Texas Central High-Speed Railway

Last Mile Analysis Report

Dallas-Houston, Texas, High-Speed Rail Project

Issue | March 27, 2015

Job number 234180-00
Texas License #:1990

Arup Texas Inc
10370 Richmond Avenue
Suite 475
Houston TX 77042
United States of America
www.arup.com

ARUP

FREESE AND NICHOLS

Table of Contents

Tables

Figures

Appendices

Executive Summary

Texas Central High-Speed Railway (TCR)[1], a private entity, desires to build a reliable, safe, and profitable passenger rail transportation system between Houston and Dallas, Texas using proven Japanese high-speed rail (HSR) technology (hereafter the “Project”). In order to obtain the required regulatory approvals, including a favorable Record of Decision (ROD) resulting from an Environmental Impact Statement (EIS) as required under the National Environmental Policy Act (NEPA), various alternatives must be developed and evaluated through a documented process that includes various technical analyses, environmental resource agency reviews, and engagement with the public and Project stakeholders. To inform this process, an evaluation of alternative corridors was undertaken and a draft *Step 1 Screening of Corridor Alternatives Report* was completed to document the analysis. This evaluation was competed in advance of the EIS Scoping process, and further updated based on input received through Scoping and through additional technical analyses. The initial draft version of the *Step 1 Screening of Corridor Alternatives Report* documented the environmental and engineering efforts completed by TCR to evaluate potential HSR corridors in advance of the formal EIS process led by the Federal Railroad Administration (FRA). The draft report also screened out routes initially considered, but found to be flawed from an engineering, environmental, or financial feasibility perspective. The Utility Corridor (UC) following high-voltage electrical transmission lines and the corridor following the BNSF Teague Line (BNSF) were both found to be potentially feasible corridors in the initial draft *Step 1 Screening of Corridor Alternatives Report* (with respect to expected impacts and financial viability) and recommended to advance.[2]

This Last Mile Analysis Report documents a more detailed comparative evaluation of the marginal costs and impacts associated with reaching progressively farther into the urban core to access terminus station locations in both the Houston and Dallas markets for the BNSF Option 1 and UC corridors initially considered potentially feasible in the draft *Step 1 Screening of Corridor Alternatives Report*. For this Last Mile Analysis, the conceptual engineering and planning efforts undertaken developed both end-segments for the recommended BNSF Option 1 and UC alignments to a sufficient and consistent level of detail to enable this

[1] Texas Central High Speed Railway (“TCR”) includes affiliates for the project to include construction and operation of the HSR.

[2] The initial draft *Step 1 Screening of Corridor Alternatives Report* (dated October 8, 2014) included the Rail Alternative following the BNSF Teague Line as one of two preferable corridors. However, further analyses and coordination efforts have revealed that potential HSR alignments within the BNSF Teague Line Corridor from Teague to milepost 64 (Houston) are not feasible (due to major engineering, financial, safety, schedule, and Project delivery concerns) and would not meet TCR’s purpose to provide reliable, safe, and economically viable high-speed passenger transportation. As such, an updated draft *Step 1 Screening of Corridor Alternatives Report* (dated March 22, 2015) was issued and these concerns have been reflected in Section 8 (Alternatives Comparison Conclusion) in this Last Mile Analysis Report.

comparative assessment of serving possible terminus station locations and to identify the most feasible terminus locations in both Houston and Dallas.

A broad array of both quantitative and qualitative evaluation criteria were considered in the comparison of Last Mile Alternatives covering project delivery (cost, schedule, and ridership), engineering (alignment, major structures, and constructability), environmental, right-of-way (ROW), land use (existing development), and terminus considerations (access to existing transportation and development opportunities).

The results of the analysis are presented in the form of numeric ratings for each of the various categories of evaluation criteria and summarized in “stoplight charts” for each Last Mile Alternative. The assigned ratings for each category of evaluation criteria are used to quantify the relative magnitude of benefits and adverse impacts each alternative has on the feasibility of the Project. In summary, the analysis revealed that reaching Downtown Houston with the Houston BNSF corridor was not financially feasible due to engineering, environmental, safety, schedule, and project delivery concerns.

For the Houston UC Alternatives, the analysis suggests that Alternative B (a terminus located at US 290/IH-610) is rated the highest when considering cost, schedule, environmental, land use, engineering, and constructability concerns associated with an alignment constructed into Downtown Houston.

For the Houston BNSF Last Mile Alternatives, the analysis suggests that Alternative A (a terminus located at SH 249/Beltway 8) is rated the highest with respect to cost, environmental, land use, engineering, and constructability concerns associated with alignments constructed into Downtown Houston.

For the Dallas Alternatives, the analysis suggests that Alternative C (a terminus located at Downtown Dallas) is rated the highest and would provide the best balance between ridership, development opportunities, and connections to existing transportation and environmental and land use impacts and constructability and engineering concerns. Dallas Alternative C (Downtown Dallas) can accommodate the Houston UC and is the preferred and recommended Dallas Last Mile Alternative under both corridor alternatives.

Finally, in comparing the Houston BNSF and Houston UC preferred Last Mile Alternatives, the Houston UC (Alternative B – US 290/IH-610) was found to be preferable to the Houston BNSF corridor (Alternative A – SH 249/Beltway 8) based on key cost, ridership, and constructability factors. The analysis made clear that following the Houston UC would allow the Project to reach further into the Houston urban area with significantly less impact and less cost than following the BNSF corridor. As explained in the updated *Step 1 Screening of Corridor Alternatives Report* (dated March 22, 2015), TCR desires to advance the study of only reasonable alternatives through the NEPA EIS process. Given the results of the analyses conducted to date, TCR is focused on the UC alignment identified in the *Step 1 Screening of Corridor Alternatives Report* and other potentially reasonable alignments within the UC.

1 Assessment Method and Criteria

The evaluation of alternative terminus station locations within the Houston and Dallas markets represents what is often referred to as a "last mile" analysis in which the marginal costs associated with reaching incrementally further into the urban core to access each station site are estimated.

A method was developed to evaluate the marginal costs and impacts for each alignment segment required to reach each terminus location for both of the alternative corridors recommended to advance in the original draft *Step 1 Screening of Corridor Alternatives Report*. As such, the conceptual engineering and planning efforts undertaken in this analysis developed both the BNSF Option 1 and UC corridors to a sufficient and consistent level of detail to enable this comparative assessment of serving possible terminus station locations.

Additional analyses and coordination efforts conducted after the initial draft *Step 1 Screening of Corridor Alternatives Report* revealed that potential HSR alignments within the BNSF Teague Line Corridor from Teague to milepost 64 (Houston) are not feasible (due to major engineering, environmental, financial, safety, schedule, and Project delivery concerns) and would not meet TCR's purpose to provide reliable, safe and economically viable high-speed passenger transportation. In accordance with these new findings, an updated *Step 1 Screening of Corridor Alternatives Report* (dated March 22, 2015) was issued. This Last Mile Analysis Report included a comparative assessment of both the UC and BNSF Option 1 corridors; however, the aforementioned concerns (detailed in the updated *Step 1 Screening of Corridor Alternatives Report*) are reflected in Section 8 (Alternatives Comparison Conclusion) in this Last Mile Analysis Report.

The overarching purpose of this Last Mile evaluation was to identify the most viable terminus locations in both Houston and Dallas for both of the two corridors. Meaningful evaluation criteria were selected that covered a broad range of engineering and environmental considerations as described in this section. For each terminus location engineering judgment, corridor understanding, and prior experience with delivery of passenger rail and heavy infrastructure projects were used in the evaluation and to rate each alternative corridor according to the evaluation criteria.

For the purposes of this Report, "Segments" refer to defined sections of an alignment, "Terminus Locations" refer to defined station sites, and "Alternatives" refer to the combination of segments from the alignment that end at a certain terminus station location.

1.1 Evaluation Method

A broad array of both quantitative and qualitative evaluation criteria were considered in the comparison of Last Mile Alternatives covering engineering, economic, station location, and environmental considerations. Criteria were categorized, and the categories were grouped. Based on the results of the analysis, a "stoplight chart" value of red, yellow, or green was assigned for each category of criteria for each alternative. Numeric values of 1, 2, and 3 were also used to represent the red, yellow, and green values, respectively. An overall rating was made for each alternative using professional judgment, considering the alternative's ratings across all categories of criteria. The evaluation method accounts for variation in the importance of potential evaluation criteria and focuses on those criteria that are most relevant to the viability of the alternatives, such as construction cost and environmental impacts.

The "stoplight chart" approach was used to be consistent with the alternative corridor screening evaluations documented in the *Step 1 Screening of Corridor Alternatives Report*. This is standard practice when the multiple criteria cannot readily be summed without a complicated weighting strategy. For example, some criteria could be quantifiably measured using GIS tools, such as the number of impacted acres of wetlands. Other criteria require a more qualitative assessment using professional judgment, such as expected risks during construction. Note that some changes were made to evaluation criteria used in this Last Mile Analysis from those used in the *Step 1 Screening of Corridor Alternatives Report* to minimize the number of qualitative criteria that arguably measure similar factors, and therefore minimize any potential "double counting".

The evaluation categories of criteria used in the comparative analysis are outlined in the following section.

1.2 Evaluation Criteria

The categories of criteria selected for comparative assessments are identified below. Key considerations used in the evaluation of each alternative are provided, along with general guidelines for how the alternatives were "scored" with respect to that category.

Group A: Project Delivery Considerations

This group contains those categories of criteria that represent the greatest impact on the economic viability of the overall Project. This includes estimated capital construction costs and revenue potential. This group also includes categories that have potential impacts on the design, regulatory approval, or construction schedule. Schedule impacts for a project of this magnitude have significant impact on the overall Project financial viability.

Ridership/Revenue Potential: The number of anticipated fee paying riders and the corresponding amount of revenue that would be generated by their purchase of tickets. An increasing number of fee paying riders generate greater revenue to offset the railroad's construction and operation costs. The evaluation category is rated 1, 2, or 3 depending on the variation from the average number of riders for all alternatives.

Schedule: The total time from beginning of construction to beginning of revenue service. The greater the duration, the greater the overall project costs due to factors such as financing and insurance costs, inflation, and contractor administrative costs. This category also includes issues associated with gaining project approval from various potential stakeholders and regulatory bodies. Issues associated with stakeholder considerations include degree of cooperation, interpretation of stakeholder's design criteria and procedures, and likely requirements for betterments to stakeholder properties can all affect the Project schedule. The evaluation category is rated 1, 2, or 3 depending on the variation from the average schedule and schedule risks for all alternatives.

Capital Construction Cost: The estimated capital construction costs for the heavy infrastructure elements of the Project. It does not include items that are of the same quantity and cost magnitude relative to all the alignments such as the vehicle fleet, maintenance facilities, and systems. This category does include major risk factors that could affect the Project's financial viability. The greater the complexity of a third party or stakeholder factor or issue, the greater the risk of a negative impact. The evaluation category is rated 1, 2, or 3 depending on the variation from the average capital cost and financial viability risk for all alternatives.

Group B: Alignment Engineering and Constructability

This group contains those categories of criteria that constitute the major infrastructure elements of the Project or that directly affect the design or construction complexity of these elements. Increasing complexity or magnitude of infrastructure requirements would translate directly to extended delivery schedules and increased Project costs.

Alignment: The total distance per segment from a common point to its terminus station location. It is measured in miles (kilometers). Higher construction costs are normally associated with longer distances (with allowances made for special conditions such as structures). This category also includes curvature along the alignment. Curves with tighter radii and higher superelevation would require more maintenance and may affect operation schedules due to speed restrictions. The evaluation category is rated 1, 2, or 3 depending on the variation of alignment length and number of speed-restricting curves for all alternatives.

Major Structure: Large and/or complex structures for crossing major highways and interchanges, rivers, rail lines, reservoirs, and other major physical barriers. The alternative alignments within each corridor cross major roadways within both Houston and Dallas. Each crossing is analyzed for vertical clearance, possible viaduct pier locations, max allowable span length, depth of viaduct bridge thickness, and constructability. The greater the number, size, height and complexity of the major structures, the greater the costs and impacts on construction duration and constructability. The evaluation category is rated 1, 2, or 3 depending on the variation of number and complexity of major structures for all alternatives.

Constructability Impacts: The degree of difficulty in constructing a segment. The greater the expected construction difficulty, the greater the risk of cost or schedule impacts. Segments requiring specially constructed approaches (including types of equipment and construction skills) would be more costly to deliver and construction schedules can be extended. Typical constructability concerns include known conflicts with major utilities, construction in densely developed areas, construction adjacent to or crossing heavily travelled highways, and construction adjacent to operating freight railroad lines. While construction of any project of this magnitude that runs through two major urban areas would involve specialized and complicated construction, the evaluation category is rated 1, 2, or 3 based on the magnitude of potential complicated and risky construction required relative to each alternative.

Group C: Environmental, ROW, and Land Use

This group contains those categories of criteria that define and quantify those issues affecting the environment, community, and land use impacts that must be mitigated. Greater complexity or size of impact would lead to greater Project costs. Significant environmental impacts would result in project delivery concerns. Further discussion is provided with respect to environmental considerations. Professional judgment was applied in assigning numeric values based on the data presented in this report, and to ensure that factors were not unduly weighted in the overall assessment.

Environmental and Wetlands: Areas and physical features along the route that encompass perennial water bodies and wetlands that would impact the design and construction of the Project. Included in this category are rivers, streams, lakes, water reservoirs, floodplains and wetlands. Increased impacts to water bodies and wetlands would increase the complexity of project permitting and also require greater mitigation to offset project impacts. Additionally, impacts to other environmental factors such as farm land, noise, threatened and endangered species, and parks and forests are evaluated in this category. The evaluation category is rated 1, 2, or 3 based on the magnitude of environmental impact relative to each alternative.

ROW Acquisitions: General extent and type of real estate required for the alternative. Normally, the higher complex usage of the property and the surrounding area's density and valuations, the greater the cost of property acquisition. Rural property is normally less expensive than urban property. The evaluation category is rated 1, 2, or 3 depending on not only the type of real estate required, but its characteristics, such as being rural or urban.

Land Use Impacts: A quantification of land uses impacted relative to surrounding location environment, type of usage, socio-economic factors, cultural resources, and community facilities. Generally, the more urbanized or complex the usage of the property impacted, the greater the Project costs. Preference is also given to those alignments that minimize impacts to largely undisturbed parcels. The evaluation category is rated 1, 2, or 3 depending on the magnitude of land use impacts relative to each alternative.

Group D: Terminus Station Location Considerations

This group includes the utilization of the surrounding area for each studied terminus location. Both Dallas and Houston have multiple commercial and economic centers spread across their respective metropolitan areas, including each having a downtown central business district. These many business districts are served by highly developed highway and roadway networks.

Access to Existing Transportation: The access to existing transportation networks would allow multiple areas and neighborhoods to access the station. Key roadway intersections and public transportation routes located near a station terminus would increase system access and attract additional potential riders. The evaluation category is rated 1, 2, or 3 depending on the variation in access to existing transportation networks near the station terminus between the alternatives.

Development Opportunities: This looks at the surrounding property use and growing development within the adjacent communities of the terminus station location. This category also evaluates the availability for property to fit a station and all its components including different types of facilities and parking. The evaluation category is rated 1, 2, or 3 depending on the variation in development opportunities near the station terminus between the alternatives.

1.3 Evaluation Criteria Ratings

Ratings for each of the various evaluation categories of criteria were determined through professional judgment and engineering considerations for the magnitude of benefits and adverse impacts each alignment segment and terminus location alternative would have on the relative feasibility of the overall Project. The following values for each evaluation criteria were used:

- Red OR “1” – Little to No Benefits OR Substantial/Major Negative Impacts
- Yellow OR “2” – Moderate Benefits OR Moderate Negative Impacts
- Green OR “3” – Substantial/Major Benefits OR Little to No Negative Impacts

In each Evaluation Group, a tally of the numbers assigned was made to arrive at an overall total for the Evaluation Group for each alternative. Group totals were then tallied to arrive at an overall score for each alternative.

2 Segments to Terminus Station Locations Considered

The distinct routes in Downtown Houston along the UC and BNSF Option 1 alignments were subdivided into segments based upon terminus station locations to create Last Mile Alternatives. Both alignments follow a common route into Dallas from a point just south of IH-20. As shown in Figure 1, there are several terminus locations for both alignments. The long "middle segment" data from the *Step 1 Screening of Corridor Alternatives Report* was used for both alignments outside the Houston and Dallas urban areas.

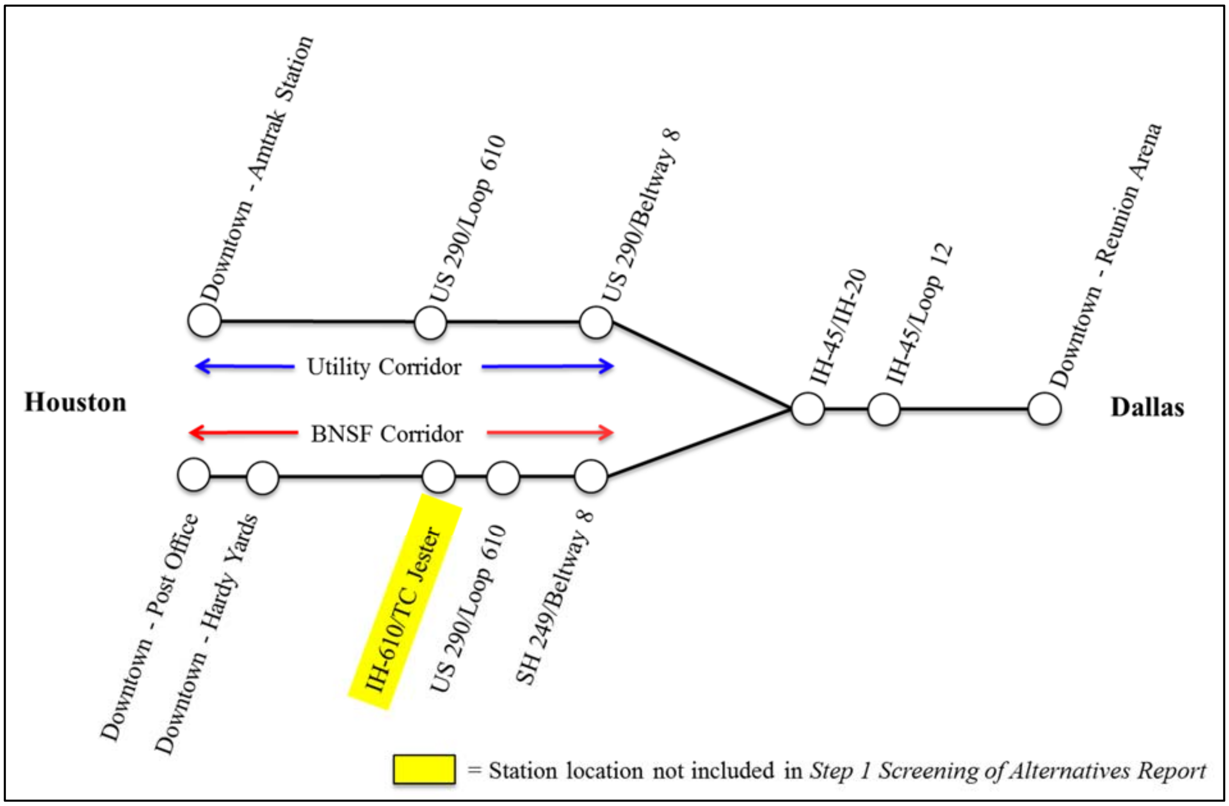

Figure 1 – Possible Terminus Station Locations

2.1 Houston – BNSF w/ Option 1 Alignment

The BNSF Option 1 alignment from Downtown Houston to the developing Grand Parkway (SH-99) was divided into seven segments. Each segment connects to the next segment and builds the alignment progressively further into the Houston urban area towards each successive terminus station location. The segments are combined as the alignment continues towards downtown Houston to produce a cumulative scenario that allows for the comparative assessment of the BNSF Houston Last Mile Alternatives. Figure 2 shows all seven segments used to approach the five station locations considered for the Houston BNSF Option 1 alignment.

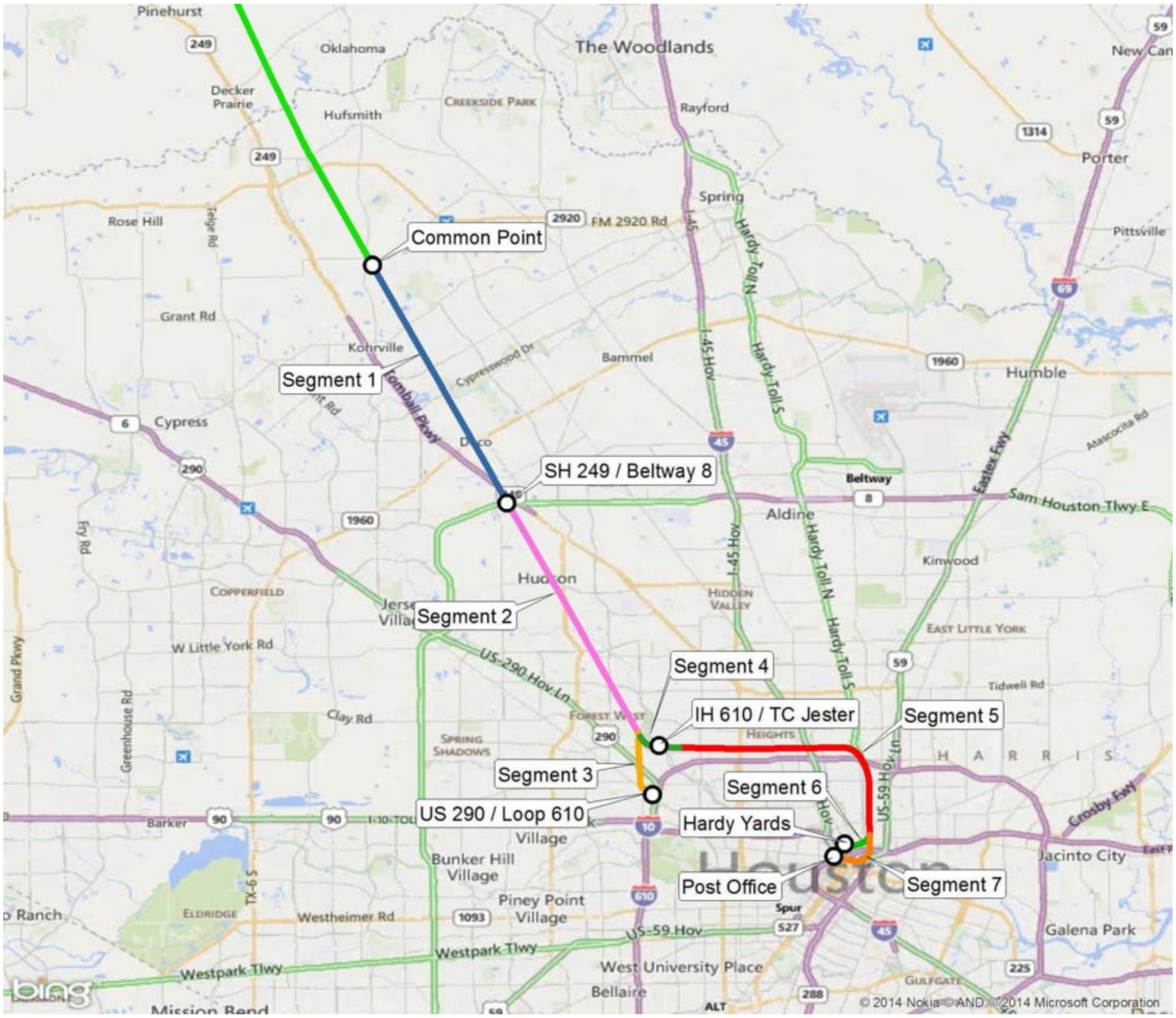

Figure 2 – BNSF Option 1 Houston Stations

2.1.1 Houston BNSF Alignment Segments (1 to 7)

The seven alignment segments were analyzed based upon length, curve data, major structures required, and projected impacts.

2.1.1.1 Houston BNSF - Segment 1

Limits

Segment 1 begins north of SH-99 at Sta. 45+867 and ends near Willowbrook Mall between Sta. 34+500 (See Appendix Figure A1). Segment 1 has a total length of approximately 7.1 mi (11.4 km).

Alignment

This segment uses the same alignment as the BNSF Option 1 corridor following the existing BNSF ROW. Segment 1 does not contain any horizontal curves that would cause speed restrictions of the HSR.

Major Structures

This segment of the alignment requires no major structures.

