

## **ITEM 10 - Information**

October 19, 2011

### Briefing on a New Sensitivity Test for the CLRP Aspirations Scenario

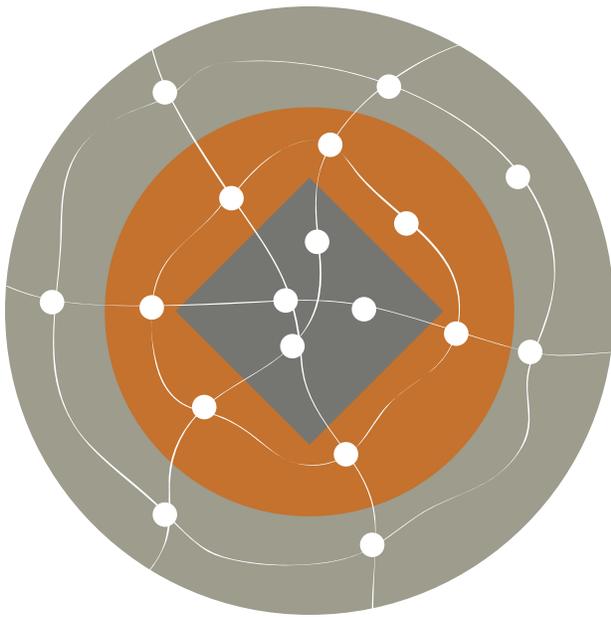
**Staff Recommendation:** Receive briefing on the results of a sensitivity test of the CLRP scenario that analyzes the impact of a lower-cost “streamlined” variably priced lane network with less new construction and more conversion of general purpose lanes to variably priced lanes.

**Issues:** None

**Background:** The “CLRP Aspirations” scenario, completed and reported to the TPB in September 2010, integrates a regional network of toll lanes and bus rapid transit with more concentrated growth in mixed-use activity centers.

# TPB CLRP Aspirations Scenario

Streamlined Variably Priced Lane Network Sensitivity Test



Draft Technical Memorandum  
September 30, 2011

National Capital Region Transportation  
Planning Board

COG/TPB Staff

Ronald F. Kirby

Director, Department of Transportation Planning

Erin M. Morrow

Transportation Engineer III

Jinchul Park

Senior Transportation Engineer

Eric Randall

Senior Transportation Engineer

Daivamani Sivasailam

Principal Transportation Engineer

Daniel Hojun Son

Transportation Engineer II

\*\*\*

### **Acknowledgements**

The report authors and staff would like to acknowledge and thank additional COG/TPB staff who provided assistance: Dusan Vuksan, Feng Xie, Jane Posey, William Bacon, and John Swanson.

**ABSTRACT**

In September 2010, the final results of the CLRP Aspirations Scenario Study were presented to the National Capital Region Transportation Planning Board (TPB). The CLRP Aspirations Scenario examined an alternate future for the region in which forecasted households and jobs were redistributed to targeted growth areas and modeled with extensive variably priced lane (VPL) and bus rapid transit (BRT) networks designed to increase accessibility to these areas. This memorandum presents the results of a sensitivity test conducted with a “streamlined” VPL network which was conducted in response to concerns about the high cost for the construction of the VPL network in the CLRP Aspirations Scenario.

All of the maps referred to in this memorandum are included in Attachment A.

## **INTRODUCTION**

The National Capital Region Transportation Planning Board's (TPB) Constrained Long Range Plan (CLRP) Aspirations Scenario was developed in an effort to pull together alternatives from previous TPB scenario studies into a comprehensive scenario that could offer a promising path forward for the region. The CLRP Aspirations Scenario is an alternative land use and transportation scenario for the year 2030 whose purpose is not just to explore a single regional challenge or experiment with a single strategy, but instead to take a comprehensive approach to long-range regional planning. The Aspirations Scenario combines an alternate land use scenario with more dense, transit-oriented development; a regional network of variably price lanes (VPLs); and high quality bus rapid transit (BRT) and circulator bus service focused on supporting the land use plan. The final report for the CLRP Aspirations Scenario study was completed and presented to the TPB in September 2010. (1) This memorandum reviews the performance of the Aspirations scenario and a land use sensitivity test that were presented in the report, and discusses a new VPL network sensitivity test which seeks to reduce construction costs without significantly compromising the performance of the VPL network.

## **PREVIOUS SCENARIO STUDIES**

As the Metropolitan Planning Organization (MPO) for the Washington region, the TPB is responsible for producing the Financially Constrained Long-Range Transportation Plan, or CLRP, which includes all regionally significant transportation projects and programs that are planned in the Washington metropolitan region over at least the next 20 years. (2) In 2000, the TPB launched the Regional Mobility and Accessibility Study (RMAS) to study land use and transportation improvements beyond the 2000 CLRP that would "improve mobility and accessibility among and between regional activity centers." (3) The RMAS evaluated five different alternative land use scenarios for the year 2030 which included shifting more households into the region, moving some projected household growth from the outer jurisdictions to the inner jurisdictions, moving some projected job growth from the inner to the outer jurisdictions, moving some projected job growth from the western side of the region to the eastern side, and moving some projected job and household growth closer to transit. (3) All of the RMAS scenarios had supporting transportation, mostly transit, improvements. All of the scenarios produced positive results, as compared to the CLRP, by slowing the anticipated growth in congestion and driving, and in most cases, increasing transit use. (1)

In 2006, TPB launched a variably priced lanes (VPL) study to analyze the potential effects of a variably priced lane network in the Washington Region. Three different scenarios looked at options for adding capacity to the region's freeways and arterials in the form of VPLs, pricing selected existing roadways in the District of Columbia, pricing the region's parkways, and adding high quality bus rapid

transit in the priced lanes. (4) The results of this study demonstrated that toll rates would vary significantly by direction, time period, and facility in order to maintain free-flow conditions. (1) A financial analysis of the scenarios showed that the scenario which incorporated all of those options (Scenario CP) was the only one that was financially feasible in that the total toll revenues approximately equaled the costs of constructing and operating the VPL network. Work related to this study was presented at the 88<sup>th</sup> Annual Meeting of the Transportation Research Board. (5)

## **THE CLRP ASPIRATIONS SCENARIO STUDY**

### **Baseline**

The Baseline for the CLRP Aspirations Scenario Study contains all of the highway and transit projects adopted for 2030 by the TPB in its 2008 CLRP. These include two high-occupancy/toll (HOT) lane corridors in Virginia: I-95/I-395 from the District of Columbia line to VA 610 in Stafford County, and I-495 (Capital Beltway) from just south of the American Legion Bridge (Maryland Line) to the I-95/I-395 interchange. There is one all-VPL facility in Maryland, the Intercounty Connector (ICC). The land use forecast for 2030 is the Round 7.2 forecast developed by Metropolitan Washington Council of Government's (COG) Metropolitan Development Policy Committee and approved by the COG Board of Directors in 2009.

### **CLRP Aspirations Scenario**

The full CLRP Aspirations Scenario contains land use and transportation components that were developed to work with and complement each other.

#### *Land Use Component*

The land use component focuses on shifting projected household and employment growth into "targeted growth areas" such as COG's Regional Activity Centers and areas around planned or existing transit infrastructure. (1) A "More Households" strategy from the RMAS was used to improve the jobs/housing balance in the region. Some forecasted job and household growth was shifted from outside the region to increase the number of households by 3.5% and the number of jobs by 1%. (1) After developing the basic framework for the scenario, TPB staff met with planning and transportation staff from local jurisdictions to discuss details of the land use assumptions and obtain comments for incorporation into the plan. All targeted growth areas received residential and employment growth in order to be transit supportive, walkable, and mixed use while reflecting local-level planning realities. (1) Under the CLRP Aspirations land use plan, an additional 11% of job growth and 42% of household growth occurs in targeted growth



### *Transportation Component*

The transportation component contains three elements: a regional network of priced lanes, an extensive bus rapid transit (BRT) network, and selected transit projects identified by the RMAS.

The scenario's transportation component focuses on supporting the land use component by providing "increased accessibility to the targeted growth areas, specifically for transit riders, carpools, and those willing to pay tolls to drive low-occupant vehicles on variably priced lanes." (I) The first element, a regional network of priced lanes, is based on Scenario CP from the TPB's VPL study described earlier. The following general guidelines went into developing the network: all freeways in the region have two VPLs in each direction with 24/7 operation (all high-occupancy vehicle (HOV) lanes are converted to VPLs and new lanes are added as needed to meet that goal); major arterials have one VPL added in each direction outside of the Beltway, all Potomac and Anacostia River crossings are tolled; and existing lanes of parkways (operated by the National Park Service) are tolled. Additional facilities are tolled as needed to alleviate chokepoints and create connectivity amongst the corridors. The priced lane network creates a total of 1,740 miles of VPLs in the region, with 959 of those being new lane miles of construction. Map 1 shows the construction of and conversion to VPLs and Maps 2.1 and 2.2 show the operational characteristics of the full VPL network in the AM and PM peak periods. Map 3 shows the lane configuration on major bridges.

The second element, a high-quality 500 mile BRT network, takes advantage of the regional network of priced lanes and is integrated with the region's Metrorail system. The BRT network provides service to new BRT stations in the regional activity centers, and makes connections to Metrorail stations and existing park-and-ride lots. The BRT network is complemented by 140 miles of circulator bus service. Map 4 shows the BRT network.

The third element comprises selected projects from the RMAS study that were added to fill in missing links in the transit network. These projects include the Purple Line Extension from Silver Spring to New Carrollton (which has since been added to the CLRP), the Georgia Avenue Transitway from Glenmont to the ICC, the US 1 Transitway from King Street Metrorail to Potomac Mills, and the VRE Extension from Manassas to Haymarket. (I)

### **Sensitivity Tests**

After the analysis of the Full scenario was completed, two sensitivity tests were conducted to separately study the effects of land use changes and pricing.

### *Land Use Only Scenario*

A land use sensitivity test was conducted using the highway and transit networks from the Baseline, and the land use component of the CLRP Aspirations Scenario, with the goal of studying the impact of land use changes alone on the performance of the transportation network. An analysis of this sensitivity test was included in the CLRP Aspirations Scenario Final Report.

### *Streamlined VPL Network Scenario*

The streamlined toll network sensitivity test was conducted after the final CLRP Aspirations Scenario report was released in response to comments that the costs for constructing the priced lane network in the Full scenario were quite high and not in keeping with the goal of the scenario being “within reach.” (1) The purpose of the Streamlined scenario was to model the effect of using the land use and transit inputs from the Full scenario with a priced lane network with significantly reduced capital cost.

Many of the highway corridors in the region have been the subject of a pricing study, as detailed in a memo to the TPB dated September 15, 2010 (6). These studies, including the I-270 Multi-modal Corridor Study, the West Side Mobility Study, and the Capital Beltway Study, were referred to in designing the Streamlined scenario’s VPL network. In addition, travel forecasting model results from the full scenario were used to locate corridors that had more capacity than warranted by the modeled volumes where it would be possible to reduce lane capacity and/or introduce directional lanes. On some freeways, the Streamlined scenario used an “add-a-lane/take-a-lane” approach by constructing one new lane and tolling one general purpose lane in order to maintain two VPLs in each direction. On radial highways and major arterials, the volume-to-capacity ratio of the toll lanes in the full VPL network was used to identify corridors in which the demand could be satisfied by directional, as opposed to bi-directional, toll lanes. The number of new interchanges to be constructed was reduced, from 155 to 97, keeping only those which provided access to activity centers or needed connectivity within the priced lane network. Map 5 shows the construction of VPLs and the conversion of GPLs to VPLs. Maps 6.1 and 6.2 show the operational characteristics of the VPL network in the AM and PM peak periods. Map 7 shows the lane configuration on major bridges. (The only change made to bridges between the Full and Streamlined VPL networks was on the 14<sup>th</sup> Street Bridge, where Alternative 11 from the 14<sup>th</sup> Street Bridge Corridor study was adopted to add capacity in the streamlined scenario.) The Streamlined VPL network reduced the number of new lane miles of construction by 30% and the number of interchanges constructed by 33% as compared to the Full VPL network.

