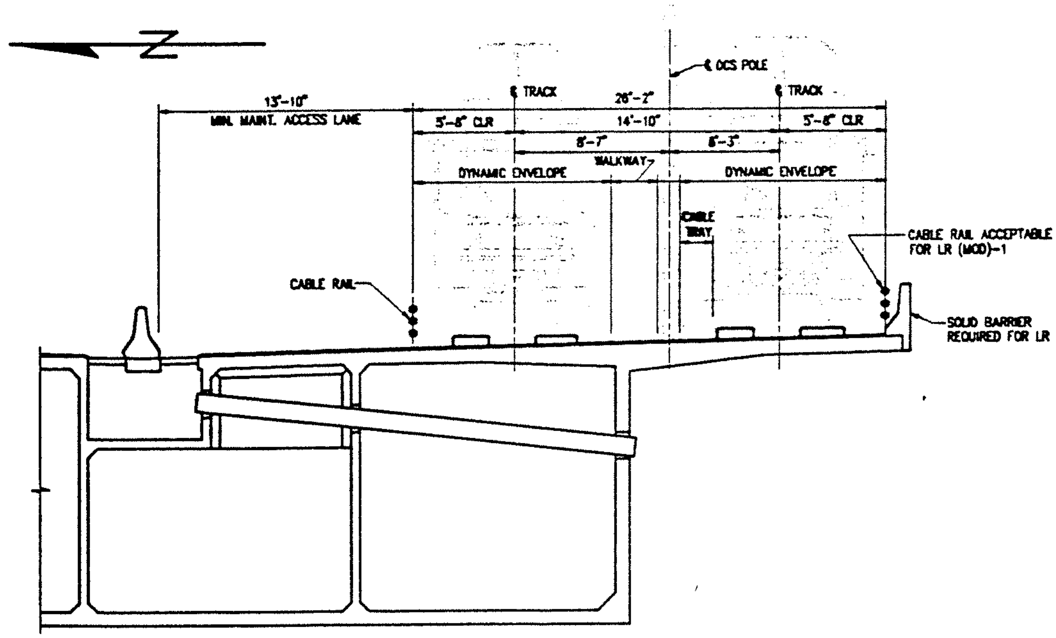


ALTERNATIVE BR-2

FIGURE 2
BR CONFIGURATIONS
(PARTIAL SECTION AT PONTOON DECK)

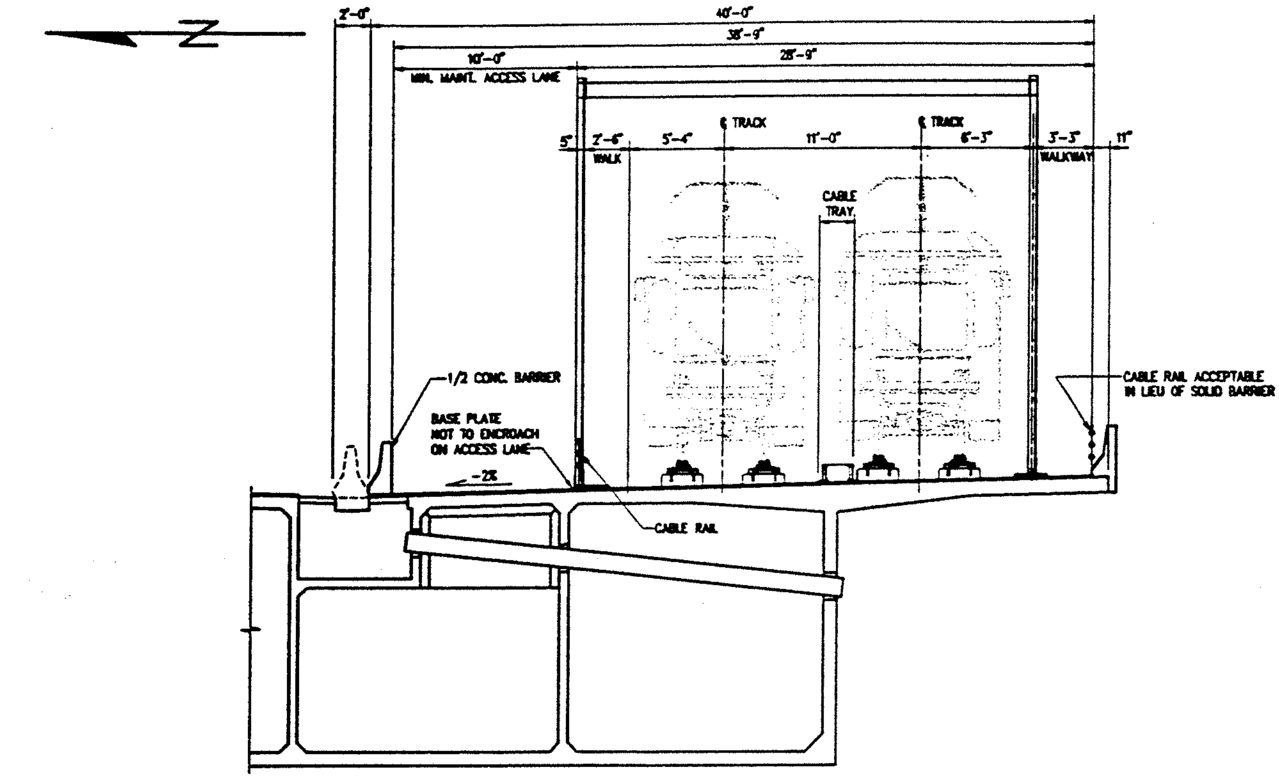


ALTERNATIVE LR-1 & LR (MOD)-1

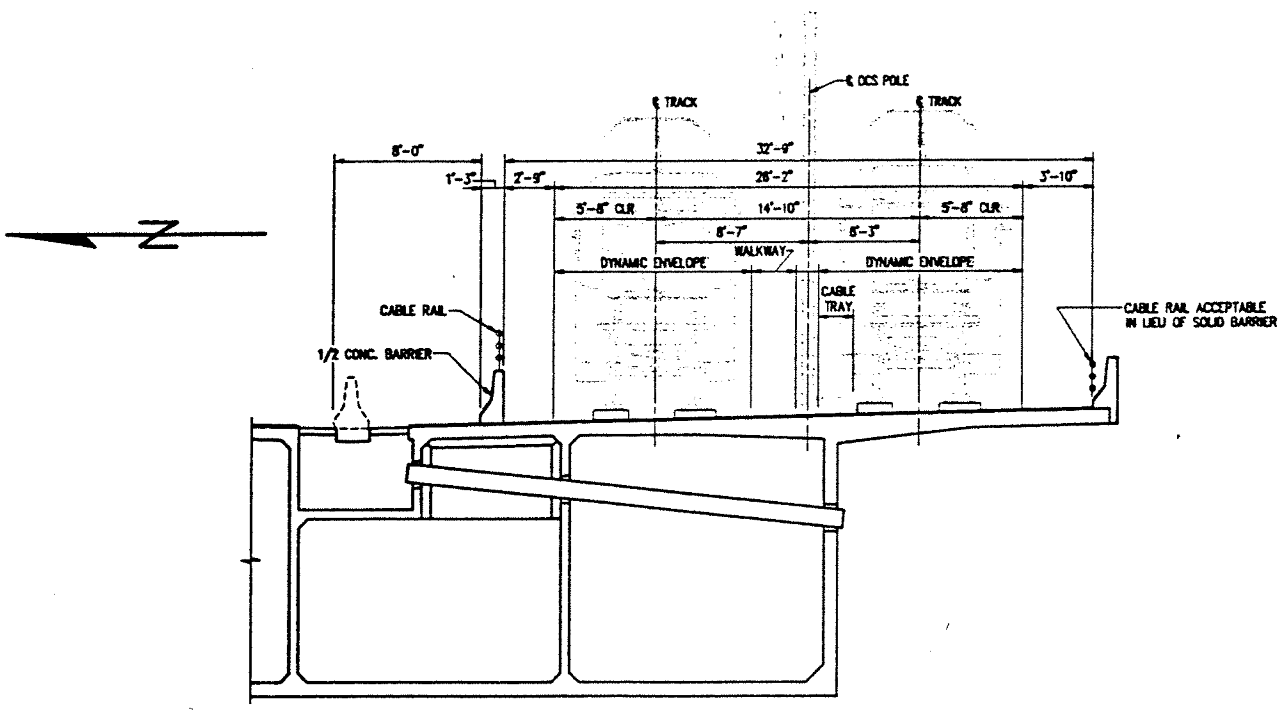


ALTERNATIVE LR-2 & LR (MOD)-2

FIGURE 3
LR & LR (MOD) CONFIGURATIONS
(PARTIAL SECTION AT PONTOON DECK)



ALTERNATIVE LR (MOD) - 3



ALTERNATIVE LR (MOD) - 4

FIGURE 4
LR (MOD) CONFIGURATIONS
(PARTIAL SECTION AT PONTOON DECK)

INTRODUCTION

This study evaluates the structural feasibility of converting the two HOV lanes of the I-90 Homer Hadley Floating Bridge to light rail. The two existing HOV lanes are located on the south 40-foot wide section of the floating bridge. The 40-foot section is divided into a 12-foot wide shoulder to the north, two 12-foot wide HOV lanes, and a 4-foot shoulder to the south (see Figure 1). The section is bounded by a concrete median barrier to the north and a concrete side barrier to the south, both of which are constructed integral with the floating bridge.

Along the majority of the floating bridge, the roadway lies directly on the floating pontoons; however, at each end of the 5,811-foot floating bridge, the roadway rises above the pontoon deck on an elevated superstructure. Figures 5 and 6 illustrate typical cross-sections of this elevated superstructure. The west end extends over 833 lineal feet and consists of two typical cross-sections. The first section is approximately 420 lineal feet with a grade separated superstructure (Figure 5) and the second section (Figure 6) consists of one continuous cross-section of approximately 413 feet in length. The east end extends nearly 126 lineal feet and has a continuous cross-section, as illustrated in Figure 6.

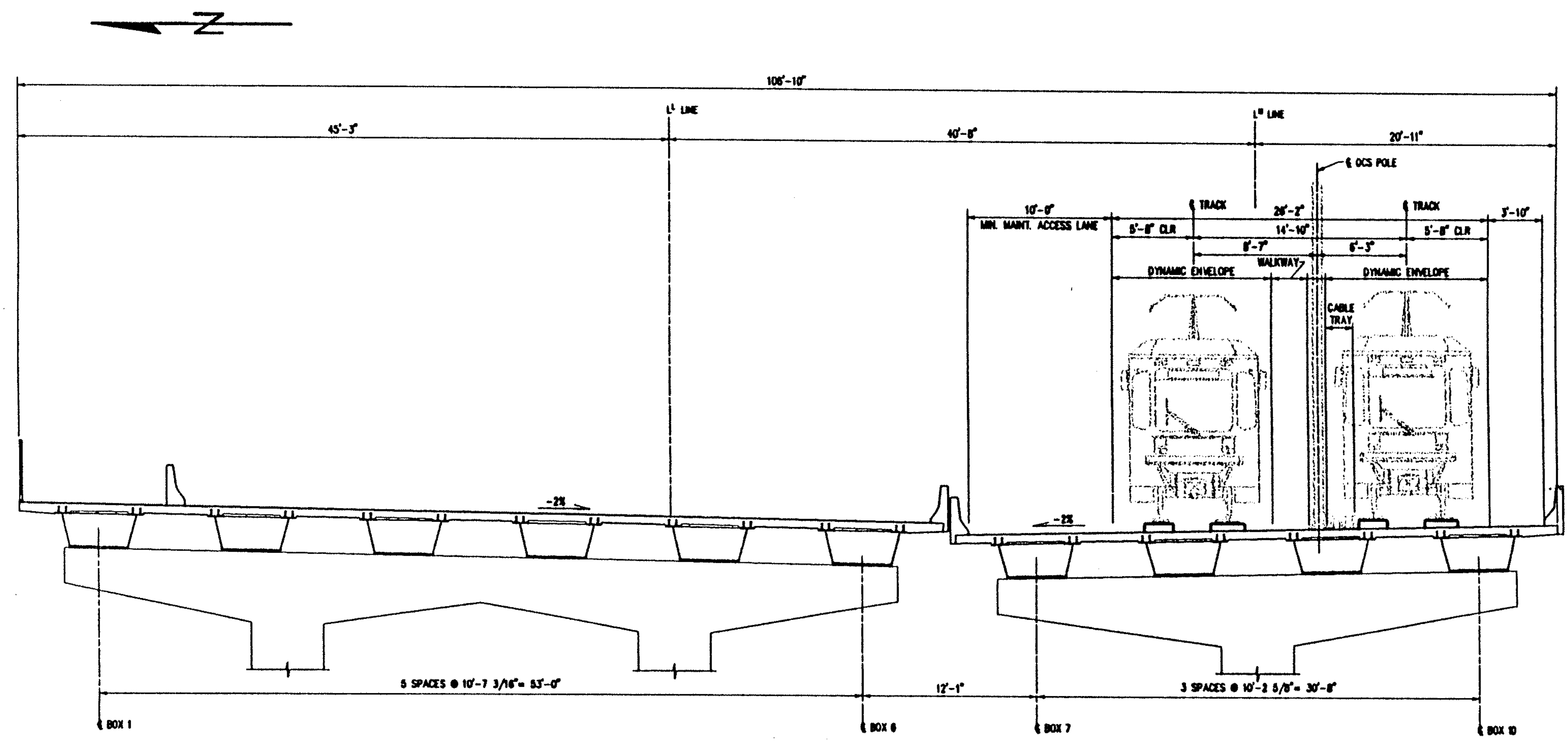


FIGURE 5
TYPICAL SECTION AT GRADE SEPARATED ELEVATED SUPERSTRUCTURE
(ALTERNATIVE LR-1 SHOWN)

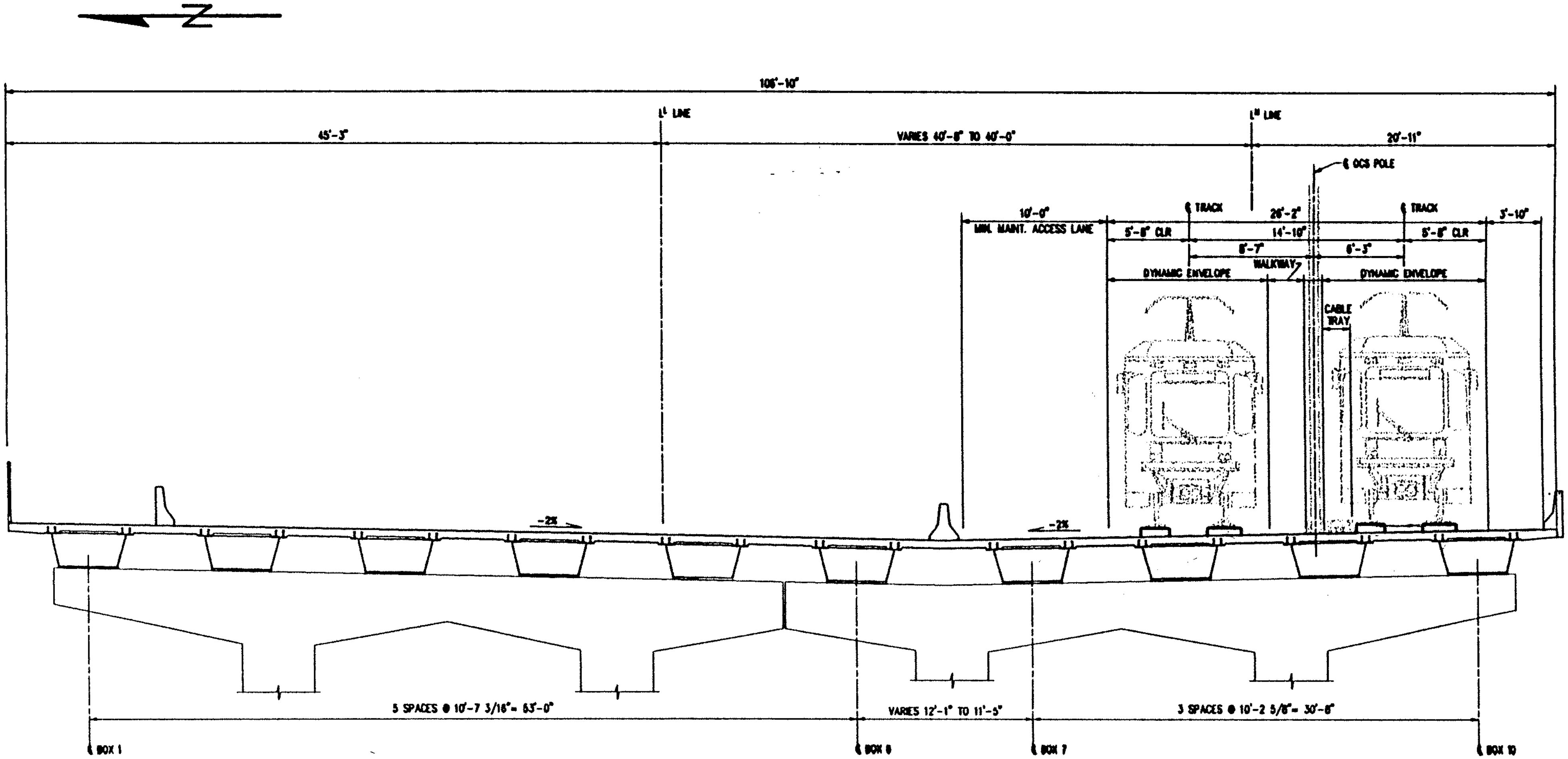


FIGURE 6
TYPICAL SECTION AT ELEVATED SUPERSTRUCTURE
(ALTERNATIVE LR-1 SHOWN)

STUDY CRITERIA

Structural Evaluation Criteria

The following criteria were used during the structural evaluation of all design alternatives:

1. The original design drawings, as noted to reflect "as-built" conditions, were used to define the structure.

2. KPFF completed all structural evaluation work using the original design criteria for the construction of the Homer Hadley (Third Lake Washington) Bridge, as prepared by the WSDOT Bridge & Structures Office in Lacey, Washington. Although KPFF did not perform a refined global analysis of the bridge, the structure, weight, and freeboard modifications resulting from this study are not anticipated to increase global loading demands.

3. The design studies were based upon both working stress and ultimate strength analyses using the allowable stresses and material design strengths provided in the original design criteria. The pontoon deck and supporting structural members were the most affected. A "zero tension" limit was placed on allowable concrete stresses in the pontoon cantilevered deck for working stress analysis.

4. Light rail loading criteria and structural performance criteria were taken from the Sound Transit document, "Light Rail Transit System - Design Criteria Manual," dated December 1999. It should be noted that this loading has been increased from the original LRT train loading for which the Homer Hadley Floating Bridge was designed. Refer to Figure 7 and the table below for a comparison between the two:

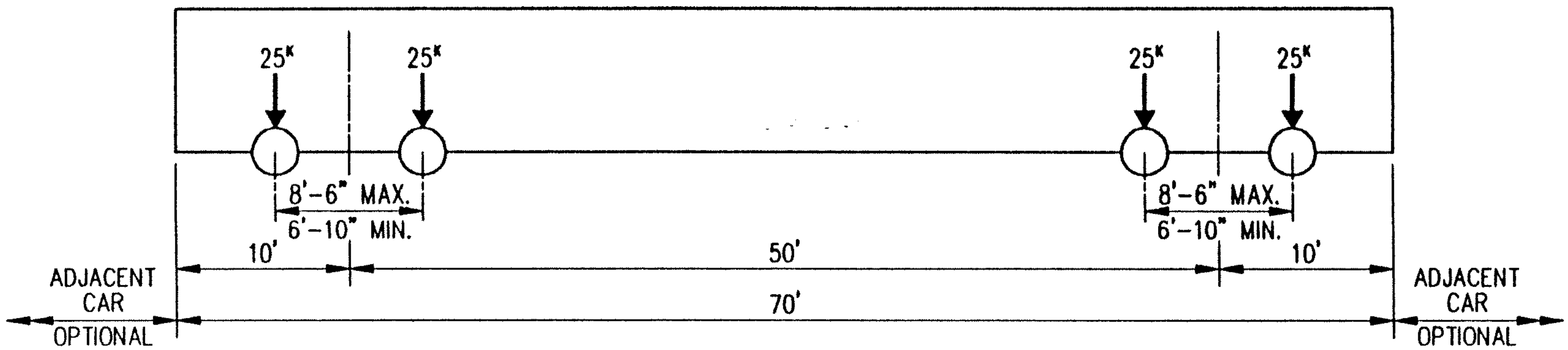
	Original LRT Train Loading (lbs/ft)	*Proposed New LRT (mod) Train Loading (lbs/ft)*	*Percent Increase*
Added LRT Dead Load per Track	67	460	587.0
Uniform LRT Live Load per Track	1,429	1,607	12.5

5. Median barrier lateral loads were in accordance with AASHTO Standards.

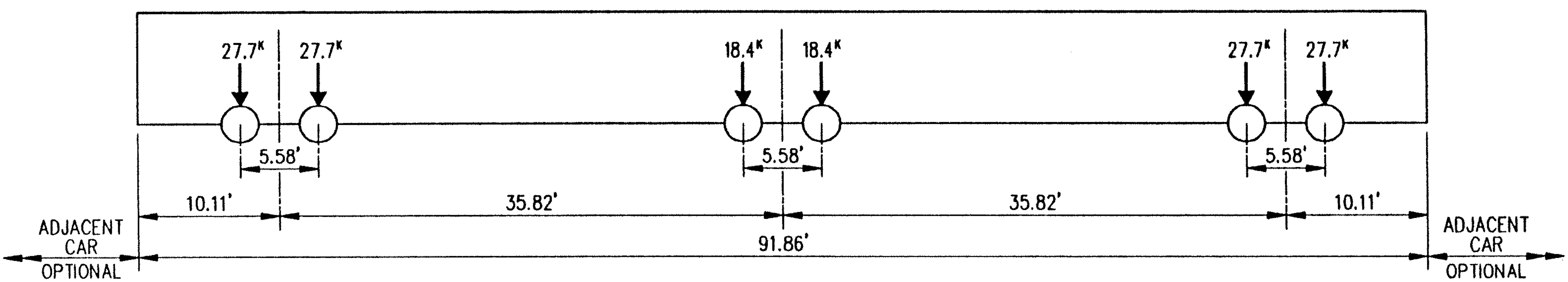
6. Vertical dead loads were based upon the following unit weights:

   a. Concrete: 160 pcf reinforced
   b. Steel: 490 pcf
   c. Deck Overlay: 150 pcf

7. Any penetrations in the top deck must be completed in a manner that does not damage the existing post-tensioning tendons. Replacement or repair of any damaged reinforcing steel must be completed to mitigate loss of load-carrying capacity.



ORIGINAL LRT VEHICLE LIVE LOADING



PROPOSED NEW LRT VEHICLE LIVE LOADING

NOTE: LOADING SHOWN ARE AXIAL LOADS.

FIGURE 7
COMPARISON OF ORIGINAL AND PROPOSED NEW LRT VEHICLE LIVE LOADING

Maintenance, Operation, and Inspection Criteria

In addition to focusing on the structural issues per se, KPFF also met with the WSDOT Floating Bridge Maintenance Office staff on February 13, 2001, to discuss the planned bridge modifications, and to solicit their input regarding potential impacts on bridge maintenance and operations. The following criteria was developed for this study:

1. WSDOT Maintenance personnel must be able to access the bridge manholes and drainage grates from a vehicle at any time without impacting the traveling public. A minimum lane width of 10'-0" is required to accomplish this.

2. A physical barrier between the LRT system and WSDOT maintenance personnel should be provided. This barrier could be in the form of a lightweight cable railing.

Weight and Balance Criteria

The draft (hence freeboard) of the bridge is an important parameter not only for bridge operations and safety, but also for maintenance considerations, such as anchor cable replacement, and for the watertight integrity of the anchor galleries. Also, radical increases in draft will affect the dynamic response of the bridge to wind and wave loading, and should be avoided even on a temporary basis. These issues were recognized to be critical for this study and it was necessary to formulate an approach to controlling the draft (freeboard) impact of each design alternative. The WSDOT Bridge & Structures Office has established the following criteria for this study:

1. The floating bridge is to remain in trim following the implementation of any design alternative. This implies that should any weight change occur which causes the bridge to list, appropriate trim ballast must be added to compensate for the out-of-balance condition to "relevel" the bridge. This is an important concept when considering roadway deck drainage considerations. Any trim ballast added must be included in the overall weight analysis for freeboard loss.

2. All loss of freeboard which may occur during construction is considered as temporary and will be mitigated to a final zero net freeboard loss.

3. During implementation of any design alternative, the bridge will gain weight (therefore, draft) for a period of time before each imposed loading can be mitigated, as described in Item 2 above. Therefore, a limit was placed on any temporary draft increase. This is necessary because of the requirement to prevent anchor cable contact between cables anchoring the Homer Hadley Bridge and the Lacey V. Morrow Bridge. This limit was established as 3 inches.

4. Calculations performed for the purpose of weight mitigation should conservatively use a unit weight for unreinforced concrete removal of 145 pcf.

Drainage Criteria

The existing concrete median barrier is located on the bridge roadway spanning over drain catch basins located in the typical pontoon top deck. There are two catch basins in each typical pontoon located approximately 186 feet apart. The top of each catch basin contains two drain grates, one on each side of the concrete median barrier. The catch basins collect debris, which must be removed periodically. Water in the catch basins drains into the lagoon between the two floating bridges (see Figure 1). Therefore, special attention must be given to the drainage aspects of the bridge for any proposed light rail addition.

Construction Criteria

Any lane closure of the general purpose lanes are to be limited to the hours of 9:00 pm to 5:00 am (nighttime).

DESCRIPTION OF STUDY ALTERNATIVES

Converting the existing HOV lanes to light rail requires the evaluation of rail system dead load and location. The dead load of the rail system will reduce the bridge freeboard and, as the rail system is located further from the center of buoyancy of the bridge, its dead load causes the bridge to lose additional freeboard and list. Since any bridge list must be leveled or trimmed with offsetting ballast, the added ballast necessary to trim the bridge further reduces the freeboard. As a result of this, several rail systems, BR, LR, and LR (mod) were evaluated. The characteristics of these systems are described in the table below:

Rail System Designation	*Rail System Description*
BR	The "basic rail" system consists of the typical superimposed dead loading for the two-track Sound Transit LRT, with a loading per route foot of 1,470 pounds.
LR	The "light rail" system consists of a minimum superimposed dead loading for the two-track Sound Transit LRT, with a loading per route foot of 800 pounds. The system was weight optimized by reducing the concrete plinth weights and eliminating the restraining rails.
LR (mod)	As the project progressed, it became clear that it would be necessary to remove the existing south concrete side barrier in order to meet the project criteria. Therefore, the LR scenario above had to be revisited and revised to include two restraining rails to preclude possibilities of derailment. These added safety features result in a new lower bound LRT superimposed dead load, LR (mod), with a loading per route foot of 920 pounds.

The light rail systems were provided to KPFF from Puget Sound Transit Consultants (PSTC) for the purpose of accomplishing this study. Copies of information provided by PSTC are located in Appendix A.

All rail system locations are located eccentric to the centerline of the bridge; consequently, they all will result in bridge freeboard loss due to placement of trim ballast. Four track locations/configurations were developed for the study in order to capture a range of impacts to the bridge. These are discussed in the table below:

Location/Configuration	*Description*
1	Location 1 positions the LRT tracks as close as possible to the concrete median barrier within the existing 40'-0" wide designated HOV lanes of the bridge, while still providing the minimum 10'-0" maintenance access lane.
2	Location 2 positions the LRT tracks as far as possible to the south within the existing designated HOV lanes of the bridge.
3	Location 3, which was included at a late stage of the study, is similar to Location 1 with respect to the position of the exterior outboard LRT track on the south cantilever; however, the remainder of the configuration was significantly revised to accommodate a 2'-0" median barrier movement to the south. The medium barrier movement is associated with a preferred westbound lane addition configuration from the westbound lane addition study. Other modifications to the configuration include the relocation of the walkway and inboard LRT track, as well as modification for the OCS pole system.
4	Location 4, which was also included at a late stage in the study, is identical to Location 1, but with the median barrier relocated 8'-0" to the south and the maintenance access road separated entirely from the LRT operational area.

