Screening and Detailed Analysis

M-0446 Ramp Metering Feasibility Study for Durham and Wake Counties

Notice

This document and its contents have been prepared and are intended solely for the North Carolina Department of Transportation's (NCDOT) information and use in relation to this project.

Atkins assumes no responsibility to any other party in respect to, or arising from, or in connection with this document and/or its contents.

This document has 207 pages including the cover.

Document History

Job Number: M-0446		Document Ref: Screening and Detailed Analysis Draft Report				
Revision	**Purpose Description**	**Originated**	**Checked**	**Reviewed**	**Authorized**	**Date**
0.5	Draft for comment	Joe Castle	JLH	Jill Hayden		08/15/12
0.6	Internal Q/C	Joe Castle	JLH	Jill Hayden	HAB	08/28/12
1.0	Submitted		JLH		HAB	09/04/12
2.0	Address comments	JG	HAB/JC	Jill Hayden/JLH	HAB	11/19/12
3.0	Submitted for review	HAB		JLH	JLH	11/21/12
4.0	Final Version	HAB	JG	JLH	HAB	02/25/13

Client Signoff

Client	NCDOT
Project	Ramp Metering Feasibility Study for Durham and Wake Counties
Document title	Screening and Detailed Analysis
Job no.	100026052
Copy no.	
Document reference	task 4 - screening and detailed analysis - final draft complete v2.docx

Table of Contents

List of Tables

List of Figures

Introduction

A key requirement of the Ramp Metering Feasibility Study is to identify which sites in the study area are suitable for ramp metering, should a decision be made to proceed. This report describes the screening and data analysis performed to select suitable sites from the list of all candidate sites.

The four-stage data analysis process included: (1) creation of a Master List; (2) initial review of all candidate sites; (3) screening analysis following the initial review to identify sites not suitable; and (4) detailed analysis of remaining sites. Figure 1 depicts a flowchart of this analysis, and maps the steps to the report sections. This figure also shows the relationship to remaining tasks.

The Master List identified 208 entrance ramps in the study area; a spreadsheet containing one row per entrance ramp (or site) was developed and used throughout the analysis to record each site's information. This Master List spreadsheet acts as a single point of reference for high-level information so that questions can be answered quickly, accurately, and with minimal review work.

The initial review of the 208 sites included:

- Collecting geometric characteristics from aerial photography and noting, in particular, which sites are freeway-to-freeway (F2F).
- Identifying the level of congestion by analysis of NCDOT's congestion data, using the bottleneck ranking application of VPP Suite.

During the screening analysis stage, sites that were not suitable to be taken forward to the next stage of analysis were identified (e.g., F2F sites, those with insufficient congestion). At the end of this stage, the steering committee agreed that 34 sites would be subjected to the detailed analysis, which included:

- Collecting and analyzing traffic flow data to identify whether volumes at each site were within acceptable limits for ramp metering.
- Verifying that the period of congestion coincided with the period of suitable volumes.
- Conducting field visits to each site.
- Investigating the cause of congestion.
- Quantifying the amount of congestion in the vicinity of the site.
- Performing an analysis of crash data.

A "Site Summary" containing the information and results from the detailed analysis for each of the 34 sites can be found in Appendix C.

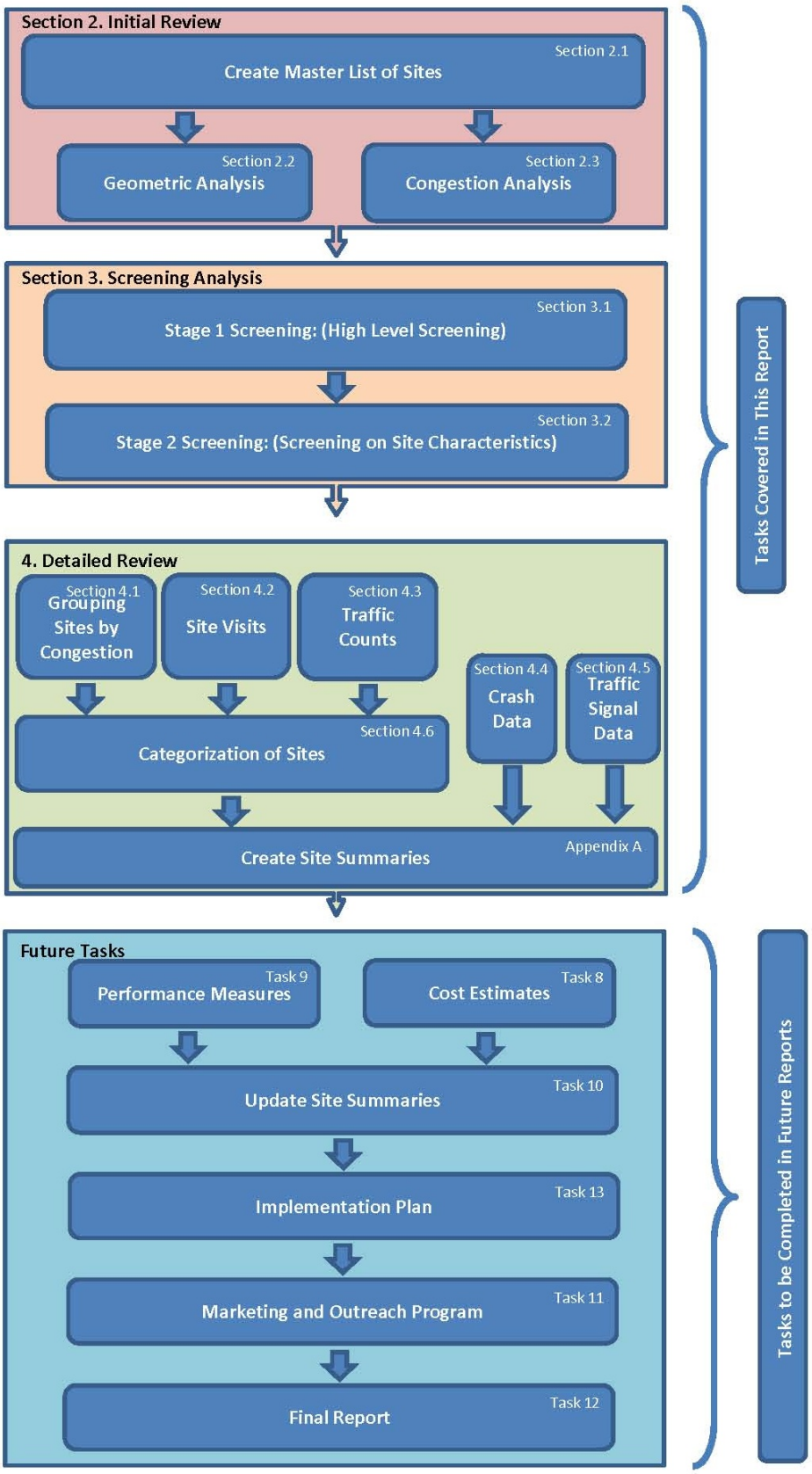


Figure 1: Relationship of Site Selection Tasks and Report Sections

Following the detailed analysis, the 34 sites were categorized as follows:

- Not Suitable: A critical reason for the site not being suitable for ramp metering has been identified, such as very low entrance ramp volumes.
- Review in Future: In some locations with more than one site in proximity, upstream sites may no longer be congested once the downstream sites have been implemented. In this case, the site should be reviewed and evaluated at a future time.
- Suitable for Taking Forward: These sites have good characteristics and demonstrated potential to reduce observed congestion and will be taken forward to the next phase—a high-level cost-benefit analysis leading to a prioritized implementation plan.

The detailed analysis identified 21 sites as suitable for taking forward. Results are shown in Table1 and Figure 2.

Table 1: Sites Suitable for Ramp Metering

Log	Freeway	Cross Street	Exit	Direction	County
002	I-40	US-15 / US-501	270	WB	Durham
009	I-40	NC-55 / Apex Hwy	278	EB	Durham
010	I-40	NC-55 / Apex Hwy	278	WB	Durham
012*	I-40	NC-147 / Durham Fwy - Southbound	279	EB-M2 (SB to EB)	Durham
014*	I-40	NC-147 / Durham Fwy - Southbound	279	WB-M2 (SB to WB)	Durham
015	I-40	Davis Dr	280	EB	Durham
017	I-40	S Miami Blvd	281	EB	Durham
019	I-40	Page Rd	282	EB	Durham
025	I-40	SR 3015 - Airport Blvd	284	EB	Wake
027	I-40	SR 1002 - Aviation Pkwy	285	EB-M1 (SB to EB)	Wake
028	I-40	SR 1002 - Aviation Pkwy	285	EB-M2 (NB to EB)	Wake
030	I-40	SR 1652 - N Harrison Ave	287	EB	Wake
043	I-40	SR 1571 - Gorman St	295	WB	Wake
056	I-40	SR 5220 - Jones Sausage Rd	303	WB	Wake
089	I-440	SR 1319 - Jones Franklin Rd	1C	NB	Wake
090	I-440	SR 1319 - Jones Franklin Rd	1C	SB	Wake
095	I-440	SR 1012 - Western Blvd	2	SB-M2 (EB to SB)	Wake
102	I-440	Lake Boone Trail	5	NB	Wake
108	I-440	US-70 / NC-50 / Glenwood Ave	7	WB-M2 (SB to WB)	Wake
133*	I-540	US-70	4	EB	Wake
135	I-540	SR 1829 - Leesville Rd	7	EB	Wake

* F2F sites that have been included in the detailed analysis to help understand the characteristics; there currently are no plans to implement these.

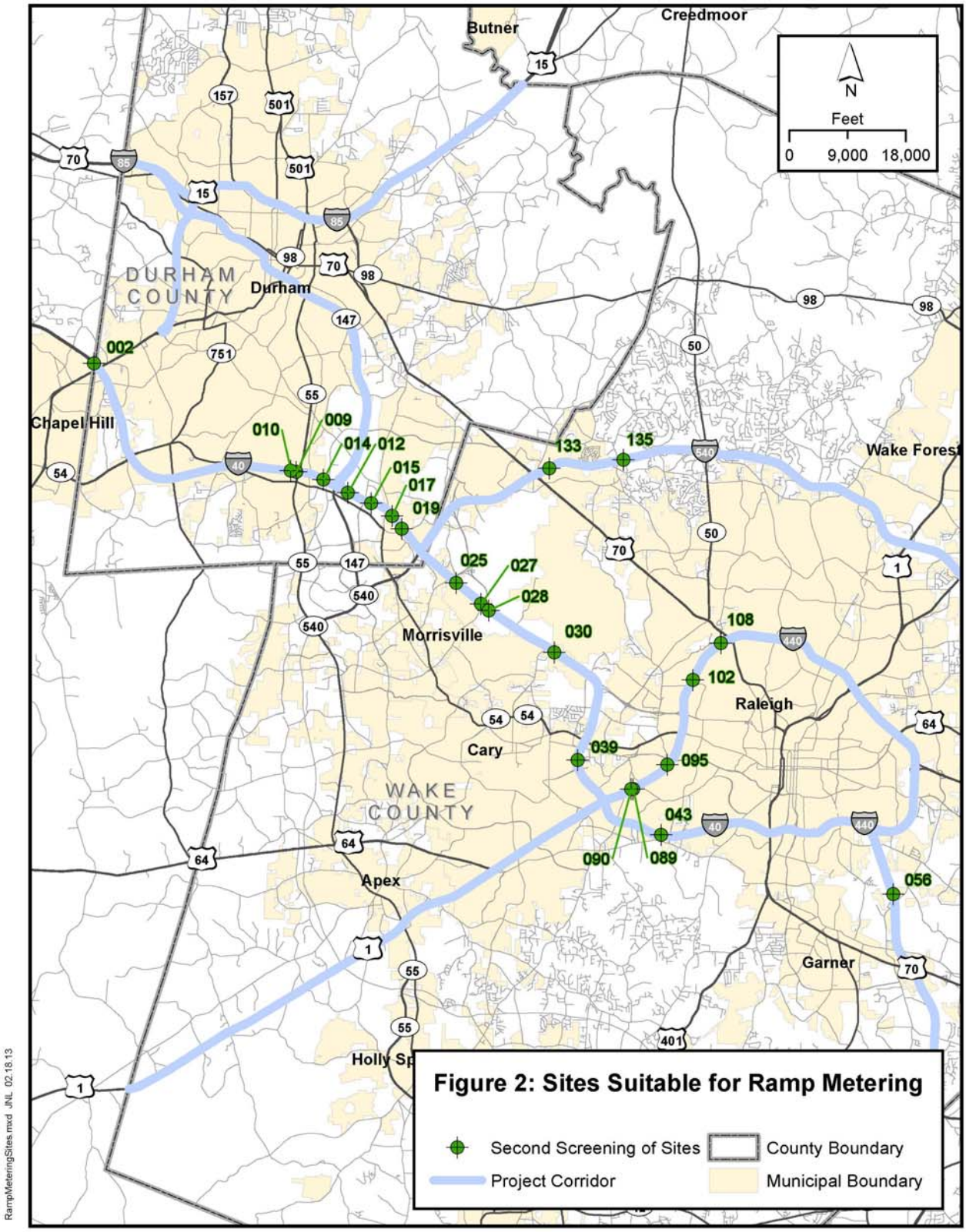


Figure 2: Sites Suitable for Ramp Metering

It is important to identify locations that are suitable in all respects for ramp metering so that the investment in the infrastructure provides positive benefits in relation to cost. In order to identify an entrance ramp that offers such benefits, its geometry, traffic volumes, and ability to improve observed congestion problems must be determined.

This report outlines the work undertaken to identify, from a list of 208 entrance ramps within the study area, those sites that are not suitable for ramp metering, and those that are suitable. The analysis completed to date has identified sites that physically can operate as ramp metering sites, have suitable traffic volumes, and are adjacent to observed congestion problems that could be improved.

The sites are further categorized into those that are not currently suitable, and those that are suitable and should be taken to the next stage, which consists of a high-level cost-benefit analysis that will be included in the Implementation Plan report. The following sections of this Screening and Data Analysis report describe the tasks carried out to categorize the sites:

- Initial Review
- Screening Analysis
- Detailed Analysis
- Summary
- Conclusions

An excerpt of the Master List summarizing how each of the 208 sites was categorized can be found in Appendix A.

Appendix B contains the assumptions made about congestion related to each potential site, and the calculations performed based on these assumptions.

Site summaries of all information collected and observations made were created for each of the 34 sites subjected to detailed analysis. These can be found in Appendix C.

1. Initial Review

The initial review of all candidate sites is shown in Figure 3.

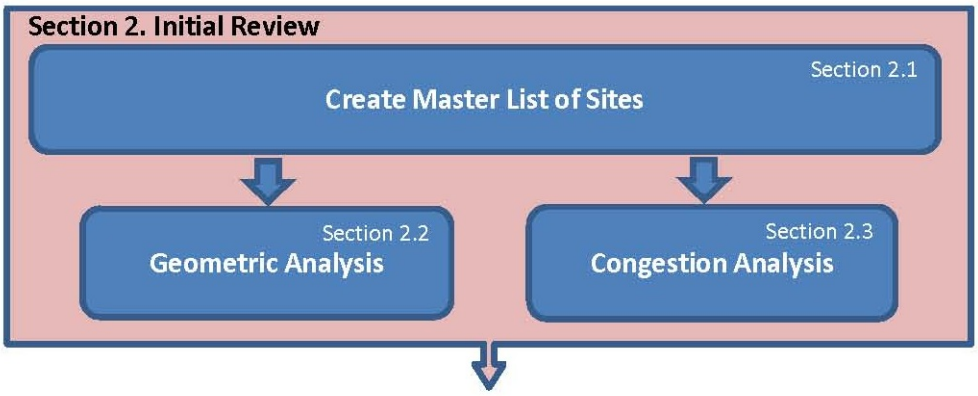


Figure 3: Relationship of Initial Review Subtasks

The initial review, which was performed to enable the screening analysis to take place, is described in the following subsections:

- 2.1. Master List
- 2.2. Geometric Analysis
- 2.3. Congestion Analysis

1.1. Master List

The Master List contains all candidate sites within the study area identified at the beginning of the study. This includes any entrance ramp onto a fully controlled access freeway, whether it is an interstate, US highway, NC primary, or other state or city route within the study area.

Each entrance ramp location is assigned one row on the Master List. Details such as freeway name, cross street name, exit number, direction, and county are also included. If there are two entrance ramps in the same direction at one location, these are recorded in separate rows as “M1” (merge 1) and “M2” (merge 2). These can be identified as the first and second merges encountered in the direction of travel on the freeway.

The Master List is used to reach agreement that all suitable candidate ramps meeting the above description were identified for consideration in the Ramp Metering Feasibility Study. Once a candidate site is identified and recorded, it remains on the Master List with a summary of related site information. In this way, any site can be ruled out from further analysis at any point during the project, with information pertaining to the recommendation recorded in the list. This process provides a robust audit trail. If information is required in the future relating to

any particular site, the Master List acts as a single point of reference for high-level information so that questions can be answered quickly.

Once the agreed-upon list of candidate sites was determined, each entrance ramp was assigned a three-digit log number. Similar to a primary key in a database, this allows any information collected about a particular entrance ramp to be recorded and quickly recalled. Additionally, the Master List can be extensively sorted and filtered, but easily returned to its original, logical order using the log numbers.

The Master List records the results of each of the different analyses performed for the candidate sites. Appendix A contains an excerpt of the Master List, which is also available in its original form as an Excel spreadsheet. This Appendix contains figures showing the locations of the 208 sites

1.2. Geometric Analysis

The geometric analysis gathered high-level information on each site and involved the following tasks:

- Identify and agree on precise locations of each candidate site
- Classify and confirm existence of an entrance ramp at each location
- Identify F2F sites
- Collect high-level geometric data

1.2.1. Precise Locations

Based on the descriptions of the candidate sites in the Master List, a Google Earth (.kmz) file was produced with a “pin” placed at the merge point of each candidate entrance ramp onto the freeway. Each pin was linked to an identifying log number for each row of the Master List.

This process facilitates a common understanding of the precise location of any candidate site, avoiding any confusion based on the descriptions. The .kmz file forms the basis for the spatial representation of any further information, such as congestion, which will assist the project team during the feasibility study.

While NCDOT cannot utilize the .kmz format at this time, its purpose for recording and agreeing upon spatial information within the project team is not diminished, and it will provide grid references that can be transferred into the NCDOT GIS system at a later date, if required.

1.2.2. Classify and Confirm Candidate Sites

Each candidate entrance ramp was classified based on the AASHTO ramp type definitions as follows:

- Direct ramp: A direct connection does not deviate greatly from its original direction. A direct ramp can be characterized by higher design speed and capacity, and could be

anything from a simple entrance ramp at a diamond interchange to a high-speed flyover ramp between two freeways that exits from the right and merges from the right.

- Indirect or loop ramp: An indirect ramp can be characterized by low-speed maneuverability and lower capacity, so that a driver must make a significant change in direction/alignment for the intended maneuver.
- Semi-direct ramp: This type of ramp requires some change in direction before reaching the intended direction. An example is a ramp that angles off to the right as it leaves the original roadway, and then curves back to the left to the destination roadway. Semi-direct ramp geometry has a much higher design speed and capacity than an indirect ramp, but not as much as a direct ramp.

The process of identifying and classifying entrance ramp locations confirmed the existence of an entrance ramp at each location. This is important as many interchanges have complicated layouts—only a detailed study or existing knowledge of the area can identify whether movements are limited. For example, although a number of entrance ramps may feed into a collector distributor road, it would only be classified as one location because there would only be one ramp metering location onto the main freeway from the collector distributor road. Ramp metering is intended to address traffic congestion on the main freeway. It is inadvisable to meter traffic from an individual ramp onto a collector distributor road where the flows and geometry are unsuitable.

1.2.3. Identify Freeway-to-Freeway (F2F) Sites

NCDOT has specified that no F2F sites should be considered for implementation in this Ramp Metering Feasibility Study. The following agreed-upon definition of an F2F site was established by the project team:

F2F is a location where access from one limited access highway to another is made, without the need to yield (apart from merging onto the freeway) or obey traffic signals.

Using this definition, 50 of the 208 candidate sites were identified as F2F; this information was recorded in the Master List so that sites can be easily distinguished and filtered accordingly.

During a review of the Master List by NCDOT, it was agreed that five F2F sites (Table 2) that have high volumes and experience congestion should be included in further analysis. This will provide the Department a better appreciation of the particular issues, safety concerns, associated costs, and potential for future improvements at these locations, and will provide a baseline for further evaluation and consideration in the future. The Department will not implement freeway-to-freeway ramp metering in the initial deployment until a better understanding of ramp metering operations is gained.

Table 2: F2F Sites Requested to be Included in Further Analysis

Log	Freeway	Cross Street	Exit	Direction	County
011	I-40	NC 147 / Durham Freeway	279	EB-M1 (NB to EB)	Durham
012	I-40	NC 147 / Durham Freeway	279	EB-M2 (SB to EB)	Durham
013	I-40	NC 147 / Durham Freeway	279	WB-M1 (NB to WB)	Durham
014	I-40	NC 147 / Durham Freeway	279	WB-M2 (SB to WB)	Durham
133	I-540	US 70	4	EB	Wake

1.2.4. High-Level Geometric Data

In addition to the fundamental information for classifying each candidate site as described above, a high-level geometric analysis identified the following characteristics for each non-F2F site:

- Origin – briefly describes the interface between the local road and the entrance ramp
- Number of origins – captures the number of entrances onto the main entrance ramp
- Lane addition – determines whether there is a lane addition from the entrance ramp onto the freeway
- Length of lane addition – records the number of feet on the freeway before the lane addition either diverged or passed the next downstream entrance ramp
- Number of entrance ramp lanes at the back of the nose – number of lanes on the ramp in the approximate location where the ramp metering stop bar would be placed
- Lane drop on entrance ramp – records whether the number of lanes on the main part of the ramp reduces along its length
- Number of freeway lanes upstream of the merge
- Number of freeway lanes downstream of the merge
- Entrance ramp length to the back of the nose – records the length of the main section of the ramp up to the approximate location where the ramp metering stop bar would be placed (see Dimension A in Figure 4)
- Entrance ramp length to the tip of the nose – records the length of the main section of the ramp to the location where it is possible to merge onto the freeway (see Dimension B in Figure 4)
- Merge length – number of feet from where it is possible to begin merging to the point of convergence, i.e., where the merge taper becomes less than the width of a vehicle (see Dimension C in Figure 4)
- Entrance ramp curve – records whether the entrance ramp is straight, slightly curved, or tightly curved
- Entrance ramp grade – identifies whether the entrance ramp is level, uphill, or downhill
- Entrance ramp shoulder – determines whether there is a shoulder, discontinuous shoulder, or no shoulder on the entrance ramp

- Freeway shoulder – identifies whether there is a shoulder, discontinuous shoulder, or no shoulder on the entrance ramp
- Observations – any noteworthy observations on the ramp layout

The distances measured for entrance ramp lengths from the beginning of the ramp to the back and tip of the gore, and the merge lengths from the tip of the gore to the end of the merge taper, are shown in Figure 4.

Geometric characteristics have been recorded in the Master List and give a useful overview of each candidate ramp metering site. While they have not yet been used to filter the sites, the information can be used in the future to further filter or rank the sites if particular criteria are identified as being either unsuitable or more relevant.

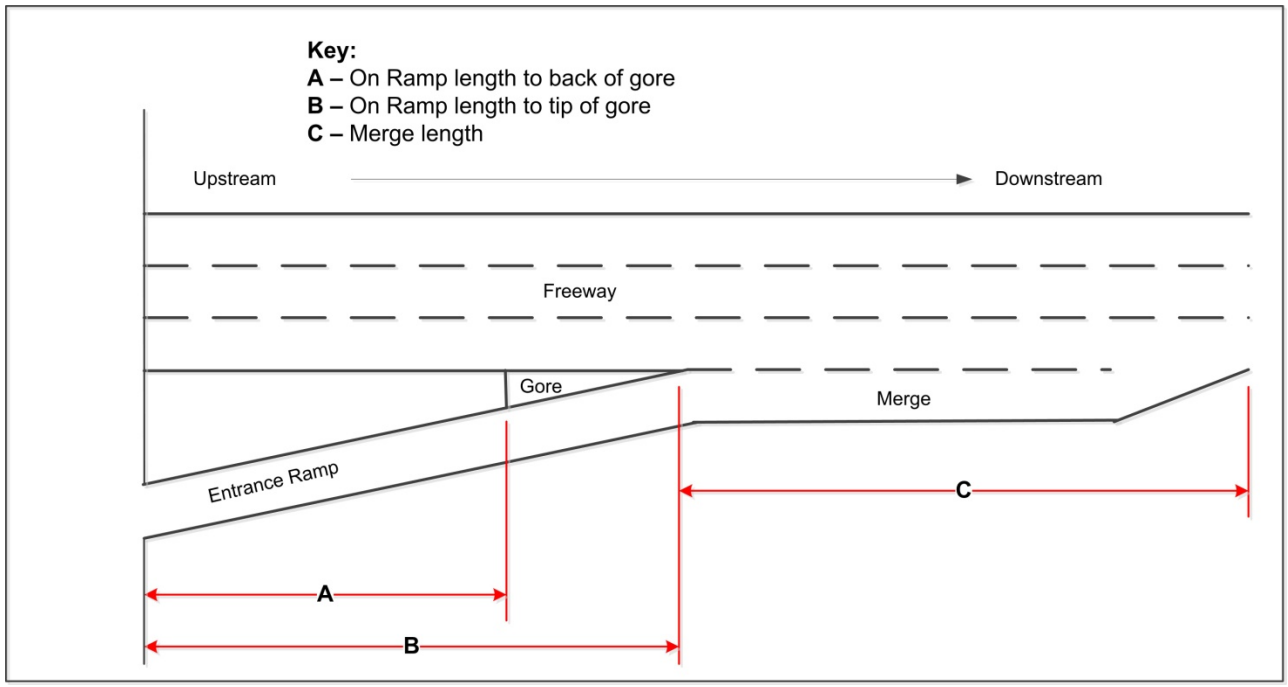


Figure 4: Measurements of Key Distances in Geometric Analysis

1.3. Congestion Analysis

The most fundamental requirement for a successful ramp metering site is that the freeway experiences regular and significant congestion. The congestion analysis identified regular and significant congestion on the freeways within the study area; this can be related back to the candidate ramp metering sites in the Master List.

1.3.1. Vehicle Probe Project (VPP) Suite

NCDOT obtains congestion data from the VPP Suite by accessing the RITIS website (www.ritis.org) administered by the University of Maryland CATT Lab. The VPP suite consists

of a number of congestion analysis tools based on probe vehicle data. The bottleneck ranking application was used to identify congestion in the study area.

1.3.2. Bottleneck Ranking Application

The bottleneck ranking application is an algorithm comparing the current speed to the reference speed to determine if a bottleneck is causing congestion. The reference speed is typically the free flow speed at night for each stretch of road. The VPP Suite only allows congestion to be identified at speeds that are 60% of the reference speed or less. If the current speed falls below 60% of the reference, the location is flagged as a potential bottleneck. This location is observed for 5 minutes, and if the speed stays below 60%, the bottleneck is confirmed. The bottleneck is not cleared until conditions have risen above the 60% threshold and held for 10 minutes. Adjacent locations in bottlenecked conditions are joined together to form the queue.

Table 3 shows the congested speeds for various reference speeds, based on the 60% value from the bottleneck algorithm in VPP Suite. These speeds would be indicative of the type of stop-start traffic the ramp metering system is designed to address.

Table 3: Congested Speed Calculated as 60% of Reference Speed

Reference Speed (mph)	Congested Speed (mph)
65	39
60	36
55	33

1.3.3. Downloading Bottleneck Data

At least one month of historical bottleneck data in the spring and fall were downloaded separately for each class of road (interstate, US highway, or NC primary). Where the maximum query size from the database allowed, the sample size was increased up to 3 months.

Neutral time periods (that is, not impacted by significant recurring traffic trends or patterns) were chosen - September to November 2011, and March to May 2011. The following specific dates were used:

- Interstate:
  - September 1 to November 30, 2011
  - March 1 to May 31, 2011
- US Highways in Wake County:
  - October 1 to 31, 2011
  - April 1 to 30, 2011
- US Highways in Durham County:

  - September 1 to November 30, 2011
  - March 1 to May 31, 2011
- State Primary Highways:
  - October 1 to November 30, 2011
  - April 1 to May 31, 2011

The bottleneck ranking application produces a table of identified bottlenecks. Each bottleneck can be selected to display a map and time spiral. The map of the location shows the average maximum length of congestion. The time spiral shows the bottlenecks by day on a clock face (see Figure 5).

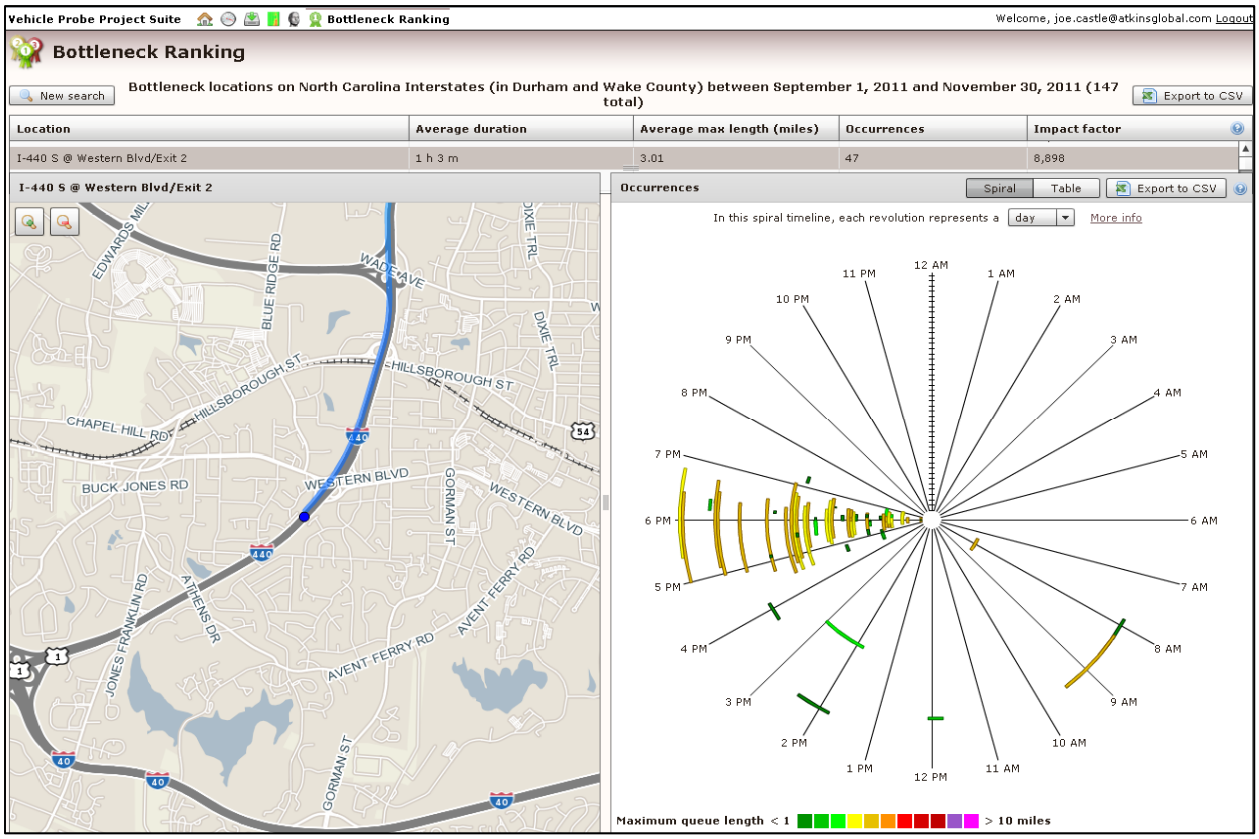


Figure 5: Example Figure Produced by Bottleneck Ranking Application

1.3.4. Filtering of Bottleneck Data

The bottleneck application records/displays all bottlenecks within the sample period, even if the bottleneck is not regular or significant. For this reason, the bottlenecks were filtered to identify those areas of congestion that are regular and significant enough to be worth considering for ramp metering intervention. Data were downloaded from the application and then analyzed in MS Excel. These data consist of a row per bottleneck with the following column headings:

- Location of the front of the queue

- Average duration in hours and minutes
- Average maximum length in miles
- Number of occurrences within the sample period

All bottlenecks are identified by a unique identification reference before filtering, to allow easy identification and differentiation in any further analysis. Any bottlenecks filtered out can still be identified in the same frame of reference, should this be required in future. The congestion reference number begins with a “C” for congestion, followed by a 3-digit reference number (e.g., C011). The “C” prevents any confusion between this reference and the log number used for candidate sites.

Using a combination of prior experience of site selection and a review of methods used in other states, a process was developed to filter the bottlenecks so that only regular and significant congestion was recorded. From the Ramp Metering National Research Report, the most comparable guidance comes from the “Arizona Ramp Metering Warrant” flowchart. This recommends that, to warrant installation of a ramp meter, that speeds near the ramp should fall below 50 mph for more than 30 minutes on 200 days per year. These figures are a reasonable cut-off to ensure that sites that do not suffer from regular congestion are not selected for ramp metering.

The VPP Suite only allows congestion to be identified at speeds that are 60% of reference speed or less, which is a more restrictive threshold than Arizona. The threshold chosen for the number of instances of congestion is two per week, 100 per year, which is a less restrictive threshold than Arizona. While this value was determined based on prior experience, it means the resulting guidelines used in this analysis are approximately equivalent to the Arizona guidelines (the more restrictive criteria balanced by the less restrictive one), and gives added confidence that these guidelines are suitable.

Based on insight from the Arizona warrant and prior experience, the following rules have been applied to the initial filtering of congestion:

- Average duration of bottlenecks must be at least 30 minutes.
- Average maximum length of congestion associated with the bottleneck must be at least 0.5 mile.
- The bottleneck must occur on average at least twice weekly over the sample period.

Bottlenecks meeting these criteria are recorded as “significant” bottleneck locations. The thresholds used are relaxed just enough so that some of the resulting locations are likely not to have sufficient congestion to justify ramp metering, once more detailed analysis including volumes and installation costs are considered in the next phase of work. This is preferable to criteria that are too restrictive, which could result in ruling out sites too early in the process.

In order to meet the criteria for being a significant bottleneck location, it must appear in either spring or the fall congestion analysis; however, the vast majority appears in both. This rule ensures that all potential significant bottlenecks are considered. Again, a detailed review will determine if the level of congestion ultimately proves to be significant enough for ramp metering.

1.3.5. Results

Many of the bottleneck locations coincide with the merge of an entrance ramp, suggesting that the merge could be the cause of congestion. Entrance ramps adjacent to the bottleneck and the associated congestion spilling back upstream are considered “congested” and were identified and recorded in the Master List. There were 77 “congested” candidate sites in 42 “significant” bottlenecks, which are totaled by type of road in Table 4. Screenshots of bottleneck maps and time spirals for each of the significant bottlenecks used to identify “congested” sites and “significant” bottlenecks are located in Appendix D Bottleneck Information.

Table 4: Number of Bottlenecks and Adjacent Candidate Sites for Each Road Type

Type of Road	Total Number of Bottlenecks in Scope of Project	Total Number of “Significant” Bottlenecks Remaining Post-Filtering	Number of Candidate Ramp Metering Sites Adjacent to “Significant” Bottleneck Congestion
Interstate	154	29	56
State	29	12	19
US – Wake	16	1	2
US – Durham	12	0	0
TOTAL	**211**	**42**	**77**

2. Screening Analysis

Before the detailed analysis began, the steering committee and the project team undertook a Screening Analysis based on the initial review of the sites. The purpose was to select the sites most likely to be suitable for ramp metering as the focus of further detailed analysis, resulting in the cost-effective use of resources by performing a detailed review only on suitable sites.

The screening analysis was split into two stages as shown in Figure 6.

- Stage 1, High Level Screening – all non-congested and most F2F sites were identified as not suitable for further analysis
- Stage 2, Screening on Site Characteristics – a review was performed to identify any sites obviously not suitable for further analysis

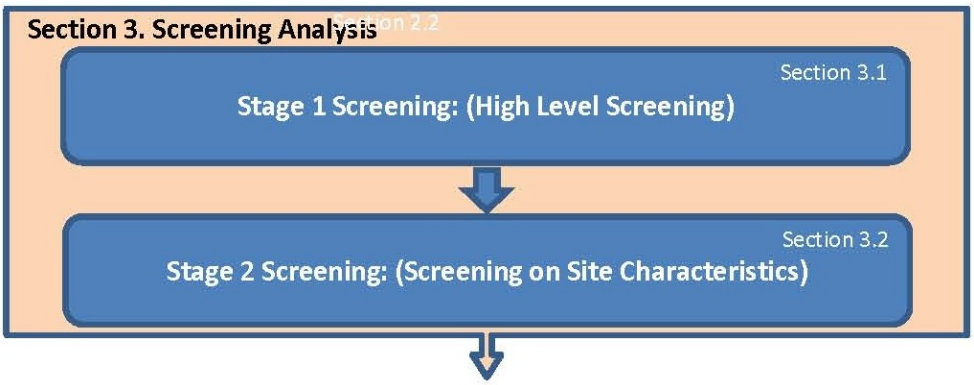


Figure 6: Relationship of Screening Analysis Subtasks

The Master List excerpt in Appendix A shows the sites that were ruled out of the detailed analysis at Stage 1 and Stage 2 of the Screening Analysis, and includes the reasons for doing so.

2.1. Stage 1 – High-Level Screening

In order to be suitable for ramp metering the candidate sites must meet the following criteria:

- Be within the study area and included in the Master List of sites
- Not be an F2F site
- Be adjacent to significant congestion on the freeway

Table 5 shows that there are 56 congested non-F2F candidate sites that are worthy of more detailed consideration.

Table 5: Numbers of Congested and Non-F2F Sites in Stage 1 Screening

	Non-F2F	F2F	All
Congested Sites	56	21	77
Total Sites	158	50	208

2.1.1. Exception to F2F Sites

As discussed in Section 1.2.3, in order to help NCDOT better appreciate some of the particular issues, associated costs, and potential for future improvements, five F2F sites were subjected to the detailed review (see Table 2, p. 14).

2.2. Stage 2 – Screening on Site Characteristics

In the second stage of the screening analysis, the 56 congested non-F2F sites were reviewed to identify any factors that would obviously rule them out as suitable sites in future. The three main reasons for ruling out sites were:

- Site subject to congestion that could be attributed to lane closures for roadway project
- Site upstream of a primary site already ruled out due to being F2F
- Site at the back of, or beyond the back of, congestion

Reason 1: Site subject to congestion that could be attributed to lane closures for roadway project

NCDOT identified that the pavement rehabilitation project on NC 147 was in the vicinity of a number of sites. This skewed the results of the site selection process because much of the congestion was caused by the roadway project. The congestion scan data indicated mid-day congestion consistent with the time of day of lane closures for the roadway project. It was decided that sites in the vicinity of this project (all sites on NC 147) would not be taken forward for further analysis at this stage. These sites could be reviewed again in the future, after the end of the pavement rehabilitation project.

Reason 2: Site upstream of a primary site already ruled out due to being F2F

Some sites were along corridors where the main bottleneck was caused by an entrance F2F ramp at the most downstream site. The steering committee has already concluded that F2F sites should be ruled out for implementation in this study (with the exception of five sites that are included in the analysis for comparative purposes, but will not be taken forward). Congestion at F2F interchanges is generally associated with high volume on all approaches. Any site upstream of an F2F site was likely to have much lower ramp volume. Therefore an upstream site, with its lower volume, has minimal impact on congestion. For this reason, several sites upstream of an F2F site have been ruled out of further analysis at this stage.

Reason 3: Site at the back of, or beyond the back of, congestion

In the congestion review, entrance ramps adjacent to each bottleneck and the associated tailback were identified as “congested.” A small number of sites were found to be near the back of the average queue. This means that not every occurrence of congestion caused by the bottleneck will affect these sites. Therefore, a small number of sites were considered to be unlikely to have a significant impact and were ruled out of further analysis in this stage.

Summary

Table 6 summarizes the reasons and number of sites ruled out in this stage.

Table 6: Sites Ruled Out from Further Analysis in Stage 2 Screening

Reason	Number of Sites
Site at the back of, or beyond the back of, congestion	7
Site upstream of a primary site already ruled out due to being F2F	5
Site subject to congestion that could be attributed to lane closures for roadway project	15
TOTAL	**27**

After removing 27 sites for the above reasons and including the five F2F sites indicated in Table 2, 34 sites remained that would be subjected to detailed analysis.

2.3. Results

Table 7 on the following page shows the 34 sites recommended to be taken forward to detailed analysis. Figure 7 shows the location of these sites.

Table 7: Sites Recommended for Detailed Analysis

Log	Freeway	Cross Street	Exit	Direction	County
002	I-40	US 15 / US-501	270	WB	Durham
009	I-40	NC 55 / Apex Hwy	278	EB	Durham
010	I-40	NC 55 / Apex Hwy	278	WB	Durham
011*	I-40	NC 147 / Durham Freeway	279	EB-M1 (NB to EB)	Durham
012*	I-40	NC 147 / Durham Freeway	279	EB-M2 (SB to EB)	Durham
013*	I-40	NC 147 / Durham Freeway	279	WB-M1 (NB to WB)	Durham
014*	I-40	NC 147 / Durham Freeway	279	WB-M2 (SB to WB)	Durham
015	I-40	Davis Dr	280	EB	Durham
016	I-40	Davis Dr	280	WB	Durham
017	I-40	S Miami Blvd	281	EB	Durham
018	I-40	S Miami Blvd	281	WB	Durham
019	I-40	Page Rd	282	EB	Durham
025	I-40	SR 3015 - Airport Blvd	284	EB	Wake
027	I-40	SR 1002 - Aviation Pkwy	285	EB-M1 (SB to EB)	Wake
028	I-40	SR 1002 - Aviation Pkwy	285	EB-M2 (NB to EB)	Wake
030	I-40	SR 1652 - N Harrison Ave	287	EB	Wake
043	I-40	SR 1571 - Gorman St	295	WB	Wake
055	I-40	SR 5220 - Jones Sausage Rd	303	EB	Wake
056	I-40	SR 5220 - Jones Sausage Rd	303	WB	Wake
089	I-440	SR 1319 - Jones Franklin Rd	1C	NB	Wake
090	I-440	SR 1319 - Jones Franklin Rd	1C	SB	Wake
091	I-440	Melbourne Rd	1D	NB	Wake
094	I-440	SR 1012 - Western Blvd	2	SB-M1 (WB to SB)	Wake
095	I-440	SR 1012 - Western Blvd	2	SB-M2 (EB to SB)	Wake
097	I-440	NC-54 / Hillsborough St	3	SB	Wake
099	I-440	SR 1728 - Wade Ave	4	NB-M2 (WB to NB)	Wake
100	I-440	SR 1728 - Wade Ave	4	SB-M1 (EB to SB)	Wake
102	I-440	Lake Boone Trail	5	NB	Wake
103	I-440	Lake Boone Trail	5	SB	Wake
104	I-440	Ridge Road	6	EB	Wake
107	I-440	US 70 / NC 50 / Glenwood Ave	7	WB-M1 (NB to WB)	Wake
108	I-440	US 70 / NC 50 / Glenwood Ave	7	WB-M2 (SB to WB)	Wake
133*	I-540	US 70	4	EB	Wake
135	I-540	SR 1829 - Leesville Rd	7	EB	Wake

* F2F sites that have been included in the detailed analysis to help understand the characteristics; there currently are no plans to implement them.