## **METHODOLOGY**

The Version 2.2 TPB Travel Forecasting Model was used to evaluate the travel implications from the different scenarios for forecast year 2030, which was TPB's planning horizon at the start of the study. The TPB maintains a four-step transportation planning model that is used to evaluate transportation plans and programs, including air quality planning, in accordance with federal requirements. (7) The modeled area includes all of the jurisdictions is shown in Figure 1.

There are two types of toll facilities in the TPB model – fixed toll facilities where the tolls do not change by time of day and are expressed in the model as a monetary value, and variably priced facilities where tolls change by time of day and are modeled as equivalent minutes that are added to the highway time. (7) The objective for representing VPLs is to specify toll rates which will result in a demand that does not degrade the operating speed, which in turn ensures that high-occupancy vehicle travel is not adversely impacted on the VPLs. (7) In the CLRP Aspirations study, a base rate of \$0.20 per mile is applied to variably priced facilities and a toll update algorithm is then applied to gradually raise the tolls on congested facilities until a free-flow volume-to-capacity (v/c) ratio, generally in the range of 0.6 to 0.8, is achieved (4). In Virginia, high-occupancy vehicles with three or more persons (HOV3+) are allowed to travel in the VPLs free of charge. In Maryland and the District of Columbia, only buses are permitted to use the VPLs without charge. (4) While there were no VPL facilities open in the Washington region when the model was calibrated, the tolls generated by the model compare reasonably well to other VPLs in place in the country. (8) The first segment of the region's first VPL facility, the ICC, opened in early 2011, with the full facility expected to open by Spring 2012. VPLs on the Capital Beltway in Virginia are under construction and scheduled to open in 2013.

## **MAJOR FINDINGS**

Table 1 shows a comparison of the Baseline and the three scenarios (Land Use Only, Full Scenario, and Streamlined Scenario) with respect to current conditions (year 2009 of the 2008 CLRP which was used to be consistent with the CLRP used for the future scenarios) for demographics and major travel and congestion indicators. The modeled area is forecasted to see significant increases in population and employment over the 21 year period. This results in similarly significant increases in vehicle miles traveled (VMT) and vehicle trips as well as congestion as seen in increases in vehicle hours of travel (VHT) and vehicle hours of delay (VHD). Vehicle hours of delay (VHD) are a good indication of congestion as it is the difference between hours of travel under congested conditions and hours of travel under free flow conditions (8). VHT and VHD are not reported as absolute numbers, but the percentage difference can be used to show a relative comparison between alternatives. Using the reported average annual delay per peak auto commuter in 2009 from the Texas Transportation Institute 2010 Urban

Mobility Report (9) and percentage increases in VHD from the travel forecasting model for home-based work person hours of delay in the peak period, future hours of annual delay were estimated along with a dollar value for annual commuter time spent in congestion. This is an average for the entire modeled area; annual delay for individual commuters would vary throughout the region based on local congestion and development density.

**Table 1: Changes in Regional Travel Indicators for 2030 CLRP Aspirations Scenarios with respect to 2009 for the TPB Modeled Area, Average Weekday (unless otherwise noted)**

	2009	2030		2030		2030		2030	
	2008 CLRP	Baseline	% Difference	Land Use Only Scenario	% Difference	Full Scenario	% Difference	Streamlined Scenario	% Difference
Population	6,705,983	8,153,358	22%	8,463,002	26%	8,463,002	26%	8,463,002	26%
Employment	4,000,202	5,159,927	29%	5,178,789	29%	5,178,789	29%	5,178,789	29%
Households	2,524,355	3,181,103	26%	3,268,667	29%	3,268,667	29%	3,268,667	29%
Vehicle Miles Traveled (VMT)	161,653,516	197,742,647	22%	196,820,973	22%	203,820,832	26%	202,180,462	25%
VMT per capita	24.11	24.25	0.6%	23.26	-3.5%	24.08	-0.1%	23.89	-0.9%
Average Trip Length	7.28	7.23	-0.7%	7.05	-3.2%	7.36	1.1%	7.3	0.3%
Vehicle Trips	22,212,705	27,344,174	23%	27,935,785	26%	27,699,528	25%	27,707,435	25%
Vehicle Trips per capita	3.31	3.35	1.2%	3.30	-0.3%	3.27	-1.2%	3.27	-1.2%
Bicycle/Pedestrian Trips	207,078	291,809	41%	340,008	64%	339,308	64%	339,310	64%
Total Transit Trips	1,162,747	1,581,950	36%	1,748,539	50%	1,801,384	55%	1,801,287	55%
HOV HBW Work Trips*	95,764	163,694	71%	159,732	67%	341,999	257%	336,343	251%
Vehicle Hours of Travel (VHT)**	-	-	34%	-	35%	-	26%	-	26%
Modeled Area VHD (VHD)**	-	-	46%	-	48%	-	29%	-	29%
Annual Delay per Peak Auto Commuter (Hours)	70***	84	20%	82	17%	72	3%	73	4%
Annual Cost of Congestion per Peak Auto Commuter (2009\$)****	\$ 1,302	\$ 1,559	20%	\$ 1,523	17%	\$ 1,345	3%	\$ 1,354	4%

\* HOV2+ for modeled years prior to 2020. HOV3+ after 2020.

\*\* VHT and VHD are reported only as relative differences

\*\*\* Forecasted percent increases in commuter person hours of delay during the peak period are from the TPB model, and applied to 2009 conditions as reported in the TTI 2010 Annual Urban Mobility Report ([http://mobility.tamu.edu/ums/congestion\\_data/tables/washi.pdf](http://mobility.tamu.edu/ums/congestion_data/tables/washi.pdf)).

\*\*\*\* Value of time estimated at \$18.60 in 2009 dollars

The rest of the analysis focuses on comparing the performance of the three scenarios relative to the Baseline for forecast year 2030. The analysis in this report supersedes that presented in the CLRP Aspirations Final Report (1): some technical corrections were made to highway and transit networks in the Full scenario, and updates were made to air quality planning assumptions for all scenarios since the completion of that report. As a result, the travel forecasting model outputs for the Full scenario changed slightly, but the overall conclusions did not change. There are different analysis geographies depending on the metric.

### **Trip Distribution Patterns**

Trip distribution is the second step in the TPB's four-step model. The trip distribution model uses the standard gravity model formulation and makes use of a composite time function that represents a blending of transit and highway travel times. (7) Trip distribution patterns can provide an indication of whether improvements were made in the various corridors. (8) The land use sensitivity test shows that for all jurisdictions that received more households and/or jobs, there were more intra-jurisdictional motorized person trips than in the Baseline and fewer long-distance inter-jurisdictional trips.

With the addition of tolled highway capacity and the BRT network, the Full scenario shows many more intra-jurisdictional trips than the Baseline (but still fewer than the Land Use Only scenario) as well as more inter jurisdictional trips than the Baseline. The Streamlined scenario, as expected, shows a similar trip distribution pattern to the Full scenario, but with slightly more intra-jurisdictional trips and slightly fewer inter-jurisdictional trips reflecting a decrease in service quality when the lane miles were reduced.

### **Regional Travel Indicators**

A regional analysis was conducted for the modeled area comparing the outcomes of the Land Use Only, Full, and Streamlined scenarios with respect to the Baseline for forecast year 2030.

**Table 2: Changes in Regional Travel Indicators with respect to Baseline for the TPB Modeled Area, 2030 Average Weekday (unless otherwise noted)**

	<b>Land Use Only Scenario</b>	<b>Full Scenario</b>	<b>Streamlined Scenario</b>
Population	3.8%	3.8%	3.8%
Employment	0.4%	0.4%	0.4%
Households	2.8%	2.8%	2.8%
Vehicle Miles Traveled (VMT)	-0.5%	3.1%	2.2%
VMT per capita	-4.1%	-0.7%	-1.5%
Average Trip Length	-2.5%	1.8%	1.0%
Vehicle Trips	2.2%	1.3%	1.3%
Vehicle Trips per capita	-1.6%	-2.4%	-2.4%
Bicycle/Pedestrian Trips	16.5%	16.3%	16.3%
Total Transit Trips	10.5%	13.9%	13.9%
HOV3+ HBW Work Trips	-2.4%	108.9%	105.5%
Vehicle Hours of Travel (VHT)	0.5%	-6.1%	-6.1%
Modeled Area VHD (VHD)	1.0%	-11.9%	-11.4%
Annual Delay per Peak Auto Commuter (Hours)	-2.4%	-13.8%	-13.1%

In all three scenarios, there are more jobs and households than in the Baseline which results in an increase in total vehicle trips in each case, with the Land Use Only having the highest increase. Overall, however, there is a small decrease in vehicle trips per capita between the Baseline and all three scenarios. The Full and Streamlined scenarios have a larger share of these new trips as HOV3+ trips than the land use scenario. For both the Full and Streamlined scenarios, the VMT increases relative to the baseline as available road capacity increases. While the Land Use Only scenario shows a small decrease in overall VMT from the Baseline, VMT increases in almost all of the inner jurisdictions, with the highest increases on major arterials. The VMT per capita in the modeled region decreases in all three scenarios. The average trip length increases in both the Full and Streamlined scenarios, but decreases in the Land Use Only scenario.

Vehicle hours of travel (VHT) decrease by the same percentage in both the Full and Streamlined scenarios, while increasing slightly in the Land Use Only scenario. The Land Use Only scenario shows a slight increase in VHT and VHD over the Baseline as vehicle trips are increased, but no additional highway capacity is added. The Full and Streamlined scenarios both show a notable decrease in VHD in the modeled area as compared to Baseline. Notably, the Streamlined scenario achieves almost the same amount of congestion reduction as the Full scenario with far fewer lane miles of new construction.

Comparing the Full and Streamlined scenarios directly, the Streamlined had fewer VHD on freeways, but more VHD on the every other facility type. All of the scenarios have a decrease in estimated delay per commuter. The delay was calculated by using the model to estimate hours of delay per mile and then multiplying that by an average current commute trip length which was factored by the percentage difference in the average trip length for the other scenarios. So while the Land Use Only scenario has more delay for the modeled area, the delay per commuter is shorter because there are more home-based work auto trips in the peak period and the average trip length is shorter. As previously stated, this is an average for the entire modeled area. The delay for individual commuters would vary throughout the region based on local congestion and development density.

Volume-to-capacity ratio is another indicator of congestion, although it is not directly related to VHD. Table 3 shows the change in the percent of highly congested lane miles by facility in the afternoon peak period for each of the scenarios as compared to the Baseline. For this analysis, highly congested is defined as having a v/c ratio over 1.0.

**Table 3: Percent of Congested Lane Miles by Facility Type, Year 2030**

Scenario	Freeways and Expressways	Major and Minor Arterials	Collectors	All Facilities
Baseline	35%	34%	17%	31%
Land Use Only Scenario	34%	35%	16%	31%
Full Scenario	23%	33%	15%	27%
Streamlined Scenario	24%	33%	15%	28%

As previously stated, a toll update algorithm is applied to gradually raise the tolls on congested facilities until a free-flow volume-to-capacity (v/c) ratio is achieved; therefore, the toll rate per mile can be used to show those VPLs that have more demand than others. High VPL toll rates in both the Full and Streamlined alternatives demonstrated that DC river crossings are major bottlenecks in the region. Other bottlenecks are created when capacity drops due to area type change, or traffic from multiple facilities merges into single VPL facility. Maps 8 and 9 show the toll rate per mile for the Full scenario in the AM and PM peak periods, respectively. Maps 10 and 11 show the toll rate per mile for the Streamlined scenario in the AM and PM peak periods, respectively. The following are the major findings that apply to bottlenecks in both alternatives:

- Traffic congestion on the bridges is more severe and wide-spread in the region during the PM peak period.