For the purpose of this study, eight separate combinations of rail types, locations and configurations were considered, and are shown in the table below. As the study progressed, it became clear that the LR (mod) system had significant advantages over the BR and LR systems; therefore, it was the only rail system type which was combined with all the locations and configurations.

Rail System	*Location/Configuration*	*Design Combination*	*Figure No.*
BR	1	BR-1	2
BR	2	BR-2	2
LR	1	LR-1	3
LR	2	LR-2	3
LR (mod)	1	LR (mod) 1	3
LR (mod)	2	LR (mod) 2	3
LR (mod)	3	LR (mod) 3	4
LR (mod)	4	LR (mod) 4	4

HYDROSTATIC ANALYSIS

Dead Load Analysis

Hydrostatic analyses were performed on the floating bridge to determine the loss of bridge freeboard (height above waterline) due to the location of the different rail configurations. Freeboard loss was based on the new rail dead loads and corresponding ballast required to trim the bridge back to a level condition. Trim ballast was assumed to be gravel and was placed in the center of the northernmost cells along the entire length of the floating bridge. The results of the study are shown in the table below:

Case	*Required Ballast depth (feet)*	*Loss of Freeboard (inches)*
BR-1	1.17	8.26
BR-2	1.30	8.76
LR-1	0.64	4.54
LR-2	0.71	4.81
LR (mod) 1	0.74	5.20
LR (mod) 2	0.82	5.51
LR (mod) 3	0.78	5.18
LR (mod) 4	0.79	5.24

As can be seen from the above table, the loss of freeboard was more sensitive to rail system type rather than rail location.

Freeboard Loss Mitigation

In order to meet the structural evaluation criteria, the loss of freeboard must be mitigated. Generally, the best means to mitigate freeboard loss is to remove dead load from the bridge. As this means becomes exhausted, an alternative and less desirable approach is to provide auxiliary buoyancy. Weight reduction options and their performance are shown in the table below. A brief description of each option follows.

Mitigation Type	*Description*	*Mitigation Performance (inches)*	*Mitigation Costs ($)*
M1	Lightweight Concrete Side Barrier	0.36	$2,407,000
M2	Lightweight Concrete Median Barrier	0.21	$2,677,000
M3	Steel Side Barrier	1.42	$2,675,000
M4	Steel Median Barrier	0.90	$2,975,000
M5	Cable Railing	2.45	$2,000,000
M6	Remove Existing Ballast	0.83	$ 250,000
M7	Remove 0.5-Inch of Overlay	1.32	$1,380,000
M8	Remove 0.5-Inch of Overlay - LR (mod) 3 Only	1.30	$1,340,000
M9	Remove 0.5-Inch of Overlay - LR (mod) 4 Only	1.13	$1,100,000
M10	One-Half Steel Median Barrier - LR (mod) 3 Only	0.56	*
M11	One-Half Steel Median Barrier - LR (mod) 4 Only	0.62	*
M12	Remove1-Inch of Overlay and Build-Back 0.25-Inch of Polymer Concrete Overlay	2.00	$5,050,000
M13	Remove 1-Inch of Overlay - LR (mod) 3 Only and Build-Back 0.25-Inch of Polymer Concrete Overlay	1.94	$4,890,000
M14	Remove 1-Inch of Overlay - LR (mod) 4 Only and Build-Back 0.25-Inch of Polymer Concrete Overlay	1.69	$4,040,000
M15	Lightweight One-Half Median Barrier - LR (mod)- 4 Only	0.15	*

* *These costs should be carried within the westbound lane expansion budget.*

Discussion of Mitigation Options

- M1 - Lightweight Concrete Side Barrier

  This option proposes to replace the existing south concrete side barrier on the south side of the bridge, with a similar shaped barrier, but constructed from a lighter weight concrete (with a density of 125 pounds/cubic foot). The net effect results in a 0.36- inch increase in freeboard.

- M2 - Lightweight Concrete Median Barrier

  Similar to M1, this option proposes to replace the existing concrete median barrier with a similar shaped barrier constructed from lightweight concrete (with a density of 125 pounds/cubic foot). The net effect results in a 0.21-inch increase in freeboard.

- M3 - Steel Side Barrier Rail

  It is proposed to replace the existing concrete side barrier on the south side of the bridge with the steel side barrier in Figure 8. By replacing this concrete side barrier with the steel alternative, it is possible to reduce this loading on the outside edge of the cantilever deck to 160 pounds/linear foot. This results in a significant weight saving and a freeboard increase of 1.42 inches.

- M4 - Steel Median Barrier

  Similar to M3, this option proposes to replace the existing concrete median barrier with the steel median barrier in Figure 9. By replacing this concrete median barrier with the steel alternative, it is possible to reduce this loading to 170 pounds/linear foot. This results in a 0.90-inch increase in freeboard.

- M5 - Cable Railing

  As the proposal is to replace HOV traffic with dedicated light rail transit, a south concrete or steel side barrier could be considered unnecessary, as the rail system has its own dedicated guardrail to protect the light rail carriages from derailing and leaving the track alignment. A much lighter, simple cable railing could be used as a replacement for the existing concrete side barrier. This would serve as a safety railing for maintenance personnel on both sides of the LRT. This proposal will reduce the uniform loading at the edge of the pontoon from a conservative 360 pounds/linear foot for the existing concrete side barrier to 15 pounds/linear foot for the cable rail. This implementation would result in a 2.45-inch increase in freeboard.

- M6 - Remove Existing Ballast

  Every pontoon has some amount of gravel ballast in it. The ballast was originally installed to align the ends of the pontoons to connect them during construction. This mitigation alternative is based on removing ballast from each pontoon based on the pontoon with the least amount of existing ballast. A review of WSDOT inspection records indicate that Pontoon H is the pontoon with the least amount of ballast. It has 14 inches of gravel ballast in one 33' x 14' cell on the south side of the bridge. The ballast density is 104 pounds per cubic foot as measured by WSDOT. The net effect (reduction in actual ballast weight combined with the reduction in associated ballast weight on the north side) results in a 0.83-inch increase in freeboard.

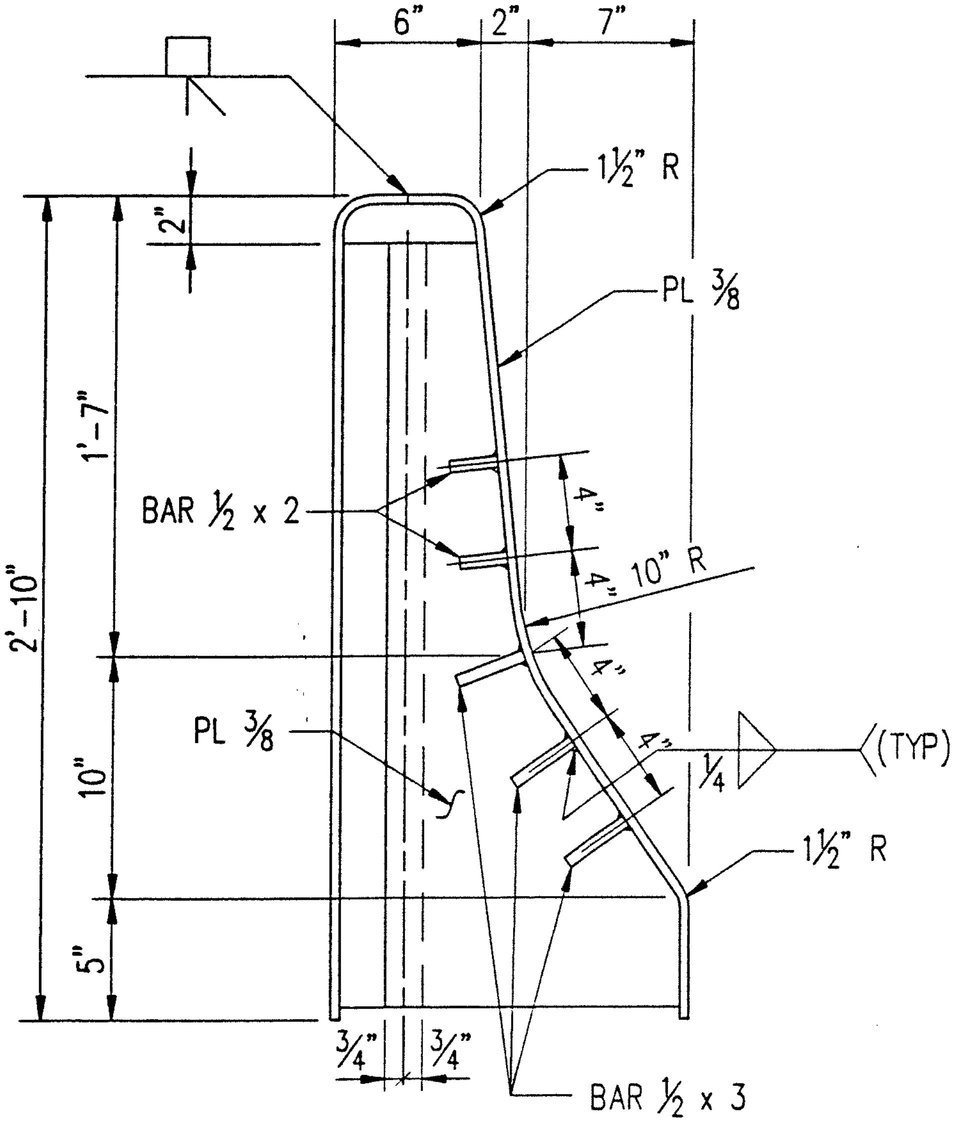


FIGURE 8
WEIGHT MITIGATION M3
STEEL SIDE BARRIER

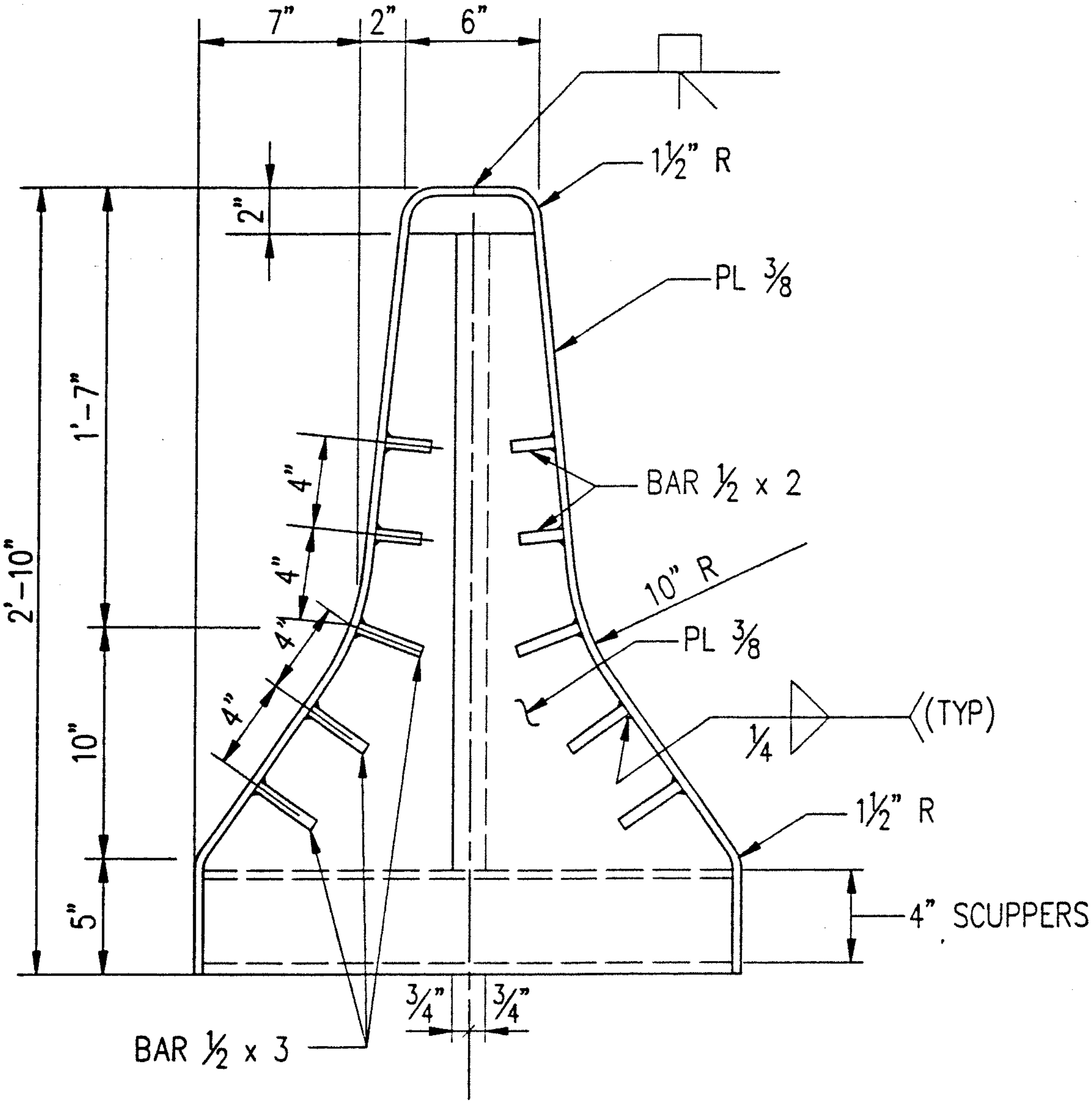


FIGURE 9
WEIGHT MITIGATION M4
STEEL MEDIAN BARRIER

- M7 - Remove 0.5-Inch of Overlay

  It is proposed to remove 1/2-inch of the existing overlay from the 40-foot wide dedicated HOV lanes on the south side of the bridge before implementation of any dedicated LRT track work. The top 1/2-inch of overlay is used as a wearing surface on the deck. Since there will no longer be heavy traffic in this area, the wearing surface would no longer be required. It has been assumed that the weight density of the overlay is 150 pounds/cubic foot. The net effect results in a 1.32-inch increase in freeboard.

- M8 - Remove 0.5-Inch of Overlay - LR (mod) 3 Only

  Similar to M7, except the available envelope of the HOV lanes is reduced from 40'-0" to 38'-9". Again, this option proposes to remove 1/2-inch of the existing overlay before implementation of any dedicated LRT track work. The net effect results in a 1.30-inch increase in freeboard (similar to M7).

- M9 - Remove 0.5-Inch of Overlay - LR (mod) 4 Only

  Similar to M7 and M8, except the available envelope of the HOV lanes is reduced to 32'-0". Again, this option proposes to remove 1/2-inch of the existing overlay before implementation of any dedicated LRT track work. The net effect results in a 1.13-inch increase in freeboard.

- M10 - One-Half Steel Median Barrier - LR (mod) 3 Only

  This option proposes to replace the existing concrete median barrier rail with a steel side barrier (illustrated in Figure 8). This new barrier configuration shall be positioned so that the toe of the barrier is a total of 2'-0" further to the south than the current concrete median barrier location (see LR (mod) 3 configuration). By replacing this concrete median barrier with the steel alternative, it is possible to reduce this loading to 160 pounds/linear foot. This results in a 0.56-inch increase in freeboard.

- M11 - One-Half Steel Median Barrier - LR (mod) 4 Only

  This option proposes to replace the existing concrete barrier with the steel side barrier in Figure 8. The position of this barrier is 8'-0" to the south of the existing concrete median barrier location. By replacing the concrete median barrier with this steel alternative, it is possible to reduce this loading to 167 pounds/linear foot. This results in a 0.62-inch increase in freeboard.

- M12 - Remove 1-Inch of Overlay and Install 0.25-Inch of Polymer Concrete Overlay

  It is proposed to remove 1-inch of the existing overlay from the 40-foot wide dedicated HOV lanes on the south side of the bridge before implementation of any dedicated LRT track work. Then a 0.25-inch of polymer concrete overlay would be installed to create a new surface finish which will help protect the deck reinforcing underneath. This is a more aggressive mitigation proposal than M7 described previously. However, this process, properly executed, will provide a functional overlay and provide reinforcing bar cover for the top deck of the pontoon. It has been assumed that the weight density of the overlay is 150 pounds/cubic foot. The net effect results in a 2.0 inch-inch increase in freeboard.

- M13 - Remove 1-Inch of Overlay - LR (mod) 3 Only and Install 0.25-Inch of Polymer Concrete Overlay

  Similar to M12, except the available envelope of the HOV lanes is reduced from 40'-0" to 38'-9". Again, this option proposes to remove 1-inch of the existing overlay and then to install 0.25-inch of polymer concrete overlay to create a new surface which will help protect the deck reinforcing. The net effect results in a 1.94-inch increase in freeboard.

- M14 - Remove 1-Inch of Overlay - LR (mod) 4 Only and Install 0.25-Inch of Polymer Concrete Overlay

  Similar to M12 and M13, except the available envelope of the HOV lanes is reduced to 32'-0". Again, this option proposes to remove 1-inch of the existing overlay and then to install 0.25-inch of polymer concrete overlay to create a new surface which will help protect the deck reinforcing. The net effect results in a 1.69-inch increase in freeboard.

- M15 - Lightweight One-Half Median Barrier - LR (mod) 4 Only

  Similar to M11, except it is proposed to replace the concrete median barrier of the LR (mod) 4 scenario with a similar lightweight concrete option. The net effect results in a 0.15-inch increase in freeboard.

Required Mitigation Modifications

Based on the above mitigation alternative performances, it is apparent that the BR rail system alternatives cannot be fully mitigated without auxiliary buoyancy attached to the pontoon. On the other hand, the LR and LR (mod) system alternatives can be fully mitigated. The following table summarizes this result:

Rail Alternative	*Preferred Mitigation Combination*	*Result Required*	*Auxiliary Buoyancy*
BR-1	M4, M5, M6, M12	Partial (6.17" < 8.26")	2.09 Inches
BR-2	M4, M5, M6, M12	Partial (6.17" < 8.76")	2.59 Inches
LR-1	M3, M4, M6, M7	Full (4.50" ≈ 4.54")	None
LR-2	M3, M4, M6, M12	Full (5.14" > 4.80")	None
LR (mod) 1	M5, M6, M12	Full (5.27" > 5.20")	None
LR (mod) 2	M5, M6, M12	Full (5.27" < 5.51")	0.24 Inches (say ok)
LR (mod) 3	M5, M6, M13	Full (5.22" > 5.18")	None
LR (mod) 4	M5, M6, M14, M15	Full (5.12" < 5.24")	0.12 Inches (say ok)

The preferred mitigation combination was developed based on a least cost approach, with the exception that the replacement of concrete barriers with steel barriers was used if no other combination could be developed to achieve the required mitigation. The reluctance to use steel barriers is based on their higher maintenance cost and the large number of drilled holes in the pontoon deck required for connecting the steel barrier.

Live Load Analysis

A hydrostatic analysis of the floating bridge with the LRT live load was accomplished to determine the bridge list and freeboard loss resulting from light rail traffic. A simple 2-dimensional model was developed for the entire floating bridge. The bridge was modeled as a continuous beam on a hydrostatic foundation. The gross section properties of the floating concrete pontoon section were used for the 5,811-foot long bridge. Support springs were based on the floating bridge hydrostatic heave-and-roll resistances. Both LRT Track Locations 1 and 2 were modeled and the following conditions were considered:

LLA-1	Two trains bypassing at midspan of the bridge (Location 1)
LLA-2	Two trains bypassing at midspan of the bridge (Location 2)
LLB-1	Two trains about to bypass at midspan of the bridge (Location 1)
LLB-2	Two trains about to bypass at midspan of the bridge (Location 2)
LLC-1	Two trains bypassing at one end of the bridge (Location 1)
LLC-2	Two trains bypassing at one end of the bridge (Location 2)

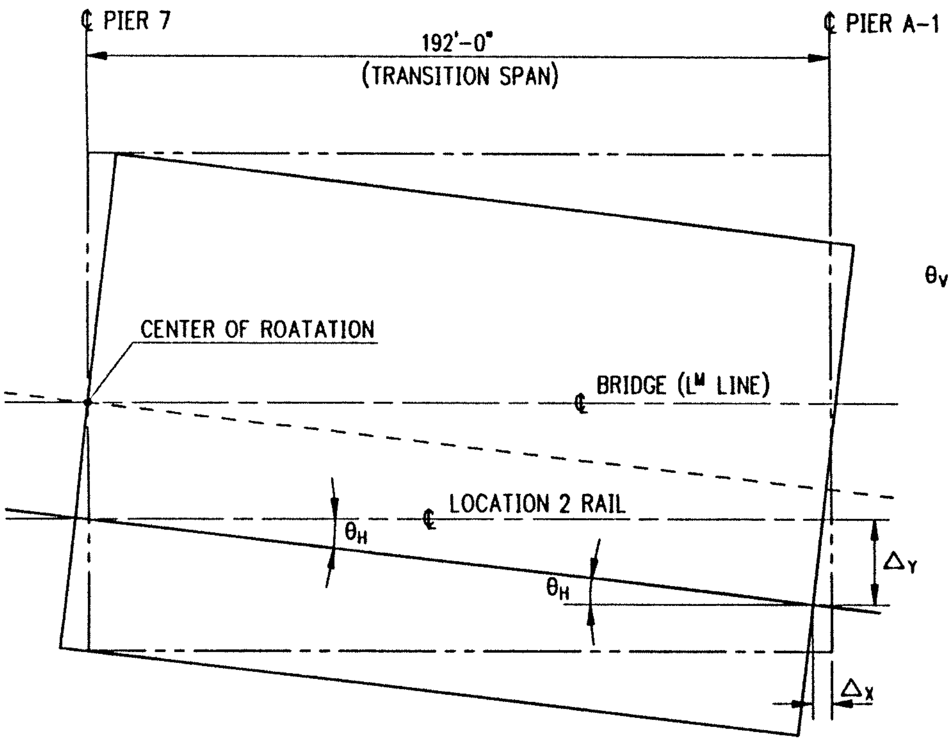
The results of the modeling are shown in Appendix C and are summarized below:

Train Location	*Freeboard Loss at South Side of the Bridge (inches)*	*Bridge List (degrees)*	*Live Load Moment Ratio*	*Live Load Torsion Ratio*
LLA-1	-9.19	0.348	0.46	0.89
LLA-2	-9.61	0.385	0.46	0.98
LLB-1	-7.65	0.327	0.16	0.76
LLB-2	-8.05	0.363	0.16	0.84
LLC-1	-9.66	0.376	0.58	0.85
LLC-2	-10.00	0.407	0.56	0.92

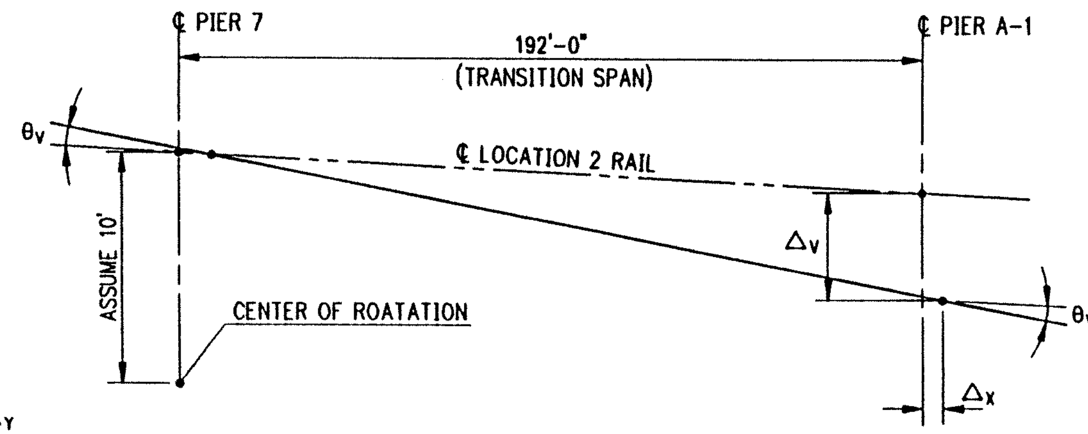
As can be seen from the above results, the freeboard loss on the bridge due to live load alone is significant. These deflections do not represent a problem to the bridge since they are transitory in nature, but they must be reviewed by Sound Transit rail designers for conformance to the light rail train tolerances. The live load moment and torsion ratios represent the ratio of 100-year storm moments and torsions to the LRT live load moments and torsions. Based on the above ratios, the LRT live loads moments appear to be within acceptable levels; but torsions are high and need to be checked. A more refined global analysis based on modeling the bridge's hydrodynamic characteristics and geometric nonlinearities will need to be performed in order to verify these results.

Motion analyses were also performed at the transition span expansion joint and are summarized in Figure 10 and the table below:

Type of Motions of the Rail at the Transition Span Expansion Joint	*Original Joint Design Requirements*	*New Motions Due to Rail Live Loading*	*Total Required for Design*
Longitudinal Movement, Δ_x (includes extra movement required for horizontal and vertical rotation)	±24 inches	±0.5 inches	±24.5 inches
Horizontal Rotation, θ_M (rotation of transition span due to transverse displacement at the floating bridge)	±1degree	±0.1 degree	±1.1 degrees
Vertical Rotation, θ_V (rotation of transition span due to its vertical displacement at the floating bridge)	2 degrees (downward)	0.2 degrees (downward)	2.2 degrees (downward)



PLAN
HORIZONTAL RAIL MOVEMENT
AT CENTERLINE PIER A-1



ELEVATION
VERTICAL LRT RAIL MOVEMENT
AT CENTERLINE PIER A-1

FIGURE 10
TYPES OF MOTION OF THE RAIL
AT THE TRANSITION SPAN EXPANSION JOINT

Hydrostatic Analysis Conclusion

KPFF met with WSDOT and Sound Transit on February 22, 2001, to discuss the results of our hydrostatic analysis. Based on this discussion, it was decided to proceed with only the LR and LR (mod) alternatives and abandon the BR system. The reasons for this conclusion are summarized below:

- The BR system requires auxiliary buoyancy. The use of auxiliary buoyancy on the floating bridge will be extremely expensive to build and maintain, and will have negative impacts on the typical maintenance operations such as anchor cable replacement.
- Auxiliary buoyancy may increase hydrodynamic loads on the bridge and cable anchors.
- Attaching auxiliary buoyancy to the floating bridge pontoons will likely require construction methods which breach the hull of the floating bridge.
- Based on the live load analysis of the bridge, there were significant deflections (approximately 10 inches) due to the light rail vehicle loading. These deflections reinforce the need to maintain a strict criteria for full mitigation of freeboard loss due to installation of the LRT system. Waiving the requirement for full mitigation of the BR system is not acceptable.
- Auxiliary buoyancy should be considered only as a last resort.

STRUCTURAL ANALYSIS

Floating Pontoon

This analysis investigated the service load stress levels and the ultimate capacity of the top deck of the pontoons of the Homer Hadley Floating Bridge due to the placement of two light rail track systems on the existing HOV lanes (which are situated on the south side of the bridge).

The typical floating pontoons (Pontoons B to Q) consist of 60 cell concrete box sections, each 75' wide by 353'-10" in length. The pontoons are bolted together end-to-end to form the continuous floating bridge. Figure 1 illustrates a cross-section of one typical pontoon.

As previously outlined in the description of study alternatives, various combinations of rail systems and locations were investigated. Refer to Figures 2 through 4 for a comparison of the cross-sections associated with each of the proposed schemes.

A scenario which removes the concrete side barrier, thus reducing the superimposed dead load on the cantilever, was also considered.

It was also necessary to investigate the deck capacity subject to a concentrated loading from the proposed overhead catenary system (OCS) poles. These poles are to be installed at 180 feet centers and provide the power to the LRT trains.

- Design Methodology

  This design study assessed the service load stresses experienced by the top deck of the pontoon as it was subjected to the addition of the proposed LRT scenarios. For service load stress levels a "zero tension" limit was placed on the allowable concrete stresses.

