SOUTH FLORIDA
FREIGHT & PASSENGER
RAIL ENHANCEMENT PROJECT

Phase 2 · New Northwood Connection

March 2014

Grade Crossing Analysis

U.S. Department of Transportation
Federal Railroad Administration

TECHNICAL MEMORANDUM

South Florida Freight and Passenger Rail Enhancement Study

Phase 2 - Full Northwood Connection (New Alignment); FPID: 434948-2

Palm Beach County, Florida

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COPIES:	
DATE:	March 7, 2014
SUBJECT:	GRADE CROSSING ANALYSIS

The Florida Department of Transportation (FDOT), in coordination with the Federal Railroad Administration (FRA), is conducting the *South Florida Freight and Passenger Rail Enhancement Study* to evaluate improved freight connectivity between the existing South Florida Rail Corridor (SFRC) and the Florida East Coast (FEC) Railway. The project will enhance freight connectivity between the existing SFRC and the FEC Railway to accommodate existing freight traffic and the projected growth in freight rail operations following the expansion of the Panama Canal and freight intermodal improvements at the Port of Palm Beach, Port Everglades, and PortMiami. The study is being conducted in compliance with federal and state regulations that require engineering and environmental analysis in compliance with the National Environmental Policy Act (known as NEPA).

The *South Florida Freight and Passenger Rail Enhancement Study* project involves three interrelated and independent projects being studied concurrently including:

- Phase 1A: Rehabilitate Existing Northwood Connection, Financial Project Number: 434948-1; ETDM Number: N/A; Palm Beach County, Florida
- Phase 1B: IRIS Northeast Connection, Financial Project Number: 433514-1; Miami-Dade County, Florida
- Phase 2: New Northwood Connection, Financial Project Number: 434948-2; ETDM: 14093; Palm Beach County, Florida

The Phase 2 proposed action for the New Northwood Connection involves the construction of a single track connection on a new alignment between the SFRC and FEC Railway. The New Northwood Connection is anticipated to require right-of-way acquisition (approximately 2 acres) within an existing industrial area. The Phase 2 proposed improvements include: the construction of approximately 3,150 linear feet of new single track between the SFRC and FEC Railway; approximately 50 feet of proposed right-of-way along the rail alignment (25 feet from track centerline on either side) to accommodate rail ballast and drainage requirements; and the implementation of new signal equipment at the grade crossings.

While the *South Florida Freight and Passenger Rail Enhancement* project would facilitate future passenger rail serve by providing connections between the SFRC and the FEC Railway, the project does not involve the development of a station or passenger rail service. The Tri-Rail Coastal Link Study (http://www.Tri-RailCoastalLinkStudy.com) proposes reintroducing passenger service along an 85-mile stretch of the FEC Railway corridor between Jupiter and Miami.

Introduction

A Categorical Exclusion (CE) is being prepared consistent with federal requirements. In support of the CE, an analysis of grade crossings has been conducted about the effects the proposed action may have upon the local roadway network. One of the crossings that has been evaluated is the proposed future Northwood Connection (Phase 2) in the City of West Palm Beach, Florida.

The new Northwood Connection (Phase 2) is a proposed future connection located north of downtown West Palm Beach. The proposed connection involves the construction of a partial Northwood Connection crossover track from the Florida East Coast (FEC) Railway to the South Florida Rail Corridor (SFRC). The new alignment would provide a direct connection from northbound SFRC to northbound FEC (and vice versa). The new alignment would eliminate the need for southbound reverse movements on the FEC, thereby improving freight service on the mainline while reducing delays.

Study Area

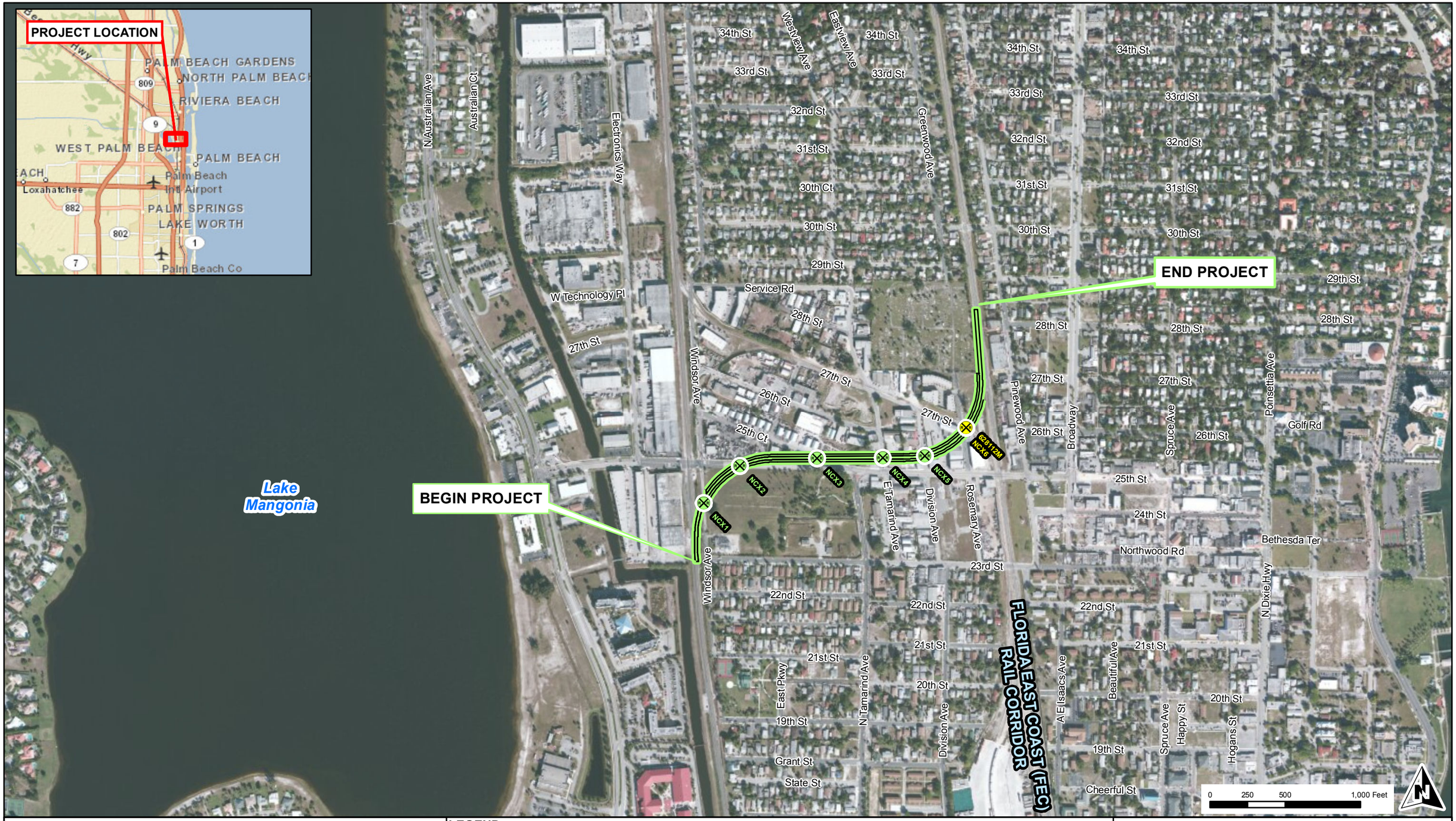
Figure 1 provides a location map of the project study area in the City of West Palm Beach. The project study area in the City of West Palm Beach is generally bound by 23rd Street to the south, Australian Avenue to the west, 30th Street to the north, and the FEC Railway to the east.

Existing Conditions

The proposed new Northwood Connection (Phase 2) would provide a direct connection from northbound SFRC to northbound FEC (and vice versa). An analysis of the impacts the proposed action would have upon the local roadway network given current traffic volumes was performed. This includes queuing and vehicular delay analyses based on existing (2013) conditions.

Six rail crossing locations are anticipated to be impacted by the new Northwood Connection (Phase 2). They are listed below with their respective grade crossing identification numbers and are shown in Figure 1.

1) Windsor Avenue south of 25th Street (NCX1)
2) 25th Street east of Windsor Avenue (NCX2)
3) 25th Court north of 25th Street (NCX3)
4) N. Tamarind Avenue between 25th Street and 26th Street (NCX4)
5) Division Avenue between 25th Street and 27th Street (NCX5)
6) Rosemary Avenue between 25th Street and 27th Street (628112M/NCX6)



SOUTH FLORIDA FREIGHT AND PASSENGER RAIL ENHANCEMENT PROJECT

LEGEND

- Phase 1A - Existing Northwood Connection Railroad Crossing
- Phase 2 - New Northwood Connection Rail Crossings
- Phase 2 - New Northwood Connection

PHASE 2 - NEW NORTHWOOD CONNECTION GRADE CROSSING LOCATION MAP

The following provides details of the methodology followed to evaluate the impacts upon local roadways at select grade crossings. A summary of the results of the analysis is also provided.