- Inbound traffic is the peak direction of all DC river crossings in AM peak except for Chain Bridge and Francis Scott Key Bridge. Outbound traffic is the peak direction of these two bridges in AM peak.
- Bottlenecks occur in VPL segments where traffic merges from major facilities or where road capacity is reduced due to lane reductions or area type change. These bottlenecks are: the southbound I-395 west of S. Joyce Street, I-95 south of the Springfield interchange, the Beltway VPLs south of Lee Highway and the American Legion Bridge, and the GW Parkway south of the Ronald Reagan Washington National Airport.
- More bottlenecks are found in the District of Columbia due to: (1) no new VPL capacity being added in the District of Columbia; (2) traffic merging into existing VPL traffic from local roads; and (3) VPL capacity dropping in DC. These segments are: New York Avenue, NW, west of New Jersey Avenue, NW, and Constitution Avenue, NW, at the eastern end of the Theodore Roosevelt Memorial Bridge.

Tolls are compared for both alternatives. No new bottlenecks were created in the Streamlined scenario in comparison to the Full scenario as the alternative was designed to reduce only excess VPL capacity from the Full scenario. Observations on the differences between the two scenarios are as follows:

- Most differences in VPL tolls vary from -30 cents/mile to +30 cents/mile between two scenarios in both AM and PM peak hours.
- Toll increases are visible where excess VPL capacity was removed: MD 201, MD 5, MD 4 and I-270 spurs in Maryland, and VA 7 west of VA 28.
- The bottleneck condition on the 14<sup>th</sup> Street Bridge in the Full scenario is alleviated due to the lane capacity increase in the Streamlined alternative, significantly reducing the bridge tolls.

### **Mode Share**

One of the goals of the scenario is to show a shift away from low-occupancy auto trips to non-motorized transit and HOV trips. Non-motorized travel (ie bicycle, pedestrian) is reflected only in the home-based work (HBW) trip rates in the model and is extracted from the total trip ends prior to trip distribution (7). Thus, non-motorized trips are influenced heavily by land use. Non-motorized trips increase in all three scenarios by over 16% as jobs and households are moved closer together in the land use assumptions.

Transit trips increase in all scenarios, more so in the Full and Streamlined scenarios which have a regional BRT and circulator network that serves activity centers and makes connections to other existing transit (i.e. subway, commuter rail). Since there was no change in the transit network between the Baseline and Land Use Only scenarios to support the new land use assumptions, the increase in transit in

the Land Use Only scenario can be largely attributed to the land use shifts as well as increases in congestion for automobile trips.

The model reports HOV3+ trips only for the HBW purpose and if the trip takes place on a designated HOV facility (all VPLs), and the trip saves at least five minutes by taking the HOV facility. (7) There are significantly fewer eligible HOV facilities in the land use scenario as compared to both of the VPL scenarios, resulting in a higher share of low occupancy vehicle trips. The assumption for the scenario study is that in Virginia, vehicles with three or more occupants are permitted to use the VPL lanes toll-free, but in Maryland and the District of Columbia, only buses are permitted to use the VPLs without charge (4). The number of HBW HOV3+ trips doubled from the Baseline in both the Full and Streamlined scenarios (108.9% and 105.5%, respectively) while the number of lane miles of HOV facilities increased by 660% and 578%, respectively. Since, the VPLs remained free for HOV trips only in Virginia, the overall number of free lane miles for HOV trips in Virginia increased by 450% and 372%, respectively. In considering the 2.4% decrease in HBW HOV3+ trips in the Land Use Only scenario, it may be noted that locating jobs in proximity to households leads to 2.5% decrease in average motorized trip length which may reduce the use of highways and major arterials where the VPLs are located.

Table 4 shows the mode split for the Baseline and all three scenarios. All three scenarios have a lower mode share for low-occupancy vehicle trips than the Baseline.

**Table 4: Mode Share, Year 2030**

<b>Trip Type</b>	<b>Baseline</b>	<b>Land Use Only Scenario</b>	<b>Full Scenario</b>	<b>Streamlined Scenario</b>
LOV* Auto Person	79.3%	78.0%	74.5%	74.6%
Transit	13.4%	14.2%	14.7%	14.7%
HOV3+ Auto Person	2.6%	2.5%	5.4%	5.3%
Non-motorized HBW trips	4.7%	5.3%	5.3%	5.3%

\*LOV - Low occupancy vehicle

### **Air Quality**

The Washington, DC region is designated as a non-attainment for ozone (VOC and NOx) and particulate matter (PM2.5 and Pre-cursor NOx). (10) Emissions for criteria pollutants were estimated for the respective non-attainment areas, shown in Map 1, using the most recently adopted air quality planning assumptions for the air quality assessment of the 2010 CLRP and the 2011-2016 Transportation Improvement Program (10). Table 5 shows the results from the emissions analysis.

**Table 5: Emissions Analysis, Year 2030**

Pollutant	Baseline Emissions	Percent Difference from Baseline		
		Land Use Only	Full	Streamlined
VOC (tons/day)*	38	1.54%	2.10%	1.74%
Nox (tons/day)*	33	0.47%	5.45%	4.39%
PM2.5 (tons/year)**	721	0.26%	4.93%	3.77%
Precursor Nox (tons/year)**	11,714	0.67%	6.13%	5.01%
CO <sub>2</sub> (,000 tons/year)***	26,911	-0.26%	2.77%	2.16%

\* Emissions estimated for the 8-hour Ozone non-attainment area

\*\* Emissions estimated for the PM2.5 non-attainment area

\*\*\* Emissions estimated for the modeled region

In the nonattainment areas, VMT and vehicle trips increase in all three scenarios as compared to the Baseline resulting in an increase in emissions of all criteria pollutants in all scenarios. Emissions for carbon dioxide (CO<sub>2</sub>), the primary greenhouse gas, were estimated for the modeled area using a speed curve developed by University of California, Riverside (11). CO<sub>2</sub> emissions increase in both toll scenarios, but decrease slightly in the Land Use Only scenario, where the decrease in regional VMT is somewhat offset by the increase in congestion and lower speeds. The air quality analysis demonstrates adherence to both the 8-hour ozone and PM2.5 budgets that have been submitted to EPA for all scenarios tested. There is currently no federal requirement for CO<sub>2</sub> reporting.

## FINANCIAL ANALYSIS

A financial analysis was performed to gauge whether the toll revenue generated by the VPL network could offset the cost of constructing the VPL network and the enhanced transit system in either the Full or Streamlined scenarios. The financial analysis for 2030 conditions in 2010 dollars considered the following:

- The cost of constructing the highway facilities
- The capital and operating cost of enhanced transit
- The toll revenue from the VPL network
- The fare revenue from the increased transit ridership

While the cost of constructing the VPLs and the toll revenue from such a system can be estimated at the state level, the cost and fare box recovery from the transit system can be estimated only at the regional level since the regional travel forecasting model is not capable of providing the increase in transit

ridership at the state level, or by the different transit types such as commuter rail, light rail, bus rapid transit, or Metrorail.

Cost of Highway Facilities: The number of new VPL miles to be constructed, the number of HOV lane miles converted to VPLs, and the number of GPL lane miles converted to VPLs were identified for each of the three states. In addition, the number of new interchanges to be constructed to support the VPL network was identified by state. Cost information was obtained from the state DOTs for new construction and conversion of existing lanes, and a regional unit cost number per lane mile and per interchange in 2010 dollars was developed. It is assumed 4% of the capital cost would be needed on an annual basis for debt financing, and 1% for maintenance of the facility, administration, and other expense. This is based on the revenue expenditure analysis of Virginia's Capital Beltway HOT Lane Project. (12) The total capital cost was calculated and amortized over a 20 year period. Annualized cost expenses which account for debt financing, maintenance and other expenses were estimated using the amortized cost.

Capital and Operating Cost of Enhanced Transit: The transit network (above and beyond the 2008 CLRP which includes the BRT and circulator networks as well as the previously described RMAS projects) is the same for both the Full and Streamlined scenarios. Therefore the transit capital cost and operating cost for the two scenarios are the same. The assumptions used the transit cost assumptions from the VPL study, which were reviewed and found to be reasonable and, with minor modifications to the inputs, were used to estimate the capital and operating cost of the enhanced transit system. Some of the capital costs such as station costs and rail cost were amortized over a 50 year period whereas rolling stock such as buses were amortized over a 20 year period.

Toll Revenue: The regional travel forecasting model output was used to develop revenue estimates for the weekday peak period. It was assumed that 50% of the peak period traffic would use the VPL lanes during the off-peak period, and during weekend and holidays. Since HOV3+ do not pay tolls on Virginia VPLs, they were excluded in the revenue estimation.

Transit Fare-Box Revenue: Based on the increase in transit ridership of the scenarios (essentially 220,000 per day in both scenarios), allocated across modes in proportion to the increased capacity and based on a typical average recovery ratio for each mode, the estimate of annual farebox revenue is \$79,400,000.

Final Cost Analysis: Table 6 shows the lane miles, number of interchanges, and capital cost information for both the Full and Streamlined VPL networks. Table 7 shows the annualized capital and operating costs for the enhanced transit network. Table 8 shows the total annualized capital and operating cost of the highway and transit system together with annualized revenue from the tolls and the fare-box revenue together. Revenue to cost ratio of one would indicate the total revenue would be sufficient to meet the capital and operating expenses of the variably priced lanes and transit. One goal of the CLRPA Aspirations Scenario Study is that the scenario be “within reach”; in the case of the financial analysis, this means that the revenue generated from tolls and transit fares should approximately cover the capital and operating costs for the system, both highway and transit. The Full scenario has a revenue to cost ratio of 0.81 at the regional level which indicates the revenue generated would be close to meeting the cost of the project. The financial analysis of the Streamlined scenario shows that the revenue to cost ratio is 1.1 indicating that the scenario could be financially feasible.

The analysis completed as part of this scenario study is not a substitute for a detailed financial analysis. It should also be noted that there is a great deal of uncertainty associated with forecasting toll revenue on VPLs. (According to Mwalwanda, the elasticity for determining optimum toll rates “is 4.0. i.e. a small 10% change in traffic can result in 40% change in revenues” (13).)

**Table 6: Year 2030 Financial Analysis of Full VPL Network and Streamlined VPL Network (2010\$)**

Scenario	Jurisdiction	New VPL	HOV to VPL (lane miles)	GPL to VPL	Number of New Interchanges	Annualized Cost (millions)	Annual Revenue
Full VPL Network	DC	5	2	198	0	\$ 49	\$ 712
	MD	558	57	182	77	\$1,834	\$ 1,237
	VA	396	207	135	78	\$1,596	\$ 1,053
Regional Total		959	266	515	155	\$3,478	\$ 3,002
Streamlined VPL Network	DC	5	1	201	0	\$ 54	\$ 649
	MD	383	57	263	56	\$1,325	\$ 1,277
	VA	278	212	135	41	\$ 989	\$ 991
Regional Total		666	270	599	97	\$ 2,367	\$ 2,917

**Table 7: Year 2030 Financial Analysis of Enhanced Transit Network (2010\$)**

	Annualized Cost (millions)	Annual Revenue (millions)
	\$321	\$79

**Table 8: Year 2030 Revenue to Cost Analysis of Full and Streamlined Scenarios (2010\$)**

Scenario	Annualized Cost (millions)	Annual Revenue (millions)	Revenue/Cost
Full Scenario	\$ 3,799	\$ 3,082	0.81
Streamlined Scenario	\$ 2,688	\$ 2,997	1.11

**ACCESSIBILITY**

Comparisons of highway accessibility to households and jobs between the Full and Streamlined scenarios were prepared to determine the change in accessibility to households and jobs with the reduction of VPL miles. VPL capacity reduction is translated into accessibility reduction in affected zones, especially in highway accessibility. When looking at transit, sporadic accessibility increases or decreases are observed but regarded as ‘not meaningful’ even though changes in the highway network assumptions marginally affect the auto access to transit.

