dcstreetcar

benning road streetcar extension feasibility study

final report

April 2013

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1.0 Introduction

This report summarizes the findings of the Benning Road Streetcar Extension Feasibility Study. The District Department of Transportation (DDOT) initiated the study to assess the engineering and planning feasibility of extending the H Street/Benning Road Streetcar line east of the Anacostia River in northeast Washington. The proposed streetcar extension would provide high-capacity and high-quality transit service to District residents and invest in infrastructure that will catalyze economic development in an emerging commercial and residential corridor. The Benning Road Streetcar Extension is part of the District's larger 37-mile streetcar network planned throughout the region.

DDOT, in partnership with WMATA, has *DC's Transit Future System Plan (2010)* to establish a new, efficient, high-quality surface-transit network that connects residents and neighborhoods to employment centers, commercial areas, recreational facilities, and multimodal transportation hubs. The recommended plan includes a network of new streetcar lines operating in eight corridors, a transitway with reserved lanes for transit along K Street NW, as well as improved bus service.

1.1 DC Streetcar System Plan

The District's proposed streetcar system consists of eight lines and includes the Georgetown to Benning Road Metrorail Station Line (see **Figure 1**). As part of the larger 37-mile network envisioned, DDOT has identified a 22-mile priority network that will build upon the two segments currently being readied for service and create a robust system that establishes the highest-priority linkages (see **Figure 2**). The Benning Road Streetcar Extension is part of this 22-mile priority network.

The initial streetcar line, referred to as the H Street/Benning Road Streetcar, is currently under construction and will run between Union Station and Oklahoma Avenue just west of the Anacostia River. The next phase of Streetcar System plan will extend the H/Benning Line across the Anacostia River. This extension is referred to as the "Benning Road Streetcar Extension."

1.2 Benning Road Streetcar Line

The Benning Road Streetcar Extension project is one of the lines planned in Phase I of the DC Streetcar System Plan and is included in the region's Constrained Long Range Transportation Plan. It will connect Ward 7 neighborhoods east of the Anacostia River with employment and activity centers located west of the river, improving an important transit corridor for District residents and workers in the northeast section of the city. It will also provide intermodal connections to the regional Metrorail system as well as to commuter rail, intercity rail and intercity bus services at Union Station via the H Street NE streetcar segment currently under construction. The streetcar line will support neighborhood development plans for a mixed-use activity center at the intersection of Minnesota Avenue and Benning Road and other areas along the corridor. Depending on the alignment options under consideration, the streetcar could support the new mixed-use Parkside community under development near the Minnesota Avenue Metrorail station and/or the neighborhood activity center at Benning Road Metrorail Station near East Capitol Street. The Benning Road Streetcar Extension aims to achieve the following:

- Provide additional transit capacity to relieve crowded bus lines that serve the corridor;
- Connect Ward 7 neighborhoods with employment and activity centers west of the river;
- Provide connections to the regional Metrorail system as well as to multimodal transportation services at Union Station; and
- Support neighborhood plans for activity centers at the Minnesota Avenue/Benning Road intersection and elsewhere on the corridor.

Figure 1: DC Streetcar Proposed 37 Miles System Plan

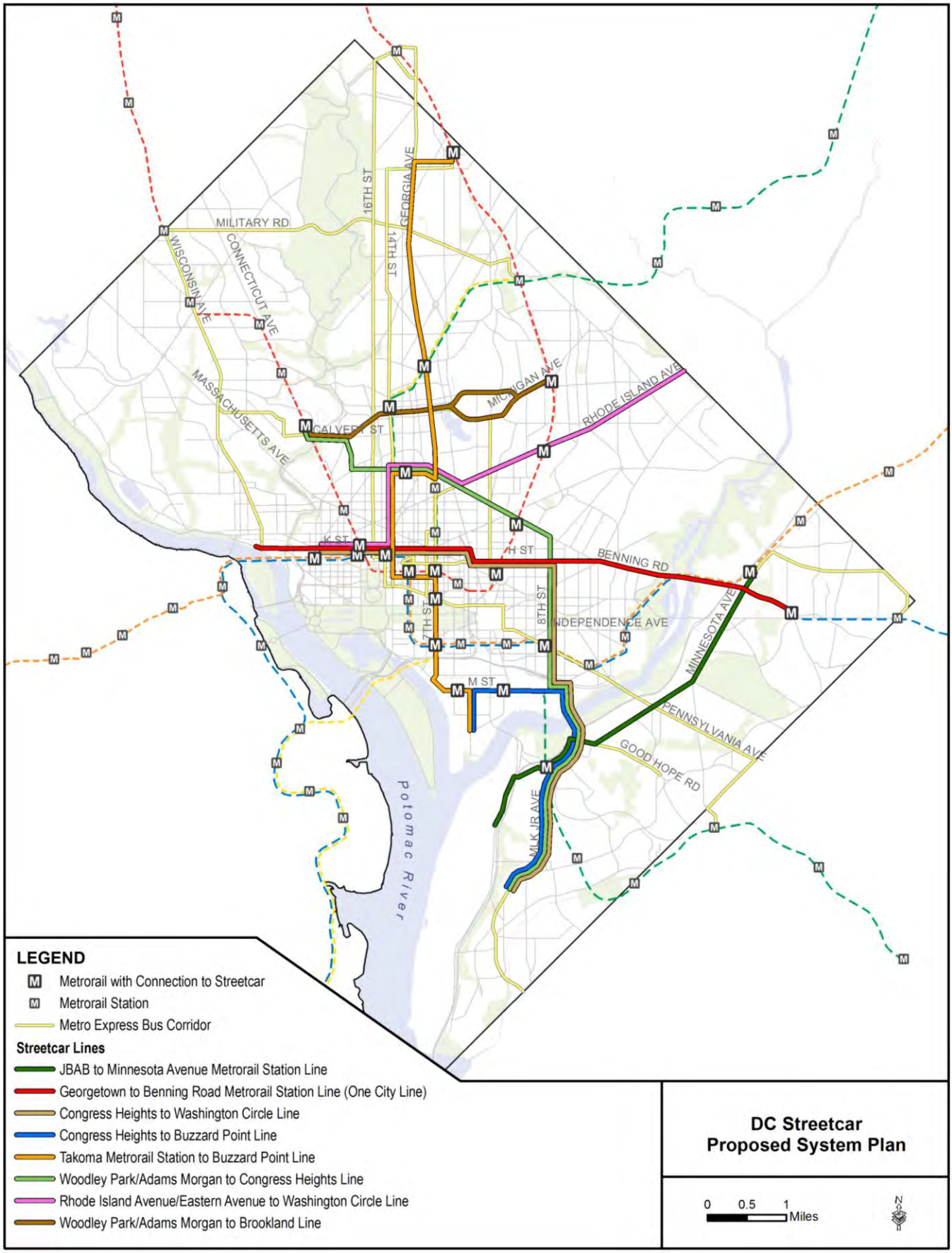
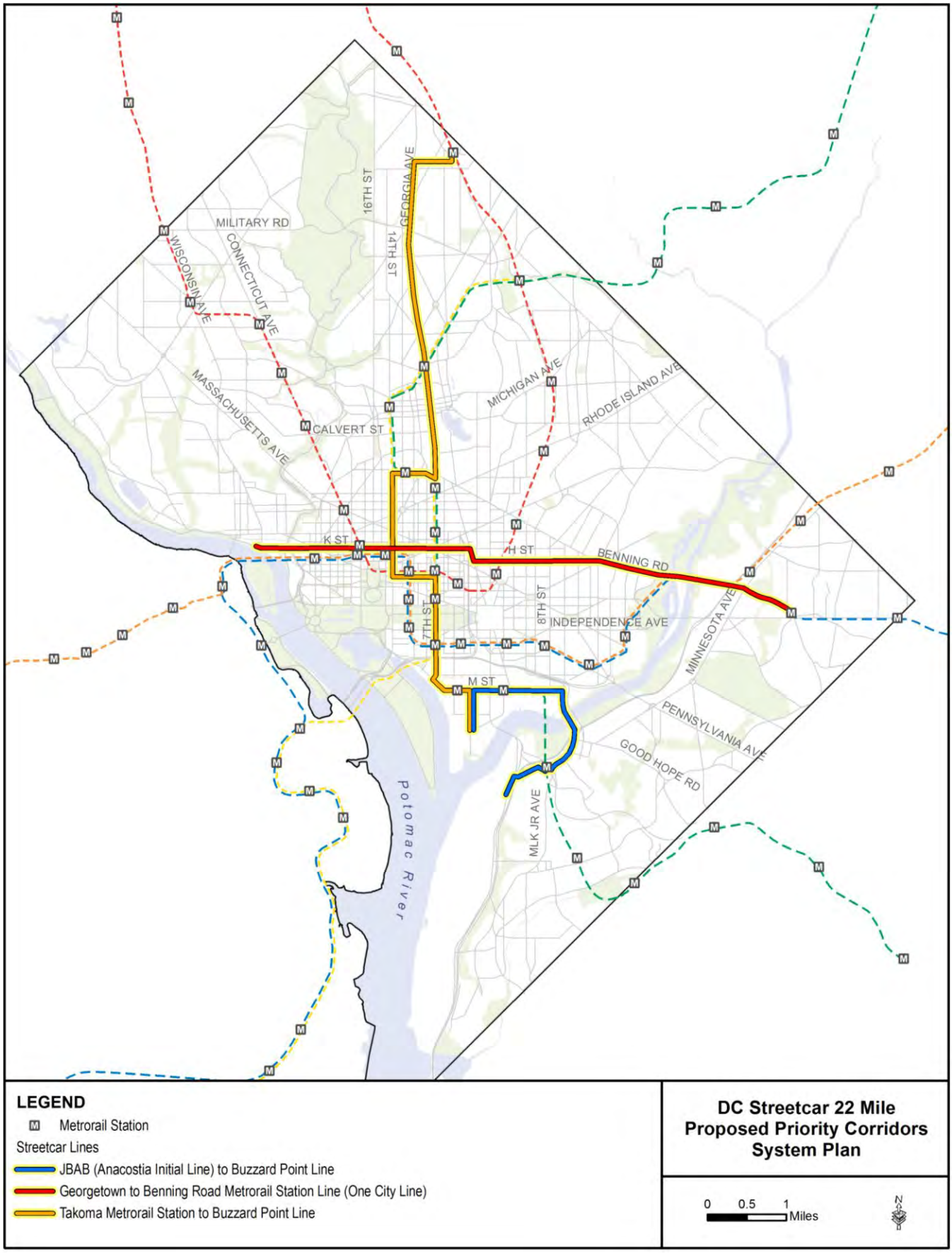


Figure 2: DC Streetcar 22-Mile Proposed Priority Corridors System Plan

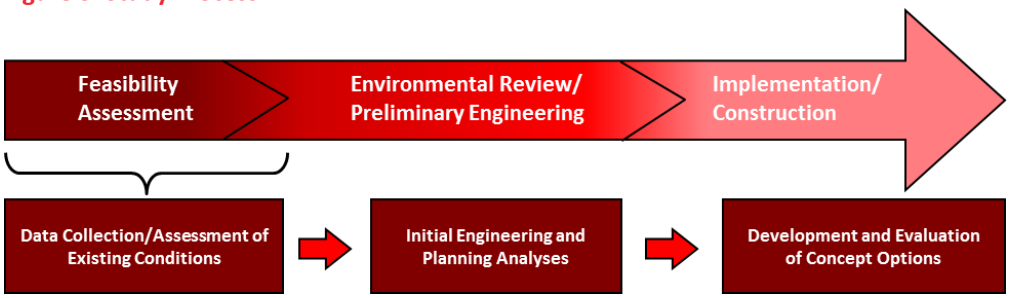


1.3 Study Process

Feasibility Analysis: The determination of the technical, operational, and financial feasibility of a proposed project or idea.

This study developed options for extending the H Street/Benning Road Streetcar east of the river in the near term within the context of other ongoing and planned infrastructure and redevelopment projects and planning studies along the corridor. This feasibility study is the first step in a multi-phase implementation process. **Figure 3** illustrates the study process. After completing an assessment of the existing conditions and an initial engineering feasibility and planning analyses, a set of design options was developed to connect to two different terminus points: the Minnesota Avenue Metrorail Station and the Benning Road Metrorail Station. After the feasibility assessment is completed, the District will conduct an environmental review of the corridor to identify any impacts to the built and natural environment.

Figure 3: Study Process



1.3.1 Terminus Options

For the initial extension of the H Street/Benning Road Streetcar across the Anacostia River two terminus options, Benning Road Metrorail Station and Minnesota Avenue Metrorail station are being considered in the feasibility study (see **Figure 4**). These terminus options are consistent with the proposed *DC Transit Future Alternatives Analysis –Update.* The choice of terminus options is important because it affects other elements of system configuration including, the initial service areas, potential stop locations, and curbside or median-running track segments and transition locations. Potential stop locations for the two options are shown in **Figure 5** and listed in **Table 1**.

Figure 4: Benning Road Streetcar Extension Terminus Options

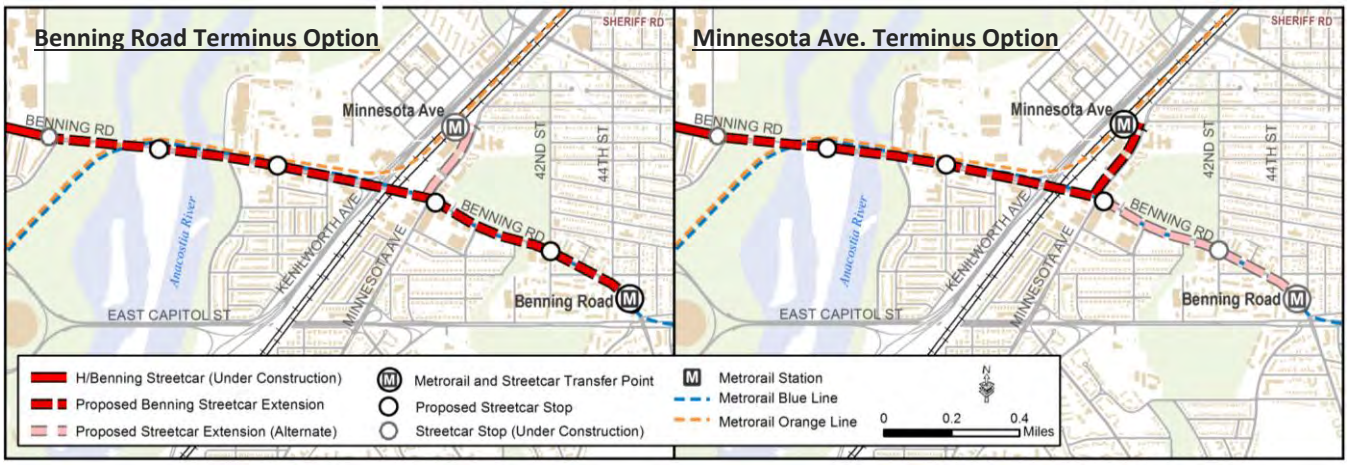


Figure 5: Benning Road Streetcar Extension Potential Stop Locations

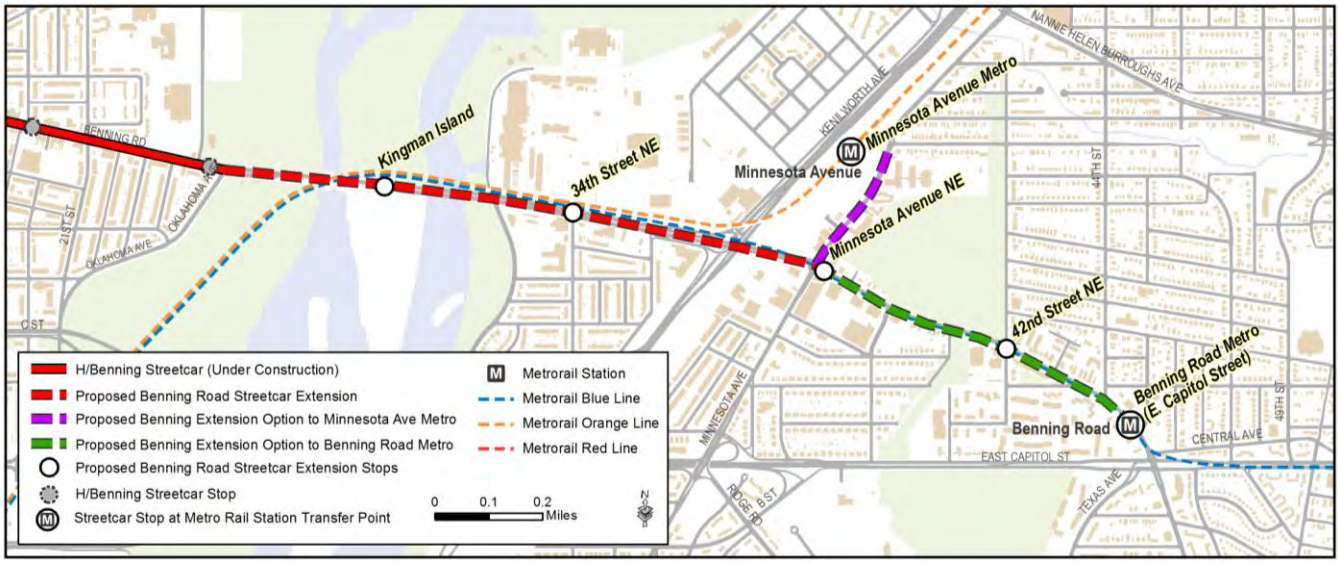


Table 1: Potential Streetcar Stop Areas for the Two Terminus Options

Minnesota Avenue Metrorail Station Terminus Option	Benning Road Metrorail Station Terminus Option
A. Kingman Island	A. Kingman Island
B. Benning Road & 34th Street NE	B. Benning Road & 34th Street NE
C. Benning Road & Minnesota Avenue NE	
D. Minnesota Avenue Metrorail Station (Orange Line) / Department of Employment Services (DOES)	
	E. Benning Road & Minnesota Avenue NE / Benning Library
	F. Benning Road & 42nd Street NE
	G. Benning Road Metrorail Station (Blue Line)

1.3.2 Planning and Engineering Challenges

The study assessed the planning and engineering challenges of extending the streetcar line to the east to either terminus point. Planning and engineering challenges include the following:

- Crossing the Anacostia River via the two existing Benning Road bridges east and west of Kingman Island;
- Crossing Kenilworth Avenue and the CSXT railroad tracks via the eastbound and westbound Benning Road viaducts, which will require reconstruction and a super-structure independent of the streetcar project;
- Locating streetcar stops where they would best service communities and development;
- Providing for more efficient flows of traffic and transit service;
- Addressing the intersections of Benning Road at Minnesota Avenue and Benning Road at East Capitol Street, both of which have high-volume traffic and serve as important community activity centers;

- Serving the Minnesota Avenue Metrorail Station and the Benning Road Metrorail Station, which have other access needs for buses, automobiles, pedestrians and bicyclists; and
- Minimizing potential impacts to right-of-way, driveway access, on-street parking, and environmental resources along the corridor.

1.4 Report Organization

This report summarizes the findings of the Benning Road Streetcar Extension Feasibility Study and is organized as follows:

Section 2: Study Area Existing Conditions

Section 3: Design Considerations

Section 4: Conceptual Alternatives

Section 5: Engineering Analysis of the Alternatives

Section 6: Ridership Forecasts

Section 7: Capital and Operating Cost Estimates

Section 8: Conclusion and Next Steps

2.0 Study Area Existing Conditions

This section of the report provides an overview of the general land use and physical characteristics of the study area and summarizes the relevant land use plans that will affect the area's future redevelopment. The study corridor extends along Benning Road from the Oklahoma Avenue NE intersection on the west (current terminus of the H Street/Benning Road Streetcar Line) to the East Capitol Street intersection on the east. The corridor also includes Minnesota Avenue from Benning Road north to the Minnesota Avenue Metrorail station Kiss & Ride area. As discussed earlier, this study developed various alignment options to connect these two terminus options.

2.1 Corridor Land Use and Transportation Elements

The corridor has four sections with varying land use, roadway and other transportation features:

- **Section A:** Benning Road – Oklahoma Avenue NE to Anacostia Avenue NE:
- **Section B:** Benning Road – Anacostia Avenue NE to Minnesota Avenue;
- **Section C:** Minnesota Avenue – Benning Road to Minnesota Avenue Metrorail Station; and
- **Section D:** Benning Road – Minnesota Avenue to Benning Road Metrorail Station.

Table 2 summarizes the existing land use patterns, transportation features, and roadway characteristics of the four corridor sections.

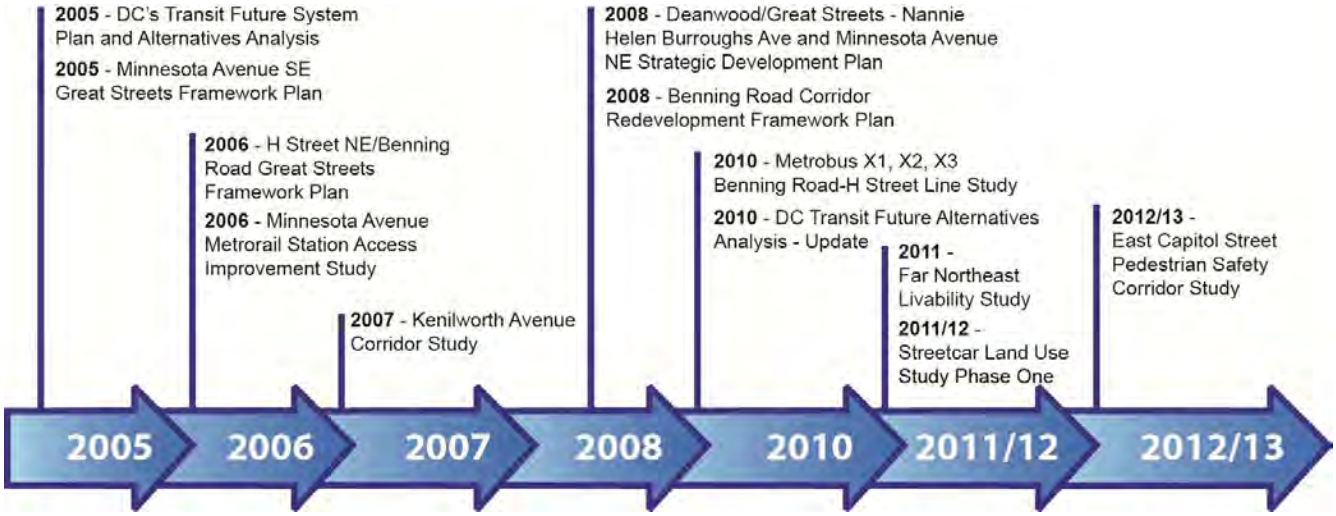
Table 2: Existing Land Use Characteristics, Transportation Features, and Roadway Characteristics

	Section Description	Land Use Characteristics and Notable Landmarks	Transportation Features	Roadway Characteristics
A	**Benning Rd.– Oklahoma Ave.NE to Anacostia Ave. NE**	•Open space •Recreational uses •Langston Golf Course, Kingman Island, RFK Stadium access	•2 bridge structures	•Typically has four lanes in each direction divided by a narrow median •Classified as Principal Arterial
B	**Benning Rd. – Anacostia Ave.NE to Minnesota Ave.**	•Residential neighborhood •River Terrace Elementary School •Potomac Electric and Power Company (PEPCO) •Some commercial to the south	•Kenilworth Avenue on - and off- ramps ramps •Benning Road Viaducts over CSX Railroad tracks and I-295	•Typically has four lanes in each direction divided by a narrow median, drops to two lanes on Benning Road Viaduct •Classified as Principal Arterial
C	**Minnesota Ave. – Dix Street to Dean Ave./Nannie Helen Burroughs Ave.**	•Major retail and community services hub for Ward 7 •DOES, DCFD Fire & EMS Station, Friendship Public Charter School, East River Park Shopping Center	•Metrorail station and Kiss & Ride facility with heavily used bus transfer and layover facility in an active neighborhood	•Generally has two travel lanes in each direction with on-street parking in this section •Classified as a Minor Arterial
D	**Benning Rd. – Minnesota Ave.to 42nd Street**	•Residential to the north and south of Benning Rd., Benning Library, Fort Mahan/ Circle Park •Commercial and residential uses are adjacent to East Capitol St. •Several community facilities	•Metrorail Station in an active neighborhood with frequent bus service	•Generally two-lanes in each direction with off-peak on-street parking

2.2 Corridor Planning Initiatives

Several planning studies for neighborhoods and transportation facilities and services along the corridor are relevant to the proposed Benning Road Streetcar Extension. Many of the studies envision sections of the corridor as key mixed-use activity centers, supportive of pedestrians and bicyclists. The studies are shown below (See **Figure 6**) and summarized in **Appendix A**.

Figure 6: Corridor Planning Initiatives Time Line



The most relevant studies to this project are the Far Northeast Livability Study, H Street NE/Benning Road Great Streets Framework Plan, the Revitalization of Minnesota Avenue Project, and the East Capitol Pedestrian Safety Corridor Study. These studies are described below.

Far Northeast Livability Study (Ongoing)

This study has found that many intersections and roadways in the Far Northeast portion of the District, including East Capitol Street, Benning Road and Sheriff Road, have been designed primarily to accommodate vehicular commuter traffic. Wide roadways with long green-phase signals encourage speeding, provide few pedestrian crossings, and discourage pedestrian use of marked crossing locations and control devices. Initial recommendations along the Benning Road Streetcar Extension corridor include:

- Full signal and crosswalks of Benning Road at the Benning Branch Library;
- Improvements at the intersection of East Capitol Street, Benning Road, Texas Avenue, and Central Avenue;
- Removal of the southbound left-turn movement at the Grant Street/Minnesota Avenue intersection;
- Provision of a southbound left-turn phase at the Minnesota Avenue/Benning Road intersection; and
- Pedestrian accommodation enhancements along 42nd Street and 44th Street.

H Street NE/Benning Road Great Streets Framework Plan (2006)

This study covered the H Street NE/Benning Road corridor from North Capitol Street to Southern Avenue SE. The plan recommended landscape treatments, such as new sidewalks, medians, curb and gutter realignments, public art, pedestrian-scaled lighting, and street trees along the corridor. It also identified major reconstruction of Benning Road from

Minnesota Avenue to 42nd Street NE, which has recently been completed and open to public use. The pedestrian facilities on the bridge over Kenilworth Avenue were recommended to be improved as part of the Kenilworth Avenue Corridor Study.