3. Detailed Analysis

This section outlines the work undertaken and the provisional results of the Detailed Review that covered the following subsections, the relationship of which is shown in Figure 8:

- 4.1. Grouping Sites by Congestion
- 4.2. Site Visits
- 4.3. Traffic Counts
- 4.4. Crash Data
- 4.5. Traffic Signal Data
- 4.6. Categorization of Sites

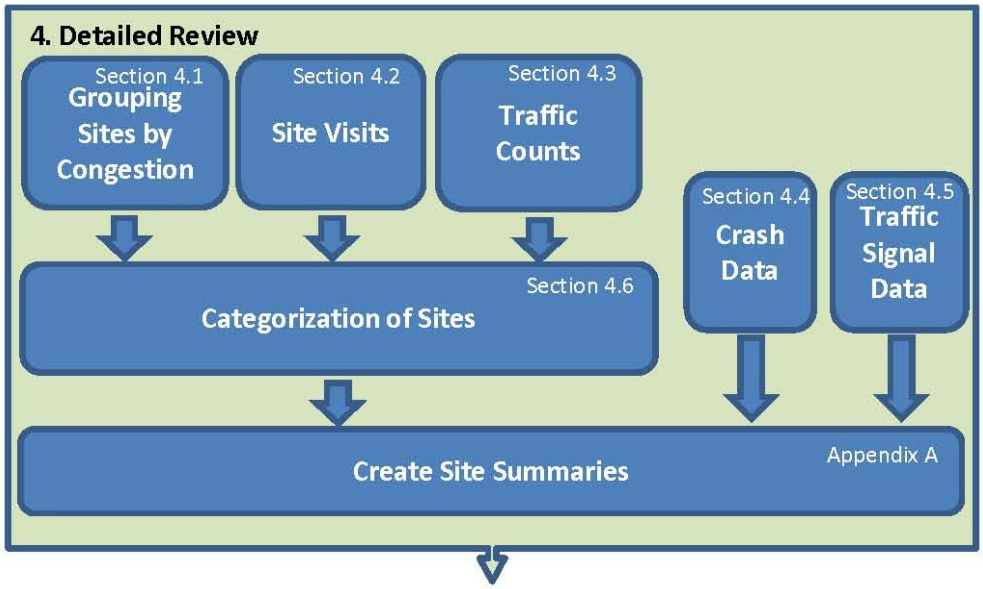


Figure 8: Relationship of Detailed Analysis Subtasks

In order to capture and present all of the information gathered during the detailed analysis, Site Summaries in Appendix C were created for each site and grouped accordingly.

3.1. Grouping of Sites by Congestion Problem

Sites have been grouped according to their related congestion problems so that decisions made about each site, which are sometimes linked to decisions for other sites, can be placed into context. Grouping is based on the following three general classifications:

- **Individual sites** involve one congestion problem that is related to only one potential ramp metering site (see Table 8).

- **Multiple sites** involve one congestion problem that is related to, or adjacent to, a number of potential ramp metering sites (see Table 9).
- **Groups of congestion** involve a number of congestion problems that exist and overlap on a stretch of freeway. For example, the spillback from a downstream congestion problem overlaps the flow breakdown point of an upstream congestion problem, or congestion problems exist at different times of the day. In this analysis, four such groups of congestion can be found (see Table 10).

Table 8: Individual Congestion Sites

Congestion Reference No.	Site Log	Freeway	Cross Street	Exit	Direction	County
C005	030	I-40	SR 1652 - N Harrison Ave	287	EB	Wake
C042	043	I-40	SR 1571 - Gorman St	295	WB	Wake
C054	056	I-40	SR 5220 - Jones Sausage Rd	303	WB	Wake
C068	002	I-40	US 15 / US 501	270	WB	Durham
C077	055	I-40	SR 5220 - Jones Sausage Rd	303	EB	Wake
C093	103	I-440	Lake Boone Trail	5	SB	Wake

Table 9: Multiple Congested Sites

Congestion Reference No.	Site Log	Freeway	Cross Street	Exit	Direction	County
C006	019	I-40	Page Rd	282	EB	Durham
C006	017	I-40	S Miami Blvd	281	EB	Durham
C006	015	I-40	Davis Dr	280	EB	Durham
C014	104	I-440	Ridge Road	6	EB	Wake
C014	102	I-440	Lake Boone Trail	5	NB	Wake
C014	099	I-440	SR 1728 - Wade Ave	4	NB-M2 (WB to NB)	Wake
C016	108	I-440	US 70 / NC 50 / Glenwood Ave	7	WB-M2 (SB to WB)	Wake
C016	107	I-440	US 70 / NC 50 / Glenwood Ave	7	WB-M1 (NB to WB)	Wake
C062	028	I-40	SR 1002 - Aviation Pkwy	285	EB-M2 (NB to EB)	Wake
C062	027	I-40	SR 1002 - Aviation Pkwy	285	EB-M1 (SB to EB)	Wake
C062	025	I-40	SR 3015 - Airport Blvd	284	EB	Wake
C086	091	I-440	Melbourne Rd	1D	NB	Wake
C086	089	I-440	SR 1319 - Jones Franklin Rd	1C	NB	Wake

Table 10: Groups of Congestion and Sites in Each Group

Congestion Group No.	Site Log	Freeway	Cross Street	Exit	Direction	County
Group 1 (C011, C030, C073)	090	I-440	SR 1319 - Jones Franklin Rd	1C	SB	Wake
	095	I-440	SR 1012 - Western Blvd	2	SB-M2 (EB to SB)	Wake
	094	I-440	SR 1012 - Western Blvd	2	SB-M1 (WB to SB)	Wake
	097	I-440	NC 54 / Hillsborough St	3	SB	Wake
	100	I-440	SR 1728 - Wade Ave	4	SB-M1 (EB to SB)	Wake
Group 2 (C032, C101)	133*	I-540	US 70	4	EB	Wake
	135	I-540	SR 1829 - Leesville Rd	7	EB	Wake
Group 3 (C051, C061)	010	I-40	NC 55 / Apex Hwy	278	WB	Durham
	014*	I-40	NC 147 / Durham Freeway	279	WB-M2 (SB to WB)	Durham
	013*	I-40	NC 147 / Durham Freeway	279	WB-M1 (NB to WB)	Durham
	016	I-40	Davis Dr	280	WB	Durham
	018	I-40	S Miami Blvd	281	WB	Durham
Group 4 (C060, C082)	012*	I-40	NC 147 / Durham Freeway	279	EB-M2 (SB to EB)	Durham
	011*	I-40	NC 147 / Durham Freeway	279	EB-M1 (NB to EB)	Durham
	009	I-40	NC 55 / Apex Hwy	278	EB	Durham

* F2F sites that have been included in the detailed analysis to help understand the characteristics; there currently are no plans to implement these sites.

Assumptions made about the congestion that could be reduced by each potential ramp metering site depend on whether the site has been classified as Individual, Multiple, or Group. These assumptions, as well as the calculations performed for Multiple and Group sites, are described in Appendix B.

3.2. Site Visits

Each potential ramp metering site has been visited to gather the following information, summarized in the Observations section of the Site Summaries in Appendix C:

- General description of location
- Confirmation of findings from the high-level geometric data analysis (Section 2.2.4)
- Sight line distances
- Ramp gradient
- Pavement condition
- Position of guardrail
- Presence of shoulder or other facility for parking of maintenance/enforcement vehicles
- Potential for altering layouts (e.g., increasing number of lanes on the entrance ramp, if required)

- Closed-circuit television (CCTV) coverage
- Presence of existing NCDOT fiber-optic communications cable
- Other general observations considered if a ramp meter is proposed for that location

3.3. Traffic Counts

In order to assess whether a site is suitable for implementation of ramp metering, it is important to understand traffic volumes on the ramp and on the freeway, both directly upstream and downstream of the merge. Maximum and minimum volumes in each of these locations are outlined in the Typical Design Criteria, and are used to determine if the traffic volumes are within acceptable limits for each site during the times of day when congestion is observed. Traffic counts were collected at locations upstream, downstream, and on the entrance ramp for each of the 35 sites. Where traffic counts were not available from NCDOT (www.traffic.com), they were collected in May and July 2012, over two weekdays.

Results of the traffic counts analysis can be found in the Traffic Volumes section of the Site Summaries, and are detailed for each hour between 6:00 AM and 8:00 PM to determine if the volumes are suitable for the operation of ramp metering. For ramp metering to be successful, the hours during which volumes are suitable must correspond with the hours during which congestion is observed. The Site Selection Comments section in the Site Summaries notes these results. If the volumes on the entrance ramp are too high, the comments also contain information on increasing the number of lanes on the entrance ramp to increase its suitability for ramp metering.

3.4. Crash Data

NCDOT provided crash data covering a period of 5 years (2007–2011) in the vicinity of each of the potential ramp metering sites. These data have been analyzed to identify rear-end, slow, or stop as well as sideswipe or same-direction accidents. These types of accidents are associated with congestion and are potentially correctible with implementation of ramp metering.

The results of the crash data analysis are expressed as a number and a percentage of overall accidents at each location, and can be found in the Crash Data section of the Site Summaries.

3.5. Traffic Signal Data

Where traffic signals are located at the intersection of the surface street and the entrance ramp, a potential ramp metering site, it is important to know the length of the platoons of traffic released by signals onto the ramp, especially where ramp volumes are high or the entrance ramp is short. This information is used to assess whether the queue management system will become overwhelmed and to address any related recommendations. Table 11

shows which sites have signals on the surface street with relatively high volumes and require queue management evaluation. Platoon lengths for these sites are therefore required and are being collected now that the sites have been identified.

Traffic signal information and comments for these sites will be added into the Site Selection Comments section of the Site Summaries.

Table 11: Sites for Which Platoon Lengths are Needed

Log	Freeway	Cross Street	Exit	Direction	County
009	I-40	NC 55 / Apex Hwy	278	EB	Durham
010	I-40	NC 55 / Apex Hwy	278	WB	Durham
015	I-40	Davis Dr	280	EB	Durham
017	I-40	S Miami Blvd	281	EB	Durham
019	I-40	Page Rd	282	EB	Durham
025	I-40	SR 3015 - Airport Blvd	284	EB	Wake
030	I-40	SR 1652 - N Harrison Ave	287	EB	Wake

3.6. Categorization of Sites

The analysis performed during the detailed review determined the following:

- Any serious physical issues that may exist at each potential ramp metering location
- Whether these issues can be rectified
- How much congestion is at the site and whether traffic volumes are suitable for metering
- Other useful factors that influence the site's suitability for ramp metering

Each potential ramp metering site has been considered in detail and in relation to any other potential ramp metering locations, and all comments and observations are noted in the Site Summaries.

From this information, it is possible to further categorize sites into the following groups:

- Not Suitable: A critical issue has been identified that makes the site not suitable for ramp metering, such as very low entrance ramp volumes.
- Review in Future: In some locations with "multiple site" or "groups of congestion," the analysis attributed the main cause of congestion to one or two of the downstream sites. In this case, sites further upstream may cease to be congested once the downstream sites are implemented, so it has been noted that the site should be further evaluated once the downstream sites have been implemented and operating for a period of time.
- Suitable for Taking Forward: These sites demonstrated good characteristics and the potential to reduce observed congestion. These sites will be taken forward into the next

stage of the process, an economic analysis will outline the implementation of ramp metering, and the sites will be prioritized for implementation.

3.7. Summary

Recommendations based on the results of the detailed review are shown in Table 12. The table is ordered as follows:

- Individual Sites – where a single identified congestion problem is adjacent to one site only
- Multiple Sites – where a single identified congestion problem is adjacent to a number of sites
- Group Sites – where multiple congestion problems overlap and form a larger congestion problem that is adjacent to a number of sites

The order that these recommendations are shown in the table is not intended to show an order of implementation of sites, nor is it meant to suggest that sites grouped together should be implemented at the same time. The prioritization of site implementation will come in a later stage.

For more information about the individual sites, including rationale for selection or ruling out, please refer to the Site Selection Comments section in the Site Summaries.

Table 12: Recommendations for Each Site

Log	Freeway	Cross Street	Exit	Direction	County	Categorization
Individual Sites						
030	I-40	SR 1652 - N Harrison Ave	287	EB	Wake	Suitable for taking forward
043	I-40	SR 1571 - Gorman St	295	WB	Wake	Suitable for taking forward
056	I-40	SR 5220 - Jones Sausage Rd	303	WB	Wake	Suitable for taking forward
002	I-40	US 15 / US-501	270	WB	Durham	Suitable for taking forward
055	I-40	SR 5220 - Jones Sausage Rd	303	EB	Wake	Not suitable
103	I-440	Lake Boone Trail	5	SB	Wake	Not Suitable
Multiple Sites (C006)						
019	I-40	Page Rd	282	EB	Durham	Suitable for taking forward
017	I-40	S Miami Blvd	281	EB	Durham	Suitable for taking forward
015	I-40	Davis Dr	280	EB	Durham	Suitable for taking

Log	Freeway	Cross Street	Exit	Direction	County	Categorization
						forward
Multiple Sites (C014)						
104	I-440	Ridge Road	6	EB	Wake	Not Suitable
102	I-440	Lake Boone Trail	5	NB	Wake	Suitable for taking forward
099	I-440	SR 1728 - Wade Ave	4	NB-M2 (WB to NB)	Wake	Not suitable
Multiple Sites (C016)						
108	I-440	US 70 / NC 50 / Glenwood Ave	7	WB-M2 (SB to WB)	Wake	Suitable for Taking Forward
107	I-440	US 70 / NC 50 / Glenwood Ave	7	WB-M1 (NB to WB)	Wake	Not suitable
Multiple Sites(C062)						
028	I-40	SR 1002 - Aviation Pkwy	285	EB-M2 (NB to EB)	Wake	Suitable for taking forward
027	I-40	SR 1002 - Aviation Pkwy	285	EB-M1 (SB to EB)	Wake	Suitable for taking forward
025	I-40	SR 3015 - Airport Blvd	284	EB	Wake	Suitable for taking forward
Multiple Sites (C086)						
091	I-440	Melbourne Rd	1D	NB	Wake	Not suitable
089	I-440	SR 1319 - Jones Franklin Rd	1C	NB	Wake	Suitable for taking forward
Group 1						
090	I-440	SR 1319 - Jones Franklin Rd	1C	SB	Wake	Suitable for taking forward
095	I-440	SR 1012 - Western Blvd	2	SB-M2 (EB to SB)	Wake	Suitable for taking forward
094	I-440	SR 1012 - Western Blvd	2	SB-M1 (WB to SB)	Wake	Review in Future
097	I-440	NC 54 / Hillsborough St	3	SB	Wake	Review in Future
100	I-440	SR 1728 - Wade Ave	4	SB-M1 (EB to SB)	Wake	Review in Future
Group 2						
133*	I-540	US 70	4	EB	Wake	Suitable for taking forward
135	I-540	SR 1829 - Leesville Rd	7	EB	Wake	Suitable for taking forward
Group 3						
010	I-40	NC 55 / Apex Hwy	278	WB	Durham	Suitable for taking

Log	Freeway	Cross Street	Exit	Direction	County	Categorization
						forward
014*	I-40	NC 147 / Durham Freeway	279	WB-M2 (SB to WB)	Durham	Suitable for taking forward
013*	I-40	NC 147 / Durham Freeway	279	WB-M1 (NB to WB)	Durham	Not suitable
016	I-40	Davis Dr	280	WB	Durham	Review in Future
018	I-40	S Miami Blvd	281	WB	Durham	Review in Future
Group 4						
012*	I-40	NC 147 / Durham Freeway	279	EB-M2 (SB to EB)	Durham	Suitable for taking forward
011*	I-40	NC 147 / Durham Freeway	279	EB-M1 (NB to EB)	Durham	Not suitable
009	I-40	NC 55 / Apex Hwy	278	EB	Durham	Suitable for taking forward

* F2F sites that have been included in the detailed analysis to help understand the characteristics; there currently are no plans to implement these sites.

4. Conclusions

This report outlined the process carried out to conduct both the Screening Analysis and the Detailed Analysis. The findings indicate those sites that have been ruled out in the screening analysis for their general characteristics, those with specific characteristics that make them unsuitable, those that should be reviewed again in the future, and those that are suitable and should be taken forward to the next stage.

Recommendations for the 34 sites subject to detailed analysis are shown in Table 12 on the preceding page, and the number of sites in each category are summarized in Table 13 and shown in Figure 9.

Table 13: Number of Sites Following Screening and Detailed Analysis

Site Categorization	Number of Sites
Total Sites	208
Ruled out in Screening Analysis	174
Not Suitable	8
Review in Future	5
Suitable for Taking Forward	21

The sites selected as suitable for taking forward for ramp metering have demonstrated acceptable or appropriate geometry, acceptable traffic volumes that will allow the system to work, and locations that are positioned to improve existing observed traffic problems.

The sites identified for future review (locations where ramp metering installation would result in reduced effectiveness) should be reconsidered after the first ramp meter sites have been installed and operated for a period of time to re-evaluate the observed congestion.

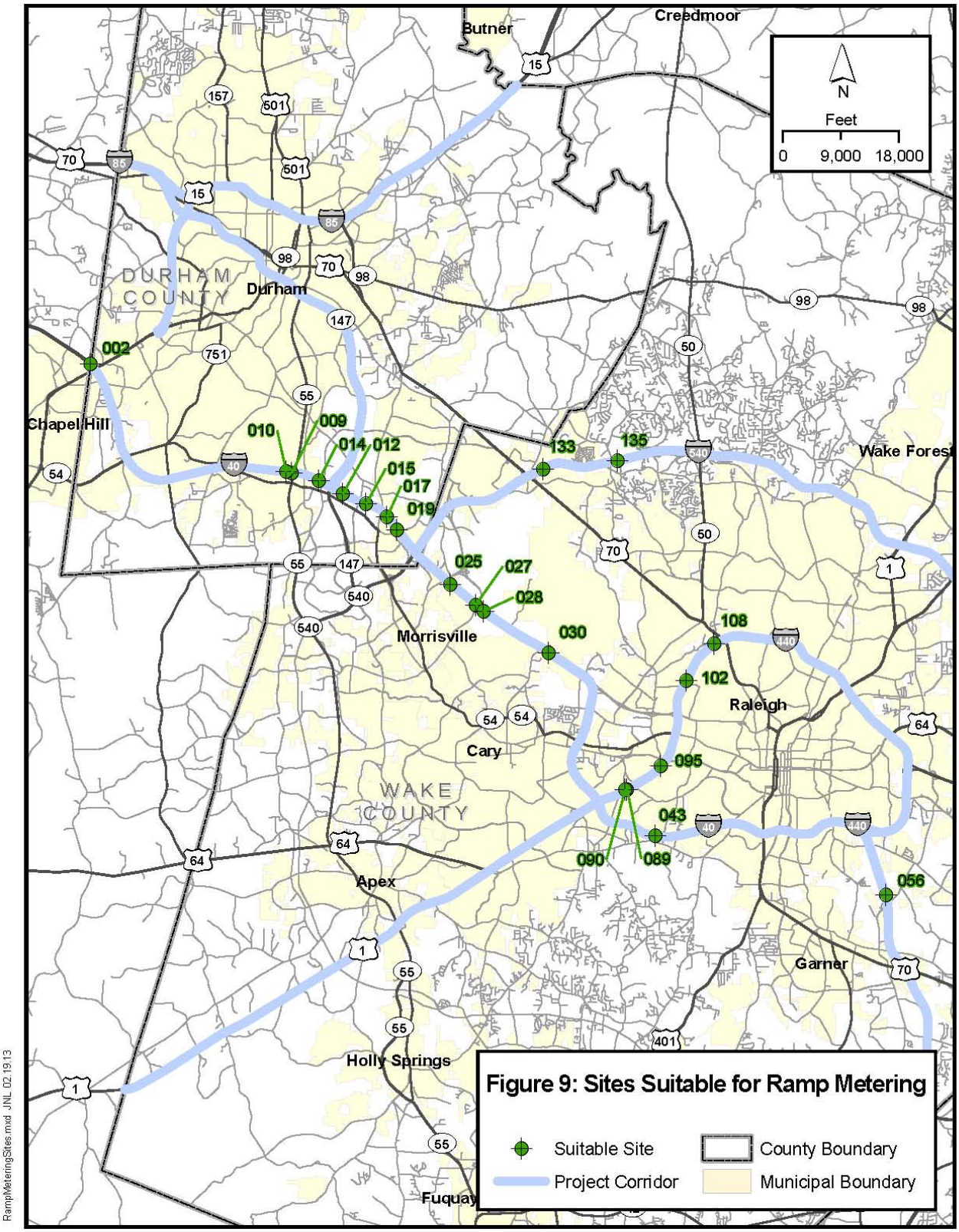


Figure 9: Sites Suitable for Ramp Metering

The next stage of the feasibility study is to use the information already collected to perform a high-level cost-benefit analysis for each site. The results will be added to the Costs and Benefits section of the Site Summaries. Following this, the most beneficial sites will be identified and prioritized for implementation. The relationship of future tasks are shown in Figure 10.

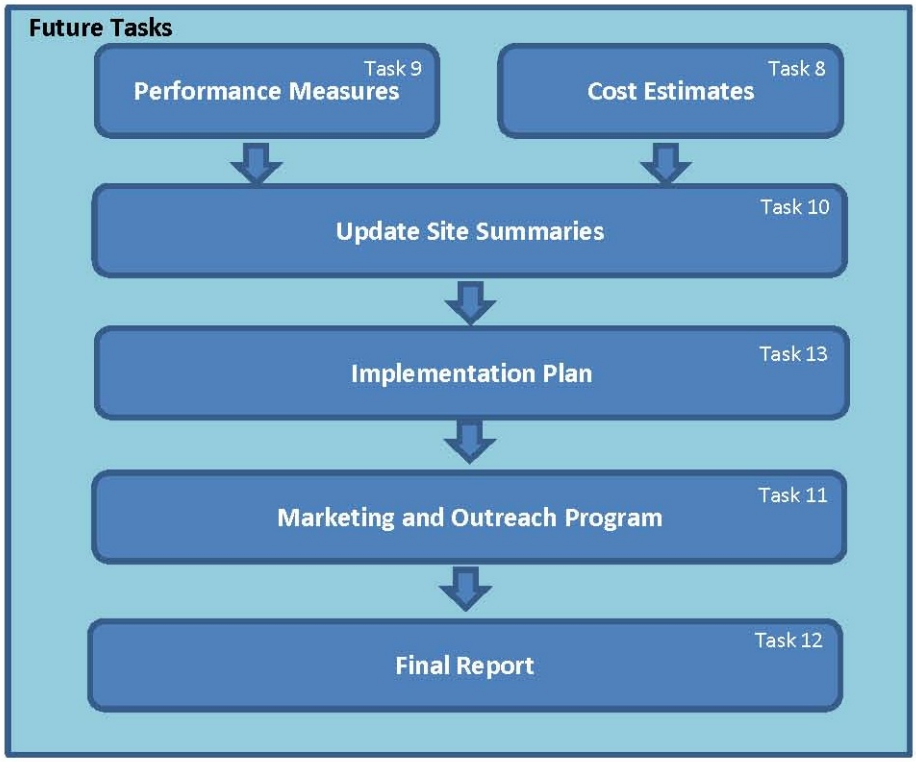


Figure 10: Relationship of Future Tasks

Appendices

Appendix A. Master List Excerpt

Table A-1 outlines the current status of all entrance ramps that were initially identified in the study area. It shows the reasons why some sites will not be considered further in the current Feasibility Study and those that will be taken forward into the next stages.

Table A-1: Summary Recommendations of all Sites

Log	Freeway	Cross Street	Exit	Direction	County	Screening Analysis Stage 1	Screening Analysis - Stage 2	Detailed Analysis	Site Status at End of Detailed Analysis
001	I-40	US-15 / US-501	270	EB	Durham	No congestion			Ruled out
002	I-40	US-15 / US-501	270	WB	Durham			Suitable	Take forward
003	I-40	NC-54	273	EB	Durham	No congestion			Ruled out
004	I-40	NC-54	273	WB	Durham	No congestion			Ruled out
005	I-40	NC-751	274	EB	Durham	No congestion			Ruled out
006	I-40	NC-751	274	WB	Durham	No congestion			Ruled out
007	I-40	Fayetteville Rd	276	EB	Durham		Site at the back or beyond the back of congestion.		Ruled out
008	I-40	Fayetteville Rd	276	WB	Durham	No congestion			Ruled out
009	I-40	NC-55 / Apex Hwy	278	EB	Durham			Suitable	Take forward
010	I-40	NC-55 / Apex Hwy	278	WB	Durham			Suitable	Take forward
011	I-40	NC-147 / Durham Freeway	279	EB-M1 (NB to EB)	Durham	F2F		Not suitable	Ruled out
012	I-40	NC-147 / Durham Freeway	279	EB-M2 (SB to EB)	Durham	F2F		Suitable	Take forward
013	I-40	NC-147 / Durham Freeway	279	WB-M1 (NB to WB)	Durham	F2F		Not suitable	Ruled out
014	I-40	NC-147 / Durham Freeway	279	WB-M2 (SB to WB)	Durham	F2F		Suitable	Take forward
015	I-40	Davis Dr	280	EB	Durham			Suitable	Take forward
016	I-40	Davis Dr	280	WB	Durham			Review in future	Ruled out
017	I-40	S Miami Blvd	281	EB	Durham			Suitable	Take forward

Log	Freeway	Cross Street	Exit	Direction	County	Screening Analysis Stage 1	Screening Analysis - Stage 2	Detailed Analysis	Site Status at End of Detailed Analysis
018	I-40	S Miami Blvd	281	WB	Durham			Review in future	Ruled out
019	I-40	Page Rd	282	EB	Durham			Suitable	Take forward
020	I-40	Page Rd	282	WB	Durham	No congestion			Ruled out
021	I-40	I-540	283	EB-M1 (SB to EB)	Durham	F2F & no congestion			Ruled out
022	I-40	I-540	283	EB-M2 (NB to EB)	Durham	F2F & no congestion			Ruled out
023	I-40	I-540	283	WB-M1 (NB to WB)	Durham	F2F & no congestion			Ruled out
024	I-40	I-540	283	WB-M2 (SB to WB)	Durham	F2F & no congestion			Ruled out
025	I-40	SR 3015 - Airport Blvd	284	EB	Wake			Suitable	Take forward
026	I-40	SR 3015 - Airport Blvd	284	WB	Wake	No congestion			Ruled out
027	I-40	SR 1002 - Aviation Pkwy	285	EB-M1 (SB to EB)	Wake			Suitable	Take forward
028	I-40	SR 1002 - Aviation Pkwy	285	EB-M2 (NB to EB)	Wake			Suitable	Take forward
029	I-40	SR 1002 - Aviation Pkwy	285	WB	Wake	No congestion			Ruled out
030	I-40	SR 1652 - N Harrison Ave	287	EB	Wake			Suitable	Take forward
031	I-40	SR 1652 - N Harrison Ave	287	WB	Wake	No congestion			Ruled out
032	I-40	SR 1728 - Wade Ave	289	EB	Wake	F2F			Ruled out
033	I-40	SR 1728 - Wade Ave	289	WB	Wake	F2F			Ruled out
034	I-40	Chapel Hill Rd / NC-54	290	EB-M1 (WB to SB)	Wake		Site at the back or beyond the back of congestion.		Ruled out
035	I-40	Chapel Hill Rd / NC-54	290	EB-M2 (EB to SB)	Wake		Site at the back or beyond the back of congestion.		Ruled out
036	I-40	Chapel Hill Rd / NC-54	290	WB-M1 (EB to NB)	Wake	No congestion			Ruled out
037	I-40	Chapel Hill Rd / NC-54	290	WB-M2 (WB to NB)	Wake	No congestion			Ruled out
038	I-40	Cary Towne Blvd	291	EB	Wake		Site upstream of a primary site		Ruled out

Log	Freeway	Cross Street	Exit	Direction	County	Screening Analysis Stage 1	Screening Analysis - Stage 2	Detailed Analysis	Site Status at End of Detailed Analysis
							already rule out as F2F.		
039	I-40	Cary Towne Blvd	291	WB	Wake	No congestion			Ruled out
040*	I-40	I-440/US 1	293	EB	Wake	F2F			Ruled out
041	I-40	I-440/US 1	293	WB	Wake	F2F			Ruled out
042	I-40	SR 1571 - Gorman St	295	EB	Wake	No congestion			Ruled out
043	I-40	SR 1571 - Gorman St	295	WB	Wake			Suitable	Take forward
044	I-40	SR 1009 - Lake Wheeler Rd	297	EB	Wake	No congestion			Ruled out
045	I-40	SR 1009 - Lake Wheeler Rd	297	WB	Wake		Site at the back or beyond the back of congestion.		Ruled out
046	I-40	US-401 / US-70 / NC-50 / S. Saunders St	298	EB	Wake	No congestion			Ruled out
047	I-40	US-401 / US-70 / NC-50 / S. Saunders St	298	WB	Wake	No congestion			Ruled out
048	I-40	SR 2026 - Hammond Rd	299	EB-M1 (SB to EB)	Wake	No congestion			Ruled out
049	I-40	SR 2026 - Hammond Rd	299	EB-M2 (NB to EB)	Wake	No congestion			Ruled out
050	I-40	SR 2026 - Hammond Rd	299	WB	Wake	No congestion			Ruled out
051	I-40	SR 2542 - Rock Quarry Rd	300	EB	Wake		Site upstream of a primary site already rule out as F2F.		Ruled out
052	I-40	SR 2542 - Rock Quarry Rd	300	WB	Wake	No congestion			Ruled out
053	I-40	I-440	301	EB	Wake	F2F			Ruled out
054	I-40	I-440	301	WB	Wake	F2F & no congestion			Ruled out
055	I-40	SR 5220 - Jones Sausage Rd	303	EB	Wake			Not suitable	Ruled out
056	I-40	SR 5220 - Jones Sausage Rd	303	WB	Wake			Suitable	Take forward
057	I-40	US 70 Bus.	306	EB-M1 (WB to EB)	Wake	F2F			Ruled out

Log	Freeway	Cross Street	Exit	Direction	County	Screening Analysis Stage 1	Screening Analysis - Stage 2	Detailed Analysis	Site Status at End of Detailed Analysis
058	I-40	US 70 Bus.	306	EB-M2 (EB to EB)	Wake	F2F			Ruled out
059	I-40	US 70 Bus.	306	WB-M1 (EB to WB)	Wake	F2F			Ruled out
060	I-40	US 70 Bus.	306	WB-M2 (WB to WB)	Wake	F2F			Ruled out
061	I-40	US 70 Clayton Bypass	309	EB	Wake	F2F & no congestion			Ruled out
062	I-40	US 70 Clayton Bypass	309	WB	Wake	F2F			Ruled out
063	I-85	NC-147 / Durham Freeway	172	NB	Durham	No entrance ramp & no congestion			Ruled out
064	I-85	NC-147 / Durham Freeway	172	SB	Durham	F2F & no congestion			Ruled out
065	I-85	Cole Mill Rd	173	NB	Durham	No congestion			Ruled out
066	I-85	Cole Mill Rd	173	SB	Durham	No congestion			Ruled out
067	I-85	US-501 / US-15	174A	NB	Durham	F2F & no congestion			Ruled out
068	I-85	Hillandale Rd	174B	NB	Durham	No congestion			Ruled out
069	I-85	Hillandale Rd	174B	SB	Durham	No congestion			Ruled out
070	I-85	NC-157 / Guess Rd	175	NB	Durham	No congestion			Ruled out
071	I-85	NC-157 / Guess Rd	175	SB	Durham	No congestion			Ruled out
072	I-85	N Duke St	176	NB	Durham	No congestion			Ruled out
073	I-85	N Duke St	176	SB	Durham	No congestion			Ruled out
074	I-85	US-501 / US-15 / N Roxboro St	177	NB	Durham	No congestion			Ruled out
075	I-85	Avondale Dr.	177	SB	Durham	No congestion			Ruled out
076	I-85	US-70	178	NB	Durham	No congestion			Ruled out
077	I-85	US-70	178	SB	Durham	No congestion			Ruled out
078	I-85	E Club Blvd	179	NB	Durham	No congestion			Ruled out

Log	Freeway	Cross Street	Exit	Direction	County	Screening Analysis Stage 1	Screening Analysis - Stage 2	Detailed Analysis	Site Status at End of Detailed Analysis
079	I-85	E Club Blvd	179	SB	Durham	No congestion			Ruled out
080	I-85	Glenn School Rd	180	NB	Durham	No congestion			Ruled out
081	I-85	Glenn School Rd	180	SB	Durham	No congestion			Ruled out
082	I-85	Red Mill Rd	182	NB	Durham	No congestion			Ruled out
083	I-85	Red Mill Rd	182	SB	Durham	No congestion			Ruled out
084	I-85	Redwood Rd	183	NB	Durham	No congestion			Ruled out
085	I-85	Redwood Rd	183	SB	Durham	No congestion			Ruled out
086	I-440	I-40	1	NB-M1 (EB to NB)	Wake	F2F			Ruled out
087	I-440	I-40	1	NB-M2 (WB to NB)	Wake	F2F			Ruled out
088	I-440	I-40	1	EB	Wake	F2F & no congestion			Ruled out
089	I-440	SR 1319 - Jones Franklin Rd	1C	NB	Wake			Suitable	Take forward
090	I-440	SR 1319 - Jones Franklin Rd	1C	SB	Wake			Suitable	Take forward
091	I-440	Melbourne Rd	1D	NB	Wake			Not suitable	Ruled out
092	I-440	SR 1012 - Western Blvd	2	NB-M1 (EB to NB)	Wake	No congestion			Ruled out
093	I-440	SR 1012 - Western Blvd	2	NB-M2 (WB to NB)	Wake	No congestion			Ruled out
094	I-440	SR 1012 - Western Blvd	2	SB-M1 (WB to SB)	Wake			Review in future	Ruled out
095	I-440	SR 1012 - Western Blvd	2	SB-M2 (EB to SB)	Wake			Suitable	Take forward
096	I-440	NC-54 / Hillsborough St	3	NB	Wake		Site at the back or beyond the back of congestion.		Ruled out
097	I-440	NC-54 / Hillsborough St	3	SB	Wake			Review in future	Ruled out
098*	I-440	SR 1728 - Wade Ave	4	NB-M1 (EB to NB)	Wake	F2F			Ruled out
099	I-440	SR 1728 - Wade Ave	4	NB-M2 (WB to NB)	Wake			Not Suitable	Ruled out
100	I-440	SR 1728 - Wade Ave	4	SB-M1 (EB to SB)	Wake			Review in future	Ruled out

Log	Freeway	Cross Street	Exit	Direction	County	Screening Analysis Stage 1	Screening Analysis - Stage 2	Detailed Analysis	Site Status at End of Detailed Analysis
101	I-440	SR 1728 - Wade Ave	4	SB-M2 (EB to SB)	Wake	F2F			Ruled out
102	I-440	Lake Boone Trail	5	NB	Wake			Suitable	Take forward
103	I-440	Lake Boone Trail	5	SB	Wake			Not suitable	Ruled out
104	I-440	Ridge Road	6	EB	Wake			Not suitable	Ruled out
105	I-440	US-70 / NC-50 / Glenwood Ave	7	EB-M1 (SB to EB)	Wake	No congestion			Ruled out
106	I-440	US-70 / NC-50 / Glenwood Ave	7	EB-M2 (NB to EB)	Wake	No congestion			Ruled out
107	I-440	US-70 / NC-50 / Glenwood Ave	7	WB-M1 (NB to WB)	Wake			Not suitable	Ruled out
108	I-440	US-70 / NC-50 / Glenwood Ave	7	WB-M2 (SB to WB)	Wake			Suitable	Take forward
109	I-440	SR 1005 - Six Forks Rd	8	EB	Wake	No congestion			Ruled out
110	I-440	SR 1005 - Six Forks Rd	8	WB	Wake	No congestion			Ruled out
111	I-440	SR 2000 - Old Wake Forest Rd	10	EB	Wake	No congestion			Ruled out
112	I-440	SR 2000 - Old Wake Forest Rd	10	WB	Wake	No congestion			Ruled out
113	I-440	US-1 / US-401 / Capital Blvd	11	EB-M1 (SB to EB)	Wake	No congestion			Ruled out
114	I-440	US-1 / US-401 / Capital Blvd	11	EB-M2 (EB to EB)	Wake	No congestion			Ruled out
115	I-440	US-1 / US-401 / Capital Blvd	11	WB-M1 (EB to WB)	Wake	No congestion			Ruled out
116	I-440	US-1 / US-401 / Capital Blvd	11	WB-M2 (WB to WB)	Wake	No congestion			Ruled out
117	I-440	Yonkers Rd	12	WB	Wake	No congestion			Ruled out
118	I-440	Brentwood Rd	12	EB	Wake	No congestion			Ruled out

Log	Freeway	Cross Street	Exit	Direction	County	Screening Analysis Stage 1	Screening Analysis - Stage 2	Detailed Analysis	Site Status at End of Detailed Analysis
119	I-440	US-64 / New Bern Ave	13	EB	Wake	No congestion			Ruled out
120	I-440	US-64 / New Bern Ave	13	NB	Wake	No congestion			Ruled out
121	I-440	US 64 / US 264	14	SB	Wake	F2F & no congestion			Ruled out
122	I-440	US 64 / US 264	14	NB	Wake	F2F & no congestion			Ruled out
123	I-440	SR 1007 - Poole Rd	15	SB	Wake	No congestion			Ruled out
124	I-440	SR 1007 - Poole Rd	15	NB	Wake	No congestion			Ruled out
125	I-440	I-40	16	NB	Wake	F2F & no congestion			Ruled out
126	I-540	I-40	1	EB	Durham	F2F & no congestion			Ruled out
127	I-540	I-40	1	WB	Durham	F2F & no congestion			Ruled out
128	I-540	Aviation Pkwy	2	EB	Wake	F2F & no congestion			Ruled out
129	I-540	Aviation Pkwy	2	WB-M1 (NB to WB)	Wake	F2F & no congestion			Ruled out
130	I-540	Aviation Pkwy	2	WB-M2 (SB to WB)	Wake	F2F & no congestion			Ruled out
131	I-540	SR 1645 - Lumley Rd	3	EB	Wake		Site at the back or beyond the back of congestion.		Ruled out
132	I-540	SR 1645 - Lumley Rd	3	WB	Wake	No congestion			Ruled out
133	I-540	US-70	4	EB	Wake	F2F		Suitable	Take forward
134	I-540	US-70	4	WB	Wake	F2F & no congestion			Ruled out
135	I-540	SR 1829 - Leesville Rd	7	EB	Wake			Suitable	Take forward
136	I-540	SR 1829 - Leesville Rd	7	WB	Wake	No congestion			Ruled out
137	I-540	NC-50 / Creedmoor Rd	9	EB	Wake	No congestion			Ruled out
138	I-540	NC-50 / Creedmoor Rd	9	WB	Wake	No congestion			Ruled out
139	I-540	SR 1005 - Six Forks Rd	11	EB	Wake	No congestion			Ruled out
140	I-540	SR 1005 - Six Forks Rd	11	WB	Wake	No congestion			Ruled out

Log	Freeway	Cross Street	Exit	Direction	County	Screening Analysis Stage 1	Screening Analysis - Stage 2	Detailed Analysis	Site Status at End of Detailed Analysis
141	I-540	SR 2000 - Falls of Neuse Rd	14	EB	Wake	No congestion			Ruled out
142	I-540	SR 2000 - Falls of Neuse Rd	14	WB	Wake	No congestion			Ruled out
143	I-540	US-1 Capital Blvd	16	EB	Wake	No congestion			Ruled out
144	I-540	US-1 Capital Blvd	16	WB	Wake	No congestion			Ruled out
145	I-540	Triangle Town Blvd	17	EB	Wake	No congestion			Ruled out
146	I-540	Triangle Town Blvd	17	WB	Wake	No congestion			Ruled out
147	I-540	US-401 / Louisburg Rd	18	EB	Wake	No congestion			Ruled out
148	I-540	US-401 / Louisburg Rd	18	WB	Wake	No congestion			Ruled out
149	I-540	SR 2215 - Buffaloe Rd	20	EB	Wake	No congestion			Ruled out
150	I-540	SR 2215 - Buffaloe Rd	20	WB	Wake	No congestion			Ruled out
151	I-540	US-64 Bus / Knightdale Blvd	24	EB	Wake	No congestion			Ruled out
152	I-540	US-64 Bus / Knightdale Blvd	24	WB	Wake	No congestion			Ruled out
153	I-540	US-64 / US-264	26	WB	Wake	F2F & no congestion			Ruled out
154	US-1	New Hill Holleman Rd	89	NB	Wake	No congestion			Ruled out
155	US-1	New Hill Holleman Rd	89	SB	Wake	No congestion			Ruled out
156	US-1	NC-55 / E Williams St	95	NB	Wake	No congestion			Ruled out
157	US-1	NC-55 / E Williams St	95	SB	Wake	No congestion			Ruled out
158	US-1	SR 1010 - Ten Ten Rd.	96	NB	Wake	No congestion			Ruled out
159	US-1	SR 1010 - Ten Ten Rd.	96	SB	Wake	No congestion			Ruled out
160	US-1	US-64 / Tryon Rd	98	NB	Wake	No congestion			Ruled out
161	US-1	US-64 / Tryon Rd	98	SB	Wake	No congestion			Ruled out