Highway Accessibility to Jobs in AM peak: Full vs. Streamlined Alternatives

The reduction of VPLs in the Streamlined scenario limits the accessibility to jobs located around the Beltway, in the District of Columbia and near the interchange of Interstate 66 and the Beltway. These accessibility reductions are expected as highway travel time increases to the zones where jobs are located.

Highway Accessibility to Households in PM peak: Full vs. Streamlined Alternatives

Using the PM peak travel time for household accessibility is more meaningful than using the AM peak travel time as the region shows distinct travel patterns by peak period. The accessibility to households by highway in the PM peak decreased to zones around the facilities where the number of VPLs was

decreased, but increased in zones where VPL capacity remained the same between the two scenarios such as along Interstate 270 and inside the Beltway in Virginia.

#### Transit accessibility to households or jobs in AM peak: Full vs. Streamlined Alternatives

Transit accessibility is virtually unchanged between the Full and Streamlined scenarios as only the highway assumptions were revised in the Streamlined alternative. While the highway assumptions affect transit accessibility in terms of changing the auto access to transit travel time, these changes are very marginal. Accessibility to both households and jobs show minimal changes, and are too small to be regarded having any meaningful impacts on the transit accessibility.

#### **CONCLUSION**

The results of the CLRP Aspirations Scenario Study and its related sensitivity tests show what can happen when land use, highway, and transit planning are designed in a synergistic way in the metropolitan Washington region.

The Land Use Only scenario showed that land use changes alone contributed to forecasted increases in transit and non-motorized trips, shorter and more intra-jurisdictional trips, and reduced regional VMT and VMT per capita. However, without highway capacity increases, the Land Use Only scenario shows that as jobs and households are moved closer together, additional demand is created on arterial roads in those jurisdictions leading to an increase in VMT and congestion.

When a network of variably priced lanes and a BRT network are added to higher density land use, both the Full and Streamlined scenarios showed significantly less congestion than with land use changes alone, but also more VMT, and longer and more vehicle trips when compared to the Baseline. All scenarios showed an increase in congestion with respect to current conditions, but the Full and Streamlined Scenarios showed significantly lower increases in total modeled area delay and annual delay per peak auto commuter than the Baseline and Land Use Only scenario. The Streamlined scenario performed well as compared to the Full scenario for significantly lower costs, showing comparable reductions in regional VHD, with less growth in VMT. The financial analysis indicates that the Streamlined scenario could be financially feasible. Further study would be needed to examine the affects of the VPLs on the adjacent GPLs and on parallel arterial facilities.

#### **NEXT STEPS**

In July 2011, the TPB approved a two-year work program to identify the TPB's regional transportation priorities. The scope of work includes analysis of both near-term and long-term strategies. Long-term strategies would cover the entire planning period, which now extends to 2040, and can include significant

changes in both transportation and land use. The CLRP Aspirations Scenario Study provides three examples of alternative planning futures for the region and offers a useful starting point for defining regional transportation and land use priorities.

Further analysis should be done to examine localized impacts of the land use and highway network changes. All roadway improvements in the CLRP Aspirations Scenario Study were focused on freeways and certain major arterials, and as shown in the analysis, many other arterials and smaller roadways in the MSA are forecasted to experience increased congestion. Since the CLRP Aspirations Scenario Study was a scenario study using sketch level planning, it did not address all of the realities of planning a regional VPL network including, but not limited to, the ability to toll existing lanes on federal roadways, the challenge of planning a network that spans a tri-state area, operational issues, and the public perception of tolling GPLs. On the last point, the TPB, in partnership with the Brookings Institution, has launched a study to investigate issues related to the public acceptability of road-use pricing under a grant from the Federal Highway Administration's (FHWA) Value Pricing Program. Findings from this research project will help inform future scenario work related to variably priced lanes.

The TPB is moving forward with new and upgraded tools to facilitate better scenario planning. A Version 2.3 Travel Forecasting Model to be adopted this fall was calibrated with up-to-date household travel and transit surveys, and highway and arterial travel data. The model will have almost twice as many Transportation Analysis Zones (TAZ) to allow better forecasting of the impact of both land use and transportation changes. Additionally, the model will be a better tool for studying mode shifts as it will report HOV2 and HOV3+ trips for all facilities and all trip purposes and perform transit assignments. Beginning in March 2012, TPB will begin using the Environmental Protection Agency's (EPA) newly released emissions modeling tool (MOVES) for air quality analysis of the CLRP and scenario studies. Additionally, TPB staff is exploring ways to use benefit cost analysis, along the lines used in its Transportation Investment Generating Economic Recovery (TIGER) grant applications, to evaluate scenarios with variably priced lanes. Using benefit cost analysis would help to quantify benefits of travel time predictability along with other benefits and costs that have not been previously quantified in TPB scenario studies.

## REFERENCES

1. Bansal, M. and D. Smith. *TPB Scenario Study: CLRP Aspirations Scenario Final Report*. National Capital Region Transportation Planning Board, September 2010.  
[http://www.mwcog.org/clrp/elements/PDFs/clrp\\_asp\\_report\\_092410\\_FINAL\\_updated.pdf](http://www.mwcog.org/clrp/elements/PDFs/clrp_asp_report_092410_FINAL_updated.pdf)
2. 2009 CLRP & FY 2010-2015 TIP Summary Brochure, National Capital Region Transportation Planning Board, October 2009.
3. McAuslan, D., and K. Ransome. *Regional Mobility and Accessibility Study: Alternative Land Use and Transportation Scenarios Phase 1 Technical Report*. National Capital Region Transportation Planning Board, November 2006.  
[http://www.mwcog.org/store/item.asp?PUBLICATION\\_ID=93](http://www.mwcog.org/store/item.asp?PUBLICATION_ID=93)
4. Eichler, M., G. M. Miller, and J. Park. *Evaluating Alternative Scenarios for a Network of Variably Priced Highway Lanes in the Metropolitan Washington Region*. National Capital Region Transportation Planning Board, February 2008.  
[http://www.mwcog.org/TPB/VPTF/docs/RVPS\\_Final\\_Report.pdf](http://www.mwcog.org/TPB/VPTF/docs/RVPS_Final_Report.pdf)
5. Eichler, M. *Methodology for an Analysis of a Regional Network of Variably Priced Highway Lanes*. Paper for the 88th Annual Meeting of the Transportation Research Board, Washington, D.C., 2009.
6. Kirby, Ron. *Memo to the Transportation Planning Board, Washington, D.C. 15 September 2010*.
7. *TPB Travel Forecasting Model, Version 2.2 Specification, Validation, and User's Guide*. National Capital Region Transportation Planning Board, March 2008
8. Vuksan D., and F. Xie. *MDOT Maryland Managed Lanes Study*. National Capital Region Transportation Planning Board, October 2010.
9. *2010 Annual Urban Mobility Report*, Texas Transportation Institute, December 2010  
[http://mobility.tamu.edu/ums/congestion\\_data/tables/washi.pdf](http://mobility.tamu.edu/ums/congestion_data/tables/washi.pdf)
10. *Air Quality Conformity Determination of the 2010 Constrained Long Range Plan and the FY 2011-2016 Transportation Improvement Program for the Washington Metropolitan Region*. National Capital Region Transportation Planning Board, November 2010.  
[http://www.mwcog.org/store/item.asp?PUBLICATION\\_ID=395](http://www.mwcog.org/store/item.asp?PUBLICATION_ID=395)
11. Barth and Boriboonsomsin, "Real-world CO<sub>2</sub> Impacts of Traffic Congestion," Paper for the 87<sup>th</sup> Meeting of the Transportation Research Board, January 2008
12. Cambridge Systematics, Inc. *Analysis of Resources for the 2006 Financially Constrained Long-Range Transportation Plan for the Washington Region*. Prepared for the National Capital Region Transportation Planning Board, September 2006.  
[http://www.mwcog.org/clrp/resources/Final\\_2006\\_Financial\\_Analysis\\_Rpt.pdf](http://www.mwcog.org/clrp/resources/Final_2006_Financial_Analysis_Rpt.pdf)
13. Mwalwanda, C. *Long-term Demand Forecasting of Managed Lanes*. Presented at 13<sup>th</sup> Transportation Research Board National Transportation Planning Applications Conference, Reno, NV, 2011.

## **Attachment A**

Map 1: Full VPL Network: Variably Priced Lanes to be Constructed/Converted as Compared to the 2008 CLRP

Map 2.1: Full Variably Priced Network: AM Peak Lane Configuration

Map 2.2: Full Variably Priced Network: PM Peak Lane Configuration

Map 3: Full VPL Network: Lane Configuration on Major Bridges

Map 4: Regional Bus Rapid Transit Network

Map 5: Streamlined VPL Network: Variably Priced Lanes to be Constructed/Converted as Compared to the 2008 CLRP