Revitalization of Minnesota Avenue Project (Ongoing)

DDOT is planning infrastructure and street improvements along Minnesota Avenue from A Street SE to Sheriff Road NE. This 1.2 mile stretch includes Benning Road intersection as well as the Minnesota Avenue Metrorail Station frontage area. Improvements include pedestrian safety treatments, utility relocations and repaving Minnesota Avenue. The project is developing final design plans for construction.

East Capitol Pedestrian Safety Corridor Study (Ongoing)

This project focuses on improving safety for pedestrians, bicyclists, motorists and transit users along East Capitol Street. The study corridor is East Capitol Street NE between Stoddert Place SE and Southern Avenue NE. This project will culminate with 30% preliminary design plans incorporating improvements such as enhanced pedestrian crossings, accessible bus stops, geometric adjustments that support intersection safety, updates to traffic signal timing and traffic calming.

2.3 Current Transit Service and Travel Demand

The following sections provide a brief summary of the current bus and rail transit coverage in the corridor, as well as current ridership levels.

2.3.1 Metrobus

The Metrobus routes currently serving the corridor, X1, X2, and X3, has one of the top five highest riderships on an average weekday in the Metrobus system, carrying about 14,000 passengers daily. The X9 Limited Stop service was established to provide additional service capacity to the route.

The Metrobus X1, X2, and X3 routes currently operate between the Minnesota Avenue Metrorail station on its eastern end and three western terminals in northwest DC. These routes operate primarily via Minnesota Avenue, Benning Road and H Street. Ridership on this line is the fourth highest in the Metrobus system as a result of the population in the service area, the popularity of destinations and the number of transfer points along the route. Existing ridership totals almost 14,000 passengers per day along these lines, and crowding has been a major issue. The Metrobus U8 operates between the Capitol Heights Metrorail Station and the Benning Heights neighborhood including the portion of Benning Road between Minnesota Avenue and East Capitol Street. The route carries over 4,000 daily riders and connects to the Metrorail system at the Capitol Heights, Minnesota Avenue, and Benning Road Stations.

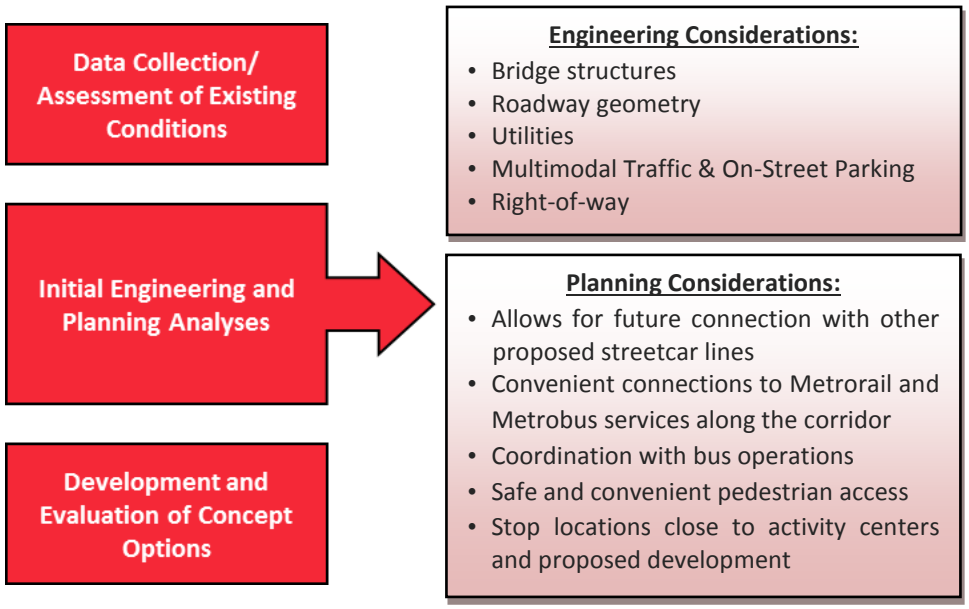
2.3.2 Metrorail

The corridor is currently served by two Metrorail lines: the Blue Line and the Orange Line. These lines offer access to the downtown DC and points east via the Benning Road station (Blue Line) and the Minnesota Avenue station (Orange Line). In 2012, 3,183 passengers boarded the Metrorail at the Benning Road Station on an average weekday. The number of passenger boardings at Minnesota Avenue on an average weekday in 2012 was 3,257. These numbers are indicative of low activity stations (relative to high ridership stations like L'Enfant Plaza and Union Station, which averaged 21,926 and 33,250 average weekday, respectively). Over the last ten years, the Benning Road and Minnesota Avenue stations have experienced marginal increases in passenger boardings. Between 2002 and 2012, average weekday boardings have increased by about 7 percent at Benning Road and by 9 percent at the Minnesota Avenue Metrorail Stations.

3.0 Design Considerations

Both engineering and planning considerations were taken into account during the development of the design options. These considerations, including the physical operating environment and urban design principles, affect numerous aspects of the design, including the location of the station stops, the track alignment, the necessity for special track work, and others. The study area has topographical and other physical characteristics that constrain the operations of a streetcar system. Consideration must be given to guideway alignment, location of the station stops and turnaround areas, traffic operations, and potential utility impacts. This section discusses the engineering and planning considerations made when assessing the feasibility of the design options. **Figure 7** summarizes the engineering and planning considerations discussed below.

Figure 7: Engineering and Planning Considerations



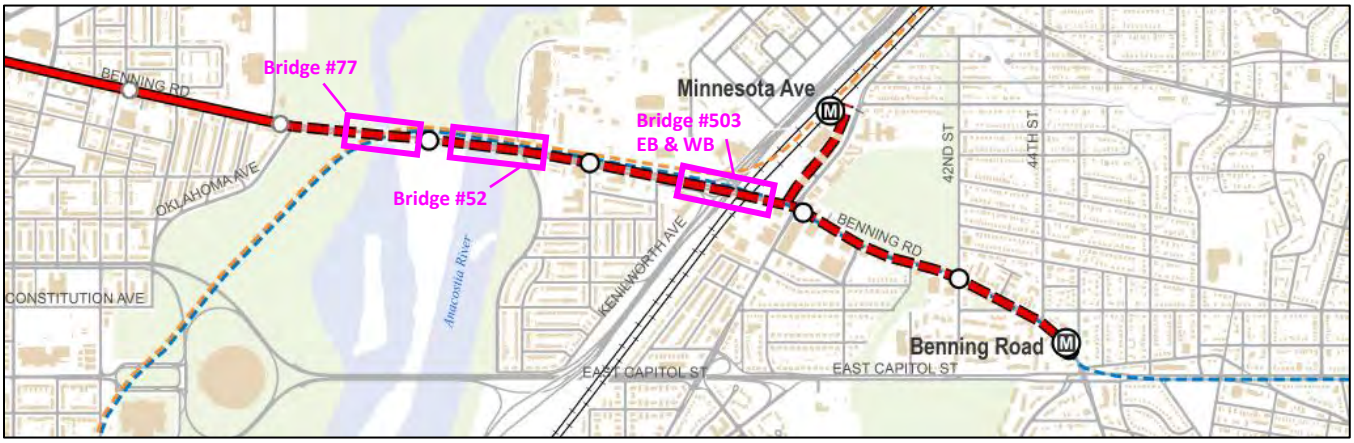
3.1 Engineering Considerations

The following sections offer a summary of engineering considerations made while assessing the various conceptual alternatives.

3.1.1 Bridge Structures

Within the study limits, Benning Road includes three bridge structures; two bridge structures over the Anacostia River (Bridge #77, Bridge #52), and one bridge (two parallel structures for eastbound and westbound traffic) over Kenilworth Avenue and the CSXT tracks (Bridge #503). **Figure 8** shows the location of these structures. Because the sufficiency of superstructure and substructure of the bridges to accommodate streetcar geometry and loadings affects the alignment options, this feasibility study includes a preliminary structural assessment.

Figure 8: Benning Road Corridor Bridge Structures

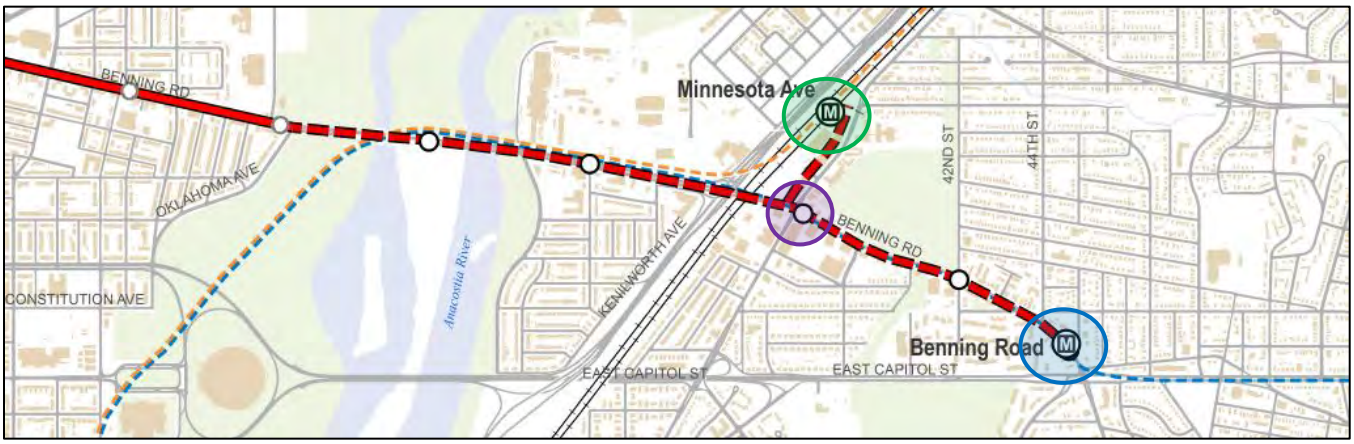


3.1.2 Roadway Geometry Considerations

The roadway geometry and traffic constraints on potential streetcar alignments are most critical at the key study intersections, where the streetcar transitions or requires roadway space for a median station platform or special track work. Three areas of constraint (see **Figure 9**) are identified for the corridor including the two termini areas:

- **Benning Road/Minnesota Avenue Intersection**
- **Minnesota Avenue Metro Station Area**
- **Benning Road Metro Station Area**

Figure 9: Intersections that may require special track work



Benning Road/Minnesota Avenue Intersection

The Benning Road/Minnesota Avenue intersection is one of these key constraint areas since this is the location where two proposed streetcar lines intersect (the other being the Bolling AFB-Minnesota Avenue line). This scenario would require the east-west alignment to cross and potentially connect to the north-south alignment within the limits of the Benning Road/Minnesota Avenue intersection.

Providing options to connect the two lines in the future would be desirable for revenue and non-revenue service needs. Where track alignments cross or connect, special track work is

required. Given the configuration of this intersection, there may not be sufficient space for all desirable special track work elements. **Figure 10** shows the configuration of the Benning Road/Minnesota Avenue intersection.

Figure 10: Benning Road/Minnesota Avenue Intersection

Minnesota Avenue Metro Station Area

As the terminal location for the proposed streetcar line, a streetcar stop and a turnaround area at the Minnesota Avenue Metrorail Station would be necessary. A turnaround area typically consists of a 200-foot segment of double track, commonly called a tail track, in dedicated guideway (separated from general traffic). **Figure 11** shows the bus terminal area by the Minnesota Avenue Metro Station.

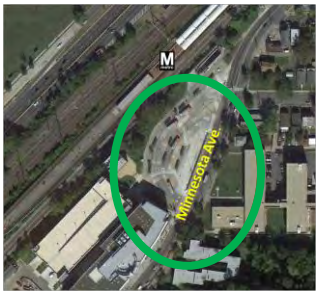
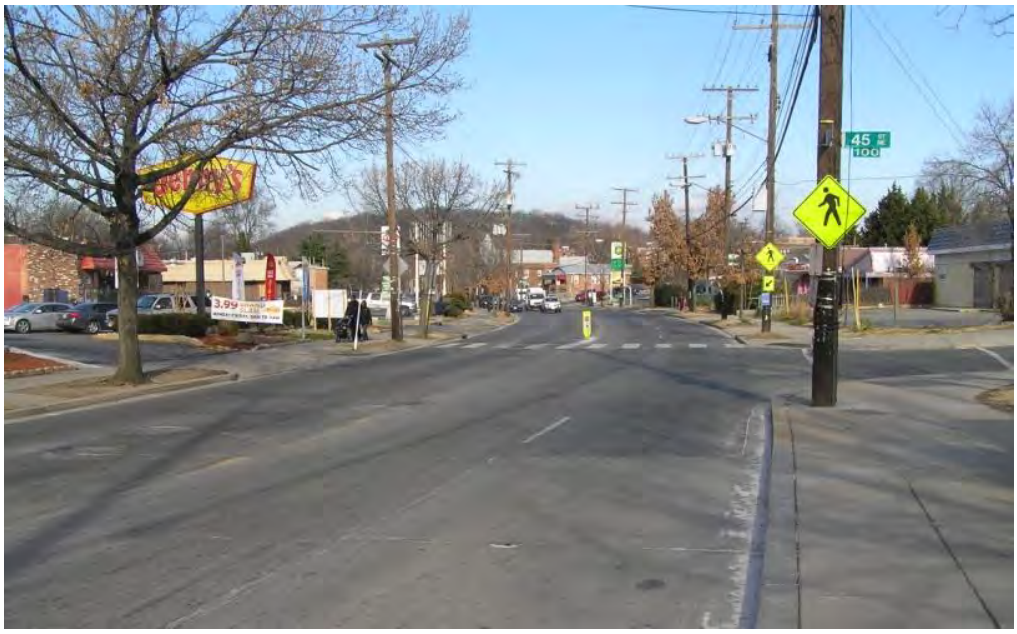


Figure 11: Bus Terminal at the Minnesota Avenue Metro Station

Benning Road Metro Station Area

The intersection of Benning Road and East Capitol Street is busy with general automobile traffic, buses and pedestrians. A Capital Bikeshare Station at the corner of the intersection creates additional bicycle traffic as well. **Figure 12** shows Benning Road in front of the Metrorail Station. A streetcar turnaround location at Benning Road Metrorail Station would require a 200-foot segment of tail track in dedicated guideway.

Figure 12: Benning Road Cross Section by the Benning Road Metro Station



Traction power substations: provide electric current to the overhead wire to power the streetcar.

Right-of-way: land that is granted, through an easement or other mechanism, for transportation purposes.

3.1.3 Utilities

Both overhead and underground utilities—including gas, water, electric, communications, storm sewer, sanitary sewer, and street lighting—are present throughout the. The proximity of the alignment to the Potomac Electric and Power Company (PEPCO) generating plant introduces potentially significant underground electric transmission and distribution utilities. The feasibility assessment refers to the DC Streetcar Design Criteria on utility rules of practice in developing an overview of potential conflicts of the proposed streetcar alignment options with these utilities. As shown in **Figure 10,** there is a significant amount of overhead utility lines at the intersection of Benning Road and Minnesota Avenue, similar to other areas along the project alignment.

3.1.4 Right-of-Way

Because the streetcar line would generally operate in mixed traffic, the requirements for right-of-way are limited to maintenance and storage facilities, traction power substations, crossover areas that require special trackwork, and any median stop platforms that would require roadway widening. Additional right-of-way might be required to achieve a minimum turning radius at certain locations. Typically, existing sidewalks can be used for curbside stop platforms and may not require additional right-of-way.

3.1.5 Multimodal Traffic

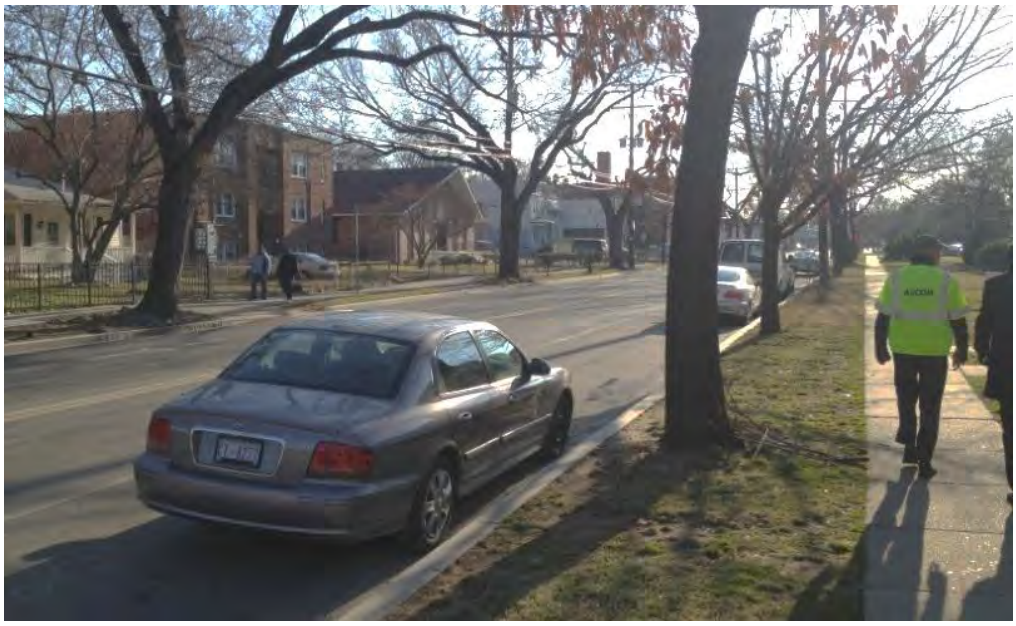
Implementation of the streetcar would require an assessment of potential impacts to other modes, such as pedestrians, bicycles, and automobiles. When in mixed traffic, a streetcar operates similar to a public transit bus. However, at certain locations, it may need to transition from a curbside to a center-running configuration. This transition typically happens at a signalized intersection by using a transit-only signal phase. During this phase, which usually lasts between 5 and 15 seconds, the concurrent traffic flow is stopped to allow cross-lane streetcar movement. Therefore, depending on the streetcar frequency, there is some potential impact to general traffic.

Additionally, median streetcar stops would require a safe crossing environment for pedestrians. Therefore, adequate median space with a safe and accessible walking environment must be provided for median stops. Finally, streetcar track can potentially be hazardous for bicyclists, especially when crossings are at oblique angles. An option is to relocate bicycle accommodations to parallel roadways or off-street facilities.

3.1.6 On-Street Parking

If on-street parking is provided along a roadway segment that is proposed for a curbside-running streetcar track lane, the parking would need to be eliminated. For example, off-peak on-street parking is provided along segments of Benning Road east of Minnesota Avenue. It would not be possible to maintain this on-street parking during any periods of the day along roadway segments with curbside-running streetcar tracks. **Figure 13** shows the potential on-street parking impact areas on Benning Road if a curb-side running option is considered.

Figure 13: Potential On-Street Parking Conflict with Curb-Side Running Alignment



As discussed above, these engineering considerations help guide where streetcar facilities can be located and what their impacts may be. Besides these more technical considerations, there are planning considerations that ensuring the proposals fit within the framework of what has been envisioned for the community by focusing on land use, place-making, and transit system integration. The following section describes these planning considerations.

3.2 Planning Considerations

Planning considerations consider how the system, such as the stop locations, transit service operating assumptions, and vehicle design considerations, affect the community and the system's riders. Although a design option may be technically feasible, other design characteristics must be considered in order to best serve the community, attract the highest ridership, and support the community character. An effective design provides the following:

- Stop locations close to activity centers (e.g., Minnesota/Benning intersection)
- Future connections with other proposed streetcar lines
- Convenient connections to Metrorail and Metrobus services along the corridor
- Coordination with bus operations
- Safe and convenient pedestrian access

To receive and collect input from the community on the design characteristics and on other "planning considerations," the project team held public meetings on September 6, 2012 and November 27, 2012. The first meeting provided an introduction about the project and gathered initial feedback from the community. The second meeting presented the conceptual alternatives that are presented in the next section and shared technical findings of the study. A summary of the meetings is included in **Appendix B**, Public Meeting Notes Summary.

4.0 Conceptual Alternatives

This section describes both conceptual alternatives for the two terminus options being considered (Minnesota Avenue Metrorail Station Terminus Option and the Benning Road Metrorail Station Terminus Option), as well as the proposed streetcar system operating assumptions at the end of the section. The following conceptual alternatives were developed based on the planning and engineering contexts described above. **Concept Alternative Plans** are attached at the end of this section.

4.1 Minnesota Avenue Metrorail Station Terminus Alignment Alternatives

This alignment option would serve the Minnesota Avenue Metrorail Station (the station is about 1,500 feet north of the Benning Road and Minnesota Avenue intersection). The **Concept Alternative Plans** for the Minnesota Avenue Metrorail Station Terminus Option at the end of the document shows the alignment, potential stop locations, and alignment transition areas being considered for this option. The following areas from east to west along the corridor have different options being considered:

- Oklahoma Avenue tie-in to existing streetcar track;
- Stop location and track alignment options at 34th Street;
- Potential streetcar transition on Benning Road at the Kenilworth Avenue southbound off-ramp;
- Stop location and track alignment options at the Minnesota Avenue intersection; and
- Stop location and special trackwork options at the Minnesota Avenue Metrorail station area.

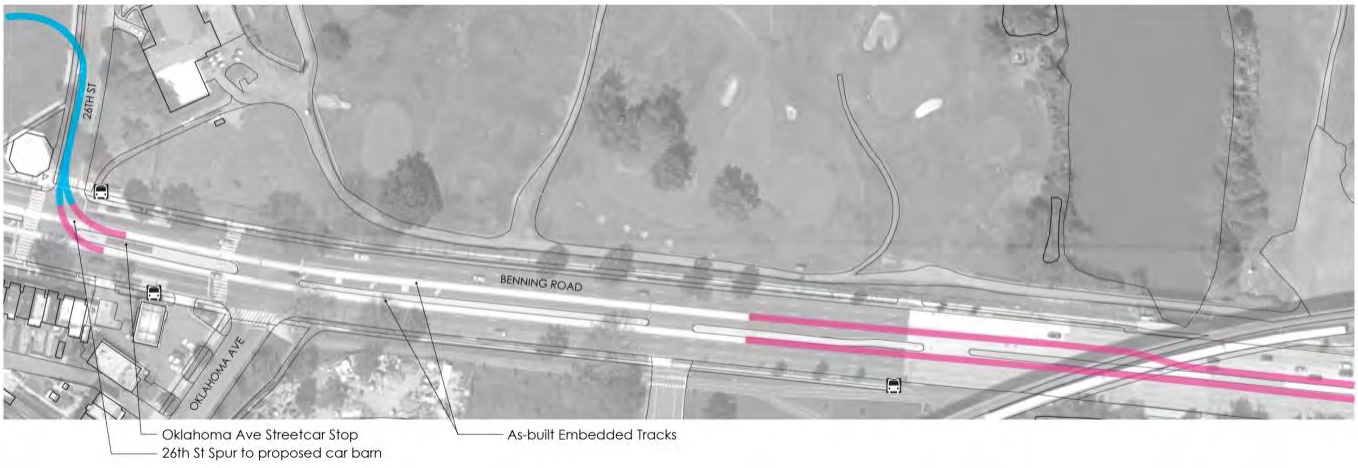
The following section illustrates the concept plans related to these five design options.

4.1.1 Oklahoma Avenue Tie-in

The connection of the Benning Road Streetcar Extension to the recently constructed H Street/Benning Road Streetcar segment involves two options for the car barn spur and westbound transition (shown below). The existing embedded tracks currently terminate immediately east of Oklahoma Avenue near the driveway to the RFK Stadium parking lot.

X.1 Oklahoma West Bound Unsignalized Transition

The westbound tracks east of the Oklahoma Avenue intersection are located to the north of the left turn lane on Benning Road to allow for westbound traffic to turn onto southbound Oklahoma Avenue. To connect to the existing tracks, westbound streetcars must transition from the inner median lane on the Benning Bridge (Anacostia River Bridge) to one lane north. In this option, westbound vehicular traffic merges from three lanes to two lanes when approaching the end of the bridge to allow the streetcar to transition. Eastbound streetcars remain in the inner median lane as constructed. The spur to the proposed car barn in this option has eastbound and westbound streetcars merging to a single curbside track as they turn onto 26th Street from Benning Road. This spur option would require a dedicated lane on 26th Street and narrowing of the existing roadway.

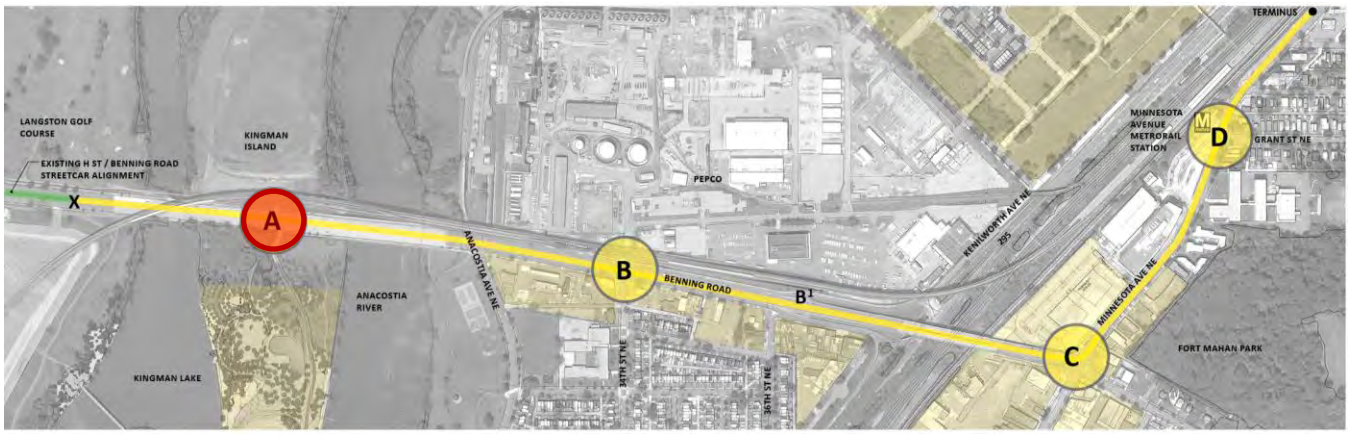


X.2 Oklahoma West Bound Signalized Transition

To avoid the westbound traffic merge after the bridge in option X1, westbound streetcars in this option transition from the inner median lane to one lane north at a signalized intersection at the RFK stadium parking driveway east of Oklahoma Avenue. Eastbound streetcars remain in the inner median lane as constructed. The spur to the proposed car barn in this option has both eastbound and westbound streetcars transitioning from the median lane on Benning Road to their own curb lanes on 26th Street at the intersection and then merging to a single track as they turn off of 26th Street into the car barn. Traffic would have to be stopped on 26th Street to allow the streetcars to turn into the car barn, but all traffic lanes could be shared. The westbound turn would require additional right-of-way to make the turn onto 26th Street and could impact the existing bus stop and streetcar stop.