  Additionally, the ultimate flexural and shear stresses of the deck resulting from LRT loadings was examined to ensure that all critical locations (primarily the cantilevered deck and adjoining interior span) had sufficient capacity at the ultimate limit state.

- Stress and Strength Check

  The concrete stresses in the top deck of the pontoon were investigated in the vicinity of the cantilever overhang on the south side of the floating bridge. A simplified 2-dimensional structural analysis computer model was created for a typical cross-section of the pontoons for the computer analysis of all the LRT loading options (refer to Figures 2 through 4). All loads and section properties were applied and distributed to predict stresses within the structure.

- Initial Analysis of All Options

All concrete compressive stresses were found to be within allowable limits. Tensile stresses were also calculated for the various design combinations. The only scenarios which did not put the top of the deck in the vicinity of the cantilever into tension, thus adhering to the "zero tension limit," was LR (mod) rail types in Locations 1, 3, and 4 without the south concrete side barrier. It should be noted that the LR systems could not be considered without a solid south side barrier since they do not incorporate restraining rails. For the other load cases, net tension stresses are developed. Refer to Table 1 for a summary of this stress check.

The cantilever overhang at the exterior wall was also investigated for ultimate strength of the prestressed post-tensioned concrete deck. It was determined that the only design combinations, which could be implemented without local strengthening of the bridge, were LR-1, LR (mod) (Locations 1, 3, and 4), and BR-1, with and without the south concrete side barrier removed for weight mitigation. Refer to Table 2 for the demand/capacity ratios for flexure and shear of the concrete deck as determined by this investigation.

The deck was also investigated for loading from the OCS power poles. The resulting stresses in the deck were checked and found to be satisfactory for the LR-1, LR mod and BR-1 loading combinations, which are the most critical pole locations for a strength check at a support. Localized punching shear capacity was also determined to be satisfactory.

- Initial Conclusions

As mentioned previously, KPFF met with WSDOT and Sound Transit on February 22, 2001, to discuss the preliminary results of the study at that time. Based on the above results of the stress and strength check at the top deck of the pontoon, it was decided to proceed with Locations 1, 3, and 4, with the south concrete side barrier removed and replaced with cable railing, as the only feasible configurations to pursue. This also resulted in the elimination of the LR system since it could not be considered without a south concrete side barrier.

The hydrostatic analysis resulted in the elimination of the BR system, and considering the above, it is clear that the field of alternatives which do not require auxiliary buoyancy or floating bridge pontoon strengthening are reduced to LR (mod) 1, 3, and 4. For this reason, these three alternatives were identified as the preferred alternatives.

- Refined Analysis

  Using the preferred alternatives (i.e., LR (mod) 1, 2, and 3, all without south concrete side barriers), all critical locations in the top deck of the pontoon were rechecked using a refined analysis. A finite element analysis was utilized because it aided in the accurate evaluation of the 2-way bending response of the top deck of the pontoon. This analysis was also useful in verifying the results obtained from the previously mentioned simplified 2-dimension SAP analysis. The "zero tension" limit was checked and the top deck was verified to meet all design criteria. Refer to Table 3 for a summary of these results.

  Similarly, the flexural strength of the top deck was checked for 1-way bending at the cantilever and 2-way bending over the interior cells. All reinforcement was determined to be adequate for the preferred load cases and LR (mod) 1, 3, and 4. Refer to Table 4 for a summary of these results.

FLOATING PONTOON SERVICE LOAD STRESS CHECK OF TOP DECK AT THE EXTERIOR WALL												
	CANTILEVER SLAB AT EXTERIOR WALL						INTERIOR SLAB AT EXTERIOR WALL					
	Concrete Stress Bottom (Compression)			Concrete Stress Top (Tension)			Concrete Stress Bottom (Compression)			Concrete Stress Top (Tension)		
Design Combination	**Demand (ksi)**	**Allowable (ksi)**	**Check (0 < Stress < 2.8)**	**Demand (ksi)**	**Allowable (ksi)**	**Check (0 < Stress < 2.8)**	**Demand (ksi)**	**Allowable (ksi)**	**Check (0 < Stress < 2.8)**	**Demand (ksi)**	**Allowable (ksi)**	**Check (0 < Stress < 2.8)**
BR-1 With Barrier	0.709	2.800	OK	-0.057	0.000	NG	1.016	2.800	OK	-0.233	0.000	NG
BR-2 With Barrier	1.219	2.800	OK	-0.567	0.000	NG	1.614	2.800	OK	-0.831	0.000	NG
LR-1 With Barrier LR (mods) 1,3,4 With Barrier	0.686	2.800	OK	-0.034	0.000	NG	0.985	2.800	OK	-0.202	0.000	NG
LR-2 With Barrier LR (mods)-2	1.172	2.800	OK	-0.520	0.000	NG	1.556	2.800	OK	-0.773	0.000	NG
BR-1 No Barrier	0.570	2.800	OK	0.082	0.000	OK	0.864	2.800	OK	-0.081	0.000	NG
BR-2 No Barrier	1.0801	2.800	OK	-0.428	0.000	NG	1.461	2.800	OK	-0.678	0.000	NG
LR (mods) 1,3,4 No Barrier	0.550	2.800	OK	0.098	0.000	OK	0.779	2.800	OK	0.007	0.000	OK
LR (mods)-2	1.033	2.800	OK	-0.381	0.000	NG	1.403	2.800	OK	-0.620	0.000	NG

Note:

\+ *Compression*

\- *Tension*

Table 1

FLEXURAL STRENGTH AND SHEAR CHECK OF CANTILEVER AT THE EXTERIOR WALL

FLEXURAL STRENGTH CHECK OF TOP DECK

		BR-1		BR-2		LR-1	LR (mod) 1, 3 & 4	LR-2	LR (mod) 2
Unfactored moment @ section due to:	***Units***	***w/Barrier***	***No Barrier***	***w/Barrier***	***No Barrier***	***w/Barrier***	***No Barrier***	***w/Barrier***	***No Barrier***
Cantilever Dead Load	k.in/ft	185	185	185	185	185	185	185	185
LRT Dead Load	k.in/ft	148	58	183	93	135	43	152	62
LRT Live Load	k.in/ft	356	356	652	652	356	356	652	652
Total Factored Moment @ Section	k.in/ft	1,205	1,088	1,893	1,776	1,189	1,069	1,853	1,736
Design Flexural Strength	k.in/ft	1,661	1,661	1,661	1,661	1,661	1,661	1,661	1,661
Demand/Capacity Ratio		0.73	0.66	1.14	1.07	0.72	0.64	1.12	1.05
Check		OK	OK	NG!!!	NG!!!	OK	OK	NG!!!	NG!!!

SHEAR STRENGTH CHECK OF TOP DECK

		BR-1		BR-2		LR-1	LR (mod) 1, 3 & 4	LR-2	LR (mod) 2
Unfactored shear @ section due to:	***Units***	***w/Barrier***	***No Barrier***	***w/Barrier***	***No Barrier***	***w/Barrier***	***No Barrier***	***w/Barrier***	***No Barrier***
Cantilever Dead Load	k/ft	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35
LRT Dead Load	k/ft	1.37	0.87	1.66	1.16	1.10	0.60	1.26	0.76
LRT Live Load	k/ft	6.45	6.45	6.45	6.45	6.45	6.45	6.45	6.45
Total Factored Moment @ Section	k/ft	18.83	18.18	19.21	18.56	18.48	17.83	18.69	18.04
Design Flexural Strength	k/ft	20.77	22.41	17.45	18.05	20.66	22.38	17.32	17.94
Demand/Capacity Ratio		0.91	0.81	1.20	1.03	0.89	0.80	1.08	1.01
Check		OK	OK	NG!!!	NG!!!	OK	OK	NG!!!	NG!!!

Table 2

STRESS CHECK OF TOP DECK OF FLOATING PONTOON AT CRITICAL LOCATIONS FOR DESIGN COMBINATIONS LR (MOD) - 1, 3, AND 4 (NO BARRIER) BASED ON FINITE ELEMENT ANALYSIS						
CANTILEVER SLAB AT THE EXTERIOR WALL						
Load Case	Concrete Stress Bottom (compression)			Concrete Stress Top (tension)		
	Demand (ksi)	Allowable (ksi)	Check (0 < Stress < 2.8)	Demand (ksi)	Allowable (ksi)	Check (0 < Stress < 2.8)
LR-1 (no barrier) and LR (Mod) 1, 3, and 4 (no barrier)	0.556	2.80	OK	0.092	0.000	OK
TOP DECK AT MIDPOINT OF EXTERIOR CELL						
Load Case	Concrete Stress Bottom (compression)			Concrete Stress Top (tension)		
	Demand (ksi)	Allowable (ksi)	Check (0 < Stress < 2.8)	Demand (ksi)	Allowable (ksi)	Check (0 < Stress < 2.8)
LR-1 (no barrier) and LR (Mod) 1, 3, and 4 (no barrier)	1.018	2.80	OK	0.162	2.80	OK

Note
- \+ Compression
- \- Tension

Table 3

FLEXURAL STRENGTH OF TOP DECK AT CRITICAL LOCATIONS FOR DESIGN COMBINATION LR (MOD) 1, 3, AND 4 (NO BARRIER)				
CAPACITY CHECK OF TRANSVERSE REINFORCING IN TOP DECK OF FLOATING PONTOON				
Location	Demand (k.in/ft)	Capacity (k.in/ft)	DC Ratio	Check
Cantilever Slab at Exterior Wall (negative moment)	1,023	1,686	0.61	OK
Top Deck at Midpoint of Exterior Cell (positive moment)	147	320	0.46	OK
CAPACITY CHECK OF LONGITUDINAL REINFORCING IN TOP DECK OF FLOATING PONTOON				
Location	Demand (k.in/ft)	Capacity (k.in/ft)	DC Ratio	Check
Negative Moment at Transverse Wall of Exterior Cell in Longitudinal Direction	88	102	0.84	OK
Positive Moment at Midspan of Exterior Cell in Longitudinal Direction	69	442	0.16	OK

Table 4

Elevated Superstructure Check

The objective of this portion of the study was to evaluate the structural impacts on the elevated superstructure portion of the Homer Hadley Floating Bridge that result from the operation of the two light rail systems on the existing HOV lanes.

The elevated superstructure of the I-90 Floating Bridge consists of 14 spans, totaling 833'-7" on its west approach and 2 spans, totaling 125'-11" on its east approach. The elevated superstructure configuration at these locations is considerably different than that on a typical floating pontoon. Refer to Figures 5 and 6 for typical sections.

The elevated superstructure consists of a composite concrete/steel structure having a concrete deck and 10 steel box girders. These structures provide the vertical transition from the level pontoon deck level to the grades of the transition spans, and the approach roadways from the east and west.

As previously outlined within the description of study alternatives, various combinations of rail systems and locations were investigated. Refer to Figures 2 through 4 for a comparison of the cross-sections pertaining to each of the proposed schemes.

- Design Methodology

  There are three structural systems for over the elevated superstructure portion of the Homer Hadley Floating Bridge. These consist of simply supported spans (Spans 1W and 14W), 3-span continuous spans (Spans 2W - 4W, Spans 5W - 7W, Spans 8W - 10W, and Spans 11W - 13W), and 2-span continuous spans (Spans 1E and 2E). Each of these structural systems has been investigated and the functional capacity checked for compatibility with the proposed addition of LRT. Table 5 summarizes the results of this investigation.

- Strength Check

  A strength check was performed to investigate the functional capacity of both the steel box girder sections and the associated composite concrete deck of the elevated superstructure. A computer model was run for the three structural systems, and the corresponding positive and negative bending moments resulting from the LRT dead and live loads were calculated.

  The application of LRT live load within the computer models were in accordance with ASSHTO 10.39.2. This article provides for the lateral distribution of live loads for bending moment relating to composite steel box girder sections. This criteria resulted in 1.5 rail system loads being applied to a box girder as an absolute maximum. It was this condition that has been checked using a moving load generator within the computer models.

Applying all project design criteria and the AASHTO LFD Code, the demand/capacity ratios at each critical location of the steel box girders were determined and are summarized in Table 5. It was concluded that all stresses were within acceptable limits and that no retrofit of the girders was necessary to meet strength design criteria.

Similarly, a strength investigation of the reinforced concrete deck subject to the proposed addition of LRT was performed and it was determined that all stresses were within the allowable limits of the AASHTO LFD Code.

- Deflection Check

  In accordance with Section 8.5.4.1B of the Sound Transit Design Criteria Manual, the deflection of longitudinal girders under live load should not exceed 1/1000 of the span length. However, on inspection of the live load deflections obtained from the computer models described above, the proposed LRT live loadings will result in deflections exceeding that allowable in each of the three structural systems. Refer to Table 5 for a comparison between the deflections caused by the LRT live load plus impact to those allowed by the design criteria.

- Vibration Check

  To limit the vibrational amplification due to the dynamic interaction between the superstructure and the proposed light rail vehicle, the first mode of flexural vibration for simple spans should not be less then 2.5 Hz and for continuous spans should not be less than 3 Hz (per the Sound Transit Design Criteria Manual, Section 8.5.4.1 A).

  On inspection of Table 5, which provides the frequency of vibration checks from the computer models for the three structural systems, all first mode frequency vibrations were within acceptable limits.

- Retrofit Proposal

  The addition of LRT live loads to the elevated superstructure of the Homer Hadley Floating Bridge will result in excessive deflections of the composite steel box girders.

  In order to reduce the excessive deflections, it is proposed to attach steel plates to the bottom flange of the box girders. These plates will stiffen the structural systems in a manner to meet all design deflection criteria. Table 6 details the size and quantity of plates, which will be necessary to retrofit each specific portion of the elevated superstructure. A total of approximately 170,608 pounds of additional steel plate will be required.

  Figure 11 illustrates a typical detail for the addition of these strengthening plates, each of which has the same width as the bottom flange of the steel box girders and vary from 3/8-inch to 1/2-inch in thickness. It will be necessary to retrofit 4 of the 10 steel box girders on the south side of the bridge. Typically, the strengthening plates, as detailed within Table 6, are attached to the positive moment regions of the girders, where required.

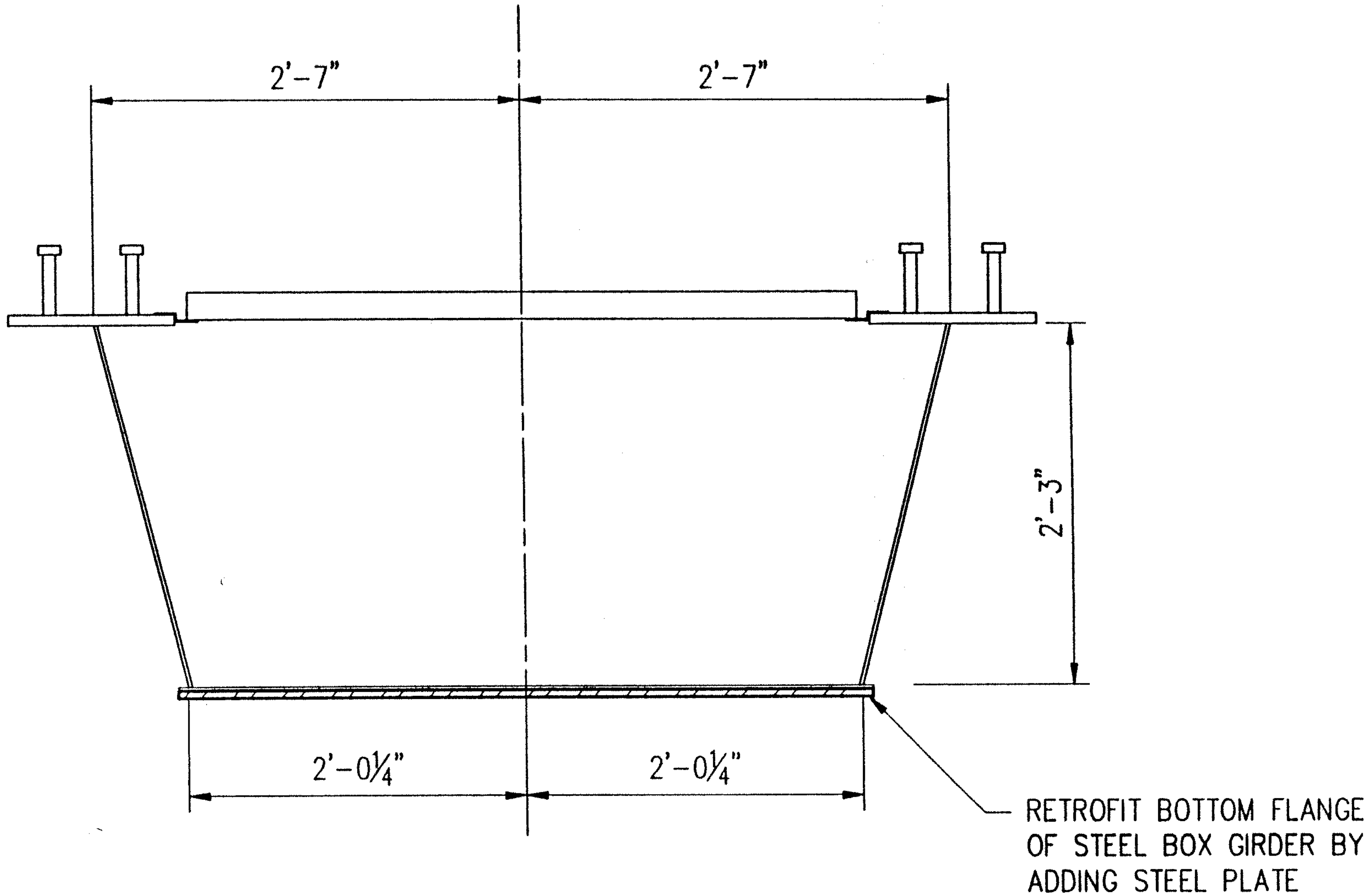


FIGURE 11

TYPICAL GIRDER SECTION

RETROFIT PROPOSAL FOR BOX GIRDERS

AT ELEVATED SUPERSTRUCTURE

It is estimated that approximately 85.3 tons of structural steel plate will be required to retrofit both the east and west approaches of the elevated superstructure of the Homer Hadley Floating Bridge. This additional weight will impact the existing freeboard of the floating bridge. Therefore, an investigation was conducted to quantify the existing ballast within the pontoons directly beneath the elevated superstructures. It was determined that there are sufficient quantities of ballast within the pontoon cells at the proper locations to provide for the ballast removal requirements under Mitigation Option M6 for the LRT dead load, plus the ballast removal requirements for the additional steel plates required on the steel box girders. Mitigation Option M6 is based on the minimum available ballast which is located in a typical pontoon without a superstructure. Reserve ballast exists under the elevated superstructure. It is proposed to mitigate any freeboard loss due to the above retrofit proposal by removing equal amounts of ballast from the pontoons directly under the superstructure which is retrofitted, thus creating a situation which maintains the current freeboard.

RETROFIT COST

Retrofit cost for the superstructure upgrade is summarized below:

Attach Steel Plates Retrofit Cost	$1,000,000
Ballast Removal Cost	50,000
Total	$1,050,000

Structure Identification	***Span***	***Structural System Type***	***Span Lengths***
A	1 and 14W	Simply Supported	66'-11" and 59'-0"
B	1E and 2E	2-Span Continuous	59'-0" and 66'-11"
C	2W - 4W 5W - 7W 8W - 10W 11W - 13 W	3-Span Continuous	59'-0", 59'-0" and 59'-0" 59'-0", 59'-0" and 58'-10" 59'-0", 59'-0" and 59'-0" 59'-0", 59'-0" and 58'-10"

Structure Identification	***STRENGTH CHECK DEMAND/CAPACITY RATIO (<1?)***		
	Positive	***Negative***	***Check***
A	0.74	N/A	OK
B	0.64	0.76	OK
C	0.69	0.86	OK

Structure Identification	***DEFLECTION CHECK DEMAND/CAPACITY RATIO (<1?)***		
	Deflection Due to LRT Live Load Plus Impact	***Allowable Deflection = L/1,000 (inch)***	***Check***
A	0.925	0.72	NG!!!
B	0.8 AND 0.85	0.71 AND 0.73	NG!!!
C	0.81, 0.756 AND 0.81	0.71, 0.71 AND 0.71	NG!!!

Structure Identification	***FREQUENCY OF VIBRATION (FIRST MODE) CHECK***		
	Actual (Hz)	***Allowable (Hz)***	***Check***
A	4.05	2.5	OK
B	3.67	3.0	OK
C	3.57	3.0	OK

Existing Elevated Superstructure Check

Table 5

Span	Retrofit Bottom Flange (by adding)	Steel Quantity/Girder (pounds)	Total Steel Quantity 4 girders (pounds)
1W	2 x PL 0.375" x 50" x 15.5' 1 x PL 0.5" x 50" x 30'	1,978 2,552	7,912 10,208
14W	2 x PL 0.375" x 50" x 15.5' 1 x PL 0.5" x 50" x 30'	1,978 2,552	7,912 10,208
1E and 2E	1 x PL 0.5" x 50" x 42.3' 1 x PL 0.5" x 50" x 43.6	3,601 3,707	14,404 14,828
2W - 4W	2 x PL 0.375" x 50" x 41.5' 1 x PL 0.375" x 50" x 20'	5,295 1,276	21,180 5,104
5W - 7W	2 x PL 0.375" x 50" x 41.5' 1 x PL 0.375" x 50" x 20'	5,295 1,276	21,180 5,104
8W - 10W	2 x PL 0.375" x 50" x 41.5' 1 x PL 0.375" x 50" x 20'	5,295 1,276	21,180 5,104
11W - 13W	2 x PL 0.375" x 50" x 41.5' 1 x PL 0.375" x 50" x 20'	5,295 1,276	21,180 5,104
Total			170,608

Structure Identification	DEFLECTION CHECK		
	Deflection Due to LRT Live Load Plus Impact (inches)	Allowable Deflection = L/1,000 (inches)	Check
A	0.65	0.72	OK
B	0.60 and 0.64	0.71 and 0.73	OK
C	0.648, 0.663 and 0.648	0.71, 071 and 0.71	OK

Structure Identification	FREQUENCY OF VIBRATION (FIRST MODE) CHECK		
	Actual (Hz)	Allowable (Hz)	Check
A	4.74	2.5	OK
B	4.15	3.0	OK
C	3.86	3.0	OK

Proposed Retrofitted Elevated Superstructure

Table 6

SUMMARY

This study evaluated the structural feasibility of converting the two HOV lanes of the Homer Hadley Floating Bridge to light rail. A project evaluation criteria was developed and several rail systems and configurations were evaluated. Hydrostatic maintenance, operation, and structural impacts were evaluated for each alternative and, where retrofits were required to meet the project criteria, they were developed and cost estimated. The main conclusions from this study are summarized below:

Study Conclusions

1. The hydrostatic analysis resulted in eliminating the BR system as a feasible LRT system.

2. The hydrostatic analysis indicated that the added weight from both LR and LR (mod) systems could be mitigated using reasonable approaches.

3. The hydrostatic analysis estimated the bridge responses during LRT loading at both midspan and at the expansion joint locations. These bridge responses need to be verified by a more rigorous hydrodynamic analysis and Sound Transit must verify that the deflections are compatible with the LRT tolerances.

4. The structural analysis eliminated Location/Configuration Option 2 as feasible. This is because this location placed LRT loads too far out on the south end of the floating bridge cantilever and overstressed the floating pontoon top deck.

5. The structural analysis showed that Location/Configuration Options 1, 3, and 4 can be utilized without overstressing the floating pontoon top deck; however, in order to accomplish this, the south concrete side barrier must be removed and replaced with a cable railing.

6. When considering the above conclusions, it becomes clear that the Alternatives LR (mod) 1, 3, and 4 are the only alternatives which could be further considered without attaching auxiliary buoyancy to the floating bridge pontoons. Because of this, all three of these options were identified as the preferred alternatives.

7. Weight mitigation requirements for the preferred alternatives involve 3 main elements:

   - Removal of the existing south concrete side barrier and replacement with a cable railing.

   - Removal of existing ballast within the floating bridge pontoon cells.

   - Removal of 1 inch of the existing concrete overlay on the south side of the concrete median barrier and replacement with 1/4-inch of polymer concrete overlay.

   In addition to the above alternatives, LR (mod) 4 required that the relocated median barrier to be constructed using lightweight concrete

8. The structural analysis of the elevated superstructure for all options identified very few problems. However, the steel box girders did not meet Sound Transit's criteria for deflection. A steel cover plate retrofit for the box girder is proposed to reduce the excessive deflections. The weight of the steel cover plates can be completely mitigated by removing additional existing gravel ballast from locations directly under the retrofitted steel box girders.

Preferred Alternatives and Costs

The study preferred Alternatives LR (mod) 1, 3 and 4, which are shown in Figures 12 through 15. LR (mod) 3 was shown in two versions (A and B) to identify two separate approaches to achieve the 10'-0" maintenance lane and LRT walkway. All options are shown with the full width of the bridge to illustrate how they may integrate with potential modifications on the westbound lanes. Costs for the preferred alternatives are shown below:

Preferred Alternative	***LRT Conversion Cost***	***Added Westbound Lane Cost***	***Total Cost***
LR (mod) 1	$12,296,000	$ 0	$12,296,000
LR (mod) 3A & 3B	$12,070,000	$15,826,000	$27,896,000
LR (mod) 4	$10,852,000	$12,001,000	$22,853,000

The above costs do not include sales tax, engineering or construction management, electrical modifications or temporary services, mitigation of traffic impacts due to the elimination of the existing HOV lanes, and LRT system installation costs.

