# I-540 Westbound Ramp Metering Analysis

ATKINS

NC Department of Transportation

Intelligent Transportation Systems Section

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# Notice

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# Introduction

The North Carolina Department of Transportation contracted with Atkins to conduct a more in-depth ramp metering analysis for four locations along I-540 as follow-up to a previous feasibility study conducted by Atkins in 2012 and 2013, *Ramp Metering Feasibility Study for Durham and Wake Counties*. That study used data collected in 2011 and 2012. The North Carolina Department of Transportation is considering these locations to be pilot ramp metering sites in North Carolina. The purpose of this study is to determine if these locations are suitable for ramp metering and if so what improvements are recommended.

This report documents:

- Data Collection
- Traffic Analysis
- Geometric Analysis
- Benefits Analysis
- Financial Analysis

# 1. Goals

The goal of this project is to conduct a more in-depth follow-up (to the previous study *Ramp Metering Feasibility Study for Durham and Wake Counties*) ramp metering analysis for the following ramps on I-540:

1. Site 136*: Leesville Road westbound
2. Site 138: Creedmoor Road westbound
3. Site 140: Six Forks Road westbound
4. Site 142: Falls of the Neuse Road westbound

*site numbers refer to the site number for each site from the previous study

It is understood these locations are candidates for the pilot implementation of ramp metering in North Carolina.

# 2. Objectives

The objectives of this study are:

- Defining which location(s) is/are  good candidate(s), operationally and financially, for ramp metering?
- If so, what specific improvements are needed for a successful implementation?
- For those locations which are not good candidates for ramp metering, documenting clearly why not?

# 3. Existing Conditions

Data has been summarized in the same manner as the previous study to maintain the consistency of the data and a single regional source for information.

A variety of data was collected at each of the four sites including:

- 24-hour traffic counts in 15 minutes intervals upstream of each of the four ramps in the study
- 24-hour traffic counts in 15 minutes intervals on each of the four ramps in the study
- AM peak hour turning movement counts at the traffic signal at the intersection of each ramp with its respective crossroad.
- Crash data
- Geometric data of the ramps
- Traffic signal timing and phasing
- Travel time runs along I-540 in the AM peak period
- Congestion scan data using the RITIS Vehicle Probe Project web-based tool

## 3.1. 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. In prior work for NCDOT, maximum and minimum volumes were described in the *Ramp Metering Feasibility Study for Durham and Wake Counties - Typical Design Criteria Report*, 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.

Results of the 24-hour 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. The Site Summaries are located in Appendix A. 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.

All traffic count data for a site was collected during the same periods on the same day to minimize issues with mismatching data. The upstream count of I-540 and its corresponding ramp count were used to derive volume downstream of the ramp merger.

## 3.2. Crash Data

NCDOT provided three (3) years' worth of crash data (2010–2013) for the mainline in the vicinity of each of the potential ramp metering sites. These data have been analyzed to identify rear-end crashes (slowing or stopping vehicles) and sideswipe crashes where both vehicles are traveling in the same direction. These types of accidents are associated with congestion and are potentially correctible with implementation of ramp metering.

## 3.3. Geometric Data

A high-level geometric analysis using aerial photography identifies the following characteristics for each of the sites:

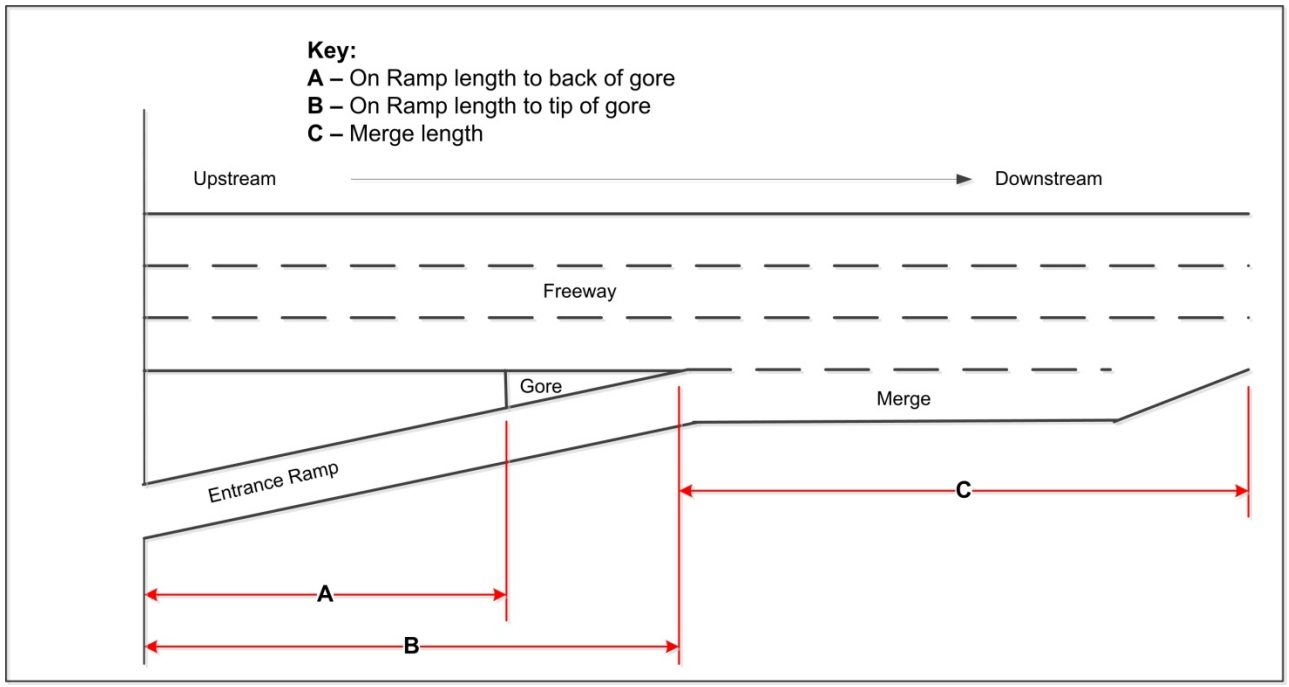
- Origin – briefly describes the interface between the local road and the entrance ramp
- Number of origins – captures the number of entrances onto the main entrance ramp
- Lane addition – determines whether there is a lane addition from the entrance ramp onto the freeway
- Length of lane addition – 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 – documents the 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 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 1)
- 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 1)
- 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 1)

- 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 1.

Geometric characteristics have been documented and to provide a useful overview of each candidate ramp metering site.

**Figure 1. Measurements of Key Distances in Geometric Analysis**




Each potential ramp metering site was 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 above
- 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., restriping to increase the number of lanes on the entrance ramp)
- 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

## 3.4. Traffic Signal Timing and Phasing

The presence of traffic signals at the intersection of the cross street and the entrance ramp have a significant impact on the operation of a ramp meter and vice versa. It is important to know the size of the platoons of traffic released by the upstream traffic signal onto a ramp, especially where ramp volumes are high or the entrance ramp is short. In this study area, protected only left turn phases create significant platoons such that the only traffic not in platoons is the right turn traffic.

Traffic signal information and comments for these sites is included in the Signalization Overview section of the Site Summaries located in Appendix A.

## 3.5. Bottleneck Tool Data

Bottleneck data from the VPP Suite was collected at 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.

### 3.5.1. Analysis of Bottleneck Data

Three months of historical bottleneck data in the spring and in the fall were downloaded separately for I-540. Neutral time periods (that is, not impacted by significant recurring traffic trends or patterns) were chosen:  March 1 to May 31, 2013 and September 1 to November 30, 2013.

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 bottleneck application records/displays all bottlenecks within the sample period, even if the bottleneck is not regular or significant. The downloaded data includes:

- 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

### 3.5.2. Results

The bottleneck locations coincide with the merge of an entrance ramp, suggesting that the merge could be a source for congestion. Entrance ramps adjacent to the bottleneck and the associated congestion spilling back upstream are considered “congested” and were identified and documented. Screenshots of bottleneck maps and time spirals for each of the significant bottlenecks used to identify “congested” sites and “significant” bottlenecks are located in the Bottleneck Information section of the Site Summaries located in Appendix A.

All locations, except Falls of the Neuse Road, met the threshold requirements for congestion to warrant a ramp meter. Falls of the Neuse Road only had 11 occurrences in the 6 months, which is significantly below the criteria of two occurrences per week. Table 1 below summarizes the results of the bottleneck data.

**Table 1. 2013 Bottleneck Data Comparison with 2011 Data**

| Location | Average Length of Congestion (miles) | | Duration of Congestion (Min.) | | Number of Occurrences | | Typical Times of Congestion | |
|---|---|---|---|---|---|---|---|---|
| | 2011 | 2013 | 2011 | 2013 | 2011 | 2013 | 2011 | 2013 |
| Leesville Road | 4.4 | 7.2 | 44.0 | 73.0 | 14.0 | 22.0 | 8:00-9:15 AM | 7:45-9:15 AM |
| Creedmoor Road | 1.5 | 3.9 | 24.5 | 51.5 | 20.5 | 43.5 | 8:00-9:00 AM | 7:30-9:30 AM |
| Six Forks Road | 1.6 | 2.8 | 20.0 | 31.0 | 10.5 | 8.5 | 8:00-9:00 AM | 7:30-9:00 AM |
| Falls of the Neuse Road | 1.1 | 0.7 | 15.0 | 24.5 | 7.5 | 5.5 | 7:30-8:30 AM * | N/A |

# 4. Analysis of Existing Conditions

## 4.1. Screening Analysis

### 4.1.1. Site Characteristics

The sites were checked to ensure the congestion is not attributable to influences other than traffic volumes. These potential influences could be road and lane closures, or construction projects. A site could also be upstream of another candidate site whereby the downstream site could be the primary source of congestion.

#### 4.1.1.1. Site Subject to Congestion from Lane Closures for a Roadway Project

For this project, there were no construction or lane closures during the study period. Since the field data collection ended, NCDOT has started reconstruction on I-440. NCDOT expects there will be traffic diversions from I-440 to I-540 due to lane closures. Atkins collected the traffic counts in 2013 prior to the I-440 project starting construction. The travel time runs were collected after the I-440 lane closures began. Therefore, additional traffic counts were collected on I-540 from NCDOT's permanent microwave radar detectors to assess if traffic diversion may be occurring that could contribute to increased congestion.

#### 4.1.1.2. Site Upstream of a Primary Site

A primary source of congestion occurs when the congestion begins at a downstream site and extends upstream into another or secondary site. If ramp metering were implemented at the upstream or secondary site the full benefit for improvements in congestion would not be realized until the primary source of congestion was addressed.

For this project, the Leesville Road ramp serves as the primary source of congestion for the Creedmoor Road ramp in the fall but not in the spring of 2013. The Creedmoor Road ramp also serves as the primary source of congestion for the Six Forks Road ramp for both the spring and fall 2013 data.

## 4.2. Analysis of Traffic Flow Data

### 4.2.1. Capacity Analysis

An operational analysis of the existing conditions was performed for the four on-ramp locations along westbound I-540 identified as potential sites for ramp metering. The on-ramps were analyzed for the AM peak hour, which is the peak direction of travel. The analysis was performed using the ramps module for merge junctions of 2010 Highway

Capacity Software (HCS), which is based on methodologies from the 2010 Highway Capacity Manual (HCM).

Traffic volumes used in the analysis of the merge junctions were developed from 24-hour traffic counts collected in December 2013. The 15-minute intervals were aggregated into hourly volumes, from which the AM peak hour volume was identified. The peak hour factor (PHF) was calculated using the highest 15-minute volume of the peak hour volume.

The HCS analysis showed that three of the four of the sites operate at LOS D or better during the AM peak hours. The analysis results are shown below in Table 2. The HCS analysis worksheets are contained in Appendix B.

**Table 2. I-540 Westbound Capacity Analysis Results**

| Location | Peak Hour Volume | | Level-of-Service | Density (pc/mi/ln) |
|---|---|---|---|---|
| | Upstream Freeway | On-Ramp | | |
| Leesville Road | 5,881 | 1,429 | F | 37.7 |
| Creedmoor Road | 5,412 | 963 | D | 33.5 |
| Six Forks Road | 5,096 | 976 | B | 19.5 |
| Falls of the Neuse Road | 4,230 | 1,520 | D | 34.1 |

### 4.2.2. Ramp Meter Suitability Analysis

A ramp meter suitability analysis examines if the right traffic characteristics exist that are favorable to ramp metering. This analysis employs two sets of criteria, one for ideal conditions and the other for acceptable conditions. This analysis compares the 24-hour traffic counts on the ramp to those on I-540. Figure 2 shows the relationship to the criteria described below.

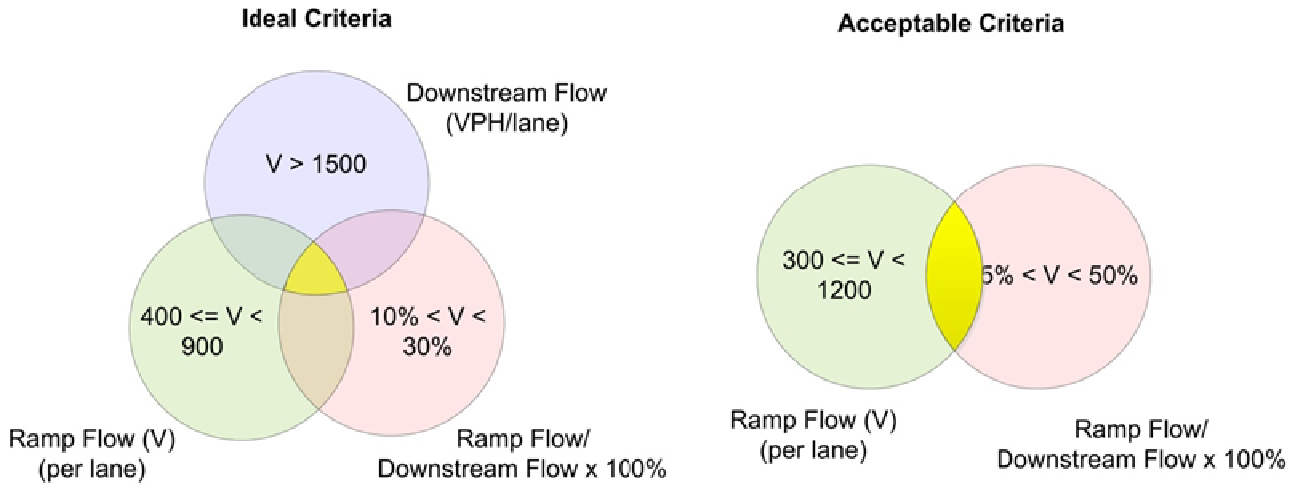
The ideal conditions are met if:

- 400 vph/lane <= ramp volume < 900 vph/lane, and
- 10% < ramp volume/I-540 downstream volume x 100% < 30%, and
- I-540 downstream volume > 1,500 vph/lane.

The acceptable conditions are met if:

- 300 vph/lane <= ramp volume < 1,200 vph/lane, and
- 5% < ramp volume/I-540 downstream volume x 100% < 50%.

**Figure 2. Ramp Meter Suitability Analysis**




Based upon the traffic counts, the results are shown in Table 3 below. The details for each ramp can be found in the Traffic Volumes section of the Site Summaries

**Table 3. Ramp Meter Suitability Analysis**

| Location | Hours Meeting Criteria | |
|---|---|---|
| | Ideal | Acceptable |
| Leesville Road | 7:15-8:45 AM | 6:15-9:15 AM |
| Creedmoor Road | 7:15-9:00 AM | 6:30-9:00 AM |
| Six Forks Road | 6:45-8:15 AM | 6:30-9:00 AM |
| Falls of the Neuse Road | 6:30-8:15 AM | 6:00-6:30 AM |

## 4.3. Crash Data Analysis

The results of three years of crash data 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 located in Appendix A. The results can be found in Table 4 below.

**Table 4. Summary of Potentially Correctable Crashes**

| Location | Crashes | | |
|---|---|---|---|
| | All Crashes | Type 21 | Type 28 |
| Leesville Road | 14 | 6 | 1 |
| Creedmoor Road | 8 | 4 | 3 |
| Six Forks Road | 5 | 2 | 3 |
| Falls of the Neuse Road | 23 | 9 | 1 |

Notes
1. Type 21 is rear end while slowing or stopped.
2. Type 28 is a sideswipe in the same direction.

## 4.4. Geometric Analysis

The analysis performed examined the following:

- Any significant physical issues that may exist at each potential ramp metering location such as:
  - Pavement width if the ramp metering deployment requires two lanes
  - Adequate acceleration distance
  - Pavement conditions
  - Sight distance issues
  - Physical constraints if ramp widening is needed
- Whether these issues can be rectified
- Other useful factors that influence the site's suitability for ramp metering

### 4.4.1. Site 136: Leesville Road

Pavement condition is adequate to support inductive loops for a ramp meter. The existing guardrail is not a constraint for a single or dual lane ramp meter. No drainage facilities are in conflict. There are two merge warning signs that might need relocation or adjustment.

If the ramp meter is two lanes, its location may require some widening for the merge area of the ramp meter lanes.

### 4.4.2. Site 138: Creedmoor Road

Pavement condition is good enough to support inductive loops for a ramp meter. There is no existing guardrail. No drainage facilities are in conflict. There are four merge warning signs that might need relocation or adjustment.

If the ramp meter is two lanes, its location may require some widening for the merge area of the ramp meter lanes.

### 4.4.3. Site 140: Six Forks Road

Pavement condition is good enough to support inductive loops for a ramp meter. The existing guardrail is not a constraint for a single or dual lane ramp meter. No drainage facilities are in conflict. There are one merge warning sign that might need relocation or adjustment.

The two-lane ramp is long enough not to require widening to accommodate a dual lane ramp.

### 4.4.4. Site 142: Falls of the Neuse Road

Pavement condition is good enough to support inductive loops for a ramp meter. The existing guardrail on the right side is not a constraint for a single or dual lane ramp meter. No drainage facilities are in conflict. There are three merge warning signs that might need relocation or adjustment.

If the ramp meter is two lanes, its location may require more widening for the merge area of the ramp meter lanes than the other sites due to the much shorter two-lane section.

## 4.5. Ramp Meter Operational Capacities

There are various ramp meter strategies that can provide capacities to meet the expected demand. These strategies are:

### 4.5.1. One Vehicle per Green (Single Lane)

In this configuration, the ramp meter operates with one vehicle per green interval with one car merging at a time. The maximum capacity observed is 900 veh/hr. The corresponding cycle length at 900 vph would be 4 seconds. The shortest reasonable length cycle is around 4.5 seconds, which includes 2 seconds of green and 2.5 seconds of all-red. This reduces the capacity to 800 vph.

### 4.5.2. Multiple Vehicles per Green (Single Lane)

In this configuration, the ramp meter usually operates with two vehicles per green interval and in some case three vehicles per green interval. Additional signage is required to

advise drivers of the restrictions. The additional capacity gained from a two-vehicle per green operation is 200-400 vph, therefore the capacity would be in the range of 1,100 to 1,200 vph. The corresponding cycle length is longer since it requires additional green or extension time to clear the second cycle. Typical cycle lengths are 6 to 6.5 seconds.

### 4.5.3. Two Lane Ramp Meter

In this configuration, two-lane ramp meters provide twice the queuing distance. Two-lane ramp meters typically release one vehicle per lane per green interval. Some states stagger each lane's release to smooth the merger. In some cases, two vehicles per lane per green are permitted in very high volumes. Typical capacities are 1600-1700 vehicles per approach. Typical cycle lengths are 6 to 6.5 seconds.

### 4.5.4. Conclusions

Texas A&M Transportation Institute's research concludes:

- Single lane ramps operate with a good quality of service at volumes less than 1,200 vph. A good quality of service is when metering availability is greater than 80%.
- A single lane ramp meter will likely have a fair quality of service with volumes between 1,200 and 1,400 vph.
- It is desirable to use two-lane ramp meters when demand exceeds 1,200 vph.
- Single lane ramp meters are not encouraged for demand greater than 1,400 vph.
- Two-lane ramp meters have a maximum capacity of approximately 1,650 vph.

Ramp meter availability is the fraction of time when the ramp meter volume exceeds the meter's capacity. It is measure of the meter's reliability to operate and regulate traffic in high volume conditions.