Assumptions

The proposed freight service on the New Northwood Connection involves relocating existing FEC freight from the FEC Railway between Northwood in West Palm Beach and northern Miami-Dade County to improve freight mobility from Jacksonville/Cocoa to PortMiami. Based on FEC coordination, up to six (6) trains in each direction (12 trains daily) are proposed on the New Northwood Connection which represents an additional two trains in each direction through the Northwood Industrial District above 2004 traffic. Historical freight levels on the FEC and SFRC are not anticipated to increase due to the proposed project.

Several assumptions have been provided for the Proposed Actions concerning the expected train operations. These are noted below, along with several assumptions utilized for the calculation of queues and vehicular delay.

- The length of the trains using the Connection will be up to 14,000 feet.
- The maximum speed of the train through the Northwood Connection will be 15 miles per hour.
- Trains will be traveling through this connection during nighttime, off-peak hours beginning after 7:00 pm.
- A maximum of 2 train crossings will occur during any one hour.
- No residual vehicle queues carry over from the first train crossing to the second train crossing.
- Hourly truck percentages along the surface streets are conservatively assumed to be 5%.
- Saturation flow rates for surface streets are estimated to be 1,900 vehicles per hour per lane. This is consistent with values used in the Highway Capacity Manual 2010.
- Opening Year for Northwood Connection Phase 2 is 2017.
- Design Year is 2035.

Data Collection

Given the current rail alignments, five roadway locations were identified within the new Northwood Connection (Phase 2) study area where traffic circulation will be impacted. Hourly traffic volume data was collected at these locations, which generally correspond to mid-block roadway locations near proposed rail crossings:

1) 25th Street east of Windsor Avenue (NCX2)
2) 25th Court north of 25th Street (NCX3)
3) N. Tamarind Avenue between 25th Street and 26th Street (NCX4)
4) Division Avenue between 27th Street and 25th Street (NCX5)
5) Rosemary Avenue between 27th Street and 25th Street (628112M/NCX6)

Data was collected in 15-minute intervals over a 48-hour period for both directions of travel on the roadway on Tuesday, September 10, 2013 and Wednesday, September 11, 2013. The collected data is included in Appendix A.

Since trains are assumed to run after 7:00 pm, hourly volumes at each location were reviewed to identify the period with the highest hourly volume recorded after 7:00 pm. By using the periods with the highest hourly volume, the subsequent analysis is considered to be conservative. These hourly volumes are summarized in tabular format in Appendix A.

Queue Analysis

When trains travel through an at-grade crossing, the vehicular traffic on the surface street must stop. With no vehicular flow, queues begin to form on the local streets at the grade crossing. An estimation of those queues given the duration of the grade crossing closure will provide an assessment of the impact the trains will have upon local street operations.

Based on the *Railroad-Highway Grade Crossing Handbook, Revised Second Edition, August 2007*, published by the Federal Highway Administration (FHWA), the following 95th Percentile Queue Length formula was used to estimate queues formed at each grade crossing.

$QL = 2*q*r*(1+p)*25$

Where, QL = *95th percentile queue length*
q = *vehicle flow rate (vehicles per lane per second)*
r = *effective red time (or effective gate closure time) in seconds*
p = *proportion of heavy vehicles in the traffic stream*
25 = *effective length of a passenger vehicle (feet)*

To determine the gate closure time, several variables must be included in the estimation. These include the train's length, the train's speed, and time needed to lower and raise the gates in advance of the train. Consistent with the *Railroad-Highway Grade Crossing Handbook, Revised Second Edition, August 2007*, the effective gate closure time formula is provided below.

*r = 35 + (train length / (1.47 * train speed in mph)*

With results of the gate closure calculation reported in seconds, the required minimum time to lower the gate prior to the arrival of the train and raise the gate after the train has completed its crossing is embedded in the equation as the '35' second adjustment factor. Assuming a train length of 14,000 feet and a speed of 15 miles per hour at the Northwood Connection, the overall time that the crossing gate would be closed is 670 seconds. This means that when a train is present and traveling through the Northwood Connection area, the crossing gates will be activated and stopping vehicular traffic for more than 11 minutes.

The majority of the five crossing locations involve minor roadways where volumes are relatively low, particularly after 7:00 pm when the trains are assumed to travel through the area. The location with the highest hourly volumes after 7:00 pm is at 25th Street east of Windsor Avenue. The existing hourly volume on 25th Street east of Windsor Avenue is nearly three times the hourly volume on any other street, which indicates a gate closure event is likely to affect 25th Street more than other locations.

The highest hourly volume after 7:00 pm on 25th Street east of Windsor Avenue was reported between 7:00 pm and 8:00 pm. Eastbound volume was recorded as 214 vehicles per hour, while the westbound volume was recorded as 157 vehicles per hour. With two travel lanes available to store queued vehicles, results of the queuing analysis indicate that if a 14,000-foot train traveling at 15 miles per hour crossed 25th Street at Windsor Avenue, the expected queue beginning at 7:00 pm would be 1,046 feet in the eastbound direction and 768 feet in the westbound direction.

Australian Avenue is a north-south street located approximately 885 west of the intersection of 25th Street and Windsor Avenue. Since the eastbound queue on 25th Street would be 1,046 feet if a train crossing began at 7:00 pm, the additional vehicles making up the remaining queue of 161 feet (1,046 feet minus 885 feet) per lane would eventually spillback onto Australian Avenue. It is anticipated that this spillback would be in both the northbound and southbound direction, thus an estimated 161 feet of queue, or six vehicles, would be stored in the northbound right-turn lane as well as in the southbound left-turn lane on Australian Avenue. The available storage distance for the northbound right-turn lane is approximately 150 feet, indicating that towards the end of the gate closure period one vehicle may slightly extend beyond the right-turn lane taper and partially stack in the outer through travel lane on Australian Avenue. For the 75-foot southbound left-turn lane, up to three vehicles may be stored in the inner through travel lane on Australian Avenue. If such queues are realized, the other through lanes on northbound and southbound Australian Avenue (which has two through lanes in each direction) could accommodate north-south traffic flow.

At the remaining grade crossing locations, queues based on existing volumes would be accommodated by the local street network within the study area without impacting other roadways. This includes SR 5/Broadway Avenue, where drivers would be able to travel north-south without impedance caused by a crossing event. Results of the queuing analysis for existing conditions are included in Appendix B.

Vehicle Delay Analysis

When a train approaches a grade crossing and the flow of vehicular traffic is halted to allow the train to continue unimpeded along its path, drivers experience delay. During the hour analyzed, a large portion of drivers will not experience any delay since the trains are assumed to traverse a crossing a maximum of two times during any one hour. In addition to the accumulated vehicular delay, delay was also calculated as an average for all vehicles during the hour, incorporating delay for drivers stopped by the train and drivers who were not. The delay formula utilized for this calculation is based on the *Railroad-Highway Grade Crossing Handbook, Revised Second Edition, August 2007.* It is the same formula used in the Highway Capacity Manual to estimate delay at a traffic signal.

The following Vehicular Delay formula was used to estimate average delay at each grade crossing.

$$D = \frac{1}{2} * [(q*Tg^2) / (1-q/d)]$$

Where, D = *vehicular delay (vehicle-minutes)*

q = vehicle arrival rate (vehicles per minute)
Tg = effective red time (or effective gate closure time) in minutes
d = vehicle departure rate, or saturation flow rate (vehicles per minute)

Vehicle delay and queues are related results with similar variables used for each calculation. However, where queues are based on the analysis of a single event, delay is typically reported as an average over an entire hour. If these stoppage events occur on a regular, cyclical basis, such as a traffic signal, the resulting delay is used as a measurement to report a level of service. However, because the train crossings at Northwood are a relatively infrequent event, occurring at most twice during an hour and only after 7:00 pm, a level of service assignment at each crossing location based solely on delay would skew the perceived impact to the motoring public. The trains are expected to be approximately 14,000 feet long and require more than 11 minutes to clear the grade crossing in the Northwood study area; drivers would experience no delay during the remainder of the hour analyzed.

Given the long duration of the event, drivers stopped by a train crossing would experience delay. This delay would be universally experienced at each of the five crossing locations. Results of the delay analysis indicate that the average vehicle delay between 7:00 pm and 8:00 pm is between 250 seconds and 280 seconds per vehicle.

However, if the accumulation of delay (reported in vehicle-minutes of delay) is evaluated, one location has more delay than the other locations. This site is 25th Street east of Windsor Avenue, which also has the most peak hour volume. At 25th Street east of Windsor Avenue, accumulated delay between 7:00 pm and 8:00 pm was calculated to be more than 1,000 vehicle-minutes. The remaining four sites have between 4 and 144 vehicle minutes of delay. Results of the delay analysis for existing conditions are included in Appendix C.