4.1.2 Kingman Island

A streetcar stop on Kingman Island will offer access to the Kingman and Heritage Islands Park, future environmental center, Langston Golf Course and Driving Range, and the various events and celebrations held on the island.

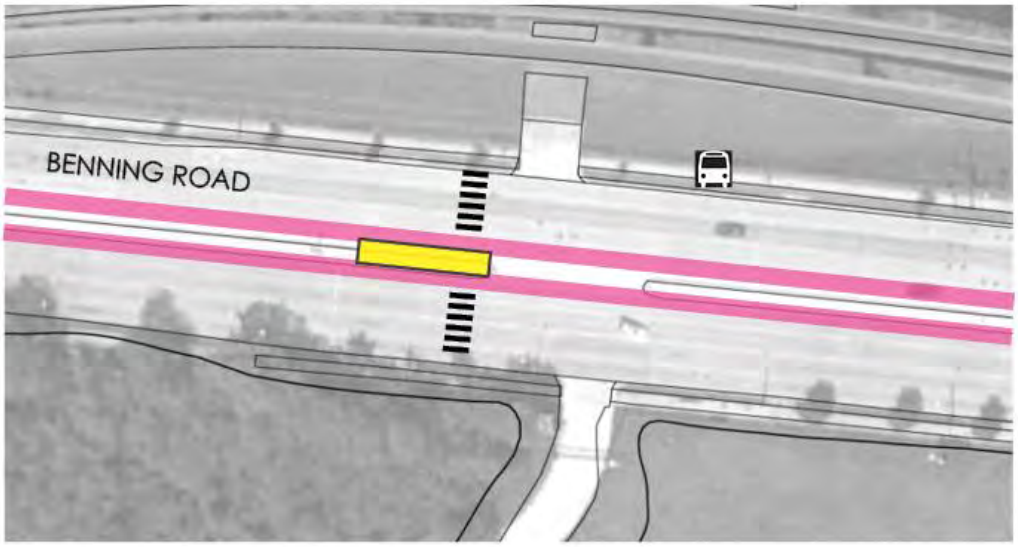


Legend

- Potential Future development
- Streetcar stop
- Median streetcar alignment
- Curbside streetcar alignment
- Alternative median alignment
- Alternative curbside alignment
- Proposed crosswalk

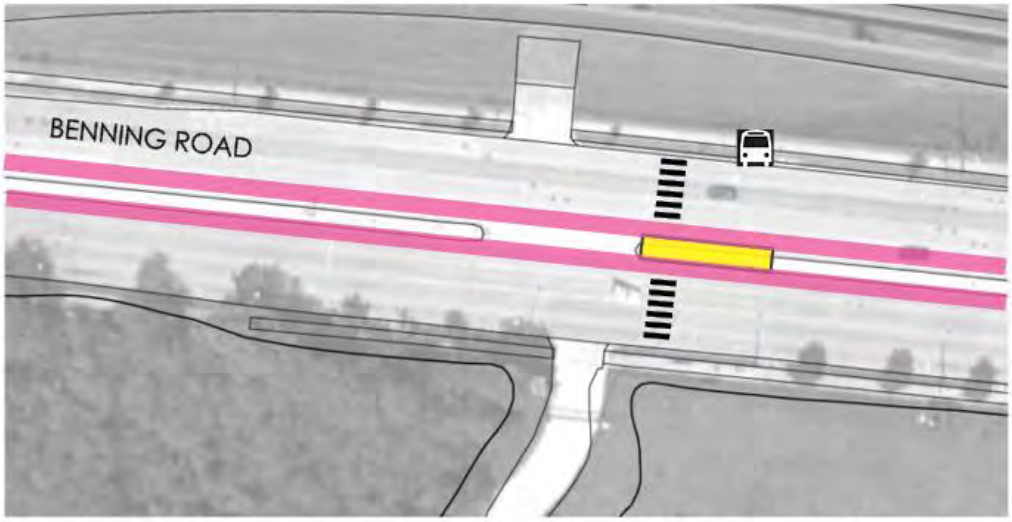
A.1 West Median Stop

Both east and westbound streetcars are in the center median lane over the Benning Bridge. A median stop west of the entrance to the driving range and Kingman Island provide direct access to these destinations. A pedestrian crosswalk is required to the median stop and eastbound left turns would be permitted to the right of the streetcar track from the through lane. The streetcar track slab under the "build-up" option would gradually descend and become level at the intersection to allow for use of the lane by mixed traffic.



A.2 East Median Stop

Both eastbound and westbound streetcars are in the center median lane over the Benning Bridge. A median stop east of the entrance to the driving range and Kingman Island trail would provide direct access to these destinations. A pedestrian crosswalk is required to the median stop. The streetcar track slab under the "build-up" option would gradually descend and become level at the intersection to allow for use of the lane by mixed traffic.



4.1.3 34th Street Intersection

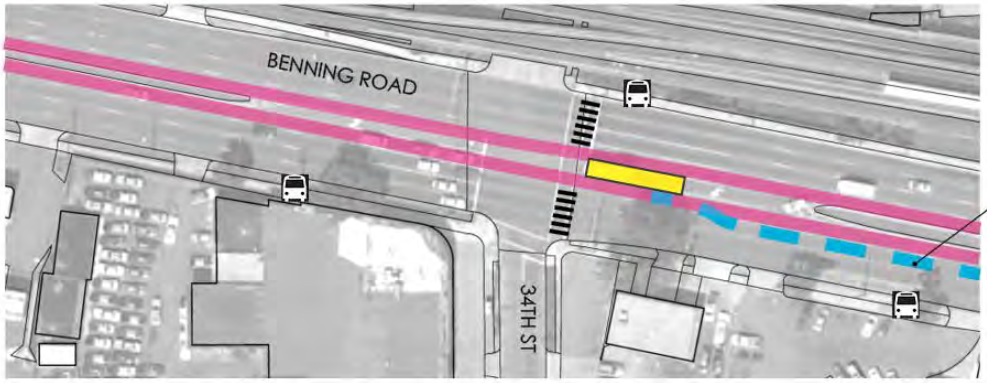
Major destinations in the River Terrace neighborhood include the Pepco plant directly north of Benning Road, and mixed commercial uses south of Benning Road. Beyond the commercial strip to the south is the River Terrace Elementary School and River Terrace residential neighborhood. The Benning Road Corridor Redevelopment Framework Plan identified a number of parcels recommended for long-term redevelopment, including retail, small office, and recreational uses. A streetcar stop near the intersection of 34th Street would provide the most direct access to the Pepco plant entrance and would serve the existing commercial area and potential future development.

Legend

- Potential Future development
- Streetcar stop
- Median streetcar alignment
- Curbside streetcar alignment
- Alternative median alignment
- Alternative curbside alignment
- Proposed crosswalk

B.1 East Median Stop

A median stop east of 34th Street provides direct access to the intersection but conflicts with westbound left pocket onto 34th Street, which needs to be eliminated. U-turns for westbound traffic could be permitted after the median west of the intersection to still allow this movement. Also, the westbound left-turns can be provided from the streetcar track lane with a protected green arrow. Streetcars are in the center median lane as they travel from or approach the Benning Bridge. Eastbound streetcars could remain in center median lane after the east median stop or transition after the stop one lane to the south, which would direct them onto the curb lane of the viaduct. Westbound streetcars are in the center median lane from the viaduct or would have to transition from the curb lane to the median lane at the ramp merge point (see B1) east of 36th street.

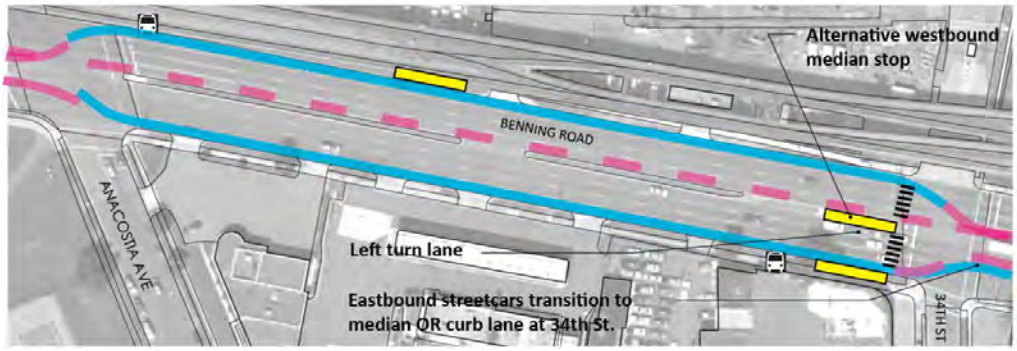


B.2 West Median Stop

A median stop west of 34th street must be setback enough to allow for eastbound left turns into the Pepco plant. A mid-block pedestrian crosswalk would be required to the station platform. Streetcars are in the center median lane as they travel from or approach the Benning Bridge. Eastbound streetcars could transition on lane to the south at the 34th street intersection to be in the curb lane of the viaduct. Westbound streetcars are in the center median lane from the viaduct or would have to transition from the curb lane to the median lane at the ramp merge point (see B1) east of 36th Street.

B.3 Curbside Stops

Curbside stops can also be accommodated at the sidewalks for both directions. This arrangement requires two transitions: at Anacostia Avenue and 34th Street. The eastbound transition could connect to the median or curb lanes of the eastbound viaduct similar to the other options.

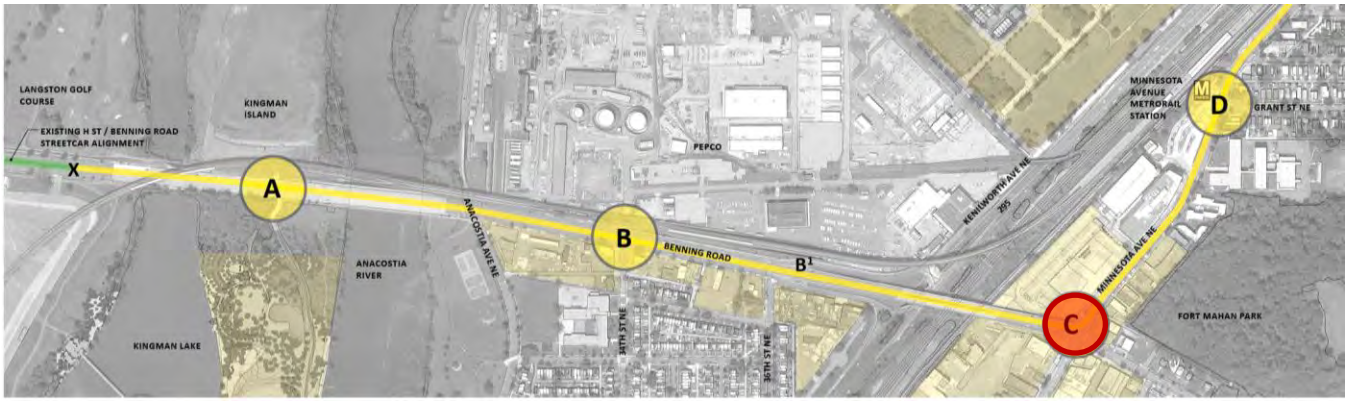


Optional Benning Road Westbound Transition at Kenilworth Off-Ramp

Westbound track could transition from curb lane to the central median lane at the ramp merge area on Benning Road. Only Benning Road westbound traffic would be stopped to allow the streetcars to make this transition. Eastbound streetcars travel in either the median or curb lane.

4.1.4 Minnesota Avenue Intersection

The intersection of Minnesota Avenue and Benning Road is the gateway to a major retail and community services hub for Ward 7, including the existing the Department of Employee Services, East River Park Shopping Center and the Benning Library, as well as planned new uses. The *Deanwood/Great Streets – Nannie Helen Burroughs Ave NE & Minnesota Ave NE Strategic Development Plan* identifies this node as a high priority redevelopment area. A civic plaza and entrance to Fort Mahan Park is proposed east of the intersection. A destination commercial center and mixed-use redevelopment of existing retail areas are proposed south and west of the intersection. In addition to redevelopment, improvements to the Minnesota Avenue streetscape are being planned as part of the Minnesota Great Streets initiative. A streetcar stop at or close to the intersection of Minnesota Avenue and Benning Road is crucial to provide riders convenient access to this activity center. However, locating streetcar stops at the intersection presents challenges due to the constraints of the viaduct immediately to the west, intersection geometry, high traffic volumes, existing bus stops, and special trackwork requirements.

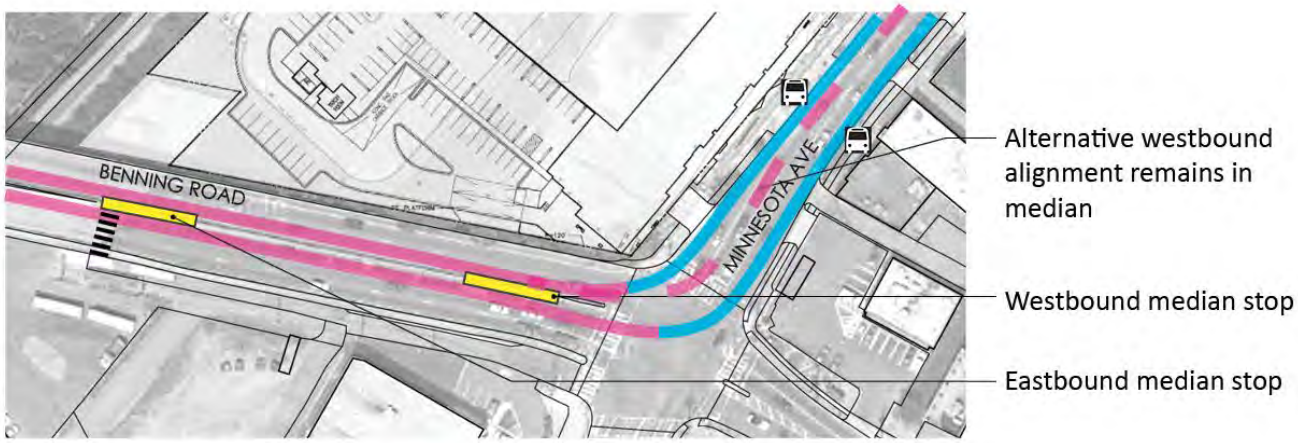


Legend

- Potential Future development
- Streetcar stop
- Median streetcar alignment
- Curbside streetcar alignment
- Alternative median alignment
- Alternative curbside alignment
- Proposed crosswalk

C.1 Median Stops on Viaduct

A median stop on the viaduct is proposed to be split, with staggered stops to allow for eastbound left turns onto Minnesota Avenue by a dedicated left-turn lane without a streetcar stop right at the intersection. This requires an eastbound stop set back from the intersection, a mid-block pedestrian crossing, and a relatively level area for the streetcars to stop on a vertical tangent as the viaduct descends to meet the grade of Minnesota Avenue. Eastbound streetcars transition at the intersection from the eastbound left-turn lane to the curb lane of Minnesota Avenue. Westbound streetcars transition from the curb or median lane of Minnesota Avenue at the intersection to the median lane of the viaduct.



C.2 Curbside Stops on Minnesota Avenue

Curbside stops on Minnesota Avenue avoid conflicts with the eastbound left turn on the viaduct but are somewhat removed from the intersection and conflict with existing heavily used bus stops. Eastbound and westbound streetcars transition from the median lanes of the viaduct to the curb lanes of Minnesota Avenue at the intersection.

C.3 Curbside Stops on Viaduct

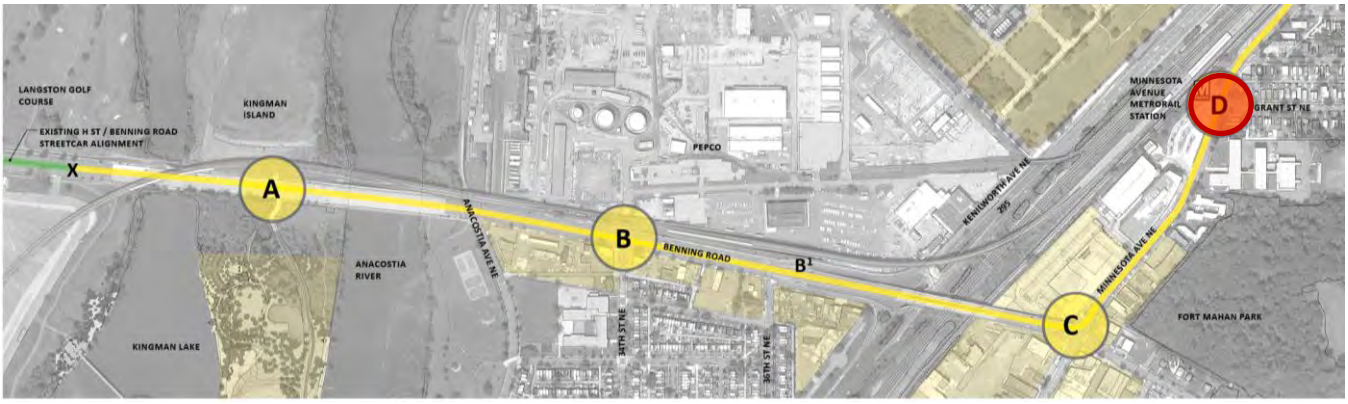
Curbside stops on the viaduct allow the stops to be close to the destinations south of the intersection and avoid impacting eastbound left turns. Platforms must be relatively level for the streetcars to stop on a vertical tangent as the viaduct descends to meet the grade of Minnesota Ave. Eastbound streetcars remain in the curb lane after the intersection. A pedestrian refuge island can be created to accommodate the southbound Minnesota Avenue onto westbound Benning Road curb to curb turning radius. Alternatively, the westbound streetcar could transition from the curb lane on Minnesota Avenue to the median lane of the viaduct to avoid a potential encroachment at the corner, but a westbound curbside stop here is no longer possible.

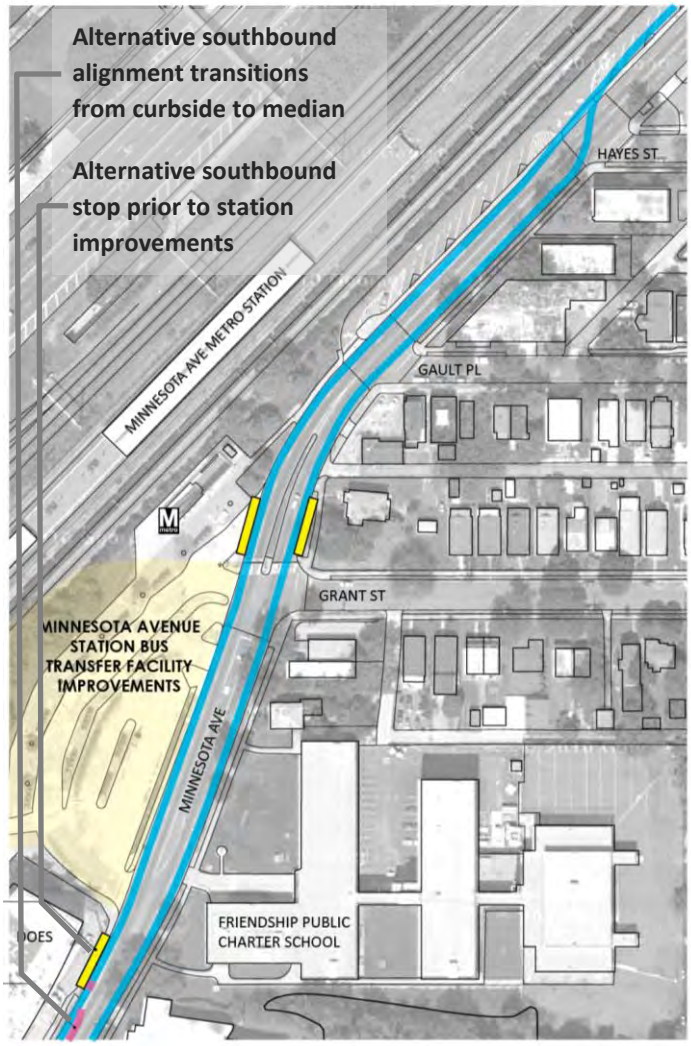
Legend

- Potential Future development
- Streetcar stop
- Median streetcar alignment
- Curbside streetcar alignment
- Alternative median alignment
- Alternative curbside alignment
- Proposed crosswalk

4.1.5 Minnesota Avenue Metrorail Station

A stop in this area would provide direct access to the Metrorail system and to the residential areas to the east and across the Kenilworth corridor to the west. A large residential, office and retail development, Parkside, is planned northwest of the Metrorail station that will significantly increase the development intensity and population in the neighborhood. As this would be a terminus stop, track crossover and tail track would need to be provided in the vicinity.





D.1 Stops by Station Entrance; Kiss & Ride Turnaround

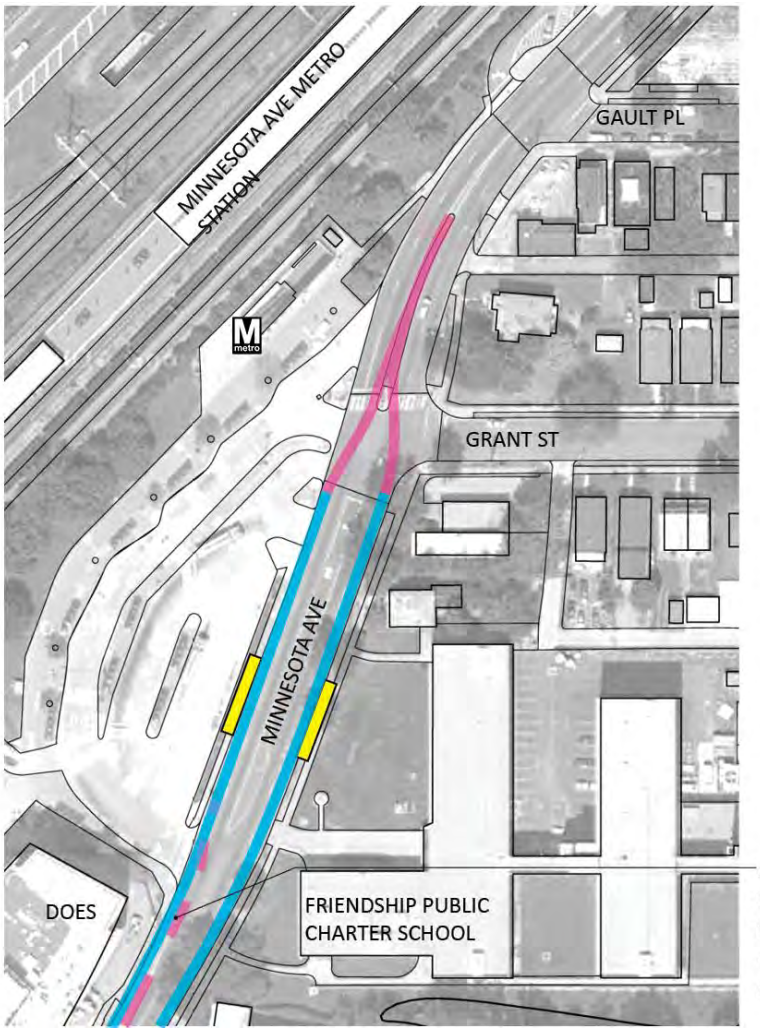
The northbound stop is located close to the Metrorail station entrance on the curbside of Minnesota Avenue north of the Grant Street intersection. The southbound stop is located at the existing entrance to the bus terminal for buses traveling southbound on Minnesota Avenue, which would require closure of this driveway and redesign of the bus terminal entrance to accommodate southbound buses. The closure of the driveway would have the benefit of consolidating driveway curbcuts, improving the pedestrian environment, but would result in a loss of one of the bus bays/layover spaces in the station bus terminal.

An alternative southbound stop is located south of the bus facility exit by the northeast corner of the Department of Employee Services (DOES) building. The southbound stop would not require pedestrians exiting the station to cross traffic lanes to reach the platform and would be conveniently located for customers and employees of the DOES building.

Northbound track is curbside-running and transitions to the special trackwork for the crossover and tail track beginning at the intersection of Hayes Street and extending onto the WMATA Kiss & Ride site. Southbound streetcars exit the turnaround near the Hayes Street intersection and transition to the curb lane of Minnesota Avenue. This turnaround would require a reduction in Kiss & Ride spaces. Southbound streetcars could alternatively transition to the median lane on Minnesota Avenue after the bus terminal exit near the DOES building.

D.2 Stops by Bus Facility; Minnesota Avenue Turnaround

Northbound and southbound stops are located on the curbsides of Minnesota Avenue between the Friendship Public Charter School and the Metrorail station bus terminal. The southbound stop may require a reduction in bus layover spaces depending on the width of the proposed sidewalk in this area. Northbound streetcars transition to a turnaround track from the curbside of Minnesota Avenue to the median of Minnesota Avenue at the intersection of Grant Street. Southbound streetcars transition from the median turnaround on Minnesota Avenue to the curbside after the Grant Street intersection. This turnaround may require the widening of Minnesota Avenue or the reduction of vehicular lanes to one lane in each direction on Minnesota Avenue. Southbound streetcars could alternatively transition from the curbside to the median lane on Minnesota Avenue at a new traffic signal located at the bus facility exit to the south.