The above information is depicted in Figure 3 and shows the relationship of volume, capacity and the resultant quality of service. From this graph, it can be seen the project sites would operate as:

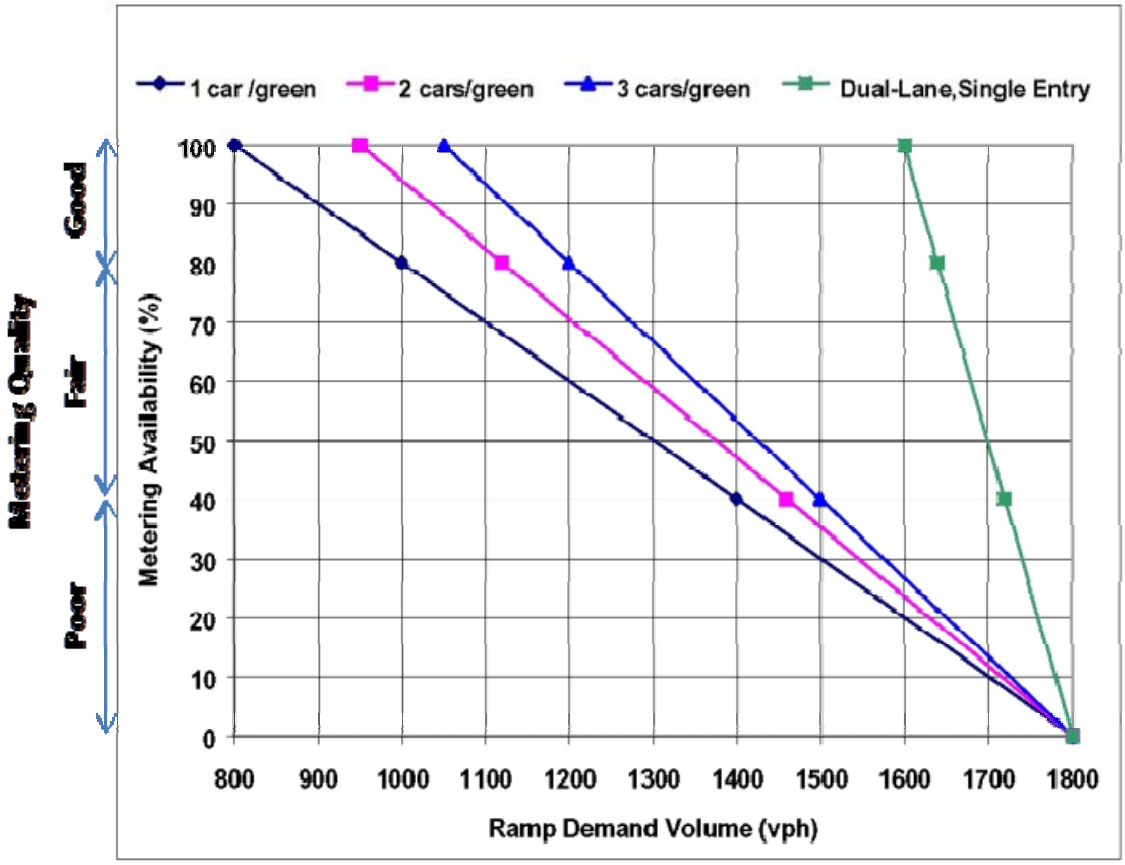
Leesville Road – Based upon the turning movement counts between 7-8 AM, the demand is 1,427 vph with 43% turning left from Leesville Road. Based upon the above guidance, a two-lane ramp meter should operate with a good quality of service.

Creedmoor Road – Based upon the turning movement counts between 7-8 AM, the demand is 960 vph with 70% turning left from Creedmoor Road. Based upon the above guidance, a two-lane ramp meter should operate with a good quality of service.

Six Forks Road – The peak hour ramp volume is 1,100 vph with 55% turning left from Six Forks Rd. Since this ramp is already two lanes wide, a two-lane ramp meter should operate with a good quality of service.

Falls of Neuse Road – The peak hour volume of 1,279 vph has 80% turning right from Falls of the Neuse Road. A two-lane ramp meter should operate with a good quality of service.

**Figure 3. Ramp Meter Quality of Service and Capacity**




## 4.6. Queuing Analysis

Using research developed by TTI, queuing can be estimated using the equation for the 95 percentile for the above ramp meter strategies.

$$L = 3.2808 \times (.250V - .00007422V2)$$

L = Required storage in ft.

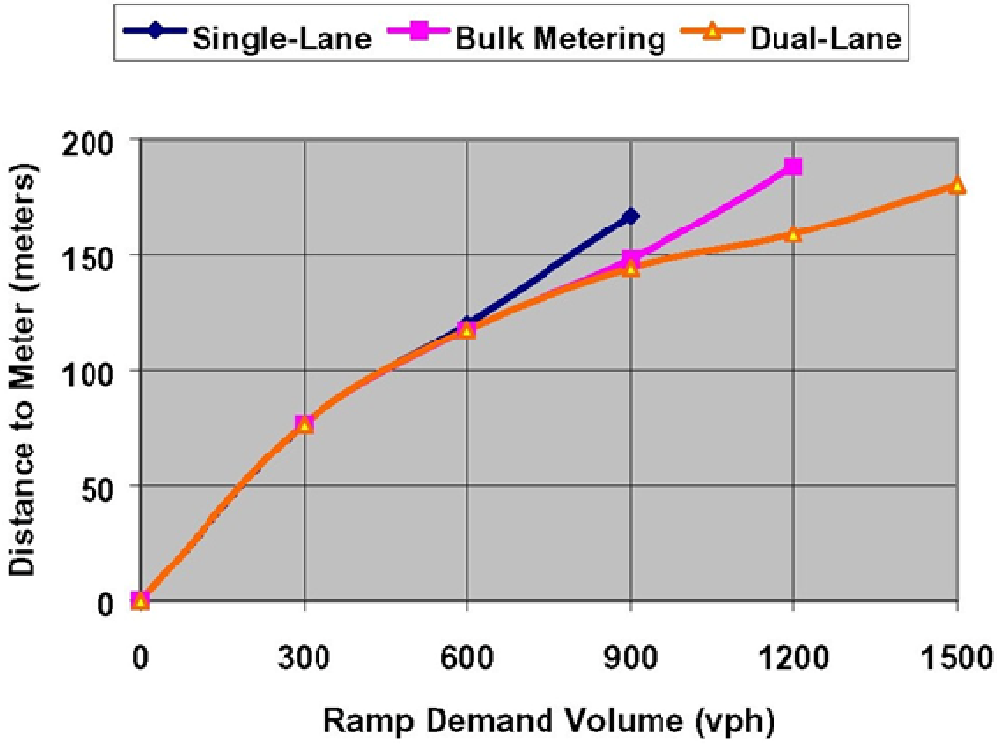
V = Demand volume in vph

This equation can be summarized in Figure 4 and Table 5. Note that bulk metering is defined as either two or three cars per green.

**Table 5. Queue Distance**

| Volume | Storage Length (ft.) | |
|---|---|---|
| | One Lane | Two Lane |
| 800 | 501 | 250.5 |
| 900 | 541 | 270.5 |
| 1000 | 577 | 288.5 |
| 1100 | 608 | 304 |
| 1200 | 634 | 317 |
| 1300 | 655 | 327.5 |
| 1400 | 672 | 336 |
| 1500 | 683 | 341.5 |
| 1600 | 689 | 344.5 |

**Figure 4. Queue Distance**




From the above equation, the queue storage requirements are summarized in Table 6 below:

**Table 6. Recommended Queue Storage**

| Location | Demand Volume (vph) | Queue Storage (ft.) | |
|---|---|---|---|
| | | Single Lane | Two Lane |
| Leesville Road | 1,427 | 675 | 462 |
| Creedmoor Road | 960 | 563 | 338 |
| Six Forks Road | 1,100 | N/A | 378 |
| Falls of the Neuse Road | 1,279 | 651 | 425 |

## 4.7. Preliminary Recommendations

From *only* the traffic and geometric analysis, and without regard to financial analysis, the following preliminary recommendations appear reasonable:

- Leesville Road (see Figure 5 in Appendix C for geometric layout)
  - Extend the existing two-lane ramp section west approximately 130’ with 720’ merge taper. This will provide at least 750’ of storage.
  - Install two-lane ramp meter
- Creedmoor Road (see Figure 6 in Appendix C for geometric layout)
  - Extend the existing two-lane ramp section west approximately 125’ with 720’ merge taper. This will provide at least 650’ of storage.
  - Install two-lane ramp meter
- Six Forks Road (see Figure 7 in Appendix C for geometric layout)
  - Install two-lane ramp meter on existing two-lane ramp. This will provide at least 550’ of storage.
- Falls of Neuse Road (see Figure 8 in Appendix C for geometric layout)
  - This ramp does not have sufficient congestion to justify improvements. If any ramp-meter specific improvements are made, they would include a two-lane ramp meter with 315’ extension of the two-lane ramp section to locate the ramp meter is the ideal location for acceleration onto I-540. Construct a 720’ merge taper.

# 5. Cost Estimates

With the exception of Falls of the Neuse Road, all the sites analyzed have significant recurring congestion as defined in the use of the RITIS bottleneck tool. Atkins reviewed their geometric characteristics and analyzed traffic volumes to confirm their suitability for ramp metering. After identifying that ramp metering will likely be effective at three of these sites, the next stage of the process is to estimate the construction costs associated with improvements that will satisfy the traffic conditions.

The cost estimates were using design criteria and planning level cost estimate templates developed in the *Ramp Metering Feasibility Study for Durham and Wake Counties.* Table 7 below summarizes the specific improvements and associated capital costs.

Program costs (procurement and integration of the control software and the controller firmware) and training separate costs. Operations and maintenance costs have been estimated using information from other states.

**Table 7. Ramp Meter Improvements**

| Location | Ramp Meter Configuration | Roadway Improvement | Capital Cost |
|---|---|---|---|
| Leesville Road | Two-lane | Extend two-lane ramp 130' with 720' merge taper | $ 238,240 |
| Creedmoor Road | Two-lane | Extend two-lane ramp 125' with 720' merge taper | $ 214,364 |
| Six Forks Road | Two-lane | None | $ 135,632 |
| Falls of the Neuse Road | Two-lane | Extend two-lane ramp 315' with 720' merge taper | $ 241,934 |
| **Total** | | | **$ 830,170** |

Detailed cost estimates for each site are included in Appendix D. These estimates include site-specific costs for:

- Geometric construction including:
  - Pavement widening
  - Pavement resurfacing
  - Earthwork
  - Guardrail and
  - Drainage where applicable
- Signal displays and supports
- Detection

- Controllers
- Signing
- Pavement markings
- Traffic control
- Contingencies

The operations costs in Table 8 are estimates as follows using data from the *Ramp Metering Feasibility Study for Durham and Wake Counties.* These are the estimated costs beyond the initial startup and after the system has been accepted.

**Table 8. Operations and Maintenance Costs**

| Location | Ramp Meter Configuration | Annual Costs O&M |
|---|---|---|
| Leesville Road | Two-lane | $ 7,491 |
| Creedmoor Road | Two-lane | $ 7,491 |
| Six Forks Road | Two-lane | $ 7,491 |
| Falls of the Neuse Road | Two-lane | $ 7,491 |
| **Total** | | **$ 29,964** |

# 6. Benefits Analysis

After identifying that ramp metering will likely be effective at three of these sites, the next stage of the process is to determine whether ramp metering will provide sufficient benefits to make installation financially viable.

## 6.1. Effectiveness Factor

In order to be conservative in the level of benefits claimed, Atkins used an effectiveness factor. All sites were reviewed to identify an "Effectiveness Factor", which is the ratio of the "Expected Delay Reduction" they would be expected to achieve. Experience in the implementation and calibration of ramp metering has found that some sites are riskier in that they might not operate optimally for the following specific reasons:

- They are a "secondary" site within the congestion, meaning that there is another downstream "primary" site that is the main cause of the bottleneck. If the primary site cannot be metered, then the secondary site does not have as much effect in alleviating the congestion because it is not the principal cause. The secondary site can only assist in congestion management once congestion from the downstream site has tailed back, and once the congestion is recovering. Therefore, an effectiveness factor of 50 percent is applied (it is estimated that the site will be effective for approximately 50 percent of the congested period).
- The site may have a short on-ramp, which means that the storage capacity for vehicles is low and, in turn, the site will operate in "queue management mode" for significant periods during congestion. Optimal operation is to reduce vehicles leaving the on-ramp during the worst congestion to help the main freeway. Queue management mode must allow more vehicles out of the on-ramp to avoid the queue spilling back onto the surface streets. Because there is a risk that the system will run sub-optimally as a result of limited storage, an effectiveness factor of between 50 and 75 percent is applied.
- Some sites meet the on-ramp flow thresholds to be suitable just for ramp metering implementation, but not for the entirety of the congested period. Ramp metering works partly by restricting flow from the on-ramp onto the main freeway, so low on-ramp flows could limit the system's ability to do this (if the flow is already low it cannot be reduced further). Where flows are outside of the recommended thresholds for a period of time during the congested period, the effectiveness factor can be adjusted to tailor the expected level of benefit proportionally. Where flows are very close to the threshold, an experienced ramp metering calibration engineer can determine how to slightly reduce the effectiveness factor, accounting for the fact that the site may occasionally run sub-optimally.

Sites with a lower effectiveness factor are shown in Table 9, with their respective reasons. For each site, the expected delay reductions have been calculated by multiplying the Expected Delay Reduction and the Effectiveness Factor.

**Table 9. Justification for Lower Effectiveness Factors**

| Freeway | Cross Street | Effectiveness Factor | Reason |
|---|---|---|---|
| I-540 | SR 1829 - Leesville Rd | 0.75 | This location is the primary cause of congestion but relative to high traffic volumes on ramps the storage is limited. This site is only effective during the first part of the build-up to congestion and the last part of the recovery of congestion; therefore, the effectiveness factor has been reduced by 25%. |
| I-540 | Creedmoor Road | 0.75 | This location is the primary cause of congestion but relative to high traffic volumes on ramps the storage is limited. This site is only effective during the first part of the build-up to congestion and the last part of the recovery of congestion; therefore, the effectiveness factor has been reduced by 25%. |
| I-540 | Six Forks Road | 0.75 | This site is secondary to those downstream but has a better ratio of volume to storage. |
| I-540 | Falls of Neuse Road | 0.5 | Bottleneck Tool indicates there is not sufficient congestion for ramp metering |

## 6.2. Financial Benefits

From the *Ramp Metering Feasibility Study for Durham and Wake Counties,* it was agreed an appropriate value of time due to delay should be $22 per hour. This rate is based on Texas Transportation Institute's (TTI) 2011 Urban Mobility Report. In that report, the monetary delay per person was calculated as $16.81 per hour. That rate can be converted by applying an average vehicle occupancy rate of 1.3, which rounds to $22 per hour. This value converts the expected reduction in passenger vehicle delay into financial terms. The same TTI report estimated the average cost of delay per truck for all types of commercial vehicles to be $88.12 per hour.

From historical traffic classification counts, the weighted delay per vehicle was calculated:

Weighted Delay per Vehicle = .90 x $22.00 + .10 x $88.12

= $28.61 per hour

The results are presented per site showing reduction in delay and monetary benefit for the low, medium, and high projections.

The reduction in delay at each site is shown in Table 10. The monetary value of the reduction in delay at each of the sites is shown in Table 11.

**Table 10. Reduction in Vehicles Hours Delayed**

| Freeway | Cross Street | Dir. | Effective-ness Factor | Annual Reduction in Delay (veh-hrs) 10% Delay Reduction | 15% Delay Reduction | 20% Delay Reduction |
|---|---|---|---|---|---|---|
| I-540 | Leesville Rd | WB | 0.75 | 3,630 | 5,445 | 7,260 |
| I-540 | Creedmoor Road | WB | 0.75 | 3,139 | 4,708 | 6,278 |
| I-540 | Six Forks Road | WB | 0.75 | 436 | 654 | 871 |
| I-540 | Falls of Neuse Road | WB | 0.50 | 63 | 94 | 125 |

**Table 11. Financial Benefits Due to Delay Reduction**

| Freeway | Cross Street | Dir. | Annual Reduction in Delay (veh-hrs) @10% | @15% | @20% | Annual Financial Benefit 10% Delay Reduction | 15% Delay Reduction | 20% Delay Reduction |
|---|---|---|---|---|---|---|---|---|
| I-540 | Leesville Rd | WB | 3,630 | 5,445 | 7,260 | $ 77,889 | $ 116,833 | $ 155,777 |
| I-540 | Creedmoor Road | WB | 3,139 | 4,708 | 6,278 | $ 67,351 | $ 101,026 | $ 134,702 |
| I-540 | Six Forks Road | WB | 436 | 654 | 871 | $ 9,349 | $ 14,024 | $ 18,698 |
| I-540 | Falls of Neuse Road | WB | 63 | 94 | 125 | $ 895 | $ 1,343 | $ 1,791 |

## 6.3. Cost-Benefit Analysis

Cost-benefit ratios have been calculated for each of the four ramp metering sites annually for 5 and 10 horizon years. This analysis uses the estimated capital costs described in Section 5, Estimated Costs, and the estimated delay benefits based on a 20 percent savings in delay.

The purpose of this analysis is to allow comparison of the relative economic conditions of each site. Therefore, only the costs directly associated with each individual site have been included (i.e., implementation cost and annual cost)

A benefit-cost ratio analysis is an established method to compare the cumulative benefits versus cumulative costs. If that ratio is greater than 1.0, then the project has positive net benefits over the analysis period. For purposes of this analysis, the program cost of $404,998 includes all the central software, training, integration, and hardware. This cost was developed in the *Ramp Metering Feasibility Study for Durham and Wake Counties.*

Benefit Cost Ratio = Cumulative Benefits / (Capital Cost Cumulative + Annual Cost + Prorated Share of Program Costs)

## 6.4. Five Year and Ten Year Benefit-to-Cost Ratios

The period of time used for economic analysis normally is the period of the useful life of the assets included for the alternatives under determines if additional sites will be financially feasible in the second 5 years, if they were not in the first 5 years. This gives the opportunity to review the site after 10 years and decide if the investment is worthwhile to continue.

A second analysis period of 5 years has been used. This conforms to NCDOT normal practice for calculating benefit-cost of this type of project. If a site "pays back" within 5 years, then it should also be economically suitable for implementation.

The difference between the five and ten year costs is the additional 5 years of annual maintenance costs and the additional 5 years of benefits.

### 6.4.1. Five Year Benefit-Cost Results

Table 12 shows the expected cost and benefit of each site for 5 years. This analysis shows that only the proposed Leesville Road and Creedmoor Road improvements are financially viable in the first five years.

**Table 12. Benefit-Cost Analysis over Five Year Period**

| Free-way | Cross Street | Direction | Annual Benefits | Implementation Cost | Annual Cost | Five-Year Total Cost | Five-Year Total Benefit | Five-Year B/C Ratio | FYRR |
|---|---|---|---|---|---|---|---|---|---|
| I-540 | Leesville Rd | WB | $142,317 | $238,240 | $7,491 | $275,695 | $711,585 | 2.58 | -42% |
| I-540 | Creedmoor Road | WB | $116,365 | $214,364 | $7,491 | $251,819 | $581,824 | 2.31 | -48% |
| I-540 | Six Forks Road | WB | $16,950 | $135,632 | $7,491 | $173,087 | $84,748 | 0.49 | -88% |
| I-540 | Falls of Neuse Road | WB | $1,624 | $241,934 | $7,491 | $279,389 | $8,118 | 0.03 | -99% |

### 6.4.2. Ten Year Benefit-Cost Results

Table 13 shows the expected cost and benefit of each site for 10 years. This analysis shows that only the proposed Leesville Road and Creedmoor Road improvements are still financially viable in ten years.

**Table 13. Benefit-Cost Analysis over Ten Year Period**

| Free-way | Cross Street | Direction | Annual Benefits | Implementation Cost | Annual Cost | Ten Year Total Cost | Ten Year Total Benefit | B/C Ratio | FYRR |
|---|---|---|---|---|---|---|---|---|---|
| I-540 | Leesville Rd | WB | $142,317 | $238,240 | $7,491 | $313,150 | $1,423,169 | 4.545 | -42% |
| I-540 | Creedmoor Road | WB | $116,365 | $214,364 | $7,491 | $289,274 | $1,163,649 | 4.023 | -48% |
| I-540 | Six Forks Road | WB | $16,950 | $135,632 | $7,491 | $210,542 | $169,496 | 0.805 | -88% |
| I-540 | Falls of Neuse Road | WB | $1,624 | $241,934 | $7,491 | $316,844 | $16,235 | 0.051 | -99% |

## 6.5. First Year Rate of Return

The first year rate of return is a calculation that determines if a proposed project has sufficient benefits in the first year to offset the cost of implementation plus one year's operation. No location meets this criteria.

## 6.6. Summary

Based upon the financial analysis the proposed Leesville Road and Creedmoor Road are financially feasible in both the five and ten-year analysis periods.

# 7. Corridor Wide Financial Analysis

As system improvement the four sites were grouped together to determine if they collectively meet the financial cost criteria. For a ten-year period with 20% reduction in delay,

| | |
|---|---|
| Combined Implementation Costs: | $ 830,170 |
| Combined Annual Costs: | $ 29,964 |
| Total Costs: | $ 1,129,810 |
| Effectiveness Factor: | 1.0 |
| Combined Annual Reduction in Delay (veh-hours): | 14,534 |
| Combined Benefits: | $ 2,772,549 |
| Corridor B/C ratio: | 2.454 |

The benefits due to delay reduction at Leesville Road and Creedmoor Road more than offset the lower benefits for Six Forks Road and Falls of Neuse Road.

Another consideration if less than all four sites are constructed there may be the potential for diversion from a metered location to an unmetered location. In particular, if Falls of Neuse Road is not constructed the potential diversion from Six Forks Road via Durant Road and Strickland Road eastward to Falls of Neuse Road is a reasonable outcome to expect.

