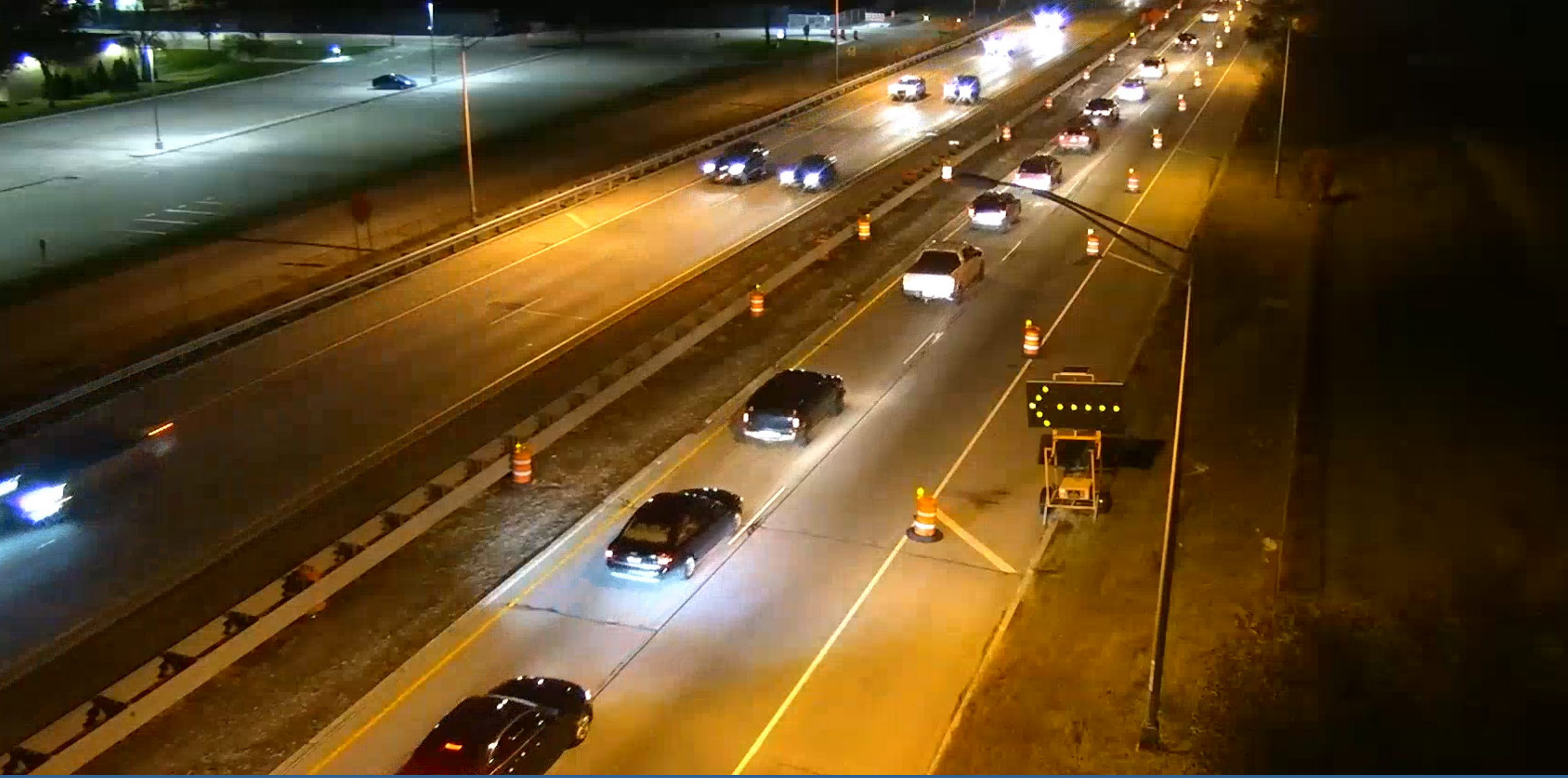

STATEWIDE WORK ZONE CAPACITY ANALYSIS

PROJECT ID: 0656-43-01

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ABSTRACT

The purpose of this study was to develop a tool for the Wisconsin Department of Transportation (WisDOT) to consistently analyze work zone capacity, queues, delay, and road user costs. Through a combination of research, 52 work zone observations at 14 sites throughout the state, collaboration with WisDOT's regional work zone engineers, and regression modeling analysis, two new tools were developed to predict work zone capacity parameters for weekly and annual scenarios.

The findings of this study showed using Wisconsin-specific work zone data enabled the calibration of HCM 6th Edition's work zone capacity model with customizations to meet WisDOT's specific needs. The recommended model includes coefficients for northern versus southern Wisconsin and used a construction intensity coefficient in lieu of the lateral clearance coefficient in the HCM 6th Edition's model. A queuing estimation methodology was built into the tools utilizing the speed-density relationship of a moving queue. Travel time delay and road user costs calculations were also incorporated into the tools.

The WEEKLY and ANNUAL tools were developed in Microsoft Excel® using Visual Basic and can import volume data, analyze up to four different lane closure scenarios in a single day, and have adjustment factors for volume growth and diversion. The recommended model and the tools developed as part of this study will enable work zone capacities, queues, delay, and road user costs to be estimated in Wisconsin using a consistent methodology. Using a calibrated model is expected to more accurately predict work zone capacity which will help maximize the efficiency of work zone lane closures.

STATEWIDE WORK ZONE CAPACITY ANALYSIS
ID: 0656-43-01

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

Prior to this project, the Wisconsin Department of Transportation (WisDOT) had been using two different methods for calculating work zone capacity parameters and relied on various tools to complete work zone capacity analysis.

WisDOT had been using the Highway Capacity Manual (HCM) 2010 work zone capacity equation [1] and Table 30.2 from the WisDOT Facilities Development Manual (FDM) 11-50-30, Work Zone Delay [2]. The regions had also been using their own capacity values based on field observations to estimate work zone delay and queueing.

WisDOT did not have a standard tool to accurately and consistently use traffic volume and work zone information to predict work zone queuing and delay. Projects had been using Quadro, the New Jersey Spreadsheet (which is primarily used for road user costs), and individual WisDOT region-developed spreadsheets to calculate queuing and delay. In the more complex major/mega projects, the microsimulation software Vissim is used for estimations, with Paramics being used in the past.

In October 2016, the 6th Edition of the HCM [3] was released and a new work zone capacity equation was developed which tends to yield higher work zone capacity when compared to the HCM 2010, FDM 11-50-30, and regional capacities. Thus, WisDOT embarked on this study to determine work zone capacity, queue, delay, and road user cost information specific to the conditions observed in Wisconsin work zones and if necessary, calibrate the HCM 6th Edition equation or develop a capacity equation based on the data collected in Wisconsin work zones.

1.1 STUDY OBJECTIVE

The primary objectives of the work zone capacity study were to:

1. Collect capacity and queue data at Wisconsin work zones throughout the state,
2. Calculate work zone capacity and queue spacing in Wisconsin work zones,
3. Calibrate the HCM 6th Edition work zone capacity equation or develop a new equation to better predict capacity and queues in Wisconsin work zones,
4. Create a map of work zone capacities across the state, and
5. Develop a software tool to calculate work zone capacity, delay, queues, and road user costs.

A literature review spanning HCM methodologies and the tools five state DOTs use to calculate work zone capacity, delay, queuing, and road user costs was performed.

Recommendations for how to proceed in Wisconsin to estimate work zone capacity, delay, queues, and road user costs stemmed from the literature review and the results of the data collection and analysis in this study.

1.2 Map of Study Sites

An objective of this study was to collect work zone capacity and queue data throughout the state of Wisconsin with the purpose of accurately calibrating a work zone capacity and queue estimation tool. Figure 1 contains a map showing the locations that were used in the calibration of the work zone capacity model.

Figure 1. Map of Work Zone Sites Used in Model Development

WORK ZONE CAPACITY OBSERVATION SUMMARY				
Location	**Project ID**	**Highway**	**Direction**	**County**
1	1228-16-71	IH 43	NB	Milwaukee
2	1100-34-70	IH 894	SB	Milwaukee
3	1030-11-79	IH 94	NB	Milwaukee
4	1060-49-70	IH 94	EB	Waukesha
5	1100-36-70	IH 41	NB	Waukesha
6	1090-30-70	IH 43	NB	Waukesha
7	1060-33-82	IH 94	WB	Milwaukee
8	1007-11-71	IH 39	NB	Rock
9	1206-04-69	USH 12/18	EB	Dane
10	1111-03-70	USH 151	NB	Dane
11	1016-03-61	IH 94	WB	Juneau
12	1020-03-76	IH 94	EB	St. Croix
13	1022-07-76	IH 94	EB	St. Croix
14	1130-49-71	IH 41	SB	Outagamie

CHAPTER 2: LITERATURE REVIEW

The project team reviewed national publications, user manuals, spreadsheets, and supplemental information from various sources cited within this report. This literature review chapter summarizes the information in a manner that supports the overall purpose of defining the current state of work zone capacity analysis in the HCM, WisDOT, and five other states.

The literature review addresses the HCM 2010, FDM 11-50-30 Table 30.2, and HCM 6th Edition work zone capacity calculation methodologies and data considered in each calculation. Additionally, the methodologies and tools used by Missouri DOT (MoDOT), Ohio DOT (ODOT), Illinois DOT (IDOT), Michigan DOT (MDOT), and Texas DOT (TxDOT) are reviewed and compared. Many of the states have developed methodologies to calculate parameters such as delay, queue length, and road user costs. It is important to note, the HCM 2010 and HCM 6th Edition only provide methodologies for work zone capacity and speed and do not cover delay, queue length, or road user costs. Thus, HCM methodologies for calculating speed are not discussed in this literature review as they are not necessary for calculating the desired parameters of capacity, delay, queue length, and road user costs.

2.1 HCM 2010 FREEWAY WORK ZONE ANALYSIS

Chapter 10 of HCM 2010 discusses freeway work zone capacity estimates [1]. The capacity reductions are divided into short-term work zone lane closures and long-term work zone lane closures. The type of barrier used to delineate the work zone and closure duration generally determines the difference between short-term and long-term work zone lane closures. Short-term closures use traffic cones or drums and can last as little as one hour while long-term closures use portable concrete barriers and can last anywhere from three days to weeks or even years.

The short-term work zone capacity calculation gives the adjusted mainline capacity for the work zone. As shown in Figure 2 below, this equation adjusts a base capacity of 1,600 passenger cars per hour per lane (pc/hr/ln) based on work zone intensity (I), the effect of heavy vehicles (f_{HV}), the number of open lanes (N) and entrance ramp presence (R).

Figure 2. HCM 2010 Short-Term Work Zone Capacity Equation

$$C_a = \{[(1600 + I) * f_{HV}] * N\} - R$$

The long-term work zone capacity gives the adjusted mainline capacity for the work zone and is based off studies conducted on long-term construction zone capacities. Default work zone capacities are summarized in Table 1 and are based on the normal lanes to reduced lanes ratio. The information in the tables below was adapted from Exhibit 10-14, HCM 2010.

Table 1. HCM 2010 Capacities of Freeway Work Zones

Condition	1 Lane Work Zone	2 Lane Work Zone	3 Lane Work Zone	4 Lane Work Zone
1 Lane Before				
2 Lanes Before	1,400			
3 Lanes Before	1,450	1,450		
4 Lanes Before	1,350	1,450	1,500	
Range	950 - 2,000	1,300 - 2,100	1,300 - 1,600	
Average Veh/hr/ln	1,400	1,450	1,500	
Pc/hr/ln	1,590	1,650	1,710	

Source: Default values and ranges from Exhibit 10-14 2010 HCM; values shown are vehicles per hour per lane unless otherwise noted.
Note: Pc/hr/ln (passenger cars per hour per lane) equivalent computed assuming level terrain, 5% heavy vehicles, and 0.90 PHF.

The vehicle per hour per lane capacities (veh/hr/ln) in Exhibit 10-14 of HCM 2010 were converted to passenger car equivalents for the purpose of computing capacity adjustment factors for work zones. The capacity adjustment factors are computed assuming the values in Exhibit 10-14 of HCM 2010 apply to 65-mph free-flow speed freeway with a base capacity (dry weather, non-work zone capacity) of 2,300 pc/hr/ln. The same capacity adjustment factors computed for a 65-mph free-flow speed freeway are assumed to apply to freeways with higher and lower free-flow speeds. In other words, the effect of the work zone on capacity is assumed to be proportional to the base capacity.

The resulting capacity adjustment factors applicable to all freeways, regardless of free-flow speed, are shown in Table 2. Values for freeway work zones with five moving lanes have been extrapolated from Exhibit 10-14 of HCM 2010.

Table 2. HCM 2010 Capacity Adjustment Factors for Work Zones

Number of Lanes Open in Work Zone	Work Zone Capacity Adjustment Factor
1	0.68
2	0.70
3	0.72
4	0.74
5	0.77

Note: Work Zone Capacity = Base Capacity * Capacity Adjustment Factor

HCM 2010 also states that work zone lane widths less than 12-ft impact vehicle speeds, which adversely affect capacity. Therefore, when lane widths are less than 12-ft, a lane width adjustment factor is applied to the adjusted work zone capacity. The resulting adjusted work zone capacity equation is found in Figure 3 below.

Figure 3. HCM 2010 Long-Term Work Zone Capacity Equation

$$C'_a = C_a * f_{LW}$$

where

C'_a = adjusted mainline capacity for long-term construction based on number of open lanes,

C_a = capacity from HCM 2010 Exhibit 10-14, and

f_{LW} = lane width adjustment factor (12-ft = 1.0; 10.0-11.9-ft = 0.91; 9.0-9.9-ft = 0.86).

The HCM 2010 does not provide a methodology for calculating work zone delay, queues, and road user costs. Within the HCM 2010, it is noted alternative tools, such as microscopic simulation software, could be used to address freeway work zone delay, queue estimates, and road user costs.

2.2 WISDOT FDM 11-50-30 WORK ZONE DELAY

The WisDOT FDM Chapter 11-50-30 provides guidelines for statewide freeway and expressway lane closures and delay [2]. These guidelines are meant to "improve work zone safety and minimize inconvenience and protect motoring public". The policy estimates capacity based on proposed lane closures and was developed from methods discussed in HCM 2010. The FDM states that understanding the capacity of the work zone allows the traffic engineer to determine expected delays and queues associated with the work zone.

Work zone capacity depends on the project location and site conditions, such as lane closures, roadway geometrics, construction activity, and lane widths. WisDOT FDM 11-50-30, Table 30-2 (see Table 3 of this report) provides values for the starting capacity, construction setting, work intensity, entrance ramp presence, effect of heavy vehicles, lane and shoulder widths, and number of open lanes.

Table 3. WisDOT FDM 11-50-30 Capacity Calculation

Table 30.2 Capacity Calculation

	Site Conditions		Rural	Urban
Choose one	Short-term construction	Start at	1600 pcphpl	1600 pcphpl
	Long-term construction	Start at	1550 w/ crossover (1750 w/o crossover)	1750 pcphpl
Choose any that apply	Close, Intense Construction Activity Proximity (Large number of work vehicles, workers, noise/dust)	Subtract	Up to 160	Up to 160
	Construction Activity Less Intense than Average (Guardrail/barrier installation, pavement repairs at intermittent spot locations, work activity across median)	Add	Up to 160	Up to 160
	11' lane width	Multiply	0.97	0.97
	10.5' lane width	Multiply	0.95	0.95
	Shoulder width < 6'	Multiply	0.97	0.97
	Heavy Vehicle/Truck Volume	Multiply	(1-%Truck)	(1-%Truck)
	Onramp within 1500' downstream of lane closure taper	Subtract	Hourly ramp volume (600 max)	Hourly ramp volume 600 max)

The values in FDM Table 30.2 are then to be input into the HCM 2010 equation [1] for adjusted work zone capacity, shown in Figure 4.

Figure 4. HCM 2010 Adjusted Work Zone Capacity Equation

$$C_a = \{[(1{,}600 + l) * f_{HV} * f_{LS}] * N\} - R$$

where

- C_a = adjusted mainline capacity,
- l = adjustment factor for type, intensity and location of the work activity, pc/h/ln (ranges from -160 pc/h/ln to +160 pc/h/ln),
- f_{HV} = adjustment for heavy vehicles as defined in HCM 2010 Equation 10-8,
- f_{LS} = adjustment for lane/shoulder widths,
- N = number of lanes open through the work zone, and
- R = adjustment for on-ramps. Ramp within 1,500-ft downstream of beginning of lane closure; Subtract hourly ramp volume (max. of 600).

Guidance suggests assuming a starting capacity of 1,600, but the user can use 1,550 or 1,750 where appropriate based on engineering judgement.

The FDM also discusses which microsimulation software is preferred to be used to determine work zone delay and queues. Intermediate to complex projects should use Quadro software. Larger, more complex projects should use Vissim. Road user costs are not discussed in FDM Chapter 11-50-30.

2.3 NCHRP 03-107 AND HCM 6TH EDITION

The foundation of the methodologies used in Chapter 10 of the HCM 6th Edition [3] stem from the results of the NCHRP 03-107 report [4,5], herein referred to as NCHRP Report. The NCHRP Report defines the work zone capacity as the maximum sustained 15-minute queue discharge (QDR) flow rate observed at the work zone lane closure or other bottleneck. The QDR flow rate is the flow rate through a work zone after a queue (i.e., backup) has formed.

The average QDR equation in Figure 5 considers the lane closure severity index (LCSI), barrier type, area type, lateral distance from the nearest open lane to the work zone, and time of day. The QDR is then adjusted to reflect a higher pre-breakdown flow rate to get the work zone capacity shown in Figure 6. Prior to a queue forming, the capacity of a work zone tends to be slightly higher than the QDR. It is important to note that these equations do not account for narrower lane widths so users may need to adjust the work zone capacity accordingly.

Figure 5. HCM 6th Edition Work Zone Queue Discharge Rate Equation

$$Average\ QDR = 2093 - 154f_{LCSI} - 194f_{barrier} - 179f_{area} + 9f_{lateral-12} - 59f_{day\_night}$$

Figure 6. HCM 6th Edition Work Zone Capacity Equation

$$c_{WZ} = \frac{QDR_{WZ}}{100 - \propto_{WZ}} * 100$$

α_{wz} = percentage drop in pre-breakdown capacity at work zone due to queuing conditions (13.4% if no local information is available).

2.3.1 Limitations

The equation in Figure 5 for estimating the QDR is based on a linear regression model and appears to have calibration limitations. For example, factors are either added or subtracted, such as subtracting 59 vehicles in nighttime conditions. Therefore, the HCM 6th Edition equation may have limitations in ambiguous situations such as "dusk" conditions – which is arguably neither day nor night. A multiplicative equation could potentially handle ambiguous situations better, however, it would create a more complicated equation that varies from the HCM 6th Edition's equation. If calibrating the HCM equation using linear regression does not provide the desired accuracy, a multiplicative equation could be considered.

2.3.2 Merge/Diverge/Weave/Crossover Segments

The QDR and work zone capacity are calculated based on basic freeway segments so other adjustments need to be made for merge segments, diverge segments, weave segments, and directional crossovers. This section discusses the adjustments that may be necessary based on the HCM 6th Edition methodologies for special situations such as merge, diverge, weave, and crossovers.

Merge segments do not affect the work zone capacity but affect the mainline queuing by moving the bottleneck to the ramp merge rather than the lane closure. Therefore, a merge introduces queuing at a lower mainline volume and the available capacity for mainline traffic is reduced. Figure 7 shows Exhibit 25-8 from the HCM 6th Edition that provides adjustment factors for available capacity upstream of the entrance ramp.

Figure 7. Available Capacity Upstream from Entrance Ramp

Work Zone Lane Configuration	On-Ramp Input Demand (pc/h)	Acceleration Lane Length (ft)							
		100	300	500	700	900	1,100	1,300	1,500
2 to 1	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	250	1.00	0.86	0.86	0.86	0.86	0.86	0.86	0.86
	500	1.00	0.70	0.70	0.70	0.70	0.70	0.70	0.70
	750	1.00	0.53	0.53	0.53	0.53	0.53	0.53	0.53
	1,000	1.00	0.49	0.45	0.40	0.40	0.40	0.40	0.40
2 to 2	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	250	1.00	0.92	0.92	0.92	0.92	0.92	0.92	0.92
	500	1.00	0.84	0.84	0.84	0.84	0.84	0.84	0.84
	750	1.00	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	1,000	1.00	0.67	0.67	0.67	0.67	0.67	0.67	0.67
3 to 2	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	250	1.00	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	500	1.00	0.87	0.87	0.87	0.87	0.87	0.86	0.86
	750	1.00	0.78	0.78	0.78	0.78	0.78	0.78	0.78
	1,000	1.00	0.70	0.70	0.70	0.70	0.70	0.70	0.70
4 to 3	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	250	1.00	0.97	0.97	0.98	0.98	0.98	0.98	0.98
	500	1.00	0.91	0.91	0.91	0.92	0.92	0.92	0.92
	750	1.00	0.85	0.85	0.85	0.86	0.86	0.86	0.86
	1,000	1.00	0.79	0.79	0.79	0.79	0.80	0.80	0.80

Exhibit 25-8
Proportion of Work Zone Queue Discharge Rate (Relative to the Basic Work Zone Capacity) Available for Mainline Flow Upstream of Merge Area

Diverge segments do not affect work zone capacity or change the bottleneck location. The work zone capacity upstream of an exit ramp is equivalent to the basic segment; however, downstream of the exit ramp the available capacity decreases. Figure 8 shows Exhibit 25-10 from the HCM 6th Edition that provides adjustment factors for available capacity downstream of the exit ramp.

Figure 8. Available Capacity Downstream from Exit Ramp.

Work Zone Lane Configuration	Off-Ramp Volume Percentage	Deceleration Lane Length (ft)							
		100	300	500	700	900	1,100	1,300	1,500
2 to 1	0.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	6.3	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.93
	12.5	0.87	0.88	0.88	0.88	0.88	0.88	0.87	0.87
	18.8	0.79	0.82	0.82	0.82	0.82	0.81	0.81	0.81
	25.0	0.72	0.76	0.76	0.75	0.75	0.75	0.75	0.75
2 to 2	0.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	6.3	0.93	0.94	0.94	0.94	0.94	0.94	0.94	0.94
	12.5	0.84	0.87	0.87	0.87	0.87	0.87	0.87	0.87
	18.8	0.76	0.81	0.81	0.81	0.81	0.81	0.81	0.81
	25.0	0.68	0.75	0.75	0.75	0.75	0.75	0.75	0.75
3 to 2	0.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	6.3	0.93	0.94	0.94	0.94	0.94	0.94	0.94	0.94
	12.5	0.86	0.87	0.87	0.87	0.87	0.87	0.87	0.87
	18.8	0.78	0.81	0.81	0.81	0.81	0.81	0.81	0.81
	25.0	0.69	0.74	0.74	0.74	0.74	0.74	0.74	0.74
4 to 3	0.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	6.3	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	12.5	0.86	0.87	0.87	0.87	0.87	0.87	0.87	0.87
	18.8	0.76	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	25.0	0.64	0.73	0.73	0.73	0.73	0.73	0.73	0.73

Exhibit 25-10
Proportion of Work Zone Capacity Available for Mainline Flow Downstream of Diverge Area

Weave segments perform like merge segments in that there is no effect on work zone capacity but affect the mainline queuing by creating a bottleneck at the entrance ramp and decreasing available capacity for mainline traffic. Chapter 25 pages 31-33 from the HCM 6th Edition provide the procedure to adjust the available capacity upstream of the weave depending on acceleration length, weaving volume, and work zone lane configuration.

At crossovers, work zone capacity depends upon the speed limit. Figure 9 shows Exhibit 25-12 from the HCM 6th Edition that provides adjustment factors to be applied to the work zone capacity based on crossover average speed. The adjustment factors are independent of the work zone lane configuration.

Figure 9. Available Capacity for a Directional Crossover

Lane Configuration	Crossover Average Speed (mi/h) 25	35	45
2 to 1 3 to 2 4 to 3	0.83	0.90	0.94

Exhibit 25-12
Proportion of Available Work Zone Capacity for a Directional Crossover in the Work Zone

2.3.3 Queue Length, Delay, and Road User Costs

As mentioned previously, the HCM 6th Edition does not provide a method for work zone queue estimation, so deterministic and simulation tools are available to estimate delay, queue length, and road user costs due to delay. For example, delay can be found from FREEVAL and QuickZone. Queue lengths can be found using Vissim and road user costs can be found with QUEWZ, QuickZone, or by multiplying delay by costs. However, various state DOTs have developed their own methodologies and tools to estimate queue, delay, and sometimes road user cost parameters. Five state DOTs have developed and used such tools that were researched as part of the literature review. A summary of their methodologies and tool capabilities is provided in the subsequent section.

2.4 State DOT Work Zone Methodologies and Tools

Information from five state DOTs about their work zone tools and calculation methodologies were gathered and compared in this literature review. All five of the state DOT tools reviewed had the ability to estimate work zone delay and queue length, which were parameters lacking in both HCM methodologies. Additionally, three state DOTs calculated road user costs within their tool. A comparison of the parameters calculated by each tool is provided in Table 4.

In Table 5, a comparison of the calculation characteristics of the state DOT tools is provided. The number of days of analysis the tool is capable of, whether there is the ability to input diversion volumes, and the underlying methodology for capacity and queue calculations is described.

Table 4. State DOT Comparison of Work Zone Parameters Calculated

		Work Zone Parameters Calculated				
State	**Tool Name**	**Capacity**	**Queue Length**	**Delay**	**Road User Costs**	**Speed**
Missouri DOT	MoDOT Work Zone Impact Analysis Spreadsheet	✓	✓	✓	✓	
Ohio DOT	Lane Closure Queue Analysis Tool	✓	✓	✓		
Illinois DOT	WorkZoneQ-Pro	✓	✓	✓	✓	✓
Michigan DOT	Construction Congestion Cost (CO^3)	✓	✓	✓	✓	✓
Texas DOT	QDAT	✓	✓	✓		

Table 5. State DOT Comparison of Work Zone Calculation Characteristics

	Calculation Characteristics			
State	**Volume Inputs**	**Diversion Inputs**	**Capacity Analysis Methodology**	**Queue Analysis Methodology**
Missouri DOT	7 days, 1-hour increments	No	Based on HCM 2010 Methodology using a manually entered base capacity.	Input-Output Method
Ohio DOT	1 day, 1-hour increments	Yes	Based on HCM 2010 Methodology using a manually entered base capacity (calibrated at -400 pcphpl based on ODOT study).	Input-Output Method
Illinois DOT	1 day, 1-hour increments	No	Methodology based on empirical data specific to Illinois.	Cell Transmission Model
Michigan DOT	5 days, 1-hour increments	Yes	Input capacity based on MDOT work zone capacity table provided in user manual.	Input-Output Method
Texas DOT	1 day, 1-hour increments	No	Based on HCM 2010 Methodology using a manually entered base capacity.	Input-Output Method

Volume Inputs

Three of the five tools enable one day of volume inputs whereas the MDOT tool enabled up to five days and the MoDOT tool enabled a full seven days (Sunday through Saturday).

Diversion Inputs

The ODOT and MDOT tools have the ability for the user to manually enter diversion estimates, which can be helpful to more accurately estimate queues and delay when motorists are anticipated to divert to another route to avoid the delays caused by a work zone. It appears in the other states' tools that diversion estimates would need to be manually subtracted from the input volumes or by using a percent diversion factor.

Capacity Methodology

Aside from IDOT's empirical method of capacity estimation based on observations at work zones in Illinois and MDOT's work zone capacity table, the other three states use the HCM 2010 methodology as the foundation for the capacity estimates. ODOT, for instance, has a suggested calibration of subtracting 400 pcphpl from the base capacity estimate provided in the HCM 2010 based on field collected work zone data in Ohio.

Queue Methodology

The queue analysis methodology and subsequent delay estimates are based on the input-output method in four states and a more complicated cell transition model in IDOT's tool. The input-output method is based on the difference between the demand volume and the queue discharge volume. The difference between the two is the number of vehicles in the queue and the subsequent length of queue based on assumptions about the queue such as vehicle length and headway. The cell transition model in IDOT's tool is more complicated but provides more robust queuing information and can model queues of different speeds.

Complexity

In order of complexity, the TxDOT tool (QDAT) appears to be the simplest followed by the ODOT and MoDOT tools. All three of these tools have components that are relevant examples to draw features from. For instance, they have simple interfaces, are easy to understand, and operate smoothly.

The MDOT and IDOT tools are complex tools that offer numerous calculation parameters (MDOT's tool, for instance, incorporates a variety of construction cost parameters). However, the learning curve to master these tools and their imbedded methodologies is steep.

Additional Background Information

Each state contacted as part of this literature review had reasons why, and information about how, they developed their tools. This information is summarized next.

2.4.1 Missouri DOT Work Zone Tool

In 2011, the state of Missouri analyzed field data on their interstate highway work zones to determine if a revision to their work zone planning tool was necessary. The results of this analysis were presented in a report titled *Missouri Work Zone Capacity: Results of Field Data Analysis* [6].

Data Collection

The analysis began by collecting volume and speed data from video cameras set at a freeway work zone for four days in each direction at the same location to study work zone capacity variation. Four measures of capacity were used for each breakdown event: maximum pre-breakdown flow, breakdown flow, maximum discharge flow, and average discharge flow. Data was taken in five-minute or shorter aggregate intervals for analysis of breakdown and queue discharge. The calculated mean breakdown and queue discharge flow rates were compared with the HCM 2000 [7].

To validate the accuracy of the field data collected, the volume counts were visually inspected, and the speeds collected were compared to those taken with a laser speed gun. Adjustments factors were applied to the data collected to improve accuracy.

Results

The results of the study showed that the queue discharge flow was lower than the pre-breakdown flow, which was also lower than the HCM 2000 value of work zone capacity. It was also found that the difference between the mean pre-breakdown flow and queue discharge flow is “due to reduced traffic flow once traffic breaks down and queues start to form”. Missouri’s original work zone planning tool assumed pre-breakdown flow and queue discharge flow were the same values. However, the study determined that the pre-breakdown flow rates should be used to forecast the onset of congestion and the mean queue discharge flow rates should be used to estimate delays under congested conditions. Therefore, it was recommended the work zone tool be adjusted to reflect these findings.

2.4.2 Ohio DOT Work Zone Tool

ODOT had used a Queue and User Cost Evaluation of Work Zones (QUEWZ) program from Texas to calculate work zone capacities and estimate queues and road user delay costs. However, the program was no longer compatible with the Microsoft Windows operating system so ODOT decided to develop a tool to replace QUEWZ and more so, align with Ohio conditions rather than the conditions in Texas. ODOT selected Cleveland State University to develop a lane closure queue analysis tool to replace QUEWZ. The tool, referred to as the Lane Closure Queue Analysis Tool, is based off research conducted around Ohio and the HCM 2010 for short-term work zones [8].

Data Collection

Data for this project was recorded at six short-term work zones in Ohio. Researchers recorded traffic classification counts in five-minute intervals at the beginning of the work zone and at entrance and exit ramps upstream of the work zone. Once queues formed, they recorded the queue discharge for one hour at the beginning of the lane closure. Lastly, the researchers recorded free-flow speeds of passenger cars and trucks either before or after the lane closure was set up and no queues were present.

Results

The resulting capacities collected from the data were compared to the HCM 2010 capacity value for short-term work zones. The study resulted in a new queue analysis tool that meets the needs of ODOT's Work Zone Traffic Managers. The tool estimates queue lengths and associated delay throughout a work zone with a short-term lane closure. ODOT is comfortable with the queue analysis and uses it today but the road user cost tool is still being evaluated.

2.4.3 Illinois DOT Work Zone Tool

The Illinois DOT hired the University of Illinois Urbana Champaign (UIUC) to research current tools used for work zone traffic analysis and develop a new queue analysis tool based on those findings [9]. The tool developed by researchers at UIUC is called WorkZone Q and is currently used by IDOT.

Data Collection

Data was collected at fourteen freeway sites, both long-term and short-term work zones, for one day. Using a camera and markers placed approximately 250-ft apart, researchers collected the time it took vehicles to travel between both markers. The markers were also used to determine vehicle speeds and headways (i.e., the time between subsequent vehicles). The work zone capacity was determined by estimating the inverse of the average headway. Queues were also observed, and lengths of queues recorded for every one-minute.

Results

Researchers compared estimated capacity, speeds, queue lengths, and delay from the field data to the capacity, speed, queue length, and delay outputs from FRESIM, QUEWZ, and QuickZone software. FRESIM software estimated free-flow speeds that were comparable to the field data but overestimated speed once queues formed. Queue lengths in FRESIM were not comparable with field data because they were either overestimated or underestimated. QUEWZ overestimated capacity and average speed while underestimating average queue length. The QuickZone software underestimated both queue lengths and total delay. The UIUC researchers developed a new tool to determine capacity, speed reduction, delay, queue lengths and user costs. The field data collected provided enough information to form speed flow curves, which is used to determine the capacity. From there, queue lengths, delay and user costs are computed.

2.4.4 Michigan DOT Work Zone Tool

The Michigan DOT (MDOT) developed a Work Zone Safety and Mobility Manual to provide general operational guidelines within a work zone [10]. This manual is in place "to improve safety and mobility in work zones by reducing congestion and traffic incidents". As part of the manual's procedures, MDOT performs a mobility analysis primarily through a tool called Construction Congestion Cost (CO3). The tool has been around for more than 20 years as the user manual was originally published on September 18, 1997. CO3 measures work zone delay, diversion, and queues during congestion as well as road user costs due to the construction. MDOT further uses the CO3 program to select traffic staging methods and determine contract period costs for construction incentives such as reducing congestion impacts.

Data Input

CO3 is a complex tool that requires numerous input values. The input data includes, but is not limited to, project information, vehicle information, capacity with and without construction, distance and speed traveled in the work zone and on the diversion route, and road user costs per hour and per mile. The Traffic Sheet within the CO3 program is primarily used to input project data and compute traffic congestion values such as delay and queues as well as road user costs. The Summary View includes the output user costs due to delay and queue lengths.

Results

MDOT suggests using the CO3 program for freeway construction, while continuing to use Synchro for construction on signalized roadways. MDOT finds the results of the CO3 program to be accurate but recommends that if other states choose to use the program, the user should fully understand it before using it in practice. There are improvements being made to the CO3 program such as better definition of the inputs and providing further explanation in developing a diversion percentage.

2.4.5 Texas DOT Work Zone Tool

The Texas DOT (TxDOT) developed a tool used for work zone traffic analysis called Q-DAT in August 2010 [11]. The tool is used for work zone traffic analysis, delay, and queue estimation as well as defining appropriate lane closure schedules. This tool is currently used by TxDOT.

Summary

Q-DAT is a tool that requires numerous input values that include, but is not limited to, speed, volume, lane closure configuration, work zone intensity, critical length of queue, maximum acceptable delay, and the schedule of work activity. The resulting output has two options: Lane Closure Schedule and Delay & Queue Estimation. The Lane Closure Schedule will identify all hours when lane(s) can be closed without exceeding a critical length of queue or maximum acceptable delay. Delay & Queue Estimation will compute those measures for a given start time, end time, and number of lanes closed. Capacity can either be manually entered by the user or calculated using the HCM 2010 methodology.

CHAPTER 3: STUDY DESIGN

This chapter contains information about the planned approach for tasks in this study. With the aim of developing an accurate model to predict work zone capacity, queues, delays, and road user costs applicable to Wisconsin freeway work zones, a sampling of data from work zones throughout the state was desired.

3.1. INVENTORY GATHERING AND DATA COLLECTION

Initial data collection goals included sampling 40 work zones distributed across the five WisDOT regions. In the SE, SW, and NE regions a goal of 10 samples in each region was set. In the NC and NW regions, where less road work was anticipated, a sample size of five in each region was the goal. It was anticipated that the sampling of sites throughout the state would enable a variety of work zone situations to be captured, including:

- Different lane closure types (2 to 1, 3 to 2, etc.),
- Urban and rural area types,
- Day and night conditions,
- High and low levels of construction intensity,
- Varying traffic volume profiles, and
- Regional differences in driver behavior.

3.1.1 Work Zone Site Monitoring

At the onset of the project, a strategy was developed to identify potential samples for the study. The project team met on a weekly basis to discuss upcoming road work zone sites that might be a good fit for the project. Traffic management plans (TMP) were reviewed for upcoming projects and regional work zone engineers were contacted about work zone activity in their regions [12]. Work zone sites that were expected to have queuing were targeted for this project because it would enable discharge rate, queue, and delay parameters to be captured and analyzed.

To identify work zone sites with potential suitability for this study, the strategy used to monitor work zone activity and queueing was flexible and robust. The strategy relied on gathering information from many sources, including:

- Correspondence with state work zone engineers,
- Correspondence with regional work zone engineers,
- Correspondence with construction project managers for specific work zone sites,
- Reviews of traffic management plans,
- Google Maps™ travel time monitoring,
- Bluetooth travel time monitoring,
- Closed Circuit Television (CCTV) video footage monitoring,
- Ground-based video collection at work zone sites, and
- Ground-based tube collection near work zone sites (on- and off-ramps).

The collaboration and technical monitoring of potential sites enabled the project team to monitor over 180 instances of work zone activity throughout the course of the study. This approach to monitor a wide range of work zone sites was integral to the success of the project. Monitoring numerous instances of work zone activity enabled the project team to identify work zones that could provide data suitable for analysis, thereby minimizing the collection and analysis of unusable data.

As the project progressed, it became evident reaching the initial sample sizes would be challenging as many monitored work zone sites in 2018 and 2019 did not produce queuing. Further hampering data sampling efforts was a lack of work zone activity in the northern regions. As a result, the project team adapted the original plan and collected data at any work zone sites with the potential of queuing. After data collection for the model development was completed in 2019, the project team had 52 samples of work zone data spread across the state at 14 different work zone sites.

3.1.2 Data Collection

In the construction seasons of years 2018 and 2019, more than 180 freeway work zone occurrences were monitored for possible inclusion in the study. Monitoring was conducted by collecting video footage near the taper point of a lane closure and at an upstream location. Video footage was obtained by cameras and if available, CCTV footage from the Traffic Management Center (TMC) [13]. Travel times were monitored by Bluetooth detectors and/or Google Maps™ Travel Time interface. Work zone instances selected for analysis in the study needed to observe queues resulting from the work zone lane closure, and not ancillary causes such as weather or incidents.