Future Conditions

For the proposed new Northwood Connection (Phase 2), construction of the proposed improvements is expected to be completed and operational for trains by 2017 with the design year as 2035. An analysis of both future years was performed to assess the impacts the proposed action will have upon the local roadway network. This includes projecting future directional hourly traffic volumes, as well as queuing and vehicular delay analyses.

Travel Demand Forecasting and Growth Rate Analysis

The Southeast Regional Planning Model (SERPM) was used to generate growth rates to be applied to existing hourly volumes in the study area. Model files were obtained for the Base Year 2005 and Horizon Year 2035. Subareas for Northwood were defined and socio-economic and model output volumes were reported from those smaller areas. Results of the 2005 Model to 2035 Model comparative analysis indicated that model volumes would increase approximately 1.36% compounded annually at the Northwood Connection site. Results of the comparative model analysis are included in Appendix D.

The model-based growth rates were then applied to the maximum existing directional hourly volumes that occur after 7:00 pm at each crossing location, which is generally between 7:00 pm and 8:00 pm. The growth rate was compounded annually to calculate a conservative directional hourly volume estimate for 2017 and 2035. These future year volumes are summarized and presented in Appendix D.

Queue Analysis

As noted previously, the estimation of queues at railroad crossings will be conducted consistent with the *Railroad-Highway Grade Crossing Handbook, Revised Second Edition, August 2007.* The 95th Percentile Queue Length formula was used to estimate queues formed for each direction of travel at each grade crossing. Analysis was conducted for both directions of traffic flow that are impacted by the railroad crossings associated with Northwood Connection (Phase 2).

Construction of the new Northwood Connection (Phase 2) will be completed by 2017. Forecasted directional hourly volumes were analyzed to estimate queues. Since the location with the highest hourly volume after 7:00 pm is at 25th Street east of Windsor Avenue, a closure event affects this crossing more than other locations.

In 2017, 25th Street east of Windsor Avenue will have two travel lanes available to store queued vehicles. Results of the queuing analysis indicate that, given the closure duration assumptions, the expected queue beginning at 7:00 pm would be approximately 1,105 feet in the eastbound direction and 811 feet in the westbound direction.

As noted previously, Australian Avenue is only 885 west of the intersection of 25th Street and Windsor Avenue. The eastbound queue on 25th Street that forms between 7:00 pm and 8:00 pm in 2017 will spillback onto Australian Avenue in both the northbound and southbound direction to form queues totaling 220 feet (1,105 feet minus 885 feet) per lane on 25th Street. An estimated 220 feet, or nine vehicles, will be stored in the northbound right-turn lane and southbound left-turn lane respectively, on Australian Avenue. Given that the available storage distance for the northbound right-turn lane is approximately 150 feet, near the end of the gate closure period in 2017 up to three vehicles may be stacking in the outer through travel lane on Australian Avenue. For the 75-foot southbound left-turn lane, up to six vehicles in 2017 may be stored in the inner through travel lane on Australian Avenue. If such queues are realized in 2017, the other through lanes on northbound and southbound Australian Avenue (which has two through lanes in each direction) could accommodate north-south traffic flow.

At the remaining grade crossing locations, queues based on 2017 volumes would be accommodated by the local street network within the study area. No adjacent roadways would be impacted by queues because of a crossing event.

A queuing analysis of 2035 conditions was also conducted at the grade crossing locations within the Northwood Connection Phase 2 study area. Based on the closure event assumptions, by 2035 queues would form on 25th Street east of Windsor Avenue between 7:00 pm and 8:00 pm that would extend 1,407 feet in the eastbound direction and 1,031 feet in the westbound direction. Eastbound traveling drivers would form queues totaling approximately 522 feet (1,407 feet minus 885 feet) per lane on 25th Street that spill back onto Australian Avenue. An

estimated 522 feet, or 21 vehicles, will be stored in the northbound right-turn lane and southbound left-turn lane, respectively, on Australian Avenue. As noted previously, the available storage distance for the northbound right-turn lane is approximately 150 feet. Results of the queuing analysis indicate that nearly 15 vehicles may stack in the outer through travel lane on Australian Avenue towards the end of the gate closure period in 2035. For the 75-foot southbound left-turn lane, up to 18 vehicles in 2035 may be stored in the inner through travel lane on Australian Avenue. If such queues are realized in 2035, the other through lanes on northbound and southbound Australian Avenue (which has two through lanes in each direction) could accommodate north-south traffic flow.

At the remaining local street crossings, vehicular queues based on 2035 forecasted volumes would be accommodated by the local street network within the study area without impacting other roadways. Results of the queuing analysis for the future conditions are included in Appendix B.

Since 2035 eastbound queues formed based on the maximum directional hourly volumes after 7:00 pm resulted in a queue spillback onto Australian Avenue, an assessment was performed to determine when a rail crossing event could occur such that a spillback does not occur. Based on this evaluation, it was determined that 2035 volumes on 25th Street east of Windsor Avenue after 9:00 pm would queue approximately 600 feet. This is less than the 885-foot storage distance provided on 25th Street before Australian Avenue. Therefore, future directional peak hour volumes after 9:00 pm can be adequately accommodated on 25th Street without spilling back onto Australian Avenue. Results of this queuing analysis are included in Appendix B.

Vehicular Delay Analysis

A future year analysis was conducted for the new Northwood Connection (Phase 2) to evaluate the amount of vehicular delay that would be accumulated because of the expected rail crossings. Since it was assumed that trains would not operate prior to 7:00 pm, the delay analysis incorporates the largest and most conservative directional hourly traffic volume after 7:00 pm.

As noted previously, a large portion of drivers will not experience any delay during the study hour since the trains are assumed to traverse a crossing a maximum of only two times during any one hour. As a result, an accumulation of vehicular delay was calculated. Future year vehicular delay was also calculated as an average delay for all vehicles, including those that were stopped by the train and those that were not. The delay formula utilized for this calculation is based on the *Railroad-Highway Grade Crossing Handbook, Revised Second Edition, August 2007.*

Given the long duration of the event, drivers stopped by a train crossing would experience some delay. This delay would be universally experienced at each of the five crossing locations. By 2017, delay analysis results indicate that the average vehicle delay between 7:00 pm and 8:00 pm at each Northwood Connection location would be between 250 seconds and 283 seconds per vehicle.

However, the accumulation of delay analysis (reported in vehicle-minutes of delay) revealed that one location will have more delay than the other locations in 2017. This site is 25th Street east of Windsor Avenue, which correspondingly also has the most peak hour volume. At 25th Street east of Windsor Avenue, accumulated delay between 7:00 pm and 8:00 pm in 2017 was calculated to be more than 1,000 vehicle-minutes. The remaining sites have between 4 and 152 vehicle minutes of delay. Results of the delay analysis for 2017 conditions are included in Appendix C.

Analysis of 2035 projected volumes between 7:00 pm and 8:00 pm continues to identify 25th Street east of Windsor Avenue as the site with the most accumulated delay within the Northwood study area. At 25th Street east of Windsor Avenue, accumulated delay was calculated to be more than 1,400 vehicle-minutes. Average vehicular delay continues to be between 250 seconds and 300 seconds per vehicle. The remaining sites have between four and 196 vehicle minutes of delay. Results of the delay analysis for 2035 conditions are included in Appendix C.

Vehicular delay within the Northwood site after 9:00 pm would be commensurately reduced given the reduction on traffic volume at each rail crossing. By 2035, the accumulated delay on 25th Street east of Windsor Avenue after 9:00 pm would be approximately 540 vehicle minutes for eastbound drivers, which is approximately 35% of the accumulated delay calculated after 7:00 pm. Overall, the average delay for all five crossings during the hour would remain between 250 seconds and 275 seconds per vehicle.

Traffic Control Devices

A variety of safety treatments exist for at-grade rail crossings to minimize train-vehicle crashes that often lead to fatalities. Some devices warn drivers that an upcoming decision must be made whether or not to cross. Others attempt to influence drivers directly by physically restricting the ability to cross when a train is present. These are referred to as passive and active traffic control devices, and they influence driver behavior and actions at rail crossings.

Active traffic control devices give advance notice to drivers of a train's approach. As a train passes over a detection circuit on a track, flashing lights, automatic gates, traffic signals and advance warning devices are activated. These types of devices dictate the action that a driver must take. Passive traffic control devices, however, only inform the driver that a crossing is present. The driver is responsible for identifying an approaching train and taking an appropriate action. Passive traffic control devices include signs and pavement markings.

Although a standardized set of warrants to justify the installation of flashing light signals has not been established, there are several criteria that should be considered when deciding the type of traffic control device to be installed. These include[1]:

- Volume of vehicular traffic
- Volume of railroad traffic
- Speed of vehicular traffic

[1] *Railroad-Highway Grade Crossing Handbook, Revised Second Edition, August 2007*, FHWA.