# 8. Conclusions

Based upon the geometric and traffic needs and the corridor-wide financial analysis, the following improvements are recommended:

- Leesville Road
  - Extend the existing two-lane ramp section west approximately 130’ with 720’ merge taper. This will provide at least 750’ of storage.
  - Install a two-lane ramp meter
- Creedmoor Road
  - Extend the existing two-lane ramp section west approximately 125’ with 720’ merge taper. This will provide at least 650’ of storage.
  - Install a two-lane ramp meter
- Six Forks Road
  - Install two-lane ramp meter on existing two-lane ramp. This will provide at least 550’ of storage.
  - No geometric improvements are needed to provide a two-lane ramp meter.
- Falls of Neuse Road
  - Extend the existing two-lane ramp section west approximately 315’ with 720’ merge taper. This will provide at least 725’ of storage.
  - Install a two-lane ramp meter

The results of this study show that two proposed improvements are justified and financially feasible without benefit cost ratios greater than 1.0. These proposed improvements are:

- Leesville Road
- Creedmoor Road

Two additional proposed ramp metering improvements at Six Forks Road and at Falls of Neuse Road are justified based upon traffic and geometric needs, but are not financially feasible since their benefits, due to associated delay reductions, are less than the cost of the improvement over both a five and ten year study period.

While the analysis has focused on reduction in delays (vehicle hours), there will be other subjective and more minor quantitative benefits as a result of ramp metering installation, including more reliable trips, reduction in fuel consumption, reduction in vehicle emissions, and reduction in crashes.

# Appendices

# Appendix A. Site Summaries

## NCDOT I-540 Westbound Ramp Metering Study

136

## Site Summary Document

### Site Details

| | |
|---|---|
| Site Number | 136 |
| Freeway | I-540 |
| Cross Street | Leesville Rd |
| Exit | 279 |
| Direction | Westbound |
| County | Wake |


### Physical Characteristics Overview

| | |
|---|---|
| Origin of Ramp | Signalized Int. w/ right turn yield |
| Lane Addition onto Main Freeway length (ft) | None |
| Number of Entrance Ramp Lanes | 2 (one left and one right) |
| Lane Drop on Entrance Ramp Before Merge | Yes |
| Number of Freeway Lanes Before Merge | 3 |
| Number of Freeway Lanes After Merge | 3 |
| Entrance Ramp Length to Back of Gore (ft) | 1200 |
| Entrance Ramp Length to Tip of Gore (ft) | 1510 |
| Merge Length (ft) | 1250 |
| Entrance Ramp Horizontal Alignment | Slight Curve |
| Entrance Ramp Vertical Alignment | -2% |
| Entrance Ramp Shoulder (Paved Full Width) | Lt-4', Rt-4' |
| Main Freeway Vertical Alignment Downstream | Level |
| Main Freeway Shoulder | Yes |
| Number of Vehicles Storage | 70 |
| Guardrail | Partial along right side of ramp |
| Pipe Crossing | None present |

### Signalization Overview

| | |
|---|---|
| Upstream Signal | Three phase, 3-way signal with right turn yield onto ramp. Left turn phasing is protected only. |
| Signal Timing | Protected NBL, yield SBR onto ramp. |
| Nearest Power Source | Signal |

### Signing Overview

| | |
|---|---|
| Existing Signing | No issue. |

## Traffic Volumes

Data collected on 12/03/2013.

| Period Beginning | Upstream Hourly Flow Rate | Downstream Hourly Flow Rate | On-Ramp Hourly Flow Rate | Downstream Flow per Lane | On-Ramp Flow per Lane | On-Ramp % of Downstream | Hour Meets Ideal Criteria for Ramp Metering | Hour Meets Acceptable Criteria for Ramp Metering |
|---|---|---|---|---|---|---|---|---|
| 0:00 | 144 | 159 | 15 | 53 | 15 | 9 | No | No |
| 1:00 | 96 | 109 | 13 | 36 | 13 | 12 | No | No |
| 2:00 | 94 | 98 | 4 | 33 | 4 | 4 | No | No |
| 3:00 | 194 | 203 | 9 | 68 | 9 | 4 | No | No |
| 4:00 | 353 | 390 | 37 | 130 | 37 | 9 | No | No |
| 5:00 | 986 | 1120 | 134 | 373 | 134 | 12 | No | No |
| 6:00 | 3113 | 3591 | 478 | 1197 | 478 | 13 | No | Yes |
| 7:00 | 5697 | 6922 | 1225 | 2307 | 1225 | 18 | No | No |
| 8:00 | 5469 | 6765 | 1296 | 2255 | 1296 | 19 | No | No |
| 9:00 | 3408 | 3991 | 583 | 1330 | 583 | 15 | No | Yes |
| 10:00 | 2161 | 2496 | 335 | 832 | 335 | 13 | No | Yes |
| 11:00 | 1867 | 2175 | 308 | 725 | 308 | 14 | No | Yes |
| 12:00 | 1648 | 2006 | 358 | 669 | 358 | 18 | No | Yes |
| 13:00 | 1849 | 2172 | 323 | 724 | 323 | 15 | No | Yes |
| 14:00 | 1804 | 2107 | 303 | 702 | 303 | 14 | No | Yes |
| 15:00 | 1983 | 2330 | 347 | 777 | 347 | 15 | No | Yes |
| 16:00 | 2371 | 2754 | 383 | 918 | 383 | 14 | No | Yes |
| 17:00 | 3191 | 3516 | 325 | 1172 | 325 | 9 | No | Yes |
| 18:00 | 2282 | 2615 | 333 | 872 | 333 | 13 | No | Yes |
| 19:00 | 1288 | 1506 | 218 | 502 | 218 | 14 | No | No |
| 20:00 | 995 | 1156 | 161 | 385 | 161 | 14 | No | No |
| 21:00 | 718 | 825 | 107 | 275 | 107 | 13 | No | No |
| 22:00 | 483 | 543 | 60 | 181 | 60 | 11 | No | No |
| 23:00 | 275 | 312 | 37 | 104 | 37 | 12 | No | No |

## Turning Movement Counts

Data collected on 12/03/2013.

| | Leesville Rd Northbound | | | | | Leesville Rd Southbound | | | | | I-540 WB Ramps Westbound | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start Time | Left | Thru | Rgt | Peds | App. Total | Left | Thru | Rgt | Peds | App. Total | Left | Thru | Rgt | Peds | App. Total | Int. Total |
| 6:15 AM | 54 | 16 | 0 | 0 | 70 | 0 | 92 | 51 | 0 | 143 | 29 | 0 | 18 | 0 | 47 | 260 |
| 6:30 AM | 75 | 43 | 0 | 0 | 118 | 0 | 144 | 78 | 0 | 222 | 61 | 0 | 11 | 0 | 72 | 412 |
| 6:45 AM | 67 | 48 | 0 | 0 | 115 | 0 | 297 | 94 | 0 | 391 | 99 | 1 | 24 | 0 | 124 | 630 |
| 7:00 AM | 90 | 83 | 0 | 0 | 173 | 0 | 258 | 110 | 0 | 368 | 83 | 0 | 24 | 0 | 107 | 648 |
| Total | 286 | 190 | 0 | 0 | 476 | 0 | 791 | 333 | 0 | 1124 | 272 | 1 | 77 | 0 | 350 | 1950 |
| | | | | | | | | | | | | | | | | |
| 7:15 AM | 126 | 147 | 0 | 0 | 273 | 0 | 262 | 183 | 0 | 445 | 81 | 1 | 38 | 0 | 120 | 838 |
| 7:30 AM | 150 | 152 | 0 | 0 | 302 | 0 | 293 | 205 | 0 | 498 | 79 | 0 | 47 | 0 | 126 | 926 |
| 7:45 AM | 160 | 137 | 0 | 0 | 297 | 0 | 336 | 195 | 0 | 531 | 54 | 0 | 37 | 0 | 91 | 919 |
| 8:00 AM | 172 | 136 | 0 | 0 | 308 | 0 | 329 | 236 | 0 | 565 | 56 | 0 | 25 | 0 | 81 | 954 |
| Total | 608 | 572 | 0 | 0 | 1180 | 0 | 1220 | 819 | 0 | 2039 | 270 | 1 | 147 | 0 | 418 | 3637 |

*Traffic Volume hourly counts begin on the hour (0:00); Turning Movement hourly totals begin on the quarter hour (0:15).

## Ramp Merge Capacity

The on-ramps were analyzed for the AM peak hour, which is the peak direction of travel. The analysis was performed using the ramps module for merge junctions of the 2010 Highway Capacity Software (HCS), which is based on methodologies from the 2010 Highway Capacity Manual (HCM).

Traffic volumes used in the analysis of the merge junctions were developed from 24-hour traffic counts collected in December 2013. The 15-minute intervals were aggregated into hourly volumes, from which the AM peak hour volume was identified. The peak hour factor (PHF) was calculated using the highest 15-minute volume of the peak hour volume.

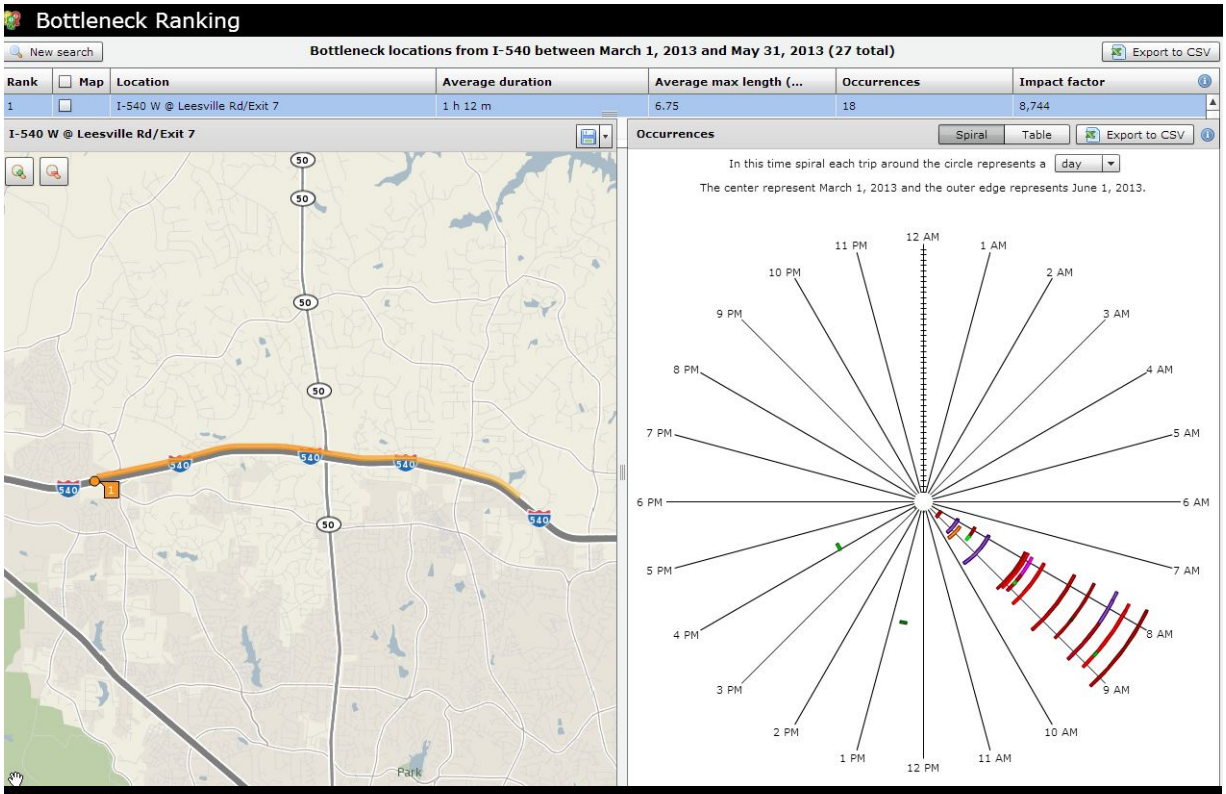
| Description | Peak Hour Volume | | Level-Of-Service (LOS) | Density (pc/mi/ln) |
|---|---|---|---|---|
| | Upstream Freeway | On-Ramp | | |
| I-540 Westbound<br>On-Ramp @ Leesville Rd | 5,881 | 1,429 | F | 37.7 |

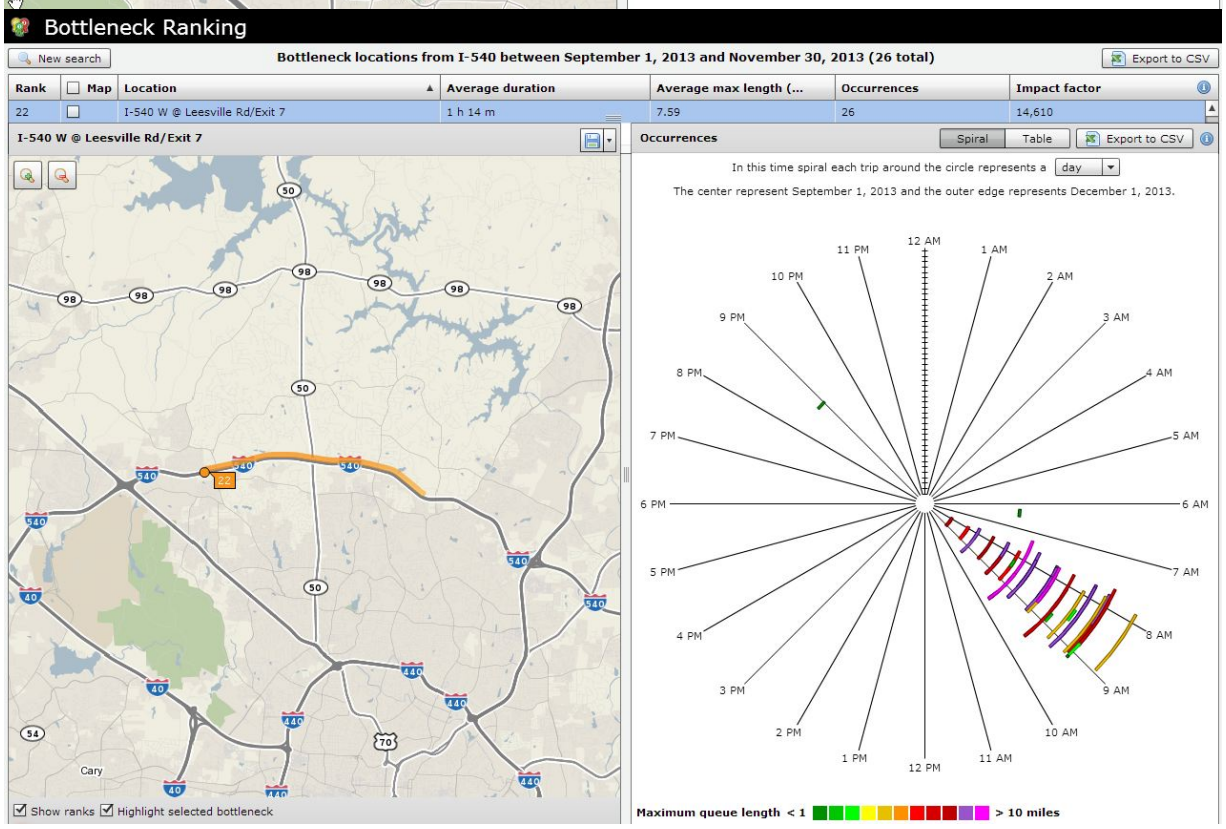
## Congestion

Congestion data was collected from the RITIS Vehicle Probe Project using Inrix data. Bottleneck occurrences are identified when the speed falls below 60% of the reference speed (85$^{th}$ percentile speed for all time periods) for greater than 5 minutes. Additional threshold criteria applied to identify bottleneck congestion that would benefit from ramp metering includes durations lasting 30 minutes and average maximum length of congestion greater than ½ mile and occurring at least twice a week (26 occurrences over the 3-month period).

| | Spring 2011 | Spring 2013 |
|---|---|---|
| Ave Length of Congestion (Miles) | 5.02 | 6.75 |
| Duration of Congestion (Min) | 47 | 72 |
| Number of Occurrences | 12 | 18 |
| Typical Times of Congestion | 08:00-09:00 | 07:45-09:15 |

| | Fall 2011 | Fall 2013 |
|---|---|---|
| Ave Length of Congestion (Miles) | 3.70 | 7.59 |
| Duration of Congestion (Min) | 41 | 74 |
| Number of Occurrences | 16 | 26 |
| Typical Times of Congestion | 08:00-09:30 | 07:45-09:15 |


Bottleneck Ranking
New search
Bottleneck locations from I-540 between March 1, 2013 and May 31, 2013 (27 total)
Export to CSV
Rank
Map
Location
Average duration
Average max length (...
Occurrences
Impact factor
1
I-540 W @ Leesville Rd/Exit 7
1 h 12 m
6.75
18
8,744
I-540 W @ Leesville Rd/Exit 7
Occurrences
Spiral
Table
Export to CSV
In this time spiral each trip around the circle represents a
day
The center represent March 1, 2013 and the outer edge represents June 1, 2013.
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
11 PM
Park


Bottleneck Ranking
New search
Bottleneck locations from I-540 between September 1, 2013 and November 30, 2013 (26 total)
Export to CSV
Rank
Map
Location
Average duration
Average max length (...
Occurrences
Impact factor
22
I-540 W @ Leesville Rd/Exit 7
1 h 14 m
7.59
26
14,610
I-540 W @ Leesville Rd/Exit 7
Occurrences
Spiral
Table
Export to CSV
In this time spiral each trip around the circle represents a
day
The center represent September 1, 2013 and the outer edge represents December 1, 2013.
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
11 PM
Cary
Show ranks
Highlight selected bottleneck
Maximum queue length < 1
> 10 miles

## Crash Data

The total number of accidents from November 2010 through October 2013 was: 14
Of these 7 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 6 (43%)
Type 28- Sideswipe, same direction: 1 (7%)

## Observations

Log 136 is a direct ramp with no sight distance issues. There is a very slight downhill grade. There is CCTV coverage of the merge area of the ramp with the mainline but trees block most of the CCTV coverage of the ramp. The ramp has large easement space but no designated pull-off area.

Long queues starting around 7:30 AM and ending around 8:30 were observed on Leesville Rd for the southbound right and northbound left turns onto the ramp. Northbound left turn traffic queued up through the upstream signal at the eastbound ramps. Southbound right turn traffic queued 500 feet upstream of the signal.

Right and left turn traffic were able to merge on the ramp without affecting the traffic signal operation. In the highest 15-minute intervals, the traffic merging onto I-540 forced traffic on I-540 westbound to slow down and created some unstable traffic flow on I-540.

## Site Selection Comments

Single lane ramp with high left turn volume could pose problems for ramp meter implementation. May require dual lane ramp meter.