3.1.3 Site Selection

Data suitable for the calibration of a work zone capacity/delay model was found at 14 work zone sites throughout Wisconsin. At many sites, multiple days of data was suitable for analysis and led to the selection of 52 total work zone samples for the study. The 52 samples included 30 observations in the SE region, 15 observations in the SW region, six observations in the NW region, and one observation in the NE region. Overall, the northern regions did not have many work zone closures resulting in capacity-related delays and queuing. Thus, the southern regions have larger sample sizes. Additional data was collected in northern regions in 2020 as a validation exercise to compare the observed capacity and queueing versus what the model predicted (results of the comparison will be included in the final project presentation).

3.2 Analysis Methodology

The analysis methodology contained a series of steps that led to the development of a work zone capacity/delay model calibrated to fit Wisconsin's observed data.

3.2.1 Capacity

Analyzing capacity at work zones has many technical components that are not available in standardized traffic volume reports. Therefore, as a foundation for analysis in this study, a work zone capacity spreadsheet was developed by the project team that calculated the parameters necessary for model calibration and tool development. The spreadsheet had many features specific to work zone analysis and included:

- Site characteristic inputs,
- Pre-breakdown capacity calculations,
- During-breakdown capacity calculations,
- Results shown in vehicle volumes and in passenger car equivalent (PCE) volumes,
- Graphical depiction of PCE flow rates, and
- Flow-rate categorizations by time period (5 minutes, 15 minutes, and hourly).

Appendix A contains spreadsheets for each of the 52 work zone samples.

3.2.2 Queues

The placement of cameras at the taper location and at an upstream location (prior to the work zone) provided a means for collecting information about the number of vehicles in a queue. Knowing the number of vehicles in the queue, the distance between the cameras, and the number of travel lanes utilized by the queue enabled the calculation of the average spacing per vehicle in the queue. Vehicle spacing is an integral part of queue estimation in freeway work zones.

In methodologies previously used by WisDOT for queue work zone estimation, a static value (30 or 40 feet per PCE) was used for vehicle spacing. Queue observations and research have shown that the vehicle spacing is a function of the speed at which vehicles are moving in the queue. In a faster moving queue, the spacing between vehicles is greater. For example, if all else remains equal, a queue with 100 vehicles moving 30 mph would be expected to be longer than a queue of 100 vehicles moving 10 mph due to the larger spacing between vehicles in the faster moving queue.

Therefore, the analysis plan included looking at the relationship between speed and vehicle spacing in queues. However, in many instances in this study, queues did not reach the upstream camera or there were other site characteristics (such as the presence of an on-ramp or off-ramp) in the queuing area that did not allow for queue calculations. As a result, the project team researched queue estimation methodologies and calculated predicted spacing per PCE using work zone queue speed and headway calculations from the following publication: "A Primer on Work Zone Safety and Mobility Performance Measurement" by FHWA (2011) (see Section 6.3 for more information on the queue methodology). When queue spacing parameters were obtainable from data collected in this study, it was used for comparison purposes to the parameters predicted by the model.

3.2.3 Parameter Selection

An objective of the Wisconsin-specific work zone study was to determine if the observed capacities in Wisconsin work zones were accurately estimated by HCM 6th Edition's model or if the equation could be calibrated to better fit Wisconsin data. HCM 6th Edition's work zone queue discharge rate is calculated by relying on the following five factors:

- Lane closure severity index,
- Barrier type (hard or soft),
- Lateral distance from nearest open lane to the work zone (in feet),
- Time of day (day or night), and
- Area type (urban or rural).

After discussions with WisDOT's regional work zone engineers, there were parameters they felt impacted work zone capacity that were not accounted for in HCM 6th Edition's methodology. The two additional parameters suspected to influence capacity were construction intensity and the WisDOT regional location of the site.

Based on the work zone engineers' past experiences, when construction activity was high, such as an adjacent lane being paved or a crane moving equipment, drivers had a tendency to change their behavior and drive slower. As a result, it was suspected that capacity was lower through work zones when there was high construction activity compared to low construction activity.

It was also suspected that driver behavior was potentially different in each of WisDOT's five distinct regions. Regional influence was a parameter that WisDOT wanted to explore as part of this project. All five regions have urban and rural areas, however if all else was equal, it was suspected that a work zone in one WisDOT region might have different capacities than a work zone in another region.

The analysis plan included looking at the influences of construction intensity and regional location of the work zone sites in addition to the factors included in the HCM 6th Edition's equation.

3.2.4 Regression Modeling

The study was designed using a linear regression modeling procedure to identify which factors had the most influence on work zone capacity. In this study, 24 different linear regression analyses were performed in model development, each using a different combination of the selected variables. Adjusted R-squared values for each linear regression were compared to identify which model included the factors that had the most influence on work zone capacity. In-depth results of the linear regression analysis can be found in Chapter 5.

3.3 TOOL DEVELOPMENT

WisDOT had a need for a tool that could be used consistently throughout the various WisDOT regions for work zone capacity, delay, queue, and road user cost estimation. There was also a need identified by the regional work zone engineers for a tool that offered weekly and annual capabilities. As part of this study, a WEEKLY tool and an ANNUAL tool were developed using Microsoft Excel® with the functionality to import data from WisDOT traffic count sources, and the ability to enter up to four different work zone closure scenarios in a single day. Chapter 6 has more detailed information about the tool development, capabilities, and how to use it.

CHAPTER 4: DATA CHARACTERISTICS

This chapter contains information about the characteristics for the specific sites monitored and used in this study and the observed capacities at each site used in analysis.

Table 6. Site Characteristics for Analysis Sites

	Project ID	Highway	Direction	County	Date	Closure Type	Barrier Type	Day/Night	Area Type	Construction Intensity	Region
1	1228-16-71	IH 43	NB	Milwaukee	11/2/18	2 to 1	Soft	Night	Urban	High	Southeast
	1228-16-71	IH 43	NB	Milwaukee	11/6/18	2 to 1	Soft	Night	Urban	High	Southeast
2	1100-34-70	IH 894	SB	Milwaukee	10/4/18	4 to 3	Soft	Day	Urban	Low	Southeast
	1100-34-70	IH 894	SB	Milwaukee	10/5/18	4 to 3	Soft	Day	Urban	Low	Southeast
	1100-34-70	IH 894	SB	Milwaukee	10/11/18	4 to 3	Soft	Day	Urban	Low	Southeast
3	1030-11-79	IH 94	NB	Milwaukee	10/24/18	3 to 1	Soft	Night	Urban	High	Southeast
4	1060-49-70	IH 94	EB	Waukesha	3/22/19	2 to 1	Soft	Day	Urban	High	Southeast
5	1100-36-70	IH 41	NB	Waukesha	3/19/19	3 to 1	Soft	Night	Urban	High	Southeast
	1100-36-70	IH 41	NB	Waukesha	3/26/19	3 to 1	Soft	Night	Urban	High	Southeast
6	1090-30-70	IH 43	NB	Waukesha	10/3/18	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	NB	Waukesha	10/18/18	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	NB	Waukesha	10/25/18	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	NB	Waukesha	11/5/18	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	NB	Waukesha	11/5/18	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	NB	Waukesha	11/6/18	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	SB	Waukesha	8/23/18	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	SB	Waukesha	10/3/19	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	SB	Waukesha	10/4/19	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	SB	Waukesha	10/18/18	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	SB	Waukesha	10/25/18	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	SB	Waukesha	11/5/18	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	SB	Waukesha	11/6/18	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	SB	Waukesha	11/6/18	2 to 1	Soft	Day	Urban	Low	Southeast
	1090-30-70	IH 43	SB	Waukesha	11/8/18	2 to 1	Soft	Day	Urban	Low	Southeast
7	1060-33-82	IH 94	WB	Milwaukee	9/5/18	4 to 3	Hard	Day	Urban	Low	Southeast
	1060-33-82	IH 94	WB	Milwaukee	9/6/18	4 to 3	Hard	Day	Urban	Low	Southeast
	1060-33-82	IH 94	WB	Milwaukee	9/11/18	4 to 3	Hard	Day	Urban	Low	Southeast
	1060-33-82	IH 94	WB	Milwaukee	9/12/18	4 to 3	Hard	Day	Urban	Low	Southeast
	1060-33-82	IH 94	WB	Milwaukee	9/17/18	4 to 3	Hard	Day	Urban	Low	Southeast
	1060-33-82	IH 94	WB	Milwaukee	9/19/18	4 to 3	Hard	Day	Urban	Low	Southeast
8	1007-11-71	IH 39	NB	Rock	8/31/18	3 to 2	Hard	Day	Urban	Low	Southwest
9a	1206-04-69	USH 12/18	EB	Dane	9/19/18	3 to 1	Soft	Night	Urban	High	Southwest
	1206-04-69	USH 12/18	EB	Dane	10/2/18	3 to 1	Soft	Night	Urban	High	Southwest
	1206-04-69	USH 12/18	EB	Dane	10/10/18	3 to 1	Soft	Night	Urban	High	Southwest
	1206-04-69	USH 12/18	WB	Dane	10/8/18	3 to 1	Soft	Night	Urban	High	Southwest
	1206-04-69	USH 12/18	WB	Dane	10/9/18	3 to 1	Soft	Night	Urban	High	Southwest
	1206-04-69	USH 12/18	WB	Dane	10/10/18	3 to 1	Soft	Night	Urban	High	Southwest
	1206-04-69	USH 12/18	WB	Dane	10/11/18	3 to 1	Soft	Night	Urban	High	Southwest
9b	1206-04-69	USH 12/18	EB	Dane	10/2/18	3 to 2	Soft	Night	Urban	High	Southwest
10	1111-03-70	USH 151	NB	Dane	9/21/18	2 to 1	Soft	Day	Rural	High	Southwest
11	1016-03-61	IH 94	WB	Juneau	4/12/19	2 to 1	Soft	Day	Rural	High	Southwest
	1016-03-61	IH 94	WB	Juneau	4/14/19	2 to 1	Soft	Day	Rural	High	Southwest
	1016-03-61	IH 94	WB	Juneau	4/15/19	2 to 1	Soft	Day	Rural	High	Southwest
	1016-03-61	IH 94	WB	Juneau	4/16/19	2 to 1	Soft	Day	Rural	High	Southwest
	1016-03-61	IH 94	WB	Juneau	4/16/19	2 to 1	Soft	Day	Rural	High	Southwest
12	1020-03-76	IH 94	EB	St. Croix	4/30/19	2 to 1	Soft	Day	Rural	High	Northwest
13	1022-07-76	IH 94	EB	St. Croix	4/23/19	2 to 1	Soft	Day	Rural	Low	Northwest
	1022-07-76	IH 94	EB	St. Croix	4/24/19	2 to 1	Soft	Day	Rural	Low	Northwest
	1022-07-76	IH 94	EB	St. Croix	4/29/19	2 to 1	Soft	Day	Rural	Low	Northwest
	1022-07-76	IH 94	EB	St. Croix	4/29/19	2 to 1	Soft	Day	Rural	Low	Northwest
	1022-07-76	IH 94	EB	St. Croix	4/30/19	2 to 1	Soft	Day	Rural	Low	Northwest
14	1130-49-71	IH 41	SB	Outagamie	7/28/18	2 to 1	Soft	Day	Urban	High	Northeast

4.1 Site Characteristics

Characteristics of the sites varied and provided a data set used to create a work zone capacity model calibrated to Wisconsin-specific work zone capacities. Table 6 on the previous page shows the site characteristics for the 52 samples used in analysis from 14 different work zone sites. The number in left column of table corresponds to map in Figure 1.

The different lane closure types included 31 (2 to 1) closures, 10 (3 to 1) closures, two (3 to 2) closures, and nine (4 to 3) closures, as shown in Table 7.

Table 7. Closure Type Statistics

Closure Type		
2 to 1	31	60%
3 to 1	10	19%
3 to 2	2	4%
4 to 3	9	17%

For barrier type, shown in Table 8, 45 of the 52 samples had soft-barrier (i.e. drum) closures and seven had hard-barrier (i.e. concrete temporary portable barrier) closures. In general, soft-barrier work zones are more temporary in nature than hard-barrier work zones, which tend to be long term.

Table 8. Barrier Type Statistics

Barrier Type		
Soft	45	87%
Hard	7	13%

Seventy-five percent of the closures occurred during the daytime, with 13 of the 52 samples occurring during the night, as shown in Table 9. Nighttime closures generally observe lower capacity than daytime closures, so it was important to make the time of day distinction.

Table 9. Time of Day Statistics

Time of Day		
Day	39	75%
Night	13	25%

Table 10 shows that 40 of the 52 samples occurred in urban areas, with 12 samples occurring in rural areas.

Table 10. Area Type Statistics

Area Type		
Urban	40	77%
Rural	12	23%

Thirty of the samples were during low construction intensity, while 22 were during high construction intensity, as shown in Table 11. Low construction intensity was defined as construction work (or lack thereof) that was unlikely to substantially impact the behavior of drivers traversing the work zone. High construction intensity was defined as active construction work that was likely to substantially impact the behavior of drivers. For example, a construction zone with workers working close to the lane line, construction activity at a site with no barrier wall, or a site with equipment working in adjacent lane could be considered as high construction activity.

Table 11. Construction Intensity Statistics

Construction Intensity		
High	22	42%
Low	30	58%

Nearly 90-percent of the samples occurred in the Southeast or Southwest regions, with the Southeast Region having 30 samples and the Southwest having 15 samples. Zero samples occurred in the North Central Region. Table 12 shows the breakdown by region, as well as a breakdown of southern region total versus northern region total.

Table 12. Region Statistics

<table>
<tr><th colspan="6">Region</th></tr>
<tr><td>SE</td><td>30</td><td>58%</td><td rowspan="2">South</td><td rowspan="2">45</td><td rowspan="2">87%</td></tr>
<tr><td>SW</td><td>15</td><td>29%</td></tr>
<tr><td>NC</td><td>0</td><td>0%</td><td rowspan="3">North</td><td rowspan="3">7</td><td rowspan="3">13%</td></tr>
<tr><td>NE</td><td>1</td><td>2%</td></tr>
<tr><td>NW</td><td>6</td><td>12%</td></tr>
</table>

4.2 CAPACITY OBSERVATIONS

The capacity of the work zone was defined by the observed queue discharge rate, which is the rate at which vehicles flow through the work zone once breakdown conditions (i.e., queuing) is observed. Observed capacities were reported in two ways: vehicles per hour per lane and passenger car equivalents (PCEs) per hour per lane. PCEs are calculated by converting trucks to passenger car equivalents (1 truck = 2 cars per the HCM 6^{th} Edition [3]) and adding the observed cars to that total. Using vehicle per hour per lane capacities can be misleading, particularly when truck percentages vary. Therefore, PCEs is the recommended evaluation parameter.

A map showing the locations of the work zone sites and the average queue discharge rates observed is shown in Figure 10. Capacities range from 1,050 PCEs per hour at a 2 to 1 closure at a SW region rural location with high construction intensity to 1,875 PCEs per hour in a 4 to 3 closure in an urban freeway environment with low construction intensity.

Figure 10. Observed Capacity Averages by Site

WORK ZONE CAPACITY OBSERVATION SUMMARY			
Location	Closure Type	Average Queue Discharge Rate	
		veh/hour/lane	PCE/hour/lane
1	2 to 1	1,300	1,350
2	4 to 3	1,500	1,675
3	3 to 1	1,000	1,300
4	2 to 1	1,250	1,475
5	3 to 1	1,075	1,200
6	2 to 1	1,400	1,650
7	4 to 3	1,775	1,875
8	3 to 2	1,500	1,725
9a	3 to 1	1,250	1,325
9b	3 to 2	1,400	1,475
10	2 to 1	975	1,050
11	2 to 1	975	1,275
12	2 to 1	825	1,175
13	2 to 1	1,050	1,400
14	2 to 1	1,325	1,400

4.3 Queue Observations

The placement of cameras at the taper location and at an upstream location provided a means for collecting information about the number of vehicles in a queue. Knowing the number of vehicles in the queue, the distance between the cameras, and the number of travel lanes utilized by the queue enabled the calculation of the average spacing per vehicle in the queue. In many samples in this study, queues did not reach the upstream camera or there were other site characteristics (such as the presence of an on-ramp or off-ramp) in the queuing area that did not allow for queue calculations. Two of the fourteen sites provided queue information that was used to validate the queue model methodology: project 1090-30-70 (location #6) and project 1060-33-82 (location #7). Project 1090-30-70 was a 2 to 1 closure that had nine queue observations samples. Project 1060-33-82 was a 4 to 3 closure that had 10 queue observations samples. The results of the queue validation are discussed in Section 6.3.2 Queue Model Validation.

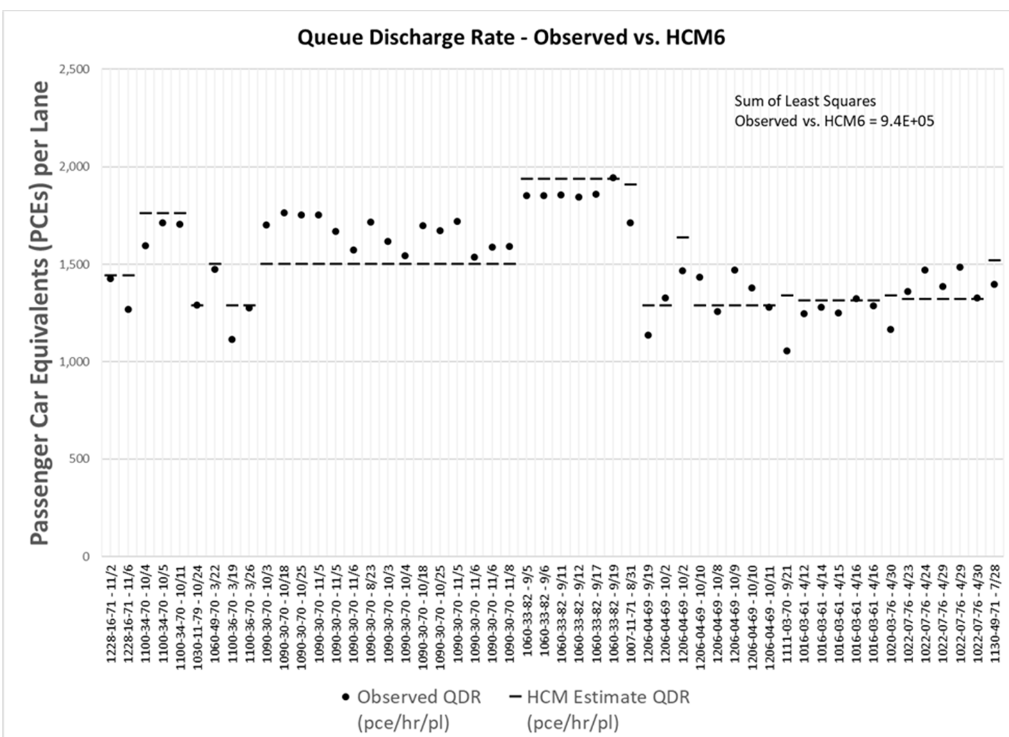
CHAPTER 5: RESULTS AND ANALYSES

The foundation of the methodologies for work zone capacities used in Chapter 10 of the HCM 6th Edition [3] stem from the results of the NCHRP Report [4,5] which defines the work zone capacity as the maximum sustained 15-minute queue discharge flow rate observed at the work zone lane closure or other bottleneck in a pre-breakdown condition. Upon the breakdown of traffic, a capacity drop is typically observed. The breakdown traffic flows are estimated using the average queue discharge rate (QDR) equation from HCM 6th Edition and the NCHRP Report. The equation considers the lane closure severity index (LCSI), barrier type, area type, lateral distance from the nearest open lane to the work zone, and time of day. This chapter summarizes how the HCM 6th Edition model compared to the observed data collected for this study and describes the development of a new recommended model for use in the State of Wisconsin.

5.1 HCM 6TH EDITION WORK ZONE MODEL COMPARISON

The HCM 6th Edition model's estimated QDR was calculated for each of the 52 samples analyzed using information from the TMPs and field observations at the work zone sites. The estimated QDR was then compared to the observed QDR for each data point. The HCM 6th Edition model estimated QDR varied from the observed data, sometimes overestimating QDR and other times underestimating QDR as shown in Figure 11 below and Appendix B in larger scale. For example, the HCM 6th Edition model overestimated the QDR on an urban 4 to 3 closure (project 1060-33-82) by an average of 66 PCEs, whereas on an urban 2 to 1 closure (project 1090-30-70), the HCM model underestimated the QDR by an average of 160 PCEs.

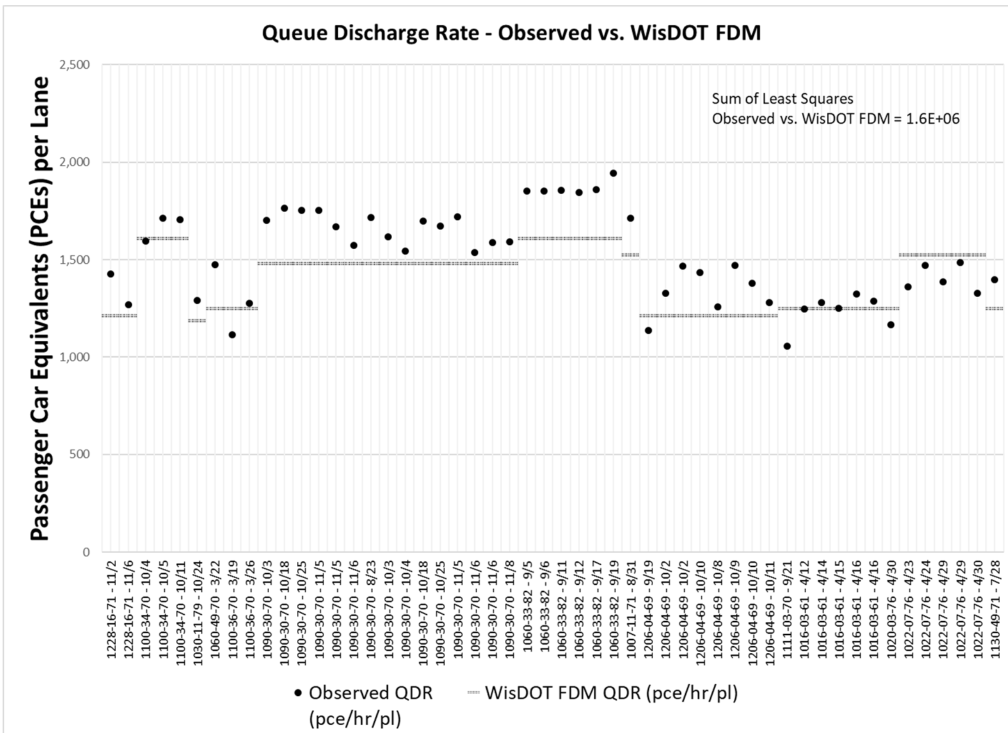
Figure 11. HCM 6th Edition Model Comparison to Observed



5.2 EXISTING WISDOT WORK ZONE MODEL COMPARISON

The observed data was also compared to estimates produced by the existing WisDOT work zone model outlined in Section 2.2 of this report [2]. The existing WisDOT work zone model's estimates were compared to the observed data in Figure 12 below and Appendix B in larger scale. This comparison resulted in a higher sum of least squares than the HCM 6th Edition model's comparison. The higher sum of least squares indicated the existing WisDOT model did not fit the observed data better than the HCM 6th Edition model. Therefore, it can be concluded the HCM 6th Edition model's estimates statistically fit the observed data better than the existing WisDOT work zone model's estimates.

Figure 12. WisDOT Model Comparison to Observed



5.3 MODEL DEVELOPMENT

While the HCM 6th Edition's model fit the observed data better than the existing WisDOT model, an objective of this study was to calibrate the HCM 6th Edition's model to improve the fit to the data observed at Wisconsin work zones. This section discusses the calibrations and adjustments made to the HCM 6th Edition's model to more closely estimate work zone capacities in Wisconsin.

The HCM 6th Edition's QDR equation considers the lane closure severity index (LCSI), barrier type, area type, lateral distance from the nearest open lane to the work zone, and time of day [3].
This study did not include lateral distance from the nearest open lane to the work zone as a variable in model development since lateral distance may vary throughout a work zone, may be different than

proposed in the TMP, is difficult to measure in an active work zone, and its definition can be interpreted inconsistently.

Construction intensity was not a factor included in the HCM 6th Edition's model. Discussions with WisDOT's regional work zone engineers found construction intensity to be a desired factor in a Wisconsin-specific model. Construction intensity is a factor in the current WisDOT work zone capacity model. Options for defining construction intensity were discussed amongst the project team based on the available data and the experiences of regional work zone engineers. The regional work zone engineers have observed less capacity when construction activity is high – such as base patching work next to an open travel lane.

Two categories of construction intensity were decided upon for evaluation: low and high. Low construction intensity and high construction intensity were defined in section 4.3 of this report. The level of construction intensity varies in different stages of many construction projects. Thus, estimating the minimum capacity during high intensity and the maximum capacity during low intensity could be beneficial, and could be done by using both high and low construction intensity factors to estimate each scenario.

WisDOT also expressed interest in having regional factors evaluated for each of the five WisDOT regions. The study evaluated each region individually, but due to a lack of available data, particularly in the northern regions, was unable to have separate region factors. To compensate for this lack of data, analysis was performed by grouping the regions into north and south regional categories.

The complete list of variables included in the model development are listed below:

- LCSI (4 to 3, 3 to 2, 3 to 1, and 2 to 1),
- Barrier type (concrete or cone/drum),
- Area type (urban or rural),
- Construction intensity (high or low), and
- WisDOT Region (SE, SW, NW, NC*, NE) and (North or South).

* Data was not available for the NC Region

TADI performed 24 different linear regression analyses in model development. LCSI and barrier type variables with a combination of the remaining variables were used in each analysis.

5.4 Results Of Regression Analysis

For each of the 24 linear regression analyses, the adjusted R-squared value is shown along with the base QDR and coefficients for each factor. The interpretation of the adjusted R-squared value is similar to a normal R-squared value, but adjusted R-squared is used when analyzing multiple regression outputs, such as in this study. The results of the regression analyses can be found in the Appendix C.

Based on the results of the regression analyses, two models (1.01 and 3.01) appeared to show most promising results. High adjusted R-squared values indicated a good statistical fit to the observed data and the coefficients were logical based on previous research and the HCM 6th Edition's model (i.e., factors such as nighttime operations, temporary barrier, and rural areas reduced capacity). Some of the other 24 models evaluated had high adjusted R-squared values but had coefficients that were illogical (e.g., a day/night coefficient that added capacity at night – see model 2.03).

A comparison of the HCM 6th Edition's equation to the two most promising models is shown below in passenger car equivalents (PCEs). The QDR in PCEs accounts for the trucks in the traffic flow and outputs the number of vehicles per hour if they were all passenger cars. Therefore, traffic flow in PCEs will always be a larger number than the number of vehicles since PCEs will turn each truck in the traffic flow to a factor greater than one of passenger cars.

Figure 13. HCM 6th Edition Model vs. Promising Models

HCM 6th Edition Model, Adj. R^2 = 0.5835

$$Average\ QDR_{PCE} = 2{,}093 - 154 f_{LCSI} - 194 f_{barrier} - 59 f_{TOD} - 179 f_{area} + 9 f_{lateral\_12}$$

Promising Model 1.01, Adj. R^2 = 0.8601

$$Average\ QDR_{PCE} = 1{,}866 - 40 f_{LCSI} - 132 f_{barrier} - 101 f_{TOD} - 205 f_{area} - 207 f_{CI} - 47 f_{regional}$$

Promising Model 3.01, Adj. R^2 = 0.8600

$$Average\ QDR_{PCE} = 1{,}867 - 42 f_{LCSI} - 134 f_{barrier} - 112 f_{TOD} - 234 f_{area} - 191 f_{CI}$$

where,

$Average\ QDR_{PCE}$ = average queue discharge flow rate (pcphpl),

f_{LCSI} = lane closure severity index; $\frac{1}{\#\ of\ open\ lanes * open\ ratio}$, where open ratio is the ratio of open lanes during construction to the total number of lanes,

$f_{barrier}$ = barrier type; concrete = 0, cone/barricade/drum = 1,

$f_{lateral\_12}$ = lateral distance from nearest open lane to the work zone; lateral distance – 12 feet,

f_{TOD} = time of day; day = 0, night = 1,

f_{area} = area type; urban =0, rural = 1,

f_{CI} = construction intensity; low = 0, high = 1, and

$f_{regional}$ = regional area; south = 0, north = 1.

5.5 Recommended Model

The main difference between the two most statistically valid models (1.01 and 3.01) was that model 3.01 did not have a regional coefficient. While both models had comparable statistical performance, 1.01 is recommended because it has a regional coefficient, which was a desirable characteristic based on feedback from regional work zone engineers. Model 1.01 predicts a PCE QDR by adjusting a base value of 1,866 pcphpl to account for the effect of six work-zone factors: lane closure severity index, barrier type, time of day, area type, construction intensity, and northern/southern region.

Figure 14. Recommended Model

Recommended Model 1.01, Adj. R^2 = 0.8601

$$Average\ QDR_{PCE} = 1{,}866 - 40f_{LCSI} - 132f_{barrier} - 101f_{TOD} - 205f_{area} - 207f_{CI} - 47f_{regional}$$

where,

$Average\ QDR_{PCE}$ = average queue discharge flow rate (pcphpl),

f_{LCSI} = lane closure severity index; $\frac{1}{\#\ of\ open\ lanes * open\ ratio}$, where open ratio is the ratio of open lanes during construction to the total number of lanes,

$f_{barrier}$ = barrier type; concrete = 0, cone/barricade/drum = 1,

f_{TOD} = time of day; day = 0, night = 1,

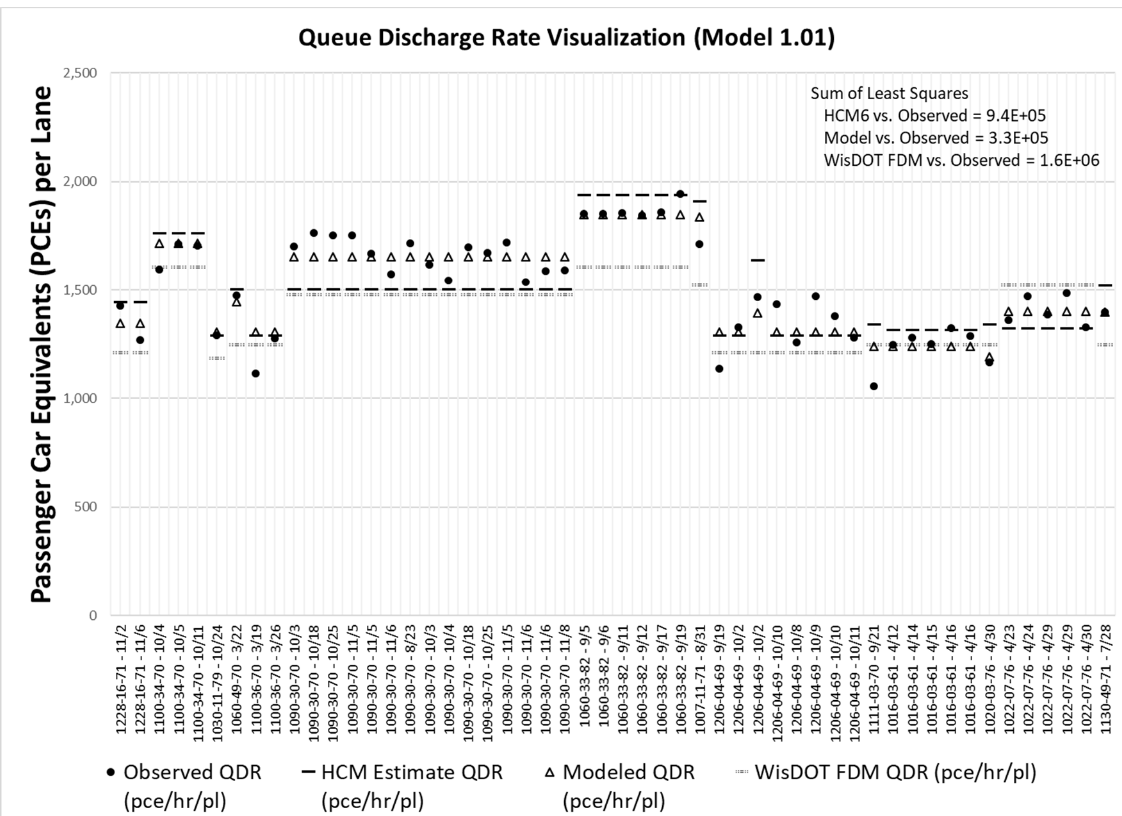
f_{area} = area type; urban =0, rural = 1,

f_{CI} = construction intensity; low = 0, high = 1, and

$f_{regional}$ = regional area; south = 0, north = 1.

The results of the recommended model 1.01 are illustrated in Figure 15 below and Appendix B in larger scale and are compared to the HCM 6th Edition's model results, the WisDOT model results, and to the observed QDRs at the 52 work zone samples analyzed in this study. The proposed model fit Wisconsin's observed data closer than the HCM 6th Edition model had predicted.

Figure 15. Recommended Model (1.01) Comparisons.



The recommended model's estimates were representative of the average QDRs at work zone projects with only a few observations and for projects with several observations. The model represents average conditions, as the day to day QDR of a work zone site fluctuates, such as seen on project 1090-30-70 on I-43 in the SE Region.

5.5.1 Passenger Car Equivalents (PCEs)

The proposed model outputs average QDR in passenger car equivalents per hour per lane. In Wisconsin, where the terrain is generally level, each heavy vehicle is equivalent to two passenger vehicles using HCM 6th Edition methodology. To convert the average QDR to vehicles per hour per lane, equations 25-41 and 25-42 from the HCM 6th Edition are used [3].

Figure 16. HCM 6th Edition PCE Volume & Heavy Vehicle Factor Equations

$$v_{i,pce} = \frac{v_i}{f_{HV}} \qquad f_{HV} = \frac{1}{1+ P_T(E_T-1)}$$

where,

$v_{i,pce}$ = demand flow rate for movement (pc/h),

v_i = demand flow rate for movement (veh/h),

f_{HV} = heavy-vehicle adjustment factor,

P_T = proportion of demand volume that consists of heavy vehicles, and

E_T = passenger car equivalent for heavy vehicles (2.0 for level terrain and 3.0 for rolling terrain, HCM 6th Edition).

To illustrate how volumes are converted to PCEs and PCEs back to volumes, the following examples are provided.

Vehicle Volume to PCE Volume Conversion

If a roadway was found to have a volume with an average flow rate of 1,200 vphpl and a heavy vehicle percentage of 10 percent, the equation to calculate the average flow rate in PCEs is as follows:

Figure 17. Vehicle Volume to PCE Volume Conversion Example

$$v_{i,pce} = \frac{1{,}200\ vphpl}{\frac{1}{1+0.10(2-1)}} = 1{,}320\ pcphpl$$

PCE Volume to Vehicle Volume Conversion

If a work zone was found to have an average passenger car equivalent QDR of 1,500 pcphpl and the roadway had a heavy vehicle percentage of 5 percent, the equation to calculate average QDR in vphpl is as follows:

Figure 18. PCE Volume to Vehicle Volume Conversion Example

$$v_i = 1{,}500\ pcphpl * \frac{1}{1+0.05(2-1)} = 1{,}428\ vphp$$

5.6 Regression Conclusions

The results of the regression analysis showed that a linear equation calibrated to Wisconsin-specific data statistically fit the average QDR more accurately than HCM 6th Edition's equation based on national data. The regression analysis also showed that the QDRs observed in specific WisDOT regions were not impactful and consistent enough to warrant individual regional factors in the recommended model. However, when the regions were grouped by north and south, as in the recommended model, a regional area factor subtracting 47 pcphpl in the northern regions was included.

The recommended model predicts a QDR by adjusting a base value of 1,866 pcphpl to account for the effect of six work-zone factors: lane closure severity index, barrier type, time of day, area type, construction intensity, and regional area. These are the same factors in the HCM 6th Edition's equation except that construction intensity was used in lieu of lateral clearance and that the additional regional factor (north or south) was added.

Due to the limited work zone QDR data available in the northern regions, future data collection and analysis could be considered to see if individual regional factors are warranted.

QDR versus Pre-Breakdown Capacity

The recommended capacity model, which was incorporated into the tools developed in this study is based on the QDR and not the pre-breakdown capacity of work zone sites. Queues occur during breakdown conditions when the QDR dictates the capacity of the work zone. Pre-breakdown capacity, which was calculated when possible in this study (see calculations on worksheets in Appendix A), was highly variably and often exceeded the QDR for only a few minutes right before queuing occurred. As a result, QDR is the recommended capacity parameter in this study for estimating the capacity, queuing, delay, and road user costs associated with work zone travel delays.

CHAPTER 6: TOOL DEVELOPMENT

6.1 PURPOSE

WisDOT had a need for a universal work zone tool that could be used consistently throughout the state to estimate capacity, queues, delay, and road user costs. Accurately estimating freeway work zone capacity, queuing, delay, and road user costs is critically important in safety and efficiently planning lane closures at freeway work zones. Doing so requires a systematic and structured approach to ensure work zone traffic management consistency statewide.

To standardize how freeway work zone capacity analysis is performed, WisDOT conducted this study which included a review best practices for estimating work zone capacity, collecting work zone data in the state of Wisconsin, and developing a model and tool for estimating work zone capacity, queuing, delay, and road user costs.

The development of a freeway work zone capacity analysis tool was done with the purpose of standardizing the methodology and deliverables for freeway work zone analysis in all WisDOT regions. Statewide work zone engineers shared their current tools for work zone analysis with the project team. The project team worked with the work zone engineers to identify the limitations of existing tools, identify their needs in a new tool, and to determine a method for easily importing traffic volume data into the tool.

Two new tools were developed. The first tool is used for analyzing weekly information. The second tool is used for analyzing annual information. The tools were developed in Microsoft Excel® and utilized Visual Basic (VBA) Programming. Both tools have similar interfaces, use the Wisconsin-Specific Work Zone Model outlined in Chapter 5, have traffic volume import functions, and output information about capacity, delay, queues, and road user costs.

6.2 TOOL INSTRUCTIONS

Instructions for using the WEEKLY tool and the ANNUAL tool are provided in this section. Both tools are locked (i.e., protected in Microsoft Excel®) and only enable editing in the input cells, which are shaded light yellow.

6.2.1 Input Tab

Both tools have identical input pages, which serve as the interface for entering information about the site and work zone characteristics. On the inputs tab, there are five sections: Project Inputs, Closure Inputs, Duration Inputs, Results, and Notes.

Project Inputs

This includes the base information about the project site: Region, County, Construction ID, Highway, Direction of Travel, Area Type, and the Normal (non-work zone) Posted Speed Limit.