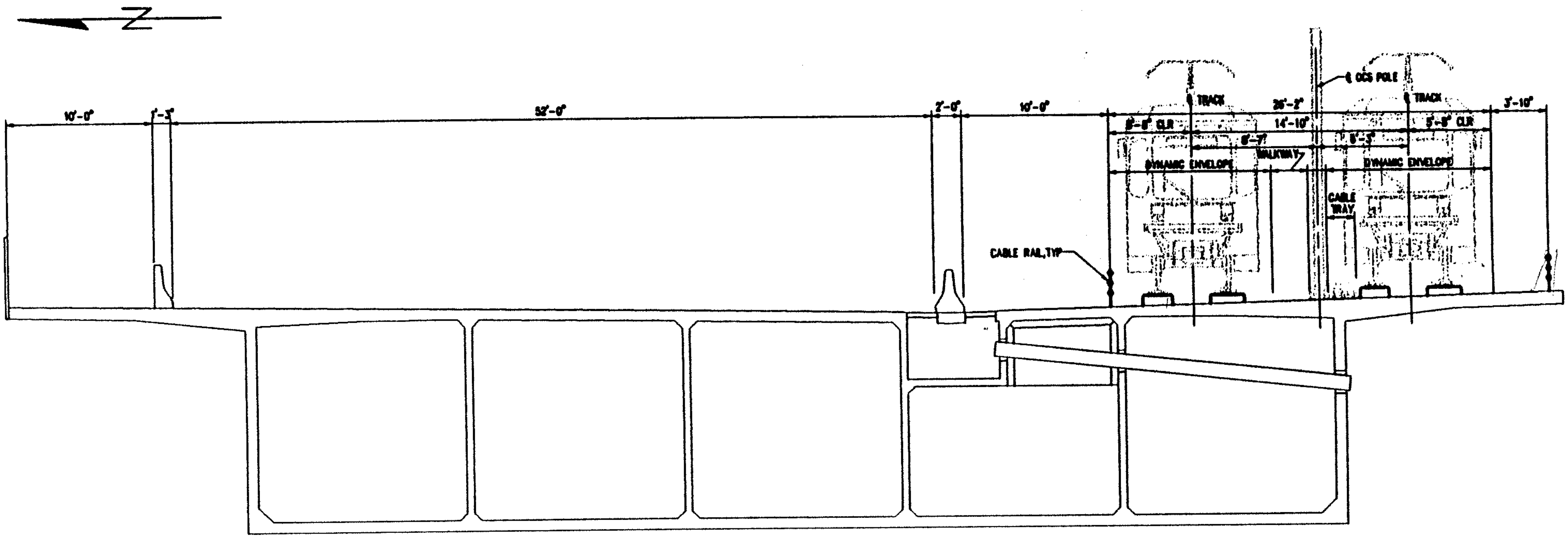


FIGURE 12
LR (MOD)-1 RAIL ALTERNATIVE
TYPICAL SECTION AT FLOATING PONTOON

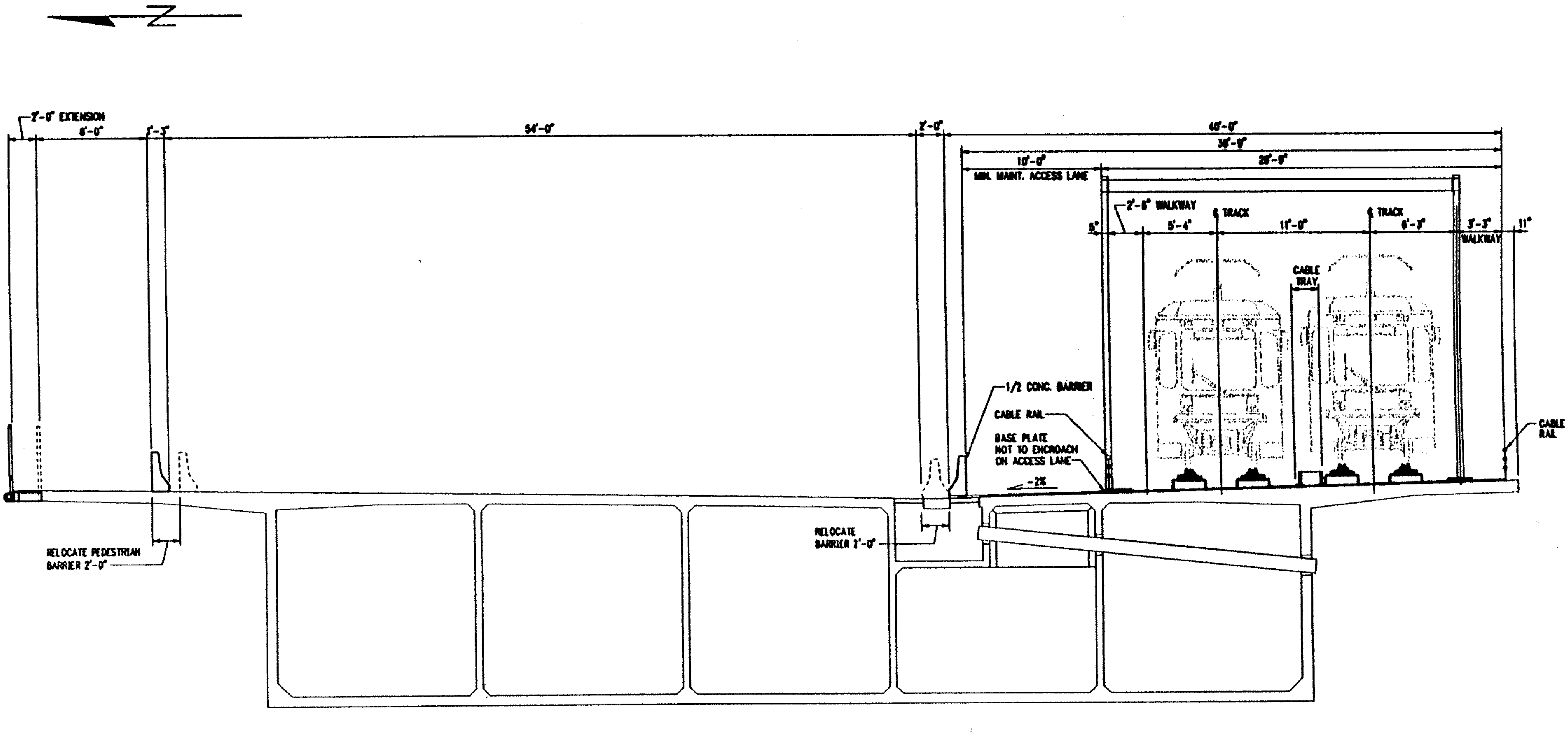


FIGURE 13
LR (MOD)-3A RAIL ALTERNATIVE
TYPICAL SECTION AT FLOATING PONTOON

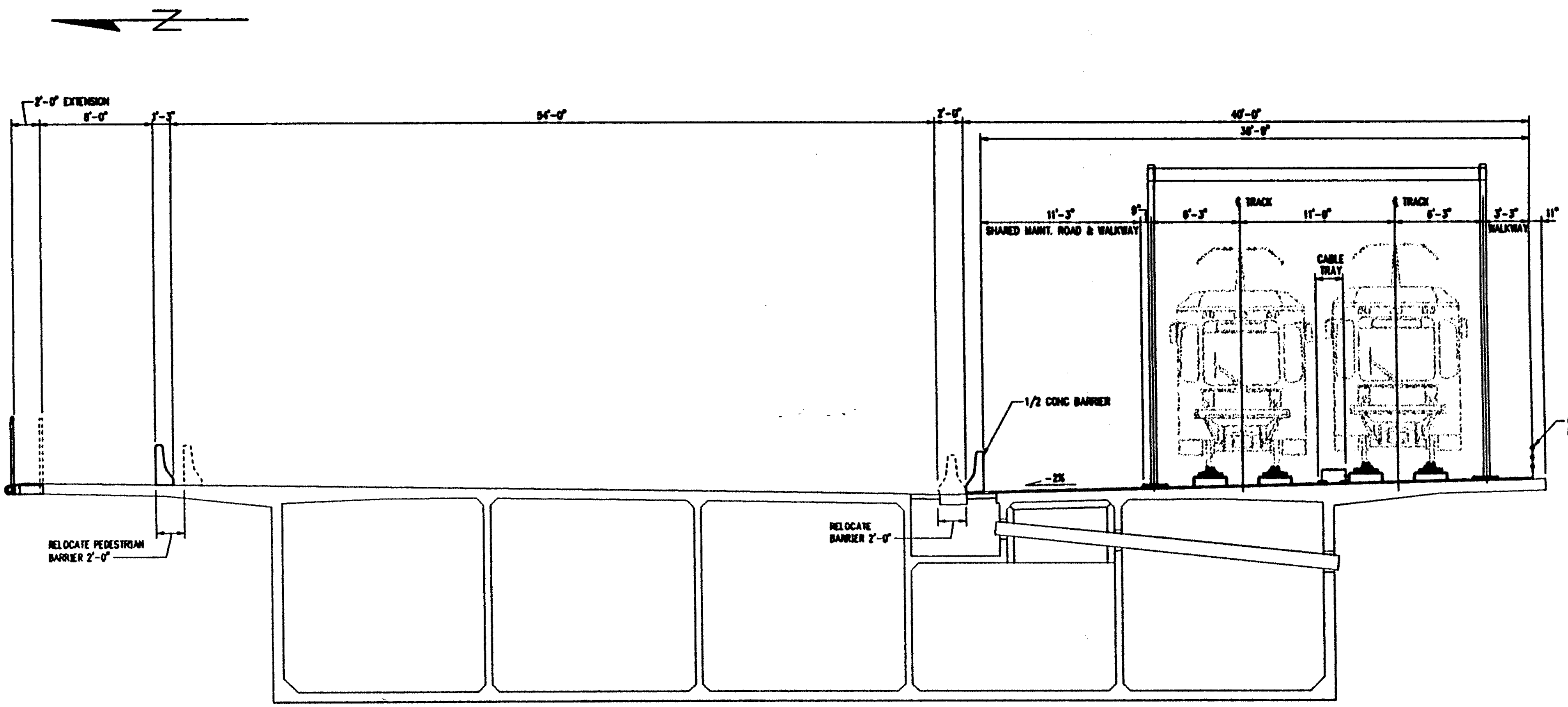


FIGURE 14
LR (MOD)-3B RAIL ALTERNATIVE
TYPICAL SECTION AT FLOATING PONTOON

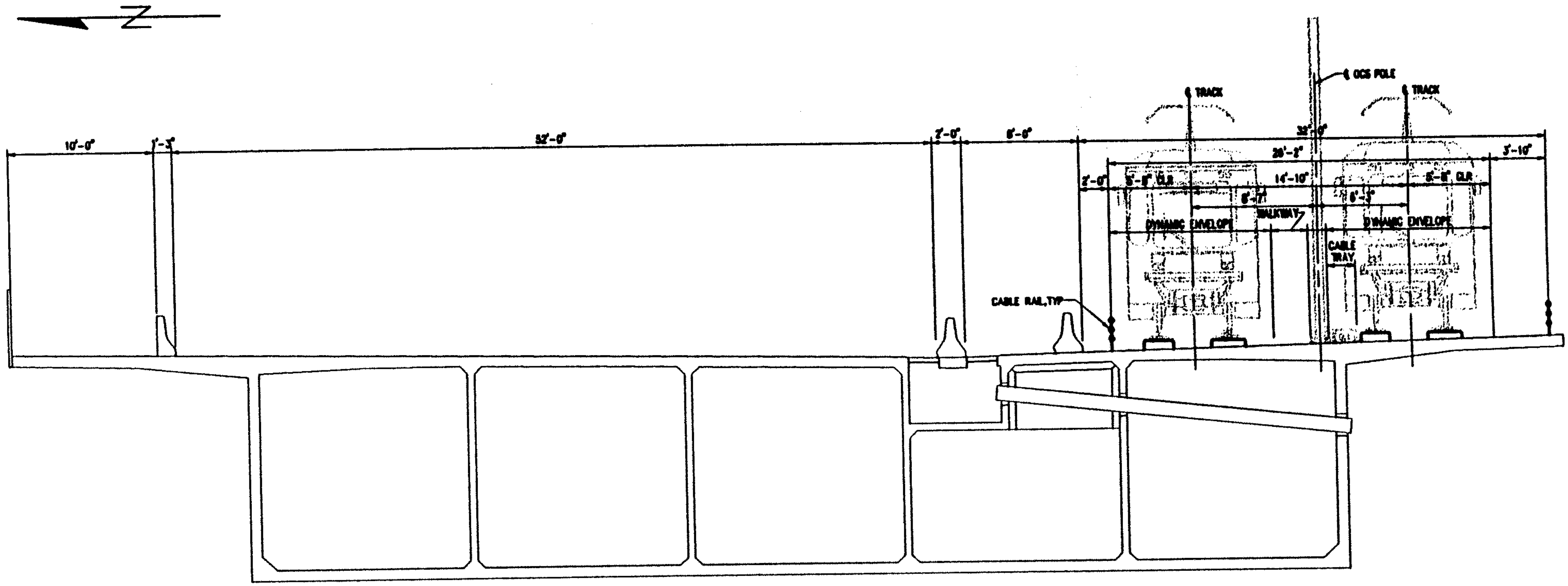


FIGURE 15
LR (MOD)-4 RAIL ALTERNATIVE
TYPICAL SECTION AT FLOATING PONTOON

Appendices

Appendix A
Light Rail Systems

Trans-Lake Washington Project
Washington State Department of Transportation
Sound Transit

TRANSMITTAL FORM

To: Rick Johnson (kpff)

Date: March 29, 2001

Subject: LRT Envelope at Floating Bridge

Filing Code:

We are transmitting the following materials:

The attached is the revised LRT envelope with side walkways.

Comments:

There are three schemes. Scheme A assumes a center OCS pole and would provide a minimum maintenance road Of 10 feet within the reduced available envelope of 38 feet. However, this scheme would locate the tracks further south from the assumed location for Alternative LR-1. Scheme B assumes a frame with side OCS poles but would provide only 8-ft wide road clear of the walkway or 10.5-ft width to be shared by the road and the walkway. Scheme C also assumes a frame with side OCS poles but with the northern pole located within the 9'-8" wide maintenance road or 12'2" width to be shared by the road and the walkway.

Please note that we require a restraining rail for all four rails to preclude possibilities of derailments but with the corresponding increase of dead load per attached memo by G. Inverso, dated 29 March,01. Side OCS poles with a frame would also increase dead loads per attached memo by G. Inverso, dated 29 March,01.

These are:
- ☒ PER YOUR REQUEST
- ☒ FOR YOUR INFORMATION
- ☐ FOR YOUR REVIEW AND APPROVAL
- ☐ FOR YOUR FILES
- ☐ FOR YOUR ACTION

Sent Via:
- ☐ U.S. MAIL
- ☒ COURIER
- ☐ EXPRESS OVERNIGHT
- ☐ OTHER – INTEROFFICE
- ☐ HAND DELIVERY/PICK UP

Sincerely,

Ivo Gustetich (PSTC)
Select Firm

cc: Less Rubstello (WSDOT), Rob Fellows (WSDOT), Barb Gilliland (ST), Andrea Tull (ST), Dave Hildebrant (TL), Jim Parsons (PSTC), Dick Rudolph (PSTC), George Inverso (PSTC)

PUGET SOUND TRANSIT CONSULTANTS COMPUTATION SHEET

PSTC

Subject: TRANSLAKE STUDY

LRT ENVELOPE @ FLOATING BRIDGE

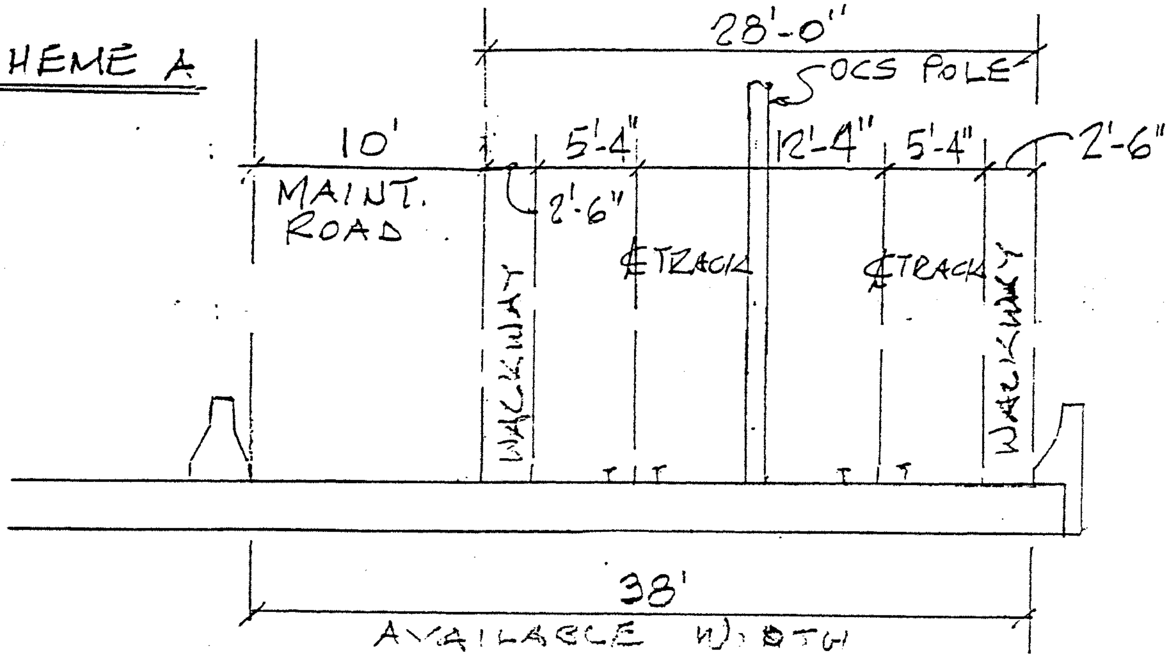
Made by: NO

Date: 3/23/01

Checked by:

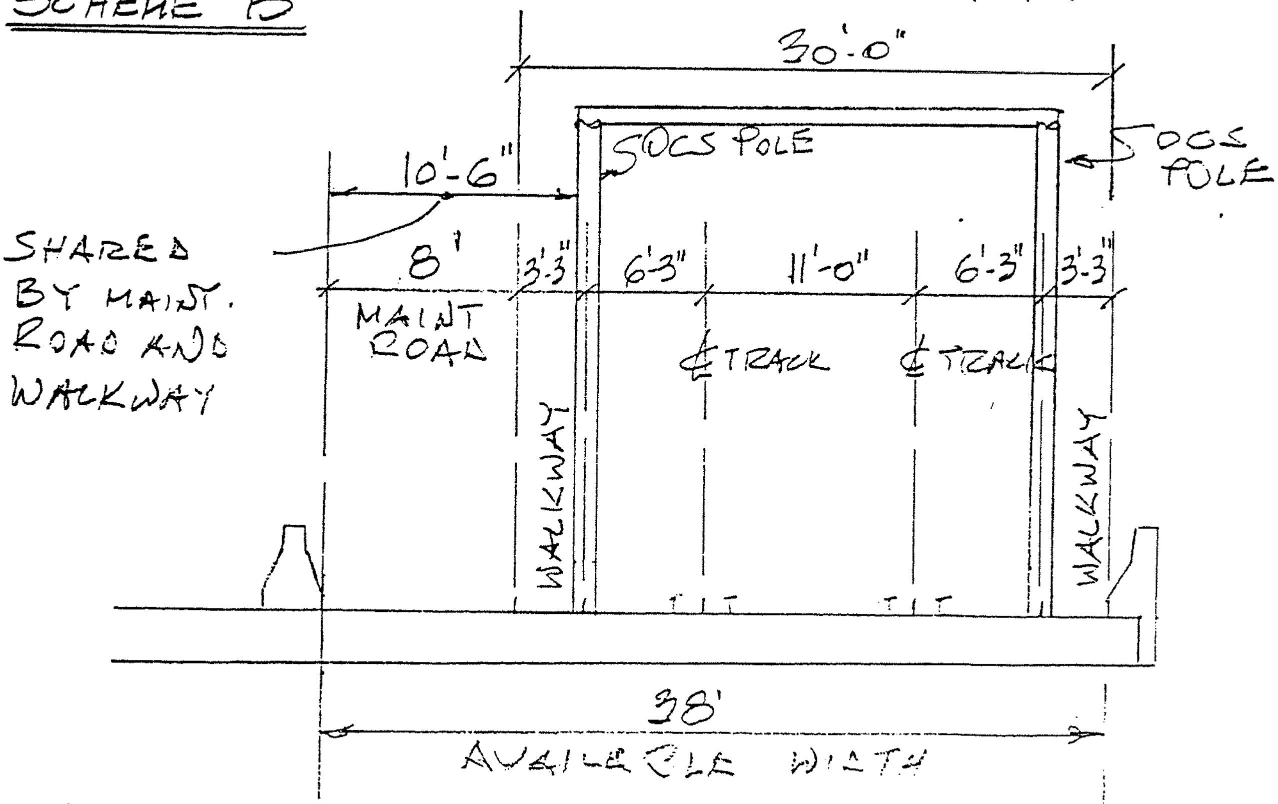
Date:

SCHEME A



NOTE. - PROVIDE RESTRAINING RAIL FOR ALL FOUR RAILS

SCHEME B



NOTE. PROVIDE RESTRAINING RAIL FOR ALL FOUR RAILS

PUGET SOUND TRANSIT CONSULTANTS COMPUTATION SHEET

Subject: TRANSLAKE STUDY

LRT ENVELOPE @ FLOATING BRIDGE

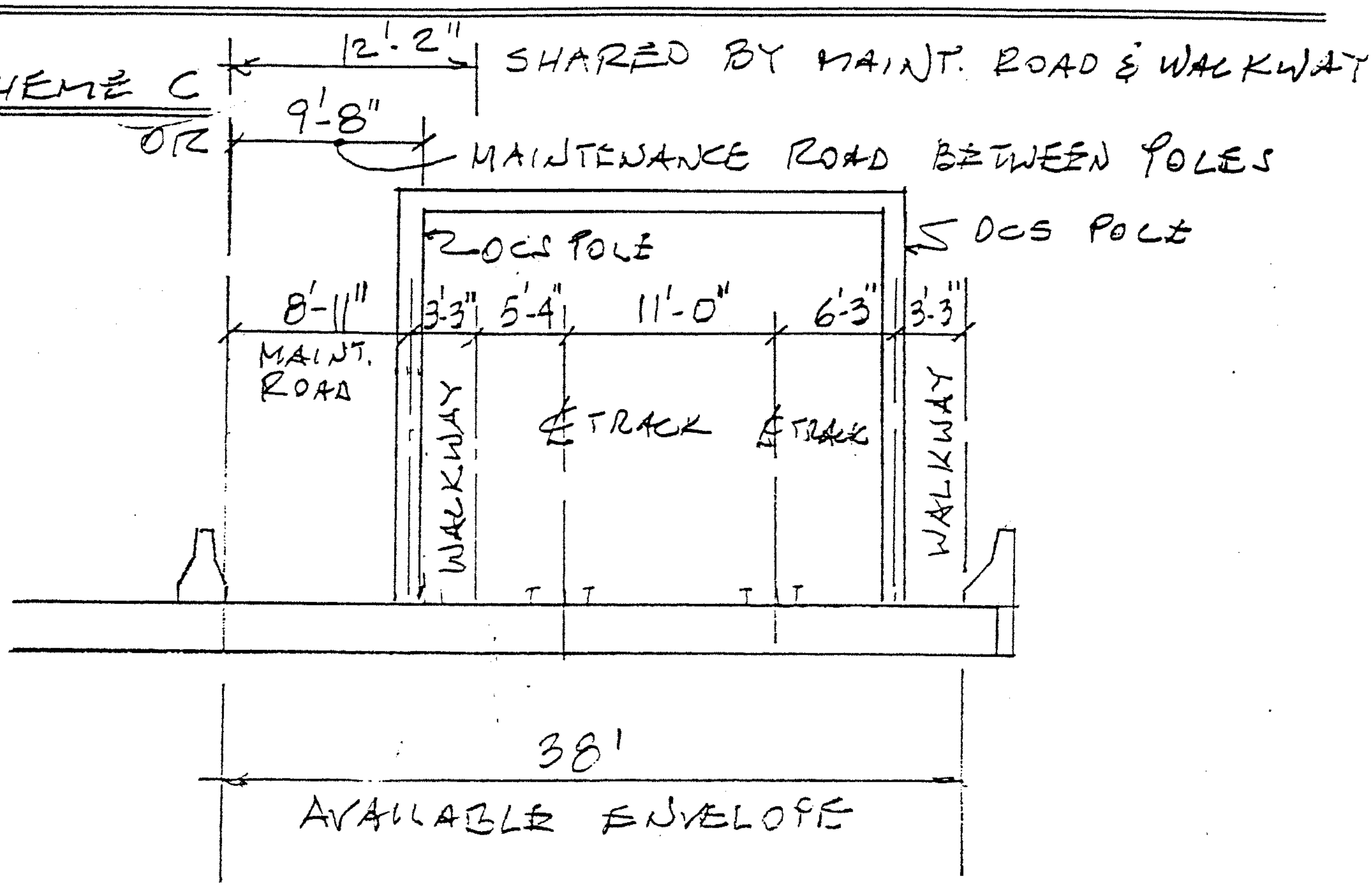
Made by: [illegible]

Date: 3/22/91

Checked by:

Date:

SCHEME C



NOTE. PROVIDE RESTRAINING RAIL FOR ALL FOUR RAILS

PSTC

Puget Sound Transit Consultants
401 S. Jackson Street
Seattle, WA 98104-2826
Phone: 206-398-5000 Fax: 206-398-5219

MEMORANDUM

TO: File

FROM: G. Inverso

DATE: 29 March 2001

SUBJECT: **Translake Study**

Light Rail Transit Dead Loads Single Fastener Plinth w/ 2 Restraining Rails

CIN: 9104-GEN010-0067

The additional dead weight added the I-90 Floating Bridge if two restraining rails were used with the Single Fastener Plinth scheme presented in a memo dated 15 February 2001 was determined. Various alterations of the OCS configuration were also considered. The following table summarizes the modified dead load per route foot.

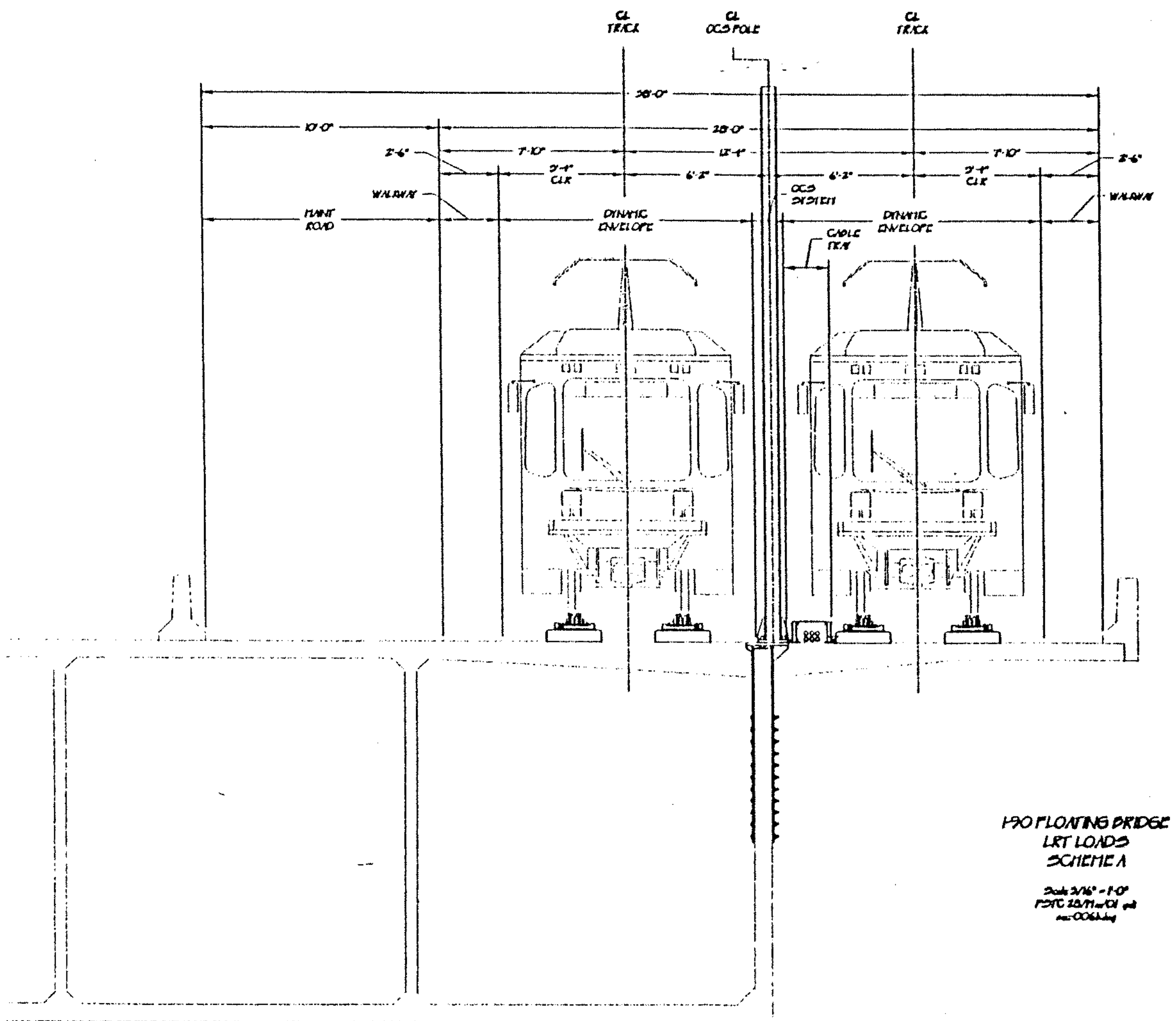
Components	Dead load (PLF)
Trackwork	740
OCS System	50
Walkway/Cable Tray	50
Miscellaneous	80
Total	920

The general assumptions for the minimal LRT dead load are similar to those used in the 15 February memo. The track work configuration was changed to include restraining rail and plinths for all four rails. The configuration includes a non-raised center walkway, and a center cable tray. Various alterations of the OCS system were evaluated with respect to dead weights. The OCS configurations are discussed in more detail in a separate memo.