## NCDOT Ramp Metering Feasibility Study

138

## Site Summary Document

### Site Details

| | |
|---|---|
| Site Number | 138 |
| Freeway | I-540 |
| Cross Street | Creedmoor Rd |
| Exit | 9 |
| Direction | Westbound |
| County | Wake |


### Physical Characteristics Overview

| | |
|---|---|
| Origin of Ramp | Signalized Int. w/ right turn free |
| Lane Addition onto Main Freeway length (ft) | None |
| Number of Entrance Ramp Lanes | 2 (Two left). Right turn is yield controlled without full lane acceleration. |
| Lane Drop on Entrance Ramp Before Merge | Yes |
| Number of Freeway Lanes Before Merge | 3 |
| Number of Freeway Lanes After Merge | 3 |
| Entrance Ramp Length to Back of Gore (ft) | 971 |
| Entrance Ramp Length to Tip of Gore (ft) | 1450 |
| Merge Length (ft) | 1100 |
| Entrance Ramp Horizontal Alignment | Straight |
| Entrance Ramp Vertical Alignment | +2.5% |
| Entrance Ramp Shoulder (Paved Full Width) | Lt-4', Rt-4' |
| Main Freeway Vertical Alignment Downstream | Level |
| Main Freeway Shoulder | Left- 12', Right- 4' |
| Number of Vehicles Storage | 60 |
| Guardrail | None present |
| Pipe Crossing | None present |

### Signalization Overview

| | |
|---|---|
| Upstream Signal | Three phase, 3-way signal with free right turn onto ramp. Left turn phasing is protected only. |
| Signal Timing | Protected NBL, yield SBR onto ramp. |
| Nearest Power Source | Signal |

### Signing Overview

| | |
|---|---|
| Existing Signing | No issue. |

## Traffic Volumes

Data collected on 12/03/2013.

| Period Beginning | Upstream Hourly Flow Rate | Downstream Hourly Flow Rate | On-Ramp Hourly Flow Rate | Downstream Flow per Lane | On-Ramp Flow per Lane | On-Ramp % of DS | | Hour Meets Ideal Criteria for Ramp Metering | Hour Meets Acceptable Criteria for Ramp Metering |
|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 158 | 172 | 14 | 57 | 14 | 8 | | No | No |
| 1:00 | 103 | 113 | 10 | 38 | 10 | 9 | | No | No |
| 2:00 | 103 | 112 | 9 | 37 | 9 | 8 | | No | No |
| 3:00 | 203 | 217 | 14 | 72 | 14 | 6 | | No | No |
| 4:00 | 337 | 386 | 49 | 129 | 49 | 13 | | No | No |
| 5:00 | 1009 | 1153 | 144 | 384 | 144 | 12 | | No | No |
| 6:00 | 3056 | 3555 | 499 | 1185 | 499 | 14 | | No | Yes |
| 7:00 | 5368 | 6228 | 860 | 2076 | 860 | 14 | | Yes | Yes |
| 8:00 | 4789 | 5695 | 906 | 1898 | 906 | 16 | | No | Yes |
| 9:00 | 3090 | 3624 | 534 | 1208 | 534 | 15 | | No | Yes |
| 10:00 | 2043 | 2367 | 324 | 789 | 324 | 14 | | No | Yes |
| 11:00 | 1835 | 2178 | 343 | 726 | 343 | 16 | | No | Yes |
| 12:00 | 1870 | 2192 | 322 | 731 | 322 | 15 | | No | Yes |
| 13:00 | 1912 | 2189 | 277 | 730 | 277 | 13 | | No | No |
| 14:00 | 1950 | 2252 | 302 | 751 | 302 | 13 | | No | Yes |
| 15:00 | 2080 | 2424 | 344 | 808 | 344 | 14 | | No | Yes |
| 16:00 | 2502 | 2899 | 397 | 966 | 397 | 14 | | No | Yes |
| 17:00 | 3399 | 3847 | 448 | 1282 | 448 | 12 | | No | Yes |
| 18:00 | 2397 | 2688 | 291 | 896 | 291 | 11 | | No | No |
| 19:00 | 1401 | 1588 | 187 | 529 | 187 | 12 | | No | No |
| 20:00 | 1123 | 1240 | 117 | 413 | 117 | 9 | | No | No |
| 21:00 | 801 | 913 | 112 | 304 | 112 | 12 | | No | No |
| 22:00 | 524 | 580 | 56 | 193 | 56 | 10 | | No | No |
| 23:00 | 306 | 338 | 32 | 113 | 32 | 9 | | No | No |

## Turning Movement Counts

Data collected on 12/03/2013.

| | Creedmoor Rd Northbound | | | | | Creedmoor Rd Southbound | | | | | I-540 WB Ramps Westbound | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start Time | Left | Thru | Rgt | Peds | App. Total | Left | Thru | Rgt | Peds | App. Total | Left | Thru | Rgt | Peds | App. Total | Int. Total |
| 6:15 AM | 56 | 54 | 0 | 0 | 110 | 0 | 99 | 68 | 0 | 167 | 38 | 0 | 40 | 0 | 78 | 355 |
| 6:30 AM | 55 | 55 | 0 | 0 | 110 | 0 | 156 | 63 | 0 | 219 | 69 | 0 | 64 | 0 | 133 | 462 |
| 6:45 AM | 87 | 75 | 0 | 0 | 162 | 0 | 173 | 89 | 0 | 262 | 75 | 1 | 52 | 0 | 128 | 552 |
| 7:00 AM | 116 | 76 | 0 | 0 | 192 | 0 | 141 | 53 | 0 | 194 | 89 | 1 | 57 | 0 | 147 | 533 |
| Total | 314 | 260 | 0 | 0 | 574 | 0 | 569 | 273 | 0 | 842 | 271 | 2 | 213 | 0 | 486 | 1902 |
| | | | | | | | | | | | | | | | | |
| 7:15 AM | 144 | 104 | 0 | 0 | 248 | 0 | 191 | 44 | 0 | 235 | 88 | 0 | 38 | 0 | 126 | 609 |
| 7:30 AM | 166 | 91 | 0 | 0 | 257 | 0 | 265 | 64 | 0 | 329 | 86 | 0 | 52 | 0 | 138 | 724 |
| 7:45 AM | 180 | 128 | 0 | 0 | 308 | 0 | 311 | 92 | 0 | 403 | 66 | 2 | 34 | 0 | 102 | 813 |
| 8:00 AM | 184 | 138 | 0 | 0 | 322 | 0 | 273 | 86 | 0 | 359 | 71 | 0 | 33 | 0 | 104 | 785 |
| Total | 674 | 461 | 0 | 0 | 1135 | 0 | 1040 | 286 | 0 | 1326 | 311 | 2 | 157 | 0 | 470 | 2931 |

*Traffic Volume hourly counts begin on the hour (0:00); Turning Movement hourly totals begin on the quarter hour (0:15).

## Ramp Merge Capacity

The on-ramps were analyzed for the AM peak hour, which is the peak direction of travel. The analysis was performed using the ramps module for merge junctions of the 2010 Highway Capacity Software (HCS), which is based on methodologies from the 2010 Highway Capacity Manual (HCM).

Traffic volumes used in the analysis of the merge junctions were developed from 24-hour traffic counts collected in December 2013. The 15-minute intervals were aggregated into hourly volumes, from which the AM peak hour volume was identified. The peak hour factor (PHF) was calculated using the highest 15-minute volume of the peak hour volume.

While the ramp merge capacity analysis shows a LOS D in the AM peak hour, a slight increase in the number of vehicles at this ramp would cause the capacity analysis results to show a LOS F.

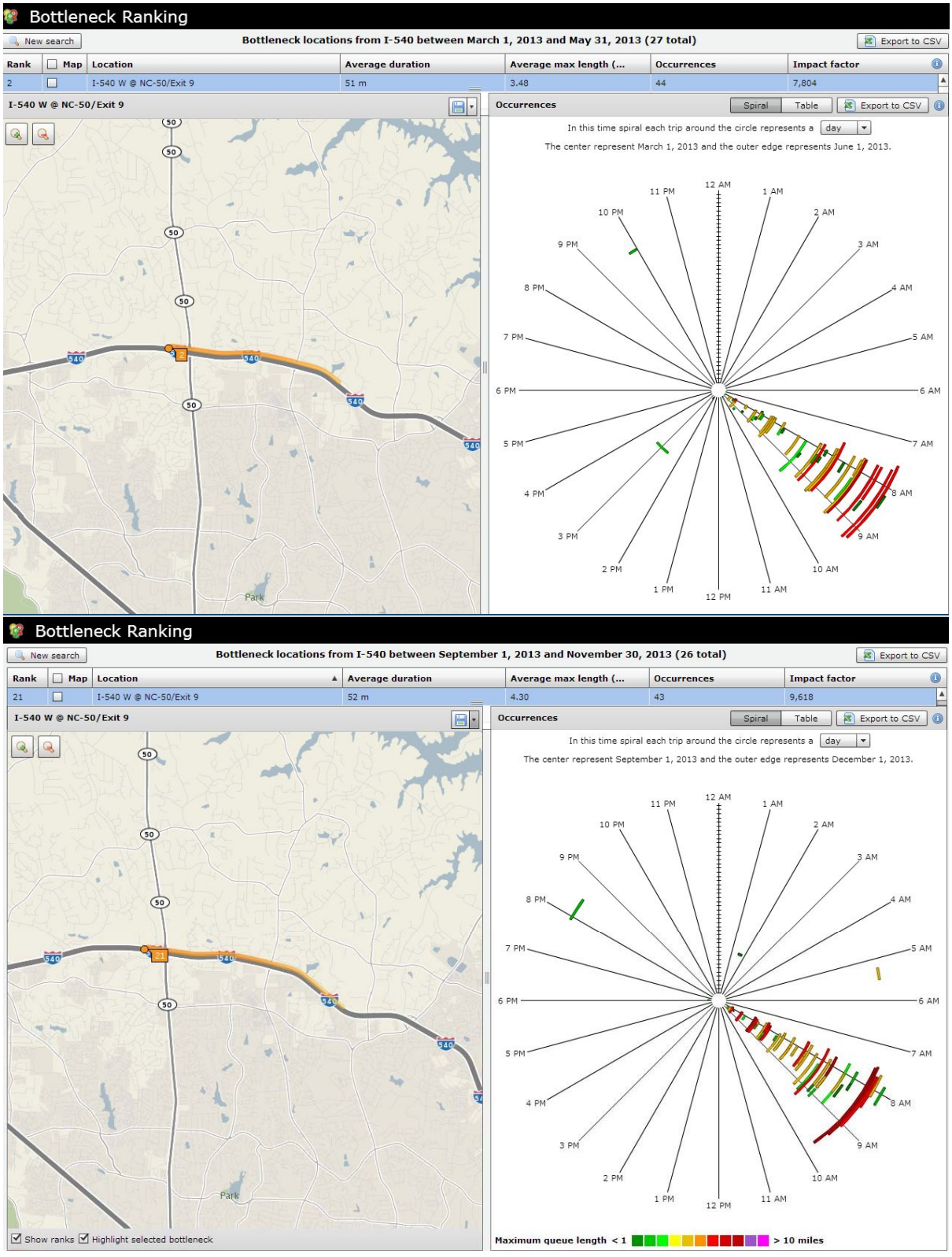
| Description | Peak Hour Volume | | Level-Of-Service (LOS) | Density (pc/mi/ln) |
|---|---|---|---|---|
| | Upstream Freeway | On-Ramp | | |
| I-540 Westbound<br>On-Ramp @ Creedmoor Rd | 5,412 | 963 | D | 33.5 |

## Congestion

Congestion data was collected from the RITIS Vehicle Probe Project using Inrix data. Bottleneck occurrences are identified when the speed falls below 60% of the reference speed (85$^{th}$ percentile speed for all time periods) for greater than 5 minutes. Additional threshold criteria applied to identify bottleneck congestion that would benefit from ramp metering includes durations lasting 30 minutes and average maximum length of congestion greater than ½ mile and occurring at least twice a week (26 occurrences over the 3-month period).

| | Spring 2011 | Spring 2013 |
|---|---|---|
| Ave Length of Congestion (Miles) | 1.31 | 3.48 |
| Duration of Congestion (Min) | 22 | 51 |
| Number of Occurrences | 22 | 44 |
| Typical Times of Congestion | 08:00-09:00 | 07:30-09:30 |

| | Fall 2011 | Fall 2013 |
|---|---|---|
| Ave Length of Congestion (Miles) | 1.72 | 4.30 |
| Duration of Congestion (Min) | 27 | 52 |
| Number of Occurrences | 19 | 43 |
| Typical Times of Congestion | 08:00-09:00 | 07:30-09:30 |


Bottleneck Ranking
New search
Bottleneck locations from I-540 between March 1, 2013 and May 31, 2013 (27 total)
Export to CSV
Rank
Map
Location
Average duration
Average max length (...
Occurrences
Impact factor
2
I-540 W @ NC-50/Exit 9
51 m
3.48
44
7,804
I-540 W @ NC-50/Exit 9
Occurrences
Spiral
Table
Export to CSV
In this time spiral each trip around the circle represents a
day
The center represent March 1, 2013 and the outer edge represents June 1, 2013.
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
11 PM
Bottleneck Ranking
New search
Bottleneck locations from I-540 between September 1, 2013 and November 30, 2013 (26 total)
Export to CSV
Rank
Map
Location
Average duration
Average max length (...
Occurrences
Impact factor
21
I-540 W @ NC-50/Exit 9
52 m
4.30
43
9,618
I-540 W @ NC-50/Exit 9
Occurrences
Spiral
Table
Export to CSV
In this time spiral each trip around the circle represents a
day
The center represent September 1, 2013 and the outer edge represents December 1, 2013.
Show ranks
Highlight selected bottleneck
Maximum queue length < 1
> 10 miles

## Crash Data

The total number of accidents from November 2010 through October 2013 was: 8
Of these 7 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 4 (50%)
Type 28- Sideswipe, same direction: 3 (38%)

## Observations

Log 138 is a direct ramp with no sight distance issues. There is a very slight uphill grade. There is CCTV coverage of the merge area of the ramp with the mainline but trees block most of the CCTV coverage of the ramp. The ramp has large easement space but no designated pull-off area. Long AM queues were observed on Creedmoor Rd for the northbound left turn onto the ramp.

Long queues starting around 7:30 AM extending until around 8:30 AM were observed on Creedmoor Rd for the northbound dual left turn lanes onto the ramp. The signal operation kept the ramp traffic is fairly tight platoons. Northbound left turn traffic queued up and filled the turn lanes between the two ramp signals.

The ramp traffic was able to merge to a single lane on the ramp without affecting the traffic signal operation until the highest peak 15 minutes. At the highest peak, the tail end of the left turn traffic had some difficulty merging onto I-540 and had to stop until there was a gap. In the highest 15-minute intervals, the traffic merging onto I-540 forced traffic on I-540 westbound to slow down and created some unstable traffic flow on I-540.

## NCDOT I-540 Westbound Ramp Metering Study

140

## Site Summary Document

### Site Details

| | |
|---|---|
| Site Number | 140 |
| Freeway | I-540 |
| Cross Street | Six Forks Rd |
| Exit | 11 |
| Direction | Westbound |
| County | Wake |


### Physical Characteristics Overview

| | |
|---|---|
| Origin of Ramp | SPUI signal |
| Lane Addition onto Main Freeway length (ft) | None |
| Number of Entrance Ramp Lanes | 2 |
| Lane Drop on Entrance Ramp Before Merge | No |
| Number of Freeway Lanes Before Merge | 3 |
| Number of Freeway Lanes After Merge | 3 |
| Entrance Ramp Length to Back of Gore (ft) | 800 |
| Entrance Ramp Length to Tip of Gore (ft) | 1150 |
| Merge Length (ft) | 330'/1950' |
| Entrance Ramp Horizontal Alignment | Straight |
| Entrance Ramp Vertical Alignment | -3% |
| Entrance Ramp Shoulder (Paved Full Width) | Lt-4', Rt-4' |
| Main Freeway Vertical Alignment Downstream | Level |
| Main Freeway Shoulder | Left- 12', Right- 12' |
| Number of Vehicles Storage | 66 |
| Guardrail | Guardrail begins at gore and continues downstream of ramp |
| Pipe Crossing | None present |

### Signalization Overview

| | |
|---|---|
| Upstream Signal | Single point urban interchange with right turn yield onto ramp. Left turn phasing is protected only. |
| Signal Timing | SPUI with dual NBL, yield SBR |
| Nearest Power Source | Signal or nearby transformer |

### Signing Overview

| | |
|---|---|
| Existing Signing | No issue. |

## Traffic Volumes

Data collected on 12/05/2013.

| Period Beginning | Upstream Hourly Flow Rate | Downstream Hourly Flow Rate | On-Ramp Hourly Flow Rate | Downstream Flow per Lane | On-Ramp Flow per Lane | On-Ramp % of DS | Hour Meets Ideal Criteria for Ramp Metering | Hour Meets Acceptable Criteria for Ramp Metering |
|---|---|---|---|---|---|---|---|---|
| 0:00 | 178 | 199 | 21 | 66 | 11 | 11 | No | No |
| 1:00 | 117 | 129 | 12 | 43 | 6 | 9 | No | No |
| 2:00 | 102 | 111 | 9 | 37 | 5 | 8 | No | No |
| 3:00 | 185 | 217 | 32 | 72 | 16 | 15 | No | No |
| 4:00 | 343 | 389 | 46 | 130 | 23 | 12 | No | No |
| 5:00 | 975 | 1096 | 121 | 365 | 61 | 11 | No | No |
| 6:00 | 3043 | 3479 | 436 | 1160 | 218 | 13 | No | No |
| 7:00 | 5096 | 6072 | 976 | 2024 | 488 | 16 | Yes | Yes |
| 8:00 | 4143 | 4938 | 795 | 1646 | 398 | 16 | No | Yes |
| 9:00 | 2918 | 3442 | 524 | 1147 | 262 | 15 | No | No |
| 10:00 | 1999 | 2407 | 408 | 802 | 204 | 17 | No | No |
| 11:00 | 1814 | 2240 | 426 | 747 | 213 | 19 | No | No |
| 12:00 | 1912 | 2364 | 452 | 788 | 226 | 19 | No | No |
| 13:00 | 1975 | 2409 | 434 | 803 | 217 | 18 | No | No |
| 14:00 | 1985 | 2439 | 454 | 813 | 227 | 19 | No | No |
| 15:00 | 2296 | 2758 | 462 | 919 | 231 | 17 | No | No |
| 16:00 | 2483 | 3097 | 614 | 1032 | 307 | 20 | No | Yes |
| 17:00 | 3245 | 4080 | 835 | 1360 | 418 | 20 | No | Yes |
| 18:00 | 2391 | 2983 | 592 | 994 | 296 | 20 | No | No |
| 19:00 | 1404 | 1705 | 301 | 568 | 151 | 18 | No | No |
| 20:00 | 1111 | 1370 | 259 | 457 | 130 | 19 | No | No |
| 21:00 | 944 | 1169 | 225 | 390 | 113 | 19 | No | No |
| 22:00 | 660 | 785 | 125 | 262 | 63 | 16 | No | No |
| 23:00 | 350 | 395 | 45 | 132 | 23 | 11 | No | No |

## Turning Movement Counts

Data collected on 12/05/2013.

| | Six Forks Rd Northbound | | | | | Six Forks Rd Southbound | | | | | I-540 WB Ramps Westbound | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start Time | Left | Thru | Rgt | Peds | App. Total | Left | Thru | Rgt | Peds | App. Total | Left | Thru | Rgt | Peds | App. Total | Int. Total |
| 6:15 AM | 68 | 21 | 0 | 0 | 89 | 7 | 51 | 29 | 0 | 87 | 34 | 0 | 6 | 0 | 40 | 216 |
| 6:30 AM | 84 | 21 | 0 | 0 | 105 | 33 | 96 | 45 | 0 | 174 | 58 | 0 | 17 | 0 | 75 | 354 |
| 6:45 AM | 80 | 42 | 0 | 0 | 122 | 41 | 144 | 70 | 0 | 255 | 98 | 0 | 14 | 0 | 112 | 489 |
| 7:00 AM | 131 | 45 | 0 | 0 | 176 | 55 | 153 | 83 | 0 | 291 | 91 | 0 | 18 | 0 | 109 | 576 |
| Total | 363 | 129 | 0 | 0 | 492 | 136 | 444 | 227 | 0 | 807 | 281 | 0 | 55 | 0 | 336 | 1635 |
| | | | | | | | | | | | | | | | | |
| 7:15 AM | 143 | 57 | 0 | 0 | 200 | 62 | 216 | 107 | 0 | 385 | 111 | 0 | 26 | 0 | 137 | 722 |
| 7:30 AM | 158 | 54 | 0 | 0 | 212 | 56 | 241 | 106 | 0 | 403 | 94 | 0 | 21 | 0 | 115 | 730 |
| 7:45 AM | 150 | 119 | 0 | 0 | 269 | 54 | 235 | 98 | 0 | 387 | 135 | 0 | 31 | 0 | 166 | 822 |
| 8:00 AM | 152 | 116 | 0 | 0 | 268 | 35 | 253 | 86 | 0 | 374 | 152 | 0 | 25 | 0 | 177 | 819 |
| Total | 603 | 346 | 0 | 0 | 949 | 207 | 945 | 397 | 0 | 1549 | 492 | 0 | 103 | 0 | 595 | 3093 |

*Traffic Volume hourly counts begin on the hour (0:00); Turning Movement hourly totals begin on the quarter hour (0:15).

## Ramp Merge Capacity

The on-ramps were analyzed for the AM peak hour, which is the peak direction of travel. The analysis was performed using the ramps module for merge junctions of the 2010 Highway Capacity Software (HCS), which is based on methodologies from the 2010 Highway Capacity Manual (HCM).

Traffic volumes used in the analysis of the merge junctions were developed from 24-hour traffic counts collected in December 2013. The 15-minute intervals were aggregated into hourly volumes, from which the AM peak hour volume was identified. The peak hour factor (PHF) was calculated using the highest 15-minute volume of the peak hour volume.