ROW Requirements, Property Impacts, and Environmental Considerations

This portion of the Project is heavily residential along both sides of the proposed ROW from the Grand Parkway to Louetta Road and from Cypresswood to just north of FM 1960. The area around FM 1960 is heavily commercial with Willowbrook Mall and satellite development adjacent to the proposed ROW. The potential for significant property impacts and displacements is high if any additional ROW is required for the proposed Project. In addition, there would be noise impacts, visual impacts, and potential changes in land use in the surrounding areas. For these reasons, the potential socio-economic, noise, land use, and community facilities impacts were considered high. There are only a few areas that are not impacted by suburban development and only a few drainage ways, which are largely channelized; therefore, the potential for impacts to biotic communities, hydrology and wetlands, endangered species, and prime farmland was considered low. Due to the lack of industrialization within this portion of the corridor, the likelihood of impacts from hazardous materials was considered low. Since this area has a large amount of recent development and is located outside the IH-610 Loop, the potential for cultural resources impacts was considered low.

2.1.1.2 Houston BNSF - Segment 2

Limits

Segment 2 starts at Sta. 34+500 south of Willowbrook Mall and ends north of TC Jester around Sta. 18+000 (See Appendix Figure A2). Segment 2 has a total length of approximately 10.3 mi (16.5 km).

Alignment

This segment uses the same alignment as the BNSF Option 1 corridor following the existing BNSF ROW. This segment continues north following along the west side of the existing BNSF Teague Line and crosses both Beltway 8 and SH 249. Segment 2 does not contain any horizontal curves that would cause speed restrictions of the train.

Major Structures

Segment 2 would require two major structures at the following locations:

- SH 249/Beltway 8 Interchange
- Sam Houston Tollway/Beltway 8

At Sta. 31+500 the alignment intersects with Beltway 8 (See Appendix Figure A1). Due to vertical and horizontal clearance requirements the alignment would need to pass above the highway. The profile was set at 65 ft (20 m) above ground to keep a minimum 16.5 ft (5.0 m) vertical clearance from Beltway 8. The total structure crossing would be 500 ft (152 m) wide with spans that are approximately 164 ft (50 m) long. Segmental bridge or steel plate girder bridge are possible options for construction.

Six sets of large overhead electrical transmission lines follow along the north side of Beltway 8. These lines are generally located between 80 ft (24 m) and 100 ft (31 m) above grade and would need to be raised above the HSR infrastructure to provide safe separation from the HSR overhead catenary.

Approximately 1640 ft (500 m) north of Beltway 8 the alignment crosses SH 249, Tomball Parkway, on a skew. The alignment would be elevated at this crossing and would reach heights of 65 ft (20 m) above ground. A structure span of approximately 787 ft (240 m) would be required to cross the entire width of SH 249 with no intermediate columns at the skewed crossing angle. Modifying the existing roadway bridge to accommodate a bridge pier may be possible, but at this early stage of planning for the Project it is more conservative to assume this arrangement. During more detailed design, it may be found that modifications to the existing roadway bridges may be more cost effective than constructing a single span HSR bridge, but it would be challenging to reconfigure SH 249 while maintaining traffic operations. An alternative design could include construction of several closely spaced structural bents that span the full width of SH 249 perpendicular to the roadway. These bents would then carry the HSR structure. During more detailed design this alternative would be reviewed to determine tradeoffs between the profile height required to accommodate the additional perpendicular bridge bents and structure required to clear span the roadway. Crossing SH 249 in this location may be the most challenging of all the major structures identified in this study.

ROW Requirements, Property Impacts, and Environmental Considerations

This portion of the alignment contains large components of commercial and industrialized areas and what appears to be low income housing. There is a large expanse of undeveloped land beginning just south of Fallbrook Drive and which continues sporadically southward to just north of Antoine Drive.

Streams in this area are largely channelized. The undeveloped land does not appear to be in agricultural uses and is likely trending toward commercial, industrial, and residential development.

Due to the developed nature of the area surrounding this segment, there would be noise impacts, visual impacts, community facilities impacts, and potential changes in land use in the surrounding areas. For these reasons, the potential socio-economic impacts were considered high. The socio-economic impacts could include environmental justice impacts due to the potential to affect low income residents.

As compared with Segment 1, there are more areas that are not impacted by development and only a few major drainage ways, which are largely channelized. Due to the expanses of undeveloped land, although likely of low habitat value, the potential for impacts to biotic communities, parks and forests, threatened and endangered species, hydrology and wetlands, and parks and forests was considered moderate.

Due to the large amount of industrialization, the potential for hazardous materials was considered high. Since this area is located outside the IH-610 Loop and is of earlier origins, the potential for cultural resources impacts was considered moderate.

2.1.1.3 Houston BNSF - Segment 3

Limits

Segment 3 begins at Sta. 18+000 north of Watonga Boulevard and ends at the Northwest Mall site just east of IH-610 (See Appendix Figure A2). Segment 3 has a total length of approximately 2.3 mi (3.7 km).

Alignment

Segment 3 alignment deviates from the BNSF Option 1 alignment to serve a potential suburban terminus location. The alignment ends at the Northwest Mall terminus location and aligns with the existing median along the center of Mangum Road heading north from the terminus location for approximately 2.3 mi (3.7 km) before crossing over US 290. The curvature required to follow Mangum Road requires the HSR alignment curvature to be at the desired minimum of 1315 ft (400 m), causing the trains to operate at a restricted speed of 35 mph (55 km/hr). Beginning near the intersection with Watonga Boulevard at Sta. 18+000, and continuing to the common starting point near SH-99.

Major Structures

This segment of alignment would require one major structure located at the intersection of Mangum Road and US 290 at approximately Sta. MR 1+800 (See Appendix Figure A2). The HSR alignment would be elevated 65 ft (20 m) and remain in the central median of Mangum Road while it crosses US 290. The intersection has limited space available for bridge piers. The center of US 290 has an HOV lane and the shoulders are at minimum widths. It does not appear that modifications to the existing highway configuration would provide for additional pier locations. Hence, at this preliminary level of analysis, it was assumed that the HSR bridge structure would need to fully span across US 290 with a span length of 242 ft (74 m).

ROW Requirements, Property Impacts, and Environmental Considerations

This alignment has large components of commercial and industrialized areas and what may be low income housing as well as large amounts of multi-family residential areas. Streams in this area are largely channelized. Near the southern terminus at IH-610 there is heavy industrial and commercial development as well as the Houston Independent School District Library Services Center and Northwest Mall. The ROW along Mangum Road is very narrow. The potential for displacements is high if any additional ROW is required for the proposed Project. In addition, there would be noise impacts, visual impacts, community facilities impacts, and potential changes in land use in the surrounding areas. For these reasons, the potential socio-economic impacts were considered high. There are only a few areas that are not impacted by development and only a few major drainage ways, which are largely channelized; therefore, the potential for impacts to biotic communities, parks and forests, threatened and endangered species, hydrology and wetlands, and prime farmland was considered low. Due to the large amount of industrialization, the potential for hazardous materials was considered high. Since this area is located outside the IH-610 Loop and is of earlier origins, the potential for cultural resources impacts was considered moderate.

2.1.1.4 Houston BNSF - Segment 4

Limits

Segment 4 begins at Sta. 18+000 and ends to the west of Oak Forest Drive at Sta. 15+600 (See Appendix Figure A2). Segment 4 has a total length of approximately 1.4 mi (2.3 km).

Alignment Description

This segment continues to follow the existing BNSF ROW crossing over the White Oak Bayou. This portion of the alignment contains tight curvature with a radius of 2865 ft (873 m). The 2865 ft (873 m) curve could cause the train to operate at a speed of about 45 mph (70 km/hr). This would cause a speed restriction on operations given the distance of the terminus location to the curve.

Major Structures

This segments does not require any major structures.

ROW Requirements, Property Impacts, and Environmental Considerations

This alignment has large components of commercial and multi-family residential areas. The eastern terminus and station would require large numbers of what appear to be commercial displacements. Much of the ROW in this area is narrow. The potential for displacements is high if any additional ROW is required for the proposed Project. In addition, there would be noise impacts, visual impacts, community facilities impacts, and potential changes in land use in the surrounding areas. For these reasons, the potential socio-economic impacts were considered high. White Oak Bayou in this area is channelized. There are only a few areas that are not impacted by existing development and the one large wooded area would not be affected by Project development; therefore, the potential for impacts to biotic communities, parks and forests, threatened and endangered species, hydrology and wetlands, and prime farmland was considered low. Due to the large amount of development, but with little industrialization, the potential for hazardous materials was considered moderate. Since this area is located outside the IH-610 Loop and is of earlier origins, the potential for cultural resources impacts was considered moderate.

2.1.1.5 Houston BNSF - Segment 5

Limits

Segment 5 starts at Sta. 15+600 and ends near Lorraine St at Sta. 3+000 (See Appendix Figure A5). Segment 5 has a total length of approximately 7.8 mi (12.6 km).

Alignment Description

This segment continues east following the existing BNSF ROW and crossing over IH-45. This segment then curves south crossing over IH-610 with a radius of 2950 ft (900 m). This would cause the train to travel at a restricted speed of about 45 mph (70 km/hr) and would cause a speed restriction given the distance from the terminus location to the curve. The alignment will also require several electrical utility line relocations.

Major Structures

This segment of alignment would require two major structures at the following locations:

- IH-610
- IH-45

Heading north from Hardy Yards, the first major structure within this segment is at IH-610 and Hardy Toll Road (See Appendix Figure A4). The T-shaped interchange located at Sta. 7+000 has numerous bridges with limited clearance to cross through the existing roadway levels and therefore the alignment must pass above the top level. The viaduct would be at 75.5 ft (23 m) above ground with spans that exceed 328 ft (100 m). The total structure length would be approximately 984 ft (300 m) long.

Crossing IH-45 at Sta. 9+700 would require one single large structure that spans the full 213 ft (65 m) (See Appendix Figure A3). In the middle of IH-45, an HOV lane was constructed and the inside shoulders were reduced to minimum widths. No additional bridge piers can be constructed in the median. Hence, the HSR viaduct would need to span the full width of IH-45 at a height of 65 ft (20 m) above ground. The use of a segmental bridge type would be ideal for this location.

ROW Requirements, Property Impacts, and Environmental Considerations

This alignment has large components of industrialized areas and large amounts of residential with low income housing. There are few expanses of undeveloped land along this portion of the corridor. Streams in this area are largely channelized. Additionally, the ROW transitions through commercial and residential areas near the southern terminus of the Hardy Tollway. The potential for displacements is very high. In addition, there would be noise impacts, visual impacts, community facilities impacts, and potential changes in land use in the surrounding areas. For these reasons, the potential socio-economic impacts were considered high. There are only a few areas that are not impacted by development and only a few major drainage ways, which are largely channelized; therefore, the potential for impacts to biotic communities, parks and forests, threatened and endangered species, hydrology and wetlands, and prime farmland was considered low. Due to the degree of industrialization, potential impacts from hazardous materials were considered high. Since portions of this area are located inside the IH-610 Loop in an older section of Houston, the potential for cultural resources impacts was considered moderate.

2.1.1.6 Houston BNSF - Segment 6

Limits

Segment 6 begins at Sta. 3+000 and ends at the former Union Pacific Railroad (UPRR) yard site called Hardy Yards, located just north of IH-10 (See Appendix Figure A5). This segment only runs for 0.8 mi (1.3 km) after curving away from the BNSF Option 1 alignment at Sta. 3+000.

Alignment Description

This segment crosses over the UPRR tracks before curving into the Hardy Yards site. The curve used to break away from the BNSF Option 1 alignment is at a radius of 1640 ft (500 m) which would allow a maximum operating speed of about 53 mph (85 km/hr). However, due to the proximity of the station, this curve would not affect cause a significant speed restriction and impact run times based on the N700-I acceleration profile.

Major Structures

This segment does not require any major structures.

ROW Requirements, Property Impacts, and Environmental Considerations

This alignment has large components of commercial and industrialized areas. There are few expanses of undeveloped land along this portion of the corridor. Streams in this area are largely channelized. Additionally, the ROW transitions through commercial and residential areas for much of its length. The potential for displacements is very high. In addition, there would be noise impacts, visual impacts, community facilities impacts, and potential changes in land use in the surrounding areas. For these reasons, the potential socioeconomic impacts were considered high. There are only a few areas that are not impacted by development and no major drainages; therefore, the potential for impacts to biotic communities, parks and forests, threatened and endangered species, hydrology and wetlands, and prime farmland was considered low. Due to the degree of industrialization, potential impacts and costs from disturbance of hazardous materials were considered high. Since portions of this area are located inside the IH-610 Loop in an older section of Houston, the potential for cultural resources impacts was considered moderate.

2.1.1.7 Houston BNSF - Segment 7

Limits

Segment 7 begins at Sta. 3+000 and ends at the old Post Office site in Downtown Houston at Sta. 0+000 (See Appendix Figure A5). Segment 7 has a total length of approximately 1.86 mi (3.0 km).

Alignment Description

This segment heads south crossing over multiple freight tracks and IH-10. Segment 7 then continues west crossing over the Buffalo Bayou multiple times on a 1970 ft (600 m) curve. Due to the highly developed nature of Downtown Houston, the alignment employs tight curvature. The 1970 ft (600 m) curve would only allow a maximum allowable speed of about 40 mph (65 km/hr). However, based on the N700-I acceleration profile, this curve would not affect run times due to its close proximity to the station terminus location.

Major Structures

This segment of alignment would require two major structures at the following locations (See Appendix Figure A5):

- Buffalo Bayou
- IH-10

The first major structure within this segment would cross over the University of Houston building, and over the Buffalo Bayou three times. At Sta. 1+300 the HSR would span the Bayou twice, cross over an electrical switching yard, and two roadway bridges. Determining bridge pier locations and span lengths would require detailed analysis. The Buffalo Bayou is designed to convey water through the city and exit into the bay. It is important that any new bridge structure does not impede the flow of water and cause flooding upstream. The structure would also need to be analyzed for the potential of scouring. The bayou is considered navigable and the United States Army Corps of Engineers (USACE) has jurisdiction, so each crossing structure must be approved and built to relevant guidelines. The HSR system’s major structure would be over 65 ft (20 m) high and have a host of complex design issues. The spans could extend beyond 460 ft (140 m) while the entire structure would be 1315 ft (400m) long.

At Sta. 2+000 the HSR crosses IH-10. IH-10 is depressed so that crossing streets travel over at grade. At this crossing, the HSR is parallel to BNSF track and 46 ft (14 m) high. IH-10 is depressed approximately 20 ft (5 m); therefore, the HSR would be approximately 62 ft (19 m) above IH-10. The central median of IH-10 already has bridge piers installed and could accommodate additional piers for future bridges. The spans could be reduced to 115 ft (35 m), which is within limits for a box-girder style bridge or segmental bridge. The total structure length would be 328 ft (100 m).

ROW Requirements, Property Impacts, and Environmental Considerations

This alignment passes through largely commercial and industrialized areas. There are few expanses of undeveloped land along this portion of the corridor. The potential for displacements is high. There would likely be noise impacts, visual impacts, community facilities impacts, and potential changes in land use in the surrounding areas. For these reasons, the potential socioeconomic impacts were considered high. There are only a few areas that are not currently developed and the major drainage channel, the Buffalo Bayou, while not channelized has been impacted by the surrounding development; therefore, the potential for impacts from the HSR to biotic communities, parks and forests, threatened and endangered species, and prime farmland was considered low, while the impact to hydrology and wetlands was considered moderate. Due to the degree of industrialization, potential impacts from disturbance of hazardous materials were considered high. Since this area is located inside the IH-610 Loop in an older section of Houston, including the area near Buffalo Bayou, the potential for cultural resources impacts was considered moderate.

2.1.2 Houston BNSF Terminus Locations (A to E)

For the BNSF with Option 1 alignment, there were five different terminus station locations. The station locations were analyzed by focusing on access to existing transportation and roadway networks, availability of property and development opportunities. These station locations are not specific to one piece of property but give more of a general area where the station could possibly be constructed.

2.1.2.1 Houston BNSF - Location A (SH 249/Beltway 8)

The intersection of SH 249 and Beltway 8 is a key roadway connection in northwest Houston, and provides access to this continually growing area (See Appendix Figure A1). Due to urban development and congestion, station locations are potentially more available outside Beltway 8 rather than inside. SH 249 is a key corridor to growing development in the northwest of Houston. SH 249 runs approximately parallel to the BNSF alignment alternative up through Tomball and to Pinehurst, where SH 249 ends.

Key Issues:

- Convenient highway access from SH 249 and Beltway 8
- Development potential for the station area
- Proximity to key employment centers
- Proximity to George Bush Intercontinental Airport
- Heavy urban congestion inside Beltway 8 with higher station location impacts

2.1.2.2 Houston BNSF - Location B (US 290/IH-610)

The intersection of US 290 and IH-610 is a key roadway connection in central-northwest Houston (See Appendix Figure A2). The area surrounding this intersection is heavily developed and congested. Despite heavy urban development, there are some potential station locations that could be developed. The location is at the southerly end of the US 290 corridor and provides direct access to both the growing development in the northwest of Houston and central Houston. The alignment alternative parallels US 290 up to the general area of Hempstead.

Key Issues:

- Convenient highway access from US 290 and IH-610
- Development potential for the station area
- Proximity to key employment centers
- Proximity to central and Downtown Houston
- Transit connectivity to downtown and the METRO LRT network via Northwest Transit Center (future planned)
- Heavy urban congestion

Segment 3 provides access to the alternative terminus location generally located near to the existing Northwest Mall site. The final location and configuration of the station and associated parking and other facilities would be developed in close coordination with potential project stakeholders. Provision for multi-modal connectivity would be a key element of station configuration, including close coordination with commuter rail development plans underway by the Gulf Coast Rail District.

2.1.2.3 Houston BNSF - Location C (IH-610/TC Jester)

In the northwest part of town, TC Jester is an arterial road that follows the bayou through a residential part of town. Despite the heavy development, there is a station location option along the BNSF line between TC Jester Blvd and Oak Forest Drive (See Appendix Figure A2). This station location would provide close proximity to IH-610 in a heavily residential part of town.

Key Issues:

- Right-of-way (ROW) acquisition
- Convenient highway access from US 290 and IH-610
- Proximity to key employment centers
- Proximity to central and Downtown Houston
- Heavy urban congestion
- Integration with surrounding neighborhoods

2.1.2.4 Houston BNSF - Location D (Hardy Yards)

The Hardy Yards location is a 50 acre (20.2 hectare) site immediately north of IH-10 in the Downtown Houston area (See Appendix Figure A5). The property is an old Union Pacific Rail Yard that is staged for mixed use development. This site provides sufficient access with less than a mile to IH-45 on the west, Hwy 59 on the east, and IH-10 on the south. This site is a rare large piece of land found in the Downtown Houston area within close proximity to Houston's central business district and a stop on the light rail line. Because of dense urban development surrounding the site, the options for the alignment to access this site are limited.

Key Issues:

- Access to IH-10, IH-45, and Hwy 59
- Proximity to key employment centers
- Proximity to central and Downtown Houston
- Convenient access to the METRO LRT network
- Congestion in urban development and ROW availability
- Heavy traffic congestion during peak hours
- Integration with surrounding neighborhoods

2.1.2.5 Houston BNSF - Location E (Downtown Houston)

Downtown Houston in this study is considered to be the area approximately bounded by IH-10 to the north, IH-45 to the west, and US 59 to the east (See Appendix Figure A5). It remains a key employment center for the Houston region and has direct light rail access to the Texas Medical Center (TMC), one of the other major employment centers of Houston. Because of dense urban development, the options for access to property for station locations in the downtown area are limited.

Key Issues:

- Access to existing METRO LRT and bus transit center
- Access to Amtrak passenger railway services
- Limited property availability
- Development potential for the station area
- Access to IH-10, IH-45, IH-610, SH 288, and US 59
- Proximity to TMC
- Alignment construction costs inside Beltway 8
- Congestion in existing rail corridors and ROW availability
- Heavy traffic congestion during peak hours
- Distance from most key employment centers other than Downtown and TMC.

2.2 Houston – UC Alignment

The UC alignment from Downtown Houston to the developing Grand Parkway (SH-99) was divided into three segments. Each segment connects to another segment and builds the alignment headed south towards different terminus station locations. The segments are combined as the alignment heads south to produce a cumulative scenario to support the comparative assessment of the Houston UC Last Mile Alternatives. Figure 3 shows all three segments used to approach the three station locations considered along the Houston UC alignment.

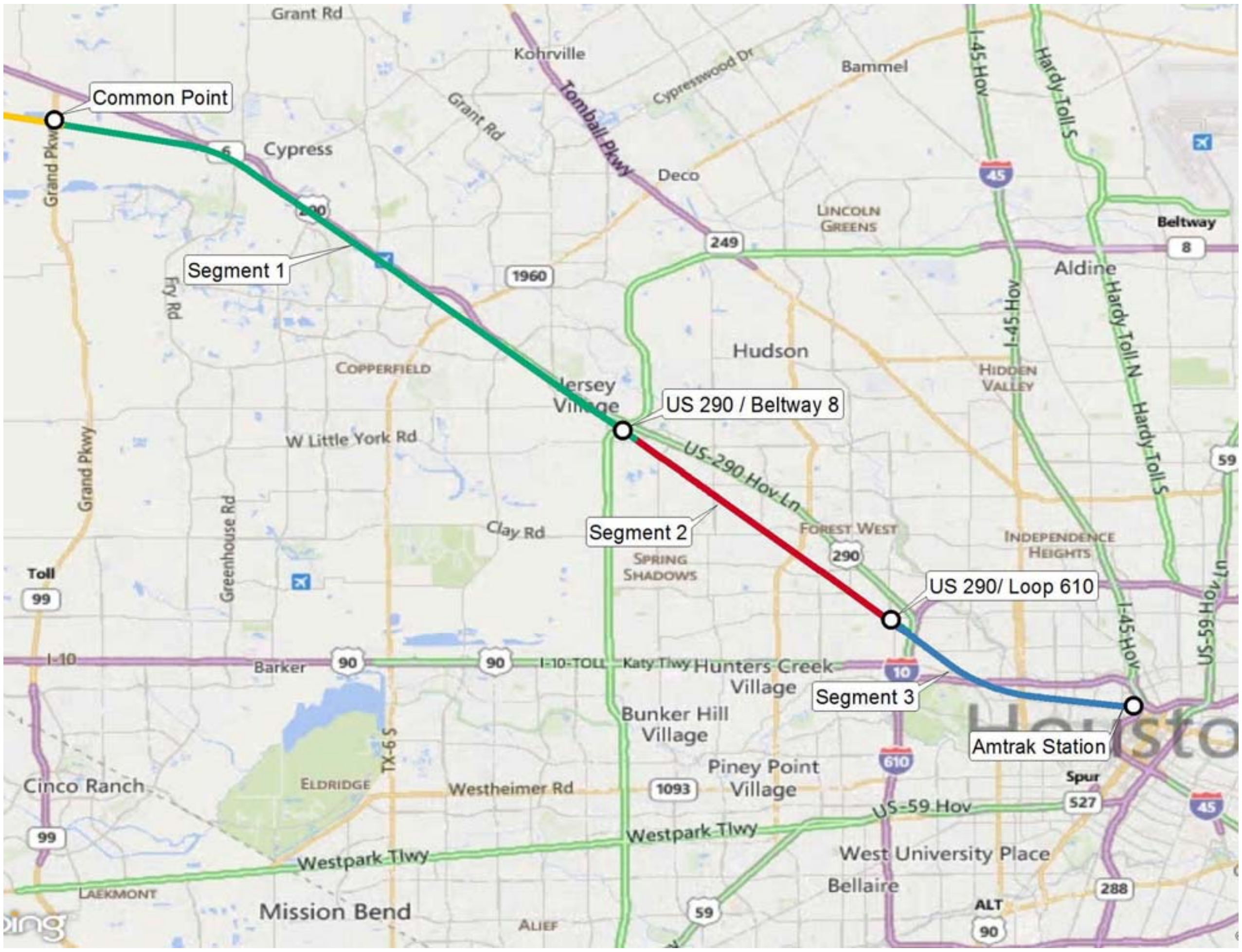

Figure 3 – UC Houston Stations

2.2.1 Houston UC - Alignment Segments (1 to 3)

The three alignment segments were analyzed by focusing on length, curve data, major structures required, and land impacts.

2.2.1.1 Houston UC - Segment 1

Limits

Segment 1 begins at Sta. 47+400 (See Appendix Figure B1), just north of SH-99 and ends to the east of Beltway 8 at Sta. 24+600 (See Appendix Figure B3). Segment 1 has a total length of 14.2 mi (22.8 km).

Alignment Description

This segment heads east crossing over SH-99. The alignment then curves southeast and follows the existing UPRR ROW crossing over Highway 6 but stopping before Beltway 8. All curves on the main alignment for this segment allow the train to operate at unrestricted speeds.

Major Structures

This segment of alignment requires two major structures at the following locations:

- Highway 6
- SH-99 - Grand Parkway

The route intersects Highway 6 Bridge at Sta. 30+000 (See Appendix Figure B2). Highway 6 is elevated to clear UPRR track so at a minimum the bridge elevation has clearance of 24.5 ft (7.4 m) above the track. Estimating a 6 ft (1.8 m) bridge deck, Highway 6 is 30.5 ft (9.2 m) above existing ground. The HSR structure would provide 16.5 ft (5.0 m) roadway clearance. Providing a 9.0 ft (2.7 m) bridge deck would require the HSR structure to be approximately 55 ft (17 m) above the ground.

