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MEMORANDUM

Date: September 2, 2016 **Update: November 1, 2019**

To: John Caruano, PD South
Five Points Working Group

From: Steve Harr, WRA

Subject: SR 1 at SR 16 Platooning Study

CC: George Spadafino, PD South
Rob Wills, WRA

Work Order Number: 31985-002

Contract Number: T201500301

Project: HEP SC, SR 1 and SR 16 Grade-Separated Intersection
Five Points Transportation Study

A grade-separated intersection is currently being designed at SR 1 at SR 16 to address safety and capacity concerns. At the November 5, 2015 public workshop for the grade-separation project, two primary questions were raised regarding downstream traffic conditions along southbound SR 1:

(1) *How will this project affect traffic signal congestion on SR 1 at points farther to the south, such as at the intersection of SR 1 and US 9/SR 404 ("Five Points")?*

(2) *What impact will the removal of the existing signal have on turning movements for cross streets/median crossovers downstream of the intersection (specifically SR 1 at Hudson Road, which is located approximately 2.2 miles south of SR 1 at SR 16)?*

The purpose of this memorandum is to summarize the studies and analyses performed to address these questions based on recent summer beach traffic conditions. Specifically, continuous traffic monitoring video cameras were utilized to obtain traffic counts for an entire week at three locations along SR 1 beginning on Friday, July 8, 2016: at Pine Haven Road, 6.5 miles north of the SR 16 traffic signal; at the signal, immediately south of SR 16; and at Cave Neck Road, 4.0 miles downstream of the SR 16 signal. These locations are depicted in **Figure 1**. To supplement the continuous traffic data, a three-hour gap study/count was performed on Saturday, July 9, 2016 from 9 AM – 12 PM along SR 1 at Hudson Road. Peak-hour volume during the gap study occurred from 10 AM – 11 AM; therefore, the same hour of data was used from the video camera recordings to perform similar gap studies. Based on guidelines in *AASHTO Geometric Design of Roads and Highways*, any gap in traffic was considered to be acceptable for an entering vehicle if it was 8.0 seconds or greater.

Update: November 1, 2019

During July and August 2019, continuous traffic monitoring video cameras were deployed again at the three monitored locations noted above, as well as the SR 1 at Hudson Road study/count location, SR 1 north of Five Points, and an upstream location, just south of the US 113 split/diverge. These locations are depicted in **Figure 1A**. Based on SR 1 Wavetronix volume data collected during the times the cameras were recording traffic, peak southbound traffic volumes occurred Thursday, July 4, 2019 from 9 AM – 10 AM, and that hour was selected for southbound gap analysis.