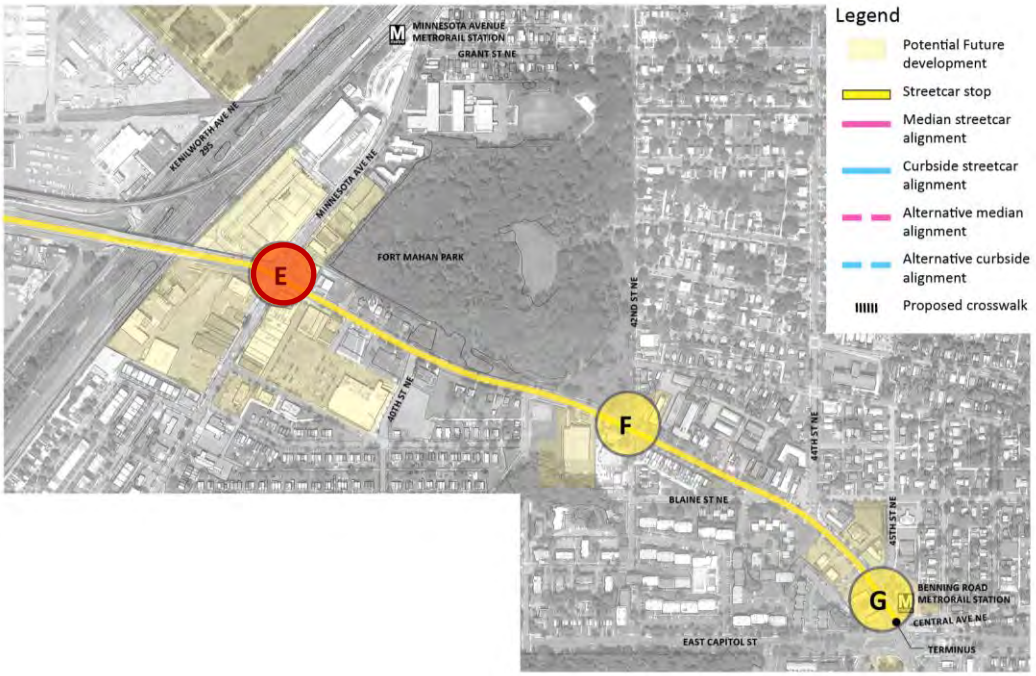
Alternative southbound alignment transitions from curbside to median at potential traffic signal at bus facility exit

4.2 Benning Road Metrorail Station Terminus Alignment Alternatives

This optional alignment would terminate at the Benning Road Metrorail Station. In addition to stop locations A, B and C described previously, this route would include stops at 42nd Street and Benning Road Metrorail Station. Because there is limited right-of-way along Benning Road, median stop at the intersection with 42nd Street would require the elimination of one through lane in each direction on Benning road. Therefore, the alignment options along Benning Road east of Minnesota Avenue generally consider curbside running tracks in both directions, which would eliminate existing on-street parking allowed during off-peak hours along Benning Road. The following alternatives for the Benning Road Metrorail Station Terminus Alignment show the alignment, potential stop locations, and alignment transition areas under consideration for this option.

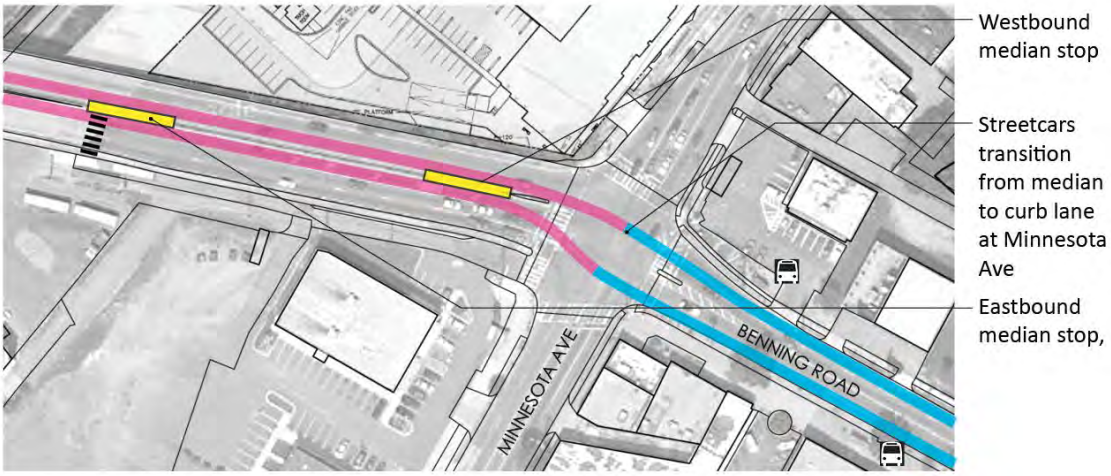
4.2.1 Minnesota Avenue Intersection

Different stop locations and alignments are possible with the streetcar continuing east on Benning Road rather than turning north onto Minnesota Avenue. It should be noted that the Minnesota Avenue intersection is approximately 0.28 miles, or a 5-minute walk from the Minnesota Avenue Metrorail Station, so it would still be possible for streetcar riders to access the Minnesota Avenue Metrorail station from a streetcar stop in this location, although it would not be as convenient.



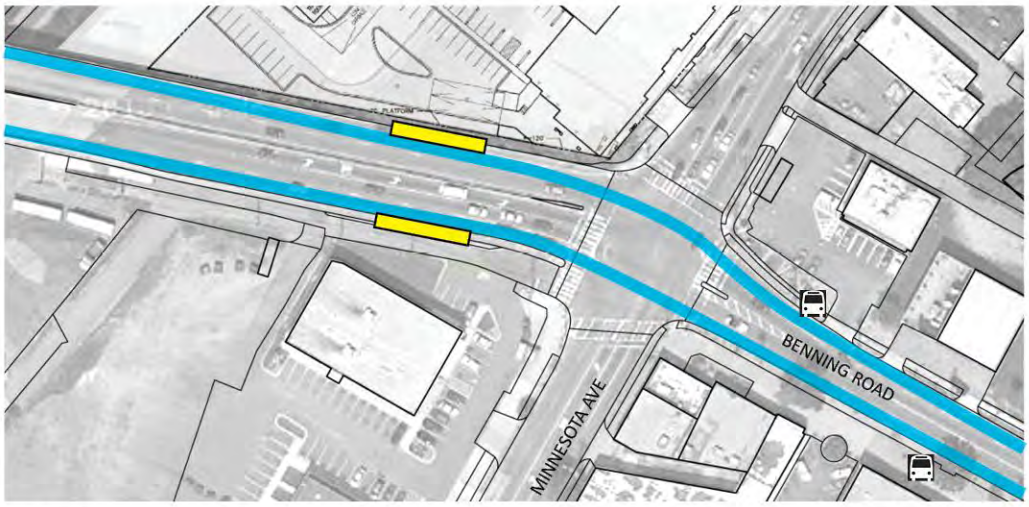
E.1 Median Stops on Viaduct

A median stop on the viaduct is proposed to be split with staggered stops to allow for eastbound left turns onto Minnesota Avenue by a dedicated left-turn lane without the influence of a streetcar right at the intersection. This arrangement requires an eastbound stop set back from the intersection, a mid-block pedestrian crossing, and a relatively level area for the streetcars to stop on a vertical tangent as the viaduct descends to meet the grade of Minnesota Avenue. This option would require both the eastbound and the westbound transition occur at the intersection, which will have an effect on traffic operations.



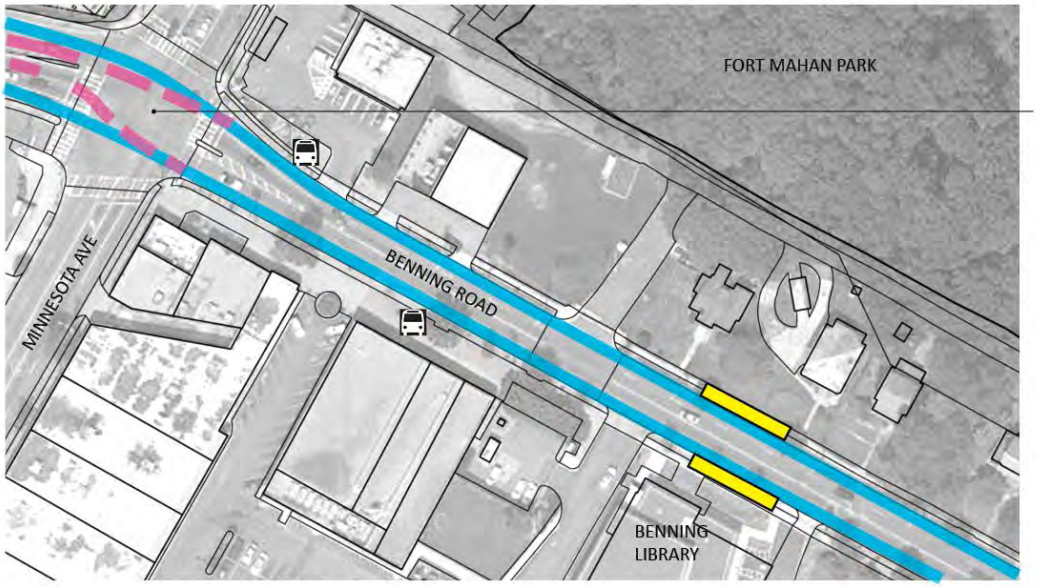
E.2 Curbside Stops on Viaduct

Curbside stops on the viaduct allow the stops to be close to the destinations south of the intersection and avoid impacting eastbound left turns. Platforms must be relatively level for the streetcars to stop on a vertical tangent as the viaduct descends to meet the grade of Minnesota Avenue. Eastbound and westbound streetcars remain in the curb lane on Benning Road before and after the intersection, reducing potential traffic effects.



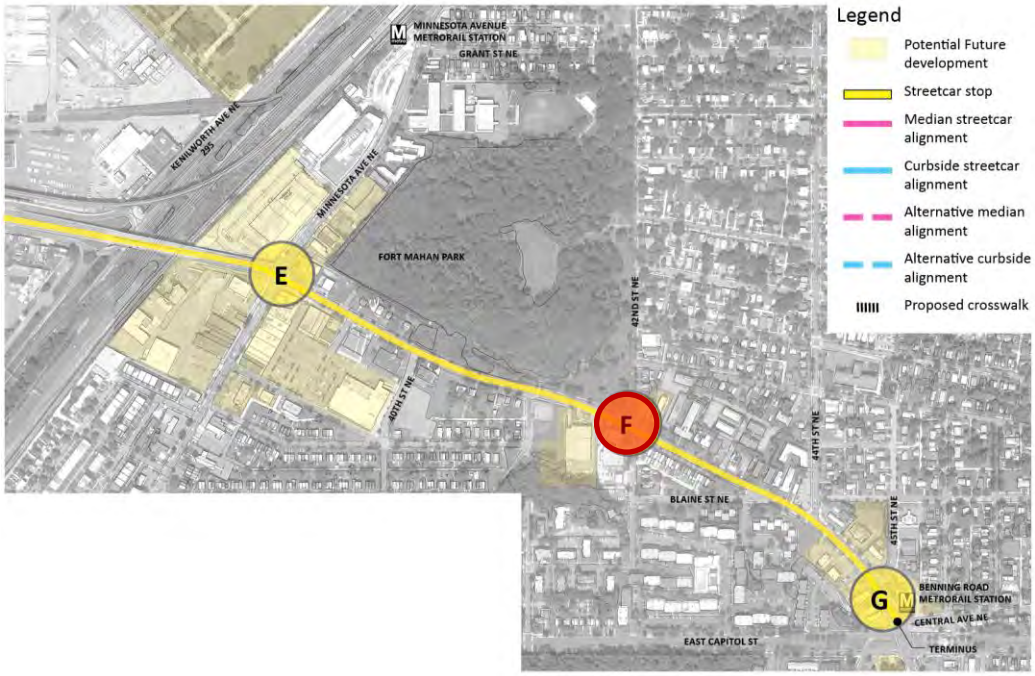
E.3 Curbside Stops East of Intersection

Stops east of the Minnesota Avenue intersection could be located in front of the Benning Library on opposite curbs. The roadway levels out at this location, and the stops do not conflict with the existing bus stops by the intersection. However, the streetcar stops are further from uses along and west of Minnesota Avenue. The eastbound and westbound streetcars may remain in the curb lane of Benning Road or transition from the median lane of the viaduct at the intersection of Minnesota Avenue depending on the preferred configuration to the west.



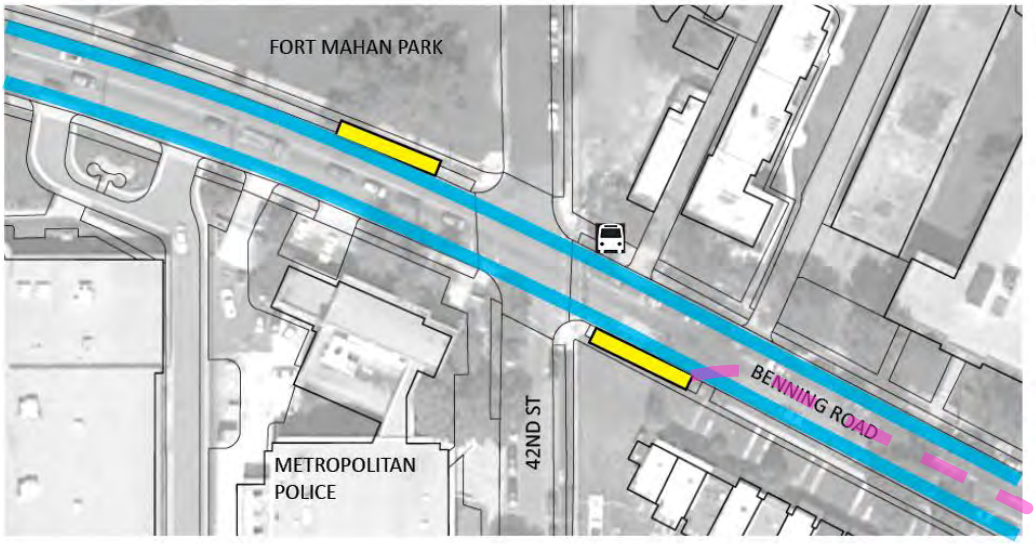
4.2.2 42nd Street Intersection

The intersection of 42nd Street would serve the residential neighborhoods north and east of Benning Road. The *Benning Road Corridor Redevelopment Framework Plan* identified two parcels for redevelopment surrounding the intersection. Recommended future development here includes a community center, moderate-density residential uses and/or neighborhood retail.



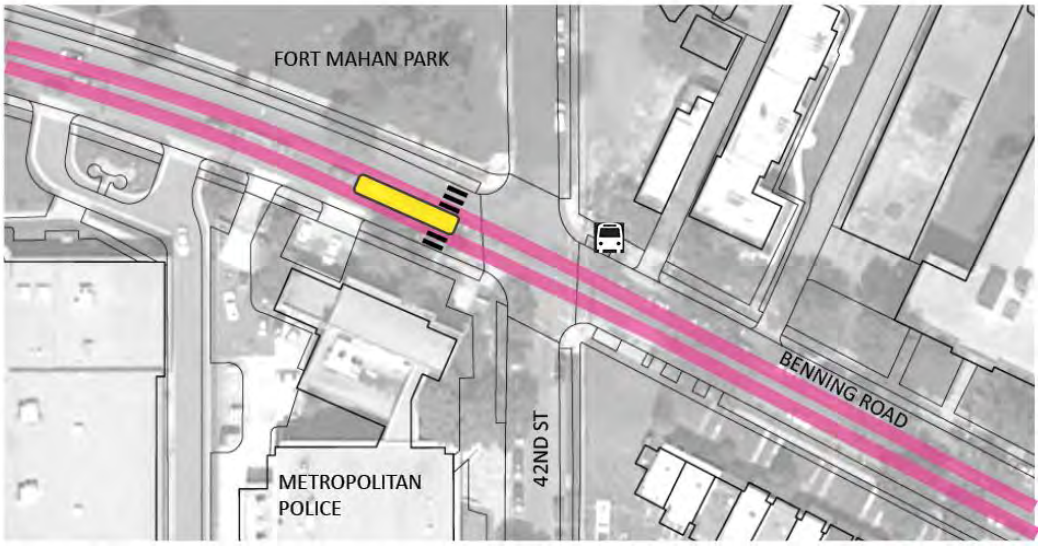
F.1 Curbside Stops

Curbside stops on the far side of the intersection serve both eastbound and westbound streetcars with curbside-running alignments.



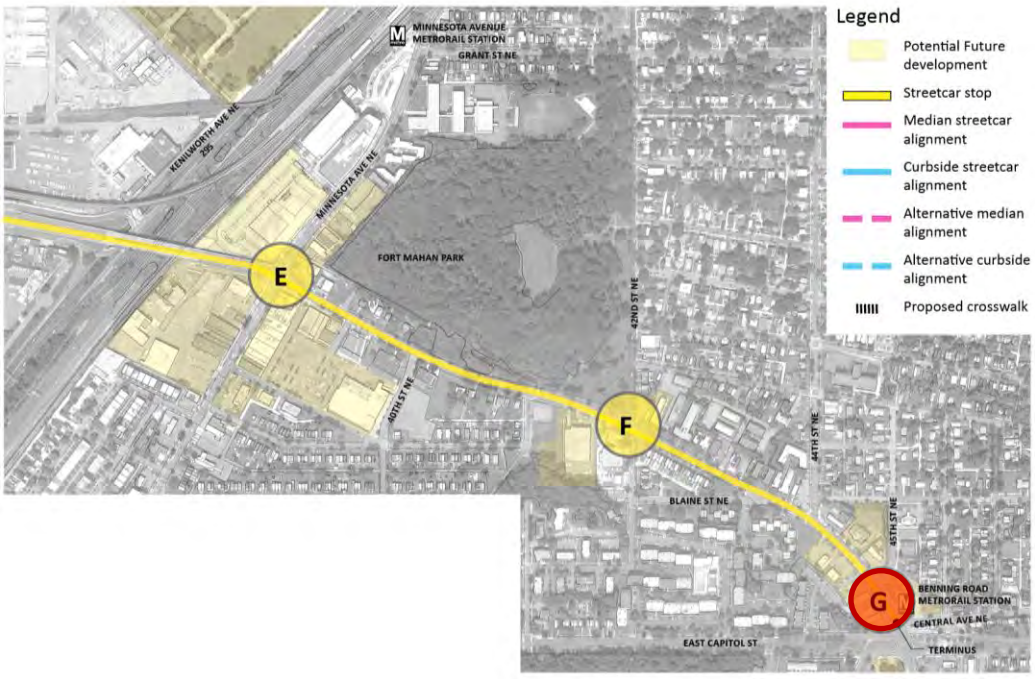
F.2 Median Stop

A median stop is located west of the intersection with both eastbound and westbound streetcars remaining in the median lane from the Minnesota Avenue intersection. A median stop would conflict with eastbound left turns onto 42nd Street. This configuration would also require eliminating one general travel lane in each direction along Benning Road to accommodate the stop.



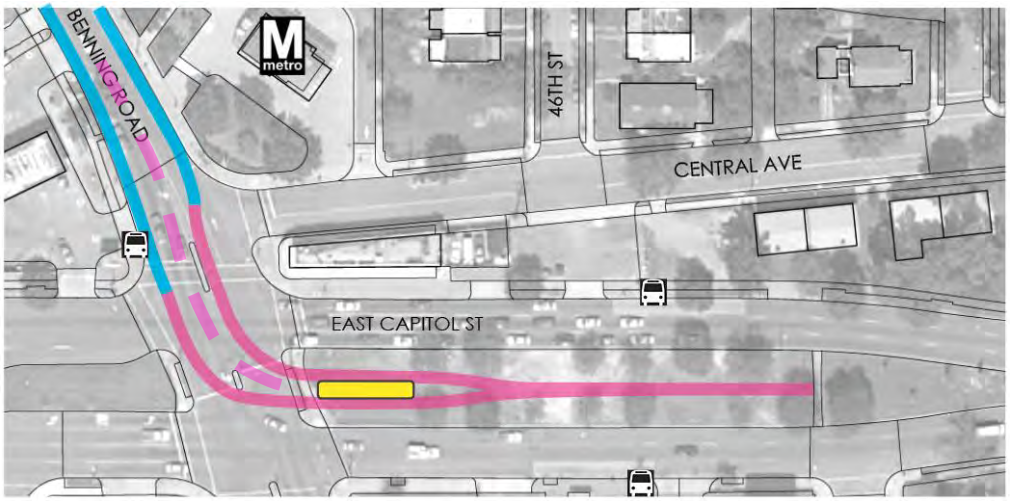
4.2.3.1 Benning Road Metrorail Station and Turnaround

Extending the Benning Road Streetcar to the Benning Road Metrorail Station would provide direct access to the Metrorail system, East Capitol Street, and the neighborhoods to the south and east. Additionally, the *Benning Road Corridor Redevelopment Framework Plan* identified several parcels for long-term transit-oriented redevelopment potential, with mixed retail, residential and small office uses.



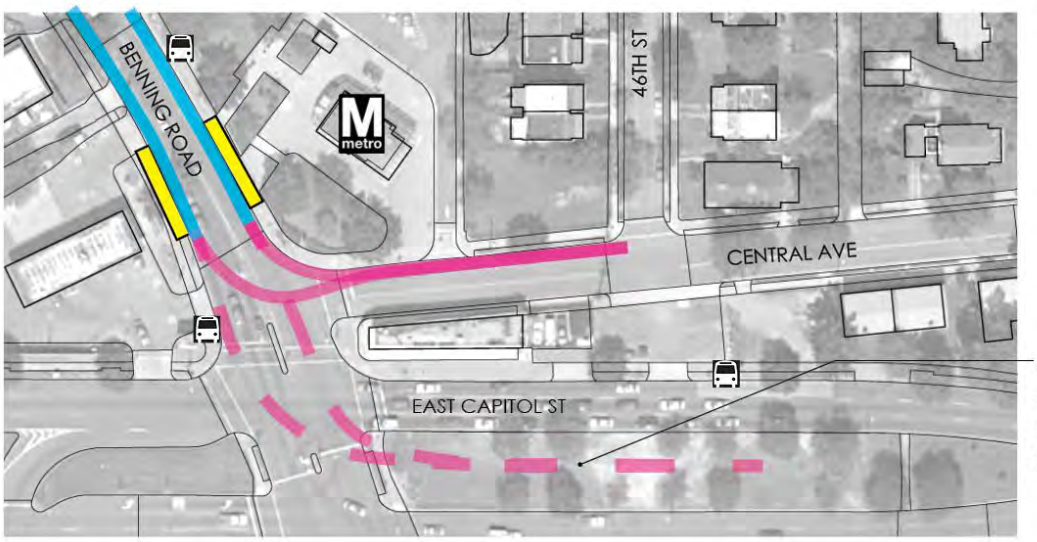
G.1 East Capitol Street Median Stop and Turnaround

A median stop is located in the median of East Capitol Street. This locates the stop out of vehicular traffic lanes and closer to uses south and east of the intersection but further from the Metrorail station entrance. This stop location conflicts with the *Far Northeast Livability Study* proposal to eliminate the East Capitol Street median and replace it with left turn lanes. Eastbound and westbound streetcars transition from curb lanes on Benning Road to the median at the East Capitol Street intersection. The streetcars would turn around in a tail track within the median east of the stop.



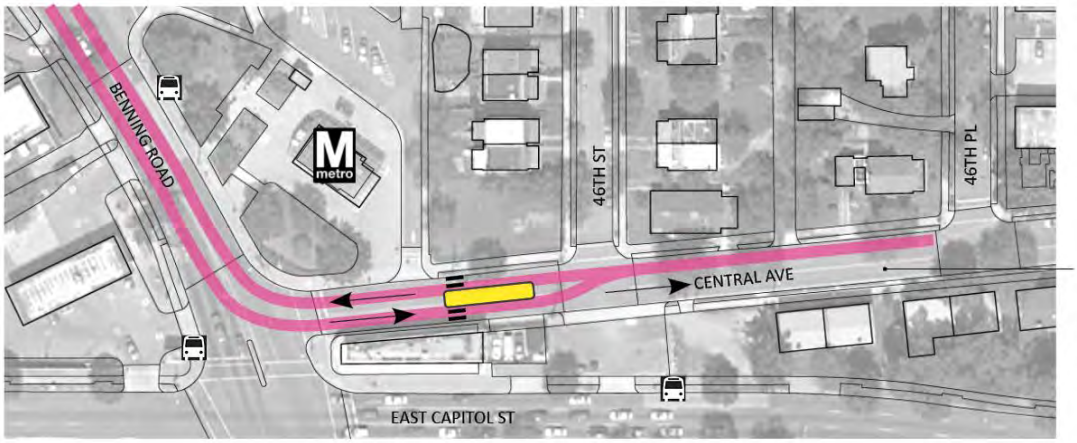
G.2 Benning Curbside Stops and Central Avenue Turnaround

Opposing streetcar stops are located curbside directly outside of the Metro station entrance. Eastbound stop may require additional right-of-way on private property, while the westbound turn could encroach into the Metro Station area. East and westbound streetcars converge to a shared turnaround track after the stops on the westbound lane of Central Avenue. This turnaround will impact the vehicular traffic of Central Avenue as it required dedicated right-of-way for operations.



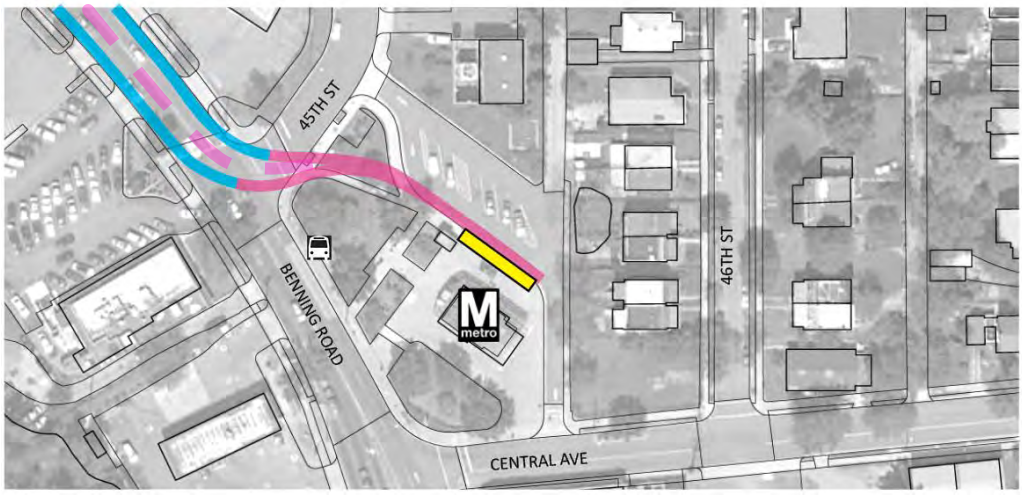
G.3 Central Avenue Median Stop and Turnaround

A median stop is located east of the metro station entrance on Central Avenue. A midblock pedestrian crosswalk is required to provide safe access to the proposed stop. East and westbound streetcars remain in median from Benning Road to Central Avenue and converge to a shared turnaround track after the stop at the intersection of 46th Street. This turnaround requires vehicular traffic to transition from two-way between Benning Road and 46th Street to one way east after 46th Street.