Frontage roads on both sides of Highway 6 Bridge are adjacent to the highway main lanes. It is possible that the HSR bridge piers would fit within the 5 ft (1.5 m) clearance between the frontage roads and main lanes. The frontage may need to be realigned to accommodate the large HSR foundations. Another alternative would be to construct the piers outside of the frontage roads and span the entire distance. This would yield a total span length of 215 ft (65.5 m). Possible structure types would be segmental and steel plate girder.

Continuing towards the outskirts of Houston, the HSR would pass over Grand Parkway Toll Road (See Appendix Figure B1). This is the last major structure before reaching the long stretch to Dallas. The major structure would span 426 ft (130 m) of the Texas Department of Transportation (TxDOT) ROW with four spans, the longest being approximately 131 ft (40 m). The distance between northbound and southbound travel lanes is sufficient for bridge piers to be placed in the median. During design, the structure's piers would be positioned to not impact future plans for additional travel lanes. TxDOT and the tolling authority would require the design to meet their specifications. The toll road's main lanes are elevated so the HSR structure would need to cross at approximately 50 ft (15 m) above ground.

ROW Requirements, Property Impacts, and Environmental Considerations

This section of the proposed ROW is largely undeveloped west of Barker-Cypress Road. East of Barker-Cypress Road to its terminus west of Beltway 8, the ROW extends through large expanses of single family residential and commercial/industrial property to the south. The residential areas are located primarily between Barker-Cypress Road and Huffmeister. There would be noise impacts, visual impacts to residential properties in this area, and potential changes in land use within the existing developments in the surrounding areas. For these reasons and because only a portion of this corridor is developed, the potential socio-economic impacts, noise impacts, visual impacts, community facilities impacts, and potential changes in land use were considered moderate.

There are large areas in the western portion of this segment that are not impacted by development and only a few major drainage ways, which are largely channelized; therefore, the potential for impacts to biotic communities, parks and forests, threatened and endangered species, hydrology and wetlands, and prime farmland was considered moderate. Due to the lack of industrialization within much of this portion of the corridor, the likelihood of impacts from hazardous materials was considered moderate. Since this area has a large amount of recent development and is located outside the IH-610 Loop, the potential for cultural resources impacts was considered low.

2.2.1.2 Houston UC - Segment 2

Limits

Segment 2 begins at Sta. 24+600 and ends at the Northwest Mall site east of IH-610 around Sta. 9+100 (See Appendix Figure B4). This segment has a total length of approximately 9.6 mi (15.5 km).

Alignment Description

This segment crosses over the UPRR track and runs southeast between Hempstead Road and the UPRR ROW. The segment first crosses over Beltway 8 and then crosses over Hempstead Road terminating at the Northwest Mall site.

The two curves crossing over Hempstead Road that are used to access the proposed station location require a radius of 3280 ft (1000 m) and 4921 ft (1500 m), respectively, but do not create speed restrictions for the HSR operations, as the HSR would be operating at reduced speeds coming into and leaving the station. All other curves within this segment allow the HSR to operate at unrestricted speeds.

Major Structures

This segment of alignment requires one major structure at the following location:

- Beltway 8

At Sta. 22+500 HSR crosses Beltway 8/US 290 interchange (See Appendix Figure B3). The alignment is set between the existing UPRR track and Hempstead Rd.

Due to limited horizontal clearance from Beltway 8 bridge pier columns, the HSR profile must travel above the interchange. Entrance and exit ramps from Beltway 8/US 290 interchange connect into Beltway 8 at the same location as the HSR crossing. The ramps are elevated 23 ft (7.0 m) higher than Beltway 8. This raised the profile of HSR to maintain a minimum 16.5 ft (5.0 m) vertical clearance from top of Beltway 8 Bridge to bottom of HSR Bridge. The total height of HSR is 24.5 ft (7.5 m) above UPRR tracks, plus Beltway bridge thickness of 6.5 ft (2 m), plus additional height of entrance ramp of 23 ft (7 m), plus 16.5 ft (5 m) of bridge clearance, and lastly the HSR bridge thickness of 10 ft (3 m). The total height of HSR at this crossing is 80.5 ft (24.5 m). There is horizontal clearance between the ramps and Beltway 8, so that piers could be placed on either side of the main lanes. This reduces the max span length to 170 ft (51.8 m). Overall length of Beltway 8 overpass is approximately 430 ft (131 m). Possible major structure types would be segmental and steel plate girder.

ROW Requirements, Property Impacts, and Environmental Considerations

This section of the proposed ROW has a large number of commercial and industrialized areas with small areas of residential development. There is very little undeveloped land along this portion of the corridor. Streams in this area are largely channelized. Near the southeastern terminus at IH-610 there is heavy industrial and commercial development as well as the Houston Independent School District Library Services Center and Northwest Mall. The potential for commercial and industrial displacements is high if any additional ROW is required. In addition, there would be some noise impacts, visual impacts and potential changes in land use in the surrounding areas; however, most of these would be in commercial or industrial areas, where their effects would be less than in residential areas. For these reasons, the potential socio-economic impacts, noise impacts, visual impacts, community facilities impacts, and potential changes in land use were considered moderate. There are only a few areas that are not impacted by development and only a few major drainages, which are largely channelized; therefore, the potential for impacts to biotic communities, parks and forests, threatened and endangered species, hydrology and wetlands, and prime farmland was considered low. Due to the degree of industrialization, potential impacts from hazardous materials were considered high.

2.2.1.3 Houston UC - Segment 3

Limits

Segment 3 begins at Sta. 9+100 and ends to the east of IH-45 near the existing Amtrak Station at Sta. 0+000 (See Appendix Figure B6). Segment 3 has a total length of approximately 5.65 mi (9.1 km).

Alignment Description

This segment runs southeast along the UPRR ROW crossing over IH-610 and IH-10. The segment then curves into the existing Amtrak Station parking lot. The curve at the station approach would be a minimum radius of 1315 ft (400 m), but would not create a speed restriction because the HSR would operate at reduced speeds coming into and leaving the station. All other curves within this segment would allow the HSR to operate at unrestricted speeds.

Major Structures

This segment of alignment requires two major structures at the following locations:

- IH-10
- IH-610

At Sta. 5+750 the HSR structure crosses IH-10, which is 13 lanes wide (See Appendix Figure B5). The total crossing distance would be 442 ft (135 m). UPRR also crosses IH-10 at this location with a wide bridge structure. Due to the proximity to the UPRR bridge structure, the HSR bridge would be required to span the entire distance. This would not be cost effective and it would be more efficient to reduce the curve radius, so that the alignment would be farther away from UPRR track. This would enable a central pier to be installed in the IH-10 median barrier, which would create a multiple span structure. Adjusting the alignment would, however, negatively impact adjacent properties.

IH-10 is a principal arterial to Downtown Houston. Segmental bridge construction would be the most logical construction method for this structure due to cost and traffic requirements. Traffic will not be impacted as this bridge type is erected.

The HSR alignment reaches IH-610 at Sta. 8+900 (See Appendix Figure B4). Due to proximity to Hempstead Road and IH-610 bridge columns, the HSR structure would pass over at a height approximately 65 ft (20 m) above ground. IH-610 is over 670 ft (204 m) wide with only a few locations to construct a bridge pier. It is expected that minor reconfiguration to the existing IH-610 bridge would permit an additional pier location in the center median. It may require that the central median shoulders be reduced from 10 ft (3 m) to 3.3 ft (1 m). Permission from TxDOT would be required to make this adjustment. Span lengths could be as long as 300 ft (91 m) depending on detailed analysis. Segmental bridge is expected to be the most cost effective bridge type.

ROW Requirements, Property Impacts, and Environmental Considerations

This section of the proposed ROW has a large number of commercial and industrialized areas. Interspersed with these areas are older, lower income residential areas, many of which are being replaced by higher-end residential development. There is very little undeveloped land along this portion of the corridor. Streams in this area are largely channelized. Near the southeastern terminus at the Amtrak Station there is industrial and commercial development. The potential for residential, commercial, and industrial displacements would be high if any additional ROW is required. In addition, there would be noise impacts, visual impacts, and potential changes in land use in the surrounding areas, which would increase as residential development continues. For these reasons, the potential socio-economic impacts, noise impacts, visual impacts, community facilities impacts, and potential changes in land use were considered high. There are only a few areas that are not impacted by development and only a few major drainage ways, which are largely channelized; therefore, the potential for impacts to biotic communities, parks and forests, threatened and endangered species, hydrology and wetlands, and prime farmland was considered low. Due to the degree of industrialization, potential impacts from hazardous materials were considered high. Since most of this alignment would be located inside the IH-610 Loop in an older section of Houston, the potential for cultural resources impacts was considered moderate.

2.2.2 Houston UC Terminus Locations (A to C)

For the UC alignment, there were three different terminus station locations. The station locations were analyzed by focusing on access to existing transportation and roadway networks, availability of property and development opportunities. These station locations are not specific to one piece of property but give more of a general area where the station could possibly be constructed.

2.2.2.1 Houston UC - Location A (US 290/Beltway 8)

The intersection of US 290 and Beltway 8 is a key roadway connection in northwest Houston, and provides access to this continually growing area (See Appendix Figure B3). Due to urban development and congestion, station locations are potentially more available outside Beltway 8 rather than inside. US 290 is a key corridor to growing development in the northwest of Houston, and connects Houston to Hempstead, Prairie View, College Station, and Austin.

Key Issues:

- Convenient highway access from US 290 and Beltway 8
- Development potential for the station area
- Proximity to key employment centers
- Proximity to Houston-Austin corridor
- Heavy urban congestion inside Beltway 8 with higher station location impacts
- Distance from IH-45 alignment option

2.2.2.2 Houston UC - Location B (US 290/IH-610)

The intersection of US 290 and IH-610 is a key roadway connection in central-northwest Houston (See Appendix Figure B4). The area surrounding this intersection is heavily developed and congested. Despite heavy urban development, there are some potential station locations that could be developed. The location is at the southerly end of the US 290 corridor and provides direct access to both the growing development in the northwest of Houston and central Houston.

Key Issues:

- Convenient highway access from US 290 and IH-610
- Development potential for the station area

- Proximity to key employment centers
- Proximity to central and Downtown Houston
- Transit connectivity to downtown and the METRO LRT network via Northwest Transit Center (future planned)
- Heavy urban congestion
- Distance from IH-45 alignment option

2.2.2.3 Houston UC - Location C (Downtown Houston)

Downtown Houston in this study is considered to be the area approximately bounded by IH-10 to the north, IH-45 to the west, and US 59 to the east (See Appendix Figure B6). It remains a key employment center for the Houston region and has direct light rail access to the Texas Medical Center (TMC), one of the other major employment centers of Houston. Because of dense urban development, the options for access to and property for station locations in the downtown area are limited.

Key Issues:

- Access to existing METRO LRT and bus transit center
- Access to Amtrak passenger railway services
- Limited property availability
- Development potential for the station area
- Access to IH-10, IH-45, IH-610, SH 288, and US 59
- Proximity to TMC
- Alignment construction costs inside Beltway 8
- Congestion in existing rail corridors and ROW availability
- Heavy traffic congestion during peak hours
- Distance from most key employment centers other than Downtown and TMC.

2.3 Dallas – Common Alignment

The UC and BNSF Option 1 alignments share the same route into Downtown Dallas starting at a point just south of IH-20. The common alignment from Downtown Dallas to IH-20 was divided into three segments. Each segment connects to another segment and builds the alignment headed north towards different terminus station locations. The segments are combined as the alignment heads south to produce a cumulative scenario to support the comparative assessment of the Last Mile Alternatives. Figure 4 shows all three segments used to approach the three station locations considered for the Dallas alignment.

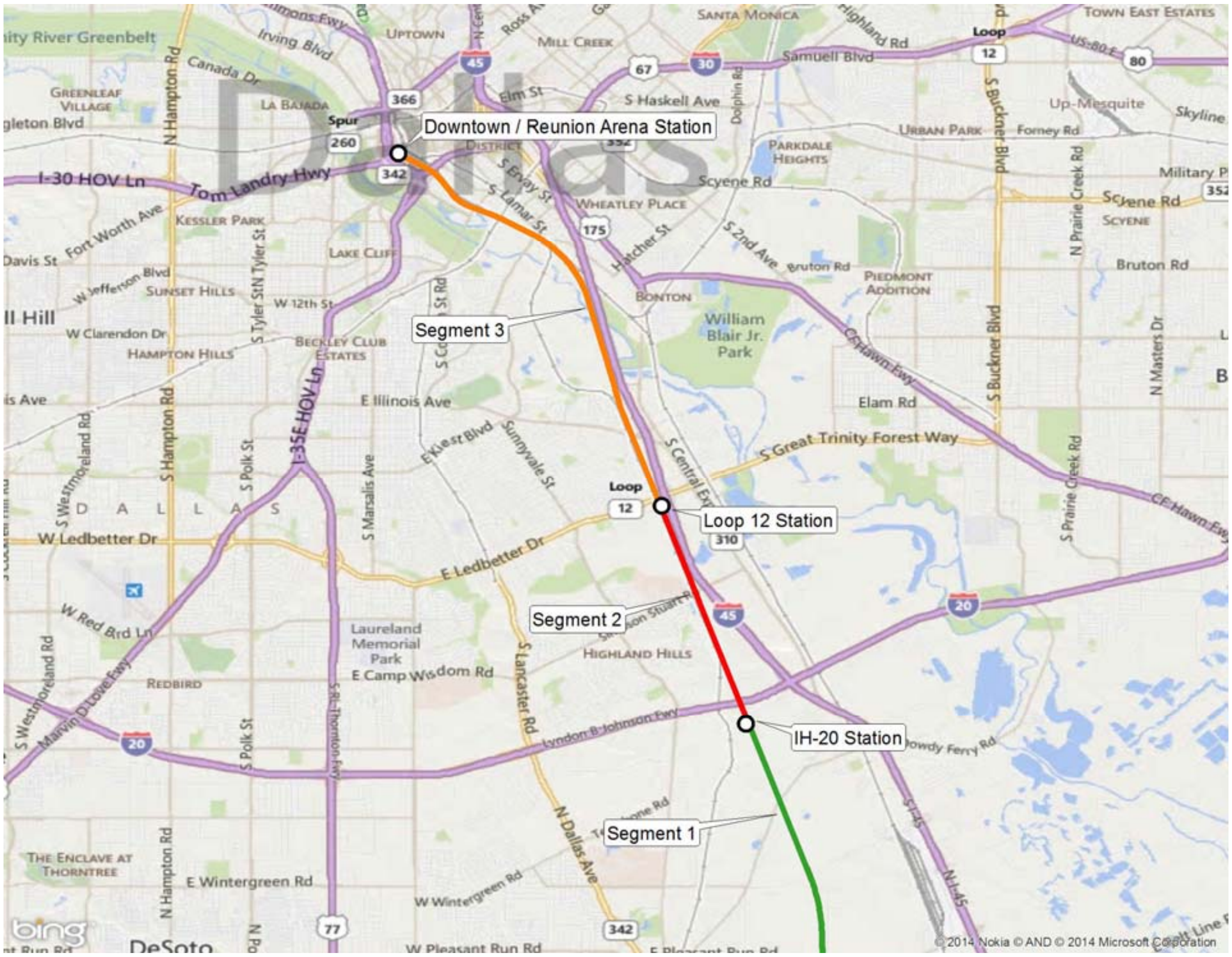

Figure 4 – Dallas Stations

2.3.1 Dallas Alignment Segments (1 to 3)

The three alignment segments were analyzed by focusing on length, curve data, major structures required, and land impacts.

2.3.1.1 Dallas - Segment 1

Limits

Segment 1 begins at Sta. 369+200 and ends just south of IH-20 at Sta. 370+400 (See Appendix Figure C1). Segment 1 has a total length of approximately 0.75 mi (1.2 km).

Alignment Description

There are no curve related speed restrictions to this segment, but the HSR would be operating at low speed entering and leaving the station.

Major Structures

This segment of the alignment requires no major structures.

ROW Requirements, Property Impacts, and Environmental Considerations

This section of the proposed ROW is largely undeveloped. South of the IH-20 interchange the land is largely undeveloped and consists primarily of woodlands and fallow lands. There would be no noise impacts and visual impacts to residential properties in this area. There would likely be some changes in land use within the surrounding areas. For these reasons and because only a small portion of this corridor is developed, the potential socioeconomic impacts, noise impacts, visual impacts, and community facilities impacts were considered low while potential changes in land use were considered moderate. Due to the amount of undeveloped areas offset by the short length of this segment, impacts to biotic communities, parks and forests, threatened and endangered species, and hydrology and wetlands would be moderate. Since there is no active farming visible along this area, the impacts to prime farmland would be moderate as a result of low development pressure countered by lack of farming activities. Due to the lack of industrial development in this area the exposure to hazardous materials was considered low. Since this area has only a small amount of recent development and is located outside IH-20, and has few large streams, the potential for cultural resources impacts was considered low.

2.3.1.2 Dallas - Segment 2

Limits

Segment 2 starts at Sta. 370+400 and ends south of Loop 12 at Sta. 375+500 (See Appendix Figure C2). Segment 2 has a total length of approximately 3.2 mi (5.1 km).

Alignment Description

This segment heads north crossing over IH-20 before reaching the UPRR ROW at Sta. 372+000. The segment then runs parallel to the existing freight line and terminates around Sta. 375+500, near Loop 12 (See Appendix Figure C2). There are no curve related speed restrictions in this segment, as the HSR would already be operating at low speed entering and leaving the station.

Major Structures

This segment of the alignment has only one major structure crossing at IH-20 (See Appendix Figure C1). Crossing IH-20 would require a relatively low-cost major structure. IH-20 is depressed without vertical obstructions to avoid. The frontage roads and main lanes are spaced with horizontal clearance to install additional bridge piers, which would keep the span length below 100 ft (30 m). The total intersection crossing would be 420 ft (128 m) and located at Sta. 370+300.

ROW Requirements, Property Impacts, and Environmental Considerations

This section of the proposed ROW is largely undeveloped. South of the IH-45/Loop 12 interchange the land is undeveloped and heavily wooded. Residential areas are scattered to the west of the corridor or are located east of IH-45. Significant noise impacts and visual impacts would not be expected to residential properties in this area and there is little developed area adjacent to the ROW that would experience potential changes in land use. For these reasons and because only a small portion of this corridor is developed, the potential socio-economic impacts were considered low. Due to the amount of wooded areas, impacts to natural communities would be high. Due to the small amount of industrialization, the potential for hazardous materials was considered low. Since this area has only a small amount of recent development and is located outside the IH-610 Loop, but does have one stream in a fairly undisturbed state, potential for cultural resources impacts was considered moderate.

2.3.1.3 Dallas - Segment 3

Limits

Segment 3 begins at Sta. 375+500 and ends near the old Reunion Arena location at Sta. 385+844 (See Appendix Figure C4). Segment 3 has a total length of approximately 6.5 mi (10.4 km).

Alignment Description

This segment heads north following the UPRR ROW crossing over Loop 12 (See Appendix Figure C2). The alignment then turns northwest towards Downtown Dallas crossing over the Trinity River and IH-30 before terminating at the old Reunion Arena site (See Appendix Figures C3 and C4).

There are six curves within this segment. The two curves on the south part of the segment are above the minimum 17,060 ft (5200 m) radius and present no speed restrictions. The next two curves heading north on the segment have radii of 8202 ft (2500 m) and 9843 ft (3000 m), respectively. These curves would require the HSR to operate at a reduced speed of approximately 85 mph (140 km/hr). The two remaining curves located just before the station terminus require a radius of 2952 ft (900 m) which would cause the HSR to operate at lower speeds of approximately 45 mph (70 km/hr). However, based on the N700-I acceleration profile, this curve would not would not affect run times due to its close proximity to the station terminus location.

Major Structures

This segment of alignment requires major structures at the following locations:

- Loop 12
- Trinity River
- IH-30

Heading north along IH-45 the HSR alignment will cross IH-45/Loop 12 interchange. This crossing would require a relatively low-cost structure with short spans of 98 ft (30 m). The total length of interchange is 1020 ft (310 m).

Approaching downtown, the HSR alignment would enter a large floodplain of the Trinity River. This area would open up to a view of Downtown Dallas with a major structure at the river crossing. The alignment approaches at a skew and would need to span the 115 ft (35 m) wide river in its entirety; therefore, the span length would be approximately 197 ft (60 m) long. The river is controlled by USACE and all structures would need to be approved prior to construction. Any improvements in the floodplain would not be permitted to negatively impact flood elevations. The area is also a wetland, so environmental impacts to the area would be expected. Offsite mitigation would likely be required for any impacts.

Continuing towards Dallas, the HSR alignment crosses IH-30 at Sta. 385+150. IH-30 is depressed while the HSR structure would be elevated 65 ft (20 m). The total bridge crossing would span over 328 ft (100 m). A bridge pier would be located in the central median of IH-30 to bisect the structure into two 165 ft (50 m) spans. A segmental bridge would be recommended for this location.

ROW Requirements, Property Impacts, and Environmental Considerations

This section of the proposed ROW is largely undeveloped south of Cedar Crest Boulevard and north of Overton Road. South of Overton Road the land is largely residential areas and is potentially low income or with low income areas. The potential for displacements is high. In addition, there would be noise impacts, visual impacts, and potential changes in land use in the surrounding developed areas. For these reasons, the potential socio-economic impacts were considered high. Due to the amount of wooded areas, and the presence of the large Trinity River floodplain with its wide riparian corridor, impacts to natural communities would be high. Due to the limited amount of industrialization, the potential for hazardous materials was considered low. Because this segment is located within the LBJ Loop, and has a vast floodplain (although much of the floodplain has been modified) potential for cultural resources impacts was considered moderate.

2.3.2 Dallas Terminus Locations (A to C)

For the common Dallas alignment, there were three different terminus station locations. The station locations were analyzed by focusing on access to existing transportation and roadway networks, availability of property and development opportunities. These station locations are not specific to one piece of property but give more of a general area where the station could possibly be constructed.

2.3.2.1 Dallas - Location A (IH-45/IH-20)

This study area is considered to be the quadrants formed by the intersection of IH-45/IH-20, approximately 10 mi (16 km) south of Downtown Dallas (See Appendix Figure C1). All alignment alternatives begin to converge south of this area, and both the UPRR and BNSF rights-of-way cross IH-20. All alignments run approximately parallel to IH-45 in this location. The area is predominately rural, with some light industrial and commercial development along with a correctional facility. It is easily accessible to both rail ROW and highway corridors. Although open parcels of land are available for station location, the long distance from the employment and commercial centers of the Metroplex may diminish its attractiveness from a ridership and development perspective.

Key Issues:

- Access to IH-45 / IH-20
- Access to railroad rights-of-way
- Availability of undeveloped land
- Distance from key employment centers
- Distance from regional public transportation network
- Lack of commercial development to enhance or support station area development opportunities.

2.3.2.2 Dallas - Location B (Loop 12)

This study area is considered to be the quadrants formed by the intersection of IH-45/Loop 12, approximately six miles south of Downtown Dallas (See Appendix Figure C2). All alignment alternatives begin to converge south of this area, and both the UPRR and BNSF rights-of-way cross Loop 12. All alignment alternatives run approximately parallel to IH-45 in this location. The area is a mix of rural, with some light industrial and commercial development. It is easily accessible to both rail ROW and highway corridors. Although open parcels of land are available for station location, the long distance from the employment and commercial centers of the Metroplex may diminish its attractiveness from a ridership and development perspective.

Key Issues:

- Access to IH-45 / Loop 12
- Access to railroad rights-of-way
- Availability of undeveloped land
- Distance from key employment centers
- Distance from regional public transportation network
- Lack of commercial development to enhance or support station area development opportunities.

2.3.2.3 Dallas - Location C (Downtown Dallas)

The Downtown Dallas study area is considered to be the area approximately bounded by IH-35E to the southeast, Woodall-Rodgers Freeway to the north, and the Trinity River to the west and southwest (See Appendix Figure C4). Both corridor alignment alternatives, BNSF and UC converge south of Dallas and pass through this study area. There are limited potential locations within this study area, in close proximity to the former Reunion Arena site and the Union Station area. The Reunion Arena and Union Station areas provide access to the existing public transportation network and Amtrak passenger rail services. The area is heavily urban with access to the roadway and highway network. The area can be accessed by all alignment alternatives entering the city of Dallas and the connection to Fort Worth (being considered under a separate study).

Key Issues:

- Access to the existing public transportation network
- Access to Amtrak passenger railway services
- Property availability
- Development potential for the station area
- Access to the existing roadway and highway network
- Access to rail rights-of-way
- Proximity to Metroplex employment centers
- Heavy traffic congestion during peak hours

3 Cost Estimates

Cost estimates were developed for the alternatives considered for Dallas, Houston BNSF Option 1, and the Houston UC. These estimates are classified as Class 5 Rough Order of Magnitude (ROM) estimates in accordance with the Association for the Advancement of Cost Engineering International (AACE International) best practices.