Figure 1. Traffic Collection and Study Locations along SR 1

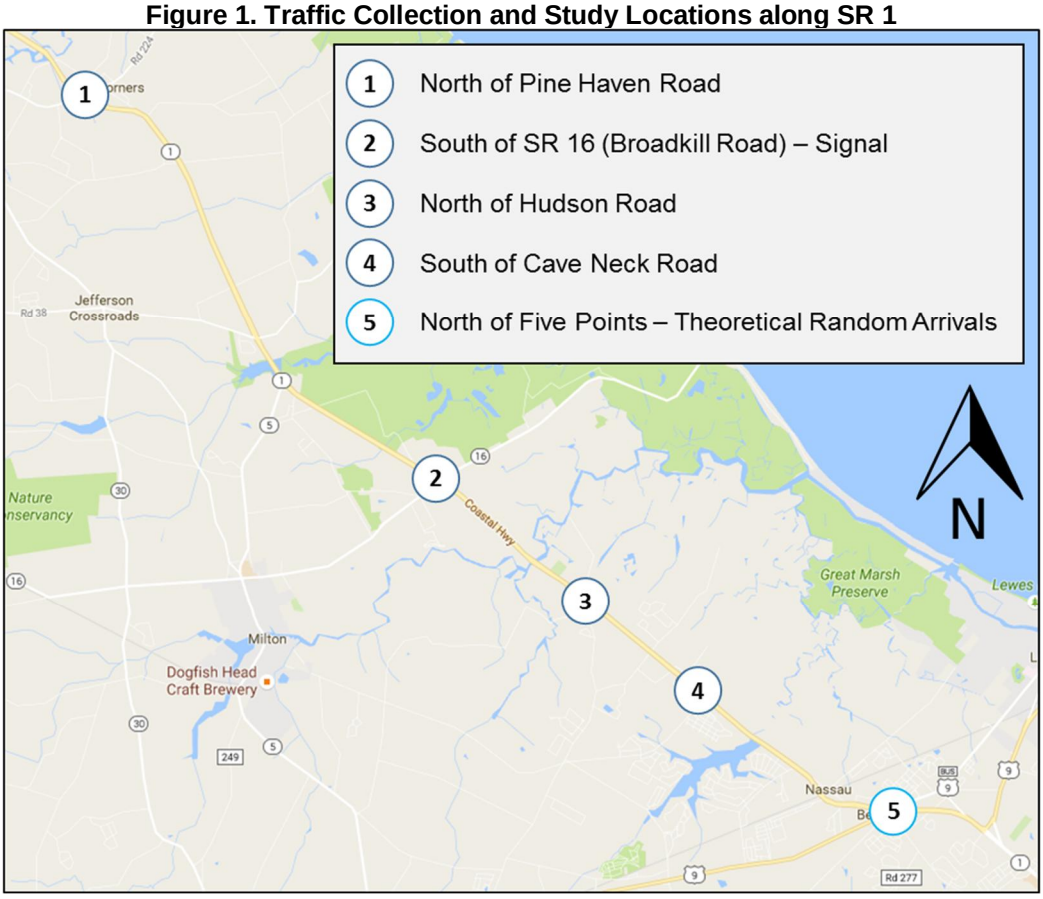
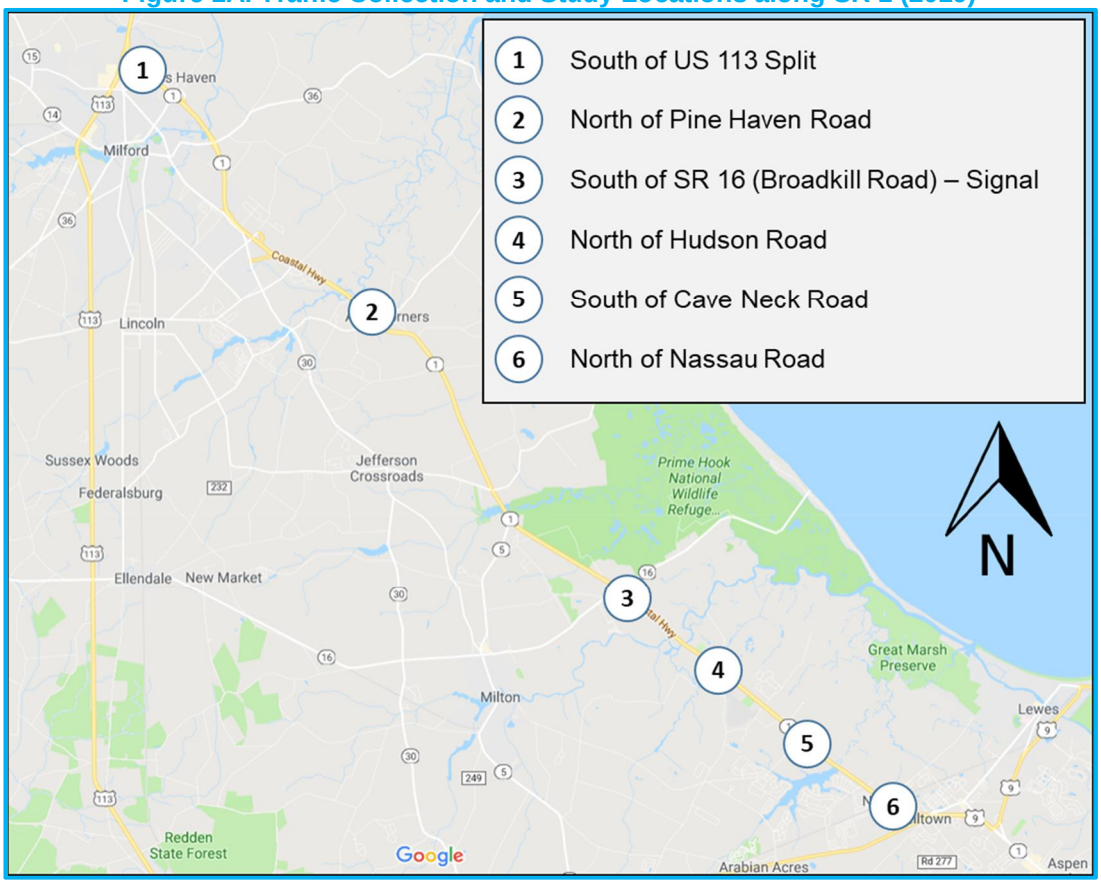