Log	Freeway	Cross Street	Exit	Direction	County	Screening Analysis Stage 1	Screening Analysis - Stage 2	Detailed Analysis	Site Status at End of Detailed Analysis
162	US-1 / US-64	SR 3977 - SE Cary Pkwy	99	NB-M1 (EB to NB)	Wake	No congestion			Ruled out
163	US-1 / US-64	SR 3977 - SE Cary Pkwy	99	NB-M2 (WB to NB)	Wake	No congestion			Ruled out
164	US-1 / US-64	SR 3977 - SE Cary Pkwy	99	SB-M1 (WB to SB)	Wake	No congestion			Ruled out
165	US-1 / US-64	SR 3977 - SE Cary Pkwy	99	SB-M2 (EB to SB)	Wake	No congestion			Ruled out
166	US-1 / US-64	SR 1313 - Walnut St	101	NB-M1 (EB to NB)	Wake		Site at the back or beyond the back of congestion.		Ruled out
167	US-1 / US-64	SR 1313 - Walnut St	101	NB-M2 (WB to NB)	Wake		Site at the back or beyond the back of congestion.		Ruled out
168	US-1 / US-64	SR 1313 - Walnut St	101	SB	Wake	No congestion			Ruled out
169	US-15/501	US-15/501	105	NB	Durham	No congestion			Ruled out
170	US-15/501	Cornwallis Rd	106	NB	Durham	No congestion			Ruled out
171	US-15/501	Cornwallis Rd	106	SB	Durham	No congestion			Ruled out
172	US-15/501	Cameron Blvd	107	NB	Durham	No congestion			Ruled out
173	US-15/501	Cameron Blvd	107	SB	Durham	No congestion			Ruled out
174	US-15/501	Morreene Dr	108A	SB	Durham	No congestion			Ruled out
175	US-15/501	NC 147	108B	SB	Durham	F2F & no congestion			Ruled out
176	US-15/501	NC 147	108C	NB	Durham	F2F & no congestion			Ruled out
177	US-15/501	US-70 Hillsborough Road	108D	NB	Durham	No congestion			Ruled out
178	NC-147 / Durham Fwy	I-40	5	NB-M1 (EB to NB)	Durham	F2F & no congestion			Ruled out
179	NC-147 / Durham Fwy	I-40	5	NB-M2 (WB to NB)	Durham	F2F & no congestion			Ruled out
180	NC-147 / Durham Fwy	I-40	5	SB-M1 (WB to SB)	Durham	F2F			Ruled out
181	NC-147 / Durham Fwy	I-40	5	SB-M2 (EB to SB)	Durham	F2F			Ruled out
182	NC-147 / Durham Fwy	SR 1121 - Cornwallis Rd	6	NB	Durham	No congestion			Ruled out
183	NC-147 / Durham Fwy	SR 1121 - Cornwallis Rd	6	SB	Durham		Site at the back or beyond the back of congestion.		Ruled out

Log	Freeway	Cross Street	Exit	Direction	County	Screening Analysis Stage 1	Screening Analysis - Stage 2	Detailed Analysis	Site Status at End of Detailed Analysis
184	NC-147 / Durham Fwy	SR 2028 - T W Alexander Dr	7	NB	Durham		Ruled out because of temporary congestion due to (NC-147 / Durham Freeway) rehabilitation project.		Ruled out
185	NC-147 / Durham Fwy	SR 2028 - T W Alexander Dr	7	SB	Durham	No congestion			Ruled out
186	NC-147 / Durham Fwy	SR 1954 - Ellis Rd	8	NB	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
187	NC-147 / Durham Fwy	SR 1954 - Ellis Rd	8	SB	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
188	NC-147 / Durham Fwy	S Briggs Ave	10	NB	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
189	NC-147 / Durham Fwy	S Briggs Ave	10	SB	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
190	NC-147 / Durham Fwy	NC-55 / S Alston Ave	11	NB-M1 NB to NB)	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
191	NC-147 / Durham Fwy	NC-55 / S Alston Ave	11	NB-M2 SB to NB)	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
192	NC-147 / Durham Fwy	NC-55 / S Alston Ave	11	SB	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
193	NC-147 / Durham Fwy	SR 1118 Fayetteville Rd	12A	SB	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
194	NC-147 / Durham Fwy	US 15/501 Bus. - Roxboro St	12B	SB	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
195	NC-147 / Durham Fwy	US 15/501 Bus. -Mangum St	12C	NB	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
196	NC-147 / Durham Fwy	SR 1445 - S Duke St	12D	NB	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
197	NC-147 / Durham Fwy	SR 1361 - Parker St	12D	SB	Durham		Ruled out because of temporary congestion due to (NC		Ruled out

Log	Freeway	Cross Street	Exit	Direction	County	Screening Analysis Stage 1	Screening Analysis - Stage 2	Detailed Analysis	Site Status at End of Detailed Analysis
198	NC-147 / Durham Fwy	SR 1127 - W Chapel Hill St	13	NB	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
199	NC-147 / Durham Fwy	SR 1127 - W Chapel Hill St	13	SB	Durham		Ruled out because of temporary congestion due to (NC		Ruled out
200	NC-147 / Durham Fwy	Swift Ave	14	NB	Durham		Ruled out because of temporary congestion due to (NC-147 / Durham Freeway) rehabilitation project.		Ruled out
201	NC-147 / Durham Fwy	Swift Ave	14	SB	Durham	No congestion			Ruled out
202	NC-147 / Durham Fwy	Elba St	15A	SB	Durham	No congestion			Ruled out
203	NC-147 / Durham Fwy	Fulton St / Hillandale Rd	15B	NB	Durham	No congestion			Ruled out
204	NC-147 / Durham Fwy	Fulton St / Hillandale Rd	15B	SB	Durham	No congestion			Ruled out
205	NC-147 / Durham Fwy	US-501 / US-15	16	NB-M1 (NB to NB)	Durham	F2F & no congestion			Ruled out
206	NC-147 / Durham Fwy	US-501 / US-15 / S Mangum St	16	NB-M2 (SB to NB)	Durham	F2F & no congestion			Ruled out
207	NC-147 / Durham Fwy	US-501 / US-15	16	SB-M1 (SB to SB)	Durham	F2F & no congestion			Ruled out
208	NC-147 / Durham Fwy	US-501 / US-15 / S Mangum St	16	SB-M2 (NB to SB)	Durham	F2F & no congestion			Ruled out

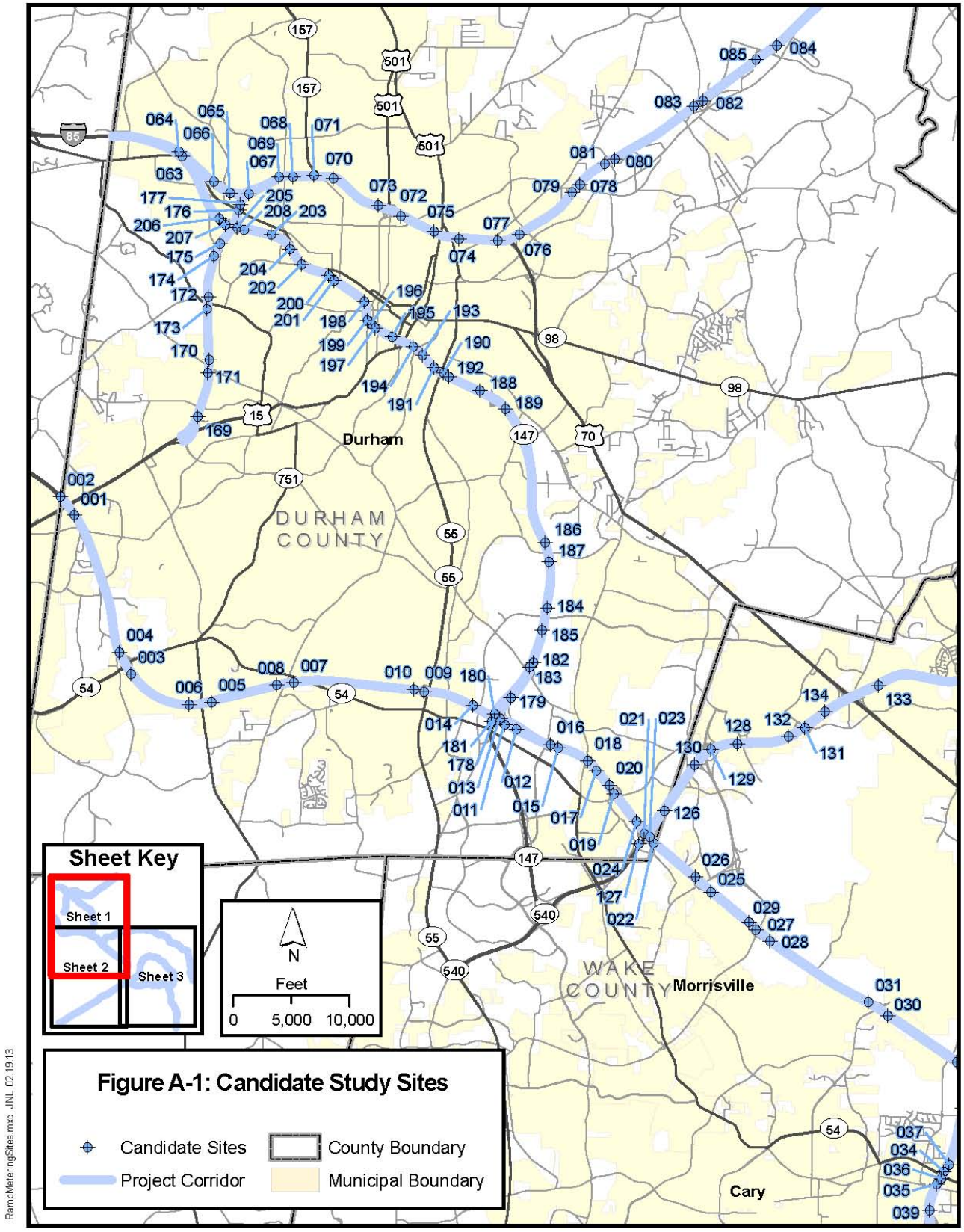


Figure A-1: Ramp Meter Study Sites (1 of 3)

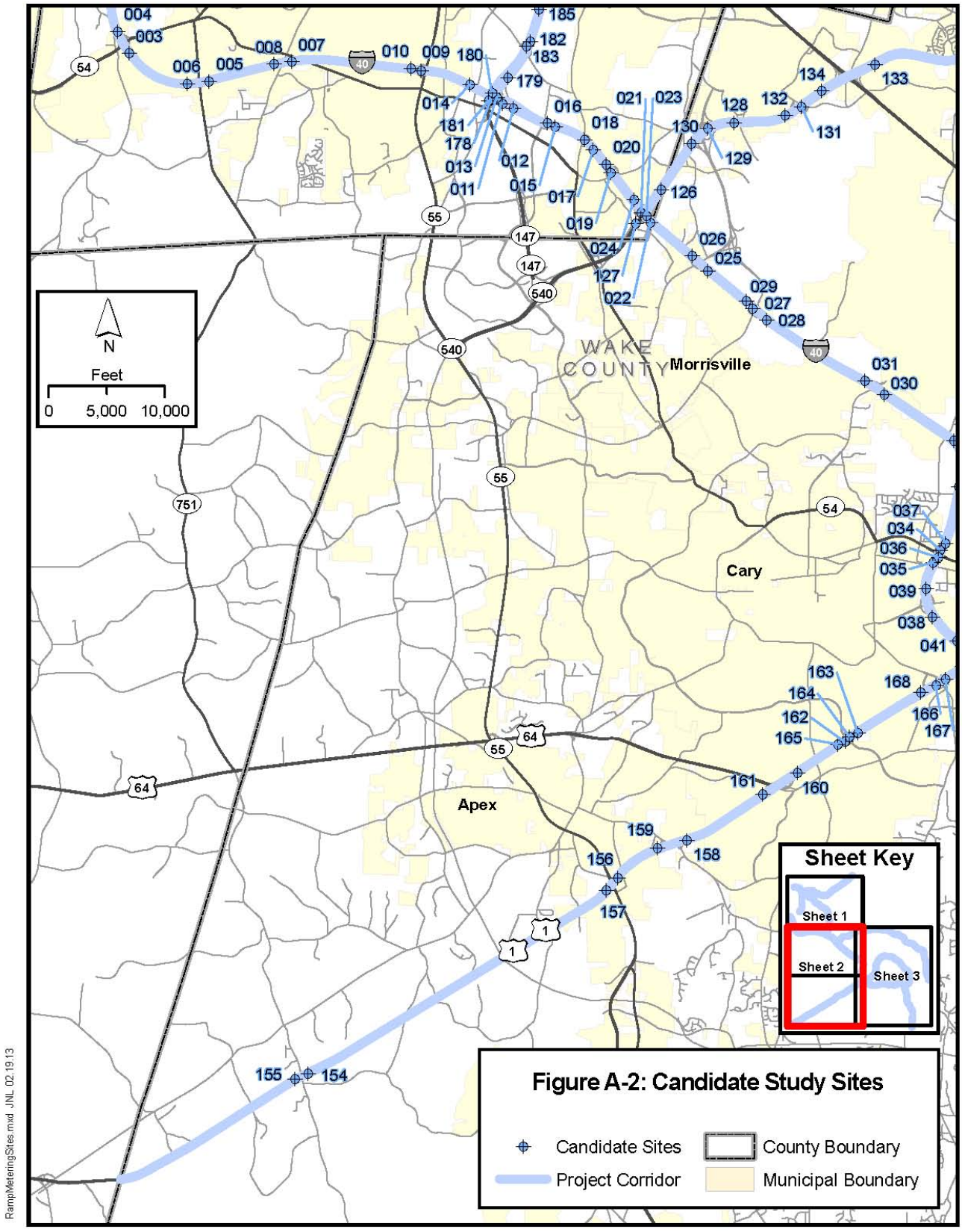


Figure A-2: Ramp Meter Study Sites (2 of 3)

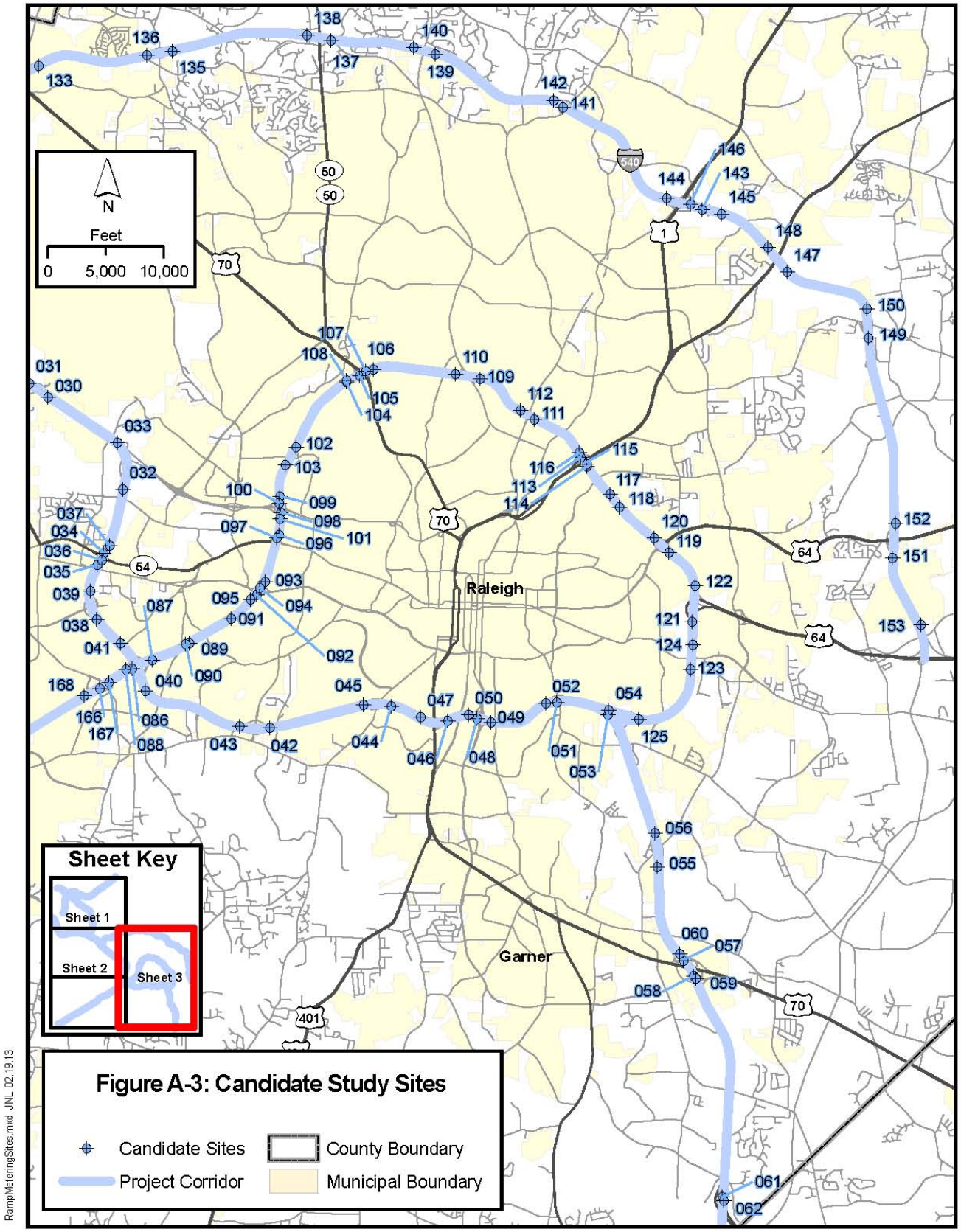


Figure A-3: Ramp Meter Study Sites (3 of 3)

Appendix B. Analysis of Congestion

B.1. Assumptions Made about the Potential Benefits of Ramp Metering

The congestion attributed to each site has been recorded in the Congestion section of the Site Summaries. The method used to analyze this congestion depends on its classification as individual, multiple, or group (see previous section). The potential impact of congestion reduction is identified by determining the length, duration, and number of occurrences of congestion, which can be impacted on by each site. These figures are used in the Performance Measures report and Implementation Plan to determine the number of vehicle-hours delay associated with each site and an assumption about the potential percentage reduction achieved by ramp metering.

The figures used in the calculations described below for Multiple and Group sites are contained in Section B.2.

Individual Sites

It is assumed that ramp metering at an individual site could provide a benefit relating to the whole congestion problem. Therefore, the length, duration, and occurrences of congestion are the same as for the associated congestion problem.

Multiple Sites

It cannot be assumed that multiple sites in the vicinity of a particular congestion problem all have an equally significant impact. There are two reasons for this:

- Ramp metering at one of the sites could completely resolve or significantly reduce the congestion problem, in which no further installations would be justified.
- In the case of a significant congestion problem where one ramp is already metered, additional ramp metering at sites within the vicinity could provide additional delay reduction at the first ramp meter.

A site that is significantly upstream of a bottleneck may not have a considerable impact on the traffic downstream of the site.

The following rules have been applied to weigh the potential impacts of sites related to a particular congestion problem:

- For the primary site, it is assumed that ramp metering could provide benefit to the whole congestion problem. Therefore, the length, duration, and occurrences of congestion are the same as for the associated congestion problem.

- For each secondary site, it is assumed that ramp metering would only provide a reduction in the congestion that occurs upstream of that site. While this is a simplification, it is considered a sensible application of engineering judgement. It allows for the fact that secondary sites might not have as significant an impact as the primary site, which is likely to be the primary cause of a congestion problem. However, it allows secondary sites to provide significant benefits where the problem is large. The following assumptions are applied for each secondary site:
  - The length of congestion is the distance from each site to the back of the queue.
  - The number of occurrences is the same for all sites in the congestion.
  - The congestion duration at a secondary site is calculated as the total congestion duration reduced by the total congestion duration that is proportional to the secondary site's distance from the primary site compared to the total congestion's length. This reflects the fact that the queue upstream of the secondary site has a shorter duration, because it reaches the site later and dissipates to this point sooner.
- If the primary site has been deemed unsuitable for ramp metering, (e.g., ramp volumes are too low) then it is assumed that the secondary site could provide a benefit to the whole congestion problem. Therefore, the length, duration, and occurrences of congestion are the same for the secondary site as for the associated congestion problem.

Group Sites

For sites classified in groups, each congestion problem might have an associated primary site; it is assumed that each primary site could provide a benefit relating to the whole congestion problem. Therefore, the length, duration, and occurrences of congestion for each site are the same as for the associated congestion problem. However, the same site could also be a secondary site for a congestion problem that starts further downstream, in which case it could provide some additional benefits.

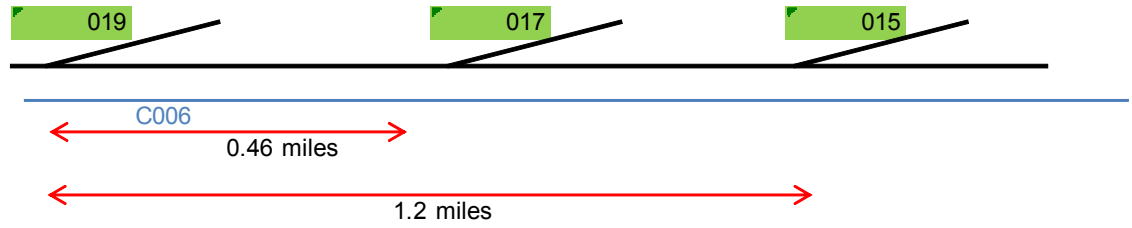
Group sites have the same assumptions for primary and secondary sites as multiple sites. Additional rules are applied if a particular site relates to two congestion problems in the group:

- The length of congestion is the weighted average of the lengths associated with the two congestion problems.
- The number of occurrences is the sum of the occurrences associated with the two congestion problems (the site can potentially impact both).
- The duration of congestion is the weighted average of the durations associated with the two congestion problems.

The resulting length, duration, and occurrences of congestion give a representative picture of the total potential impact of installing ramp metering at a site.

B.2. Calculations Performed for Multiple and Group Sites

The following figures show the calculations made for each Multiple and Group site using the assumptions above.



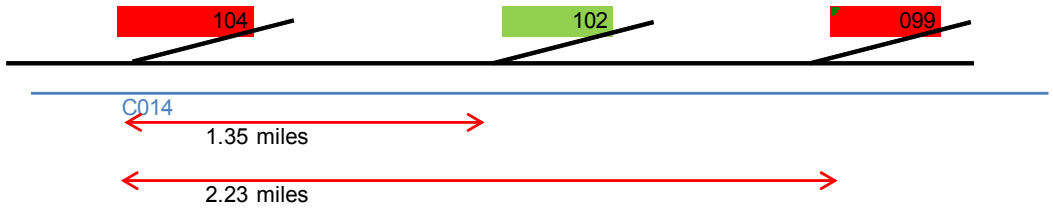
Congestion	length (miles)	no. of occurrences	duration (min)
C006	2.71	66	64

Site 019	length (miles)	no. of occurrences	duration (min)
C006	2.71	66	64

Site 017	length (miles)	no. of occurrences	duration (min)
C006	2.25	66	53

Site 015	length (miles)	no. of occurrences	duration (min)
C006	1.51	66	36

Figure B-1: Multiple Congestion Site C006



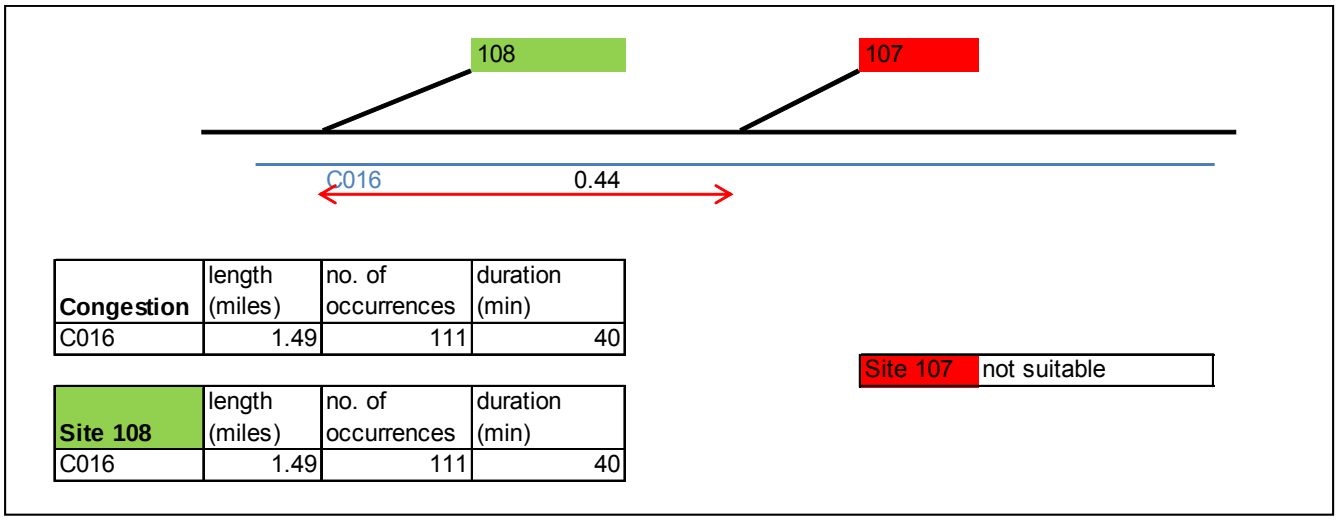
Congestion	length (miles)	no. of occurrences	duration (min)
C014	2.71	66	64

Site 102	length (miles)	no. of occurrences	duration (min)
C014	2.71	66	64

Have assumed benefit on full length of C014

Site 099	not suitable
Site 104	not suitable

Figure B-2: Multiple Congestion Site C014

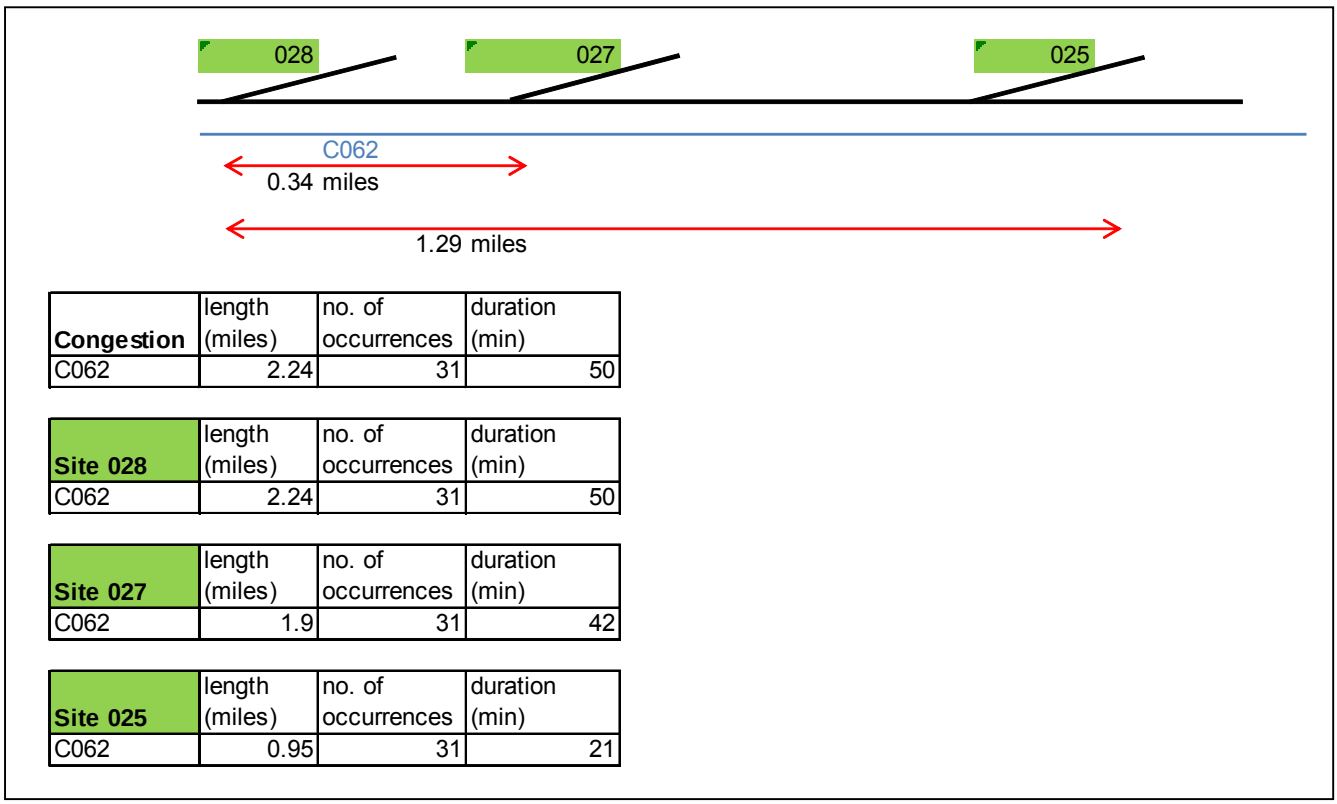


Congestion	length (miles)	no. of occurrences	duration (min)
C016	1.49	111	40

Site 108	length (miles)	no. of occurrences	duration (min)
C016	1.49	111	40

Site 107	not suitable

Figure B-3: Multiple Congestion Site C016



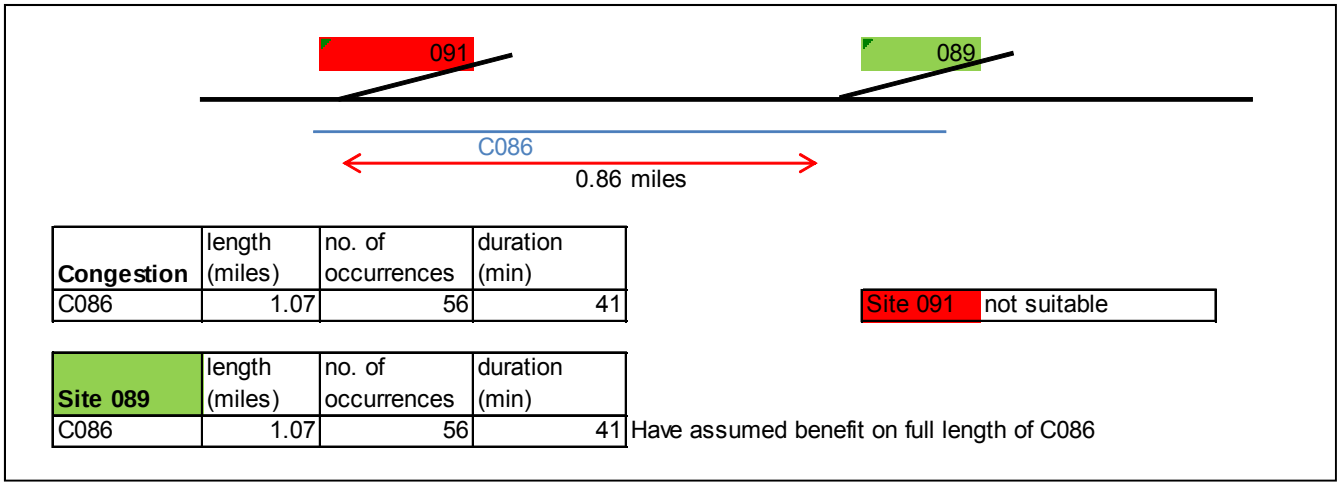
Congestion	length (miles)	no. of occurrences	duration (min)
C062	2.24	31	50

Site 028	length (miles)	no. of occurrences	duration (min)
C062	2.24	31	50

Site 027	length (miles)	no. of occurrences	duration (min)
C062	1.9	31	42

Site 025	length (miles)	no. of occurrences	duration (min)
C062	0.95	31	21

Figure B-4: Multiple Congestion Site C062

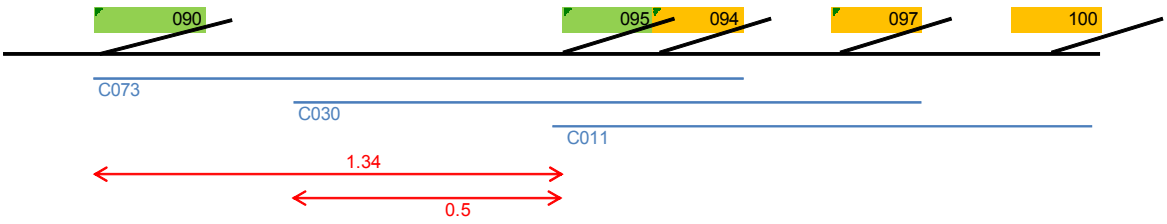


Congestion	length (miles)	no. of occurrences	duration (min)
C086	1.07	56	41

Site 091	not suitable

Site 089	length (miles)	no. of occurrences	duration (min)	
C086	1.07	56	41	Have assumed benefit on full length of C086

Figure B-5: Multiple Congestion Site C086



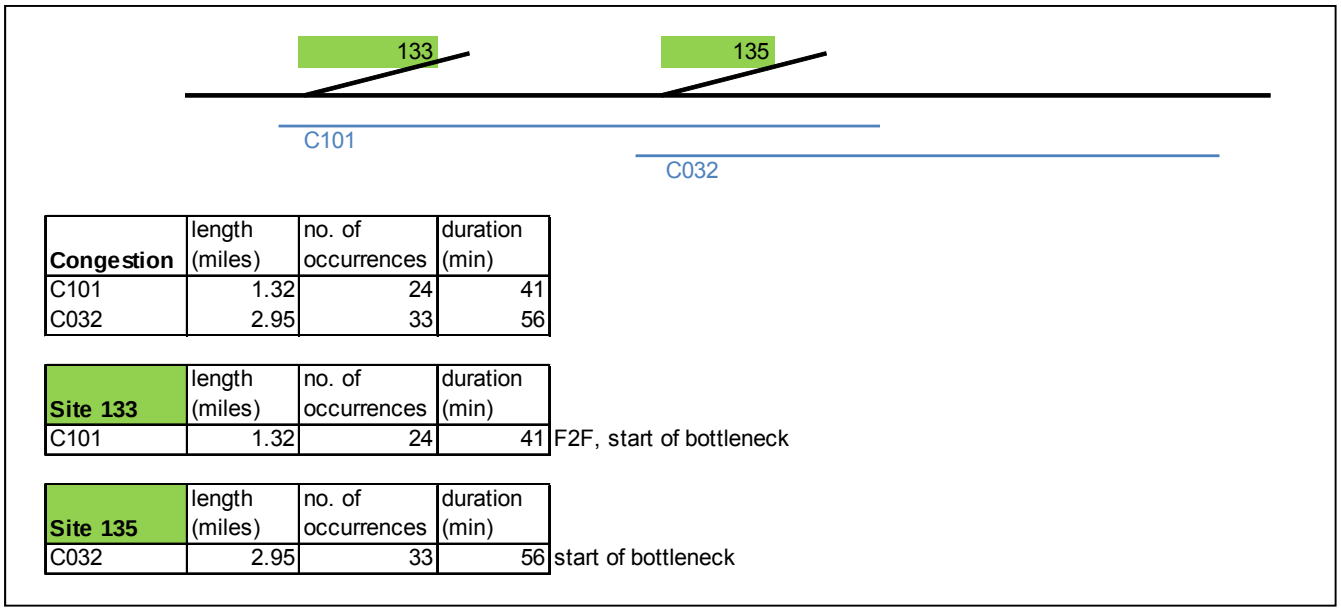
Congestion	length (miles)	no. of occurrences	duration (min)
C073	2.52	25	43
C030	2.18	50	50
C011	3.01	47	63

Site 094	review in future
Site 097	review in future
Site 100	review in future

Site 090	length (miles)	no. of occurrences	duration (min)	
C073	2.52	25	43	start of bottleneck

Site 095	length (miles)	no. of occurrences	duration (min)	impact	
C030	2.18	50	50	5450	half a mile downstream ... assume 95 totally able to mitigate
C011	3.01	47	63	8912.61	start of bottleneck
Total	2.582165	97	56.29897	14101.2	

Figure B-6: Group Congestion Site 1

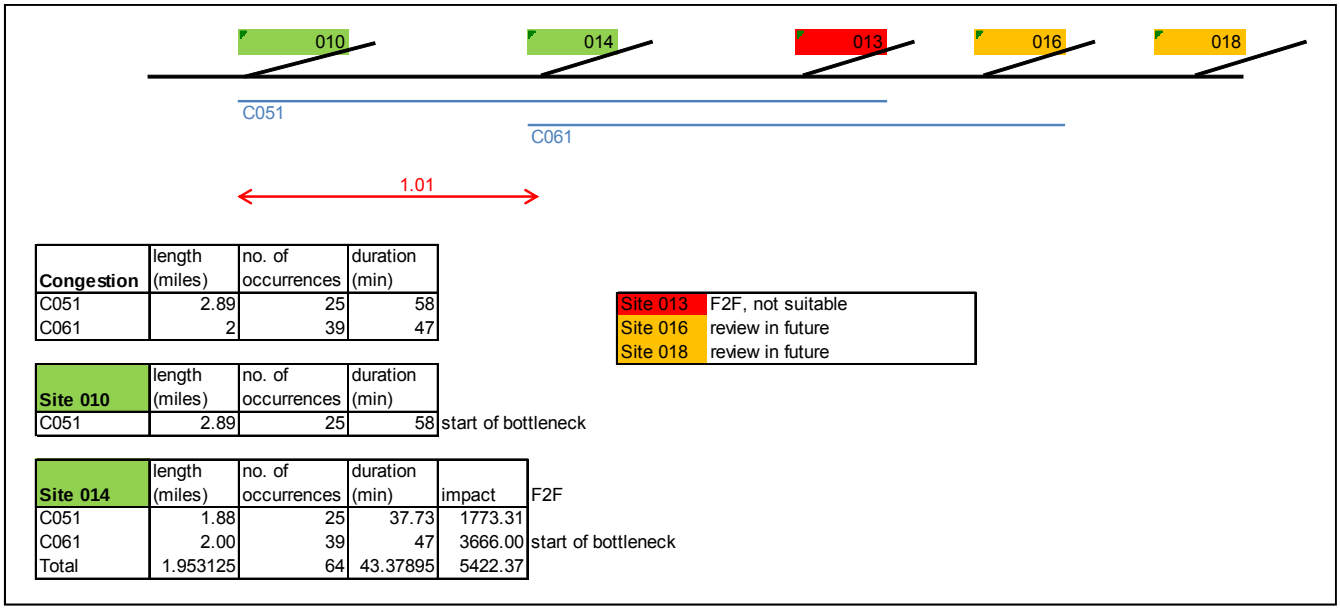


Congestion	length (miles)	no. of occurrences	duration (min)
C101	1.32	24	41
C032	2.95	33	56

Site 133	length (miles)	no. of occurrences	duration (min)	
C101	1.32	24	41	F2F, start of bottleneck

Site 135	length (miles)	no. of occurrences	duration (min)	
C032	2.95	33	56	start of bottleneck

Figure B-7: Group Congestion Site 2



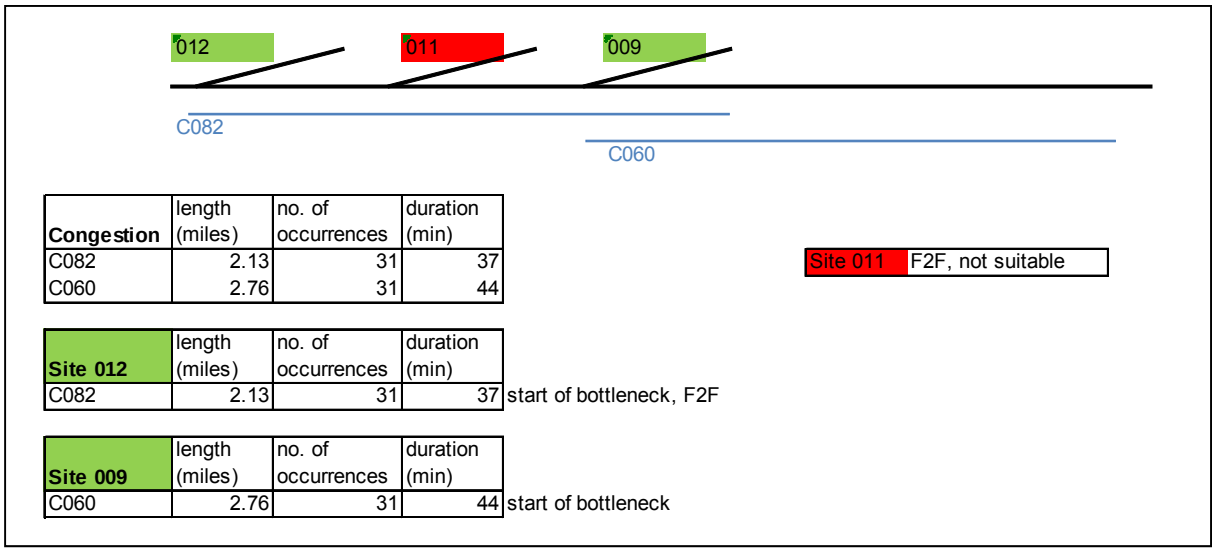
Congestion	length (miles)	no. of occurrences	duration (min)
C051	2.89	25	58
C061	2	39	47

Site 013	F2F, not suitable
Site 016	review in future
Site 018	review in future

Site 010	length (miles)	no. of occurrences	duration (min)	
C051	2.89	25	58	start of bottleneck

Site 014	length (miles)	no. of occurrences	duration (min)	impact	F2F
C051	1.88	25	37.73	1773.31	
C061	2.00	39	47	3666.00	start of bottleneck
Total	1.953125	64	43.37895	5422.37	

Figure B-8: Group Congestion Site 3



Congestion	length (miles)	no. of occurrences	duration (min)
C082	2.13	31	37
C060	2.76	31	44

Site 011 F2F, not suitable

Site 012	length (miles)	no. of occurrences	duration (min)	
C082	2.13	31	37	start of bottleneck, F2F

Site 009	length (miles)	no. of occurrences	duration (min)	
C060	2.76	31	44	start of bottleneck

Figure B-9: Group Congestion Site 4

Appendix C. Site Summaries

The Site Summaries presented here do not include the costs and benefits, which are developed in the Performance Measures report and the Implementation Plan.

Sites with very low traffic volumes that are not suitable for ramp metering will show no congestion in the congestion table of the site summary. Sites that are upstream of primary sites and have been recommended for future consideration also will show no congestion in the congestion table of the site summary.

If sites are not suitable for ramp metering (e.g., sites 104 and 099) the congestion has been allocated to the other sites within the same congestion problem. For this example, it would be site 102 because only it would be able to address this congestion problem to any degree.

If the site is upstream of a primary site that is suitable but near the upstream end of the queue, all of the congestion in that location has been assigned to the downstream (primary) site. This is because ramp metering in this location is likely to reduce the length of the upstream queue. Therefore, it is impossible to say at this stage whether the upstream site would ever be useful, i.e. the downstream site might solve the problem by reducing the length of the queue and hence the upstream site would no longer be within the congestion problem queue.

C.1. Individual Sites

Site Summaries 002, 030, 043, 055, 056, and 103 have been included in this section.