Map 6.1: Streamlined Variably Priced Network: AM Peak Lane Configuration

Map 6.2: Streamlined Variably Priced Network: PM Peak Lane Configuration

Map 7: Streamlined VPL Network: Lane Configuration on Major Bridges

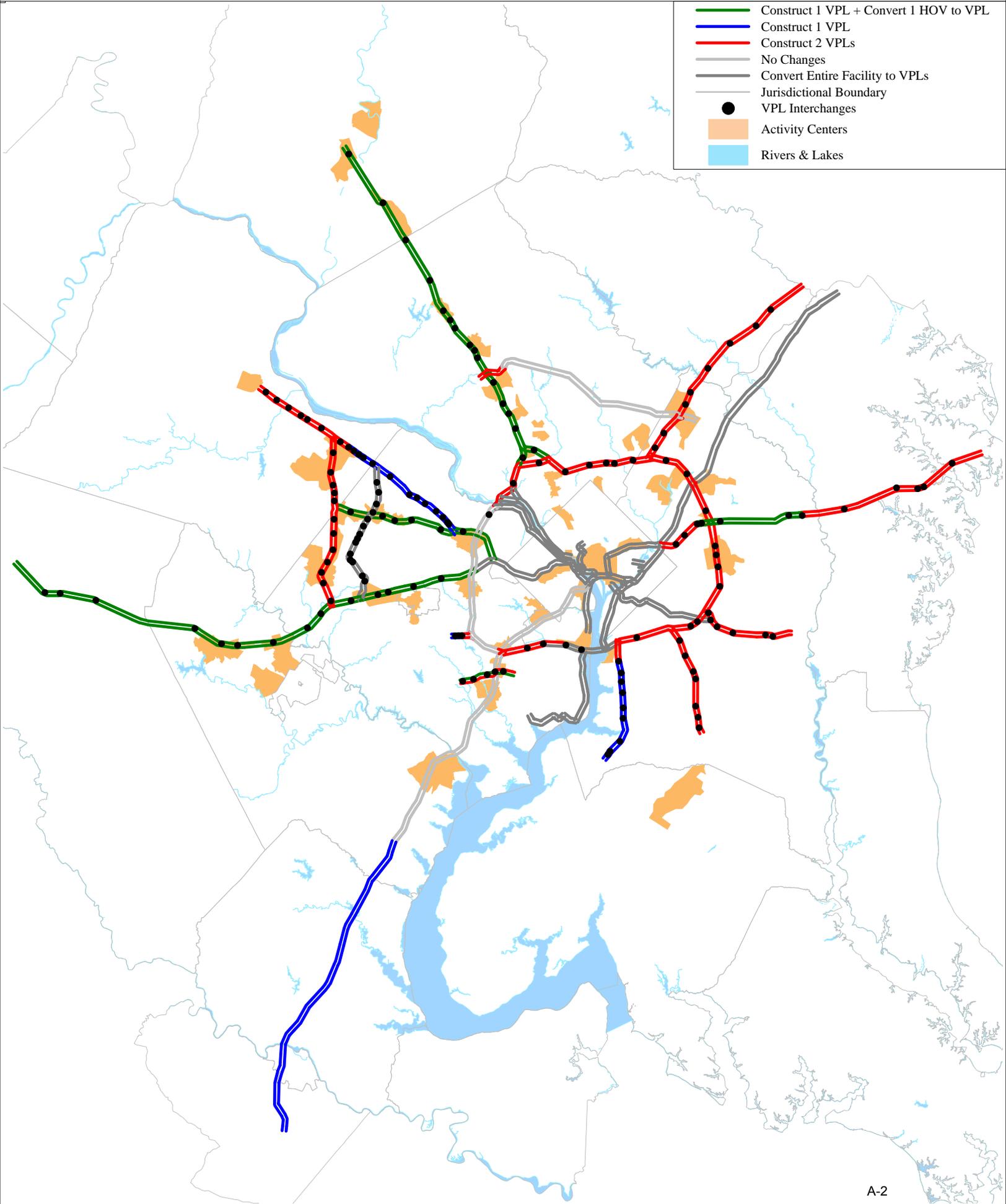
Map 8: Full Variably Prices Lane Network: AM Peak Toll Rate per Mile (2010\$)

Map 9: Full Variably Prices Lane Network: PM Peak Toll Rate per Mile (2010\$)

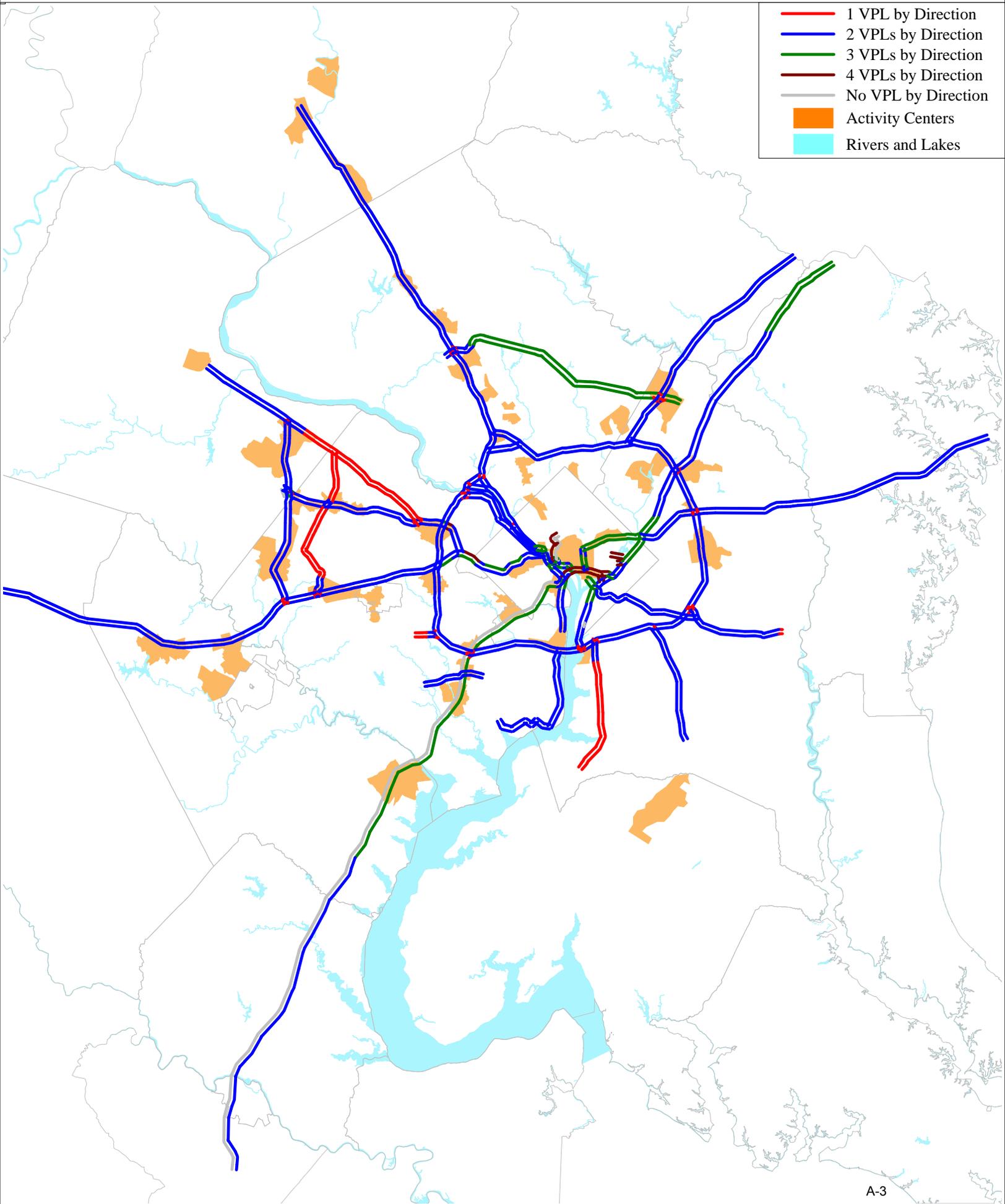
Map 10: Streamlined Variably Prices Lane Network: AM Peak Toll Rate per Mile (2010\$)

Map 11: Streamlined Variably Prices Lane Network: PM Peak Toll Rate per Mile (2010\$)

