INTERCHANGE OPERTIONS STUDY

Interstate 77 / Wallings Road Interchange

City of Broadview Heights, Cuyahoga County, Ohio

Prepared For:

City of Broadview Heights
Department of Engineering
9543 Broadview Road
Broadview Heights, OH 44147
&
ODOT District 12
5500 Transportation Boulevard
Garfield Heights, OH 44125

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MAY 2016 (Rev. 7/12/16)

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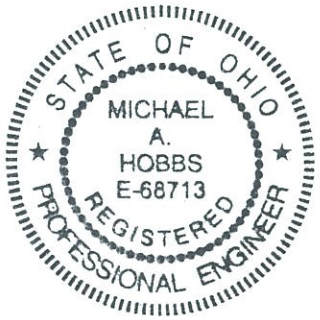
Engineer's Seal



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I. Purpose:

The City of Broadview Heights retained the services of GPD Group to perform an Interchange Operations Study (IOS) for the Interstate 77 / Wallings Road interchange. The purpose of this study is to determine if the improvements proposed as part of the *Wallings Road Interchange Alternative Evaluation* Letter, submitted to the Ohio Department of Transportation (ODOT) District 12 on May 10, 2016, will degrade the operation of Interstate 77 (I-77) in the immediate vicinity of the Wallings Road interchange and if so, what actions are required to address such degradation.

II. Study Area

The study area includes Wallings Road from just west of the Wallings Road / West Mill Road intersection to just east of the Wallings Road / Interstate 77 NB Entrance Ramp / Mill Road intersection, as well as Mill Road from Wallings Road to just south of the I-77 NB Exit Ramp. The study area also includes the I-77 freeway segments entering / exiting the Wallings Road interchange as wells as the merge and diverge points of the Wallings Road entrance / exit ramps. See **Figure 1** for a map of the study area.

III. Certified Traffic Volumes:

For the Wallings Road Interchange Operations Study, GPD Group supplied manual turning movement traffic counts for all study intersections to the ODOT Office of Statewide Planning and Research and requested that ODOT develop the certified traffic volumes for the Opening Year 2020 and Design Year 2040 traffic conditions for the Wallings Road corridor. Additionally, ODOT was also requested to develop certified traffic volumes for the I-77 / Wallings Road interchange which includes all entrance and exit ramps as well as mainline I-77 in the immediate vicinity of the interchange. Certified Traffic Plates were obtained from the ODOT Office of Statewide Planning and Research on January 29th, 2016 and are contained in **Appendix A**. These plates contain the Opening Year 2020 and Design Year 2040 ADT, AM Peak hour and PM Peak hour traffic volumes along with TD and T24 design designations.

IV. Alternatives Considered:

For the purpose of analyzing the I-77 / Wallings Road interchange, the following two (2) scenarios were evaluated:

'No-Build':

The 'No-Build' scenario assumes no changes to the existing roadway configuration or traffic operations at the interchange or surrounding roadway and is the base condition to which the subsequent alternative is compared. See **Figure 2** for a depiction of the existing traffic conditions.

'Build':

The 'Build' scenario incorporates the following proposed improvements:

- Wallings Road / I-77 NB Entrance Ramp / Mill Road Intersection:
  - Construct an EB Left turn lane
  - Construct a WB Left turn lane
  - Construct a WB Right turn lane
  - Construct a NB Left turn lane

- Wallings Road / I-77 SB Ramps Intersection:
  - Construct an EB Right turn lane
  - Construct a WB Left turn lane
  - Construct a SB Right turn lane

- Wallings Road / West Mill Road Intersection:
  - Convert existing WB Thru lane to a shared left-thru lane
  - Construct an additional WB Thru lane that would terminate approximately 400' to the west of the West Mill Road intersection

The improvements listed above will require modification to signal phasing and timings and widening of Wallings Road within the study area, including the bridge over I-77. See **Figure 3** for a conceptual rendering of the proposed improvements for the study area.

V. Traffic Analysis:

Methodology:

Capacity analyses were performed for the AM and PM peak hours for the Design Year 2040 traffic conditions in order to determine the operating conditions experienced by each intersection, freeway segment, ramp merge and ramp diverge junction. The Opening Year was not considered for analysis because the Design Year accounts for the highest amount of traffic that will utilize the I-77 / Wallings Road interchange, therefore all improvements will be designed for the Design Year conditions.

The intersection capacity analyses were performed for the AM and PM peak hours utilizing the computer programs HCS 2010 – Version 6.80 (developed by McTrans Corporation) and Synchro Version 8 (developed by Trafficware). HCS 2010 is based on the 2010 Highway Capacity Manual (HCM) and the 2009 Manual of Uniform Traffic Control Devices (MUTCD). Based on criteria established by ODOT, HCS 2010 is used to determine the required number of lanes and the lane assignments at intersections (i.e. the needed intersection capacity). HCS 2010 looks at each intersection individually and does not take into account the interaction between multiple closely spaced intersections. For this reason the HCS analysis was supplemented by additional capacity analysis software, Synchro and SimTraffic - Version 8 (developed by Trafficware). Synchro differs from HCS 2010 as it can provide a macroscopic analysis of an entire roadway system and takes into account the

interactions and impact of traffic which travels from one intersection to the next. Refer to the *Wallings Road Interchange Alternatives Evaluation* Letter submitted to ODOT District 12 on May 10, 2016 for further explanation of why the HCS 2010 analysis was supplemented with Synchro analysis.

Synchro analysis results reported for the signalized study intersections are based on the Highway Capacity Manual (HCM) 2000 calculation outputs from the Synchro software which are comparable to Highway Capacity Software (HCS) outputs. The HCM 2000 outputs were used in place of the HCM 2010 outputs because currently the HCM 2010 outputs cannot calculate a delay for a single lane operating with a protected left turn phase (i.e. EB approach of the Wallings Road / I-77 NB Entrance Ramp / Mill Road intersection). HCM 2010 outputs will continue to be utilized to report the results for the unsignalized study intersections.

Capacity analyses for freeway segments and ramp merge / diverge junctions were performed utilizing Highway Capacity Software (HCS) 2010 (Version 6.70) from the McTrans Transportation Research Center. Analysis results are based on the Highway Capacity Manual (HCM) 2010. Each freeway segment, ramp merge and ramp diverge junction of the I-77 / Wallings Road interchange was assigned a specific number for purposes of this evaluation. See **Figure 4** for a location key map that identifies the freeway segments, ramp merge and ramp diverge junctions.

Intersection Analysis:

Intersection capacity analysis was performed for the Design Year 2040 traffic conditions in order to determine the operating conditions experienced by each intersection. The quality of the operating conditions experienced by an intersection is measured in terms of Level-of-Service (LOS), which is determined by the amount of delay experienced by motorists. Levels-of-Service can range from LOS A to LOS F. Level-of-Service ratings of A, B, and C are considered to be in the acceptable range. Level-of-Service D is typically considered acceptable in urban and suburban areas (which this study area has been determined to be within). Levels-of-Service E and F are considered below average with significant levels of delay experienced by vehicles. The Level-of-Service thresholds vary for signalized and unsignalized intersections. The thresholds related to average control delay for both signalized and unsignalized intersections are shown below in **Table 1**.

Table 1: Level-of-Service Criteria for Intersections

Level-of-Service	Delay Threshold – Signalized (Sec)	Delay Threshold – Unsignalized (Sec)
A	< 10	< 10
B	> 10 - 20	> 10 – 15
C	> 20 - 35	> 15 – 25
D	> 35 - 55	> 25 - 35
E	> 55 - 80	> 35 - 50
F	> 80	> 50

HCS Analysis:

In order to maintain a consistent baseline when comparing the Design Year 2040 'No-Build' to 'Build' traffic conditions cycle lengths of 100 seconds and 70 seconds were utilized for the AM and PM peak hours, respectively. **Table 2** below summarizes the HCS Intersection Capacity Analysis and details the Levels-of-Service and delay experienced under the Design Year 2040 'No-Build' and 'Build' conditions for the signalized intersections within the study area. See **Appendix B** for the HCS Intersection Capacity Analysis printouts.

Table 2: HCS Intersection Capacity Analysis Summary – Signalized Intersections
Design Year 2040 'No-Build' vs. 'Build' Conditions

Intersection / Movement	'No-Build' Conditions				'Build' Conditions			
	AM Peak		PM Peak		AM Peak		PM Peak	
	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)
Wallings Road / I-77 SB Ramps								
Eastbound Thru	F	72.2	C	26.9	D	39.1	C	34.3
Eastbound Right					B	11.9	C	20.0
Eastbound Approach	*E*	*72.2*	*C*	*26.9*	*C*	*33.3*	*C*	*30.6*
Westbound Left	E	73.0	F	181.1	C	22.7	B	15.2
Westbound Thru					A	5.9	B	14.3
Westbound Approach	*E*	*73.0*	*F*	*181.1*	*B*	*10.9*	*B*	*14.4*
Southbound Left	E	68.0	B	13.7	C	34.1	B	17.0
Southbound Right	E	79.0	F	245.3	C	32.1	D	35.7
Southbound Approach	*E*	*73.3*	*F*	*182.7*	*C*	*33.1*	*C*	*30.6*
Intersection Total	***E***	***72.6***	***F***	***147.0***	***C***	***29.8***	***C***	***27.3***
Wallings Road / I-77 NB Entrance Ramp / Mill Road								
Eastbound Left	F	118.7	D	42.4	D	37.4	B	12.9
Eastbound Thru					A	9.0	B	14.7
Eastbound Right								
Eastbound Approach	*F*	*118.7*	*D*	*42.4*	*C*	*30.3*	*B*	*14.1*
Westbound Left	F	119.6	B	16.7	C	27.2	B	19.9
Westbound Thru					C	28.7	B	17.7
Westbound Right					C	33.4	B	17.5
Westbound Approach	*F*	*119.6*	*B*	*16.7*	*C*	*31.6*	*B*	*17.7*
Northbound Left	F	118.2	D	42.8	C	27.8	B	18.6
Northbound Thru					C	31.0	B	15.5
Northbound Right								
Northbound Approach	*F*	*118.2*	*D*	*42.8*	*C*	*29.9*	*B*	*17.8*
Intersection Total	***F***	***118.8***	***D***	***37.7***	***C***	***30.5***	***B***	***15.9***

Note: Orange highlighted cells indicate a Level of Service E.
Red highlighted cells indicate a Level of Service F.

As shown in **Table 2** above, the analysis of the Design Year 2040 'No-Build' traffic conditions indicates that the two (2) ramp terminal intersections are projected to operate with unacceptable Levels-of-Service under the design year conditions. The Design Year 2040 'Build' traffic scenario incorporates the proposed improvements to increase capacity and demonstrates that all movements and approaches are anticipated to operate with an acceptable LOS D or better with the overall intersections operating at LOS C or better during both peak hours once the improvements are completed.

Synchro Analysis:

Existing traffic signal timings including cycle lengths, splits and clearance intervals were incorporated into the capacity analysis to assess the Design Year 2040 'No-Build' operating conditions at the study intersections. While it is understood that signal timing adjustments would likely be made in the future as traffic volumes change, the existing signal timings were maintained in order to maintain a consistent baseline when comparing against the 'Build' option.

Table 3 below summarizes the HCM Intersection Capacity Analysis and details the Levels-of-Service and delay experienced under the Design Year 2040 'No-Build' and 'Build' conditions for the signalized intersections within the study area. See **Appendix B** for the HCM Intersection Capacity Analysis printouts.

Table 3: HCM Intersection Capacity Analysis Summary – Signalized Intersections
Design Year 2040 'No-Build' vs. 'Build' Conditions

Intersection / Movement	'No-Build' Conditions				'Build' Conditions			
	AM Peak		PM Peak		AM Peak		PM Peak	
	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)
Wallings Road / I-77 SB Ramps								
Eastbound Thru	C	30.4	F	200.9	B	19.1	C	22.9
Eastbound Right					A	7.2	B	14.8
Eastbound Approach	*C*	*30.4*	*F*	*200.9*	*B*	*16.6*	*C*	*20.8*
Westbound Left	D	44.2	F	733.1	D	35.3	A	4.3
Westbound Thru					A	6.9	A	5.6
Westbound Approach	*D*	*44.2*	*F*	*733.1*	*B*	*15.3*	*A*	*5.4*
Southbound Left	D	38.2	B	14.3	D	48.0	C	22.7
Southbound Right	C	32.2	F	99.5	D	37.1	C	25.6
Southbound Approach	*D*	*35.3*	*E*	*76.5*	*D*	*42.7*	*C*	*24.8*
Intersection Total	***C***	***33.4***	***F***	***240.3***	***C***	***21.0***	***B***	***19.9***

Note: Orange highlighted cells indicate a Level of Service E.
Red highlighted cells indicate a Level of Service F.

Table 3: HCM Intersection Capacity Analysis Summary – Signalized Intersections
Design Year 2040 'No-Build' vs. 'Build' Conditions (Cont.)

Intersection / Movement	'No-Build' Conditions				'Build' Conditions			
	AM Peak		PM Peak		AM Peak		PM Peak	
	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)
Wallings Road / I-77 NB Entrance Ramp / Mill Road								
Eastbound Left	F	219.9	F	151.3	A	6.7	A	5.0
Eastbound Thru					B	12.4	A	5.2
Eastbound Right								
Eastbound Approach	*F*	*219.9*	*F*	*151.3*	*A*	*8.1*	*A*	*5.2*
Westbound Left	F	88.9	D	35.7	C	23.4	B	14.4
Westbound Thru					C	25.1	B	163
Westbound Right					C	25.3	B	14.7
Westbound Approach	*F*	*88.9*	*D*	*35.7*	*C*	*25.2*	*B*	*15.6*
Northbound Left	F	122.4	D	36.7	D	36.7	C	27.8
Northbound Thru					D	50.1	B	19.0
Northbound Right								
Northbound Approach	*F*	*122.4*	*D*	*36.7*	*D*	*45.3*	*C*	*25.5*
Intersection Total	***F***	***169.8***	***F***	***95.0***	***C***	***20.3***	***B***	***13.2***

Note: Orange highlighted cells indicate a Level of Service E.
Red highlighted cells indicate a Level of Service F.

As shown in **Table 3** above, the analysis of the Design Year 2040 'No-Build' traffic conditions indicates that the two (2) signalized intersections within the study area are projected to operate with unacceptable Levels-of-Service under the Design Year conditions. The Design Year 2040 'Build' traffic scenario incorporates the proposed improvements to increase capacity and demonstrates that all movements and approaches are anticipated to operate with an acceptable LOS D or better with the overall intersections operating at LOS C or better during both peak hours once the improvements are completed.

Table 4 on the following page summarizes the HCM Intersection Capacity Analysis and details the Levels-of-Service and delay experienced under the Design Year 2040 'No-Build' and 'Build' traffic conditions for the unsignalized intersections within the study area. See **Appendix B** for the intersection capacity analysis printouts.

Table 4: HCM Intersection Capacity Analysis Summary – Unsignalized Intersections
Design Year 2040 'No-Build' vs. 'Build' Conditions

Intersection / Movement	'No-Build' Conditions				'Build' Conditions			
	AM Peak		PM Peak		AM Peak		PM Peak	
	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)
Wallings Road / West Mill Road								
Westbound Left-Thru	B	12.1	A	8.7	B	12.1	A	8.7
Westbound Approach	*A*	*0.4*	*A*	*0.1*	*A*	*0.5*	*A*	*0.4*
Northbound Left-Right	E	40.6	F	58.1	E	38.4	C	23.6
Northbound Approach	*E*	*40.6*	*F*	*58.1*	*E*	*38.4*	*C*	*23.6*
Mill Road / I-77 NB Exit Ramp								
Eastbound Left	B	13.3	C	15.4	B	13.3	C	15.4
Eastbound Right	A	9.2	A	9.7	A	9.2	A	9.7
Eastbound Approach	*B*	*12.0*	*B*	*13.7*	B	12.0	B	13.7

Note: Orange highlighted cells indicate a Level of Service E.
Red highlighted cells indicate a Level of Service F.

As shown in **Table 4** above, the analysis of the Design Year 2040 'No-Build' traffic conditions shows that the NB approach of the Wallings Road / West Mill Road intersection would be expected to operate with unacceptable Levels-of-Service due to the constant flow of traffic along Wallings Road creating minimal gaps in traffic to allow West Mill Road vehicles to enter Wallings Road. This deficiency will be mitigated with the proposed improvements during the PM Peak Hour under the Design Year 2040 'Build' condition but not during the AM Peak hour. Although this intersection is projected to operate at an unacceptable LOS E during the AM Peak hour it should be noted that motorists will experience slightly less delay under the proposed 'Build' condition as compared to the 'No-Build' condition.

Constrained Traffic Volumes:

Constrained traffic occurs when all the traffic desiring to enter the freeway cannot do so. The cause of constrained traffic is when the Volume-to-Capacity (V/C) Ratio is greater than 1.0. In these instances, it is necessary to determine the difference between the volumes entering the freeway in the 'No-Build' condition from the 'Build' condition. According to Section 550.2 of the ODOT Location and Design Manual, Volume I, an improvement is deemed to have the potential to degrade the freeway operation if the release of the constrained traffic increases the traffic volumes on the downstream freeway mainline by more than 2.00%.

Based on the results of the HCS intersection capacity analysis performed as part of this IOS, it was determined that the Design Year 2040 I-77 traffic volumes are constrained at the Wallings Road Interchange in the 'No-Build' scenario during the peak hours. The constrained volume analysis of the Wallings Road / I-77 NB Entrance Ramp indicates that the EB left, WB right and NB thru movements are all constrained as the V/C ratio for each exceeds 1.0 during the AM Peak hour. The constrained volume analysis of the Wallings

Road / I-77 SB Entrance Ramp indicates that the EB right movement during the AM Peak hour and the WB left turn movement during the PM Peak hour are also constrained with their V/C ratios exceeding 1.0. With these turning movements being constrained it means that the I-77 NB and SB Entrance Ramp volumes are also constrained and therefore less traffic is entering the freeway than what is depicted in the certified traffic plates. **Table 5** below compares the constrained vehicular volumes from the 'No-Build' condition to the unconstrained vehicular volumes in the 'Build' condition.

Table 5: Constrained Traffic Volume Comparison – 'No-Build' vs. 'Build' Conditions

Highway Analysis Point	'No-Build' Condition		'Build' Condition	
	AM Peak	PM Peak	AM Peak	PM Peak
I-77 Northbound				
M-1 (Wallings Road Entrance Ramp)	1,031	*	1,200	*
F-3 (Wallings Road to Pleasant Valley Road)	5,981	*	6,150	*
I-77 Southbound				
M-2 (Wallings Road Entrance Ramp)	310	193	330	210
F-6 (Wallings Road to SR-82)	3,880	5,493	3,900	5,510

*Traffic Volume Not Constrained

These constrained traffic volumes were incorporated into the 'No-Build' conditions and the unconstrained traffic volumes were incorporated into the 'Build' conditions for the HCS analysis of freeway segments and ramp merge junctions. The constrained traffic volumes are shown in **Figure 5** and the calculations are contained in **Appendix C**.

As previously mentioned in the beginning of this section, Section 550.2 of the ODOT Location and Design Manual, Volume I, deems that an improvement has the potential to degrade the freeway operation if it increases the traffic on the downstream freeway mainline by more than 2.00%. The constrained traffic volume analysis indicates that only the improvements at the Wallings Road / I-77 NB Entrance Ramp / Mill Road intersection have the potential to degrade freeway operation during the AM Peak hour under the Design Year 2040 'Build' condition. The constrained traffic volume calculations indicate that 169 more vehicles will enter I-77 NB during the AM Peak hour under the 'Build' condition as compared to the 'No-Build' condition. This is a 2.83% increase in the mainline I-77 traffic volume, which is greater than 2.00%, and according to the Location and Design Manual this increase in traffic may potentially degrade freeway operation and warrants further analysis. This additional analysis was performed and is detailed in the subsequent section.

Freeway Section Analysis:

The quality of the operating conditions experienced by a freeway segment is measured in terms of Level-of-Service (LOS) which is determined by the density of traffic on the road. The density of traffic is measured by passenger cars per mile per lane (pc/mi/ln). Levels-of-Service can range from LOS A to LOS F. Level-of-Service ratings of A, B, and C are

considered to be in the acceptable range with little to no delay to motorists. Level-of-Service D is typically considered acceptable in urban and suburban areas and is the grade where motorists begin to slow down and experience congestion. Levels-of-Service E and F are considered unacceptable with significant congestion and delay experienced by motorists. **Table 6** below identifies the LOS criteria for freeway segments.

Table 6: Level-of-Service Criteria for Basic Freeway Segments

Level of Service	Density (pc/mi/ln)
A	0 - 11
B	> 11 - 18
C	> 18 - 26
D	> 26 - 35
E	> 35 - 45
F	> 45

Table 7 below summarizes the HCS Freeway Capacity Analysis and details the Levels-of-Service and density experienced under the Design Year 2040 'No-Build' and 'Build' traffic conditions of the basic freeway segments within the study area. See **Appendix D** for the HCS Freeway Capacity Analysis printouts.

Table 7: Mainline Freeway Segment Levels-of-Service Summary – Design Year 2040 'No-Build' vs. 'Build' Conditions

Freeway Segment	'No-Build' Conditions				'Build' Conditions			
	AM Peak		PM Peak		AM Peak		PM Peak	
	LOS	Density (pc/mi/ln)	LOS	Density (pc/mi/ln)	LOS	Density (pc/mi/ln)	LOS	Density (pc/mi/ln)
I-77 Northbound								
F-1 (SR-82 to Wallings Road)	D	33.1	D	26.4	D	33.1	D	26.4
F-2 (I-77 / Wallings Road Interchange)	D	31.0	C	24.3	D	31.0	C	24.3
F-3 (Wallings Road to Pleasant Valley Road)	E	41.5	D	26.9	E	43.9	D	26.9
I-77 Southbound								
F-4 (Pleasant Valley Road to Wallings Road)	C	23.9	F	53.1	C	23.9	F	53.1
F-5 (I-77 / Wallings Road Interchange)	C	22.0	D	34.0	C	22.0	D	34.0
F-6 (Wallings Road to SR-82)	C	19.7	D	32.1	C	19.8	D	32.3

Note: Orange highlighted cells indicate a Level of Service E.
Red highlighted cells indicate a Level of Service F.

As shown in **Table 7** on the previous page, the results of the mainline freeway analyses indicate that all freeway segments are anticipated to operate with acceptable Levels-of-Service of D or better under the Design Year 2040 'No-Build' and 'Build' conditions with the exception of the I-77 NB from Wallings Road to Pleasant Valley Road segment (F-3) during the AM Peak hour and the I-77 SB from Pleasant Valley Road to Wallings Road

segment (F-4) during the PM Peak hour. The freeway segment F-4 operates at a LOS F during the PM Peak hour due to the large amount of commuters traveling south from the Cleveland area. This section of freeway will not provide sufficient capacity under the Design Year 2040 'No-Build' condition and since no improvements are proposed as part of this IOS this segment will continue to operate at a LOS F under the 'Build' condition. Further, the changes proposed with this IOS will in no way impact the operation of freeway segment F-4.