- Speed of railroad traffic
- Volume of pedestrian traffic
- Collision history
- Sight distance limitations.

At crossing locations where improved visibility for approaching traffic of the crossing is desired, cantilevered flashing light signals are typically used. Cantilevered flashing light signals are generally used when the following conditions are present[2].

- Multilane roadways (two or more lanes in one direction).
- Roadways with paved shoulders or a parking lane that would require a post-mounted light to be more than 10 feet from the edge of the travel lane.
- Roadside foliage obstructing the view of post-mounted flashing light signals.
- Roadside obstacle, such as utility poles, that obstruct visibility, and where minor lateral adjustments do not improve visibility.
- Distracting backgrounds such as an excessive number of neon signs.
- Horizontal or vertical curves where the extension of flashing lights over the travel lane would provide sufficient visibility for the required stopping sight distance.

A typical cantilevered installation consists of one pair of cantilevered lights on each roadway approach. These are supplemented by a pair of lights mounted on the supporting mast, consistent with Chapter 8C of the *Manual on Uniform Traffic Control Devices, 2009* (MUTCD, FHWA 2009).

Automatic gates provide a physical barrier across the travel lanes of a roadway when a train is approaching or within a crossing. They are combined with a flashing light signal to provide additional warning for drivers. Typically, within three seconds of the activation of flashing lights due to the presence of a train, the automatic gates will begin their descent across the roadway. They remain in this down position while the train traverses the crossing and rise upward in no more than 12 seconds when the train clears the crossing.

On two-way streets, automatic gates should cover enough of the roadway's approach to physically block motorists from driving around the gate. On multi-lane roadways, an opening of approximately 6 feet may be provided to accommodate emergency vehicles.

The need for automatic gates should consider the following factors[3]:

- Multiple mainline railroad tracks.
- Multiple tracks where a train on or near the crossing can obscure the movement of another train approaching the crossing.
- High speed train operation combined with limited sight distance.
- A combination of high speed and moderately high volume roadway and railroad traffic.
- Presence of school buses, transit buses, or farm vehicles in the traffic flow.

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[2] *Railroad-Highway Grade Crossing Handbook, Revised Second Edition, August 2007*, FHWA.
[3] *Railroad-Highway Grade Crossing Handbook, Revised Second Edition, August 2007*, FHWA.

- Presence of trucks carrying hazardous materials, particularly if sight distance is obstructed.
- Continuance of collisions after installing flashing lights.
- Presence of passenger trains.

The implementation of four quadrant gates is a variation of automatic gates where gates extend across both the approach and departure lanes of a roadway. They provide additional visual constraints for motorists, and restrict nearly all movements over the crossing when the gates have been lowered. Four quadrant gates are considered a supplemental safety treatment for quiet zones.

A quiet zone is a section of a rail line at least one-half mile in length that contains one or more consecutive public highway-rail grade crossings at which locomotive horns are not routinely sounded. Under the Train Horn Rule (49 CFR Part 222), locomotive engineers must begin to sound train horns at least 15 seconds, and no more than 20 seconds, in advance of all public grade crossings. In a quiet zone, railroads have been directed to cease the routine sounding of their horns when approaching public highway-rail grade crossings.

Conclusions

The grade crossing analysis at the new Northwood Connection (Phase 2) was based on certain assumptions about the length and speed of the proposed trains. It also assumed that trains would be active only during nighttime, off-peak hours beginning after 7:00 pm, and that no more than two train crossings would occur in a single hour. Given these parameters, results indicated that eastbound vehicular queues incurred at the rail crossing on 25th Street and Windsor Avenue would spillback onto Australian Avenue, an adjacent north-south roadway. By 2035, it is forecasted that future year traffic volumes may increase such that queues could begin to extend into the travel lanes on Australian Avenue at the end of the gate closure period.

It is recommended that the future year, post-7:00 pm traffic conditions at the intersection of Australian Avenue and 25th Street be monitored to determine if rail crossing events are affecting traffic flow on Australian Avenue during said events. It was determined that if the rail crossing events occurred after 9:00 pm, then traffic volumes on 25th Street and other roadways within the Northwood area would be sufficiently reduced such that queues due to a crossing event would not spillback onto Australian Avenue or other upstream roadways. As a result, the monitoring of traffic conditions at the intersection of Australian Avenue and 25th Street would not be necessary under this operating scenario.

Adequate clearance time of approximately 20 minutes is needed between the two crossing events to allow drivers in queue to complete the rail crossing prior to the next rail crossing event. This ensures that no driver is affected by both crossing events without the opportunity to cross.

Traffic control devices at the five new rail crossings within the new Northwood Connection (Phase 2) study area should be installed in accordance with the latest editions of the *Railroad-Highway Grade Crossing Handbook,* and the *Manual on Uniform Traffic Control Devices* (MUTCD). A variety of devices may be considered, including cantilevered flashing light signals and

automatic gates that will positively influence driver behavior. An evaluation of the proposed new Northwood Connection (Phase 2) crossings should be performed to ensure drivers will stop at each crossing.

Appendix A

Traffic Volume Data

County: 93
Station: 0002
Description: 25TH ST EAST OF WINDSOR AVE
Start Date: 09/10/2013
Start Time: 0000

	Direction: E					Direction: W					Combined
Time	1st	2nd	3rd	4th	Total	1st	2nd	3rd	4th	Total	Total
0000	14	9	9	12	44	8	11	10	10	39	83
0100	7	7	8	5	27	8	7	2	1	18	45
0200	3	8	3	3	17	5	4	4	3	16	33
0300	3	2	0	6	11	6	7	2	4	19	30
0400	6	4	5	10	25	1	2	9	6	18	43
0500	7	13	21	22	63	10	14	10	18	52	115
0600	44	43	32	42	161	22	19	35	29	105	266
0700	47	92	99	92	330	43	49	49	57	198	528
0800	66	69	65	62	262	58	49	38	48	193	455
0900	63	46	47	44	200	39	53	39	51	182	382
1000	63	63	64	46	236	35	50	38	43	166	402
1100	50	48	47	62	207	48	44	49	45	186	393
1200	73	61	54	56	244	66	54	53	46	219	463
1300	66	52	48	61	227	43	44	51	48	186	413
1400	60	62	73	63	258	48	52	66	57	223	481
1500	59	56	72	82	269	56	63	61	69	249	518
1600	70	61	76	78	285	75	61	78	92	306	591
1700	75	68	73	75	291	78	84	78	58	298	589
1800	61	59	50	49	219	65	57	51	59	232	451
1900	50	48	43	41	182	40	44	34	39	157	339
2000	45	35	31	29	140	29	32	31	34	126	266
2100	28	30	20	17	95	26	21	29	28	104	199
2200	24	10	20	14	68	20	23	15	19	77	145
2300	17	9	11	4	41	15	5	12	7	39	80
24-Hour Totals:					3902					3408	7310

Peak Volume Information

	Direction: E		Direction: W		Combined Directions	
	Hour	Volume	Hour	Volume	Hour	Volume
A.M.	715	349	715	213	715	562
P.M.	1630	297	1630	332	1630	629
Daily	715	349	1630	332	1630	629

Generated by SPS 5.0.21

County: 93
Station: 0002
Description: 25TH ST EAST OF WINDSOR AVE
Start Date: 09/11/2013
Start Time: 0000

	Direction: E					Direction: W					Combined
Time	1st	2nd	3rd	4th	Total	1st	2nd	3rd	4th	Total	Total
0000	7	7	7	6	27	14	11	7	5	37	64
0100	4	7	2	9	22	7	4	7	4	22	44
0200	3	8	1	1	13	6	6	3	2	17	30
0300	4	2	1	2	9	1	1	3	4	9	18
0400	3	4	4	3	14	4	4	6	3	17	31
0500	10	14	23	25	72	8	14	10	22	54	126
0600	30	41	40	44	155	23	19	33	37	112	267
0700	54	106	90	85	335	49	46	49	61	205	540
0800	67	79	70	64	280	70	48	52	41	211	491
0900	56	49	48	52	205	34	43	39	50	166	371
1000	51	53	44	55	203	41	50	51	45	187	390
1100	51	57	53	50	211	46	43	50	41	180	391
1200	59	49	60	66	234	50	50	77	57	234	468
1300	54	59	70	63	246	61	48	63	55	227	473
1400	54	72	68	74	268	65	52	70	64	251	519
1500	65	61	62	63	251	57	60	48	57	222	473
1600	81	60	69	63	273	79	76	77	93	325	598
1700	65	72	83	69	289	89	65	67	58	279	568
1800	68	59	60	51	238	58	51	58	61	228	466
1900	62	61	53	38	214	42	42	35	38	157	371
2000	40	40	25	40	145	36	31	44	33	144	289
2100	27	18	25	21	91	40	44	29	17	130	221
2200	22	17	17	14	70	27	24	21	23	95	165
2300	18	15	11	13	57	15	17	7	5	44	101
24-Hour Totals:					3922					3553	7475