Closure Inputs

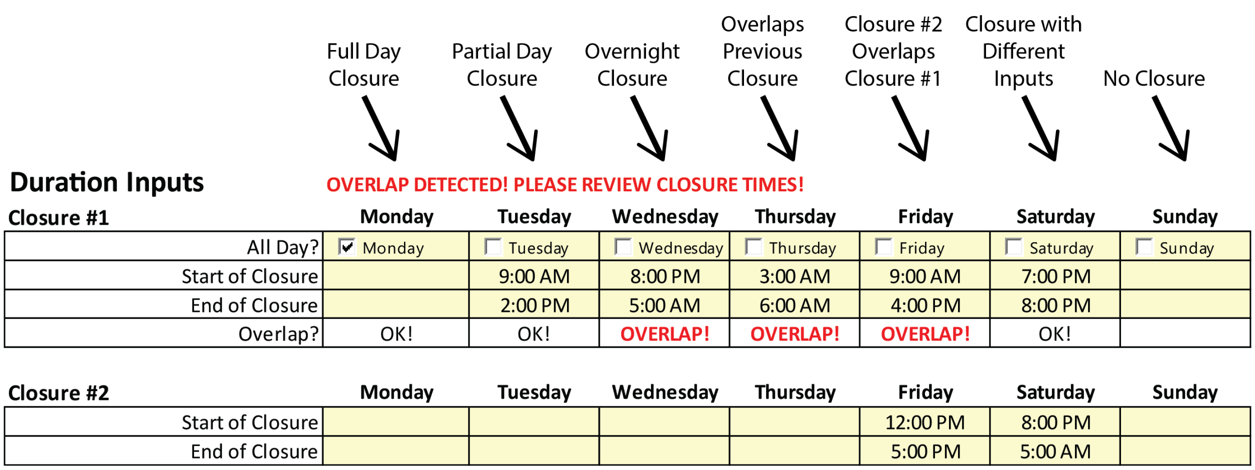
The type of closure, barrier type, and construction intensity is entered here. The lane closure type represents the number of lanes open prior to and in the closure, such as a 2 to 1 closure. The barrier type represents type of barrier used in the work zone: "hard" representing concrete temporary portable barrier and "soft" representing cones and drums. Construction intensity can be set to "low" or "high". Low construction intensity is defined as construction work that is unlikely to substantially impact the behavior of drivers traversing the work zone. High construction intensity is defined as active construction work that was likely to substantially impact the behavior of drivers. If there are circumstances that do not fall within the categories, there is a manual capacity adjustment input discussed later that may be used to adjust the model.

Duration Inputs

The duration input enables the user flexibility to enter a variety of work zone closure scenarios. A work zone site may have different closure types on different days of the week or may even have different closure types on the same day. For example, a 4 to 3 lane closure might be used during the afternoon but modified to a 4 to 2 closure later in the evening. The tool has been designed to give the user the ability to enter lane closures for each of the seven days in a week, and up to four different lane closure types per day.

Figure 19 has an illustration of different lane closure scenarios. If a user has two closures that overlap each other in time, an "overlap" error notification will appear.

Figure 19. Lane Closure Duration Inputs with Overlap Error



Closure #1	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
All Day?	☑ Monday	☐ Tuesday	☐ Wednesday	☐ Thursday	☐ Friday	☐ Saturday	☐ Sunday
Start of Closure		9:00 AM	8:00 PM	3:00 AM	9:00 AM	7:00 PM	
End of Closure		2:00 PM	5:00 AM	6:00 AM	4:00 PM	8:00 PM	
Overlap?	OK!	OK!	OVERLAP!	OVERLAP!	OVERLAP!	OK!	

Closure #2	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Start of Closure					12:00 PM	8:00 PM	
End of Closure					5:00 PM	5:00 AM	

Results

The results section of the tools shows the estimated daytime and nighttime capacity of the work zone for up to four different lane closure scenarios. For the purpose of consistency, nighttime is considered from 6pm to 6am. The capacity impacts of the various other model factors are also shown in the results section.

There is a manual input adjustment (in PCEs) that is also provided in the results section. The manual adjustment should be used with caution, but might be helpful in situations that do not fall into a specific category – for example, a work zone with medium construction intensity that may not see the same capacity impacts as a site with high construction intensity.

Notes

The notes section provides an area for the user to document any pertinent information about the project.

Print Button

A print button is provided on the inputs tab in both the WEEKLY and ANNUAL tools. In the WEEKLY tool, the print button will print the inputs tab and the weekly chart output. In the ANNUAL tool, the print button will print only the inputs tab as the outputs for a whole year of data is best viewed within the tool.

6.2.2 Volume Import Tab

Both tools have volume import functions that enable the user to select a file to import after pressing the desired "import data" button. The WEEKLY tool can import data from two sources: a Jackalope SQL Weekly or 48-hour Excel file, or from a WisTransPortal Weekly or 48-hour Excel file. The ANNUAL tool can import data from a Jackalope SQL Annual Excel file.

The volume import tab includes three adjustment factors: a location adjustment factor, a growth adjustment factor, and a diversion adjustment percentage.

Location Adjustment Factor

The location adjustment factor enables the user to adjust volume from a nearby count site that is not at the exact location of the closure. For example, if an AADT at a nearby count location is 60,000-vpd and the AADT at closure location is 90,000-vpd (but continuous count information is not available), input 1.5 for location adjustment factor (90,000/60,000).

Growth Adjustment Factor

The growth adjustment factor enables the user to adjust volume by a growth factor. This can be useful in sensitivity analysis or if there is expected growth in an area.

Diversion Percentage Adjustment

The diversion percentage adjustment enables a user to estimate how much traffic will divert to a different route prior to the work zone.

6.2.3 Calculations Tab

The calculations tab contains tables where the queue miles, queue minutes, and queue costs are calculated for both directions for each hour of analysis. Queue miles were estimated using the queue model discussed in Section 6.3. The queue model estimates average headways based on multiple factors regarding the specific work zone being analyzed. The underlying premise of the model is that a faster moving queue will have larger spacing between vehicles than a slower moving queue.

The growth and diversion factors are also editable on the calculations tab and the changes will be reflected on the other tabs.

6.2.4 Queue Miles, Queue Minutes, Queue Costs Charts

The queue miles, queue minutes, and queue costs are the three main outputs of the tool. On the WEEKLY tool, the charts are contained on a single tab called "Weekly Chart". On the ANNUAL tool, each chart has its own respective tab. The charts show results by day and by hour in tabular format for both directions. For each output table, cells are highlighted a certain color based on a range provided. The growth and diversion factors are also editable on the charts tab(s) and the changes will be reflected on the other tabs.

6.3 Queue Length Model

When queues form at a work zone, they are generally characterized as moving queues rather than stand-still queues. Stand-still queues often occur at signalized intersections and have their length commonly estimated by assuming 25 feet per vehicle. By applying this assumption to moving queues at work zones, the length of work zone queues can be underestimated. Moving queues typically observe more space between vehicles than stand-still queues, and the faster the average speed of a moving queue, the larger the spacing becomes.

WisDOT previously used a fixed value, as many other states do, to represent the average spacing of vehicles. A fixed value, however, does not account for differences in queue spacing resulting from the speeds of the roadway and the severity of the closure. For example, a queue in a 4 lane to 3 lane closure would be expected to move faster than a queue stemming from a 3 lane to 1 lane closure. Thus, to more accurately model queues, a model based on the speed-density relationship pertaining to roadway speed and closure was developed in this project.

6.3.1 Queue Model Development

Internationally, there are a multitude of published methodologies for estimating queue length. Some, such as the Wiedemann 99 car following model [14], are used in microsimulation software such as VISSIM, and are data intensive and complicated. Others models simply rely on a fixed value of distance per passenger car equivalent (PCE) multiplied by the number of vehicles per lane of queue.

The project team searched for a methodology that would offer more accuracy than assuming a fixed value of length per PCE but would also be feasible using data inputs in WisDOT's work zone capacity model.

The proposed solution was identified in a generalized linear speed-density relationship published in the HCM 6th Edition [3] and a generalized average queue speed equation published in "A Primer on Work Zone Safety and Mobility Performance Measurement" by the Federal Highway Administration [15]. Using the relationships displayed in Figure 20 [3] and Figure 21 [15], the project team developed a model for average PCE headway (the average distance between the front axle of a vehicle and the front axle of the vehicle following behind it) as a function of free-flow speed, free-flow capacity, and work zone capacity.

Figure 20. Speed/Density Relationship (HCM 6th Edition Exhibit 4-2)

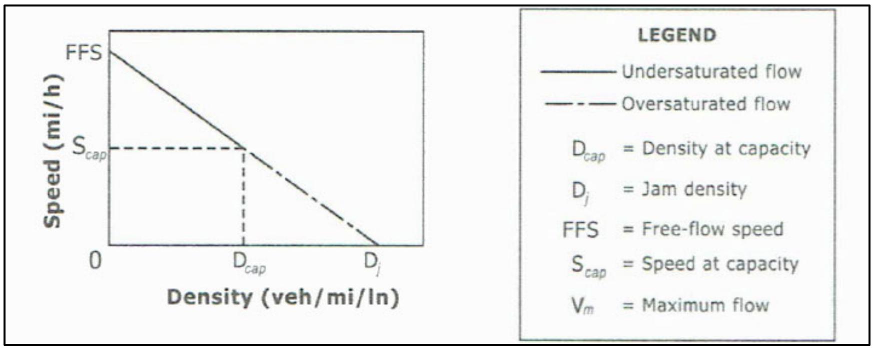
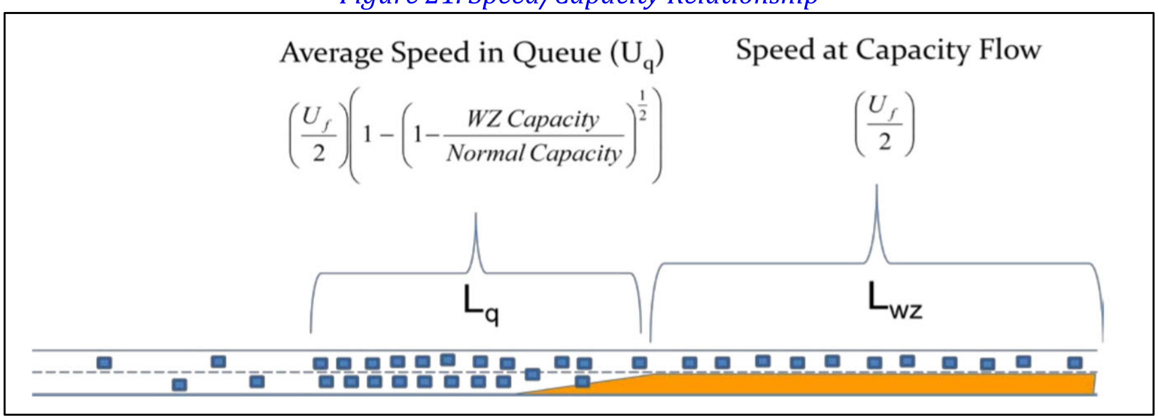


Figure 21. Speed/Capacity Relationship



U_f = Free-Flow Speed (MPH)

The proposed model has the following assumptions [3]:

- A jam density of 190 PCE/mi (default value in HCM 6th Edition for traffic at zero speed, which equates to a spacing of 27.8 feet per PCE), and
- A free-flow density of 20 PCE/mi (equates to a basic freeway segment operation LOS C, which is the lowest LOS level free-flow speeds typically occur).

Inserting these assumptions into the linear speed/density model previously shown in Figure 20 yields the chart in Figure 22 and equation in Figure 23 relating speed to average PCE headway (i.e., spacing).

Figure 22. Average PCE Headway vs. Speed

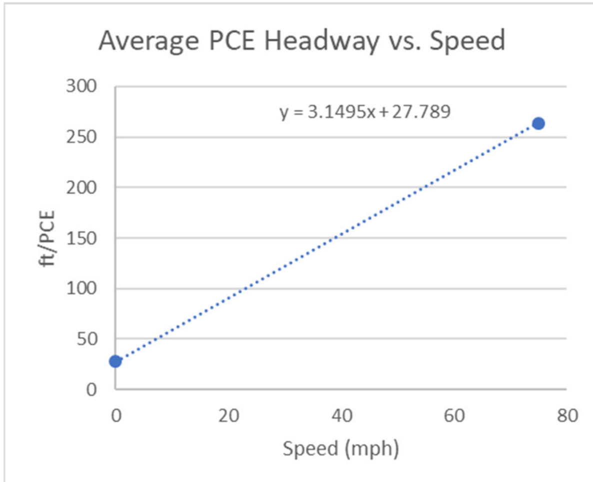


Figure 23. Average PCE Headway Equation

$$Average\ PCE\ Headway = 3.1495 * Speed + 27.789$$

To estimate the average speed of the queue, "A Primer on Work Zone Safety and Mobility Performance Measurement" by FHWA [15] shows the average speed in a work zone queue can be estimated by the equation in Figure 24.

Figure 24. Average Work Zone Queue Speed Equation

$$Average\ WZ\ Queue\ Speed = \left(\frac{FFS}{2}\right)\left(1 - \left(1 - \frac{WZ\ QDR * \#\ of\ open\ lanes}{FFC * \#\ of\ normal\ lanes}\right)^{\frac{1}{2}}\right)$$

where,

FFS = free flow speed (mi/hr),
WZ QDR = work zone queue discharge rate (pc/hr/ln), and
FFC = free-flow capacity (pc/hr/ln).

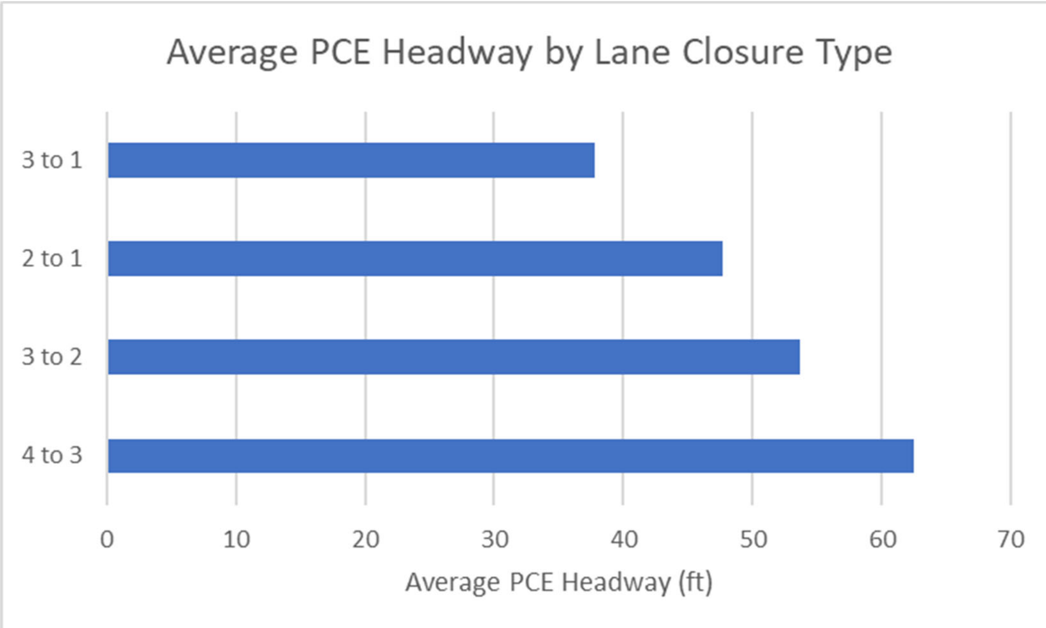
By combing the two equations in Figures 23 & 24, average PCE headway can be estimated by the following equation shown in Figure 25.

Figure 25. Average PCE Headway Equation

$$Average\ PCE\ Headway = (3.1495)\left(\frac{FFS}{2}\right)\left(1 - \left(1 - \frac{WZ\ QDR * \#\ of\ open\ lanes}{FFC * \#\ of\ normal\ lanes}\right)^{\frac{1}{2}}\right) + 27.789$$

Applying this model to data collected for the 52 work zone samples in this work zone capacity study resulted in the average PCE headways for the analyzed lane closure types as shown in Figure 26. The results are consistent with the expectations that the average headway per PCE is greater than 25 feet, and that more severe closures would result in slower speeds and tighter vehicle spacing. Less severe closures, such as a 4 to 3 closure, would be expected to have faster speeds and greater spacing between vehicles.

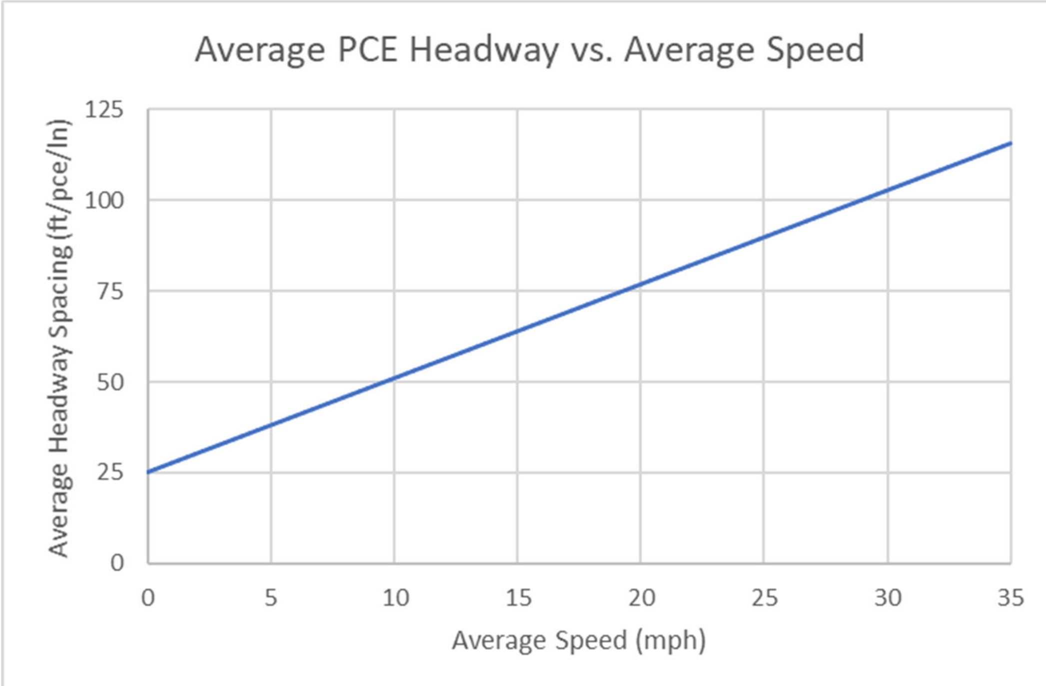
Figure 26. Average PCE Headway by Lane Closure Type



6.3.2 Queue Model Validation

As discussed earlier, conditions that would enable queue spacing observations in the field were limited in this study due to the lack of queues that reached upstream camera locations and because queues were often impacted by upstream on or off-ramps. The project team was able to obtain queue information on projects 1090-30-70 (2 to 1) and 1060-33-82 (4 to 3) and the data is shown in Appendix D. The queue model estimates a PCE headway of approximately 50-feet for project 1090-30-70, while the average of the nine observations for this project was approximately 56 feet. The queue model estimates a PCE headway of approximately 63-feet for project 1060-33-82, while the average of the 10 observations for this project was approximately 64-feet. The results of the queue analysis showed that PCE headways observed in the field were consistent with the model's methodology and that they were larger than 30-feet or 40-feet static value previously used in WisDOT tools. Also, as shown in Figure 27, the trendline from the 19 queue observations show that higher speeds lead to larger headway spacing, which was expected.

Figure 27. Queue Analysis Average Headway vs. Average Speed based on 19 Observations



6.3.3 Early Merging Disclaimer

It should be noted that the queue model assumes full utilization of the available lanes for queuing. There are some circumstances motorists may merge much earlier than the designated taper. When this happens, the resulting queue may be longer than the model's prediction because vehicles are stacking in less lanes than are available.

6.3.4 Queue Model Conclusion

The proposed model for estimating the average spacing of vehicles in queues in work zones shown in Figure 25 is based on relationships found in the HCM 6th Edition [3] and FHWA publications [15]. It is expected to provide more accurate estimates of queue length than using a fixed value (e.g., 40 feet per PCE) in all work zone situations yet is derived from information already available in the work zone capacity tool.

The model has been programmed into the WisDOT work zone capacity tools and is used to calculate the anticipated queue length in miles. As noted earlier, if early merging is suspected, the resulting queue may be longer than the model's prediction because the model assumes all available lanes are used for queue storage.

CHAPTER 7: CONCLUSIONS

The purpose of this project was to help WisDOT develop a tool to consistently analyze work zone capacity, queues, delay, and road user costs. Through a combination of research, data collection at work zones throughout the state, collaboration with WisDOT's regional work zone engineers, and regression modeling analysis, two new tools were developed in Microsoft Excel® to predict work zone capacity parameters for WEEKLY and ANNUAL scenarios, respectively.

The findings of this study showed that using Wisconsin-specific work zone data enabled the calibration of the HCM 6th Edition's work zone capacity model with customizations asked for by WisDOT's regional work zone engineers. The recommended model includes coefficients for Northern WisDOT regions versus Southern WisDOT regions and a coefficient for work zone intensity (high or low) in lieu of the lateral clearance coefficient of HCM 6th Edition's model. Defining and measuring lateral clearance is challenging due to the inherent variability within work zone areas. The recommended model is based on 52 work zone capacity observations and a queuing estimation methodology that is a function of the speed-density relationship of a moving queue.

The tools developed as part of this study enable work zone capacities, queues, delay, and road user costs to be estimated using a consistent methodology. The tools were designed to be user friendly, yet have advanced capabilities, such as the ability to import weekly or annual volume data and enter up to four different lane closure scenarios in a single day. All calculations are performed using passenger car equivalent (PCE) volumes to promote consistent interpretation. The tools also have adjustments for volume growth and traffic diversion parameters. Lastly, there is a manual adjustment that should be used with caution but is available if engineering judgement dictate's its use.

The analysis performed in this study enabled the calibration and customization of the HCM 6th Edition's capacity model equation to be more representative of conditions observed in Wisconsin work zones. From one day to the next, the capacity of work zones has a degree of variability, and the model and tools developed in this study are meant to represent average conditions. The outputs of the tools should be considered as such, an expectation of the average conditions with the understanding that on a day to day basis, there will be some variability in the capacity, queues, delay, and road user costs of a particular site. The model also assumes that all available lanes will be used for queuing. Therefore, in situations where early merging is anticipated and vehicles do not use all available lanes, queue expectations should be adjusted based on anticipated lane usage.

In conclusion, the recommended Work Zone Capacity Model along with the WEEKLY and ANNUAL tools provide a consistent means for calculating work zone capacity, queuing, delay, and road user costs in Wisconsin.

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APPENDIX A

CAPACITY AND QUEUE DISCHARGE RATE SPREADSHEETS FOR 52 WORK ZONE SAMPLES

Work Zone Capacity
Queue Discharge Flow Rates

IH 43 NB Milwaukee County Daphne Road (1228-16-71)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	NB
Construction ID:	1228-16-71
Nearest Crossroad:	Daphne Road
County:	Milwaukee
Date:	11/2/2018
Day of Week:	Friday
Area Type:	Urban
Time of Day:	12:00 AM to 11:10 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Temp Pavement
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	6
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 PM
Time Closure Ended •	11:55 PM

Describe Construction Activity: During construction, I-43 will be maintained with two lanes in each direction with reduced shoulders, shifting of lanes, and reduced lane widths. Nighttime closures will be required for demolition, girder erection, deck forming, deck slab, sidewalk, and storm sewer construction.

Notes: No prebreakdown analysis.

PRE-BREAKDOWN CAPACITY

Select Times - >	*Start Time:*	12:00 AM	End Time:	12:05 AM
	Max Pre-Breakdown Capacity (Observed)			
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
0	*0*	per 5 minutes	*0*	*0*
0	*0*	per 15 minutes	*0*	*0*
0	*0*	per hour	*0*	*0*
0	***0***	**Max Flow Rate$_s$***	***0***	***0***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

		Pre-Breakdown Capacity (Estimated)		
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
132	*132*	per 5 minutes	*137*	*137*
396	*396*	per 15 minutes	*411*	*411*
1,592	***1,592***	**per hour**	***1,649***	***1,649***
1,583	***1,583***	**Max Flow Rate$_s$***	***1,643***	***1,643***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

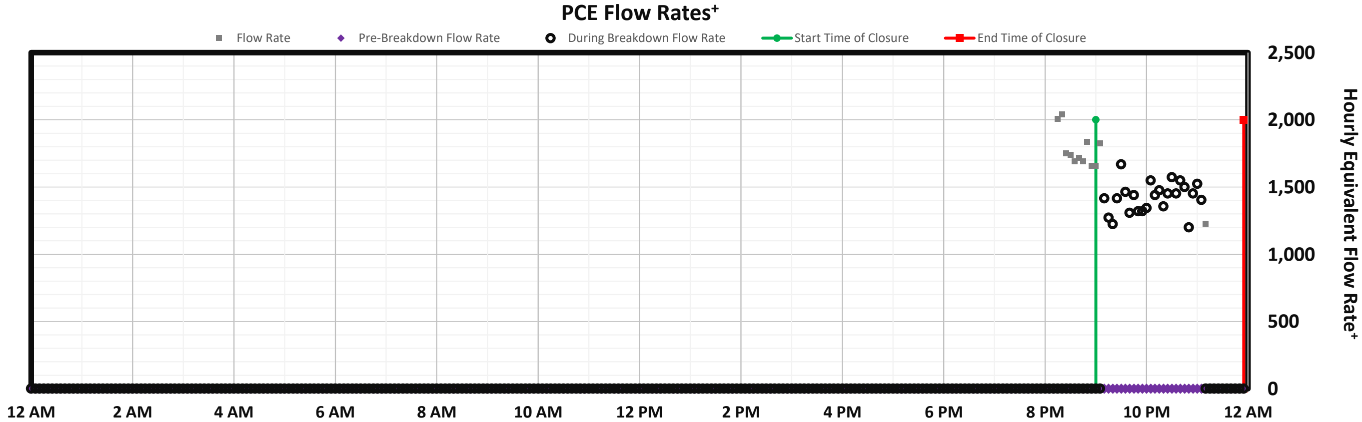
Select Times - >	*Start Time:*	9:10 PM	End Time:	11:10 PM
		Queue Discharge Flow Rates (Collected Near Bottleneck)		
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
114 *per 5 minutes*	**3.8%**	**41%**	**59%**	**118** *per 5 minutes*

		---- Minimum Observed Queue Discharge Rate ----		
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
96	*96*	per 5 minutes	*100*	*100*
315	*315*	per 15 minutes	*326*	*326*
1,339	*1,339*	per hour	*1,395*	*1,395*

		Average Observed Queue Discharge Rate		
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
114	*114*	per 5 minutes	*118*	*118*
343	*343*	per 15 minutes	*356*	*356*
1,379	***1,379***	**per hour**	***1,428***	***1,428***
1,389	***1,389***	**HCM 6 Estimate**	***1,442***	***1,442***

		Maximum Observed Queue Discharge Rate		
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
130	*130*	per 5 minutes	*139*	*139*
371	*371*	per 15 minutes	*381*	*381*
1,414	*1,414*	per hour	*1,460*	*1,460*

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 43 NB Milwaukee County Daphne Road (1228-16-71)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.142

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	NB
Construction ID:	1228-16-71
Nearest Crossroad:	Daphne Road
County:	Milwaukee
Date:	11/6/2018
Day of Week:	Tuesday
Area Type:	Urban
Time of Day:	9:00 PM to 10:55 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Temp Pavement
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	6
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 PM
Time Closure Ended •	11:55 PM

Describe Construction Activity: During construction, I-43 will be maintained with two lanes in each direction with reduced shoulders, shifting of lanes, and reduced lane widths. Nighttime closures will be required for demolition, girder erection, deck forming, deck slab, sidewalk, and storm sewer construction.

Notes: Closure began at 9pm.
Good candidate for both analysis. Very good example with good CCTV footage at beginning of taper.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	9:00 PM	End Time:	10:20 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
125	*125*	per 5 minutes	*130*	*130*
350	*350*	per 15 minutes	*370*	*370*
1,238	*1,238*	per hour	*1,324*	*1,324*
1,400	*1,400*	Max Flow Rate$_s$*	*1,480*	*1,480*

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
117	*117*	per 5 minutes	*122*	*122*
349	*349*	per 15 minutes	*363*	*363*
1,405	***1,405***	**per hour**	***1,467***	***1,467***
1,398	*1,398*	Max Flow Rate$_s$*	*1,452*	*1,452*

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

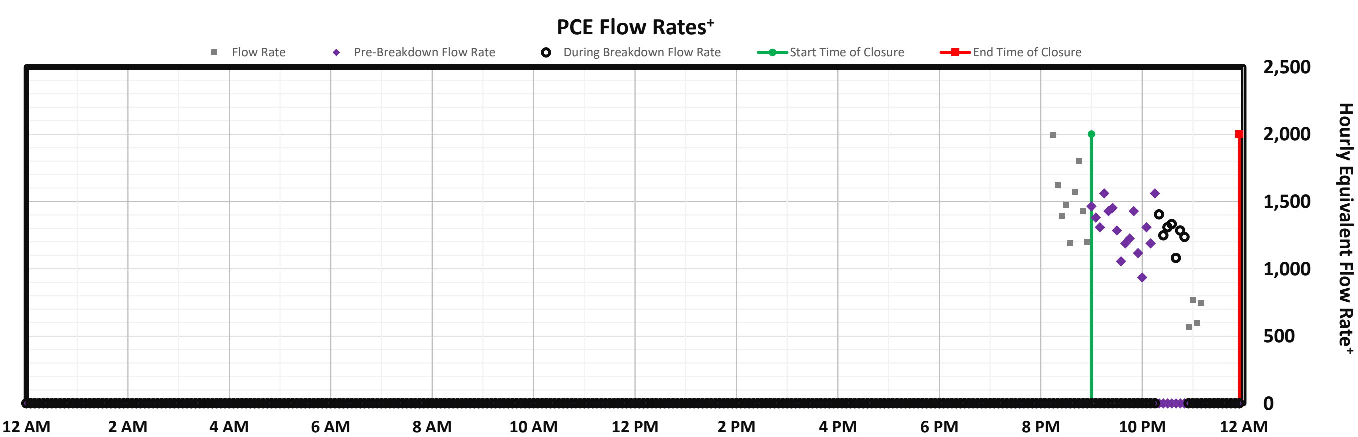
DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	10:20 PM	End Time:	10:55 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
101 *per 5 minutes*	4.4%	32%	68%	106 *per 5 minutes*

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
86	*86*	per 5 minutes	*90*	*90*
286	*286*	per 15 minutes	*300*	*300*
1,217	*1,217*	per hour	*1,270*	*1,270*

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
101	*101*	per 5 minutes	*106*	*106*
303	*303*	per 15 minutes	*314*	*314*
1,217	***1,217***	**per hour**	***1,270***	***1,270***
1,382	*1,382*	HCM 6 Estimate	*1,442*	*1,442*

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
112	*112*	per 5 minutes	*117*	*117*
314	*314*	per 15 minutes	*330*	*330*
1,217	*1,217*	per hour	*1,270*	*1,270*



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 894 SB Milwaukee County Loc #1 - Beloit Rd (1100-34-70)

PCE Conversion Factor: 2.00

Pre-Breakdown Capacity Drop Factor (PBCDF): 0.134

0.109 <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 894
Direction	SB
Construction ID:	1100-34-70
Nearest Crossroad:	Loc #1 - Beloit Rd
County:	Milwaukee
Date:	10/4/2018
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	1:30 PM to 6:00 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	4
Work Zone Speed Limit	50 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	7
Downstream Ramps (within 3mi)	6
Construction Duration (short/long)	Long
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	4
# of lanes open during construction	3
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Outside and inside shoulders and median reconditioning and drainage system improvements; Resurface and restripe to 4 lanes in each direction

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	1:30 PM	End Time:	3:40 PM

Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
140	*420*	per 5 minutes	*160*	*479*
395	*1,185*	per 15 minutes	*448*	*1,344*
1,472	*4,415*	per hour	*1,678*	*5,034*
1,580	**4,740**	**Max Flow Rate$_s$***	**1,792**	**5,376**

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
139	*417*	per 5 minutes	*154*	*461*
418	*1,254*	per 15 minutes	*462*	*1,386*
1,664	**4,992**	**per hour**	**1,843**	**5,529**
1,672	**5,017**	**Max Flow Rate$_s$***	**1,848**	**5,545**

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	3:40 PM	End Time:	6:00 PM

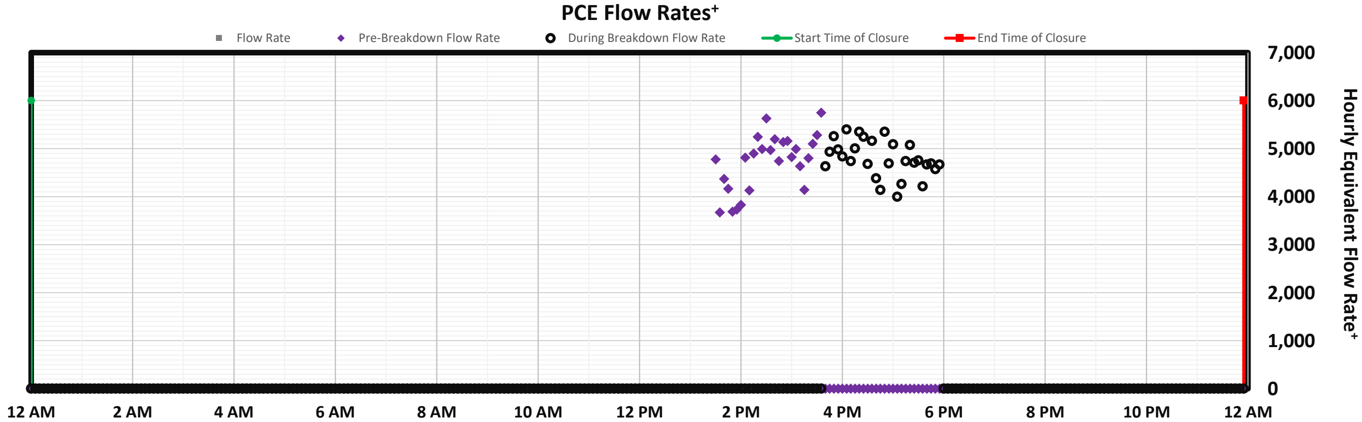
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
361 *per 5 minutes*	**10.6%**	**35%**	**65%**	**399** *per 5 minutes*

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
100	*301*	per 5 minutes	*111*	*333*
323	*969*	per 15 minutes	*361*	*1,083*
1,386	*4,159*	per hour	*1,539*	*4,616*

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
120	*361*	per 5 minutes	*133*	*399*
362	*1,086*	per 15 minutes	*400*	*1,200*
1,441	**4,323**	**per hour**	**1,596**	**4,788**
1,591	**4,773**	**HCM 6 Estimate**	**1,759**	**5,278**

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
137	*411*	per 5 minutes	*150*	*450*
396	*1,187*	per 15 minutes	*433*	*1,300*
1,517	*4,550*	per hour	*1,673*	*5,018*

PCE Flow Rates+



+ **Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.**

Work Zone Capacity
Queue Discharge Flow Rates

IH 894 SB Milwaukee County Loc #1 - Beloit Rd (1100-34-70)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.114

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 894
Direction	SB
Construction ID:	1100-34-70
Nearest Crossroad:	Loc #1 - Beloit Rd
County:	Milwaukee
Date:	10/5/2018
Day of Week:	Friday
Area Type:	Urban
Time of Day:	1:15 PM to 5:50 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	4
Work Zone Speed Limit	50 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	7
Downstream Ramps (within 3mi)	6
Construction Duration (short/long)	Long
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	4
# of lanes open during construction	3
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Outside and inside shoulders and median reconditioning and drainage system improvements; Resurface and restripe to 4 lanes in each direction

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	*Start Time:*	1:15 PM	End Time:	3:40 PM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
152	*455*	per 5 minutes	*169*	*506*
433	*1,300*	per 15 minutes	*484*	*1,451*
1,594	*4,781*	per hour	*1,779*	*5,338*
1,733	***5,200***	**Max Flow Rate$_s$***	***1,935***	***5,804***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
151	*453*	per 5 minutes	*165*	*496*
451	*1,354*	per 15 minutes	*495*	*1,485*
1,804	***5,413***	**per hour**	***1,980***	***5,939***
1,806	***5,417***	**Max Flow Rate$_s$***	***1,980***	***5,941***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	*Start Time:*	3:40 PM	End Time:	5:50 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
392 *per 5 minutes*	9.6%	32%	68%	430 *per 5 minutes*

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
116	*349*	per 5 minutes	*129*	*387*
377	*1,130*	per 15 minutes	*407*	*1,220*
1,547	*4,640*	per hour	*1,692*	*5,076*

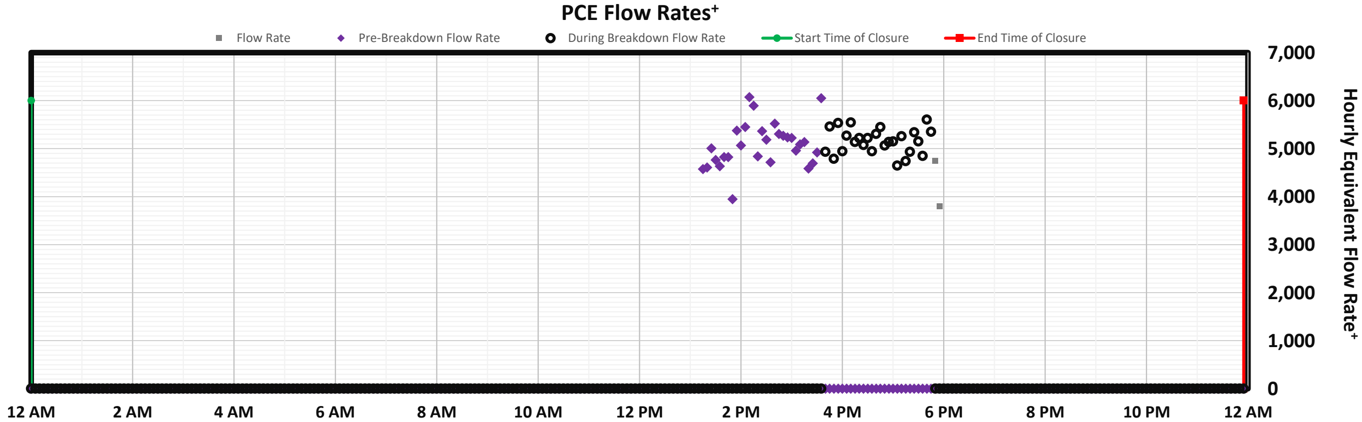
---------------- Average Observed Queue Discharge Rate ----------------

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
131	*392*	per 5 minutes	*143*	*430*
391	*1,173*	per 15 minutes	*429*	*1,286*
1,562	***4,687***	**per hour**	***1,715***	***5,144***
1,605	***4,815***	**HCM 6 Estimate**	***1,759***	***5,278***

-------------------------- Maximum Observed Queue Discharge Rate --------------------------

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
143	*428*	per 5 minutes	*156*	*467*
402	*1,206*	per 15 minutes	*443*	*1,329*
1,577	*4,732*	per hour	*1,742*	*5,225*

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates
IH 894 SB Milwaukee County Beloit Road (1100-34-70)

PCE Conversion Factor: **2.00**

Pre-Breakdown Capacity Drop Factor (PBCDF): **0.134**

0.075 <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 894
Direction	SB
Construction ID:	1100-34-70
Nearest Crossroad:	Beloit Road
County:	Milwaukee
Date:	10/11/2018
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	2:15 PM to 4:00 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	4
Work Zone Speed Limit	50 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	7
Downstream Ramps (within 3mi)	6
Construction Duration (short/long)	Long
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	4
# of lanes open during construction	3
Lane widths	11 ft
Significant grade?	No
Time Closure Began	12:00 AM
Time Closure Ended	11:55 PM

Describe Construction Activity: Outside and inside shoulders and median reconditioning and drainage system improvements; Resurface and restripe to 4 lanes in each direction

Notes:

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	2:15 PM	End Time:	3:00 PM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
140	420	per 5 minutes	159	477
410	1,229	per 15 minutes	460	1,381
1,561	4,684	per hour	1,759	5,276
1,639	4,916	Max Flow Rate$_s$*	1,841	5,524

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
147	441	per 5 minutes	164	492
442	1,325	per 15 minutes	492	1,475
1,764	5,293	per hour	1,968	5,903
1,766	5,299	Max Flow Rate$_s$*	1,966	5,898

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times ->	Start Time:	3:00 PM	End Time:	4:00 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
382 per 5 minutes	11.5%	41%	59%	426 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
120	360	per 5 minutes	134	402
369	1,106	per 15 minutes	406	1,218
1,528	4,584	per hour	1,704	5,112

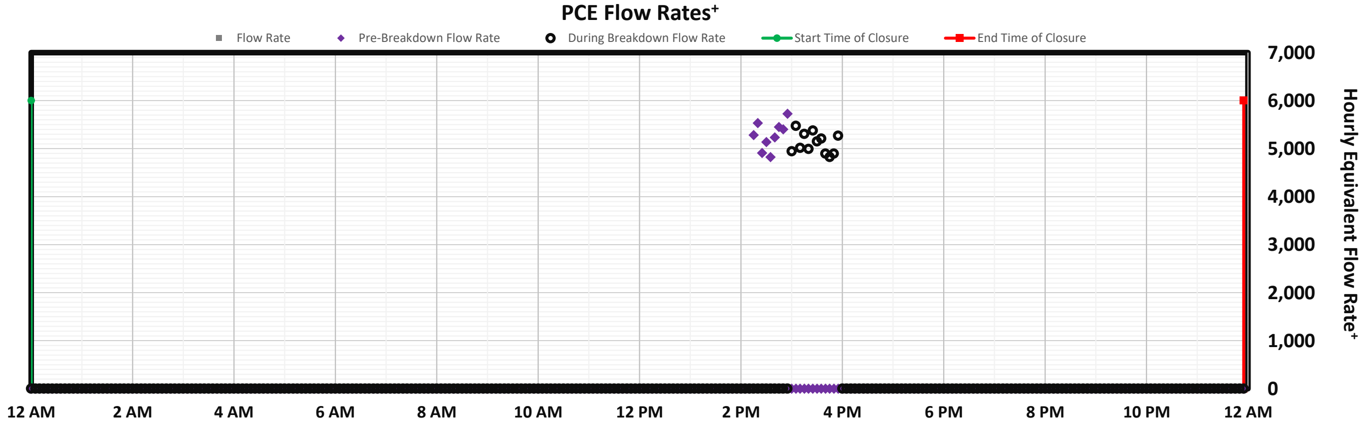
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
127	382	per 5 minutes	142	426
382	1,147	per 15 minutes	426	1,277
1,528	4,584	per hour	1,704	5,112
1,578	4,733	HCM 6 Estimate	1,759	5,278

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
137	411	per 5 minutes	152	456
399	1,196	per 15 minutes	439	1,316
1,528	4,584	per hour	1,704	5,112

PCE Flow Rates+



\+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 NB Milwaukee County Ryan Road (1030-11-79)

PCE Conversion Factor:	**2.00**
Pre-Breakdown Capacity Drop Factor (PBCDF):	**0.134**
<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]	

TRAFFIC ANALYSIS & DESIGN, INC. — WISCONSIN DEPARTMENT OF TRANSPORTATION

Version 1.8

Site Data	
Highway:	IH 94
Direction	NB
Construction ID:	1030-11-79
Nearest Crossroad:	Ryan Road
County:	Milwaukee
Date:	10/24/2018
Day of Week:	Wednesday
Area Type:	Urban
Time of Day:	9:45 PM to 10:25 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	60 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Uneven
Upstream Ramps (within 3mi)	3
Downstream Ramps (within 3mi)	4
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	3
# of lanes open during construction	1
Lane widths	10.5 ft
Significant grade?	No
Time Closure Began •	9:50 PM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Widening Freeway

Notes: Poor video quality on footage.