The freeway segment F-3 is of particular importance because it is the freeway segment that corresponds to the constrained traffic analysis mentioned in the previous section. As previously mentioned, the 'Build' improvements at the Wallings Road / I-77 NB Entrance Ramp / Mill Road intersection will increase the amount of traffic entering this segment by 2.83% which may potentially degrade freeway operation and warranted further analysis. The freeway analysis indicates that this segment operates at a LOS E under the 'No-Build' condition and will continue to operate at a LOS E under the 'Build' condition with only 2.4 pc/mi/ln being added, or a 5.78% increase. The results indicate that this freeway segment will operate at the same Level-of-Service under the 'Build' condition as it did under the 'No-Build' condition and the slight increase in density that will occur under the 'Build' condition is insignificant as it will maintain the same Level-of-Service.

Ramp Junction Analyses:

Merging and diverging areas of influence are considered separately from the mainline segment analysis. Merge / diverge analyses were performed for the ramp movements of the I-77 / Wallings Road interchange. **Table 8** below summarizes the LOS criteria for freeway merge and diverge areas of influence.

Table 8: Level-of-Service Criteria for Freeway Merge and Diverge Areas of Influence

Level of Service	Density (pc/mi/ln)
A	0 – 10
B	> 10 – 20
C	> 20 – 28
D	> 28 – 35
E	> 35
F	Demand Exceeds Capacity

Table 9, on the following page, summarizes the HCS Ramp Areas of Influence Analysis and details the Levels-of-Service and density experienced under the Design Year 2040 'No-Build' and 'Build' traffic conditions of these ramp areas of influence. See **Appendix D** for the HCS Ramp Areas of Influence analyses printouts.

Table 9: Ramp Areas of Influence Levels-of-Service Summary – Design Year 2040 'No-Build' vs. 'Build' Conditions

Freeway Segment	'No-Build' Conditions				'Build' Conditions			
	AM Peak		PM Peak		AM Peak		PM Peak	
	LOS	Density (pc/mi/ln)	LOS	Density (pc/mi/ln)	LOS	Density (pc/mi/ln)	LOS	Density (pc/mi/ln)
D-1 (I-77 NB Ramp)	D	29.9	C	25.7	D	29.9	C	25.7
D-2 (I-77 SB Ramp)	C	22.8	F	37.7	C	22.8	F	37.7
M-1 (I-77 NB Ramp)	D	33.2	C	23.0	D	34.6	C	23.0
M-2 (I-77 SB Ramp)	B	19.9	D	28.0+	C	20.0+	D	28.2

As shown in **Table 9** above, the analyses of the Design Year 2040 'No-Build' and 'Build' traffic conditions shows that all ramp merge / diverge junctions are anticipated to operate with acceptable Levels-of-Service of D or better with the exception of the I-77 SB Exit Ramp to Wallings Road (D-2) during the PM Peak hour. These results can be confirmed as accurate, as the freeway section analysis indicates the freeway section (F-4) preceding the D-2 diverge junction also fails during the PM Peak hour. The density for the M-1 merge junction during the AM Peak hour and the M-2 merge junction during both peak hours slightly increased from the 'No-Build' to 'Build' condition with no changes in Level-of-Service or operation. The reason for this increase was that the 'No-Build' condition had constrained traffic volumes and the 'Build' condition unconstrained these volumes and therefore slightly increased the density experienced at these merge junctions. It should be noted that the operation of these merge junctions will not degrade with the additional unconstrained traffic volume.

Storage Length Calculations and Recommendations:

Storage length calculations are performed in order to determine the required length for each auxiliary turn lane based on the Design Year 2040 peak hour traffic volumes. The required storage length is a function of the signal cycle length (if a signalized intersection is being analyzed), lane assignments, and turning movement demand. The required storage length at a signalized intersection can be minimized by utilizing the shortest, most reasonable signal cycle length. The ODOT Location and Design Manual, Volume I specifies that a storage length must provide enough storage to contain the number of vehicles per lane group per signal cycle. The recommended lengths were determined based on these calculations, site conditions (i.e. the locations of existing roadways or private driveways), access management, and engineering judgment. **Table 10** on the following page shows the calculated turn lane lengths for the recommended turn lanes under the Design Year 2040 'Build' conditions. See **Appendix E** for the actual storage length calculations.

Table 10: Auxiliary Turn Lane Recommended Storage Lengths – Design Year 2040 'Build' Conditions			
Intersection	Storage Length (ft)		
	Turn Lane Calculated Length	Thru Back-Up	Recommended
Wallings Road / I-77 SB Ramps EB Right Turn Lane	325′	855′	325′
Wallings Road / I-77 SB Ramps WB Left Turn Lane	200′	350′	100′
Wallings Road / I-77 SB Ramps SB Right Turn Lane	387.5′	325′	400′
Wallings Road / I-77 NB Entrance Ramp / Mill Road EB Left Turn Lane	800′	400′	450′
Wallings Road / I-77 NB Entrance Ramp / Mill Road WB Left Turn Lane	100′	175′	100′
Wallings Road / I-77 NB Entrance Ramp / Mill Road WB Right Turn Lane	325′	175′	325′
Wallings Road / I-77 NB Entrance Ramp / Mill Road NB Left Turn Lane	325′	325′	325′

* - All storage length calculations include the 50′ diverging taper

As shown in **Table 10** above, a majority of the turn lanes are recommended to be constructed at the calculated storage length. The length of the WB left turn lane at the Wallings Road / I-77 SB Ramps intersection and the EB left turn lane at the Wallings Road / I-77 NB Entrance Ramp / Mill Road intersection are constrained by their close proximity to one another. These turn lanes will be located on the bridge over I-77 and will back into one another with approximately 550′ of pavement on the bridge, from stop bar to stop bar. The WB left turn lane at the Wallings Road / I-77 SB Ramps intersection was given the minimal amount of storage length required, 100′ (50′ of storage with a 50′ taper), with the EB left turn lane at the Wallings Road / I-77 NB Entrance Ramp / Mill Road intersection receiving the remaining 450′ of bridge deck pavement. This was recommended due to the large difference in magnitude of the left turning traffic volume at the two (2) intersections.

VI. Summary and Recommendations:

In Summary, The City of Broadview Heights retained the services of GPD Group to perform an Interchange Operations Study (IOS) for the Interstate 77 / Wallings Road interchange. The purpose of this study was to determine if the improvements proposed as part of the *Wallings Road Interchange Alternative Evaluation* Letter, submitted to the Ohio Department of Transportation (ODOT) District 12 on May 10, 2016, will degrade the operation of Interstate 77 (I-77) in the immediate vicinity of the Wallings Road interchange and if so, what actions are required to address such degradation. The findings of this Interchange Operations Study are summarized below:

- The intersection capacity analysis indicated that the recommended improvements proposed as part of the 'Build' condition will increase capacity and reduce congestion and delay at both ramp terminal intersections in the I-77 / Wallings Road interchange as well as the Wallings Road / West Mill Road intersection.

- The freeway section analysis and ramp merge / diverge analysis results indicate that the proposed improvements along Wallings Road will not degrade the operation of I-77 under the Design Year 2040 traffic conditions and as such, does not require any mitigating measures.

This study recommends the following roadway improvements:

- Wallings Road / I-77 NB Entrance Ramp / Mill Road Intersection:
  - Construct a EB Left turn lane
  - Construct a WB Left turn lane
  - Construct a WB Right turn lane
  - Construct a NB Left turn lane

- Wallings Road / I-77 SB Ramps Intersection:
  - Construct a EB Right turn lane
  - Construct a WB Left turn lane
  - Construct a SB Right turn lane

- Wallings Road / West Mill Road Intersection:
  - Convert existing WB Thru lane to a shared left-thru lane
  - Construct an additional WB Thru lane that would terminate approximately 400' to the west

The roadway improvements detailed above should be pursued as each individual improvement will contribute to the overall function of the I-77 / Wallings Road interchange and allow it to continue to provide for the current needs and future demands expected by the traveling public while sustaining acceptable traffic operations. No improvements to the mainline of Interstate 77 are being recommended, or are required as part of this study.

FIGURES

N

N.T.S.

FIGURE 1

STUDY AREA MAP

MAY 2016

GPD GROUP.

Glaus, Pyle, Schomer, Burns & DeHaven, Inc.

CAD FILE: O:\2015\2015406\CUP\00000\TRAFFIC\DOCS\INTERCHANGE OPERATIONS STUDY\FIGURES\FIGURE 1.DWG
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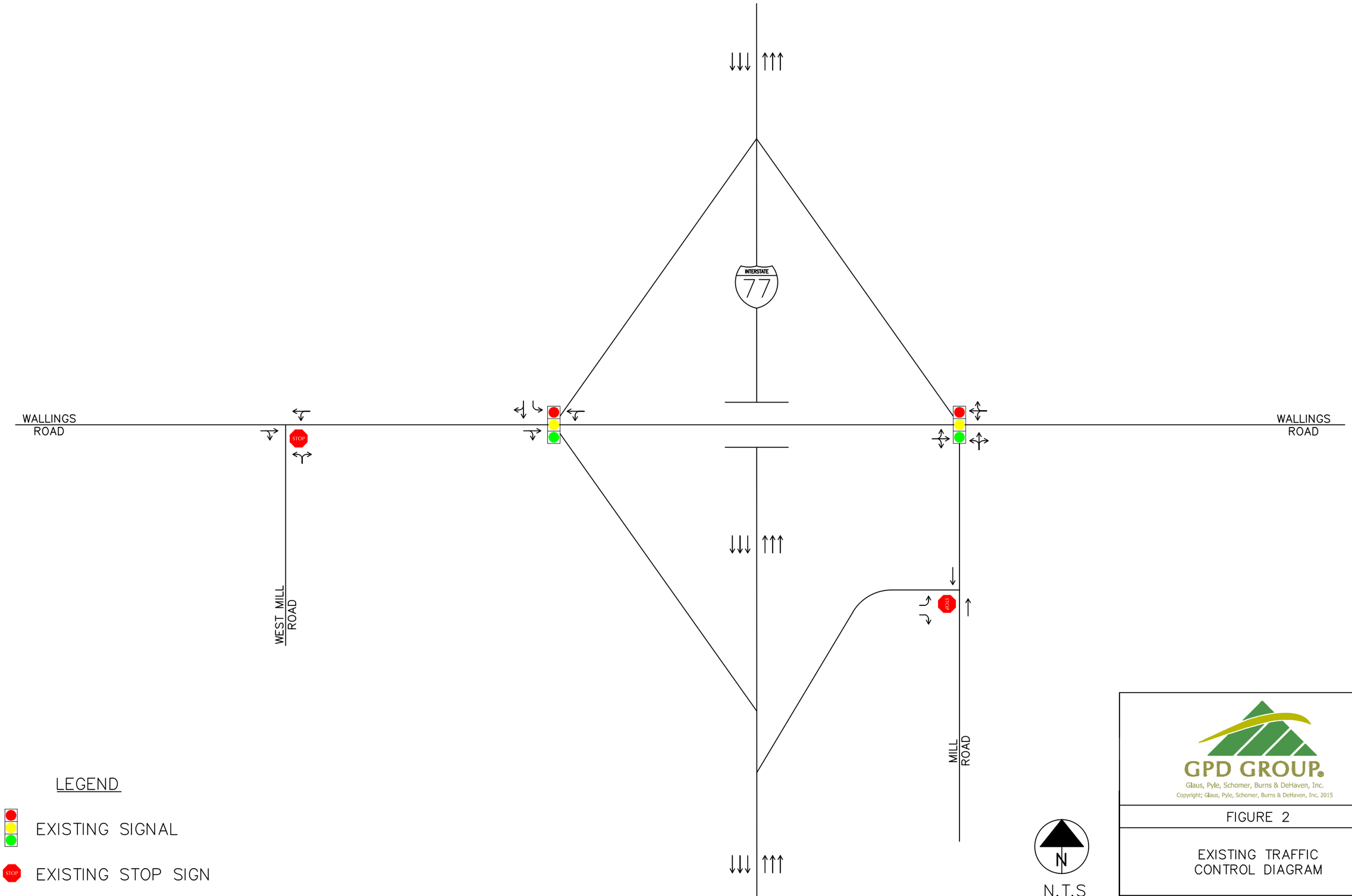

GPD GROUP
Glaus, Pyle, Schomer, Burns & DeHaven, Inc.

FIGURE 2

EXISTING TRAFFIC
CONTROL DIAGRAM

MAY 2016

Drawing File: D:\2015\2015406\CUY\000000\traffic\docs\Interchange Operations Study\Figures\Figure 2_Existing Conditions.dwg Layout: Sheet 1
Date: May 10, 2016 Time: 11:35 am Twist: -1.57079633
Technician: bferrell

WALLINGS RD.

W. MILL RD.

MILL RD.

LEGEND

RAISED MEDIAN	PROPOSED PAVEMENT
CURB AND GUTTER	PROPOSED BRIDGE
EXISTING PAVEMENT	SIGNALIZED INTERSECTION
PROPOSED SIDEWALK	

N

0 80

40 160

Horizontal Scale in Feet

GPD GROUP.

Glaus, Pyle, Schomer, Burns & DeHaven, Inc.

FIGURE 3

PROPOSED IMPROVEMENTS RENDERING

MAY 2016

Drawing File: O:\2015\2015406\DUY\00000\traffic\docs\Interchange Operations Study\Figures\Interchange Rendering.dwg Layout: Roll Plot
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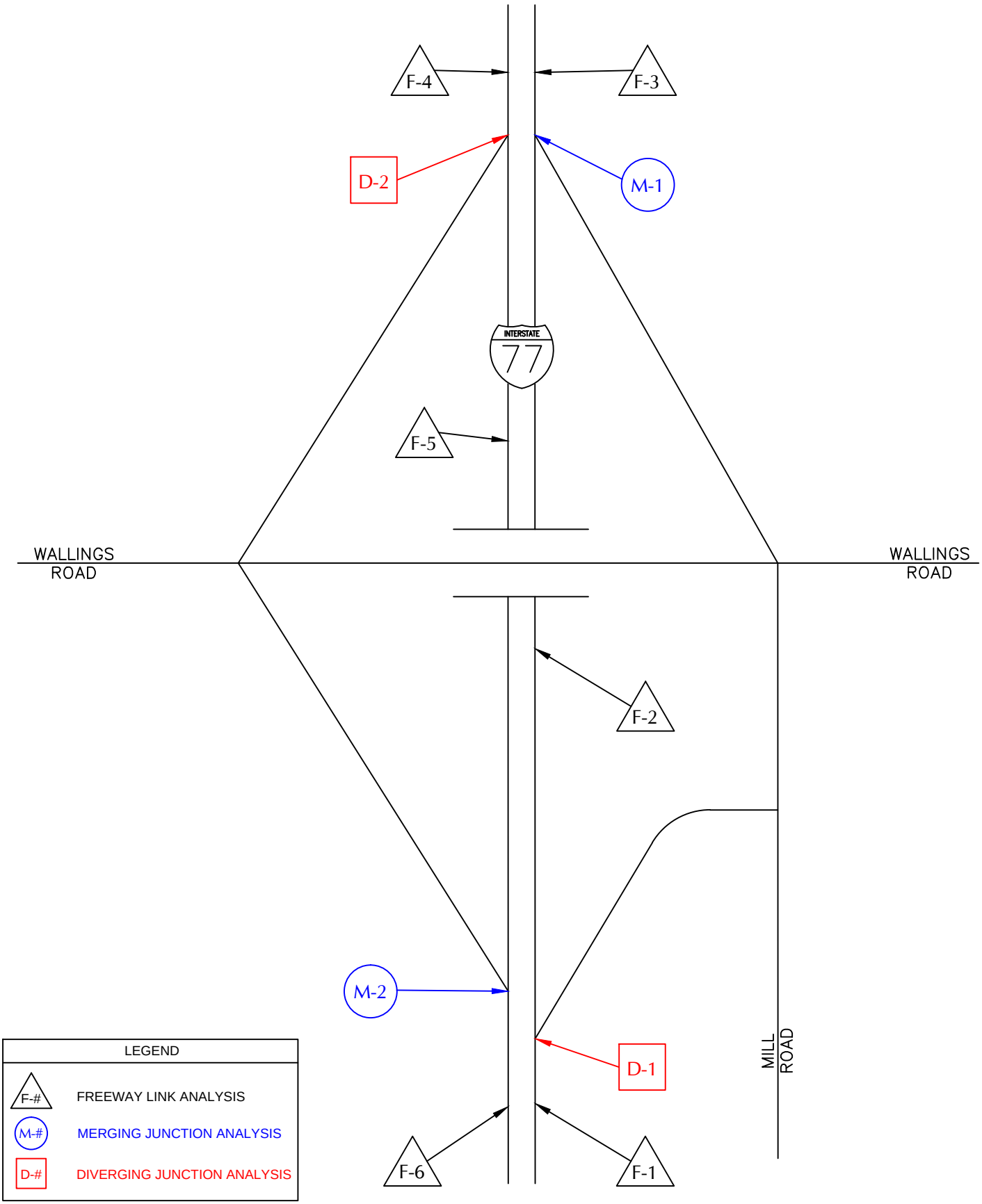

N

N.T.S.

FIGURE 4

FREEWAY LOCATION
KEY MAP

MAY 2016

GPD GROUP.
Glaus, Pyle, Schomer, Burns & DeHaven, Inc.

CAD FILE: O:\2015\2015406\CUY\00000\TRAFFIC\DOCS\INTERCHANGE OPERATIONS STUDY\FIGURES\FIGURE 4.DWG
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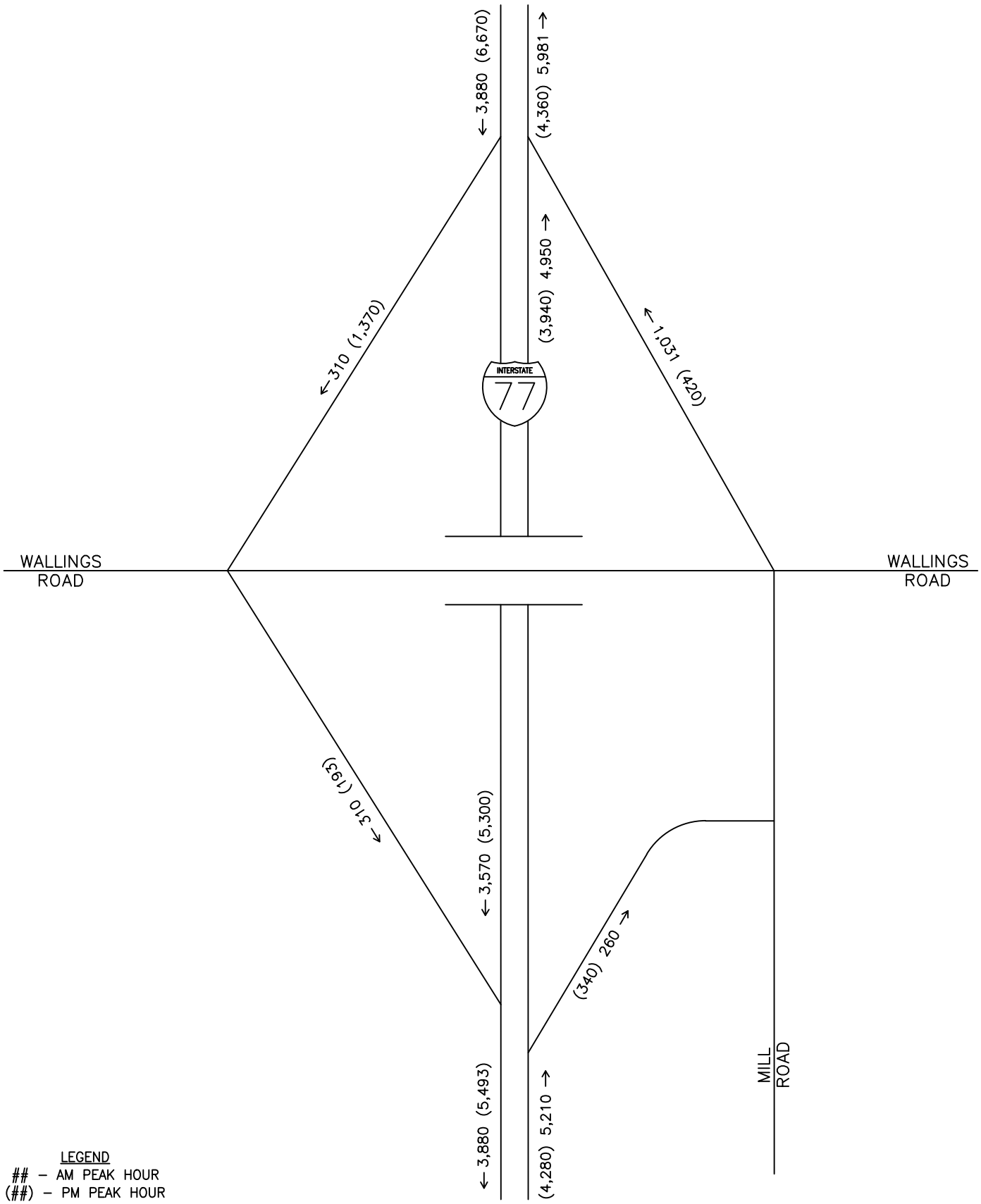

N

N.T.S.

FIGURE 5

DESIGN YEAR 2040 'NO–BUILD'
CONSTRAINED TRAFFIC VOLUMES

MAY 2016 (REV. 7/12/16)

GPD GROUP.
Glaus, Pyle, Schomer, Burns & DeHaven, Inc.

CAD FILE: O:\2015\2015406\CUY\00000\TRAFFIC\DOCS\INTERCHANGE OPERATIONS STUDY\FIGURES\FIGURE 5_CONSTRAINED VOLUMES.DWG
DATE: 7/12/2016 TIME: 9:28:41 AM
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APPENDIX A
CERTIFIED TRAFFIC PLATES

INTER-OFFICE COMMUNICATION

TO: **Brian Blayney, P.E., Traffic Planning Engineer, District 12**

FROM: Joshua Kieselbach, P.E., Transportation Engineer, Office of Statewide Planning & Research, Modeling & Forecasting Section

SUBJECT: **CUY-CR57-4.42, No PID**

DATE: January 29, 2016

In reply to a request dated December 1, 2015, the request for certified traffic for the subject project has been completed. The tables below list the requested design designations. In addition three plates are attached showing the 2020/2040 ADT, AM DHV and PM DHV.

	I-77					
location	*north of Wallings Rd.*	*south of Wallings Rd.*	*SB off-ramp*	*SB on-ramp*	*NB off-ramp*	*NB on-ramp*
2020 ADT:	93380	81900	9050	2400	2770	7600
2040 ADT:	107740	95980	9560	2700	2810	7710
K:	0.10	0.10	0.14	0.12	0.12	0.16
2040 DHV:	11010	9790	1370	330	340	1200
D:	0.61	0.56	1.00	1.00	1.00	1.00
T24:	0.07	0.07	0.01	0.03	0.03	0.01
TD:	0.04	0.04	0.01	0.02	0.02	0.01

Table 1: I-77 Mainline & Ramps

	Wallings Rd.					
location	*west of Wright Rd.*	*west of Skyline Dr.*	*west of W. Mill Rd.*	*west of I-77 SB*	*west of I-77 NB*	*east of I-77 NB*
2020 ADT:	18090	18100	18200	17500	13130	7030
2040 ADT:	18940	18980	19080	18390	13730	7370
K:	0.10	0.10	0.10	0.10	0.10	0.10
2040 DHV:	1960	1980	1980	1900	1350	750
D:	0.73	0.72	0.72	0.75	0.80	0.61
T24:	0.02	0.02	0.01	0.01	0.02	0.02
TD:	0.01	0.01	0.01	0.01	0.01	0.01

Table 2: Wallings Rd.