3.1 Estimating Approach

The estimates were developed for each of the alternatives to determine the relative cost difference between Dallas alternatives, Houston BNSF alternatives, and Houston UC alternatives. The estimates include the following key differentiators:

- Heavy civil infrastructure for the HSR alignment (at grade, cut, and viaduct)
- Crash walls
- Complexity factors for sections of the alignment within urban and suburban areas
- Roadway grade separations
- HSR trackwork
- Major structures
- HSR stations

Key assumptions used in the development of estimates included:

- Estimates were developed to evaluate the heavy infrastructure costs only to support the comparative assessment of competing alternatives in Dallas and Houston.
- Historical benchmark data were used from Arup's internal database of international HSR projects. Rates and costs were normalized for construction in the Texas market.
- The estimates assume normal ground conditions. No allowances were made for ground decontamination or discovery of archaeological artifacts and their consequential effects on the Project.
- The estimates did not include impact mitigation costs for compensatory works or betterments to existing utilities, roadways, or developments.
- Unit rates used reflect the cost of direct construction and include labor, equipment, and materials.
- The quantities in the estimates are conceptual in nature and would require refinement as more information becomes available and the design progresses.
- A construction contingency allowance of 25% was included.

3.2 Last Mile Alternatives Cost Estimation

Each Last Mile Alternative for both the UC and BNSF alignments was estimated using a segmental buildup between a common starting point outside of Dallas or Houston and a unique terminus location in the city. Additionally, the UC or BNSF Option 1 "middle segment" cost from *Step 1 Screening of Corridor Alternatives Report* was included to obtain a normalized cost comparison.

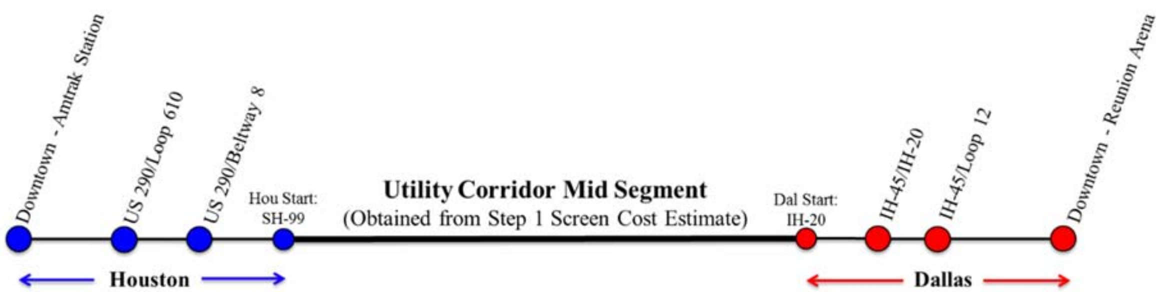

Figure 5 – Schematic Representation of Cost Estimate Segments Used to Produce Last Mile Alternative Costs for the UC

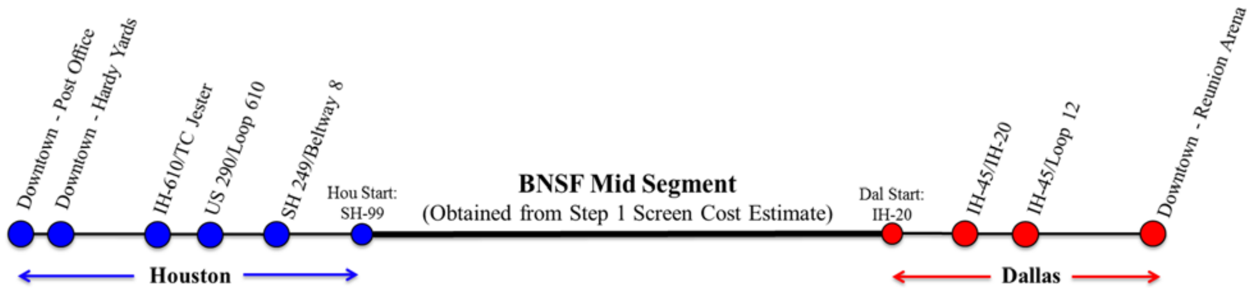

Figure 6 – Schematic Representation of Cost Estimate Segments used to produce Last Mile Alternative Costs for the BNSF Option 1 Corridor

Each alternative was estimated based on the following infrastructure categories:

- Heavy Civil Infrastructure
- Complexity Factors
- Grade Separations
- Major Structures

3.2.1 Heavy Civil Infrastructure Cost Impacts

The heavy civil infrastructure was broken down into the following five major section types:

1. Low, Medium, and High Embankment
2. Low, Medium, and High Embankment with Crash Wall
3. Cut
4. Viaduct (due to development)
5. Viaduct (due to wetlands)

In order to determine the heavy civil infrastructure section types, conceptual profiles were generated for all alternatives to determine the length of alignment suitable for embankment, cut, or viaduct due to interaction with existing infrastructure. Additionally, an alignment review was performed to determine the percentage of the embankment portions of the alignment within the existing freight railroad ROW that would require construction of a crash wall.

Table 1 shows the percentages used to estimate each alternative section type. For the “middle segment,” the *Step 1 Screening of Corridor Alternatives Report* assessment was used to approximate infrastructure costs. The percentages shown in Table 1 do not include any infrastructure for the “middle segment” of any alternative.

Table 1 – Percentages of Section Types for Each "Last Mile Alternative"

Section Type	Hou UC Alt A	Hou UC Alt B	Hou UC Alt C	Hou BNSF Alt A	Hou BNSF Alt B	Hou BNSF Alt C	Hou BNSF Alt D	Hou BNSF Alt E	Dal Alt A	Dal Alt B	Dal Alt C
Embankment	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cut	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Viaduct (from development)	20%	20%	15%	25%	20%	20%	15%	10%	15%	40%	45%
Avg/Medium Viaduct (from development)	80%	75%	80%	70%	75%	75%	75%	75%	85%	60%	55%
High Viaduct (from development)	0%	0%	0%	5%	5%	5%	10%	15%	0%	0%	0%
Viaduct (from wetlands)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Embankment w/ Crash Wall	0%	5%	5%	0%	0%	0%	0%	0%	0%	0%	0%

3.2.2 Complexity Factors Cost Impacts

The alternatives were broken down into the following complexity factor categories based on reviews of the alignments:

- Dense Urban (100% cost premium)
- Urban (20% cost premium)
- Developed (10% cost premium)
- Undeveloped (0% cost premium)

Table 2 shows the percentages used to estimate each alternative complexity factor. For the "middle segment," percentages from the *Step 1 Screening of Corridor Alternatives Report* were used. The percentages shown in Table 2 do not include any infrastructure for the "middle segment" of any alternative.

Table 2 – Complexity Factor Percentages for Each Alternative

Complexity Factor	Hou UC Alt A	Hou UC Alt B	Hou UC Alt C	Hou BNSF Alt A	Hou BNSF Alt B	Hou BNSF Alt C	Hou BNSF Alt D	Hou BNSF Alt E	Dal Alt A	Dal Alt B	Dal Alt C
Dense Urban	0%	0%	1%	0%	0%	0%	0%	7%	0%	0%	0%
Urban	0%	38%	49%	100%	100%	100%	100%	93%	0%	0%	17%
Developed	73%	45%	36%	0%	0%	0%	0%	0%	0%	79%	75%
Undeveloped	27%	17%	14%	0%	0%	0%	0%	0%	100%	21%	8%

3.2.3 Grade Separations Cost Impacts

Cost allowances were made for grade separated roadway crossings required along at-grade portions of the alignment. These allowances account for structures to cross roadways within at-grade sections of the alignment and the additional costs associated with maintaining live traffic during construction operations. For each alternative, the total number of road crossings were counted based on visual inspections using Google Earth.

Table 3 shows the total number of roadway crossings for each alternative. For the "middle segment," quantities from the *Step 1 Screening of Corridor Alternatives Report* were used. The roadway crossing counts shown in Table 3 do not include any infrastructure for the "middle segment" of any alternative.

Table 3 – Number or Roadway Crossings for Each Alternative

	Hou UC Alt A	Hou UC Alt B	Hou UC Alt C	Hou BNSF Alt A	Hou BNSF Alt B	Hou BNSF Alt C	Hou BNSF Alt D	Hou BNSF Alt E	Dal Alt A	Dal Alt B	Dal Alt C
# of Roads Along Alignment	17	28	108	10	29	25	66	89	0	3	29

3.2.4 Major Structures Cost Impacts

Several major structures described in the *Step 1 Screening of Corridor Alternatives Report* would be required through the segment alternatives. The following lists the major structures included in the cost estimate (from the *Step 1 Screening of Corridor Alternatives Report*):

- SH 249/Beltway 8 Interchange
- Sam Houston Tollway/Beltway 8
- IH-45
- IH-610
- IH-10
- Buffalo Bayou
- US 290
- SH-99 (Grand Parkway)
- IH-20
- Loop 12
- Trinity River
- IH-30

3.3 Exclusions

Similar to the *Step 1 Screening of Corridor Alternatives Report*, the following items have not been included as part of this conceptual cost estimate comparison:

- ROW costs and/or demolition of existing structures
- All system costs (including):
  - signaling
  - catenary
  - traction power stations
  - communications
- Rolling stock
- Program/soft costs (including):
  - preliminary design
  - final design
  - project management for design and construction
  - construction administration and management
  - legal fees
  - permit costs, local planning obligations, agreements, and any fees associated with these
  - review fees

  - surveys
  - testing
  - inspections
  - insurance
  - contractors' bond
  - tax
  - owner's contingency
  - escalation/inflation/deflation beyond Q1 2012
- Owner's direct management costs, running and maintenance costs
- The costs or impacts of latent environmental issues that may result in litigation or development delays
- Removal of any of the works at the end of their useful life — including allowance for any residual value
- Financing charges
- Credits for capital taxation allowances
- Compensatory costs to other interested parties
- Maintenance costs
- Hard rock excavations or the impact of encountering unfavorable soil conditions, hazardous materials, or poor working conditions during the construction process

3.4 Cost Estimate Results

The figures and table below show the normalized comparison of conceptual capital cost totals for each Last Mile Alternative for the Utility and BNSF corridor alignments for Houston and Dallas resulting from the estimating method described. Each figure shows the percentage of additional cost in comparison to a 1.00 "middle segment."

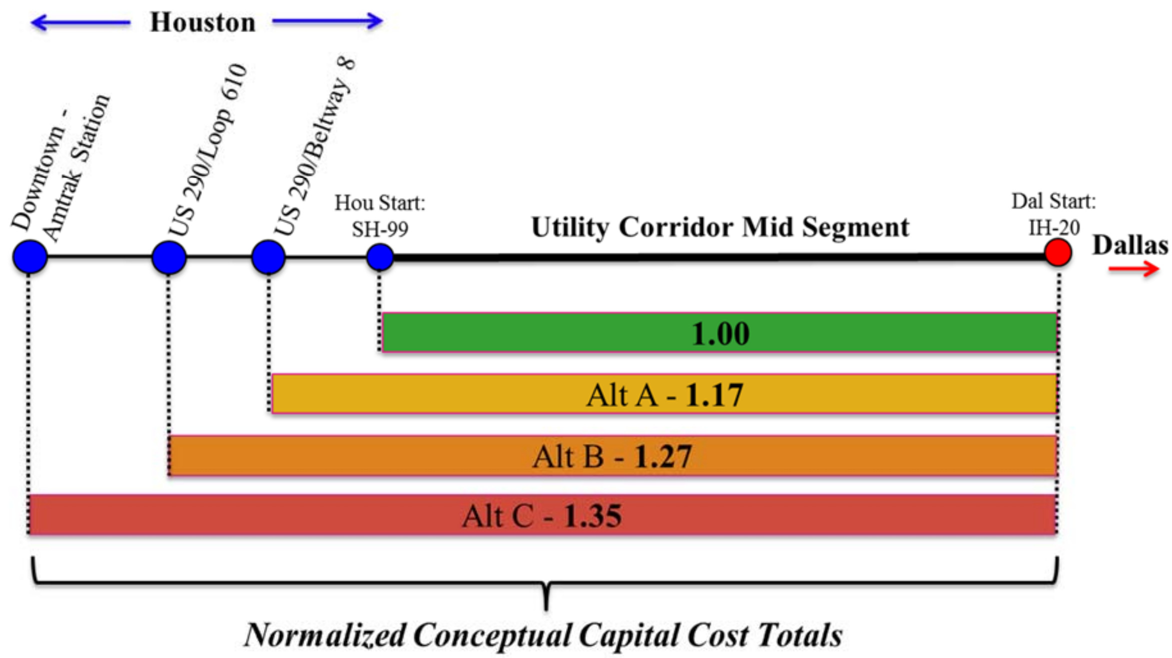

Figure 7 – Normalized Costs: Houston (UC)

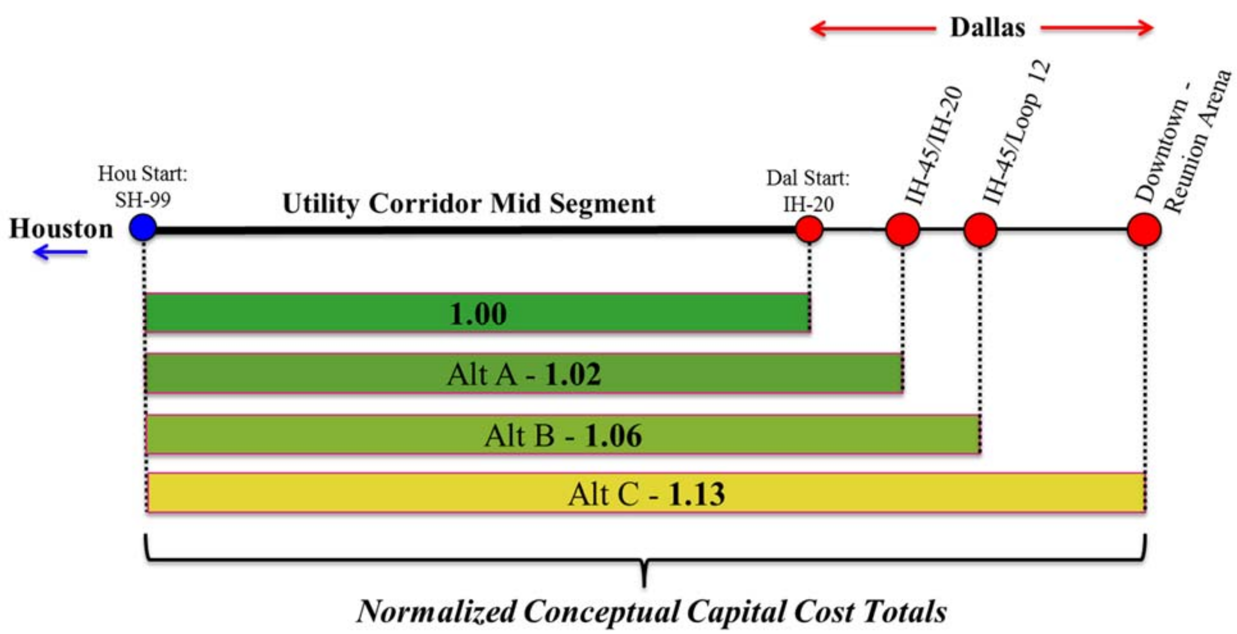

Figure 8 – Normalized Costs: Dallas (UC)

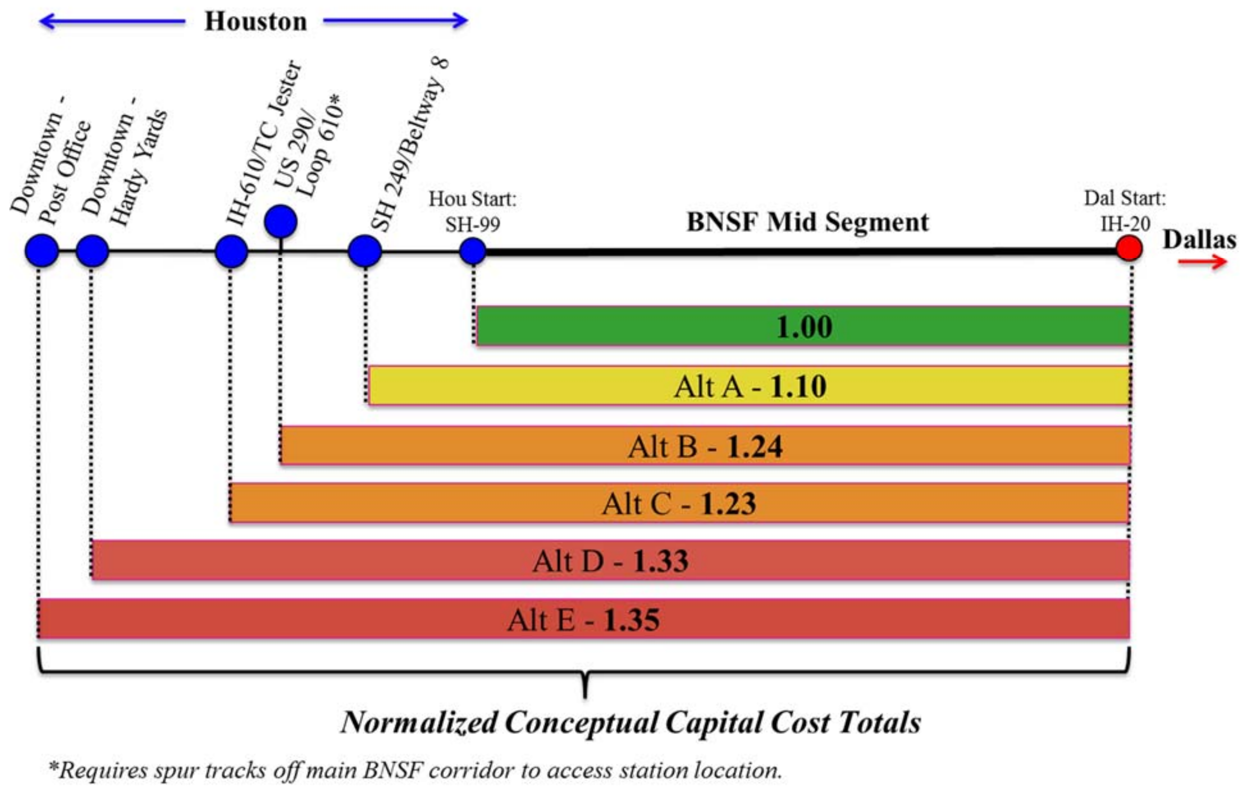

Figure 9 – Normalized Costs: Houston (BNSF)

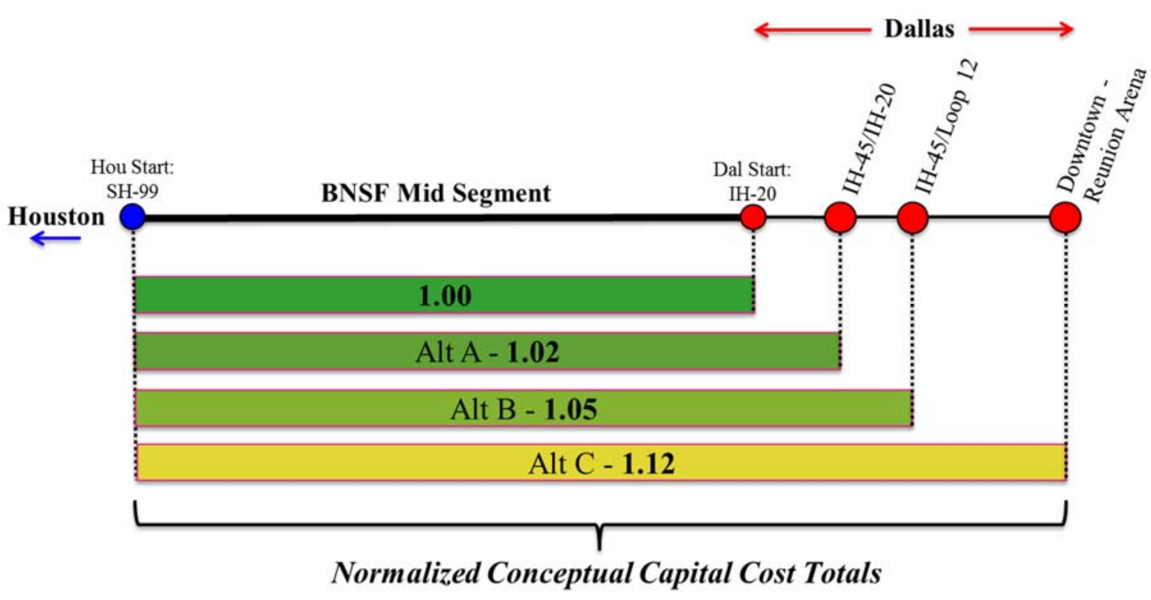

Figure 10 – Normalized Costs: Dallas (BNSF)

Table 4 – Summary of Normalized Conceptual Capital Cost Totals

Utility Corridor*		
	Alternative	**Normalized Cumulative**
UC Dallas	Alternative C	1.13
	Alternative B	1.06
	Alternative A	1.02
UC Middle	UC Mid Segment	1.00
UC Houston	Alternative A	1.17
	Alternative B	1.27
	Alternative C	1.35

**Costs include infrastructure and station*

BNSF Option 1 Corridor*		
	Alternative	**Normalized Cumulative**
BNSF Dallas	Alternative C	1.12
	Alternative B	1.05
	Alternative A	1.02
BNSF Middle	BNSF Mid Segment	1.00
BNSF Houston	Alternative A	1.10
	Alternative B	1.24
	Alternative C	1.23
	Alternative D	1.33
	Alternative E	1.36

**Costs include infrastructure and station*

Table 5 – Combined Summary of Normalized Conceptual Capital Cost Totals

Utility Corridor

		Houston Alternatives			
		Starting Point	A	B	C
Dallas Alternatives	Starting Point	1.00	1.17	1.27	1.35
	A	1.02	**1.19**	**1.30**	**1.38**
	B	1.06	**1.23**	**1.33**	**1.41**
	C	1.13	**1.30**	**1.40**	**1.48**

**Costs include infrastructure and station*

BNSF Option 1 Corridor

		Houston Alternatives					
		Starting Point	A	B	C	D	E
Dallas Alternatives	Starting Point	1.00	1.10	1.24	1.23	1.33	1.36
	A	1.02	**1.12**	**1.26**	**1.25**	**1.35**	**1.39**
	B	1.05	**1.15**	**1.29**	**1.29**	**1.38**	**1.42**
	C	1.12	**1.22**	**1.36**	**1.35**	**1.45**	**1.48**

**Costs include infrastructure and station*

4 Schedule

The construction method for the HSR system would be similar for all options being considered for the last mile analysis as all alignment options for the last mile are assumed to be on elevated viaduct. For the viaduct substructure (foundations and columns), we are assuming one crew can complete the foundations and columns on either side of a standard span within 35 working days allowing for concrete curing time. Another five working days would be required to construct the superstructure resulting in a standard span construction duration of 40 working days.

In order to accelerate the completion for the construction of the HSR, we envision that the long “middle segment” would be split into construction packages with a minimum distance of 15 mi (24 km). However, given the higher complexity and viaduct section type, construction packages with a minimum distance of 5 mi (8 km) are considered appropriate for the Last Mile segments. In this high-level assessment for each package, we considered 10 crews would be working concurrently. Each alternative was packaged to achieve a construction duration no more than five years.

The estimated durations for each Last Mile Alternative is listed in Section 6.

5 Ridership

A comparative ridership analysis was conducted using the results outlined in the *Texas Central High-Speed Railway: Ridership and Revenue Forecast: Base Case Report* dated August 2014 by Steer Davies Gleave (SDG) and the data obtained by the Louis Berger Group (LBG) and reported in the *Investment Grade Ridership and Revenue Report* dated February 2013.

As part of the initial study, the ridership and revenue were studied using 16 scenarios of different station combinations in the Houston and Dallas Areas.

The Houston Station regions evaluated included the following:

- Houston Downtown (including Amtrak, Post Office, and Hardy Yards)
- Houston Loop 610
- Houston Suburban

The Dallas Station regions evaluated included the following:

- Downtown Dallas (Reunion Arena)
- Dallas Suburban Loop 12
- Dallas Suburban IH-20

5.1 Ridership Results

In order to effectively analyze the ridership data on a comparative basis for the purposes of this Last Mile study, the ridership number for the shortest alignment, utilizing the Dallas IH-45/IH-20 station (Dallas Terminus A) and Houston Beltway

8 stations (Houston Terminus A) was set as the Base Case. The figure below shows the percent change in revenue based on the station locations.