Three configurations of the LRT, OCS system, Walkways and Bridge Maintenance Access are shown in the attached sketches. The representation of the bridge is approximate. The dead weight for these schemes should be covered by the above table. It should be noted that some form of curb or warning strip is needed with these scheme to assure maintenance vehicles and personnel stay clear of the vehicle dynamic envelopes. .

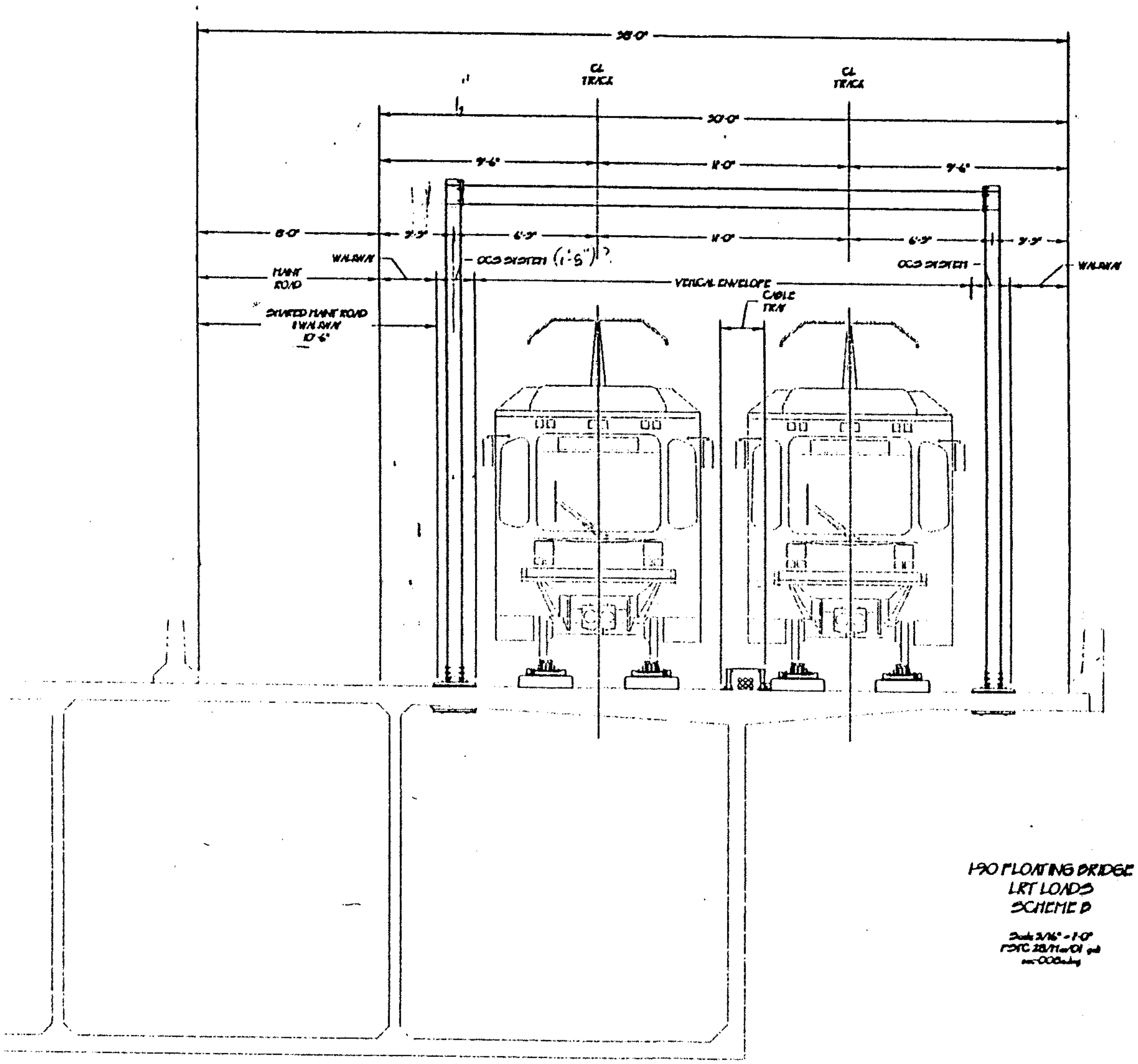
A 80 pounds per lineal foot miscellaneous dead load was added. This is to account for varying weight of materials and to cover uncertainty about unknown items. These can include deck leveling, drainage and such items that could develop during preliminary design.

cc: I. Gustetich
A. Borst
R. Rudolph
J. Parsons
D. Donatelli
PDCC



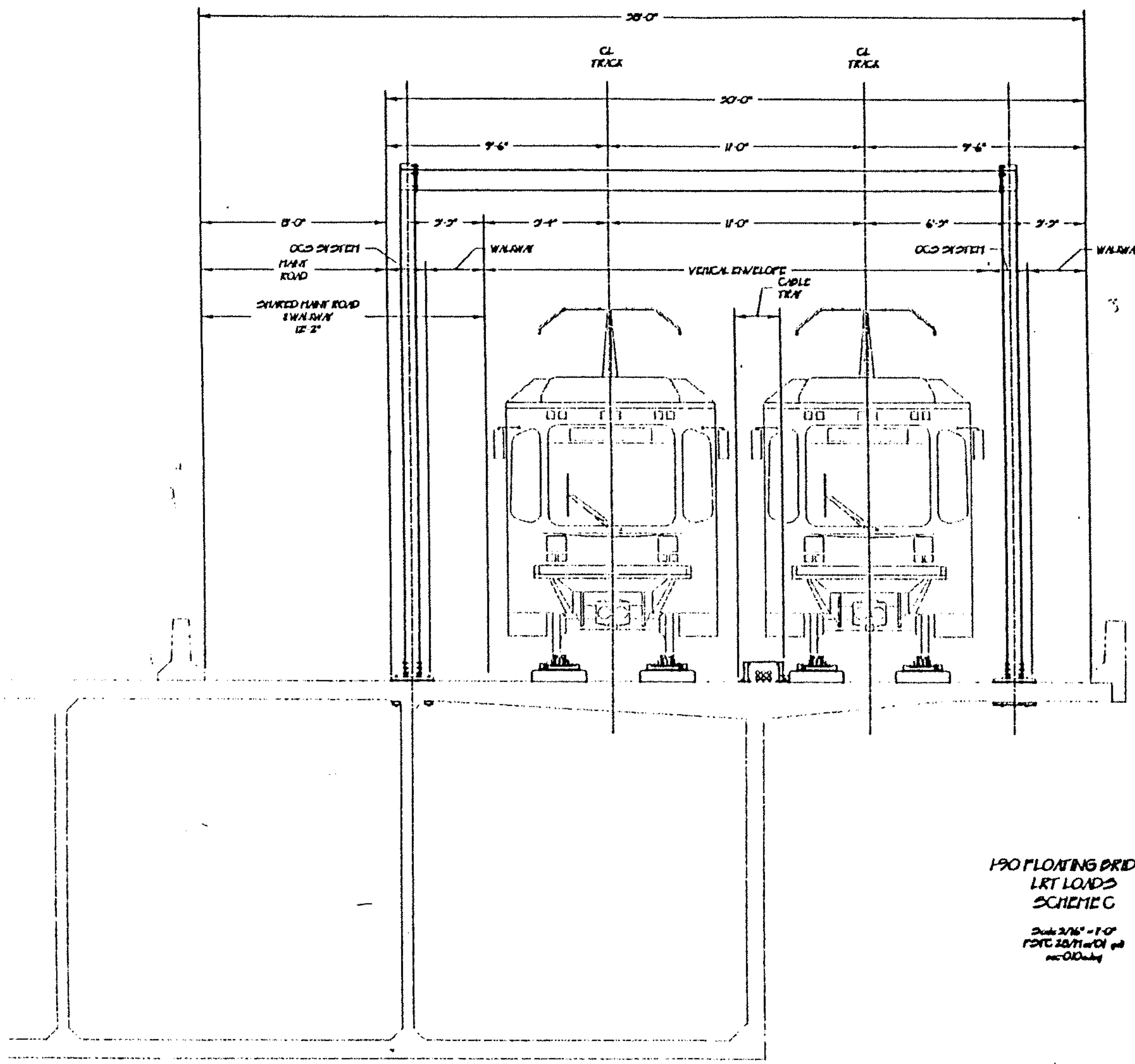
I-90 FLOATING BRIDGE
LRT LOADS
SCHEME A

Scale 3/16" = 1'-0"



I-90 FLOATING BRIDGE
LRT LOADS
SCHEME B

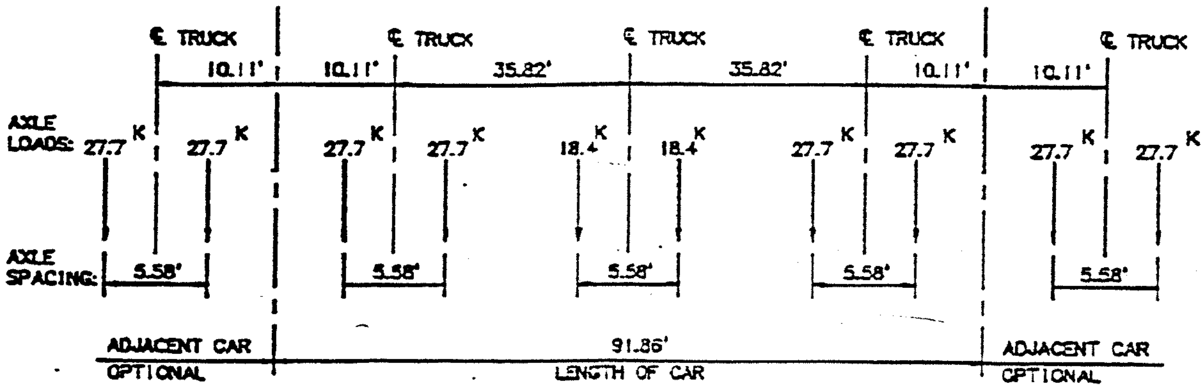
Scale 3/16" = 1'-0"
FSTC 28/Mar/01



I-90 FLOATING BRIDGE
LRT LOADS
SCHEME C

Scale 3/16" = 1'-0"

FIGURE 8-1
LIGHT RAIL VEHICLE DESIGN LOAD



LIGHT RAIL VEHICLE LOADING

NOTES:

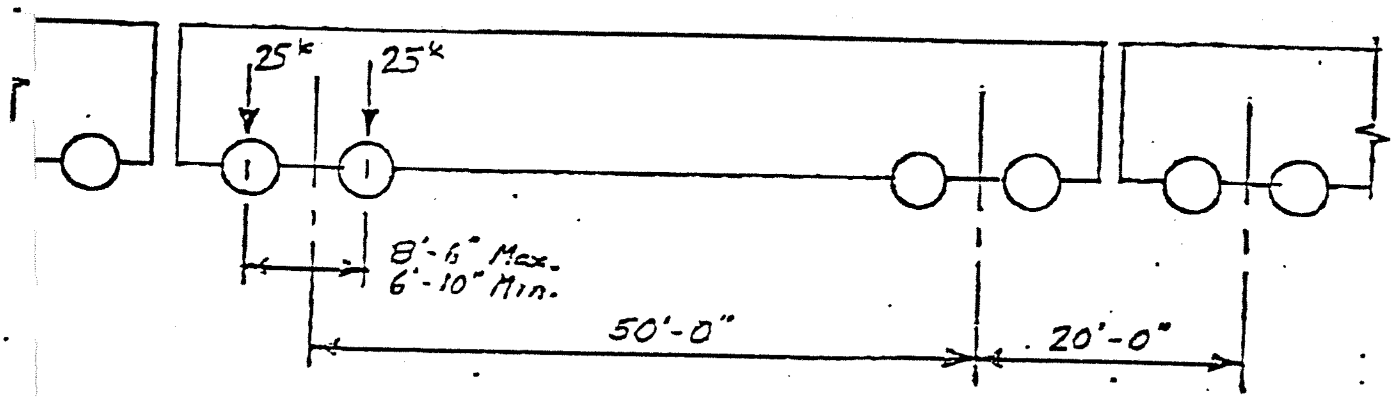
1. AXLE LOAD IN KIPS
2. THE TRAIN SHALL CONSIST OF EITHER ONE, TWO, THREE, OR FOUR CARS, WHICHEVER PRODUCES THE MAXIMUM LOAD FOR THE ELEMENT UNDER CONSIDERATION.
3. THIS DIAGRAM DEPICTS THE CONFIGURATION OF A PROTOTYPICAL LIGHT RAIL VEHICLE THAT WAS USED FOR PRELIMINARY DESIGN. FINAL DESIGN SHALL BE BASED ON THE ACTUAL CONFIGURATION OF THE SELECTED VEHICLE.

Proposed New LRT Vehicle Live Loading

Live Load

HS 20 Truck or Lane Loading shall be used without modification. Military Loading of 2-24 kip axles at 4' centers shall also be considered.

The reversible lanes shall also be designed for the Rapid Transit Loading of the Puget Sound Governmental Conference Rail Rapid Transit Design Criteria shown below.



Car Length	70'
Car Height	12' Max
Car Width	10'
Speed on Bridge	45 mph
Axle Load	25 kips
Impact	$\frac{100\ LL}{DL + LL}$ 30% Max
Lane Width	14' Min.
Traction Force	15%
Wind	300 lbs per lin. ft. of train
Rail Weight	100 lbs per yard

Original LRT Vehicle Live Loading

Acceleration and Deceleration Rate	3.5 mph/sec Max.
Number of Cars per Train Unit	8 Max.
Number of Trains on Bridge at Same Time	2 - 1 in each direction
Allowable Grade	5% Max.

Rapid Transit Loading shall be used in combination with the Highway Loadings, considering each track of Rapid Transit as a lane for use of the multiple lane reduction factor.

In addition to Section 1.2.9 of AASHTO Specifications, 60% of the resultant live load stresses shall be used when produced by loading 6 or more traffic lanes simultaneously. (Ontario Code)

Under towing and construction conditions, the top slab of roadway pontoons shall be adequate to take an H-10 loading.

Under the elevated roadway, the top slab of the pontoon shall be designed for a single H-10 maintenance truck.

Live Load Impact

Impact shall be applied in computing local stresses in the roadway slabs and superstructure only, not for overall pontoon stresses.

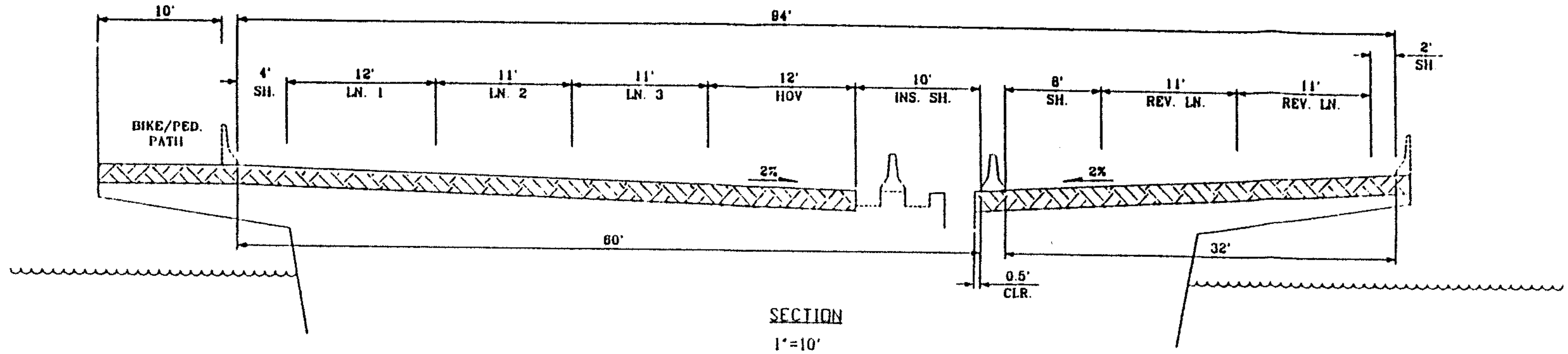
Rick Johnson

From: "Bill Cichanski" <billjc@kpff.com>
To: "Rick Johnson" <rickj@kpff.com>
Sent: Thursday, March 29, 2001 2:35 PM
Subject: Fw: Mercer Island/I-90: Homer Hadley LRT Sections

Rick - I belive these are the illustrations that HNTB agreed to send. Bill
----- Original Message -----
From: "Jeff Highley" <JHighley@HNTB.com>
To: "William J. Cichanski (E-mail)" <billjc@kpff.com>; "Patrick Clarke (E-mail)" <CLARKEP@WSDOT.WA.GOV>; "Arkin Chan (E-mail)" <ChanAS@WSDOT.WA.GOV>; "Lesly W. Chan (E-mail)" <chanle@WSDOT.WA.GOV>; "Denise Cieri (E-mail)" <cierid@WSDOT.WA.GOV>; "Rosario Revilla (E-mail)" <Revilla@WSDOT.WA.GOV>
Cc: "Bill James" <WJAMES@HNTB.com>
Sent: Wednesday, March 28, 2001 12:30 PM
Subject: Mercer Island/I-90: Homer Hadley LRT Sections

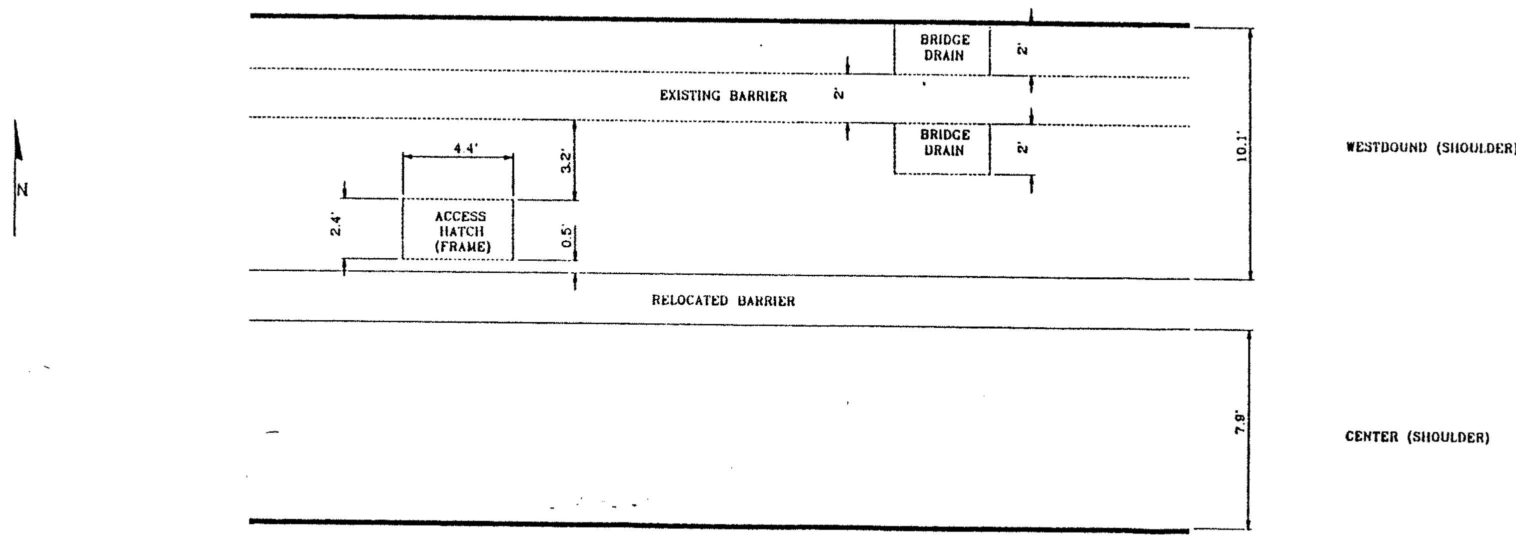
> Drawings for Homer Hadley "Interim before LRT" sections have been uploaded
> to the HNTB FTP site (ftp.hntb.com) under ftpout/28799/5hntb
> ftp://ftp.hntb.com/ftpout/28799/5hntb/
>
> The following AutoCAD files are available:
>
> 5tsecLR1.dwg - Option 1
> 5tsecLR2.dwg - Option 2
> 5tsecLR3.dwg - Option 3
>
> The corresponding MicroStation files are also available:
>
> 5tsecLR1(2d).dgn - Option 1 (2D)
> 5tsecLR2(2d).dgn - Option 2 (2D)
> 5tsecLR3(2d).dgn - Option 3 (2D)
>
> All Options have the same median barrier (separating westbound from the
> center roadway) placement, which is 6" from the access hatch frame. This
is
> considered the minimum clearance allowable. As Bill put it, the barrier
is
> as far North while being South of the access hatches. Additional
clearance
> may be found to be needed as the Options are further investigated. With
the
> assumed clearance and a 2' wide replacement barrier, the center roadway
> envelope would be 32'. This would allow a 8' shoulder, two 11' lanes, and
a
> 2' shy on the south side.

>
> Option 1 (westbound) - provides a 4' outside shy, 12' outside lane (Lane 1),
> two 11' center lanes, 12' HOV Lane, and a 10' inside shoulder - maintenance
> access. The bike/ped path is unchanged.
>
> Option 2 (westbound) - provides a 4' outside shy, four 11' travel lanes, and
> a 12' inside shoulder - maintenance access. The bike/ped path is unchanged.
>
> Option 3 (westbound) - provides a 8' outside shoulder, four 11' travel
> lanes, and a 10' inside shoulder - maintenance access. The bike/ped path
> would need to be widened 2' (HH2) in order to maintain a 10' wide facility.
>
> Feel free to let me know if you have any questions, comments, or difficulty
> accessing the files.
>
> Jeffrey Highley
> HNTB Corporation
> Bellevue Corporate Plaza
> 600 108th Ave NE, Suite 400
> Bellevue, Washington 98004-5110
> mailto:jhighley@hntb.com
> 425-450-2525 direct
> 425-453-9179 fax
>



SECTION
1"=10'

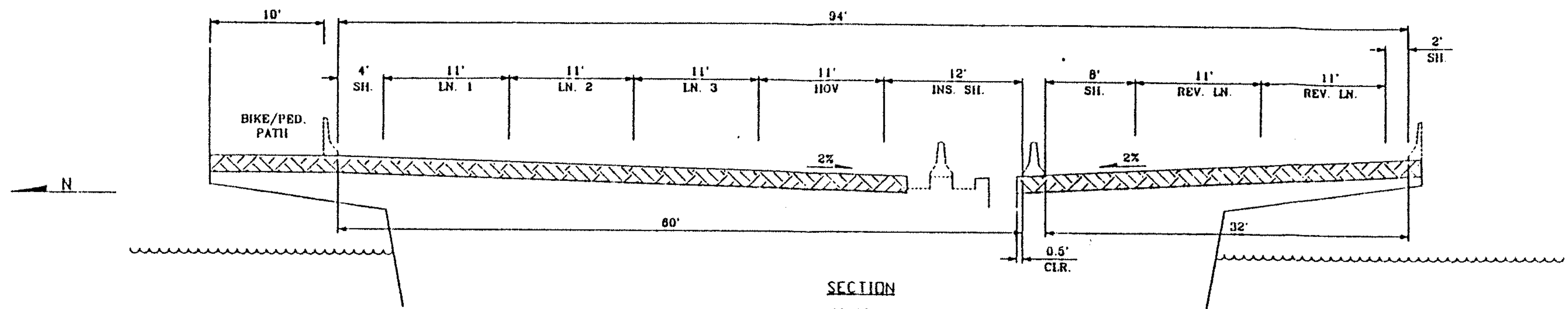
ALTERNATIVE R-8A
INTERIM BEFORE LRT (OPTION 1)
WESTBOUND/CENTER ROADWAY
HOMER M. HADLEY FLOATING BRIDGE



PLAN
1"=5'

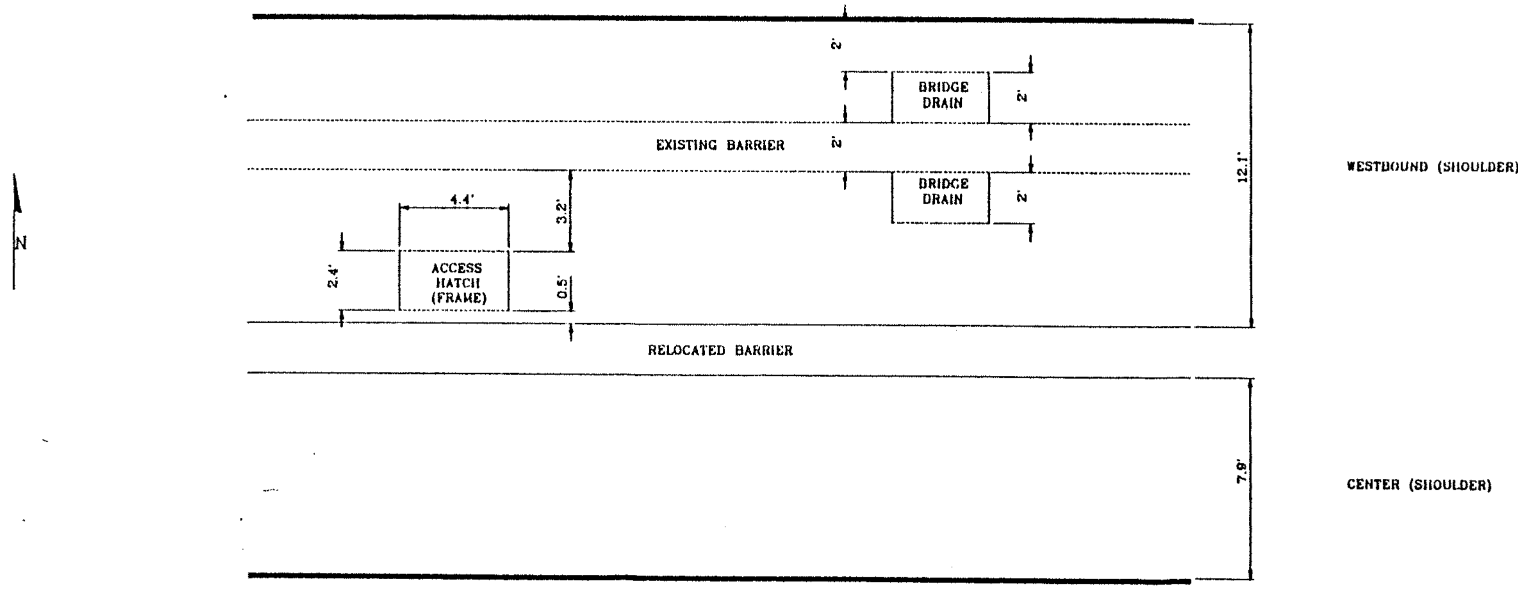
DESIGNED BY	REGION NO. 10	STATE WASH	FED AID PROJ NO.	ENVIRONMENTAL AND ENGINEERING SERVICE CENTER	SOUND TRANSIT; Washington State Department of Transportation; HNTB The HNTB Companies	SOUND TRANSIT REGIONAL EXPRESS MERCER ISLAND PROJECT GROUP I-90 TWO-WAY TRANSIT OPERATIONS	LRT-
ENTERED BY	JOB NUMBER					ALT R-8 HOMER M. HADLEY BRIDGE INTERIM BEFORE LRT (OPTION 1)	SHEET of SHEETS
CHECKED BY	CONTRACT NO.						
PROJ. ENGR.							
DIST. ADM.							
DATE	DATE	REVISION	BY				

FILE PATH & NAME 100269 :SR90 LIGHT RAIL STUDY\WCCAMNC\STECLR1.DWG
JOB # 100269 JOB NAME Floating Bridge LRT
PLOTTED DATE & TIME MAR 30 2001 7:17:59 AM
UPDATED BY RICKI
PLOT SCALE 1=1
PCP FILE ---
PLOT
XREFS • • • NO XREFS ATTACHED • • •



SECTION
1'=10'

ALTERNATIVE R-8A
INTERIM BEFORE LRT (OPTION 2)
WESTBOUND/CENTER ROADWAY
HOMER M. HADLEY FLOATING BRIDGE



PLAN
1'=5'

DESIGNED BY				
ENTERED BY				
CHECKED BY				
PROJ. ENGR.				
DIST. ADM.	DATE	DATE	REVISION	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER		
CONTRACT NO.		