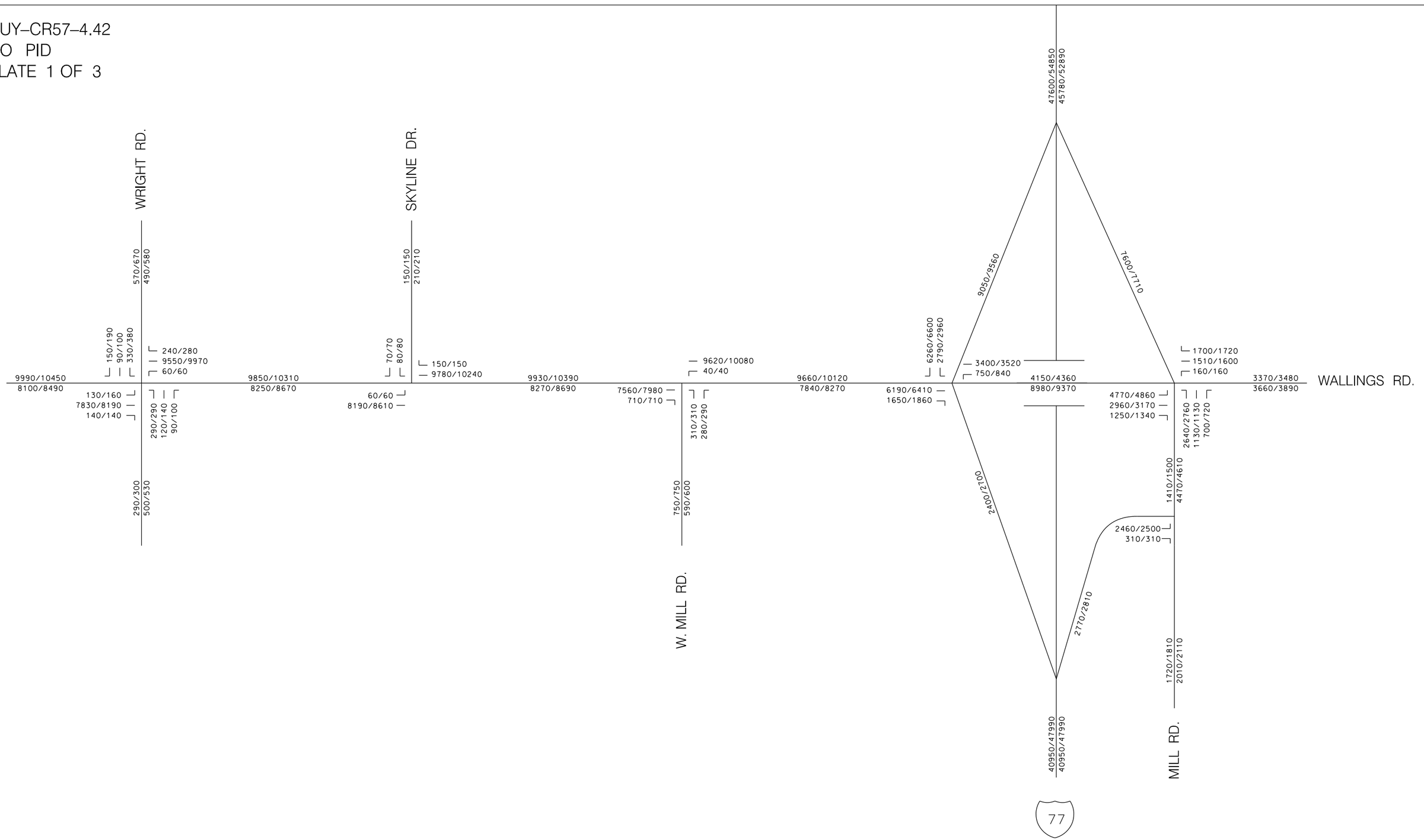
	Wright Rd.		Skyline Dr.	W. Mill Rd.	Mill Rd.	
location	*north of Wallings Rd.*	*south of Wallings Rd.*	*north of Wallings Rd.*	*south of Wallings Rd.*	*north of I-77 NB off-ramp*	*south of I-77 NB off-ramp*
2020 ADT:	1060	790	360	1340	5880	3730
2040 ADT:	1250	830	360	1350	6110	3920
K:	0.16	0.14	0.11	0.16	0.10	0.12
2040 DHV:	200	120	40	220	610	470
D:	0.55	0.67	0.50	0.64	0.75	0.53
T24:	0.02	0.03	0.00	0.03	0.02	0.02
TD:	0.01	0.02	0.00	0.02	0.01	0.01

Table 3: Side Streets

If you have any questions, please contact me at Joshua.Kieselbach@dot.ohio.gov or (614) 752-5747.

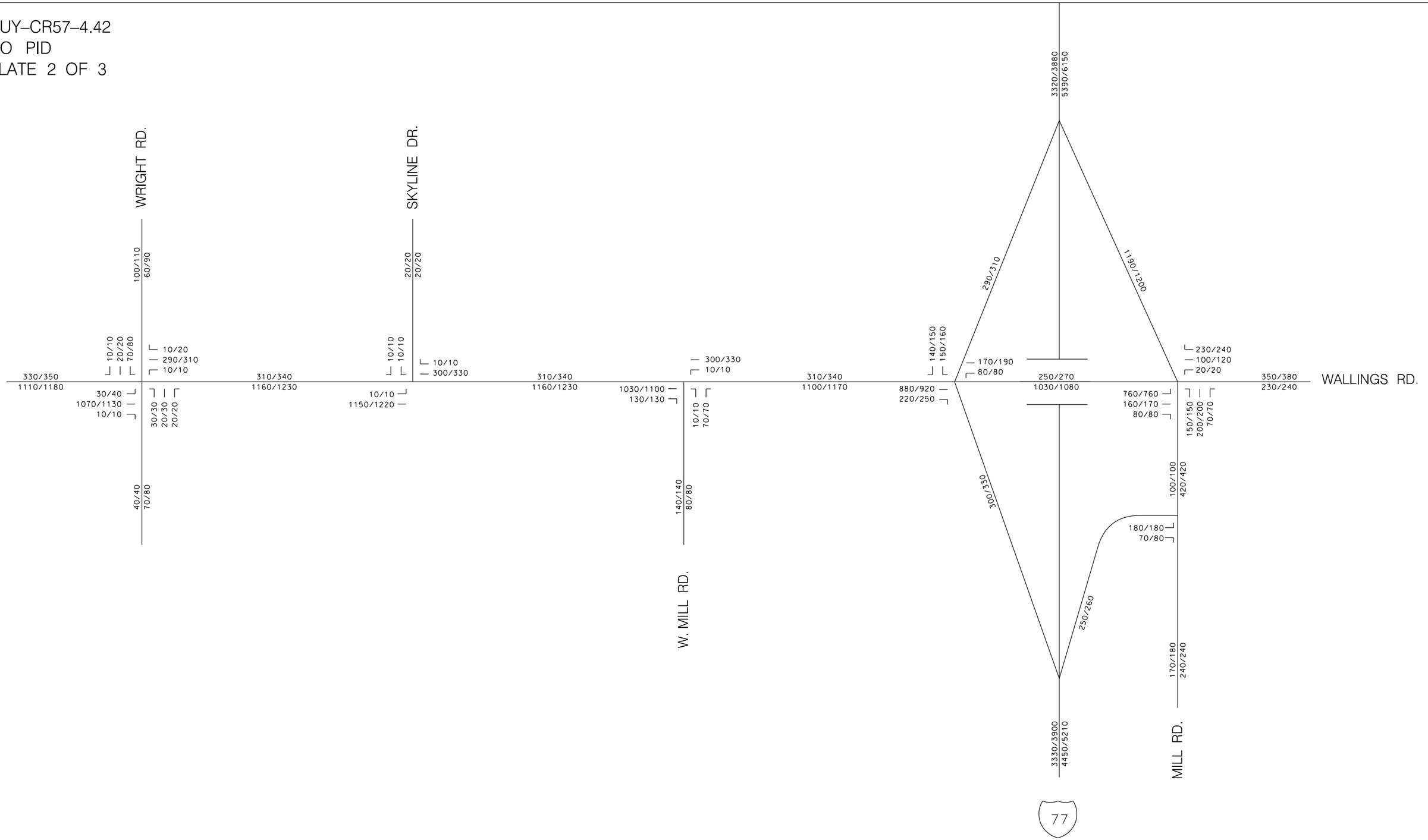
c: M. Byram, OSPR – G. Giaimo, OSPR – File

CUY–CR57–4.42
NO PID
PLATE 1 OF 3



CUY–CR57–4.42 NO PID	
2020 /2040 ADT	
OHIO DEPARTMENT OF TRANSPORTATION	
OFFICE OF STATEWIDE PLANNING & RESEARCH	
JANUARY 29, 2016	NOT TO SCALE

CUY–CR57–4.42
NO PID
PLATE 2 OF 3



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2020 /2040 AM DHV	
OHIO DEPARTMENT OF TRANSPORTATION	
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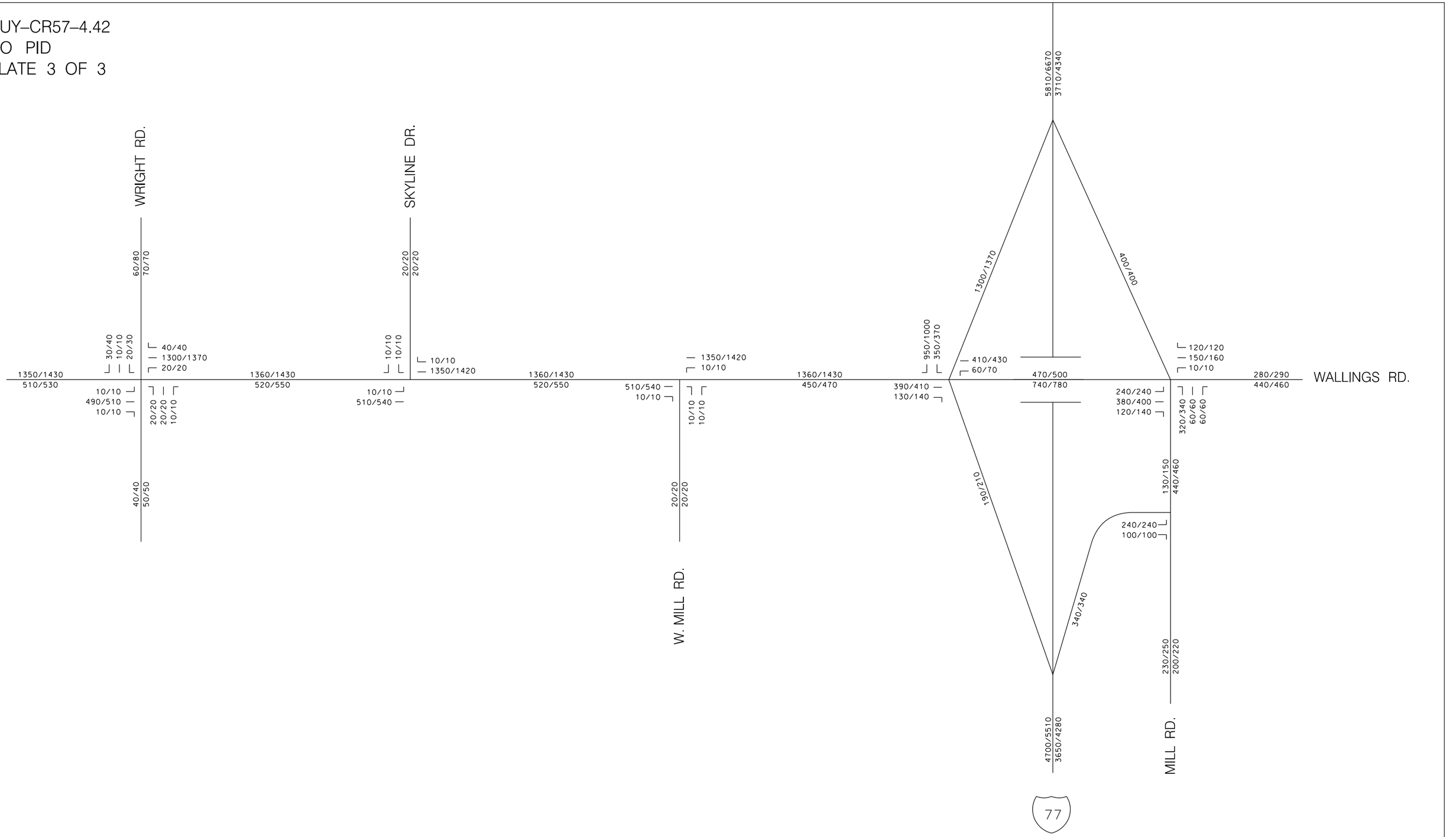
JANUARY 29, 2016	NOT TO SCALE

CUY–CR57–4.42
NO PID
PLATE 3 OF 3



CUY–CR57–4.42 NO PID	
2020 /2040 PM DHV	
OHIO DEPARTMENT OF TRANSPORTATION	
OFFICE OF STATEWIDE PLANNING & RESEARCH	
JANUARY 29, 2016	NOT TO SCALE

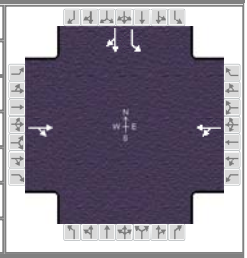
APPENDIX B
INTERSECTION CAPACITY ANALYSIS

HCS CAPACITY ANALYSIS

DESIGN YEAR 2040 'NO-BUILD' CONDITIONS

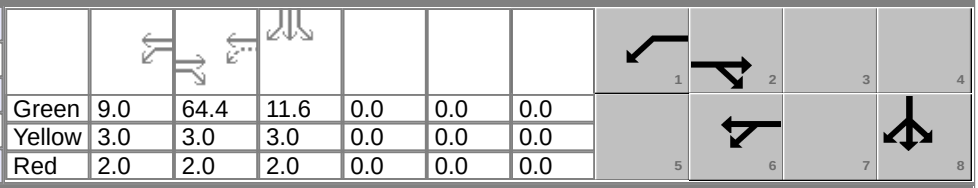
HCS 2010 Signalized Intersection Results Summary

General Information				Intersection Information	
Agency	GPD Group			Duration, h	0.25
Analyst	Brett M. Ferrell	Analysis Date	Mar 2, 2016	Area Type	Other
Jurisdiction	City of Broadview Heights	Time Period	AM Peak Hour	PHF	0.92
Urban Street	Wallings Road	Analysis Year	2040	Analysis Period	1> 7:00
Intersection	Wallings Road / I-77 SB…	File Name	1. Wallings Rd_I-77 SB_Design Year 2040 'No-Bu…		
Project Description	Design Year 2040 'No-Build' AM Peak Hour				



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h		920	250	80	190					160	0	150

Signal Information			
Cycle, s	100.0	Reference Phase	2
Offset, s	0	Reference Point	End
Uncoordinated	Yes	Simult. Gap E/W	On
Force Mode	Fixed	Simult. Gap N/S	On



Green	9.0	64.4	11.6	0.0	0.0	0.0						
Yellow	3.0	3.0	3.0	0.0	0.0	0.0						
Red	2.0	2.0	2.0	0.0	0.0	0.0						

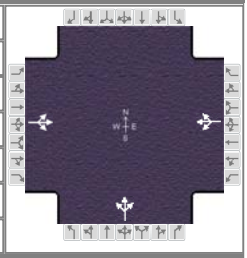
Timer Results	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Assigned Phase		2	1	6				8
Case Number		8.3	0.0	14.0				10.0
Phase Duration, s		69.4	14.0	83.4				16.6
Change Period, ($Y+R_c$), s		5.0	5.0	5.0				5.0
Max Allow Headway (*MAH*), s		2.3	0.0	2.3				4.2
Queue Clearance Time (g_s), s		66.4		10.4				12.1
Green Extension Time (g_e), s		0.0	0.0	2.0				0.0
Phase Call Probability		1.00		1.00				1.00
Max Out Probability		1.00		0.00				1.00

Movement Group Results	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Assigned Movement		2	12	1	6					3	8	18
Adjusted Flow Rate (*v*), veh/h		1272			293					174	163	
Adjusted Saturation Flow Rate (*s*), veh/h/ln		1812			327					1792	1594	
Queue Service Time (g_s), s		64.4			8.4					9.5	10.1	
Cycle Queue Clearance Time (g_c), s		64.4			8.4					9.5	10.1	
Green Ratio (*g/C*)		0.64			0.78					0.12	0.12	
Capacity (*c*), veh/h		1167			303					208	185	
Volume-to-Capacity Ratio (*X*)		1.090			0.969					0.837	0.882	
Back of Queue (*Q*), ft/ln (95 th percentile)		1353.8			394.1					235.4	240.8	
Back of Queue (*Q*), veh/ln (95 th percentile)		54.2			15.8					9.4	9.6	
Queue Storage Ratio (*RQ*) (95 th percentile)		0.00			0.00					0.00	0.00	
Uniform Delay (d_1), s/veh		17.8			30.1					43.3	43.5	
Incremental Delay (d_2), s/veh		54.4			42.9					24.7	35.4	
Initial Queue Delay (d_3), s/veh		0.0			0.0					0.0	0.0	
Control Delay (*d*), s/veh		72.2			73.0					68.0	79.0	
Level of Service (LOS)		F			E					E	E	
Approach Delay, s/veh / LOS	72.2	E		73.0	E		0.0			73.3	E	
Intersection Delay, s/veh / LOS	72.6						E					

Multimodal Results	EB		WB		NB		SB	
Pedestrian LOS Score / LOS								
Bicycle LOS Score / LOS								

HCS 2010 Signalized Intersection Results Summary

General Information				Intersection Information	
Agency	GPD Group			Duration, h	0.25
Analyst	Brett M. Ferrell	Analysis Date	Mar 2, 2016	Area Type	Other
Jurisdiction	City of Broadview Heights	Time Period	AM Peak Hour	PHF	0.92
Urban Street	Wallings Road	Analysis Year	2040	Analysis Period	1> 7:00
Intersection	Wallings Road / I-77 NB…	File Name	2. Wallings Rd_I-77 NB_Mill Road_Design Year 2…		
Project Description	Design Year 2040 'No-Build' AM Peak Hour				



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h	760	170	80	20	120	240	150	200	70			

Signal Information			
Cycle, s	100.0	Reference Phase	2
Offset, s	0	Reference Point	End
Uncoordinated	Yes	Simult. Gap E/W	On
Force Mode	Fixed	Simult. Gap N/S	On

							1	2	3	4	
Green	42.0	20.2	22.8	0.0	0.0	0.0	5	6	7	8	
Yellow	3.0	3.0	3.0	0.0	0.0	0.0					
Red	2.0	2.0	2.0	0.0	0.0	0.0					

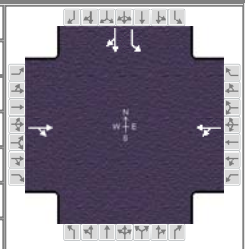
Timer Results	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Assigned Phase	5	2		6		4		
Case Number	0.0	14.0		8.3		12.0		
Phase Duration, s	47.0	72.2		25.2		27.8		
Change Period, ($Y+R_c$), s	5.0	5.0		5.0		5.0		
Max Allow Headway (*MAH*), s	0.0	3.7		3.7		3.2		
Queue Clearance Time (g_s), s		44.0		22.2		24.8		
Green Extension Time (g_e), s	0.0	6.7		0.0		0.0		
Phase Call Probability		1.00		1.00		1.00		
Max Out Probability		0.12		1.00		1.00		

Movement Group Results	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Assigned Movement	5	2	12	1	6	16	7	4	14			
Adjusted Flow Rate (*v*), veh/h		1098			413			457				
Adjusted Saturation Flow Rate (*s*), veh/h/ln		1267			1659			1795				
Queue Service Time (g_s), s		42.0			11.4			22.8				
Cycle Queue Clearance Time (g_c), s		42.0			20.2			22.8				
Green Ratio (*g/C*)		0.67			0.20			0.23				
Capacity (*c*), veh/h		915			373			409				
Volume-to-Capacity Ratio (*X*)		1.200			1.107			1.115				
Back of Queue (*Q*), ft/ln (95 th percentile)		1355.6			637.1			694.7				
Back of Queue (*Q*), veh/ln (95 th percentile)		54.2			25.5			27.8				
Queue Storage Ratio (*RQ*) (95 th percentile)		0.00			0.00			0.00				
Uniform Delay (d_1), s/veh		18.0			40.9			38.6				
Incremental Delay (d_2), s/veh		100.7			78.8			79.6				
Initial Queue Delay (d_3), s/veh		0.0			0.0			0.0				
Control Delay (*d*), s/veh		118.7			119.6			118.2				
Level of Service (LOS)		F			F			F				
Approach Delay, s/veh / LOS	118.7	F		119.6	F		118.2	F		0.0		
Intersection Delay, s/veh / LOS	118.8						F					

Multimodal Results	EB		WB		NB		SB	
Pedestrian LOS Score / LOS								
Bicycle LOS Score / LOS								

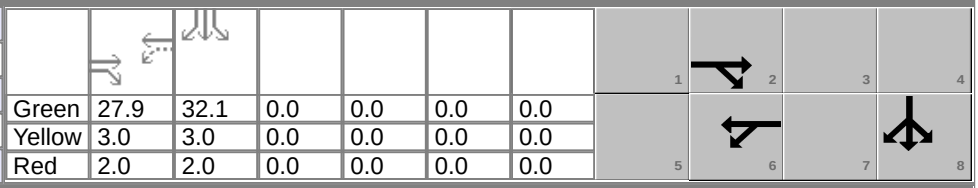
HCS 2010 Signalized Intersection Results Summary

General Information				Intersection Information	
Agency	GPD Group			Duration, h	0.25
Analyst	Brett M. Ferrell	Analysis Date	Mar 2, 2016	Area Type	Other
Jurisdiction	City of Broadview Heights	Time Period	PM Peak Hour	PHF	0.92
Urban Street	Wallings Road	Analysis Year	2040	Analysis Period	1> 7:00
Intersection	Wallings Road / I-77 SB…	File Name	3. Wallings Rd_I-77 SB_Design Year 2040 'No-Bu…		
Project Description	Design Year 2040 'No-Build' PM Peak Hour				



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h		410	140	70	430					370	0	1000

Signal Information			
Cycle, s	70.0	Reference Phase	2
Offset, s	0	Reference Point	End
Uncoordinated	Yes	Simult. Gap E/W	On
Force Mode	Fixed	Simult. Gap N/S	On



	EB		WB			
Green	27.9	32.1	0.0	0.0	0.0	0.0
Yellow	3.0	3.0	0.0	0.0	0.0	0.0
Red	2.0	2.0	0.0	0.0	0.0	0.0

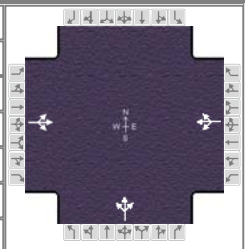
Timer Results	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Assigned Phase		2		6				8
Case Number		8.0		8.0				10.0
Phase Duration, s		32.9		32.9				37.1
Change Period, ($Y+R_c$), s		5.0		5.0				5.0
Max Allow Headway (*MAH*), s		2.2		2.2				4.3
Queue Clearance Time (g_s), s		23.0		29.9				34.1
Green Extension Time (g_e), s		0.7		0.0				0.0
Phase Call Probability		1.00		1.00				1.00
Max Out Probability		0.23		1.00				1.00