Peak Volume Information

	Direction: E		Direction: W		Combined Directions	
	Hour	Volume	Hour	Volume	Hour	Volume
A.M.	715	348	745	231	715	574
P.M.	1715	292	1615	335	1600	598
Daily	715	348	1615	335	1600	598

Generated by SPS 5.0.21

County: 93
Station: 0003
Description: 25TH COURT NORTH OF 25TH STREET (ONEWAY)
Start Date: 09/10/2013
Start Time: 0000

Direction: N

Time	1st	2nd	3rd	4th	Total
0000	3	1	1	0	5
0100	1	2	1	0	4
0200	0	0	0	1	1
0300	2	0	0	0	2
0400	0	0	1	1	2
0500	0	1	0	1	2
0600	6	15	11	9	41
0700	10	15	11	7	43
0800	10	9	19	11	49
0900	9	12	13	10	44
1000	11	12	11	15	49
1100	17	12	15	14	58
1200	17	24	20	11	72
1300	13	12	13	16	54
1400	16	6	15	20	57
1500	21	9	16	16	62
1600	17	16	29	21	83
1700	17	12	14	12	55
1800	9	10	11	7	37
1900	11	12	6	5	34
2000	5	4	5	1	15
2100	11	5	3	3	22
2200	5	4	6	0	15
2300	2	5	2	5	14
24-Hour Totals:					820

Peak Volume Information

	Hour	Volume
A.M.	830	51
P.M.	1600	83
Daily	1600	83

Generated by SPS 5.0.21

County: 93
Station: 0003
Description: 25TH COURT NORTH OF 25TH STREET (ONEWAY)
Start Date: 09/11/2013
Start Time: 0000

Direction: N

Time	1st	2nd	3rd	4th	Total
0000	1	2	0	0	3
0100	1	2	0	1	4
0200	0	0	0	0	0
0300	0	0	1	1	2
0400	0	2	2	1	5
0500	1	1	2	2	6
0600	10	12	13	2	37
0700	10	14	10	13	47
0800	13	12	16	16	57
0900	10	5	10	11	36
1000	13	10	13	11	47
1100	13	12	12	19	56
1200	13	12	17	13	55
1300	13	20	16	17	66
1400	16	19	8	13	56
1500	20	18	24	23	85
1600	21	7	21	24	73
1700	15	17	11	9	52
1800	8	9	7	14	38
1900	10	7	4	8	29
2000	11	14	3	6	34
2100	5	5	6	7	23
2200	3	2	0	2	7
2300	2	2	0	1	5
24-Hour Totals:					823

Peak Volume Information

	Hour	Volume
A.M.	800	57
P.M.	1515	86
Daily	1515	86

Generated by SPS 5.0.21

County: 93
Station: 0004
Description: N. TAMARIND AVE BTWN 25TH ST & 26TH ST
Start Date: 09/10/2013
Start Time: 0000

	Direction: N					Direction: S					Combined
Time	1st	2nd	3rd	4th	Total	1st	2nd	3rd	4th	Total	Total
0000	0	0	0	0	0	0	0	0	0	0	0
0100	0	0	0	0	0	1	0	0	0	1	1
0200	0	1	0	0	1	0	0	0	0	0	1
0300	0	2	0	0	2	0	0	0	0	0	2
0400	0	2	0	2	4	0	1	0	0	1	5
0500	3	6	8	5	22	1	2	2	5	10	32
0600	4	5	1	4	14	3	10	7	3	23	37
0700	5	11	13	12	41	3	3	5	5	16	57
0800	10	6	9	11	36	3	10	8	11	32	68
0900	9	13	8	7	37	8	22	11	6	47	84
1000	6	8	20	12	46	10	12	7	10	39	85
1100	9	12	14	8	43	10	13	9	16	48	91
1200	13	14	11	15	53	17	17	6	16	56	109
1300	13	12	11	6	42	8	9	9	16	42	84
1400	10	12	9	11	42	6	8	9	5	28	70
1500	9	16	17	16	58	12	18	16	13	59	117
1600	15	11	10	8	44	20	18	10	8	56	100
1700	11	4	8	10	33	18	8	8	15	49	82
1800	7	11	8	2	28	6	9	6	7	28	56
1900	7	8	7	8	30	8	8	4	5	25	55
2000	3	2	5	2	12	4	4	8	3	19	31
2100	4	3	3	1	11	2	0	4	3	9	20
2200	2	1	2	1	6	1	5	1	2	9	15
2300	2	0	0	2	4	2	1	1	3	7	11
24-Hour Totals:					609					604	1213

Peak Volume Information

	Direction: N		Direction: S		Combined Directions	
	Hour	Volume	Hour	Volume	Hour	Volume
A.M.	715	46	845	52	845	93
P.M.	1515	64	1515	67	1515	131
Daily	1515	64	1515	67	1515	131

Generated by SPS 5.0.21

County: 93
Station: 0004
Description: N. TAMARIND AVE BTWN 25TH ST & 26TH ST
Start Date: 09/11/2013
Start Time: 0000

	Direction: N					Direction: S					Combined
Time	1st	2nd	3rd	4th	Total	1st	2nd	3rd	4th	Total	Total
0000	2	0	1	0	3	0	0	0	2	2	5
0100	0	0	2	0	2	0	0	0	0	0	2
0200	0	0	0	0	0	1	0	0	0	1	1
0300	0	0	0	0	0	0	1	0	0	1	1
0400	0	2	0	1	3	0	0	1	0	1	4
0500	5	6	9	3	23	1	2	1	2	6	29
0600	3	4	2	5	14	10	5	3	10	28	42
0700	7	11	21	11	50	5	10	11	2	28	78
0800	17	17	6	7	47	5	11	14	13	43	90
0900	6	12	12	11	41	4	8	12	10	34	75
1000	10	10	12	12	44	6	10	16	13	45	89
1100	15	14	18	14	61	15	13	13	14	55	116
1200	6	16	16	7	45	15	10	16	13	54	99
1300	9	11	9	15	44	10	14	21	14	59	103
1400	15	13	12	15	55	10	7	19	13	49	104
1500	16	8	10	12	46	15	13	13	7	48	94
1600	9	8	10	7	34	20	10	11	17	58	92
1700	11	10	9	7	37	10	8	7	13	38	75
1800	3	8	5	5	21	4	8	8	7	27	48
1900	7	4	6	6	23	4	5	8	6	23	46
2000	4	1	7	2	14	5	7	10	3	25	39
2100	2	2	4	1	9	1	4	1	3	9	18
2200	2	4	1	2	9	4	1	3	1	9	18
2300	1	2	0	1	4	3	2	0	1	6	10
24-Hour Totals:					629					649	1278

Peak Volume Information

	Direction: N		Direction: S		Combined Directions	
	Hour	Volume	Hour	Volume	Hour	Volume
A.M.	730	66	800	43	730	95
P.M.	1415	56	1430	60	1430	111
Daily	730	66	1430	60	1100	116

Generated by SPS 5.0.21

County: 93
Station: 0005
Description: DAVISON AVE BTWN 27TH ST & 25TH ST
Start Date: 09/10/2013
Start Time: 0000

	Direction: N					Direction: S					Combined
Time	1st	2nd	3rd	4th	Total	1st	2nd	3rd	4th	Total	Total
0000	0	0	0	0	0	0	0	0	0	0	0
0100	0	0	0	0	0	0	0	0	0	0	0
0200	0	0	0	0	0	0	0	0	0	0	0
0300	0	0	0	0	0	0	0	0	0	0	0
0400	0	0	0	0	0	0	0	0	0	0	0
0500	1	0	0	0	1	0	1	0	0	1	2
0600	1	0	0	1	2	0	0	0	0	0	2
0700	1	3	3	0	7	0	1	0	0	1	8
0800	1	1	2	1	5	1	0	1	4	6	11
0900	0	1	1	1	3	0	0	1	3	4	7
1000	0	2	1	4	7	0	2	1	1	4	11
1100	2	1	2	0	5	4	1	0	0	5	10
1200	1	0	0	4	5	1	1	0	0	2	7
1300	0	2	0	1	3	3	1	0	1	5	8
1400	0	0	1	2	3	0	2	1	2	5	8
1500	2	0	0	1	3	2	0	1	0	3	6
1600	1	0	0	1	2	5	2	2	0	9	11
1700	1	2	1	0	4	0	1	0	3	4	8
1800	1	0	1	0	2	0	0	0	0	0	2
1900	0	0	0	0	0	0	0	0	1	1	1
2000	0	0	0	0	0	0	0	0	0	0	0
2100	0	0	1	0	1	0	0	0	0	0	1
2200	0	0	0	0	0	0	0	1	0	1	1
2300	0	0	0	0	0	0	0	0	0	0	0
24-Hour Totals:					53					51	104