G.4 Kiss & Ride Site Stop and Turnaround

An off-street single platform stop is located on the site of the existing Benning Road Metrorail station Kiss & Ride facility. The location would provide direct access to the Metrorail station but would eliminate the Kiss & Ride facility and impact the intersection with 45th Street. A new traffic signal would be required at the intersection with 45th Street with a special signal phase to allow the eastbound and westbound streetcars to cross to/from the curb lanes of Benning Road in and out of the Metrorail station site. The turning radius requirement for the westbound track may require redesign of the intersection of 45th Street.



4.3 General Operating Strategy

4.3.1 Frequency and Span of Service

Streetcar service assumptions are based on DDOT proposed service plans for the H Street/Benning Road Streetcar Line. The proposed frequency of service for the line is every 10 minutes in both directions throughout the entire service day. The proposed span of service is as follows:

- Monday through Thursday: 6:00 AM to 12:00 AM
- Friday: 6:00 AM to 2:00 AM
- Saturday: 8:00 AM to 2:00 AM
- Sunday: 8:00 AM to 10:00 PM

4.3.2 Fare Structure

DDOT's proposed fare structure for the streetcar service would be similar to the DC Circulator service. Based on the existing fare structure, the streetcar service would have the following fares:

- Cash = $1.00
- SmarTrip Card = $1.00
- Senior/Disabled = $0.50
- Transfers to/from Metrobus, DC Circulator = Free (SmarTrip Card only)
- Transfers to/from Metrorail = $0.50 (SmarTrip Card only)

4.3.3 Background Bus Service

Table 3 summarizes the Metrobus routes operating in the study area and their respective weekly ridership:

Table 3: 2012 Weekly Ridership

Metrobus Line	Route	Weekday	Saturday	Sunday
U4	Sherriff Road-River Terrace Line	1,262	553	387
U5,6	Mayfair-Marshall Heights Line	3,368	1,719	1,385
U8	Capitol Heights-Benning Heights Line	5,365	3,191	1,876
V7,8,9	Minnesota Avenue – M Street Line	4,232	2,099	1,570
X1,3	Benning Road Line	1,151	0	0
X2	Benning Road-H Street Line	13,661	8,541	5,558
X8	Maryland Avenue Line	1,158	379	264
X9	Benning Road-H Street Limited	1,612	0	0
96,97	East Capitol Street – Cardozo Line	5,083	2,118	1,805
A31,32,33	Anacostia High School Line	64	0	0
E32	Eastern High School Line	19	0	0
W4	Deanwood – Alabama Avenue Line	5,456	2,772	2,399

These routes are not proposed to be modified as part of the streetcar extension project, because their service areas typically extend to locations well beyond the study area. However, three Metrobus routes – the X1, X2 and X3 – could be modified in response to the implementation of the proposed Minnesota Avenue Metrorail Station option of the H Street/Benning Road Streetcar Line, if streetcar service is extended west beyond Union Station into the downtown business district in future phases.

4.4 Concept Alternative Plans

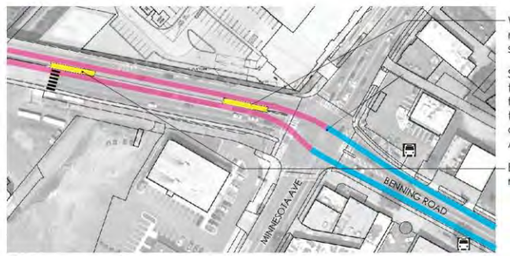
Benning Road Streetcar - *Benning Road Metro Terminus Alternatives*

Legend

- POTENTIAL FUTURE DEVELOPMENT*
- STREETCAR STOP
- MEDIAN STREETCAR ALIGNMENT
- CURBSIDE STREETCAR ALIGNMENT
- ALTERNATIVE MEDIAN ALIGNMENT
- ALTERNATIVE CURBSIDE ALIGNMENT
- PROPOSED CROSSWALK

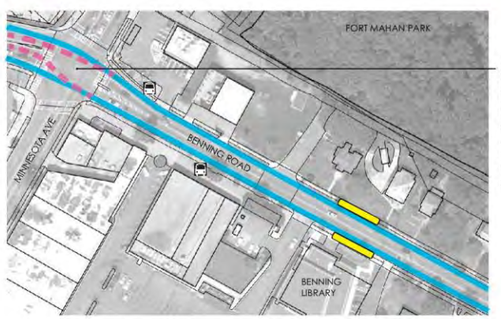
*Potential future development sites were identified in: the 2008 *Benning Road Corridor Redevelopment Framework Plan* and the 2008 *Deanwood / Great Streets - Nannie Helen Burroughes Ave NE & Minnesota Ave NE Strategic Development Plan* by the District of Columbia Office of Planning; and the 2006 WMATA *Minnesota Avenue Metrorail Station Access Improvement Study*.

E Minnesota Ave Intersection



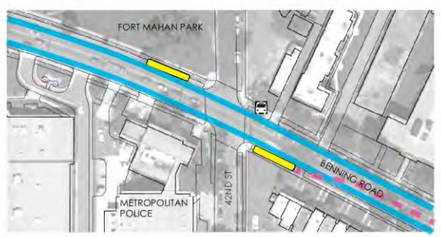
E.1

E.2

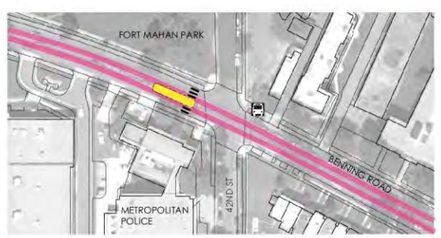


E.3

F 42nd St Intersection

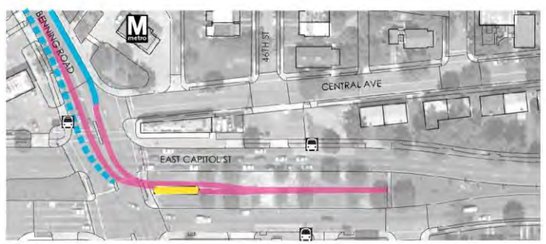


F.1

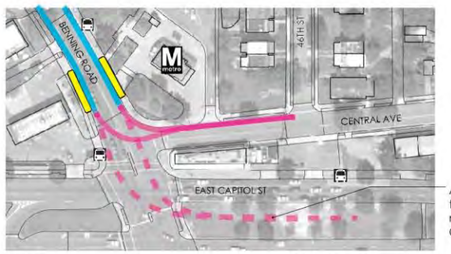


F.2

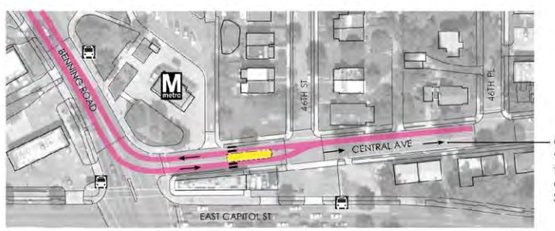
G Benning Rd Metro Station



G.1



G.2



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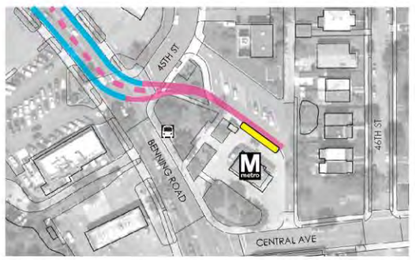
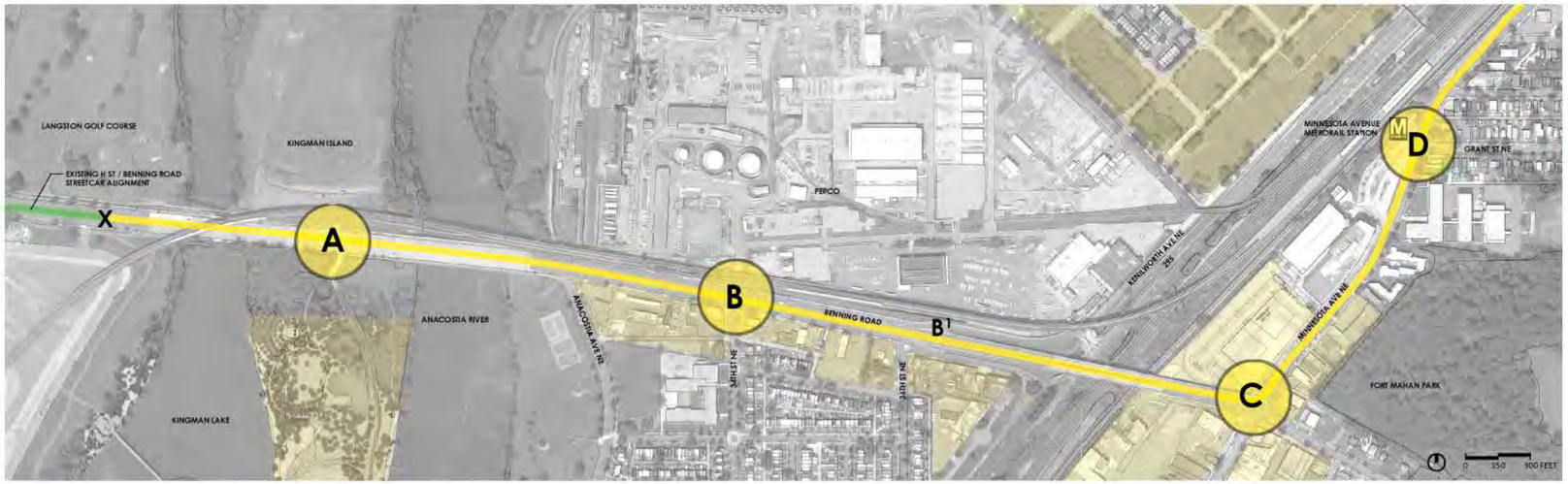


G.4

Minnesota Ave Metro Terminus Alternatives



Legend

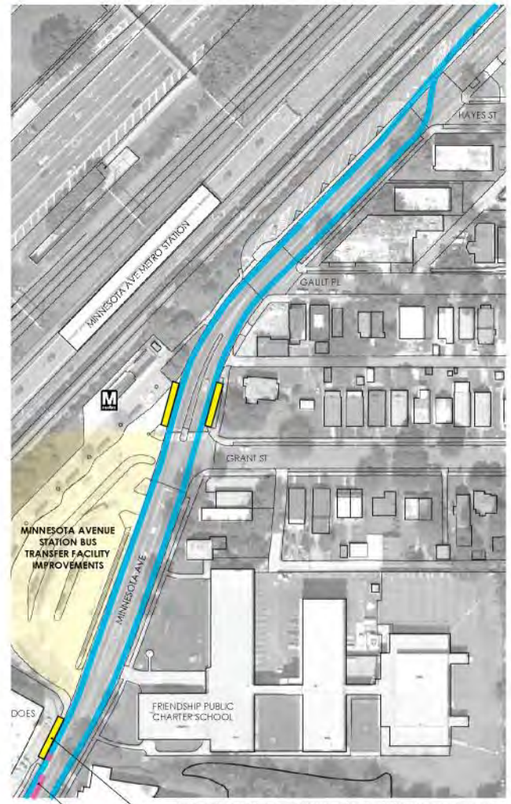
- POTENTIAL FUTURE DEVELOPMENT*
- STREETCAR STOP
- MEDIAN STREETCAR ALIGNMENT
- CURBSIDE STREETCAR ALIGNMENT
- ALTERNATIVE MEDIAN ALIGNMENT
- ALTERNATIVE CURBSIDE ALIGNMENT
- PROPOSED CROSSWALK

A Kingman Island

B 34th St Intersection

C Minnesota Ave Intersection

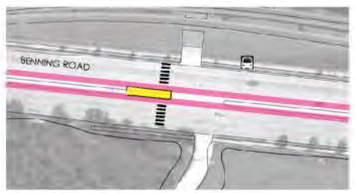
D Minnesota Ave Metro Station



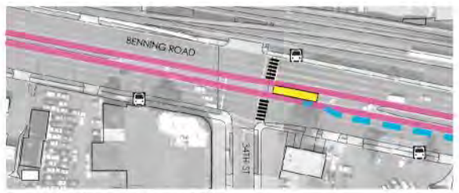
D.1

Alternative southbound stop prior to station improvements

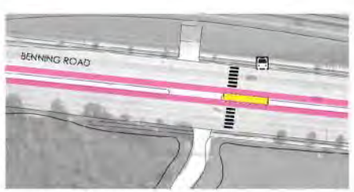
Alternative southbound alignment transitions from curbside to median



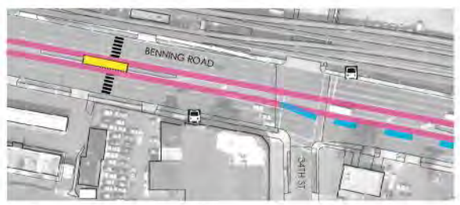
A.1 West Median Stop



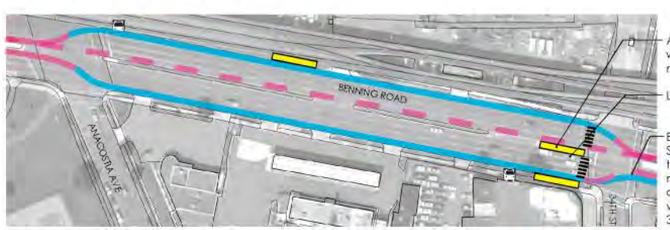
B.1 East Median Stop



A.2 East Median Stop



B.2 West Median Stop

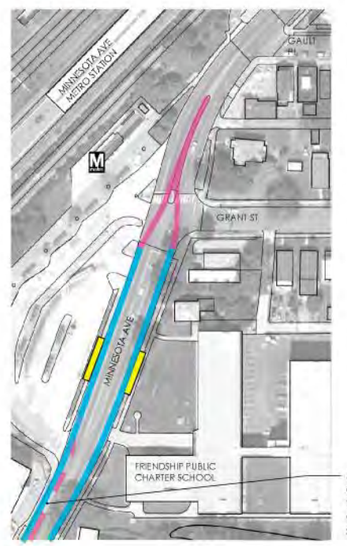


B.3 Curbside Stops

C.1

C.2

C.3



D.2

5.0 Engineering Analysis of the Alternatives

This section presents the feasibility analysis of the conceptual alternatives introduced in Section 3, with a focus on the engineering considerations of the corridor. Various trade-offs in terms of system operations are associated with each design option, particularly given the physical characteristics of the corridor. The purpose of this section is to present the trade-offs (pros and cons) associated with each design characteristic of the system. The next phases of project development will consider these trade-offs and develop a set of design alternatives to advance to the next phase of design. This section is organized as follows:

- Guideway design
- System requirements
- Environmental Constraints
- Ridership
- Capital and Operating Cost Estimates

Streetcar track slab: pavement and structural support of the track that is embedded in the street.

Physical clearance envelope: the minimum amount of space needed for the streetcar to operate.

Tangent track: length of track that is absolutely straight.

5.1 Guideway Configuration

One of the main advantages of streetcar is its ability to travel in mixed traffic lanes in an urban environment. Track alignment design establishes a series of horizontal and vertical geometric components that, when connected together, create a guideway for the streetcar to operate. Streetcar platforms are designed for accessibility (including Americans with Disabilities Act (ADA) requirements) and operational efficiency purposes. Also, as described in the earlier sections, the streetcar track slab has a minimum depth requirement that needs to be accommodated by the bridge structures in the corridor. As a result, guideway configuration impacts the streetcar track design, stops and turnaround locations, traffic operations, and utilities. The DC Streetcar Design Criteria and DC Streetcar Standard Drawings, both dated January 2012, were used as the basis for conceptual track design.

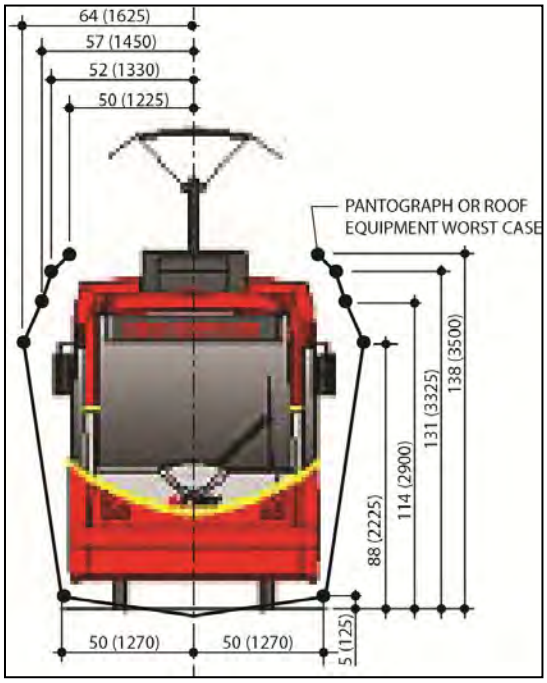
Several primary design needs affected the conceptual track design:

1. Tying to the existing center-running streetcar track at Oklahoma Avenue;
2. Crossing three bridges in the corridor;
3. Locating a turnaround area at either terminus;
4. Accommodating special trackwork at the Minnesota Avenue/Benning Road intersection to allow for future streetcar connectivity as shown in the *DC Transit Future Alternatives Analysis –Update*; and
5. Running streetcars in existing roadway typical cross-section while minimizing potential impacts to right-of-way, utility, traffic, and on-street parking.

5.1.1 Typical Section Development

Vehicle clearance design defines a physical clearance envelope, into which no object can intrude for the streetcar to operate safely. The clearance envelope is derived by the physical properties of the streetcar, track alignment, and construction and maintenance tolerances. **Figure 14** shows the physical clearance envelope of a streetcar vehicle on level tangent track (not on a curve) as identified in DDOT's standards.

Figure 14: Vehicle Clearance Envelope Indicated as in DDOT's Design Standards



Based on the physical clearance envelope (**Figure 15**), the vehicle needs at least an 11-foot wide travel lane to operate on tangent (i.e. straight) track. When the streetcar vehicle is not traveling on a tangent, the vehicle needs a 12-foot wide lane to allow for the overhang of the vehicle. However, the existing travel lanes within the study area are less than 12 feet; the center turn lanes are between 10 and 11 feet wide, the inside travel lanes are 10 feet wide, and the outside travel lanes are 10 feet wide with an additional 1 foot wide gutter pan. Therefore, the 12 foot travel lane will require widening of the overall typical section (or street). The extent of widening of the existing typical section was dictated by the streetcar guideway location within the section.

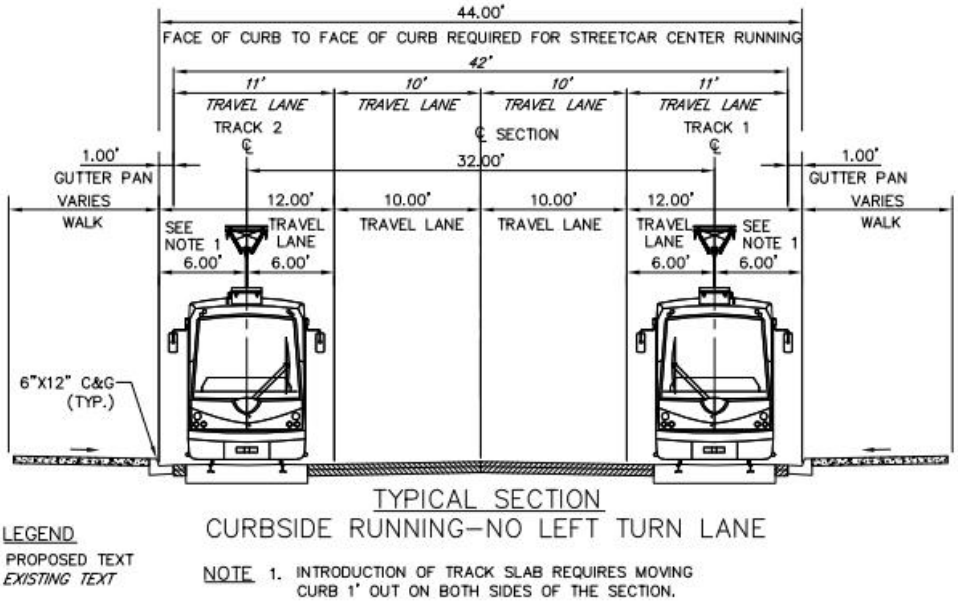
Gutter pan: width of the storm drain gutter.

Pantograph: the apparatus mounted on the roof of the streetcar to collect power through contact with an overhead contact wire.

Curbside Running

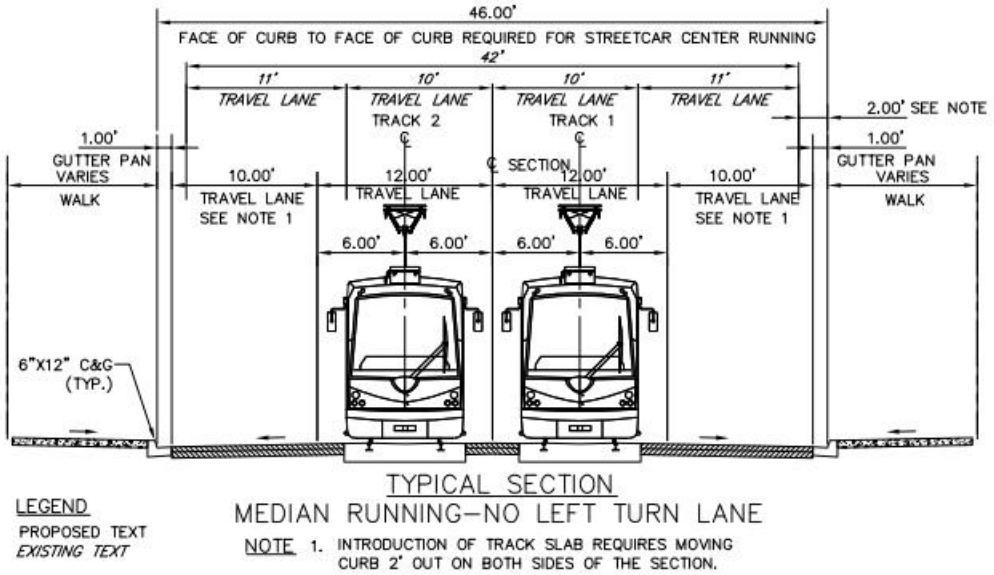
Where curbside guideway is considered, the centerline of streetcar alignment is 6 feet toward the curb line from the pavement strip that delineates the right and left travel lanes. This places the centerline of track 5 feet from the existing curb line. To accommodate the clearance envelope of 6 feet on either side of centerline of track, the typical section would need to be widened by 1 foot on either side of the section, creating a proposed section 44 feet wide, or 2 feet wider than the existing 42 feet wide section. **Figure 15** illustrates this section.

Figure 15: Typical Section – Curbside Running & No Left-Turn Lane



Where median running guideway is considered, the centerline of streetcar alignment is set 6 feet toward the curb line from the pavement strip that delineates the travel lanes at about the centerline of roadway. This creates a 12 foot center to center track spacing, and effectively widens the center travel lanes from 10 feet wide to 12 feet wide. Adding two 10 feet wide outside travel lanes and two 1 foot wide gutter pans creates a typical section 46 feet wide, or 4 feet wider than the existing 42 feet wide section. **Figure 16** illustrates this section.

Figure 16: Typical Section – Median Running & No Left-Turn Lane



Basing track alignment design in accordance with these design criteria, specifically in relation to spiraled curves and minimum component lengths, would require significant roadway reconstruction. Based on these initial findings and after discussions with senior DDOT staff, track designs were modified to closely match the roadway geometry, while maintaining the minimum curve radius of 66 feet. A detailed discussion on design criteria, additional typical

cross sections, and design elements are included in **Appendix C**, Conceptual Track Alignments Analysis Technical Memorandum.

Station Platforms

Spatial requirements for the introduction of platforms within a typical section varied depending on curbside or median running scenarios. These are requirements for an efficient and safe waiting, boarding, and alighting environment. A level boarding surface and minimal gap between the vehicle and the station platform allow passengers simply step onto the vehicle, which improves operating efficiency by reducing dwell time (time spent at stops for boarding and alighting passengers). As shown in **Figure 17**, the distance between the center of the vehicle to the edge of platform is 4.2 feet, less than the 6 feet. In other words, the streetcar vehicle needs to get closer to the curb at the platforms. It is possible to introduce reverse curves in the track alignment to move the alignment closer to the curb line. This would locate the edge of platform at the proposed curb line and maintain the proposed 12 feet wide travel lane. However, this needs to be reviewed at the next level of design. When the streetcar stop needs to be located within a median running guideway schematic, the overall roadway limits must be widened by as much as 16 feet, 8 feet both sides, to accommodate the median streetcar stop platform. **Figure 18** illustrates this section.

Dwell time: the time in seconds that a transit vehicle is stopped for the purpose of serving passengers.

Reverse curves: Two adjoining horizontal curves of opposite direction.

Spiral curve: gradual change in curvature from a straight section of track to a curved section of track.