PRE-BREAKDOWN CAPACITY

Select Times - >	*Start Time:*	**9:45 PM**	End Time:	**9:50 PM**
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
98	*98*	per 5 minutes	*124*	*124*
0	*0*	per 15 minutes	*0*	*0*
1,176	*1,176*	per hour	*1,488*	*1,488*
0	***0***	**Max Flow Rate$_s$***	***0***	***0***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
97	*97*	per 5 minutes	*124*	*124*
294	*294*	per 15 minutes	*372*	*372*
1,168	***1,168***	**per hour**	***1,493***	***1,493***
1,174	***1,174***	**Max Flow Rate$_s$***	***1,489***	***1,489***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

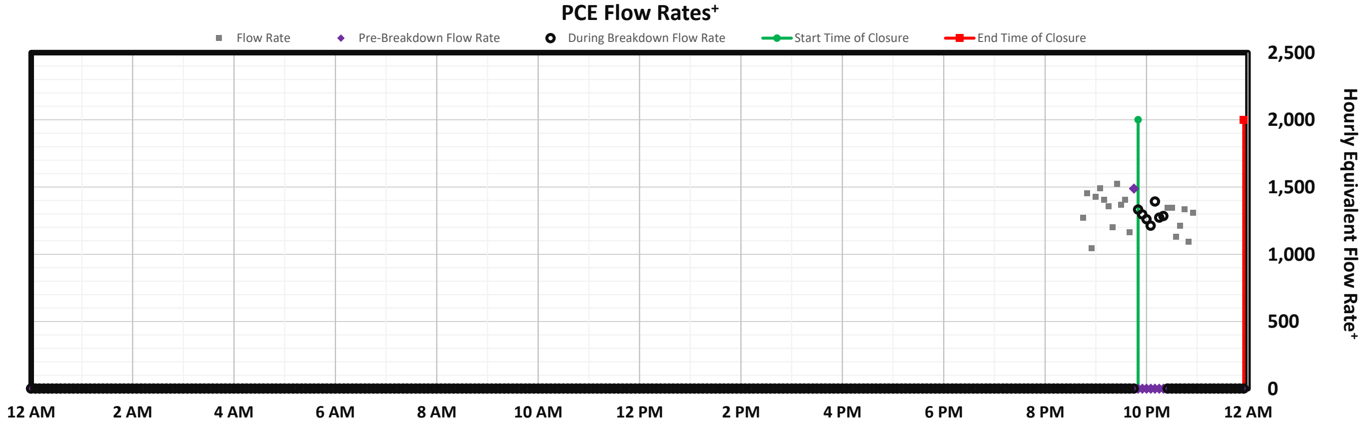
Select Times - >	*Start Time:*	**9:50 PM**	End Time:	**10:25 PM**
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
84 *per 5 minutes*	**27.8%**	**14%**	**86%**	**108** *per 5 minutes*

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
80	*80*	per 5 minutes	*101*	*101*
249	*249*	per 15 minutes	*314*	*314*
1,011	*1,011*	per hour	*1,293*	*1,293*

Average Observed Queue Discharge Rate				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
84	*84*	per 5 minutes	*108*	*108*
254	*254*	per 15 minutes	*322*	*322*
1,011	***1,011***	**per hour**	***1,293***	***1,293***
1,008	***1,008***	**HCM 6 Estimate**	***1,288***	***1,288***

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
88	*88*	per 5 minutes	*116*	*116*
259	*259*	per 15 minutes	*329*	*329*
1,011	*1,011*	per hour	*1,293*	*1,293*

PCE Flow Rates⁺



⁺ **Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.**

Work Zone Capacity
Queue Discharge Flow Rates

IH 94 EB Waukesha County CTH P (1060-49-70)

PCE Conversion Factor: **2.00**

Pre-Breakdown Capacity Drop Factor (PBCDF): **0.134**

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	EB
Construction ID:	1060-49-70
Nearest Crossroad:	CTH P
County:	Waukesha
Date:	3/22/2019
Day of Week:	Friday
Area Type:	Urban
Time of Day:	12:00 AM to 11:30 AM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	3
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity:
Moving operation for Median Cable Barrier and Guardrail installation with shoulder closures and crossing storm sewer work will inlcude nighttime lane closures

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
121	121	per 5 minutes	142	142
359	359	per 15 minutes	425	425
1,438	1,438	per hour	1,701	1,701
1,437	1,437	Max Flow Rate$_s$*	1,702	1,702

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	10:25 AM	End Time:	11:30 AM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
104 per 5 minutes	18.1%	37%	63%	123 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
74	74	per 5 minutes	93	93
242	242	per 15 minutes	303	303
1,241	1,241	per hour	1,470	1,470

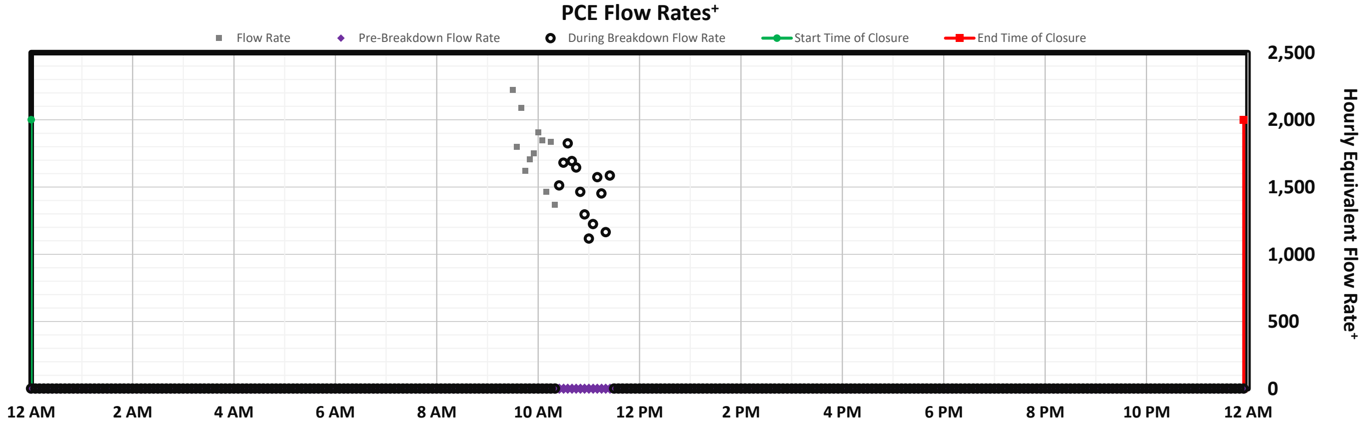
---- Average Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
104	104	per 5 minutes	123	123
311	311	per 15 minutes	368	368
1,246	1,246	per hour	1,473	1,473
1,271	1,271	HCM 6 Estimate	1,501	1,501

---- Maximum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
129	129	per 5 minutes	152	152
371	371	per 15 minutes	433	433
1,250	1,250	per hour	1,476	1,476

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates
IH 41 NB Waukesha County 124th Street (1100-36-70)

PCE Conversion Factor: 2.00

Pre-Breakdown Capacity Drop Factor (PBCDF): 0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

TADI TRAFFIC ANALYSIS & DESIGN, INC. — WISCONSIN DEPARTMENT OF TRANSPORTATION

Version 1.8

Site Data	
Highway:	IH 41
Direction	NB
Construction ID:	1100-36-70
Nearest Crossroad:	124th Street
County:	Waukesha
Date:	3/19/2019
Day of Week:	Tuesday
Area Type:	Urban
Time of Day:	12:00 AM to 10:30 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	7
Downstream Ramps (within 3mi)	7
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	3
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	9:30 PM
Time Closure Ended •	11:55 PM

Describe Construction Activity:
Mill and overlay of the existing pavement surface, beam guard repair, median concrete barrier repair and light base repair, replace light poles, inlet and manhole adjustments/reconstructions, and grading are also included in the project. Entrance and exit ramps within project limits will also be resurfaced.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
97	97	per 5 minutes	107	107
292	292	per 15 minutes	320	320
1,170	1,170	per hour	1,288	1,288
1,166	1,166	Max Flow Rate$_s$*	1,278	1,278

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	9:30 PM	End Time:	10:30 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
84 per 5 minutes	10.1%	16%	84%	93 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
74	74	per 5 minutes	84	84
243	243	per 15 minutes	265	265
1,013	1,013	per hour	1,115	1,115

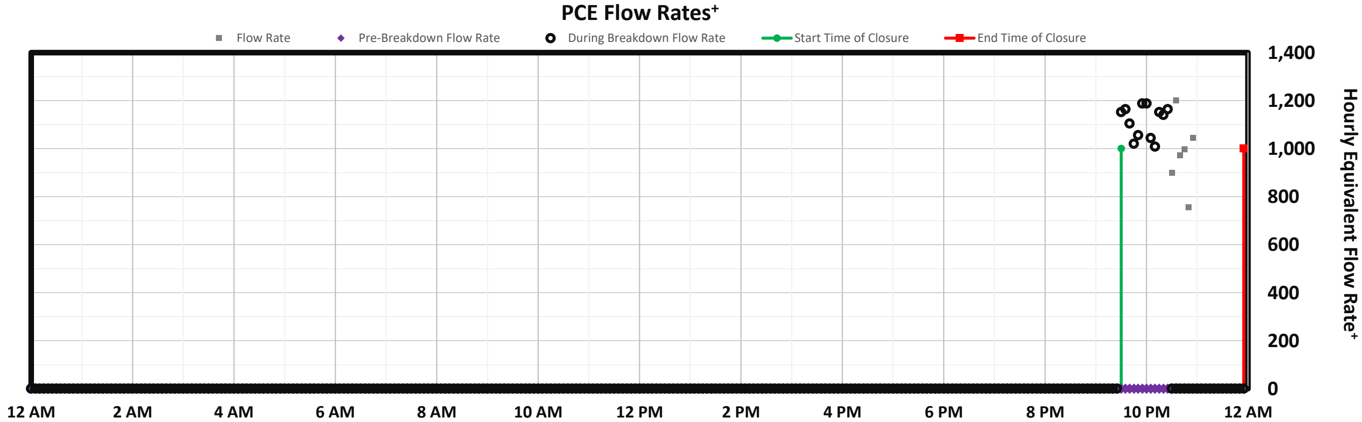
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
84	84	per 5 minutes	93	93
253	253	per 15 minutes	277	277
1,013	1,013	per hour	1,115	1,115
1,170	1,170	HCM 6 Estimate	1,288	1,288

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
90	90	per 5 minutes	99	99
263	263	per 15 minutes	288	288
1,013	1,013	per hour	1,115	1,115

PCE Flow Rates⁺



⁺ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 41 NB Waukesha County 124th Street (1100-36-70)

PCE Conversion Factor: **2.00**

Pre-Breakdown Capacity Drop Factor (PBCDF): **0.134**

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 41
Direction	NB
Construction ID:	1100-36-70
Nearest Crossroad:	124th Street
County:	Waukesha
Date:	3/26/2019
Day of Week:	Tuesday
Area Type:	Urban
Time of Day:	12:00 AM to 10:30 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	7
Downstream Ramps (within 3mi)	7
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	3
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	9:30 PM
Time Closure Ended •	11:55 PM

Describe Construction Activity:
Mill and overlay of the existing pavement surface, beam guard repair, median concrete barrier repair and light base repair, replace light poles, inlet and manhole adjustments/reconstructions, and grading are also included in the project. Entrance and exit ramps within project limits will also be resurfaced.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
112	112	per 5 minutes	123	123
337	337	per 15 minutes	369	369
1,341	1,341	per hour	1,472	1,472
1,348	1,348	Max Flow Rate$_s$*	1,477	1,477

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

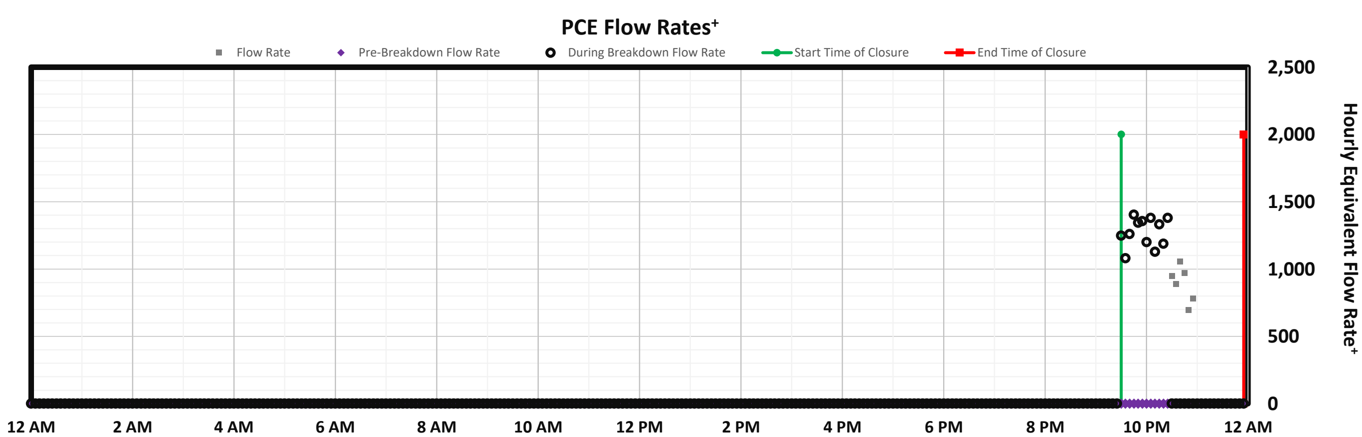
Select Times ->	Start Time:	9:30 PM	End Time:	10:30 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
97 per 5 minutes	9.8%	24%	76%	106 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
83	83	per 5 minutes	90	90
267	267	per 15 minutes	299	299
1,161	1,161	per hour	1,275	1,275

Average Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
97	97	per 5 minutes	106	106
292	292	per 15 minutes	320	320
1,161	1,161	per hour	1,275	1,275
1,173	1,173	HCM 6 Estimate	1,288	1,288

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
109	109	per 5 minutes	117	117
308	308	per 15 minutes	342	342
1,161	1,161	per hour	1,275	1,275



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 43 NB Waukesha County Moorland Road (1090-30-70)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

TADI TRAFFIC ANALYSIS & DESIGN, INC.

Version 1.8

Site Data	
Highway:	IH 43
Direction	NB
Construction ID:	1090-30-70
Nearest Crossroad:	Moorland Road
County:	Waukesha
Date:	10/3/2018
Day of Week:	Wednesday
Area Type:	Urban
Time of Day:	12:00 AM to 1:00 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

No-prebreakdown. Good breakdown capacity. Around 1pm ends.

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
141	141	per 5 minutes	165	165
421	421	per 15 minutes	496	496
1,665	1,665	per hour	1,966	1,966
1,684	1,684	Max Flow Rate$_s$*	1,983	1,983

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

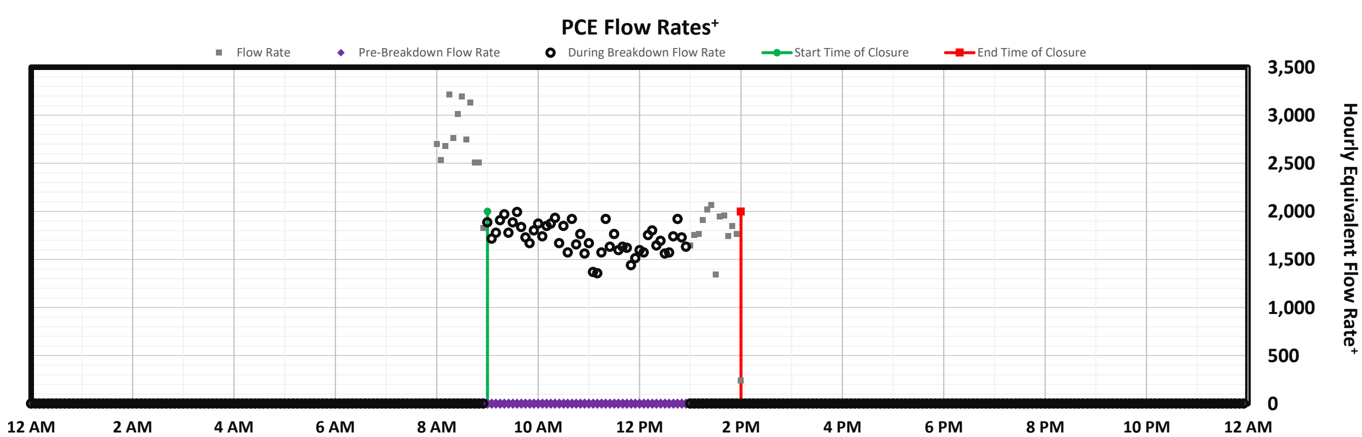
DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times ->	Start Time:	9:00 AM	End Time:	1:00 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
122 per 5 minutes	17.5%	57%	43%	143 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
90	90	per 5 minutes	113	113
303	303	per 15 minutes	358	358
1,332	1,332	per hour	1,584	1,584

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
122	122	per 5 minutes	143	143
365	365	per 15 minutes	429	429
1,442	1,442	per hour	1,702	1,702
1,278	1,278	HCM 6 Estimate	1,501	1,501

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
145	145	per 5 minutes	166	166
413	413	per 15 minutes	476	476
1,578	1,578	per hour	1,835	1,835



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 43 NB Waukesha County Moorland Road (1090-30-70)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.161

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	NB
Construction ID:	1090-30-70
Nearest Crossroad:	Moorland Road
County:	Waukesha
Date:	10/18/2018
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	9:05 AM to 10:30 AM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

Accident occurred upstream at ~10:31am, so changed during breakdown end time to 10:30am

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	9:05 AM	End Time:	9:20 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
170	170	per 5 minutes	189	189
464	464	per 15 minutes	526	526
1,855	1,855	per hour	2,104	2,104
1,855	1,855	Max Flow Rate$_s$*	2,104	2,104

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
146	146	per 5 minutes	170	170
439	439	per 15 minutes	509	509
1,755	1,755	per hour	2,037	2,037
1,755	1,755	Max Flow Rate$_s$*	2,037	2,037

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

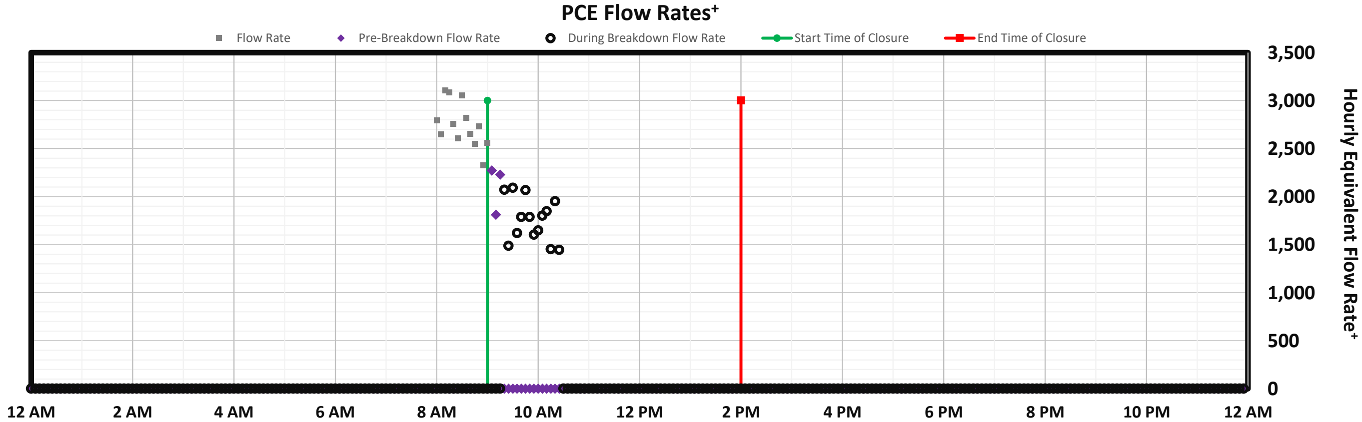
Select Times ->	Start Time:	9:20 AM	End Time:	10:30 AM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
126 per 5 minutes	16.3%	53%	47%	147 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
100	100	per 5 minutes	120	120
346	346	per 15 minutes	404	404
1,508	1,508	per hour	1,759	1,759

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
126	126	per 5 minutes	147	147
380	380	per 15 minutes	441	441
1,520	1,520	per hour	1,764	1,764
1,291	1,291	HCM 6 Estimate	1,501	1,501

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
152	152	per 5 minutes	174	174
411	411	per 15 minutes	471	471
1,530	1,530	per hour	1,772	1,772

PCE Flow Rates⁺



⁺ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 43 NB Waukesha County Moorland Rd (1090-30-70)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	NB
Construction ID:	1090-30-70
Nearest Crossroad:	Moorland Rd
County:	Waukesha
Date:	10/25/2018
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	12:00 AM to 1:35 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
0	*0*	per 5 minutes	*0*	*0*
0	*0*	per 15 minutes	*0*	*0*
0	*0*	per hour	*0*	*0*
0	***0***	**Max Flow Rate$_s$***	***0***	***0***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
144	*144*	per 5 minutes	*169*	*169*
431	*431*	per 15 minutes	*507*	*507*
1,719	***1,719***	**per hour**	***2,026***	***2,026***
1,724	***1,724***	**Max Flow Rate$_s$***	***2,028***	***2,028***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

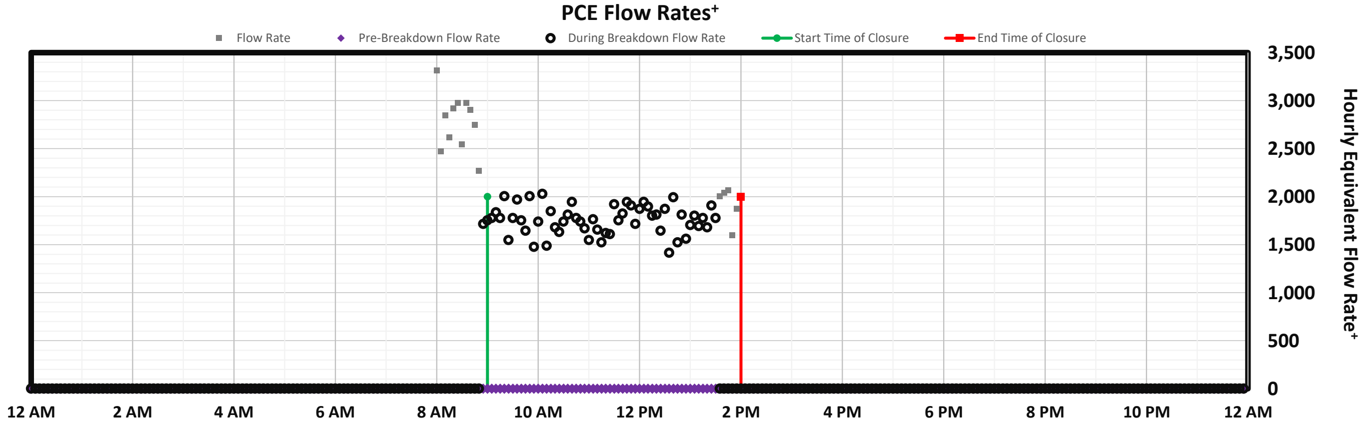
Select Times - >	Start Time:	8:55 AM	End Time:	1:35 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
124 *per 5 minutes*	**17.6%**	**53%**	**47%**	**146** *per 5 minutes*

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
101	*101*	per 5 minutes	*118*	*118*
334	*334*	per 15 minutes	*396*	*396*
1,441	*1,441*	per hour	*1,700*	*1,700*

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
124	*124*	per 5 minutes	*146*	*146*
373	*373*	per 15 minutes	*439*	*439*
1,489	***1,489***	**per hour**	***1,754***	***1,754***
1,276	***1,276***	**HCM 6 Estimate**	***1,501***	***1,501***

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
148	*148*	per 5 minutes	*169*	*169*
414	*414*	per 15 minutes	*476*	*476*
1,566	*1,566*	per hour	*1,836*	*1,836*

PCE Flow Rates+



+ **Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.**

Work Zone Capacity

Queue Discharge Flow Rates

IH 43 NB Waukesha County Moorland Road (1090-30-70)

PCE Conversion Factor:	**2.00**
Pre-Breakdown Capacity Drop Factor (PBCDF):	**0.134**

<-- Observed PBCDF
[1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

TADI TRAFFIC ANALYSIS & DESIGN, INC. — WISCONSIN DEPARTMENT OF TRANSPORTATION

Version 1.8

Site Data	
Highway:	IH 43
Direction	NB
Construction ID:	1090-30-70
Nearest Crossroad:	Moorland Road
County:	Waukesha
Date:	11/5/2018
Day of Week:	Monday
Area Type:	Urban
Time of Day:	12:00 AM to 10:15 AM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

Queue ends at 10:15am. Restarts at 11:30. Divided into two spreadsheets (this is 1 of 2).

PRE-BREAKDOWN CAPACITY

Select Times - >	*Start Time:*	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
0	*0*	per 5 minutes	*0*	*0*
0	*0*	per 15 minutes	*0*	*0*
0	*0*	per hour	*0*	*0*
0	***0***	**Max Flow Rate$_s$***	***0***	***0***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
140	*140*	per 5 minutes	*168*	*168*
422	*422*	per 15 minutes	*506*	*506*
1,687	***1,687***	**per hour**	***2,026***	***2,026***
1,687	***1,687***	**Max Flow Rate$_s$***	***2,026***	***2,026***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

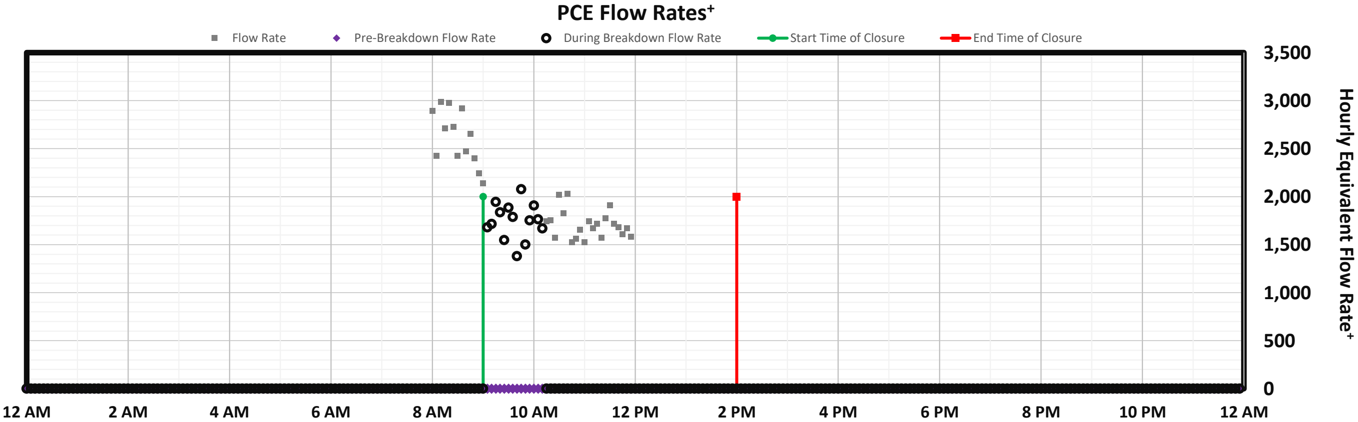
Select Times - >	*Start Time:*	9:05 AM	End Time:	10:15 AM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
122 *per 5 minutes*	**19.8%**	**44%**	**56%**	**146** *per 5 minutes*

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
98	*98*	per 5 minutes	*115*	*115*
339	*339*	per 15 minutes	*413*	*413*
1,455	*1,455*	per hour	*1,751*	*1,751*

---------------- Average Observed Queue Discharge Rate ----------------				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
122	*122*	per 5 minutes	*146*	*146*
365	*365*	per 15 minutes	*439*	*439*
1,461	***1,461***	**per hour**	***1,754***	***1,754***
1,253	***1,253***	**HCM 6 Estimate**	***1,501***	***1,501***

-------------------------- Maximum Observed Queue Discharge Rate --------------------------				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
138	*138*	per 5 minutes	*173*	*173*
392	*392*	per 15 minutes	*458*	*458*
1,465	*1,465*	per hour	*1,758*	*1,758*

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 43 NB Waukesha County Moorland Road (1090-30-70)

PCE Conversion Factor: 2.00

Pre-Breakdown Capacity Drop Factor (PBCDF): 0.134

0.147 <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	NB
Construction ID:	1090-30-70
Nearest Crossroad:	Moorland Road
County:	Waukesha
Date:	11/5/2018
Day of Week:	Monday
Area Type:	Urban
Time of Day:	10:15 AM to 11:50 AM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

1st queue ends at 10:15am. Restarts at 11:35. Divided into two spreadsheets (this is 2 of 2).

PRE-BREAKDOWN CAPACITY

Select Times -> Start Time: 10:15 AM End Time: 11:35 AM

Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
148	148	per 5 minutes	169	169
417	417	per 15 minutes	489	489
1,472	1,472	per hour	1,717	1,717
1,668	1,668	Max Flow Rate$_s$*	1,956	1,956

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
137	137	per 5 minutes	161	161
411	411	per 15 minutes	482	482
1,644	1,644	per hour	1,926	1,926
1,644	1,644	Max Flow Rate$_s$*	1,926	1,926

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times -> Start Time: 11:35 AM End Time: 11:50 AM

Queue Discharge Flow Rates (Collected Near Bottleneck)

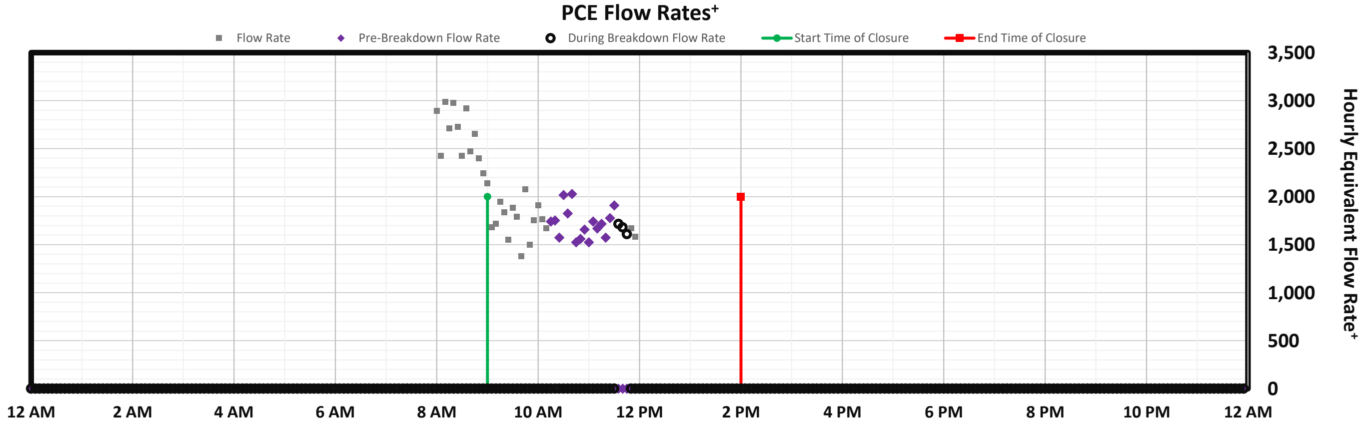
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
119 per 5 minutes	17.1%	59%	41%	139 per 5 minutes

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
114	114	per 5 minutes	134	134
356	356	per 15 minutes	417	417
1,424	1,424	per hour	1,668	1,668

Average Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
119	119	per 5 minutes	139	139
356	356	per 15 minutes	417	417
1,424	1,424	per hour	1,668	1,668
1,281	1,281	HCM 6 Estimate	1,501	1,501

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
122	122	per 5 minutes	143	143
356	356	per 15 minutes	417	417
1,424	1,424	per hour	1,668	1,668

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 43 NB Waukesha County Moorland Road (1090-30-70)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	NB
Construction ID:	1090-30-70
Nearest Crossroad:	Moorland Road
County:	Waukesha
Date:	11/6/2018
Day of Week:	Tuesday
Area Type:	Urban
Time of Day:	12:00 AM to 12:30 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
132	132	per 5 minutes	153	153
395	395	per 15 minutes	457	457
1,574	1,574	per hour	1,819	1,819
1,580	1,580	Max Flow Rate$_s$*	1,827	1,827

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times ->	Start Time:	9:15 AM	End Time:	12:30 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
115 per 5 minutes	15.6%	50%	50%	132 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
93	93	per 5 minutes	106	106
295	295	per 15 minutes	348	348
1,318	1,318	per hour	1,521	1,521

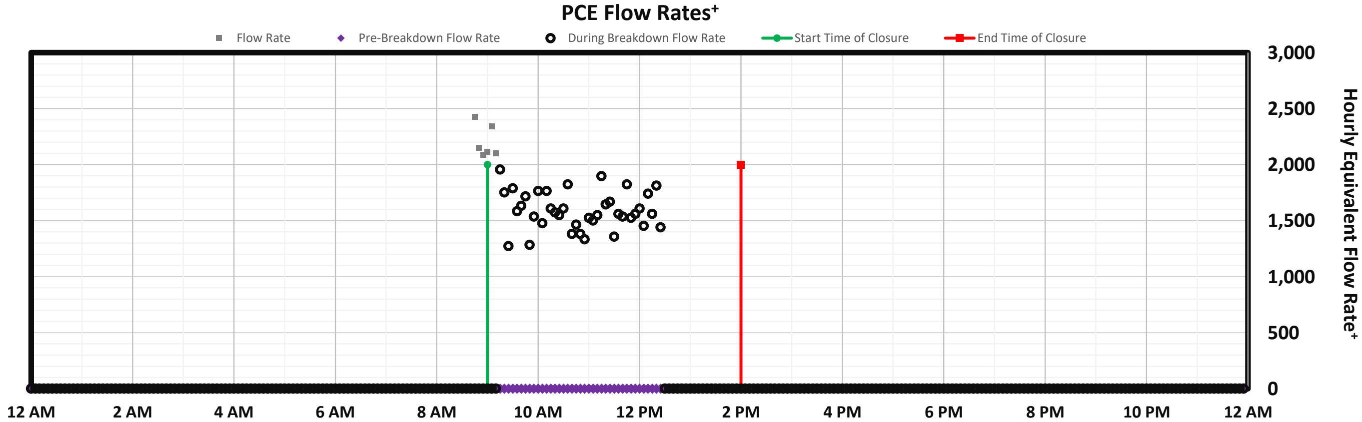
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
115	115	per 5 minutes	132	132
342	342	per 15 minutes	396	396
1,363	1,363	per hour	1,575	1,575
1,298	1,298	HCM 6 Estimate	1,501	1,501

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
140	140	per 5 minutes	163	163
370	370	per 15 minutes	434	434
1,393	1,393	per hour	1,627	1,627

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 43 SB Waukesha County 124th St (1090-30-70)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.152

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	SB
Construction ID:	1090-30-70
Nearest Crossroad:	124th St
County:	Waukesha
Date:	8/23/2018
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	9:05 AM to 12:50 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	10:00 AM
Time Closure Ended •	1:30 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Breakdown times based on Amy S notes; Lane width and clearance depends on the stage of the project.