Movement Group Results	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Assigned Movement		2	12	1	6					3	8	18
Adjusted Flow Rate (*v*), veh/h		598			543					402	1087	
Adjusted Saturation Flow Rate (*s*), veh/h/ln		1799			888					1792	1594	
Queue Service Time (g_s), s		21.0			6.9					11.0	32.1	
Cycle Queue Clearance Time (g_c), s		21.0			27.9					11.0	32.1	
Green Ratio (*g/C*)		0.40			0.40					0.46	0.46	
Capacity (*c*), veh/h		717			413					822	731	
Volume-to-Capacity Ratio (*X*)		0.834			1.317					0.490	1.487	
Back of Queue (*Q*), ft/ln (95 th percentile)		356.9			973.8					177.6	2161	
Back of Queue (*Q*), veh/ln (95 th percentile)		14.3			39.0					7.1	86.4	
Queue Storage Ratio (*RQ*) (95 th percentile)		0.00			0.00					0.00	0.00	
Uniform Delay (d_1), s/veh		19.0			22.2					13.2	19.0	
Incremental Delay (d_2), s/veh		7.9			159.0					0.5	226.3	
Initial Queue Delay (d_3), s/veh		0.0			0.0					0.0	0.0	
Control Delay (*d*), s/veh		26.9			181.1					13.7	245.3	
Level of Service (LOS)		C			F					B	F	
Approach Delay, s/veh / LOS	26.9	C		181.1	F		0.0			182.7	F	
Intersection Delay, s/veh / LOS	147.0						F					

Multimodal Results	EB		WB		NB		SB	
Pedestrian LOS Score / LOS								
Bicycle LOS Score / LOS								

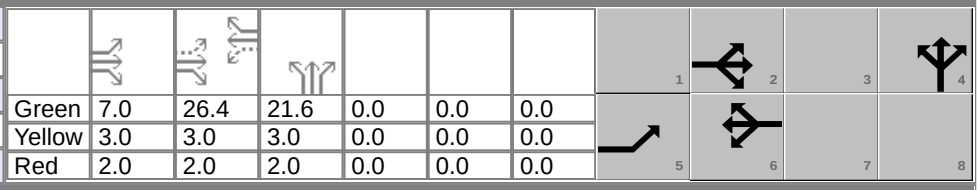
HCS 2010 Signalized Intersection Results Summary

General Information				Intersection Information	
Agency	GPD Group			Duration, h	0.25
Analyst	Brett M. Ferrell	Analysis Date	Mar 2, 2016	Area Type	Other
Jurisdiction	City of Broadview Heights	Time Period	PM Peak Hour	PHF	0.92
Urban Street	Wallings Road	Analysis Year	2040	Analysis Period	1> 7:00
Intersection	Wallings Road / I-77 NB…	File Name	4. Wallings Rd_I-77 NB_Mill Road_Design Year 2…		
Project Description	Design Year 2040 'No-Build' PM Peak Hour				



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h	240	400	140	10	160	120	340	60	60			

Signal Information			
Cycle, s	70.0	Reference Phase	2
Offset, s	0	Reference Point	End
Uncoordinated	Yes	Simult. Gap E/W	On
Force Mode	Fixed	Simult. Gap N/S	On



Green	7.0	26.4	21.6	0.0	0.0	0.0	1	2	3	4		
Yellow	3.0	3.0	3.0	0.0	0.0	0.0	5	6	7	8		
Red	2.0	2.0	2.0	0.0	0.0	0.0						

Timer Results	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Assigned Phase	5	2		6		4		
Case Number	0.0	14.0		8.3		12.0		
Phase Duration, s	12.0	43.4		31.4		26.6		
Change Period, ($Y+R_c$), s	5.0	5.0		5.0		5.0		
Max Allow Headway (*MAH*), s	0.0	3.3		3.3		3.3		
Queue Clearance Time (g_s), s		40.4		11.6		21.0		
Green Extension Time (g_e), s	0.0	0.0		2.9		0.1		
Phase Call Probability		1.00		1.00		1.00		
Max Out Probability		1.00		0.07		1.00		

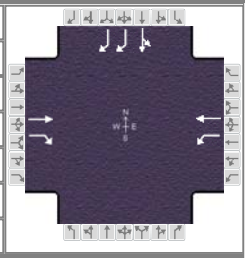
Movement Group Results	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Assigned Movement	5	2	12	1	6	16	7	4	14			
Adjusted Flow Rate (*v*), veh/h		848			315			500				
Adjusted Saturation Flow Rate (*s*), veh/h/ln		1449			1769			1774				
Queue Service Time (g_s), s		7.0			0.0			19.0				
Cycle Queue Clearance Time (g_c), s		38.4			9.6			19.0				
Green Ratio (*g/C*)		0.55			0.38			0.31				
Capacity (*c*), veh/h		864			720			547				
Volume-to-Capacity Ratio (*X*)		0.981			0.438			0.913				
Back of Queue (*Q*), ft/ln (95 th percentile)		516.2			157.4			394				
Back of Queue (*Q*), veh/ln (95 th percentile)		20.6			6.3			15.8				
Queue Storage Ratio (*RQ*) (95 th percentile)		0.00			0.00			0.00				
Uniform Delay (d_1), s/veh		16.6			16.6			23.3				
Incremental Delay (d_2), s/veh		25.9			0.2			19.5				
Initial Queue Delay (d_3), s/veh		0.0			0.0			0.0				
Control Delay (*d*), s/veh		42.4			16.7			42.8				
Level of Service (LOS)		D			B			D				
Approach Delay, s/veh / LOS	42.4	D		16.7	B		42.8	D		0.0		
Intersection Delay, s/veh / LOS	37.7						D					

Multimodal Results	EB		WB		NB		SB	
Pedestrian LOS Score / LOS								
Bicycle LOS Score / LOS								

DESIGN YEAR 2040 'BUILD' CONDITIONS

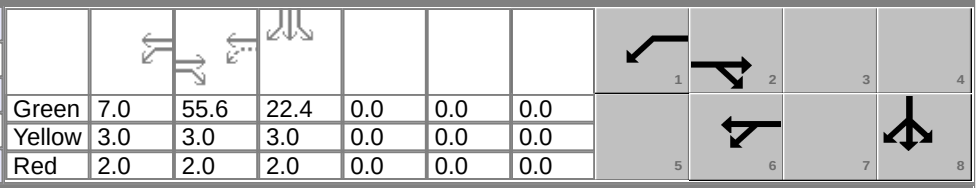
HCS 2010 Signalized Intersection Results Summary

General Information				Intersection Information	
Agency	GPD Group			Duration, h	0.25
Analyst	Brett M. Ferrell	Analysis Date	Mar 2, 2016	Area Type	Other
Jurisdiction	City of Broadview Heights	Time Period	AM Peak Hour	PHF	0.92
Urban Street	Wallings Road	Analysis Year	2040	Analysis Period	1> 7:00
Intersection	Wallings Road / I-77 SB…	File Name	5. Wallings Rd_I-77 SB_Design Year 2040 'Synch…		
Project Description	Design Year 2040 'Synchro-Build' AM Peak Hour				



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h		920	250	80	190					160	0	150

Signal Information			
Cycle, s	100.0	Reference Phase	2
Offset, s	0	Reference Point	End
Uncoordinated	Yes	Simult. Gap E/W	On
Force Mode	Fixed	Simult. Gap N/S	On



Green	7.0	55.6	22.4	0.0	0.0	0.0						
Yellow	3.0	3.0	3.0	0.0	0.0	0.0						
Red	2.0	2.0	2.0	0.0	0.0	0.0						

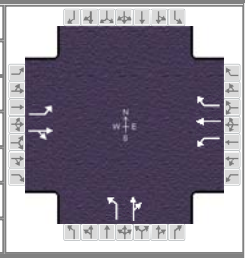
Timer Results	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Assigned Phase		2	1	6				8
Case Number		7.3	1.0	4.0				11.0
Phase Duration, s		60.6	12.0	72.6				27.4
Change Period, ($Y+R_c$), s		5.0	5.0	5.0				5.0
Max Allow Headway (*MAH*), s		2.1	2.1	2.1				4.2
Queue Clearance Time (g_s), s		52.4	3.8	6.0				10.3
Green Extension Time (g_e), s		0.7	0.0	1.1				1.1
Phase Call Probability		1.00	1.00	1.00				1.00
Max Out Probability		0.60	0.11	0.00				0.02

Movement Group Results	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Assigned Movement		2	12	1	6					3	8	18
Adjusted Flow Rate (*v*), veh/h		1000	272	87	207						174	163
Adjusted Saturation Flow Rate (*s*), veh/h/ln		1881	1610	1810	1881						1792	1425
Queue Service Time (g_s), s		50.4	9.0	1.8	4.0						8.3	4.7
Cycle Queue Clearance Time (g_c), s		50.4	9.0	1.8	4.0						8.3	4.7
Green Ratio (*g/C*)		0.56	0.56	0.65	0.68						0.22	0.22
Capacity (*c*), veh/h		1046	895	229	1272						401	638
Volume-to-Capacity Ratio (*X*)		0.956	0.304	0.381	0.162						0.433	0.255
Back of Queue (*Q*), ft/ln (95 th percentile)		833.7	136.3	92.5	62.3						163.7	72.7
Back of Queue (*Q*), veh/ln (95 th percentile)		33.1	5.5	3.7	2.5						6.5	2.9
Queue Storage Ratio (*RQ*) (95 th percentile)		0.00	0.42	0.93	0.00						0.00	0.15
Uniform Delay (d_1), s/veh		21.0	11.9	22.3	5.9						33.3	31.9
Incremental Delay (d_2), s/veh		18.0	0.1	0.4	0.0						0.7	0.2
Initial Queue Delay (d_3), s/veh		0.0	0.0	0.0	0.0						0.0	0.0
Control Delay (*d*), s/veh		39.1	11.9	22.7	5.9						34.1	32.1
Level of Service (LOS)		D	B	C	A						C	C
Approach Delay, s/veh / LOS	33.3	C		10.9	B		0.0			33.1	C	
Intersection Delay, s/veh / LOS	29.8						C					

Multimodal Results	EB		WB		NB		SB	
Pedestrian LOS Score / LOS								
Bicycle LOS Score / LOS								

HCS 2010 Signalized Intersection Results Summary

General Information				Intersection Information	
Agency	GPD Group			Duration, h	0.25
Analyst	Brett M. Ferrell	Analysis Date	Mar 2, 2016	Area Type	Other
Jurisdiction	City of Broadview Heights	Time Period	AM Peak Hour	PHF	0.92
Urban Street	Wallings Road	Analysis Year	2040	Analysis Period	1> 7:00
Intersection	Wallings Road / I-77 NB…	File Name	8. Wallings Rd_I-77 NB_Mill Road_Design Year 2…		
Project Description	Design Year 2040 'Synchro-Build' AM Peak Hour				



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h	760	170	80	20	120	240	150	200	70			

Signal Information			
Cycle, s	100.0	Reference Phase	2
Offset, s	0	Reference Point	End
Uncoordinated	Yes	Simult. Gap E/W	On
Force Mode	Fixed	Simult. Gap N/S	On

							1	2	3	4	
Green	29.0	27.0	29.0	0.0	0.0	0.0	5	6	7	8	
Yellow	3.0	3.0	3.0	0.0	0.0	0.0					
Red	2.0	2.0	2.0	0.0	0.0	0.0					

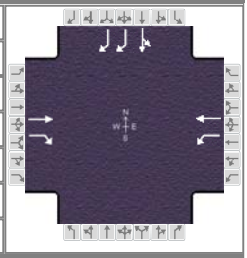
Timer Results	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Assigned Phase	5	2		6		4		
Case Number	1.0	4.0		5.3		10.0		
Phase Duration, s	34.0	66.0		32.0		34.0		
Change Period, ($Y+R_c$), s	5.0	5.0		5.0		5.0		
Max Allow Headway (*MAH*), s	3.1	3.2		3.2		3.2		
Queue Clearance Time (g_s), s	31.0	9.0		16.1		15.9		
Green Extension Time (g_e), s	0.0	1.4		1.2		0.8		
Phase Call Probability	1.00	1.00		1.00		1.00		
Max Out Probability	1.00	0.00		0.03		0.00		

Movement Group Results	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Assigned Movement	5	2	12	1	6	16	7	4	14			
Adjusted Flow Rate (*v*), veh/h	826	272		22	130	261	163	293				
Adjusted Saturation Flow Rate (*s*), veh/h/ln	1810	1779		1125	1881	1610	1810	1797				
Queue Service Time (g_s), s	29.0	7.0		1.4	5.4	14.1	7.0	13.9				
Cycle Queue Clearance Time (g_c), s	29.0	7.0		1.4	5.4	14.1	7.0	13.9				
Green Ratio (*g/C*)	0.58	0.61		0.27	0.27	0.27	0.29	0.29				
Capacity (*c*), veh/h	873	1085		376	508	435	525	521				
Volume-to-Capacity Ratio (*X*)	0.947	0.250		0.058	0.257	0.600	0.311	0.563				
Back of Queue (*Q*), ft/ln (95 th percentile)	607.5	112		17.3	109.8	234.9	138.2	253.8				
Back of Queue (*Q*), veh/ln (95 th percentile)	24.3	4.5		0.7	4.4	9.4	5.5	10.2				
Queue Storage Ratio (*RQ*) (95 th percentile)	1.69	0.00		0.09	0.00	0.72	0.33	0.00				
Uniform Delay (d_1), s/veh	18.8	9.0		27.2	28.6	31.8	27.7	30.1				
Incremental Delay (d_2), s/veh	18.6	0.0		0.0	0.1	1.6	0.1	0.9				
Initial Queue Delay (d_3), s/veh	0.0	0.0		0.0	0.0	0.0	0.0	0.0				
Control Delay (*d*), s/veh	37.4	9.0		27.2	28.7	33.4	27.8	31.0				
Level of Service (LOS)	D	A		C	C	C	C	C				
Approach Delay, s/veh / LOS	30.3	C		31.6	C		29.9	C		0.0		
Intersection Delay, s/veh / LOS	30.5						C					

Multimodal Results	EB		WB		NB		SB	
Pedestrian LOS Score / LOS								
Bicycle LOS Score / LOS								

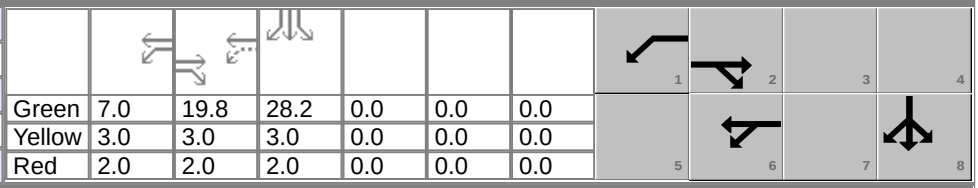
HCS 2010 Signalized Intersection Results Summary

General Information				Intersection Information	
Agency	GPD Group			Duration, h	0.25
Analyst	Brett M. Ferrell	Analysis Date	Mar 2, 2016	Area Type	Other
Jurisdiction	City of Broadview Heights	Time Period	PM Peak Hour	PHF	0.92
Urban Street	Wallings Road	Analysis Year	2040	Analysis Period	1> 7:00
Intersection	Wallings Road / I-77 SB…	File Name	7. Wallings Rd_I-77 SB_Design Year 2040 'Synch…		
Project Description	Design Year 2040 'Synchro-Build' PM Peak Hour				



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h		410	140	70	430					370	0	1000

Signal Information			
Cycle, s	70.0	Reference Phase	2
Offset, s	0	Reference Point	End
Uncoordinated	Yes	Simult. Gap E/W	On
Force Mode	Fixed	Simult. Gap N/S	On



Green	7.0	19.8	28.2	0.0	0.0	0.0
Yellow	3.0	3.0	3.0	0.0	0.0	0.0
Red	2.0	2.0	2.0	0.0	0.0	0.0

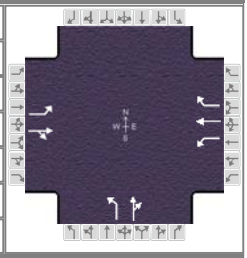
Timer Results	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Assigned Phase		2	1	6				8
Case Number		7.3	1.0	4.0				11.0
Phase Duration, s		24.8	12.0	36.8				33.2
Change Period, ($Y+R_c$), s		5.0	5.0	5.0				5.0
Max Allow Headway (*MAH*), s		2.1	2.1	2.1				4.3
Queue Clearance Time (g_s), s		17.6	3.8	14.6				27.8
Green Extension Time (g_e), s		0.3	0.0	0.7				0.3
Phase Call Probability		1.00	1.00	1.00				1.00
Max Out Probability		0.91	0.10	0.00				1.00

Movement Group Results	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Assigned Movement		2	12	1	6					3	8	18
Adjusted Flow Rate (*v*), veh/h		446	152	76	467						402	1087
Adjusted Saturation Flow Rate (*s*), veh/h/ln		1881	1610	1810	1881						1792	1425
Queue Service Time (g_s), s		15.6	5.2	1.8	12.6						12.1	25.8
Cycle Queue Clearance Time (g_c), s		15.6	5.2	1.8	12.6						12.1	25.8
Green Ratio (*g/C*)		0.28	0.28	0.41	0.45						0.40	0.40
Capacity (*c*), veh/h		532	455	342	855						722	1148
Volume-to-Capacity Ratio (*X*)		0.838	0.334	0.223	0.547						0.557	0.947
Back of Queue (*Q*), ft/ln (95 th percentile)		315.3	82.7	30.1	210.2						203.1	378.4
Back of Queue (*Q*), veh/ln (95 th percentile)		12.5	3.3	1.2	8.3						8.1	15.1
Queue Storage Ratio (*RQ*) (95 th percentile)		0.00	0.25	0.30	0.00						0.00	0.76
Uniform Delay (d_1), s/veh		23.6	19.9	15.1	13.9						16.1	20.2
Incremental Delay (d_2), s/veh		10.7	0.2	0.1	0.4						1.0	15.5
Initial Queue Delay (d_3), s/veh		0.0	0.0	0.0	0.0						0.0	0.0
Control Delay (*d*), s/veh		34.3	20.0	15.2	14.3						17.0	35.7
Level of Service (LOS)		C	C	B	B						B	D
Approach Delay, s/veh / LOS	30.6	C		14.4	B		0.0			30.6	C	
Intersection Delay, s/veh / LOS	27.3						C					

Multimodal Results	EB		WB		NB		SB	
Pedestrian LOS Score / LOS								
Bicycle LOS Score / LOS								

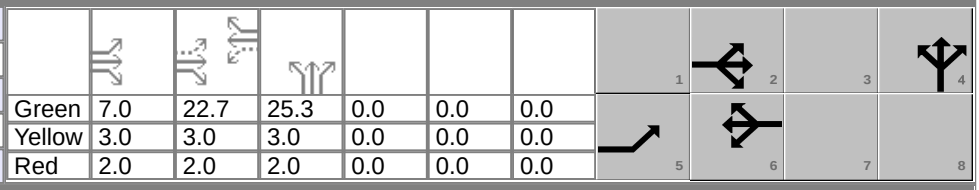
HCS 2010 Signalized Intersection Results Summary

General Information				Intersection Information	
Agency	GPD Group			Duration, h	0.25
Analyst	Brett M. Ferrell	Analysis Date	Mar 2, 2016	Area Type	Other
Jurisdiction	City of Broadview Heights	Time Period	PM Peak Hour	PHF	0.92
Urban Street	Wallings Road	Analysis Year	2040	Analysis Period	1> 7:00
Intersection	Wallings Road / I-77 NB…	File Name	8. Wallings Rd_I-77 NB_Mill Road_Design Year 2…		
Project Description	Design Year 2040 'Synchro-Build' PM Peak Hour				



Demand Information	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Demand (*v*), veh/h	240	400	140	10	160	120	340	60	60			

Signal Information			
Cycle, s	70.0	Reference Phase	2
Offset, s	0	Reference Point	End
Uncoordinated	Yes	Simult. Gap E/W	On
Force Mode	Fixed	Simult. Gap N/S	On



Green	7.0	22.7	25.3	0.0	0.0	0.0
Yellow	3.0	3.0	3.0	0.0	0.0	0.0
Red	2.0	2.0	2.0	0.0	0.0	0.0

Timer Results	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Assigned Phase	5	2		6		4		
Case Number	1.0	4.0		5.3		10.0		
Phase Duration, s	12.0	39.7		27.7		30.3		
Change Period, ($Y+R_c$), s	5.0	5.0		5.0		5.0		
Max Allow Headway (*MAH*), s	3.1	3.2		3.2		3.3		
Queue Clearance Time (g_s), s	8.5	19.1		7.8		13.5		
Green Extension Time (g_e), s	0.0	1.8		1.8		0.9		
Phase Call Probability	1.00	1.00		1.00		1.00		
Max Out Probability	1.00	0.01		0.01		0.01		

Movement Group Results	EB			WB			NB			SB		
Approach Movement	L	T	R	L	T	R	L	T	R	L	T	R
Assigned Movement	5	2	12	1	6	16	7	4	14			
Adjusted Flow Rate (*v*), veh/h	261	587		11	174	130	370	130				
Adjusted Saturation Flow Rate (*s*), veh/h/ln	1810	1797		842	1881	1610	1810	1726				
Queue Service Time (g_s), s	6.5	17.1		0.7	4.8	4.2	11.5	3.7				
Cycle Queue Clearance Time (g_c), s	6.5	17.1		5.8	4.8	4.2	11.5	3.7				
Green Ratio (*g/C*)	0.45	0.50		0.32	0.32	0.32	0.36	0.36				
Capacity (*c*), veh/h	598	891		314	610	522	654	624				
Volume-to-Capacity Ratio (*X*)	0.436	0.659		0.035	0.285	0.250	0.565	0.209				
Back of Queue (*Q*), ft/ln (95 th percentile)	103.8	257.4		5.7	87.9	64.7	204.9	62.3				
Back of Queue (*Q*), veh/ln (95 th percentile)	4.2	10.3		0.2	3.5	2.6	8.2	2.5				
Queue Storage Ratio (*RQ*) (95 th percentile)	0.29	0.00		0.03	0.00	0.20	0.48	0.00				
Uniform Delay (d_1), s/veh	12.7	13.2		19.9	17.6	17.4	17.9	15.4				
Incremental Delay (d_2), s/veh	0.2	1.4		0.0	0.1	0.1	0.7	0.1				
Initial Queue Delay (d_3), s/veh	0.0	0.0		0.0	0.0	0.0	0.0	0.0				
Control Delay (*d*), s/veh	12.9	14.7		19.9	17.7	17.5	18.6	15.5				
Level of Service (LOS)	B	B		B	B	B	B	B				
Approach Delay, s/veh / LOS	14.1	B		17.7	B		17.8	B		0.0		
Intersection Delay, s/veh / LOS	15.9						B					

Multimodal Results	EB		WB		NB		SB	
Pedestrian LOS Score / LOS								
Bicycle LOS Score / LOS								