# Map 1: Full VPL Network: Variably Priced Lanes to be Constructed/Converted as Compared to the 2008 CLRP

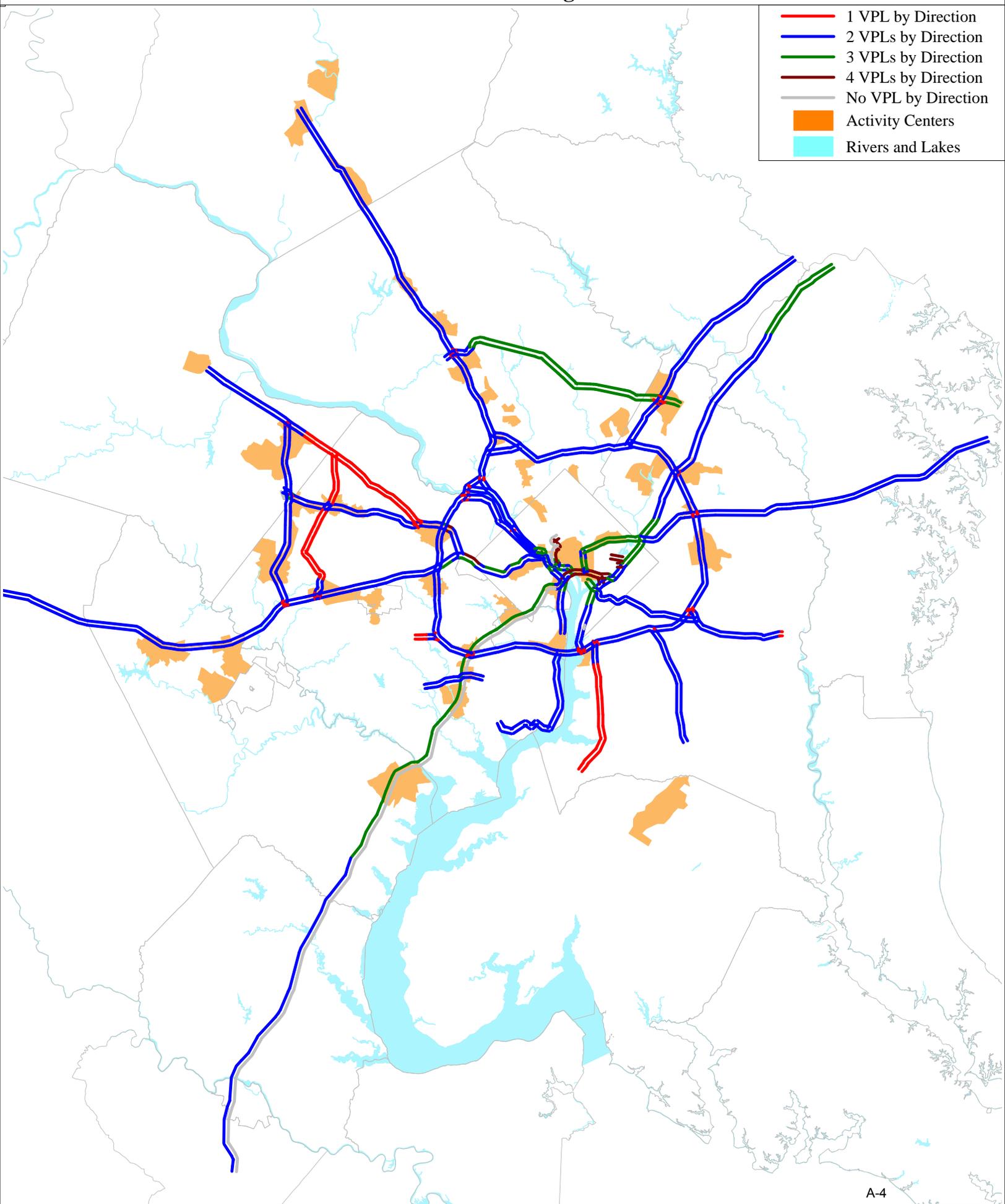


**Map 2.1: Full Variably Priced Lane Network  
AM Peak Lane Configuration**

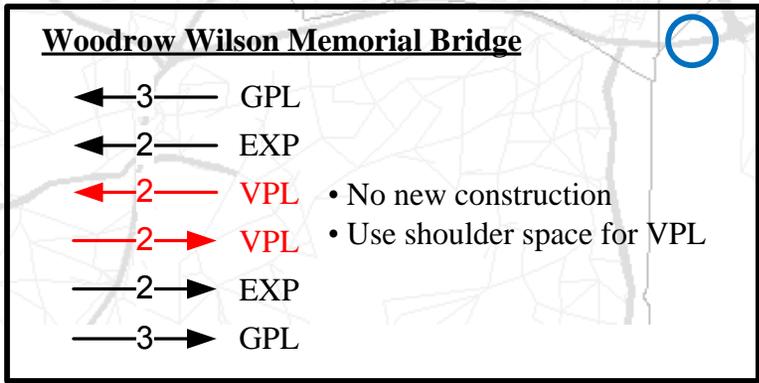
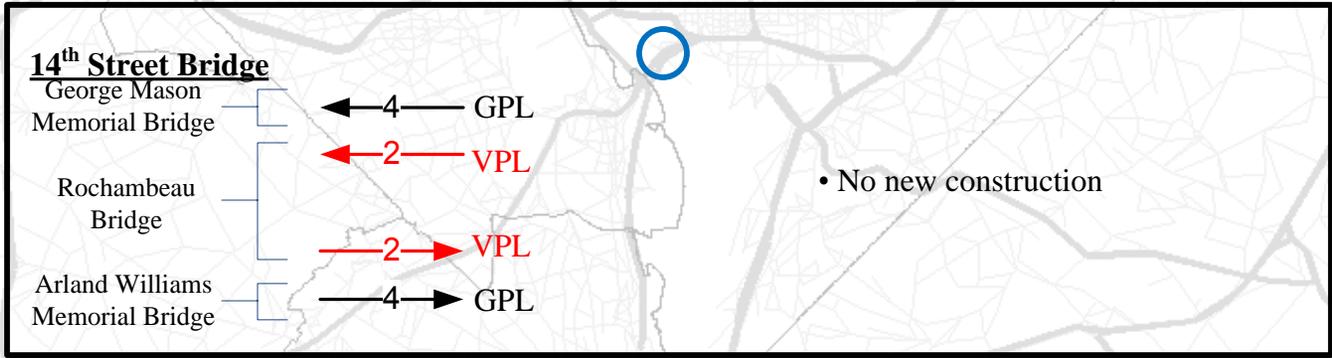
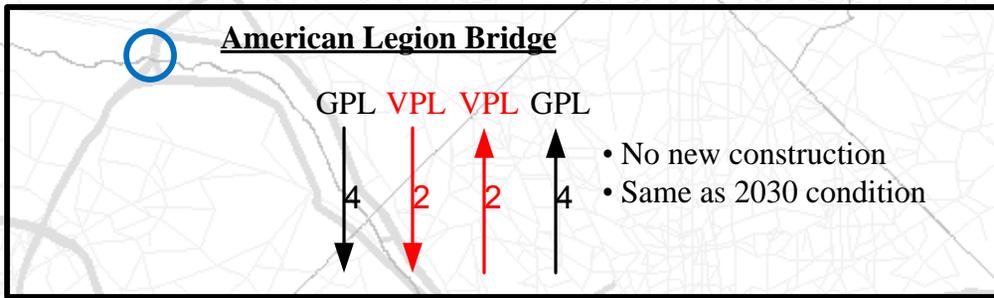


- 1 VPL by Direction
- 2 VPLs by Direction
- 3 VPLs by Direction
- 4 VPLs by Direction
- No VPL by Direction
- Activity Centers
- Rivers and Lakes

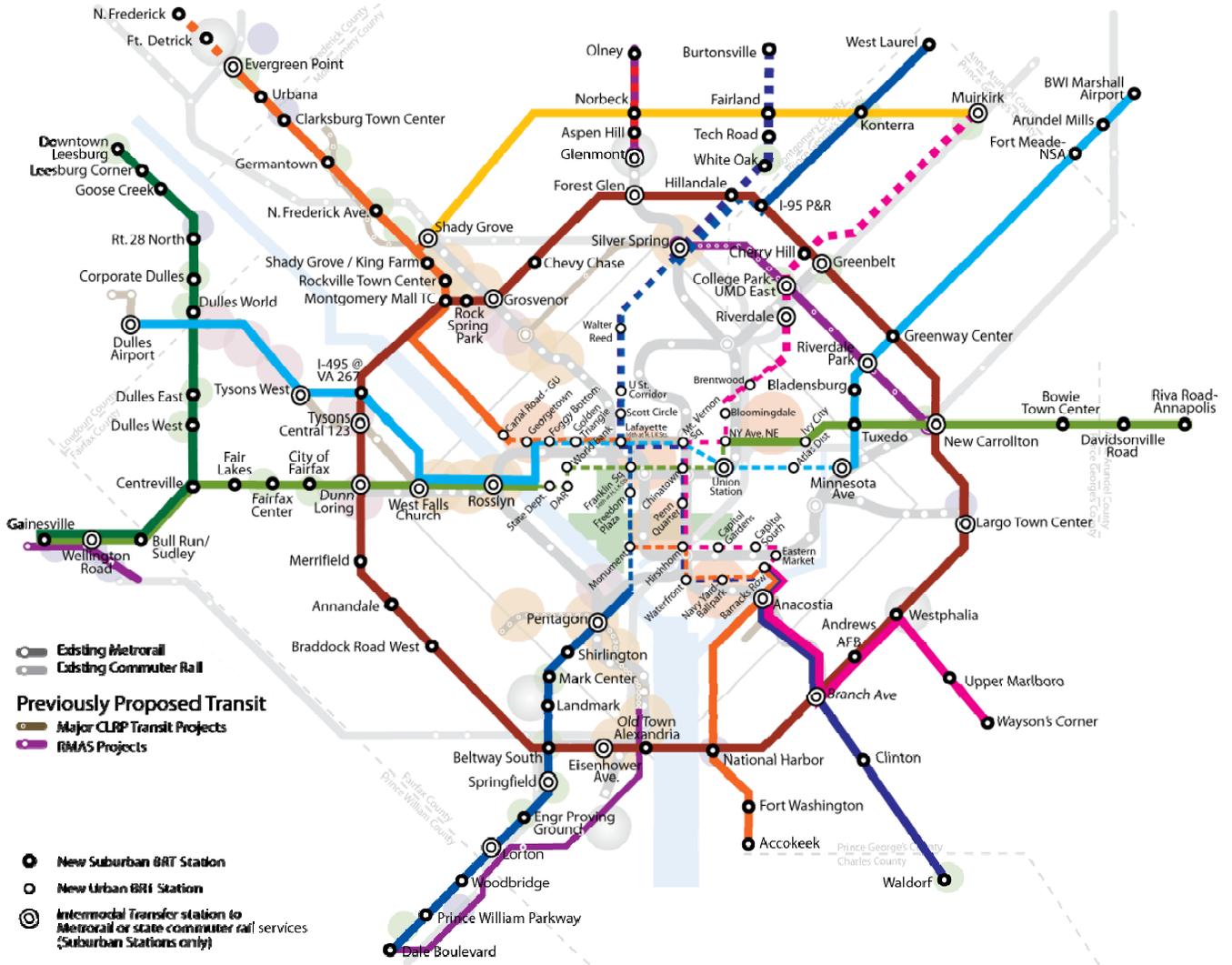
**Map 2.2: Full Variably Priced Lane Network  
PM Peak Lane Configuration**



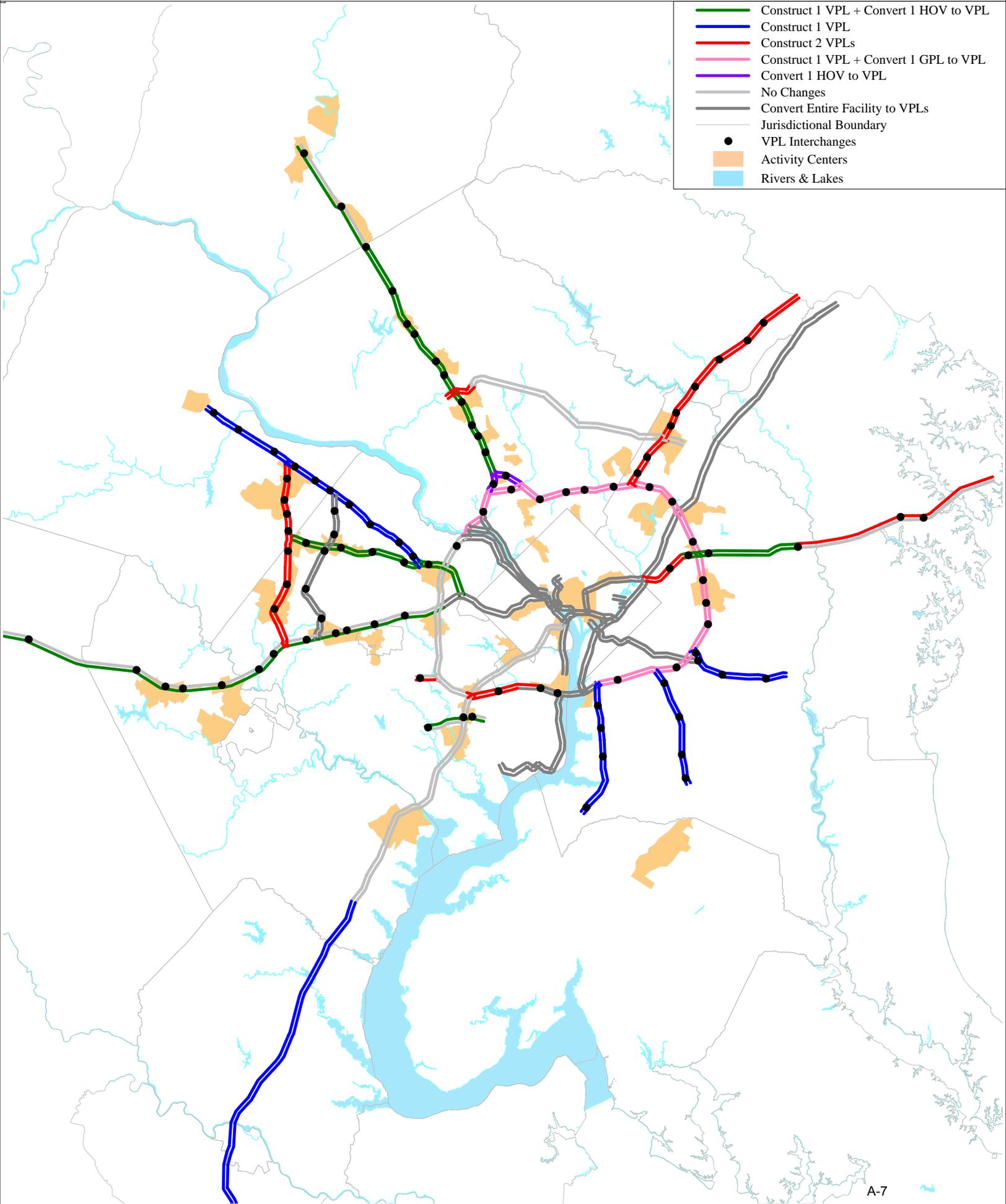
# Map 3: Full VPL Network: Lane Configuration on Major Bridges: AM Peak