Site Summary

002

Site Details

Site Number	002
Freeway	I-40
Cross Street	US-15 / US-501
Exit	270
Direction	WB
County	Durham

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	Yes
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	918
On Ramp Length to Tip of Gore (ft)	1207
Merge Length (ft)	757
On Ramp Horizontal Alignment	Straight
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	Discontinuous
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	53
Guardrail	None Present
Pipe Crossing	None Present

Signalization Overview

Upstream Signal	3-way signal; ramp entry from: dual lefts, right turn on red, thru
Nearest Power Source	Traffic signal cabinet: inside corner of ramp & intersection

Signing Overview

Existing Signing	Left Lane Merge signs may cause conflict with ramp metering.

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	740	854	114	285	114	13	No
07:00	1438	1689	251	563	251	15	No
08:00	1596	1906	310	635	310	16	Yes
09:00	1544	1859	315	620	315	17	Yes
10:00	1470	1794	325	598	325	18	Yes
11:00	1416	1784	368	595	368	21	Yes
12:00	1479	1912	433	637	433	23	Yes
13:00	1634	2041	407	680	407	20	Yes
14:00	1726	2171	445	724	445	21	Yes
15:00	1823	2302	480	767	480	21	Yes
16:00	2211	2746	536	915	536	20	Yes
17:00	2475	3163	689	1054	689	22	Yes
18:00	1978	2522	544	841	544	22	Yes
19:00	1253	1635	382	545	382	23	Yes
20:00	958	1267	309	422	309	24	Yes

Congestion

Congestion	**C068**
Ave Length of Congestion (Miles)	2
Duration of Congestion (Min)	55
Calculated Number of Occurrences per Year	116
Typical Times of Congestion	14:00-19:00

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 42
Of these 32 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 29 (52%)
Type 28- Sideswipe, same direction: 9 (0%)

Observations

Log 002 is a long direct ramp. There are no sight distance issues. CCTV coverage is of end half of the ramp. The ramp has a slight -4% downhill grade that flattens out near the merge location. The ramp begins as 2 lanes that merge to 1 lane after about 300'. There is a guardrail on the right side just before the ramp merges onto the mainline. Overall, observations indicate this is a good candidate for a ramp meter. A moderate sized shoulder width of 4' on each side could allow for converting the ramp to 2 lanes for the entire ramp length.

Site Selection Comments

This entrance ramp has good physical characteristics generally.
The flows are within acceptable limits for ramp metering during most of the day and especially when congestion is observed.

There is an off side lane drop downstream of the end of the merge, however it appears that the congestion is caused by the merge.

On the whole, this looks like a promising site, but need to understand whether the congestion is caused by the merge or by the downstream lane drop, local knowledge or observation required.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

030

Site Details

Site Number	030
Freeway	I-40
Cross Street	SR 1652 – N Harrison Ave
Exit	287
Direction	EB
County	Wake

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	4
Number of Freeway Lanes After Merge	4
On Ramp Length to Back of Gore (ft)	1,074
On Ramp Length to Tip of Gore (ft)	1,366
Merge Length (ft)	1,072
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	Discontinuous
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	62
Guardrail	Extensive along right side
Pipe Crossing	None Present

Signalization Overview

Upstream Signal	3-way signal; ramp entry from: left, right turn on red, thru
Nearest Power Source	Traffic signal cabinet: near corner of ramp & intersection

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	2425	2794	369	698	369	13	Yes
07:00	4564	5657	1093	1414	1093	19	Yes
08:00	4884	5949	1065	1487	1065	18	Yes
09:00	3707	4393	686	1098	686	16	Yes
10:00	3126	3671	546	918	546	15	Yes
11:00	3157	3842	685	960	685	18	Yes
12:00	3153	3903	751	976	751	19	Yes
13:00	3136	3842	707	961	707	18	Yes
14:00	3510	4268	758	1067	758	18	Yes
15:00	4491	5497	1006	1374	1006	18	Yes
16:00	5764	6879	1115	1720	1115	16	Yes
17:00	5781	7111	1331	1778	1331	19	No
18:00	4680	5513	833	1378	833	15	Yes
19:00	2934	3446	512	862	512	15	Yes
20:00	2284	2721	437	680	437	16	Yes

Congestion

Congestion	**C005**
Ave Length of Congestion (Miles)	4.81
Duration of Congestion (Min)	64
Calculated Number of Occurrences per Year	76
Typical Times of Congestion	17:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 71
Of these 65 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 55 (77%)
Type 28- Sideswipe, same direction: 10 (14%)

Observations

Log 030 is a direct ramp with no sight distance issues. The ramp has a moderate downhill slope of 4-6% for its entire length. There is only spotty CCTV coverage of the ramp. There is a guardrail on the right side of most of the ramp's length. A large shoulder for maintenance vehicles / enforcement at the merge section of the ramp. The NCDOT fiber is on the other side of the freeway mainline.

Site Selection Comments

This entrance ramp has good physical characteristics.

The flows are outside of acceptable limits during the first part of the peak as the on-slip flows are too high.

Increasing the number of lanes on the entrance ramp would make the flows within acceptable limits during the period of observed congestion.

The four lanes downstream diverge into two, two lane links one mile downstream of the site, this could cause a merging problem allied to the merge congestion. This is something which ramp metering should be able to address.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

043

Site Details

Site Number	043
Freeway	I-40
Cross Street	SR 1571 – Gorman St
Exit	295
Direction	WB
County	Wake

Physical Characteristics Overview

Origin of Ramp	Signalized
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	1,383
On Ramp Length to Tip of Gore (ft)	1,585
Merge Length (ft)	623
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slight Uphill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	80
Guardrail	Right side of 1st half of ramp
Pipe Crossing	None present

Signalization Overview

Upstream Signal	3-way signal; ramp entry from: left, right turn on red, thru
Nearest Power Source	Traffic signal cabinet: far corner of ramp & intersection

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	2925	3348	423	1116	423	13	Yes
07:00	4793	5537	744	1846	744	13	Yes
08:00	4398	5104	706	1701	706	14	Yes
09:00	3337	3756	419	1252	419	11	Yes
10:00	2639	2942	304	981	304	10	Yes
11:00	2544	2900	356	967	356	12	Yes
12:00	2609	2967	358	989	358	12	Yes
13:00	2623	2986	363	995	363	12	Yes
14:00	2727	3121	395	1040	395	13	Yes
15:00	3009	3429	420	1143	420	12	Yes
16:00	3520	3963	443	1321	443	11	Yes
17:00	3803	4261	459	1420	459	11	Yes
18:00	3099	3495	396	1165	396	11	Yes
19:00	1847	2070	224	690	224	11	No
20:00	1413	1620	208	540	208	13	No

Congestion

Primary Congestion	**C042**
Ave Length of Congestion (Miles)	2.08
Duration of Congestion (Min)	42
Calculated Number of Occurrences per Year	197
Typical Times of Congestion	08:00 – 09:00

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 41
Of these 28 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 23 (56%)
Type 28- Sideswipe, same direction: 5 (12%)

Observations

Log 043 is a direct ramp with no sight distance issues. The ramp has a slight uphill slope that flattens out toward the merge point. The pavement has many areas of cracking and poor condition. There is a gravel pull off at the beginning of the ramp and a guardrail at the midsection. No CCTV coverage was found.

Site Selection Comments

This site has good geometry and physical characteristics.

Traffic flows are within acceptable limits during periods of observed congestion.

This could be a good site, but it will be necessary to check whether the site has been affected by construction during the period when data was collected for analysis, or since.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

055

Site Details

Site Number	055
Freeway	I-40
Cross Street	SR 5220 – Jones Sausage Rd
Exit	303
Direction	EB
County	Wake

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	1,054
On Ramp Length to Tip of Gore (ft)	1,354
Merge Length (ft)	817
On Ramp Horizontal Alignment	Straight
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	61
Guardrail	None present
Pipe Crossing	None present

Signalization Overview

Upstream Signal	3-way signal; ramp entry from: left, right yield, thru
Nearest Power Source	Traffic signal cabinet: far corner of ramp & intersection

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1418	1564	146	521	146	9	No
07:00	2093	2249	156	750	156	7	No
08:00	1950	2110	160	703	160	8	No
09:00	1779	1932	154	644	154	8	No
10:00	1757	1899	142	633	142	7	No
11:00	1848	2011	163	670	163	8	No
12:00	1848	2030	183	677	183	9	No
13:00	2080	2236	157	745	157	7	No
14:00	2363	2518	155	839	155	6	No
15:00	3179	3364	185	1121	185	6	No
16:00	3518	3718	200	1239	200	5	No
17:00	3962	4183	221	1394	221	5	No
18:00	3041	3232	191	1077	191	6	No
19:00	1938	2066	128	689	128	6	No
20:00	1471	1569	99	523	99	6	No

Congestion

Primary Congestion	**C077**
Ave Length of Congestion (Miles)	2.1
Duration of Congestion (Min)	31
Calculated Number of Occurrences per Year	152
Typical Times of Congestion	16:30 – 18:00

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 7
Of these 3 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 2 (29%)
Type 28- Sideswipe, same direction: 1 (14%)

Observations

Log 055 is a direct ramp with no sight distance issues. The ramp has a downhill 4-5% slope that flattens out toward the merge point. There is a gravel pull off at the beginning of the ramp. A guardrail is on the right side at the mainline merge area. The CCTV coverage is only of the merge area and from far away.

Site Selection Comments

This entrance ramp has good physical characteristics.

The entrance ramp flow is far too low. The flows are outside of acceptable limits for ramp metering all day.

Site Categorization

Not Suitable

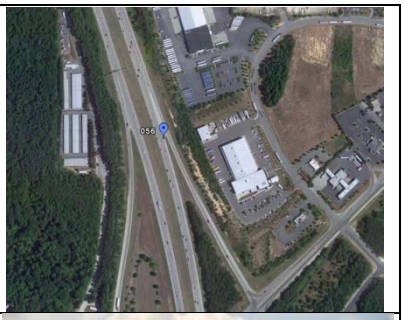
Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

056

Site Details

Site Number	056
Freeway	I-40
Cross Street	SR 5220 – Jones Sausage Rd
Exit	303
Direction	WB
County	Wake



Physical Characteristics Overview

Origin of Ramp	Priority Intersection & Right Hand Free Flow Link
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	1,081
On Ramp Length to Tip of Gore (ft)	1,395
Merge Length (ft)	822
On Ramp Horizontal Alignment	Straight
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	Discontinuous
Main Freeway Vertical Alignment Downstream	Slight Downhill
Main Freeway Shoulder	Yes
Number of Vehicles Storage	63
Guardrail	None present
Pipe Crossing	None present

Signalization Overview

Upstream Signal	Unsignalized. Ramp entry from left, right (free), thru
Nearest Power Source	DMS in median

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	4459	4963	505	1654	505	10	Yes
07:00	5504	6338	834	2113	834	13	Yes
08:00	4356	4950	594	1650	594	12	Yes
09:00	3060	3430	370	1143	370	11	Yes
10:00	2411	2727	316	909	316	12	Yes
11:00	2245	2537	292	846	292	11	No
12:00	2221	2516	296	839	296	12	No
13:00	2348	2655	307	885	307	12	Yes
14:00	2329	2615	286	872	286	11	No
15:00	2319	2645	326	882	326	12	Yes
16:00	2876	3271	396	1090	396	12	Yes
17:00	3042	3389	347	1130	347	10	Yes
18:00	2256	2503	248	834	248	10	No
19:00	1539	1711	172	570	172	10	No
20:00	1399	1515	116	505	116	8	No

Congestion

Congestion	**C054**
Ave Length of Congestion (Miles)	2.94
Duration of Congestion (Min)	37
Calculated Number of Occurrences per Year	144
Typical Times of Congestion	07:30 – 08:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 18
Of these 5 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 2 (11%)
Type 28- Sideswipe, same direction: 3 (17%)

Observations

Log 056 is a direct ramp with no sight distance issues. The ramp has a downhill 3-4% slope. There is a gravel pull off at the beginning of the ramp. A guardrail is on the right side at the mainline merge area. The CCTV coverage is of only the mainline merge area. There is some cracking in the concrete pavement.

Site Selection Comments

This site has good geometry and physical characteristics.

Flows are acceptable during the observed period of congestion.

Entrance ramp flows are generally quite low.

There is an end of freeway diverge 1.5 miles downstream, but congestion appears to be a merging problem from this site.

This appears to be a good site, but need to check cause of congestion through local knowledge or observation.

Site Categorization

Suitable for taking forward.

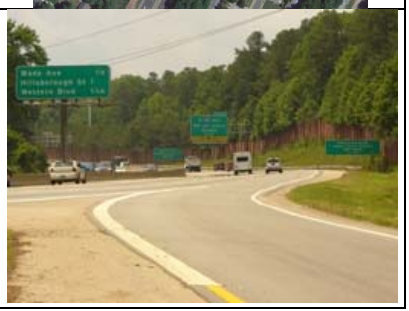
Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

103

Site Details

Site Number	103
Freeway	I-440
Cross Street	Lake Boone Trail
Exit	5
Direction	SB
County	Wake



Physical Characteristics Overview

Origin of Ramp	Signalized Intersection
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	570
On Ramp Length to Tip of Gore (ft)	855
Merge Length (ft)	623
On Ramp Horizontal Alignment	Straight
On Ramp Vertical Alignment	Slight Uphill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	33
Guardrail	Right side of most of ramp; not present at beginning and end
Pipe Crossing	None present

Signalization Overview

Upstream Signal	3-way signal; ramp entry from: left, right turn on red, thru
Nearest Power Source	Traffic Signal Cabinet: inside corner of ramp & intersection

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	2161	2288	127	763	127	6	No
07:00	4399	4670	271	1557	271	6	No
08:00	4821	5083	263	1694	263	5	No
09:00	3472	3756	284	1252	284	8	No
10:00	2810	3101	292	1034	292	9	No
11:00	2738	3086	348	1029	348	11	Yes
12:00	2946	3341	396	1114	396	12	Yes
13:00	3009	3375	367	1125	367	11	Yes
14:00	3143	3595	452	1198	452	13	Yes
15:00	3460	3971	511	1324	511	13	Yes
16:00	3935	4566	631	1522	631	14	Yes
17:00	3348	3896	548	1299	548	14	Yes
18:00	3335	3679	344	1226	344	9	Yes
19:00	2399	2632	233	877	233	9	No
20:00	1842	2009	167	670	167	8	No

Congestion

Primary Congestion	**C093**
Ave Length of Congestion (Miles)	1.55
Duration of Congestion (Min)	32
Calculated Number of Occurrences per Year	148
Typical Times of Congestion	08:00 – 09:00

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 29
Of these 21 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 17 (59%)
Type 28- Sideswipe, same direction: 4 (14%)

Observations

Log 103 is a direct ramp with a slight uphill slope of about 4%. There is a guardrail along most of the right side. The CCTV coverage is of the end 1/2 of the ramp and mainline merge area. The pavement is in good condition.

Site Selection Comments

This on ramp has good geometry apart from being short, with only enough storage capacity for approximately 33 vehicles.

Flow are outside of acceptable limits during congestion, the entrance ramp flow is too low for ramp metering.

Site Categorization

Not Suitable.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

C.2. Multiple Sites

C.2.1. Congestion Ref C006

Site Summaries 015, 017, and 019 are included in this section.

Site Summary

015

Site Details

Site Number	015
Freeway	I-40
Cross Street	Davis Dr
Exit	280
Direction	EB
County	Durham

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection
Lane Addition onto Main Freeway length (ft)	2,768
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	N
Number of Freeway Lanes Before Merge	4
Number of Freeway Lanes After Merge	5
On Ramp Length to Back of Gore (ft)	1,052
On Ramp Length to Tip of Gore (ft)	1,256
Merge Length (ft)	-
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slight Uphill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	61
Guardrail	None present
Pipe Crossing	No Issue

Signalization Overview

Upstream Signal	4 way: ramp entry from: left, thru, right yield
Nearest Power Source	CCTV at NC-147 interchange

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	2167	2245	79	449	79	3	No
07:00	4396	4554	158	911	158	3	No
08:00	5957	6189	232	1238	232	4	No
09:00	4634	4809	176	962	176	4	No
10:00	3509	3710	201	742	201	5	No
11:00	3498	3838	340	768	340	9	Yes
12:00	3809	4129	320	826	320	8	Yes
13:00	3869	4143	274	829	274	7	No
14:00	3973	4341	369	868	369	8	Yes
15:00	4484	5143	659	1029	659	13	Yes
16:00	5377	6545	1169	1309	1169	18	Yes
17:00	6090	7258	1169	1452	1169	16	Yes
18:00	4791	5422	631	1084	631	12	Yes
19:00	3255	3519	264	704	264	7	No
20:00	2592	2728	136	546	136	5	No

Congestion

Primary Congestion	**C006**
Ave Length of Congestion (Miles)	1.51
Duration of Congestion (Min)	36
Calculated Number of Occurrences per Year	265
Typical Times of Congestion	16:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 15
Of these 12 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 9 (60%)
Type 28- Sideswipe, same direction: 3 (20%)

Observations

Log 015 is a direct ramp. There are bushes on the left that create a potential sight distance issue at the beginning of the ramp. There is a maintenance vehicle pull off halfway down the ramp. CCTV coverage is of the very beginning and end of the ramp. The slope is slightly downhill at the beginning of the ramp and flattens out at the merge area.

Site Selection Comments

This entrance ramp has a slight curve and some visibility issues have been observed as a result of vegetation, this problem is not insurmountable. There is a lane addition at this site, which drops at the next downstream location (site 17). Congestion is observed to occur at times when the flows in the vicinity of the site are within acceptable limits. This site may contribute to relieving congestion problem C006.

Site Categorization

Suitable for taking forward.

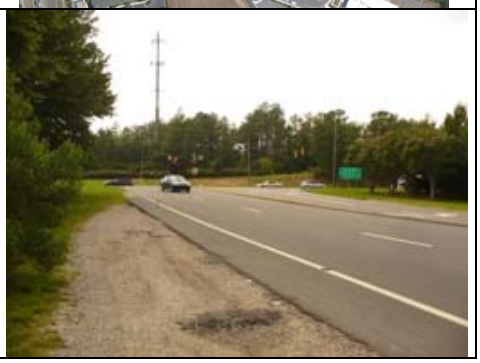
Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

017

Site Details

Site Number	017
Freeway	I-40
Cross Street	S Miami Blvd
Exit	281
Direction	EB
County	Durham



Physical Characteristics Overview

Origin of Ramp	Signalized Intersection
Lane Addition onto Main Freeway length (ft)	1,313
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	Y
Number of Freeway Lanes Before Merge	4
Number of Freeway Lanes After Merge	5
On Ramp Length to Back of Gore (ft)	953
On Ramp Length to Tip of Gore (ft)	1150
Merge Length (ft)	-
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	55
Guardrail	None present
Pipe Crossing	None present

Signalization Overview

Upstream Signal	3-way signal; ramp entry from: dual lefts, right turn on red
Nearest Power Source	Traffic signal cabinet: far corner of ramp & intersection

Signing Overview

Existing Signing	Left Lane Merge signs may cause conflict with ramp metering.

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	2276	2649	373	530	373	14	Yes
07:00	4603	5108	505	1022	505	10	Yes
08:00	6281	6737	456	1347	456	7	Yes
09:00	4811	5206	395	1041	395	8	Yes
10:00	3677	4031	355	806	355	9	Yes
11:00	3792	4198	407	840	407	10	Yes
12:00	4039	4473	434	895	434	10	Yes
13:00	4077	4531	455	906	455	10	Yes
14:00	4308	4774	467	955	467	10	Yes
15:00	5081	5753	673	1151	673	12	Yes
16:00	6338	7357	1019	1471	1019	14	Yes
17:00	6950	8003	1053	1601	1053	13	Yes
18:00	5750	6559	809	1312	809	12	Yes
19:00	3583	4032	449	806	449	11	Yes
20:00	2727	3003	276	601	276	9	No

Congestion

Primary Congestion	**C006**
Ave Length of Congestion (Miles)	2.25
Duration of Congestion (Min)	53
Calculated Number of Occurrences per Year	265
Typical Times of Congestion	16:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 28
Of these 24 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 18 (64%)
Type 28- Sideswipe, same direction: 6 (21%)

Observations

Log 017 is a direct ramp. It begins as 2 lanes that merge to one about halfway down the ramp. There is a slight downhill slope that flattens out at the merge area. There is a guardrail along the right side of the middle section of the ramp due to a steep drop-off behind the shoulder. CCTV coverage is only of end of ramp / merge area.

Site Selection Comments

There is a slight curve on the entrance ramp but no sight issues are recorded. The site has a lane addition which drops at the next downstream off ramp (Site 19), this weaving section could be an additional cause of congestion. The physical characteristics are generally good.

Traffic flows are within acceptable limits during the observed period of congestion. This location should be suitable for assisting in the relief of congestion at congestion problem C006.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

019

Site Details

Site Number	019
Freeway	I-40
Cross Street	Page Rd
Exit	282
Direction	EB
County	Durham

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection & Right Hand Free Flow Link
Lane Addition onto Main Freeway length (ft)	2,016
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	N
Number of Freeway Lanes Before Merge	4
Number of Freeway Lanes After Merge	5
On Ramp Length to Back of Gore (ft)	562
On Ramp Length to Tip of Gore (ft)	657
Merge Length (ft)	-
On Ramp Horizontal Alignment	Tight Curve
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	32
Guardrail	None present
Pipe Crossing	None present

Signalization Overview

Upstream Signal	4-way signal; ramp entry from: left, right turn yield, thru
Nearest Power Source	Traffic signal cabinet: corner of off-ramp & intersection

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	2406	2504	99	501	99	4	No
07:00	3900	4087	187	817	187	5	No
08:00	4357	4600	244	920	244	5	No
09:00	3544	3748	204	750	204	5	No
10:00	3061	3252	191	650	191	6	No
11:00	3367	3676	309	735	309	8	Yes
12:00	3531	3875	344	775	344	9	Yes
13:00	3494	3812	318	762	318	8	Yes
14:00	3768	4106	339	821	339	8	Yes
15:00	4497	4992	495	998	495	10	Yes
16:00	4928	6039	1111	1208	1111	18	Yes
17:00	4898	6133	1235	1227	1235	20	Yes
18:00	4493	5113	620	1023	620	12	Yes
19:00	3050	3332	282	666	282	8	No
20:00	2413	2629	217	526	217	8	No

Congestion

Primary Congestion	**C006**
Ave Length of Congestion (Miles)	2.71
Duration of Congestion (Min)	64
Calculated Number of Occurrences per Year	265
Typical Times of Congestion	16:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 57
Of these 43 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 31 (54%)
Type 28- Sideswipe, same direction: 12 (21%)

Observations

Log 019 is a loop ramp with an uphill grade of around 3%. There are no major sight distance issues. There is CCTV coverage of the end of the ramp and the merge area. The inside edge of the ramp is a curb; there is a good area for maintenance vehicle pull off on the left. A NCDOT fiber-optic pull box is located near the merge point.

Site Selection Comments

This entrance ramp is short and curved but there are no sight issues noted. The ramp flow is fairly high so caution is necessary when considering this against the ramp length.
The flows are within acceptable limits during the observed period of congestion.
This site is a lane gain and the flow breakdown point is just downstream of the tip of the gore. This is the primary site for congestion problem C006.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

C.2.2. Congestion Ref C014

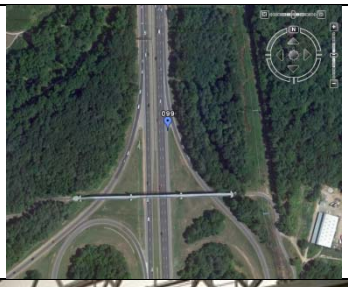
Site Summaries 099, 102, and 104 are included in this section.

Site Summary

099

Site Details

Site Number	099
Freeway	I-440
Cross Street	SR 1728 – Wade Ave
Exit	4
Direction	NB-M2
County	Wake



Physical Characteristics Overview

Origin of Ramp	Freeflow Link
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	1,214
On Ramp Length to Tip of Gore (ft)	1,602
Merge Length (ft)	582
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Slight Downhill
Main Freeway Shoulder	Yes
Number of Vehicles Storage	70
Guardrail	None present
Pipe crossing	None present

Signalization Overview

Upstream Signal	3-way signal; ramp entry from: free right only
Nearest Power Source	CCTV cabinet upstream of ramp merge

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1736	1763	28	588	28	2	No
07:00	4171	4239	68	1413	68	2	No
08:00	5188	5293	106	1764	106	2	No
09:00	3715	3804	89	1268	89	2	No
10:00	3055	3137	83	1046	83	3	No
11:00	3079	3192	113	1064	113	4	No
12:00	3293	3415	122	1138	122	4	No
13:00	3325	3461	137	1154	137	4	No
14:00	3460	3602	142	1201	142	4	No
15:00	3908	4057	150	1352	150	4	No
16:00	4621	4740	119	1580	119	3	No
17:00	4951	5042	91	1681	91	2	No
18:00	4156	4253	97	1418	97	2	No
19:00	2739	2826	87	942	87	3	No
20:00	1937	1999	63	666	63	3	No

Congestion

Primary Congestion	**C014**
Ave Length of Congestion (Miles)	-
Duration of Congestion (Min)	-
Calculated Number of Occurrences per Year	-
Typical Times of Congestion	17:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 21
Of these 15 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 11 (52%)
Type 28- Sideswipe, same direction: 4 (19%)

Observations

Log 099 is a very long direct ramp that comes from Wade Ave. It acts as a freeway-to-freeway ramp. There are no sight distance issues. It has a slight downhill grade. There is a potential maintenance/enforcement vehicle parking area near the end of the ramp on the left. There is a guardrail starting at the mainline merge area. CCTV coverage is of the end 1/4 of the ramp and of the mainline merge area.

Site Selection Comments

This entrance ramp is close to the back of the queue formed by congestion C014 so any benefit would be minimal. Although it does not have any geometrical issues, the entrance ramp flow are, at most, half of the required minimum so ramp metering would not be able to operate at this location.

Site Categorization

Not suitable.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

102

Site Details

Site Number	102
Freeway	I-440
Cross Street	Lake Boone Trail
Exit	5
Direction	NB
County	Wake

Physical Characteristics Overview

Origin of Ramp	Priority Intersection
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	872
On Ramp Length to Tip of Gore (ft)	1,206
Merge Length (ft)	520
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slight Uphill
On Ramp Shoulder (Paved Full Width)	Yes
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	51
Guardrail	Entire right side of ramp
Pipe Crossing	None present

Signalization Overview

Upstream Signal	Unsignalized. Ramp entry from: left, right
Nearest Power Source	CCTV upstream of ramp

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	2649	2777	128	926	128	5	No
07:00	4531	4865	335	1622	335	7	Yes
08:00	4134	4457	323	1486	323	7	Yes
09:00	3271	3650	380	1217	380	10	Yes
10:00	2625	3114	489	1038	489	16	Yes
11:00	2746	3308	563	1103	563	17	Yes
12:00	2892	3442	551	1147	551	16	Yes
13:00	2948	3443	496	1148	496	14	Yes
14:00	3162	3824	662	1275	662	17	Yes
15:00	3461	4231	770	1410	770	18	Yes
16:00	4037	5023	986	1674	986	20	Yes
17:00	3877	4749	872	1583	872	18	Yes
18:00	3147	3586	439	1195	439	12	Yes
19:00	2274	2609	335	870	335	13	Yes
20:00	1967	2175	208	725	208	10	No

Congestion

Congestion	**C014**
Ave Length of Congestion (Miles)	2.71
Duration of Congestion (Min)	64
Calculated Number of Occurrences per Year	265
Typical Times of Congestion	17:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 18
Of these 13 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 12 (67%)
Type 28- Sideswipe, same direction: 1 (6%)

Observations

Log 102 is a direct ramp that begins at a non-signalized 3 way intersection. Since there is no signal or dedicated left turn lane onto the ramp, it was observed that left-turners onto the ramp caused a large queue. It was noted that this ramp congestion is caused by hospital traffic. A guardrail is along the entire right side of the ramp due to steep back slope behind the guardrail. The ramp has a slight uphill slope. The CCTV coverage is only of the mainline merge area. There is potential maintenance/enforcement vehicle parking toward the end of the ramp.

Site Selection Comments

The geometric and physical characteristics at this location seem to be good for ramp metering. Although this is not the primary site for congestion problem C014 it may be able to reduce the problem which extends back from the downstream site. Congestion at this location is observed at times when the flows are within acceptable limits.

It has been observed that a queue of left turners forms at the priority junction on the surface street. This should not cause a problem for ramp metering and ramp metering will not exacerbate it.

Site Categorization

Suitable for taking forward.

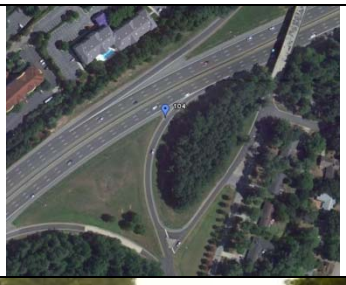
Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

104

Site Details

Site Number	104
Freeway	I-440
Cross Street	Ridge Rd
Exit	6
Direction	EB
County	Wake



Physical Characteristics Overview

Origin of Ramp	Priority Intersection & Right Hand Freeflow Link
Lane Addition onto Main Freeway length (ft)	270
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	4
On Ramp Length to Back of Gore (ft)	355
On Ramp Length to Tip of Gore (ft)	586
Merge Length (ft)	-
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	21
Guardrail	Only at end of ramp; merge area
Pipe Crossing	None present

Signalization Overview

Upstream Signal	Unsignalized
Nearest Power Source	Transformer on Ridge Rd

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1835	1881	46	470	46	2	No
07:00	4130	4363	233	1091	233	5	No
08:00	4323	4617	294	1154	294	6	No
09:00	3494	3650	157	913	157	4	No
10:00	3021	3138	118	785	118	4	No
11:00	3398	3529	131	882	131	4	No
12:00	3406	3575	169	894	169	5	No
13:00	3438	3601	163	900	163	5	No
14:00	3753	3915	163	979	163	4	No
15:00	4309	4483	175	1121	175	4	No
16:00	5230	5434	205	1359	205	4	No
17:00	5512	5757	245	1439	245	4	No
18:00	4159	4306	147	1076	147	3	No
19:00	2865	2958	94	740	94	3	No
20:00	2137	2235	99	559	99	4	No

Congestion

Primary Congestion	**C014**
Ave Length of Congestion (Miles)	-
Duration of Congestion (Min)	-
Calculated Number of Occurrences per Year	-
Typical Times of Congestion	17:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 49
Of these 36 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 29 (59%)
Type 28- Sideswipe, same direction: 7 (14%)

Observations

Log 104 ramp has a unique geometry at the start of the ramp. The ramp comes from a residential area but from the other direction Ridge Rd has access to the ramp and a stop sign that allows cars to cross the ramp and continue to the residential area.

From this point to the mainline merge is fairly short and the merge area on the mainline is fairly short. The ramp has a steep 7% downhill grade. The ramp has good full CCTV coverage and room on left grass for maintenance vehicles. Strange geometry creates short ramp and short merge area. Ramp meter installation may be difficult.

Site Selection Comments

There is a very short weaving section here as a result of a lane addition followed by a lane drop after 270ft. Vehicles diverging to Glenwood Avenue could be a significant contributor to the congestion problem C014.

The flows at this site are too low to meter, so it is not practical to consider this site further because metering here will not impact on the congestion problem.

Site Categorization

Not suitable.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

C.2.3. Congestion Ref C016

Site Summaries 107 and 108 for the following to be included in this section.

Site Summary

107

Site Details

Site Number	107
Freeway	I-404
Cross Street	US-70 / NC-50 / Glenwood Ave
Exit	7
Direction	WB-M1
County	Wake

Physical Characteristics Overview

Origin of Ramp	Freeflow Link
Lane Addition onto Main Freeway length (ft)	458
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	4
On Ramp Length to Back of Gore (ft)	803
On Ramp Length to Tip of Gore (ft)	940
Merge Length (ft)	-
On Ramp Horizontal Alignment	Tight Curve
On Ramp Vertical Alignment	Slight Uphill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	47
Guardrail	None present
Pipe Crossing	None present

Signalization Overview

Upstream Signal	Unsignalized; ramp entry from free right
Nearest Power Source	CCTV near ramp merge

Signing Overview

Existing Signing	Possible issue with yield sign

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	2196	2230	35	558	35	2	No
07:00	4582	4673	91	1168	91	2	No
08:00	4795	4894	100	1224	100	2	No
09:00	3519	3640	121	910	121	3	No
10:00	2742	2834	93	709	93	3	No
11:00	2535	2654	119	663	119	4	No
12:00	2651	2796	145	699	145	5	No
13:00	2900	3016	117	754	117	4	No
14:00	2909	3042	133	760	133	4	No
15:00	3136	3282	146	820	146	4	No
16:00	3338	3502	164	875	164	5	No
17:00	3765	3921	156	980	156	4	No
18:00	3015	3126	111	781	111	4	No
19:00	1988	2041	53	510	53	3	No
20:00	1490	1539	49	385	49	3	No

Congestion

Congestion	**C016**
Ave Length of Congestion (Miles)	-
Duration of Congestion (Min)	-
Calculated Number of Occurrences per Year	-
Typical Times of Congestion	17:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 67
Of these 40 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 31 (46%)
Type 28- Sideswipe, same direction: 9 (13%)

Observations

Log 107 ramp is a loop ramp with a slight 3% uphill grade. The mainline merge area is fairly short before the downstream exit. Good CCTV coverage of merge area and mainline merge; tree cover prohibits CCTV coverage of most of loop ramp area. Overall, observations indicate this is a good candidate for a ramp meter.

Site Selection Comments

This site has a short entrance ramp that is tightly curved. The flows at this site are not suitable for metering at any time of the day as flows are too low on the entrance ramp.

Site Categorization

Not suitable.

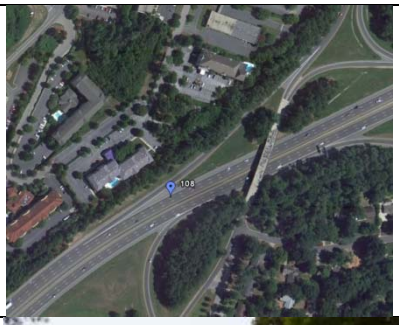
Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

108

Site Details

Site Number	108
Freeway	I-440
Cross Street	US-70 / NC-50 / Glenwood Ave
Exit	7
Direction	WB-M2
County	Wake



Physical Characteristics Overview

Origin of Ramp	Freeflow Link
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	1,276
On Ramp Length to Tip of Gore (ft)	1,687
Merge Length (ft)	468
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slight Uphill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	74
Guardrail	None present
Pipe Crossing	None present

Signalization Overview

Upstream Signal	Unsignalized; ramp entry from free right
Nearest Power Source	CCTV near end of ramp

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	2703	3140	437	1047	437	14	Yes
07:00	4387	5241	854	1747	854	16	Yes
08:00	3970	4797	828	1599	828	17	Yes
09:00	3120	3773	653	1258	653	17	Yes
10:00	2544	3103	559	1034	559	18	Yes
11:00	2527	3107	580	1036	580	19	Yes
12:00	2650	3289	639	1096	639	19	Yes
13:00	2692	3393	701	1131	701	21	Yes
14:00	2852	3570	719	1190	719	20	Yes
15:00	3026	3775	749	1258	749	20	Yes
16:00	3389	4224	835	1408	835	20	Yes
17:00	3372	4177	805	1392	805	19	Yes
18:00	2540	3300	760	1100	760	23	Yes
19:00	1798	2374	577	791	577	24	Yes
20:00	1542	2059	517	686	517	25	Yes

Congestion

Congestion	**C016**
Ave Length of Congestion (Miles)	1.49
Duration of Congestion (Min)	40
Calculated Number of Occurrences per Year	445
Typical Times of Congestion	17:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 36
Of these 26 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 20(56%)
Type 28- Sideswipe, same direction: 6 (17%)

Observations

Log 108 is a long direct flat ramp. There are no sight distance issues. CCTV coverage is of end half of ramp (with more coverage if trees trimmed). Overall, observations indicate this is a good candidate for a ramp meter.

Site Selection Comments

This entrance ramp has good physical and geometric characteristics for ramp metering.

This is the primary site for congestion problem C016 and the flows are within acceptable limits during the time that congestion is observed.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

C.2.4. Congestion Ref C062

Site Summaries 025, 027, and 028 for the following to be included in this section.

Site Summary

025

Site Details

Site Number	025
Freeway	I-40
Cross Street	SR 3015 – Airport Blvd
Exit	284
Direction	EB
County	Wake

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection
Lane Addition onto Main Freeway length (ft)	No
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	4
Number of Freeway Lanes After Merge	4
On Ramp Length to Back of Gore (ft)	1,197
On Ramp Length to Tip of Gore (ft)	1,560
Merge Length (ft)	639
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	Discontinuous
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	69
Guardrail	On right side at end of ramp/merge area
Pipe Crossing	None Present

Signalization Overview

Upstream Signal	4-way signal; ramp entry from: left, right turn on red
Nearest Power Source	Traffic signal cabinet: far corner of ramp & intersection

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1978	2153	176	538	176	8	No
07:00	4025	4429	404	1107	404	9	Yes
08:00	5288	5773	485	1443	485	8	Yes
09:00	3998	4415	417	1104	417	9	Yes
10:00	2961	3324	363	831	363	11	Yes
11:00	3074	3511	437	878	437	12	Yes
12:00	3202	3714	512	928	512	14	Yes
13:00	3259	3708	450	927	450	12	Yes
14:00	3461	3932	471	983	471	12	Yes
15:00	4241	4819	578	1205	578	12	Yes
16:00	5537	6503	966	1626	966	15	Yes
17:00	5839	6934	1095	1734	1095	16	Yes
18:00	5024	5730	706	1433	706	12	Yes
19:00	2996	3375	379	844	379	11	Yes
20:00	2205	2511	306	628	306	12	Yes

Congestion

Congestion	**C062**
Ave Length of Congestion (Miles)	0.95
Duration of Congestion (Min)	21
Calculated Number of Occurrences per Year	124
Typical Times of Congestion	17:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 17
Of these 14 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 12 (71%)
Type 28- Sideswipe, same direction: 2 (12%)

Observations

Log 025 is a direct, but slightly curvy ramp with a downhill slope of about 3%. There are no issues with sight distance. A guardrail is near the end of the ramp at the merge point. There is CCTV coverage of only the merge area.

Site Selection Comments

This ramp has good physical and geometric characteristics. The flows are within acceptable limits during most of the day and particularly during times of observed congestion.

This on ramp is close to the back of congestion problem C062, but should be investigated further as it could provide a positive benefit.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

027

Site Details

Site Number	027
Freeway	I-40
Cross Street	SR 1002 – Aviation Pkwy
Exit	285
Direction	EB-M1
County	Wake

Physical Characteristics Overview

Origin of Ramp	Free Flow Link
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	4
Number of Freeway Lanes After Merge	4
On Ramp Length to Back of Gore (ft)	811
On Ramp Length to Tip of Gore (ft)	962
Merge Length (ft)	886
On Ramp Horizontal Alignment	Tight Curve
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	47
Guardrail	None present
Pipe Crossing	None present

Signalization Overview

Upstream Signal	None present (free)
Nearest Power Source	Traffic signal cabinet from off-ramp signal.

Signing Overview

Existing Signing	No issue.

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1961	2221	260	555	260	12	No
07:00	4131	4717	586	1179	586	12	Yes
08:00	5543	6184	641	1546	641	10	Yes
09:00	4375	4868	493	1217	493	10	Yes
10:00	3170	3637	468	909	468	13	Yes
11:00	3219	3709	490	927	490	13	Yes
12:00	3522	4023	502	1006	502	12	Yes
13:00	3485	3958	473	990	473	12	Yes
14:00	3768	4324	556	1081	556	13	Yes
15:00	4527	5204	677	1301	677	13	Yes
16:00	6136	6771	635	1693	635	9	Yes
17:00	6412	7127	716	1782	716	10	Yes
18:00	5619	6193	575	1548	575	9	Yes
19:00	3610	4119	509	1030	509	12	Yes
20:00	2346	2816	470	704	470	17	Yes

Congestion

Congestion	**C062**
Ave Length of Congestion (Miles)	1.9
Duration of Congestion (Min)	42
Calculated Number of Occurrences per Year	124
Typical Times of Congestion	17:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 26
Of these 16 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 14 (54%)
Type 28- Sideswipe, same direction: 2 (8%)

Observations

Log 027 is a loop ramp with flat slope. There are no major sight distance issues. There is CCTV coverage of the entire ramp and the merge area. The inside edge of the ramp is a curb; there is a small area for maintenance vehicle pull off on the left. There is a guard rail at the end of the ramp at the merge area.

Site Selection Comments

This entrance ramp is relatively short and curved, so this must be born in mind when considering its ultimate suitability. The on ramp flow is toward the lower end of the acceptable range during congested periods, this compliments the challenging nature of the geometric layout of the site.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

028

Site Details

Site Number	028
Freeway	I-40
Cross Street	SR 1002 – Aviation Pkwy
Exit	285
Direction	EB-M2
County	Wake

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	4
Number of Freeway Lanes After Merge	4
On Ramp Length to Back of Gore (ft)	1,223
On Ramp Length to Tip of Gore (ft)	1,376
Merge Length (ft)	709
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	Discontinuous
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	71
Guardrail	None Present
Pipe Crossing	None Present

Signalization Overview

Upstream Signal	3-way signal; ramp entry from: right turn on red, thru
Nearest Power Source	Traffic signal cabinet: far corner of ramp & intersection

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	2221	2389	168	597	168	7	No
07:00	4717	5039	322	1260	322	6	Yes
08:00	6184	6514	330	1628	330	5	Yes
09:00	4868	5137	270	1284	270	5	No
10:00	3637	3870	233	967	233	6	No
11:00	3709	3966	257	991	257	6	No
12:00	4023	4303	280	1076	280	7	No
13:00	3958	4215	257	1054	257	6	No
14:00	4324	4562	238	1140	238	5	No
15:00	5204	5488	284	1372	284	5	No
16:00	6771	7179	408	1795	408	6	Yes
17:00	7127	7507	380	1877	380	5	Yes
18:00	6193	6453	260	1613	260	4	No
19:00	4119	4332	213	1083	213	5	No
20:00	2816	2956	141	739	141	5	No

Congestion

Congestion	**C062**
Ave Length of Congestion (Miles)	2.24
Duration of Congestion (Min)	50
Calculated Number of Occurrences per Year	124
Typical Times of Congestion	17:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 40
Of these 23 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 13 (33%)
Type 28- Sideswipe, same direction: 10(25%)

Observations

Log 028 is a direct ramp with no sight distance issues. The ramp has a relatively flat slope for its entire length. There is a steep bank on the right side of the beginning of the ramp that begins 4' back from the edge of pavement. CCTV coverage is only of end of ramp / merge area.

Site Selection Comments

This on ramp has good geometric and physical characteristics. This is the primary site for congestion problem C062. The traffic flows are not suitable for metering most of the day with low on-slip flows. However the on-slip flows are just within acceptable limits during the period that congestion has been observed.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

C.2.5. Congestion Ref C086

Site Summaries 089 and 091 for the following to be included in this section.