ENVIRONMENTAL AND ENGINEERING SERVICE CENTER

SOUND TRANSIT
Washington State Department of Transportation
HNTB The HNTB Companies

SOUND TRANSIT REGIONAL EXPRESS
MERCER ISLAND PROJECT GROUP
I-90 TWO-WAY TRANSIT OPERATIONS
ALT R-8 HOMER M. HADLEY BRIDGE
INTERIM BEFORE LRT (OPTION 2)

LRT

FILE PATH & NAME XREFS \100269 (SP90 LIGHT RAIL STUDY)\INCOMING\15TSECLR2.DWG
JOB # 100269
JOB NAME Floating Bridge LRT
PLOTTED DATE & TIME MAR 30, 2001 7:23:34 AM
UPDATED BY RICKT
PLOT SCALE 1=1
PCP FILE ---
PLOT VIEW
XREFS: * * * NO XREFS ATTACHED * * *
\$\$\$\$SYTIME\$\$\$\$\$ DGNSPEC \$\$\$PLOTTED

Puget Sound Transit Consultants
401 S. Jackson Street
Seattle, WA 98104-2826
Phone: 206-398-5000 Fax: 206-398-5219

DRAFT MEMORANDUM

TO: File

FROM: G. Inverso

DATE: 29 March 2001

SUBJECT: **Trans Lake Study**
Various OCS Support Configurations

CIN: 9104-GEN010-0068

Various configurations for the OCS supports were reviewed relative to dead weight the Light Rail Transit (LRT) system is expected to impose on the I-90 floating bridge. The primary alternative reviewed was an OCS frame with a pinned base. A second alternative using dual cantilevered poles was evaluated. The weights of these alternatives were compared to the standard configuration of a single cantilevered pole with a fixed base. The results are summarized in the following table.

Support System	Support Weight (plf)	OCS System Weight w/o Rounding (plf)	OCS System Weight Used (plf)
Single Cantilevered Pole	22	32	40
Frame	28	38	40
Dual Cantilevered Pole	40	50	50

The following observations were made.

OCS frames add approximately 6 pound per rout foot (plf) more dead weight to the structure than a single cantilevered OCS pole. However, giving the rounding conventions used in estimating dead weights (rounding up to the nearest 10 pound) used at this conceptual level of design, the difference in weight does not change the reported OCS system weight of 40 plf. The OCS frame alternative can be treated as a wash at this level of design.

Dual Cantilevered OCS poles add approximately 18 plf more dead load to the structure than a single cantilevered pole. This brings the total OCS system Weight to 50 plf. Dual cantilevered OCS poles add significantly to the LRT dead weight.

To be conservative the 50 plf should be used to estimate the weights for a general OCS system for this conceptual level of design.

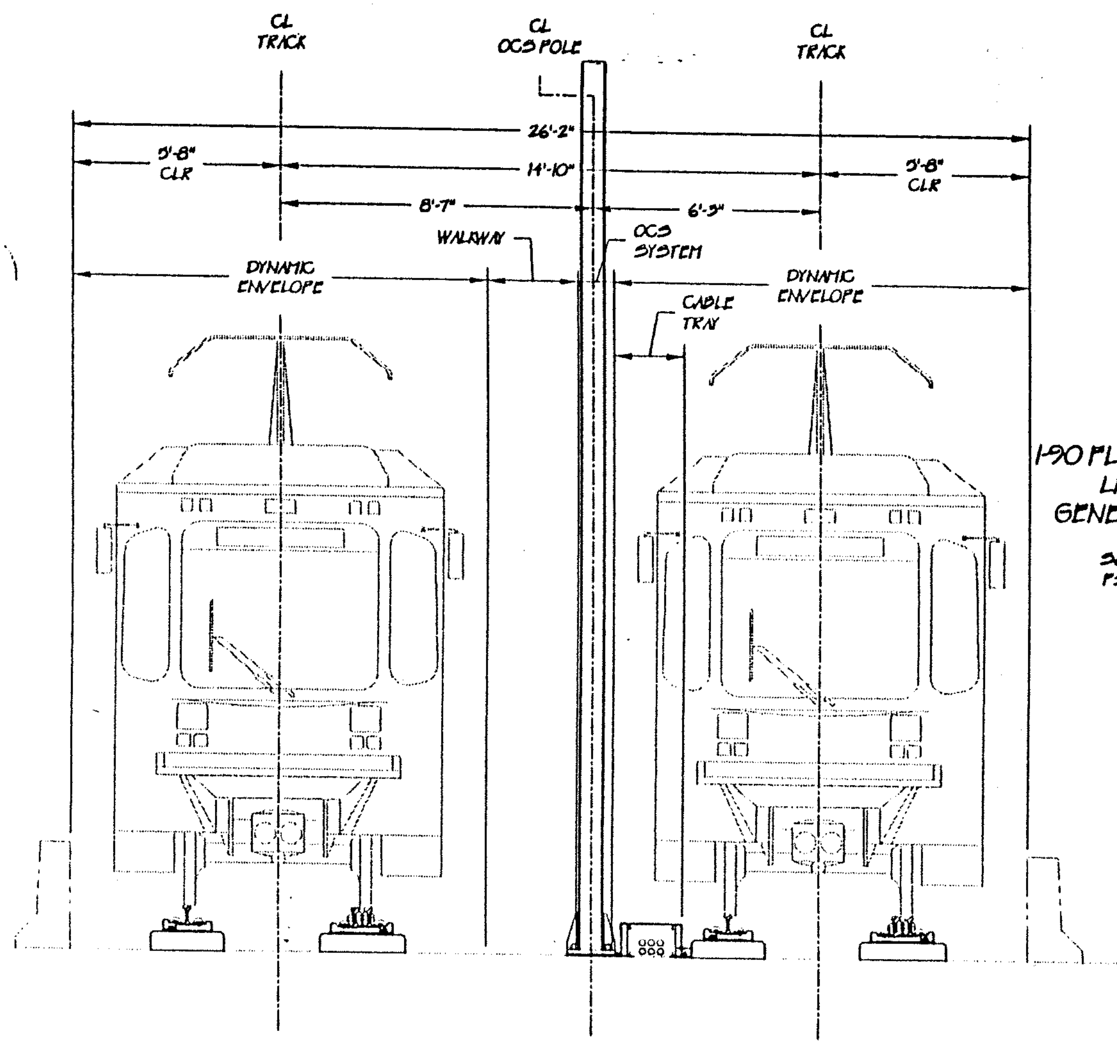
There is a caveat regarding the placements of cantilevered poles and frames.

Cantilevered poles require fixed foundations. Systems people have given large diameter high strength bolts that need to be developed in the foundations. It appears the bases need to develop the full plastic moment of the pole. To accommodate these corresponding high base moments on the floating bridge, the poles were located at cross wall in the bridge. The decks may be too thin to sustain such high moments. A steel U-shaped bracket was used to make the moment connection to the cross wall. The steel bracket requires substantially less weight than the additional volume of concrete needed to develop the same moment. Cantilevered poles should be used only where they can be placed directly over a cross wall.

Frames have pinned bases for major axis bending. Fixity needs to be provided to develop fully the minor axis plastic capacity. Steel base plates through bolted to the deck can provide the needed fixity for frames. Thus, frames can be used on the cantilevered wings of the bridge deck. There is more locations where a frame can be used.

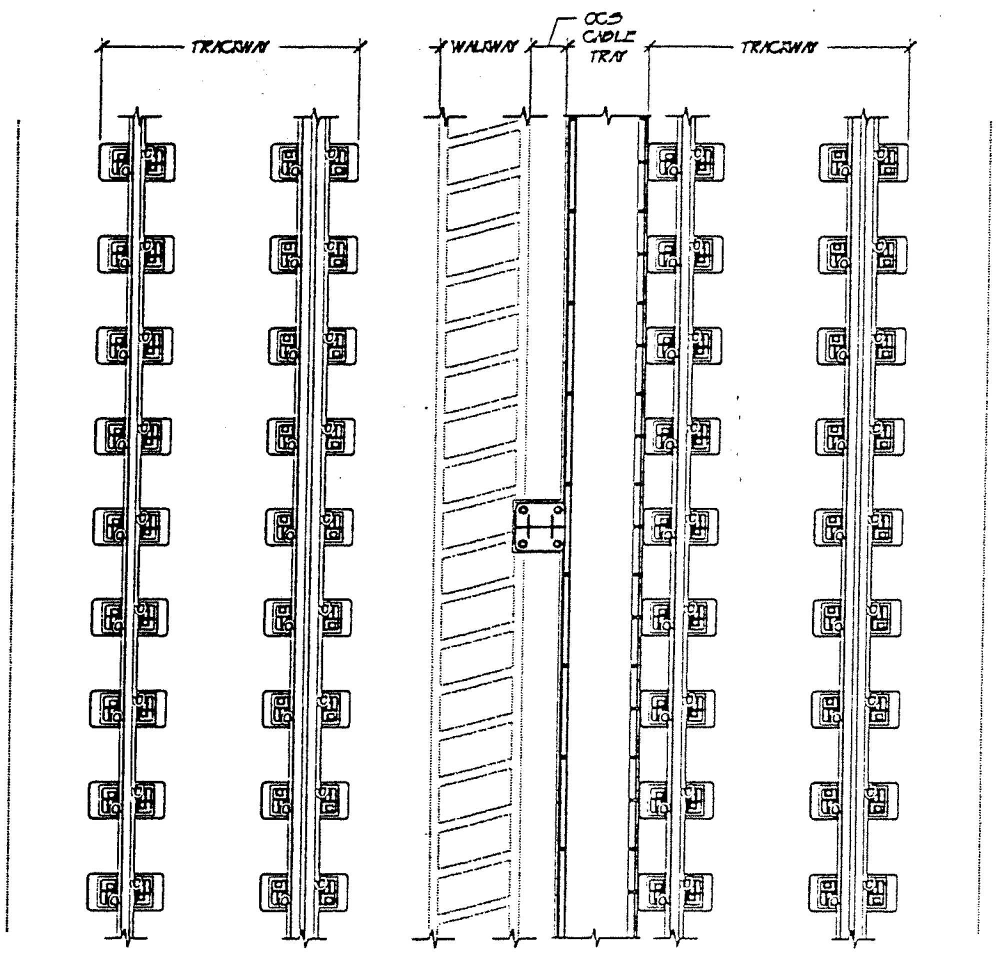
The designs of these alternative OCS support systems were based on the loading given in LTK memo dated 24 August 2000 entitled *Loading Calculations for DS700 OCS Poles.* The assumptions are the same as used in the PSTC memo dated 2 November 2000 entitled *Assumptions for Calculating Light Rail Transit Dead Loads*. These include 180-foot spacing for supports and two (2) overlaps each involving four (4) additional supports. See the 2 November memo for more detail.

cc: I. Gustetich
A. Borst
R. Rudolph
J. Parsons
D. Donatelli
PDCC



I-90 FLOATING BRIDGE
LRT LOADS
GENERAL SECTION

ickt @kpff.com



I-90 FLOATING BRIDGE
LRT LOADS
GENERAL PLAN

Scale 3/16" = 1'-0"
[illegible]
[illegible]

Transmittal

PSTC

Post-it® Fax Note 7671	Date 11/6	# of pages ▸ 4
To Rick Johnson	From Charlie Evans	
Co./Dept. KPFF	Co. WSDOT	
Phone # (206) 622-5822	Phone # (360) 705-7222	
Fax # 8130	Fax # 6814	

Puget Sound Transit Consultants
401 S. Jackson Street
Seattle, WA 98104-2826
(206) 398-5000; Fax: 206-398-5219

To: Patrick T Clarke
Bridge and Structures Office
P.O. Box 47340
Olympia WA 98504-7340

From: Jim Parsons

PSTC

Contract/Task: No 42526 I-90 Rail Conversion Study *Date:* November 3, 2000

CIN number: 9104-1-GEN000-0405

cc: Don Billen – Sound Transit

Lindsay Yamane and Dave Hilderbrand – Parametrix

PDCC: LDCC

Via:	*for your:*	*the following:*		
☐ mail	☒ information/use	☐ shop drawings	☐ change order	☐ specifications
☐ fax	☐ approval	☐ copy of letter	☐ plans	☐ other Calculations
☐ fedex	☐ review/comment	☐ prints	☐ samples	

Drawing	*rev. no.*	*Description*	*copies*	*date*
		Memorandum – Translake Study – Assumptions for calculations of Light Rail Transit Dead Loads	1	11/2/00

If enclosures are not as noted, kindly notify us at once

Comments:
Attached are the calculated dead loads for the two track Sound Transit LRV applied to the I-90 Lake Washington Crossing as agreed to in our meeting of October 24, 2000.

Signature: [signature] for Jim

Puget Sound Transit Consultants
401 S. Jackson Street
Seattle, WA 98104-2826
Phone: 206-398-5000 Fax: 206-398-5219

MEMORANDUM

TO: File

FROM: G. Inverso

DATE: 2 November, 2000

SUBJECT: **Translake Study**
Assumption for Calculation of Light Rail Transit Dead Loads

CIN:

The Superposed Dead Loads for adding Light Rail Transit (LRT) to the I-90 floating bridge were calculated. The following table summarizes the dead load per route foot.

Component	Dead Load (LBF/FT)
Trackwork	1300
OCS System	40
Walkway	130
Total	1,470

The following are assumptions made when calculating the dead load for LRT loads on the I-90 floating bridge.

1.) The floating bridge spans will not contain special trackwork including crossovers, pocket tracks, turnouts and such.

2.) The same trackwork configuration that applies to the tangent aerial guideway applies to the floating bridge. The trackwork configuration used is given in Standard Trackwork Drawing KS023 Rev 1 8-17-00. The following assumptions were made.

A.) Plinths are normal weight concrete. Reinforced concrete unit weight of 160 LBF/FT³ was used per the Design Criteria Manual (DCM) and WSDOT.

B.) Design used six (6) rail pads per plinth.

C.) Guardrails are present.

3.) OCS System will be similar to that developed for the Tangent Aerial Guideway for Ds-700 as presented in LTK memo dated 24 August 2000 entitled *Loading Calculations for DS700 OCS Poles*. The following assumptions are included:

A.) The system average weights are based on 3600-feet with nominal 180-foot pole spacing.

B.) There are two overlaps. Each overlap includes four (4) additional poles paired with a typical pole.

C.) The poles are mounted at the existing pontoon crosswalls with a U-shaped steel bracket.

Memorandum

4.). Walkway / Cable Trays was assumed to be mounted to the deck. The following assumptions were made.

A.) Walkway consists of a plate deck stiffened by single angles and supported by longitudinal structural channels mounted on the deck.

B.) Cable Trays only contain fiber optic cables without metal conduits. There are no traction power or switching cables in the cable tray.

5.) Attached sketch shows the general layout of the LRT system contributing to dead load.

A spreadsheet was developed so each of these assumptions can be investigated and varied.

PUGET SOUND TRANSIT CONSULTANTS COMPUTATION SHEET

PSTC

Subject: TRANSLAKE STUDY

LRT ENVELOPE AT FLOATING BRIDGE

Page ___ of ___

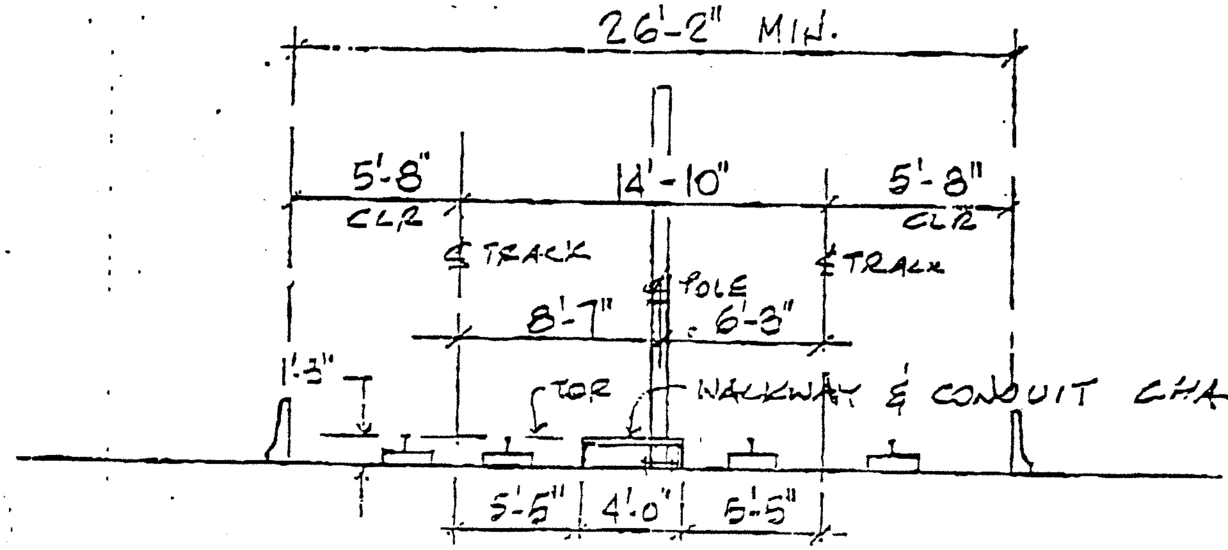
Made by: LUO

Date: 10/2/00

Checked by:

Date:

FOR DIRECT FIXATION FASTENERS:



TYPICAL SECTION

TANGENT TRACK

assume guard rails per std dwgs.

Puget Sound Transit Consultants
401 S. Jackson Street
Seattle, WA 98104-2826
Phone: 206-398-5000 Fax: 206-398-5219

MEMORANDUM

ATTACHMENT:

DRAFT

TO: File

FROM: G. Inverso

DATE: 15 February 2001

SUBJECT: **Translake Study**

Light Rail Transit Dead Loads Revisited

CIN: 9104-GEN010-0041

The superposed dead loads for adding Light Rail Transit (LRT) to the I-90 floating bridge were revisited to determine a realistic minimum. Several of the standard trackwork and walkway assumptions were modified. The following table summarizes the modified dead load per route foot. These can be considered the ~~greatest~~ lower bound for LRT dead load.

Components	Dead load (LBF/FT)
Trackwork	630
OCS System	40
Walkway/Cable Tray	50
Miscellaneous	80
Total	**800**

The general lay out of the LRT system is shown on the attached plan and section. The overall dimensions of the layout have not changed.

There were three major changes from the configuration given in the original memorandum of 2 November 2000 describing the assumption for initial dead load calculations.

1.) The guardrail configuration was changed to a restraining rail configuration. Both are methods to address derail. Guardrails provide a second set of rails set 10 inches inside the running rails. These limit the excursions of the train to 10 inches once it derails. A restraining rail is an additional rail bolted to one of the running rails. Its constrains the flange of the wheels and reduces the likelihood of the train derailing. Weight savings derived from this change include the following. There is one less rail. The guardrail configuration has four (4) rails; the restraining rail configuration has three (3) rails. Even though the restraining rail fastener is larger and heavier than a standard rail fastener, the hardware and grout needed to mount the two guardrails are eliminated, which leads to net savings. The width of the concrete plinths can be reduced.

2.) Single Fastener Plinths were used. The Standard Trackwork Drawings call for 2 to 6 Fastener Plinths. They also called for a 6-inch minimum, 10-inch preferred edge distance between the centered line of the fastener and the (longitudinal) end of the plinth. Finally, the Standards called for a 10-inch gap between plinths. Many of these assumptions were relaxed to develop the single fastener plinth. The guardrail configuration requires a 2-fastener plinth. By using the restraining rail configuration, a 1-fastener plinth can suffice. The 6-inch minimum longitudinal edge distance was used. The 10-inch gap was widened to 18-inches. This allowed a 30-inch fastener spacing with the minimum longitudinal length of concrete. The transverse widths of the plinths were reduce to the minimum. Two widths were used. One for the standard fastener and one for the restraining rail fastener. It should be noted that the track plinth, hardware, and rails for the restraining rails make the trackwork dead loads asymmetric about the centerline of the track by approximately 5-inches. This slight asymmetry may be used to help with listing.

3.) The raised walkway was removed. The walkway would be on the deck. A closed cable tray capable of being stepped on was used to enclose the fiber optic cables discussed in the 2 November memo.

The OCS system and contents of the cable tray remained unchanged from the 2 November memo. An 80 pounds per lineal foot miscellaneous load was added. This is to account for varying weight of materials and to cover uncertainty about unknown items. These can include deck leveling, drainage and such items that could develop during preliminary design.

cc: Ivo Gustetich
Art Barst
Jack Rudolph

Sound Transit / Link Light Rail

Superposed Dead Weight – I-90 Floating Bridge.

Tangent Guideway – Single Fastener Plinths; No Raised Walkway; No Special Trackwork. Normal Weight Concrete

Summary Weight/Length

Trackwork (lbf/ft)	**630**
OCS System (lbf/ft)	**40**
Walkway/Cable Tray (lbf/ft)	**50**
Total (lbf/ft)	**720**

Appendix B
Meeting Minutes

SOUNDTRANSIT

Meeting Notes

Design Contract
Subject File Code
Meeting ID #

Date: 10/24/00 **Time:** 9:00am **Location:** WSDOT Bridge Division Office -- Lacey, WA

Subject: Convertibility of I-90 to Light Rail Transit

Meeting Summary:

Don Billen and Rob Fellows provided an overview of the Translake Project.

Chuck Ruth indicated that the 3rd Lake Floating Bridge was designed for LRT load, as it was understood at that time.

Dick Rudolph presented the 1985 Metro Multi-Corridor Study. It concluded that a LRT only application on I-90 would result in a 2.3 inch loss of freeboard.

Art Borts presented the 1991 Regional Transit Project Study, which analyzed joint bus/rail operation. It found standard rail with joint bus operation would result in a 2 foot loss of freeboard, low profile rail 1 foot loss, and bolting only the head of the rail to the deck would cause a 5 inch loss. They examined grinding the deck as a way to avoid adding an additional paying layer but determined this would be infeasible – an opinion strongly echoed by WSDOT staff present. The study also looked at rail joints where the fixed and floating portions of the bridge meet and found a joint could be designed to accommodate the bridge movements. SkyTrain over the Fraser River in Vancouver, BC has similar joints. This study concluded the loss of freeboard associated with joint operations would be a significant problem, but the loss with LRT only would be much less. (However, the study did not recalculate the loss of freeboard for LRT only.) The 1991 study used a 135,000 90' LRT vehicle. The bridge was designed for a 100,000 load 60' vehicle.

Art Borst described the 1998 D-2 Roadway study which looked at joint bus/rail use. The study used a 148,00 crush load 90' LRT vehicle. The load increased between 1991 and 1998 due to the decision to use low-floor vehicles. This results in a 13% lbs/linear foot heavier load than the facility design vehicle. The 1998 study found a low profile rail rolled in Europe which minimizes the amount of new paving needed for joint operations, but concluded 65-70% of the D2 superstructure would require strengthening.

There are four structures in the I-90 corridor that require analysis – D2 Roadway, Mt. Baker Tunnel, floating bridge, and the East Channel tunnel.

Chuck Ruth recommended starting with analysis of the floating bridge, as this is the potential fatal flaw area in the corriodr. PSTC will provide a minimum LRT cross-section with design loads by November 3rd. Denise C. will provide five scenarios that have been analyzed in the current REX project for adding outer roadway HOV lanes. WSDOT will develop a scope-of-work for KPFF. We will reconvene on 11/16 to review all this material.

KPFF will deliver an analysis of the floating portion of the bridge between January 1- 31st.

SOUNDTRANSIT

Meeting Notes

Action Items	Responsibility
Schedule follow-up meeting	Don Billen
Deliver LRT cross-section and loads to KPFF	Jim Parsons
Develop floating bridge-analysis scope-of-work	Chuck Ruth/Rick Johnson

Handouts

Attendees: (or attach sign in sheet):

Don Billen; Patrick Clark, WSDOT Bridge; Dick Rudolph, PSTC; Jim Parsons, PSTC; Art Borst, PSTC; Dave Hilderbrant, Parametrix; Frank Higgins, WSDOT Bridge; Jerry Weigel, WSDOT Bridge; Geoff Swett, WSDOT Bridge; Rick Johnson, KPFF; Denise Cieri, WSDOT Design; Rob Fellows, WSDOT OUM; Chuck Ruth, WSDOT Bridge

Notes taken by: Page of

kpff Consulting Engineers
1201 Third Avenue, Suite 900
Seattle, Washington 98101
(206) 622-5822 Fax (206) 622-8130

MEETING NOTES

Date 2/1/01
Job # 100269.24
Project I-90 LRT Conversion Study
Subject Floating Bridge
Mtg Place WSDOT Maint. Office

Attendees:

Pat Clark, WSDOT
Charlie, Evans, WSDOT
Lester Rubstello, WSDOT
Pat Moyland, WSDOT
Archie Allen, WSDOT
Don Billen, Sound Transit
Art Borst, PSTC
Rick Johnson, KPFF

The meet was set up to kick off KPFF study work on converting existing HOV lanes on the I-90 Homer Hadley Bridge to light rail transit use. The results of the meeting were as follows:

1. The LRT conversion study should look at two rail location options within the area currently occupied by the HOV lanes. These two cases should consider a northern most scenario and southern most scenario to bracket the full range of options. It was discussed whether this study should consider the effect of median barrier movements proposed in a separate I-90 Homer Hadley study which is looking at adding one additional westbound lane to the floating bridge. The discussion concluded that this study should proceed based on the existing median barrier location only and should not try to combine the two studies.

2. KPFF brought up that the original proposed LRT rail dead loads are going to cause a significant freeboard reductions in the bridge, i.e. more than 7 inches, and requested a light weight rail solution be developed as an alternate for this study. PSTC agreed to provide a lightweight rail option to KPFF by February 14, 2001. Both the original proposed rail and lightweight rail layouts will be carried forth in the study.

3. For the purpose of accomplishing the study it was important to identify two key clearance dimensions. These dimensions were discussed in the meeting and summarized below:

   1) The LRT vehicle has a dynamic envelope that must not be encroached upon. This envelope brackets the vehicle and it maximum lateral excursions. For the purposes of this study this dimension was set at 5'-8" from the centerline of a track.

   2) WSDOT bridge maintenance personnel must be able to access the bridge manholes and drainage grates from a vehicle on the south side of the median barrier. Bridge maintenance requires a minimum lane width of 10'-0" to accomplish this.

   Based on the above two dimension the centerline of the track can be no closer than 15'-8" from the south face of the existing median barrier.

4. The next meeting was set for 1:00 February 22 at KPFF offices, 1201 3rd Ave, Suite 900 in Downtown Seattle. This meeting would inform Sound Transit on the work and progress to day for the study. KPFF indicated that the study would not be complete until the end of March.

cc: Attendees.

4. Railroad Safety

- Maintenance workers should be trained in railroad safety classes.
- Flaggers may be less of a concern if a cable barrier is placed between the shy area and 10-foot access route.
- Work could be at night if the railroad has scheduled closures. Maintenance will need to add a second shift for night work.
- More night work may mean variances from the city for light and noise ordinances.
- Boom trucks to remove transformers may have a footprint wider than 10 feet and would have to scheduled around railroad operations or work from the lane on the other side of median barrier with traffic closures.

5. Electrical

- Railroad must study grounding requirements to ensure that adequate grounding of DC power and rails (for static charges) is performed. Do not want stray current on the bridge and there is no good ground, except through cable anchors, which is undesirable.
- Safety procedures are required when working in the vicinity of the power lines with a boom truck.

6. South Cantilever Maintenance Access From the Deck

WSDOT may need access agreement with the Railroad to cross the tracks to perform maintenance on the south side.

7. UBIT

UBIT cannot reach across cantilever to view the underside of the cantilever. The truck is 30 feet from the edge. UBIT required for some access on the east elevated structure.

8. Emergency Response Plan

Access to bilge pumps on the south side will need a revision of the Emergency Response Access Plan due to revisions caused by track interferences. Can pipes be accessed by a hose laid across the tracks while pumper truck is in access space?