Peak Volume Information

	Direction: N		Direction: S		Combined Directions	
	Hour	Volume	Hour	Volume	Hour	Volume
A.M.	645	8	800	6	800	11
P.M.	1230	6	1545	9	1415	12
Daily	1015	9	1545	9	1015	17

Generated by SPS 5.0.21

County: 93
Station: 0005
Description: DAVISON AVE BTWN 27TH ST & 25TH ST
Start Date: 09/11/2013
Start Time: 0000

	Direction: N					Direction: S					Combined
Time	1st	2nd	3rd	4th	Total	1st	2nd	3rd	4th	Total	Total
0000	0	1	0	0	1	0	0	0	0	0	1
0100	0	0	0	0	0	0	0	0	0	0	0
0200	0	0	0	0	0	0	0	0	0	0	0
0300	0	0	0	0	0	0	0	0	0	0	0
0400	0	0	0	0	0	0	0	0	0	0	0
0500	0	0	0	0	0	0	0	0	0	0	0
0600	1	0	1	1	3	0	0	0	0	0	3
0700	2	0	4	0	6	0	0	0	0	0	6
0800	2	0	1	1	4	2	1	0	0	3	7
0900	2	0	0	0	2	1	1	1	1	4	6
1000	0	0	0	1	1	0	0	1	1	2	3
1100	1	3	0	0	4	1	1	0	0	2	6
1200	1	0	0	2	3	2	1	0	2	5	8
1300	2	2	0	0	4	0	1	2	0	3	7
1400	0	1	0	1	2	0	0	0	0	0	2
1500	0	0	1	2	3	1	0	1	0	2	5
1600	0	2	0	0	2	6	1	2	1	10	12
1700	1	1	0	1	3	0	1	1	1	3	6
1800	0	0	1	0	1	0	0	1	1	2	3
1900	0	1	0	1	2	0	0	2	0	2	4
2000	0	0	0	0	0	1	0	0	0	1	1
2100	0	0	0	0	0	0	0	0	0	0	0
2200	0	0	0	0	0	0	0	0	0	0	0
2300	0	0	0	0	0	0	0	0	0	0	0
24-Hour Totals:					41					39	80

Peak Volume Information

	Direction: N		Direction: S		Combined Directions	
	Hour	Volume	Hour	Volume	Hour	Volume
A.M.	645	7	730	3	730	9
P.M.	1230	6	1600	10	1530	13
Daily	645	7	1600	10	1530	13

Generated by SPS 5.0.21

County: 93
Station: 0006
Description: ROSEMARY AVE BTWN 27TH ST AND 25TH ST
Start Date: 09/10/2013
Start Time: 0000

	Direction: N					Direction: S					Combined
Time	1st	2nd	3rd	4th	Total	1st	2nd	3rd	4th	Total	Total
0000	0	0	0	0	0	0	0	0	0	0	0
0100	0	0	0	0	0	0	0	0	0	0	0
0200	0	0	0	0	0	0	0	0	0	0	0
0300	0	0	0	0	0	0	0	0	0	0	0
0400	0	0	0	0	0	0	0	0	0	0	0
0500	0	1	0	1	2	0	1	0	0	1	3
0600	0	0	0	0	0	0	0	0	0	0	0
0700	0	0	1	0	1	0	0	0	5	5	6
0800	0	1	0	2	3	0	2	0	2	4	7
0900	2	0	0	1	3	0	0	0	1	1	4
1000	3	1	1	1	6	0	1	0	2	3	9
1100	2	2	0	2	6	2	2	1	2	7	13
1200	0	3	1	1	5	0	0	0	2	2	7
1300	4	4	0	1	9	1	1	3	1	6	15
1400	1	1	2	1	5	1	2	0	3	6	11
1500	0	1	4	0	5	0	1	3	0	4	9
1600	1	0	0	0	1	0	1	0	1	2	3
1700	0	2	0	0	2	1	0	1	0	2	4
1800	1	0	0	1	2	0	1	0	0	1	3
1900	0	1	0	1	2	1	0	0	1	2	4
2000	1	1	1	0	3	0	2	0	0	2	5
2100	1	0	0	0	1	0	0	0	0	0	1
2200	0	0	0	0	0	1	0	0	0	1	1
2300	0	0	0	0	0	0	0	0	0	0	0
24-Hour Totals:					56					49	105

Peak Volume Information

	Direction: N		Direction: S		Combined Directions	
	Hour	Volume	Hour	Volume	Hour	Volume
A.M.	815	5	730	7	730	9
P.M.	1230	10	1245	7	1245	16
Daily	1230	10	730	7	1245	16

Generated by SPS 5.0.21

County: 93
Station: 0006
Description: ROSEMARY AVE BTWN 27TH ST AND 25TH ST
Start Date: 09/11/2013
Start Time: 0000

	Direction: N					Direction: S					Combined
Time	1st	2nd	3rd	4th	Total	1st	2nd	3rd	4th	Total	Total
0000	0	0	0	1	1	0	1	0	0	1	2
0100	0	0	0	0	0	0	0	0	0	0	0
0200	0	0	0	0	0	0	0	0	0	0	0
0300	0	0	0	0	0	0	0	0	0	0	0
0400	0	0	0	0	0	0	0	0	0	0	0
0500	0	0	1	0	1	0	0	0	0	0	1
0600	0	1	0	0	1	0	1	0	0	1	2
0700	0	1	0	0	1	0	1	0	3	4	5
0800	1	0	0	0	1	0	1	1	1	3	4
0900	3	0	1	1	5	2	1	1	1	5	10
1000	1	1	2	0	4	1	2	1	2	6	10
1100	0	1	1	1	3	1	0	1	0	2	5
1200	1	1	3	1	6	1	1	3	2	7	13
1300	0	1	0	1	2	1	0	0	1	2	4
1400	3	1	2	2	8	3	4	5	1	13	21
1500	3	0	3	0	6	2	0	1	3	6	12
1600	1	0	3	1	5	1	0	1	0	2	7
1700	0	0	1	2	3	1	0	1	0	2	5
1800	1	0	1	1	3	0	2	0	3	5	8
1900	0	0	1	0	1	0	0	0	0	0	1
2000	0	2	0	1	3	0	0	0	0	0	3
2100	1	0	0	0	1	0	0	0	0	0	1
2200	0	0	0	0	0	0	1	0	0	1	1
2300	0	0	0	0	0	0	0	0	0	0	0
24-Hour Totals:					55					60	115

Peak Volume Information

	Direction: N		Direction: S		Combined Directions	
	Hour	Volume	Hour	Volume	Hour	Volume
A.M.	845	4	745	5	845	9
P.M.	1400	8	1345	13	1400	21
Daily	1400	8	1345	13	1400	21

Generated by SPS 5.0.21

Appendix B

Queuing Analysis

TABLE B-1
QUEUING ANALYSIS
EXISTING CONDITIONS (2013)
NORTHWOOD CONNECTION PHASE 2

					Northbound/Eastbound Approach				Southbound/Westbound Approach		
LOCATION	**Number of Lanes**	**Train Length (feet)**	**Gate Down Time (seconds)**		**NB/EB Max Hourly Volume (after 7 pm)**	**Vehicle Flow Rate (vehicles per lane per second)**	**Queue Length (95th Percentile)**		**SB/WB Max Hourly Volume (after 7 pm)**	**Vehicle Flow Rate (vehicles per lane per second)**	**Queue Length (95th Percentile)**
25th Street east of Windsor Avenue	4	14,000	670		214	0.0297	1,046		157	0.0218	768
25th Court north of 25th Street	1	14,000	670		34	0.0094	333		0	0.0000	0
N. Tamarind Avenue between 25th St and 26th St	2	14,000	670		23	0.0064	225		23	0.0064	225
Division Avenue between 27th St and 25th St	2	14,000	670		0	0.0000	0		1	0.0003	10
Rosemary Avenue between 27th St and 25th St	2	14,000	670		3	0.0008	30		0	0.0000	0

ASSUMPTIONS

Train length is 14,000 feet
Train speed at Northwood Connections is 15 mph
Trains will run after 7:00 pm
A maximum of 2 train crossings per hour
Saturation Flow Rate is 1,900 vehicles per hour per lane
Truck percentage assumed to be 5%
Roadway traffic volume data was collected on 9/10/2013 and 9/11/2013
r, Time gate is down = 35 + (Train Length/(1.47*train speed in mph))

Queue Length (95th Percentile) = QL (feet)

QL = 2*q*r*(1 + p)*25

q = vehicle flow rate (vehicles per lane per second)
r = effective red time (seconds)
p = proportion of heavy vehicles in traffic flow

'25' represents the effective length of a passenger car

Source: ***Railroad-Highway Grade Crossing Handbook, Revised Second Edition*** **, August 2007, FHWA**