Site Summary

089

Site Details

Site Number	089
Freeway	I-440
Cross Street	SR 1319 – Jones Franklin Rd
Exit	1C
Direction	NB
County	Wake

Physical Characteristics Overview

Origin of Ramp	Signalised Intersection & Right Hand Freeflow Link
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	2
Number of Freeway Lanes After Merge	2
On Ramp Length to Back of Gore (ft)	1,120
On Ramp Length to Tip of Gore (ft)	1,438
Merge Length (ft)	195
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slight Uphill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	65
Guardrail	Length of ramp except for last 200 ft.
Pipe crossing	None present

Signalization Overview

Upstream Signal	3-way signal; ramp entry from: left, right turn on red, thru
Nearest Power Source	DMS in median

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1335	1560	225	780	225	14	No
07:00	2644	3108	465	1554	465	15	Yes
08:00	2700	3147	447	1573	447	14	Yes
09:00	2132	2387	256	1194	256	11	No
10:00	1920	2145	225	1072	225	10	No
11:00	2216	2488	272	1244	272	11	No
12:00	2192	2503	311	1252	311	12	Yes
13:00	2410	2695	285	1347	285	11	No
14:00	2660	2984	324	1492	324	11	Yes
15:00	3137	3476	339	1738	339	10	Yes
16:00	3780	4234	454	2117	454	11	Yes
17:00	3475	3985	510	1992	510	13	Yes
18:00	1614	1990	377	995	377	19	Yes
19:00	1408	1645	237	822	237	14	No
20:00	1367	1555	189	778	189	12	No

Congestion

Primary Congestion	**C086**
Ave Length of Congestion (Miles)	1.07
Duration of Congestion (Min)	41
Calculated Number of Occurrences per Year	225
Typical Times of Congestion	08:00 – 09:00

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 15
Of these 8 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 7 (47%)
Type 28- Sideswipe, same direction: 1 (7%)

Observations

Log 089 is a direct ramp. There is some vegetation at the beginning of the ramp that could pose a sight distance issue. There is a guardrail along the entire right side of the ramp. There is a 3-5% uphill slope. No CCTV coverage was observed.

Site Selection Comments

This site has some physical issues with visibility, relating to vegetation so they are not insurmountable.

This site is at the tail end of congestion problem C086, it may give some benefit at the bottleneck which is 0.86 miles downstream, however it is not ideal at the downstream site (Log 091) is not suitable for ramp metering.

The flows and physical characteristics of this site are otherwise good for ramp metering.

Site Categorization

Suitable for taking forward.

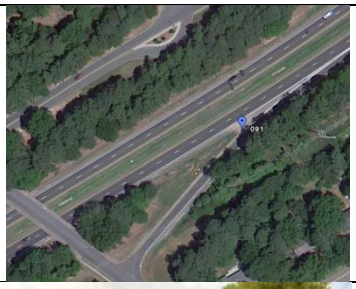
Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

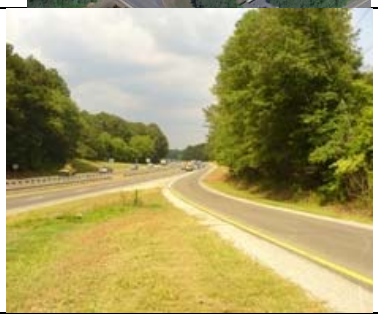
Site Summary

091

Site Details

Site Number	091
Freeway	I-440
Cross Street	Melbourne Rd
Exit	1D
Direction	NB
County	Wake





Physical Characteristics Overview

Origin of Ramp	Priority Intersection
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	2
Number of Freeway Lanes After Merge	2
On Ramp Length to Back of Gore (ft)	323
On Ramp Length to Tip of Gore (ft)	654
Merge Length (ft)	194
On Ramp Horizontal Alignment	Straight
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	19
Guardrail	None present
Pipe Crossing	None present

Signalization Overview

Upstream Signal	Unsignalized residential; ramp entry from left, right
Nearest Power Source	Transformer on Kaplan Dr

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1335	1433	98	716	98	7	No
07:00	2644	2919	276	1460	276	9	No
08:00	2700	3008	308	1504	308	10	No
09:00	2132	2276	145	1138	145	6	No
10:00	1920	2037	118	1019	118	6	No
11:00	2216	2307	91	1153	91	4	No
12:00	2192	2303	111	1151	111	5	No
13:00	2410	2520	110	1260	110	4	No
14:00	2660	2784	125	1392	125	4	No
15:00	3137	3289	152	1644	152	5	No
16:00	3780	3902	122	1951	122	3	No
17:00	3475	3622	147	1811	147	4	No
18:00	1614	1723	110	862	110	6	No
19:00	1408	1493	85	746	85	6	No
20:00	1367	1429	62	714	62	4	No

Congestion

Primary Congestion	**C086**
Ave Length of Congestion (Miles)	-
Duration of Congestion (Min)	-
Calculated Number of Occurrences per Year	-
Typical Times of Congestion	08:00 – 09:00

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 10
Of these 7 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 7 (70%)
Type 28- Sideswipe, same direction: 0 (0%)

Site Selection Comments

This location has a very short on-ramp meaning that there is very little storage capacity.

The flows on the on-ramp are outside of the ,limits of acceptability for ramp metering during the entire day.

This is the primary site for congestion problem C086, but is not suitable for ramp metering for both geometric and traffic flow reasons.

Site Categorization

Not suitable.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

C.3. Group Sites

C.3.1. Group 1: Congestion Refs C011, C030, C073

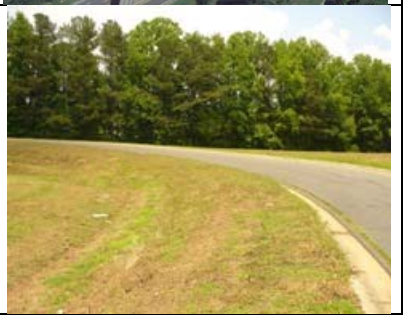
Site Summaries 090, 094, 095, 097, and 100 are included in this section:

Site Summary

090

Site Details

Site Number	090
Freeway	I-440
Cross Street	SR 1319 – Jones Franklin Rd
Exit	1C
Direction	SB
County	Wake



Physical Characteristics Overview

Origin of Ramp	Signalized Intersection & Right Hand Freeflow Link
Lane Addition onto Main Freeway length (ft)	1,117
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	2
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	336
On Ramp Length to Tip of Gore (ft)	529
Merge Length (ft)	-
On Ramp Horizontal Alignment	Tight Curve
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	No
Number of Vehicles Storage	20
Guardrail	None present
Pipe Crossing	None present

Signalization Overview

Upstream Signal	3-way signal; ramp entry from: left, right yield, thru
Nearest Power Source	Traffic signal cabinet: corner of off-ramp & intersection

Signing Overview

Existing Signing	No issue.

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	871	1159	288	386	288	25	No
07:00	1903	2613	710	871	710	27	Yes
08:00	2428	3094	666	1031	666	22	Yes
09:00	1869	2302	434	767	434	19	Yes
10:00	1766	2071	306	690	306	15	Yes
11:00	1828	2157	330	719	330	15	Yes
12:00	2086	2448	363	816	363	15	Yes
13:00	2059	2418	360	806	360	15	Yes
14:00	2279	2611	332	870	332	13	Yes
15:00	2583	2964	381	988	381	13	Yes
16:00	3271	3765	495	1255	495	13	Yes
17:00	3405	3955	550	1318	550	14	Yes
18:00	2761	3164	403	1055	403	13	Yes
19:00	1895	2140	245	713	245	11	No
20:00	1355	1558	203	519	203	13	No

Congestion

Congestion	**C073**
Ave Length of Congestion (Miles)	2.52
Duration of Congestion (Min)	43
Calculated Number of Occurrences per Year	100
Typical Times of Congestion	17:00 – 19:00

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 66
Of these 22 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 10 (15%)
Type 28- Sideswipe, same direction: 12 (18%)

Observations

Log 090 is a loop ramp that starts with two approaches that merge into the one lane of the ramp. The ramp has a fairly steep downhill slope of 6-9%. There is a guardrail in the mainline merge area to protect a radar traffic detector. There is a steep drop-off on the left and right sides of the ramp. No CCTV coverage was observed. The pavement has moderate cracking. The exit to I-40 is located only 1/4 mile after the end of the ramp, which could cause merging cars from the loop ramp merging left at the same time as mainline cars merging right to get on I-40.

Site Selection Comments

Traffic flows are within suitable limits during the period that congestion is observed. Congestion caused by vehicles on freeway travelling through junction weaving across to lane gain and vice versa. The weaving distance is approximately 300ft. Ramp metering should be able to address this issue as the flow breakdown point appears to be downstream of the end of the gore.

Local knowledge should be sought to validate the cause of congestion.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

094

Site Details

Site Number	094
Freeway	I-440
Cross Street	SR 1012 – Western Blvd
Exit	2
Direction	SB-M1
County	Wake

Physical Characteristics Overview

Origin of Ramp	Freeflow Link
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	2
Number of Freeway Lanes After Merge	2
On Ramp Length to Back of Gore (ft)	663
On Ramp Length to Tip of Gore (ft)	871
Merge Length (ft)	726
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	No
Number of Vehicles Storage	38
Guardrail	None present (bridge rail)
Pipe Crossing	None present

Signalization Overview

Upstream Signal	Unsignalized: Ramp entry from free right (2 ramp directions)
Nearest Power Source	CCTV at ramp merge

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	997	1074	77	537	77	7	No
07:00	2355	2497	142	1248	142	6	No
08:00	3135	3350	216	1675	216	6	No
09:00	2427	2623	197	1312	197	7	No
10:00	2063	2234	171	1117	171	8	No
11:00	1893	2151	258	1076	258	12	No
12:00	2406	2708	302	1354	302	11	Yes
13:00	2419	2721	303	1361	303	11	Yes
14:00	2561	2855	294	1428	294	10	No
15:00	2843	3160	317	1580	317	10	Yes
16:00	3248	3651	403	1825	403	11	Yes
17:00	3265	3830	565	1915	565	15	Yes
18:00	3253	3588	335	1794	335	9	Yes
19:00	2129	2364	235	1182	235	10	No
20:00	1618	1810	193	905	193	11	No

Congestion

Congestion	-
Ave Length of Congestion (Miles)	-
Duration of Congestion (Min)	-
Calculated Number of Occurrences per Year	-
Typical Times of Congestion	-

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 99
Of these 72 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 55 (56%)
Type 28- Sideswipe, same direction: 17 (17%)

Observations

Log 094 is a curved ramp that has significant sight distance issues caused by heavy vegetation close to the side of the road crossing the bridge. The ramp merges into the mainline left lane. There are no shoulders over the section of the ramp that is a bridge. There is a guardrail at the merge area. CCTV coverage includes the mainline, merge area, and end of the ramp. The CCTV cannot see past the bridge due to tree cover. This section of the freeway mainline has a high density of on/off ramps. Overall, the bridge and poor sight distance are issues that could prevent safe ramp meter operation.

Site Selection Comments

This site has poor, though possibly not insurmountable problems with geometry. The congestion is mainly caused by site Log 090 and 095 downstream, when ramp metering is installed there it will reduce the congestion adjacent to this site. It is recommended that this site be considered again in future after the downstream sites have been implemented and an evaluation of their effectiveness has taken place.

Site Categorization

Review in future.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

095

Site Details

Site Number	095
Freeway	I-440
Cross Street	SR 1012 – Western Blvd
Exit	2
Direction	SB-M2
County	Wake

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection
Lane Addition onto Main Freeway length (ft)	1,231
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	2
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	899
On Ramp Length to Tip of Gore (ft)	1,135
Merge Length (ft)	-
On Ramp Horizontal Alignment	Straight
On Ramp Vertical Alignment	Slight Uphill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	No
Number of Vehicles Storage	52
Guardrail	Lengthy section of guardrail along right side of ramp in vicinity of ramp meter. Steep Slopes behind guardrail.
Pipe Crossing	None present

Signalization Overview

Upstream Signal	Unsignalized: Ramp entry from free right
Nearest Power Source	Signal cabinet at Blue Ridge Rd & Western Blvd

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	965	1027	63	342	63	6	No
07:00	2272	2395	123	798	123	5	No
08:00	2883	3026	143	1009	143	5	No
09:00	2141	2276	135	759	135	6	No
10:00	1956	2098	142	699	142	7	No
11:00	2089	2247	158	749	158	7	No
12:00	2340	2527	187	842	187	7	No
13:00	2396	2565	169	855	169	7	No
14:00	2549	2738	189	913	189	7	No
15:00	2966	3177	211	1059	211	7	No
16:00	3689	3988	299	1329	299	7	No
17:00	3777	4105	328	1368	328	8	Yes
18:00	3124	3325	201	1108	201	6	No
19:00	2179	2309	130	770	130	6	No
20:00	1595	1697	102	566	102	6	No

Congestion

Congestion	**C030, C011**
Ave Length of Congestion (Miles)	2.58
Duration of Congestion (Min)	56
Calculated Number of Occurrences per Year	389
Typical Times of Congestion	17:00 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 14
Of these 5 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 4 (29%)
Type 28- Sideswipe, same direction: 1 (7%)

Observations

Log 095 is a long direct ramp with a flat slope. The ramp begins with a strong curve but does not appear to cause sight distance issues. There is a guardrail at the mainline merge area. A CCTV is located at the next exit to the north and might be able to see the ramp merge and mainline at Log 095.

Site Selection Comments

This site has low flow on the entrance ramp, however it is just within limits during the observed period of congestion.

The congestion problem at this site is likely to be cause by weaving as a result of the lane addition and lane drop in short succession downstream.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

097

Site Details

Site Number	097
Freeway	I-440
Cross Street	NC-54 / Hillsborough St
Exit	3
Direction	SB
County	Wake

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection & Right Hand Freeflow Filter
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	Yes
Number of Freeway Lanes Before Merge	2
Number of Freeway Lanes After Merge	2
On Ramp Length to Back of Gore (ft)	525
On Ramp Length to Tip of Gore (ft)	723
Merge Length (ft)	534
On Ramp Horizontal Alignment	Tight Curve
On Ramp Vertical Alignment	Slight Uphill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Slight Downhill
Main Freeway Shoulder	Yes
Number of Vehicles Storage	30
Guardrail	None present
Pipe Crossing	None present

Signalization Overview

Upstream Signal	Unsignalized; Ramp entry from free right
Nearest Power Source	CCTV cabinet at end of ramp

Signing Overview

Existing Signing	No issues

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1169	1222	53	611	53	4	No
07:00	2628	2762	135	1381	135	5	No
08:00	3364	3550	187	1775	187	5	No
09:00	2506	2676	170	1338	170	6	No
10:00	2083	2251	168	1126	168	7	No
11:00	2137	2395	258	1197	258	11	No
12:00	2353	2642	289	1321	289	11	No
13:00	2403	2722	319	1361	319	12	Yes
14:00	2552	2871	319	1436	319	11	Yes
15:00	2896	3200	304	1600	304	10	Yes
16:00	3558	3956	398	1978	398	10	Yes
17:00	3313	3840	528	1920	528	14	Yes
18:00	3055	3363	309	1682	309	9	Yes
19:00	2120	2339	220	1170	220	9	No
20:00	1619	1845	227	923	227	12	No

Congestion

Congestion	-
Ave Length of Congestion (Miles)	-
Duration of Congestion (Min)	-
Calculated Number of Occurrences per Year	-
Typical Times of Congestion	-

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 46
Of these 27 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 24 (52%)
Type 28- Sideswipe, same direction: 3 (7%)

Observations

Log 097 is a loop ramp with two approaches that merge into the one lane of the ramp. The ramp has an uphill slope of about 5%. The ramp has curbs on both sides of the ramp, which prohibit a good maintenance/enforcement vehicle pull-off area. The CCTV coverage is good for the end half of the ramp due to tree coverage. This ramp has poor pavement condition. There is a guardrail at the mainline merge area.

Site Selection Comments

This site has poor, though possibly not insurmountable problems with geometry. The congestion is mainly caused by site Log 090 and 095 downstream, when ramp metering is installed there it will reduce the congestion adjacent to this site. It is recommended that this site be considered again in future after the downstream sites have been implemented and an evaluation of their effectiveness has taken place.

Site Categorization

Review in future.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

100

Site Details

Site Number	100
Freeway	I-440
Cross Street	SR 1728 – Wade Ave
Exit	4
Direction	SB-M1
County	Wake

Physical Characteristics Overview

Origin of Ramp	Freeflow Link
Lane Addition onto Main Freeway length (ft)	433
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	N
Number of Freeway Lanes Before Merge	2
Number of Freeway Lanes After Merge	2
On Ramp Length to Back of Gore (ft)	740
On Ramp Length to Tip of Gore (ft)	959
Merge Length (ft)	-
On Ramp Horizontal Alignment	Tight Curve
On Ramp Vertical Alignment	Level
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Discontinuous
Number of Vehicles Storage	43
Guardrail	Only at end of ramp
Pipe Crossing	None present

Signalization Overview

Upstream Signal	Unsignalized. Ramp entry from free right
Nearest Power Source	CCTV cabinet on other side of freeway

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1246	1315	69	658	69	5	No
07:00	2693	2930	237	1465	237	8	No
08:00	3219	3485	266	1742	266	8	No
09:00	2451	2649	199	1325	199	7	No
10:00	2103	2254	151	1127	151	7	No
11:00	2099	2287	188	1144	188	8	No
12:00	2322	2573	252	1287	252	10	No
13:00	2365	2585	221	1293	221	9	No
14:00	2517	2751	234	1376	234	9	No
15:00	2796	3046	250	1523	250	8	No
16:00	3232	3556	324	1778	324	9	Yes
17:00	3131	3524	393	1762	393	11	Yes
18:00	3024	3269	245	1635	245	7	No
19:00	2024	2176	152	1088	152	7	No
20:00	1534	1676	143	838	143	9	No

Congestion

Congestion	-
Ave Length of Congestion (Miles)	-
Duration of Congestion (Min)	-
Calculated Number of Occurrences per Year	-
Typical Times of Congestion	-

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 67
Of these 46 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 34 (51%)
Type 28- Sideswipe, same direction: 12 (18%)

Observations

Log 100 is a loop ramp that comes from Wade Ave. It acts as a freeway-freeway ramp. There are no sight distance issues. It has an uphill grade of about 4%. There is a bad patch of asphalt and shoulder pavement near the end of the ramp approaching the merge area. There is a guardrail starting at the merge area up to the bridge. There is CCTV coverage of the end quarter of the ramp and of the merge area.

Site Selection Comments

This site has poor, though possibly not insurmountable problems with geometry. The congestion is mainly caused by site Log 090 and 095 downstream, when ramp metering is installed there it will reduce the congestion adjacent to this site. It is recommended that this site be considered again in future after the downstream sites have been implemented and an evaluation of their effectiveness has taken place.

Site Categorization

Review in future

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

C.3.2. Group 2: Congestion Refs C032, C101

Site Summaries 133 and 135 for the following to be included in this section:

Site Summary

133

Site Details

Site Number	133
Freeway	I-540
Cross Street	US-70
Exit	4
Direction	Eastbound
County	Wake

Physical Characteristics Overview

Origin of Ramp	Freeflow Link
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	2
Lane Drop on Ramp Before Merge	Yes
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	1,000
On Ramp Length to Tip of Gore (ft)	1,584
Merge Length (ft)	3,000
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Slightly Downhill
On Ramp Shoulder (Paved Full Width)	Yes
Main Freeway Vertical Alignment Downstream	Slight Uphill
Main Freeway Shoulder	Yes
Number of Vehicles Storage	116
Guardrail	Along right side of ramp
Pipe crossing	None present

Signalization Overview

Upstream Signal	None present; dual F2F ramps merge to single ramp
Nearest Power Source	Transformer on Mt. Herman Rd

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	518	1138	620	379	310	54	No
07:00	1274	2280	1006	760	503	44	Yes
08:00	1654	2445	791	815	396	32	Yes
09:00	1355	1918	563	639	282	29	No
10:00	1103	1640	537	547	268	33	No
11:00	1173	1857	684	619	342	37	Yes
12:00	1269	1879	610	626	305	32	Yes
13:00	1374	2194	820	731	410	37	Yes
14:00	1599	2737	1138	912	569	42	Yes
15:00	2197	3337	1140	1112	570	34	Yes
16:00	3681	5960	2279	1987	1139	38	Yes
17:00	4374	6269	1895	2090	948	30	Yes
18:00	3479	4356	878	1452	439	20	Yes
19:00	1956	2685	730	895	365	27	Yes
20:00	1259	1947	688	649	344	35	Yes

Congestion

Congestion	**C101**
Ave Length of Congestion (Miles)	1.32
Duration of Congestion (Min)	41
Calculated Number of Occurrences per Year	96
Typical Times of Congestion	17:30-18:00

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 14
Of these 10 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 8 (57%)
Type 28- Sideswipe, same direction: 2 (14%)

Observations

Site 133 entrance ramp is a convergence of the Glenwood Ave eastbound fly-over ramp (2 lanes) and the Glenwood Ave westbound ramp (1 lane). The single right lane of the Glenwood Ave westbound ramp merges into the two Glenwood Ave EB lanes. The combined Glenwood Ave eastbound/westbound entrance ramp (2 lanes) then merges with I-540. The furthest right lane drops after about 1000 ft; the second right lane drops after about 3000' from where the ramp meets the mainline.

Cars coming from the Glenwood Ave eastbound fly-over were observed to be traveling at high speeds and at much greater volumes than the Glenwood Ave westbound ramp. A slight downhill grade of negative 1-2% was measured at various locations along ramp. A guardrail is located along the right edge of pavement for about 1000' around the location of the merge onto the freeway mainline. Pavement and shoulder were observed to be sufficiently wide and in good condition. No nearby CCTV coverage, communications source, or power source were observed. There is some area for maintenance vehicle parking on the right shoulder.

Site Selection Comments

This location has been identified as F2F during the site selection process, otherwise:

This site appears to have good overall physical characteristics and the traffic flows are acceptable for ramp metering during most of the day. The congestion analysis shows that the congestion tends to occur between 17:30 and 18:30 which matches the times when the flows are appropriate for metering.

Care should be taken in the design and placement of the queue for ramp metering because of the two ramps merging into one ramp before merging onto the interstate.

Concerns over vehicles traveling on the fly-over ramp going at nearly highway speed, serious consideration needs to be given to sightlines, stopping distances and queue warnings during the design of this site.

This is an F2F site.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

135

Site Details

Site Number	135
Freeway	I-540
Cross Street	SR 1829 – Leesville Rd
Exit	7
Direction	EB
County	Wake

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection & Righthand Freeflow Link
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	Yes
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	1,070
On Ramp Length to Tip of Gore (ft)	1,420
Merge Length (ft)	520
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Downhill
On Ramp Shoulder (Paved Full Width)	Yes
Main Freeway Vertical Alignment Downstream	Downhill
Main Freeway Shoulder	Yes
Number of Vehicles Storage	62
Guardrail	Right side of ramp
Pipe crossing	Not in the way of ramp meter location

Signalization Overview

Upstream Signal	3-way signal; ramp entry from: left, right yield, thru
Nearest Power Source	Traffic Signal Cabinet: inside corner of ramp & intersection

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	914	1207	293	402	293	24	No
07:00	1631	2317	686	772	686	30	Yes
08:00	1833	2516	683	839	683	27	Yes
09:00	1364	1788	424	596	424	24	Yes
10:00	1021	1351	330	450	330	24	Yes
11:00	1334	1665	331	555	331	20	Yes
12:00	1426	1737	312	579	312	18	Yes
13:00	1573	1919	346	640	346	18	Yes
14:00	1995	2395	400	798	400	17	Yes
15:00	2771	3260	489	1087	489	15	Yes
16:00	3871	4400	529	1467	529	12	Yes
17:00	4641	5254	613	1751	613	12	Yes
18:00	1932	2394	462	798	462	19	Yes
19:00	1018	1312	294	437	294	22	No
20:00	908	1132	224	377	224	20	No

Congestion

Congestion	**C032**
Ave Length of Congestion (Miles)	2.95
Duration of Congestion (Min)	56
Calculated Number of Occurrences per Year	132
Typical Times of Congestion	17:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 5
Of these 2 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 2 (40%)
Type 28- Sideswipe, same direction: 0 (0%)

Observations

Log 135 is a long direct ramp. There are no sight distance issues. CCTV coverage is of end quarter of ramp. The ramp has a slight downhill grade. The ramp begins as 2 lanes that merge to 1 lane after about 300'. There is a vehicle pull-off and a guardrail on the right side just before the ramp merges onto the mainline. Overall, observations indicate this is a good candidate for a ramp meter. A moderate sized shoulder width of 4.5' on each side could allow for converting the ramp to 2 lanes for the entire ramp length.

Site Selection Comments

This site has good geometry and it has flows within the acceptable limits during the observed times of congestion.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

C.3.3. Group 3: Congestion Refs C051, C061

Site Summaries 010, 013, 014, 016, 018, are included in this section:

Site Summary

010

Site Details

Site Number	010
Freeway	I-40
Cross Street	NC-55 / Apex Hwy
Exit	278
Direction	WB
County	Durham

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	Y
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	1302
On Ramp Length to Tip of Gore (ft)	1634
Merge Length (ft)	927
On Ramp Horizontal Alignment	Straight
On Ramp Vertical Alignment	Level
On Ramp Shoulder (Paved Full Width)	Yes
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	75
Guardrail	Full length of right side of ramp, steep slopes.
Pipe Crossing	No issue.

Signalization Overview

Upstream Signal	4-way signal; ramp entry from: dual lefts, right turn on red, right turn overlap phase, thru
Nearest Power Source	Signal cabinet located on far corner of intersection away from ramp.

Signing Overview

Existing Signing	No issue.

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1417	1862	445	621	445	24	Yes
07:00	2990	3756	766	1252	766	20	Yes
08:00	3581	4415	834	1472	834	19	Yes
09:00	3373	3884	511	1295	511	13	Yes
10:00	2714	3102	389	1034	389	13	Yes
11:00	2834	3266	432	1089	432	13	Yes
12:00	2939	3437	498	1146	498	14	Yes
13:00	2959	3433	474	1144	474	14	Yes
14:00	2875	3327	452	1109	452	14	Yes
15:00	3084	3641	557	1214	557	15	Yes
16:00	3869	4591	722	1530	722	16	Yes
17:00	4737	5555	818	1852	818	15	Yes
18:00	4120	4725	605	1575	605	13	Yes
19:00	2504	2817	313	939	313	11	Yes
20:00	1660	1898	238	633	238	13	No

Congestion

Primary Congestion	**C051**
Ave Length of Congestion (Miles)	2.89
Duration of Congestion (Min)	58
Calculated Number of Occurrences per Year	100
Typical Times of Congestion	17:30 – 19:00

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 3
Of these 2 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 2 (67%)
Type 28- Sideswipe, same direction: 0 (0%)

Observations

Log 010 is a direct ramp with no sight distance issues. The ramp has a very slight downhill slope. Toward the end of the ramp there is a guardrail on the right due to a steep drop-off behind the guardrail. There is good CCTV coverage of the entire ramp and mainline merge. The NCDOT fiber-optic cable is located along the ramp and mainline.

Site Selection Comments

This site has good geometry for Ramp metering. The flows are within acceptable limits during the observed period of congestion. This site can address the entirety of congestion problem C051 but would not affect C061.

Site Categorization

Suitable for taking forward

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

013

Site Details

Site Number	013
Freeway	I-40
Cross Street	NC-147 / Durham Fwy
Exit	279
Direction	WB-M1
County	Durham

Physical Characteristics Overview

Origin of Ramp	Free Flow Link
Lane Addition onto Main Freeway length (ft)	500
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	4
Number of Freeway Lanes After Merge	5
On Ramp Length to Back of Gore (ft)	790
On Ramp Length to Tip of Gore (ft)	950
Merge Length (ft)	-
On Ramp Horizontal Alignment	Tight Curve
On Ramp Vertical Alignment	Slight Uphill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Discontinuous
Number of Vehicles Storage	45
Guardrail	Begins at ramp merge
Pipe Crossing	None present

Signalization Overview

Upstream Signal	None Present
Nearest Power Source	Unknown

Signing Overview

Existing Signing	None Present

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1590	1599	9	320	9	1	No
07:00	3398	3433	35	687	35	1	No
08:00	4120	4163	43	833	43	1	No
09:00	3822	3846	25	769	25	1	No
10:00	2998	3026	29	605	29	1	No
11:00	3033	3065	33	613	33	1	No
12:00	3180	3220	40	644	40	1	No
13:00	3183	3209	26	642	26	1	No
14:00	3093	3117	24	623	24	1	No
15:00	3273	3309	36	662	36	1	No
16:00	4024	4070	47	814	47	1	No
17:00	4743	4821	78	964	78	2	No
18:00	4133	4167	35	833	35	1	No
19:00	2668	2689	21	538	21	1	No
20:00	1802	1812	11	362	11	1	No

Congestion

Congestion	-
Ave Length of Congestion (Miles)	-
Duration of Congestion (Min)	-
Calculated Number of Occurrences per Year	-
Typical Times of Congestion	-

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 54
Of these 32 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 24 (44%)
Type 28- Sideswipe, same direction: 8 (15%)

Observations

Log 013 is loop ramp with a slight uphill grade of between 3-4%. There are no sight distance issues. There is CCTV coverage of the first quarter and the last quarter of the ramp (trees block CCTV coverage of the middle section). The inside edge of the ramp is a curb; there is not a good area for maintenance vehicle pull off. A NCDOT fiber-optic pull box was located near the merge point.

Site Selection Comments

The entrance ramp flow at this location is far too low to be considered for Ramp metering.

This is an F2F site.

Site Categorization

Not suitable.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

014

Site Details

Site Number	014
Freeway	I-40
Cross Street	NC-147 / Durham Fwy
Exit	279
Direction	WB-M2
County	Durham

Physical Characteristics Overview

Origin of Ramp	Free Flow Link
Lane Addition onto Main Freeway length (ft)	No
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	2,400
On Ramp Length to Tip of Gore (ft)	2,930
Merge Length (ft)	760
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Level
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	139
Guardrail	None present
Pipe Crossing	None present

Signalization Overview

Upstream Signal	None
Nearest Power Source	Vehicle detector or CCTV at end of ramp

Signing Overview

Existing Signing	Potential conflict with Durham City Limit sign.

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1543	2058	516	686	516	25	Yes
07:00	3326	3873	548	1291	548	14	Yes
08:00	4071	4427	357	1476	357	8	Yes
09:00	3699	4001	302	1334	302	8	Yes
10:00	2923	3335	412	1112	412	12	Yes
11:00	2971	3381	410	1127	410	12	Yes
12:00	3089	3433	344	1144	344	10	Yes
13:00	3090	3457	367	1152	367	11	Yes
14:00	3016	3535	519	1178	519	15	Yes
15:00	3175	3929	755	1310	755	19	Yes
16:00	3953	4925	972	1642	972	20	Yes
17:00	4688	5275	587	1758	587	11	Yes
18:00	4066	4371	306	1457	306	7	Yes
19:00	2614	2856	243	952	243	8	No
20:00	1770	1957	187	652	187	10	No

Congestion

Congestion	**C051 , C061**
Ave Length of Congestion (Miles)	1.95
Duration of Congestion (Min)	43
Calculated Number of Occurrences per Year	257
Typical Times of Congestion	17:30 – 19:00, 17:30 – 18:30

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 16
Of these 10 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 9 (56%)
Type 28- Sideswipe, same direction: 1 (6%)

Observations

Log 014 is a direct ramp with no sight issues and fairly flat slope. CCTV coverage has no blockage, but distance could be an issue depending on zoom capabilities. A NCDOT fiber-optic cable was located along the ramp.

Site Selection Comments

This site has good physical characteristics, apart from being F2F. The flows are within acceptable parameters during the observed periods of congestion.
The congestion associated with this site is a blend of C051 and C061. This site is the primary site for C061.

This site is F2F.

Site Categorization

Suitable for taking forward.

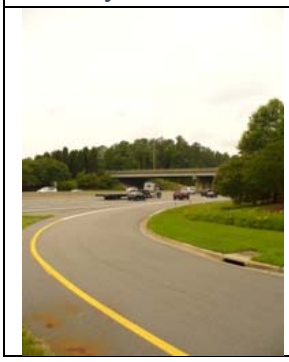
Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

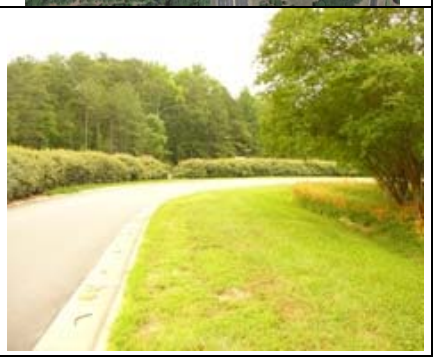
Site Summary

016

Site Details

Site Number	016
Freeway	I-40
Cross Street	Davis Dr
Exit	280
Direction	WB
County	Durham





Physical Characteristics Overview

Origin of Ramp	Signalised Intersection and Right Hand Free Flow Link
Lane Addition onto Main Freeway length (ft)	No
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	4
Number of Freeway Lanes After Merge	4
On Ramp Length to Back of Gore (ft)	609
On Ramp Length to Tip of Gore (ft)	802
Merge Length (ft)	442
On Ramp Horizontal Alignment	Tight Curve
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	35
Guardrail	None present
Pipe crossing	None present

Signalization Overview

Upstream Signal	4-way signal; ramp entry from: left, thru, right yield
Nearest Power Source	Traffic Signal Cabinet: far corner of ramp & intersection

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	2525	2682	157	671	157	6	No
07:00	5457	5772	316	1443	316	5	Yes
08:00	6371	6730	359	1682	359	5	Yes
09:00	5505	5724	219	1431	219	4	No
10:00	4085	4245	160	1061	160	4	No
11:00	3889	4113	224	1028	224	5	No
12:00	4086	4298	213	1075	213	5	No
13:00	4078	4259	181	1065	181	4	No
14:00	4054	4207	153	1052	153	4	No
15:00	4235	4493	258	1123	258	6	No
16:00	5344	5705	361	1426	361	6	Yes
17:00	6546	7037	491	1759	491	7	Yes
18:00	5590	5862	273	1466	273	5	No
19:00	3555	3691	137	923	137	4	No
20:00	2290	2358	69	590	69	3	No

Congestion

Congestion	-
Ave Length of Congestion (Miles)	-
Duration of Congestion (Min)	-
Calculated Number of Occurrences per Year	-
Typical Times of Congestion	-

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 67
Of these 54 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 40 (60%)
Type 28- Sideswipe, same direction: 14 (21%)

Observations

Log 016 is loop ramp with a downhill grade of between 4-5%. There are no major sight distance issues. There is CCTV coverage of the first quarter and the last quarter of the ramp (trees block CCTV coverage of the middle section). The inside edge of the ramp is a curb; there is not a good area for maintenance vehicle pull off. A NCDOT fiber-optic pull box is located near the merge point.

Site Selection Comments

This site suffers from some poor geometric issues, such as a tight curve and being relatively short, these problems are no insurmountable. This site is however very close to the tail end of the congestion and it is suggested that it is reconsidered in future after sites 010 and 014 have been implemented and evaluated.

Site Categorization

Review in future.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

018

Site Details

Site Number	018
Freeway	I-40
Cross Street	S Miami Blvd
Exit	281
Direction	WB
County	Durham

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection
Lane Addition onto Main Freeway length (ft)	2,533
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	N
Number of Freeway Lanes Before Merge	4
Number of Freeway Lanes After Merge	5
On Ramp Length to Back of Gore (ft)	715
On Ramp Length to Tip of Gore (ft)	836
Merge Length (ft)	-
On Ramp Horizontal Alignment	Tight Curve
On Ramp Vertical Alignment	Slight Downhill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	41.5
Guardrail	Right side at end of ramp
Pipe Crossing	None present

Signalization Overview

Upstream Signal	3-way signal; ramp entry: left, right turn on red, right turn overlap phase, thru
Nearest Power Source	Traffic signal cabinet: far corner of ramp & intersection

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	3702	3797	96	759	96	3	No
07:00	7026	7198	172	1440	172	2	No
08:00	6698	6927	229	1385	229	3	No
09:00	4746	4954	208	991	208	4	No
10:00	4035	4190	155	838	155	4	No
11:00	3992	4196	204	839	204	5	No
12:00	4147	4387	240	877	240	5	No
13:00	4048	4285	238	857	238	6	No
14:00	4036	4237	201	847	201	5	No
15:00	4626	4859	234	972	234	5	No
16:00	5941	6283	342	1257	342	5	Yes
17:00	6202	6622	420	1324	420	6	Yes
18:00	4387	4685	298	937	298	6	No
19:00	2745	2909	164	582	164	6	No
20:00	2103	2216	113	443	113	5	No

Congestion

Congestion	-
Ave Length of Congestion (Miles)	-
Duration of Congestion (Min)	-
Calculated Number of Occurrences per Year	-
Typical Times of Congestion	-

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 23
Of these 13 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 8 (35%)
Type 28- Sideswipe, same direction: 5 (21%)

Observations

Log 018 is a loop ramp with no sight distance issues. It has a slight downhill slope that flattens out at the merge area. There is a guardrail on the right side where the ramp meets the mainline. CCTV coverage of most of the ramp, depending on tree foliage. There is a section of bad asphalt about 1/3 of the way down there ramp. A maintenance vehicle pull off area is located at the beginning of the ramp.

Site Selection Comments

This site suffers from some poor geometric issues, such as a tight curve and being relatively short, these problems are no insurmountable. This site is however very close to the tail end of the congestion and it is suggested that it is reconsidered in future after sites 010 and 014 have been implemented and evaluated.

Site Categorization

Review in future.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

C.3.4. Group 4: Congestion Refs C060, C082

Site Summaries 009, 011, and 012 are included in this section:

Site Summary

009

Site Details

Site Number	009
Freeway	I-40
Cross Street	NC-55 / Apex Highway
Exit	278
Direction	EB
County	Durham

Physical Characteristics Overview

Origin of Ramp	Signalized Intersection
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	720
On Ramp Length to Tip of Gore (ft)	948
Merge Length (ft)	956
On Ramp Horizontal Alignment	Tight Curve
On Ramp Vertical Alignment	Slight Uphill
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Slight Uphill
Main Freeway Shoulder	Yes
Number of Vehicles Storage	41
Guardrail	None Present
Pipe Crossing	None Present

Signalization Overview

Upstream Signal	4-way signal; ramp entry from: left, right turn on red, thru
Nearest Power Source	Traffic signal cabinet: across intersection from ramp side

Signing Overview

Existing Signing	No Conflicts

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1462	1907	445	636	445	23	Yes
07:00	3251	4017	766	1339	766	19	Yes
08:00	4361	5194	834	1731	834	16	Yes
09:00	3354	3865	511	1288	511	13	Yes
10:00	2463	2851	389	950	389	14	Yes
11:00	2385	2817	432	939	432	15	Yes
12:00	2596	3094	498	1031	498	16	Yes
13:00	2781	3255	474	1085	474	15	Yes
14:00	2823	3275	452	1092	452	14	Yes
15:00	2984	3541	557	1180	557	16	Yes
16:00	3366	4088	722	1363	722	18	Yes
17:00	3611	4429	818	1476	818	18	Yes
18:00	3137	3742	605	1247	605	16	Yes
19:00	2250	2563	313	854	313	12	Yes
20:00	1880	2118	238	706	238	11	No

Congestion

Congestion	C060
Ave Length of Congestion (Miles)	2.76
Duration of Congestion (Min)	44
Calculated Number of Occurrences per Year	124
Typical Times of Congestion	08:00 – 09:00

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 48
Of these 23 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 18 (38%)
Type 28- Sideswipe, same direction: 5 (10%)

Observations

Log 009 is a loop ramp with a slight uphill grade of between 2-4%. There is a guardrail toward the end of the ramp on the right side that continues up to the bridge where the mainline merge area begins. There is good CCTV coverage of the end half of the ramp. A section of poor asphalt cover is located in the middle section of the ramp. The right inside of the ramp is a curb; the left outside edge has a good area for maintenance vehicle pull-off.

Site Selection Comments

This entrance ramp is curved and quite short, although there are no sight issues noted and the entrance ramp flow is relatively low so these problems should not be insurmountable.
The flows are within acceptable limits during the observed period of congestion. ramp metering at this entrance ramp should provide improvements in congestion problem C060.

Site Categorization

Suitable for taking forward.

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

011

Site Details

Site Number	011
Freeway	I-40
Cross Street	NC-147 / Durham Fwy
Exit	279
Direction	EB-M1
County	Durham

Physical Characteristics Overview

Origin of Ramp	Free Flow Link
Lane Addition onto Main Freeway length (ft)	None
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	No
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	3
On Ramp Length to Back of Gore (ft)	1200
On Ramp Length to Tip of Gore (ft)	1430
Merge Length (ft)	460
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Level
On Ramp Shoulder (Paved Full Width)	No
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	69
Guardrail	None present
Pipe Crossing	None Present

Signalization Overview

Upstream Signal	None Present
Nearest Power Source	None near. Possible from CCTV at Davis Drive or Office Park

Signing Overview

Existing Signing	No issue.

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1677	1678	2	559	2	0	No
07:00	3615	3617	3	1206	3	0	No
08:00	4980	4985	5	1662	5	0	No
09:00	3819	3823	4	1274	4	0	No
10:00	2800	2807	7	936	7	0	No
11:00	2755	2762	7	921	7	0	No
12:00	2931	2937	6	979	6	0	No
13:00	3128	3135	8	1045	8	0	No
14:00	3139	3145	7	1048	7	0	No
15:00	3413	3419	6	1140	6	0	No
16:00	3968	3978	10	1326	10	0	No
17:00	4353	4369	16	1456	16	0	No
18:00	3675	3681	6	1227	6	0	No
19:00	2480	2483	3	828	3	0	No
20:00	1999	2002	3	667	3	0	No

Congestion

Congestion	-
Ave Length of Congestion (Miles)	-
Duration of Congestion (Min)	-
Calculated Number of Occurrences per Year	-
Typical Times of Congestion	-

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 6
Of these 4 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 3 (50%)
Type 28- Sideswipe, same direction: 1 (17%)

Observations

Log 011 is a direct ramp with no sight distance issues. There is a very slight uphill grade. There is CCTV coverage of the end half of the ramp. The ramp has large easement space but no designated pull-off area. No traffic was observed on the ramp, which may change once the toll road is expanded.

Site Selection Comments

This location is just upstream of site 012 which would make a good ramp metering site if it were not F2F. This site, 011, however has an extremely low flow and would be impossible to meter, so cannot mitigate against the congestion problem caused by the downstream entrance ramp.