PRE-BREAKDOWN CAPACITY

Select Times - >	*Start Time:*	9:05 AM	End Time:	10:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
154	*154*	per 5 minutes	*175*	*175*
424	*424*	per 15 minutes	*507*	*507*
1,576	*1,576*	per hour	*1,869*	*1,869*
1,696	*1,696*	Max Flow Rate$_s$*	*2,026*	*2,026*

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
141	*141*	per 5 minutes	*166*	*166*
423	*423*	per 15 minutes	*497*	*497*
1,688	*1,688*	per hour	*1,983*	*1,983*
1,693	*1,693*	Max Flow Rate$_s$*	*1,990*	*1,990*

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

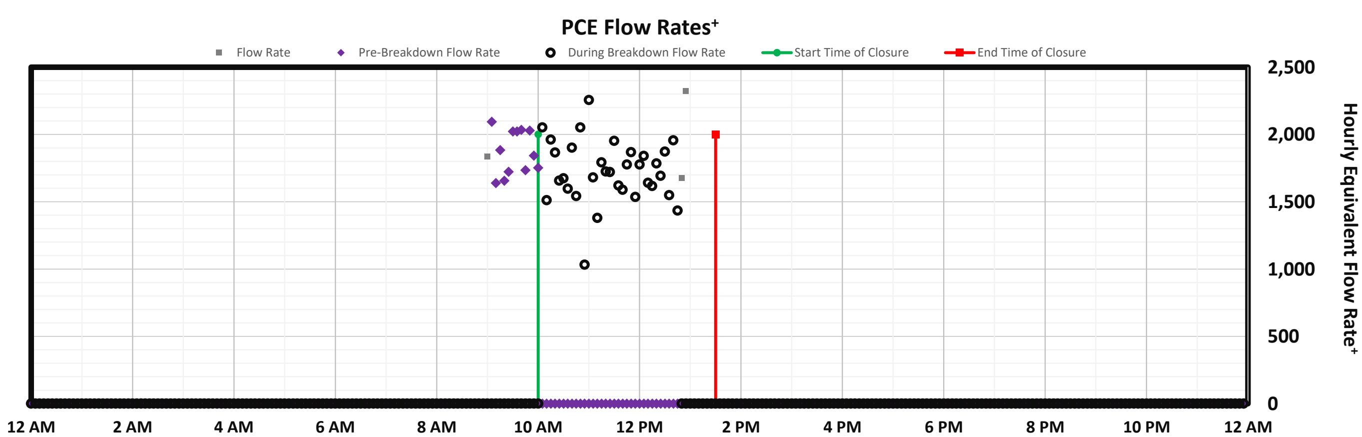
DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	*Start Time:*	10:05 AM	End Time:	12:50 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
122 *per 5 minutes*	17.7%	55%	45%	144 *per 5 minutes*

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
72	*72*	per 5 minutes	*86*	*86*
328	*328*	per 15 minutes	*386*	*386*
1,435	*1,435*	per hour	*1,691*	*1,691*

Average Observed Queue Discharge Rate				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
122	*122*	per 5 minutes	*144*	*144*
366	*366*	per 15 minutes	*431*	*431*
1,462	*1,462*	per hour	*1,718*	*1,718*
1,275	*1,275*	HCM 6 Estimate	*1,501*	*1,501*

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
155	*155*	per 5 minutes	*188*	*188*
394	*394*	per 15 minutes	*461*	*461*
1,493	*1,493*	per hour	*1,759*	*1,759*



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 43 SB Waukesha County Sunnyslope (1090-30-70)

PCE Conversion Factor: 2.00

Pre-Breakdown Capacity Drop Factor (PBCDF): 0.134

Version 1.8

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Site Data	
Highway:	IH 43
Direction	SB
Construction ID:	1090-30-70
Nearest Crossroad:	Sunnyslope
County:	Waukesha
Date:	10/3/2019
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	12:00 AM to 12:25 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	10:30 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
132	132	per 5 minutes	157	157
395	395	per 15 minutes	469	469
1,569	1,569	per hour	1,868	1,868
1,579	1,579	Max Flow Rate$_s$*	1,877	1,877

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

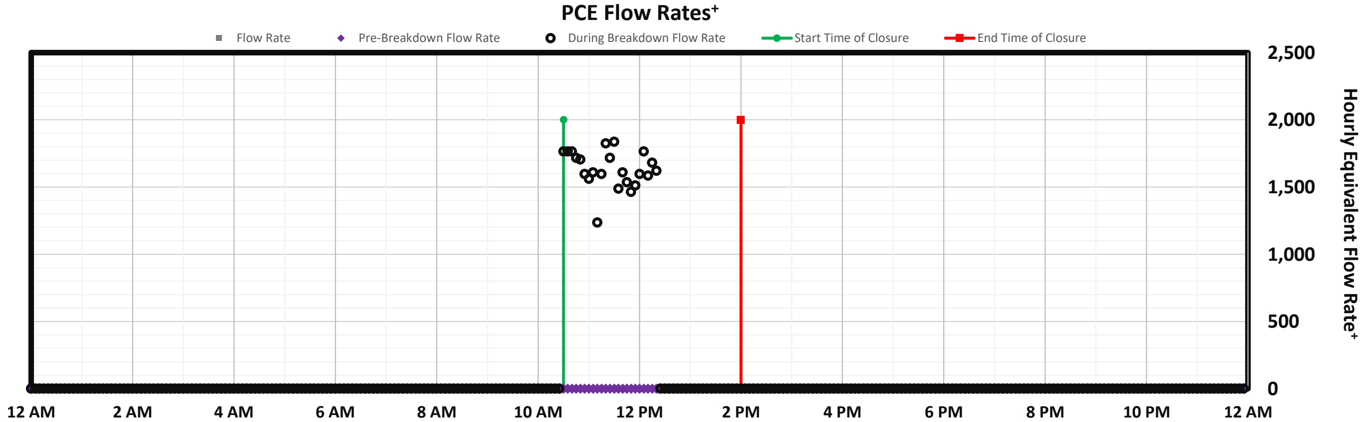
Select Times - >	Start Time:	10:30 AM	End Time:	12:25 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
115 per 5 minutes	18.8%	53%	47%	136 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
86	86	per 5 minutes	103	103
306	306	per 15 minutes	367	367
1,330	1,330	per hour	1,582	1,582

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
115	115	per 5 minutes	136	136
342	342	per 15 minutes	406	406
1,358	1,358	per hour	1,618	1,618
1,264	1,264	HCM 6 Estimate	1,501	1,501

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
126	126	per 5 minutes	153	153
368	368	per 15 minutes	448	448
1,384	1,384	per hour	1,660	1,660

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 43 SB Waukesha County Sunnyslope (1090-30-70)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	SB
Construction ID:	1090-30-70
Nearest Crossroad:	Sunnyslope
County:	Waukesha
Date:	10/4/2019
Day of Week:	Friday
Area Type:	Urban
Time of Day:	12:00 AM to 1:00 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	1:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
127	127	per 5 minutes	153	153
378	378	per 15 minutes	455	455
1,479	1,479	per hour	1,782	1,782
1,511	1,511	Max Flow Rate$_s$*	1,822	1,822

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

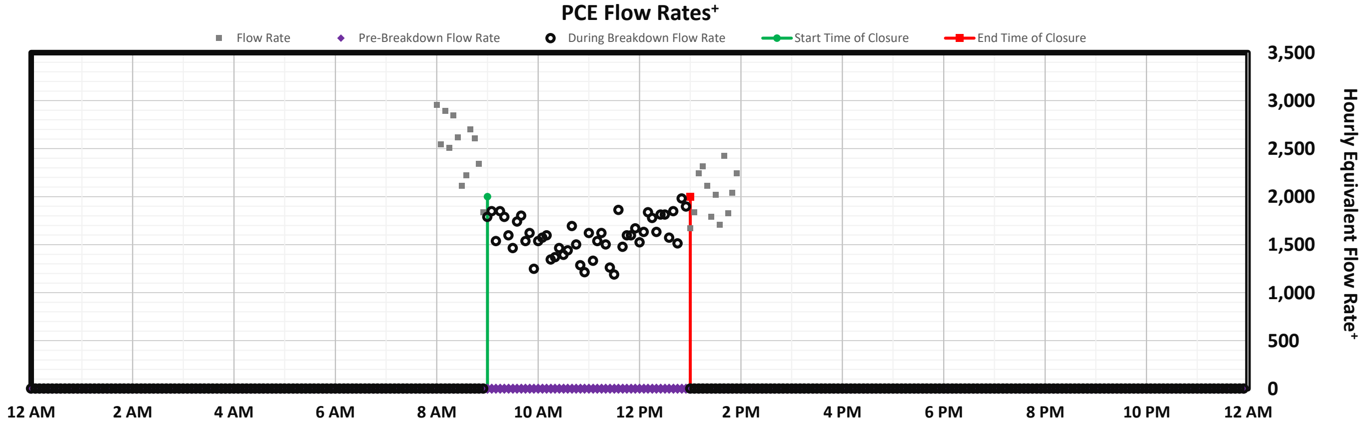
Select Times ->	Start Time:	9:00 AM	End Time:	1:00 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
110 per 5 minutes	20.4%	52%	48%	132 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
83	83	per 5 minutes	99	99
271	271	per 15 minutes	329	329
1,171	1,171	per hour	1,432	1,432

---------------- Average Observed Queue Discharge Rate ----------------				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
110	110	per 5 minutes	132	132
327	327	per 15 minutes	394	394
1,281	1,281	per hour	1,543	1,543
1,247	1,247	HCM 6 Estimate	1,501	1,501

-------------------------- Maximum Observed Queue Discharge Rate --------------------------				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
144	144	per 5 minutes	165	165
393	393	per 15 minutes	449	449
1,478	1,478	per hour	1,736	1,736

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 43 SB Waukesha County 124th (1090-30-70)

PCE Conversion Factor:	**2.00**
Pre-Breakdown Capacity Drop Factor (PBCDF):	**0.134**

<-- Observed PBCDF
[1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	SB
Construction ID:	1090-30-70
Nearest Crossroad:	124th
County:	Waukesha
Date:	10/18/2018
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	12:00 AM to 10:30 AM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

PRE-BREAKDOWN CAPACITY

Select Times - >	*Start Time:*	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
0	*0*	per 5 minutes	*0*	*0*
0	*0*	per 15 minutes	*0*	*0*
0	*0*	per hour	*0*	*0*
0	***0***	**Max Flow Rate$_s$***	***0***	***0***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
136	*136*	per 5 minutes	*162*	*162*
411	*411*	per 15 minutes	*490*	*490*
1,643	***1,643***	**per hour**	***1,960***	***1,960***
1,643	***1,643***	**Max Flow Rate$_s$***	***1,960***	***1,960***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

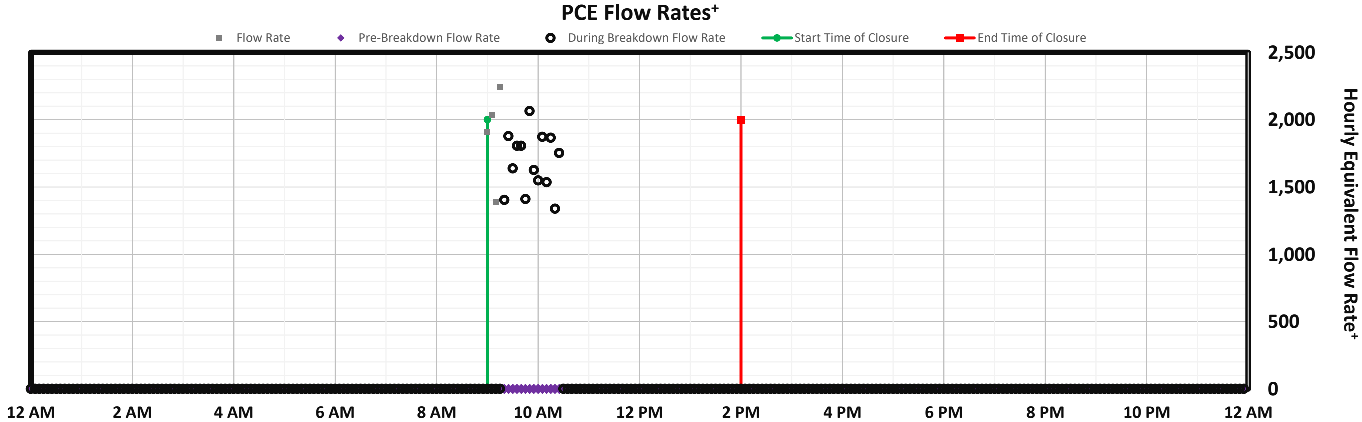
Select Times - >	*Start Time:*	9:20 AM	End Time:	10:30 AM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
118 *per 5 minutes*	**18.8%**	**46%**	**54%**	**140** *per 5 minutes*

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
94	*94*	per 5 minutes	*112*	*112*
336	*336*	per 15 minutes	*395*	*395*
1,413	*1,413*	per hour	*1,689*	*1,689*

Average Observed Queue Discharge Rate				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
118	*118*	per 5 minutes	*140*	*140*
356	*356*	per 15 minutes	*424*	*424*
1,423	***1,423***	**per hour**	***1,697***	***1,697***
1,264	***1,264***	**HCM 6 Estimate**	***1,501***	***1,501***

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
149	*149*	per 5 minutes	*172*	*172*
376	*376*	per 15 minutes	*444*	*444*
1,431	*1,431*	per hour	*1,705*	*1,705*

PCE Flow Rates+



+ **Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.**

Work Zone Capacity

Queue Discharge Flow Rates

IH 43 SB Waukesha County 124th (1090-30-70)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	SB
Construction ID:	1090-30-70
Nearest Crossroad:	124th
County:	Waukesha
Date:	10/25/2018
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	12:00 AM to 1:00 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
134	134	per 5 minutes	161	161
403	403	per 15 minutes	484	484
1,606	1,606	per hour	1,931	1,931
1,613	1,613	Max Flow Rate$_s$*	1,937	1,937

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times ->	Start Time:	9:30 AM	End Time:	1:00 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
116 per 5 minutes	20.1%	49%	51%	140 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
84	84	per 5 minutes	109	109
301	301	per 15 minutes	366	366
1,290	1,290	per hour	1,572	1,572

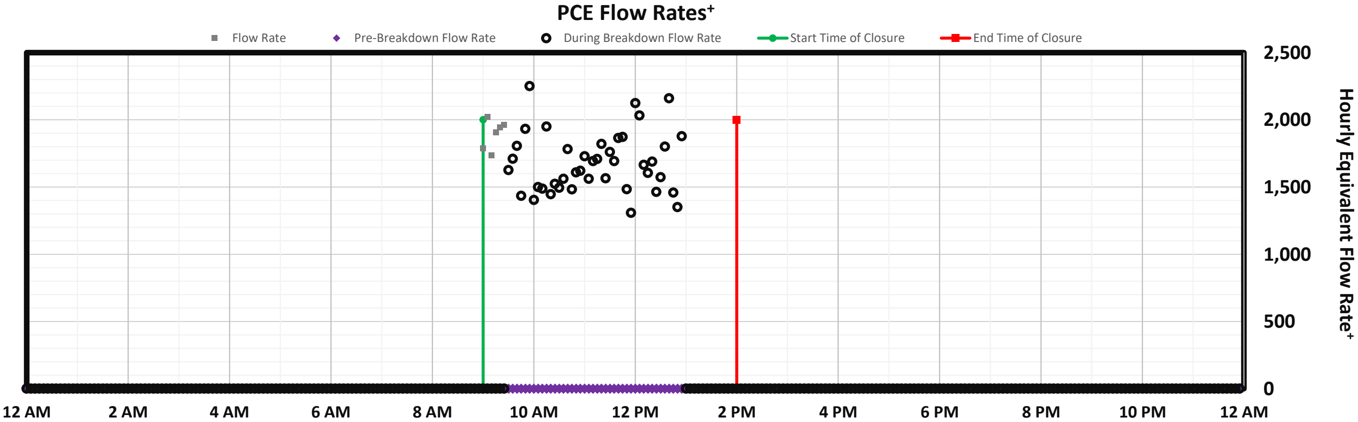
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
116	116	per 5 minutes	140	140
349	349	per 15 minutes	419	419
1,391	1,391	per hour	1,672	1,672
1,250	1,250	HCM 6 Estimate	1,501	1,501

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
152	152	per 5 minutes	188	188
414	414	per 15 minutes	485	485
1,477	1,477	per hour	1,743	1,743

PCE Flow Rates⁺



⁺ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 43 SB Waukesha County Sunnyslope Road (1090-30-70)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.052

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	SB
Construction ID:	1090-30-70
Nearest Crossroad:	Sunnyslope Road
County:	Waukesha
Date:	11/5/2018
Day of Week:	Monday
Area Type:	Urban
Time of Day:	9:00 AM to 1:00 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	9:00 AM	End Time:	12:45 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
146	146	per 5 minutes	174	174
386	386	per 15 minutes	454	454
1,484	1,484	per hour	1,751	1,751
1,543	1,543	Max Flow Rate$_s$*	1,816	1,816

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
142	142	per 5 minutes	166	166
426	426	per 15 minutes	497	497
1,704	1,704	per hour	1,988	1,988
1,704	1,704	Max Flow Rate$_s$*	1,988	1,988

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

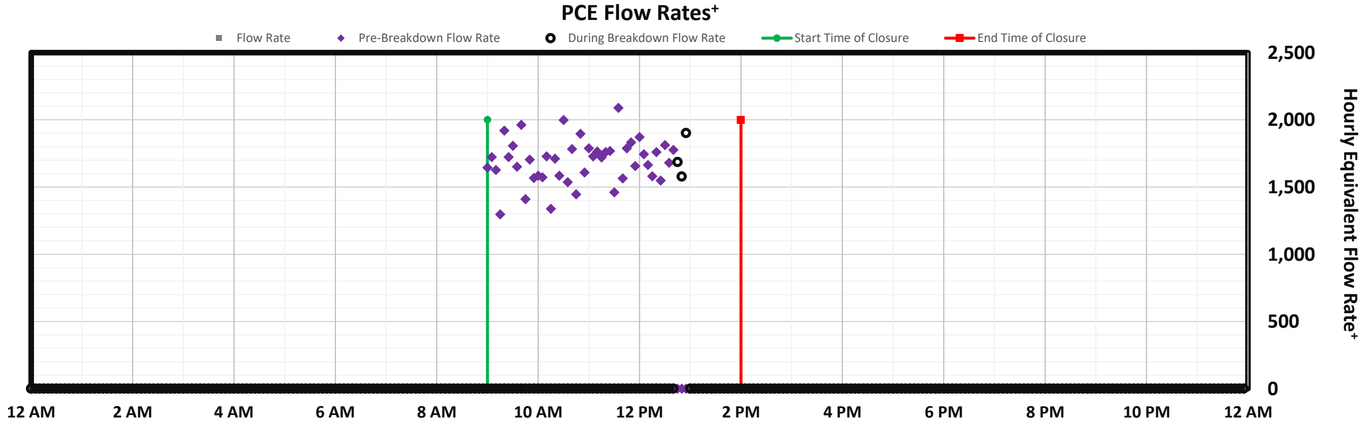
Select Times - >	Start Time:	12:45 PM	End Time:	1:00 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
123 per 5 minutes	16.7%	45%	55%	144 per 5 minutes

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
114	114	per 5 minutes	132	132
369	369	per 15 minutes	431	431
1,476	1,476	per hour	1,722	1,722

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
123	123	per 5 minutes	144	144
369	369	per 15 minutes	431	431
1,476	1,476	per hour	1,722	1,722
1,287	1,287	HCM 6 Estimate	1,501	1,501

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
136	136	per 5 minutes	159	159
369	369	per 15 minutes	431	431
1,476	1,476	per hour	1,722	1,722

PCE Flow Rates⁺



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 43 SB Waukesha County 124th (1090-30-70)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.171

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	SB
Construction ID:	1090-30-70
Nearest Crossroad:	124th
County:	Waukesha
Date:	11/6/2018
Day of Week:	Tuesday
Area Type:	Urban
Time of Day:	9:05 AM to 10:10 AM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

(1 of 2)

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	9:05 AM	End Time:	9:40 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
128	*128*	per 5 minutes	*160*	*160*
376	*376*	per 15 minutes	*464*	*464*
1,399	*1,399*	per hour	*1,710*	*1,710*
1,504	***1,504***	**Max Flow Rate$_s$***	***1,854***	***1,854***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Pre-Breakdown Capacity (Estimated)				
124	*124*	per 5 minutes	*148*	*148*
377	*377*	per 15 minutes	*454*	*454*
1,486	***1,486***	**per hour**	***1,775***	***1,775***
1,507	***1,507***	**Max Flow Rate$_s$***	***1,814***	***1,814***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

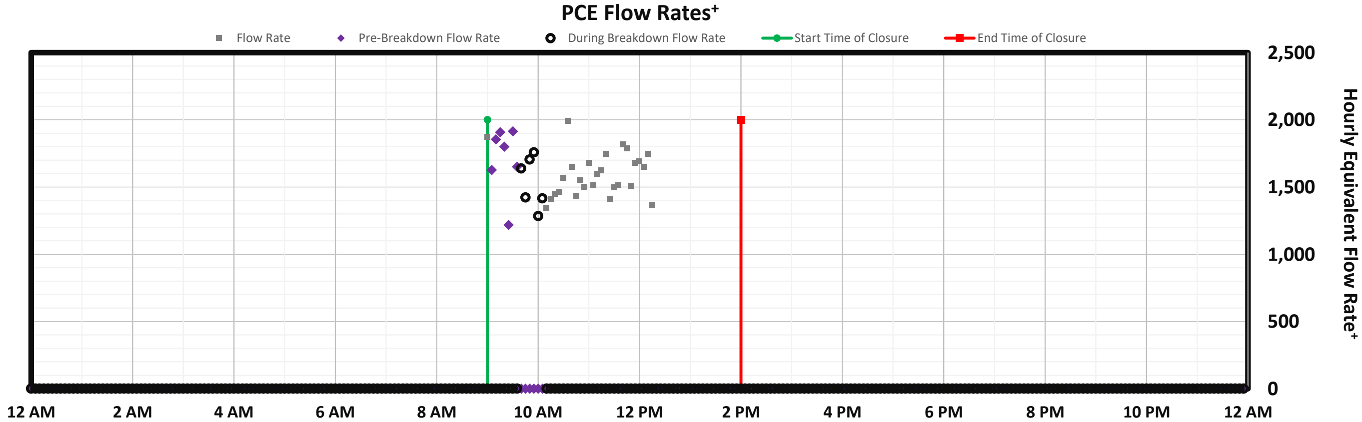
Select Times - >	Start Time:	9:40 AM	End Time:	10:10 AM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
107 *per 5 minutes*	19.4%	57%	43%	128 *per 5 minutes*

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
---- Minimum Observed Queue Discharge Rate ----				
89	*89*	per 5 minutes	*107*	*107*
308	*308*	per 15 minutes	*372*	*372*
1,287	*1,287*	per hour	*1,537*	*1,537*

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Average Observed Queue Discharge Rate				
107	*107*	per 5 minutes	*128*	*128*
326	*326*	per 15 minutes	*393*	*393*
1,287	***1,287***	**per hour**	***1,537***	***1,537***
1,257	***1,257***	**HCM 6 Estimate**	***1,501***	***1,501***

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Maximum Observed Queue Discharge Rate				
119	*119*	per 5 minutes	*147*	*147*
338	*338*	per 15 minutes	*407*	*407*
1,287	*1,287*	per hour	*1,537*	*1,537*

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 43 SB Waukesha County 124th (1090-30-70)

PCE Conversion Factor: 2.00

Pre-Breakdown Capacity Drop Factor (PBCDF): 0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	SB
Construction ID:	1090-30-70
Nearest Crossroad:	124th
County:	Waukesha
Date:	11/6/2018
Day of Week:	Tuesday
Area Type:	Urban
Time of Day:	12:00 AM to 12:00 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

(2 of 2) During breakdown only. Pre-breakdown didn't have a sustained 15 minute period.

PRE-BREAKDOWN CAPACITY

Select Times - > Start Time: 12:00 AM End Time: 12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
129	129	per 5 minutes	153	153
385	385	per 15 minutes	460	460
1,536	1,536	per hour	1,835	1,835
1,541	1,541	Max Flow Rate$_s$*	1,839	1,839

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - > Start Time: 10:40 AM End Time: 12:00 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
111 per 5 minutes	19.2%	43%	57%	133 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
99	99	per 5 minutes	117	117
309	309	per 15 minutes	368	368
1,298	1,298	per hour	1,559	1,559

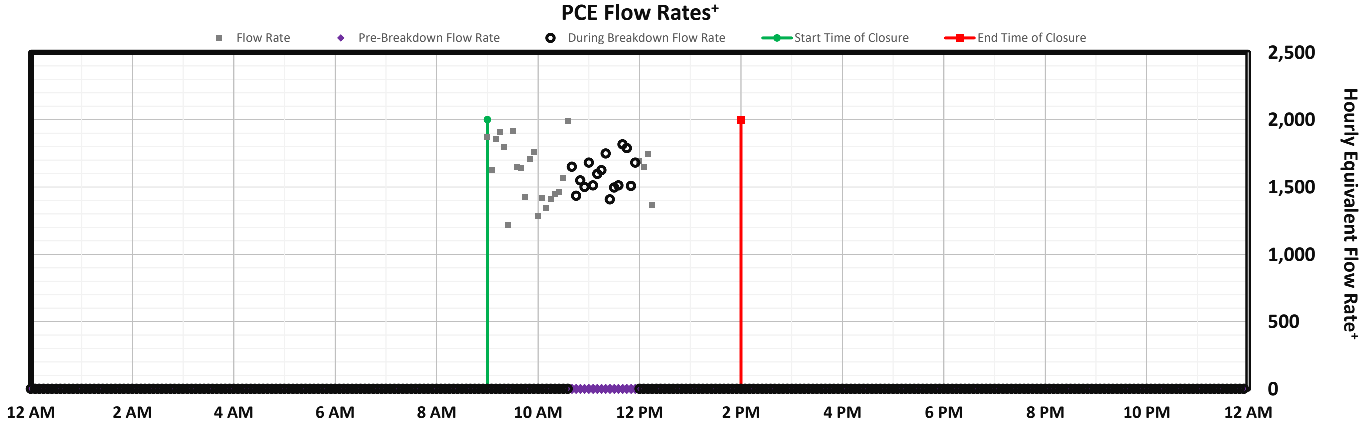
---- Average Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
111	111	per 5 minutes	133	133
334	334	per 15 minutes	398	398
1,330	1,330	per hour	1,589	1,589
1,259	1,259	HCM 6 Estimate	1,501	1,501

---- Maximum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
132	132	per 5 minutes	151	151
364	364	per 15 minutes	426	426
1,358	1,358	per hour	1,614	1,614

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 43 SB Waukesha County 124th (1090-30-70)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
0.125	<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 43
Direction	SB
Construction ID:	1090-30-70
Nearest Crossroad:	124th
County:	Waukesha
Date:	11/8/2018
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	9:00 AM to 12:00 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	9:00 AM
Time Closure Ended •	2:00 PM

Describe Construction Activity: Bridge Rehabilitation

Notes: Lane width and clearance depends on the stage of the project.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	9:00 AM	End Time:	9:45 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
144	144	per 5 minutes	174	174
395	395	per 15 minutes	455	455
1,543	1,543	per hour	1,795	1,795
1,580	1,580	Max Flow Rate$_s$*	1,820	1,820

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Pre-Breakdown Capacity (Estimated)				
131	131	per 5 minutes	155	155
394	394	per 15 minutes	466	466
1,558	1,558	per hour	1,840	1,840
1,575	1,575	Max Flow Rate$_s$*	1,863	1,863

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

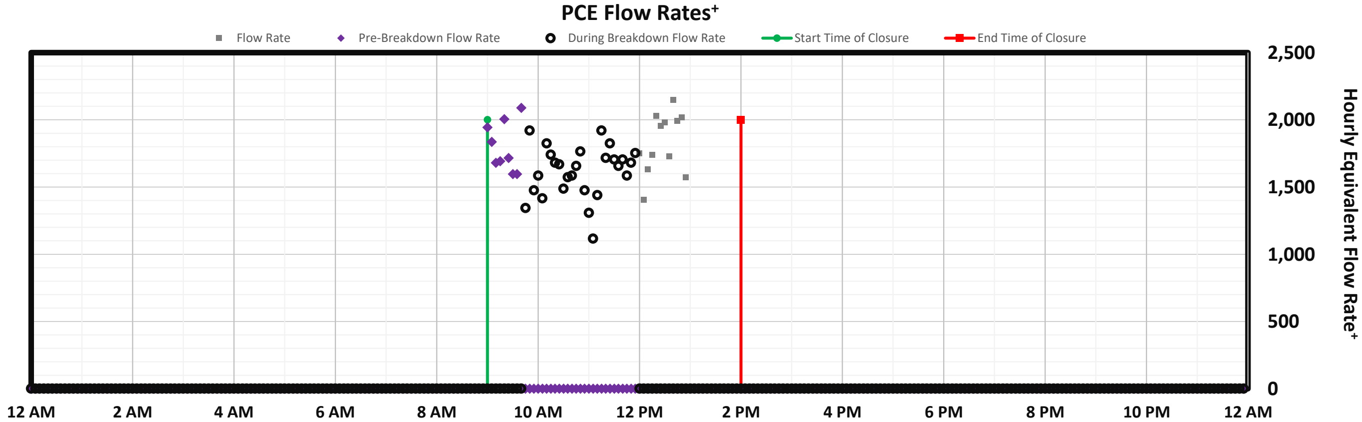
Select Times - >	Start Time:	9:45 AM	End Time:	12:00 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
114 per 5 minutes	18.3%	49%	51%	135 per 5 minutes

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
---- Minimum Observed Queue Discharge Rate ----				
83	83	per 5 minutes	93	93
289	289	per 15 minutes	322	322
1,308	1,308	per hour	1,541	1,541

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Average Observed Queue Discharge Rate				
114	114	per 5 minutes	135	135
341	341	per 15 minutes	403	403
1,349	1,349	per hour	1,593	1,593
1,268	1,268	HCM 6 Estimate	1,501	1,501

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
Maximum Observed Queue Discharge Rate				
134	134	per 5 minutes	160	160
382	382	per 15 minutes	455	455
1,406	1,406	per hour	1,634	1,634

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 94 WB Milwaukee County 121st Street (1060-33-82)

TADI Traffic Analysis & Design, Inc. — Wisconsin Department of Transportation

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.005 <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1060-33-82
Nearest Crossroad:	121st Street
County:	Milwaukee
Date:	9/5/2018
Day of Week:	Wednesday
Area Type:	Urban
Time of Day:	3:00 PM to 6:05 PM
Barrier Type:	Hard
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	50 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	8
Downstream Ramps (within 3mi)	3
Construction Duration (short/long)	Long
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	4
# of lanes open during construction	3
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Removing and replacing Sunnyslope bridge with increased shoulder width, upgrade signs, replace lighting.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	3:00 PM	End Time:	3:50 PM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
151	454	per 5 minutes	161	484
439	1,318	per 15 minutes	466	1,397
1,698	5,094	per hour	1,806	5,417
1,757	5,272	Max Flow Rate$_s$*	1,863	5,588

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
169	507	per 5 minutes	176	527
510	1,530	per 15 minutes	530	1,589
2,068	6,203	per hour	2,140	6,421
2,040	6,121	Max Flow Rate$_s$*	2,118	6,355

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	3:50 PM	End Time:	6:05 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
439 per 5 minutes	3.9%	55%	45%	456 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
120	361	per 5 minutes	127	380
397	1,191	per 15 minutes	413	1,240
1,725	5,175	per hour	1,793	5,378

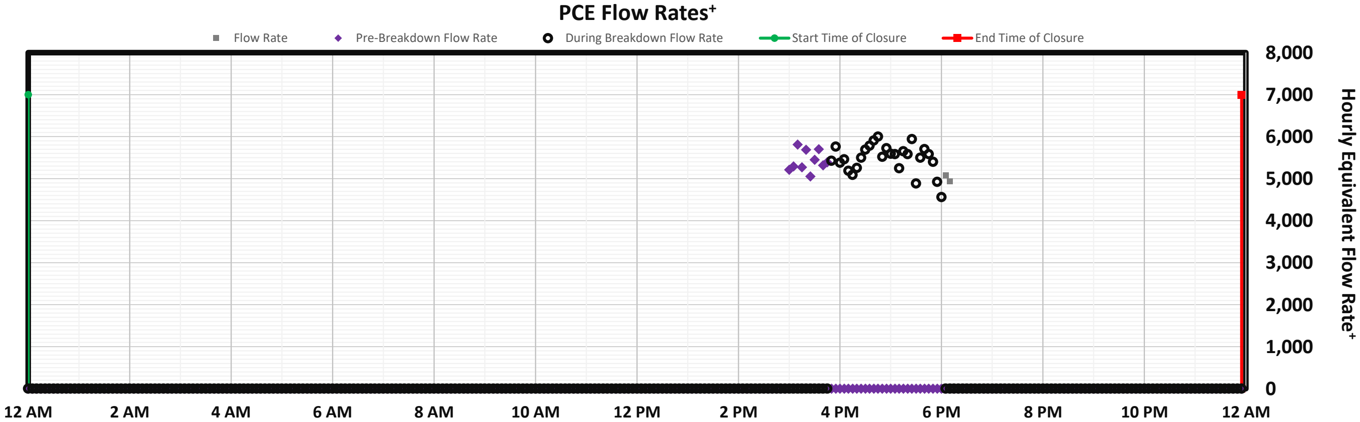
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
146	439	per 5 minutes	152	456
442	1,325	per 15 minutes	459	1,376
1,791	5,372	per hour	1,854	5,561
1,863	5,588	HCM 6 Estimate	1,935	5,806

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
162	486	per 5 minutes	167	500
478	1,435	per 15 minutes	491	1,474
1,838	5,515	per hour	1,895	5,684

PCE Flow Rates+



\+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 WB Milwaukee County 121st Street (1060-33-82)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
0.025	<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1060-33-82
Nearest Crossroad:	121st Street
County:	Milwaukee
Date:	9/6/2018
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	3:00 PM to 6:00 PM
Barrier Type:	Hard
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	50 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	8
Downstream Ramps (within 3mi)	3
Construction Duration (short/long)	Long
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	4
# of lanes open during construction	3
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Removing and replacing Sunnyslope bridge with increased shoulder width, upgrade signs, replace lighting.