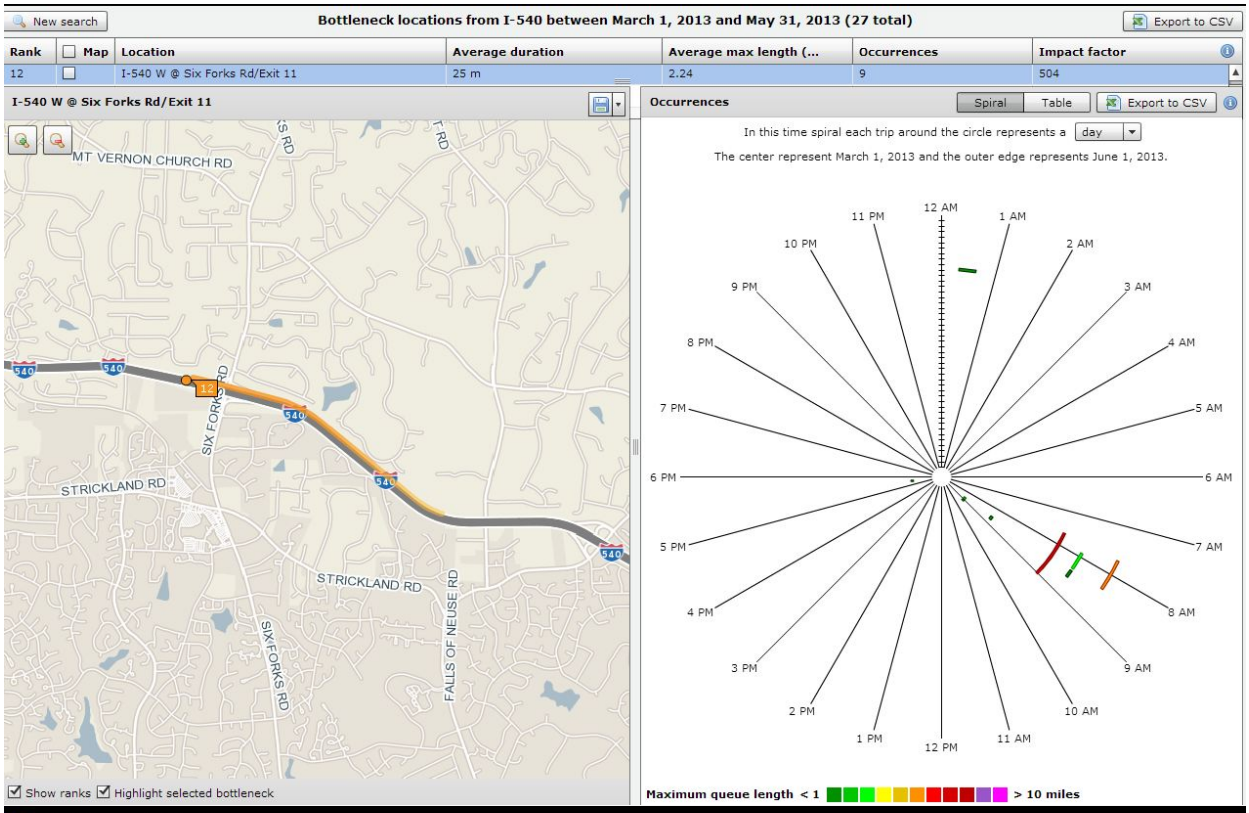
| Description | Peak Hour Volume | | Level-Of-Service (LOS) | Density (pc/mi/ln) |
|---|---|---|---|---|
| | Upstream Freeway | On-Ramp | | |
| I-540 Westbound<br>On-Ramp @ Six Forks Rd | 5,096 | 976 | B | 19.5 |

## Congestion

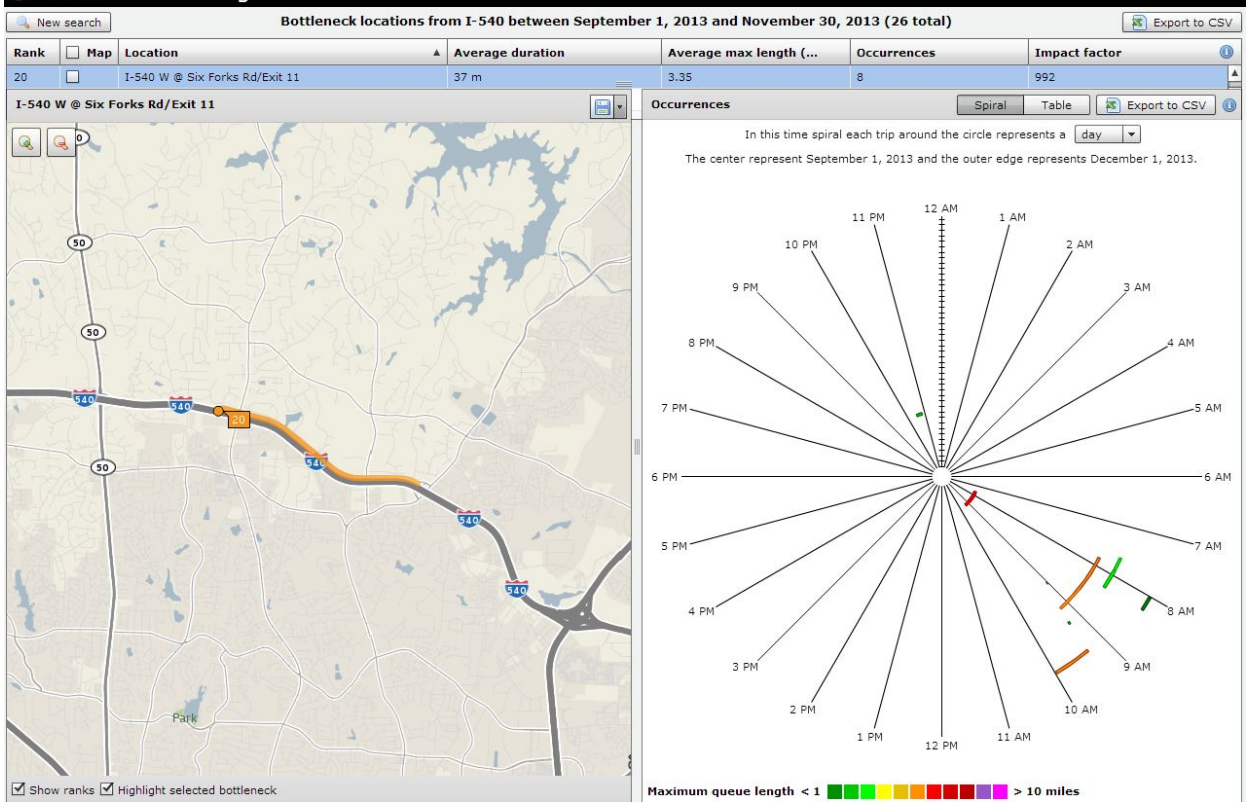
Congestion data was collected from the RITIS Vehicle Probe Project using Inrix data. Bottleneck occurrences are identified when the speed falls below 60% of the reference speed (85$^{th}$ percentile speed for all time periods) for greater than 5 minutes. Additional threshold criteria applied to identify bottleneck congestion that would benefit from ramp metering includes durations lasting 30 minutes and average maximum length of congestion greater than ½ mile and occurring at least twice a week (26 occurrences over the 3-month period).

| | Spring 2011 | Spring 2013 |
|---|---|---|
| Ave Length of Congestion (Miles) | 1.53 | 2.24 |
| Duration of Congestion (Min) | 17 | 25 |
| Number of Occurrences | 12 | 9 |
| Typical Times of Congestion | N/A | 07:30-09:00 |

| | Fall 2011 | Fall 2013 |
|---|---|---|
| Ave Length of Congestion (Miles) | 1.71 | 3.35 |
| Duration of Congestion (Min) | 23 | 37 |
| Number of Occurrences | 9 | 8 |
| Typical Times of Congestion | 08:00-09:00 | 7:30-09:00 |




## Bottleneck Ranking



## Crash Data

The total number of accidents from November 2010 through October 2013 was: 5
Of these 5 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 2 (40%)
Type 28- Sideswipe, same direction: 3 (60%)

## Observations

Log 140 is a two lane direct ramp with no sight distance issues. The right lane merges 330’ downstream and the other lane merges with the mainline 1950’ downstream. There is a very slight downhill grade. There is CCTV coverage of the entire ramp. The ramp has large easement space but no designated pull-off area.

Southbound AM right turn traffic from Six Forks Road was light. The northbound AM peak began at 7:30 AM. Largest observed queue was 20 cars.

The signal operation provides for tight platoons of traffic northbound onto the ramp. The ramp traffic was able to merge into a single lane on the ramp without affecting the traffic signal operation. Some problems with the right run traffic onto the ramp merging with the left turn traffic onto the ramp.

Starting around 7:30 AM, the traffic merging onto I-540 forced traffic on I-540 westbound to slow down and created some unstable traffic flow on I-540 in the two outside westbound lanes.

## NCDOT I-540 Westbound Ramp Metering Study

142

## Site Summary Document

### Site Details

| | |
|---|---|
| Site Number | 142 |
| Freeway | I-540 |
| Cross Street | Falls of the Neuse Rd |
| Exit | 11 |
| Direction | Westbound |
| County | Wake |


### Physical Characteristics Overview

| | |
|---|---|
| Origin of Ramp | Signal |
| Lane Addition onto Main Freeway length (ft) | None |
| Number of Entrance Ramp Lanes | 2 |
| Lane Drop on Entrance Ramp Before Merge | No |
| Number of Freeway Lanes Before Merge | 3 |
| Number of Freeway Lanes After Merge | 3 |
| Entrance Ramp Length to Back of Gore (ft) | 1400 |
| Entrance Ramp Length to Tip of Gore (ft) | 1750 |
| Merge Length (ft) | 800 |
| Entrance Ramp Horizontal Alignment | Slight Curve |
| Entrance Ramp Vertical Alignment | -2% |
| Entrance Ramp Shoulder (Paved Full Width) | Lt-4', Rt-10' |
| Main Freeway Vertical Alignment Downstream | Level |
| Main Freeway Shoulder | Left- 12', Right- 12' |
| Number of Vehicles Storage | 78 |
| Guardrail | Guardrail along right side of ramp. |
| Pipe Crossing | None present |

### Signalization Overview

| | |
|---|---|
| Upstream Signal | Four way signal with right turn on red onto ramp. Left turn phasing is protected only. |
| Signal Timing | Protected NBL, SBR has right turn on red and overlap phase. |
| Nearest Power Source | Signal or nearby transformer |

### Signing Overview

| | |
|---|---|
| Existing Signing | No issue. |

## Traffic Volumes

Data collected on 12/05/2013.

| Period Beginning | Upstream Hourly Flow Rate | Downstream Hourly Flow Rate | On-Ramp Hourly Flow Rate | Downstream Flow per Lane | On-Ramp Flow per Lane | On-Ramp % of Downstream | Hour Meets Ideal Criteria for Ramp Metering | Hour Meets Acceptable Criteria for Ramp Metering |
|---|---|---|---|---|---|---|---|---|
| 0:00 | 158 | 192 | 34 | 64 | 34 | 18 | No | No |
| 1:00 | 120 | 135 | 15 | 45 | 15 | 11 | No | No |
| 2:00 | 83 | 101 | 18 | 34 | 18 | 18 | No | No |
| 3:00 | 168 | 212 | 44 | 71 | 44 | 21 | No | No |
| 4:00 | 300 | 374 | 74 | 125 | 74 | 20 | No | No |
| 5:00 | 827 | 1093 | 266 | 364 | 266 | 24 | No | No |
| 6:00 | 2536 | 3436 | 900 | 1145 | 900 | 26 | No | Yes |
| 7:00 | 4230 | 5750 | 1520 | 1917 | 1520 | 26 | No | No |
| 8:00 | 3442 | 4704 | 1262 | 1568 | 1262 | 27 | No | No |
| 9:00 | 2390 | 3453 | 1063 | 1151 | 1063 | 31 | No | Yes |
| 10:00 | 1680 | 2356 | 676 | 785 | 676 | 29 | No | Yes |
| 11:00 | 1539 | 2240 | 701 | 747 | 701 | 31 | No | Yes |
| 12:00 | 1681 | 2356 | 675 | 785 | 675 | 29 | No | Yes |
| 13:00 | 1788 | 2462 | 674 | 821 | 674 | 27 | No | Yes |
| 14:00 | 1804 | 2534 | 730 | 845 | 730 | 29 | No | Yes |
| 15:00 | 2094 | 2865 | 771 | 955 | 771 | 27 | No | Yes |
| 16:00 | 2281 | 3103 | 822 | 1034 | 822 | 26 | No | Yes |
| 17:00 | 2836 | 3744 | 908 | 1248 | 908 | 24 | No | Yes |
| 18:00 | 2097 | 2831 | 734 | 944 | 734 | 26 | No | Yes |
| 19:00 | 1238 | 1707 | 469 | 569 | 469 | 27 | No | Yes |
| 20:00 | 958 | 1321 | 363 | 440 | 363 | 27 | No | Yes |
| 21:00 | 847 | 1131 | 284 | 377 | 284 | 25 | No | No |
| 22:00 | 554 | 716 | 162 | 239 | 162 | 23 | No | No |
| 23:00 | 280 | 389 | 109 | 130 | 109 | 28 | No | No |

## Turning Movement Counts

Data collected on 12/05/2013.

Groups Printed - Cars, PU, Vans - Heavy Trucks

| | Falls of Neuse Rd Northbound | | | | | Falls of Neuse Rd Southbound | | | | | -540 WB Ramps_Falls Valley D Eastbound | | | | | I-540 WB Ramps_Falls Valley Dr Westbound | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start Time | Left | Thru | Rgt | Peds | App. Total | Left | Thru | Rgt | Peds | App. Total | Left | Thru | Rgt | Peds | App. Total | Left | Thru | Rgt | Peds | App. Total | Int. Total |
| 6:15 AM | 17 | 99 | 1 | 0 | 117 | 6 | 106 | 139 | 0 | 251 | 12 | 2 | 22 | 0 | 36 | 3 | 10 | 3 | 0 | 16 | 420 |
| 6:30 AM | 34 | 105 | 4 | 0 | 143 | 3 | 157 | 229 | 0 | 389 | 23 | 1 | 31 | 0 | 55 | 10 | 23 | 3 | 0 | 36 | 623 |
| 6:45 AM | 42 | 157 | 3 | 0 | 202 | 6 | 233 | 252 | 0 | 491 | 45 | 2 | 39 | 0 | 86 | 13 | 14 | 7 | 0 | 34 | 813 |
| 7:00 AM | 54 | 105 | 11 | 0 | 170 | 2 | 258 | 319 | 0 | 579 | 38 | 3 | 41 | 0 | 82 | 16 | 42 | 3 | 0 | 61 | 892 |
| Total | 147 | 466 | 19 | 0 | 632 | 17 | 754 | 939 | 0 | 1710 | 118 | 8 | 133 | 0 | 259 | 42 | 89 | 16 | 0 | 147 | 2748 |
| | | | | | | | | | | | | | | | | | | | | | |
| 7:15 AM | 57 | 174 | 5 | 0 | 236 | 2 | 360 | 347 | 0 | 709 | 24 | 4 | 51 | 0 | 79 | 14 | 36 | 3 | 0 | 53 | 1077 |
| 7:30 AM | 73 | 186 | 13 | 0 | 272 | 6 | 359 | 230 | 0 | 595 | 31 | 3 | 104 | 0 | 138 | 27 | 44 | 6 | 0 | 77 | 1082 |
| 7:45 AM | 55 | 315 | 18 | 0 | 388 | 11 | 366 | 227 | 0 | 604 | 34 | 8 | 89 | 0 | 131 | 24 | 34 | 3 | 0 | 61 | 1184 |
| 8:00 AM | 60 | 242 | 14 | 0 | 316 | 5 | 318 | 230 | 0 | 553 | 50 | 5 | 85 | 0 | 140 | 25 | 28 | 3 | 0 | 56 | 1065 |
| Total | 245 | 917 | 50 | 0 | 1212 | 24 | 1403 | 1034 | 0 | 2461 | 139 | 20 | 329 | 0 | 488 | 90 | 142 | 15 | 0 | 247 | 4408 |

*Traffic Volume hourly counts begin on the hour (0:00); Turning Movement hourly totals begin on the quarter hour (0:15).

## Ramp Merge Capacity

The on-ramps were analyzed for the AM peak hour, which is the peak direction of travel. The analysis was performed using the ramps module for merge junctions of the 2010 Highway Capacity Software (HCS), which is based on methodologies from the 2010 Highway Capacity Manual (HCM).

Traffic volumes used in the analysis of the merge junctions were developed from 24-hour traffic counts collected in December 2013. The 15-minute intervals were aggregated into hourly volumes, from which the AM peak hour volume was identified. The peak hour factor (PHF) was calculated using the highest 15-minute volume of the peak hour volume.

| Description | Peak Hour Volume | | Level-Of-Service (LOS) | Density (pc/mi/ln) |
|---|---|---|---|---|
| | Upstream Freeway | On-Ramp | | |
| I-540 Westbound<br>On-Ramp @ Falls of the Neuse Rd | 4,230 | 1,520 | D | 34.1 |

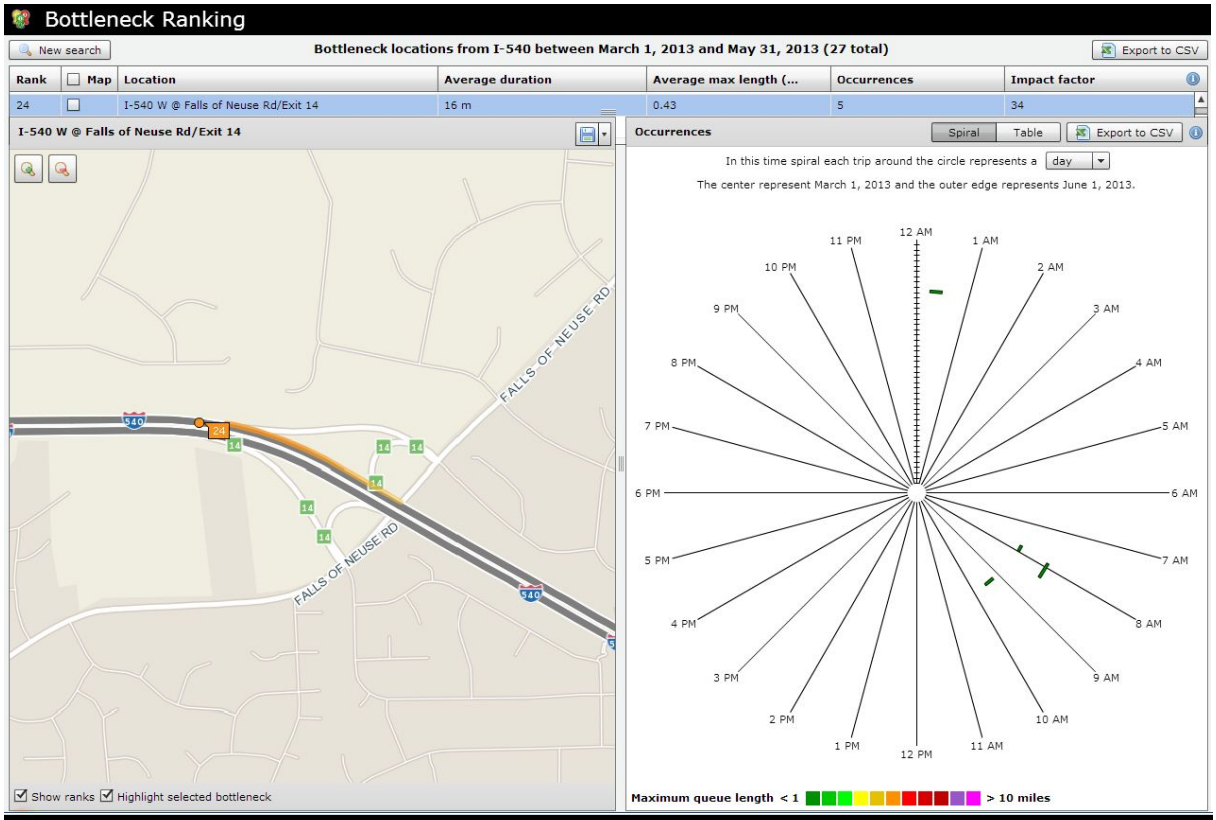
## Congestion

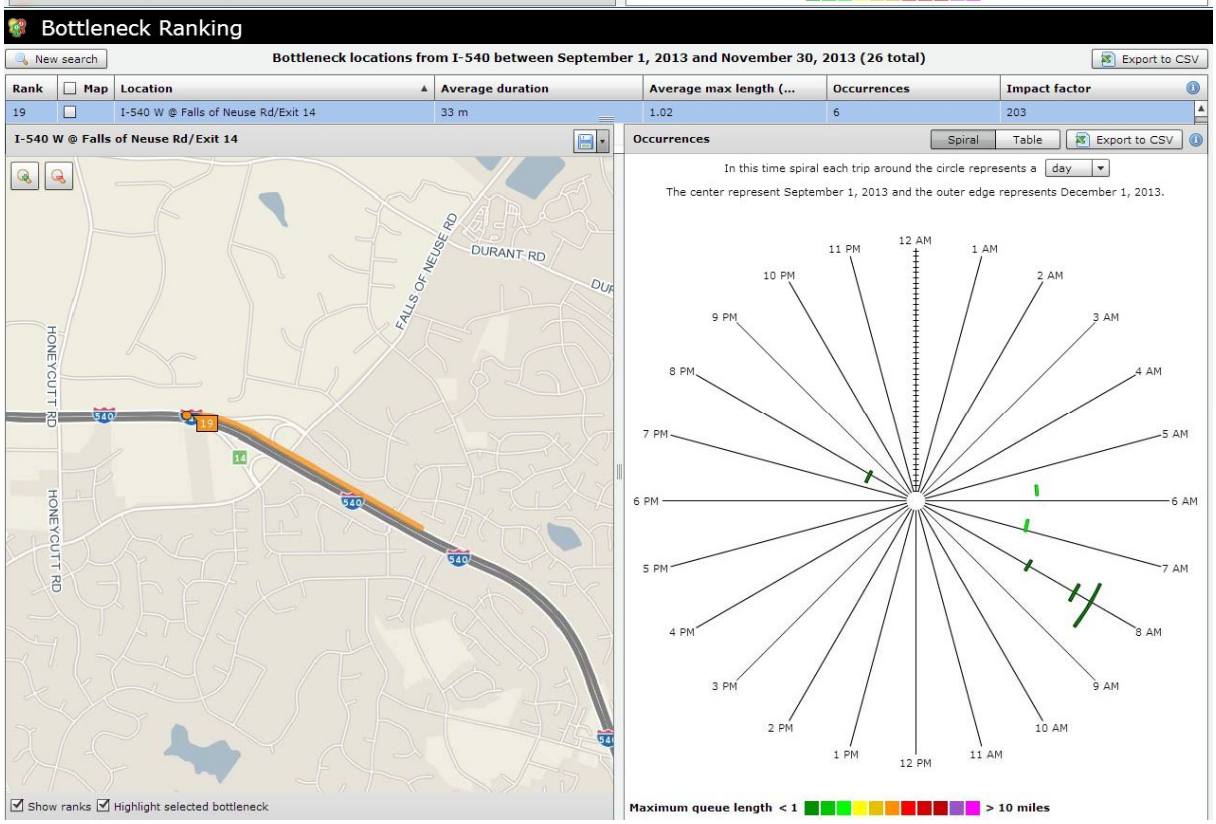
Congestion data was collected from the RITIS Vehicle Probe Project using Inrix data. Bottleneck occurrences are identified when the speed falls below 60% of the reference speed (85$^{th}$ percentile speed for all time periods) for greater than 5 minutes. Additional threshold criteria applied to identify bottleneck congestion that would benefit from ramp metering includes durations lasting 30 minutes and average maximum length of congestion greater than ½ mile and occurring at least twice a week (26 occurrences over the 3-month period).

| | Spring 2011 | Spring 2013 |
|---|---|---|
| Ave Length of Congestion (Miles) | 1.32 | 0.43 |
| Duration of Congestion (Min) | 16 | 16 |
| Number of Occurrences | 4 | 5 |
| Typical Times of Congestion | N/A | 7:30-8:30 * |

Note: this location fails bottleneck test for the required number of bottlenecks.

| | Fall 2011 | Fall 2013 |
|---|---|---|
| Ave Length of Congestion (Miles) | 0.96 | 1.02 |
| Duration of Congestion (Min) | 14 | 33 |
| Number of Occurrences | 11 | 6 |
| Typical Times of Congestion | N/A | N/A |


Bottleneck Ranking
New search
Bottleneck locations from I-540 between March 1, 2013 and May 31, 2013 (27 total)
Export to CSV
Rank
Map
Location
Average duration
Average max length (...
Occurrences
Impact factor
24
I-540 W @ Falls of Neuse Rd/Exit 14
16 m
0.43
5
34
I-540 W @ Falls of Neuse Rd/Exit 14
Occurrences
Spiral
Table
Export to CSV
In this time spiral each trip around the circle represents a
day
The center represent March 1, 2013 and the outer edge represents June 1, 2013.
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
11 PM
FALLS OF NEUSE RD
Show ranks
Highlight selected bottleneck
Maximum queue length < 1
> 10 miles


Bottleneck Ranking
New search
Bottleneck locations from I-540 between September 1, 2013 and November 30, 2013 (26 total)
Export to CSV
Rank
Map
Location
Average duration
Average max length (...
Occurrences
Impact factor
19
I-540 W @ Falls of Neuse Rd/Exit 14
33 m
1.02
6
203
I-540 W @ Falls of Neuse Rd/Exit 14
Occurrences
Spiral
Table
Export to CSV
In this time spiral each trip around the circle represents a
day
The center represent September 1, 2013 and the outer edge represents December 1, 2013.
12 AM
1 AM
2 AM
3 AM
4 AM
5 AM
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
8 PM
9 PM
10 PM
11 PM
FALLS OF NEUSE RD
DURANT RD
HONEYCUTT RD
Show ranks
Highlight selected bottleneck
Maximum queue length < 1
> 10 miles

### Crash Data

The total number of accidents from November 2010 through October 2013 was: 23
Of these 10 were accidents which can be associated with congestion:
Type 21-Rear end, slow or stop: 9 (39%)
Type 28- Sideswipe, same direction: 1 (4%)

### Observations

Log 142 is a direct ramp with no sight distance issues. The right lane merges about halfway down the ramp. There is a very slight downhill grade and a steep drop off behind the guardrail. There is CCTV coverage for most of the ramp. The ramp has large easement space but no designated pull-off area.