# Map 4: Regional Bus Rapid Transit Network

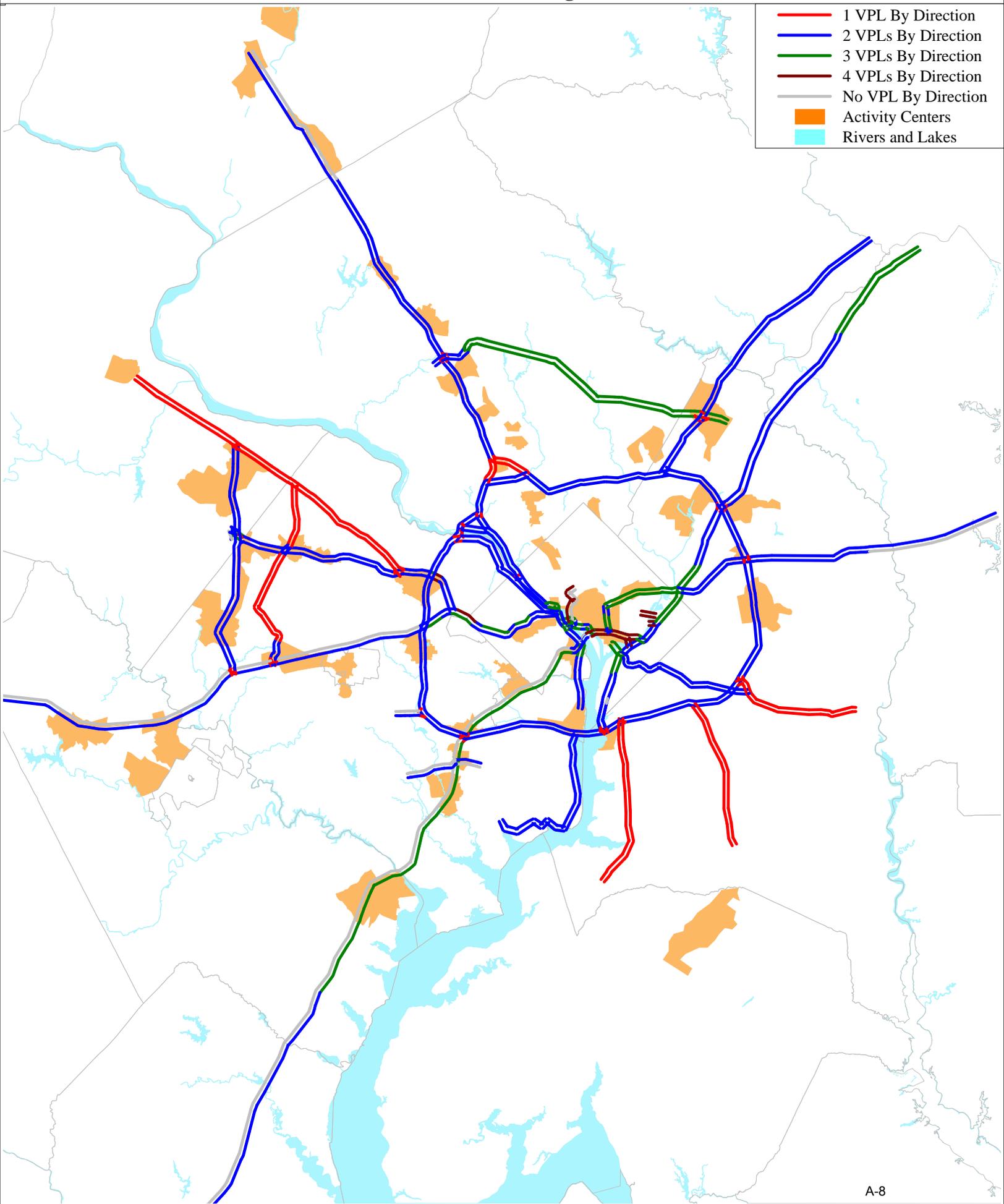


# Map 5: Streamlined VPL Network: Variably Priced Lanes to be Constructed/Converted as Compared to the 2008 CLRP



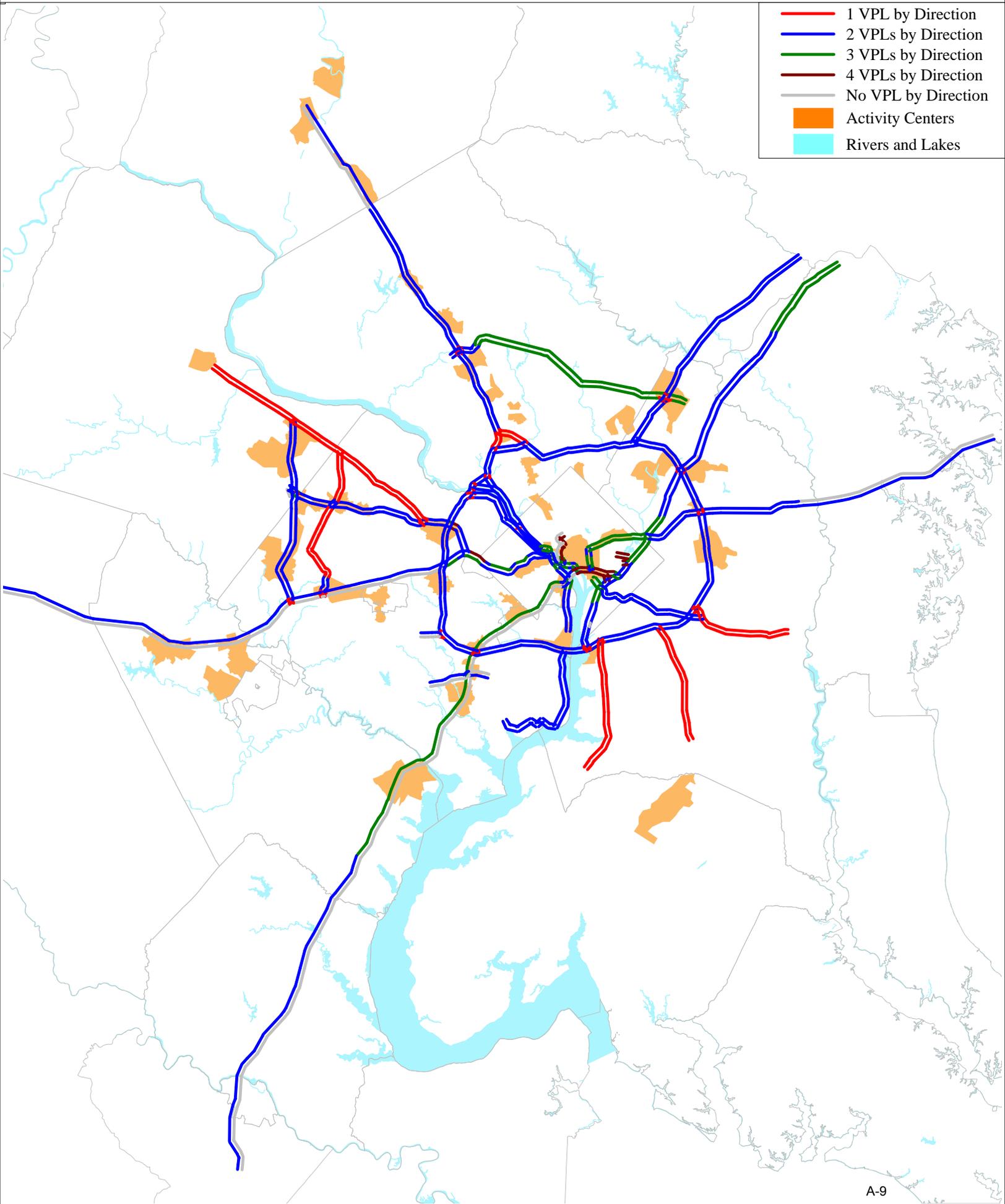
- Construct 1 VPL + Convert 1 HOV to VPL
- Construct 1 VPL
- Construct 2 VPLs
- Construct 1 VPL + Convert 1 GPL to VPL
- Convert 1 HOV to VPL
- No Changes
- Convert Entire Facility to VPLs
- Jurisdictional Boundary
- VPL Interchanges
- Activity Centers
- Rivers & Lakes

# Map 6.1: Streamlined Variably Priced Lane Network AM Peak Lane Configuration

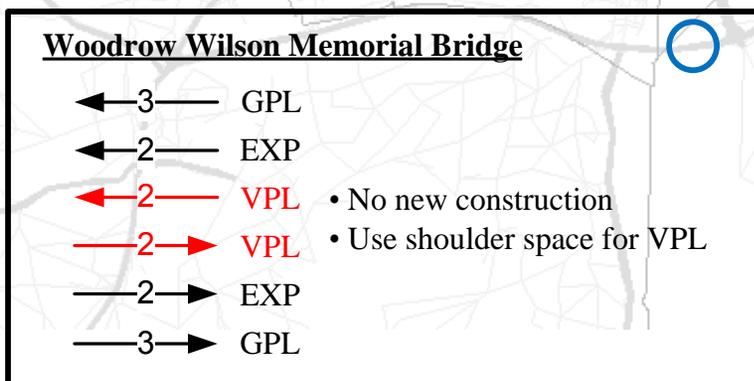
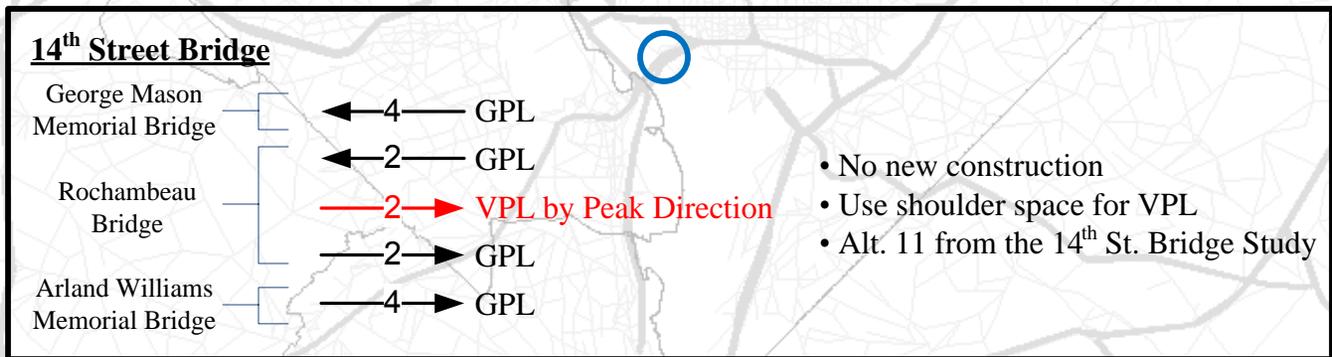
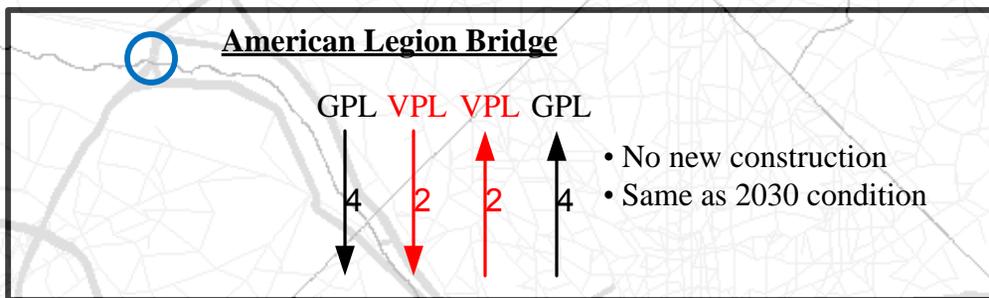


- 1 VPL By Direction
- 2 VPLs By Direction
- 3 VPLs By Direction
- 4 VPLs By Direction
- No VPL By Direction
- Activity Centers
- Rivers and Lakes