TABLE B-2
QUEUING ANALYSIS
OPENING YEAR CONDITIONS (2017)
NORTHWOOD CONNECTION PHASE 2

					Northbound/Eastbound Approach				Southbound/Westbound Approach		
LOCATION	**Number of Lanes**	**Train Length (feet)**	**Gate Down Time (seconds)**		**NB/EB Max Hourly Volume (after 7 pm)**	**Vehicle Flow Rate (vehicles per lane per second)**	**Queue Length (95th Percentile)**		**SB/WB Max Hourly Volume (after 7 pm)**	**Vehicle Flow Rate (vehicles per lane per second)**	**Queue Length (95th Percentile)**
25th Street east of Windsor Avenue	4	14,000	670		226	0.0314	1,105		166	0.0231	811
25th Court north of 25th Street	1	14,000	670		36	0.0100	352		0	0.0000	0
N. Tamarind Avenue between 25th St and 26th St	2	14,000	670		24	0.0067	235		24	0.0067	235
Division Avenue between 27th St and 25th St	2	14,000	670		0	0.0000	0		1	0.0003	10
Rosemary Avenue between 27th St and 25th St	2	14,000	670		3	0.0008	30		0	0.0000	0

ASSUMPTIONS

Train length is 14,000 feet
Train speed at Northwood Connections is 15 mph
Trains will run after 7:00 pm
A maximum of 2 train crossings per hour
Saturation Flow Rate is 1,900 vehicles per hour per lane
Truck percentage assumed to be 5%
Roadway traffic volume data was collected on 9/10/2013 and 9/11/2013
r, Time gate is down = 35 + (Train Length/(1.47*train speed in mph))

Queue Length (95th Percentile) = QL (feet)

QL = 2*q*r*(1 + p)*25

q = vehicle flow rate (vehicles per lane per second)
r = effective red time (seconds)
p = proportion of heavy vehicles in traffic flow

'25' represents the effective length of a passenger car

Source: ***Railroad-Highway Grade Crossing Handbook, Revised Second Edition*** **, August 2007, FHWA**

TABLE B-3
QUEUING ANALYSIS
DESIGN YEAR CONDITIONS (2035)
NORTHWOOD CONNECTION PHASE 2

					Northbound/Eastbound Approach				Southbound/Westbound Approach		
LOCATION	Number of Lanes	Train Length (feet)	Gate Down Time (seconds)		NB/EB Max Hourly Volume (after 7 pm)	Vehicle Flow Rate (vehicles per lane per second)	Queue Length (95th Percentile)		SB/WB Max Hourly Volume (after 7 pm)	Vehicle Flow Rate (vehicles per lane per second)	Queue Length (95th Percentile)
25th Street east of Windsor Avenue	4	14,000	670		288	0.0400	1,407		211	0.0293	1,031
25th Court north of 25th Street	1	14,000	670		46	0.0128	450		0	0.0000	0
N. Tamarind Avenue between 25th St and 26th St	2	14,000	670		31	0.0086	303		31	0.0086	303
Division Avenue between 27th St and 25th St	2	14,000	670		0	0.0000	0		1	0.0003	10
Rosemary Avenue between 27th St and 25th St	2	14,000	670		4	0.0011	40		0	0.0000	0

ASSUMPTIONS

Train length is 14,000 feet
Train speed at Northwood Connections is 15 mph
Trains will run after 7:00 pm
A maximum of 2 train crossings per hour
Saturation Flow Rate is 1,900 vehicles per hour per lane
Truck percentage assumed to be 5%
Roadway traffic volume data was collected on 9/10/2013 and 9/11/2013
r, Time gate is down = 35 + (Train Length/(1.47*train speed in mph))

Queue Length (95th Percentile) = QL (feet)

QL = 2*q*r*(1 + p)*25

q = vehicle flow rate (vehicles per lane per second)
r = effective red time (seconds)
p = proportion of heavy vehicles in traffic flow

'25' represents the effective length of a passenger car

Source: ***Railroad-Highway Grade Crossing Handbook, Revised Second Edition*** **, August 2007, FHWA**

TABLE B-4
QUEUING ANALYSIS
DESIGN YEAR CONDITIONS (2035) After 9:00 PM
NORTHWOOD CONNECTION PHASE 2

					Northbound/Eastbound Approach				Southbound/Westbound Approach		
LOCATION	Number of Lanes	Train Length (feet)	Gate Down Time (seconds)		NB/EB Max Hourly Volume (after 9 pm)	Vehicle Flow Rate (vehicles per lane per second)	Queue Length (95th Percentile)		SB/WB Max Hourly Volume (after 9 pm)	Vehicle Flow Rate (vehicles per lane per second)	Queue Length (95th Percentile)
25th Street east of Windsor Avenue	4	14,000	670		122	0.0169	597		175	0.0243	855
25th Court north of 25th Street	1	14,000	670		30	0.0083	294		0	0.0000	0
N. Tamarind Avenue between 25th St and 26th St	2	14,000	670		12	0.0033	118		12	0.0033	118
Division Avenue between 27th St and 25th St	2	14,000	670		1	0.0003	10		0	0.0000	0
Rosemary Avenue between 27th St and 25th St	2	14,000	670		1	0.0003	10		0	0.0000	0

ASSUMPTIONS

Train length is 14,000 feet
Train speed at Northwood Connections is 15 mph
Trains will run after 7:00 pm
A maximum of 2 train crossings per hour
Saturation Flow Rate is 1,900 vehicles per hour per lane
Truck percentage assumed to be 5%
Roadway traffic volume data was collected on 9/10/2013 and 9/11/2013
r, Time gate is down = 35 + (Train Length/(1.47*train speed in mph))

Queue Length (95th Percentile) = QL (feet)

QL = 2*q*r*(1 + p)*25

q = vehicle flow rate (vehicles per lane per second)
r = effective red time (seconds)
p = proportion of heavy vehicles in traffic flow

'25' represents the effective length of a passenger car

Source: ***Railroad-Highway Grade Crossing Handbook, Revised Second Edition*** **, August 2007, FHWA**

Appendix C

Vehicular Delay Analysis

TABLE C-1
DELAY ANALYSIS
EXISTING CONDITIONS (2013)
NORTHWOOD CONNECTION PHASE 2

				Northbound/Eastbound Approach					Southbound/Westbound Approach				
LOCATION	Number of Lanes	Train Length (feet)	Gate Down Time per Event (seconds)	NB/EB Max Hourly Volume (after 7 pm)	Arrival Rate (vehicles per minute)	Departure Rate (vehicles per minute)	Vehicular Delay (vehicle-minutes)	Average Vehicular Delay (seconds per vehicle)	SB/WB Max Hourly Volume (after 7 pm)	Arrival Rate (vehicles per minute)	Departure Rate (vehicles per minute)	Vehicular Delay (vehicle-minutes)	Average Vehicular Delay (seconds per vehicle)
25th Street east of Windsor Avenue	4	14,000	670	214	3.5667	31.67	1,002.4	281.0	157	2.6167	31.67	711.3	271.9
25th Court north of 25th Street	1	14,000	670	34	0.5667	31.67	143.9	253.9	0	0.0000	31.67	0.0	-
N. Tamarind Avenue between 25th St and 26th St	2	14,000	670	23	0.3833	31.67	96.8	252.4	23	0.3833	31.67	96.8	252.4
Division Avenue between 27th St and 25th St	2	14,000	670	0	0.0000	31.67	0.0	-	1	0.0167	31.67	4.2	249.5
Rosemary Avenue between 27th St and 25th St	2	14,000	670	3	0.0500	31.67	12.5	249.8	0	0.0000	31.67	0.0	-

ASSUMPTIONS

Train length is 14,000 feet
Train speed at Northwood Connections is 15 mph
Trains will run after 7:00 pm
A maximum of 2 train crossings per hour
Saturation Flow Rate is 1,900 vehicles per hour per lane
Truck percentage assumed to be 5%
Roadway traffic volume data was collected on 9/10/2013 and 9/11/2013
r, Time gate is down = 35 + (Train Length/(1.47*train speed in mph))

Vehicular Delay = V (vehicle minutes of delay)

$V = 1/2 * [(q*T_G^2)/(1 - q/d)]$

q = arrival rate (vehicles per minute)
T_G = Gate down time (minutes)
d = departure rate, or saturation flow rate (vehicles per minute)

Source: ***Railroad-Highway Grade Crossing Handbook, Revised Second Edition*** **, August 2007, FHWA**