Table 6 – Percent Change in Revenue Based on Station Locations

% Change in Revenue Based on Station Locations			Houston		
			Houston Suburban	Houston Loop 610	Houston Downtown
			UC Alt A	UC Alt B	UC Alt C
			BNSF Alt A	BNSF Alt B/C	BNSF Alt D/E
Dallas	Dallas IH-45/IH-20	Dal Alt A	BC* (0.0%)	6.7%	9.2%
	Dallas Loop 12/IH-45	Dal Alt B	0.9%	7.7%	10.1%
	Dallas Downtown	Dal Alt C	8.0%	14.9%	17.5%

**Dallas IH-45/IH-20 and Houston Suburban assumed to be the Base Case*

To further evaluate the various alternatives, a revenue-cost comparison analysis was performed to evaluate the alternatives by comparing the ratio of difference in revenue to difference in cost. The figure below shows the revenue cost ratios for both the UC and BNSF Corridor Alternatives *using Alternative A as a Base Case.*

Table 7 – Ridership & Cost Ratio for UC Alternatives (Alt A as Base Case)

UTILITY CORRIDOR		Difference in Revenue	Difference in Cost	RATIO (Ridership/Cost)
Houston UC Alt A	Dallas Alt A*	1.00	1.00	1.00
	Dallas Alt B	1.01	1.03	0.98
	Dallas Alt C	1.08	1.09	0.99
Houston UC Alt B	Dallas Alt A	1.07	1.09	0.98
	Dallas Alt B	1.08	1.11	0.97
	Dallas Alt C	1.15	1.17	0.98
Houston UC Alt C	Dallas Alt A	1.09	1.15	0.95
	Dallas Alt B	1.10	1.18	0.93
	Dallas Alt C	1.17	1.24	0.95

**Dallas IH-45/IH-20 and Houston Suburban assumed to be the Base Case*

Table 8 – Ridership and Cost Ratio for BNSF Corridor Alternatives

BNSF CORRIDOR		Difference in Revenue	Difference in Cost	RATIO (Ridership/Cost)
Houston BNSF Alt A	Dallas Alt A*	1.00	1.00	1.00
	Dallas Alt B	1.01	1.03	0.98
	Dallas Alt C	1.08	1.09	1.00
Houston BNSF Alt B	Dallas Alt A	1.07	1.12	0.95
	Dallas Alt B	1.08	1.15	0.94
	Dallas Alt C	1.15	1.21	0.95
Houston BNSF Alt C	Dallas Alt A	1.07	1.12	0.96
	Dallas Alt B	1.08	1.14	0.94
	Dallas Alt C	1.15	1.20	0.96
Houston BNSF Alt D	Dallas Alt A	1.09	1.20	0.91
	Dallas Alt B	1.10	1.23	0.90
	Dallas Alt C	1.17	1.29	0.91
Houston BNSF Alt E	Dallas Alt A	1.09	1.23	0.88
	Dallas Alt B	1.10	1.26	0.87
	Dallas Alt C	1.17	1.32	0.89

**Dallas IH-45/IH-20 and Houston Suburban assumed to be the Base Case*

6 Evaluation of Last Mile Alternatives

The Last Mile Alternatives are made up of segments from the alignment that end at a certain terminus station location. For consistency, each alternative was evaluated based on the key issues and impacts associated with the following:

- Project Delivery (Ridership, Cost, Schedule)
- Alignment Segment Engineering and Constructability
- Environmental, ROW, and Land Use Impacts
- Terminus Engineering and Constructability

6.1 Houston BNSF Alignment

As noted in the *Step 1 Screening of Corridor Alternatives Report* (dated 3/22/15), the BNSF Mid Segment has major financial, schedule, and project delivery concerns associated with long lengths of shared freight corridors. As such, these concerns are reflected consistently in the “cost” and “schedule” rating categories of all BNSF Alternatives.

6.1.1 Houston BNSF Alternative A (SH 249/Beltway 8)

Alternative A is made up of Segment 1 and terminates at Location A (SH 249/Beltway 8) near the Willowbrook Mall site. This alternative would be mostly viaduct at a low to medium height and have a total length of approximately 7.0 mi (11.4 km). Alternative A does not require a major structure but would have minor traffic issues crossing over ten local roads.

This alternative has an additional 10% cost from the BNSF Option 1 “middle segment.” A 100% urban complexity factor was added to the cost due to the alignment’s close proximity to freight tracks and a mixture of residential and industrial properties.

BNSF Alternative A extends for 7.0 mi (11.4 km) south. Based on the construction method logistics (see Section 4), we presume the alternative would result in a completion of 5.0 calendar years and in one construction package.

The key issues and evaluation of Alternative A are summarized in Table 9 below:

Table 9 – Alternative A (Houston BNSF) Key Impacts

Evaluation Categories	Key Issues/Impacts	Reference	Rating
Project Delivery			
Cost	• Normalized Cumulative Cost: 1.10	Section 3.4	3
Schedule	• 5.0 Years for Completion • 1 Construction Package	Section 4	2
Ridership	• Average Ridership Increase (compared to Alt A Base Case) – 3.0% • Average Ridership/Cost Ratio – 0.99	Section 5	1
Alignment Engineering and Constructability			
Major Structures	• No major structures required	NA	3
Alignment	• Total length is 8.1 mi (11.4 km)	Section 2.1.1.1	3
Constructability Impacts	• Adjacent to existing BNSF ROW	Section 2.1.1.1	3
Environmental, ROW, and Land Use			
Environmental & Wetlands	• Minimal impacts	Section 2.1.1.1	3
ROW Acquisitions	• Heavily residential along both sides of the proposed ROW from the Grand Parkway to Louetta Road and from Cypresswood to just north of FM 1960	Section 2.1.1.1	2
Land Use Impacts	• Heavily commercial with Willowbrook Mall and satellite development	Section 2.1.1.1	2
Terminus Engineering			
Access to Existing Transportation	• Highway access from SH 249 and Beltway 8 • Proximity to George Bush International Airport	Section 2.1.2.1	2
Development Opportunities	• Close proximity to Willowbrook Mall but limited space for development	Section 2.1.2.1	1

6.1.2 Houston BNSF Alternative B (US 290/IH-610)

Alternative B consists of Segment 1, Segment 2, and Segment 3 and terminates at Location B (US 290/IH-610) near the Northwest Mall. This alternative would be mostly medium height viaduct with a total length of 19.6 mi (31.6 km).

This alternative has an additional 24% cost from the BNSF Option 1 "middle segment." A 100% urban complexity factor was added to the cost due to close proximity to freight tracks and a mixture of residential and industrial properties.

BNSF Alternative B extends for 19.6 mi (31.6 km) toward the Downtown Houston area. Based on the construction method logistics, we presume the alternative would result in a completion of 4.3 calendar years and be split into three construction package, each extending 6.5 mi (10.5 km).

The key issues and evaluation of Alternative B are summarized in Table 10 below:

Table 10 – Alternative B (Houston BNSF) Key Impacts

Evaluation Categories	**Key Issues/Impacts**	**Reference**	**Rating**
Project Delivery			
Cost	• Normalized Cumulative Cost: 1.24	Section 3.4	2
Schedule	• 4.3 Years for Completion • 3 Construction Packages	Section 4	2
Ridership	• Average Ridership Increase (compared to Alt A Base Case) - 9.8% • Average Ridership/Cost Ratio – 0.95	Section 5	2
Alignment Engineering and Constructability			
Major Structures	Requires three major structures: • SH 249/Beltway 8 • Sam Houston Tollway/Beltway 8 • US 290	Section 2.1.1.2 Section 2.1.1.3	2
Alignment	• Total length is 19.6 mi (31.6 km) • Speed restriction near Watonga Blvd.	Section 2.1.1.1 Section 2.1.1.2 Section 2.1.1.3	2
Constructability Impacts	• Structure over SH 249, Beltway 8 and US 290 • Viaduct down the center of Mangum Road	Section 2.1.1.2 Section 2.1.1.3	2
Environmental, ROW, and Land Use			
Environmental & Wetlands	• Minimal impacts	Section 2.1.1.3	3
ROW Acquisitions	• ROW along Mangum is very narrow and the potential for displacements is high if any additional ROW is required	Section 2.1.1.3	1
Land Use Impacts	• Large components of commercial and industrialized areas and what may be low income housing as well as large amounts of multi-family residential areas	Section 2.1.1.3	1
Terminus Engineering			
Access to Existing Transportation	• Highway access from US 290 and IH-610 • Transit connectivity to downtown and the METRO LRT network via Northwest Transit Center (future planned)	Section 2.1.2.2	3
Development Opportunities	• Southerly end of the US 290 corridor and provides direct access to both the growing development in the northwest of Houston and central Houston	Section 2.1.2.2	3

6.1.3 Houston BNSF Alternative C (IH-610/TC Jester)

Alternative C consists of Segment 1, Segment 2 and Segment 4 and terminates at Location C (IH-610/TC Jester). This alternative would be mostly viaduct at medium height and have a total length of approximately 18.8 mi (30.2 km).

This alternative was found to have a 23% higher cost than the BNSF Option 1 "middle segment." A 100% urban complexity factor was added to the cost given the alignment's proximity to freight tracks and residential and industrial properties.

BNSF Alternative C extends for 18.8 mi (30.2 km) toward the Downtown Houston area. Based on the construction method logistics, we presume the alternative would result in a completion of 4.3 calendar years and be split into three construction packages, each extending 6.3 mi (10.1 km).

The key issues and evaluation of Alternative C are summarized in Table 11 below:

Table 11 – Alternative C (Houston BNSF) Key Impacts

Evaluation Categories	**Key Issues/Impacts**	**Reference**	**Rating**
Project Delivery			
Cost	• Normalized Cumulative Cost: 1.23	Section 3.4	2
Schedule	• 4.3 Years for Completion • 3 Construction Packages	Section 4	2
Ridership	• Average Ridership Increase (compared to Alt A Base Case) - 9.8% • Average Ridership/Cost Ratio – 0.95	Section 5	2
Alignment Engineering and Constructability			
Major Structures	Requires two major structures: • SH 249/Beltway 8 • Sam Houston Tollway/Beltway 8	Section 2.1.1.2	2
Alignment	• Total length is 18.8 mi (30.2 km)	Section 2.1.1.1 Section 2.1.1.2 Section 2.1.1.4	2
Constructability Impacts	• Structure over SH 249 and Beltway 8	Section 2.1.1.2	2
Environmental, ROW, and Land Use			
Environmental & Wetlands	• Minimal impacts	Section 2.1.1.4	3
ROW Acquisitions	• Eastern terminus and station would require large numbers of what appears to be commercial displacements	Section 2.1.1.4	2
Land Use Impacts	• Potential changes in land use in the surrounding areas near White Oak Bayou	Section 2.1.1.4	2
Terminus Engineering			
Access to Existing Transportation	• Highway Access from US 290 and IH-610	Section 2.1.2.3	2
Development Opportunities	• Minimal development opportunities	Section 2.1.2.3	1

6.1.4 Houston BNSF Alternative D (Hardy Yards)

Alternative D consists of Segment 1, Segment 2, Segment 4, Segment 5, and Segment 6 and terminates at Location D (Hardy Yards). This alternative would be mostly viaduct at medium height and have a total length of approximately 27.4 mi (44.1 km).

This alternative was estimated to be 33% more costly than the BNSF Option 1 “middle segment.” A 100% urban complexity factor was added to the cost due to the alignment’s close proximity to freight tracks and a mixture of residential and industrial properties.

BNSF Alternative D extends for 27.4 mi (44.1 km) toward the Downtown Houston area. Based on the construction method logistics, we presume the alternative would result in a completion of 4.6 calendar years and be split into four construction packages, each extending 6.9 mi (11.1 km).

The key issues and evaluation of Alternative D are summarized in Table 12 below:

Table 12 – Alternative D (Houston BNSF) Key Impacts

Evaluation Categories	**Key Issues/Impacts**	**Reference**	**Rating**
Project Delivery			
Cost	• Normalized Cumulative Cost: 1.33	Section 3.4	1
Schedule	• 4.6 Years for Completion • 4 Construction Packages	Section 4	2
Ridership	• Average Ridership Increase (compared to Alt A Base Case) - 12.3% • Average Ridership/Cost Ratio – 0.91	Section 5	3
Alignment Engineering and Constructability			
Major Structures	Requires four major structures: • SH 249/Beltway 8 • Sam Houston Tollway/Beltway 8 • IH-45 • IH-610	Section 2.1.1.2 Section 2.1.1.5	1
Alignment	• Total length is 27.4 mi (44.1 km) • Curve speed restriction near TC Jester and IH-610	Section 2.1.1.1 Section 2.1.1.2 Section 2.1.1.4 Section 2.1.1.5 Section 2.1.1.6	1
Constructability Impacts	• Structure over SH 249, Beltway 8, IH-45, and IH-610 • Crosses over existing freight tracks near Hardy Yard	Section 2.1.1.2 Section 2.1.1.5 Section 2.1.1.6	1
Environmental, ROW, and Land Use			
Environmental & Wetlands	• Due to the degree of industrialization, potential impacts from hazardous materials were considered high	Section 2.1.1.6	1
ROW Acquisitions	• ROW transitions through commercial and residential areas for much of its length and very high potential for displacements	Section 2.1.1.6	1
Land Use Impacts	• The alignment has large components of commercial and industrialized areas • There are few expanses of undeveloped land along this portion of the corridor	Section 2.1.1.6	1
Terminus Engineering			
Access to Existing Transportation	• Highway access from IH-10, IH-45, and Hwy 59 • Convenient Access to the METRO LRT	Section 2.1.2.4	3
Development Opportunities	• This is a rare large piece of land found in the Downtown Houston area within close proximity to Houston's central business district and a stop on the light rail line	Section 2.1.2.4	3

6.1.5 Houston BNSF Alternative E (Downtown Houston)

Alternative E consists of Segment 1, Segment 2, Segment 4, Segment 5 and Segment 6 and terminates at Location E (Downtown Houston) near the old Post Office site. This alternative would be mostly viaduct at medium height and have a total length of approximately 28.5 mi (45.8 km).

This alternative has an additional 36% cost from the BNSF Option 1 "middle segment." A 93% urban complexity factor and 7% dense urban complexity factor was added to the cost due to the alignments close proximity to freight tracks and a mixture of residential and industrial properties.

BNSF Alternative E extends for 28.5 mi (45.8 km) toward the Downtown Houston area. Based on the construction method logistics, we presume the alternative would result in a completion of 4.7 calendar years and be split into four construction packages, each extending 7.1 mi (14.4 km).

The key issue and evaluation of Alternative E are summarized in Table 13 below:

Table 13 – Alternative E (Houston BNSF) Key Impacts

Evaluation Categories	**Key Issues/Impacts**	**Reference**	**Rating**
Project Delivery			
Cost	• Normalized Cumulative Cost: 1.36	Section 3.4	1
Schedule	• 4.7 Years for Completion • 4 Construction Packages	Section 4	2
Ridership	• Average Ridership Increase (compared to Alt A Base Case) - 12.3% • Average Ridership/Cost Ratio – 0.88	Section 5	3
Alignment Engineering and Constructability			
Major Structures	Requires six major structures: • SH 249/Beltway 8 • Sam Houston Tollway/Beltway 8 • IH-45 • IH-610 • Buffalo Bayou • IH-10	Section 2.1.1.2 Section 2.1.1.5 Section 2.1.1.7	1
Alignment	• Total length is 28.5 mi (45.8 km) • Curve speed restriction near TC Jester and IH-610	Section 2.1.1.1 Section 2.1.1.2 Section 2.1.1.4 Section 2.1.1.5 Section 2.1.1.7	1
Constructability Impacts	• Structure over SH 249, Beltway 8, IH-45, and IH-610 • 3 structures over Buffalo Bayou and 1 structure over University of Houston Building	Section 2.1.1.2 Section 2.1.1.5 Section 2.1.1.7	1

Environmental, ROW, and Land Use			
Environmental & Wetlands	• Due to the degree of industrialization, potential impacts from hazardous materials were considered high.	Section 2.1.1.7	1
ROW Acquisitions	• This alignment has large components of commercial and industrialized areas. The potential for displacements is high.	Section 2.1.1.7	1
Land Use Impacts	• This alignment has large components of commercial and industrialized areas. • There are few expanses of undeveloped land along this portion of the corridor. • There would likely be noise impacts, visual impacts, community facilities impacts, and potential changes in land use in the surrounding areas. For these reasons, the potential socio-economic impacts were considered high.	Section 2.1.1.7	1
Terminus Engineering			
Access to Existing Transportation	• Highway access from IH-10, IH-45, IH-610, SH 288, and US 59 • Access to existing METRO LRT and bus transit center • Access to Amtrak passenger railway services	Section 2.1.2.5	3
Development Opportunities	• Has direct light rail access to the Texas Medical Center (TMC), one of the major employment centers of Houston	Section 2.1.2.5	3

6.2 Houston UC Alignment

6.2.1 Houston UC Alternative A (US 290/Beltway 8)

Alternative A consists of Segment 1 and terminates at Location A (US 290/Beltway 8).

This alternative has an additional 17% cost than the UC "middle segment." A 73% complexity factor was added to the cost due to the alignment's close proximity to freight tracks and a mixture of residential and industrial properties.

UC Alternative A extends for 14.2 mi (22.80 km) toward the Downtown Houston area. Based on the construction method logistics, we presume the alternative would result in a completion of 4.9 calendar years and be split into two construction packages, each extending 7.1 mi (11.4 km).

The key issues and evaluation of Alternative A are summarized in Table 14 below:

Table 14 – Alternative A (Houston UC) Key Impacts

Evaluation Categories	**Key Issues/Impacts**	**Reference**	**Rating**
Project Delivery			
Cost	• Normalized Cumulative Cost: 1.17	Section 3.4	3
Schedule	• 4.9 Years for Completion • 2 Construction Packages	Section 4	2
Ridership	• Average Ridership Increase (compared to Alt A Base Case) – 3.0% • Average Ridership/Cost Ratio – 0.99	Section 5	1
Alignment Engineering and Constructability			
Major Structures	Requires two major structures: • Highway 6 • SH-99 - Grand Parkway	Section 2.2.1.1	2
Alignment	• Total length is 14.2 mi (22.8 km)	Section 2.2.1.1	3
Constructability Impacts	• Spans over Highway 6 and SH-99 • Frontage roads on both sides of Hwy 6 Bridge are adjacent to the highway mainlanes (requires frontage road realignment or large spans)	Section 2.2.1.1	2
Environmental, ROW, and Land Use			
Environmental & Wetlands	• Impacts to biotic communities, parks and forests, threatened and endangered species, and hydrology and wetlands would be moderate • Exposure to hazardous materials considered moderate	Section 2.2.1.1	2
ROW Acquisitions	• West of Barker-Cypress Rd: ROW is largely undeveloped • East of Barker-Cypress Rd: ROW extends through large expanses of single family residential and commercial/industrial property	Section 2.2.1.1	2
Land Use Impacts	• West of Barker-Cypress Rd: No noise or visual impacts • East of Barker-Cypress Rd: Moderate socio-economic impacts, noise impacts, visual impacts, community facilities impacts, and potential changes in land	Section 2.2.1.1	2
Terminus Engineering			
Access to Existing Transportation	• Highway access from US 290 and Beltway 8	Section 2.2.2.1	2

Development Opportunities	• US 290 is a key corridor to growing development and connects Houston to Hempstead, Prairie View, College Station, and Austin • Despite urban development there are some locations (especially outside Beltway 8) with development potential for station area	Section 2.2.2.1	2

6.2.2 Houston UC Alternative B (US 290/IH-610)

Alternative B consists of Segment 1 and Segment 2 and terminates at Location B (US 290/IH-610) near the Northwest mall site.

This alternative has an additional 27% cost from the UC "middle segment." A 38% urban complexity factor and 45% developed complexity factor was added to the cost due to the alignment's close proximity to freight tracks and a mixture of residential and industrial properties.

UC Alternative B extends for 23.4 mi (38.3 km) toward the Downtown Houston area. Based on the construction method logistics, we presume the alternative would result in a completion of 5 calendar years and be split into three construction packages, each extending 7.8 mi (12.6 km).

The key issues and evaluation of Alternative B are summarized in Table 15 below:

Table 15 – Alternative B (Houston UC) Key Impacts

Evaluation Categories	**Key Issues/Impacts**	**Reference**	**Rating**
Project Delivery			
Cost	• Normalized Cumulative Cost: 1.27	Section 3.4	2
Schedule	• 5 Years for Completion • 3 Construction Packages	Section 4	2
Ridership	• Average Ridership Increase (compared to Alt A Base Case) – 9.8% • Average Ridership/Cost Ratio – 0.98	Section 5	3
Alignment Engineering and Constructability			
Major Structures	Requires two major structures: • Highway 6 • SH-99 - Grand Parkway • Beltway 8	Section 2.2.1.1 Section 2.2.1.2	2
Alignment	• Total length is 23.4 mi (38.3 km) • Speed Restrictions at curves over Hempstead Rd	Section 2.2.1.1 Section 2.2.1.2	2

Constructability Impacts	• Spans over Highway 6, SH-99, and Beltway 8 • Frontage roads on both sides of Hwy 6 Bridge are adjacent to the highway mainlanes (requires frontage road realignment or large spans) • Elevated alignment above Beltway 8 at a height of 24.5 m	Section 2.2.1.1 Section 2.2.1.2	2
Environmental, ROW, and Land Use			
Environmental & Wetlands	• Impacts to biotic communities, parks and forests, threatened and endangered species, and hydrology and wetlands would be moderate (west of Beltway 8) and low (east of Beltway 8) • East of Beltway 8: Exposure to hazardous materials considered moderate	Section 2.2.1.1 Section 2.2.1.2	2
ROW Acquisitions	• West of Barker-Cypress Rd: ROW is largely undeveloped • East of Barker-Cypress Rd: ROW extends through large expanses of single family residential and commercial/industrial property • East of Beltway 8: ROW is largely commercial/industrial	Section 2.2.1.1 Section 2.2.1.2	2
Land Use Impacts	• West of Barker-Cypress Rd: No noise or visual impacts • East of Barker-Cypress Rd: Moderate socio-economic impacts, noise impacts, visual impacts, community facilities impacts, and potential changes in land • East of Beltway 8: potential for commercial and industrial displacements is high	Section 2.2.1.1 Section 2.2.1.2	2
Terminus Engineering			
Access to Existing Transportation	• Highway access from US 290 and IH-610 • Transit connectivity to downtown and the METRO LRT network via Northwest Transit Center (future planned)	Section 2.2.2.2	3
Development Opportunities	• South end of US 290 corridor is a key corridor to growing development in the northwest of Houston and central Houston • Despite heavy urban development there are some locations with development potential for station area	Section 2.2.2.2	3

6.2.3 Houston UC Alternative C (Downtown Houston)

Alternative C consists of Segment 1, Segment 2, and Segment 3 and terminates at Location C (Downtown Houston) near the Amtrak Station site.

This alternative has an additional 35% cost from the UC "middle segment." A 50% urban complexity factor and 36% developed complexity factor was added to the cost due to the alignment's close proximity to freight tracks and a mixture of residential and industrial properties.

UC Alternative C extends for 29.5 mi (47.4 km) toward the Downtown Houston area. Based on the construction method logistics, we presume the alternative would result in a completion of 4.7 calendar years and be split into four construction package, each extending 7.4 mi (11.9 km).

The key issues and evaluation of Alternative C are summarized in Table 16 below:

Table 16 – Alternative C (Houston UC) Key Impacts

Evaluation Categories	**Key Issues/Impacts**	**Reference**	**Rating**
Project Delivery			
Cost	• Normalized Cumulative Cost: 1.35	Section 3.4	1
Schedule	• 4.7 Years for Completion • 4 Construction Packages	Section 4	2
Ridership	• Average Ridership Increase (compared to Alt A Base Case) – 12.3% • Average Ridership/Cost Ratio – 0.94	Section 5	3
Alignment Engineering and Constructability			
Major Structures	Requires two major structures: • Highway 6 • SH-99 - Grand Parkway • Beltway 8 • IH-10 • H-610	Section 2.2.1.1 Section 2.2.1.2 Section 2.2.1.3	1
Alignment	• Total length is 29.5 mi (47.40 km) • Speed restrictions at curves over Hempstead Road and near existing Amtrak Station Parking Lot (no significant operational impacts given proximity to station)	Section 2.2.1.1 Section 2.2.1.2 Section 2.2.1.3	1

Constructability Impacts	• Spans over Highway 6, SH-99, Beltway 8, IH-10, and IH-610 • Frontage roads on both sides of Hwy 6 Bridge are adjacent to the highway main lanes (requires frontage road realignment or large spans) • Elevated alignment above Beltway 8 at a height of 24.5 m • Wide elevated structure required to cross IH-10 (13 lanes) in vicinity of UPRR bridge structure • Elevated alignment above IH-610 at a height of 20m	Section 2.2.1.1 Section 2.2.1.2 Section 2.2.1.3	1
Environmental, ROW, and Land Use			
Environmental & Wetlands	• Impacts to biotic communities, parks and forests, threatened and endangered species, and hydrology and wetlands would be moderate (west of Beltway 8) and low (east of Beltway 8) • East of Beltway 8: Exposure to hazardous materials considered moderate • East of Northwest Mall: Exposure to hazardous materials considered high	Section 2.2.1.1 Section 2.2.1.2 Section 2.2.1.3	1
ROW Acquisitions	• West of Barker-Cypress Rd: ROW is largely undeveloped • East of Barker-Cypress Rd: ROW extends through large single family residential and commercial/industrial property • East of Beltway 8: ROW is largely commercial/industrial	Section 2.2.1.1 Section 2.2.1.2 Section 2.2.1.3	1
Land Use Impacts	• West of Barker-Cypress Rd: No noise or visual impacts • East of Barker-Cypress Rd: Moderate socio-economic impacts, noise impacts, visual impacts, community facilities impacts, and potential changes in land • East of Northwest Mall: High socio-economic impacts, noise impacts, visual impacts, community facilities impacts, and potential changes in land • East of Beltway 8: potential for commercial, industrial, and residential displacements is high	Section 2.2.1.1 Section 2.2.1.2 Section 2.2.1.3	1
Terminus Engineering			
Access to Existing Transportation	• Highway access from IH-10, IH-45, IH-610, SH 288, and US 59 • Access to existing METRO LRT and bus transit center • Access to Amtrak	Section 2.2.2.3	3

Development Opportunities	• Downtown Houston remains a key employment center • Dense urban development limits development potential for station area	Section 2.2.2.3	2

6.3 Dallas Common Alignment

6.3.1 Dallas Alternative A (IH-45/IH-20)

Alternative A consists of Segment 1 and terminates at Location A (IH-45/IH-20).