Figure 1A. Traffic Collection and Study Locations along SR 1 (2019)



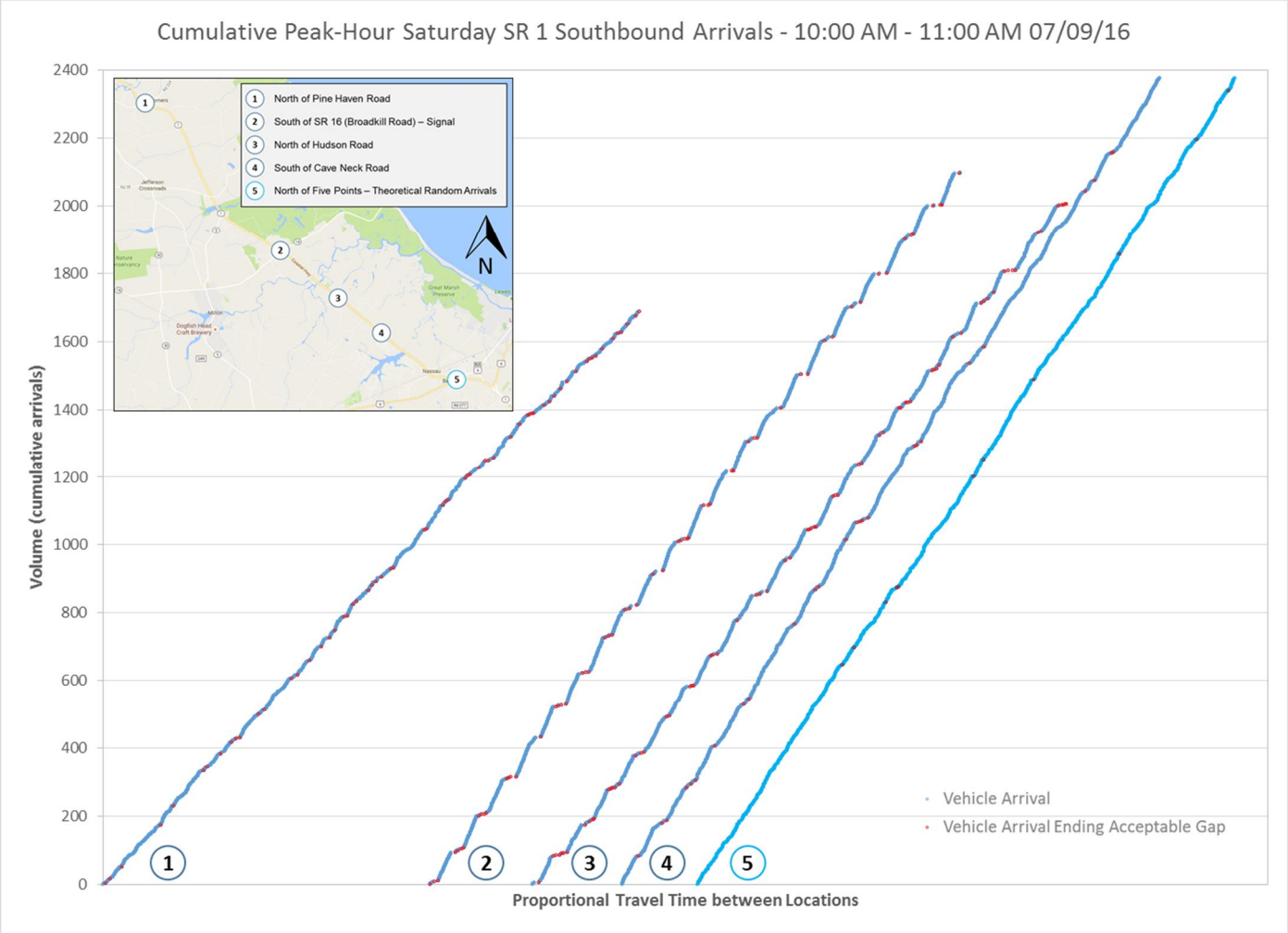
The results of the four/six gap studies along SR 1 are presented in **Figure 2 and 2A** by depicting cumulative vehicle arrivals over time. Presenting traffic data in this format allows one to visually identify cyclical patterns that appear in the vehicular arrivals as a result of the signal operation. As anticipated, at Pine Haven Road where traffic is theoretically "random" and uninterrupted, vehicle arrivals are relatively consistent and uniform, with no discernable pattern to when acceptable gaps occur. Conversely, immediately south of the SR 16 signal, there are definitive cycles of platoons clearing (i.e., during the southbound green intervals) and extended periods of gap time (i.e., during the southbound red intervals).