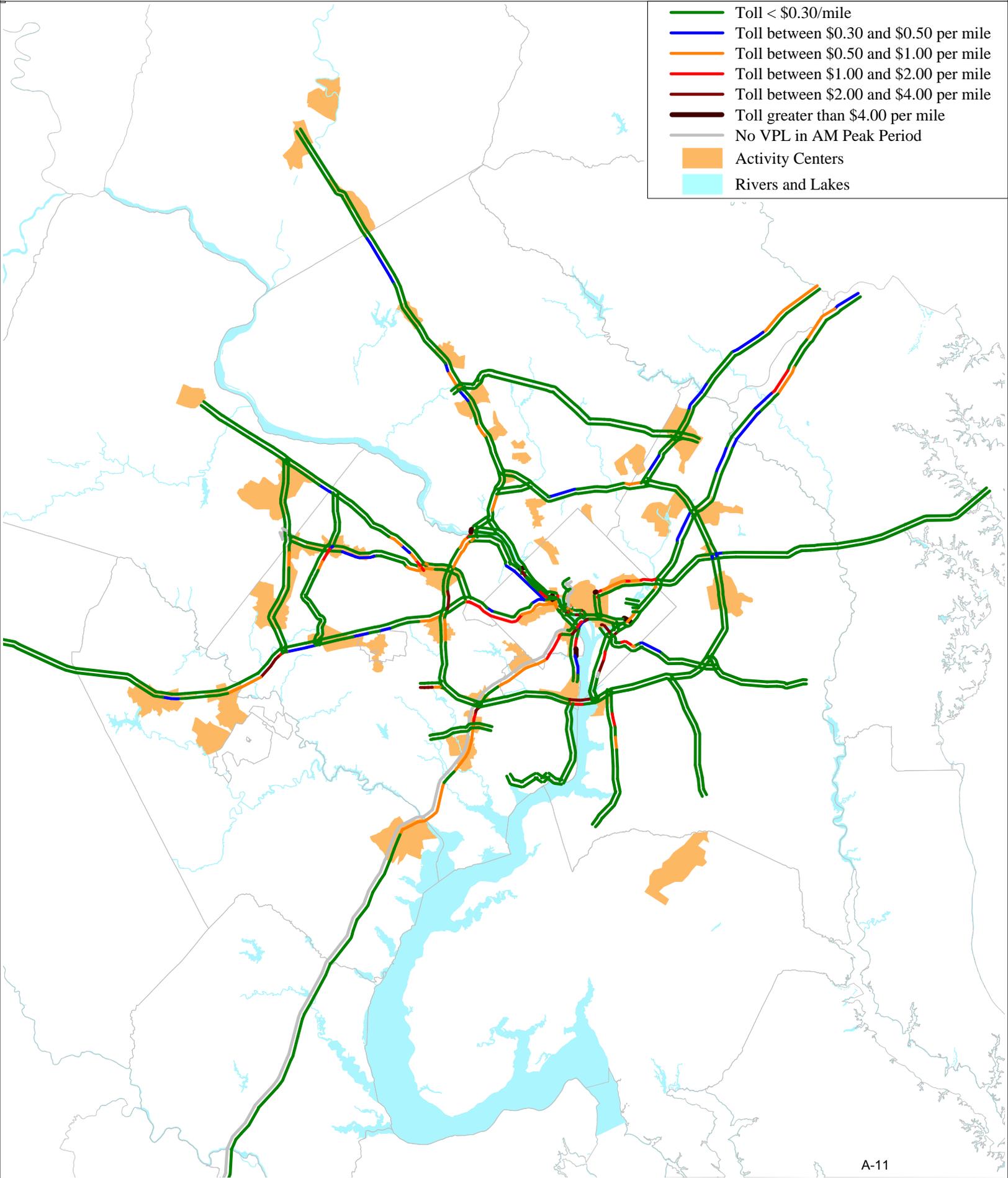
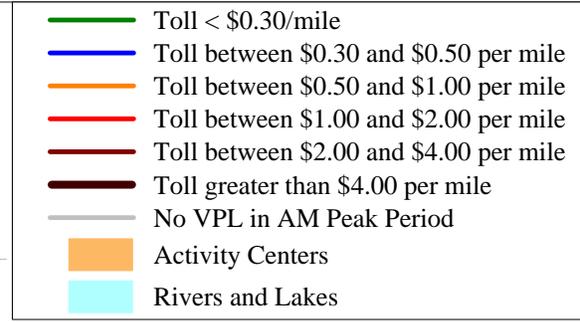
**Map 6.2: Streamlined Variably Priced Lane Network  
PM Peak Lane Configuration**



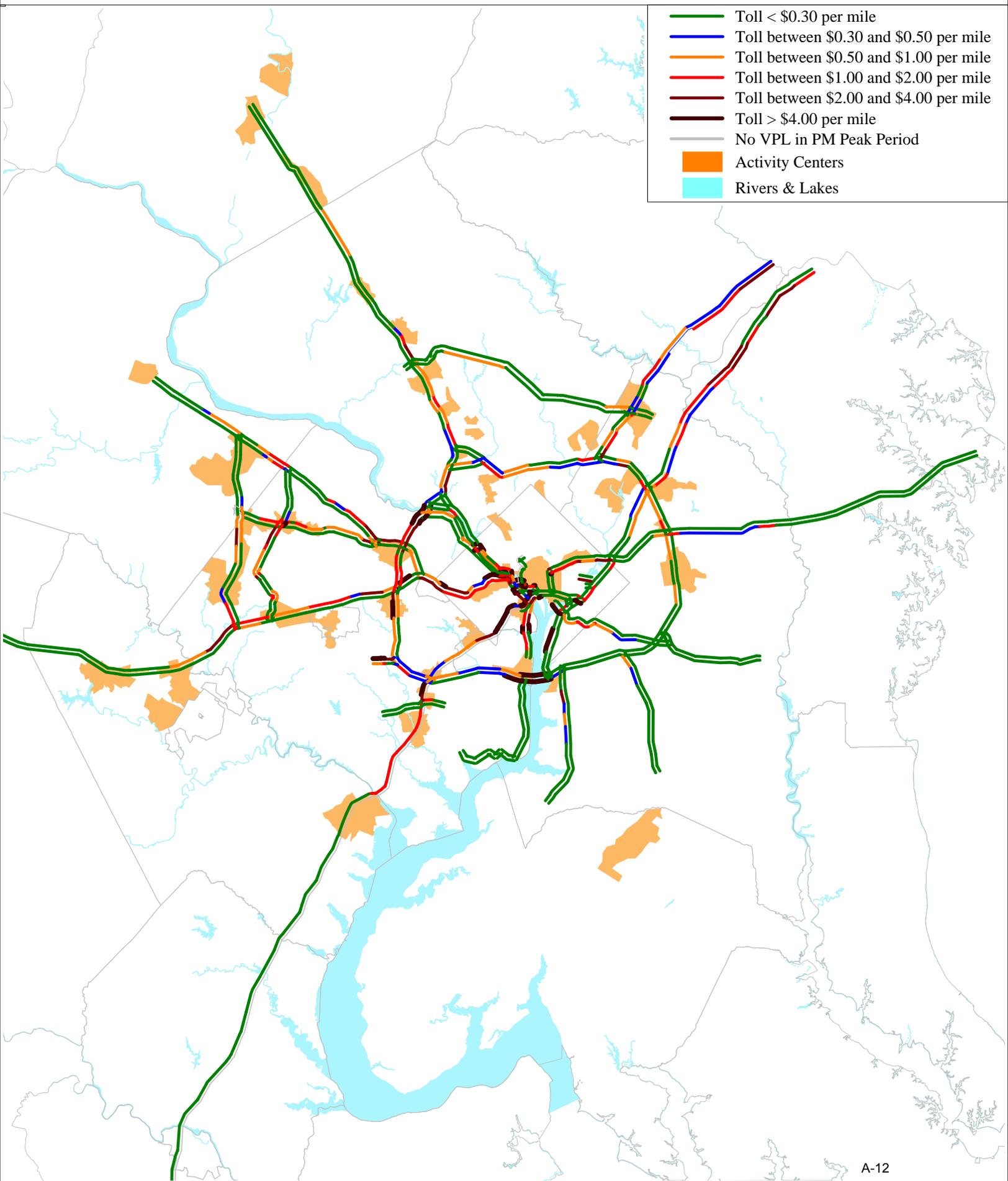
# Map 7: Streamlined VPL Network: Lane Configuration on Major Bridges: AM Peak



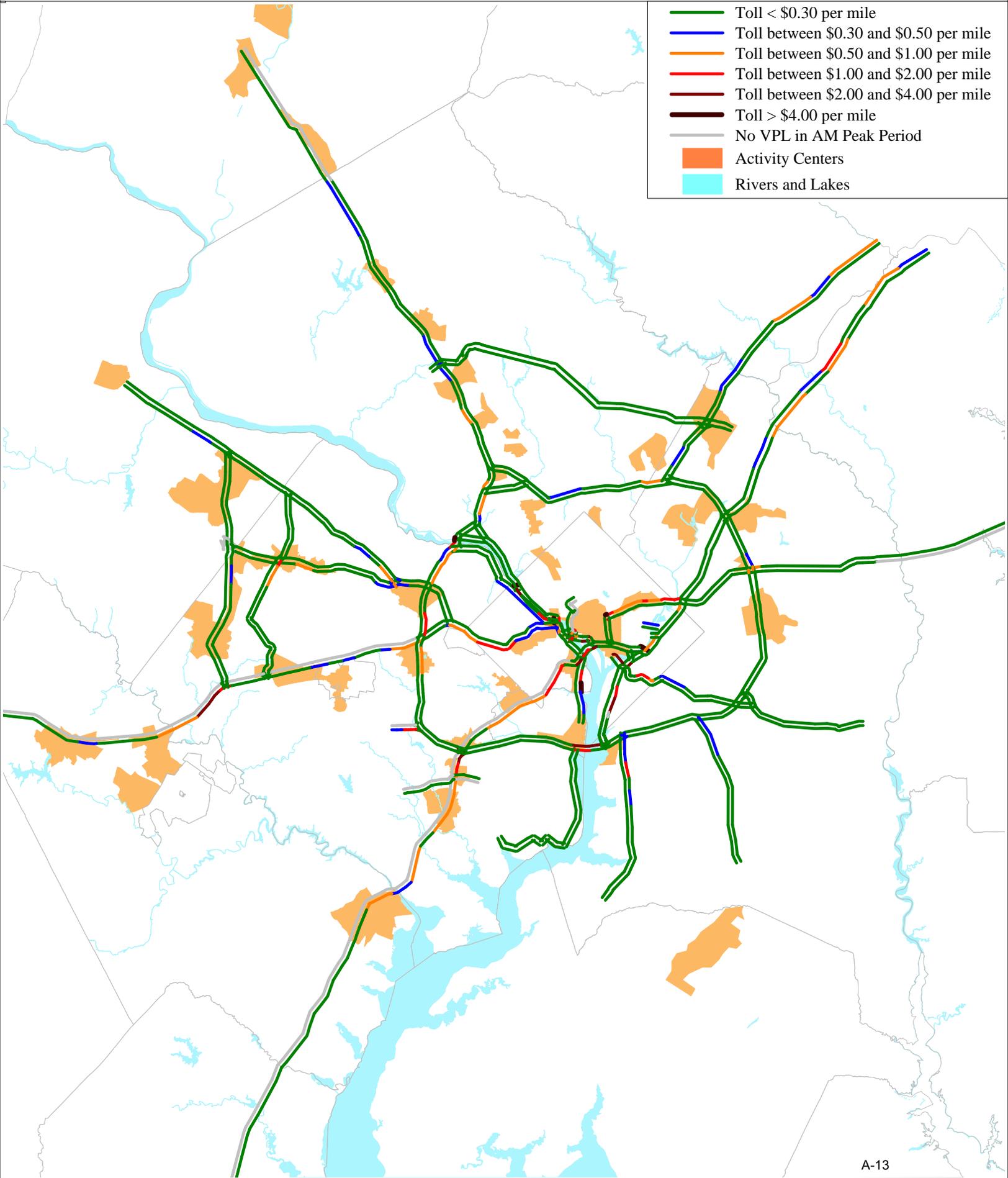
**Map 8: Full Variably Priced Lane Network**  
**AM Peak Toll Rate per Mile (2010\$)**  
**Year 2030**



# Map 9: Full Variably Priced Lane Network PM Peak Toll Rate per Mile (2010\$) Year 2030



**Map 10: Streamlined Variably Priced Lane Network**  
**AM Peak Toll Rate per Mile (2010\$)**  
**Year 2030**



# Map 11: Streamlined Variably Priced Lane Network PM Peak Toll Rate per Mile (2010\$) Year 2030

- Toll < \$0.30 per mile
- Toll between \$0.30 and \$0.50 per mile
- Toll between \$0.50 and \$1.00 per mile
- Toll between \$1.00 and \$2.00 per mile
- Toll between \$2.00 and \$4.00 per mile
- Toll > \$4.00 per mile
- No VPL in PM Peak Period
- Activity Centers
- Rivers & Lakes