This alternative has an additional 2% cost from the UC or BNSF Option 1 "middle segment." No urban complexity factors were included because the alignment is not in close proximity to freight tracks or developed areas.

Dallas Alternative A extends for 0.75 mi (1.20 km) toward the Downtown Dallas area. In conclusion, based on the described durations, we presume the alternative would result in a completion of 0.50 calendar years and be constructed under one package.

The key issues and evaluation of Alternative A are summarized in Table 17 below:

Table 17 – Alternative A (Dallas) Key Impacts

Evaluation Categories	**Key Issues/Impacts**	**Reference**	**Rating**
Project Delivery			
Cost	• Normalized Cumulative Cost: 1.02	Section 3.4	3
Schedule	• 0.5 Years for Completion • 1 Construction Package	Section 4	3
Ridership	• Average Ridership Increase (compared to Alt A Base Case) – 5.3% • Average Ridership/Cost Ratio – 0.95	Section 5	1
Alignment Engineering and Constructability			
Major Structures	• No major structures	Section 2.3.1.1	3
Alignment	• Total length is 0.75 mi (1.20 km)	Section 2.3.1.1	3
Constructability Impacts	• No major impacts	Section 2.3.1.1	3
Environmental, ROW, and Land Use			
Environmental & Wetlands	• Impacts to biotic communities, parks and forests, threatened and endangered species, and hydrology and wetlands would be moderate • Exposure to hazardous materials considered low	Section 2.3.1.1	2
ROW Acquisitions	• ROW is largely undeveloped (consisting of woodlands and fallow lands)	Section 2.3.1.1	3

Land Use Impacts	• No noise or visual impacts to residential areas • Potential changes in land use considered moderate	Section 2.3.1.1	2
Terminus Engineering			
Access to Existing Transportation	• Highway access from IH-45 and IH-20 • Large distance from Dallas regional public transportation network	Section 2.3.2.1	1
Development Opportunities	• Lack of commercial development to enhance or support station area development opportunities • Long distance from the employment and commercial centers of the Metroplex may diminish its attractiveness from a ridership and development perspective • Area is a mix of rural with some light industrial and commercial development	Section 2.3.2.1	1

6.3.2 Dallas Alternative B (Loop 12)

Alternative B consists of Segment 1 and Segment 2 and terminates at Location B (Loop 12).

This alternative has an additional 5% and 6% cost from the BNSF Option 1 “middle segment” and UC “middle segment,” respectively. A 79% developed complexity factor was added to the cost due to the alignment’s close proximity to freight tracks and a mixture of residential and industrial properties.

Dallas Alternative B extends for 3.9 mi (6.30 km) toward the Downtown Dallas area. In conclusion, based on the described durations, we presume the alternative would result in a completion of 2.60 calendar years and be constructed under one package.

The key issues and evaluation of Alternative B are summarized in Table 18 below:

Table 18 – Alternative B (Dallas) Key Impacts

Evaluation Categories	**Key Issues/Impacts**	**Reference**	**Rating**
Project Delivery			
Cost	• Normalized Cumulative Cost: 1.06	Section 3.4	3
Schedule	• 2.6 Years for Completion • 1 Construction Package	Section 4	3
Ridership	• Average Ridership Increase (compared to Alt A Base Case) – 6.2% • Average Ridership/Cost Ratio – 0.94	Section 5	2
Alignment Engineering and Constructability			
Major Structures	Requires one major structure: • IH-20	Section 2.3.1.1 Section 2.3.1.2	2

Alignment	• Total length is 3.9 mi (6.30 km)	Section 2.3.1.1 Section 2.3.1.2	2
Constructability Impacts	• Spans over IH-20 (relatively low cost major structure due to adequate space for bridge piers)	Section 2.3.1.1 Section 2.3.1.2	2
Environmental, ROW, and Land Use			
Environmental & Wetlands	• Due to the amount wooded areas, impacts to natural communities would be high • Exposure to hazardous materials considered low	Section 2.3.1.1 Section 2.3.1.2	2
ROW Acquisitions	• ROW is largely undeveloped (heavily wooded)	Section 2.3.1.1 Section 2.3.1.2	3
Land Use Impacts	• Little developed area adjacent to the ROW that would experience potential changes in land use • Potential changes in land use considered moderate	Section 2.3.1.1 Section 2.3.1.2	2
Terminus Engineering			
Access to Existing Transportation	• Highway access from IH-45 and Loop 12 • Large distance from Dallas regional public transportation network	Section 2.3.2.2	1
Development Opportunities	• Long distance from the employment and commercial centers of the Metroplex may diminish its attractiveness from a ridership and development perspective • Area is a mix of rural with some light industrial and commercial development	Section 2.3.2.2	1

6.3.3 Dallas Alternative C (Downtown Dallas)

Alternative C consists of Segment 1, Segment 2, and Segment 3 and terminates at Location C (Downtown Dallas) near the old Reunion Arena site.

This alternative has an additional 12% and 13% cost from the BNSF Option 1 "middle segment" and UC "middle segment," respectively. A 17% urban complexity factor and 75% developed complexity factor was added to the cost due to the alignment's close proximity to freight tracks and a mixture of residential and industrial properties.

Dallas Alternative C extends for 10.4 mi (16.70 km) toward the Downtown Dallas area. In conclusion, based on the described durations, we presume the alternative would result in a completion of 3.5 calendar years and be split into two construction packages, each extending 5.2 mi (8.35 km).

The key issues and evaluation of Alternative C are summarized in Table 19 below:

Table 19 – Alternative C (Dallas) Key Impacts

Evaluation Categories	**Key Issues/Impacts**	**Reference**	**Rating**
Project Delivery			
Cost	• Normalized Cumulative Cost: 1.13	Section 3.4	2
Schedule	• 3.5 Years for Completion • 2 Construction Packages	Section 4	3
Ridership	• Average Ridership Increase (compared to Alt A Base Case) – 13.5% • Average Ridership/Cost Ratio – 0.95	Section 5	3
Alignment Engineering and Constructability			
Major Structures	Requires four major structures: • IH-20 • Loop 12 • Trinity River • IH-30	Section 2.3.1.1 Section 2.3.1.2 Section 2.3.1.3	2
Alignment	• Total length is 10.4 mi (16.70 km) • Additional length relatively insignificant • Six curves with speed restrictions (no significant operational impacts due to proximity to station)	Section 2.3.1.1 Section 2.3.1.2 Section 2.3.1.3	2
Constructability Impacts	• Spans over IH-20, Loop 12, Trinity River, and IH-30 (IH-20 and Loop 12 crossings relatively low cost major structure due to adequate space for bridge piers) • Skewed crossing of Trinity River (requires coordination with USACE)	Section 2.3.1.1 Section 2.3.1.2 Section 2.3.1.3	2
Environmental, ROW, and Land Use			
Environmental & Wetlands	• Due to the amount wooded areas and Trinity River floodplain locations, impacts to natural communities would be high • Exposure to hazardous materials considered low	Section 2.3.1.1 Section 2.3.1.2 Section 2.3.1.3	2
ROW Acquisitions	• South of Cedar Crest: largely undeveloped • North of Cedar Crest: largely residential areas	Section 2.3.1.1 Section 2.3.1.2 Section 2.3.1.3	2
Land Use Impacts	• South of Cedar Crest: largely undeveloped • North of Cedar Crest: largely low income residential areas (potential for displacements/socioeconomic impacts) • Potential impact to cultural resources considered moderate	Section 2.3.1.1 Section 2.3.1.2 Section 2.3.1.3	2

Terminus Engineering			
Access to Existing Transportation	• Highway access from IH-35E, Woodall-Rodgers Freeway, and urban roadway network • Access to the existing Dallas public transportation network • Access to Amtrak	Section 2.3.2.3	3
Development Opportunities	• Close proximity to Metroplex employment centers • Urban development limits locations for development potential for station area	Section 2.3.2.3	3

7 Summary of Last Mile Analysis (Stoplight Charts)

The stoplight charts below summarize the ratings for the various alignment alternatives described in the preceding sections.

Amongst the Houston BNSF Alternatives, the analysis suggests that the Houston BNSF Last Mile Alternative A is rated the highest due to cost, environmental, land use, engineering, and constructability concerns associated with an alignment constructed into Downtown Houston.

Amongst the Houston UC Alternatives, the analysis suggests that the Houston UC Last Mile Alternative B is rated the highest mainly due to cost, schedule, environmental, land use, engineering, and constructability concerns associated with an alignment constructed into Downtown Houston.

Amongst the Dallas Alternatives, the analysis suggest that Dallas Last Mile Alternative C is rated the highest and would provide the most ridership, development opportunities, and connections to existing transportation without relatively significant environmental and land use impacts or major constructability and engineering concerns.

7.1 Summary of Alternatives Houston BNSF Alternatives

	Houston BNSF Ratings				
	Alt A	**Alt B**	**Alt C**	**Alt D**	**Alt E**
Evaluation Categories	Belt. 8	Loop 610	TC Jester	Hardy Yards	Post Office
Project Delivery					
Cost	**3**	2	2	1	1
Schedule	**2**	2	2	2	2
Ridership	**1**	2	2	3	3
Alignment Engineering and Constructability					
Major Structures	**3**	2	2	1	1
Alignment	**3**	2	2	1	1
Constructability Impacts	**3**	2	2	1	1
Environmental, ROW, and Land Use					
Environmental & Wetlands	**3**	3	3	1	1
ROW Acquisitions	**2**	1	2	1	1
Land Use Impacts	**2**	1	2	1	1
Terminus Engineering					
Access to Existing Transportation	**2**	3	2	3	3
Development Opportunities	**1**	3	1	3	3
TOTAL	**25**	**23**	**22**	**18**	**18**

7.2 Summary of Houston UC Alternatives

Evaluation Categories	**Houston UC Ratings**		
	Alt A	**Alt B**	**Alt C**
	Belt 8	Loop 610	Amtrak
Project Delivery			
Cost	3	**2**	1
Schedule	2	**2**	2
Ridership	1	**3**	3
Alignment Engineering and Constructability			
Major Structures	2	**2**	1
Alignment	3	**2**	1
Constructability Impacts	2	**2**	1
Environmental, ROW, and Land Use			
Environmental & Wetlands	2	**2**	1
ROW Acquisitions	2	**2**	1
Land Use Impacts	2	**2**	1
Terminus Engineering			
Access to Existing Transportation	2	**3**	3
Development Opportunities	2	**3**	2
TOTAL	**23**	**25**	**17**

7.3 Summary of Dallas Alternatives

Evaluation Categories	**Dallas Ratings**		
	Alt A	**Alt B**	**Alt C**
	IH-20	Loop 12	Reunion
Project Delivery			
Cost	3	3	**2**
Schedule	3	3	**3**
Ridership	1	2	**3**
Alignment Engineering and Constructability			
Major Structures	3	2	**2**
Alignment	3	2	**2**
Constructability Impacts	3	2	**2**
Environmental, ROW, and Land Use			
Environmental & Wetlands	2	2	**2**
ROW Acquisitions	3	3	**2**
Land Use Impacts	2	2	**2**
Terminus Engineering			
Access to Existing Transportation	1	1	**3**
Development Opportunities	1	1	**3**
TOTAL	**25**	**23**	**26**

8 Alternative Comparison Conclusion

This analysis was performed to independently identify the most viable terminus location in both Dallas and Houston for each of the potential HSR corridor alignments. In summary, the following alternatives rated the highest within the three Last Mile comparisons for the two alternative corridors:

- Houston BNSF – Last Mile Alternative A (SH 249/Beltway 8)
- Houston UC – Last Mile Alternative B (US 290/IH-610)
- Dallas BNSF and UC – Last Mile Alternative C (Downtown Dallas)

However, the evaluation results can also be used to support the comparative assessment of the two competing Project corridors themselves, BNSF and UC. In comparing the preferred terminus locations in Houston for each corridor, the BNSF Last Mile Alternative A (SH 249/Beltway 8) and the Houston UC Last Mile Alternative B (US 290/IH-610), the following key comparative assessments can be noted:

- Cost:
  - The analysis made clear that following the UC alignment would allow the Project to reach further into the Houston urban area at less cost than following the BNSF alignment alternative. The cost to construct from Reunion Arena in Dallas to Houston is consistently more expensive using the BNSF corridor than the UC, as follows:
    - Reunion Arena to Beltway 8 – BNSF Total Cost is 4.1% higher
    - Reunion Arena to Loop 610 – BNSF Total Cost is 5.3% higher
    - Reunion Arena to Amtrak/Post Office – BNSF Total Cost is 6.7% higher
  - The Houston BNSF "middle segment" is 6.5% more expensive than the Houston UC "middle segment."
  - While the differences in each case are less than 10%, these are based on total Project cost – and 4-7% of the total project cost is significant when considering this is a 240 mile long project
- Ridership:
  - The Houston UC Last Mile Alternative B is projected to have 6.7% higher ridership than the Houston BNSF Last Mile Alternative A. This can be attributed to the preferred terminus location along each corridor identified through this analysis, which found that reaching further into the urban core along the UC was found to be the preferred approach in the evaluation, while along the BNSF corridor reaching the IH-610 loop was found too costly and difficult.
- Constructability:
  - The BNSF "middle segment" has major financial, schedule, and project delivery concerns associated with long lengths of shared freight corridors in

the BNSF "middle segment" (for more information see the *Step 1 Screening of Corridor Alternatives Report* dated 3/22/15).

Based on these key comparative elements, the Houston UC Alternative B (US 290/IH-610) is the preferred and recommended Houston Last Mile Alternative.

Dallas Alternative C (Downtown Dallas) can accommodate the Houston UC Alignment and is the preferred and recommended Dallas Last Mile Alternative.

Appendix A

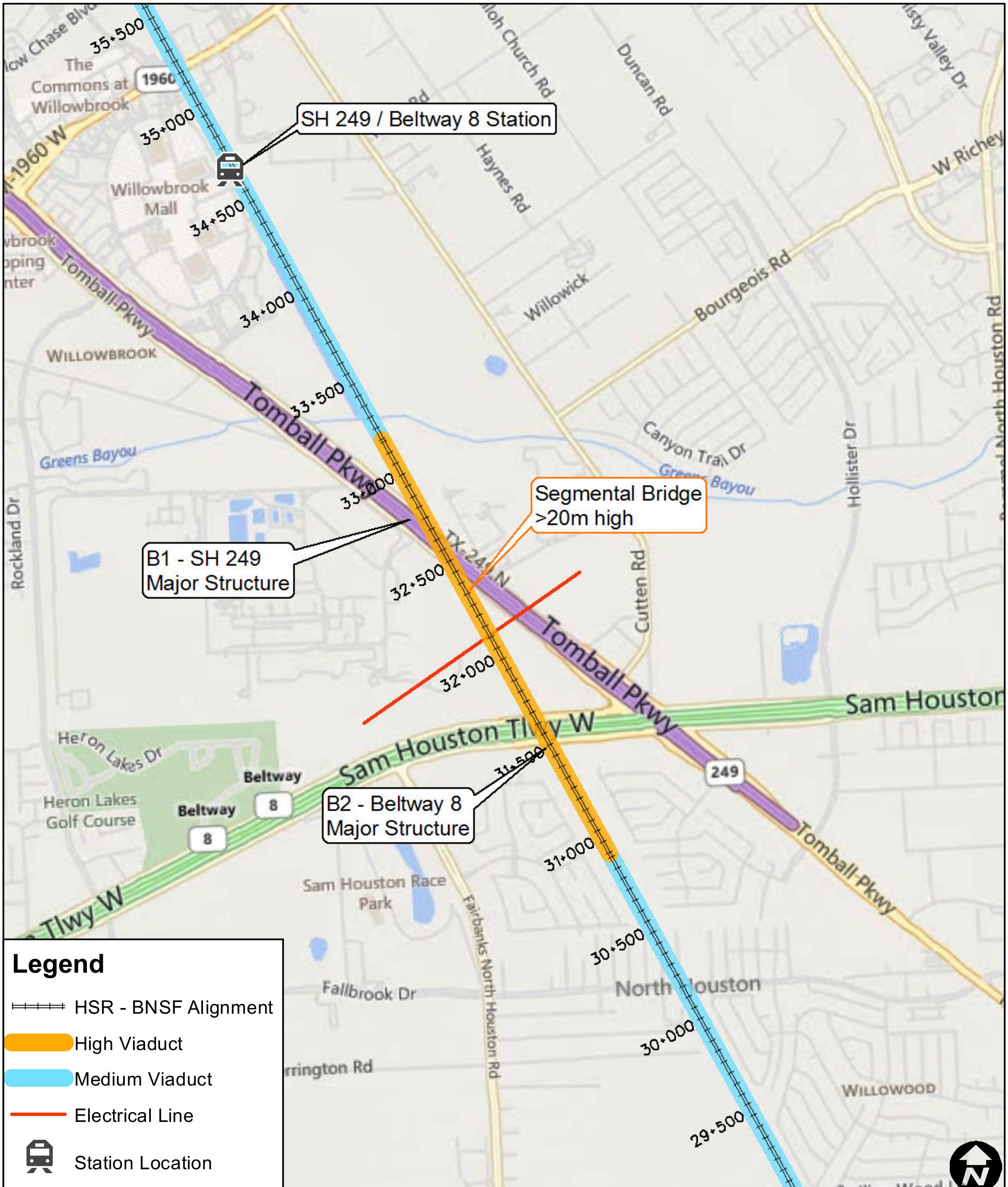

FIGURE A1

SH 249 / Beltway 8 Interchange

BNSF Corridor

Feet: 0, 600, 1200, 2400
Meters: 0, 175, 350, 700

Date Saved: 12/12/2014
Document Path: H:\TRANSPORATION\Working\BNSF_Corridor_Maps_HoustonToDallas.mxd