SYNCHRO CAPACITY ANALYSIS

DESIGN YEAR 2040 'NO-BUILD' CONDITIONS

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	920	250	80	190	0	0	0	0	160	0	150
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		5.5			5.5					5.5	5.5	
Lane Util. Factor		1.00			1.00					1.00	1.00	
Frt		0.97			1.00					1.00	0.85	
Flt Protected		1.00			0.99					0.95	1.00	
Satd. Flow (prot)		1827			1854					1787	1599	
Flt Permitted		1.00			0.22					0.95	1.00	
Satd. Flow (perm)		1827			410					1787	1599	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	1000	272	87	207	0	0	0	0	174	0	163
RTOR Reduction (vph)	0	8	0	0	0	0	0	0	0	0	136	0
Lane Group Flow (vph)	0	1264	0	0	294	0	0	0	0	174	27	0
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Turn Type		NA		Perm	NA					Perm	NA	
Protected Phases		2			6						8	
Permitted Phases				6						8		
Actuated Green, G (s)		64.3			64.3					14.7	14.7	
Effective Green, g (s)		64.3			64.3					14.7	14.7	
Actuated g/C Ratio		0.71			0.71					0.16	0.16	
Clearance Time (s)		5.5			5.5					5.5	5.5	
Vehicle Extension (s)		3.0			3.0					3.0	3.0	
Lane Grp Cap (vph)		1305			292					291	261	
v/s Ratio Prot		0.69									0.02	
v/s Ratio Perm					c0.72					c0.10		
v/c Ratio		0.97			1.01					0.60	0.10	
Uniform Delay, d1		11.9			12.9					34.9	32.0	
Progression Factor		1.00			2.08					1.00	1.00	
Incremental Delay, d2		18.4			17.5					3.3	0.2	
Delay (s)		30.4			44.2					38.2	32.2	
Level of Service		C			D					D	C	
Approach Delay (s)		30.4			44.2			0.0			35.3	
Approach LOS		C			D			A			D	

Intersection Summary			
HCM 2000 Control Delay	33.4	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.93		
Actuated Cycle Length (s)	90.0	Sum of lost time (s)	11.0
Intersection Capacity Utilization	99.6%	ICU Level of Service	F
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	760	170	80	20	120	240	150	200	70	0	0	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		5.3			5.3			5.3				
Lane Util. Factor		1.00			1.00			1.00				
Frt		0.99			0.91			0.98				
Flt Protected		0.96			1.00			0.98				
Satd. Flow (prot)		1794			1716			1807				
Flt Permitted		0.18			0.90			0.98				
Satd. Flow (perm)		333			1547			1807				
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	826	185	87	22	130	261	163	217	76	0	0	0
RTOR Reduction (vph)	0	3	0	0	69	0	0	8	0	0	0	0
Lane Group Flow (vph)	0	1095	0	0	344	0	0	448	0	0	0	0
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Turn Type	pm+pt	NA		Perm	NA		Perm	NA				
Protected Phases	5	2			6			4				
Permitted Phases	2			6			4					
Actuated Green, G (s)		59.7			19.7			19.7				
Effective Green, g (s)		59.7			19.7			19.7				
Actuated g/C Ratio		0.66			0.22			0.22				
Clearance Time (s)		5.3			5.3			5.3				
Vehicle Extension (s)		3.0			3.0			3.0				
Lane Grp Cap (vph)		758			338			395				
v/s Ratio Prot		c0.53										
v/s Ratio Perm		c0.43			0.22			0.25				
v/c Ratio		1.44			1.02			1.13				
Uniform Delay, d1		15.1			35.1			35.1				
Progression Factor		0.96			1.00			1.00				
Incremental Delay, d2		205.3			53.7			87.3				
Delay (s)		219.9			88.9			122.4				
Level of Service		F			F			F				
Approach Delay (s)		219.9			88.9			122.4			0.0	
Approach LOS		F			F			F			A	

Intersection Summary			
HCM 2000 Control Delay	169.8	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.43		
Actuated Cycle Length (s)	90.0	Sum of lost time (s)	17.5
Intersection Capacity Utilization	114.4%	ICU Level of Service	H
Analysis Period (min)	15		

c Critical Lane Group

Intersection	
Int Delay, s/veh	2.1

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Vol, veh/h	1100	130	10	330	10	70
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	1	1	1	1	1	1
Mvmt Flow	1196	141	11	359	11	76

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	1337	0	1646	1266
Stage 1	-	-	-	-	1266	-
Stage 2	-	-	-	-	380	-
Critical Hdwy	-	-	4.11	-	6.41	6.21
Critical Hdwy Stg 1	-	-	-	-	5.41	-
Critical Hdwy Stg 2	-	-	-	-	5.41	-
Follow-up Hdwy	-	-	2.209	-	3.509	3.309
Pot Cap-1 Maneuver	-	-	519	-	110	207
Stage 1	-	-	-	-	266	-
Stage 2	-	-	-	-	694	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	519	-	107	207
Mov Cap-2 Maneuver	-	-	-	-	107	-
Stage 1	-	-	-	-	266	-
Stage 2	-	-	-	-	676	-

Approach	EB	WB	NB
HCM Control Delay, s	0	0.4	40.6
HCM LOS			E

Minor Lane/Major Mvmt	NBLn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	185	-	-	519	-
HCM Lane V/C Ratio	0.47	-	-	0.021	-
HCM Control Delay (s)	40.6	-	-	12.1	0
HCM Lane LOS	E	-	-	B	A
HCM 95th %tile Q(veh)	2.2	-	-	0.1	-

Intersection	
Int Delay, s/veh	5.2

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Vol, veh/h	180	80	0	240	100	0
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Stop	Stop	Free	Free	Free	Free
RT Channelized	-	Stop	-	None	-	None
Storage Length	0	50	-	-	-	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	1	1	1	1
Mvmt Flow	196	87	0	261	109	0

Major/Minor	Minor2		Major1		Major2	
Conflicting Flow All	370	109	109	0	-	0
Stage 1	109	-	-	-	-	-
Stage 2	261	-	-	-	-	-
Critical Hdwy	6.42	6.22	4.11	-	-	-
Critical Hdwy Stg 1	5.42	-	-	-	-	-
Critical Hdwy Stg 2	5.42	-	-	-	-	-
Follow-up Hdwy	3.518	3.318	2.209	-	-	-
Pot Cap-1 Maneuver	630	945	1488	-	-	-
Stage 1	916	-	-	-	-	-
Stage 2	783	-	-	-	-	-
Platoon blocked, %				-	-	-
Mov Cap-1 Maneuver	630	945	1488	-	-	-
Mov Cap-2 Maneuver	630	-	-	-	-	-
Stage 1	916	-	-	-	-	-
Stage 2	783	-	-	-	-	-

Approach	EB	NB	SB
HCM Control Delay, s	12	0	0
HCM LOS	B		

Minor Lane/Major Mvmt	NBL	NBT	EBLn1	EBLn2	SBT	SBR
Capacity (veh/h)	1488	-	630	945	-	-
HCM Lane V/C Ratio	-	-	0.311	0.092	-	-
HCM Control Delay (s)	0	-	13.3	9.2	-	-
HCM Lane LOS	A	-	B	A	-	-
HCM 95th %tile Q(veh)	0	-	1.3	0.3	-	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	410	140	70	430	0	0	0	0	370	0	1000
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		5.5			5.5					5.5	5.5	
Lane Util. Factor		1.00			1.00					1.00	1.00	
Frt		0.97			1.00					1.00	0.85	
Flt Protected		1.00			0.99					0.95	1.00	
Satd. Flow (prot)		1817			1868					1787	1599	
Flt Permitted		1.00			0.15					0.95	1.00	
Satd. Flow (perm)		1817			280					1787	1599	
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	446	152	76	467	0	0	0	0	402	0	1087
RTOR Reduction (vph)	0	15	0	0	0	0	0	0	0	0	210	0
Lane Group Flow (vph)	0	583	0	0	543	0	0	0	0	402	877	0
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Turn Type		NA		pm+pt	NA					Perm	NA	
Protected Phases		2		1	6						8	
Permitted Phases				6						8		
Actuated Green, G (s)		19.1			30.5					38.5	38.5	
Effective Green, g (s)		19.1			30.5					38.5	38.5	
Actuated g/C Ratio		0.24			0.38					0.48	0.48	
Clearance Time (s)		5.5			5.5					5.5	5.5	
Vehicle Extension (s)		3.0			3.0					3.0	3.0	
Lane Grp Cap (vph)		433			215					859	769	
v/s Ratio Prot		0.32			c0.17						c0.55	
v/s Ratio Perm					c0.79					0.22		
v/c Ratio		1.35			2.53					0.47	1.14	
Uniform Delay, d1		30.4			24.8					13.9	20.8	
Progression Factor		1.00			1.51					1.00	1.00	
Incremental Delay, d2		170.4			695.6					0.4	78.7	
Delay (s)		200.9			733.1					14.3	99.5	
Level of Service		F			F					B	F	
Approach Delay (s)		200.9			733.1			0.0			76.5	
Approach LOS		F			F			A			E	

Intersection Summary			
HCM 2000 Control Delay	240.3	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.80		
Actuated Cycle Length (s)	80.0	Sum of lost time (s)	16.9
Intersection Capacity Utilization	132.3%	ICU Level of Service	H
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	240	400	140	10	160	120	340	60	60	0	0	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		5.3			5.3			5.3				
Lane Util. Factor		1.00			1.00			1.00				
Frt		0.98			0.94			0.98				
Flt Protected		0.98			1.00			0.96				
Satd. Flow (prot)		1808			1773			1782				
Flt Permitted		0.48			0.96			0.96				
Satd. Flow (perm)		876			1704			1782				
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	261	435	152	11	174	130	370	65	65	0	0	0
RTOR Reduction (vph)	0	9	0	0	32	0	0	7	0	0	0	0
Lane Group Flow (vph)	0	839	0	0	283	0	0	493	0	0	0	0
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Turn Type	pm+pt	NA		Perm	NA		Perm	NA				
Protected Phases	5	2			6			4				
Permitted Phases	2			6			4					
Actuated Green, G (s)		43.4			19.7			26.0				
Effective Green, g (s)		43.4			19.7			26.0				
Actuated g/C Ratio		0.54			0.25			0.32				
Clearance Time (s)		5.3			5.3			5.3				
Vehicle Extension (s)		3.0			3.0			3.0				
Lane Grp Cap (vph)		670			419			579				
v/s Ratio Prot		c0.26										
v/s Ratio Perm		c0.42			0.17			0.28				
v/c Ratio		1.25			0.68			0.85				
Uniform Delay, d1		18.3			27.3			25.2				
Progression Factor		1.63			1.00			1.00				
Incremental Delay, d2		121.5			8.5			11.5				
Delay (s)		151.3			35.7			36.7				
Level of Service		F			D			D				
Approach Delay (s)		151.3			35.7			36.7			0.0	
Approach LOS		F			D			D			A	

Intersection Summary			
HCM 2000 Control Delay	95.0	HCM 2000 Level of Service	F
HCM 2000 Volume to Capacity ratio	1.18		
Actuated Cycle Length (s)	80.0	Sum of lost time (s)	17.5
Intersection Capacity Utilization	98.0%	ICU Level of Service	F
Analysis Period (min)	15		

c Critical Lane Group

Intersection	
Int Delay, s/veh	0.7

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Vol, veh/h	540	10	10	1420	10	10
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	1	1	1	1	1	1
Mvmt Flow	587	11	11	1543	11	11

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	598	0	2157	592
Stage 1	-	-	-	-	592	-
Stage 2	-	-	-	-	1565	-
Critical Hdwy	-	-	4.11	-	6.41	6.21
Critical Hdwy Stg 1	-	-	-	-	5.41	-
Critical Hdwy Stg 2	-	-	-	-	5.41	-
Follow-up Hdwy	-	-	2.209	-	3.509	3.309
Pot Cap-1 Maneuver	-	-	984	-	53	508
Stage 1	-	-	-	-	555	-
Stage 2	-	-	-	-	190	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	984	-	49	508
Mov Cap-2 Maneuver	-	-	-	-	49	-
Stage 1	-	-	-	-	555	-
Stage 2	-	-	-	-	175	-

Approach	EB	WB	NB
HCM Control Delay, s	0	0.1	58.1
HCM LOS			F

Minor Lane/Major Mvmt	NBLn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	89	-	-	984	-
HCM Lane V/C Ratio	0.244	-	-	0.011	-
HCM Control Delay (s)	58.1	-	-	8.7	0
HCM Lane LOS	F	-	-	A	A
HCM 95th %tile Q(veh)	0.9	-	-	0	-

Intersection	
Int Delay, s/veh	6.6

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Vol, veh/h	240	100	0	220	150	0
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Stop	Stop	Free	Free	Free	Free
RT Channelized	-	Stop	-	None	-	None
Storage Length	0	50	-	-	-	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	1	1	1	1
Mvmt Flow	261	109	0	239	163	0

Major/Minor	Minor2		Major1		Major2	
Conflicting Flow All	402	163	163	0	-	0
Stage 1	163	-	-	-	-	-
Stage 2	239	-	-	-	-	-
Critical Hdwy	6.42	6.22	4.11	-	-	-
Critical Hdwy Stg 1	5.42	-	-	-	-	-
Critical Hdwy Stg 2	5.42	-	-	-	-	-
Follow-up Hdwy	3.518	3.318	2.209	-	-	-
Pot Cap-1 Maneuver	604	882	1422	-	-	-
Stage 1	866	-	-	-	-	-
Stage 2	801	-	-	-	-	-
Platoon blocked, %				-	-	-
Mov Cap-1 Maneuver	604	882	1422	-	-	-
Mov Cap-2 Maneuver	604	-	-	-	-	-
Stage 1	866	-	-	-	-	-
Stage 2	801	-	-	-	-	-

Approach	EB	NB	SB
HCM Control Delay, s	13.7	0	0
HCM LOS	B		

Minor Lane/Major Mvmt	NBL	NBT	EBLn1	EBLn2	SBT	SBR
Capacity (veh/h)	1422	-	604	882	-	-
HCM Lane V/C Ratio	-	-	0.432	0.123	-	-
HCM Control Delay (s)	0	-	15.4	9.7	-	-
HCM Lane LOS	A	-	C	A	-	-
HCM 95th %tile Q(veh)	0	-	2.2	0.4	-	-

DESIGN YEAR 2040 'BUILD' CONDITIONS

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	920	250	80	190	0	0	0	0	160	0	150
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		5.0	5.0	5.0	5.0						5.0	5.0
Lane Util. Factor		1.00	1.00	1.00	1.00						1.00	0.88
Frt		1.00	0.85	1.00	1.00						1.00	0.85
Flt Protected		1.00	1.00	0.95	1.00						0.95	1.00
Satd. Flow (prot)		1881	1599	1787	1881						1787	2814
Flt Permitted		1.00	1.00	0.11	1.00						0.95	1.00
Satd. Flow (perm)		1881	1599	214	1881						1787	2814
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	1000	272	87	207	0	0	0	0	174	0	163
RTOR Reduction (vph)	0	0	95	0	0	0	0	0	0	0	0	140
Lane Group Flow (vph)	0	1000	177	87	207	0	0	0	0	0	174	23
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Turn Type		NA	Perm	pm+pt	NA					Perm	NA	Perm
Protected Phases		2		1	6						8	
Permitted Phases			2	6						8		8
Actuated Green, G (s)		65.1	65.1	75.7	75.7						14.3	14.3
Effective Green, g (s)		65.1	65.1	75.7	75.7						14.3	14.3
Actuated g/C Ratio		0.65	0.65	0.76	0.76						0.14	0.14
Clearance Time (s)		5.0	5.0	5.0	5.0						5.0	5.0
Vehicle Extension (s)		3.0	3.0	3.0	3.0						3.0	3.0
Lane Grp Cap (vph)		1224	1040	250	1423						255	402
v/s Ratio Prot		c0.53		c0.02	0.11							
v/s Ratio Perm			0.11	0.24							0.10	0.01
v/c Ratio		0.82	0.17	0.35	0.15						0.68	0.06
Uniform Delay, d1		13.0	6.8	14.3	3.3						40.7	37.0
Progression Factor		1.00	1.00	2.40	2.02						1.00	1.00
Incremental Delay, d2		6.1	0.4	0.8	0.2						7.3	0.1
Delay (s)		19.1	7.2	35.3	6.9						48.0	37.1
Level of Service		B	A	D	A						D	D
Approach Delay (s)		16.6			15.3			0.0			42.7	
Approach LOS		B			B			A			D	

Intersection Summary			
HCM 2000 Control Delay	21.0	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.76		
Actuated Cycle Length (s)	100.0	Sum of lost time (s)	15.0
Intersection Capacity Utilization	75.6%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	760	170	80	20	120	240	150	200	70	0	0	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.0	5.0		5.0	5.0	5.0	5.0	5.0				
Lane Util. Factor	1.00	1.00		1.00	1.00	1.00	1.00	1.00				
Frt	1.00	0.95		1.00	1.00	0.85	1.00	0.96				
Flt Protected	0.95	1.00		0.95	1.00	1.00	0.95	1.00				
Satd. Flow (prot)	1787	1791		1787	1881	1599	1787	1808				
Flt Permitted	0.58	1.00		0.59	1.00	1.00	0.95	1.00				
Satd. Flow (perm)	1091	1791		1114	1881	1599	1787	1808				
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	826	185	87	22	130	261	163	217	76	0	0	0
RTOR Reduction (vph)	0	15	0	0	0	147	0	13	0	0	0	0
Lane Group Flow (vph)	826	257	0	22	130	114	163	280	0	0	0	0
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Turn Type	pm+pt	NA		Perm	NA	Perm	Perm	NA				
Protected Phases	5	2			6			4				
Permitted Phases	2			6		6	4					
Actuated Green, G (s)	70.5	70.5		32.7	32.7	32.7	19.5	19.5				
Effective Green, g (s)	70.5	70.5		32.7	32.7	32.7	19.5	19.5				
Actuated g/C Ratio	0.70	0.70		0.33	0.33	0.33	0.20	0.20				
Clearance Time (s)	5.0	5.0		5.0	5.0	5.0	5.0	5.0				
Vehicle Extension (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0				
Lane Grp Cap (vph)	997	1262		364	615	522	348	352				
v/s Ratio Prot	c0.27	0.14			0.07			c0.15				
v/s Ratio Perm	c0.31			0.02		0.07	0.09					
v/c Ratio	0.83	0.20		0.06	0.21	0.22	0.47	0.80				
Uniform Delay, d1	8.5	5.1		23.1	24.3	24.4	35.7	38.4				
Progression Factor	0.38	2.39		1.00	1.00	1.00	1.00	1.00				
Incremental Delay, d2	3.4	0.3		0.3	0.8	1.0	1.0	11.8				
Delay (s)	6.7	12.4		23.4	25.1	25.3	36.7	50.1				
Level of Service	A	B		C	C	C	D	D				
Approach Delay (s)		8.1			25.2			45.3			0.0	
Approach LOS		A			C			D			A	

Intersection Summary			
HCM 2000 Control Delay	20.3	HCM 2000 Level of Service	C
HCM 2000 Volume to Capacity ratio	0.86		
Actuated Cycle Length (s)	100.0	Sum of lost time (s)	15.0
Intersection Capacity Utilization	86.1%	ICU Level of Service	E
Analysis Period (min)	15		

c Critical Lane Group

Intersection	
Int Delay, s/veh	2

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Vol, veh/h	1100	130	10	330	10	70
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	1	1	1	1	1	1
Mvmt Flow	1196	141	11	359	11	76

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	1337	0	1467	1266
Stage 1	-	-	-	-	1266	-
Stage 2	-	-	-	-	201	-
Critical Hdwy	-	-	4.11	-	6.615	6.215
Critical Hdwy Stg 1	-	-	-	-	5.415	-
Critical Hdwy Stg 2	-	-	-	-	5.815	-
Follow-up Hdwy	-	-	2.209	-	3.5095	3.3095
Pot Cap-1 Maneuver	-	-	519	-	130	207
Stage 1	-	-	-	-	266	-
Stage 2	-	-	-	-	816	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	519	-	127	207
Mov Cap-2 Maneuver	-	-	-	-	127	-
Stage 1	-	-	-	-	266	-
Stage 2	-	-	-	-	795	-

Approach	EB	WB	NB
HCM Control Delay, s	0	0.5	38.4
HCM LOS			E

Minor Lane/Major Mvmt	NBLn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	192	-	-	519	-
HCM Lane V/C Ratio	0.453	-	-	0.021	-
HCM Control Delay (s)	38.4	-	-	12.1	0.1
HCM Lane LOS	E	-	-	B	A
HCM 95th %tile Q(veh)	2.1	-	-	0.1	-

Intersection	
Int Delay, s/veh	5.2

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Vol, veh/h	180	80	0	240	100	0
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Stop	Stop	Free	Free	Free	Free
RT Channelized	-	Stop	-	None	-	None
Storage Length	0	50	-	-	-	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	1	1	1	1
Mvmt Flow	196	87	0	261	109	0

Major/Minor	Minor2		Major1		Major2	
Conflicting Flow All	370	109	109	0	-	0
Stage 1	109	-	-	-	-	-
Stage 2	261	-	-	-	-	-
Critical Hdwy	6.42	6.22	4.11	-	-	-
Critical Hdwy Stg 1	5.42	-	-	-	-	-
Critical Hdwy Stg 2	5.42	-	-	-	-	-
Follow-up Hdwy	3.518	3.318	2.209	-	-	-
Pot Cap-1 Maneuver	630	945	1488	-	-	-
Stage 1	916	-	-	-	-	-
Stage 2	783	-	-	-	-	-
Platoon blocked, %				-	-	-
Mov Cap-1 Maneuver	630	945	1488	-	-	-
Mov Cap-2 Maneuver	630	-	-	-	-	-
Stage 1	916	-	-	-	-	-
Stage 2	783	-	-	-	-	-

Approach	EB	NB	SB
HCM Control Delay, s	12	0	0
HCM LOS	B		

Minor Lane/Major Mvmt	NBL	NBT	EBLn1	EBLn2	SBT	SBR
Capacity (veh/h)	1488	-	630	945	-	-
HCM Lane V/C Ratio	-	-	0.311	0.092	-	-
HCM Control Delay (s)	0	-	13.3	9.2	-	-
HCM Lane LOS	A	-	B	A	-	-
HCM 95th %tile Q(veh)	0	-	1.3	0.3	-	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	410	140	70	430	0	0	0	0	370	0	1000
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		5.0	5.0	5.0	5.0						5.0	5.0
Lane Util. Factor		1.00	1.00	1.00	1.00						1.00	0.88
Frt		1.00	0.85	1.00	1.00						1.00	0.85
Flt Protected		1.00	1.00	0.95	1.00						0.95	1.00
Satd. Flow (prot)		1881	1599	1787	1881						1787	2814
Flt Permitted		1.00	1.00	0.27	1.00						0.95	1.00
Satd. Flow (perm)		1881	1599	501	1881						1787	2814
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	446	152	76	467	0	0	0	0	402	0	1087
RTOR Reduction (vph)	0	0	96	0	0	0	0	0	0	0	0	337
Lane Group Flow (vph)	0	446	56	76	467	0	0	0	0	0	402	750
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Turn Type		NA	Perm	pm+pt	NA					Perm	NA	Perm
Protected Phases		2		1	6						8	
Permitted Phases			2	6						8		8
Actuated Green, G (s)		25.8	25.8	36.4	36.4						23.6	23.6
Effective Green, g (s)		25.8	25.8	36.4	36.4						23.6	23.6
Actuated g/C Ratio		0.37	0.37	0.52	0.52						0.34	0.34
Clearance Time (s)		5.0	5.0	5.0	5.0						5.0	5.0
Vehicle Extension (s)		3.0	3.0	3.0	3.0						3.0	3.0
Lane Grp Cap (vph)		693	589	363	978						602	948
v/s Ratio Prot		c0.24		0.02	c0.25							
v/s Ratio Perm			0.04	0.09							0.22	c0.27
v/c Ratio		0.64	0.10	0.21	0.48						0.67	0.79
Uniform Delay, d1		18.3	14.5	10.1	10.7						19.8	21.0
Progression Factor		1.00	1.00	0.40	0.38						1.00	1.00
Incremental Delay, d2		4.6	0.3	0.3	1.5						2.8	4.6
Delay (s)		22.9	14.8	4.3	5.6						22.7	25.6
Level of Service		C	B	A	A						C	C
Approach Delay (s)		20.8			5.4			0.0			24.8	
Approach LOS		C			A			A			C	