Northbound left turn was relatively light, at 7:20 AM the queue was 12 cars.

Southbound right turn traffic backed up to 2100’ to Litchford Rd. at 7:15 AM.

### Site Selection Comments

Ramp traffic is well-organized platoons. Starting around 7:00 AM, the traffic merging onto I-540 forced traffic on I-540 westbound to slow down and created some unstable traffic flow on I-540.

# Appendix B. Highway Capacity Analysis Worksheets

HCS 2010: Freeway Merge and Diverge Segments Release 6.41

Phone: Fax:
E-mail:

## Merge Analysis

| | |
|---|---|
| Analyst: | TDK |
| Agency/Co.: | Atkins |
| Date performed: | 12/18/2013 |
| Analysis time period: | AM Peak |
| Freeway/Dir of Travel: | I-540 Westbound |
| Junction: | Leesville Rd |
| Jurisdiction: | 136 |
| Analysis Year: | 2013 Existing |
| Description: | I-540 Ramp Metering Study |

## Freeway Data

| | | |
|---|---|---|
| Type of analysis | Merge | |
| Number of lanes in freeway | 3 | |
| Free-flow speed on freeway | 70.0 | mph |
| Volume on freeway | 5881 | vph |

## On Ramp Data

| | | |
|---|---|---|
| Side of freeway | Right | |
| Number of lanes in ramp | 1 | |
| Free-flow speed on ramp | 45.0 | mph |
| Volume on ramp | 1429 | vph |
| Length of first accel/decel lane | 1500 | ft |
| Length of second accel/decel lane | | ft |

## Adjacent Ramp Data (if one exists)

| | | |
|---|---|---|
| Does adjacent ramp exist? | No | |
| Volume on adjacent Ramp | | vph |
| Position of adjacent Ramp | | |
| Type of adjacent Ramp | | |
| Distance to adjacent Ramp | | ft |

## Conversion to pc/h Under Base Conditions

| Junction Components | Freeway | Ramp | Adjacent Ramp | |
|---|---|---|---|---|
| Volume, V (vph) | 5881 | 1429 | | vph |
| Peak-hour factor, PHF | 0.97 | 0.89 | | |
| Peak 15-min volume, v15 | 1516 | 401 | | v |
| Trucks and buses | 3 | 2 | | % |
| Recreational vehicles | 0 | 0 | | % |
| Terrain type: | Level | Level | | |
| Grade | % | % | % | |
| Length | mi | mi | mi | |
| Trucks and buses PCE, ET | 1.5 | 1.5 | | |
| Recreational vehicle PCE, ER | 1.2 | 1.2 | | |

```
Heavy vehicle adjustment, fHV          0.985       0.990
Driver population factor, fP           1.00        1.00
Flow rate, vp                          6154        1622                    pcph

____________________________Estimation of V12 Merge Areas____________________________

                 L  =            (Equation 13-6 or 13-7)
                  EQ
                 P  =    0.619   Using Equation  1
                  FM
                 v  = v  (P  ) =  3812   pc/h
                  12   F   FM

_____________________________________Capacity Checks_____________________________________

                           Actual        Maximum         LOS F?
     v                     7776          7200            Yes
      FO
     v  or v               2342 pc/h     (Equation 13-14 or 13-17)
      3     av34
Is   v  or v      > 2700 pc/h?           No
      3     av34
Is   v  or v      > 1.5 v  /2            No
      3     av34          12
If yes, v    = 3812                   (Equation 13-15, 13-16, 13-18, or 13-19)
        12A

_____________________Flow Entering Merge Influence Area_____________________
                    Actual        Max Desirable         Violation?
     v              7776          4600                  Yes
      R12
_________________Level of Service Determination (if not F)_________________

Density, D = 5.475 + 0.00734 v  + 0.0078 v   - 0.00627 L   =   37.7    pc/mi/ln
          R                   R          12            A
Level of service for ramp-freeway junction areas of influence  F

_____________________________Speed Estimation_____________________________

Intermediate speed variable,                M  = 1.079
                                             S
Space mean speed in ramp influence area,    S  = 39.8    mph
                                             R
Space mean speed in outer lanes,            S  = 63.2    mph
                                             O
Space mean speed for all vehicles,          S  = 44.8    mph
_____________________________________________________________________________
```

HCS 2010: Freeway Merge and Diverge Segments Release 6.41

Phone: Fax:
E-mail:

## Merge Analysis

| | |
|---|---|
| Analyst: | TDK |
| Agency/Co.: | Atkins |
| Date performed: | 12/18/2013 |
| Analysis time period: | AM Peak |
| Freeway/Dir of Travel: | I-540 Westbound |
| Junction: | Creedmoor Rd |
| Jurisdiction: | 138 |
| Analysis Year: | 2013 Existing |
| Description: | I-540 Ramp Metering Study |

## Freeway Data

| | | |
|---|---|---|
| Type of analysis | Merge | |
| Number of lanes in freeway | 3 | |
| Free-flow speed on freeway | 70.0 | mph |
| Volume on freeway | 5412 | vph |

## On Ramp Data

| | | |
|---|---|---|
| Side of freeway | Right | |
| Number of lanes in ramp | 1 | |
| Free-flow speed on ramp | 45.0 | mph |
| Volume on ramp | 963 | vph |
| Length of first accel/decel lane | 1500 | ft |
| Length of second accel/decel lane | | ft |

## Adjacent Ramp Data (if one exists)

| | | |
|---|---|---|
| Does adjacent ramp exist? | No | |
| Volume on adjacent Ramp | | vph |
| Position of adjacent Ramp | | |
| Type of adjacent Ramp | | |
| Distance to adjacent Ramp | | ft |

## Conversion to pc/h Under Base Conditions

| Junction Components | Freeway | Ramp | Adjacent Ramp | |
|---|---|---|---|---|
| Volume, V (vph) | 5412 | 963 | | vph |
| Peak-hour factor, PHF | 0.92 | 0.87 | | |
| Peak 15-min volume, v15 | 1471 | 277 | | v |
| Trucks and buses | 5 | 4 | | % |
| Recreational vehicles | 0 | 0 | | % |
| Terrain type: | Level | Level | | |
| Grade | % | % | % | |
| Length | mi | mi | mi | |
| Trucks and buses PCE, ET | 1.5 | 1.5 | | |
| Recreational vehicle PCE, ER | 1.2 | 1.2 | | |

```
Heavy vehicle adjustment, fHV          0.976       0.980
Driver population factor, fP           1.00        1.00
Flow rate, vp                          6030        1129                    pcph

____________________________Estimation of V12 Merge Areas____________________________

                 L  =            (Equation 13-6 or 13-7)
                  EQ
                 P  =    0.619   Using Equation  1
                  FM
                 v  = v  (P  ) =  3736   pc/h
                  12   F   FM

_____________________________________Capacity Checks_____________________________________

                           Actual        Maximum         LOS F?
     v                     7159          7200            No
      FO
     v  or v               2294 pc/h     (Equation 13-14 or 13-17)
      3     av34
Is   v  or v      > 2700 pc/h?           No
      3     av34
Is   v  or v      > 1.5 v  /2            No
      3     av34          12
If yes, v    = 3736                   (Equation 13-15, 13-16, 13-18, or 13-19)
        12A

_________________________Flow Entering Merge Influence Area_________________________
                    Actual        Max Desirable         Violation?
     v              7159          4600                  Yes
      R12
_________________Level of Service Determination (if not F)_________________

Density, D = 5.475 + 0.00734 v  + 0.0078 v   - 0.00627 L   =   33.5    pc/mi/ln
          R                   R          12            A
Level of service for ramp-freeway junction areas of influence  D

_______________________________Speed Estimation_______________________________

Intermediate speed variable,                M  = 0.692
                                             S
Space mean speed in ramp influence area,    S  = 50.6    mph
                                             R
Space mean speed in outer lanes,            S  = 63.5    mph
                                             O
Space mean speed for all vehicles,          S  = 54.2    mph
_____________________________________________________________________________
```

HCS 2010: Freeway Merge and Diverge Segments Release 6.41

Phone: Fax:
E-mail:

## Merge Analysis

| | |
|---|---|
| Analyst: | TDK |
| Agency/Co.: | Atkins |
| Date performed: | 12/18/2013 |
| Analysis time period: | AM Peak |
| Freeway/Dir of Travel: | I-540 Westbound |
| Junction: | Six Forks Rd |
| Jurisdiction: | 140 |
| Analysis Year: | 2013 Existing |
| Description: | I-540 Ramp Metering Study |

## Freeway Data

| | | |
|---|---|---|
| Type of analysis | Merge | |
| Number of lanes in freeway | 3 | |
| Free-flow speed on freeway | 70.0 | mph |
| Volume on freeway | 5096 | vph |

## On Ramp Data

| | | |
|---|---|---|
| Side of freeway | Right | |
| Number of lanes in ramp | 2 | |
| Free-flow speed on ramp | 45.0 | mph |
| Volume on ramp | 976 | vph |
| Length of first accel/decel lane | 800 | ft |
| Length of second accel/decel lane | 1500 | ft |

## Adjacent Ramp Data (if one exists)

| | | |
|---|---|---|
| Does adjacent ramp exist? | No | |
| Volume on adjacent Ramp | | vph |
| Position of adjacent Ramp | | |
| Type of adjacent Ramp | | |
| Distance to adjacent Ramp | | ft |

## Conversion to pc/h Under Base Conditions

| Junction Components | Freeway | Ramp | Adjacent Ramp | |
|---|---|---|---|---|
| Volume, V (vph) | 5096 | 976 | | vph |
| Peak-hour factor, PHF | 0.90 | 0.95 | | |
| Peak 15-min volume, v15 | 1416 | 257 | | v |
| Trucks and buses | 4 | 4 | | % |
| Recreational vehicles | 0 | 0 | | % |
| Terrain type: | Level | Level | | |
| Grade | % | % | % | |
| Length | mi | mi | mi | |
| Trucks and buses PCE, ET | 1.5 | 1.5 | | |
| Recreational vehicle PCE, ER | 1.2 | 1.2 | | |

```
Heavy vehicle adjustment, fHV          0.980       0.980
Driver population factor, fP           1.00        1.00
Flow rate, vp                          5775        1048                    pcph

____________________________Estimation of V12 Merge Areas____________________________

                 L  =            (Equation 13-6 or 13-7)
                  EQ
                 P  =    0.555   Using Equation  0
                  FM
                 v  = v  (P  ) =  3205   pc/h
                  12   F   FM

_____________________________________Capacity Checks_____________________________________

                           Actual        Maximum         LOS F?
     v                     6823          7200            No
      FO
     v  or v               2570 pc/h     (Equation 13-14 or 13-17)
      3     av34
Is   v  or v      > 2700 pc/h?           No
      3     av34
Is   v  or v      > 1.5 v  /2            Yes
      3     av34          12
If yes, v    = 3300                   (Equation 13-15, 13-16, 13-18, or 13-19)
        12A

_________________________Flow Entering Merge Influence Area_________________________
                    Actual        Max Desirable         Violation?
     v              6823          4600                  No
      12A
_________________Level of Service Determination (if not F)_________________

Density, D = 5.475 + 0.00734 v  + 0.0078 v   - 0.00627 L   =   19.5    pc/mi/ln
          R                   R           12            A
Level of service for ramp-freeway junction areas of influence  B

_______________________________Speed Estimation_______________________________

Intermediate speed variable,                M  = 0.344
                                             S
Space mean speed in ramp influence area,    S  = 60.4    mph
                                             R
Space mean speed in outer lanes,            S  = 62.4    mph
                                             O
Space mean speed for all vehicles,          S  = 61.1    mph
_____________________________________________________________________________
```

HCS 2010: Freeway Merge and Diverge Segments Release 6.41

Phone: Fax:
E-mail:

## Merge Analysis

| | |
|---|---|
| Analyst: | TDK |
| Agency/Co.: | Atkins |
| Date performed: | 12/18/2013 |
| Analysis time period: | AM Peak |
| Freeway/Dir of Travel: | I-540 Westbound |
| Junction: | Falls of Neuse Rd |
| Jurisdiction: | 142 |
| Analysis Year: | 2013 Existing |
| Description: | I-540 Ramp Metering Study |

## Freeway Data

| | | |
|---|---|---|
| Type of analysis | Merge | |
| Number of lanes in freeway | 3 | |
| Free-flow speed on freeway | 70.0 | mph |
| Volume on freeway | 4230 | vph |

## On Ramp Data

| | | |
|---|---|---|
| Side of freeway | Right | |
| Number of lanes in ramp | 1 | |
| Free-flow speed on ramp | 45.0 | mph |
| Volume on ramp | 1520 | vph |
| Length of first accel/decel lane | 1200 | ft |
| Length of second accel/decel lane | | ft |

## Adjacent Ramp Data (if one exists)

| | | |
|---|---|---|
| Does adjacent ramp exist? | No | |
| Volume on adjacent Ramp | | vph |
| Position of adjacent Ramp | | |
| Type of adjacent Ramp | | |
| Distance to adjacent Ramp | | ft |

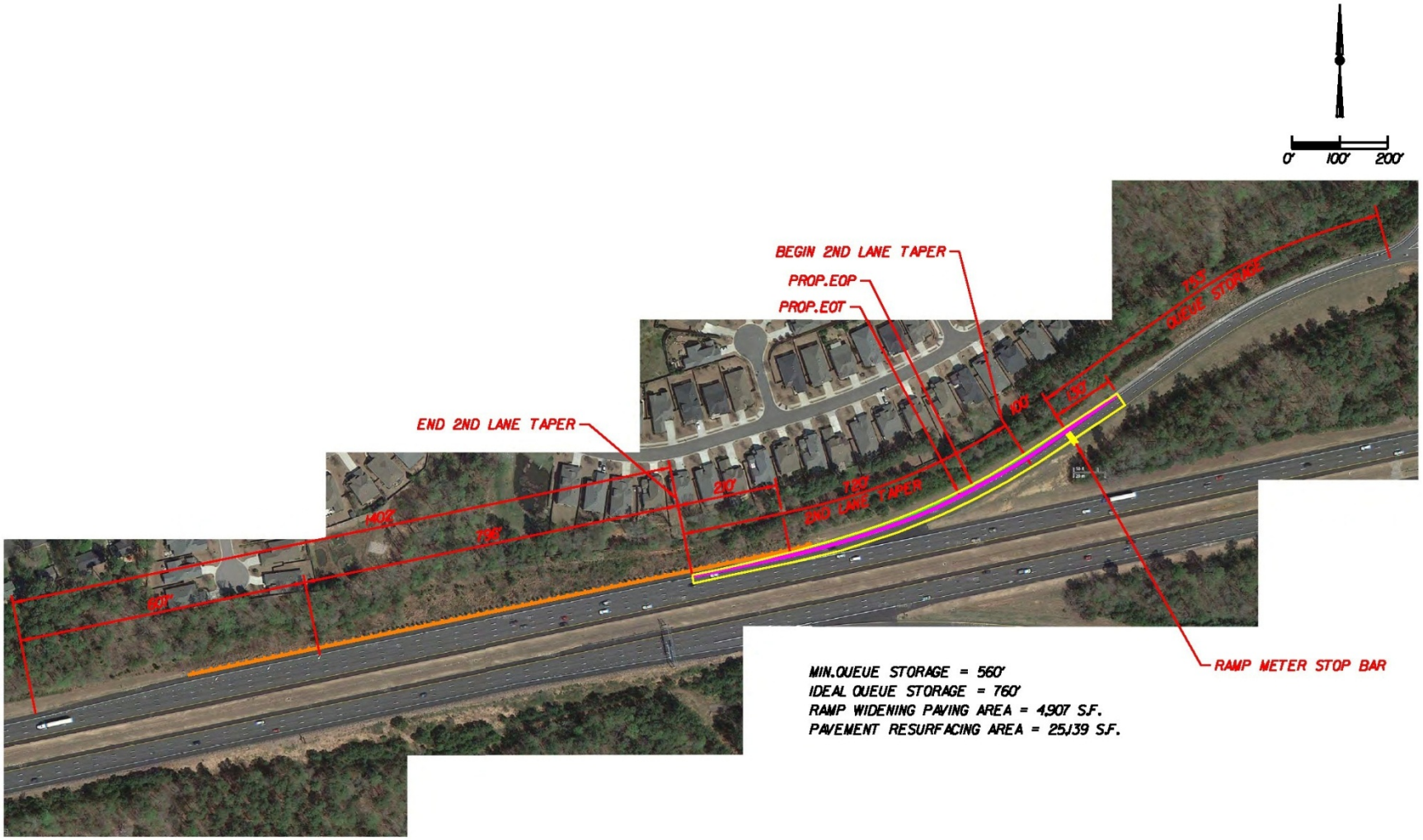
## Conversion to pc/h Under Base Conditions

| Junction Components | Freeway | Ramp | Adjacent Ramp | |
|---|---|---|---|---|
| Volume, V (vph) | 4230 | 1520 | | vph |
| Peak-hour factor, PHF | 0.90 | 0.85 | | |
| Peak 15-min volume, v15 | 1175 | 447 | | v |
| Trucks and buses | 5 | 1 | | % |
| Recreational vehicles | 0 | 0 | | % |
| Terrain type: | Level | Level | | |
| Grade | % | % | % | |
| Length | mi | mi | mi | |
| Trucks and buses PCE, ET | 1.5 | 1.5 | | |
| Recreational vehicle PCE, ER | 1.2 | 1.2 | | |