Update by: 02271

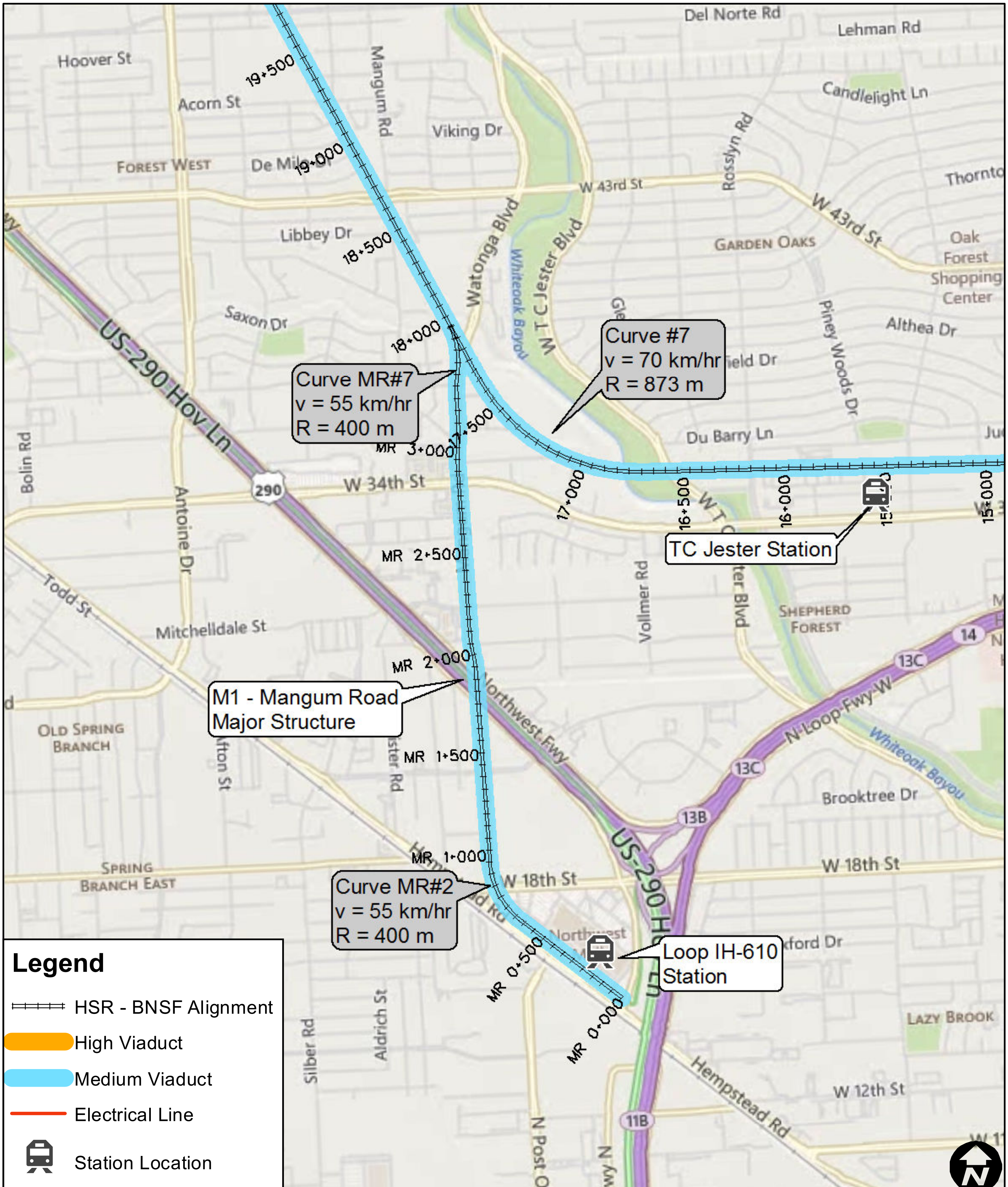

FIGURE A2	Mangum Road BNSF Corridor	Feet 0 600 1200 2400 0 175 350 700 Meters

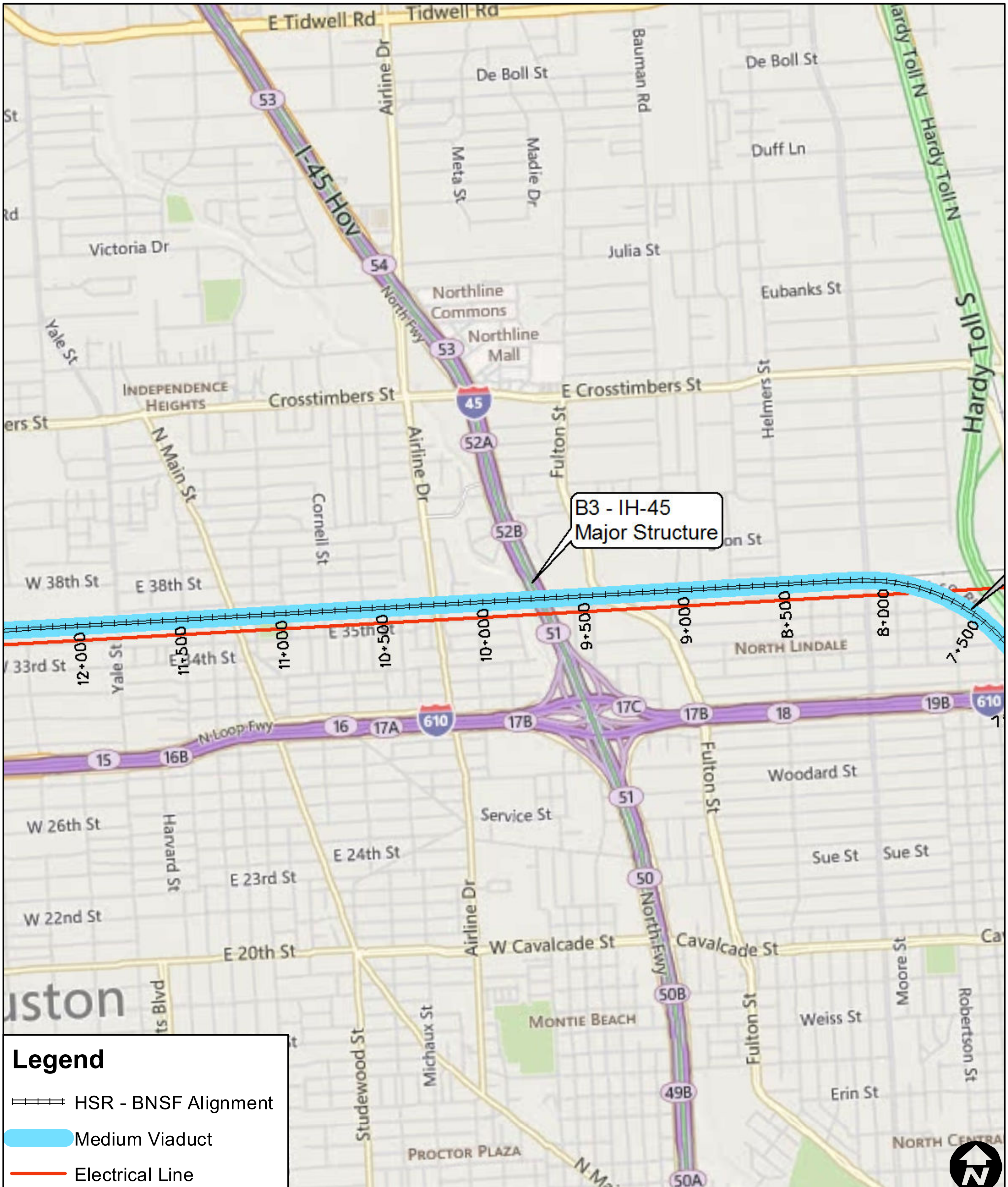

FIGURE A3

IH-45

BNSF Corridor

Feet
0 600 1200 2400
0 175 350 700
Meters

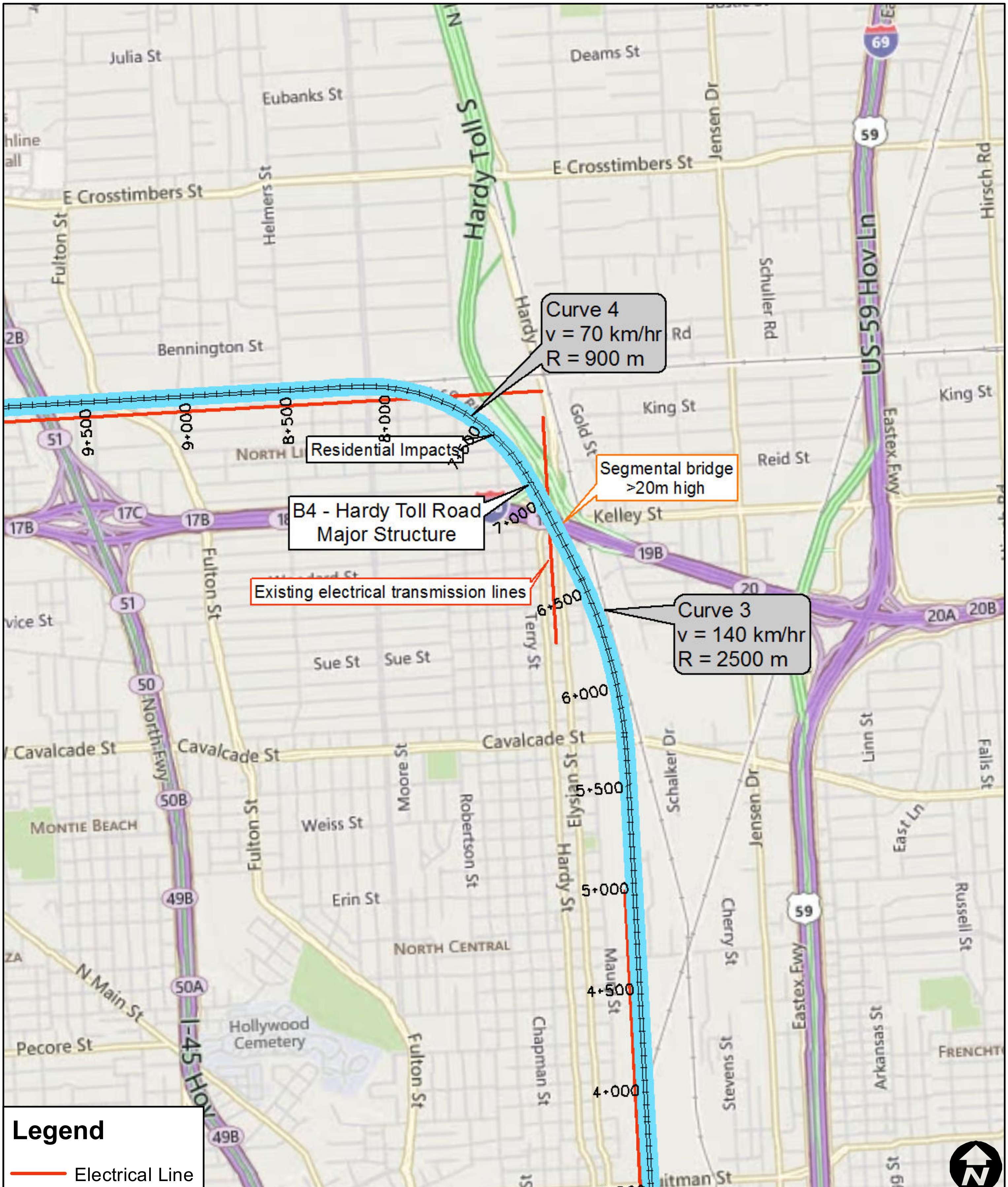

FIGURE A4

Hardy Toll Road/IH-610 Interchange

BNSF Corridor

Feet: 0 600 1200 2400
Meters: 0 175 350 700

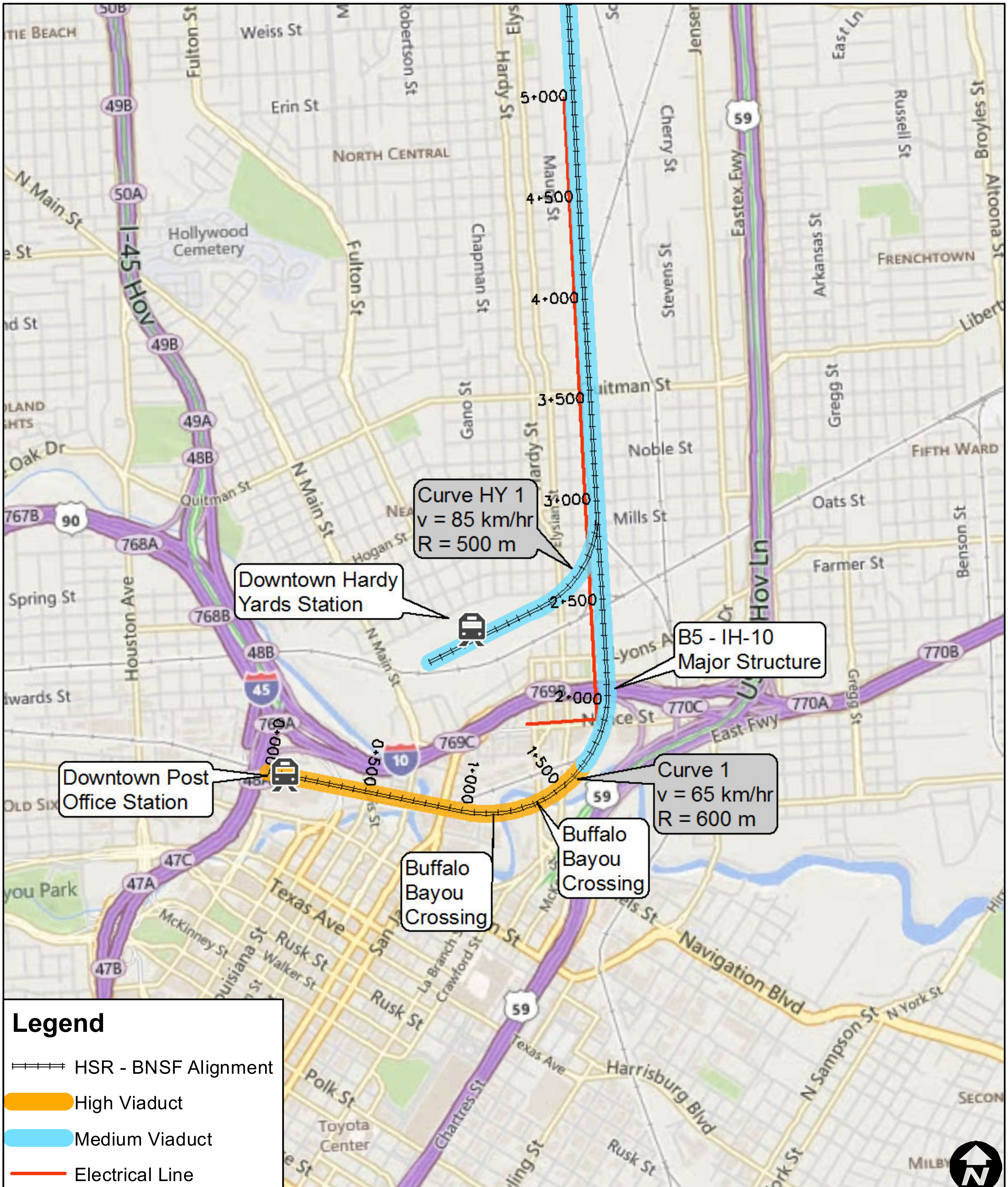

FIGURE A5

Downtown Houston

BNSF Corridor

Date Saved: 12/12/2014
Document Path: H:\TRANSPORATION\Working\BNSF_Corridor_Maps_HoustonToDallas.mxd

Update by: 02271

Appendix B

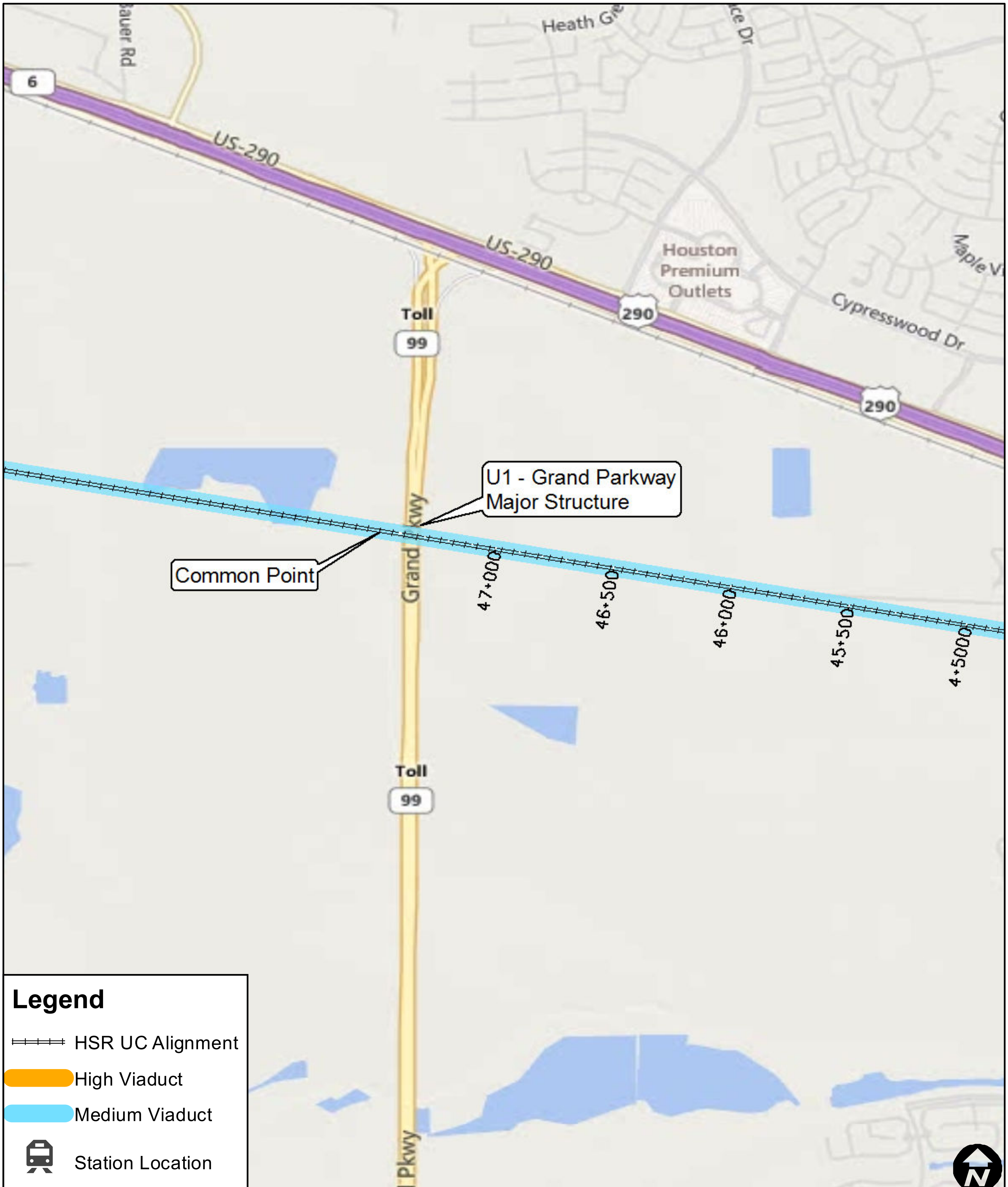

FIGURE B1

Utility Corridor Common Point

Feet
0 600 1200 2400
0 175 350 700
Meters

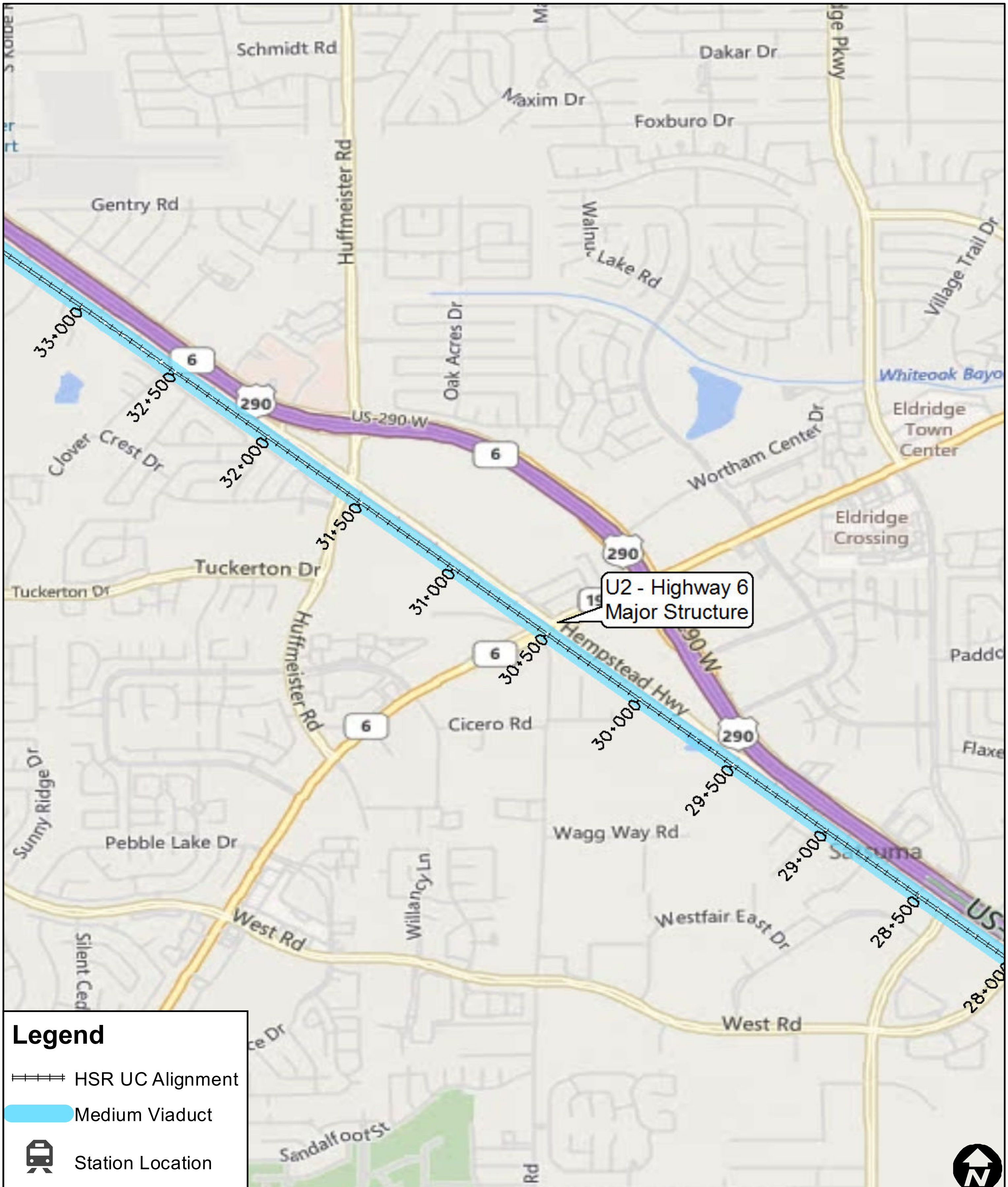

FIGURE B2	Highway 6 Utility Corridor	Feet: 0, 600, 1200, 2400 Meters: 0, 175, 350, 700

Date Saved: 12/12/2014
Document Path: H:\TRANSPORATION\Working\Utility_Corridor_Route_Houston_Stations.mxd
Update by: 02271

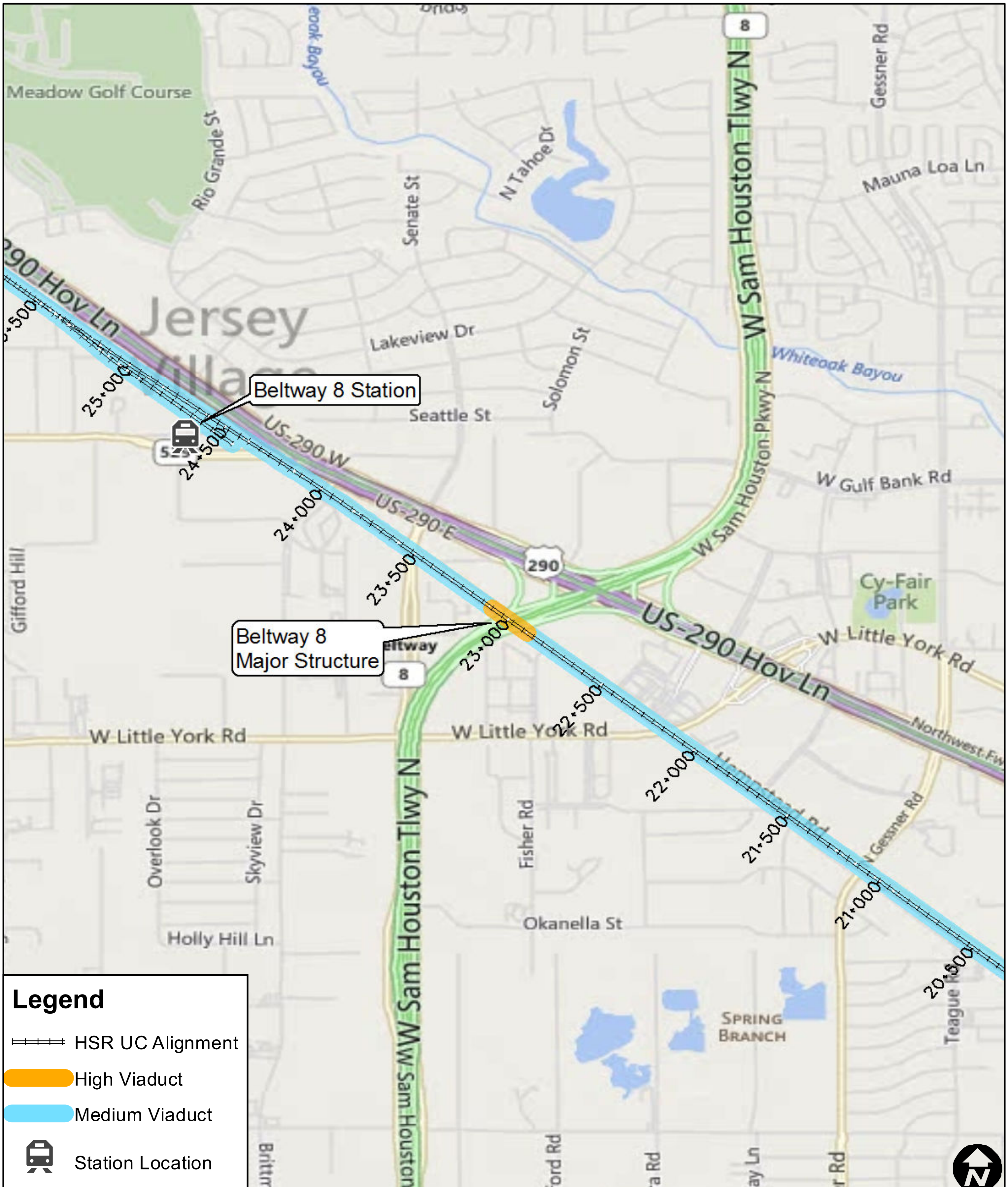

FIGURE B3

Beltway 8

Utility Corridor

Feet: 0 600 1200 2400
Meters: 0 175 350 700

Date Saved: 12/12/2014
Document Path: H:\TRANSPORATION\Working\Utility_Corridor_Route_Houston_Stations.mxd

Update by: 02271

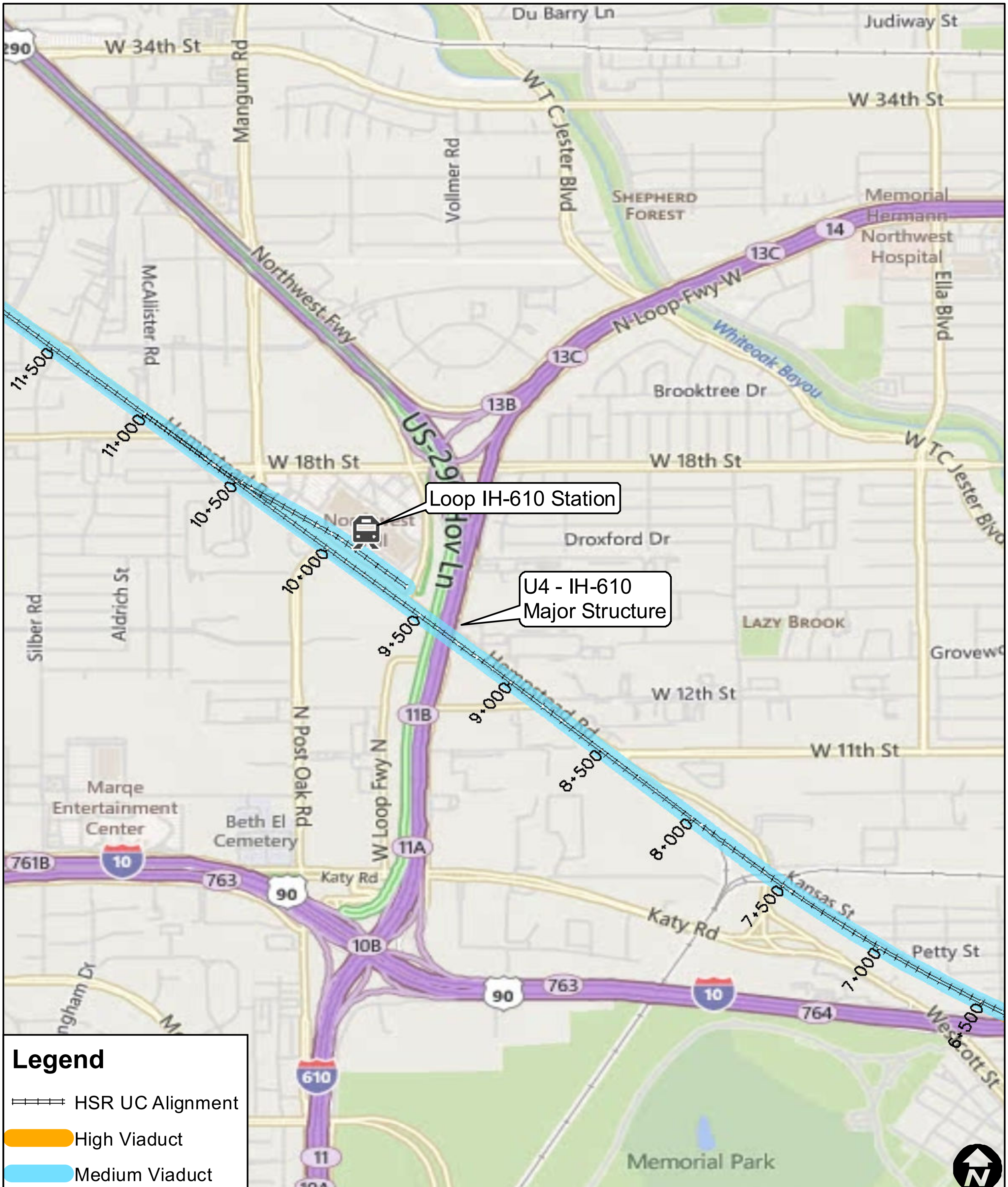

FIGURE B4

IH-610

Utility Corridor

Feet
0 600 1200 2400
0 175 350 700
Meters

Date Saved: 12/12/2014
Document Path: H:\TRANSPORATION\Working\Utility_Corridor_Route_Houston_Stations.mxd
Update by: 02271