Figure 17: Typical Section - Curbside Running – Side Platform

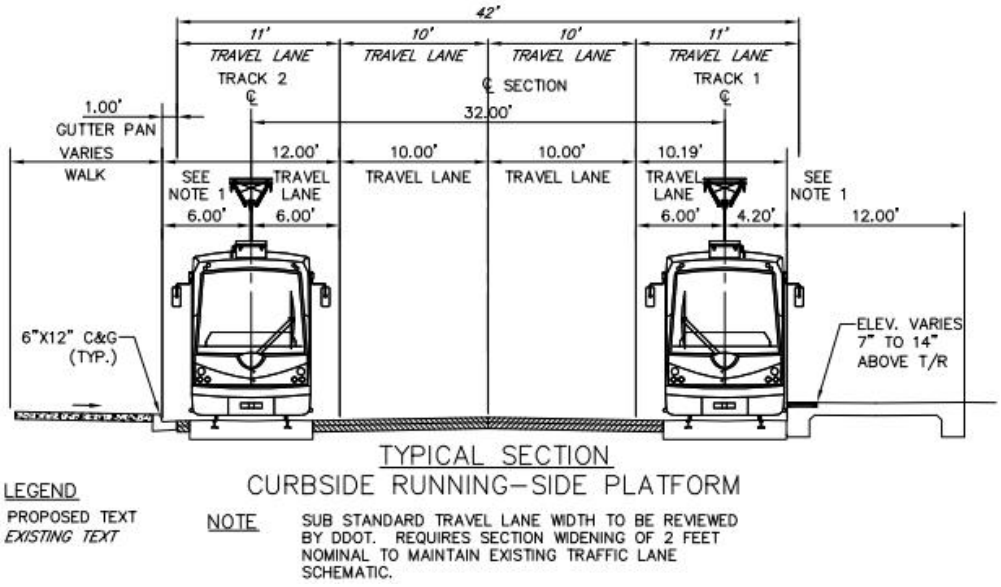
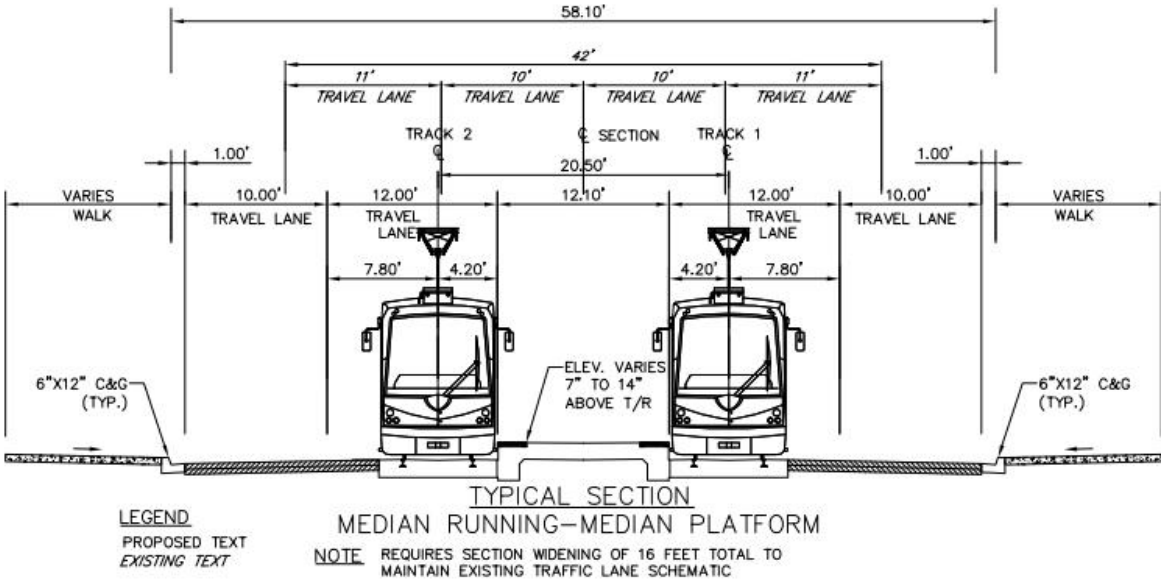


Figure 18: Typical Section - Median Running – Median Platform



Summary Findings for Track Design Feasibility Assessment

Appendix C, Conceptual Track Alignments Analysis Technical Memorandum shows the conceptual design of the various options introduced in Section 4 and the pros and cons of these options from a track alignment perspective. These findings are summarized below:

1. Curbside travel lane widths along the corridor are generally 11 feet, except for on the structures (i.e. the three bridges as identified earlier), where they are 10 feet for all lanes. Center lanes are generally 10 feet. DDOT design standards indicate 11-foot lanes would be acceptable in tangent sections (10.67 feet is the total clearance envelope). However, on curved roadway sections, the lane widths need to be wider to allow for the clearance envelope of the streetcar vehicle. For the purposes of this feasibility analysis, 12-foot lanes were used to locate streetcar tracks. This would require widening of the roadway by 1 foot on either side for a total of 2 feet when it is running curbside. If tracks are median running, where travel lanes are generally 10 feet, the roadway needs to be widened by 2 feet on either side for a total of 4 feet. Additionally, median platforms would require 16 feet of widening, if it is desirable to maintain the existing lane configurations (i.e. the number of lanes). Locating streetcar track in the existing narrower-than-ideal cross-sections would likely require design exceptions, which need to be addressed at subsequent detailed design stages.

2. Basing track alignment design in accordance with these design criteria, specifically in relation to spiraled curves and minimum component lengths, would require significant roadway reconstruction and traffic control modifications. These effects can be reduced by removing spirals in many of the curves, introducing relatively short geometric element lengths, and the creation of aggressively short reverse curves when transitioning from median to curbside running, while keeping the minimum curve radius of 66 feet. However, these would changes result in a five mile per hour reduction in operating speed, potential noise effects as the streetcar negotiates the curvature, and increased maintenance required to mitigate rail wear.

3. Track transitions between curbside running to median running, and vice versa, require special signalization and potential intersection geometry modifications. Minimizing these potential transitions would help save costs and improve operational efficiencies.

4. The intersection of Minnesota Avenue and Benning Road would need to be reprofiled (raised and flattened) to accommodate special trackwork that allows for north-south and east-west connectivity. This could potentially have negative visual and right-of-way impacts.

5. Streetcar turnaround areas in both termini options, if located in the median, would require either lane taking or roadway widening or, if located elsewhere, displacement of an existing function such as median space or kiss & ride space.

5.2 Structures

As discussed earlier, the sufficiency of superstructure and substructure of the bridges to accommodate streetcar geometry and loadings was assessed. The proposed streetcar guideway track section is a full-depth embedded track slab, typically between 11 and 18 inches deep. Because the pavement thickness of the bridges is less than the required full-depth embedded track slab, the depth of the bridge needs to increase in order to accommodate streetcar tracks, the loads of the streetcar vehicle, and the streetcar track slab. The three bridges assessed in the study are:

- Benning Road Bridge over the Anacostia River (Bridge No. 52)
- Benning Road Bridge over Kingman Lake (Bridge No. 77)
- Benning Road Viaduct (Bridge No. 503 Eastbound and Bridge No. 503 Westbound) over Kenilworth Avenue and the CSXT Railroad tracks

5.2.1 Benning Road Bridge over the Anacostia River (Bridge No. 52)

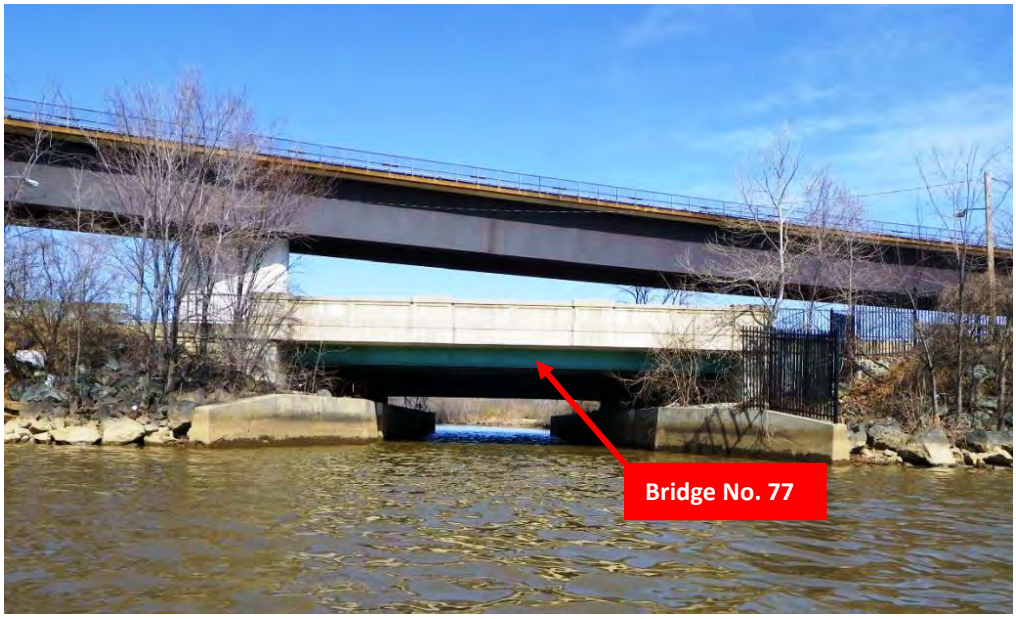
Bridge No. 52 (as shown in **Figure 19**) is a five-span continuous steel multi-girder structure with a reinforced concrete deck supported on reinforced concrete abutments and piers. The bridge was constructed in 2004 and carries eight lanes of divided two-way Benning Road over the Anacostia River. The structure is approximately 556 feet long with a curb-to-curb width of approximately 87 feet and an out-to-out width of approximately 119 feet. The bridge has a 7.9-foot wide concrete median and 10.8-foot wide sidewalks on each side. The bridge is oriented east-west. It is not currently posted for any weight restrictions.

Figure 19: Benning Road Bridge over the Anacostia River (Bridge No. 52)

5.2.2 Benning Road Bridge over Kingman Island (Bridge No. 77)

Bridge No. 77 (as shown in **Figure 20**) is a single-span steel multi-girder structure. The bridge carries eight lanes of divided two-way Benning Road traffic over Kingman Lake. Kingman Lake is a tidal overflow reservoir for the Anacostia River with no navigational traffic. The structure is 62.0 feet in length with an out-to-out width of 114 feet. The structure was replaced in 2000 with modified reinforced concrete abutments. The new abutments are set back from the old abutments, and the old abutments function as channel walls and were reinforced at the top. The bridge is also oriented east-west. It is not currently posted for any weight restrictions.

Figure 20: Benning Road Bridge over Kingman Island (Bridge No. 77)



The feasibility analysis showed that these two bridges are capable of carrying the streetcar loads, based on the criteria explained in detail in **Appendix D**, Bridge Impact Analysis for Anacostia River and Kingman Lake Bridges Technical Memorandum. Both the "build-up" and "build-down" options would be acceptable, although the build-up option is easier to implement. However, it requires that the center lanes of the bridge be dedicated to streetcar only.

5.2.3 Benning Road Viaduct (Bridge No. 503 Westbound (WB))

Bridge 503 WB was built in 1936, with major reconstruction occurring in 1982. The seven-span bridge is 470 feet long, with a maximum span length of 97 feet and a curb-to-curb width of 30.5 feet. Although the routine 2010 inspection report indicated that bridge superstructure was in good condition, load ratings in the report indicated that the structure had reached its estimated remaining fatigue life in 2010. Additionally, the bridge substructure was rated in satisfactory-to-poor condition according to the 2010 inspection report, and could potentially require substantial repairs to restore it to good working condition.

The existing structure geometry presents a major challenge in accommodating the streetcar. The bridge width is not wide enough to carry two lanes of vehicular traffic in addition to a dedicated lane for a streetcar, which requires that the streetcar operate in mixed-traffic. To accommodate the track rails in a mixed-traffic lane, the existing deck would need to be thickened. This work would result in costly utility relocation and modifications to the diaphragms. Reconstruction of the deck for the mixed-traffic lane configuration could also potentially interfere with the girders.

Another geometric concern with the existing structure is that it does not currently meet standards for vertical clearance over the CSX railroad. DDOT, as specified in their Design and Engineering Manual, requires a minimum vertical clearance of 23 feet, unless otherwise directed by the railroad. The bridge currently has a vertical clearance of 22 feet and 4 inches over the railroad.

5.2.4 Benning Road Viaduct (Bridge No. 503 Eastbound (EB))

Bridge No. 503 EB was built in 1961, with major reconstruction occurring in 1989. The seven-span bridge is 470 feet long, with a maximum span length of 98 feet, and a curb-to-curb width of 29 feet. Although the 2010 inspection report indicated that bridge superstructure was in good condition, load ratings indicated that the structure had reached its estimated remaining fatigue life in 2010. The bridge sufficiency rating was reported as 52.3 percent in 2008 by Federal Highway Administration (FHWA). Bridges with a sufficiency rating of less than 50.0 are eligible for replacement or rehabilitation under the FHWA Highway Bridge Replacement and Rehabilitation Program.

DDOT has programmed Bridge 503 for reconstruction. Future design efforts for this bridge should include accommodations for streetcar as well as pedestrian and bike facilities. **Figures 21, 22 and 23** show illustrations of how a future bridge could accommodate the general travel lanes, streetcar, pedestrian and bike facilities that correspond to C1, C2 and C3 options of the Concept Alternative Plans. The total width of the bridge depends on the potential location of a streetcar stop with C1 option requiring the widest and C2 the narrowest cross section.

Figure 21: Benning Road Viaduct Cross Section – Option C1

Figure 22: Benning Road Viaduct Cross Section – Option C2

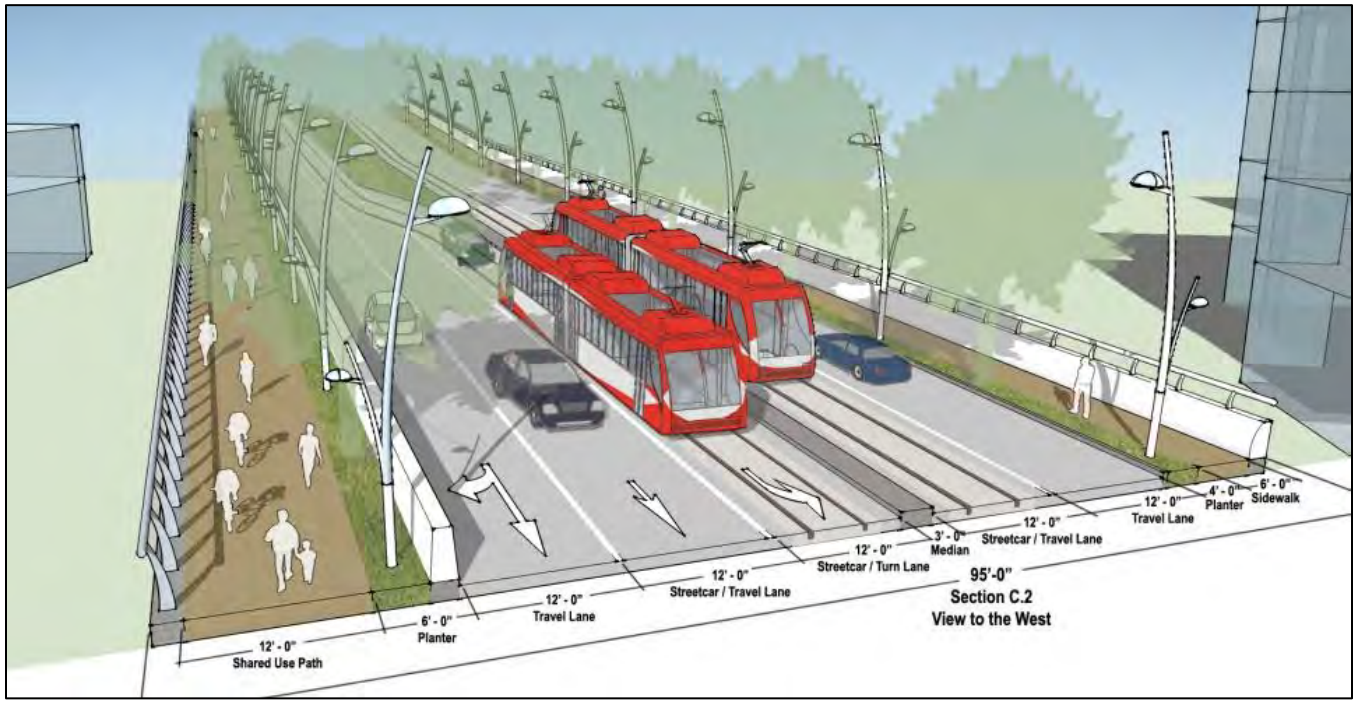
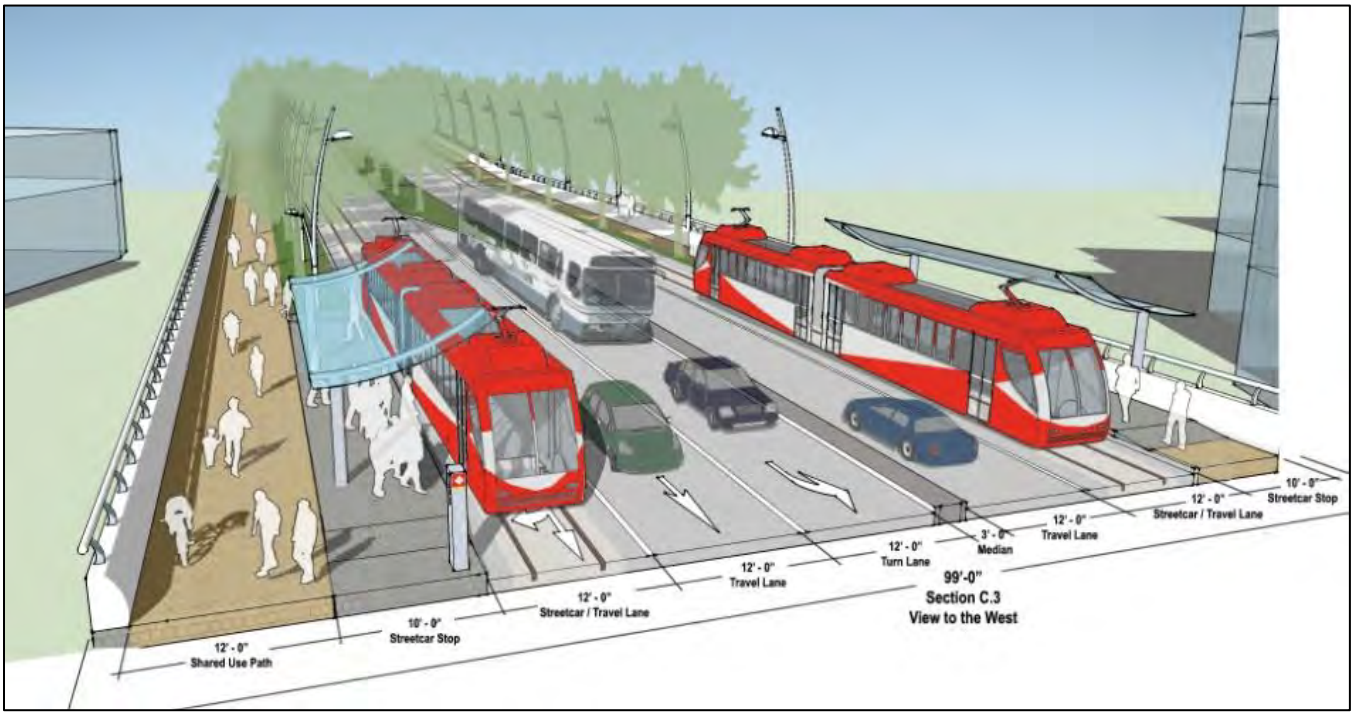


Figure 23: Benning Road Viaduct Cross Section – Option C3



5.2.5 Stop Locations and Pedestrian Access

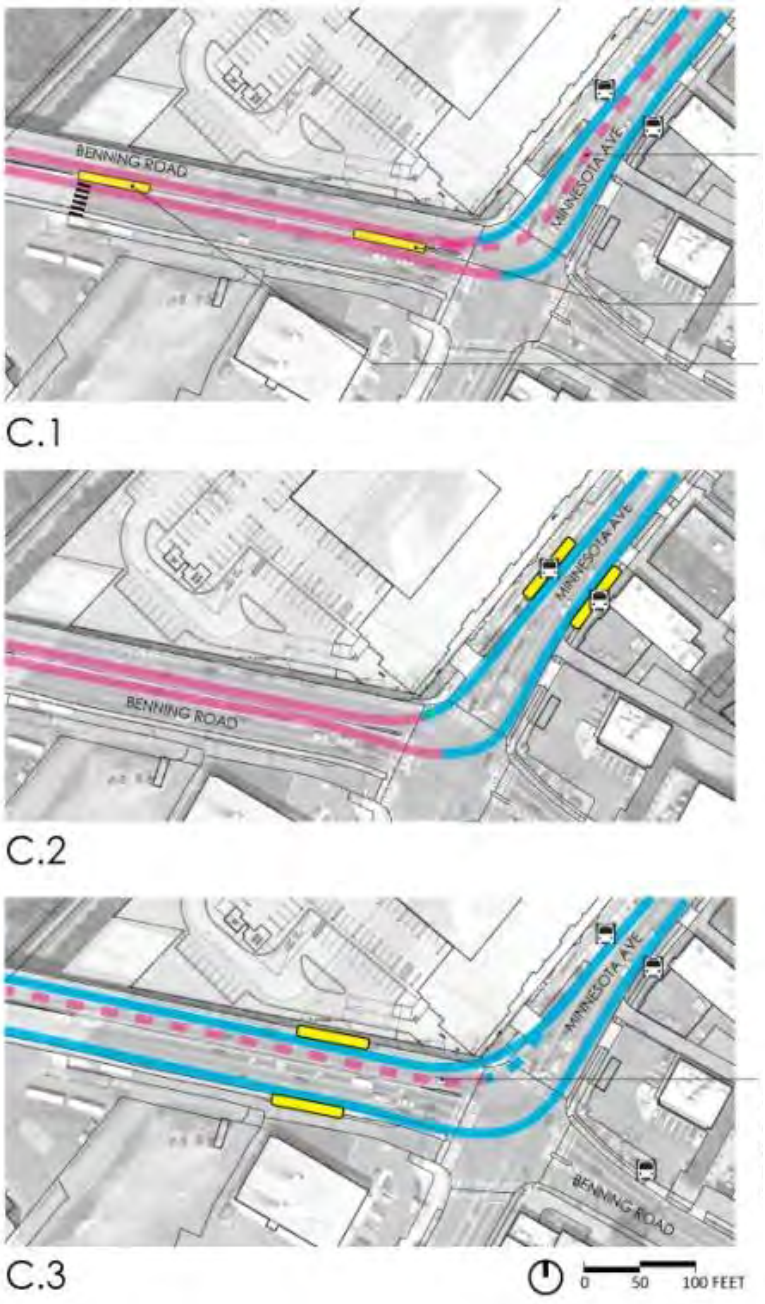
Curbside and median platforms provide the same level of access to pedestrians unless one side of the street is more developed and will remain to be that way for the foreseeable future. This, in turn, would favor curbside stops. All of the stop locations, as indicated in the Concept Alternative Plans, have similar levels of pedestrian access.

Curbside stops can be shared with other bus services as long as the height of the platform is compatible with the buses on the corridor. Near-level boarding (10 inch stop platform height with 14 inch high streetcar vehicle floor) with ADA ramps would allow for bus doors to open without being obstructed. Median stops would require left-side doors on buses to make them shareable, which is not currently available on the Metrobus. When streetcar and bus serve provide similar service to the same market, it would be more advantageous to have them share stops. However, if the transit service is or can be configured in a more distinguished manner (i.e. the bus service provides local/more frequent service and streetcar provides limited stop/express service or vice versa), then the need for collocating streetcar and bus stops becomes less of an issue. When the full east-west streetcar line (Benning Road to Georgetown) is completed, it may be advantageous to implement such a service. However, because the H Street/Benning Road streetcar line that is currently under construction only goes to Union Station, it would be better to provide shared stops so that riders do not need to make a choice in selecting between streetcar and bus. The C option series and Option G1 (See Chapter 4) warrant additional discussion as they are located at the median of the two busiest intersections in the study area.

Proposed Stops at Minnesota Avenue & Benning Road Intersection

Having stop locations on Benning Road as indicated in Option C1 and C3 would be desirable to provide access to the retail areas south of Benning Road (See **Figure 24**). However, these options require a wider bridge cross-section. Furthermore, Option C1 has split stops and may require a new signalized pedestrian crossing for the eastbound stop. Members of the community in attendance at the two public meetings held for the project did not indicate a strong preference towards having a stop presence on Benning Road, but they expressed concerns related to traffic congestion at this location. Therefore, stop locations on Minnesota Avenue as shown on C2 are also acceptable and should be considered.