Notes:

---------------------------- PRE-BREAKDOWN CAPACITY ----------------------------

Select Times - >	Start Time:	3:00 PM	End Time:	3:50 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
161	482	per 5 minutes	173	518
446	1,338	per 15 minutes	475	1,425
1,737	5,210	per hour	1,839	5,518
1,784	5,352	Max Flow Rate$_s$*	1,900	5,700

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
170	510	per 5 minutes	178	533
511	1,534	per 15 minutes	535	1,604
2,050	6,151	per hour	2,139	6,418
2,046	6,137	Max Flow Rate$_s$*	2,138	6,415

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

-------------- DURING BREAKDOWN QUEUE DISCHARGE RATE --------------

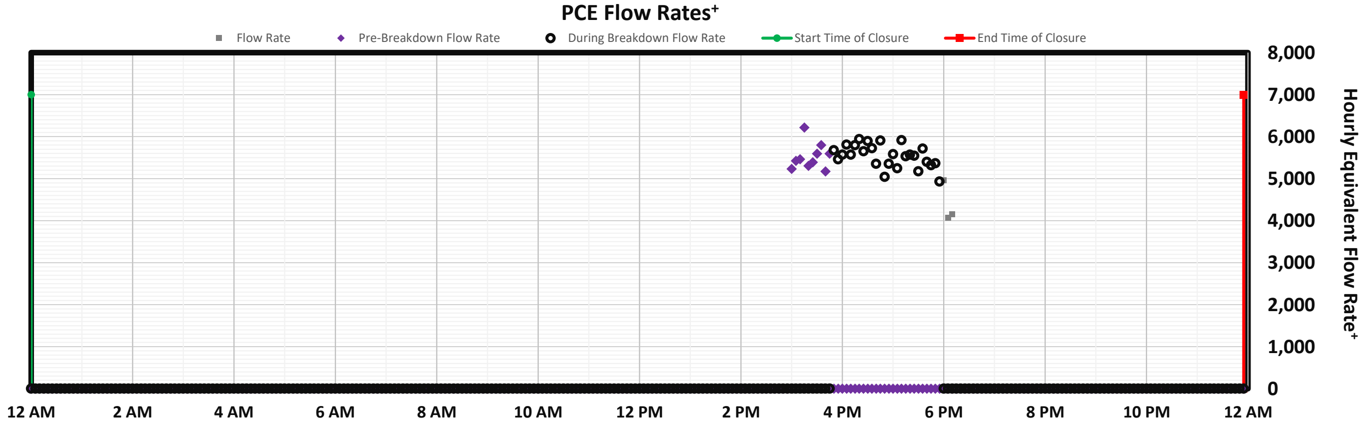
Select Times - >	Start Time:	3:50 PM	End Time:	6:00 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
442 per 5 minutes	4.5%	55%	45%	462 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
132	396	per 5 minutes	137	411
418	1,254	per 15 minutes	434	1,301
1,738	5,214	per hour	1,813	5,440

---------------- Average Observed Queue Discharge Rate ----------------				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
147	442	per 5 minutes	154	462
443	1,329	per 15 minutes	463	1,389
1,775	5,326	per hour	1,853	5,558
1,852	5,555	HCM 6 Estimate	1,935	5,806

-------------------------- Maximum Observed Queue Discharge Rate --------------------------				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
159	478	per 5 minutes	165	495
468	1,404	per 15 minutes	486	1,457
1,813	5,439	per hour	1,898	5,695

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 WB Milwaukee County 113th Street (1060-33-82)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.004

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1060-33-82
Nearest Crossroad:	113th Street
County:	Milwaukee
Date:	9/11/2018
Day of Week:	Tuesday
Area Type:	Urban
Time of Day:	3:00 PM to 5:50 PM
Barrier Type:	Hard
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	50 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	8
Downstream Ramps (within 3mi)	3
Construction Duration (short/long)	Long
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	4
# of lanes open during construction	3
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Removing and replacing Sunnyslope bridge with increased shoulder width, upgrade signs, replace lighting.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	3:00 PM	End Time:	3:40 PM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
151	454	per 5 minutes	161	484
439	1,318	per 15 minutes	466	1,397
1,697	5,090	per hour	1,811	5,433
1,757	5,272	Max Flow Rate$_s$*	1,863	5,588

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
170	511	per 5 minutes	177	532
512	1,536	per 15 minutes	532	1,596
2,069	6,208	per hour	2,143	6,429
2,048	6,143	Max Flow Rate$_s$*	2,128	6,383

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	3:40 PM	End Time:	5:50 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
443 per 5 minutes	3.9%	58%	42%	460 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
130	389	per 5 minutes	136	407
413	1,240	per 15 minutes	431	1,294
1,734	5,202	per hour	1,812	5,435

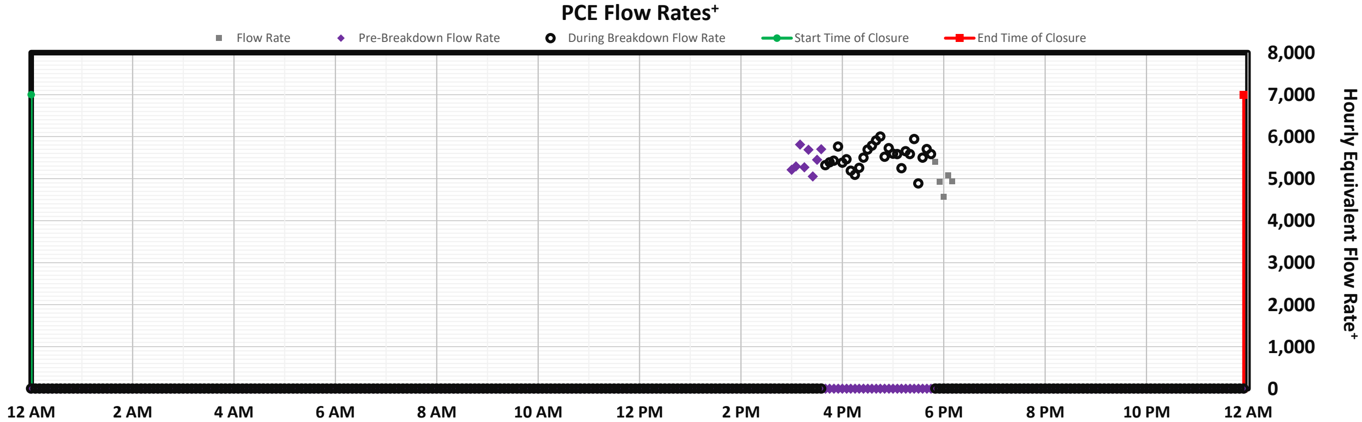
---------------- Average Observed Queue Discharge Rate ----------------

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
148	443	per 5 minutes	153	460
443	1,330	per 15 minutes	461	1,382
1,792	5,376	per hour	1,856	5,568
1,862	5,586	HCM 6 Estimate	1,935	5,806

-------------------------- Maximum Observed Queue Discharge Rate --------------------------

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
162	486	per 5 minutes	167	500
478	1,435	per 15 minutes	491	1,474
1,838	5,515	per hour	1,895	5,684

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 WB Milwaukee County 121st Street (1060-33-82)

PCE Conversion Factor:	**2.00**
Pre-Breakdown Capacity Drop Factor (PBCDF):	**0.134**
	0.104

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1060-33-82
Nearest Crossroad:	121st Street
County:	Milwaukee
Date:	9/12/2018
Day of Week:	Wednesday
Area Type:	Urban
Time of Day:	6:30 AM to 8:50 AM
Barrier Type:	Hard
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	50 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	8
Downstream Ramps (within 3mi)	3
Construction Duration (short/long)	Long
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	4
# of lanes open during construction	3
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Removing and replacing Sunnyslope bridge with increased shoulder width, upgrade signs, replace lighting.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	*Start Time:*	**6:30 AM**	**End Time:**	**7:15 AM**
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
169	*507*	per 5 minutes	*181*	*542*
484	*1,453*	per 15 minutes	*515*	*1,545*
1,824	*5,472*	per hour	*1,939*	*5,816*
1,937	***5,812***	**Max Flow Rate$_s$***	***2,060***	***6,180***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
164	*493*	per 5 minutes	*177*	*530*
496	*1,487*	per 15 minutes	*533*	*1,599*
1,984	***5,953***	**per hour**	***2,132***	***6,396***
1,983	***5,948***	**Max Flow Rate$_s$***	***2,132***	***6,395***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

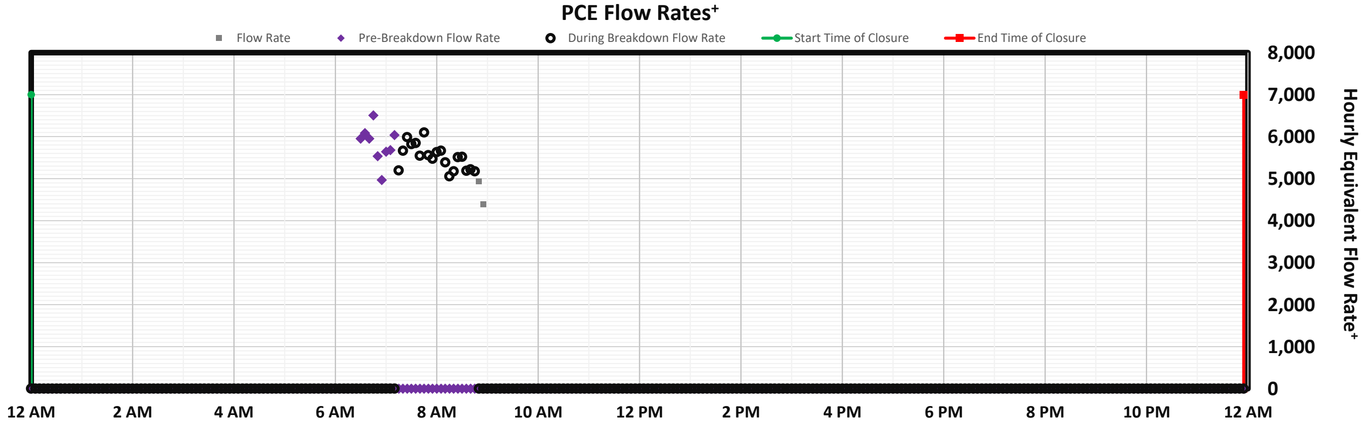
Select Times - >	*Start Time:*	**7:15 AM**	**End Time:**	**8:50 AM**
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
427 *per 5 minutes*	**7.6%**	**57%**	**43%**	**459** *per 5 minutes*

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
129	*386*	per 5 minutes	*140*	*421*
390	*1,171*	per 15 minutes	*433*	*1,298*
1,650	*4,951*	per hour	*1,793*	*5,378*

---------------- Average Observed Queue Discharge Rate ----------------				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
142	*427*	per 5 minutes	*153*	*459*
429	*1,288*	per 15 minutes	*462*	*1,385*
1,719	***5,156***	**per hour**	***1,846***	***5,539***
1,799	***5,397***	**HCM 6 Estimate**	***1,935***	***5,806***

-------------------------- Maximum Observed Queue Discharge Rate --------------------------				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
162	*485*	per 5 minutes	*169*	*508*
461	*1,384*	per 15 minutes	*490*	*1,471*
1,765	*5,295*	per hour	*1,885*	*5,655*

PCE Flow Rates+



+ **Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.**

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 WB Milwaukee County 121st Street (1060-33-82)

PCE Conversion Factor:	**2.00**
Pre-Breakdown Capacity Drop Factor (PBCDF):	**0.134**

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

TADI TRAFFIC ANALYSIS & DESIGN, INC. — WISCONSIN DEPARTMENT OF TRANSPORTATION

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1060-33-82
Nearest Crossroad:	121st Street
County:	Milwaukee
Date:	9/17/2018
Day of Week:	Monday
Area Type:	Urban
Time of Day:	12:00 AM to 4:45 PM
Barrier Type:	Hard
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	50 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramp Closure (within 3mi)	No
Downstream Ramp Closure (within 3mi)	No
Construction Duration (short/long)	Long
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	4
# of lanes open during construction	3
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Removing and replacing Sunnyslope bridge with increased shoulder width, upgrade signs, replace lighting.

Notes: During breakdown only.

Hwy 100 on-ramp occurs just prior to taper. Could be impacting the pre-breakdown maximum sustained flow.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	**0**	**Max Flow Rate$_s$***	**0**	**0**

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
169	508	per 5 minutes	179	536
509	1,526	per 15 minutes	537	1,612
2,035	**6,105**	**per hour**	**2,148**	**6,444**
2,034	**6,103**	**Max Flow Rate$_s$***	**2,149**	**6,446**

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	3:15 PM	End Time:	4:45 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
440 per 5 minutes	5.7%	61%	39%	464 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
128	385	per 5 minutes	138	414
415	1,245	per 15 minutes	445	1,334
1,737	5,211	per hour	1,837	5,512

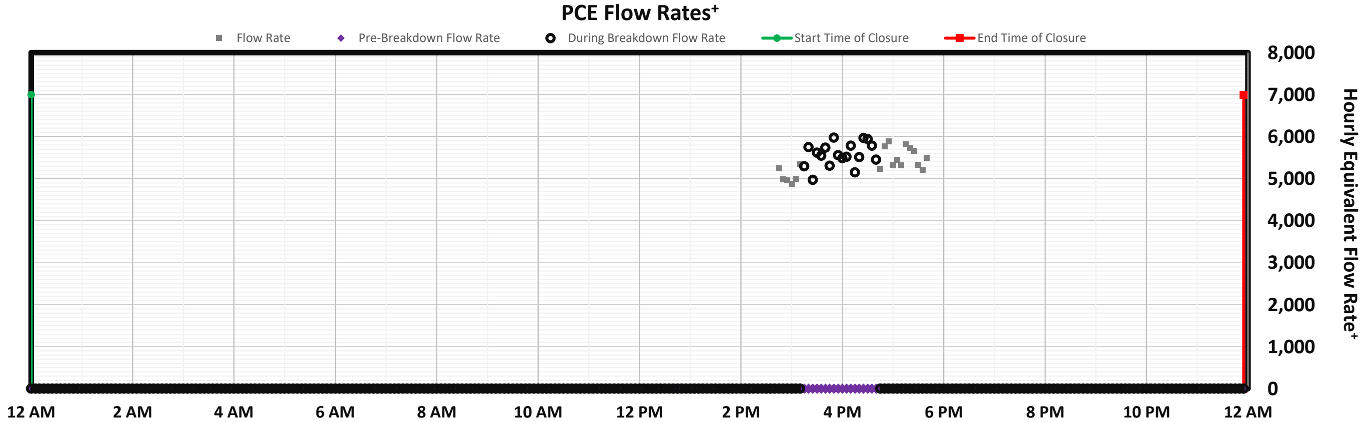
---------------- Average Observed Queue Discharge Rate ----------------

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
147	440	per 5 minutes	155	464
440	1,321	per 15 minutes	465	1,396
1,762	**5,287**	**per hour**	**1,860**	**5,581**
1,832	**5,495**	**HCM 6 Estimate**	**1,935**	**5,806**

-------------------------- Maximum Observed Queue Discharge Rate --------------------------

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
159	476	per 5 minutes	166	498
468	1,405	per 15 minutes	491	1,474
1,789	5,368	per hour	1,881	5,642

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 WB Milwaukee County 121st Street (1060-33-82)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.015

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1060-33-82
Nearest Crossroad:	121st Street
County:	Milwaukee
Date:	9/19/2018
Day of Week:	Wednesday
Area Type:	Urban
Time of Day:	2:45 PM to 5:05 PM
Barrier Type:	Hard
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	50 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramp Closure (within 3mi)	No
Downstream Ramp Closure (within 3mi)	No
Construction Duration (short/long)	Long
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	4
# of lanes open during construction	3
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Removing and replacing Sunnyslope bridge with increased shoulder width, upgrade signs, replace lighting.

Notes:

Hwy 100 on-ramp occurs just prior to taper. Could be impacting the pre-breakdown maximum sustained flow.

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	2:45 PM	End Time:	3:40 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
166	497	per 5 minutes	175	525
466	1,399	per 15 minutes	493	1,480
1,778	5,333	per hour	1,896	5,687
1,865	5,596	Max Flow Rate$_s$*	1,973	5,920

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
179	537	per 5 minutes	186	559
538	1,614	per 15 minutes	561	1,682
2,156	6,467	per hour	2,245	6,734
2,152	6,456	Max Flow Rate$_s$*	2,242	6,726

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

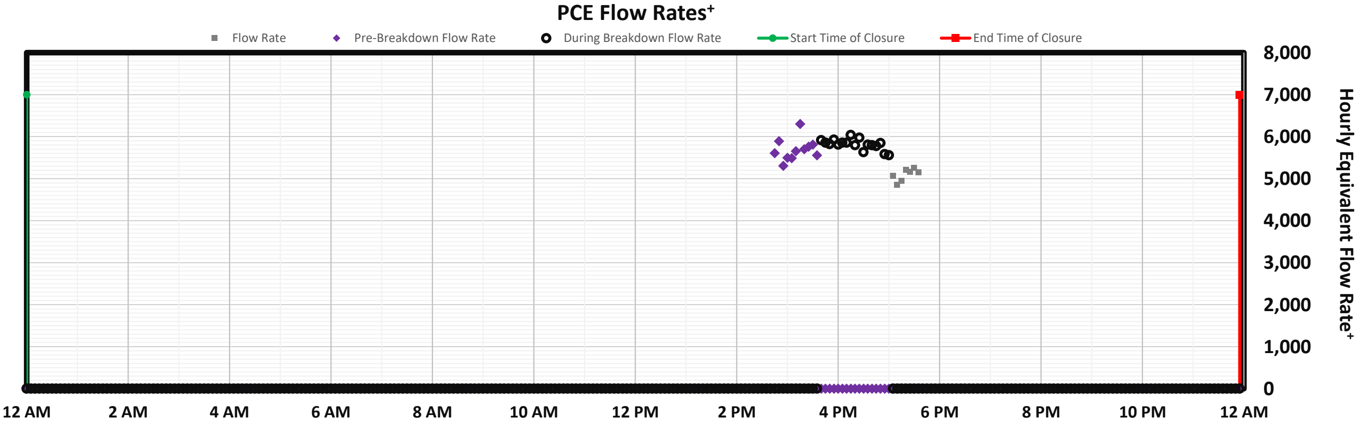
Select Times ->	Start Time:	3:40 PM	End Time:	5:05 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
465 per 5 minutes	4.2%	62%	38%	484 per 5 minutes

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
148	445	per 5 minutes	154	463
454	1,361	per 15 minutes	472	1,415
1,858	5,573	per hour	1,931	5,792

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
155	465	per 5 minutes	161	484
466	1,398	per 15 minutes	485	1,456
1,867	5,600	per hour	1,944	5,832
1,857	5,570	HCM 6 Estimate	1,935	5,806

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
162	485	per 5 minutes	168	503
479	1,436	per 15 minutes	495	1,484
1,874	5,621	per hour	1,952	5,857

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 39 NB Rock County Loc #5 - Rockton Rd (1007-11-71)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.182

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 39
Direction	NB
Construction ID:	1007-11-71
Nearest Crossroad:	Loc #5 - Rockton Rd
County:	Rock
Date:	8/31/2018
Day of Week:	Friday
Area Type:	Urban
Time of Day:	1:30 PM to 6:40 PM
Barrier Type:	Hard
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	4
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	4
Downstream Ramps (within 3mi)	4
Construction Duration (short/long)	Long
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	3
# of lanes open during construction	2
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM
Describe Construction Activity:	
Notes:	

PRE-BREAKDOWN CAPACITY

Select Times - >	*Start Time:*	1:30 PM	End Time:	5:00 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
164	*327*	per 5 minutes	*194*	*387*
460	*920*	per 15 minutes	*524*	*1,048*
1,699	*3,398*	per hour	*1,925*	*3,850*
1,840	***3,680***	**Max Flow Rate$_s$***	***2,096***	***4,192***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
144	*289*	per 5 minutes	*165*	*330*
432	*864*	per 15 minutes	*494*	*989*
1,730	***3,459***	**per hour**	***1,979***	***3,958***
1,727	***3,454***	**Max Flow Rate$_s$***	***1,978***	***3,956***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

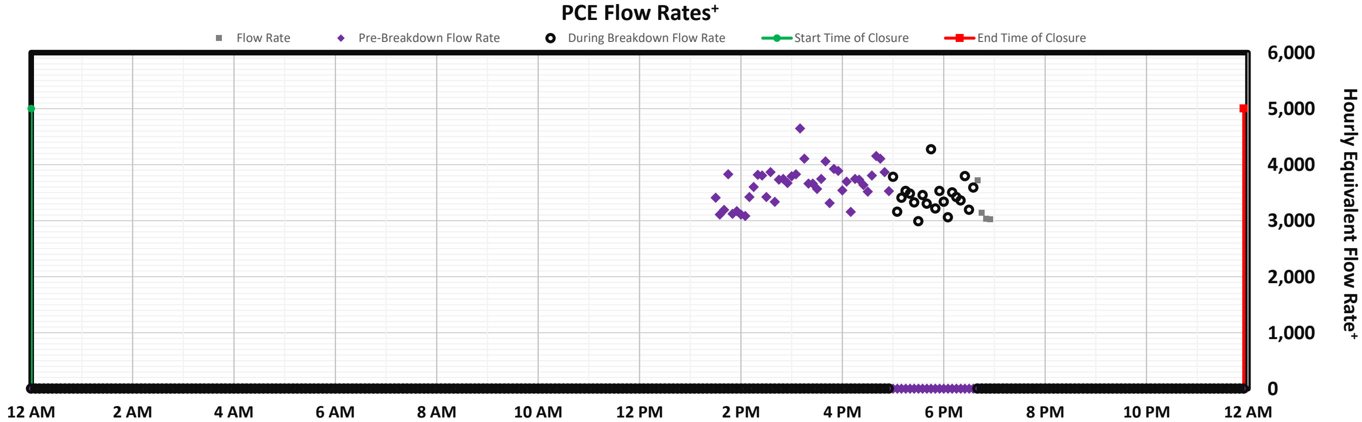
Select Times - >	*Start Time:*	5:00 PM	End Time:	6:40 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
250	**14.4%**	**40%**	**60%**	**286**
per 5 minutes				*per 5 minutes*

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
107	*213*	per 5 minutes	*125*	*249*
352	*704*	per 15 minutes	*406*	*812*
1,485	*2,970*	per hour	*1,699*	*3,397*

Average Observed Queue Discharge Rate				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
125	*250*	per 5 minutes	*143*	*286*
374	*748*	per 15 minutes	*428*	*856*
1,498	***2,996***	**per hour**	***1,714***	***3,428***
1,665	***3,331***	**HCM 6 Estimate**	***1,906***	***3,811***

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
155	*310*	per 5 minutes	*178*	*356*
403	*806*	per 15 minutes	*460*	*919*
1,516	*3,032*	per hour	*1,732*	*3,464*

PCE Flow Rates+



+ **Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.**

Work Zone Capacity
Queue Discharge Flow Rates

USH 12/18 EB Dane County Park Street (1206-04-69)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	USH 12/18
Direction	EB
Construction ID:	1206-04-69
Nearest Crossroad:	Park Street
County:	Dane
Date:	9/19/2018
Day of Week:	Wednesday
Area Type:	Urban
Time of Day:	12:00 AM to 10:00 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	9
Downstream Ramps (within 3mi)	7
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	3
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began	8:00 PM
Time Closure Ended	11:55 PM

Describe Construction Activity: Replace the deteriorating concrete joints and fibrecrete patches placed in a previous rehabilitation project.

Notes:

CRS: changed from Fish Hatchery to Park CCTV count because the taper down to 1 lane occurred closer to Park Street. Park CCTV captured good during breakdown video. No pre-breakdown since after it's down two one lane breakdown occurred almost immediately.

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
103	103	per 5 minutes	109	109
309	309	per 15 minutes	327	327
1,240	1,240	per hour	1,314	1,314
1,235	1,235	Max Flow Rate$_s$*	1,309	1,309

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times ->	Start Time:	8:15 PM	End Time:	10:00 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
89 per 5 minutes	5.8%	23%	77%	94 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
67	67	per 5 minutes	73	73
235	235	per 15 minutes	248	248
1,054	1,054	per hour	1,111	1,111

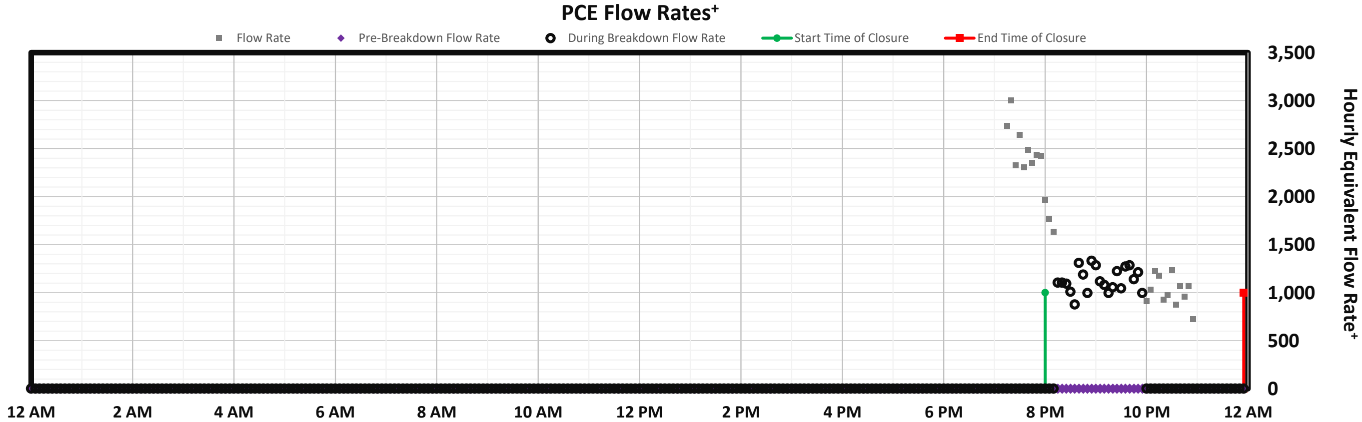
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
89	89	per 5 minutes	94	94
267	267	per 15 minutes	283	283
1,074	1,074	per hour	1,138	1,138
1,217	1,217	HCM 6 Estimate	1,288	1,288

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
106	106	per 5 minutes	111	111
291	291	per 15 minutes	311	311
1,096	1,096	per hour	1,170	1,170

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

USH 12/18 EB Dane County Todd Drive (1206-04-69)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	USH 12/18
Direction	EB
Construction ID:	1206-04-69
Nearest Crossroad:	Todd Drive
County:	Dane
Date:	10/2/2018
Day of Week:	Tuesday
Area Type:	Urban
Time of Day:	12:00 AM to 10:20 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	6
Downstream Ramps (within 3mi)	9
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	3
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	8:00 PM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Replace the deteriorating concrete joints and fibrecrete patches placed in a previous rehabilitation project.

Notes:

Good video.

PRE-BREAKDOWN CAPACITY

Select Times ->	*Start Time:*	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
0	*0*	per 5 minutes	*0*	*0*
0	*0*	per 15 minutes	*0*	*0*
0	*0*	per hour	*0*	*0*
0	***0***	**Max Flow Rate$_s$***	***0***	***0***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
122	*122*	per 5 minutes	*128*	*128*
364	*364*	per 15 minutes	*383*	*383*
1,456	***1,456***	**per hour**	***1,535***	***1,535***
1,457	***1,457***	**Max Flow Rate$_s$***	***1,532***	***1,532***

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times ->	*Start Time:*	8:10 PM	End Time:	10:20 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
106 *per 5 minutes*	5.0%	20%	80%	111 *per 5 minutes*

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
57	*57*	per 5 minutes	*63*	*63*
255	*255*	per 15 minutes	*275*	*275*
1,212	*1,212*	per hour	*1,286*	*1,286*

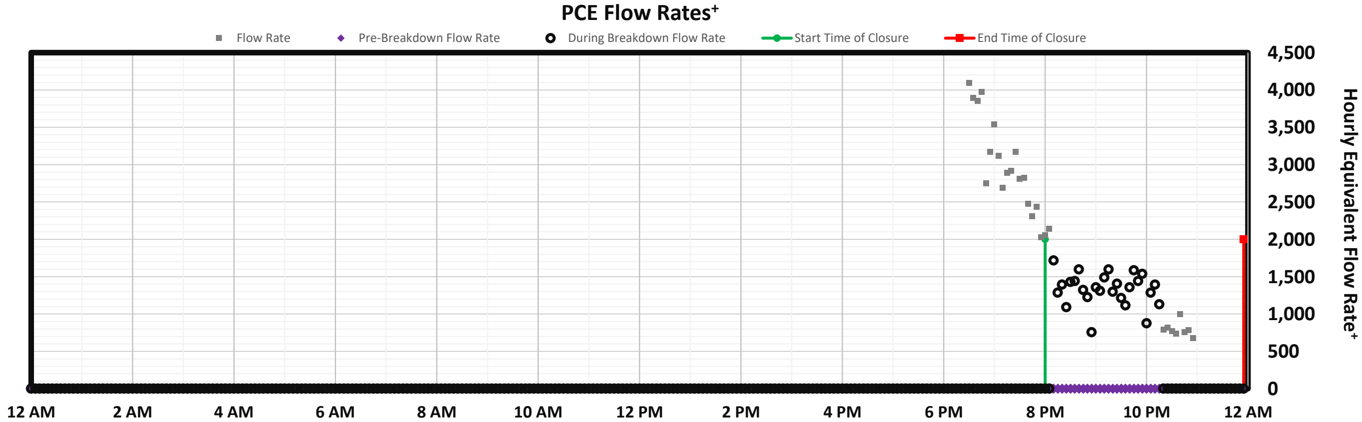
---------------- Average Observed Queue Discharge Rate ----------------

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
106	*106*	per 5 minutes	*111*	*111*
315	*315*	per 15 minutes	*332*	*332*
1,261	***1,261***	**per hour**	***1,329***	***1,329***
1,226	***1,226***	**HCM 6 Estimate**	***1,288***	***1,288***

-------------------------- Maximum Observed Queue Discharge Rate --------------------------

Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
140	*140*	per 5 minutes	*143*	*143*
365	*365*	per 15 minutes	*380*	*380*
1,322	*1,322*	per hour	*1,391*	*1,391*

PCE Flow Rates+



+ **Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.**

Work Zone Capacity

Queue Discharge Flow Rates

USH 12/18 EB Dane County Todd Drive (1206-04-69)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	USH 12/18
Direction	EB
Construction ID:	1206-04-69
Nearest Crossroad:	Todd Drive
County:	Dane
Date:	10/2/2018
Day of Week:	Tuesday
Area Type:	Urban
Time of Day:	12:00 AM to 7:45 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	6
Downstream Ramps (within 3mi)	9
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	3
# of lanes open during construction	2
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	7:00 PM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Replace the deteriorating concrete joints and fibrecrete patches placed in a previous rehabilitation project.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
134	269	per 5 minutes	141	283
400	801	per 15 minutes	421	843
1,612	3,224	per hour	1,695	3,390
1,601	3,203	Max Flow Rate$_s$*	1,686	3,371

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times ->	Start Time:	7:00 PM	End Time:	7:45 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
233 per 5 minutes	5.2%	40%	60%	245 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
99	197	per 5 minutes	103	206
324	648	per 15 minutes	338	675
1,396	2,792	per hour	1,468	2,936

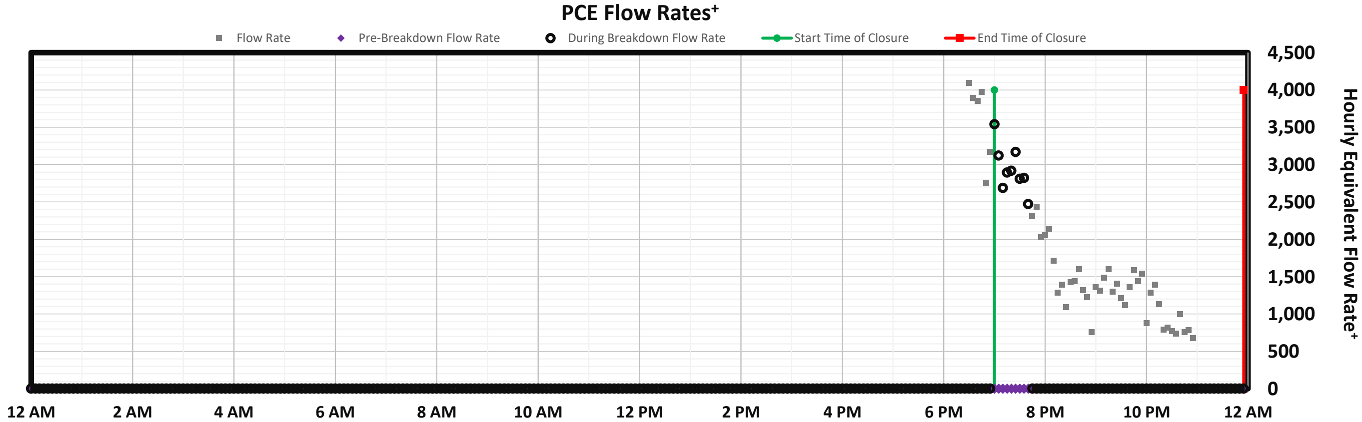
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
116	233	per 5 minutes	122	245
347	693	per 15 minutes	365	730
1,396	2,792	per hour	1,468	2,936
1,554	3,109	HCM 6 Estimate	1,635	3,269

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
141	281	per 5 minutes	148	295
369	738	per 15 minutes	390	779
1,396	2,792	per hour	1,468	2,936

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

USH 12/18 EB Dane County Monona (1206-04-69)

PCE Conversion Factor: 2.00

Pre-Breakdown Capacity Drop Factor (PBCDF): 0.134

|<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	USH 12/18
Direction	EB
Construction ID:	1206-04-69
Nearest Crossroad:	Monona
County:	Dane
Date:	10/10/2018
Day of Week:	Wednesday
Area Type:	Urban
Time of Day:	12:00 AM to 9:25 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	7
Downstream Ramps (within 3mi)	7
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	3
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	8:00 PM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Replace the deteriorating concrete joints and fibrecrete patches placed in a previous rehabilitation project.

Notes: No breakdown indicated.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
131	131	per 5 minutes	138	138
389	389	per 15 minutes	413	413
1,556	1,556	per hour	1,656	1,656
1,557	1,557	Max Flow Rate$_s$*	1,654	1,654

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	8:00 PM	End Time:	9:25 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
113 per 5 minutes	6.0%	36%	64%	120 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
99	99	per 5 minutes	103	103
309	309	per 15 minutes	329	329
1,310	1,310	per hour	1,397	1,397

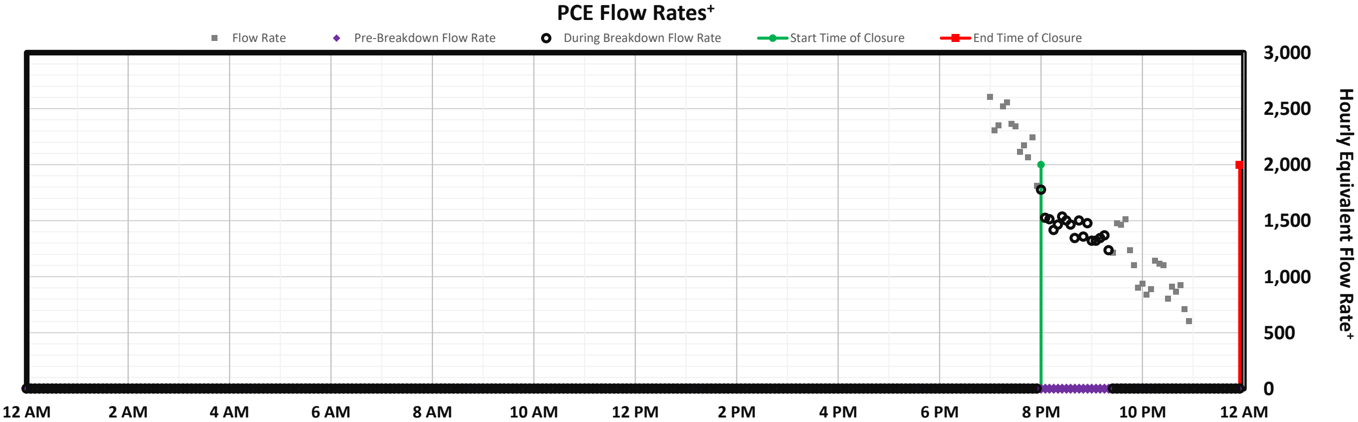
---- Average Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
113	113	per 5 minutes	120	120
337	337	per 15 minutes	358	358
1,347	1,347	per hour	1,435	1,435
1,215	1,215	HCM 6 Estimate	1,288	1,288

---- Maximum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
143	143	per 5 minutes	148	148
385	385	per 15 minutes	401	401
1,401	1,401	per hour	1,489	1,489

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

USH 12/18 WB Dane County West Broadway (1206-04-69)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

Version 1.8

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Site Data	
Highway:	USH 12/18
Direction	WB
Construction ID:	1206-04-69
Nearest Crossroad:	West Broadway
County:	Dane
Date:	10/8/2018
Day of Week:	Monday
Area Type:	Urban
Time of Day:	12:00 AM to 9:55 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	5
Downstream Ramps (within 3mi)	9
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	3
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	8:00 PM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Replace the deteriorating concrete joints and fibrecrete patches placed in a previous rehabilitation project.

Notes: 3-2 from 7pm-8pm
3-1 from 8pm-overnight

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	**0**	**Max Flow Rate$_s$***	**0**	**0**

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
120	120	per 5 minutes	125	125
354	354	per 15 minutes	371	371
1,389	**1,389**	**per hour**	**1,453**	**1,453**
1,416	**1,416**	**Max Flow Rate$_s$***	**1,483**	**1,483**

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	8:05 PM	End Time:	9:55 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
104 per 5 minutes	4.6%	31%	69%	109 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
77	77	per 5 minutes	79	79
278	278	per 15 minutes	286	286
1,172	1,172	per hour	1,230	1,230

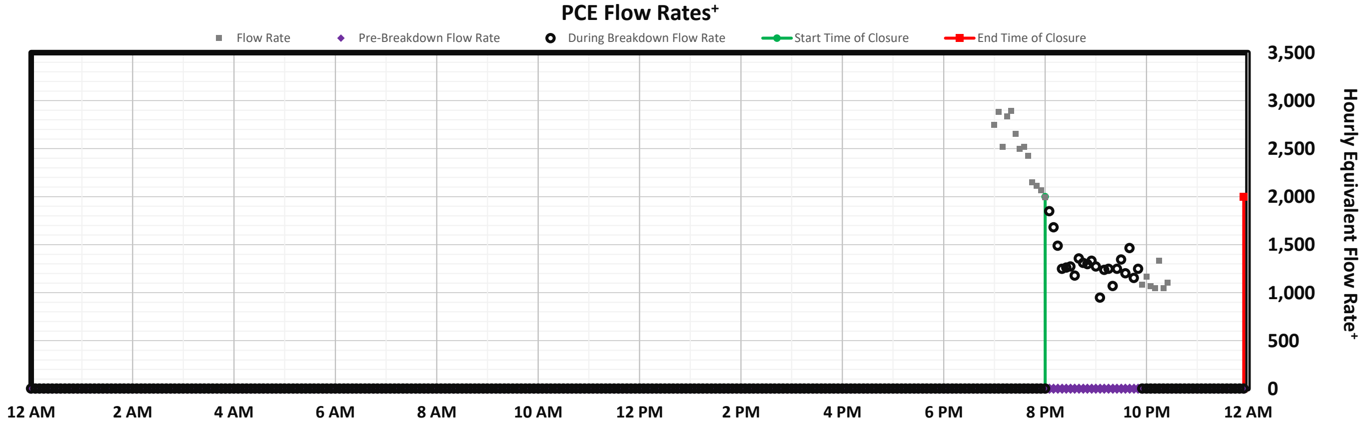
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
104	104	per 5 minutes	109	109
307	307	per 15 minutes	321	321
1,203	**1,203**	**per hour**	**1,258**	**1,258**
1,231	**1,231**	**HCM 6 Estimate**	**1,288**	**1,288**

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
150	150	per 5 minutes	154	154
401	401	per 15 minutes	418	418
1,321	1,321	per hour	1,378	1,378

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

USH 12/18 WB Dane County West Broadway (1206-04-69)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

|<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	USH 12/18
Direction	WB
Construction ID:	1206-04-69
Nearest Crossroad:	West Broadway
County:	Dane
Date:	10/9/2018
Day of Week:	Tuesday
Area Type:	Urban
Time of Day:	12:00 AM to 10:05 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	5
Downstream Ramps (within 3mi)	9
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	3
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	8:00 PM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Replace the deteriorating concrete joints and fibrecrete patches placed in a previous rehabilitation project.