South of the signal, the platooning effects on the recorded vehicle arrivals progressively dissipates: at Hudson Road, 2.2 miles south of the signal, there are still noticeable cyclical trends to the arrivals. At Cave Neck Road, 4.0 miles south of the signal, the arrival patterns resemble the free-flow uniform arrivals at Pine Haven Road much more closely than the platoon/gap cycles observed at the signal. Based on this visual evaluation, it can be determined that arrivals at Five Points, 6.7 miles south of the SR 1 at SR 16 signal, are free-flow, exhibiting virtually no platooning effects from the upstream signal. Furthermore, hourly traffic volume increases from Pine Haven Road to SR 16 and then to Cave Neck Road suggest that the SR 1 at SR 16 signal is not significantly "metering" the traffic volume arriving at the beach although the public perception is often the contrary. Specifically, the traffic signal is initially "condensing" traffic into platoons and potentially forcing more traffic to take alternate/bypass routes and join farther downstream; however, the overall impact to traffic volumes entering the beach area appears to be relatively negligible.

Presently, there are similar "condensing" effects along southbound SR 1 from the Little Heaven signals (grade-separation construction currently underway) about 20 miles north of SR 16. However, this platooning traffic from much farther north of SR 16 returns to free-flowing and "random" arrivals/gaps well in advance of SR 16 primarily because