This is an F2F site.

Site Categorization

Not suitable

Site will be given a score for ease of implementation (analogous to cost) and level of benefits. This score will be used to rank sites in order of priority for implementation.

Site Summary

012

Site Details

Site Number	012
Freeway	I-40
Cross Street	NC-147 / Durham Fwy
Exit	279
Direction	EB-M2
County	Durham

Physical Characteristics Overview

Origin of Ramp	Free Flow Link
Lane Addition onto Main Freeway length (ft)	> 1 Mile
Number of Entrance Ramp Lanes	1
Lane Drop on Ramp Before Merge	Yes
Number of Freeway Lanes Before Merge	3
Number of Freeway Lanes After Merge	4
On Ramp Length to Back of Gore (ft)	3,150
On Ramp Length to Tip of Gore (ft)	3,770
Merge Length (ft)	-
On Ramp Horizontal Alignment	Slight Curve
On Ramp Vertical Alignment	Level
On Ramp Shoulder (Paved Full Width)	Yes
Main Freeway Vertical Alignment Downstream	Level
Main Freeway Shoulder	Yes
Number of Vehicles Storage	182
Guardrail	None Present
Pipe Crossing	None Present

Signalization Overview

Upstream Signal	None Present
Nearest Power Source	CCTV at Davis Dr. Possible closer power source could be from the nearby office park.

Signing Overview

Existing Signing	No issue

Traffic Volumes

Period Beginning	Upstream Hourly Volume Rate	Downstream Hourly Volume Rate	Entrance Ramp Hourly Volume Rate	Downstream Volume Per Lane	Entrance Ramp Volume Per Lane	Entrance Ramp % Of Downstream Volume	Hour Meets Acceptable Criteria For Ramp Metering
06:00	1919	3006	1087	752	1087	36	Yes
07:00	3793	5626	1834	1407	1834	33	No
08:00	4415	6390	1976	1598	1976	31	No
09:00	3347	4667	1320	1167	1320	28	No
10:00	2605	3669	1064	917	1064	29	Yes
11:00	2733	3883	1150	971	1150	30	Yes
12:00	2912	4146	1234	1036	1234	30	No
13:00	3027	4217	1190	1054	1190	28	Yes
14:00	3078	4416	1339	1104	1339	30	No
15:00	3363	5212	1849	1303	1849	35	No
16:00	3928	6221	2294	1555	2294	37	No
17:00	4164	5976	1812	1494	1812	30	No
18:00	3379	4787	1409	1197	1409	29	No
19:00	2206	3063	857	766	857	28	Yes
20:00	1892	2633	742	658	742	28	Yes

Congestion

Congestion	**C082**
Ave Length of Congestion (Miles)	2.13
Duration of Congestion (Min)	37
Calculated Number of Occurrences per Year	124
Typical Times of Congestion	08:00 – 09:00

Crash Data

The total number of accidents from January 2007 to Dec 2011 was: 7
Of these 5 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 4 (57%)
Type 28- Sideswipe, same direction: 1 (14%)