Notes: 3-2 from 7pm-8pm
3-1 from 8pm-overnight

Westbound off-ramp to West Broadway gets a lot of diversion traffic.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
137	137	per 5 minutes	144	144
410	410	per 15 minutes	430	430
1,615	1,615	per hour	1,697	1,697
1,638	1,638	Max Flow Rate$_s$*	1,719	1,719

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	8:05 PM	End Time:	10:05 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
119 per 5 minutes	4.8%	42%	58%	125 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
101	101	per 5 minutes	107	107
317	317	per 15 minutes	332	332
1,337	1,337	per hour	1,412	1,412

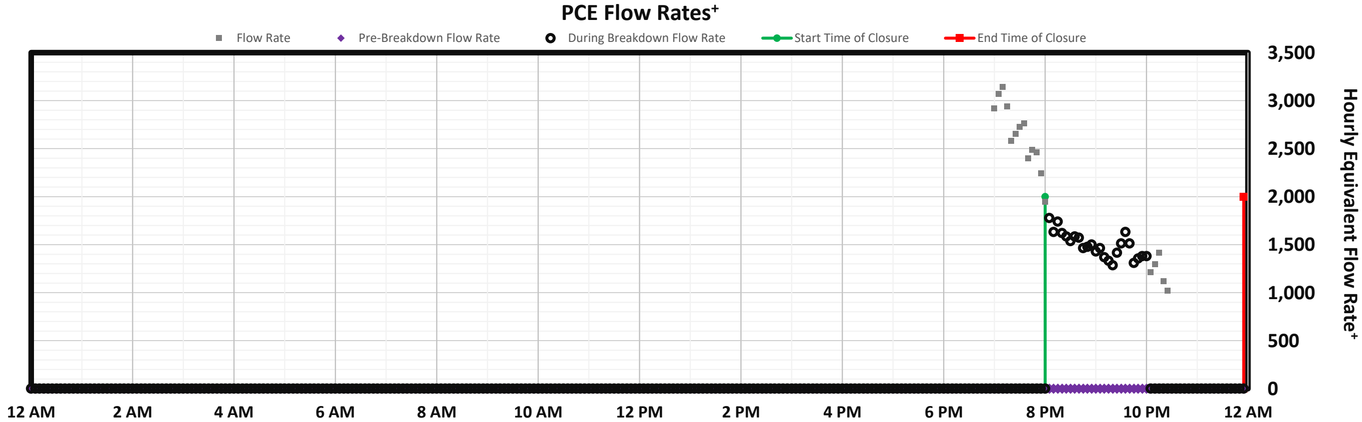
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
119	119	per 5 minutes	125	125
355	355	per 15 minutes	372	372
1,399	1,399	per hour	1,470	1,470
1,229	1,229	HCM 6 Estimate	1,288	1,288

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
143	143	per 5 minutes	148	148
418	418	per 15 minutes	429	429
1,514	1,514	per hour	1,576	1,576

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

USH 12/18 WB Dane County Rimrock Road (1206-04-69)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	USH 12/18
Direction	WB
Construction ID:	1206-04-69
Nearest Crossroad:	Rimrock Road
County:	Dane
Date:	10/10/2018
Day of Week:	Wednesday
Area Type:	Urban
Time of Day:	12:00 AM to 9:50 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	7
Downstream Ramps (within 3mi)	7
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	3
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	8:00 PM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Replace the deteriorating concrete joints and fibrecrete patches placed in a previous rehabilitation project.

Notes:

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
129	129	per 5 minutes	134	134
383	383	per 15 minutes	399	399
1,532	1,532	per hour	1,594	1,594
1,533	1,533	Max Flow Rate$_s$*	1,597	1,597

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	8:10 PM	End Time:	9:50 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
111 per 5 minutes	4.3%	33%	67%	116 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
96	96	per 5 minutes	101	101
308	308	per 15 minutes	324	324
1,304	1,304	per hour	1,359	1,359

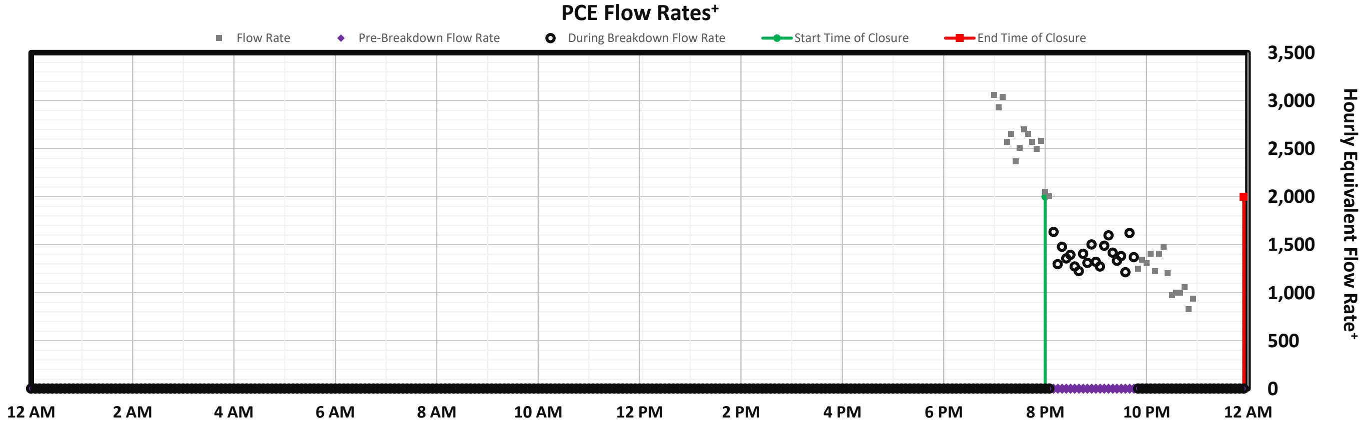
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
111	111	per 5 minutes	116	116
332	332	per 15 minutes	346	346
1,326	1,326	per hour	1,380	1,380
1,235	1,235	HCM 6 Estimate	1,288	1,288

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
130	130	per 5 minutes	136	136
365	365	per 15 minutes	375	375
1,351	1,351	per hour	1,404	1,404

PCE Flow Rates+



\+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

USH 12/18 WB Dane County West Broadway (1206-04-69)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	USH 12/18
Direction	WB
Construction ID:	1206-04-69
Nearest Crossroad:	West Broadway
County:	Dane
Date:	10/11/2018
Day of Week:	Thursday
Area Type:	Urban
Time of Day:	12:00 AM to 11:00 PM
Barrier Type:	Soft
Day or Night	Night
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	55 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	5
Downstream Ramps (within 3mi)	9
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	3
# of lanes open during construction	1
Lane widths	11 ft
Significant grade?	No
Time Closure Began •	8:00 PM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Replace the deteriorating concrete joints and fibrecrete patches placed in a previous rehabilitation project.

Notes: Gap in counts 10:05pm and 10:30pm

3-2 from 7pm-8pm
3-1 from 8pm-overnight

Ramp to Broadway within taper closed.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
117	117	per 5 minutes	124	124
352	352	per 15 minutes	371	371
1,406	1,406	per hour	1,476	1,476
1,409	1,409	Max Flow Rate$_s$*	1,486	1,486

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

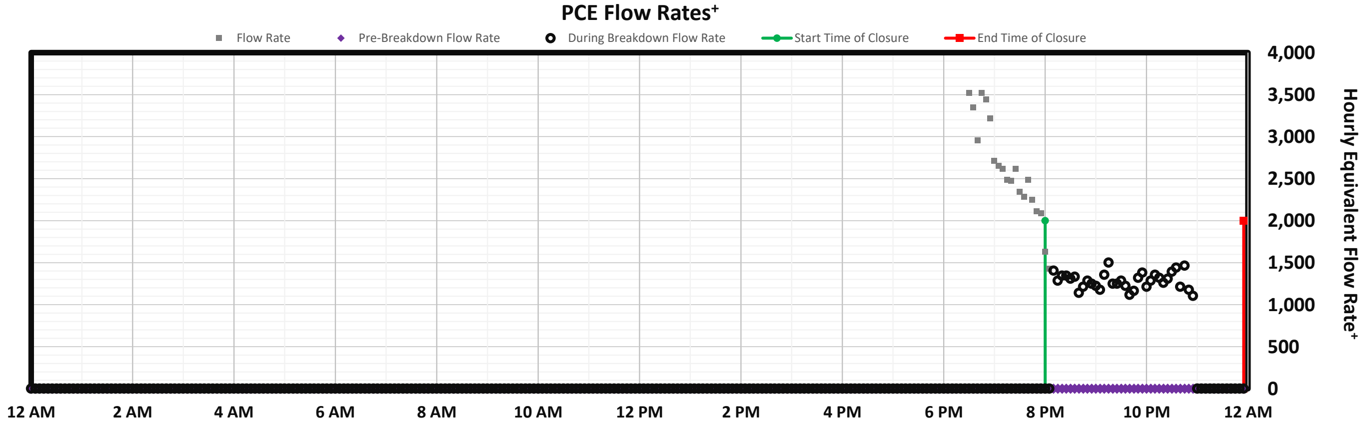
Select Times - >	Start Time:	8:10 PM	End Time:	11:00 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
102 per 5 minutes	5.4%	35%	65%	107 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
89	89	per 5 minutes	92	92
275	275	per 15 minutes	292	292
1,195	1,195	per hour	1,256	1,256

Average Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
102	102	per 5 minutes	107	107
305	305	per 15 minutes	322	322
1,217	1,217	per hour	1,279	1,279
1,222	1,222	HCM 6 Estimate	1,288	1,288

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
117	117	per 5 minutes	125	125
328	328	per 15 minutes	345	345
1,245	1,245	per hour	1,329	1,329

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

USH 151 NB Dane County Loc #3 - N of CTH VV (1111-03-70)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.283 <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	USH 151
Direction	NB
Construction ID:	1111-03-70
Nearest Crossroad:	Loc #3 - N of CTH VV
County:	Dane
Date:	9/21/2018
Day of Week:	Friday
Area Type:	Rural
Time of Day:	2:00 PM to 6:40 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	4
Work Zone Speed Limit	55 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM
Describe Construction Activity:	
Notes:	

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	2:00 PM	End Time:	3:00 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
124	*124*	per 5 minutes	*137*	*137*
332	*332*	per 15 minutes	*368*	*368*
1,236	*1,236*	per hour	*1,361*	*1,361*
➤ *1,328*	*1,328*	Max Flow Rate$_s$*	*1,472*	*1,472*

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
94	*94*	per 5 minutes	*102*	*102*
284	*284*	per 15 minutes	*307*	*307*
1,127	*1,127*	per hour	*1,218*	*1,218*
1,137	*1,137*	Max Flow Rate$_s$*	*1,228*	*1,228*

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

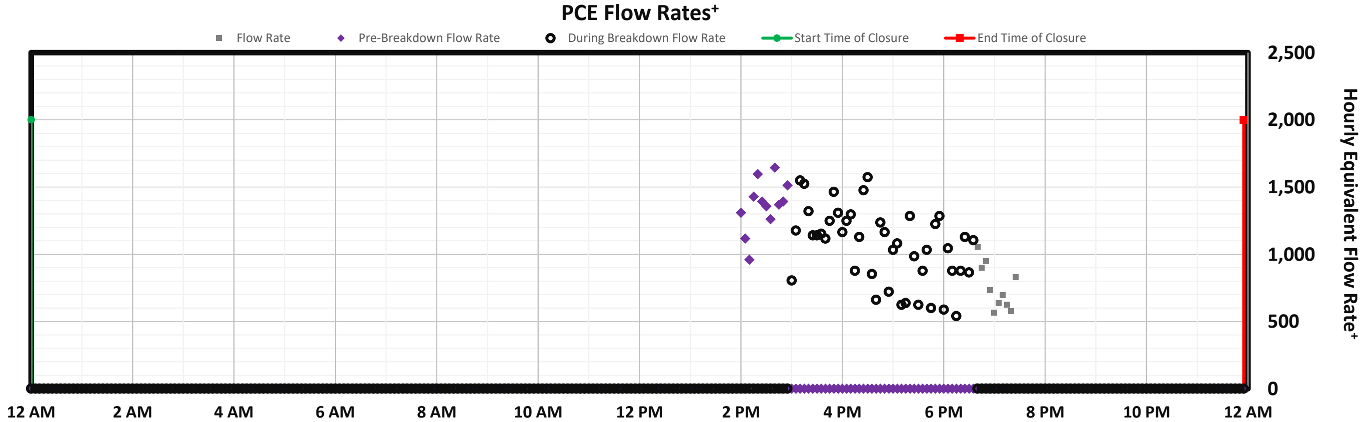
Select Times - >	Start Time:	3:00 PM	End Time:	6:40 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
82 *per 5 minutes*	8.0%	52%	48%	88 *per 5 minutes*

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
43	*43*	per 5 minutes	*45*	*45*
181	*181*	per 15 minutes	*191*	*191*
812	*812*	per hour	*879*	*879*

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
82	*82*	per 5 minutes	*88*	*88*
246	*246*	per 15 minutes	*266*	*266*
➤ *976*	*976*	per hour	*1,055*	*1,055*
1,241	*1,241*	HCM 6 Estimate	*1,340*	*1,340*

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
120	*120*	per 5 minutes	*131*	*131*
337	*337*	per 15 minutes	*366*	*366*
1,192	*1,192*	per hour	*1,281*	*1,281*

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 WB Juneau County STH 80 (1016-03-61)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1016-03-61
Nearest Crossroad:	STH 80
County:	Juneau
Date:	4/12/2019
Day of Week:	Friday
Area Type:	Rural
Time of Day:	12:00 AM to 7:55 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	1
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity:
Miscellaneous bridge rehabilitation activities:
- Polymer overlay.
- Concrete repair with cathodic protection to girders, pier caps, abutments.
- Wrap steel pier columns in petroleum tape to prevent further corrosion.
- Painting bearings and any exposed steel

Notes: Temporary speed declaration during polymer.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
97	97	per 5 minutes	120	120
291	291	per 15 minutes	360	360
1,162	1,162	per hour	1,440	1,440
1,163	1,163	Max Flow Rate$_s$*	1,441	1,441

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

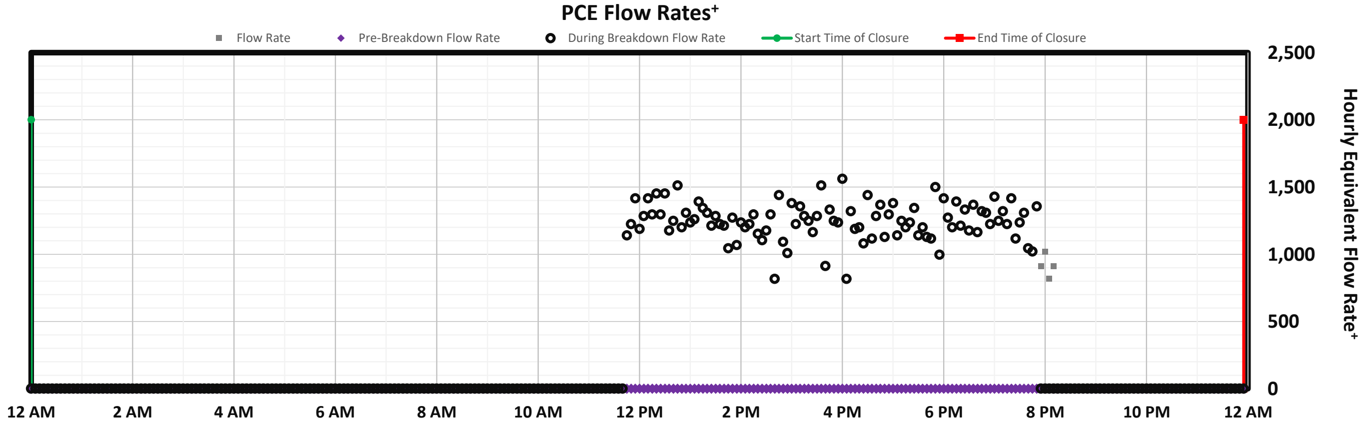
Select Times - >	Start Time:	11:45 AM	End Time:	7:55 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
84 per 5 minutes	24.0%	18%	82%	104 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
50	50	per 5 minutes	68	68
217	217	per 15 minutes	274	274
946	946	per hour	1,157	1,157

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
84	84	per 5 minutes	104	104
252	252	per 15 minutes	312	312
1,006	1,006	per hour	1,247	1,247
1,059	1,059	HCM 6 Estimate	1,313	1,313

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
105	105	per 5 minutes	130	130
279	279	per 15 minutes	350	350
1,063	1,063	per hour	1,330	1,330

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 94 WB Juneau County STH 80 (1016-03-61)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1016-03-61
Nearest Crossroad:	STH 80
County:	Juneau
Date:	4/14/2019
Day of Week:	Sunday
Area Type:	Rural
Time of Day:	12:00 AM to 7:00 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	1
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity:
Miscellaneous bridge rehabilitation activities:
- Polymer overlay.
- Concrete repair with cathodic protection to girders, pier caps, abutments.
- Wrap steel pier columns in petroleum tape to prevent further corrosion.
- Painting bearings and any exposed steel

Notes: Closures restricted to weekdays; closed lanes depends on work being conducted.
Temporary speed declaration during polymer.

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
107	107	per 5 minutes	123	123
321	321	per 15 minutes	369	369
1,290	1,290	per hour	1,478	1,478
1,285	1,285	Max Flow Rate$_s$*	1,477	1,477

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times ->	Start Time:	10:45 AM	End Time:	7:00 PM

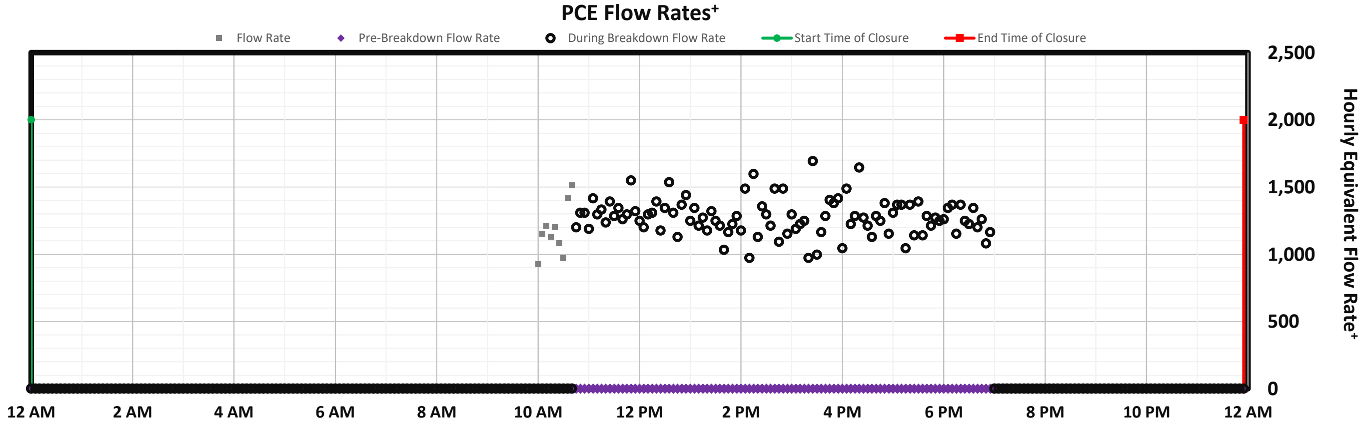
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
93 per 5 minutes	15.0%	20%	80%	106 per 5 minutes

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
65	65	per 5 minutes	81	81
229	229	per 15 minutes	284	284
1,040	1,040	per hour	1,214	1,214

Average Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
93	93	per 5 minutes	106	106
278	278	per 15 minutes	320	320
1,117	1,117	per hour	1,280	1,280
1,141	1,141	HCM 6 Estimate	1,313	1,313

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
121	121	per 5 minutes	141	141
314	314	per 15 minutes	350	350
1,172	1,172	per hour	1,335	1,335

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 WB Juneau County STH 80 (1016-03-61)

PCE Conversion Factor: 2.00

Pre-Breakdown Capacity Drop Factor (PBCDF): 0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1016-03-61
Nearest Crossroad:	STH 80
County:	Juneau
Date:	4/15/2019
Day of Week:	Monday
Area Type:	Rural
Time of Day:	12:00 AM to 6:00 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	1
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity:
Miscellaneous bridge rehabilitation activities:
- Polymer overlay.
- Concrete repair with cathodic protection to girders, pier caps, abutments.
- Wrap steel pier columns in petroleum tape to prevent further corrosion.
- Painting bearings and any exposed steel

Notes: Closures restricted to weekdays; closed lanes depends on work being conducted.
Temporary speed declaration during polymer.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
88	88	per 5 minutes	120	120
264	264	per 15 minutes	360	360
1,057	1,057	per hour	1,445	1,445
1,054	1,054	Max Flow Rate$_s$*	1,439	1,439

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	2:00 PM	End Time:	6:00 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
76 per 5 minutes	36.4%	16%	84%	104 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
53	53	per 5 minutes	71	71
185	185	per 15 minutes	250	250
820	820	per hour	1,162	1,162

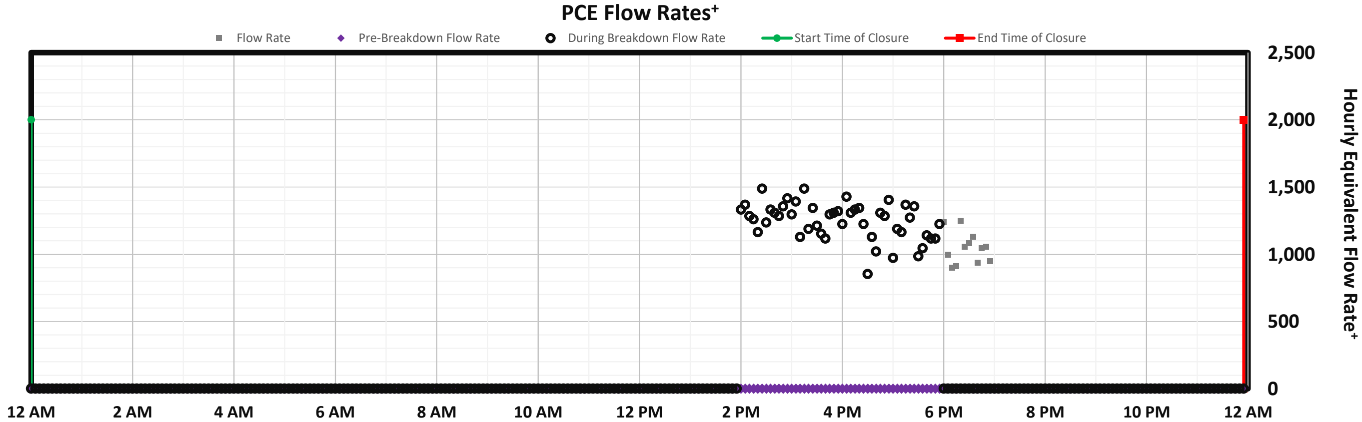
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
76	76	per 5 minutes	104	104
228	228	per 15 minutes	312	312
916	916	per hour	1,251	1,251
962	962	HCM 6 Estimate	1,313	1,313

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
99	99	per 5 minutes	124	124
262	262	per 15 minutes	342	342
1,007	1,007	per hour	1,326	1,326

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 WB Juneau County STH 80 (1016-03-61)

PCE Conversion Factor: 2.00

Pre-Breakdown Capacity Drop Factor (PBCDF): 0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1016-03-61
Nearest Crossroad:	STH 80
County:	Juneau
Date:	4/16/2019
Day of Week:	Tuesday
Area Type:	Rural
Time of Day:	12:00 AM to 5:35 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	1
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity:
Miscellaneous bridge rehabilitation activities:
- Polymer overlay.
- Concrete repair with cathodic protection to girders, pier caps, abutments.
- Wrap steel pier columns in petroleum tape to prevent further corrosion.
- Painting bearings and any exposed steel

Notes: Closures restricted to weekdays; closed lanes depends on work being conducted.
Temporary speed declaration during polymer.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
87	87	per 5 minutes	126	126
261	261	per 15 minutes	380	380
1,053	1,053	per hour	1,527	1,527
1,044	1,044	Max Flow Rate$_s$*	1,518	1,518

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	2:00 PM	End Time:	5:35 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
75 per 5 minutes	45.4%	13%	87%	109 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
55	55	per 5 minutes	77	77
190	190	per 15 minutes	279	279
821	821	per hour	1,181	1,181

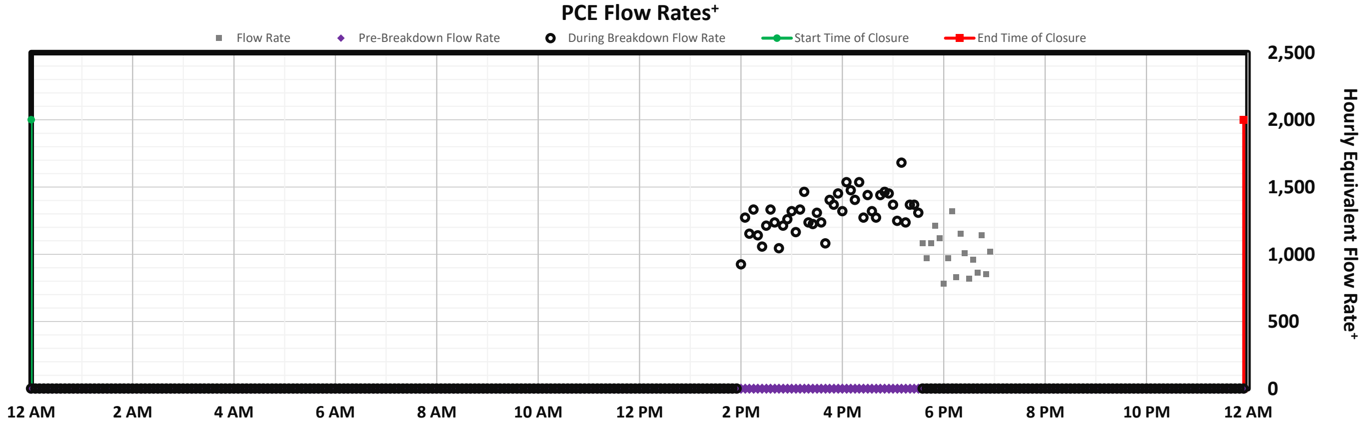
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
75	75	per 5 minutes	109	109
226	226	per 15 minutes	329	329
912	912	per hour	1,323	1,323
903	903	HCM 6 Estimate	1,313	1,313

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
93	93	per 5 minutes	140	140
254	254	per 15 minutes	368	368
982	982	per hour	1,415	1,415

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates
IH 94 WB Juneau County STH 80 (1016-03-61)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	WB
Construction ID:	1016-03-61
Nearest Crossroad:	STH 80
County:	Juneau
Date:	4/16/2019
Day of Week:	Tuesday
Area Type:	Rural
Time of Day:	12:00 AM to 6:50 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	1
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Left
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity:
Miscellaneous bridge rehabilitation activities:
- Polymer overlay.
- Concrete repair with cathodic protection to girders, pier caps, abutments.
- Wrap steel pier columns in petroleum tape to prevent further corrosion.
- Painting bearings and any exposed steel

Notes: Closures restricted to weekdays; closed lanes depends on work being conducted.
Temporary speed declaration during polymer.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
88	88	per 5 minutes	124	124
263	263	per 15 minutes	373	373
1,049	1,049	per hour	1,488	1,488
1,053	1,053	Max Flow Rate$_s$*	1,492	1,492

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	2:00 PM	End Time:	6:50 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
76 per 5 minutes	41.8%	14%	86%	108 per 5 minutes

Minimum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
54	54	per 5 minutes	85	85
186	186	per 15 minutes	267	267
811	811	per hour	1,157	1,157

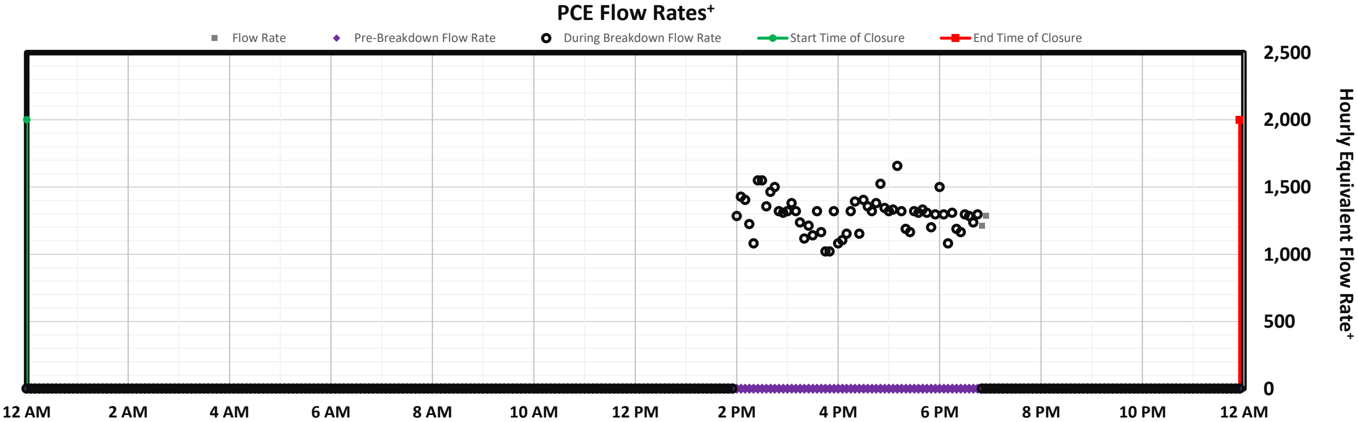
Average Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
76	76	per 5 minutes	108	108
228	228	per 15 minutes	323	323
908	908	per hour	1,289	1,289
926	926	HCM 6 Estimate	1,313	1,313

Maximum Observed Queue Discharge Rate

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
103	103	per 5 minutes	138	138
272	272	per 15 minutes	371	371
991	991	per hour	1,375	1,375

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 94 EB St. Croix County STH 65 (1020-03-76)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	EB
Construction ID:	1020-03-76
Nearest Crossroad:	STH 65
County:	St. Croix
Date:	4/30/2019
Day of Week:	Tuesday
Area Type:	Rural
Time of Day:	12:00 AM to 1:40 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	4
Work Zone Speed Limit	60 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Temp Pavement
Upstream Ramps (within 3mi)	1
Downstream Ramps (within 3mi)	1
Construction Duration (short/long)	Intermediate
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began	12:00 AM
Time Closure Ended	11:55 PM

Describe Construction Activity:
Replace IH 94 WB over 130th Street bridge. Approaching roadway will be realigned and pavement will be replaced.

Notes: Reduced speed limit will follow guidance in TGM

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
79	79	per 5 minutes	111	111
235	235	per 15 minutes	330	330
963	963	per hour	1,348	1,348
941	941	Max Flow Rate$_s$*	1,318	1,318

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

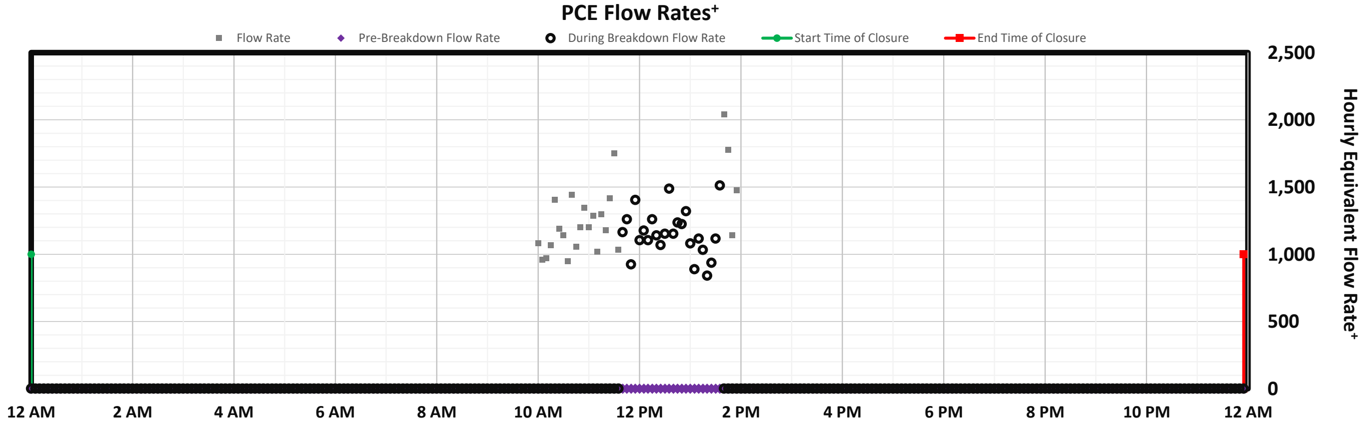
Select Times - >	Start Time:	11:40 AM	End Time:	1:40 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
69 per 5 minutes	39.9%	10%	90%	96 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
47	47	per 5 minutes	70	70
164	164	per 15 minutes	234	234
801	801	per hour	1,119	1,119

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
69	69	per 5 minutes	96	96
204	204	per 15 minutes	285	285
834	834	per hour	1,167	1,167
958	958	HCM 6 Estimate	1,340	1,340

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
88	88	per 5 minutes	126	126
233	233	per 15 minutes	323	323
860	860	per hour	1,209	1,209

PCE Flow Rates⁺



⁺ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 EB St. Croix County CTH NN (1022-07-76)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.159

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	EB
Construction ID:	1022-07-76
Nearest Crossroad:	CTH NN
County:	St. Croix
Date:	4/23/2019
Day of Week:	Tuesday
Area Type:	Rural
Time of Day:	2:30 PM to 5:15 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Intermediate
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Concrete pavement Repair

Notes: TMP not found. Used info from 1020-06-75
Check barrier type on video. This says concrete barrier. They could have both been used out there.
Speed limit will be reduced according to TGM 13-5-6.

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	2:30 PM	End Time:	3:35 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
113	113	per 5 minutes	151	151
301	301	per 15 minutes	405	405
1,053	1,053	per hour	1,459	1,459
1,204	1,204	Max Flow Rate$_s$*	1,620	1,620

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
100	100	per 5 minutes	131	131
302	302	per 15 minutes	395	395
1,197	1,197	per hour	1,573	1,573
1,207	1,207	Max Flow Rate$_s$*	1,579	1,579

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

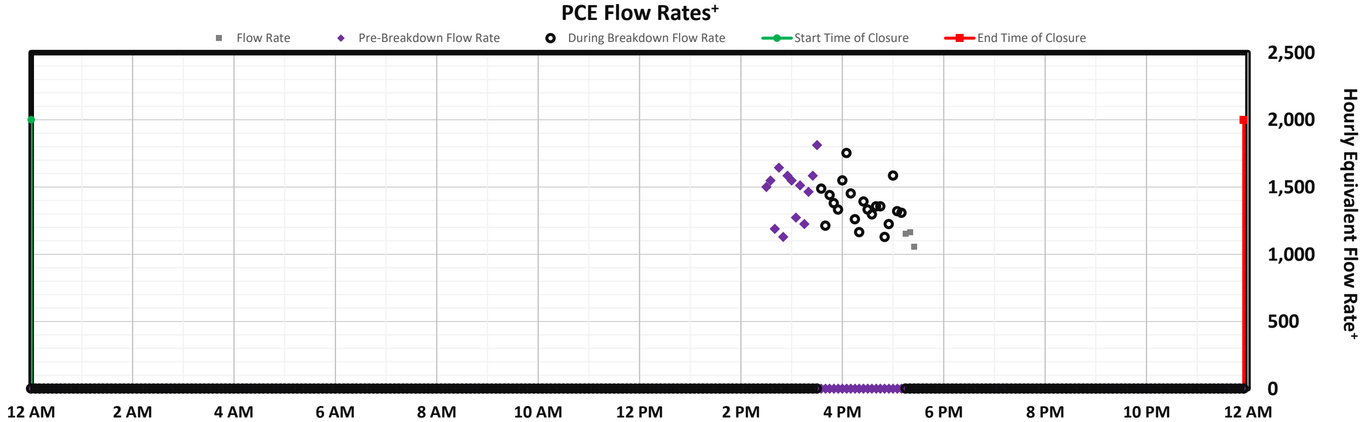
Select Times ->	Start Time:	3:35 PM	End Time:	5:15 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
87 per 5 minutes	30.9%	18%	82%	114 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
69	69	per 5 minutes	94	94
233	233	per 15 minutes	309	309
1,004	1,004	per hour	1,310	1,310

---- Average Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
87	87	per 5 minutes	114	114
261	261	per 15 minutes	342	342
1,036	1,036	per hour	1,362	1,362
1,010	1,010	HCM 6 Estimate	1,322	1,322

---- Maximum Observed Queue Discharge Rate ----				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
113	113	per 5 minutes	146	146
301	301	per 15 minutes	396	396
1,053	1,053	per hour	1,396	1,396

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 94 EB St. Croix County CTH NN (1022-07-76)

PCE Conversion Factor:	**2.00**
Pre-Breakdown Capacity Drop Factor (PBCDF):	**0.134**
	0.081

<-- Observed PBCDF
[1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	EB
Construction ID:	1022-07-76
Nearest Crossroad:	CTH NN
County:	St. Croix
Date:	4/24/2019
Day of Week:	Wednesday
Area Type:	Rural
Time of Day:	3:00 PM to 4:25 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Intermediate
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Concrete pavement Repair

Notes: TMP not found. Used info from 1020-06-75
Check barrier type on video. This says concrete barrier. They could have both been used out there.
Speed limit will be reduced according to TGM 13-5-6.