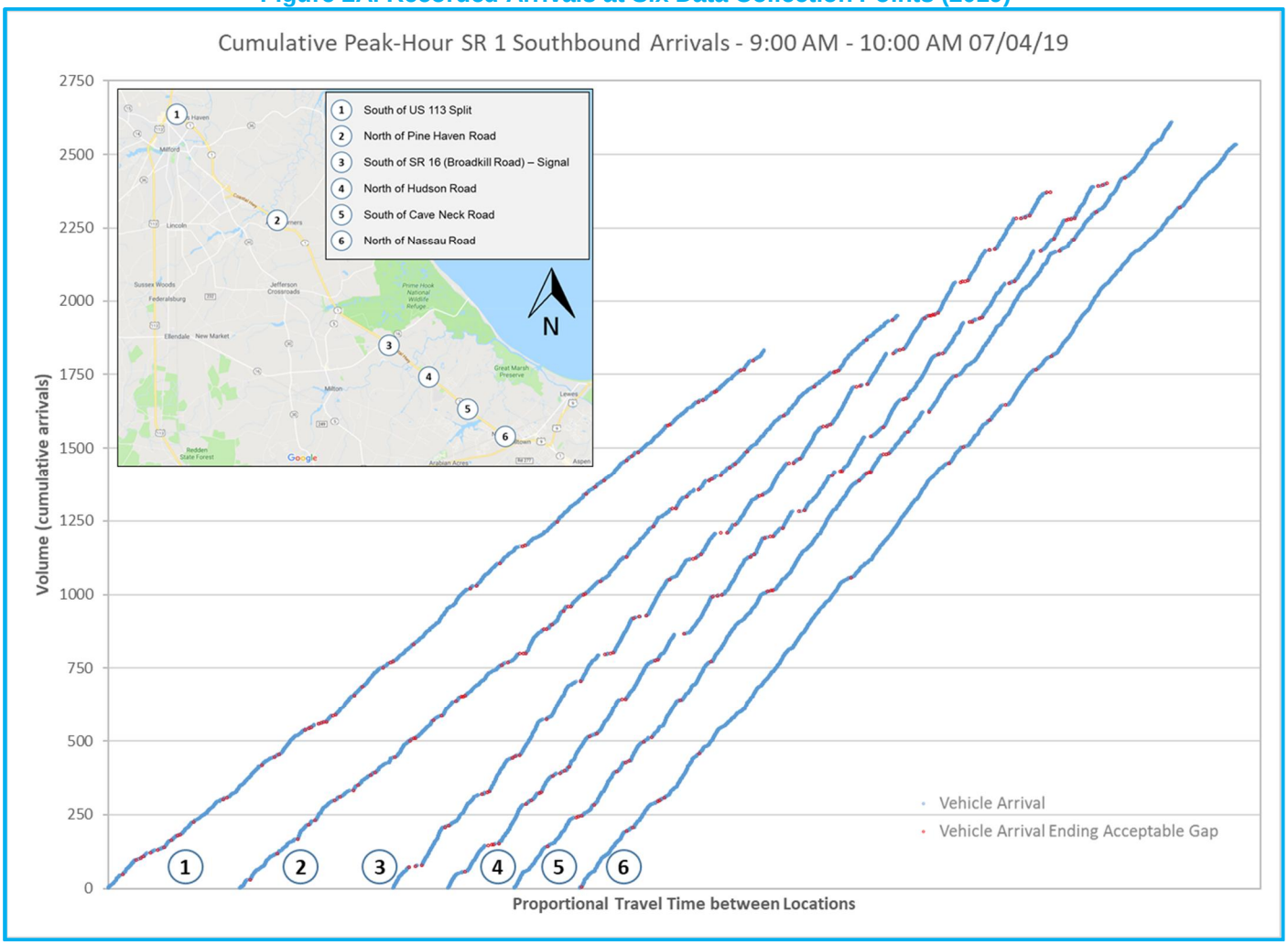
of the significant downstream distance and traffic split (i.e., volume loss) in north Milford at the SR 1/US 113 diverge, where roughly 40 to 50 percent of southbound motorists utilize US 113 to continue south during summer peak periods. The dissipation of the traffic platoons is evident in the visual evaluation of the Pine Haven Road arrivals in **Figure 2** (number 1 below).