Appendix D. Bottleneck Information

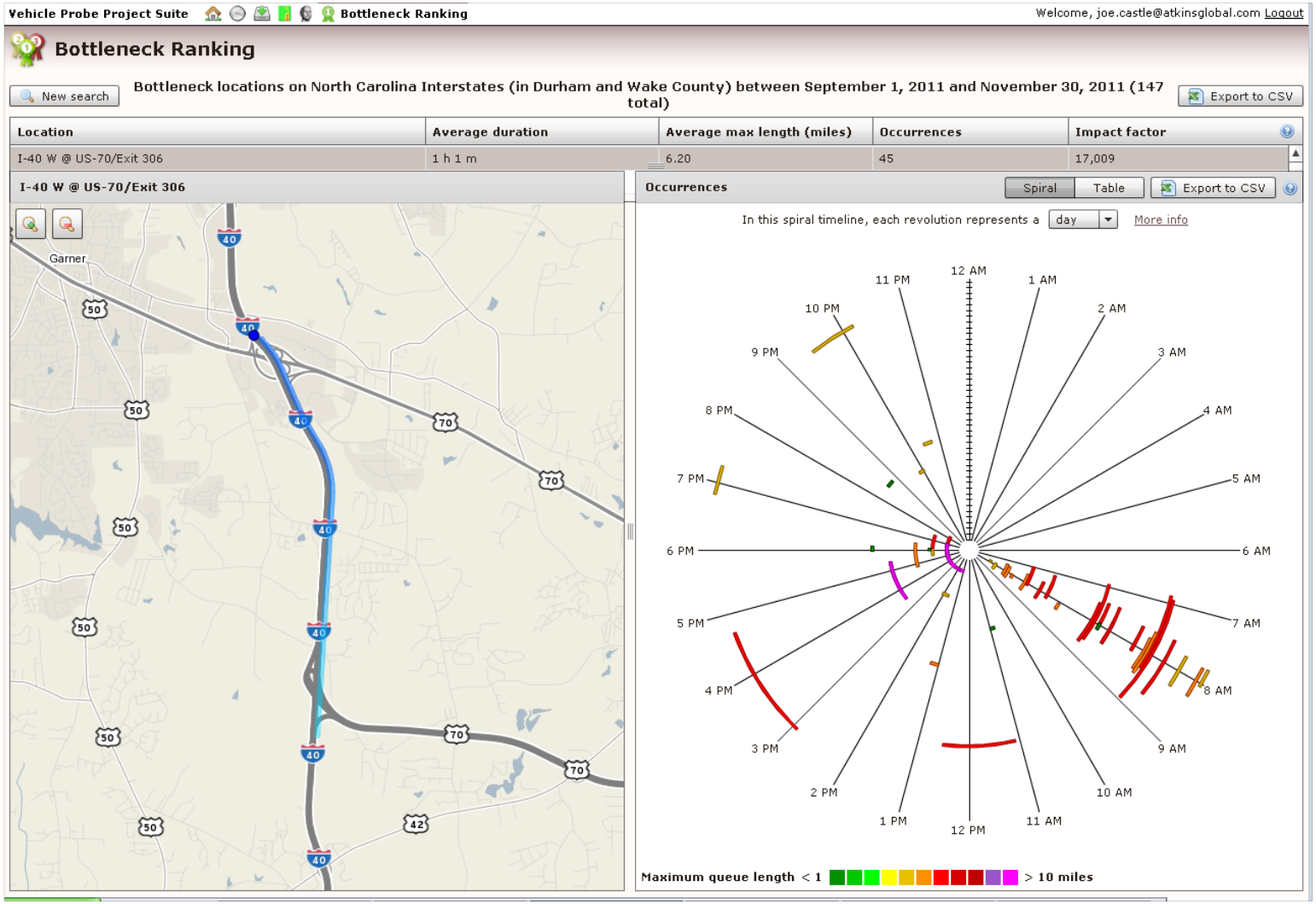


Figure D-1: Congestion Location 002

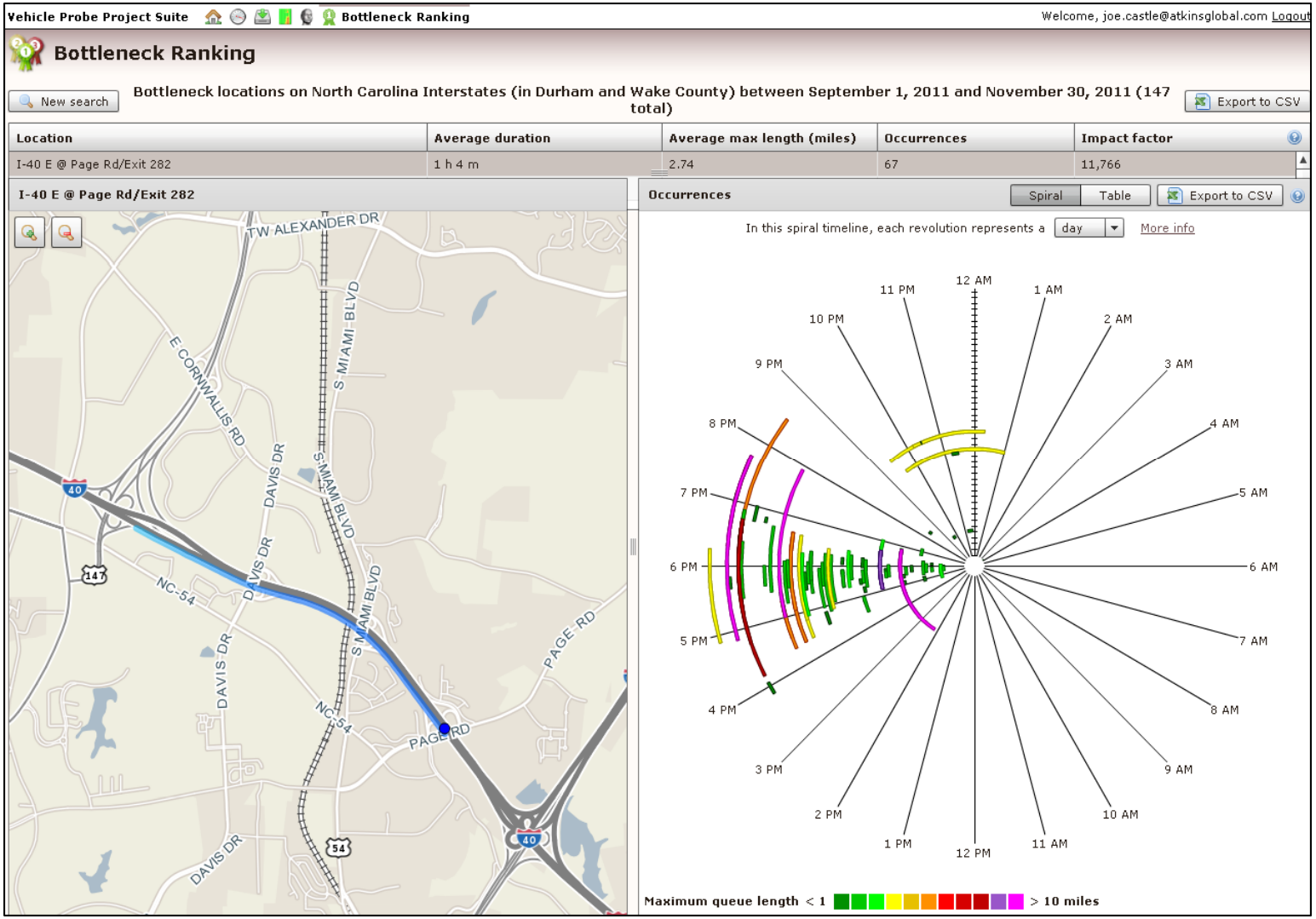


Figure D-2: Congestion Location 006

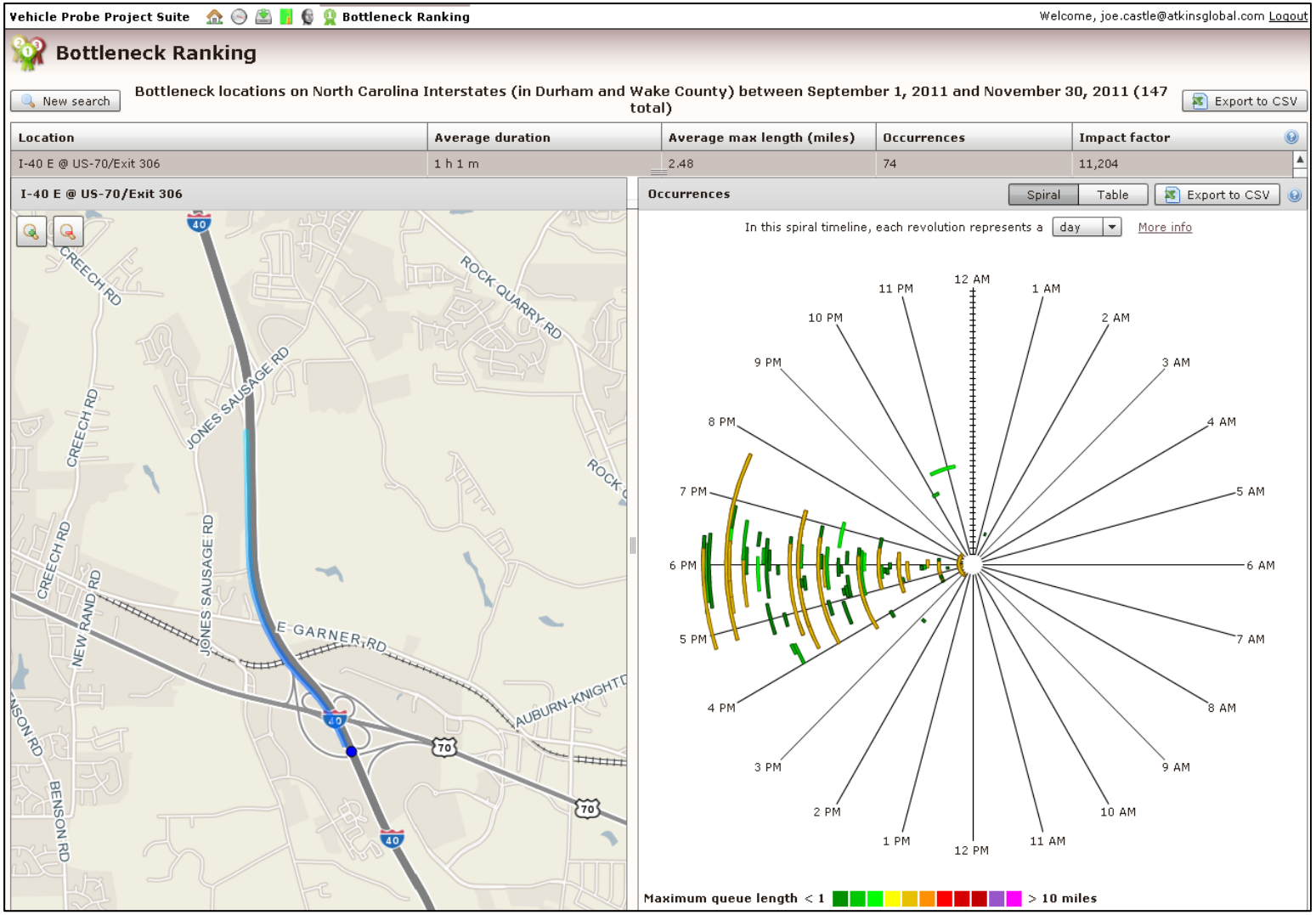


Figure D-3: Congestion Location 009

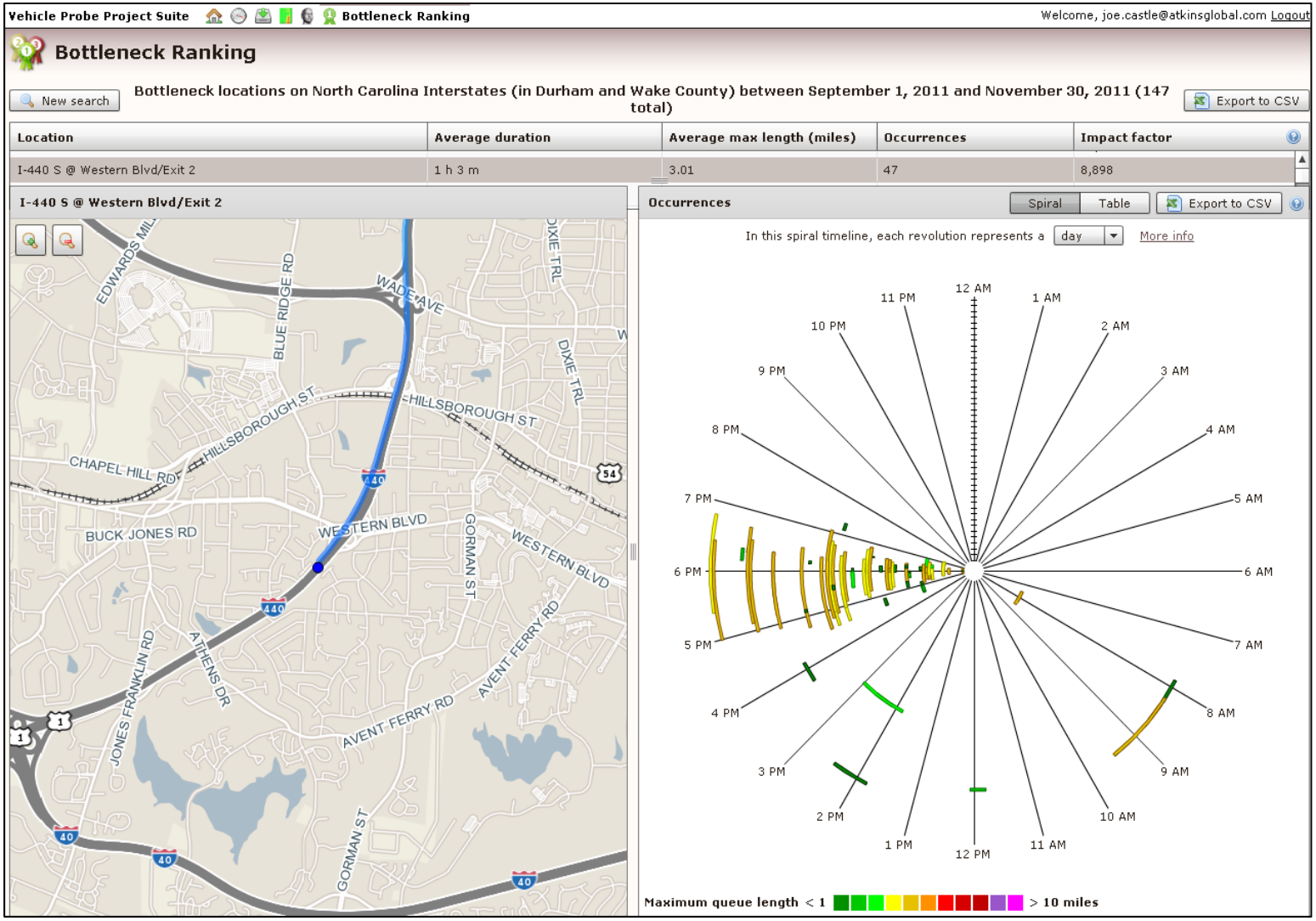


Figure D-4: Congestion Location 011

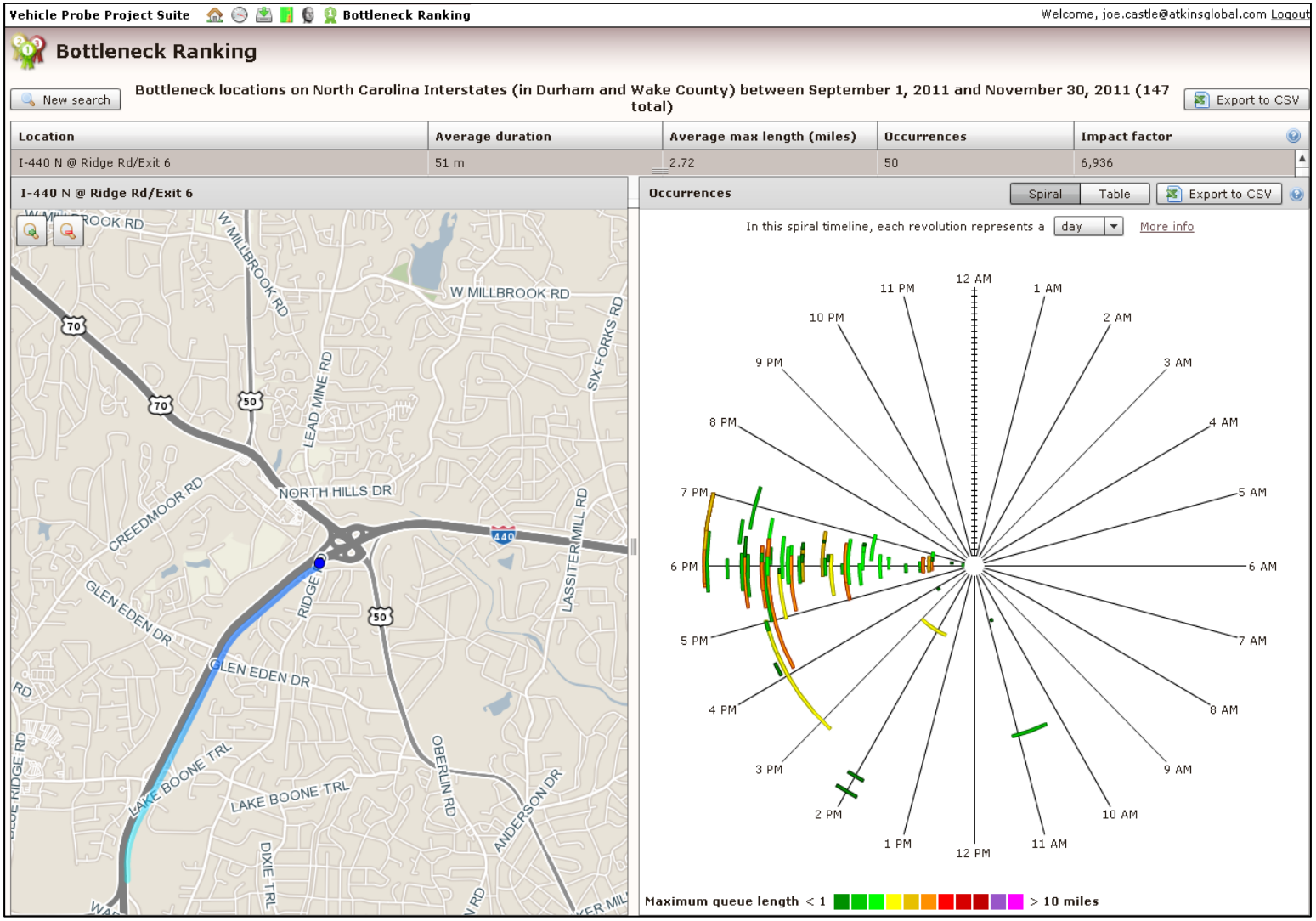


Figure D-5: Congestion Location 014

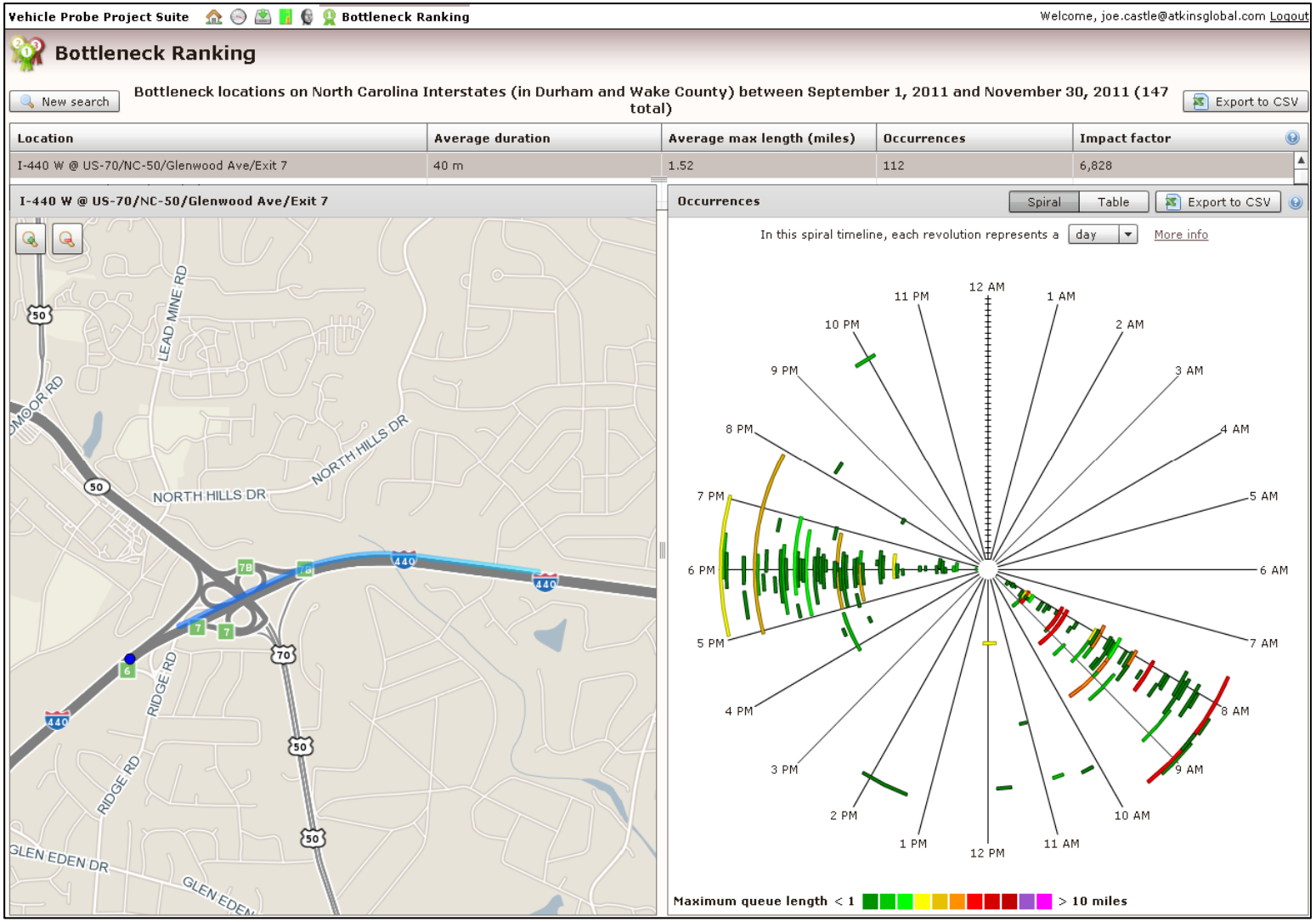


Figure D-6: Congestion Location 016

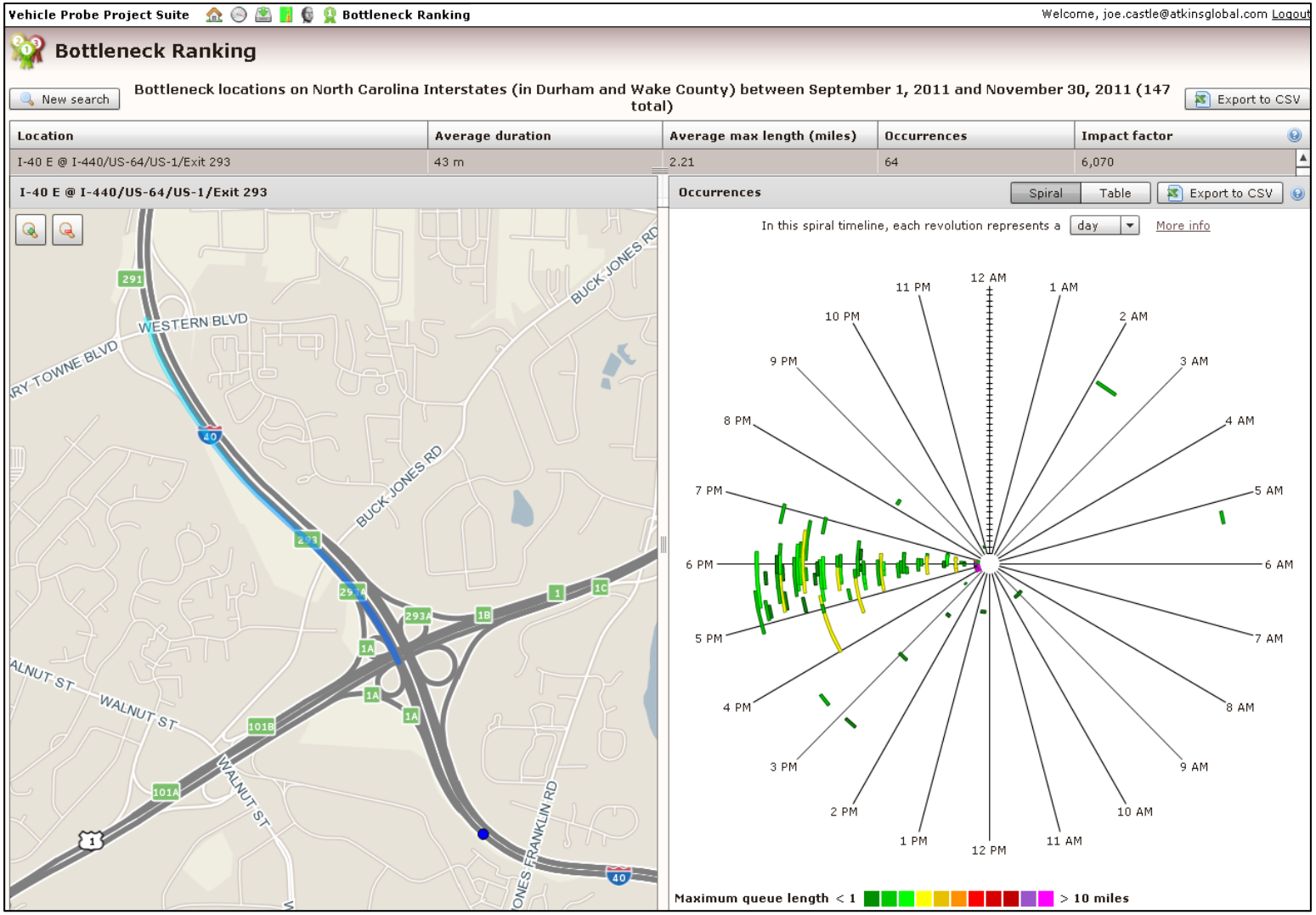


Figure D-7: Congestion Location 020

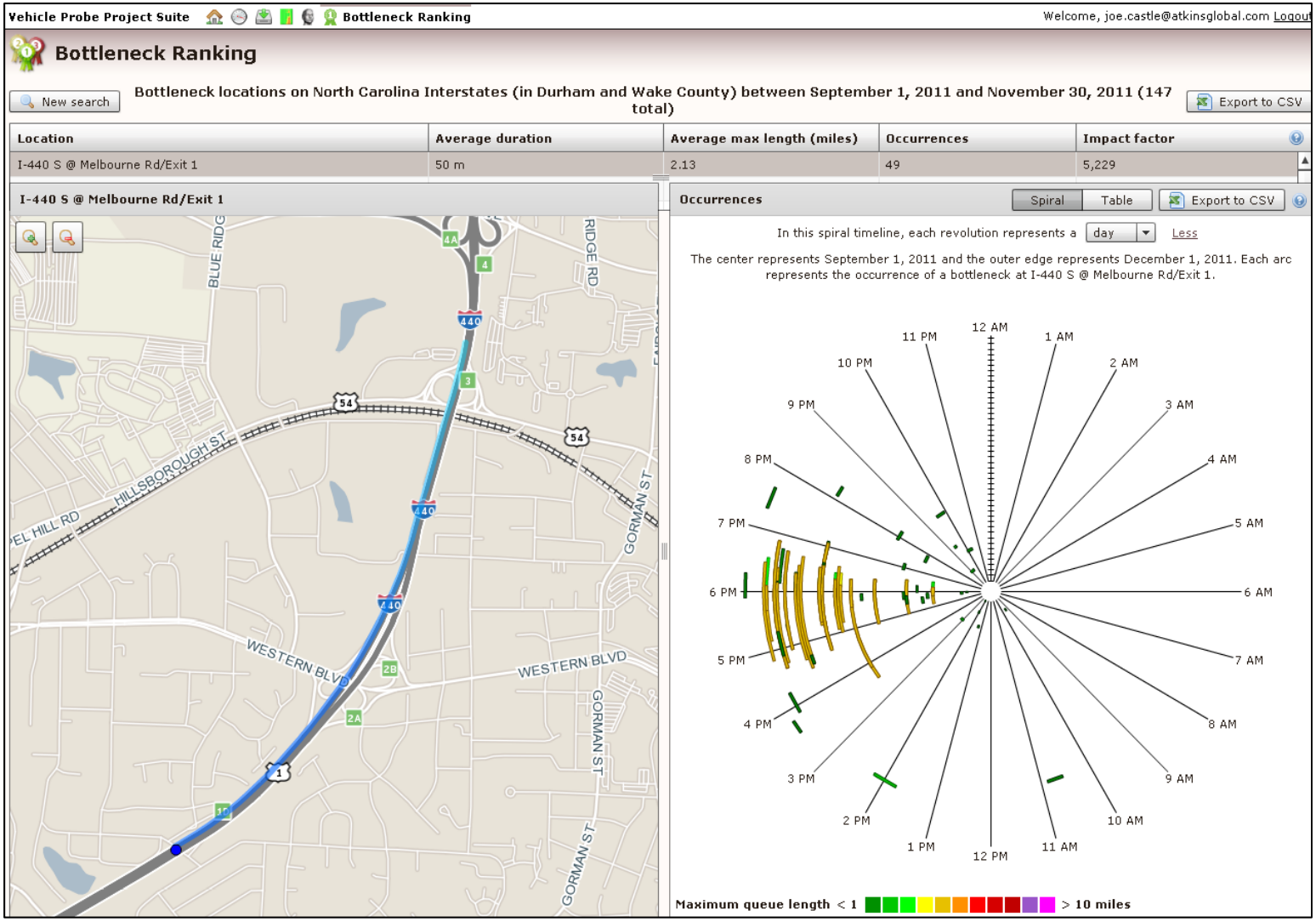


Figure D-8: Congestion Location 030

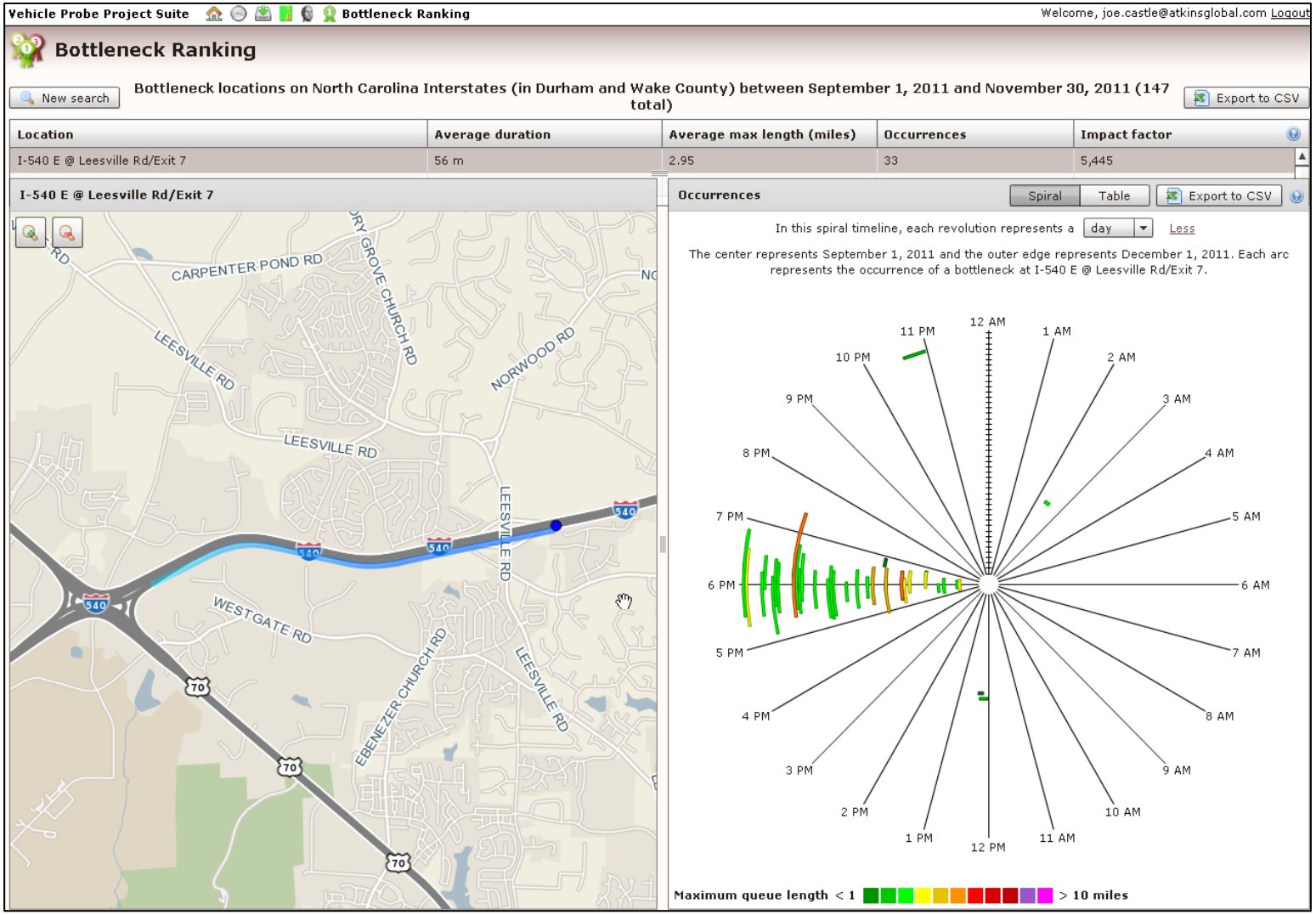


Figure D-9: Congestion Location 032

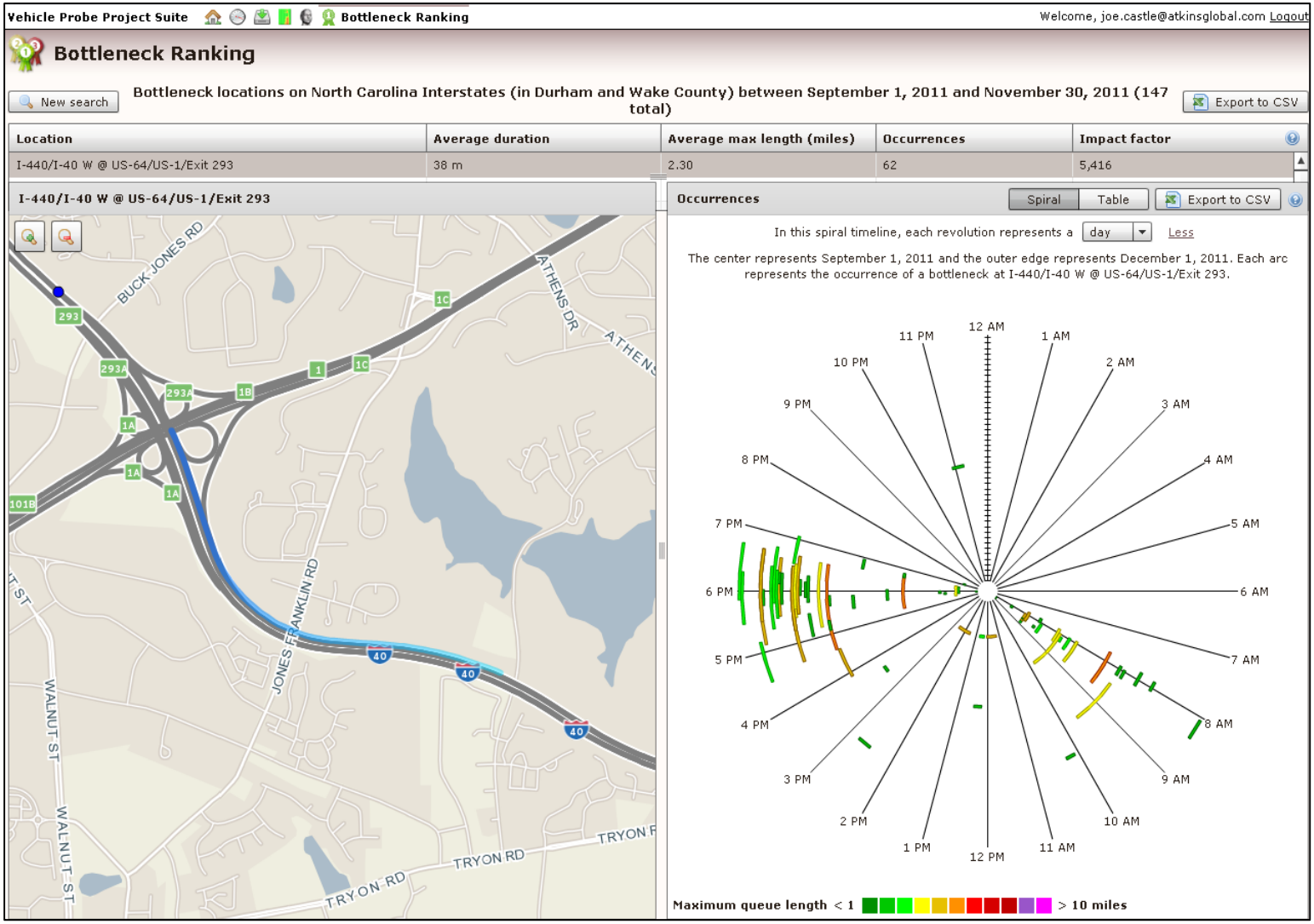


Figure D-10: Congestion Location 035

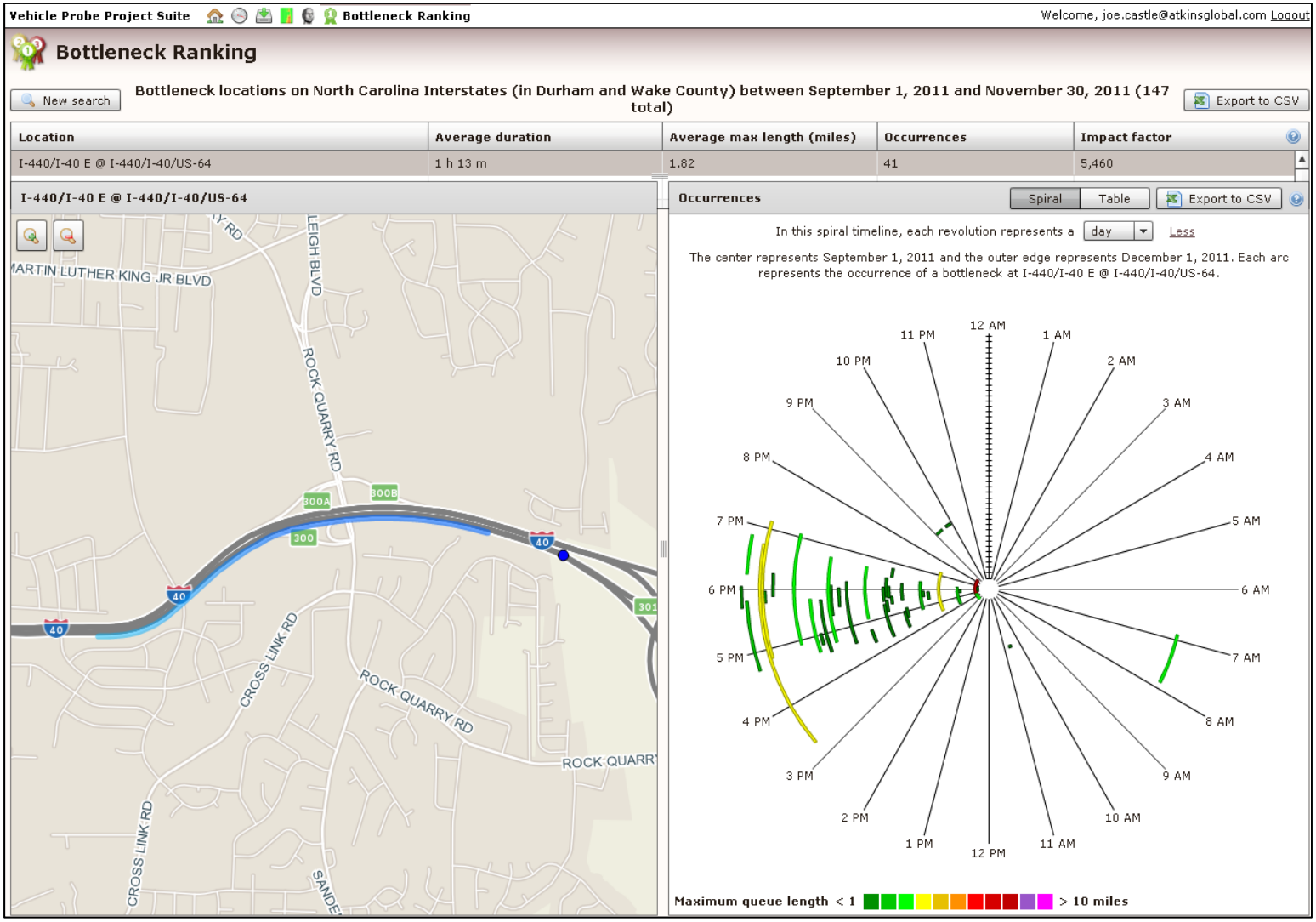


Figure D-11: Congestion Location 041

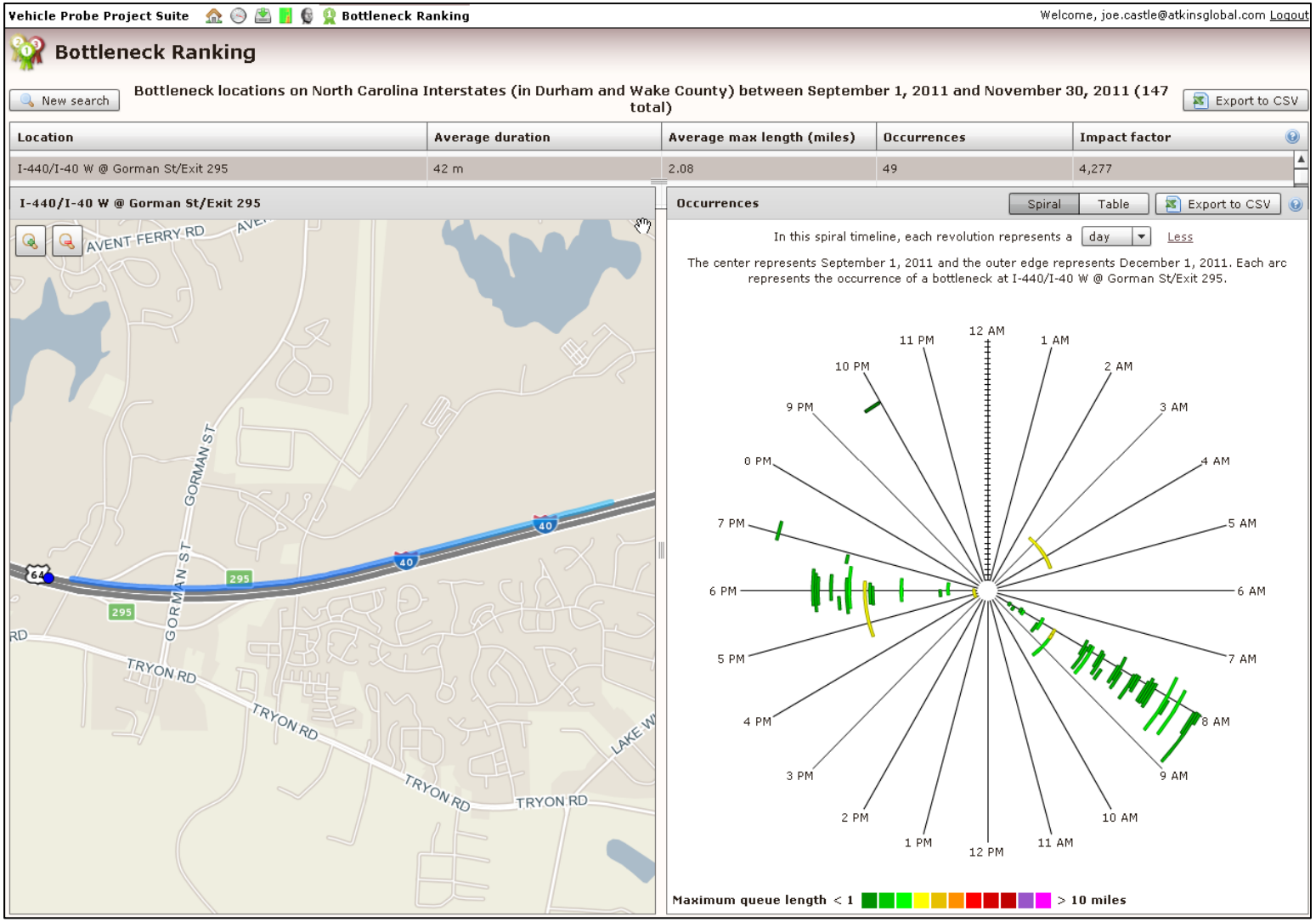


Figure D-12: Congestion Location 042

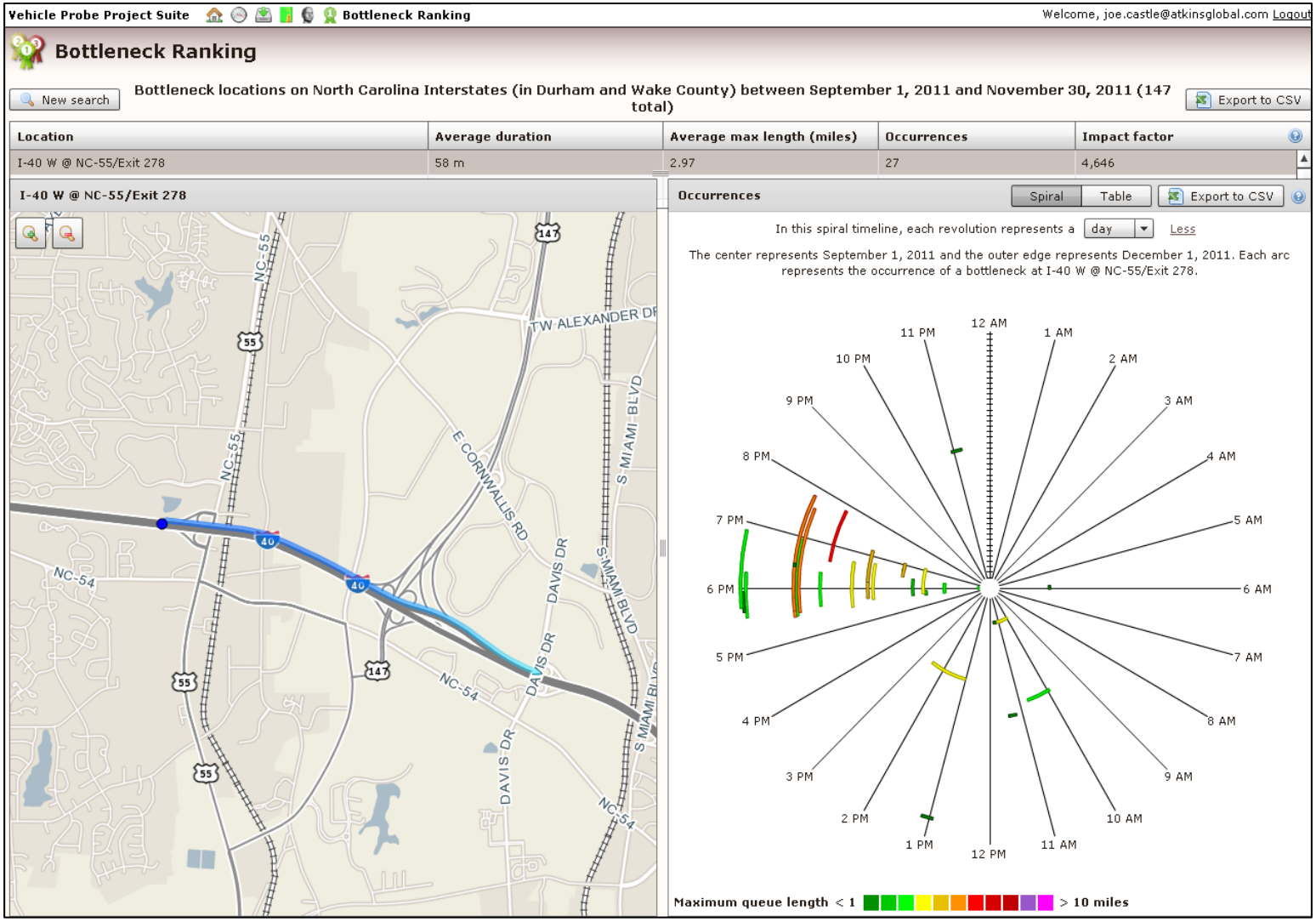


Figure D-13: Congestion Location 051

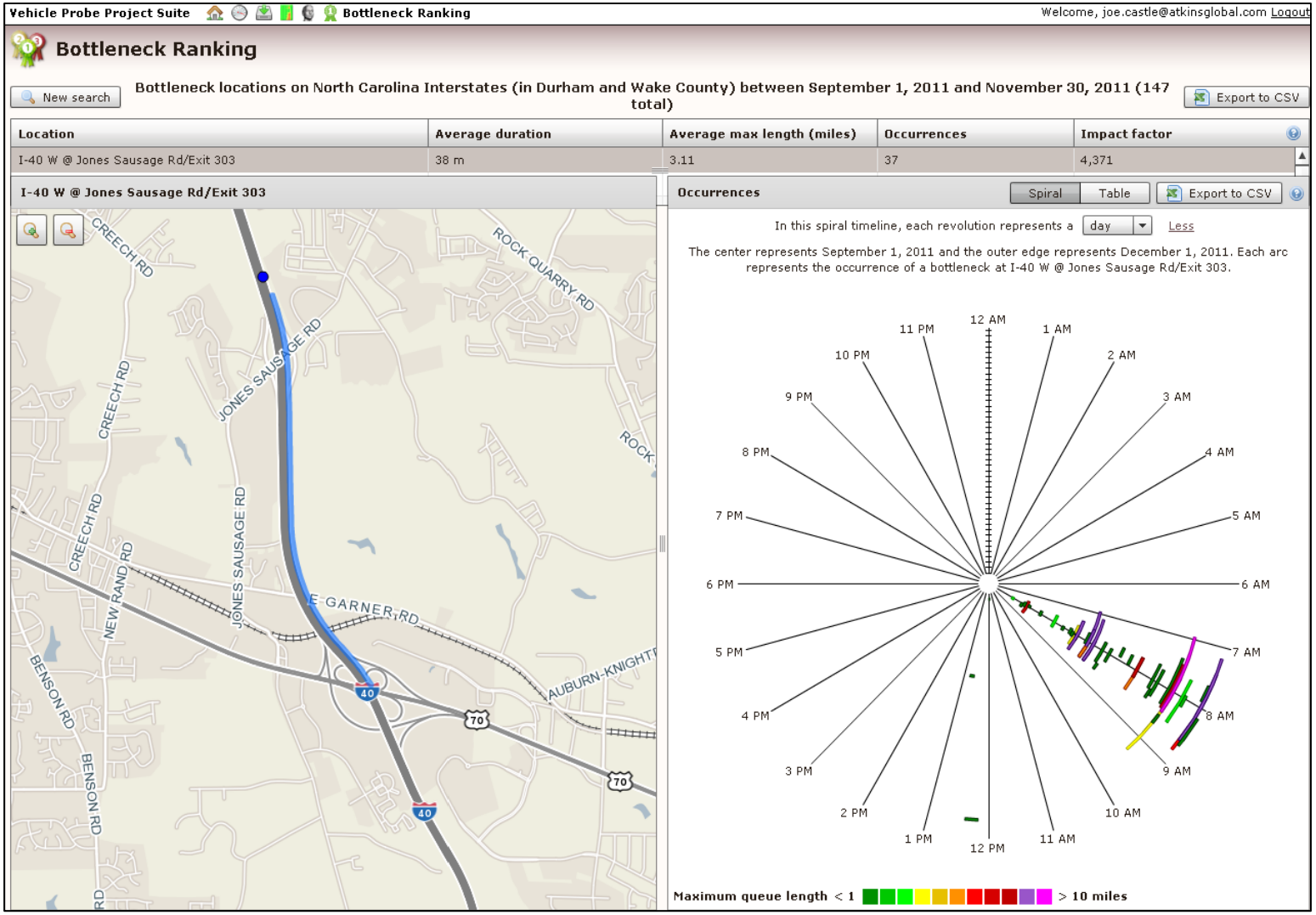


Figure D-14: Congestion Location 054

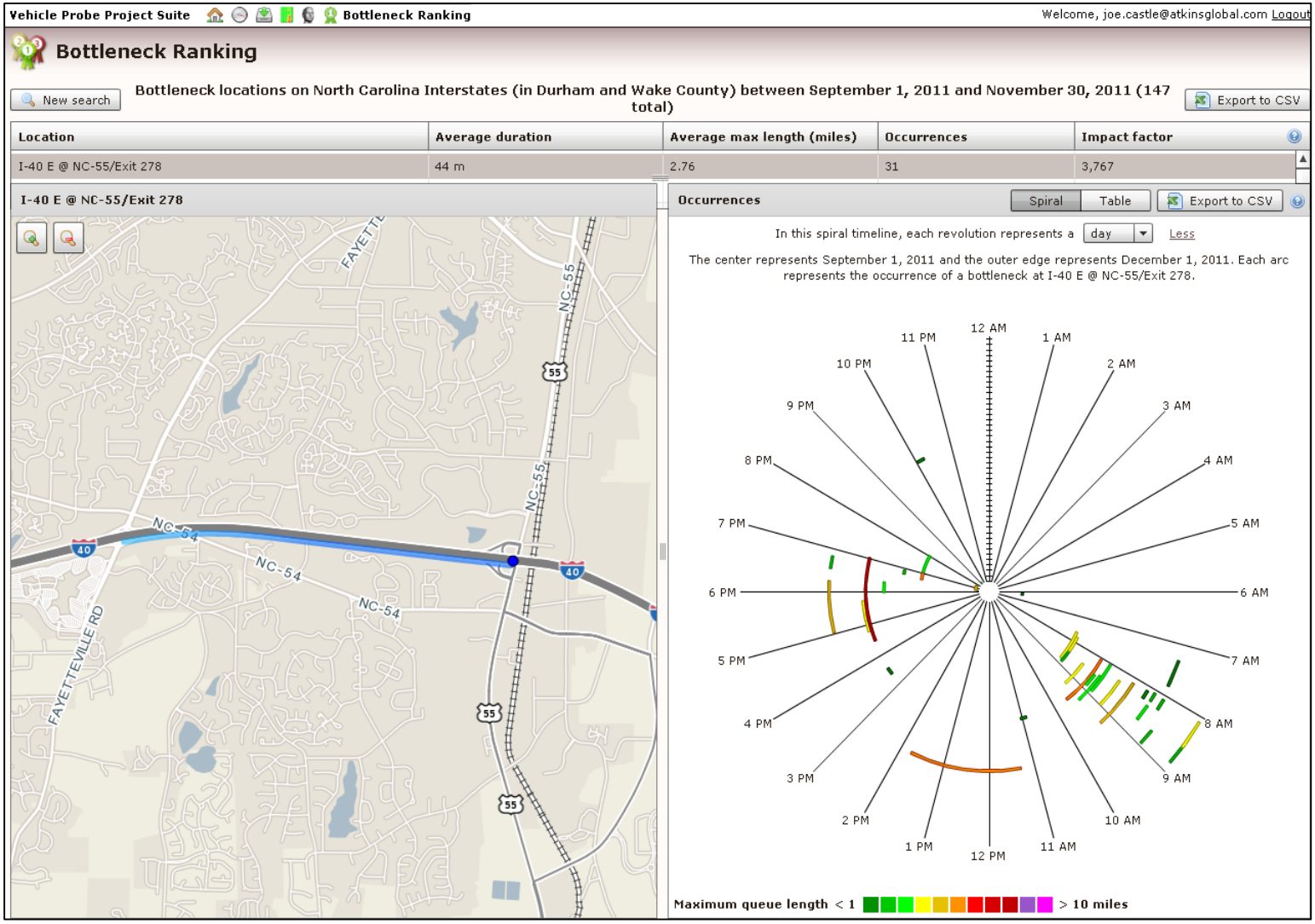


Figure D-15: Congestion Location 060

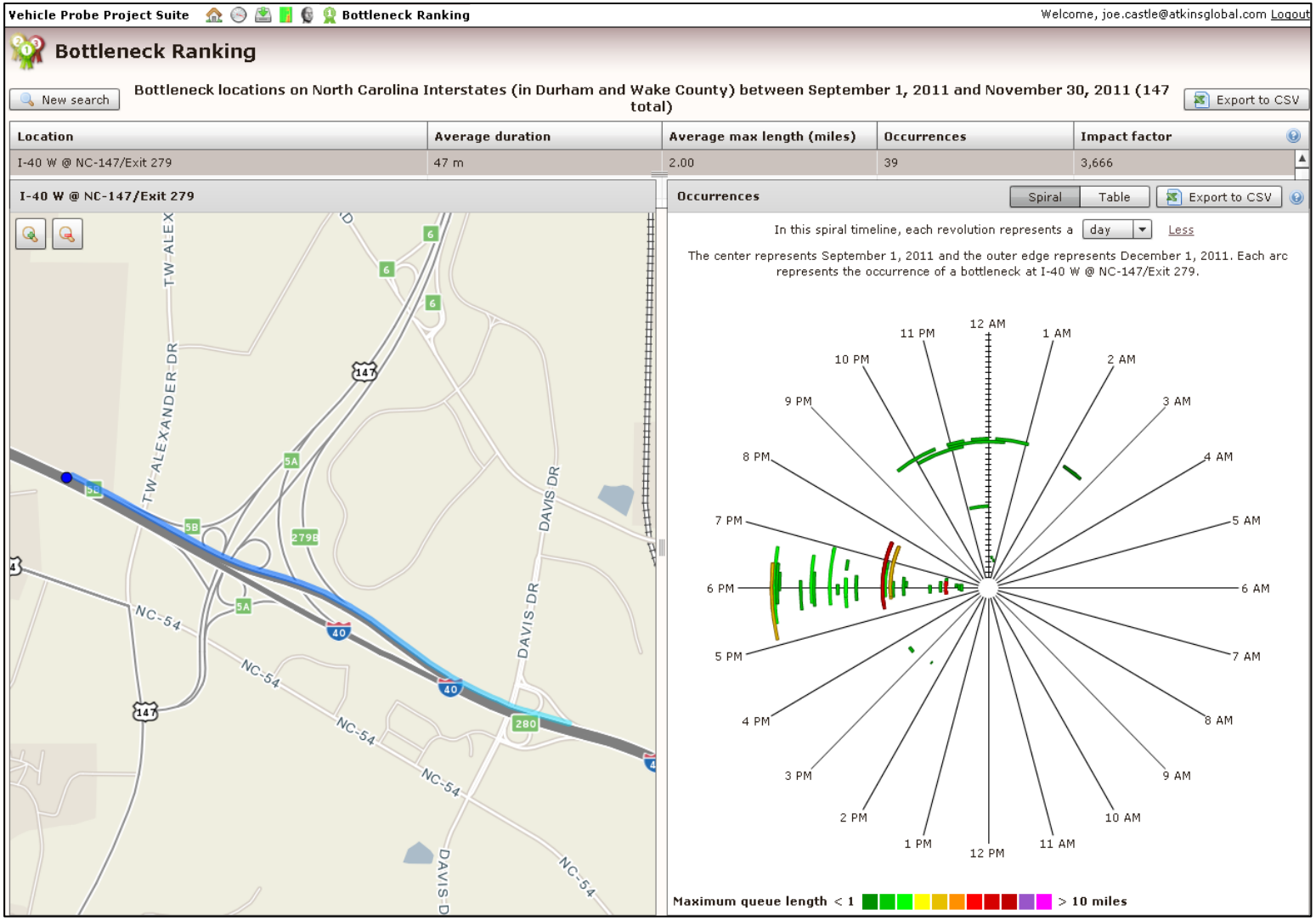


Figure D-16: Congestion Location 061

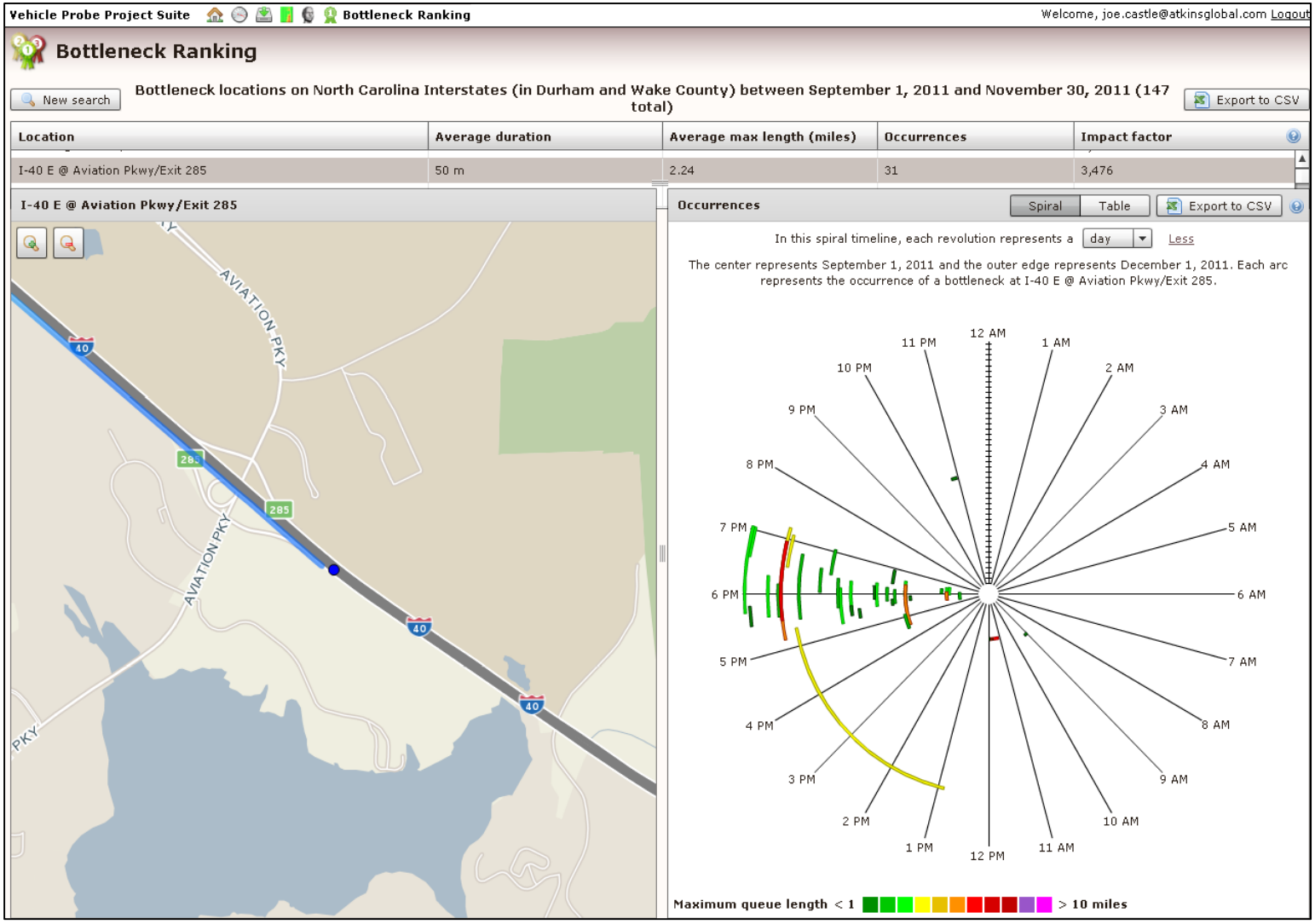


Figure D-17: Congestion Location 062

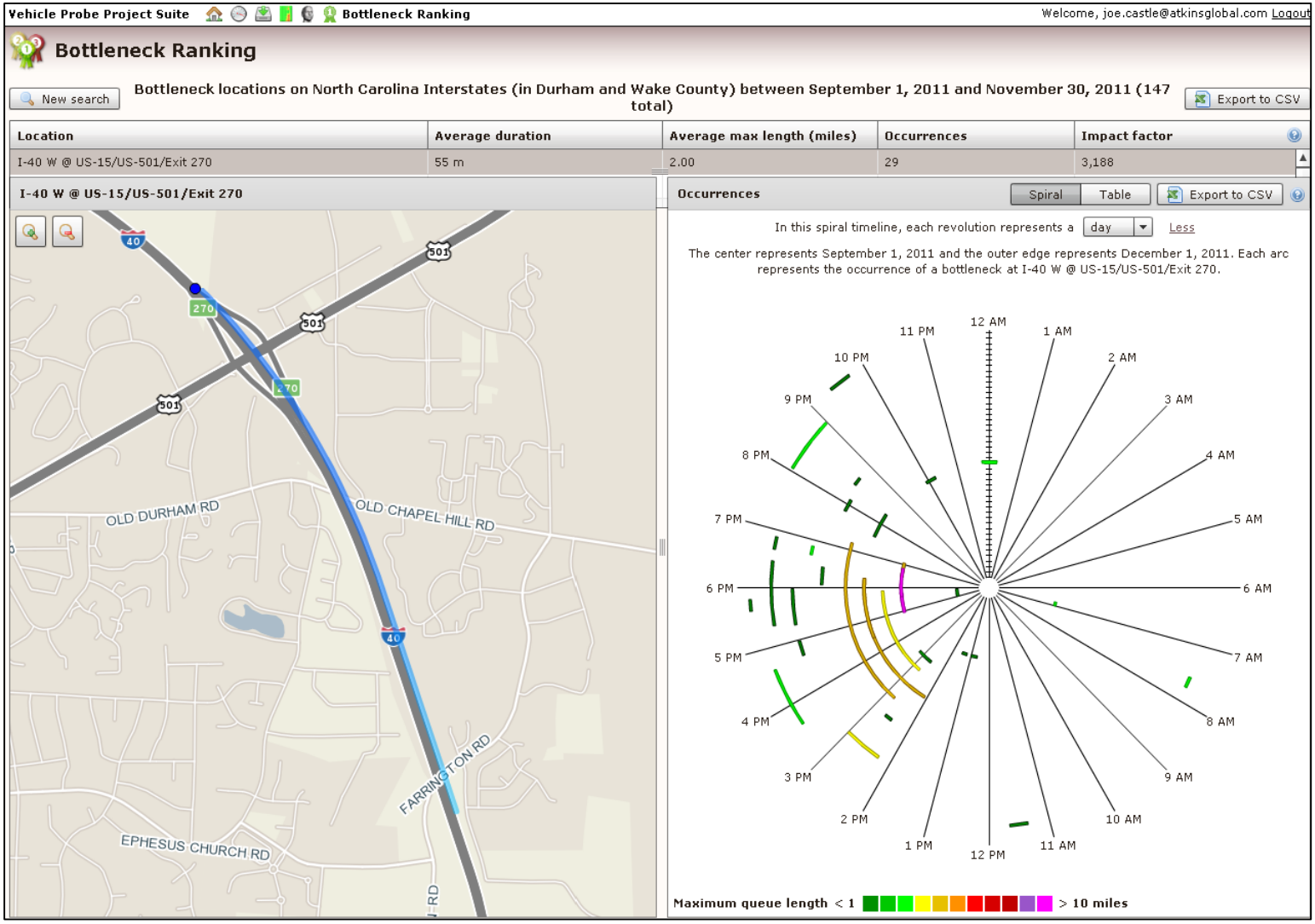