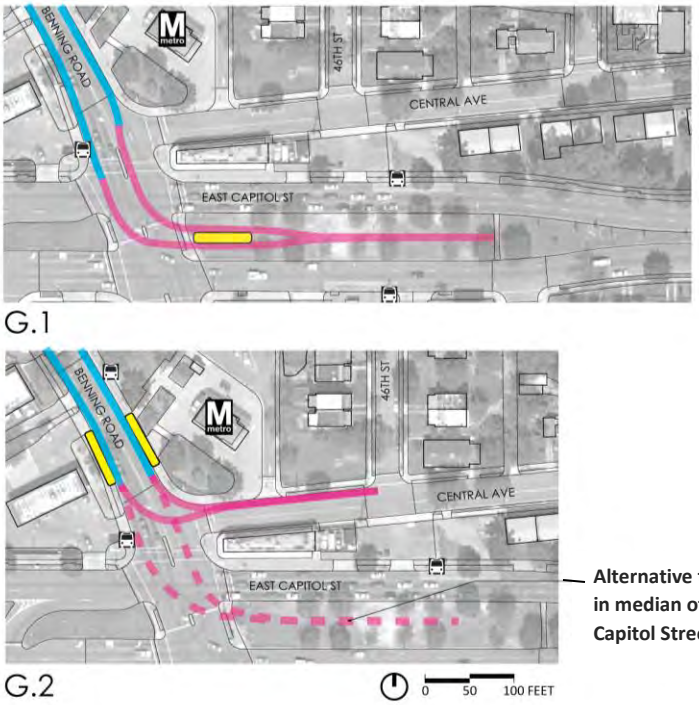
Figure 24: Proposed Stops at Minnesota Avenue & Benning Road Intersection (C-Series)

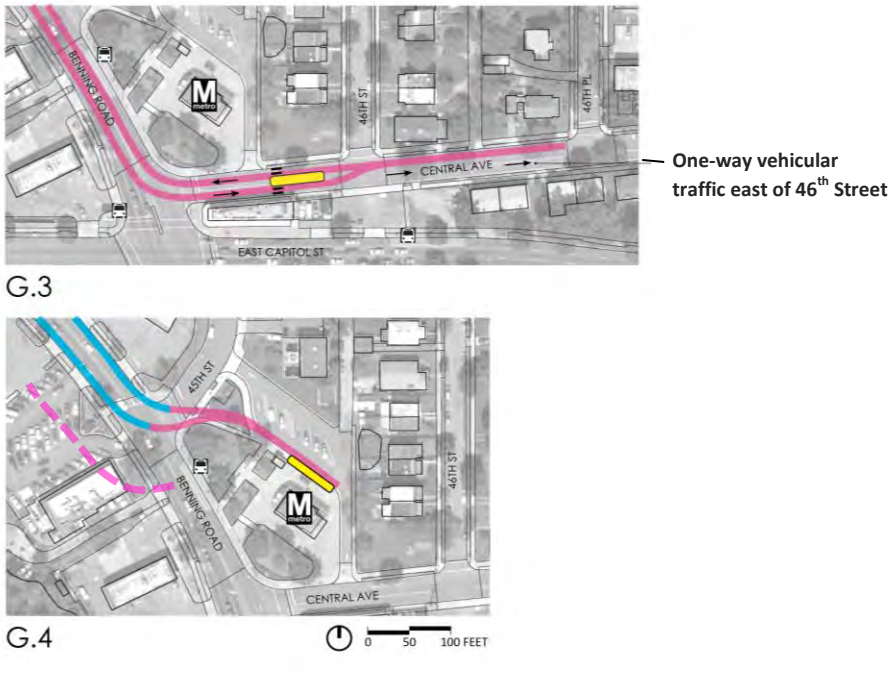


Proposed Stops at East Capitol Street & Benning Road Intersection

As shown in **Figure 25**, Option G1 has the streetcar stop and the turnaround in the median of East Capitol Street. DDOT's East Capitol Street Pedestrian Safety Corridor Study proposes to keep this median to improve the pedestrian environment. Therefore, any potential station design should facilitate improving the pedestrian realm of the median. Options G2 and G3 use Central Avenue for the turnaround area, while G4 uses the kiss & ride area of the Benning Road Metro Station. All options would require a transit-only phase and would equally constrain the traffic operations at this already-busy intersection.

Figure 25: Proposed Stops at East Capitol Street & Benning Road Intersection (G-Series)





5.3 Traffic and On-Street Parking

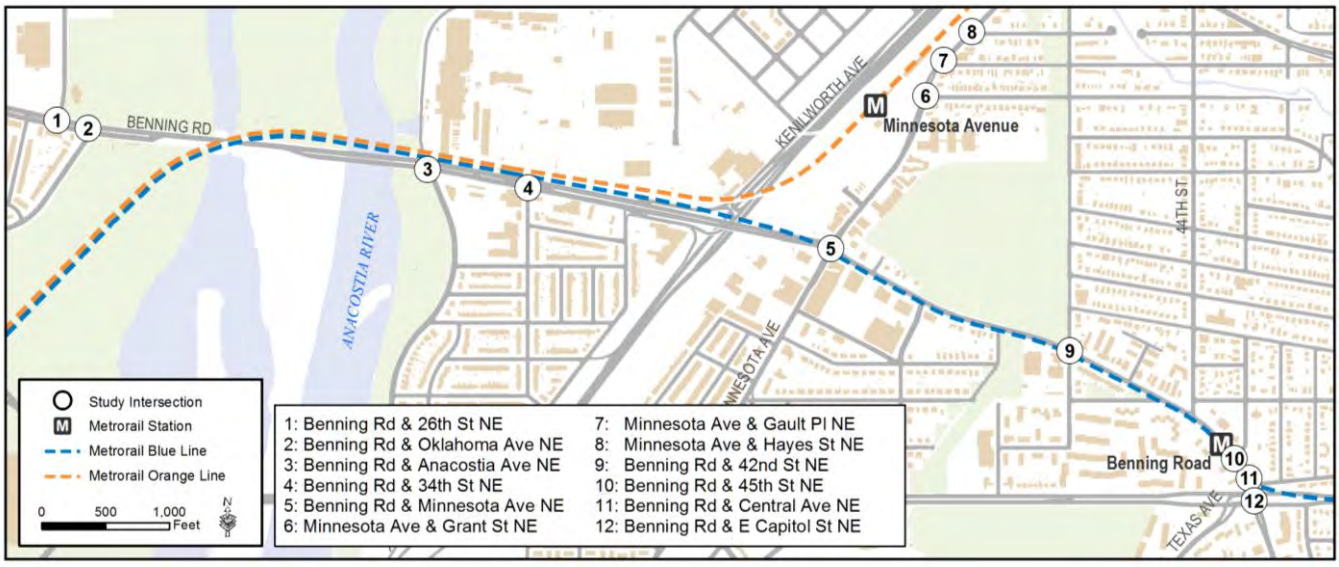
Benning Road is a principal east-west arterial street that links downtown DC to suburban neighborhoods in the District as well as in Maryland. The Average Annual Daily Volume on the Benning Road Bridge segment is estimated to be 44,400 vehicles (Source: DDOT Traffic Volume Map 2010).

Minnesota Avenue is a northeast-southwest minor arterial street that runs parallel to I-295/DC-295 and crosses major intersections such as Massachusetts Avenue, SE, East Capitol Street, Benning Road and Eastern Avenue on the north.

As explained previously, when in mixed traffic, a streetcar operates similar to a public transit bus. However, at certain locations, it may need to transition from a curbside to a center-running configuration. This transition typically happens at a signalized intersection through the use of a transit-only signal phase, which may have some effects on general traffic. Additionally, the large turning radius of the vehicle may require some geometric modifications at the intersections where the streetcar makes a turn, including lane striping changes. Median streetcar stops would require a safe crossing environment for pedestrians. Adequate median space with a safe and accessible walking environment should therefore be provided for median stops. Mid-block median stops may require a signalized pedestrian crossing as well. Finally, streetcar track can potentially be hazardous for bicyclists. A cyclist's tires can become stuck in the narrow flangeway gap next to the running surface of each rail. Bicycle turning movements across tracks are a particular focus of attention, especially where riders cross tracks at shallow oblique angles. In the case of the proposed extension, bicycle accommodations should be relocated when possible to parallel roadways or off street facilities.

This feasibility study analyzed these potential effects associated with a future streetcar line. The study intersections along Benning Road and Minnesota Avenue include eight signalized intersections and four unsignalized intersections, listed below and shown in **Figure 26**.

Figure 26: Study Intersections on Benning Road and Minnesota Avenue



Signalized Intersections:

- Benning Road and 26th Street, NE
- Benning Road and Oklahoma Avenue, NE
- Benning Road and Anacostia Avenue, NE
- Benning Road and 34th Street, NE
- Benning Road and Minnesota Avenue, NE
- Benning Road and 42nd Street, NE
- Benning Road and East Capital Street, NE
- Minnesota Avenue, NE and Grant Street, NE

Unsignalized Intersections:

- Benning Road and Central Avenue, NE
- Benning Road and 45th Street, NE
- Minnesota Avenue, NE and Gault Place, NE
- Minnesota Avenue, NE and Hayes Street, NE

5.3.1 Traffic Operations Analysis

Peak period turning movement counts were performed at the study intersections on Wednesday, September 15, 2010 and Tuesday, June 12, 2012. The AM peak hour and PM peak hour along the Benning Road and Minnesota Avenue corridors at the study intersections were determined as 7:30 a.m. to 8:30 a.m. and 5:00 p.m. to 6:00 p.m., respectively. A traffic operations analysis was performed for the study intersections using Synchro 8.0 and VISSIM based on the methodology outlined in the 2010 edition of the Highway Capacity Manual (HCM). The analysis examined the AM and PM peak hour operational conditions at the corridor intersections for the existing year 2012 conditions, no-build year 2040 conditions, and for the proposed build alternatives for the year 2040. Impacts to peak hour operations were assessed using Measures of Effectiveness (MOEs), including delay expressed as seconds per vehicle (sec/veh) and Level of Service (LOS), for the existing condition and proposed conditions at the study intersections. The detailed analysis results are included in **Appendix E**, Traffic Analysis Technical Memorandum.

Intersection LOS analysis provides a measure of delay and service condition for all approaches to the intersection. The HCM 2010 edition uses LOS as a qualitative measure to describe the operating conditions at signalized and unsignalized intersections based on control delay per vehicle (seconds). The LOS range of A through F represents driving conditions from best to worst, respectively. LOS A represents free-flow conditions with no congestion, and LOS F represents severe congestion, significant delays, queues, and stop-go conditions. For the purpose of this study, LOS D or better was assumed to be acceptable at intersections for urban conditions. **Table 4** presents the LOS thresholds for signalized and unsignalized intersections per the HCM 2010.

Table 4: LOS Thresholds for Signalized and Unsignalized Intersections

Control Delay at Signalized Intersections		Control Delay at Unsignalized Intersections	
Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
<= 10	A	<= 10	A
> 10 – 20	B	> 10 – 15	B
> 20 – 35	C	> 15 – 25	C
> 35 – 55	D	> 25 – 35	D
> 55 – 80	E	> 35 – 50	E
> 80	F	> 50	F

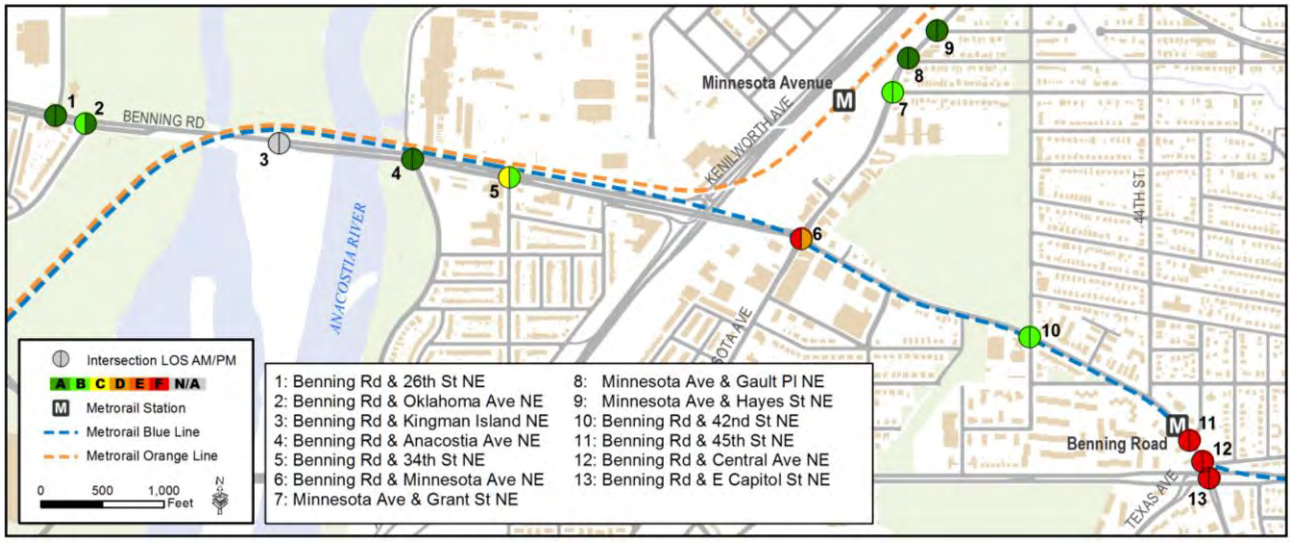
Source: HCM 2010.

The Metropolitan Washington Council of Governments (MWCOG) Version 2.3 Model was used to compare and generate traffic volumes between the years 2012 and 2040 in order to analyze the regional traffic growth patterns. The results from the MWCOG Model show an average 0.86 percent annual growth rate along Benning Road and East Capitol Street between 2012 and 2040. This annual growth rate results in a total growth of 27 percent of existing traffic volumes from 2012 to 2040.

2040 Background (No Build) Traffic Conditions

This section summarizes the delay and LOS results from VISSIM at each study intersection during AM and PM peak hours for 2040 background conditions without streetcar, also referred as No Build. **Figure 27** shows the 2040 background (No Build) traffic operations results. The two most congested intersections in the study area, Benning Road and Minnesota Avenue, and Benning Road and East Capitol Street, operate with a level of service F, while all the other study intersections operate acceptably under 2040 background (No Build) conditions.

Figure 27: 2040 Background (No Build) Intersection Level of Service



Benning Road and Minnesota Avenue

During the AM peak hour, the intersection of Benning Road and Minnesota Avenue is projected to operate at LOS F, with the overall intersection delay of 123.0 seconds per vehicle. Delays in the AM are attributed to the high traffic demand going westbound into downtown and limited existing roadway capacity during the AM peak hour. The Benning Road and Minnesota Avenue intersection is proposed to have a right-turn, two through lanes and a left-turn lane in the southbound direction as part of the Minnesota Avenue Revitalization project. In addition to these capacity improvements, it may be necessary to add a second eastbound left-turn lane to provide adequate capacity by 2040. This improvement needs to be further investigated with the subsequent environmental assessment.

Benning Road and East Capitol Street

The intersection of Benning Road and East Capitol Street is projected to experience long delays (over 200 seconds per vehicle) during both AM and PM peak hours. These delays can mainly be attributed to inefficient traffic operations at the intersection. The existing geometry restricts the possibility of running the eastbound and westbound traffic on East Capitol Street concurrently and the northbound and southbound traffic on Benning Road concurrently, resulting in long wait times for all vehicles at the intersection. The congestion at this intersection also impacts the traffic operations at Central Avenue and 45th Street intersections, which experience LOS F during both AM and PM peak hours. The Benning Road and East Capitol Street intersection would require additional capacity improvements as part of the 2040 No Build conditions.

These potential improvements include the provision of the following:

- Westbound left-turn lane;
- Dual eastbound left-turn lanes;
- Northbound left-turn lane;
- Restriction of Texas Avenue at East Capitol Street to right-in/right-out access; and
- Geometric modifications to the intersection to allow for concurrent left-turns (left-turns occurring at the same time as opposed to the current split phase operation).

The remaining intersections operate under acceptable LOS D or better during the AM and PM peak hours in the 2040 No-Build condition.

2040 Build (With Streetcar) Traffic Conditions

At the intersections which operate acceptably in 2040 conditions, streetcar operations either did not affect the LOS or worsened it by one letter while still maintaining acceptable level of service levels. As explained earlier, the streetcar is assumed to run every 10 minutes, which results in 6 streetcar vehicles/potential transit-only phases per hour per direction. Therefore, not every signal cycle in an hour (usually between 27 to 30 cycles per hour) will experience a transit-only phase, which would last between 10 and 15 seconds. At the two most congested intersections, because they are already at or beyond their traffic operational capacity, streetcar increased delays more significantly than the rest of the study intersections. On-going studies of these intersections are addressing the needs of all users of these intersections, particularly pedestrians.

Benning Road and Minnesota Avenue Intersection

Option C2 would have the least impact on traffic flow because the streetcar vehicle simply follows general traffic. C1 option has split stops on Benning Road, which would slightly increase traffic delay (in the range of two to three percent). Option C3 would increase the intersection delay by about nine percent compared to the 2040 background traffic conditions because it requires a transit-only phase to make a turn from Benning Road onto Minnesota Avenue. The E series options that require track transitions would have a similar impact as in Option C3.

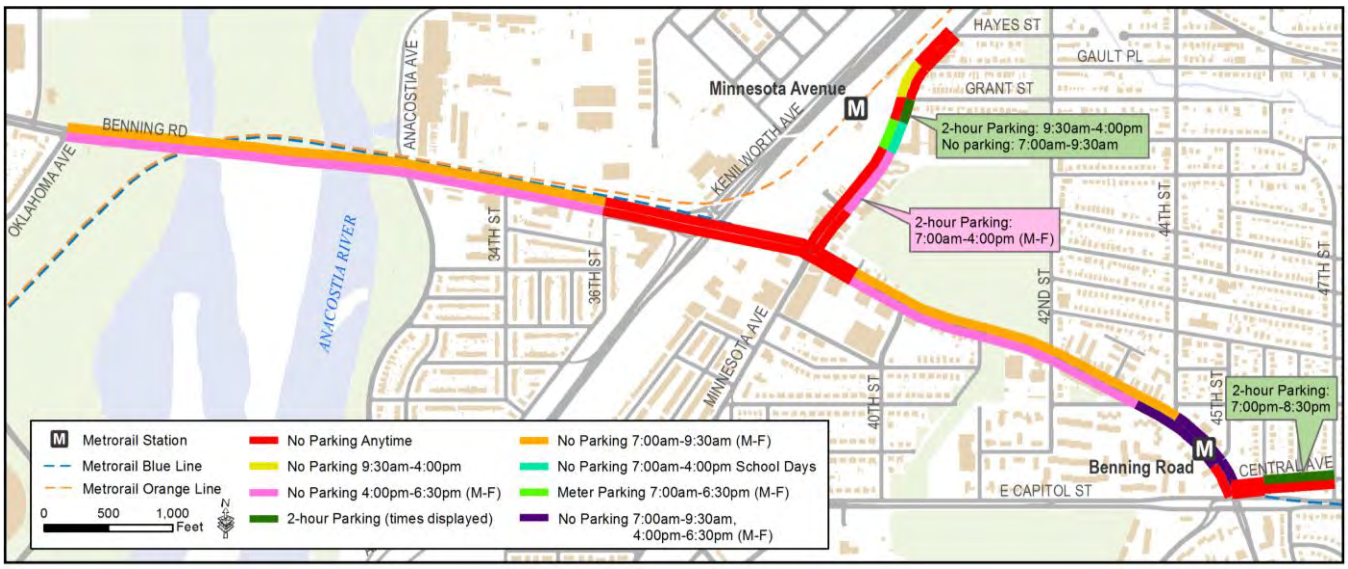
Benning Road and East Capitol Street Intersection

The intersection of Benning Road and East Capitol Street has higher delays than the Benning Road and Minnesota Avenue intersection, so the effects of streetcar would be more pronounced. The delay increase associated with a transit-only phase at this intersection would be about 17 percent.

5.3.2 On-Street Parking Impacts

If on-street parking is currently provided along a roadway segment that is considering a curbside-running streetcar track lane, the parking would need to be eliminated. For example, off-peak on-street parking is provided along segments of Benning Road east of Minnesota Avenue; however, it would not be possible to maintain on-street parking during any periods of the day along roadway segments with curbside-running streetcar tracks. **Figure 28** shows the potential on-street parking conflict on Benning Road if a curb-side running option is considered.

Figure 28: Current On Street Parking Configuration



It is possible to have on-street parking with a curbside running alignment, if parking can be provided to the right of the streetcar track as illustrated in **Figure 29**. However, this would require widening the roadways in the Benning Road corridor.

Figure 29: Illustration of Curbside Running Track with On-Street Parking

5.3.3 Utilities

Because the corridor is located in a fully developed and urbanized location, numerous existing utilities, both aerial and subsurface, are present within the project limits. A limited inventory of existing surface and subsurface utilities was performed using available documentation and observation. Topographical survey and/or geophysical prospecting techniques were not employed at this time but are strongly recommended for further design activities. **Table 5** summarizes the existing utilities found in the study area.

Table 5: Existing Utilities

Utility Type	Utility Owner	Description
Gas	Washington Gas	Underground distribution lines and service connections; size and locations varies.
Water	DC Water (WASA)	Underground distribution lines and service connections; size and locations vary (4" to 30"). Fire hydrants are located throughout corridor.
Electric	Potomac Electric and Power Company (PEPCO)	Aerial – Overhead wires mounted typically to wooden poles are found throughout the project area along both sides of the roadways; size and type unknown. Subsurface – Underground facilities throughout project. Extensive underground transmission and distribution facilities from the western project limit to the Benning Road Viaduct, typically in the westbound roadway, including twin 69kv electric cable pipes and several multi-way duct banks ranging in size from 4-way(W) to 24W ductbanks. Although information is not available for the eastern project area, it is believed that transmission lines are present in and around East Capitol Street. Along Minnesota Avenue, underground electric is typically beneath the southbound lanes except for limited areas between grant and Hayes Streets.
Telephone	Verizon Communications	Aerial – Overhead wires mounted typically to wooden poles are found throughout the project area along both sides of the roadways; size and type unknown. Subsurface – Underground facilities present throughout corridor. Along Benning Road, west of Minnesota Avenue, underground facilities are typically found beneath the eastbound roadway. East of Minnesota Avenue, underground telephone facilities are typically beneath the westbound lane of Benning Road. For the area along Minnesota Avenue, underground facilities are beneath the northbound lanes.
Communication/ CATV	TBD	Aerial – Overhead communication wires mounted typically to wooden poles are observed throughout the project area along both sides of the roadways; size and type unknown. Subsurface – Unknown
Street Lighting	District Department of Transportation	Street lighting is present throughout the project limits including bridge mounted lights. Luminaires are typically cobra-head style mounted on aluminum poles or wooden utility poles. Along Benning Road and Minnesota Avenue, lighting mounted to wooden poles are fed from an overhead power source, whereas bridge-mounted street lights are on dedicated aluminum poles and fed via underground service.
Traffic Signals/ Enforcement	District Department of Transportation and Metropolitan Police Department	DDOT standard traffic signals, control cabinets, and cameras and devices are present throughout the project and are typically surface mounted on a standalone pole or foundation. DDOT cameras are typically for traffic surveillance while the MPD owned facilities are for red light and speed enforcement. Underground facilities including manholes, hand holes, and conduit are also present to services the aboveground equipment. Size and location of underground facilities are unknown.
Sanitary Sewer	DC Water (WASA)	Underground service connections and trunk lines are located throughout the project limits, primarily along Minnesota Avenue and along Benning Road east of Minnesota Avenue; size and location varies.
Storm Drainage	DC Water (WASA)	Storm runoff is conveyed by gutters to catch basins; size and location of drainage piping varies.
Rail	Washington Metropolitan Transportation Authority (WMATA) and CSX	Project is adjacent to WMATA and CSX facilities. As such, underground utilities may be present. Project crosses beneath and over existing rail facilities.

As stated, this inventory of existing utilities is limited and as such all utilities may not be accurately accounted. It is recommended that coordination with facility owners occur as the design advances. Based on District guidelines, where existing utility information is not available or is incomplete, the minimum depths to top of utility shown in **Table 6** have been used:

Table 6: Utility Depth

Utility Type	Minimum Depth
Gas	3 feet
Water	4 feet
Sanitary Sewer	10.5 feet
Storm Drainage	5.5 feet

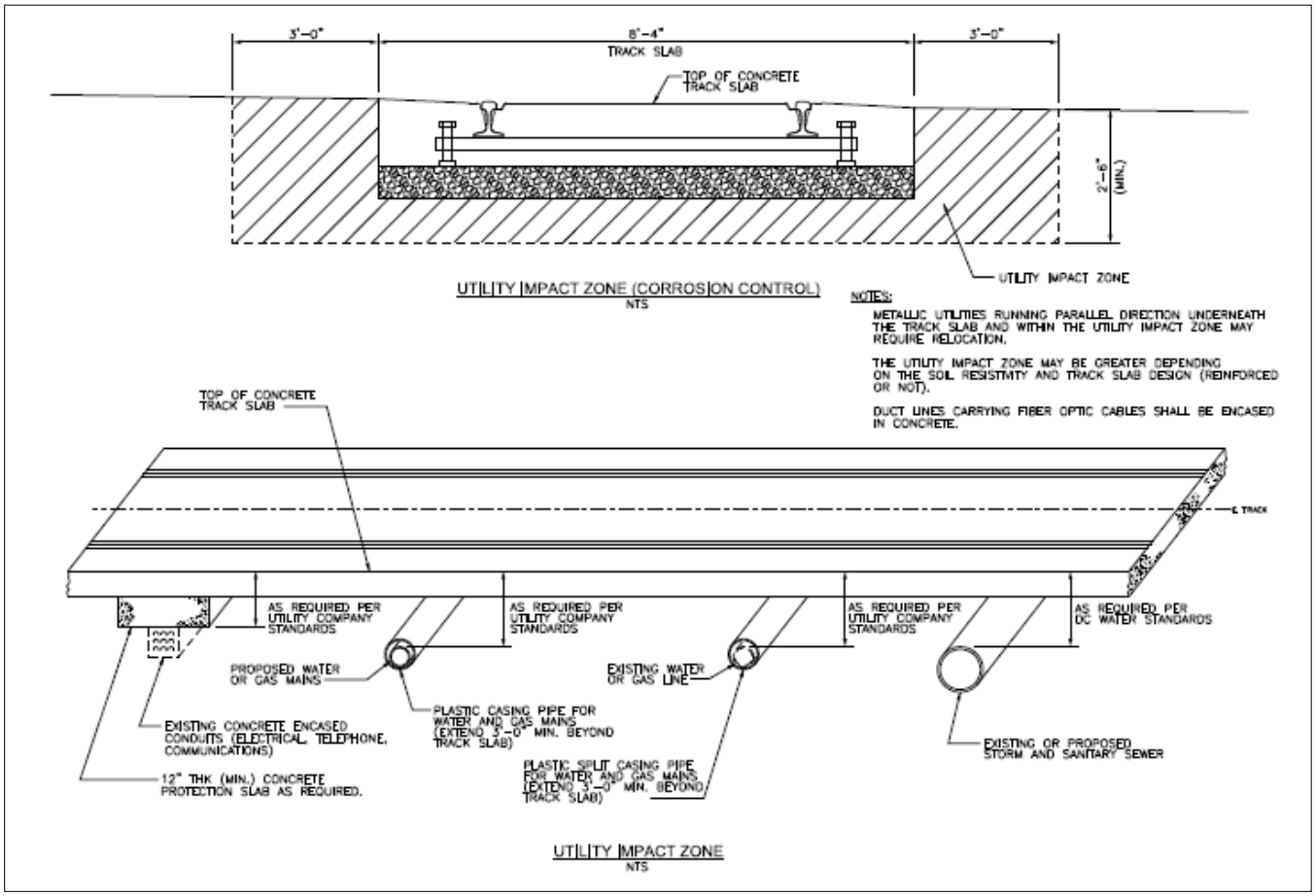
Conflict Assessment

To minimize future disturbances to the streetcar line, a utility-free envelope is used in this study to identify of conflicts with existing utilities and the placement of proposed utilities. This utility-free envelope is the width of track slab and has nominal depth of 30 inches (see **Figure 30**). Existing utilities that cross beneath this envelope in a perpendicular fashion are typically considered not to be in conflict for the purpose of this feasibility study. However, significant costs would be incurred if a utility does not permit their facility to perpendicularly cross beneath the track slab because construction of a new separate main to eliminate crossing laterals would be required. Such action is not considered by this study at this time.