9. Railings

- Median barrier can become one sided traffic barrier.
- Cable railing at the south side is okay if no traffic and if train derailment is not a concern and there is no possibility of a train going over the edge and into the water.

10. STEEL BARRIERS

- Bolt pullout could be a problem if insufficient numbers of bolts are used.

- Replacement versus patching. Steel barriers need to be replaced after being damaged. Concrete can be patched.

11. CLEANING AROUND RAILS

- Spray and wash down will require Vac-Tor truck to suck up water. No dirty water in the lake.

- Sound Transit may need to consider vacuuming debris around tracks.

12. DRAINAGE

Not a concern with raised rails and gaps every 5 to 10 feet.

13. LIVE LOAD DISPLACEMENTS

Effects on slackening and tightening anchor cables.—fatigue, shims at anchor, and well extensions for freeboard loss.

14. AUXILIARY BUOYANCY

- Interference with cables, ducts, bilge piping, and storm drains.

- There needs to be room to turn boat around.

15. FUTURE STUDY

- Stray currents from the trains is a problem because the bridge cannot be grounded.

- Cathodic protection of the bridge reinforcing may be required if that is feasible.

Prepared by: Paul Brallier

PAB:pab:cjs

cc: All Attendees

100269

WSDOT I-90 LIGHT RAIL TRANSIT STUDY

DRAFT MEETING MINUTES

Date: February 22, 2001

Time: 1:00 p.m.

Place: KPFF/Seattle

Attendees:

Jane Farquharson - Earth Tech
Don Billen - Sound Transit
Art Borst - PSTC
Les Rubstello - WSDOT
Pat Moylan - WSDOT
Archie Allen - WSDOT
Charlie Evans - WSDOT Bridge
Patrick Clarke - WSDOT Bridge
Izzat Hasayen - KPFF
Bill Cichanski - KPFF
Paul Brallier - KPFF

1. LRT CONFIGURATIONS AND DEAD LOAD

   a. Introduction: LRT, in general, LRT on I-90, Translake Study

      Les Rubstello summarized the Light Rail Transit (LRT) program and planning studies to provide LRT across Lake Washington over SR 520 or I-90.

   b. LRT Configuration: KPFF summarized the general arrangement and clearances of the two proposed alignments for LRT on the I-90 floating bridge. Two figures were presented (enclosed) that illustrate the alignments. Key aspects of the alignments include:

      - All alignments are south of the current traffic median.

      - Alternatives BR1 and BR2 utilize the typical LRT ~~light-weight~~ cross-section. This arrangement weighs 1470 pounds/foot. They use approximately 12' long by 6" minimum tall by 2'-8" wide concrete plinths and separate derailment guardrails.

- Alternatives LWT1 and LWT2 utilize a modified LRT cross-section. This arrangement weighs 800 pounds/linear foot. They use approximately 1 foot long by 6 inches (minimum) tall by 2'-4" wide single fastener concrete plinths. LWT alternatives include a restraining rail that is integral with one of the running rails to prevent derailments.

- BR1 and LWT1: These provide a 10-foot access lane between the train dynamic envelope and the median barrier.

- BR2 and LWT2: These provide a 13'-10" access lane between the train dynamic envelope and the median barrier, but the south rail is as close to the edge of the bridge as possible.

c. Design Criteria Comparison: The original bridge light rail design and the proposed design loading criteria were presented by KPFF.

2. WEIGHT AND BALANCE

a. Dead Load: The effects of LRT dead load on the bridge freeboard was presented by KPFF. The floating bridge must remain at an even keel with the dead loads in place. Since the LRT dead load is south of the bridge centerline, additional gravel ballast must be added to the north cells of the pontoons to level the bridge. The change in bridge freeboard is summarized as follows:

LRT Alternatives (dead loads)	***Change in Freeboard***
BR-1 (1,470 plf)	- 8.2-inch
BR-2	- 8.7-inch*
LWT-1 (800 plf)	- 4.5-inch
LWT-2	- 4.7-inch*

* Alternatives BR-2 and LWR-2 do not include added structure weight for strengthening the cantilever.

b. Mitigation: Various modifications to the existing bridge to mitigate the effects of the LRT dead loads on the bridge freeboard were presented by KPFF. These include the following:

- Remove and replace the bridge concrete median barrier with a steel barrier. This has negative impacts to the maintenance operations due to the difficulty of repairing damaged steel barriers after a traffic accident and the higher level of maintenance of steel as compared to concrete.

- Remove and replace the bridge concrete traffic barrier on the south side of the bridge with a steel post and cable rails. This is similar to those used on the bridge pontoons below the elevated roadway. Without vehicle traffic, a concrete barrier is no longer required. Sound Transit noted that with the guardrail or restraining rails for the train derailments would be contained, thus only a safety cable barrier was required to prevent people from stepping off the bridge. This was recommended as a feasible alternative by Sound Transit.

- Remove 1/2-inch of the existing bridge concrete overlay south of the median barrier. The top 1/2-inch of overlay is considered a wearing surface. There is no longer a need for the wearing surface since there will no longer be heavy vehicle traffic on the maintenance access lane. Removing greater amounts of overlay were not considered feasible because 1-inch of the 1 1/2-inch overlay is considered part of the reinforcing steel cover. Concrete cover is crucial for the corrosion protection of the reinforcing steel.

- Remove all of the ballast on the south side of the pontoon with the minimum amount of ballast and remove the same amount of ballast in all the remaining pontoons.

- Auxiliary buoyancy could be added to the pontoons to increase the freeboard.

These weight mitigation alternatives provide the following increase in freeboard:

Mitigation Alternative	*Increase in Freeboard*
1. Steel Median	0.9-inch
2. Cable Barrier on South Side	2.5-inch
3. Remove 1/2-inch Overlay (40 feet wide)	1.3-inch
5. Remove Existing Ballast	0.8-inch
5. Auxiliary Buoyancy	As Required

If the Lightweight Rail Alternatives LWT1 and LWT2 are used in conjunction with Mitigation Alternatives 2, 3, and 4, there would be no measurable decrease in the bridge freeboard. This eliminates the need for steel median barriers and auxiliary buoyancy for the typical pontoon. It was discussed and decided to proceed with the study of the following:

Configuration	*Change in Freeboard*
Light Weight Rail Alternative 1 (LWT1)	- 4.5-inch
Cable Barrier on South Side	2.5-inch
Remove 1/2-Inch Overlay (40 feet wide)	1.3-inch
Remove Existing Ballast	0.8-inch
Total Change in Freeboard	- 0.1-inch

c. Live Load: KPFF presented the results of an investigation into the LRT live load-induced displacements and forces on the floating bridge for the following conditions:

- Midspan: Two Trains Bypassing
- Midspan: Two Trains About to Bypass
- Bridge Ends: Two Trains Bypassing
- Bridge Ends: Two Trains About to Bypass

The displacements caused by these cases affect the bridge:

- Effects at Anchor Cables: Concern was raised by the WSDOT Maintenance on the effects of these displacements on the anchor cable shims.

- Effects at Expansion Joints and to Rail Joints: The ability of the rails to accommodate these live load displacements is not known at this time. KPFF will summarize the live load and 1 year storm event displacements at the transition spans. These will be transmitted to Art Borst to have a rail designer determine how to accommodate the displacements in the rail joints.

- Live Load Mitigation: Mitigating the effects of the LRT live load will not be studied further until the effects of the live load displacements (described above) are considered with respect to the rail joint design. Auxiliary buoyancy could be considered at the cross pontoons if the live load displacement needs to be reduced. More accurate estimates of the live load displacements will likely show that the actual displacements are less that calculated above. If needed, the live load displacement could be determined by loading the bridge with moving water trucks that simulate the LRT loading.

3. STRUCTURAL MODIFICATIONS

KPFF presented the results of the investigation of the structural capacity of the bridge cross-section against the BR1 and BR2 alternatives. It was shown that the BR1 alternative results in a condition of zero net tension in the top fiber of the cantilever and that BR2 results in 500 psi tension. The later exceeds the bridge design criteria and is not acceptable. The LWT1 and LWT2 alternatives had not yet been checked, but they will be less severe that BR1 and BR2 because of the lower dead load. By inspection, it was also determined that the LWT2 would also exceed the bridge design criteria. It was discussed and determined that the only alternative that should be studied further is LWT1, the lightweight alternative that provides a 10-foot access lane.

Later communications between Izzat Hasayen and Sound Transit indicated that derailment is not a load case that needs to be considered for LWT1 and LWT2.

The structural effects of the loads on elevated structure had not yet been determined.

The structural effects of the loads on the approach span box girders was discussed briefly, but it is out of the scope of this study.

4. MAINTENANCE IMPACTS

KPFF presented various aspects of the impacts of the alternatives on bridge maintenance activities. Key elements include:

- ATV-type vehicles are needed to drive down the access lane.
- There should be a safety cable barrier to separate maintenance activities from the LRT dynamic envelope. It was indicated that maintenance would have free access to the bridge if they stayed between the median barrier and the safety cable barrier.
- Under bridge inspection trucks (UBITs) will not be able reach the cantilever of the approach spans for inspection. Inspection scaffolding will need to be installed.
- Access and Maintenance Agreements between Sound Transit and WSDOT will need to be arranged.
- Access to the tracks during operations will be prohibited for all practical purposes.
- Trains will have to be stopped during an emergency event which requires access to the bilge piping.

5. OTHER ISSUES

a. Electrical Grounding and Stray Currents: The design of the LRT needs to be revised to account for the difficulty of grounding electrical circuits on the lake. Art Borst noted that stray currents are virtually unavoidable and could present corrosion potentials to the reinforcing on the bridge which are not epoxy-coated.

6. TO DO LISTS

KPFF provide Art Borst with live load displacements at the transition spans.

Art Borst to have rail designer's study feasibility of rail joint at transition span given live load displacements.

Meet with HOV study group to consider possible median barrier alignments and their impact on LRT arrangements.

Prepared by: Paul Brallier

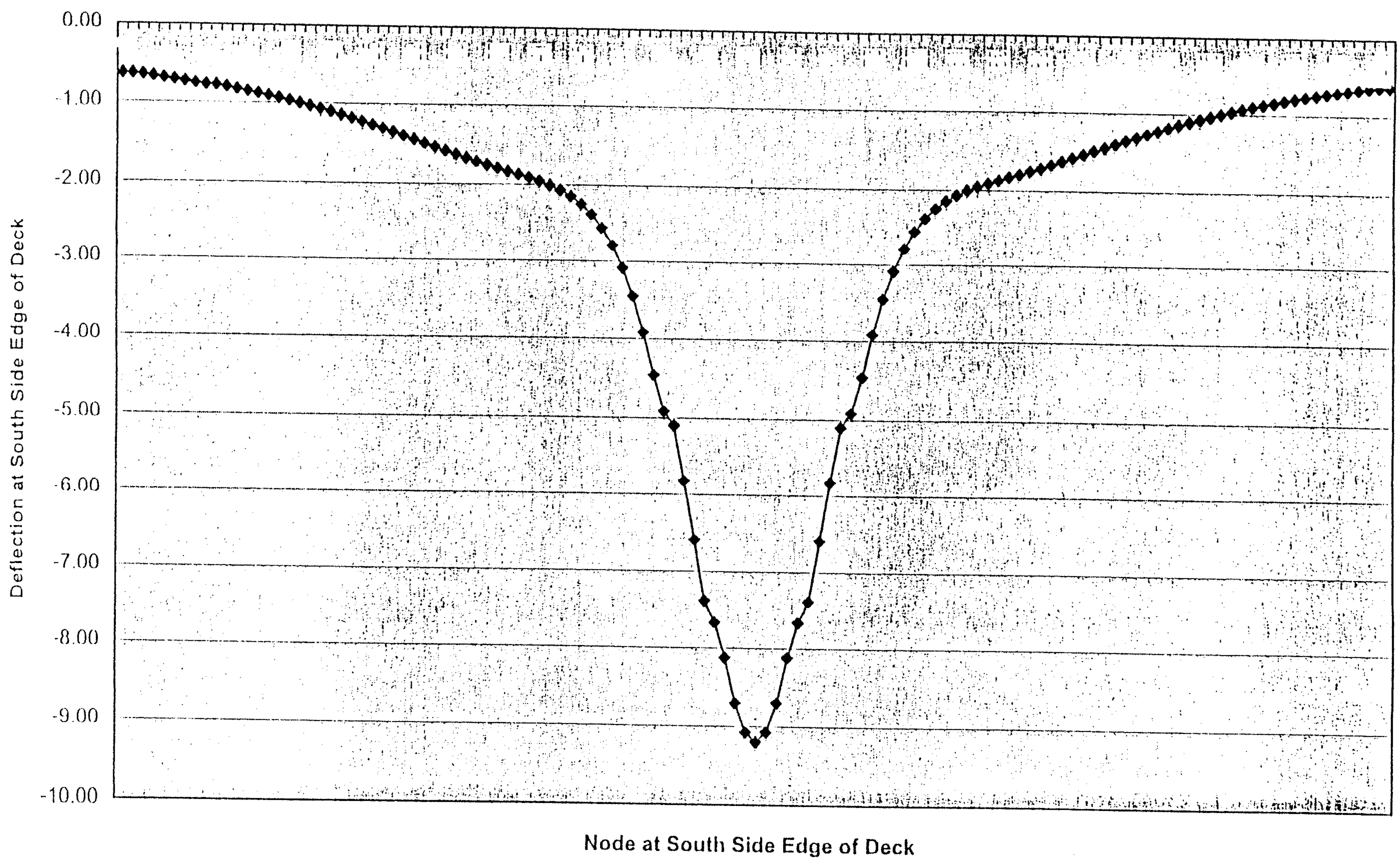
PAB:pab:cjs

cc: All Attendees

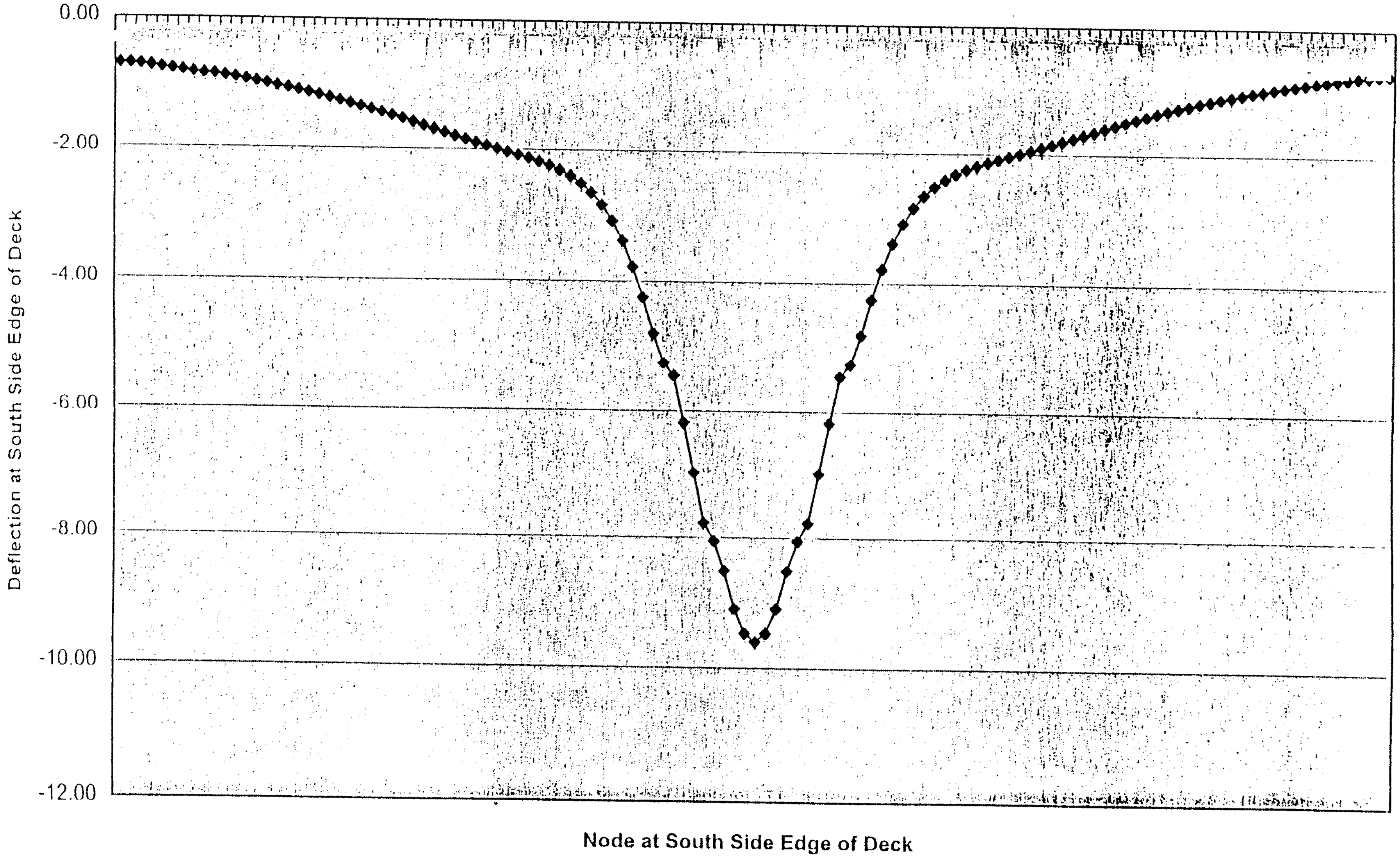
100269

Appendix C
Results of Live Load Hydrostatic Analysis

TWO TRAINS BY-PASSING AT MIDSPAN (INBOARD RAIL LOCATION)

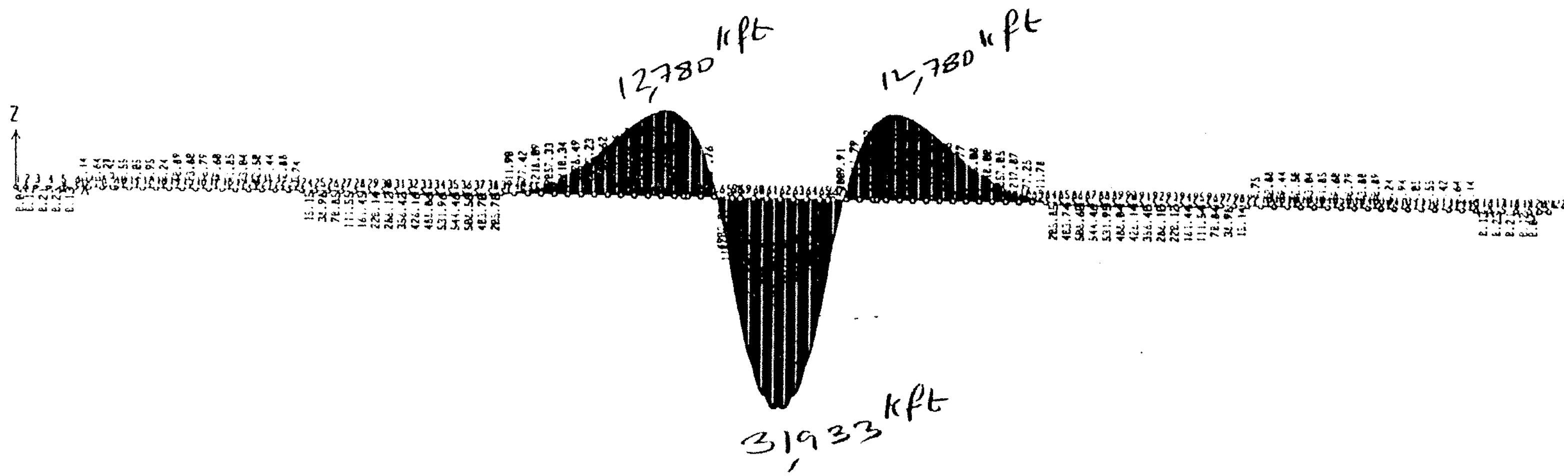


TWO TRAINS BYPASSING AT MIDSPAN (OUTBOARD RAIL LOCATION)



Two Trains Bypassing @ Midspan

(Outboard Rail Location)



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SAP2000

3/22/01 9:44:46

Torsional Moments

Two Trains By-Passing at Midspan
(Inboard Rail Location)

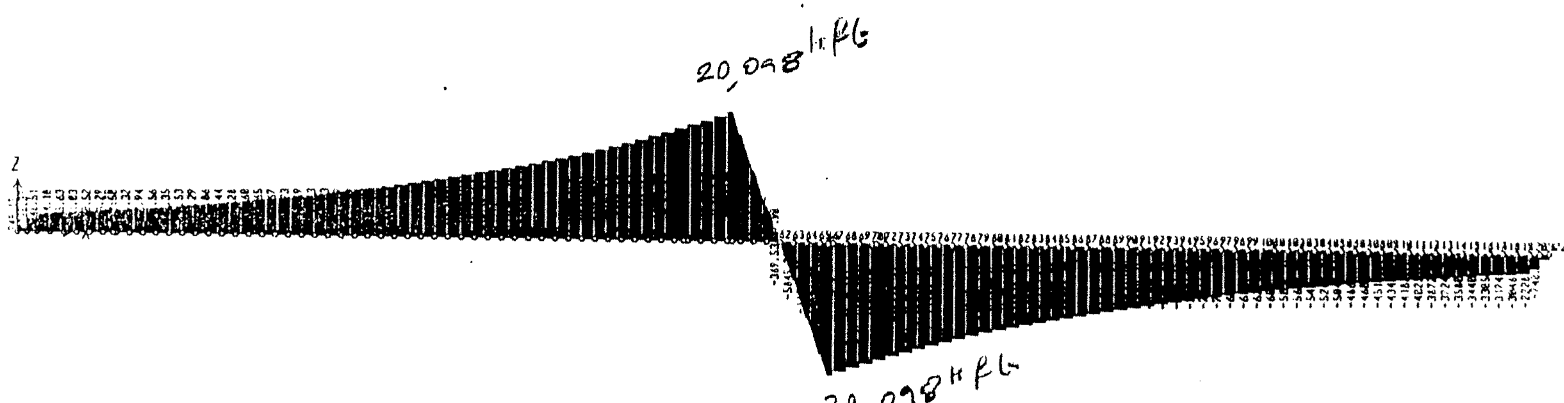
SAP2000 v7.40 - File:Live_Load - Torsion Diagram (LIVE1A) - Kip-ft Units

SAP2000

3/22/01 10:00:49

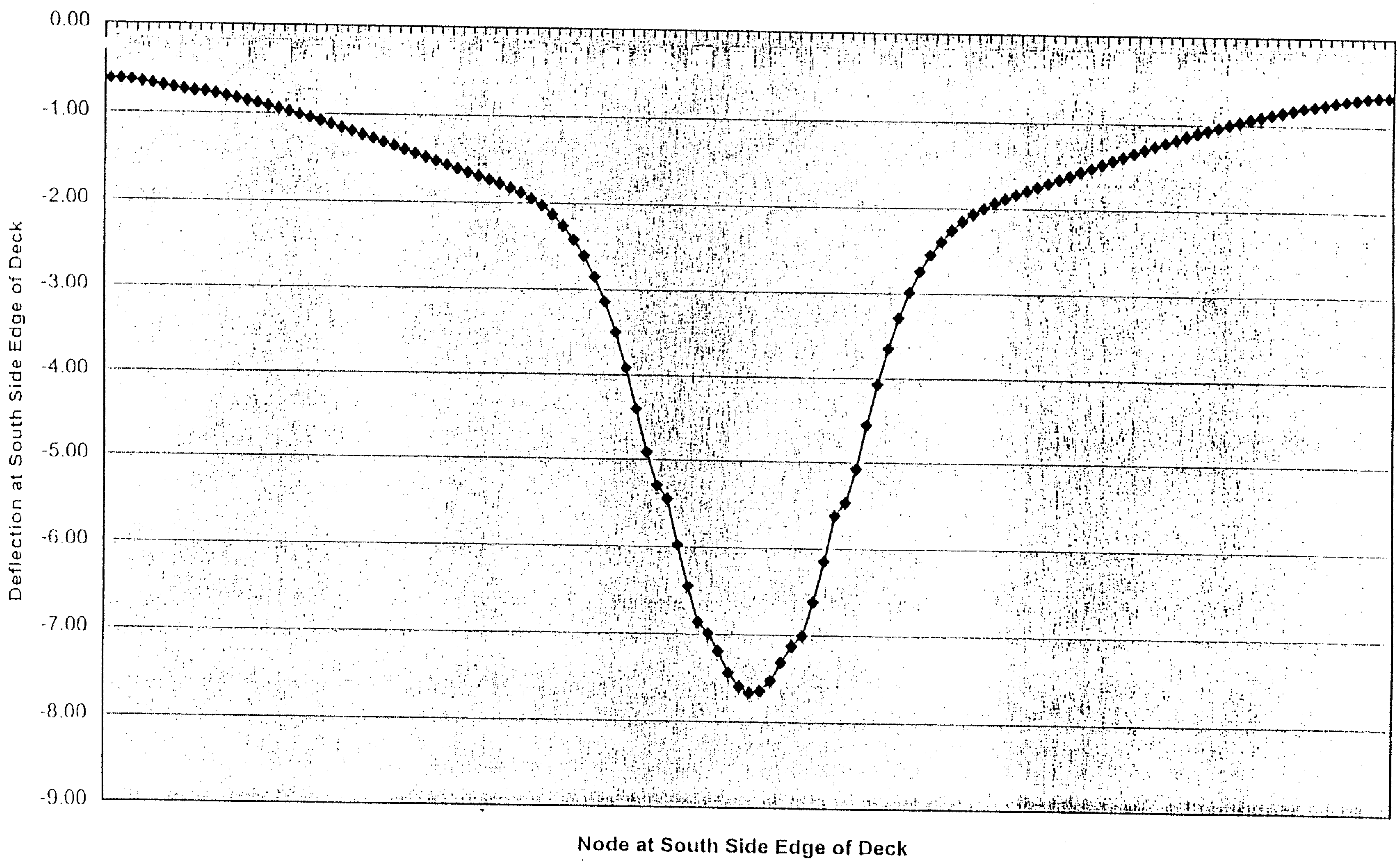
Two Trains Bypassing @ Midspan

(Outboard Rail Location)