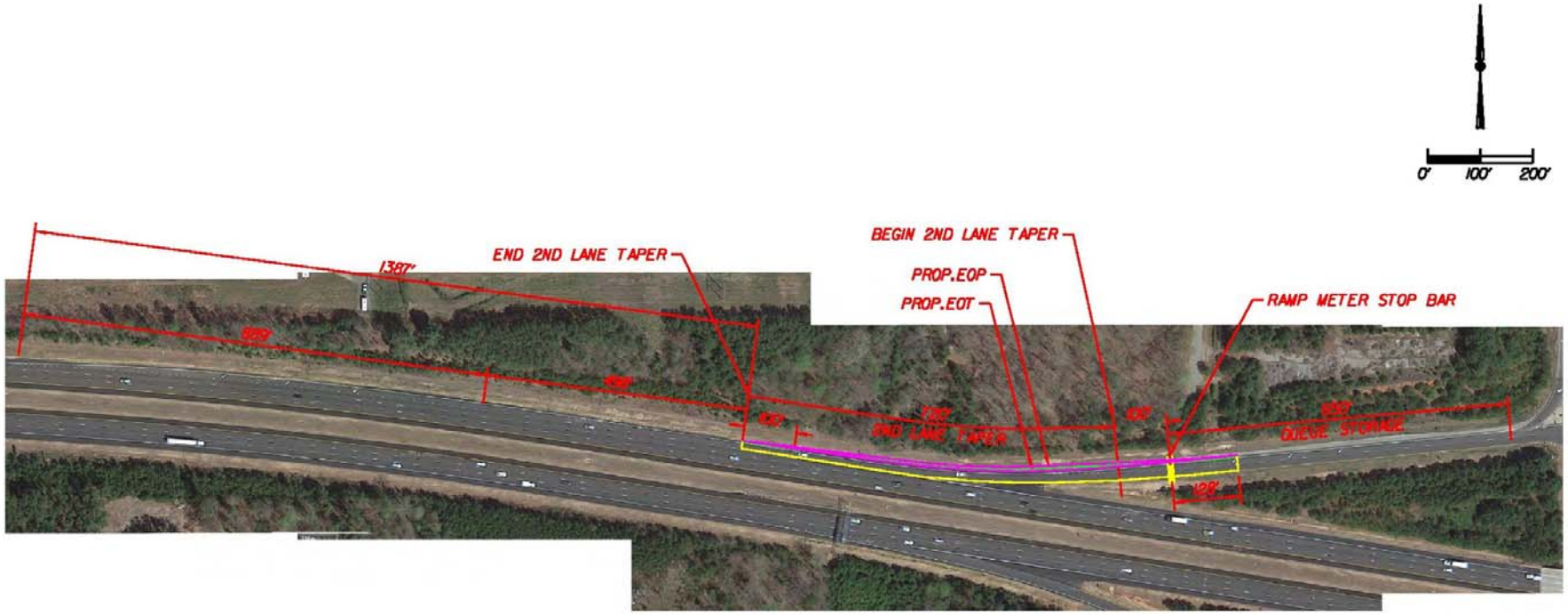
```
Heavy vehicle adjustment, fHV          0.976       0.995
Driver population factor, fP           1.00        1.00
Flow rate, vp                          4818        1797                    pcph

____________________________Estimation of V12 Merge Areas____________________________

                 L  =            (Equation 13-6 or 13-7)
                  EQ
                 P  =    0.611   Using Equation  1
                  FM
                 v  = v  (P  ) =  2944   pc/h
                  12   F   FM

_____________________________________Capacity Checks_____________________________________

                           Actual        Maximum         LOS F?
     v                     6615          7200            No
      FO
     v  or v               1874 pc/h     (Equation 13-14 or 13-17)
      3     av34
Is   v  or v      > 2700 pc/h?           No
      3     av34
Is   v  or v      > 1.5 v  /2            No
      3     av34          12
If yes, v    = 2944                   (Equation 13-15, 13-16, 13-18, or 13-19)
        12A

_____________________Flow Entering Merge Influence Area_____________________
                    Actual        Max Desirable         Violation?
     v              6615          4600                  Yes
      R12
_________________Level of Service Determination (if not F)_________________

Density, D = 5.475 + 0.00734 v  + 0.0078 v   - 0.00627 L   =   34.1    pc/mi/ln
          R                   R          12            A
Level of service for ramp-freeway junction areas of influence  D

_____________________________Speed Estimation_____________________________

Intermediate speed variable,                M  = 0.660
                                             S
Space mean speed in ramp influence area,    S  = 51.5    mph
                                             R
Space mean speed in outer lanes,            S  = 65.1    mph
                                             O
Space mean speed for all vehicles,          S  = 54.8    mph
_____________________________________________________________________________
```

# Appendix C. Geometric Layouts

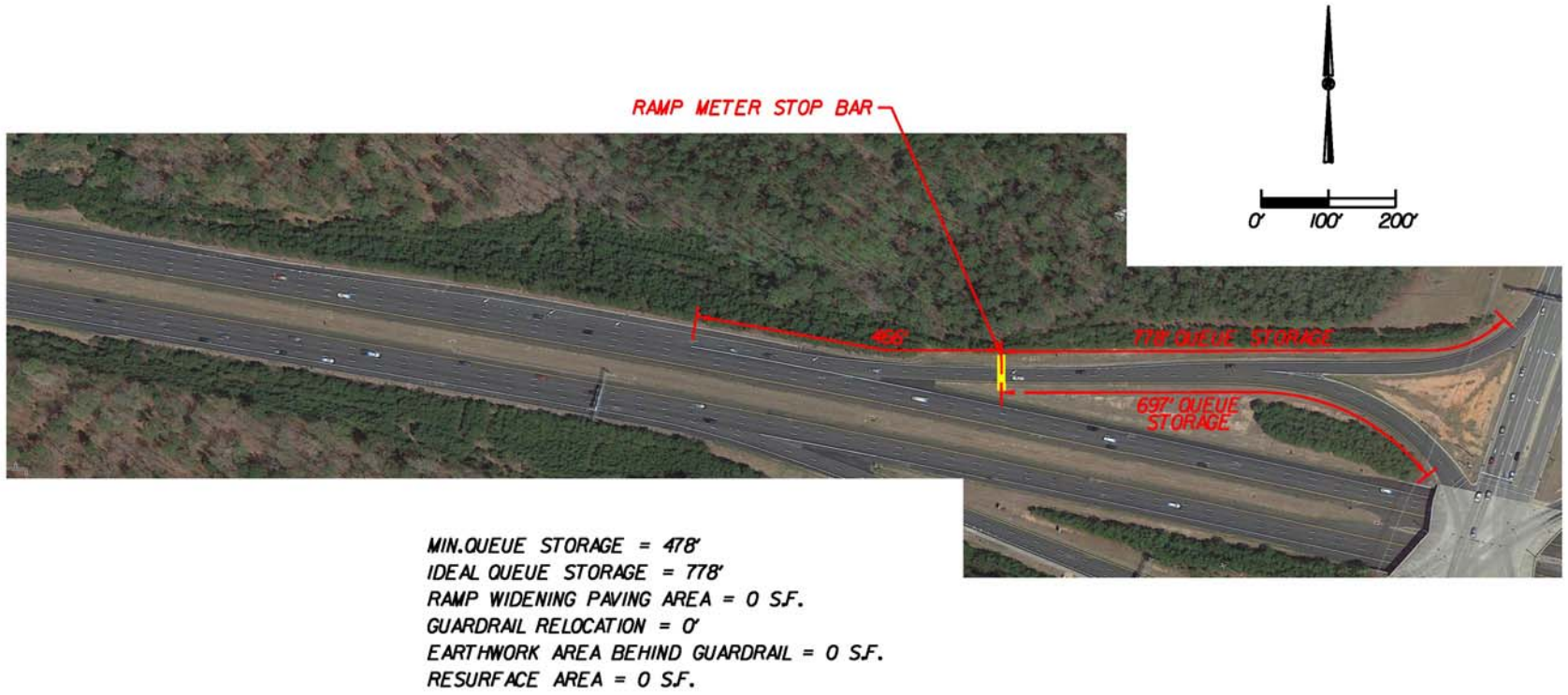
**Figure 5. Proposed Improvements – Leesville Road**



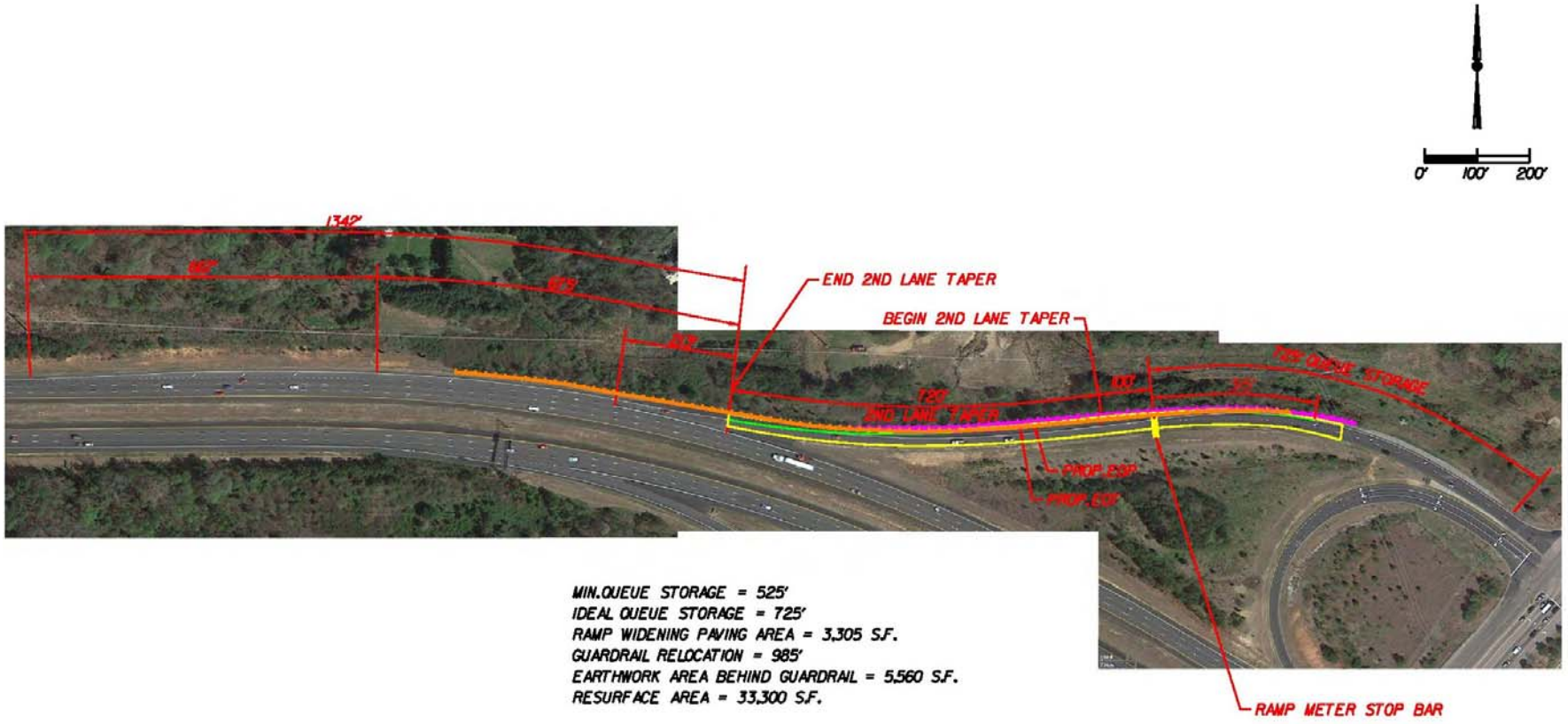
## Figure 6. Proposed Improvements – Creedmoor Road



## Figure 7. Proposed Improvements – Six Forks Road



## Figure 8. Proposed Improvements – Falls of Neuse Road



# Appendix D. Cost Estimates

**Typical Design and Construction Costs**
**Site Assumptions Checklist**

**Log No.:** 136 **Ramp:** Leesville Road
**Location:** I-540 Westbound

| | |
|---|---|
| Two Lane Ramp Widening (Y/N): | Y |
| Length of Two Lane Ramp Widening (ft.): | 985 |
| Distance from Stopbar to W3-8 sign (ft.): | 885 |
| Pipe Crossings (Y/N): | N |
| Retaining Walls (Y/N): | N |
| Fill (Y/N): | N |
| Guardrail Other than for Ramp Meter Equipment (Y/N): | N |
| Install Guardrail (one side or two) | 2 |
| Nearest Power Source (ft.): | 1095 |

Notes

Nearest power source is traffic signal.
Install pedestal poles on both sides, protect with guardrail both sides of ramp
Connect to City of Raleigh fiber-optic communciations network.
Modify splicing in City signal cabinet.
Mount CCTV on existing signal pole.

## Typical Design and Construction Costs
## Two Lane Ramp Meter

**Log No.:** 136 **Ramp:** Leesville Road
**Location:** I-540 Westbound

| Categories / Description | Unit | Quantity | Unit Cost | Total Cost | Assumptions |
|---|---|---|---|---|---|
| Earthwork and Structures | | | | | |
| Retaining Wall 5' High | LF | 0 | $ 250.00 | $ - | |
| Retaining Wall 10' High | LF | 0 | $ 475.00 | $ - | |
| Excavation | CY | 0 | $ 4.00 | $ - | |
| Fill | CY | 206 | $ 5.00 | $ 1,030.00 | From measured areas @ 20' depth. |
| Seeding | SY | 3633 | $ 2.50 | $ 9,082.50 | Seeding along pavement widening and around trench, conduit, pull box, and foundation areas |
| **Subtotal** | | | | **$ 10,112.50** | |
| Guardrail | | | | | |
| Guardrail Rail | LF | 1235 | $ 15.00 | $ 18,525.00 | From measured area |
| Guardrail Approach End Treatment | EA | 2 | $ 1,500.00 | $ 3,000.00 | |
| **Subtotal** | | | | **$ 21,525.00** | |
| Paving | | | | | |
| Ramp Widening | SY | 545 | $ 32.00 | $ 17,447.11 | From measured area |
| Pavement Resurfacing | SY | 2793 | $ 12.00 | $ 33,518.67 | From measured area |
| **Subtotal** | | | | **$ 50,965.78** | |
| Drainage | | | | | |
| Pipe | LF | 0 | $ 44.00 | $ - | |
| **Subtotal** | | | | **$ -** | |
| Signalization | | | | | |
| 6'x6' loops | EA | 10 | $ 394.50 | $ 3,945.00 | One queue, three passage and one clearance |
| Detector Lead-in Cable | EA | 390 | $ 1.50 | $ 585.00 | Assumed setback distance 350' |
| MVDS detector | EA | 1 | $ 1,800.00 | $ 1,800.00 | Mainline detection |
| Detector pole | EA | 1 | $ 6,000.00 | $ 6,000.00 | |
| Pullbox (Std.) | EA | 6 | $ 300.00 | $ 1,800.00 | |
| Conduit (Trenched) | LF | 3125 | $ 6.00 | $ 18,750.00 | All purposes |
| Conduit (Directional Drilled) | LF | 100 | $ 14.00 | $ 1,400.00 | Two ramp crossings, mult. conduits |
| Modify Electrical Service | EA | 1 | $ 3,000.00 | $ 3,000.00 | |
| Electrical Conductors | LF | 1095 | $ 5.00 | $ 5,475.00 | |
| 2070 Controller and Cabinet | EA | 1 | $ 14,000.00 | $ 14,000.00 | |
| Firmware/Calibration | EA | 1 | $ 5,300.00 | $ 5,300.00 | |
| Cabinet Foundation | EA | 1 | $ 450.00 | $ 450.00 | |
| 45' Mast Arm Poles and Foundation | EA | 0 | $ 15,000.00 | $ - | |
| Pedestal Pole | EA | 2 | $ 1,000.00 | $ 2,000.00 | dual pedestals |
| Three Section Signal Head | EA | 2 | $ 1,000.00 | $ 2,000.00 | |
| One Section Signal Head | EA | 2 | $ 500.00 | $ 1,000.00 | Ramp meter advance signal |
| Signal Cable | LF | 505 | $ 2.75 | $ 1,388.75 | |
| **Subtotal** | | | | **$ 68,893.75** | |

## Typical Design and Construction Costs
## Two Lane Ramp Meter

**Log No.:** 136 **Ramp:** Leesville Road
**Location:** I-540 Westbound

| Categories | Description | Unit | Quantity | Unit Cost | Total Cost | Assumptions |
|---|---|---|---|---|---|---|
| ITS and Communications | | | | | | |
| | CCTV Camera | EA | 1 | $ 4,000.00 | $ 4,000.00 | |
| | CCTV Cabinet | EA | 1 | $ 5,000.00 | $ 5,000.00 | |
| | CCTV Pole with riser | EA | 0 | $ 3,000.00 | $ - | |
| | 1" Riser | EA | 1 | $ 400.00 | $ 400.00 | |
| | Serial Communications | EA | 350 | $ 2.00 | $ 700.00 | Link to MVDS |
| | Splice Enclosure | EA | 2 | $ 1,000.00 | $ 2,000.00 | Link to SMFO |
| | Pullbox (Special Size) | EA | 1 | $ 1,750.00 | $ 1,750.00 | For splice enclosure |
| | Interconnect Center | EA | 2 | $ 1,500.00 | $ 3,000.00 | In cabinet |
| | Modify splice in City signal cabinet | EA | 1 | $ 2,200.00 | $ 2,200.00 | |
| | Fiber-optic Drop Cable (six strands) | LF | 1195 | $ 2.00 | $ 2,390.00 | Drop cable to controller cabinet, Same distance to power source plus 300' for proposed CCTV on ramp |
| | Ethernet Switch | EA | 2 | $ 2,000.00 | $ 4,000.00 | CCTV and ramp meter controller |
| **Subtotal** | | | | | **$ 25,440.00** | |
| Pavement Marking | | | | | | |
| | Pavement Marking Removal | LF | 640 | $ 0.62 | $ 396.80 | 40 mph design speed. 110' transitions, 100' narrowed lane |
| | Raised Pavement Markers | EA | 15 | $ 4.50 | $ 67.50 | Along skip line only |
| | White Edge Line | LF | 1135 | $ 0.95 | $ 1,078.25 | 110' transitions, 100' narrowed lane |
| | Yellow Edge Line | LF | 1135 | $ 0.95 | $ 1,078.25 | 110' transitions, 100' narrowed lane |
| | White Skip Line | LF | 1135 | $ 0.24 | $ 269.56 | |
| | 24" Stop Bar | LF | 12 | $ 7.00 | $ 84.00 | |
| **Subtotal** | | | | | **$ 2,974.36** | |
| Signing | | | | | | |
| | Remove existing single and dual post | EA | 4 | $ 100.00 | $ 400.00 | |
| | W3-8, Ramp Metered When Flashing | EA | 2 | $ 650.00 | $ 1,300.00 | Sign and post only |
| | W3-4, Be Prepared to Stop | EA | 1 | $ 650.00 | $ 650.00 | Sign and post |
| | R10-6, Stop Here on Red | EA | 1 | $ 175.00 | $ 175.00 | Pedestal mounted |
| | R10-28, XX Vehicles Per Green | EA | 1 | $ 175.00 | $ 175.00 | Pedestal mounted |
| | W4-1L, Merge Left | EA | 1 | $ 650.00 | $ 650.00 | |
| **Subtotal** | | | | | **$ 3,350.00** | |
| Subtotal Construction | | | | | **$ 183,261.39** | |
| | Traffic Control | | | 20% | $ 36,652.28 | |
| | Contingencies | | | 10% | $ 18,326.14 | |
| **Total Construction** | | | | | **$ 238,239.81** | |

| | | |
|---|---|---|
| Design | 26% | $ 61,942.35 |
| Construction Administration | 10% | $ 23,823.98 |
| **Total Design and Construction** | | **$ 324,006.14** |

**Typical Design and Construction Costs**
**Site Assumptions Checklist**

**Log No.:** 138 **Ramp:** Creedmoor Road
**Location:** I-540 Westbound

| | |
|---|---|
| Two Lane Ramp Widening (Y/N): | y |
| Length of Two Lane Ramp Widening (ft.): | 250 |
| Distance from Stopbar to W3-8 sign (ft.): | 800 |
| Pipe Crossings (Y/N): | N |
| Retaining Walls (Y/N): | N |
| Fill (Y/N): | N |
| Guardrail Other than for Ramp Meter Equipment (Y/N): | N |
| Install Guardrail (one side or two) | 2 |
| Nearest Power Source (ft.): | 950 |

Notes

Nearest power source is traffic signal.
Install pedestal poles on both sides, protect with guardrail both sides of ramp
Connect to City of Raleigh fiber-optic communciations network.
Modify splicing in City signal cabinet.
Mount CCTV on existing signal pole.