Intersection Summary			
HCM 2000 Control Delay	19.9	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.71		
Actuated Cycle Length (s)	70.0	Sum of lost time (s)	15.0
Intersection Capacity Utilization	65.9%	ICU Level of Service	C
Analysis Period (min)	15		

c Critical Lane Group

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	240	400	140	10	160	120	340	60	60	0	0	0
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	5.0	5.0		5.0	5.0	5.0	5.0	5.0				
Lane Util. Factor	1.00	1.00		1.00	1.00	1.00	1.00	1.00				
Frt	1.00	0.96		1.00	1.00	0.85	1.00	0.93				
Flt Protected	0.95	1.00		0.95	1.00	1.00	0.95	1.00				
Satd. Flow (prot)	1787	1808		1787	1881	1599	1787	1740				
Flt Permitted	0.54	1.00		0.44	1.00	1.00	0.95	1.00				
Satd. Flow (perm)	1019	1808		833	1881	1599	1787	1740				
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	261	435	152	11	174	130	370	65	65	0	0	0
RTOR Reduction (vph)	0	14	0	0	0	82	0	47	0	0	0	0
Lane Group Flow (vph)	261	573	0	11	174	48	370	83	0	0	0	0
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Turn Type	pm+pt	NA		Perm	NA	Perm	Perm	NA				
Protected Phases	5	2			6			4				
Permitted Phases	2			6		6	4					
Actuated Green, G (s)	40.1	40.1		25.7	25.7	25.7	19.9	19.9				
Effective Green, g (s)	40.1	40.1		25.7	25.7	25.7	19.9	19.9				
Actuated g/C Ratio	0.57	0.57		0.37	0.37	0.37	0.28	0.28				
Clearance Time (s)	5.0	5.0		5.0	5.0	5.0	5.0	5.0				
Vehicle Extension (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0				
Lane Grp Cap (vph)	686	1035		305	690	587	508	494				
v/s Ratio Prot	0.05	c0.32			0.09			0.05				
v/s Ratio Perm	0.17			0.01		0.03	c0.21					
v/c Ratio	0.38	0.55		0.04	0.25	0.08	0.73	0.17				
Uniform Delay, d1	7.7	9.4		14.2	15.4	14.4	22.6	18.8				
Progression Factor	0.61	0.37		1.00	1.00	1.00	1.00	1.00				
Incremental Delay, d2	0.3	1.8		0.2	0.9	0.3	5.2	0.2				
Delay (s)	5.0	5.2		14.4	16.3	14.7	27.8	19.0				
Level of Service	A	A		B	B	B	C	B				
Approach Delay (s)		5.2			15.6			25.5			0.0	
Approach LOS		A			B			C			A	

Intersection Summary			
HCM 2000 Control Delay	13.2	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.67		
Actuated Cycle Length (s)	70.0	Sum of lost time (s)	15.0
Intersection Capacity Utilization	77.6%	ICU Level of Service	D
Analysis Period (min)	15		

c Critical Lane Group

Intersection	
Int Delay, s/veh	0.5

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Vol, veh/h	540	10	10	1420	10	10
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	1	1	1	1	1	1
Mvmt Flow	587	11	11	1543	11	11

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	598	0	1385	592
Stage 1	-	-	-	-	592	-
Stage 2	-	-	-	-	793	-
Critical Hdwy	-	-	4.11	-	6.615	6.215
Critical Hdwy Stg 1	-	-	-	-	5.415	-
Critical Hdwy Stg 2	-	-	-	-	5.815	-
Follow-up Hdwy	-	-	2.209	-	3.5095	3.3095
Pot Cap-1 Maneuver	-	-	984	-	147	508
Stage 1	-	-	-	-	554	-
Stage 2	-	-	-	-	409	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	984	-	136	508
Mov Cap-2 Maneuver	-	-	-	-	136	-
Stage 1	-	-	-	-	554	-
Stage 2	-	-	-	-	377	-

Approach	EB	WB	NB
HCM Control Delay, s	0	0.4	23.6
HCM LOS			C

Minor Lane/Major Mvmt	NBLn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	215	-	-	984	-
HCM Lane V/C Ratio	0.101	-	-	0.011	-
HCM Control Delay (s)	23.6	-	-	8.7	0.3
HCM Lane LOS	C	-	-	A	A
HCM 95th %tile Q(veh)	0.3	-	-	0	-

Intersection	
Int Delay, s/veh	6.6

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Vol, veh/h	240	100	0	220	150	0
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Stop	Stop	Free	Free	Free	Free
RT Channelized	-	Stop	-	None	-	None
Storage Length	0	50	-	-	-	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	1	1	1	1
Mvmt Flow	261	109	0	239	163	0

Major/Minor	Minor2		Major1		Major2	
Conflicting Flow All	402	163	163	0	-	0
Stage 1	163	-	-	-	-	-
Stage 2	239	-	-	-	-	-
Critical Hdwy	6.42	6.22	4.11	-	-	-
Critical Hdwy Stg 1	5.42	-	-	-	-	-
Critical Hdwy Stg 2	5.42	-	-	-	-	-
Follow-up Hdwy	3.518	3.318	2.209	-	-	-
Pot Cap-1 Maneuver	604	882	1422	-	-	-
Stage 1	866	-	-	-	-	-
Stage 2	801	-	-	-	-	-
Platoon blocked, %				-	-	-
Mov Cap-1 Maneuver	604	882	1422	-	-	-
Mov Cap-2 Maneuver	604	-	-	-	-	-
Stage 1	866	-	-	-	-	-
Stage 2	801	-	-	-	-	-

Approach	EB	NB	SB
HCM Control Delay, s	13.7	0	0
HCM LOS	B		

Minor Lane/Major Mvmt	NBL	NBT	EBLn1	EBLn2	SBT	SBR
Capacity (veh/h)	1422	-	604	882	-	-
HCM Lane V/C Ratio	-	-	0.432	0.123	-	-
HCM Control Delay (s)	0	-	15.4	9.7	-	-
HCM Lane LOS	A	-	C	A	-	-
HCM 95th %tile Q(veh)	0	-	2.2	0.4	-	-

APPENDIX C
CONSTRAINED TRAFFIC ANALYSIS

Constrained Traffic Volume Analysis – Design Year 2040

Wallings Road / Interstate 77 NB Entrance Ramp / Mill Road Intersection

AM Peak Hour

'No-Build Condition'

Movement	VPH	V/C Ratio	Capacity Constrained	Volume Entering Freeway
Eastbound Left	760	1.200	Yes	634
Westbound Right	240	1.107	Yes	217
Northbound Thru	200	1.115	Yes	180
			Total	***1,031***

Constrained Movement Calculation:

$$\frac{EB\ Left\ VPH}{EB\ Left\ V/C\ Ratio} = \frac{760}{1.200} = 634 \textbf{ VPH}$$

$$\frac{WB\ Right\ VPH}{WB\ Right\ V/C\ Ratio} = \frac{240}{1.107} = 217 \textbf{ VPH}$$

$$\frac{NB\ Thru\ VPH}{NB\ Thru\ V/C\ Ratio} = \frac{200}{1.115} = 180 \textbf{ VPH}$$

'Build' Condition

Movement	VPH	V/C Ratio	Capacity Constrained	Volume Entering Freeway
Eastbound Left	760	0.947	No	760
Westbound Right	240	0.600	No	240
Northbound Thru	200	0.563	No	200
			Total	***1,200***

Comparison between 'No-Build' and 'Build' Conditions Calculation:

1200 – 1031 = 169 more VPH entering the freeway after improvement is constructed

$\left(\frac{169}{(4{,}950 + 1031)}\right) * 100 = 2.83\%$ more traffic added to freeway due to improvements

2.83% > 2.00% Therefore, improvement may degrade freeway operation and warrants additional analysis

Constrained Traffic Volume Analysis – Design Year 2040

Wallings Road / Interstate 77 NB Entrance Ramp / Mill Road Intersection

PM Peak Hour

'No-Build Condition'

Movement	VPH	V/C Ratio	Capacity Constrained	Volume Entering Freeway
Eastbound Left	240	0.981	No	240
Westbound Right	120	0.438	No	120
Northbound Thru	60	0.913	No	60
			Total	***420***

'Build' Condition

Movement	VPH	V/C Ratio	Capacity Constrained	Volume Entering Freeway
Eastbound Left	240	0.436	No	240
Westbound Right	120	0.250	No	120
Northbound Thru	60	0.209	No	60
			Total	***420***

The proposed improvement will NOT degrade freeway operation

Constrained Traffic Volume Analysis – Design Year 2040

Wallings Road / Interstate 77 SB Ramps

AM Peak Hour

'No-Build Condition'

Movement	VPH	V/C Ratio	Capacity Constrained	Volume Entering Freeway
Eastbound Right	250	1.090	Yes	230
Westbound Left	80	0.969	No	80
			Total	***310***

Constrained Movement Calculation:

$$\frac{EB\ Right\ VPH}{EB\ Right\ V/C\ Ratio} = \frac{250}{1.090} = 230\ \textbf{VPH}$$

'Build' Condition

Movement	VPH	V/C Ratio	Capacity Constrained	Volume Entering Freeway
Eastbound Right	250	0.304	No	250
Westbound Left	80	0.381	No	80
			Total	***330***

Because the freeway segment impacted by this constrained traffic evaluation is projected to operate at acceptable Levels-of-Service under the full demand volume, the check of the 2.00% rule is not required.

Constrained Traffic Volume Analysis – Design Year 2040

Wallings Road / Interstate 77 SB Ramps

PM Peak Hour

'No-Build Condition'

Movement	VPH	V/C Ratio	Capacity Constrained	Volume Entering Freeway
Eastbound Right	140	0.834	No	140
Westbound Left	70	1.317	Yes	53
			Total	***193***

Constrained Movement Calculation:

$$\frac{WB\ Left\ VPH}{WB\ Left\ V/C\ Ratio} = \frac{70}{1.317} = 53 \textbf{ VPH}$$

'Build' Condition

Movement	VPH	V/C Ratio	Capacity Constrained	Volume Entering Freeway
Eastbound Right	140	0.334	No	140
Westbound Left	70	0.223	No	70
			Total	***210***

Because the freeway segment impacted by this constrained traffic evaluation is projected to operate at acceptable Levels-of-Service under the full demand volume, the check of the 2.00% rule is not required.

APPENDIX D
HCS FREEWAY CAPACITY ANALYSIS

DESIGN YEAR 2040 'NO-BUILD' CONDITIONS

FREEWAY SECTION ANALYSIS

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	AM Peak Hour
Freeway/Direction:	I-77 Northbound
From/To:	F-1
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Flow Inputs and Adjustments

Volume, V	5210	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1416	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	1.70	%
Segment length	1.02	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1925	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1925	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	58.1	mi/h
Number of lanes, N	3	
Density, D	33.1	pc/mi/ln
Level of service, LOS	D	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	AM Peak Hour
Freeway/Direction:	I-77 Northbound
From/To:	F-2
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Flow Inputs and Adjustments

Volume, V	4950	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1345	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	-0.65	%
Segment length	0.58	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1829	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1829	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	59.0	mi/h
Number of lanes, N	3	
Density, D	31.0	pc/mi/ln
Level of service, LOS	D	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	AM Peak Hour
Freeway/Direction:	I-77 Northbound
From/To:	F-3
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Flow Inputs and Adjustments

Volume, V	5981	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1625	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	-1.19	%
Segment length	0.64	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	2210	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	2210	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	53.2	mi/h
Number of lanes, N	3	
Density, D	41.5	pc/mi/ln
Level of service, LOS	E	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	AM Peak Hour
Freeway/Direction:	I-77 Southbound
From/To:	F-4
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Flow Inputs and Adjustments

Volume, V	3880	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1054	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	1.70	%
Segment length	0.29	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1434	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1434	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	60.0	mi/h
Number of lanes, N	3	
Density, D	23.9	pc/mi/ln
Level of service, LOS	C	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	AM Peak Hour
Freeway/Direction:	I-77 Southbound
From/To:	F-5
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Flow Inputs and Adjustments

Volume, V	3570	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	970	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	0.38	%
Segment length	0.50	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1319	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1319	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	60.0	mi/h
Number of lanes, N	3	
Density, D	22.0	pc/mi/ln
Level of service, LOS	C	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	AM Peak Hour
Freeway/Direction:	I-77 Southbound
From/To:	F-6
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Flow Inputs and Adjustments

Volume, V	3880	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1054	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	-0.99	%
Segment length	1.22	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1434	pc/h/ln

Speed Inputs and Adjustments

Lane width	12.0	ft
Right-side lateral clearance	6.0	ft
Total ramp density, TRD	0.50	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Base	
FFS or BFFS	75.4	mi/h
Lane width adjustment, fLW	0.0	mi/h
Lateral clearance adjustment, fLC	0.0	mi/h
TRD adjustment	1.8	mi/h
Free-flow speed, FFS	73.6	mi/h

LOS and Performance Measures

Flow rate, vp	1434	pc/h/ln
Free-flow speed, FFS	73.6	mi/h
Average passenger-car speed, S	72.9	mi/h
Number of lanes, N	3	
Density, D	19.7	pc/mi/ln
Level of service, LOS	C	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	PM Peak Hour
Freeway/Direction:	I-77 Northbound
From/To:	F-1
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Flow Inputs and Adjustments

Volume, V	4280	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1163	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	1.70	%
Segment length	1.02	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1582	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1582	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	60.0	mi/h
Number of lanes, N	3	
Density, D	26.4	pc/mi/ln
Level of service, LOS	D	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	PM Peak Hour
Freeway/Direction:	I-77 Northbound
From/To:	F-2
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Flow Inputs and Adjustments

Volume, V	3940	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1071	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	-0.65	%
Segment length	0.58	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1456	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1456	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	60.0	mi/h
Number of lanes, N	3	
Density, D	24.3	pc/mi/ln
Level of service, LOS	C	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	PM Peak Hour
Freeway/Direction:	I-77 Northbound
From/To:	F-3
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Flow Inputs and Adjustments

Volume, V	4360	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1185	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	-1.19	%
Segment length	0.64	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1611	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1611	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	60.0	mi/h
Number of lanes, N	3	
Density, D	26.9	pc/mi/ln
Level of service, LOS	D	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	PM Peak Hour
Freeway/Direction:	I-77 Southbound
From/To:	F-4
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Flow Inputs and Adjustments

Volume, V	6670	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1812	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	1.70	%
Segment length	0.29	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	2465	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	2465	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	46.4	mi/h
Number of lanes, N	3	
Density, D	53.1	pc/mi/ln
Level of service, LOS	F	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	PM Peak Hour
Freeway/Direction:	I-77 Southbound
From/To:	F-5
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Flow Inputs and Adjustments

Volume, V	5300	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1440	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	0.38	%
Segment length	0.50	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1959	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1959	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	57.7	mi/h
Number of lanes, N	3	
Density, D	34.0	pc/mi/ln
Level of service, LOS	D	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	PM Peak Hour
Freeway/Direction:	I-77 Southbound
From/To:	F-6
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Flow Inputs and Adjustments

Volume, V	5493	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1493	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	-0.99	%
Segment length	1.22	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	2030	pc/h/ln

Speed Inputs and Adjustments

Lane width	12.0	ft
Right-side lateral clearance	6.0	ft
Total ramp density, TRD	0.50	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Base	
FFS or BFFS	75.4	mi/h
Lane width adjustment, fLW	0.0	mi/h
Lateral clearance adjustment, fLC	0.0	mi/h
TRD adjustment	1.8	mi/h
Free-flow speed, FFS	73.6	mi/h

LOS and Performance Measures

Flow rate, vp	2030	pc/h/ln
Free-flow speed, FFS	73.6	mi/h
Average passenger-car speed, S	63.3	mi/h
Number of lanes, N	3	
Density, D	32.1	pc/mi/ln
Level of service, LOS	D	

DIVERGE AREA OF INFLUENCE ANALYSIS

Phone: Fax:
E-mail:

Diverge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	AM Peak Hour
Freeway/Dir of Travel:	I-77 Northbound
Junction:	D-1
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Freeway Data

Type of analysis	Diverge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	5210	vph

Off Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-Flow speed on ramp	35.0	mph
Volume on ramp	260	vph
Length of first accel/decel lane	530	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent ramp	1031	vph
Position of adjacent ramp	Downstream	
Type of adjacent ramp	On	
Distance to adjacent ramp	3100	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway		Ramp		Adjacent Ramp		
Volume, V (vph)	5210		260		1031		vph
Peak-hour factor, PHF	0.94		0.94		0.94		
Peak 15-min volume, v15	1386		69		274		v
Trucks and buses	4		2		1		%
Recreational vehicles	0		0		0		%
Terrain type:	Grade		Grade		Grade		
Grade	1.70	%	1.20	%	-1.60	%	
Length	1.02	mi	0.20	mi	0.20	mi	
Trucks and buses PCE, ET	1.5		1.5		1.5		
Recreational vehicle PCE, ER	1.2		1.2		1.2		

Heavy vehicle adjustment, fHV	0.980	0.990	0.995	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	5653	279	1102	pcph

Estimation of V12 Diverge Areas

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 0.606 Using Equation 9

$v_{12} = v_R + (v_F - v_R) P_{FD}$ = 3535 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
$v_{Fi} = v_F$	5653	6900	No
$v_{FO} = v_F - v_R$	5374	6900	No
v_R	279	2000	No
v_3 or v_{av34}	2118 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34}	> 2700 pc/h?	No	
Is v_3 or v_{av34}	> 1.5 v_{12} /2	No	

If yes, v_{12A} = 3535 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Diverge Influence Area

	Actual	Max Desirable	Violation?
v_{12}	3535	4400	No

Level of Service Determination (if not F)

Density, $D = 4.252 + 0.0086 v_R - 0.009 L_{12}$ = 29.9 pc/mi/ln

Level of service for ramp-freeway junction areas of influence D

Speed Estimation

Intermediate speed variable, D_S = 0.453

Space mean speed in ramp influence area, S_R = 51.8 mph

Space mean speed in outer lanes, S_0 = 61.5 mph

Space mean speed for all vehicles, S = 55.1 mph

Phone: Fax:
E-mail:

Diverge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	AM Peak Hour
Freeway/Dir of Travel:	I-77 Southbound
Junction:	D-2
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Freeway Data

Type of analysis	Diverge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	3880	vph

Off Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-Flow speed on ramp	35.0	mph
Volume on ramp	310	vph
Length of first accel/decel lane	625	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent ramp	312	vph
Position of adjacent ramp	Downstream	
Type of adjacent ramp	On	
Distance to adjacent ramp	2650	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway	Ramp	Adjacent Ramp	
Volume, V (vph)	3880	310	312	vph
Peak-hour factor, PHF	0.94	0.94	0.94	
Peak 15-min volume, v15	1032	82	83	v
Trucks and buses	4	1	2	%
Recreational vehicles	0	0	0	%
Terrain type:	Grade	Grade	Grade	
Grade	1.70 %	3.65 %	-2.39 %	
Length	0.29 mi	0.21 mi	0.22 mi	
Trucks and buses PCE, ET	1.5	1.5	1.5	
Recreational vehicle PCE, ER	1.2	1.2	1.2	

Heavy vehicle adjustment, fHV	0.980	0.995	0.990	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	4210	331	335	pcph

Estimation of V12 Diverge Areas

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 0.640 Using Equation 9

$v_{12} = v_R + (v_F - v_R) P_{FD}$ = 2812 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
$v_{Fi} = v_F$	4210	6900	No
$v_{FO} = v_F - v_R$	3879	6900	No
v_R	331	2000	No
v_3 or v_{av34}	1398 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34}	> 2700 pc/h?	No	
Is v_3 or v_{av34}	> 1.5 v_{12} /2	No	

If yes, v_{12A} = 2812 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Diverge Influence Area

	Actual	Max Desirable	Violation?
v_{12}	2812	4400	No

Level of Service Determination (if not F)

Density, $D = 4.252 + 0.0086 v_R - 0.009 L_D$ = 22.8 pc/mi/ln

Level of service for ramp-freeway junction areas of influence C

Speed Estimation

Intermediate speed variable, D_S = 0.458

Space mean speed in ramp influence area, S_R = 51.8 mph

Space mean speed in outer lanes, S_0 = 64.3 mph

Space mean speed for all vehicles, S = 55.3 mph

HCS 2010: Freeway Merge and Diverge Segments Release 6.70

Phone: Fax:
E-mail:

Diverge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	PM Peak Hour
Freeway/Dir of Travel:	I-77 Northbound
Junction:	D-1
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Freeway Data

Type of analysis	Diverge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	4280	vph

Off Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-Flow speed on ramp	35.0	mph
Volume on ramp	340	vph
Length of first accel/decel lane	530	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent ramp	420	vph
Position of adjacent ramp	Downstream	
Type of adjacent ramp	On	
Distance to adjacent ramp	3100	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway		Ramp		Adjacent Ramp		
Volume, V (vph)	4280		340		420		vph
Peak-hour factor, PHF	0.94		0.94		0.94		
Peak 15-min volume, v15	1138		90		112		v
Trucks and buses	4		2		1		%
Recreational vehicles	0		0		0		%
Terrain type:	Grade		Grade		Grade		
Grade	1.70	%	1.20	%	-1.60	%	
Length	1.02	mi	0.20	mi	0.20	mi	
Trucks and buses PCE, ET	1.5		1.5		1.5		
Recreational vehicle PCE, ER	1.2		1.2		1.2		

Heavy vehicle adjustment, fHV	0.980	0.990	0.995	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	4644	365	449	pcph

Estimation of V12 Diverge Areas

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 0.627 Using Equation 9

$v_{12} = v_R + (v_F - v_R) P_{FD}$ = 3048 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
$v_{Fi} = v_F$	4644	6900	No
$v_{FO} = v_F - v_R$	4279	6900	No
v_R	365	2000	No
v_3 or v_{av34}	1596 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34}	> 2700 pc/h?	No	
Is v_3 or v_{av34}	> 1.5 v_{12} /2	No	

If yes, v_{12A} = 3048 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Diverge Influence Area

	Actual	Max Desirable	Violation?
v_{12}	3048	4400	No

Level of Service Determination (if not F)

Density, $D = 4.252 + 0.0086\, v_R - 0.009\, L_D$ = 25.7 pc/mi/ln

Level of service for ramp-freeway junction areas of influence C

Speed Estimation

Intermediate speed variable, D_S = 0.461

Space mean speed in ramp influence area, S_R = 51.7 mph

Space mean speed in outer lanes, S_0 = 63.5 mph

Space mean speed for all vehicles, S = 55.2 mph

Phone: Fax:
E-mail:

Diverge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	PM Peak Hour
Freeway/Dir of Travel:	I-77 Southbound
Junction:	D-2
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Freeway Data

Type of analysis	Diverge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	6670	vph

Off Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-Flow speed on ramp	35.0	mph
Volume on ramp	1370	vph
Length of first accel/decel lane	625	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent ramp	195	vph
Position of adjacent ramp	Downstream	
Type of adjacent ramp	On	
Distance to adjacent ramp	2650	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway	Ramp	Adjacent Ramp	
Volume, V (vph)	6670	1370	195	vph
Peak-hour factor, PHF	0.94	0.94	0.94	
Peak 15-min volume, v15	1774	364	52	v
Trucks and buses	4	1	2	%
Recreational vehicles	0	0	0	%
Terrain type:	Grade	Grade	Grade	
Grade	1.70 %	3.65 %	-2.39 %	
Length	0.29 mi	0.21 mi	0.22 mi	
Trucks and buses PCE, ET	1.5	1.5	1.5	
Recreational vehicle PCE, ER	1.2	1.2	1.2	