Pending direction from utility owners or results of subsurface investigation to occur in future design phases, existing utilities are considered to be in conflict under any of the following conditions:

- If they are located underneath the streetcar alignment within the required depth running in any horizontal direction.
- If they are deeper than the 30 inch envelope depth but running parallel and beneath the slab as this would limit access to the utility for future maintenance or repair of the utility line.
- Other, as directed by utility company standards and minimum offsets.

Figure 30: Utility Impact Zone



Source: DDOT, DC Streetcar Design Criteria, 2012

In addition to conflicts associated with the above mentioned slab envelope, conflicts with existing utilities will also occur as a result of required changes to curb lines and medians, proposed platforms, dedicated guideway infrastructure, and other streetcar facilities such as specialized track work.

For those existing utilities that are not in direct conflict, and/or for proposed utilities, protection measures are required within a three-foot buffer surrounding the track slab (see **Figure 30**). One reason for this measure is to provide corrosion control. For existing and proposed water and gas lines, a plastic casing pipe (split pipe for existing utilities) is recommended beneath and extending three-feet beyond the slab. For utilities in encased conduits (underground electric, telephone and communication) a one-foot thick concrete slab is recommend to be placed above the ductbank.

Utility Conflicts

Using available utility information, an assessment of potential conflicts was conducted for the different terminus and alignment alternatives being considered. Generally, numerous underground utilities are in conflict with the proposed streetcar throughout the corridor and above ground utilities are impacted at select locations, typically where side running options are proposed. For purposes of this study, additional conflict length was assumed at locations where the streetcar alignment transitions from center to side running, or vice versa, to account for design refinements or utility work zones. Conflicts have been grouped by alignment option and utility type for ease of comparison and assembly of terminus

alternative layouts; a complete tabular listing is located in the **Appendix F,** Utilities Technical Memorandum. **Table 7** below is a summation of key conflicts between existing utilities and proposed streetcar alignments.

Table 7: Summary of Key Utility Conflicts by Project Segment

Project Segment	Terminus Alternative(s)	Alignment Option(s)	Key Utility Conflicts
Benning Road from 26th Street to Benning Road Viaduct	Minnesota Avenue Metro Terminus and Benning Road Metro Terminus	X1 and X2 A1 and A2 B1, B2, and B3	• Extensive underground electric, water, and gas lines run parallel and beneath slab of center running and side running alignments. Electric facilities include transmission and distribution feeders. • Numerous utilities including gas, water, electric, and telephone carried beneath Bridge 52 and Bridge 77. Selection of build-up or build-down concept will determine impacts and relocation strategy. • Utility poles with aerial facilities, street lights, and traffic signals impacted with side running option B3 between Anacostia Avenue and 34th Street.
Benning Road from Benning Road Viaduct to Minnesota Avenue Intersection	Minnesota Avenue Metro Terminus and Benning Road Metro Terminus	Mainline C1, C2, and C3 E1, E2, and E3	• Underground gas and electric impacted by center running alignment in vicinity of viaduct. • Extensive above and below ground conflicts at Minnesota Avenue intersection for all options. • Utility poles with aerial facilities, street lights, and traffic signals impacted with side running options.
Minnesota Avenue from Benning Road to Hayes Street	Minnesota Avenue Metro Terminus	C1, C2, and C3 D1 and D2	• Underground water, gas and telephone facilities conflict with side running options. • Limited impacts to utility poles with aerial facilities and street lights with side running options along southbound roadway in vicinity of Grant Street to Hayes Street.
Benning Road from Minnesota Avenue to East Capitol Street	Benning Road Metro Terminus	E1, E2, and E3 F1 and F2 G1, G2, G3, and G4	• Impacts to aboveground facilities along westbound Benning Road associated with E series, and along both sides of roadway with F and G alignment options. • Underground water and telephone conflicts. • Full extent of utility impacts is unknown in the vicinity of Benning Road Metro Station and East Capitol Street due to lack of available data.

To facilitate the streetcar line, structural work on the bridges is required; this work will impact existing utilities. Within the study limits, Benning Road includes three bridge structures: Bridge 77 over Kingman Lake, Bridge 52 over the Anacostia River, and the Benning Road Viaduct (two parallel structures for eastbound and westbound traffic) over Kenilworth Avenue, Anacostia Freeway and the CSXT tracks. Bridges 52 and 77 will be modified to allow for proposed streetcar infrastructure, but the viaduct will be replaced in its entirety (this work is being designed by others) and will require utility relocations to accept embedded track slab. Impacts to utilities carried by bridges 52 and 77 will greatly depend on whether the streetcar track is placed in a shared lane with vehicular traffic or has its own dedicated lane that is raised similar to a median. At this time, selection of the shared use option will affect existing utilities mounted to the underside of the existing deck slab. At a minimum, existing utilities will require temporary support and reattachment as the deck is replaced to accommodate embedded track. A better assessment of the extent of impacts will require further coordination.

Similarly, additional utility conflicts may arise where specialized trackwork is required at the Minnesota Avenue intersection. Because intersecting track alignments must maintain the same grades, and hold a flat cross-slope relative to top of rail at all special trackwork elements, re-grading the entire intersection and its approaches may be necessary. This would affect additional utilities that are beyond the track slab conflict zone and may entail resetting of valves, manholes, fire hydrants, traffic signal equipment, utility poles, and street lights. These related grading conflicts are not itemized in **Appendix F**.

5.4 Systems Requirements

The streetcar vehicles on the line are propelled by electric powered traction motors, which draw energy from a source external to the vehicle. The components which deliver this power are defined as the Traction Power Supply and Distribution system. The Traction Power Supply and Distribution system draws power from an outside source, typically a public utility, converts the power to the form required for use by streetcar vehicles at a series of fixed installations known as Traction Power Substations (TPSS), and delivers it to the transit vehicle via an overhead contact wire system (OCS), known as a catenary. The power is transferred from the OCS to the streetcar vehicle via a pantograph, which is mounted on top of the streetcar vehicle and maintains continuous contact with the catenary wire while in operation. The Traction Power Supply and Distribution system consists of the following:

- Connection between the external power system and the TPSS;
- All internal equipment within the TPSS required to modify the power;
- Distribution conduit from the TPSS to the guideway, including undergrade duct bank;
- Catenary wire;
- Structural system for maintaining catenary height and alignment; and
- Running rails, rail bonding, and return cabling which complete the path of electric current back to the TPSS.

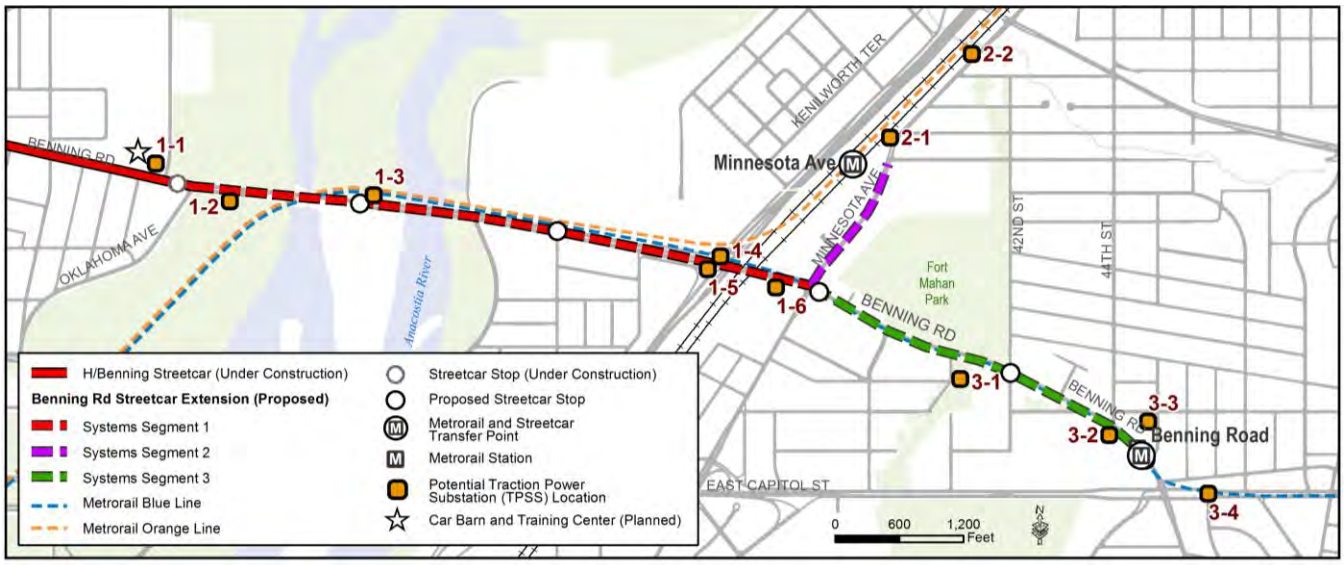
For purposes of the TPSS study, the terminus options were not analyzed separately, and the overall alignment was broken into three segments, referred to as “Systems Segments” (see **Figure 30**). The segments are as follows:

- **Systems Segment 1** – Benning Road between the eastern terminus of the H Street/Benning Road project and the Benning Road/Minnesota Avenue intersection (approximately 0.6 miles in length);

- **Systems Segment 2** – Benning Road between the Benning Road/ Minnesota Avenue intersection and the Benning Road/East Capitol Street intersection (approximately 0.8 miles in length); and
- **Systems Segment 3** – Benning Road between the Benning Road/ Minnesota Avenue intersection and the Metrorail Station on Minnesota Avenue (approximately 0.3 miles in length).

The study assumed that one TPSS would be located in each Systems Segment. In terms of the two terminus options considered in the study, Systems Segments 1 and 2 would comprise the Minnesota Avenue Metrorail Station Terminus Option, and System Segments 1 and 3 would comprise the Benning Road Metrorail Station Terminus Option. **Figure 31** shows the potential TPSS locations in each systems segment.

Figure 31: Potential Traction Power Substation Locations



Only one TPSS may be necessary for each Systems Segment. As the project progresses to the next phase, the following tasks are recommended to be completed:

- Research right-of-way for each of the potential locations identified in this report. Focus on DDOT right–of-way first, then private right of way. Right of way values should be developed for purposes of cost estimating.
- Perform a traction power modeling study to validate the number of TPSS proposed in this study. The parameters/design criteria for this study are very well defined in the DC Streetcar Design Criteria, Chapter 13.
- Develop architectural decorative enclosure renderings for the TPSS units. DDOT may either choose to use previously developed decorative enclosures or develop new ones that better complement the existing communities. While the TPSS enclosure is not important from an overall engineering and construction perspective, it will be important when presenting to the public for location of a TPSS in the community.
- Commence discussions with the local power utility. Determine if capacity of existing system is sufficient to support the streetcar requirements. Understand the availability of existing utility lines to serve the substations. This will be one of several factors to be considered in selecting the TPSS locations.

5.5 Environmental Constraints

A preliminary environmental scan was conducted for the two proposed streetcar alignments. The alignments were reviewed for conformance with local land use, zoning and local plans, as well as potential effects on neighborhoods and community resources, environmental justice, parks and parklands, historic and cultural resources, property acquisition and displacements, traffic, hazardous and contaminated materials, air quality, noise and vibration, water resources, protected species and habitats, utilities, and construction impacts.

Figures 32 and 33 show the environmental constraints identified during this review. Existing conditions and specific findings for each environmental resource are attached as **Appendix G**, Environmental Constraints. Key findings of the environmental scan are summarized below:

- **Conformance with Local Plans** – Relevant plans refer to extending the Benning Road Streetcar to the Benning Road Metro Station or the Minnesota Avenue Metro Station, none discuss the option for interoperability between the two termini.

- **Parks and Parklands** – The National Park Service (NPS)-owned Fort Mahan Park (See image, left), abutting Alignment 1, may be affected if any right-of-way for project facilities is needed. Potential impacts would need to be documented as part of a Section 4(f)/ Section 6(f) Evaluation in a later detailed environmental study.

- **Cultural Resources** – The Langston Golf Course located west of the Anacostia River and north of Benning Road and the Fort Mahan Park abutting Alignment 1 are listed on the National Register of Historic Places. Any potential impacts would require Section 106 documentation as part of a detailed environmental study.

- **Noise and Vibration** – A number of sensitive noise receptors exist along both alignments (e.g. schools, churches and the Benning Library (See image, left). Noise and vibration for construction and operation of the streetcar would need to be assessed in a detailed environmental study.

- **Hazardous Materials** – For a PEPCO power plant, which is a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site, and a number of other Recognized Environmental Condition (REC) sites (e.g. gas stations) that may exist along both alignments, further assessment during a detailed environmental study would be needed.

Mahan Park

Benning Library

Figure 32: Environmental Constraints- Alignment 1 (Benning Road Terminus Station)

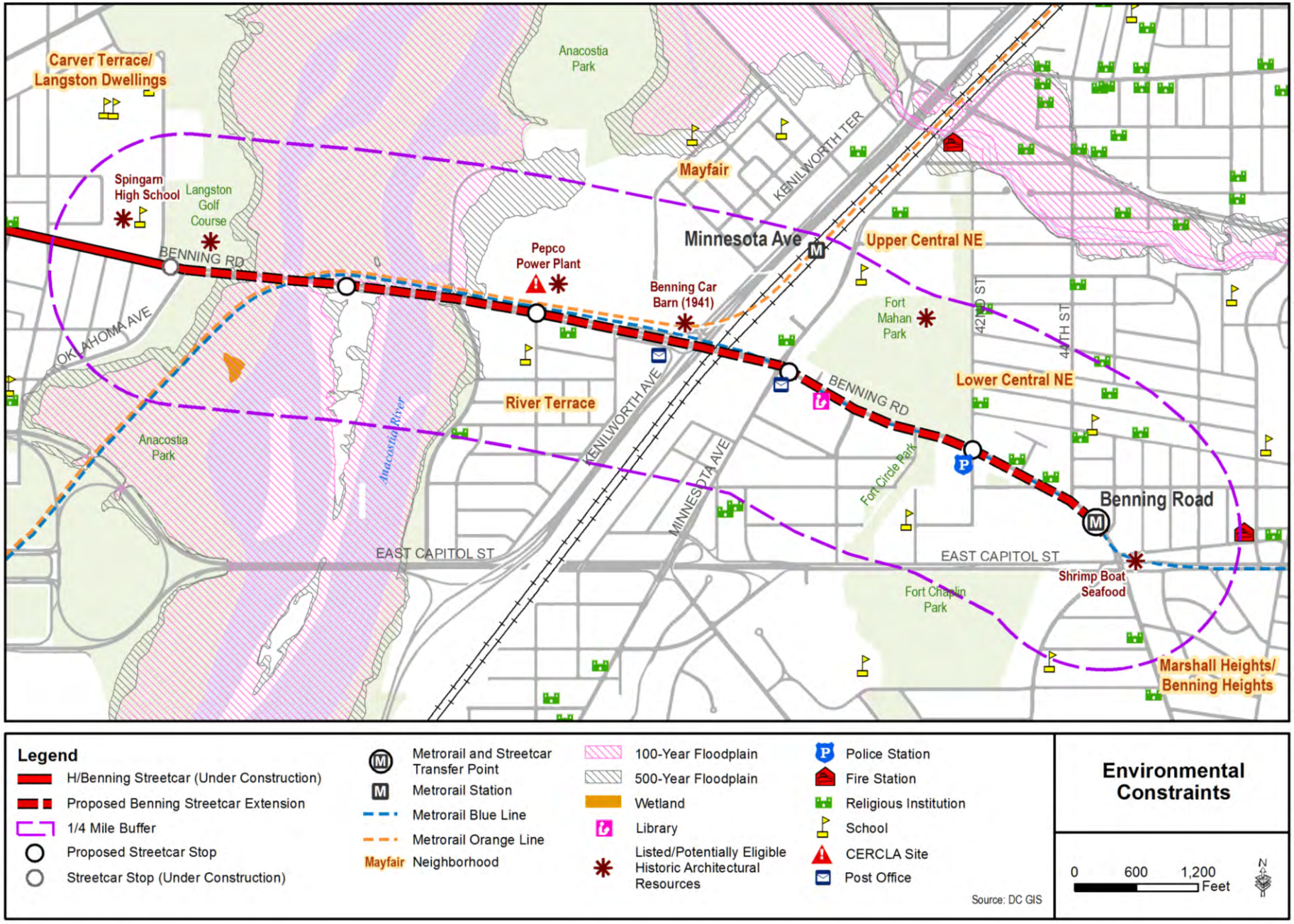
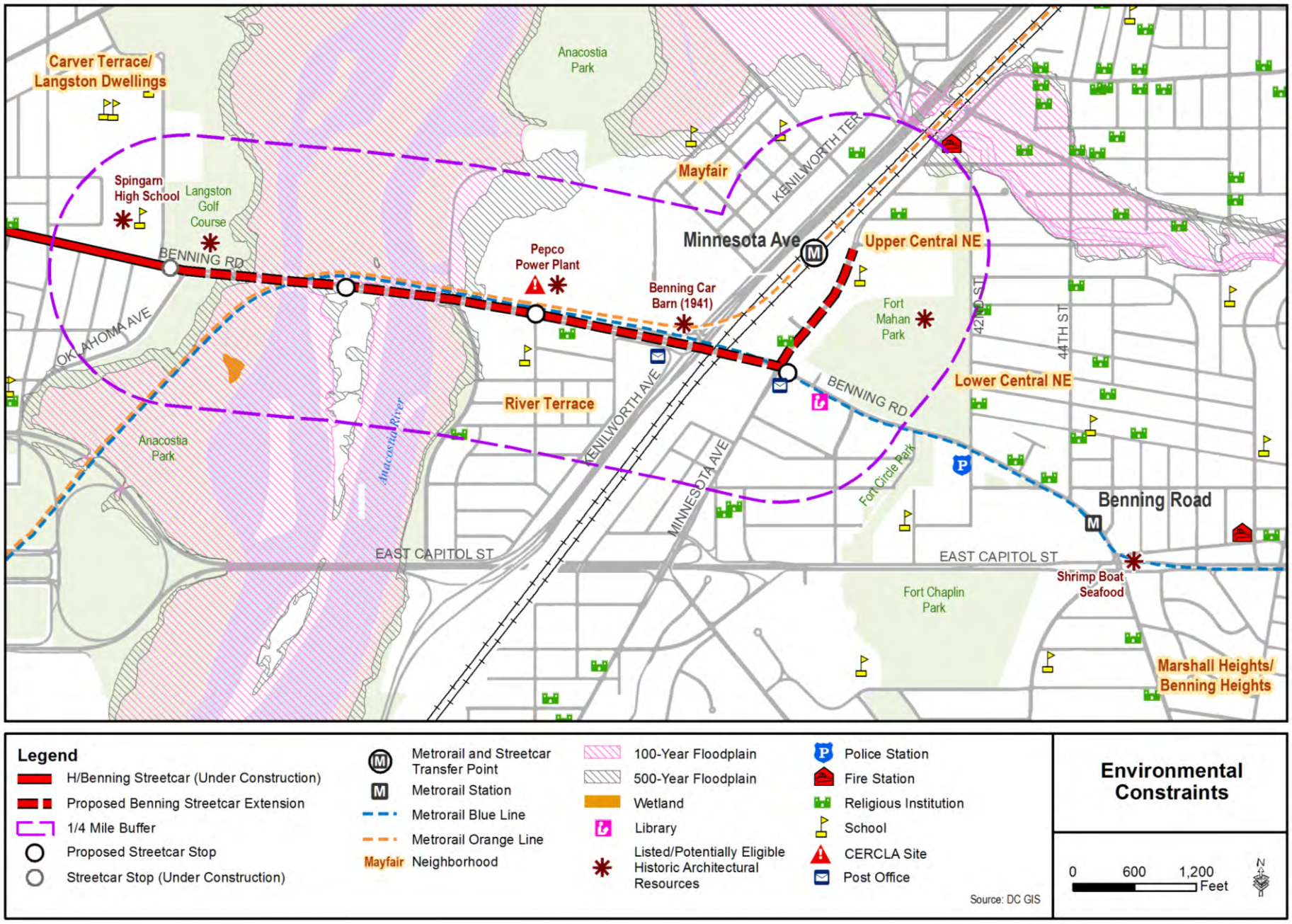


Figure 33: Environmental Constraints- Alignment 2 (Minnesota Ave.)



6.0 Ridership Forecasts

Based on the ridership forecasts prepared for the project using the regional forecasting model, the Benning Road Streetcar Extension segment is projected to have approximately 550 and 3,500 daily riders for the Minnesota Avenue Terminus Option and the Benning Road Terminus Option, respectively by 2040. These values are in addition to the projected initial Oklahoma Avenue to Union Station H Street/Benning Road Streetcar segment daily ridership of 4,250. The increased ridership for the Benning Road Metro Station Extension is likely due to the additional stop (5 total stops compared to 4 stops **Table 8** summarizes the ridership projections. **Appendix H**, Ridership Forecasts, provides more detailed information.

Table 8: 2040 Projected Daily Streetcar Ridership

Streetcar Segment	2040 Daily Streetcar Ridership*
Initial H Street/Benning Road Streetcar Line between Oklahoma Avenue and Union Station (under construction)	4,250
1) With Benning Road Metro Station Extension	7,750
2) With Minnesota Avenue Metro Station Extension	4,800

*Assumes that no buses are removed from service as planned; land use reflects 2040 Metropolitan Washington Council of Governments (MWCOG) forecasts.

7.0 Capital and Operating Cost Estimates

7.1 Capital Costs

The preliminary capital cost estimates for the two termini options are estimated for the project as shown in **Table 9**. The preliminary estimates include a 50 percent contingency to account for uncertainties and result in costs in the order of $41 million to $48 million per mile. As the design of the project advances, this contingency can be reduced. The estimates do not include potential right of way acquisition costs, or costs for reconstructing Benning Road Viaducts and the intersection of Benning Road and Minnesota Avenue.

Table 9: Preliminary Capital Cost Estimates

Streetcar Segment	Preliminary Cost Estimate (2012 Dollars)
Benning Road Metro Station Extension	$78,054,000
Minnesota Avenue Metro Station Extension	$70,811,000

The preliminary capital cost estimates consist of guideway and track elements, station stops, systems, utilities, traffic signals, vehicles, professional services and contingencies. The detailed cost calculations are included in **Appendix I**, Capital and Operating Cost Estimate Calculations.

7.2 Operating and Maintenance (O&M) Costs

O&M costs for the proposed service were estimated based on O&M costs per revenue vehicle hour of similar streetcar services operating in the United States. These unit costs take into account annual recurring costs associated with labor, material and supplies, utilities, and fuel, and include costs for rail vehicle operations, vehicle maintenance, non-vehicle maintenance, and administrative activities. Unit costs for operating and maintenance expenses were estimated to be $224.09 per revenue hour. **Tables 10** and **11** show the O&M costs for the two terminus options.

Table 10: O&M Cost for the Minnesota Avenue Metrorail Station Terminus Option*

Streetcar Segment	Annual Revenue Hours	Preliminary Cost Estimate (2012 Dollars)
Union Station to Minnesota Avenue Metrorail Station	51,568	$11,556,000
Minnesota Avenue Metro Station Extension Only (starting from Oklahoma Avenue)	21,582	$4,836,000

*The operating costs were allocated based on travel time proportions of the extension segment to the overall alignment from Union Station to Minnesota Avenue Metrorail Station.

Table 11: O&M Cost for the Benning Road Metrorail Station Terminus Option*

Streetcar Segment	Annual Revenue Hours	Preliminary Cost Estimate (2012 Dollars)
Union Station to Benning Road Metrorail Station	51,568	$11,556,000
Benning Road Metro Station Extension Only (starting from Oklahoma Avenue)	24,153	$5,413,000

*The operating costs were allocated based on travel time proportions of the extension segment to the overall alignment from Union Station to Benning Road Avenue Metrorail Station.

8.0 Conclusion and Next Steps

DDOT will study in more detail the options to extend the current H Street/Benning Road streetcar alignment either to the Minnesota Avenue Metrorail station or the Benning Road Metrorail station. Both terminals are centers of activity and offer multimodal connections. The Benning Road Metrorail station terminus option offers more riders (by about 3,000 daily riders) compared to the Minnesota Avenue Metrorail station terminus option. However, it also comes with a 10 percent higher capital cost. Both options require the following accommodations:

- Structural modifications to the existing bridges
- Potential roadway widening
- Significant utility coordination and relocation
- Reprofiling of the Benning Road and Minnesota Avenue intersection
- Several TPSS installations
- Potential right-of-way needs at the termini locations to accommodate stops and turnaround area

The next steps in project development include an environmental document of the various impacts associated with the streetcar and related roadway improvements. DDOT's plan to reconstruct the Benning Road Viaduct should be done in a fashion that does not preclude future streetcar plans. Additionally, any future design or construction activities in the study area (on Benning Road or on Minnesota Avenue) should consider the future streetcar alignments.

There is a need for traffic operations and pedestrian safety improvements at several locations in the study area. The Benning Road and Minnesota Avenue is one of those locations and requires a system-level thinking (i.e. better street grid and connectivity) as opposed to only localized, spot improvements. The multimodal operations and the needs of streetcar need to be studied in more detail between the intersection and the Minnesota Avenue Metrorail station including the kiss & ride area, which could potentially be used for a streetcar turnaround area.

The environmental process will require continued coordination with agencies as well as the public in order to arrive at the best solutions from the transportation and community perspectives.

Prepared for:

District of Columbia Department of Transportation
Washington Metropolitan Area Transportation Authority

Prepared by:

AECOM