## Typical Design and Construction Costs
## Two Lane Ramp Meter

**Log No.:** 138 **Ramp:** Creedmoor Road
**Location:** I-540 Westbound

| Categories | Description | Unit | Quantity | Unit Cost | Total Cost | Assumptions |
|---|---|---|---|---|---|---|
| Earthwork and Structures | | | | | | |
| | Retaining Wall 5' High | LF | 0 | $ 250.00 | $ - | |
| | Retaining Wall 10' High | LF | 0 | $ 475.00 | $ - | |
| | Excavation | CY | 0 | $ 4.00 | $ - | |
| | Fill | CY | 364 | $ 5.00 | $ 1,820.00 | From measured area @ 2' depth. |
| | Seeding | SY | 2860 | $ 2.50 | $ 7,150.00 | Seeding along pavement widening and around trench, conduit, pull box, and foundation areas |
| **Subtotal** | | | | | **$ 8,970.00** | |
| Guardrail | | | | | | |
| | Guardrail Rail | LF | 500 | $ 15.00 | $ 7,500.00 | From measured area |
| | Guardrail Approach End Treatment | EA | 2 | $ 1,500.00 | $ 3,000.00 | |
| **Subtotal** | | | | | **$ 10,500.00** | |
| Paving | | | | | | |
| | Ramp Widening | SY | 558 | $ 32.00 | $ 17,845.33 | From measured area |
| | Pavement Resurfacing | SY | 2840 | $ 12.00 | $ 34,085.33 | From measured area |
| **Subtotal** | | | | | **$ 51,931.00** | |
| Drainage | | | | | | |
| | Pipe | LF | 0 | $ 44.00 | $ - | |
| **Subtotal** | | | | | **$ -** | |
| Signalization | | | | | | |
| | 6'x6' loops | EA | 10 | $ 394.50 | $ 3,945.00 | One queue, three passage and one clearance |
| | Detector Lead-in Cable | EA | 390 | $ 1.50 | $ 585.00 | Assumed setback distance 350' |
| | MVDS detector | EA | 1 | $ 1,800.00 | $ 1,800.00 | Mainline detection |
| | Detector pole | EA | 1 | $ 6,000.00 | $ 6,000.00 | |
| | Pullbox (Std.) | EA | 6 | $ 300.00 | $ 1,800.00 | |
| | Conduit (Trenched) | LF | 2335 | $ 6.00 | $ 14,010.00 | All purposes |
| | Conduit (Directional Drilled) | LF | 100 | $ 14.00 | $ 1,400.00 | Two ramp crossings, mult. conduits |
| | Modify Electrical Service | EA | 1 | $ 3,000.00 | $ 3,000.00 | |
| | Electrical Conductors | LF | 950 | $ 5.00 | $ 4,750.00 | |
| | 2070 Controller and Cabinet | EA | 1 | $14,000.00 | $ 14,000.00 | |
| | Firmware/Calibration | EA | 1 | $ 5,300.00 | $ 5,300.00 | |
| | Cabinet Foundation | EA | 1 | $ 450.00 | $ 450.00 | |
| | 45' Mast Arm Poles and Foundation | EA | 0 | $15,000.00 | $ - | |
| | Pedestal Pole | EA | 2 | $ 1,000.00 | $ 2,000.00 | dual pedestals |
| | Three Section Signal Head | EA | 2 | $ 1,000.00 | $ 2,000.00 | |
| | One Section Signal Head | EA | 2 | $ 500.00 | $ 1,000.00 | Ramp meter advance signal |
| | Signal Cable | LF | 505 | $ 2.75 | $ 1,388.75 | |
| **Subtotal** | | | | | **$ 63,428.75** | |

## Typical Design and Construction Costs
## Two Lane Ramp Meter

**Log No.:** 138 **Ramp:** Creedmoor Road
**Location:** I-540 Westbound

| Categories / Description | Unit | Quantity | Unit Cost | Total Cost | Assumptions |
|---|---|---|---|---|---|
| Communications | | | | | |
| CCTV Camera | EA | 1 | $ 4,000.00 | $ 4,000.00 | |
| CCTV Cabinet | EA | 1 | $ 5,000.00 | $ 5,000.00 | |
| CCTV Pole with riser | EA | 0 | $ 3,000.00 | $ - | |
| 1" Riser | EA | 1 | $ 400.00 | $ 400.00 | |
| Serial Communications | EA | 350 | $ 2.00 | $ 700.00 | Link to MVDS |
| Splice Enclosure | EA | 1 | $ 1,000.00 | $ 1,000.00 | Link to SMFO |
| Pullbox (Special Size) | EA | 1 | $ 1,750.00 | $ 1,750.00 | For splice enclosure |
| Modify splice in City signal cabinet | EA | 1 | $ 2,200.00 | $ 2,200.00 | |
| Interconnect Center | EA | 2 | $ 1,500.00 | $ 3,000.00 | In cabinet |
| Fiber-optic Drop Cable (six strands) | LF | 1050 | $ 2.00 | $ 2,100.00 | Drop cable to controller cabinet, Same distance to power source plus 300' for proposed CCTV on ramp |
| Ethernet Switch | EA | 2 | $ 2,000.00 | $ 4,000.00 | CCTV and ramp meter controller |
| **Subtotal** | | | | **$ 24,150.00** | |
| Pavement Marking | | | | | |
| Pavement Marking Removal | LF | 640 | $ 0.62 | $ 396.80 | 40 mph design speed. 110' transitions, 100' narrowed lane |
| Raised Pavement Markers | EA | 12 | $ 4.50 | $ 54.00 | Along skip line only |
| White Edge Line | LF | 950 | $ 0.95 | $ 902.50 | 110' transitions, 100' narrowed lane |
| Yellow Edge Line | LF | 950 | $ 0.95 | $ 902.50 | 110' transitions, 100' narrowed lane |
| White Skip Line | LF | 950 | $ 0.24 | $ 225.63 | |
| 24" Stop Bar | LF | 12 | $ 7.00 | $ 84.00 | |
| **Subtotal** | | | | **$ 2,565.43** | |
| Signing | | | | | |
| Remove existing single and dual post | EA | 4 | $ 100.00 | $ 400.00 | |
| W3-8, Ramp Metered When Flashing | EA | 2 | $ 650.00 | $ 1,300.00 | Sign and post only |
| W3-4, Be Prepared to Stop | EA | 1 | $ 650.00 | $ 650.00 | Sign and post |
| R10-6, Stop Here on Red | EA | 1 | $ 175.00 | $ 175.00 | Pedestal mounted |
| R10-28, XX Vehicles Per Green | EA | 1 | $ 175.00 | $ 175.00 | Pedestal mounted |
| W4-1L, Merge Left | EA | 1 | $ 650.00 | $ 650.00 | |
| **Subtotal** | | | | **$ 3,350.00** | |
| Subtotal Construction | | | | **$ 164,895.18** | |
| Traffic Control | | | 20% | $ 32,979.04 | |
| Contingencies | | | 10% | $ 16,489.52 | |
| **Total Construction** | | | | **$ 214,363.73** | |

| | | |
|---|---|---|
| Design | 26% | $ 55,734.57 |
| Construction Administration | 10% | $ 21,436.37 |
| **Total Design and Construction** | | **$ 291,534.67** |

**Typical Design and Construction Costs**
**Site Assumptions Checklist**

**Log No.:** 140 **Ramp:** Six Forks Road
**Location:** I-540 Westbound

| | |
|---|---|
| Two Lane Ramp Widening (Y/N): | N |
| Length of Two Lane Ramp Widening (ft.): | 0 |
| Distance from Stopbar to W3-8 sign (ft.): | 900 |
| Pipe Crossings (Y/N): | N |
| Retaining Walls (Y/N): | N |
| Fill (Y/N): | N |
| Guardrail Other than for Ramp Meter Equipment (Y/N): | N |
| Install Guardrail (one side or two) | 2 |
| Nearest Power Source (ft.): | 700 |

Notes

Nearest power source is traffic signal.
Install pedestal poles on both sides, protect with guardrail on both sides of ramp
Connect to City of Raleigh fiber-optic communciations network.
Modify splicing in City signal cabinet.
Install new wood pole for CCTV camera.

## Typical Design and Construction Costs
## Two Lane Ramp Meter

**Log No.:** 140 **Ramp:** Six Forks Road
**Location:** I-540 Westbound

| Categories / Description | Unit | Quantity | Unit Cost | Total Cost | Assumptions |
|---|---|---|---|---|---|
| Earthwork and Structures | | | | | |
| Retaining Wall 5' High | LF | 0 | $ 250.00 | $ - | |
| Retaining Wall 10' High | LF | 0 | $ 475.00 | $ - | |
| Excavation | CY | 0 | $ 4.00 | $ - | |
| Fill | CY | 0 | $ 5.00 | $ - | |
| Seeding | SY | 1426 | $ 2.50 | $ 3,565.00 | Seeding along pavement widening and around trench, conduit, pull box, and foundation areas |
| **Subtotal** | | | | **$ 3,565.00** | |
| Guardrail | | | | | |
| Guardrail Rail | LF | 500 | $ 15.00 | $ 7,500.00 | |
| Guardrail Approach End Treatment | EA | 2 | $ 1,500.00 | $ 3,000.00 | |
| **Subtotal** | | | | **$ 10,500.00** | |
| Paving | | | | | |
| Ramp Widening | SY | 0 | $ 32.00 | $ - | |
| Pavement Resurfacing | SY | 0 | $ 12.00 | $ - | |
| **Subtotal** | | | | **$ -** | |
| Drainage | | | | | |
| Pipe | LF | 0 | $ 44.00 | $ - | |
| **Subtotal** | | | | **$ -** | |
| Signalization | | | | | |
| 6'x6' loops | EA | 10 | $ 394.50 | $ 3,945.00 | One queue, three passage and one clearance |
| Detector Lead-in Cable | EA | 390 | $ 1.50 | $ 585.00 | Assumed setback distance 350' |
| MVDS detector | EA | 1 | $ 1,800.00 | $ 1,800.00 | Mainline detection |
| Detector pole | EA | 1 | $ 6,000.00 | $ 6,000.00 | |
| Pullbox (Std.) | EA | 6 | $ 300.00 | $ 1,800.00 | |
| Conduit (Trenched) | LF | 2085 | $ 6.00 | $ 12,510.00 | All purposes |
| Conduit (Directional Drilled) | LF | 50 | $ 14.00 | $ 700.00 | One ramp crossing, mult. conduits |
| Modify Electrical Service | EA | 1 | $ 3,000.00 | $ 3,000.00 | |
| Electrical Conductors | LF | 700 | $ 5.00 | $ 3,500.00 | |
| 2070 Controller and Cabinet | EA | 1 | $14,000.00 | $ 14,000.00 | |
| Firmware/Calibration | EA | 1 | $ 5,300.00 | $ 5,300.00 | |
| Cabinet Foundation | EA | 1 | $ 450.00 | $ 450.00 | |
| 45' Mast Arm Poles and Foundation | EA | 0 | $15,000.00 | $ - | |
| Pedestal Pole | EA | 2 | $ 1,000.00 | $ 2,000.00 | dual pedestals |
| Three Section Signal Head | EA | 2 | $ 1,000.00 | $ 2,000.00 | |
| One Section Signal Head | EA | 2 | $ 500.00 | $ 1,000.00 | Ramp meter advance signal |
| Signal Cable | LF | 505 | $ 2.75 | $ 1,388.75 | |
| **Subtotal** | | | | **$ 59,978.75** | |

## Typical Design and Construction Costs
## Two Lane Ramp Meter

**Log No.:** 140 **Ramp:** Six Forks Road
**Location:** I-540 Westbound

| Categories / Description | Unit | Quantity | Unit Cost | Total Cost | Assumptions |
|---|---|---|---|---|---|
| Communications | | | | | |
| CCTV Camera | EA | 1 | $ 4,000.00 | $ 4,000.00 | |
| CCTV Cabinet | EA | 1 | $ 5,000.00 | $ 5,000.00 | |
| CCTV Pole with riser | EA | 1 | $ 3,000.00 | $ 3,000.00 | |
| 1" Riser | EA | 0 | $ 400.00 | $ - | |
| Serial Communications | EA | 350 | $ 2.00 | $ 700.00 | Link to MVDS |
| Splice Enclosure | EA | 1 | $ 1,000.00 | $ 1,000.00 | Link to SMFO |
| Pullbox (Special Size) | EA | 1 | $ 1,750.00 | $ 1,750.00 | For splice enclosure |
| Modify splice in City signal cabinet | EA | 1 | $ 2,200.00 | $ 2,200.00 | Link to SMFO |
| Interconnect Center | EA | 2 | $ 1,500.00 | $ 3,000.00 | In cabinet |
| Fiber-optic Drop Cable (six strands) | LF | 800 | $ 2.00 | $ 1,600.00 | Drop cable to controller cabinet, Same distance to power source plus 300' for proposed CCTV on ramp |
| Ethernet Switch | EA | 2 | $ 2,000.00 | $ 4,000.00 | CCTV and ramp meter controller |
| **Subtotal** | | | | **$ 26,250.00** | |
| Pavement Marking | | | | | |
| Pavement Marking Removal | LF | 640 | $ 0.62 | $ 396.80 | 40 mph design speed. 110' transitions, 100' narrowed lane |
| Raised Pavement Markers | EA | 0 | $ 4.50 | $ - | Along skip line only |
| White Edge Line | LF | 320 | $ 0.95 | $ 304.00 | 110' transitions, 100' narrowed lane |
| Yellow Edge Line | LF | 320 | $ 0.95 | $ 304.00 | 110' transitions, 100' narrowed lane |
| White Skip Line | LF | 0 | $ 0.24 | $ - | |
| 24" Stop Bar | LF | 12 | $ 7.00 | $ 84.00 | |
| **Subtotal** | | | | **$ 1,088.80** | |
| Signing | | | | | |
| Remove existing single and dual post | EA | 0 | $ 100.00 | $ - | |
| W3-8, Ramp Metered When Flashing | EA | 2 | $ 650.00 | $ 1,300.00 | Sign and post only |
| W3-4, Be Prepared to Stop | EA | 1 | $ 650.00 | $ 650.00 | Sign and post |
| R10-6, Stop Here on Red | EA | 1 | $ 175.00 | $ 175.00 | Pedestal mounted |
| R10-28, XX Vehicles Per Green | EA | 1 | $ 175.00 | $ 175.00 | Pedestal mounted |
| W4-1L, Merge Left | EA | 1 | $ 650.00 | $ 650.00 | |
| **Subtotal** | | | | **$ 2,950.00** | |
| Subtotal Construction | | | | **$ 104,332.55** | |
| Traffic Control | | | 20% | $ 20,866.51 | |
| Contingencies | | | 10% | $ 10,433.26 | |
| **Total Construction** | | | | **$ 135,632.32** | |
| Design | | | 26% | $ 35,264.40 | |
| Construction Administration | | | 10% | $ 13,563.23 | |
| **Total Design and Construction** | | | | **$ 184,459.95** | |

**Typical Design and Construction Costs**
**Site Assumptions Checklist**

**Log No.:** 142 **Ramp:** Falls of the Neuse Rd.
**Location:** I-540 Westbound

| | |
|---|---|
| Two Lane Ramp Widening (Y/N): | Y |
| Length of Two Lane Ramp Widening (ft.): | 1180 |
| Distance from Stopbar to W3-8 sign (ft.): | 1075 |
| Pipe Crossings (Y/N): | N |
| Retaining Walls (Y/N): | N |
| Fill (Y/N): | N |
| Guardrail Other than for Ramp Meter Equipment (Y/N): | Y |
| Install Guardrail (one side or two) | 1 |
| Nearest Power Source (ft.): | 1300 |

Notes

Nearest power source is traffic signal.
Install pedestal poles on both sides, protect with guardrail left side only of ramp

Connect to City of Raleigh fiber-optic communciations network.
Modify splicing in City signal cabinet.
Install new wood pole for CCTV camera.

## Typical Design and Construction Costs
## Two Lane Ramp Meter

**Log No.:** 142 **Ramp:** Falls of the Neuse Rd.
**Location:** I-540 Westbound

| Categories / Description | Unit | Quantity | Unit Cost | Total Cost | Assumptions |
|---|---|---|---|---|---|
| Earthwork and Structures | | | | | |
| Retaining Wall 5' High | LF | 0 | $ 250.00 | $ - | |
| Retaining Wall 10' High | LF | 0 | $ 475.00 | $ - | |
| Excavation | CY | 0 | $ 4.00 | $ - | |
| Fill | CY | 2059 | $ 5.00 | $ 10,296.30 | |
| Seeding | SY | 1826 | $ 2.50 | $ 4,565.00 | Seeding along pavement widening and around trench, conduit, pull box, and foundation areas |
| **Subtotal** | | | | **$ 14,861.30** | |
| Guardrail | | | | | |
| Relocate Guardrail Rail | LF | 985 | $ 15.00 | $ 14,775.00 | |
| Treatment | EA | 1 | $ 1,500.00 | $ 1,500.00 | |
| **Subtotal** | | | | **$ 16,275.00** | |
| Paving | | | | | |
| Ramp Widening | SY | 367 | $ 32.00 | $ 11,751.11 | |
| Pavement Resurfacing | SY | 3700 | $ 12.00 | $ 44,400.00 | |
| **Subtotal** | | | | **$ 56,151.11** | |
| Drainage | | | | | |
| Pipe | LF | 0 | $ 44.00 | $ - | |
| **Subtotal** | | | | **$ -** | |
| Signalization | | | | | |
| 6'x6' loops | EA | 10 | $ 394.50 | $ 3,945.00 | One queue, three passage and one clearance |
| Detector Lead-in Cable | EA | 390 | $ 1.50 | $ 585.00 | Assumed setback distance 350' |
| MVDS detector | EA | 1 | $ 1,800.00 | $ 1,800.00 | Mainline detection |
| Detector pole | EA | 1 | $ 6,000.00 | $ 6,000.00 | |
| Pullbox (Std.) | EA | 6 | $ 300.00 | $ 1,800.00 | |
| Conduit (Trenched) | LF | 2685 | $ 6.00 | $ 16,110.00 | All purposes |
| Conduit (Directional Drilled) | LF | 50 | $ 14.00 | $ 700.00 | One ramp crossing, mult. conduits |
| Modify Electrical Service | EA | 1 | $ 3,000.00 | $ 3,000.00 | |
| Electrical Conductors | LF | 1300 | $ 5.00 | $ 6,500.00 | |
| 2070 Controller and Cabinet | EA | 1 | $14,000.00 | $ 14,000.00 | |
| Firmware/Calibration | EA | 1 | $ 5,300.00 | $ 5,300.00 | |
| Cabinet Foundation | EA | 1 | $ 450.00 | $ 450.00 | |
| 45' Mast Arm Poles and Foundation | EA | 0 | $15,000.00 | $ - | |
| Pedestal Pole | EA | 2 | $ 1,000.00 | $ 2,000.00 | dual pedestals |
| Three Section Signal Head | EA | 2 | $ 1,000.00 | $ 2,000.00 | |
| One Section Signal Head | EA | 2 | $ 500.00 | $ 1,000.00 | Ramp meter advance signal |
| Signal Cable | LF | 505 | $ 2.75 | $ 1,388.75 | |
| **Subtotal** | | | | **$ 66,578.75** | |

## Typical Design and Construction Costs
## Two Lane Ramp Meter

**Log No.:** 142 **Ramp:** Falls of the Neuse Rd.
**Location:** I-540 Westbound

| Categories / Description | Unit | Quantity | Unit Cost | Total Cost | Assumptions |
|---|---|---|---|---|---|
| Communications | | | | | |
| CCTV Camera | EA | 1 | $ 4,000.00 | $ 4,000.00 | |
| CCTV Cabinet | EA | 1 | $ 5,000.00 | $ 5,000.00 | |
| CCTV Pole with riser | EA | 1 | $ 3,000.00 | $ 3,000.00 | |
| 1" Riser | EA | 0 | $ 400.00 | $ - | |
| Serial Communications | EA | 350 | $ 2.00 | $ 700.00 | Link to MVDS |
| Splice Enclosure | EA | 1 | $ 1,000.00 | $ 1,000.00 | Link to SMFO |
| Pullbox (Special Size) | EA | 1 | $ 1,750.00 | $ 1,750.00 | For splice enclosure |
| Modify splice in City signal cabinet | EA | 1 | $ 2,200.00 | $ 2,200.00 | |
| Interconnect Center | EA | 2 | $ 1,500.00 | $ 3,000.00 | In cabinet |
| Fiber-optic Drop Cable (six strands) | LF | 1400 | $ 2.00 | $ 2,800.00 | Drop cable to controller cabinet, Same distance to power source plus 300' for proposed CCTV on ramp |
| Ethernet Switch | EA | 2 | $ 2,000.00 | $ 4,000.00 | CCTV and ramp meter controller |
| **Subtotal** | | | | **$ 27,450.00** | |
| Pavement Marking | | | | | |
| Pavement Marking Removal | LF | 640 | $ 0.62 | $ 396.80 | 40 mph design speed. 110' transitions, 100' narrowed lane |
| Raised Pavement Markers | EA | 15 | $ 4.50 | $ 67.50 | Along skip line only |
| White Edge Line | LF | 320 | $ 0.95 | $ 304.00 | 110' transitions, 100' narrowed lane |
| Yellow Edge Line | LF | 320 | $ 0.95 | $ 304.00 | 110' transitions, 100' narrowed lane |
| White Skip Line | LF | 1180 | $ 0.24 | $ 280.25 | |
| 24" Stop Bar | LF | 12 | $ 7.00 | $ 84.00 | |
| **Subtotal** | | | | **$ 1,436.55** | |
| Signing | | | | | |
| Remove existing single and dual post | EA | 4 | $ 100.00 | $ 400.00 | |
| W3-8, Ramp Metered When Flashing | EA | 2 | $ 650.00 | $ 1,300.00 | Sign and post only |
| W3-4, Be Prepared to Stop | EA | 1 | $ 650.00 | $ 650.00 | Sign and post |
| R10-6, Stop Here on Red | EA | 1 | $ 175.00 | $ 175.00 | Pedestal mounted |
| R10-28, XX Vehicles Per Green | EA | 1 | $ 175.00 | $ 175.00 | Pedestal mounted |
| W4-1L, Merge Left | EA | 1 | $ 650.00 | $ 650.00 | |
| **Subtotal** | | | | **$ 3,350.00** | |
| Subtotal Construction | | | | **$ 186,102.71** | |
| Traffic Control | | | 20% | $ 37,220.54 | |
| Contingencies | | | 10% | $ 18,610.27 | |
| **Total Construction** | | | | **$ 241,933.52** | |

| | | |
|---|---|---|
| Design | 26% | $ 62,902.72 |
| Construction Administration | 10% | $ 24,193.35 |
| **Total Design and Construction** | | **$ 329,029.59** |

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