Heavy vehicle adjustment, fHV	0.980	0.995	0.990	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	7238	1465	210	pcph

Estimation of V12 Diverge Areas

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 0.512 Using Equation 9

$v_{12} = v_R + (v_F - v_R) P_{FD}$ = 4419 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
$v_{Fi} = v_F$	7238	6900	Yes
$v_{FO} = v_F - v_R$	5773	6900	No
v_R	1465	2000	No
v_3 or v_{av34}	2819 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34}	> 2700 pc/h?	Yes	
Is v_3 or v_{av34}	> 1.5 v_{12} /2	No	

If yes, v_{12A} = 4538 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Diverge Influence Area

	Actual	Max Desirable	Violation?
v_{12A}	4538	4400	Yes

Level of Service Determination (if not F)

Density, $D = 4.252 + 0.0086\, v_R - 0.009\, L_{12}$ = 37.7 pc/mi/ln

Level of service for ramp-freeway junction areas of influence F

Speed Estimation

Intermediate speed variable,	D_S = 0.560	
Space mean speed in ramp influence area,	S_R = 49.9	mph
Space mean speed in outer lanes,	S_0 = 59.2	mph
Space mean speed for all vehicles,	S = 53.0	mph

MERGE AREA OF INFLUENCE ANALYSIS

Phone: Fax:
E-mail:

Merge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	AM Peak Hour
Freeway/Dir of Travel:	I-77 Northbound
Junction:	M-1
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Freeway Data

Type of analysis	Merge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	4950	vph

On Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-flow speed on ramp	35.0	mph
Volume on ramp	1031	vph
Length of first accel/decel lane	1030	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent Ramp	260	vph
Position of adjacent Ramp	Upstream	
Type of adjacent Ramp	Off	
Distance to adjacent Ramp	3100	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway	Ramp	Adjacent Ramp	
Volume, V (vph)	4950	1031	260	vph
Peak-hour factor, PHF	0.92	0.92	0.92	
Peak 15-min volume, v15	1345	280	71	v
Trucks and buses	4	1	2	%
Recreational vehicles	0	0	0	%
Terrain type:	Grade	Grade	Grade	
Grade	-0.65 %	-1.60 %	1.20 %	
Length	0.58 mi	0.20 mi	0.20 mi	
Trucks and buses PCE, ET	1.5	1.5	1.5	
Recreational vehicle PCE, ER	1.2	1.2	1.2	

Heavy vehicle adjustment, fHV	0.980	0.995	0.990	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	5488	1126	285	pcph

Estimation of V12 Merge Areas

L_{EQ} = 1300.92 (Equation 13-6 or 13-7)

P_{FM} = 0.606 Using Equation 3

$v_{12} = v_F (P_{FM})$ = 3328 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
v_{FO}	6614	6900	No
v_3 or v_{av34}	2160 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34} > 2700 pc/h?		No	
Is v_3 or v_{av34} > 1.5 v_{12} /2		Yes	

If yes, v_{12A} = 3328 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Merge Influence Area

	Actual	Max Desirable	Violation?
v_{12A}	4454	4600	No

Level of Service Determination (if not F)

Density, $D_R = 5.475 + 0.00734\ v_R + 0.0078\ v_{12} - 0.00627\ L_A$ = 33.2 pc/mi/ln

Level of service for ramp-freeway junction areas of influence D

Speed Estimation

Intermediate speed variable,	M_S = 0.584	
Space mean speed in ramp influence area,	S_R = 49.5	mph
Space mean speed in outer lanes,	S_0 = 54.0	mph
Space mean speed for all vehicles,	S = 50.9	mph

HCS 2010: Freeway Merge and Diverge Segments Release 6.80

Phone: Fax:
E-mail:

Merge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	AM Peak Hour
Freeway/Dir of Travel:	I-77 Southbound
Junction:	M-2
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Freeway Data

Type of analysis	Merge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	3570	vph

On Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-flow speed on ramp	35.0	mph
Volume on ramp	310	vph
Length of first accel/decel lane	1100	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent Ramp	310	vph
Position of adjacent Ramp	Upstream	
Type of adjacent Ramp	Off	
Distance to adjacent Ramp	2650	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway	Ramp	Adjacent Ramp	
Volume, V (vph)	3570	310	310	vph
Peak-hour factor, PHF	0.92	0.92	0.92	
Peak 15-min volume, v15	970	84	84	v
Trucks and buses	4	2	1	%
Recreational vehicles	0	0	0	%
Terrain type:	Grade	Grade	Grade	
Grade	0.38 %	-2.39 %	3.65 %	
Length	0.50 mi	0.22 mi	0.21 mi	
Trucks and buses PCE, ET	1.5	1.5	1.5	
Recreational vehicle PCE, ER	1.2	1.2	1.2	

Heavy vehicle adjustment, fHV	0.980	0.990	0.995	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	3958	340	339	pcph

Estimation of V12 Merge Areas

L_{EQ} = 836.37 (Equation 13-6 or 13-7)

P_{FM} = 0.608 Using Equation 3

$v_{12} = v_F (P_{FM})$ = 2408 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
v_{FO}	4298	6900	No
v_3 or v_{av34}	1550 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34}	> 2700 pc/h?	No	
Is v_3 or v_{av34}	> 1.5 v_{12} /2	Yes	

If yes, v_{12A} = 2408 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Merge Influence Area

	Actual	Max Desirable	Violation?
v_{12A}	2748	4600	No

Level of Service Determination (if not F)

Density, $D_R = 5.475 + 0.00734\ v_R + 0.0078\ v_{12} - 0.00627\ L_A$ = 19.9 pc/mi/ln

Level of service for ramp-freeway junction areas of influence B

Speed Estimation

Intermediate speed variable,	M_S = 0.305	
Space mean speed in ramp influence area,	S_R = 54.5	mph
Space mean speed in outer lanes,	S_0 = 56.2	mph
Space mean speed for all vehicles,	S = 55.1	mph

Phone: Fax:
E-mail:

Merge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	PM Peak Hour
Freeway/Dir of Travel:	I-77 Northbound
Junction:	M-1
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Freeway Data

Type of analysis	Merge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	3940	vph

On Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-flow speed on ramp	35.0	mph
Volume on ramp	420	vph
Length of first accel/decel lane	1030	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent Ramp	340	vph
Position of adjacent Ramp	Upstream	
Type of adjacent Ramp	Off	
Distance to adjacent Ramp	3100	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway		Ramp		Adjacent Ramp		
Volume, V (vph)	3940		420		340		vph
Peak-hour factor, PHF	0.92		0.92		0.92		
Peak 15-min volume, v15	1071		114		92		v
Trucks and buses	4		1		2		%
Recreational vehicles	0		0		0		%
Terrain type:	Grade		Grade		Grade		
Grade	-0.65	%	-1.60	%	1.20	%	
Length	0.58	mi	0.20	mi	0.20	mi	
Trucks and buses PCE, ET	1.5		1.5		1.5		
Recreational vehicle PCE, ER	1.2		1.2		1.2		

Heavy vehicle adjustment, fHV	0.980	0.995	0.990	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	4368	459	373	pcph

Estimation of V12 Merge Areas

L_{EQ} = 918.50 (Equation 13-6 or 13-7)

P_{FM} = 0.606 Using Equation 3

$v_{12} = v_F (P_{FM})$ = 2648 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
v_{FO}	4827	6900	No
v_3 or v_{av34}	1720 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34}	> 2700 pc/h?	No	
Is v_3 or v_{av34}	> 1.5 v_{12} /2	Yes	

If yes, v_{12A} = 2648 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Merge Influence Area

	Actual	Max Desirable	Violation?
v_{12A}	3107	4600	No

Level of Service Determination (if not F)

Density, $D_R = 5.475 + 0.00734\ v_R + 0.0078\ v_{12} - 0.00627\ L_A$ = 23.0 pc/mi/ln

Level of service for ramp-freeway junction areas of influence C

Speed Estimation

Intermediate speed variable,	M_S = 0.336	
Space mean speed in ramp influence area,	S_R = 54.0	mph
Space mean speed in outer lanes,	S_0 = 55.6	mph
Space mean speed for all vehicles,	S = 54.5	mph

HCS 2010: Freeway Merge and Diverge Segments Release 6.80

Phone: Fax:
E-mail:

Merge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	PM Peak Hour
Freeway/Dir of Travel:	I-77 Southbound
Junction:	M-2
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'No-Build'

Freeway Data

Type of analysis	Merge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	5300	vph

On Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-flow speed on ramp	35.0	mph
Volume on ramp	193	vph
Length of first accel/decel lane	1100	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent Ramp	1370	vph
Position of adjacent Ramp	Upstream	
Type of adjacent Ramp	Off	
Distance to adjacent Ramp	2650	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway	Ramp	Adjacent Ramp	
Volume, V (vph)	5300	193	1370	vph
Peak-hour factor, PHF	0.92	0.92	0.92	
Peak 15-min volume, v15	1440	52	372	v
Trucks and buses	4	2	1	%
Recreational vehicles	0	0	0	%
Terrain type:	Grade	Grade	Grade	
Grade	0.38 %	-2.39 %	3.65 %	
Length	0.50 mi	0.22 mi	0.21 mi	
Trucks and buses PCE, ET	1.5	1.5	1.5	
Recreational vehicle PCE, ER	1.2	1.2	1.2	

Heavy vehicle adjustment, fHV	0.980	0.990	0.995	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	5876	212	1497	pcph

Estimation of V12 Merge Areas

L_{EQ} = 1219.43 (Equation 13-6 or 13-7)

P_{FM} = 0.608 Using Equation 3

$v_{12} = v_F (P_{FM})$ = 3574 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
v_{FO}	6088	6900	No
v_3 or v_{av34}	2302 pc/h	(Equation 13-14 or 13-17)	

Is v_3 or v_{av34} > 2700 pc/h? No

Is v_3 or v_{av34} > 1.5 v_{12} /2 Yes

If yes, v_{12A} = 3574 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Merge Influence Area

	Actual	Max Desirable	Violation?
v_{12A}	3786	4600	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, v_{12} - 0.00627\, L_A$ = 28.0+ pc/mi/ln

Level of service for ramp-freeway junction areas of influence D

Speed Estimation

Intermediate speed variable,	M_S = 0.416	
Space mean speed in ramp influence area,	S_R = 52.5	mph
Space mean speed in outer lanes,	S_0 = 53.5	mph
Space mean speed for all vehicles,	S = 52.9	mph

DESIGN YEAR 2040 'BUILD' CONDITIONS

FREEWAY SECTION ANALYSIS

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	AM Peak Hour
Freeway/Direction:	I-77 Northbound
From/To:	F-1
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Flow Inputs and Adjustments

Volume, V	5210	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1416	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	1.70	%
Segment length	1.02	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1925	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1925	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	58.1	mi/h
Number of lanes, N	3	
Density, D	33.1	pc/mi/ln
Level of service, LOS	D	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	AM Peak Hour
Freeway/Direction:	I-77 Northbound
From/To:	F-2
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Flow Inputs and Adjustments

Volume, V	4950	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1345	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	-0.65	%
Segment length	0.58	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1829	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1829	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	59.0	mi/h
Number of lanes, N	3	
Density, D	31.0	pc/mi/ln
Level of service, LOS	D	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	AM Peak Hour
Freeway/Direction:	I-77 Northbound
From/To:	F-3
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Flow Inputs and Adjustments

Volume, V	6150	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1671	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	-1.19	%
Segment length	0.64	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	2273	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	2273	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	51.8	mi/h
Number of lanes, N	3	
Density, D	43.9	pc/mi/ln
Level of service, LOS	E	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	AM Peak Hour
Freeway/Direction:	I-77 Southbound
From/To:	F-4
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Flow Inputs and Adjustments

Volume, V	3880	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1054	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	1.70	%
Segment length	0.29	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1434	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1434	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	60.0	mi/h
Number of lanes, N	3	
Density, D	23.9	pc/mi/ln
Level of service, LOS	C	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	AM Peak Hour
Freeway/Direction:	I-77 Southbound
From/To:	F-5
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Flow Inputs and Adjustments

Volume, V	3570	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	970	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	0.38	%
Segment length	5.00	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1319	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1319	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	60.0	mi/h
Number of lanes, N	3	
Density, D	22.0	pc/mi/ln
Level of service, LOS	C	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	AM Peak Hour
Freeway/Direction:	I-77 Southbound
From/To:	F-6
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Flow Inputs and Adjustments

Volume, V	3900	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1060	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	-0.99	%
Segment length	1.22	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1441	pc/h/ln

Speed Inputs and Adjustments

Lane width	12.0	ft
Right-side lateral clearance	6.0	ft
Total ramp density, TRD	0.50	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Base	
FFS or BFFS	75.4	mi/h
Lane width adjustment, fLW	0.0	mi/h
Lateral clearance adjustment, fLC	0.0	mi/h
TRD adjustment	1.8	mi/h
Free-flow speed, FFS	73.6	mi/h

LOS and Performance Measures

Flow rate, vp	1441	pc/h/ln
Free-flow speed, FFS	73.6	mi/h
Average passenger-car speed, S	72.8	mi/h
Number of lanes, N	3	
Density, D	19.8	pc/mi/ln
Level of service, LOS	C	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	PM Peak Hour
Freeway/Direction:	I-77 Northbound
From/To:	F-1
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Flow Inputs and Adjustments

Volume, V	4280	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1163	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	1.70	%
Segment length	1.02	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1582	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1582	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	60.0	mi/h
Number of lanes, N	3	
Density, D	26.4	pc/mi/ln
Level of service, LOS	D	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	PM Peak Hour
Freeway/Direction:	I-77 Northbound
From/To:	F-2
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Flow Inputs and Adjustments

Volume, V	3940	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1071	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	-0.65	%
Segment length	0.58	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1456	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1456	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	60.0	mi/h
Number of lanes, N	3	
Density, D	24.3	pc/mi/ln
Level of service, LOS	C	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	PM Peak Hour
Freeway/Direction:	I-77 Northbound
From/To:	F-3
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Flow Inputs and Adjustments

Volume, V	4360	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1185	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	-1.19	%
Segment length	0.64	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1611	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1611	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	60.0	mi/h
Number of lanes, N	3	
Density, D	26.9	pc/mi/ln
Level of service, LOS	D	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	PM Peak Hour
Freeway/Direction:	I-77 Southbound
From/To:	F-4
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Flow Inputs and Adjustments

Volume, V	6670	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1812	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	1.70	%
Segment length	0.29	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	2465	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	2465	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	46.4	mi/h
Number of lanes, N	3	
Density, D	53.1	pc/mi/ln
Level of service, LOS	F	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	PM Peak Hour
Freeway/Direction:	I-77 Southbound
From/To:	F-5
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Flow Inputs and Adjustments

Volume, V	5300	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1440	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	0.38	%
Segment length	0.50	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	1959	pc/h/ln

Speed Inputs and Adjustments

Lane width	-	ft
Right-side lateral clearance	-	ft
Total ramp density, TRD	-	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Measured	
FFS or BFFS	60.0	mi/h
Lane width adjustment, fLW	-	mi/h
Lateral clearance adjustment, fLC	-	mi/h
TRD adjustment	-	mi/h
Free-flow speed, FFS	60.0	mi/h

LOS and Performance Measures

Flow rate, vp	1959	pc/h/ln
Free-flow speed, FFS	60.0	mi/h
Average passenger-car speed, S	57.7	mi/h
Number of lanes, N	3	
Density, D	34.0	pc/mi/ln
Level of service, LOS	D	

Phone: Fax:
E-mail:

Operational Analysis

Analyst:	Brett M. Ferrell
Agency or Company:	GPD Group
Date Performed:	3/2/2016
Analysis Time Period:	PM Peak Hour
Freeway/Direction:	I-77 Southbound
From/To:	F-6
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Flow Inputs and Adjustments

Volume, V	5510	veh/h
Peak-hour factor, PHF	0.92	
Peak 15-min volume, v15	1497	v
Trucks and buses	4	%
Recreational vehicles	0	%
Terrain type:	Grade	
Grade	-0.99	%
Segment length	1.22	mi
Trucks and buses PCE, ET	1.5	
Recreational vehicle PCE, ER	1.2	
Heavy vehicle adjustment, fHV	0.980	
Driver population factor, fp	1.00	
Flow rate, vp	2036	pc/h/ln

Speed Inputs and Adjustments

Lane width	12.0	ft
Right-side lateral clearance	6.0	ft
Total ramp density, TRD	0.50	ramps/mi
Number of lanes, N	3	
Free-flow speed:	Base	
FFS or BFFS	75.4	mi/h
Lane width adjustment, fLW	0.0	mi/h
Lateral clearance adjustment, fLC	0.0	mi/h
TRD adjustment	1.8	mi/h
Free-flow speed, FFS	73.6	mi/h

LOS and Performance Measures

Flow rate, vp	2036	pc/h/ln
Free-flow speed, FFS	73.6	mi/h
Average passenger-car speed, S	63.1	mi/h
Number of lanes, N	3	
Density, D	32.3	pc/mi/ln
Level of service, LOS	D	

DIVERGE AREA OF INFLUENCE ANALYSIS

Phone: Fax:
E-mail:

Diverge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	AM Peak Hour
Freeway/Dir of Travel:	I-77 Northbound
Junction:	D-1
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Freeway Data

Type of analysis	Diverge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	5210	vph

Off Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-Flow speed on ramp	35.0	mph
Volume on ramp	260	vph
Length of first accel/decel lane	530	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent ramp	1200	vph
Position of adjacent ramp	Downstream	
Type of adjacent ramp	On	
Distance to adjacent ramp	3100	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway	Ramp	Adjacent Ramp	
Volume, V (vph)	5210	260	1200	vph
Peak-hour factor, PHF	0.94	0.94	0.94	
Peak 15-min volume, v15	1386	69	319	v
Trucks and buses	4	2	1	%
Recreational vehicles	0	0	0	%
Terrain type:	Grade	Grade	Grade	
Grade	1.70 %	1.20 %	-1.60 %	
Length	1.02 mi	0.20 mi	0.20 mi	
Trucks and buses PCE, ET	1.5	1.5	1.5	
Recreational vehicle PCE, ER	1.2	1.2	1.2	

Heavy vehicle adjustment, fHV	0.980	0.990	0.995	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	5653	279	1283	pcph

Estimation of V12 Diverge Areas

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 0.606 Using Equation 9

$v_{12} = v_R + (v_F - v_R) P_{FD}$ = 3535 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
$v_{Fi} = v_F$	5653	6900	No
$v_{FO} = v_F - v_R$	5374	6900	No
v_R	279	2000	No
v_3 or v_{av34}	2118 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34}	> 2700 pc/h?	No	
Is v_3 or v_{av34}	> 1.5 v_{12} /2	No	

If yes, v_{12A} = 3535 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Diverge Influence Area

	Actual	Max Desirable	Violation?
v_{12}	3535	4400	No

Level of Service Determination (if not F)

Density, $D = 4.252 + 0.0086\, v_R - 0.009\, L_{12}$ = 29.9 pc/mi/ln

Level of service for ramp-freeway junction areas of influence D

Speed Estimation

Intermediate speed variable, D_S = 0.453

Space mean speed in ramp influence area, S_R = 51.8 mph

Space mean speed in outer lanes, S_0 = 61.5 mph

Space mean speed for all vehicles, S = 55.1 mph

Phone: Fax:
E-mail:

Diverge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	AM Peak Hour
Freeway/Dir of Travel:	I-77 Southbound
Junction:	D-2
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Freeway Data

Type of analysis	Diverge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	3880	vph

Off Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-Flow speed on ramp	35.0	mph
Volume on ramp	310	vph
Length of first accel/decel lane	625	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent ramp	330	vph
Position of adjacent ramp	Downstream	
Type of adjacent ramp	On	
Distance to adjacent ramp	2650	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway	Ramp	Adjacent Ramp	
Volume, V (vph)	3880	310	330	vph
Peak-hour factor, PHF	0.94	0.94	0.94	
Peak 15-min volume, v15	1032	82	88	v
Trucks and buses	4	1	2	%
Recreational vehicles	0	0	0	%
Terrain type:	Grade	Grade	Grade	
Grade	1.70 %	3.65 %	-2.39 %	
Length	0.29 mi	0.21 mi	0.22 mi	
Trucks and buses PCE, ET	1.5	1.5	1.5	
Recreational vehicle PCE, ER	1.2	1.2	1.2	

Heavy vehicle adjustment, fHV	0.980	0.995	0.990	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	4210	331	355	pcph

Estimation of V12 Diverge Areas

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 0.640 Using Equation 9

$v_{12} = v_R + (v_F - v_R) P_{FD}$ = 2812 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
$v_{Fi} = v_F$	4210	6900	No
$v_{FO} = v_F - v_R$	3879	6900	No
v_R	331	2000	No
v_3 or v_{av34}	1398 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34}	> 2700 pc/h?	No	
Is v_3 or v_{av34}	> 1.5 v_{12} /2	No	

If yes, v_{12A} = 2812 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Diverge Influence Area

	Actual	Max Desirable	Violation?
v_{12}	2812	4400	No

Level of Service Determination (if not F)

Density, $D = 4.252 + 0.0086\, v_R - 0.009\, L_{12}$ = 22.8 pc/mi/ln

Level of service for ramp-freeway junction areas of influence C

Speed Estimation

Intermediate speed variable,	D_S = 0.458	
Space mean speed in ramp influence area,	S_R = 51.8	mph
Space mean speed in outer lanes,	S_0 = 64.3	mph
Space mean speed for all vehicles,	S = 55.3	mph

HCS 2010: Freeway Merge and Diverge Segments Release 6.70

Phone: Fax:
E-mail:

Diverge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	PM Peak Hour
Freeway/Dir of Travel:	I-77 Northbound
Junction:	D-1
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Freeway Data

Type of analysis	Diverge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	4280	vph

Off Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-Flow speed on ramp	35.0	mph
Volume on ramp	340	vph
Length of first accel/decel lane	530	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent ramp	420	vph
Position of adjacent ramp	Downstream	
Type of adjacent ramp	On	
Distance to adjacent ramp	3100	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway		Ramp		Adjacent Ramp		
Volume, V (vph)	4280		340		420		vph
Peak-hour factor, PHF	0.94		0.94		0.94		
Peak 15-min volume, v15	1138		90		112		v
Trucks and buses	4		2		1		%
Recreational vehicles	0		0		0		%
Terrain type:	Grade		Grade		Grade		
Grade	1.70	%	1.20	%	-1.60	%	
Length	1.02	mi	0.20	mi	0.20	mi	
Trucks and buses PCE, ET	1.5		1.5		1.5		
Recreational vehicle PCE, ER	1.2		1.2		1.2		

Heavy vehicle adjustment, fHV	0.980	0.990	0.995	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	4644	365	449	pcph

Estimation of V12 Diverge Areas

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 0.627 Using Equation 9

$v_{12} = v_R + (v_F - v_R) P_{FD}$ = 3048 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
$v_{Fi} = v_F$	4644	6900	No
$v_{FO} = v_F - v_R$	4279	6900	No
v_R	365	2000	No
v_3 or v_{av34}	1596 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34}	> 2700 pc/h?	No	
Is v_3 or v_{av34}	> 1.5 v_{12} /2	No	