---------------------------- PRE-BREAKDOWN CAPACITY ----------------------------

Select Times - >	*Start Time:*	**3:00 PM**	**End Time:**	**3:20 PM**
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
100	*100*	per 5 minutes	*139*	*139*
295	*295*	per 15 minutes	*400*	*400*
1,155	*1,155*	per hour	*1,581*	*1,581*
1,180	***1,180***	**Max Flow Rate$_s$***	***1,600***	***1,600***

*** Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.**

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
105	*105*	per 5 minutes	*140*	*140*
319	*319*	per 15 minutes	*426*	*426*
1,270	***1,270***	**per hour**	***1,698***	***1,698***
1,275	***1,275***	**Max Flow Rate$_s$***	***1,704***	***1,704***

*** Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.**

-------------- DURING BREAKDOWN QUEUE DISCHARGE RATE --------------

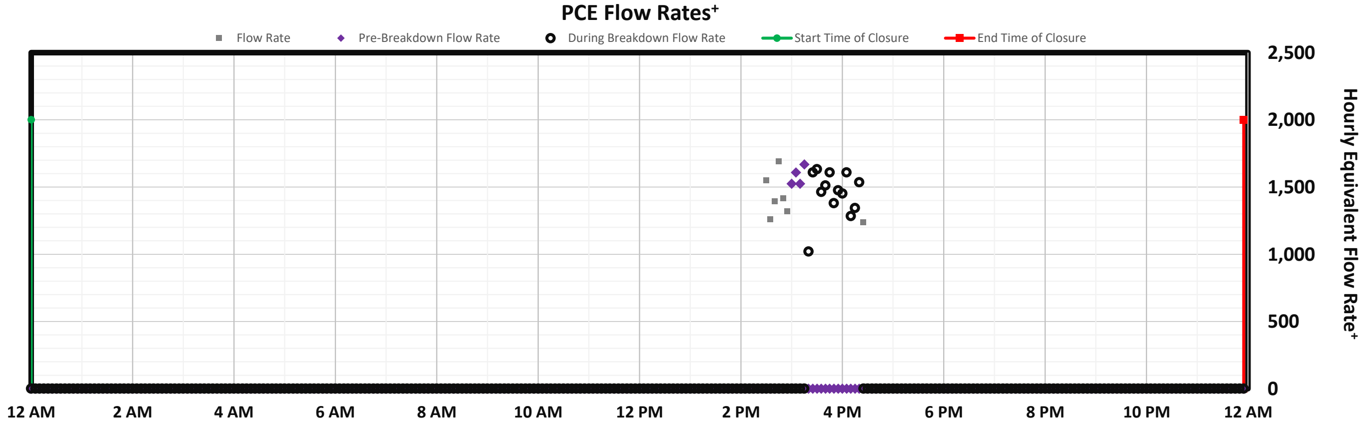
Select Times - >	*Start Time:*	**3:20 PM**	**End Time:**	**4:25 PM**
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	**% Trucks**	**SU Split**	**Semi Split**	**Ave PCE Flow**
91	**33.4%**	**20%**	**80%**	**121**
per 5 minutes				*per 5 minutes*

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
60	*60*	per 5 minutes	*85*	*85*
259	*259*	per 15 minutes	*347*	*347*
1,078	*1,078*	per hour	*1,449*	*1,449*

---------------- Average Observed Queue Discharge Rate ----------------				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
91	*91*	per 5 minutes	*121*	*121*
276	*276*	per 15 minutes	*369*	*369*
1,100	***1,100***	**per hour**	***1,471***	***1,471***
991	***991***	**HCM 6 Estimate**	***1,322***	***1,322***

-------------------------- Maximum Observed Queue Discharge Rate --------------------------				
Vehicles/Lane	***Vehicles***	***Time Period***	***PCEs/Lane***	***PCEs***
104	*104*	per 5 minutes	*136*	*136*
290	*290*	per 15 minutes	*392*	*392*
1,122	*1,122*	per hour	*1,492*	*1,492*

PCE Flow Rates⁺



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 94 EB St. Croix County CTH NN (1022-07-76)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

|<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	EB
Construction ID:	1022-07-76
Nearest Crossroad:	CTH NN
County:	St. Croix
Date:	4/29/2019
Day of Week:	Monday
Area Type:	Rural
Time of Day:	12:00 AM to 12:55 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Intermediate
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Concrete pavement Repair

Notes: TMP not found. Used info from 1020-06-75
Check barrier type on video. This says concrete barrier. They could have both been used out there.
Speed limit will be reduced according to TGM 13-5-6.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
99	99	per 5 minutes	135	135
298	298	per 15 minutes	402	402
1,188	1,188	per hour	1,603	1,603
1,191	1,191	Max Flow Rate$_s$*	1,608	1,608

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

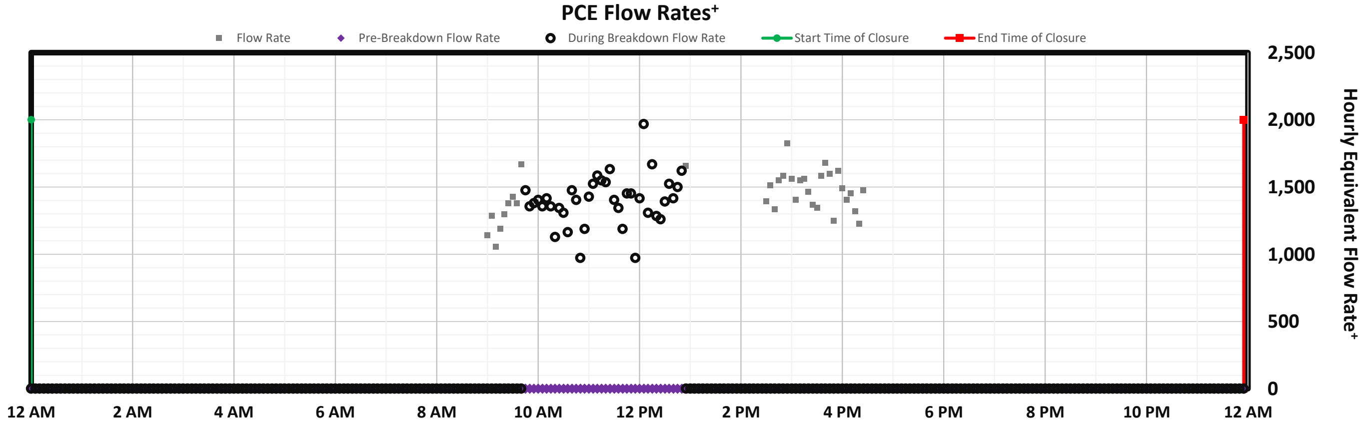
Select Times - >	Start Time:	9:45 AM	End Time:	12:55 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
86 per 5 minutes	35.3%	16%	84%	117 per 5 minutes

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
57	57	per 5 minutes	81	81
224	224	per 15 minutes	297	297
979	979	per hour	1,293	1,293

Average Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
86	86	per 5 minutes	117	117
258	258	per 15 minutes	348	348
1,029	1,029	per hour	1,388	1,388
977	977	HCM 6 Estimate	1,322	1,322

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
121	121	per 5 minutes	164	164
303	303	per 15 minutes	412	412
1,068	1,068	per hour	1,458	1,458

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 EB St. Croix County CTH NN (1022-07-76)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134

<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	EB
Construction ID:	1022-07-76
Nearest Crossroad:	CTH NN
County:	St. Croix
Date:	4/29/2019
Day of Week:	Monday
Area Type:	Rural
Time of Day:	12:00 AM to 4:15 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Intermediate
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Concrete pavement Repair

Notes: TMP not found. Used info from 1020-06-75
Check barrier type on video. This says concrete barrier. They could have both been used out there.
Speed limit will be reduced according to TGM 13-5-6.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	12:05 AM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
0	0	per 5 minutes	0	0
0	0	per 15 minutes	0	0
0	0	per hour	0	0
0	0	Max Flow Rate$_s$*	0	0

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
107	107	per 5 minutes	143	143
321	321	per 15 minutes	429	429
1,284	1,284	per hour	1,714	1,714
1,283	1,283	Max Flow Rate$_s$*	1,714	1,714

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

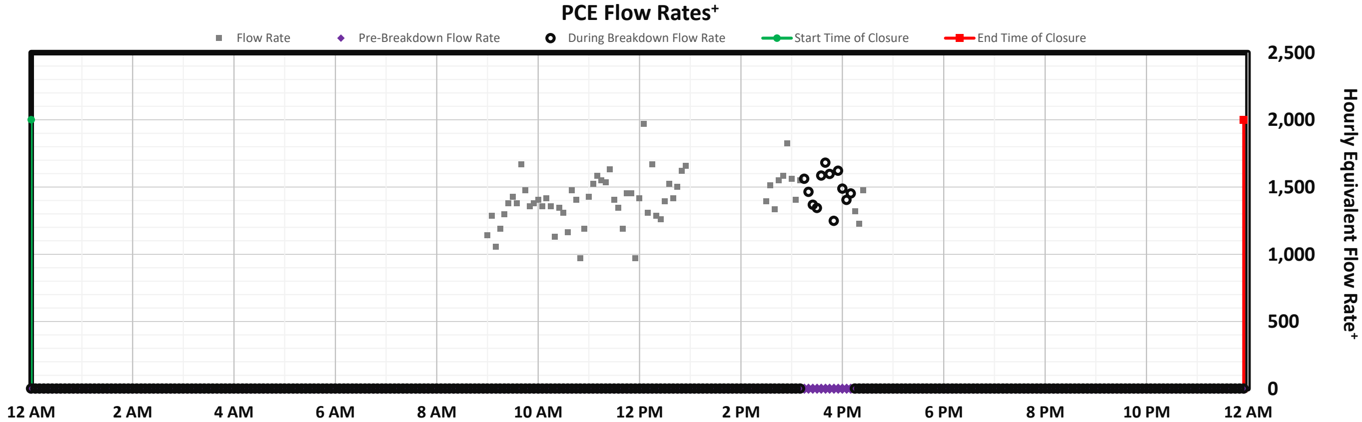
Select Times - >	Start Time:	3:15 PM	End Time:	4:15 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
93 per 5 minutes	33.5%	13%	87%	124 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
79	79	per 5 minutes	104	104
256	256	per 15 minutes	348	348
1,112	1,112	per hour	1,484	1,484

---- Average Observed Queue Discharge Rate ----				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
93	93	per 5 minutes	124	124
278	278	per 15 minutes	371	371
1,112	1,112	per hour	1,484	1,484
991	991	HCM 6 Estimate	1,322	1,322

---- Maximum Observed Queue Discharge Rate ----				
Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
107	107	per 5 minutes	140	140
301	301	per 15 minutes	405	405
1,112	1,112	per hour	1,484	1,484

PCE Flow Rates⁺



⁺ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity

Queue Discharge Flow Rates

IH 94 EB St. Croix County CTH NN (1022-07-76)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
0.156	<-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 94
Direction	EB
Construction ID:	1022-07-76
Nearest Crossroad:	CTH NN
County:	St. Croix
Date:	4/30/2019
Day of Week:	Tuesday
Area Type:	Rural
Time of Day:	1:40 PM to 5:30 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	2
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	2
Construction Duration (short/long)	Intermediate
Construction Intensity	Low
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: Concrete pavement Repair

Notes: TMP not found. Used info from 1020-06-75
Check barrier type on video. This says concrete barrier. They could have both been used out there.
Speed limit will be reduced according to TGM 13-5-6.

PRE-BREAKDOWN CAPACITY

Select Times ->	Start Time:	1:40 PM	End Time:	1:55 PM
Max Pre-Breakdown Capacity (Observed)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
106	106	per 5 minutes	149	149
277	277	per 15 minutes	393	393
1,108	1,108	per hour	1,572	1,572
1,108	1,108	Max Flow Rate$_s$*	1,572	1,572

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
95	95	per 5 minutes	128	128
286	286	per 15 minutes	384	384
1,141	1,141	per hour	1,532	1,532
1,144	1,144	Max Flow Rate$_s$*	1,538	1,538

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

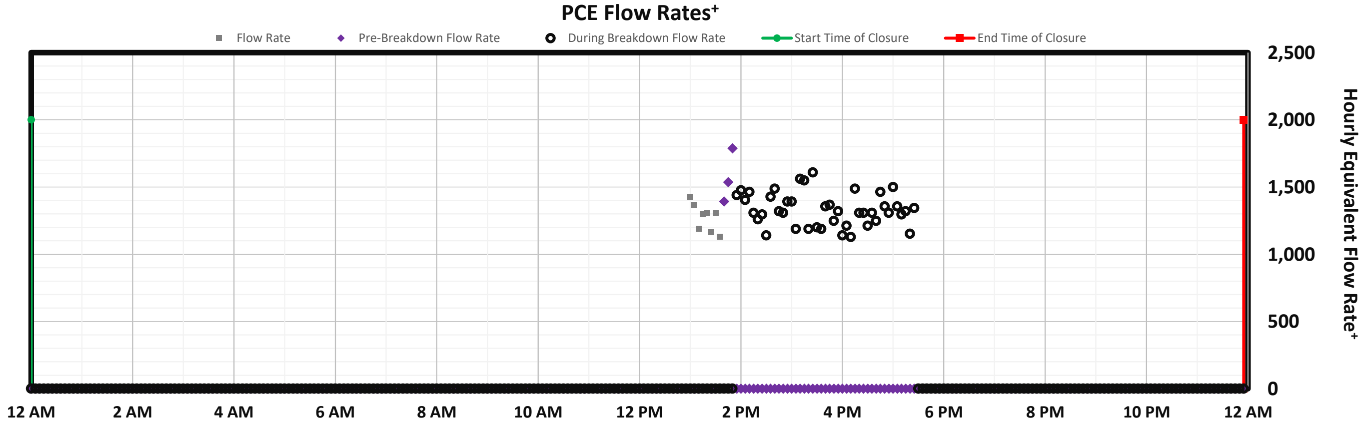
Select Times ->	Start Time:	1:55 PM	End Time:	5:30 PM
Queue Discharge Flow Rates (Collected Near Bottleneck)				
Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
83 per 5 minutes	34.6%	16%	84%	111 per 5 minutes

Minimum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
66	66	per 5 minutes	94	94
219	219	per 15 minutes	290	290
946	946	per hour	1,272	1,272

Average Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
83	83	per 5 minutes	111	111
248	248	per 15 minutes	333	333
988	988	per hour	1,327	1,327
983	983	HCM 6 Estimate	1,322	1,322

Maximum Observed Queue Discharge Rate				
Vehicles/Lane	*Vehicles*	*Time Period*	*PCEs/Lane*	*PCEs*
101	101	per 5 minutes	134	134
275	275	per 15 minutes	362	362
1,055	1,055	per hour	1,385	1,385

PCE Flow Rates+



+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

Work Zone Capacity
Queue Discharge Flow Rates

IH 41 SB Outagamie County Loc 1 - Maloney Rd (1130-49-71)

PCE Conversion Factor:	2.00
Pre-Breakdown Capacity Drop Factor (PBCDF):	0.134
	0.108 <-- Observed PBCDF [1-(during breakdown average hourly capacity/ max pre-breakdown 15-min flow rate hourly equivalent)]

Version 1.8

Site Data	
Highway:	IH 41
Direction	SB
Construction ID:	1130-49-71
Nearest Crossroad:	Loc 1 - Maloney Rd
County:	Outagamie
Date:	7/28/2018
Day of Week:	Saturday
Area Type:	Urban
Time of Day:	12:00 AM to 6:00 PM
Barrier Type:	Soft
Day or Night	Day
Min Lateral Clearance to Work Zone (ft)	4
Work Zone Speed Limit	70 mph
Non-Work Zone Speed Limit	70 mph
Roadway Surface	Normal
Upstream Ramps (within 3mi)	2
Downstream Ramps (within 3mi)	4
Construction Duration (short/long)	Short
Construction Intensity	High
Lane Transition Type (conventional/zipper)	Conventional
Lane(s) Closed (left, right, middle)	Right
# of permanent lanes	2
# of lanes open during construction	1
Lane widths	12 ft
Significant grade?	No
Time Closure Began •	12:00 AM
Time Closure Ended •	11:55 PM

Describe Construction Activity: High friction surface treatment on bridges.

Notes: No breakdown indicated.

PRE-BREAKDOWN CAPACITY

Select Times - >	Start Time:	12:00 AM	End Time:	11:55 PM

Max Pre-Breakdown Capacity (Observed)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
131	131	per 5 minutes	137	137
370	370	per 15 minutes	392	392
1,394	1,394	per hour	1,481	1,481
1,480	1,480	Max Flow Rate$_s$*	1,568	1,568

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

Pre-Breakdown Capacity (Estimated)

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
126	126	per 5 minutes	135	135
379	379	per 15 minutes	404	404
1,516	1,516	per hour	1,615	1,615
1,516	1,516	Max Flow Rate$_s$*	1,614	1,614

* Maximum Sustained Flow Rate equals the max 15-minute flow rate observed multiplied by 4 to calculate an hourly equivalent.

DURING BREAKDOWN QUEUE DISCHARGE RATE

Select Times - >	Start Time:	10:00 AM	End Time:	6:00 PM

Queue Discharge Flow Rates (Collected Near Bottleneck)

Ave Flow	% Trucks	SU Split	Semi Split	Ave PCE Flow
109 per 5 minutes	6.4%	69%	31%	117 per 5 minutes

---- Minimum Observed Queue Discharge Rate ----

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
88	88	per 5 minutes	92	92
274	274	per 15 minutes	292	292
1,235	1,235	per hour	1,318	1,318

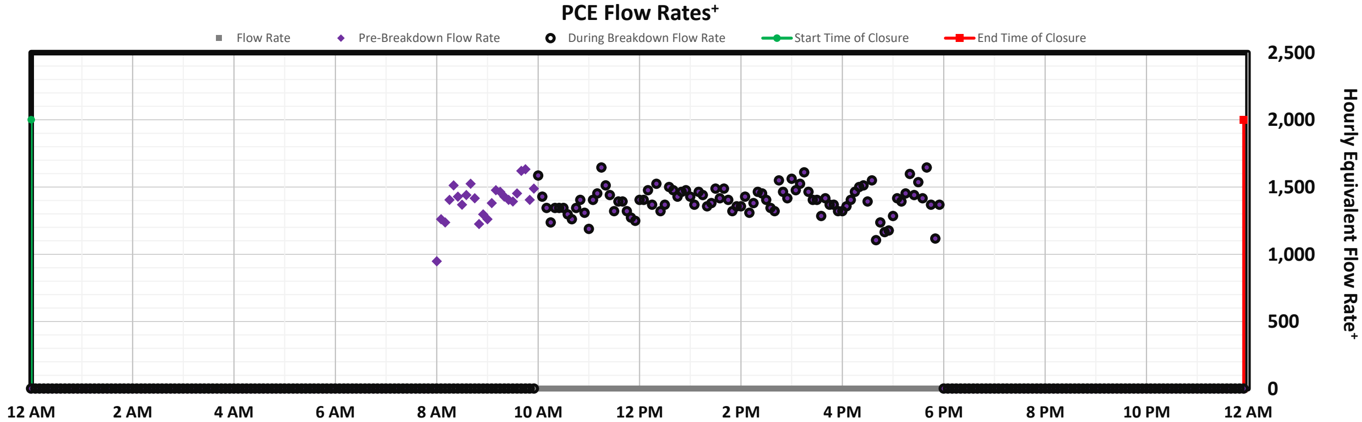
---------------- Average Observed Queue Discharge Rate ----------------

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
109	109	per 5 minutes	117	117
328	328	per 15 minutes	349	349
1,313	1,313	per hour	1,399	1,399
1,427	1,427	HCM 6 Estimate	1,519	1,519

-------------------------- Maximum Observed Queue Discharge Rate --------------------------

Vehicles/Lane	Vehicles	Time Period	PCEs/Lane	PCEs
131	131	per 5 minutes	137	137
370	370	per 15 minutes	384	384
1,394	1,394	per hour	1,465	1,465

PCE Flow Rates+

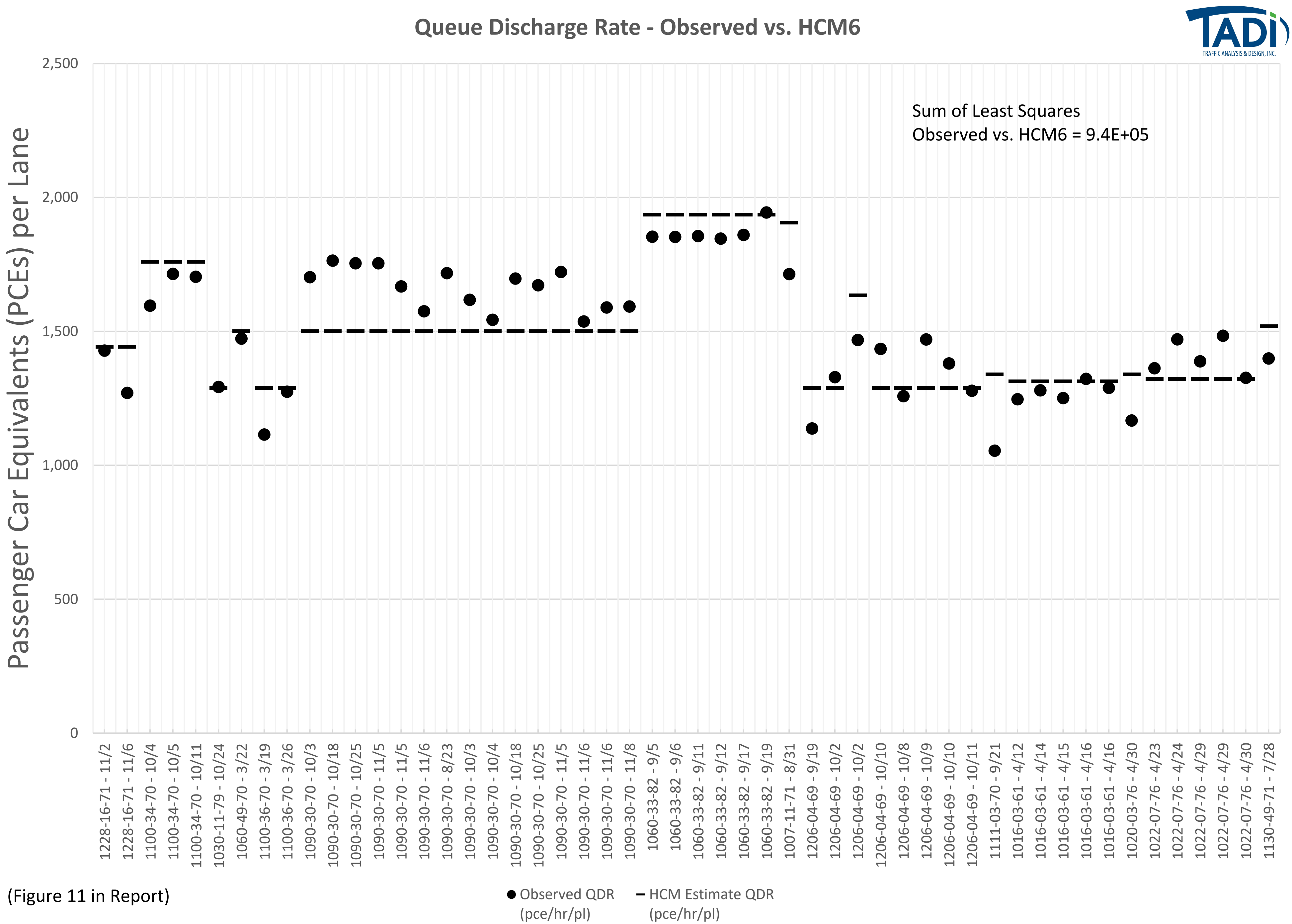


+ Hourly Equivalent Flow Rate equals the 5-minute flow rate observed multiplied by 12 to calculate an hourly equivalent.

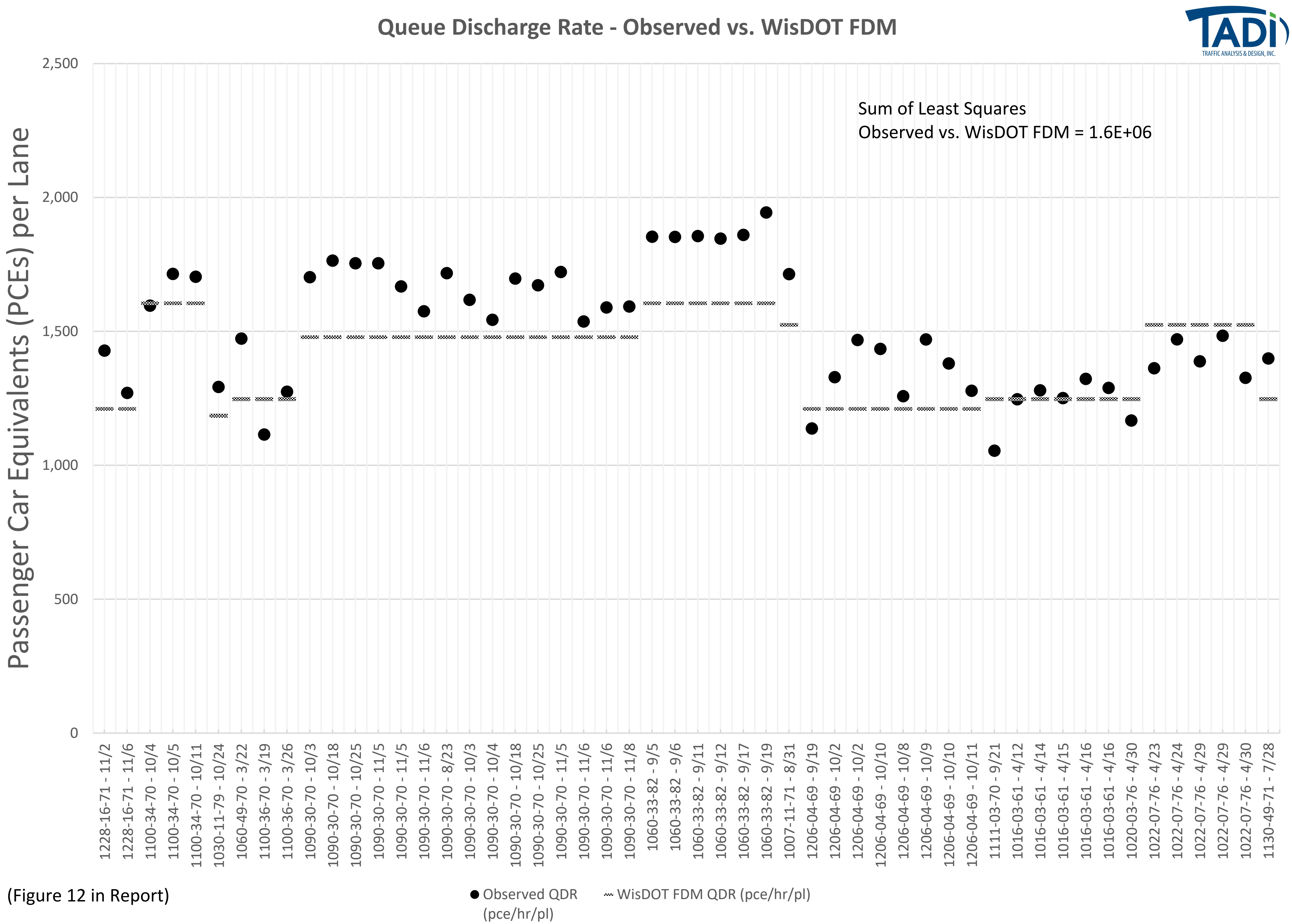
APPENDIX B

MODEL TO OBSERVED DATA COMPARISON GRAPHS IN LARGER SCALE

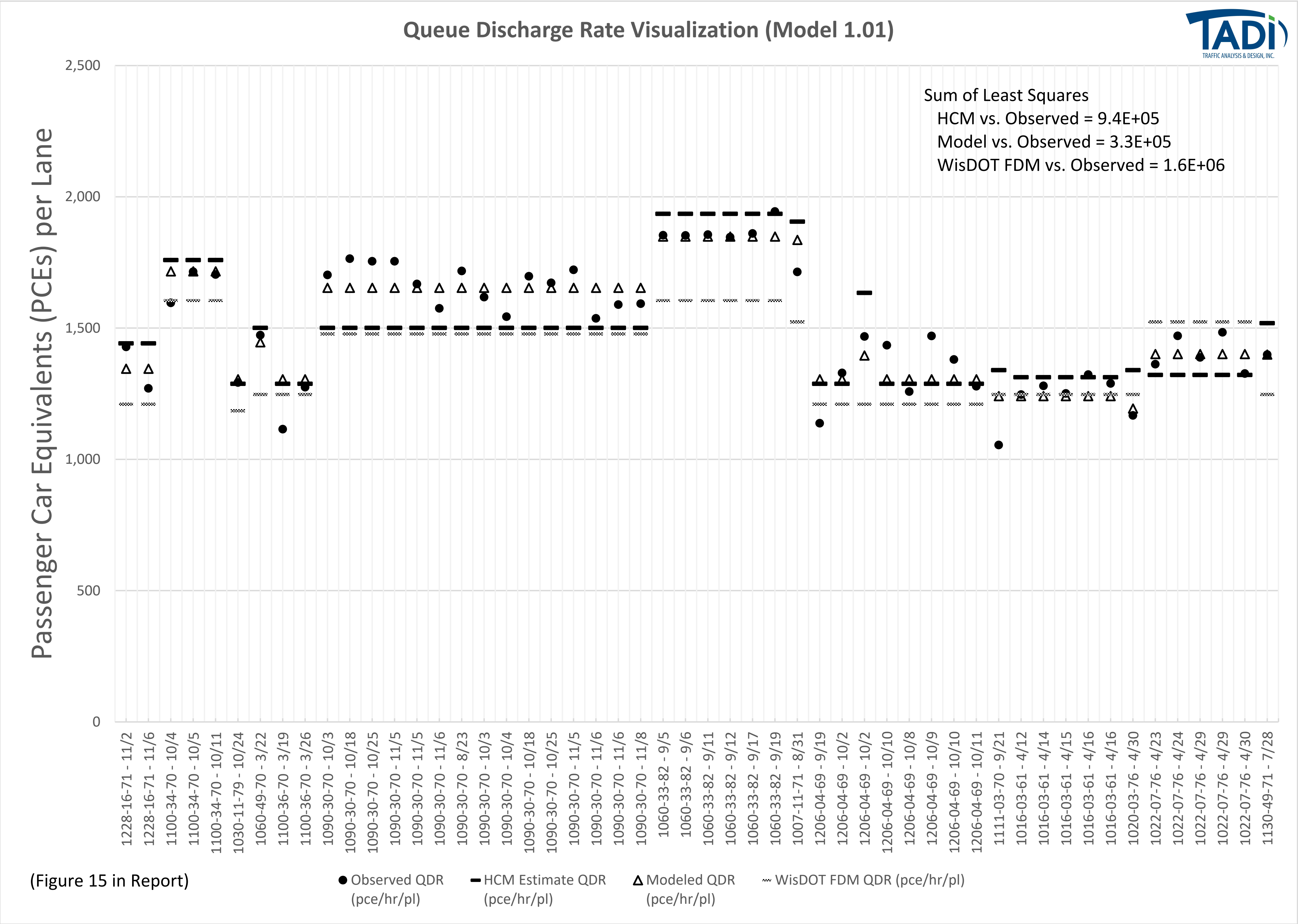
(FIGURES 11, 12, AND 15 FROM REPORT)



(Figure 11 in Report)



(Figure 12 in Report)


Queue Discharge Rate Visualization (Model 1.01)
TADI
TRAFFIC ANALYSIS & DESIGN, INC.
Sum of Least Squares
HCM vs. Observed = 9.4E+05
Model vs. Observed = 3.3E+05
WisDOT FDM vs. Observed = 1.6E+06
Passenger Car Equivalents (PCEs) per Lane
2,500
2,000
1,500
1,000
500
0
1228-16-71 - 11/2
1228-16-71 - 11/6
1100-34-70 - 10/4
1100-34-70 - 10/5
1100-34-70 - 10/11
1030-11-79 - 10/24
1060-49-70 - 3/22
1100-36-70 - 3/19
1100-36-70 - 3/26
1090-30-70 - 10/3
1090-30-70 - 10/18
1090-30-70 - 10/25
1090-30-70 - 11/5
1090-30-70 - 11/5
1090-30-70 - 11/6
1090-30-70 - 8/23
1090-30-70 - 10/3
1090-30-70 - 10/4
1090-30-70 - 10/18
1090-30-70 - 10/25
1090-30-70 - 11/5
1090-30-70 - 11/6
1090-30-70 - 11/6
1090-30-70 - 11/8
1060-33-82 - 9/5
1060-33-82 - 9/6
1060-33-82 - 9/11
1060-33-82 - 9/12
1060-33-82 - 9/17
1060-33-82 - 9/19
1007-11-71 - 8/31
1206-04-69 - 9/19
1206-04-69 - 10/2
1206-04-69 - 10/2
1206-04-69 - 10/10
1206-04-69 - 10/8
1206-04-69 - 10/9
1206-04-69 - 10/10
1206-04-69 - 10/11
1111-03-70 - 9/21
1016-03-61 - 4/12
1016-03-61 - 4/14
1016-03-61 - 4/15
1016-03-61 - 4/16
1016-03-61 - 4/16
1020-03-76 - 4/30
1022-07-76 - 4/23
1022-07-76 - 4/24
1022-07-76 - 4/29
1022-07-76 - 4/29
1022-07-76 - 4/30
1130-49-71 - 7/28
(Figure 15 in Report)
Observed QDR (pce/hr/pl)
HCM Estimate QDR (pce/hr/pl)
Modeled QDR (pce/hr/pl)
WisDOT FDM QDR (pce/hr/pl)

APPENDIX C

Wisconsin-Specific Work Zone Model Development & Linear Regression Results

Recommended Model

			Coefficients									
Model	Adjusted R Squared	Intercept	Lane Closure Type	Barrier Type	Day/ Night	Area Type	Const. Intensity	Northern Region	SW	NE	NW	Lat. Clear.
HCM 6 Equation	0.5835	2,093	-154	-194	-59	-179						9
1.01	0.8601	1,866	-40	-132	-101	-205	-207	-47				
3.01	0.8600	1,867	-42	-134	-112	-234	-191					
4.01	0.8580	1,863	-41	-127	-107	-220	-215	-32	24			
2.01	0.8548	1,863	-42	-127	-116	-232	-207		26	-47	-20	
1.05	0.8517	1,875	-58	-116		-152	-264	-65				
2.05	0.8504	1,870	-50	-122		-125	-286		4	38	-108	
3.05	0.8486	1,877	-63	-117		-185	-249					
2.03	0.8341	1,871	-41	-142	52		-333		-34	84	-225	
2.07	0.8332	1,866	-28	-158			-305		-42	52	-235	
2.02	0.8249	1,865	-46	-132	-309	-427			27	-242	153	
4.02	0.8076	1,876	-43	-152	26		-281	-187	-60			
1.07	0.8054	1,865	-38	-151			-306	-180				
1.03	0.8034	1,869	-47	-141	36		-320	-172				
3.02	0.7927	1,870	-49	-144	-277	-325						
1.02	0.7905	1,871	-50	-145	-274	-341		38				
3.03	0.7426	1,876	-61	-159	84		-318					
3.07	0.7356	1,866	-41	-186			-281					
2.06	0.6851	1,924	-122	-116		-193			-131	-166	-6	
2.04	0.6643	1,901	-52	-204	-115				-201	-193	-225	
2.08	0.6419	1,923	-93	-172					-220	-165	-198	
3.06	0.6403	1,922	-157	-77		-229						
1.06	0.6388	1,922	-156	-80		-258		61				
1.04	0.5420	1,886	-81	-185	-165			-167				
3.04	0.4914	1,893	-95	-202	-117							
1.08	0.4900	1,918	-147	-135				-118				
3.08	0.4685	1,916	-143	-159								

APPENDIX D

1090-30-70 (Location #6) - Queue Calcs (2-->1)

Date	Time @ 112th CCTV	Time @ 124th CCTV	Distance	Car	HV	PCE	ft/pce/ln
10/3/2018	11:26:21 AM	11:33:14 AM	4,540	100	26	152	59.7
10/3/2018	11:53:40 AM	12:01:02 PM	4,540	91	27	145	62.6
10/19/2018	10:00:46 AM	10:09:14 AM	4,540	126	24	174	52.2
10/19/2018	11:49:45 AM	11:55:39 AM	3,470	91	25	141	49.2
11/16/2018	10:09:56 AM	10:14:51 AM	4,070	100	17	134	60.7
4/12/2019	12:48:23 PM	12:54:17 PM	4,070	117	22	161	50.6
4/12/2019	1:40:14 PM	1:48:07 PM	4,070	135	26	187	43.5
4/18/2019	12:39:39 PM	12:43:38 PM	3,470	69	17	103	67.4
4/18/2019	1:14:41 PM	1:24:41 PM	4,070	102	18	138	59.0

Avg. Speed (ft/s)	Avg. Speed (mph)
11.0	7.5
10.3	7.0
8.9	6.1
9.8	6.7
13.8	9.4
11.5	7.8
8.6	5.9
14.5	9.9
6.8	4.6

Min	43.5
Average	56.1
Median	59.0
Max	67.4

1060-33-82 (Location #7) - Queue Calcs (4-->3)

Date	Time @ 113th CCTV	Time @ 121st CCTV	Distance	Car	HV	PCE	ft/pce/ln
9/5/2018	4:58:36 PM	5:00:43 PM	2,625	157	2	161	65.2
9/5/2018	5:47:07 PM	5:48:50 PM	2,625	128	6	140	75.0
9/6/2018	4:00:09 PM	4:02:04 PM	3,175	172	8	188	67.6
9/6/2018	5:15:17 PM	5:17:21 PM	3,175	188	8	204	62.3
9/11/2018	4:58:44 PM	5:00:24 PM	2,625	163	3	169	62.1
9/11/2018	5:24:07 PM	5:25:27 PM	2,625	128	5	138	76.1
9/12/2018	8:02:48 AM	8:04:38 AM	2,625	150	10	170	61.8
9/12/2018	8:15:14 AM	8:17:43 AM	2,625	193	13	219	47.9
9/17/2018	4:50:57 PM	4:52:52 PM	2,810	170	8	186	60.4
9/19/2018	4:31:57 PM	4:33:54 PM	2,810	167	6	179	62.8

Avg. Speed (ft/s)	Avg. Speed (mph)
20.7	14.1
25.5	17.4
27.6	18.8
25.6	17.5
26.2	17.9
32.8	22.4
23.9	16.3
17.6	12.0
24.4	16.7
24.0	16.4

Min	47.9
Average	64.1
Median	62.5
Max	76.1