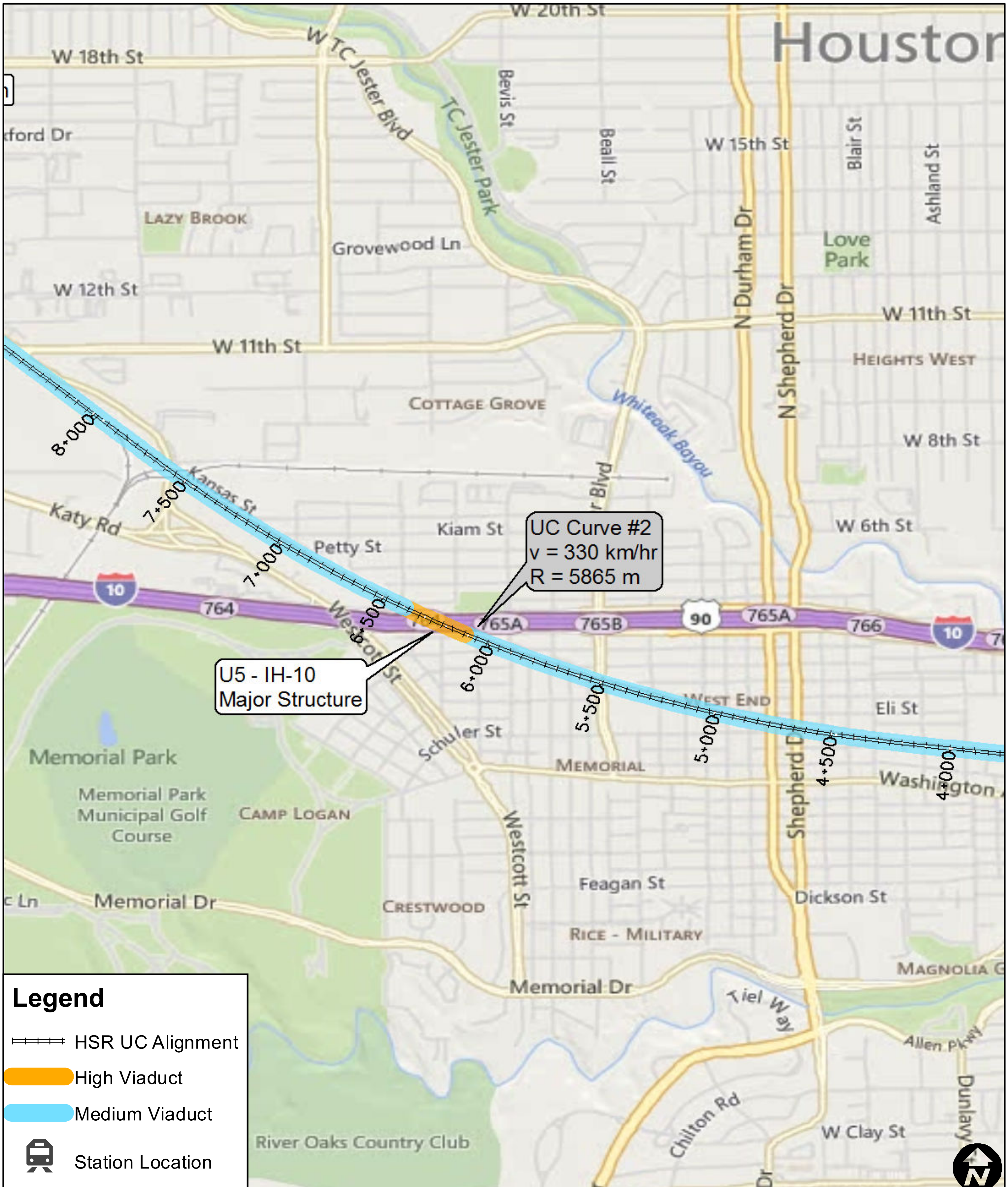

FIGURE B5

IH-10
Utility Corridor

Date Saved: 12/12/2014
Document Path: H:\TRANSPORATION\Working\Utility_Corridor_Route_Houston_Stations.mxd
Update by: 02271

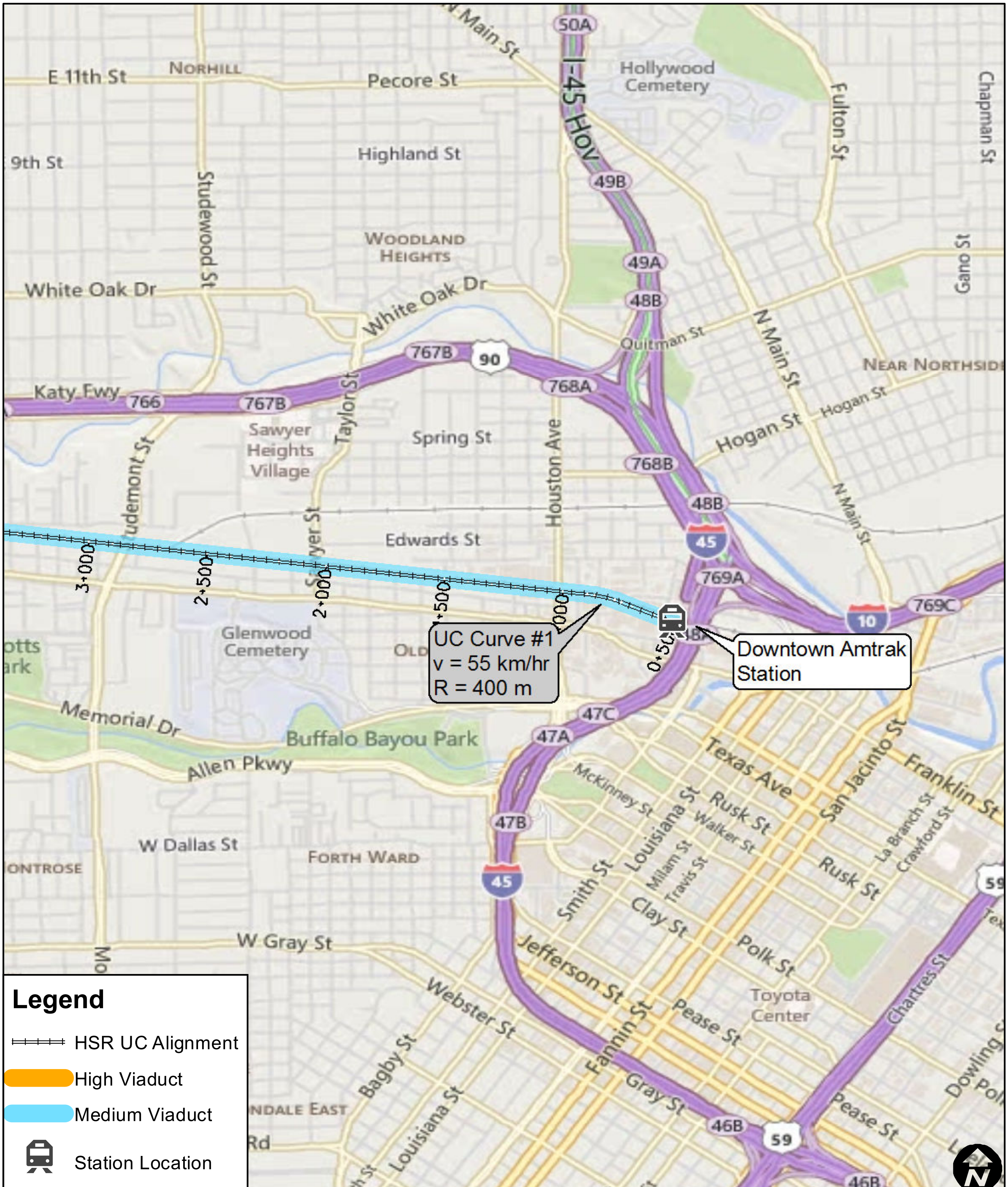

FIGURE B6

Downtown Houston

Utility Corridor

Feet: 0 600 1200 2400

Meters: 0 175 350 700

Appendix C

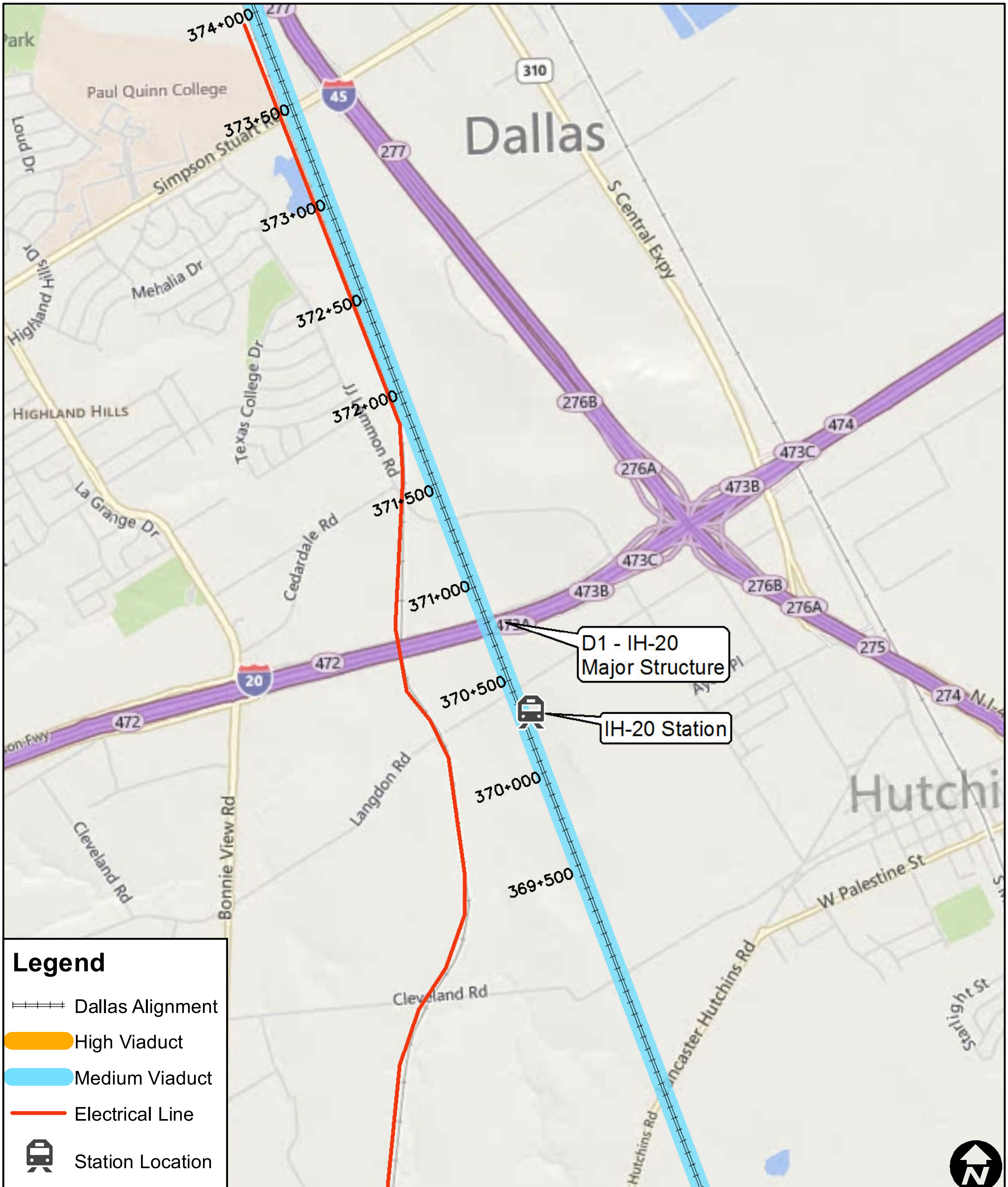

FIGURE C1

Loop 12

Dallas Corridor

Feet
0 600 1200 2400
0 175 350 700
Meters

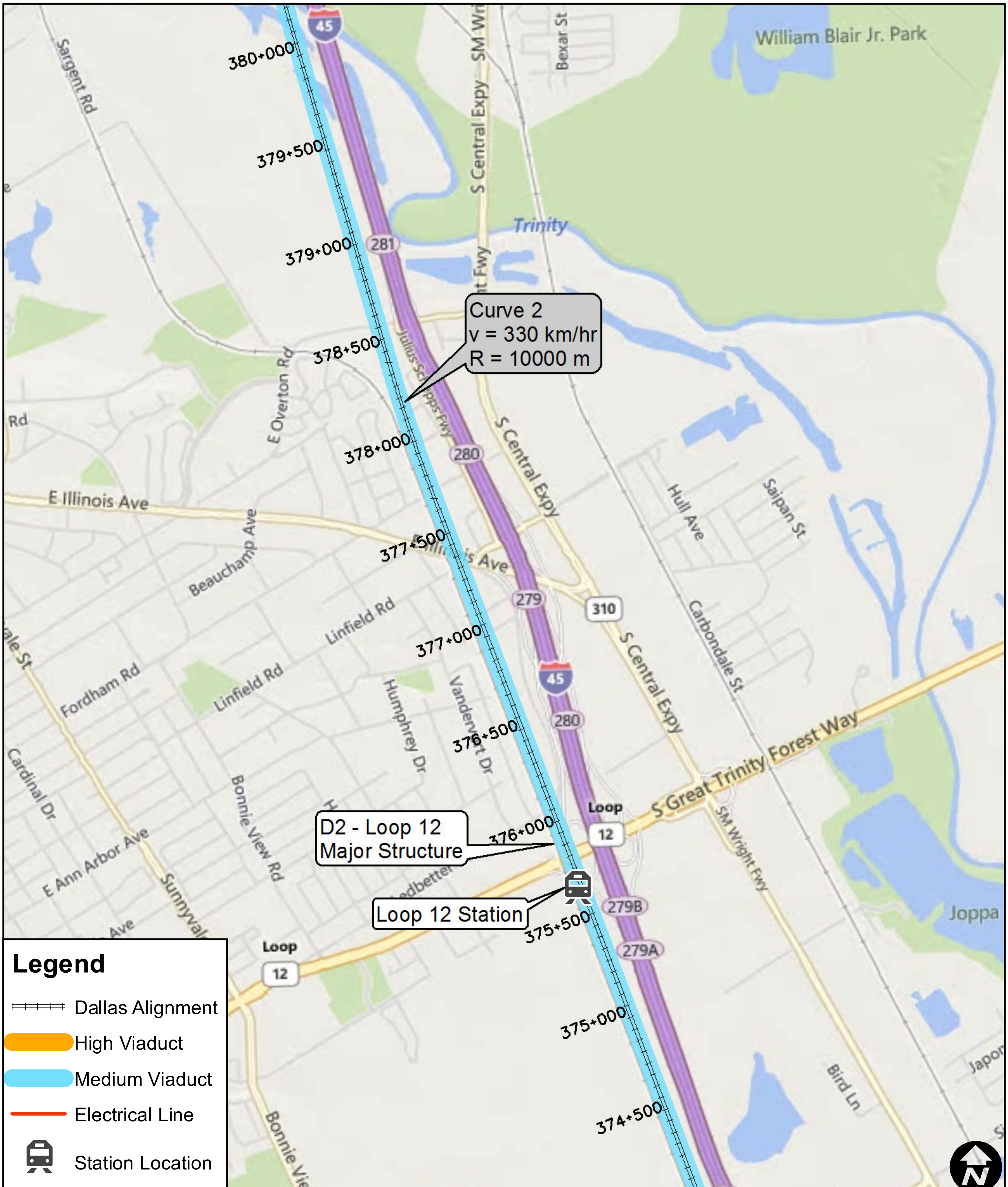

FIGURE C2

Loop 12

Dallas Corridor

Feet: 0, 600, 1200, 2400
Meters: 0, 175, 350, 700

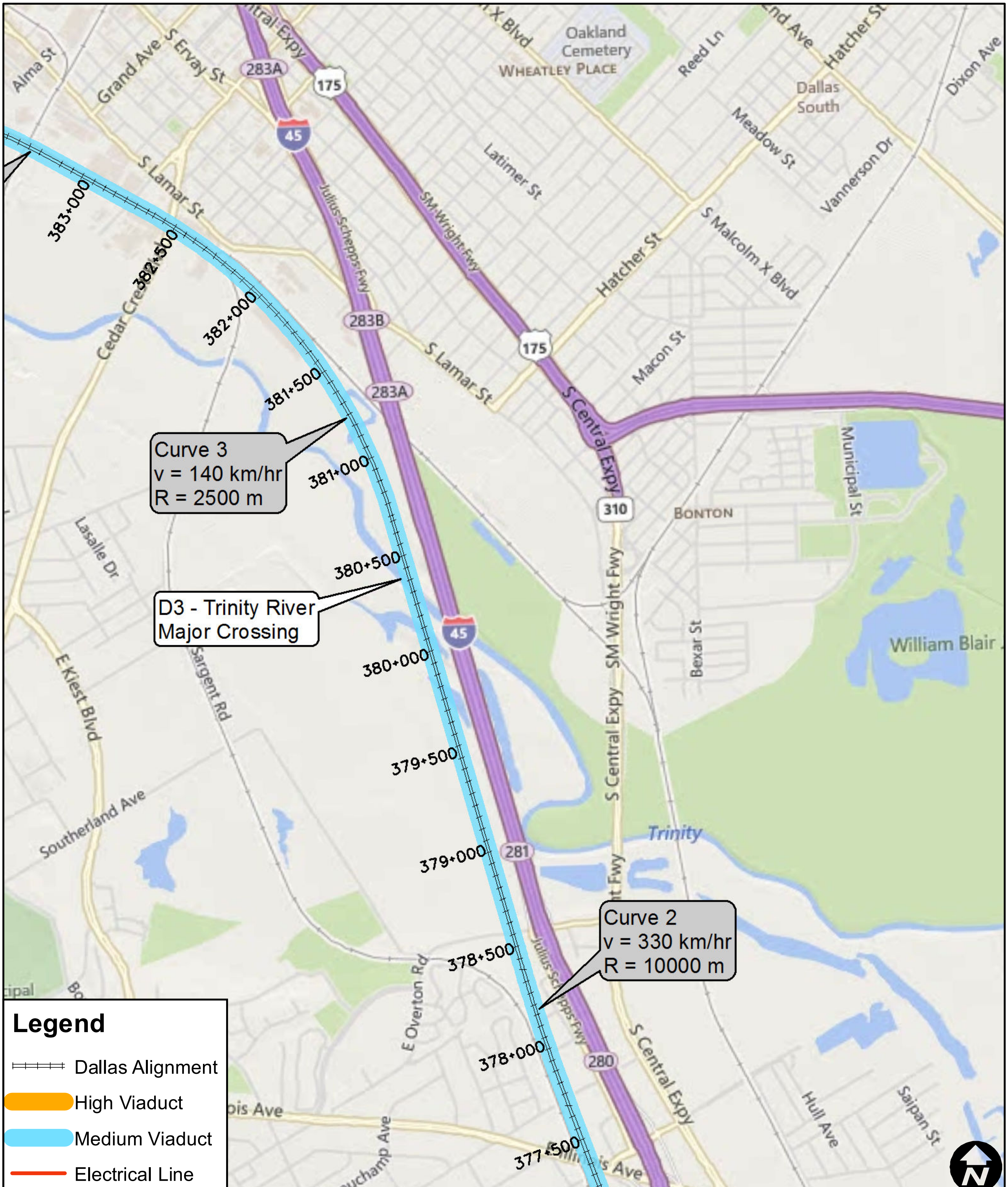

FIGURE C3

Trinity River Crossing

Dallas Corridor

Feet: 0, 600, 1200, 2400
Meters: 0, 175, 350, 700

Date Saved: 12/12/2014
Document Path: H:\TRANSPORATION\Working\BNSF_Corridor_Maps_HoustonToDallas.mxd
Update by: 02271

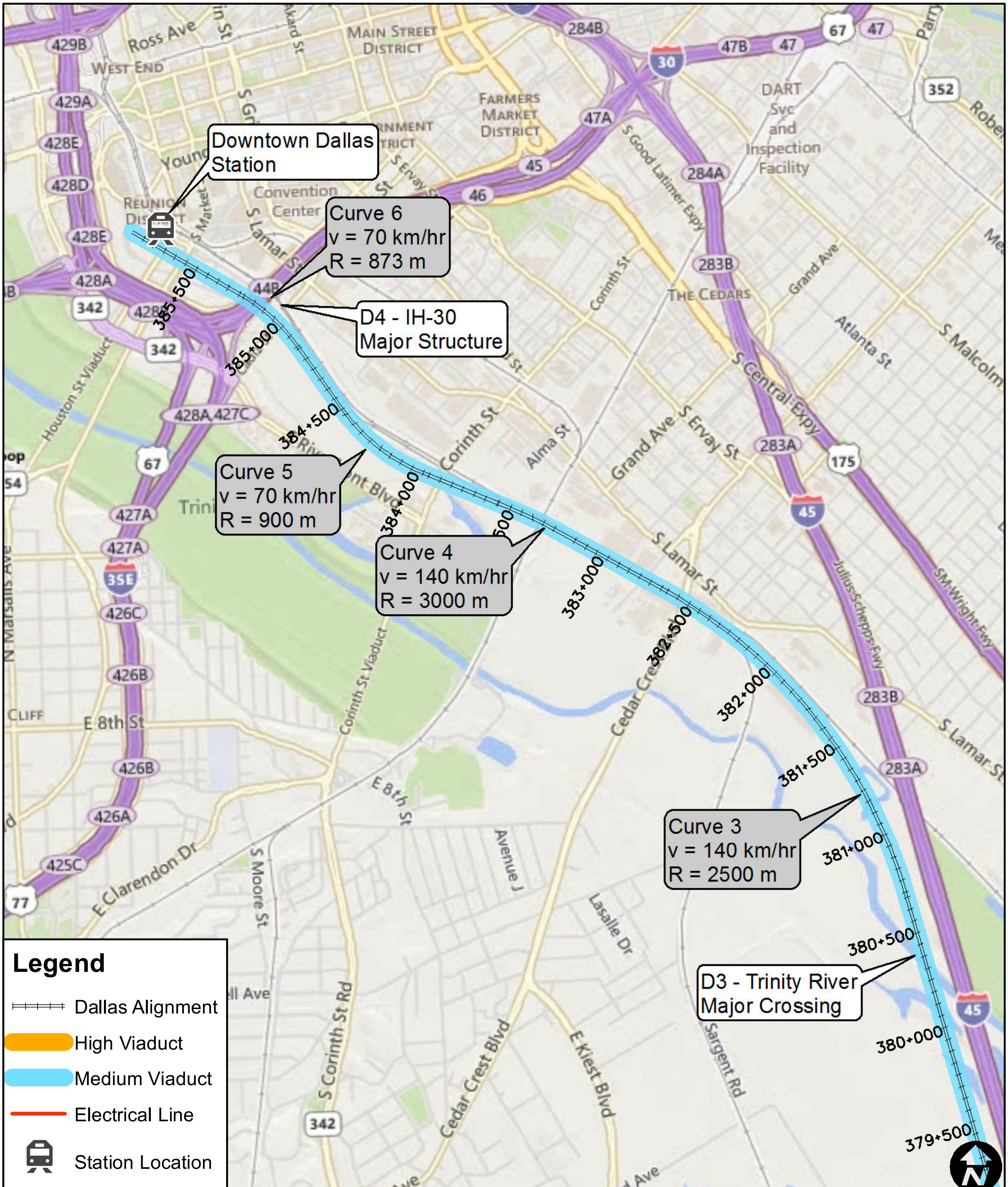

FIGURE C4

Downtown Dallas

Dallas Corridor

Feet: 0, 600, 1200, 2400
Meters: 0, 175, 350, 700

Date Saved: 12/12/2014
Document Path: H:\TRANSPORATION\Working\BNSF_Corridor_Maps_HoustonToDallas.mxd

Update by: 02271