If yes, v_{12A} = 3048 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Diverge Influence Area

	Actual	Max Desirable	Violation?
v_{12}	3048	4400	No

Level of Service Determination (if not F)

Density, $D = 4.252 + 0.0086\, v_R - 0.009\, L_D$ = 25.7 pc/mi/ln

Level of service for ramp-freeway junction areas of influence C

Speed Estimation

Intermediate speed variable, D_S = 0.461

Space mean speed in ramp influence area, S_R = 51.7 mph

Space mean speed in outer lanes, S_0 = 63.5 mph

Space mean speed for all vehicles, S = 55.2 mph

HCS 2010: Freeway Merge and Diverge Segments Release 6.70

Phone: Fax:
E-mail:

Diverge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	PM Peak Hour
Freeway/Dir of Travel:	I-77 Southbound
Junction:	D-2
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Freeway Data

Type of analysis	Diverge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	6670	vph

Off Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-Flow speed on ramp	35.0	mph
Volume on ramp	1370	vph
Length of first accel/decel lane	625	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent ramp	210	vph
Position of adjacent ramp	Downstream	
Type of adjacent ramp	On	
Distance to adjacent ramp	2650	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway	Ramp	Adjacent Ramp	
Volume, V (vph)	6670	1370	210	vph
Peak-hour factor, PHF	0.94	0.94	0.94	
Peak 15-min volume, v15	1774	364	56	v
Trucks and buses	4	1	2	%
Recreational vehicles	0	0	0	%
Terrain type:	Grade	Grade	Grade	
Grade	1.70 %	3.65 %	-2.39 %	
Length	0.29 mi	0.21 mi	0.22 mi	
Trucks and buses PCE, ET	1.5	1.5	1.5	
Recreational vehicle PCE, ER	1.2	1.2	1.2	

Heavy vehicle adjustment, fHV	0.980	0.995	0.990	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	7238	1465	226	pcph

Estimation of V12 Diverge Areas

L_{EQ} = (Equation 13-12 or 13-13)

P_{FD} = 0.512 Using Equation 9

$v_{12} = v_R + (v_F - v_R) P_{FD}$ = 4419 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
$v_{Fi} = v_F$	7238	6900	Yes
$v_{FO} = v_F - v_R$	5773	6900	No
v_R	1465	2000	No
v_3 or v_{av34}	2819 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34}	> 2700 pc/h?	Yes	
Is v_3 or v_{av34}	> 1.5 v_{12} /2	No	

If yes, v_{12A} = 4538 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Diverge Influence Area

	Actual	Max Desirable	Violation?
v_{12A}	4538	4400	Yes

Level of Service Determination (if not F)

Density, $D = 4.252 + 0.0086\, v_R - 0.009\, L_{12}$ = 37.7 pc/mi/ln

Level of service for ramp-freeway junction areas of influence F

Speed Estimation

Intermediate speed variable,	D_S = 0.560	
Space mean speed in ramp influence area,	S_R = 49.9	mph
Space mean speed in outer lanes,	S_0 = 59.2	mph
Space mean speed for all vehicles,	S = 53.0	mph

MERGE AREA OF INFLUENCE ANALYSIS

Phone: Fax:
E-mail:

Merge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	AM Peak Hour
Freeway/Dir of Travel:	I-77 Northbound
Junction:	M-1
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Freeway Data

Type of analysis	Merge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	4950	vph

On Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-flow speed on ramp	35.0	mph
Volume on ramp	1200	vph
Length of first accel/decel lane	1030	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent Ramp	260	vph
Position of adjacent Ramp	Upstream	
Type of adjacent Ramp	Off	
Distance to adjacent Ramp	3100	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway	Ramp	Adjacent Ramp	
Volume, V (vph)	4950	1200	260	vph
Peak-hour factor, PHF	0.92	0.92	0.92	
Peak 15-min volume, v15	1345	326	71	v
Trucks and buses	4	1	2	%
Recreational vehicles	0	0	0	%
Terrain type:	Grade	Grade	Grade	
Grade	-0.65 %	-1.60 %	1.20 %	
Length	0.58 mi	0.20 mi	0.20 mi	
Trucks and buses PCE, ET	1.5	1.5	1.5	
Recreational vehicle PCE, ER	1.2	1.2	1.2	

Heavy vehicle adjustment, fHV	0.980	0.995	0.990	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	5488	1311	285	pcph

Estimation of V12 Merge Areas

L_{EQ} = 1340.51 (Equation 13-6 or 13-7)

P_{FM} = 0.606 Using Equation 3

$v_{12} = v_F (P_{FM})$ = 3328 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
v_{FO}	6799	6900	No
v_3 or v_{av34}	2160 pc/h	(Equation 13-14 or 13-17)	

Is v_3 or v_{av34} > 2700 pc/h? No

Is v_3 or v_{av34} > 1.5 v_{12} /2 Yes

If yes, v_{12A} = 3328 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Merge Influence Area

	Actual	Max Desirable	Violation?
v_{12A}	4639	4600	Yes

Level of Service Determination (if not F)

Density, $D_R = 5.475 + 0.00734 v_R + 0.0078 v_{12} - 0.00627 L_A$ = 34.6 pc/mi/ln

Level of service for ramp-freeway junction areas of influence D

Speed Estimation

Intermediate speed variable,	M_S = 0.652	
Space mean speed in ramp influence area,	S_R = 48.3	mph
Space mean speed in outer lanes,	S_0 = 54.0	mph
Space mean speed for all vehicles,	S = 50.0	mph

Phone: Fax:
E-mail:

Merge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	AM Peak Hour
Freeway/Dir of Travel:	I-77 Southbound
Junction:	M-2
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Freeway Data

Type of analysis	Merge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	3570	vph

On Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-flow speed on ramp	35.0	mph
Volume on ramp	330	vph
Length of first accel/decel lane	1100	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent Ramp	310	vph
Position of adjacent Ramp	Upstream	
Type of adjacent Ramp	Off	
Distance to adjacent Ramp	2650	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway		Ramp		Adjacent Ramp		
Volume, V (vph)	3570		330		310		vph
Peak-hour factor, PHF	0.92		0.92		0.92		
Peak 15-min volume, v15	970		90		84		v
Trucks and buses	4		2		1		%
Recreational vehicles	0		0		0		%
Terrain type:	Grade		Grade		Grade		
Grade	0.38	%	-2.39	%	3.65	%	
Length	0.50	mi	0.22	mi	0.21	mi	
Trucks and buses PCE, ET	1.5		1.5		1.5		
Recreational vehicle PCE, ER	1.2		1.2		1.2		

Heavy vehicle adjustment, fHV	0.980	0.990	0.995	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	3958	362	339	pcph

Estimation of V12 Merge Areas

L_{EQ} = 841.08 (Equation 13-6 or 13-7)

P_{FM} = 0.608 Using Equation 3

$v_{12} = v_F (P_{FM})$ = 2408 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
v_{FO}	4320	6900	No
v_3 or v_{av34}	1550 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34}	> 2700 pc/h?	No	
Is v_3 or v_{av34}	> 1.5 v_{12} /2	Yes	

If yes, v_{12A} = 2408 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Merge Influence Area

	Actual	Max Desirable	Violation?
v_{12A}	2770	4600	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, v_{12} - 0.00627\, L_A$ = 20.0+ pc/mi/ln

Level of service for ramp-freeway junction areas of influence C

Speed Estimation

Intermediate speed variable,	M_S = 0.306	
Space mean speed in ramp influence area,	S_R = 54.5	mph
Space mean speed in outer lanes,	S_0 = 56.2	mph
Space mean speed for all vehicles,	S = 55.1	mph

Phone: Fax:
E-mail:

Merge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	PM Peak Hour
Freeway/Dir of Travel:	I-77 Northbound
Junction:	M-1
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Freeway Data

Type of analysis	Merge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	3940	vph

On Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-flow speed on ramp	35.0	mph
Volume on ramp	420	vph
Length of first accel/decel lane	1030	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent Ramp	340	vph
Position of adjacent Ramp	Upstream	
Type of adjacent Ramp	Off	
Distance to adjacent Ramp	3100	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway		Ramp		Adjacent Ramp		
Volume, V (vph)	3940		420		340		vph
Peak-hour factor, PHF	0.92		0.92		0.92		
Peak 15-min volume, v15	1071		114		92		v
Trucks and buses	4		1		2		%
Recreational vehicles	0		0		0		%
Terrain type:	Grade		Grade		Grade		
Grade	-0.65	%	-1.60	%	1.20	%	
Length	0.58	mi	0.20	mi	0.20	mi	
Trucks and buses PCE, ET	1.5		1.5		1.5		
Recreational vehicle PCE, ER	1.2		1.2		1.2		

Heavy vehicle adjustment, fHV	0.980	0.995	0.990	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	4368	459	373	pcph

Estimation of V12 Merge Areas

L_{EQ} = 918.50 (Equation 13-6 or 13-7)

P_{FM} = 0.606 Using Equation 3

$v_{12} = v_F (P_{FM})$ = 2648 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
v_{FO}	4827	6900	No
v_3 or v_{av34}	1720 pc/h	(Equation 13-14 or 13-17)	
Is v_3 or v_{av34}	> 2700 pc/h?	No	
Is v_3 or v_{av34}	> 1.5 v_{12} /2	Yes	

If yes, v_{12A} = 2648 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Merge Influence Area

	Actual	Max Desirable	Violation?
v_{12A}	3107	4600	No

Level of Service Determination (if not F)

Density, $D_R = 5.475 + 0.00734\ v_R + 0.0078\ v_{12} - 0.00627\ L_A$ = 23.0 pc/mi/ln

Level of service for ramp-freeway junction areas of influence C

Speed Estimation

Intermediate speed variable,	M_S = 0.336	
Space mean speed in ramp influence area,	S_R = 54.0	mph
Space mean speed in outer lanes,	S_0 = 55.6	mph
Space mean speed for all vehicles,	S = 54.5	mph

Phone: Fax:
E-mail:

Merge Analysis

Analyst:	Brett M. Ferrell
Agency/Co.:	GPD Group
Date performed:	3/2/2016
Analysis time period:	PM Peak Hour
Freeway/Dir of Travel:	I-77 Southbound
Junction:	M-2
Jurisdiction:	City of Broadview Heights
Analysis Year:	2040
Description:	Design Year 2040 'Build'

Freeway Data

Type of analysis	Merge	
Number of lanes in freeway	3	
Free-flow speed on freeway	60.0	mph
Volume on freeway	5300	vph

On Ramp Data

Side of freeway	Right	
Number of lanes in ramp	1	
Free-flow speed on ramp	35.0	mph
Volume on ramp	210	vph
Length of first accel/decel lane	1100	ft
Length of second accel/decel lane		ft

Adjacent Ramp Data (if one exists)

Does adjacent ramp exist?	Yes	
Volume on adjacent Ramp	1370	vph
Position of adjacent Ramp	Upstream	
Type of adjacent Ramp	Off	
Distance to adjacent Ramp	2650	ft

Conversion to pc/h Under Base Conditions

Junction Components	Freeway	Ramp	Adjacent Ramp	
Volume, V (vph)	5300	210	1370	vph
Peak-hour factor, PHF	0.92	0.92	0.92	
Peak 15-min volume, v15	1440	57	372	v
Trucks and buses	4	2	1	%
Recreational vehicles	0	0	0	%
Terrain type:	Grade	Grade	Grade	
Grade	0.38 %	-2.39 %	3.65 %	
Length	0.50 mi	0.22 mi	0.21 mi	
Trucks and buses PCE, ET	1.5	1.5	1.5	
Recreational vehicle PCE, ER	1.2	1.2	1.2	

Heavy vehicle adjustment, fHV	0.980	0.990	0.995	
Driver population factor, fP	1.00	1.00	1.00	
Flow rate, vp	5876	231	1497	pcph

Estimation of V12 Merge Areas

L_{EQ} = 1223.50 (Equation 13-6 or 13-7)

P_{FM} = 0.608 Using Equation 3

$v_{12} = v_F (P_{FM})$ = 3574 pc/h

Capacity Checks

	Actual	Maximum	LOS F?
v_{FO}	6107	6900	No
v_3 or v_{av34}	2302 pc/h	(Equation 13-14 or 13-17)	

Is v_3 or v_{av34} > 2700 pc/h? No

Is v_3 or v_{av34} > 1.5 v_{12} /2 Yes

If yes, v_{12A} = 3574 (Equation 13-15, 13-16, 13-18, or 13-19)

Flow Entering Merge Influence Area

	Actual	Max Desirable	Violation?
v_{12A}	3805	4600	No

Level of Service Determination (if not F)

Density, $D_R = 5.475 + 0.00734\ v_R + 0.0078\ v_{12} - 0.00627\ L_A$ = 28.2 pc/mi/ln

Level of service for ramp-freeway junction areas of influence D

Speed Estimation

Intermediate speed variable,	M_S = 0.419	
Space mean speed in ramp influence area,	S_R = 52.5	mph
Space mean speed in outer lanes,	S_0 = 53.5	mph
Space mean speed for all vehicles,	S = 52.8	mph

APPENDIX E
STORAGE LENGTH CALCULATIONS

STORAGE LENGTH CALCULATIONS

DESIGN YEAR 2040 'BUILD' TRAFFIC VOLUMES - AM PEAK HOUR

GPD GROUP
Glaus, Pyle, Schomer, Burns & DeHaven, Inc.

Wallings Road / I-77 SB Ramps

ANTICIPATED CYCLE LENGTH: 100 SEC.
DESIGN SPEED: 35 MPH

WALLINGS ROAD EASTBOUND

MOVEMENT:			THRU		RIGHT
VOLUME:			920		250
LANE GROUP:			THRU		RIGHT
LANE GROUP VOLUME:			920		250
NUMBER OF LANES:			1		1
VEHICLES PER CYCLE:			26		7
CONTROLLING LANE GROUP:			X		
DECELERATION LENGTH:					50
STORAGE LENGTH:			855		275
TOTAL TURN LANE LENGTH:			***855***		***325***
TURN LANE LENGTH PER LANE			***855***		***325***

WALLINGS ROAD WESTBOUND

MOVEMENT:	LEFT		THRU		
VOLUME:	80		190		
LANE GROUP:	LEFT		THRU		
LANE GROUP VOLUME:	80		190		
NUMBER OF LANES:	1		1		
VEHICLES PER CYCLE:	3		6		
CONTROLLING LANE GROUP:			X		
DECELERATION LENGTH:	50				
STORAGE LENGTH:	150		250		
TOTAL TURN LANE LENGTH:	***200***		***250***		
TURN LANE LENGTH PER LANE	***200***		***250***		

NORTHBOUND N/A

MOVEMENT:					
VOLUME:					
LANE GROUP:					
LANE GROUP VOLUME:					
NUMBER OF LANES:					
VEHICLES PER CYCLE:					
CONTROLLING LANE GROUP:					
DECELERATION LENGTH:					
STORAGE LENGTH:					
TOTAL TURN LANE LENGTH:					
TURN LANE LENGTH PER LANE					

I-77 SOUTHBOUND EXIT RAMP

MOVEMENT:	LEFT		THRU		RIGHT
VOLUME:	160		0		150
LANE GROUP:		LEFT/THRU			RIGHT
LANE GROUP VOLUME:		160			150
NUMBER OF LANES:		1			2
VEHICLES PER CYCLE:		5			5
CONTROLLING LANE GROUP:		X			
DECELERATION LENGTH:					100
STORAGE LENGTH:		200			200
TOTAL TURN LANE LENGTH:		***200***			***300***
TURN LANE LENGTH PER LANE		***200***			***150***

RECOMMENDED STORAGE LENGTHS INCLUDE 50' DIVERGING TAPER

STORAGE LENGTH CALCULATIONS

DESIGN YEAR 2040 'BUILD' TRAFFIC VOLUMES - PM PEAK HOUR

GPD GROUP
Glaus, Pyle, Schomer, Burns & DeHaven, Inc.

Wallings Road / I-77 SB Ramps

ANTICIPATED CYCLE LENGTH: 70 SEC.
DESIGN SPEED: 35 MPH

WALLINGS ROAD EASTBOUND

MOVEMENT:			THRU		RIGHT
VOLUME:			410		140
LANE GROUP:			THRU		RIGHT
LANE GROUP VOLUME:			410		140
NUMBER OF LANES:			1		1
VEHICLES PER CYCLE:			8		3
CONTROLLING LANE GROUP:			X		
DECELERATION LENGTH:					50
STORAGE LENGTH:			325		150
TOTAL TURN LANE LENGTH:			***325***		***200***
TURN LANE LENGTH PER LANE			***325***		***200***

WALLINGS ROAD WESTBOUND

MOVEMENT:	LEFT		THRU		
VOLUME:	70		430		
LANE GROUP:	LEFT		THRU		
LANE GROUP VOLUME:	70		430		
NUMBER OF LANES:	1		1		
VEHICLES PER CYCLE:	2		9		
CONTROLLING LANE GROUP:			X		
DECELERATION LENGTH:	50				
STORAGE LENGTH:	100		350		
TOTAL TURN LANE LENGTH:	***150***		***350***		
TURN LANE LENGTH PER LANE	***150***		***350***		

NORTHBOUND N/A

MOVEMENT:					
VOLUME:					
LANE GROUP:					
LANE GROUP VOLUME:					
NUMBER OF LANES:					
VEHICLES PER CYCLE:					
CONTROLLING LANE GROUP:					
DECELERATION LENGTH:					
STORAGE LENGTH:					
TOTAL TURN LANE LENGTH:					
TURN LANE LENGTH PER LANE					

I-77 SOUTHBOUND EXIT RAMP

MOVEMENT:	LEFT		THRU		RIGHT
VOLUME:	370		0		1000
LANE GROUP:		LEFT/THRU			RIGHT
LANE GROUP VOLUME:		370			1000
NUMBER OF LANES:		1			2
VEHICLES PER CYCLE:		8			20
CONTROLLING LANE GROUP:					X
DECELERATION LENGTH:					100
STORAGE LENGTH:		325			675
TOTAL TURN LANE LENGTH:		***325***			***775***
TURN LANE LENGTH PER LANE		***325***			***387.5***

RECOMMENDED STORAGE LENGTHS INCLUDE 50' DIVERGING TAPER

STORAGE LENGTH CALCULATIONS

DESIGN YEAR 2040 'BUILD' TRAFFIC VOLUMES - AM PEAK HOUR

GPD GROUP
Glaus, Pyle, Schomer, Burns & DeHaven, Inc.

Wallings Road / I-77 NB Entrance Ramp / Mill Road

ANTICIPATED CYCLE LENGTH: 100 SEC.
DESIGN SPEED: 35 MPH

WALLINGS ROAD EASTBOUND

MOVEMENT:	LEFT		THRU		RIGHT
VOLUME:	760		170		80
LANE GROUP:	LEFT		THRU/RIGHT		
LANE GROUP VOLUME:	760			250	
NUMBER OF LANES:	1			1	
VEHICLES PER CYCLE:	22			7	
CONTROLLING LANE GROUP:	X				
DECELERATION LENGTH:	50				
STORAGE LENGTH:	750			275	
TOTAL TURN LANE LENGTH:	***800***			***275***	
TURN LANE LENGTH PER LANE	***800***			***275***	

WALLINGS ROAD WESTBOUND

MOVEMENT:	LEFT		THRU		RIGHT
VOLUME:	20		120		240
LANE GROUP:	LEFT		THRU		RIGHT
LANE GROUP VOLUME:	20		120		240
NUMBER OF LANES:	1		1		1
VEHICLES PER CYCLE:	1		4		7
CONTROLLING LANE GROUP:			X		X
DECELERATION LENGTH:	50				50
STORAGE LENGTH:	50		175		275
TOTAL TURN LANE LENGTH:	***100***		***175***		***325***
TURN LANE LENGTH PER LANE	***100***		***175***		***325***

MILL ROAD NORTHBOUND

MOVEMENT:	LEFT		THRU		RIGHT
VOLUME:	150		200		70
LANE GROUP:	LEFT		THRU/RIGHT		
LANE GROUP VOLUME:	150			270	
NUMBER OF LANES:	1			1	
VEHICLES PER CYCLE:	5			8	
CONTROLLING LANE GROUP:				X	
DECELERATION LENGTH:	50				
STORAGE LENGTH:	200			325	
TOTAL TURN LANE LENGTH:	***250***			***325***	
TURN LANE LENGTH PER LANE	***250***			***325***	

SOUTHBOUND N/A

MOVEMENT:					
VOLUME:					
LANE GROUP:					
LANE GROUP VOLUME:					
NUMBER OF LANES:					
VEHICLES PER CYCLE:					
CONTROLLING LANE GROUP:					
DECELERATION LENGTH:					
STORAGE LENGTH:					
TOTAL TURN LANE LENGTH:					
TURN LANE LENGTH PER LANE					

RECOMMENDED STORAGE LENGTHS INCLUDE 50' DIVERGING TAPER

STORAGE LENGTH CALCULATIONS

DESIGN YEAR 2040 'BUILD' TRAFFIC VOLUMES - PM PEAK HOUR

Wallings Road / I-77 NB Entrance Ramp / Mill Road

ANTICIPATED CYCLE LENGTH: 70 SEC.
DESIGN SPEED: 35 MPH

WALLINGS ROAD EASTBOUND

MOVEMENT:	LEFT		THRU		RIGHT
VOLUME:	240		400		140
LANE GROUP:	LEFT		THRU/RIGHT		
LANE GROUP VOLUME:	240			540	
NUMBER OF LANES:	1			1	
VEHICLES PER CYCLE:	5			11	
CONTROLLING LANE GROUP:				X	
DECELERATION LENGTH:	50				
STORAGE LENGTH:	200			400	
TOTAL TURN LANE LENGTH:	***250***			***400***	
TURN LANE LENGTH PER LANE	***250***			***400***	

WALLINGS ROAD WESTBOUND

MOVEMENT:	LEFT		THRU		RIGHT
VOLUME:	10		160		120
LANE GROUP:	LEFT		THRU		RIGHT
LANE GROUP VOLUME:	10		160		120
NUMBER OF LANES:	1		1		1
VEHICLES PER CYCLE:	1		4		3
CONTROLLING LANE GROUP:			X		X
DECELERATION LENGTH:	50				50
STORAGE LENGTH:	50		175		150
TOTAL TURN LANE LENGTH:	***100***		***175***		***200***
TURN LANE LENGTH PER LANE	***100***		***175***		***200***

MILL ROAD NORTHBOUND

MOVEMENT:	LEFT		THRU		RIGHT
VOLUME:	340		60		60
LANE GROUP:	LEFT		THRU/RIGHT		
LANE GROUP VOLUME:	340			120	
NUMBER OF LANES:	1			1	
VEHICLES PER CYCLE:	7			3	
CONTROLLING LANE GROUP:	X				
DECELERATION LENGTH:	50				
STORAGE LENGTH:	275			150	
TOTAL TURN LANE LENGTH:	***325***			***150***	
TURN LANE LENGTH PER LANE	***325***			***150***	

SOUTHBOUND N/A

MOVEMENT:					
VOLUME:					
LANE GROUP:					
LANE GROUP VOLUME:					
NUMBER OF LANES:					
VEHICLES PER CYCLE:					
CONTROLLING LANE GROUP:					
DECELERATION LENGTH:					
STORAGE LENGTH:					
TOTAL TURN LANE LENGTH:					
TURN LANE LENGTH PER LANE					

RECOMMENDED STORAGE LENGTHS INCLUDE 50' DIVERGING TAPER