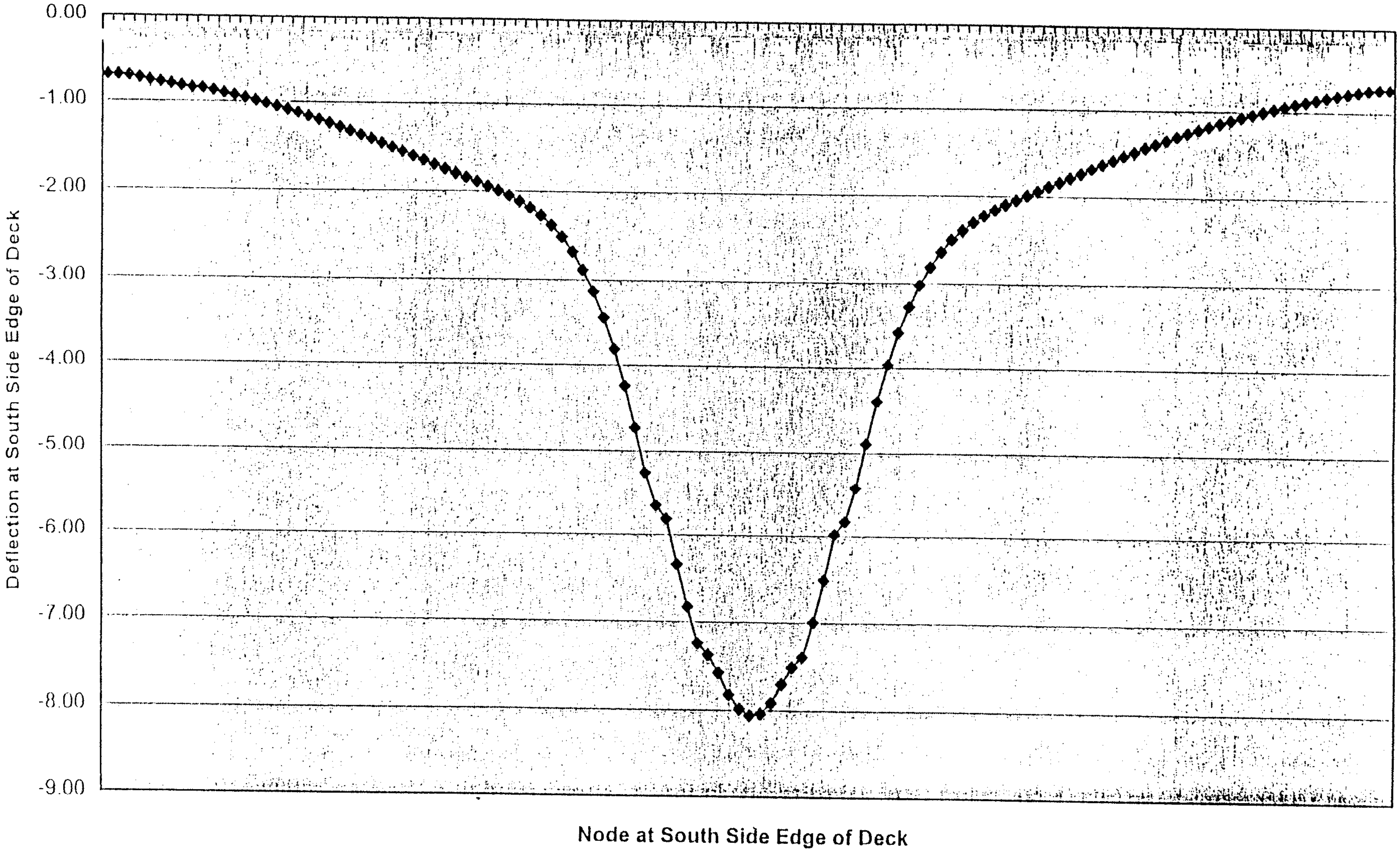


SAP2000 v7.40 - File:Live_Load - Torsion Diagram (LIVE1B) - Kip-ft Units

TWO TRAINS ABOUT TO BYPASS AT MIDSPAN (INBOARD RAIL LOCATION)



TWO TRAINS ABOUT TO BYPASS AT MIDSPAN (OUTBOARD RAIL LOCATION)

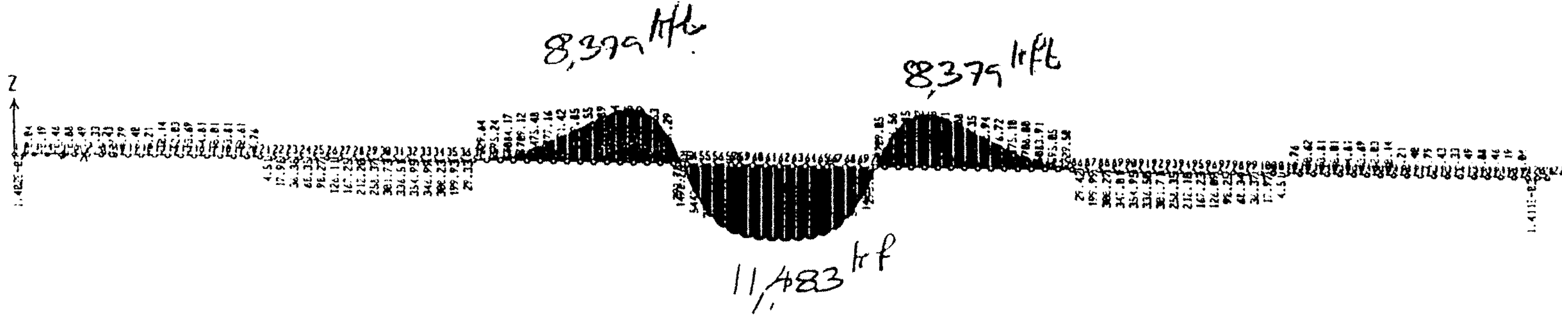


SAP2000

3/22/01 10:02:00

Two Trains about to Bypass @ Midspan

(Inboard Rail Location)



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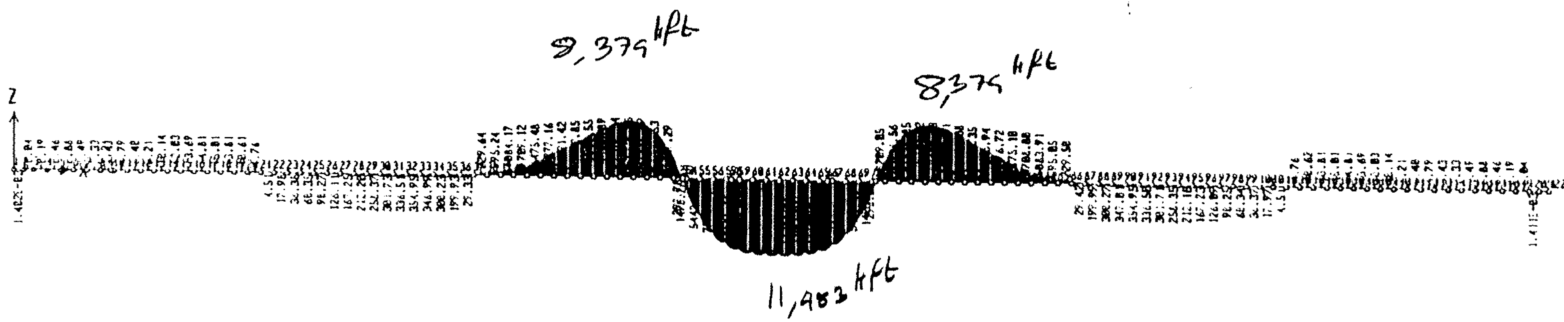
SAP2000

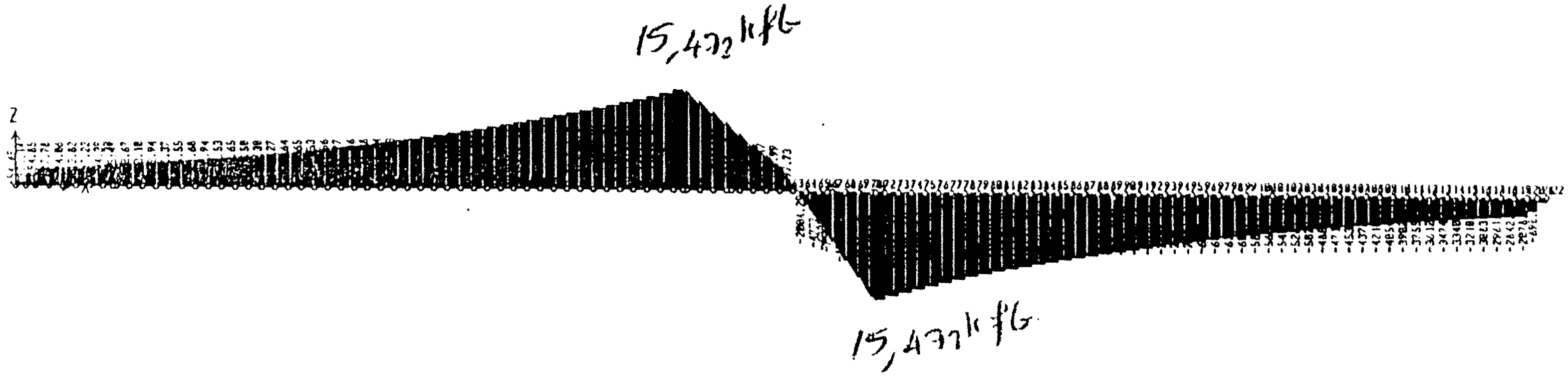
3/22/01 10:17:44



SAP2000 v7.40 - File:Live_Load - Moment 3-3 Diagram (LIVE2B) - Kip-ft Units

Two Trains about to Bypass @ Midspan

(Inboard Rail Location)



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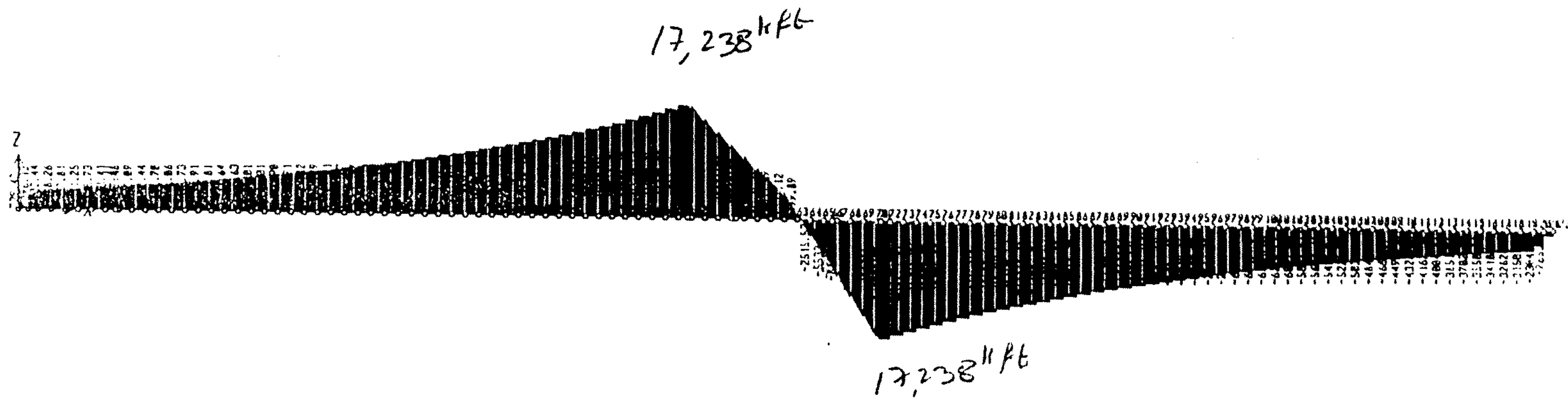
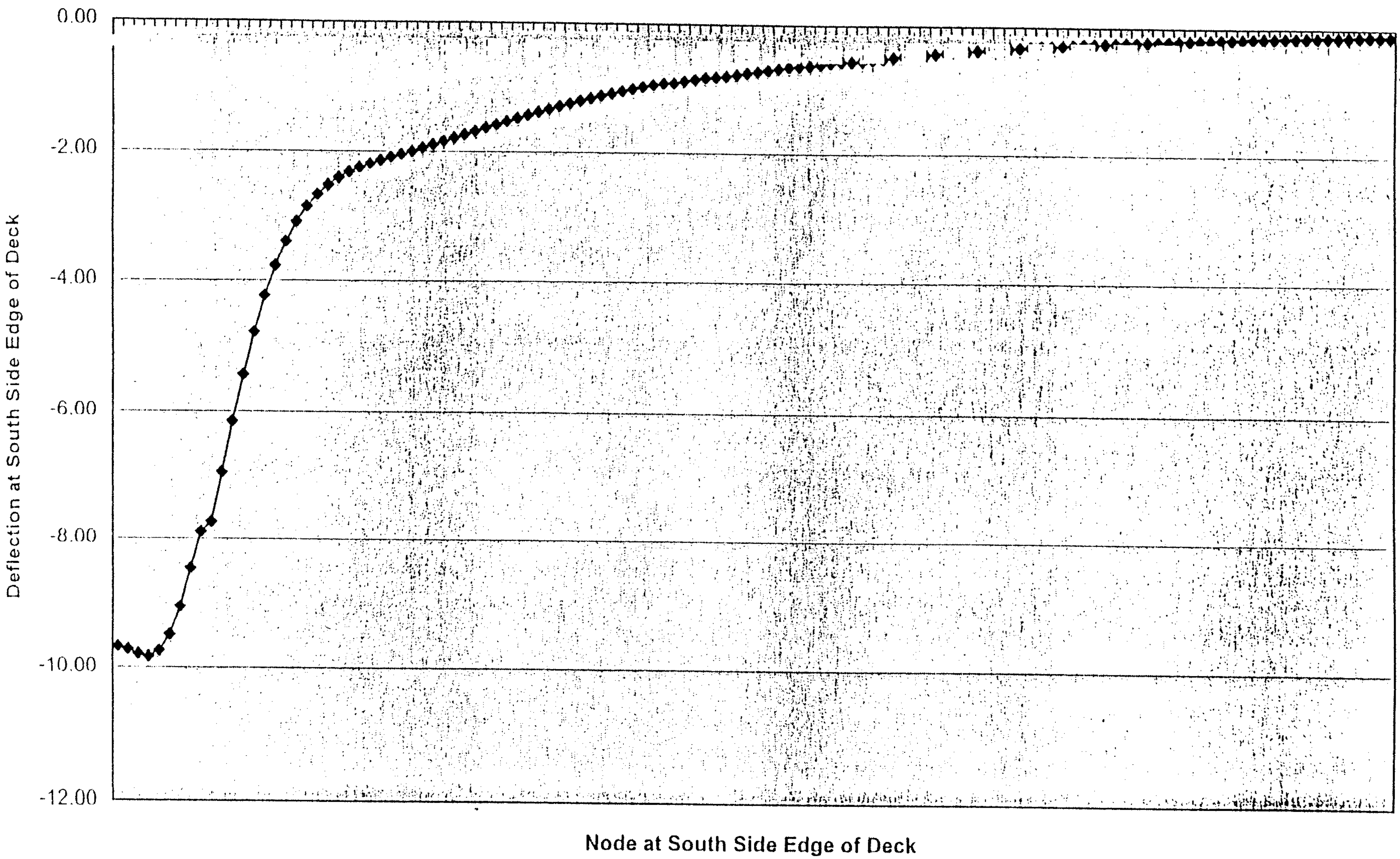
Two Trains about to Bypass @ Midspan

(Outboard Rail Location)

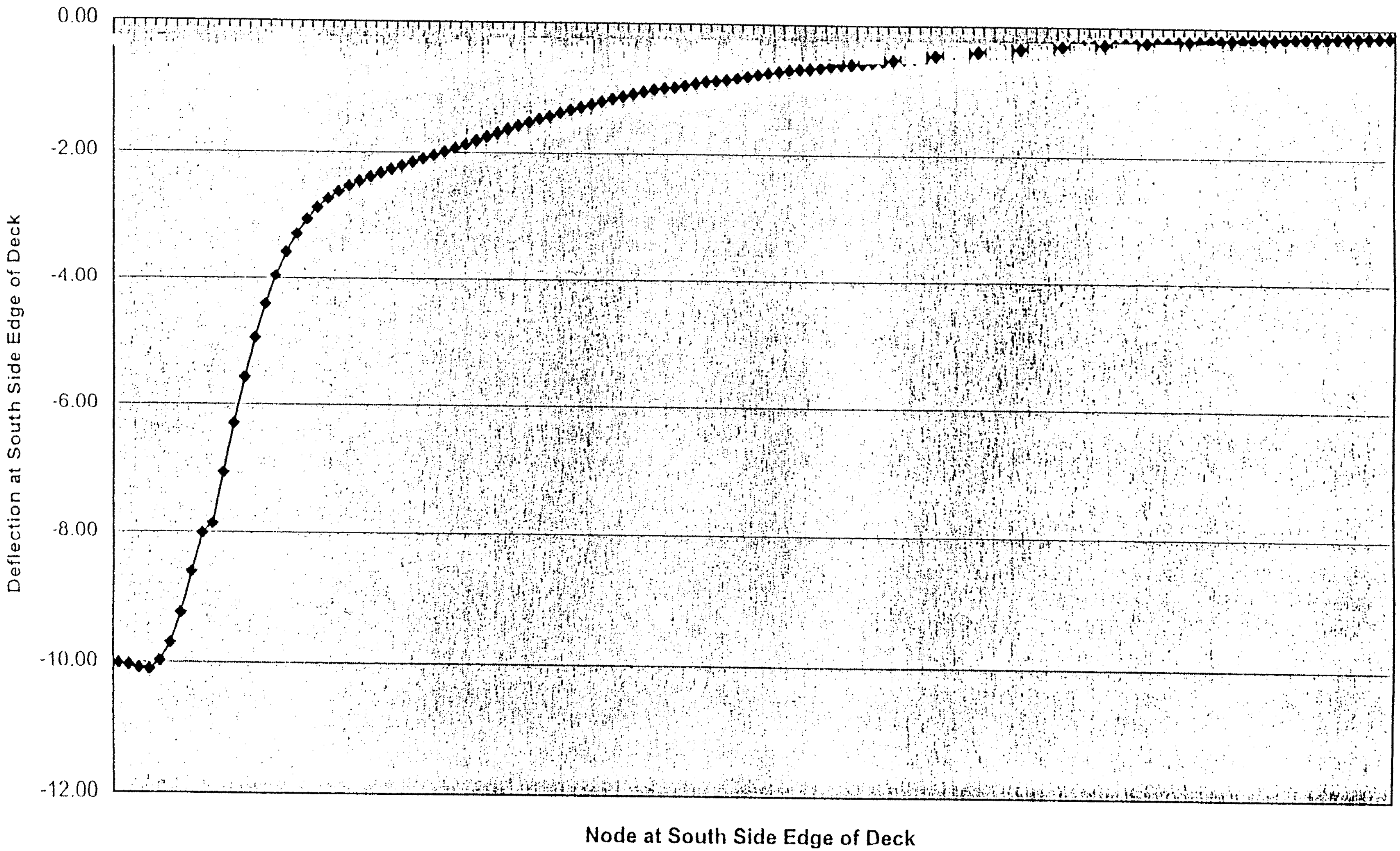


SAP2000 v7.40 - File:Live_Load - Torsion Diagram (LIVE2B) - Kip-ft Units

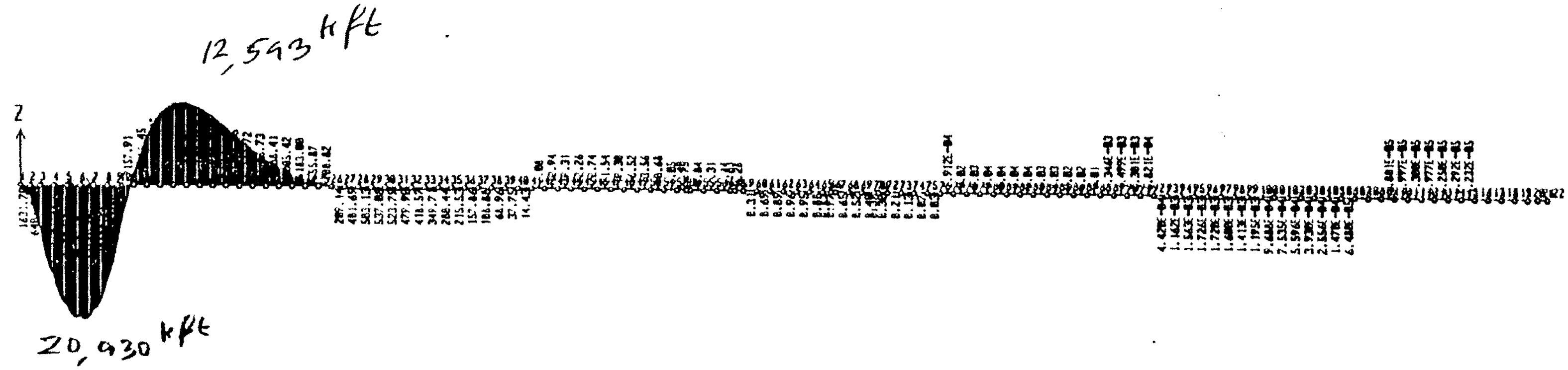
TWO TRAINS BYPASSING AT ONE END OF THE BRIDGE (INBOARD RAIL LOCATION)



TWO TRAINS BYPASSING AT ONE END OF THE BRIDGE (OUTBOARD RAIL LOCATION)



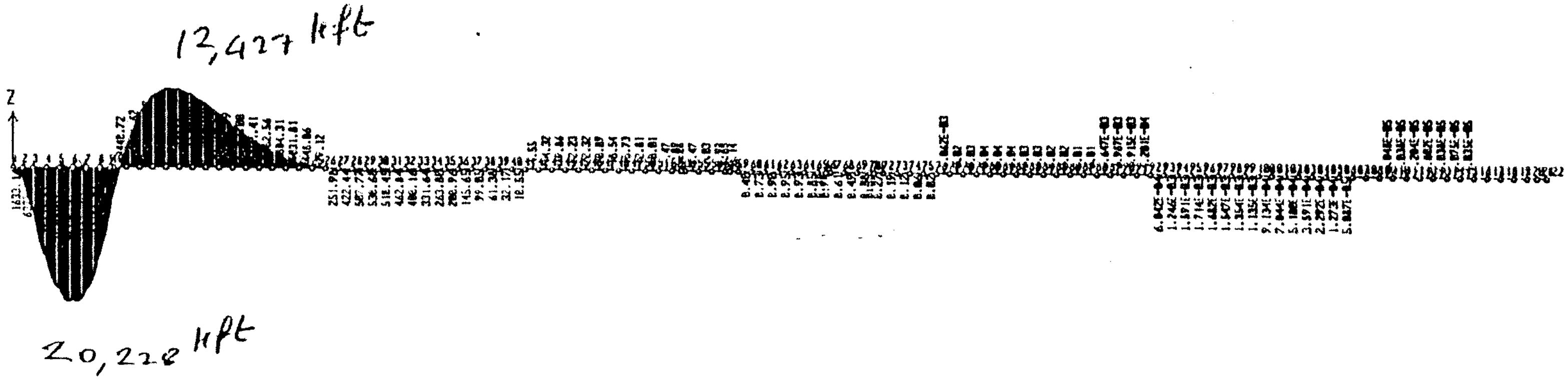
Two Trains Bypassing @ one end of Bridge
(Inboard Rail Location)



SAP2000 v7.40 - File:Live_Load - Moment 3-3 Diagram (LIVE3A) - Kip-ft Units

Two Trains Bypassing @ One End of Bridge

(Outboard Rail Location)

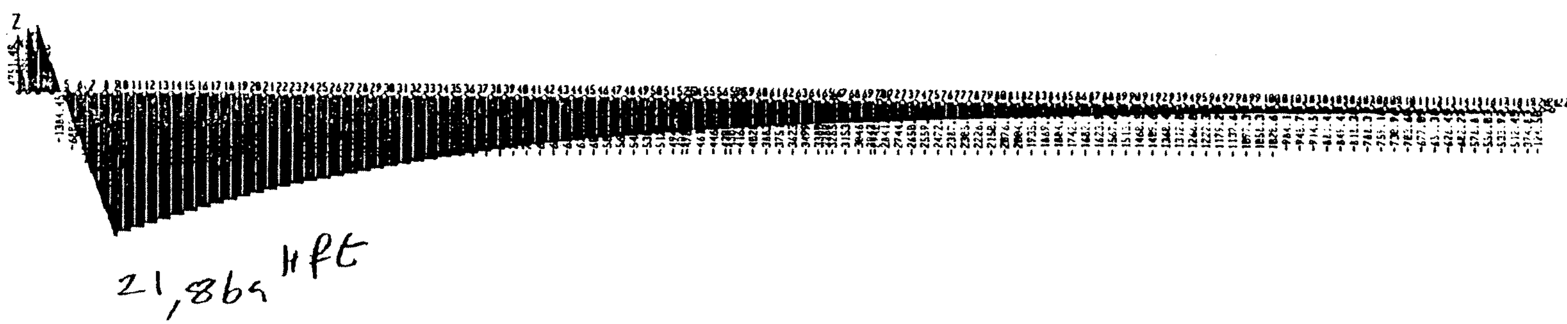


Two Trains Bypassing @ one end of Bridge

(Inboard Rail Location)

Two Trains Bypassing @ one end of Bridge

(Outboard Rail Location)



SAP2000 v7.40 - File:Live_Load - Torsion Diagram (LIVE3B) - Kip-ft Units

Appendix D

Cost Estimate Summaries

kpff Consulting Engineers

Homer Hadley (Interstate 90) Floating Bridge
Structural Feasibility Study

LR-1 Mod. Scenerio Rundate: 4/27/2001
Estimate of Probable Construction Cost All Amounts Rounded

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	AMOUNT (2001$)
1	Mobilization				$859,856
2	M5, Cable Barrier Rail	1	LS	$2,000,000	$2,000,000
3	M6, Remove Ballast	1	LS	$250,000	$250,000
4	M12, Remove 1 inch of overlay	19123	Cu. Ft.	$144	$2,753,760
5	M12, Install 1/4 Polymer concrete overlay	229480	Sq. Ft.	$10	$2,294,800
6	Superstructure Retrofit	1	LS	$1,050,000	$1,050,000
7	Traffic Control	1	LS	$250,000	$250,000
8					
9					
10				Subtotal:	$9,458,416
11					
12			Contingency at 30%:		$2,837,525

TOTAL ESTIMATED COST - (2001$)	$12,295,941

This estimate does not include:
Wa. State Sales Tax
Engineering and Construction Management
Electrical Modifications and Temporary Services
LRT System Installation Costs

kpff Consulting Engineers

Homer Hadley (Interstate 90) Floating Bridge
Structural Feasibility Study

LR-3 Mod. Scenerio Rundate: 4/27/2001
Estimate of Probable Construction Cost All Amounts Rounded

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	AMOUNT (2001$)
1	Mobilization				$844,079
2	M5, Cable Barrier Rail	1	LS	$2,000,000	$2,000,000
3	M6, Remove Ballast	1	LS	$250,000	$250,000
4	M12, Remove 1 inch of overlay	18526	Cu. Ft.	$144	$2,667,705
5	M12, Install 1/4 Polymer concrete overlay	222308.8	Sq. Ft.	$10	$2,223,088
6	Superstructure Retrofit	1	LS	$1,050,000	$1,050,000
7	Traffic Control	1	LS	$250,000	$250,000
8					
9					
10				**Subtotal:**	$9,284,872
11					
12			**Contingency at 30%:**		$2,785,462

TOTAL ESTIMATED COST - (2001$)	$12,070,333

<u>This estimate does not include:</u>
Wa. State Sales Tax
Engineering and Construction Management
Electrical Modifications and Temporary Services
LRT System Installation Costs

kpff Consulting Engineers

Homer Hadley (Interstate 90) Floating Bridge
Structural Feasibility Study

LR-3 Mod. Scenerio associated HOV widening Costs Rundate: 4/27/2001
Estimate of Probable Construction Cost All Amounts Rounded

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	AMOUNT (2001$)
1	Mobilization				$1,106,700.00
2	Relocate Pedestrain Barrier	1	LS	$2,675,000	$2,675,000
3	Relocate Median Barrier	1	LS	$2,975,000	$2,975,000
4	Modify Deck Drains	1	LS	$117,000	$117,000
5	Replace Expansion Joints	1	LS	$4,800,000	$4,800,000
6	Traffic Control	1	LS	$500,000	$500,000
7					
8				**Subtotal:**	$12,173,700
9					
10			**Contingency at 30%:**		$3,652,110

TOTAL ESTIMATED COST - (2001$)	$15,825,810

<u>This estimate does not include:</u>
Wa. State Sales Tax
Engineering and Construction Management
Electrical Modifications and Temporary Services
LRT System Installation Costs

kpff Consulting Engineers

Homer Hadley (Interstate 90) Floating Bridge
Structural Feasibility Study

LR-4 Mod. Scenerio associated HOV widening Costs
Estimate of Probable Construction Cost

Rundate: 4/27/2001
All Amounts Rounded

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	AMOUNT (2001$)
1	Mobilization				$839,200.00
2	Relocate Median Barrier	1	LS	$2,975,000	$2,975,000
3	Modify Deck Drains	1	LS	$117,000	$117,000
4	Replace Expansion Joints	1	LS	$4,800,000	$4,800,000
5	Traffic Control	1	LS	$500,000	$500,000
6					
7				Subtotal:	$9,231,200
8					
9			Contingency at 30%:		$2,769,360

TOTAL ESTIMATED COST - (2001$)	$12,000,560

<u>This estimate does not include:</u>
Wa. State Sales Tax
Engineering and Construction Management
Electrical Modifications and Temporary Services
LRT System Installation Costs