TABLE C-2
DELAY ANALYSIS
OPENING YEAR CONDITIONS (2017)
NORTHWOOD CONNECTION PHASE 2

				Northbound/Eastbound Approach					Southbound/Westbound Approach				
LOCATION	**Number of Lanes**	**Train Length (feet)**	**Gate Down Time per Event (seconds)**	**NB/EB Max Hourly Volume (after 7 pm)**	**Arrival Rate (vehicles per minute)**	**Departure Rate (vehicles per minute)**	**Vehicular Delay (vehicle-minutes)**	**Average Vehicular Delay (seconds per vehicle)**	**SB/WB Max Hourly Volume (after 7 pm)**	**Arrival Rate (vehicles per minute)**	**Departure Rate (vehicles per minute)**	**Vehicular Delay (vehicle-minutes)**	**Average Vehicular Delay (seconds per vehicle)**
25th Street east of Windsor Avenue	4	14,000	670	226	3.7667	31.67	1,066.2	283.1	166	2.7667	31.67	756.0	273.3
25th Court north of 25th Street	1	14,000	670	36	0.6000	31.67	152.5	254.2	0	0.0000	31.67	0.0	-
N. Tamarind Avenue between 25th St and 26th St	2	14,000	670	24	0.4000	31.67	101.0	252.6	24	0.4000	31.67	101.0	252.6
Division Avenue between 27th St and 25th St	2	14,000	670	0	0.0000	31.67	0.0	-	1	0.0167	31.67	4.2	249.5
Rosemary Avenue between 27th St and 25th St	2	14,000	670	3	0.0500	31.67	12.5	249.8	0	0.0000	31.67	0.0	-

ASSUMPTIONS

Train length is 14,000 feet
Train speed at Northwood Connections is 15 mph
Train speed at IRIS is 20 mph
Trains will run after 7:00 pm
A maximum of 2 train crossings per hour
Saturation Flow Rate is 1,900 vehicles per hour per lane
Truck percentage assumed to be 5%
Roadway traffic volume data was collected on 9/10/2013 and 9/11/2013
r, Time gate is down = 35 + (Train Length/(1.47*train speed in mph))

Source: ***Railroad-Highway Grade Crossing Handbook, Revised Second Edition*** **, August 2007, FHWA**

Vehicular Delay = V (vehicle minutes of delay)

$V = 1/2 * [(q*T_G^2)/(1 - q/d)]$

q = arrival rate (vehicles per minute)
T_G = Gate down time (minutes)
d = departure rate, or saturation flow rate (vehicles per minute)

TABLE C-3
DELAY ANALYSIS
DESIGN YEAR CONDITIONS (2035)
NORTHWOOD CONNECTION PHASE 2

				Northbound/Eastbound Approach					Southbound/Westbound Approach				
LOCATION	Number of Lanes	Train Length (feet)	Gate Down Time per Event (seconds)	NB/EB Max Hourly Volume (after 7 pm)	Arrival Rate (vehicles per minute)	Departure Rate (vehicles per minute)	Vehicular Delay (vehicle-minutes)	Average Vehicular Delay (seconds per vehicle)	SB/WB Max Hourly Volume (after 7 pm)	Arrival Rate (vehicles per minute)	Departure Rate (vehicles per minute)	Vehicular Delay (vehicle-minutes)	Average Vehicular Delay (seconds per vehicle)
25th Street east of Windsor Avenue	4	14,000	670	288	4.8000	31.67	1,410.9	293.9	211	3.5167	31.67	986.6	280.5
25th Court north of 25th Street	1	14,000	670	46	0.7667	31.67	195.9	255.6	0	0.0000	31.67	0.0	-
N. Tamarind Avenue between 25th St and 26th St	2	14,000	670	31	0.5167	31.67	131.0	253.5	31	0.5167	31.67	131.0	253.5
Division Avenue between 27th St and 25th St	2	14,000	670	0	0.0000	31.67	0.0	-	1	0.0167	31.67	4.2	249.5
Rosemary Avenue between 27th St and 25th St	2	14,000	670	4	0.0667	31.67	16.7	249.9	0	0.0000	31.67	0.0	-

ASSUMPTIONS

Train length is 14,000 feet
Train speed at Northwood Connections is 15 mph
Trains will run after 7:00 pm
A maximum of 2 train crossings per hour
Saturation Flow Rate is 1,900 vehicles per hour per lane
Truck percentage assumed to be 5%
Roadway traffic volume data was collected on 9/10/2013 and 9/11/2013
r, Time gate is down = 35 + (Train Length/(1.47*train speed in mph))

Vehicular Delay = V (vehicle minutes of delay)

$V = 1/2 * [(q*T_G^2)/(1 - q/d)]$

q = arrival rate (vehicles per minute)
T_G = Gate down time (minutes)
d = departure rate, or saturation flow rate (vehicles per minute)

Source: ***Railroad-Highway Grade Crossing Handbook, Revised Second Edition*** **, August 2007, FHWA**

TABLE C-4
DELAY ANALYSIS
DESIGN YEAR CONDITIONS (2035) After 9:00 PM
NORTHWOOD CONNECTION PHASE 2

					Northbound/Eastbound Approach						Southbound/Westbound Approach				
LOCATION	**Number of Lanes**	**Train Length (feet)**	**Gate Down Time per Event (seconds)**		**NB/EB Max Hourly Volume (after 9 pm)**	**Arrival Rate (vehicles per minute)**	**Departure Rate (vehicles per minute)**	**Vehicular Delay (vehicle-minutes)**	**Average Vehicular Delay (seconds per vehicle)**		**SB/WB Max Hourly Volume (after 9 pm)**	**Arrival Rate (vehicles per minute)**	**Departure Rate (vehicles per minute)**	**Vehicular Delay (vehicle-minutes)**	**Average Vehicular Delay (seconds per vehicle)**
25th Street east of Windsor Avenue	4	14,000	670		122	2.0333	31.67	541.9	266.5		175	2.9167	31.67	801.2	274.7
25th Court north of 25th Street	1	14,000	670		30	0.5000	31.67	126.7	253.4		0	0.0000	31.67	0.0	-
N. Tamarind Avenue between 25th St and 26th St	2	14,000	670		12	0.2000	31.67	50.2	251.0		12	0.2000	31.67	50.2	251.0
Division Avenue between 27th St and 25th St	2	14,000	670		1	0.0167	31.67	4.2	249.5		0	0.0000	31.67	0.0	-
Rosemary Avenue between 27th St and 25th St	2	14,000	670		1	0.0167	31.67	4.2	249.5		0	0.0000	31.67	0.0	-

ASSUMPTIONS

Train length is 14,000 feet
Train speed at Northwood Connections is 15 mph
Trains will run after 7:00 pm
A maximum of 2 train crossings per hour
Saturation Flow Rate is 1,900 vehicles per hour per lane
Truck percentage assumed to be 5%
Roadway traffic volume data was collected on 9/10/2013 and 9/11/2013
r, Time gate is down = 35 + (Train Length/(1.47*train speed in mph))

Vehicular Delay = V (vehicle minutes of delay)

$V = 1/2 * [(q*T_G^2)/(1 - q/d)]$

q = arrival rate (vehicles per minute)
T_G = Gate down time (minutes)
d = departure rate, or saturation flow rate (vehicles per minute)

Source: ***Railroad-Highway Grade Crossing Handbook, Revised Second Edition*** **, August 2007, FHWA**

Appendix D

Transportation Model Growth Rate Analysis

Northwood Connection (Phase 2)

	Total Population (POP_05/35)	Total Employment (TOTE_05/35)	Traffic Volume
2005	636,941	273,816	52,689,858
2035	836,007	413,373	74,142,290
Growth Rate	1.04%	1.70%	1.36%

SUMMARY OF EXISTING AND FUTURE YEAR VOLUMES

	Existing Conditions (2013)		Opening Year Conditions (2015)		Opening Year Conditions (2017)		Design Year Conditions (2035)		
LOCATION	**Max Hourly NB/EB Volume (after 7 pm)**	**Max Hourly SB/WB Volume (after 7 pm)**	**2015 Hourly NB/EB Volume (after 7 pm)**	**2015 Hourly SB/WB Volume (after 7 pm)**	**2017 Hourly NB/EB Volume (after 7 pm)**	**2017 Hourly SB/WB Volume (after 7 pm)**	**2035 Hourly NB/EB Volume (after 7 pm)**	**2035 Hourly SB/WB Volume (after 7 pm)**	**COMMENT**
Northwood Connection Phase 2 (WPB)									
25th Street east of Windsor Avenue	214	157	220	161	226	166	288	211	
25th Court north of 25th Street	34	n/a	35	n/a	36	n/a	46	n/a	one-way street
N. Tamarind Avenue between 25th St and 26th St	23	23	24	24	24	24	31	31	
Division Avenue between 27th St and 25th St	0	1	0	1	0	1	0	1	
Rosemary Avenue between 27th St and 25th St	3	0	3	0	3	0	4	0	

- Volumes collected on Tuesday, September 10th and Wednesday, September 11th.
- ADTs reported from day with highest recorded volume.
- Peak hour volumes are reported from the day with the highest volume at each location, and from the hour with the highest volume at each location
- Maximum hourly volumes after 7 pm are reported from the day with the highest volume at each location.
- Northwood Connections compound growth rate used to forecasts future year volumes is 1.36%.