Figure D-18: Congestion Location 068

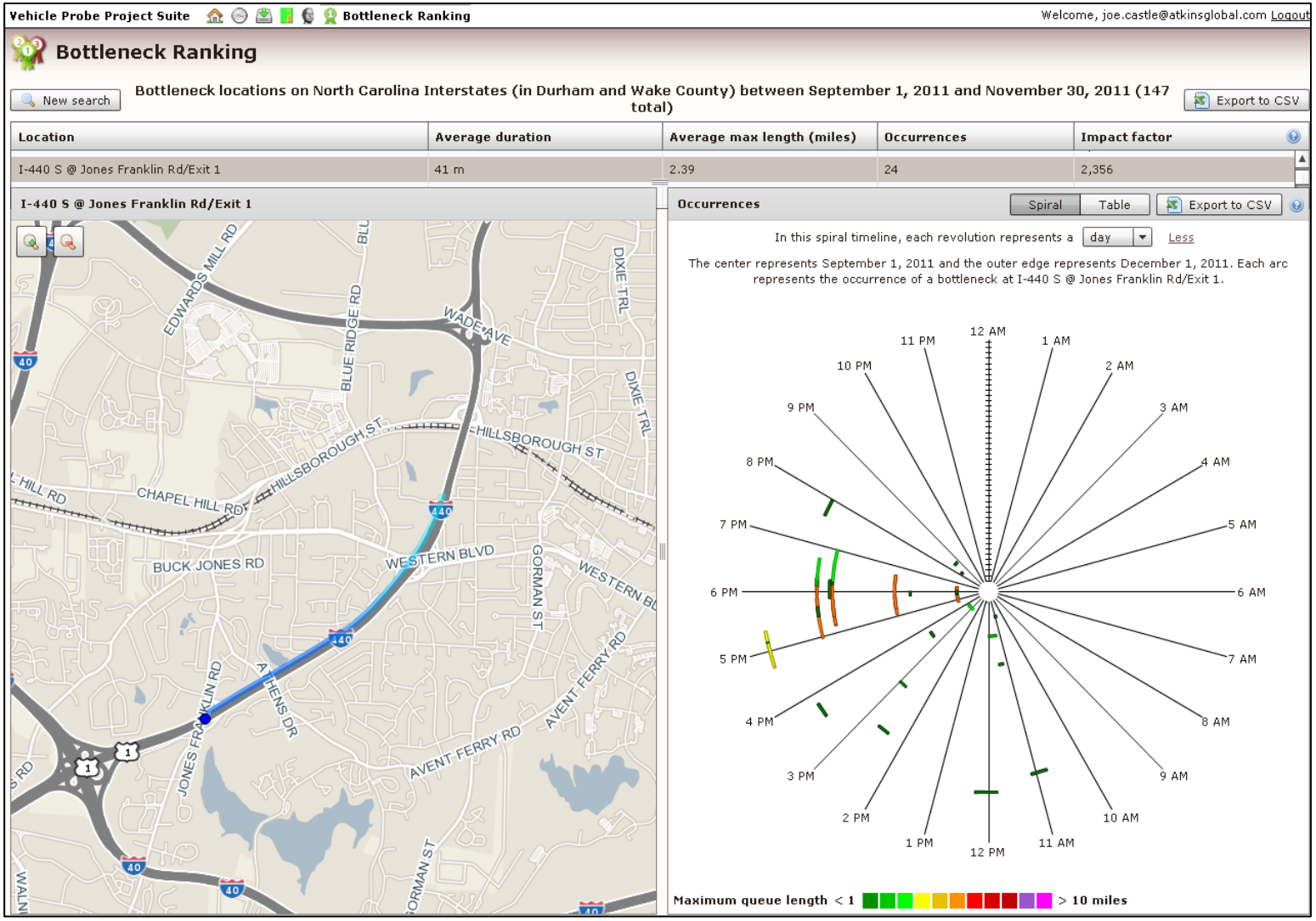


Figure D-19: Congestion Location 073

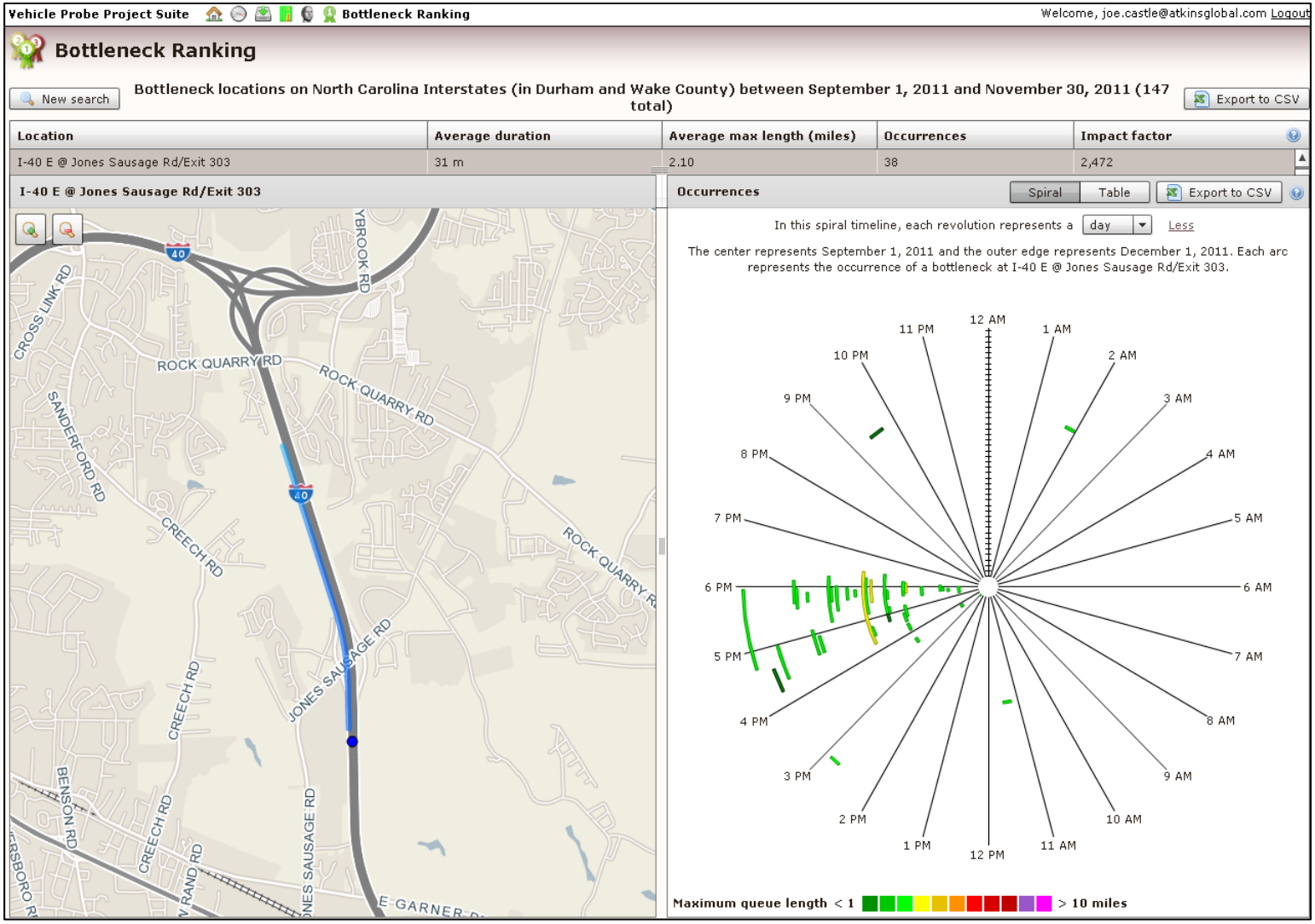


Figure D-20: Congestion Location 077

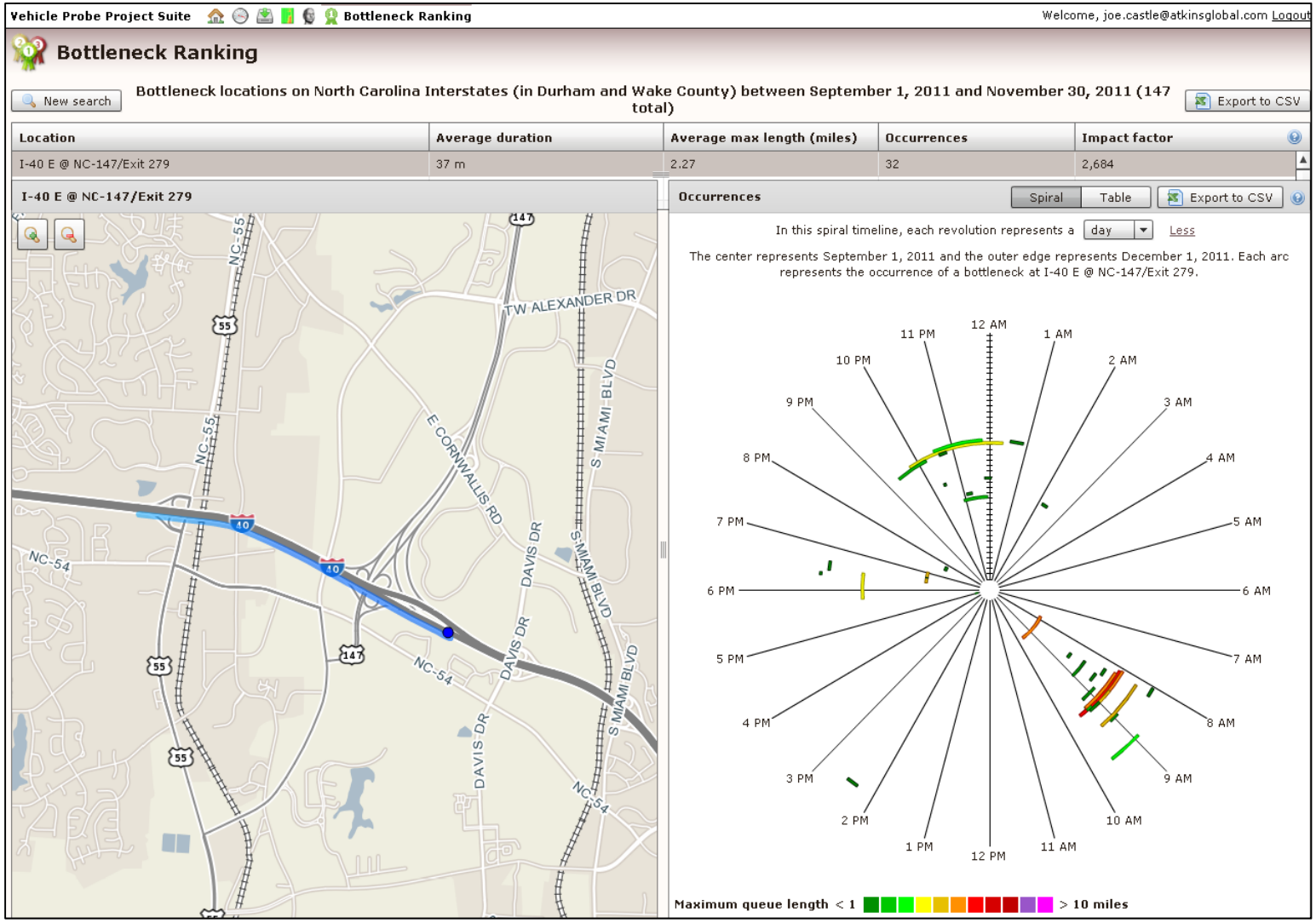


Figure D-21: Congestion Location 082

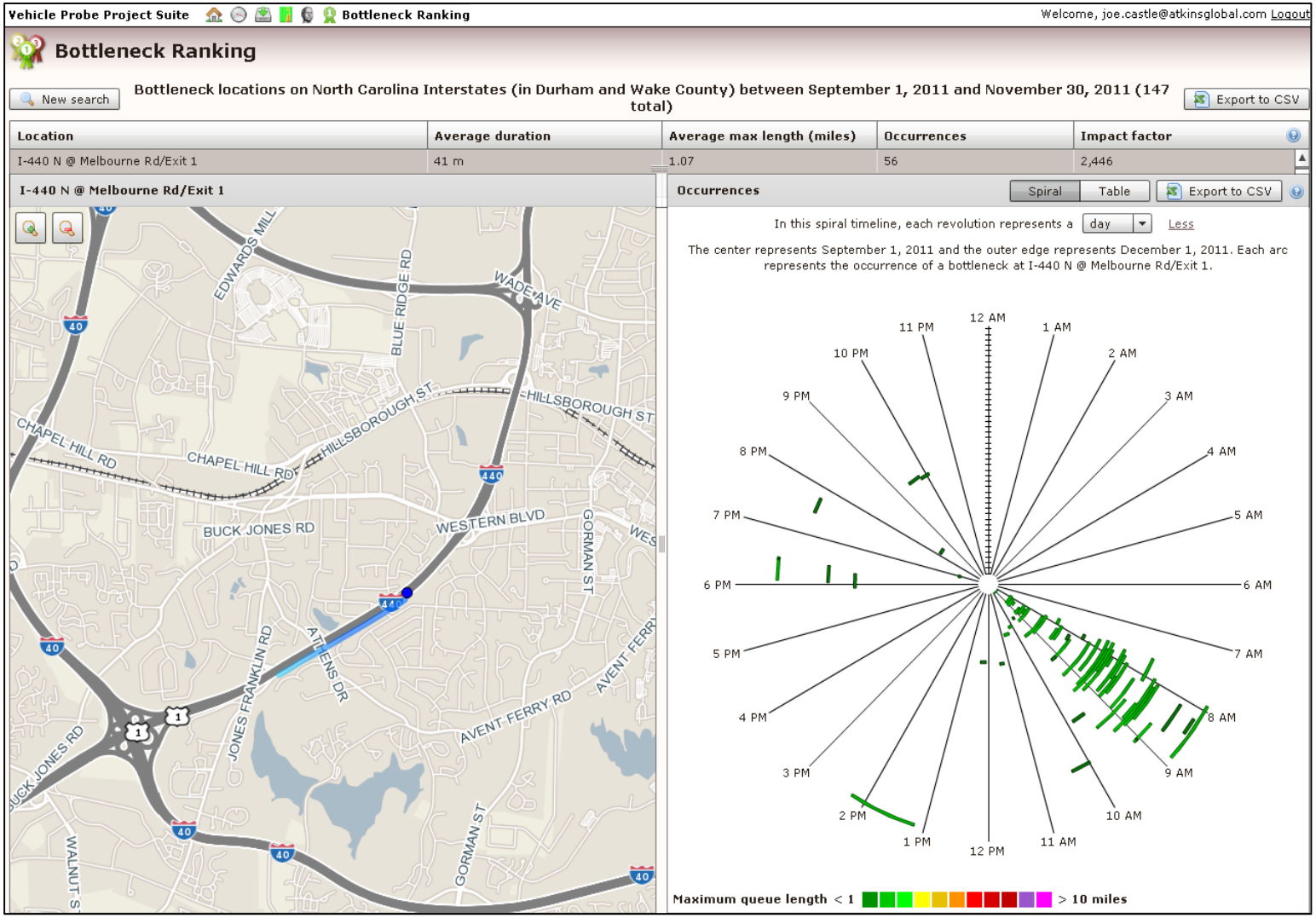


Figure D-22: Congestion Location 086

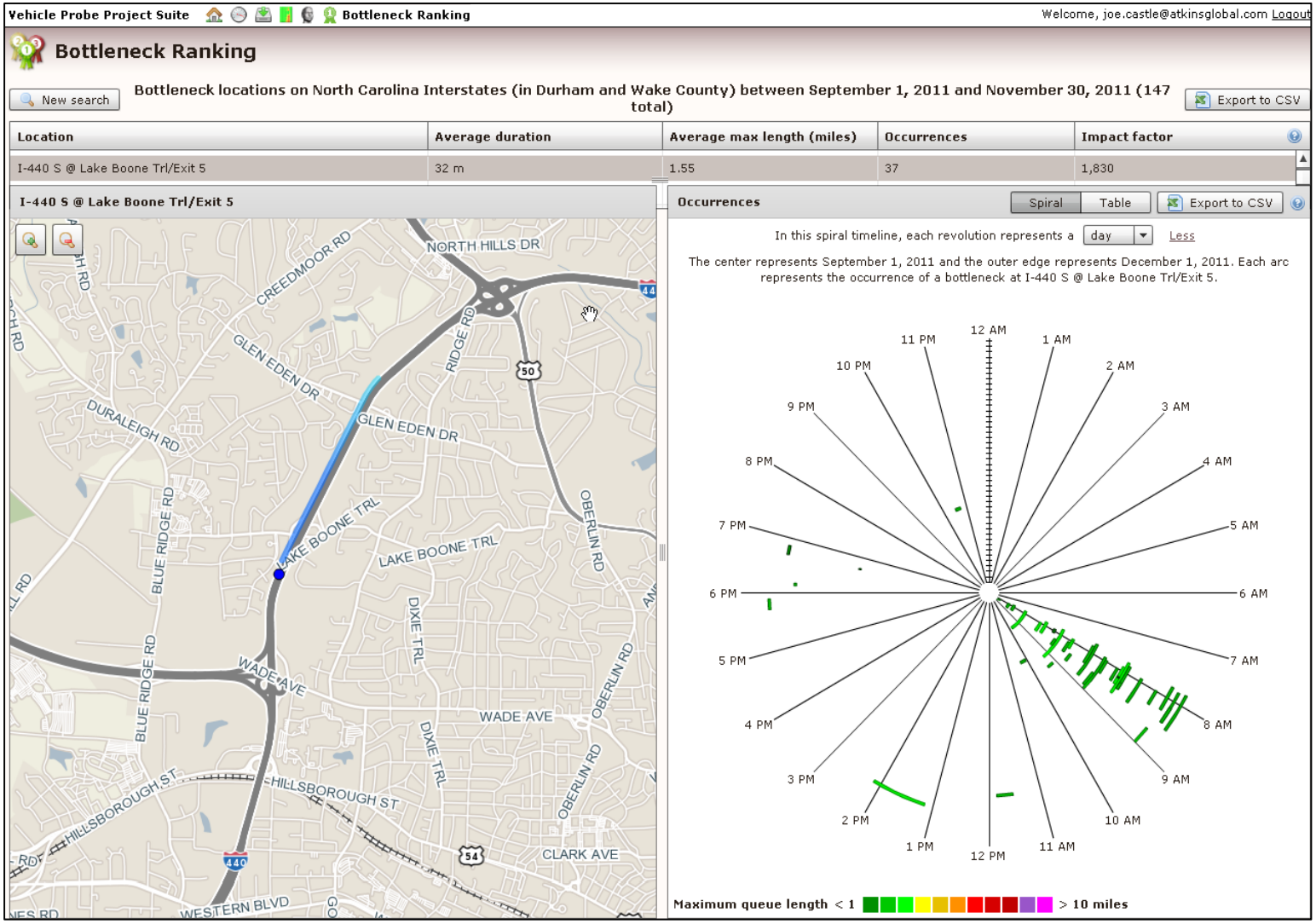


Figure D-23: Congestion Location 093

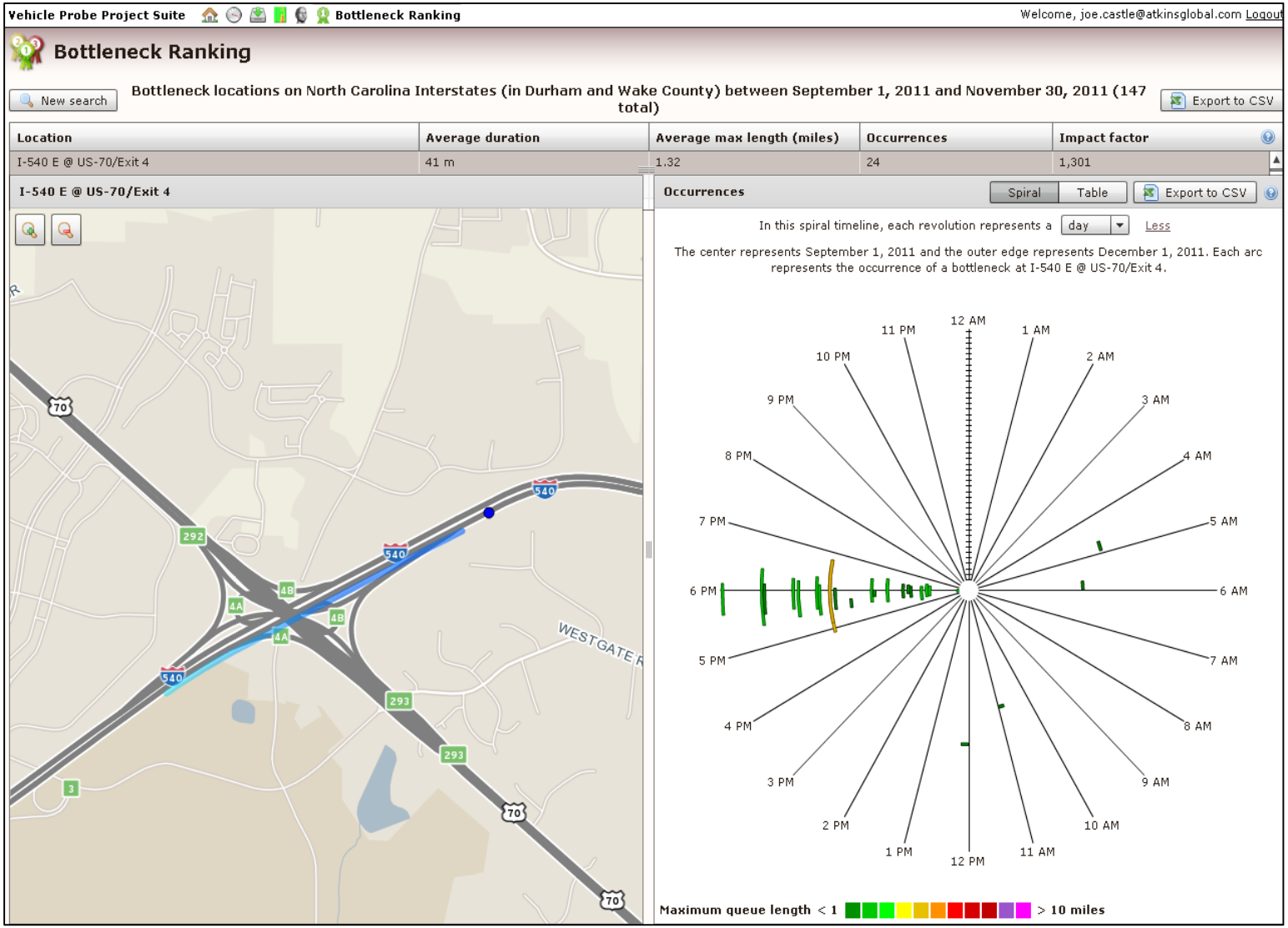


Figure D-24: Congestion Location 101

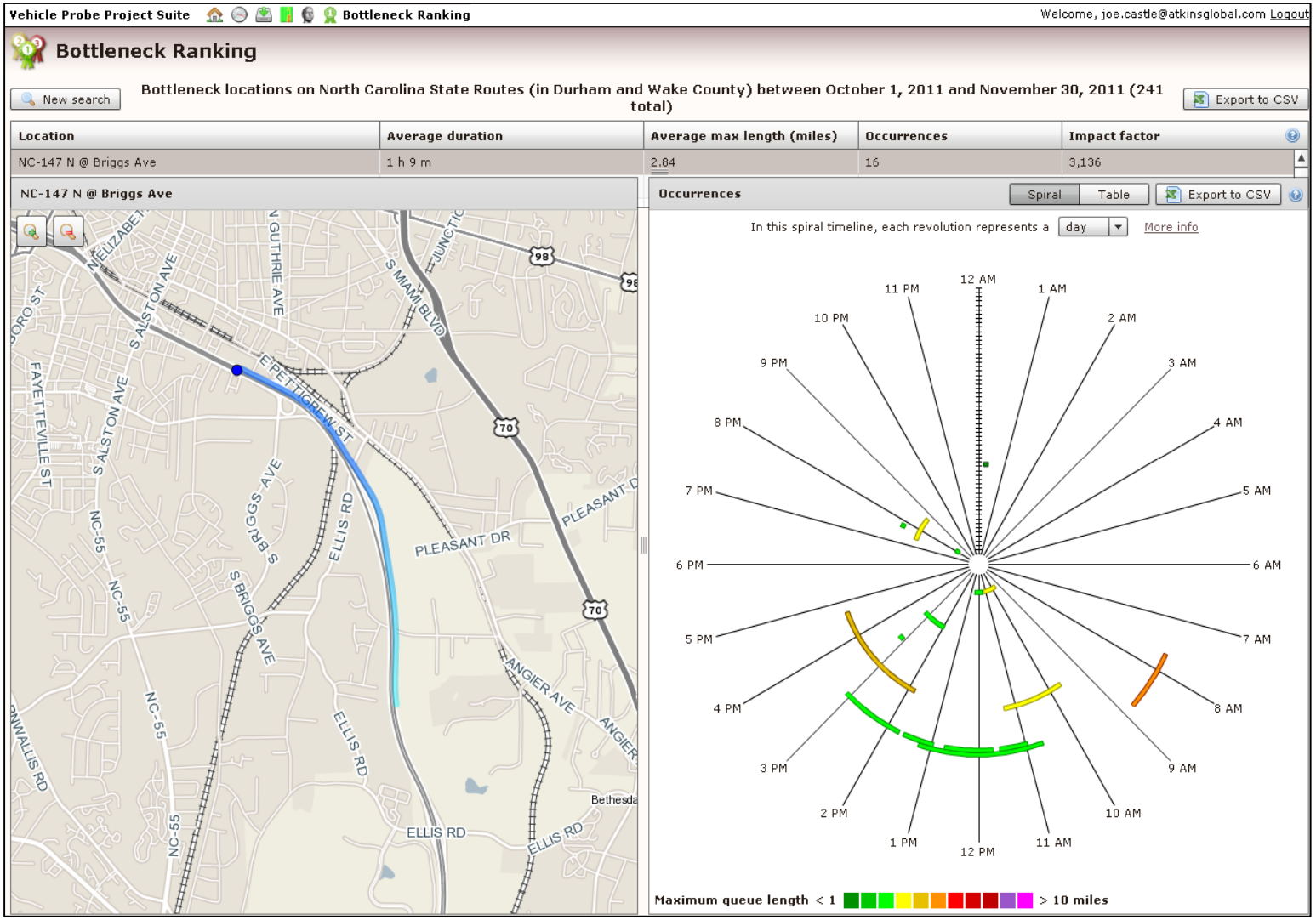


Figure D-25: Congestion Location 148

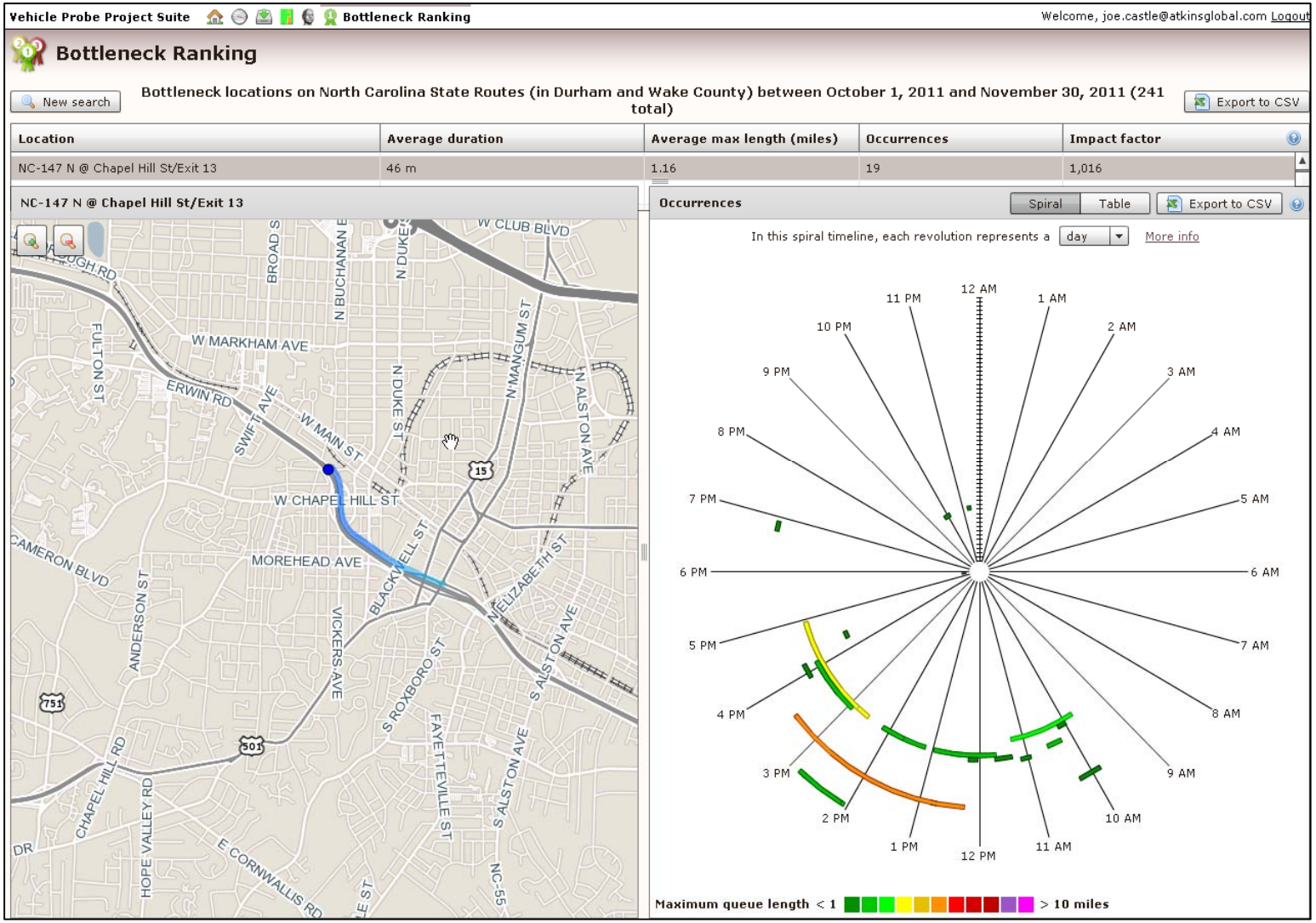


Figure D-26: Congestion Location 149

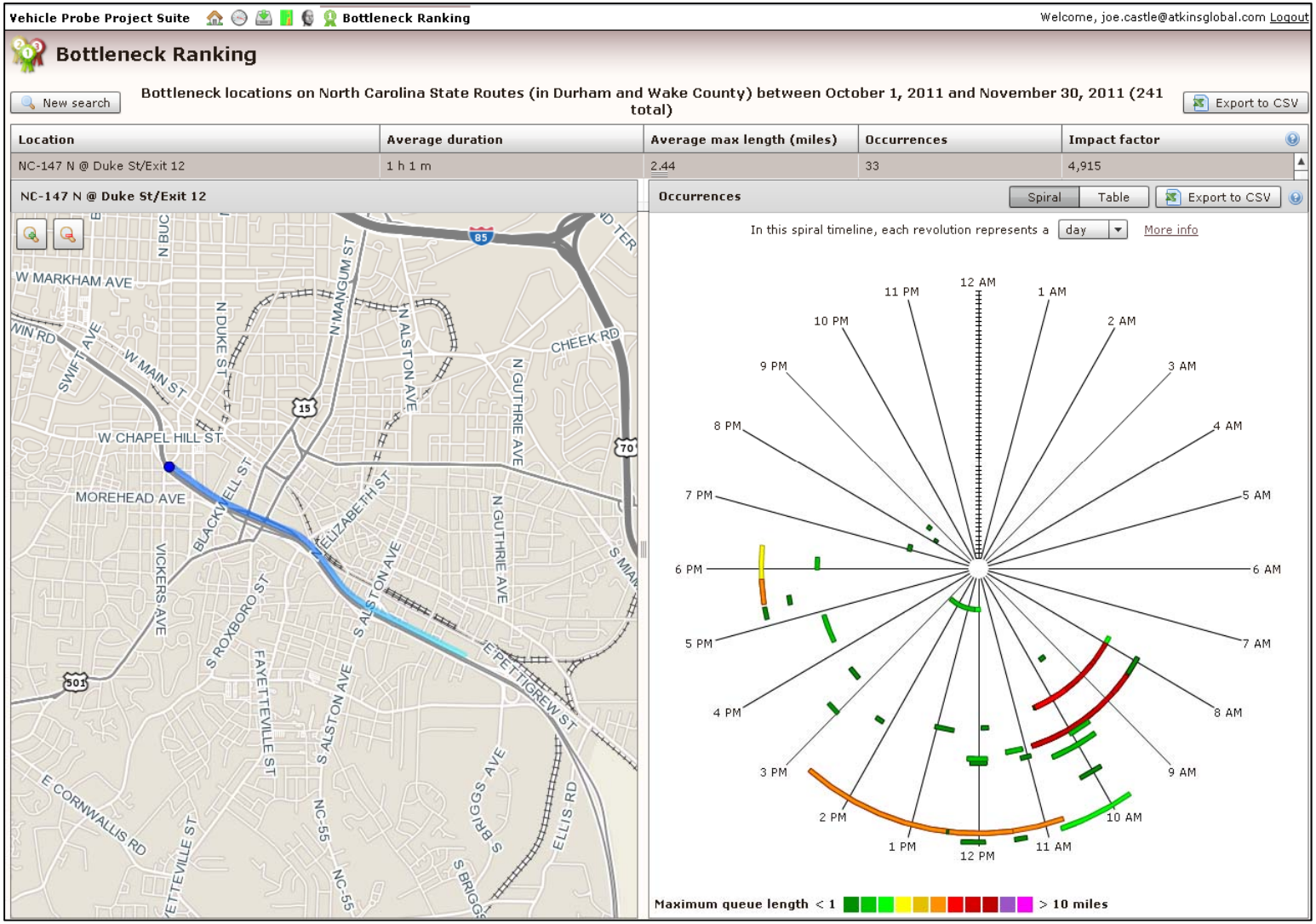


Figure D-27: Congestion Location 151

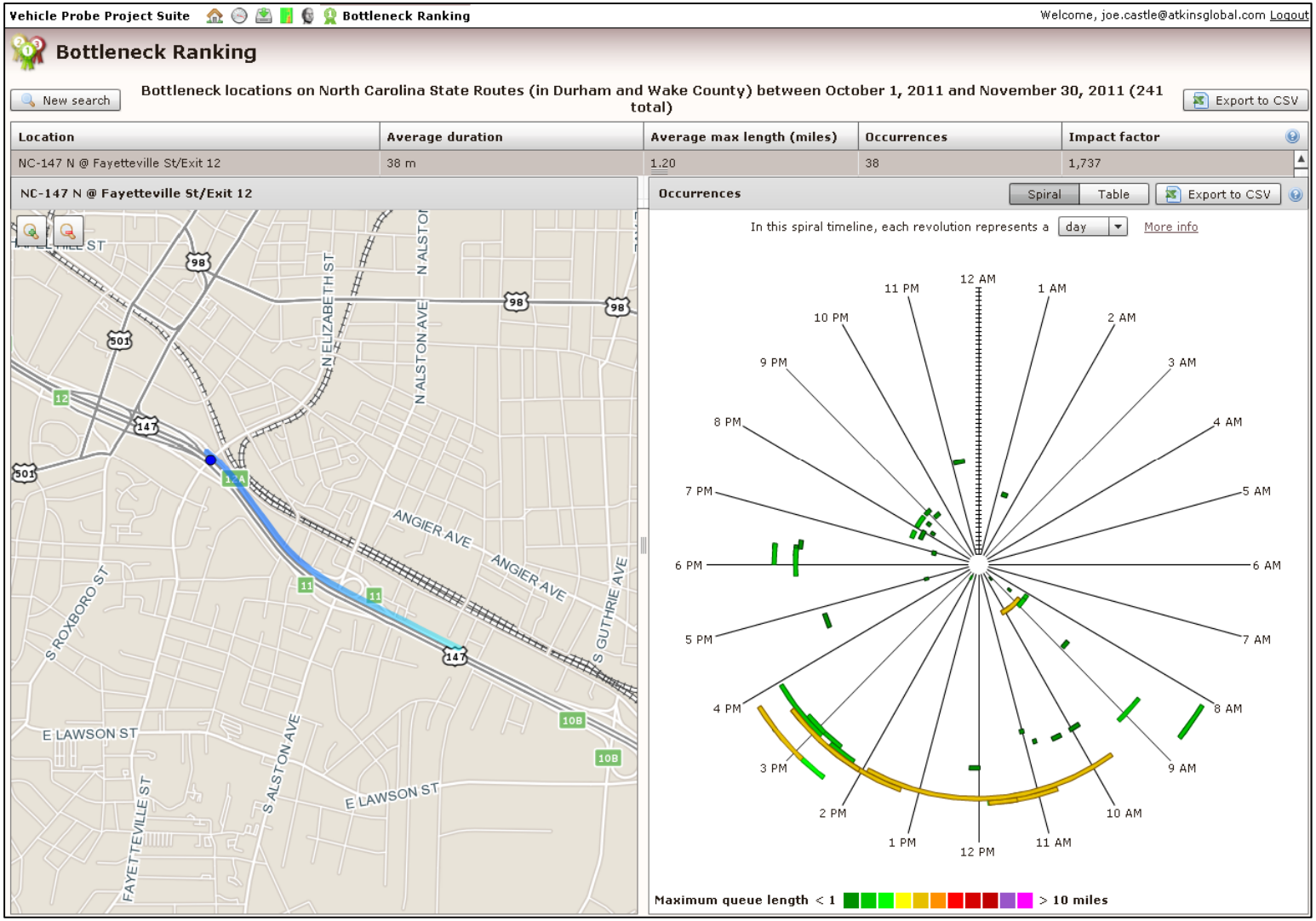


Figure D-28: Congestion Location 154

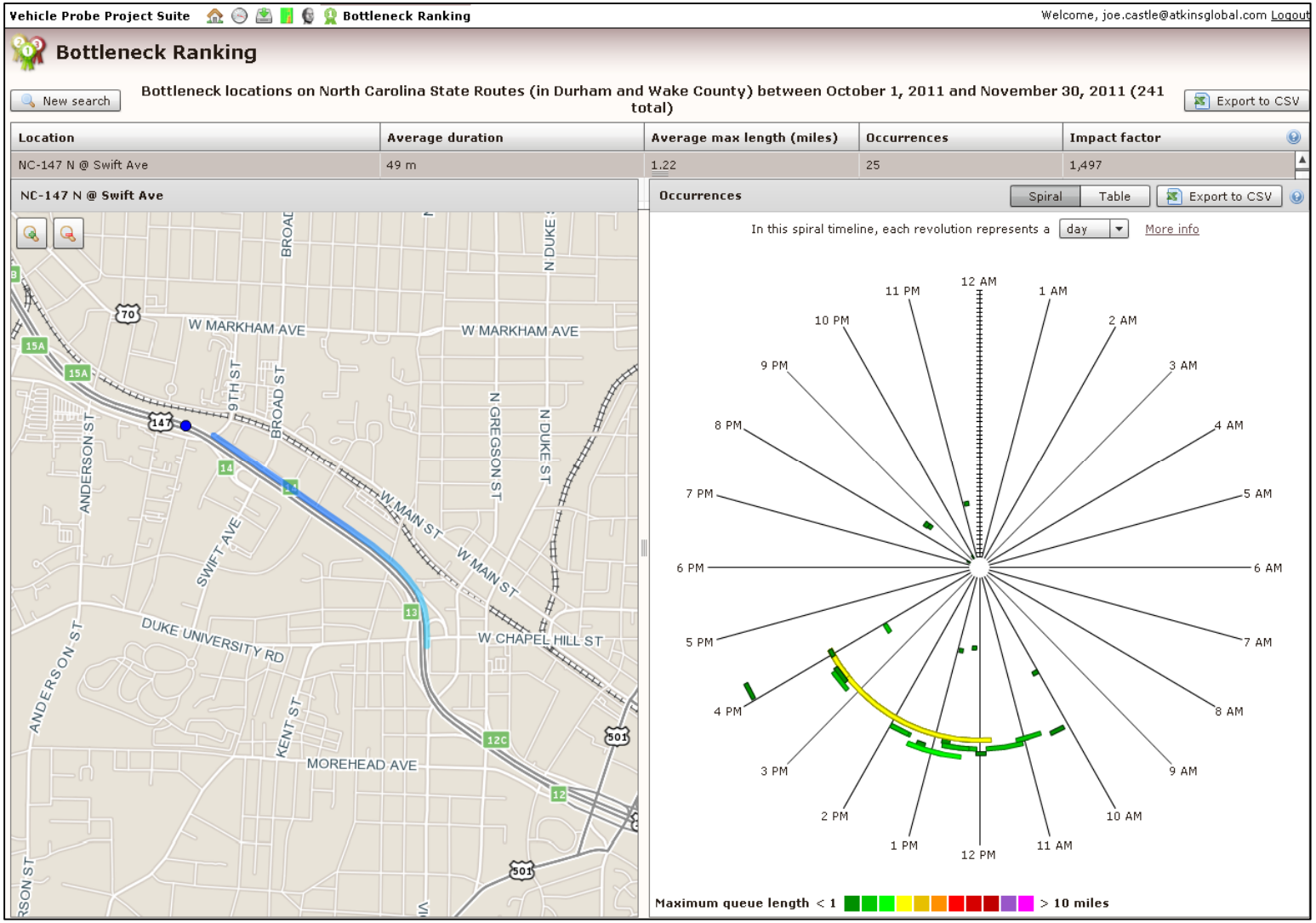


Figure D-29: Congestion Location 159

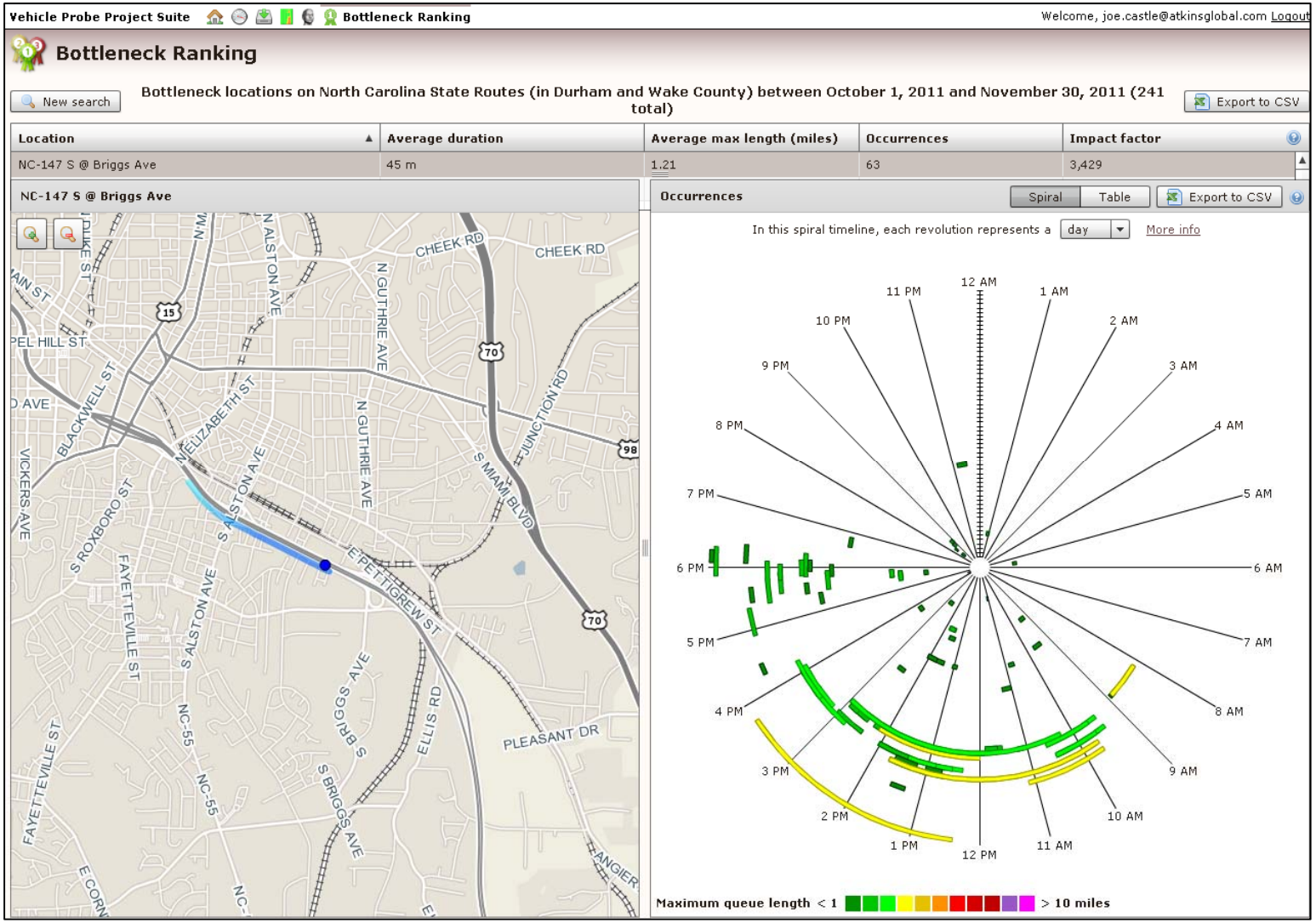


Figure D-30: Congestion Location 162

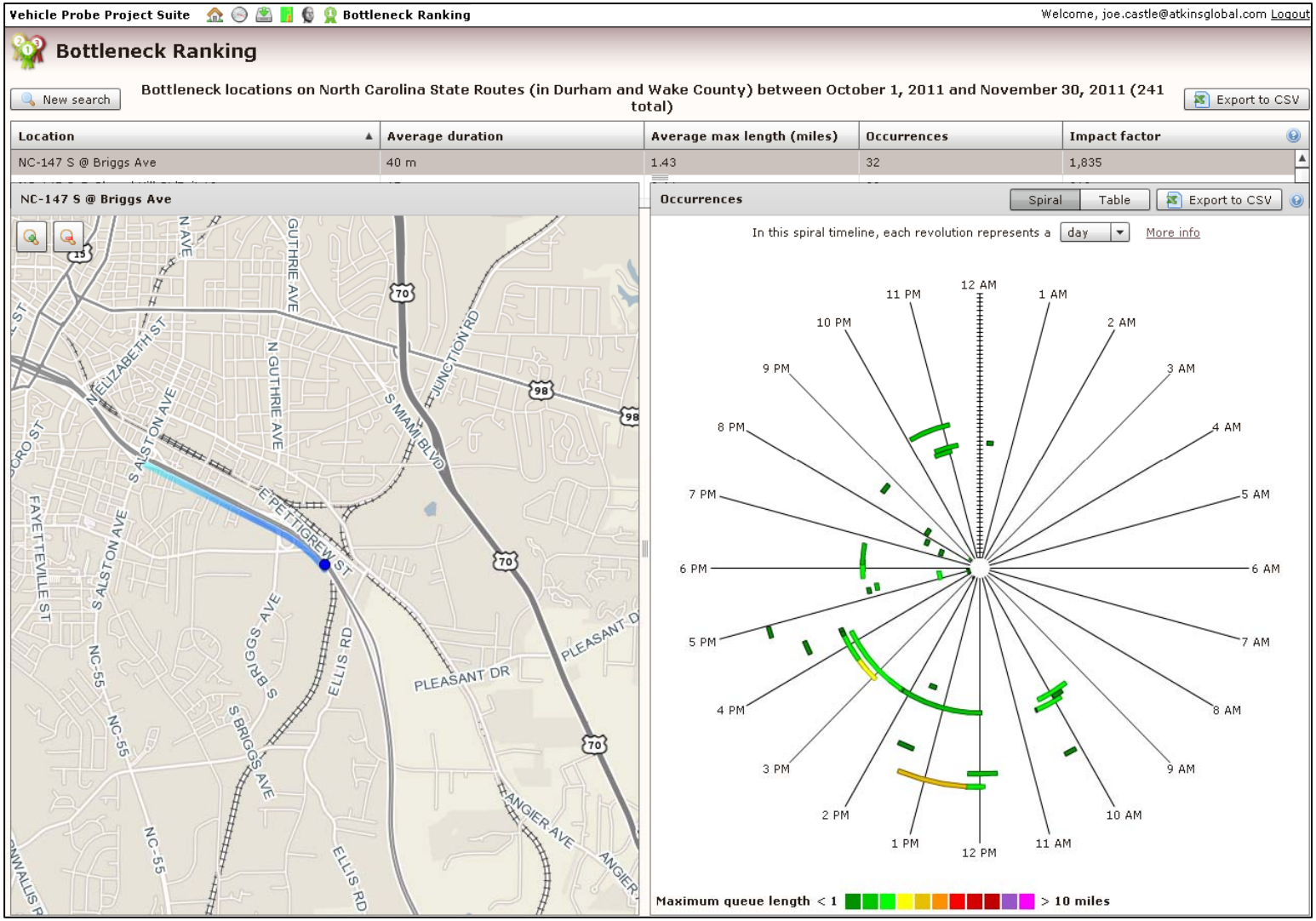


Figure D-31: Congestion Location 163

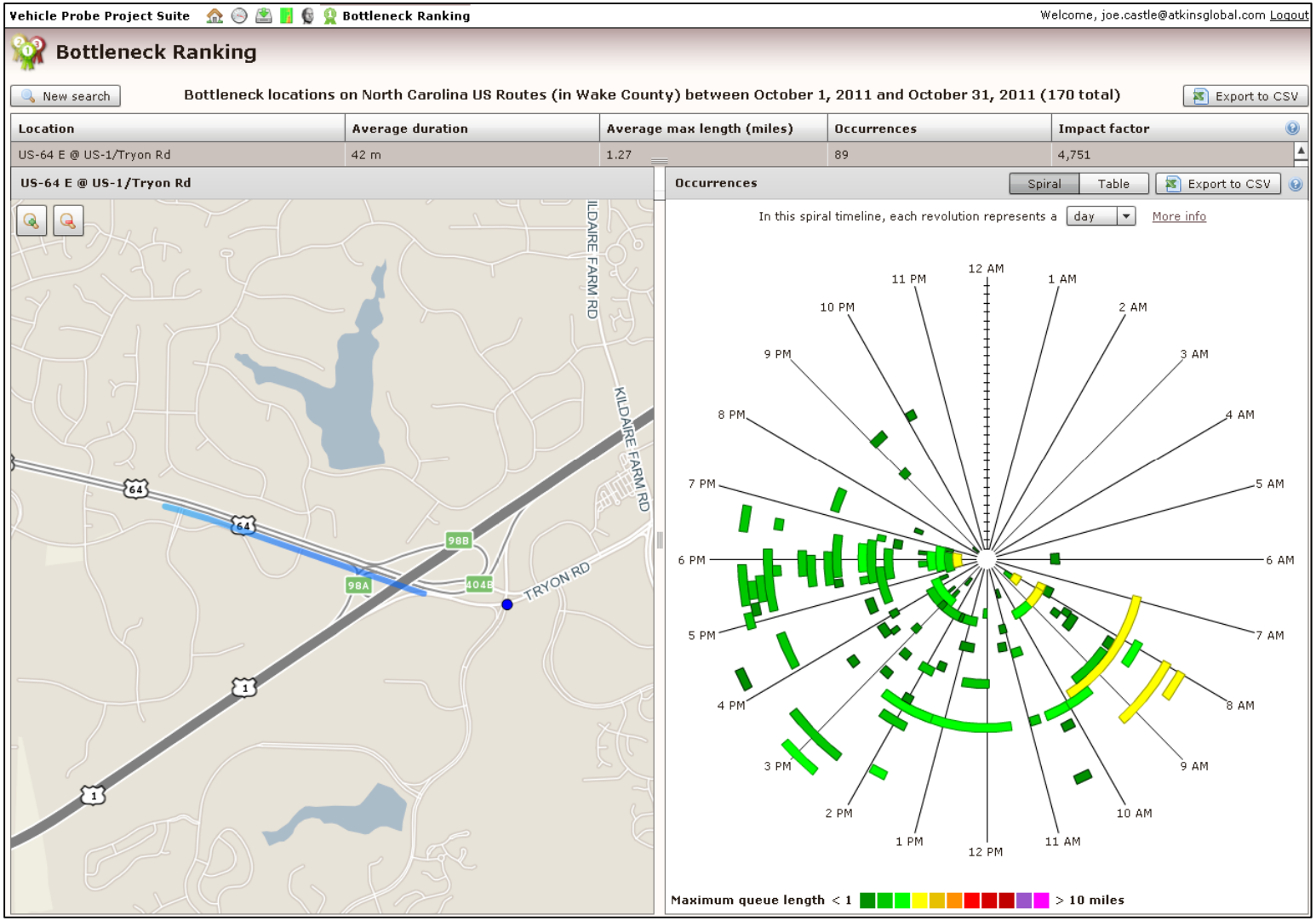


Figure D-32: Congestion Location 179

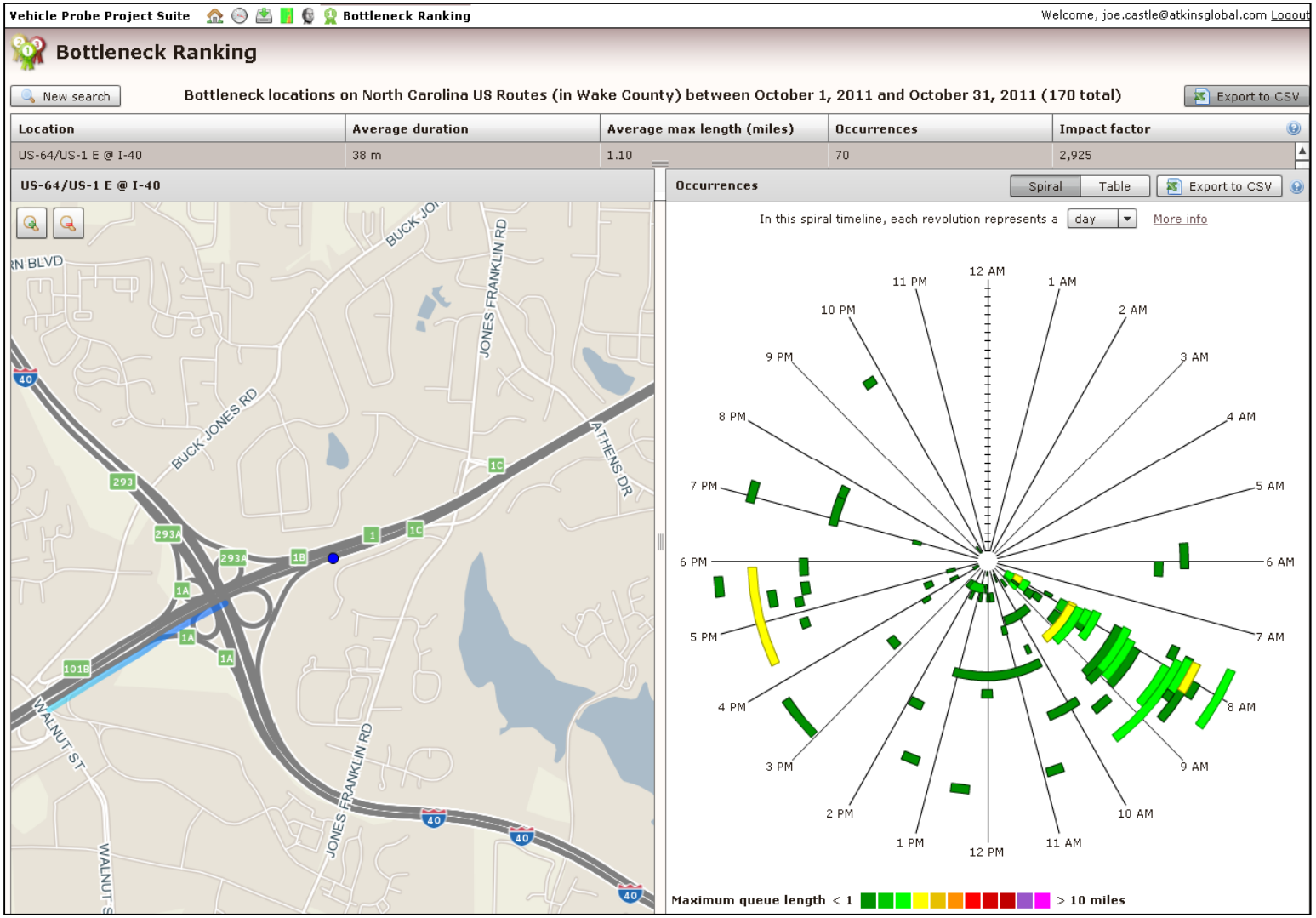


Figure D-33: Congestion Location 184

Alf Badgett, PE
Atkins
5200 Seventy-Seven Center Drive
Suite 500
Charlotte, NC 28217

Email: Alf.badgett@atkinsglobal.com
Telephone: 704-522-7275
Direct telephone:704-665-4403
Fax: 704-525-2838