Figure 2. Recorded Arrivals at Four Data Collection Points with Comparison to Theoretical Random Arrivals



As an additional evaluation exercise, the same traffic volume arriving at Cave Neck Road was randomly "simulated" throughout a theoretical hour using Microsoft Excel's random number generator, assigning arrival times according to a uniform distribution (i.e., each time of arrival had the same probability of being selected as each other point in time within the hour). This data is also presented in **Figure 2** as theoretical arrivals at Five Points (number 5 above), which illustrates the same lack of platooning effects from the SR 1 at SR 16 signal.

Figure 2A. Recorded Arrivals at Six Data Collection Points (2019)



Peak-hour traffic volumes increased from about 1,700 vehicles at Pine Haven Road to about 2,100 vehicles between SR 16 and Hudson Road and then to almost 2,400 vehicles at Cave Neck Road. At Pine Haven Road and Cave Neck Road, acceptable gaps were generally short and spaced relatively random throughout the peak hour. Consequently, total acceptable gap time duration was 2.7 minutes at Pine Haven Road and 1.4 minutes at Cave Neck Road. Conversely, at the two locations where arrivals are impacted by the signal at SR 16, gaps were longer and clustered together. Total gap time at the signal was 12.3 minutes and at Hudson Road was 6.8 minutes. This further supports the finding that the effects of the upstream signal are lost well before arriving at Five Points. However, some intersections closer to the SR 16 signal, such as Hudson Road, may see a noticeable decrease in available gap time after the new interchange is constructed. Because Hudson Road would likely experience fewer and shorter gaps due to the SR 16 interchange, close monitoring of safety and operational impacts is recommended. Prior to that, this location will be included in an upcoming study initiated by DelDOT Traffic/Safety for all of the unsignalized median crossovers along SR 1 in Kent and Sussex Counties to determine if short-term safety improvements are justified or if longer-term modifications should be considered (e.g., included as part of the SR 1 at SR 16 interchange project as an “off-site” improvement).

To further assess the gap data obtained in the studies based on common statistical analyses, the volumes were broken down into "cycles" based on the 22 periods of extended gaps identified in the SR 16 and Hudson Road data. These "cycles" would correspond to a 164-second average actuated cycle length at the SR 16 signal, which runs "system free" (i.e., fully-actuated) 24 hours per day. **Table 1** presents the gap standard deviation (i.e., a mathematical measure for variation in a dataset) at the four count locations and compares them to the theoretical random arrivals at Five Points. **Table 1A** presents the gap standard deviation at the six 2019 count locations. As indicated, the gap standard deviation significantly decreases at the locations farther downstream from the SR 1 at SR 16 signal, which is consistent with the dispersion of any platooning effects from the signal.

Table 1. Observed Gap Standard Deviation

Location	Gap Standard Deviation (sec)
Pine Haven Road	2.6
SR 16	3.8
Hudson Road	2.8
Cave Neck Road	1.6
Random Arrivals at Five Points (Cave Neck Road volume)	1.5

Table 1A. Observed Gap Standard Deviation (2019)

Location	Gap Standard Deviation (sec)
US 113	2.2
Pine Haven Road	2.3
SR 16	2.9
Hudson Road	2.8
Cave Neck Road	1.6
Nassau Road	1.3

A final way to visualize the dissipation of the signal impacts on the vehicular arrival patterns is to graph the frequency of gaps. **Figure 3** presents this data for the four data locations in four graphs from north to south. **Figure 3A** presents this data for the four data locations repeated during the 2019 study and two additional locations. Because each location has a large number of 0- to 3-second gaps, gaps more than 3 seconds were analyzed. Free-flow unmetered arrivals at Pine Haven Road depict a typical exponentially decreasing count, with no observed gaps above 23 seconds and very few gaps greater than about 10 seconds. Comparatively, the graph at SR 16 is much "flatter" – with many gaps in the 20- to 30-second range with a maximum of 49 seconds. Hudson Road begins to return to the expected free-flow shape, with some higher-duration gaps present as well; and by Cave Neck Road, there is a full return to the exponential decline with no long-duration outliers.

Figure 3. Frequency Graphs for Gap Times at Data Collection Locations

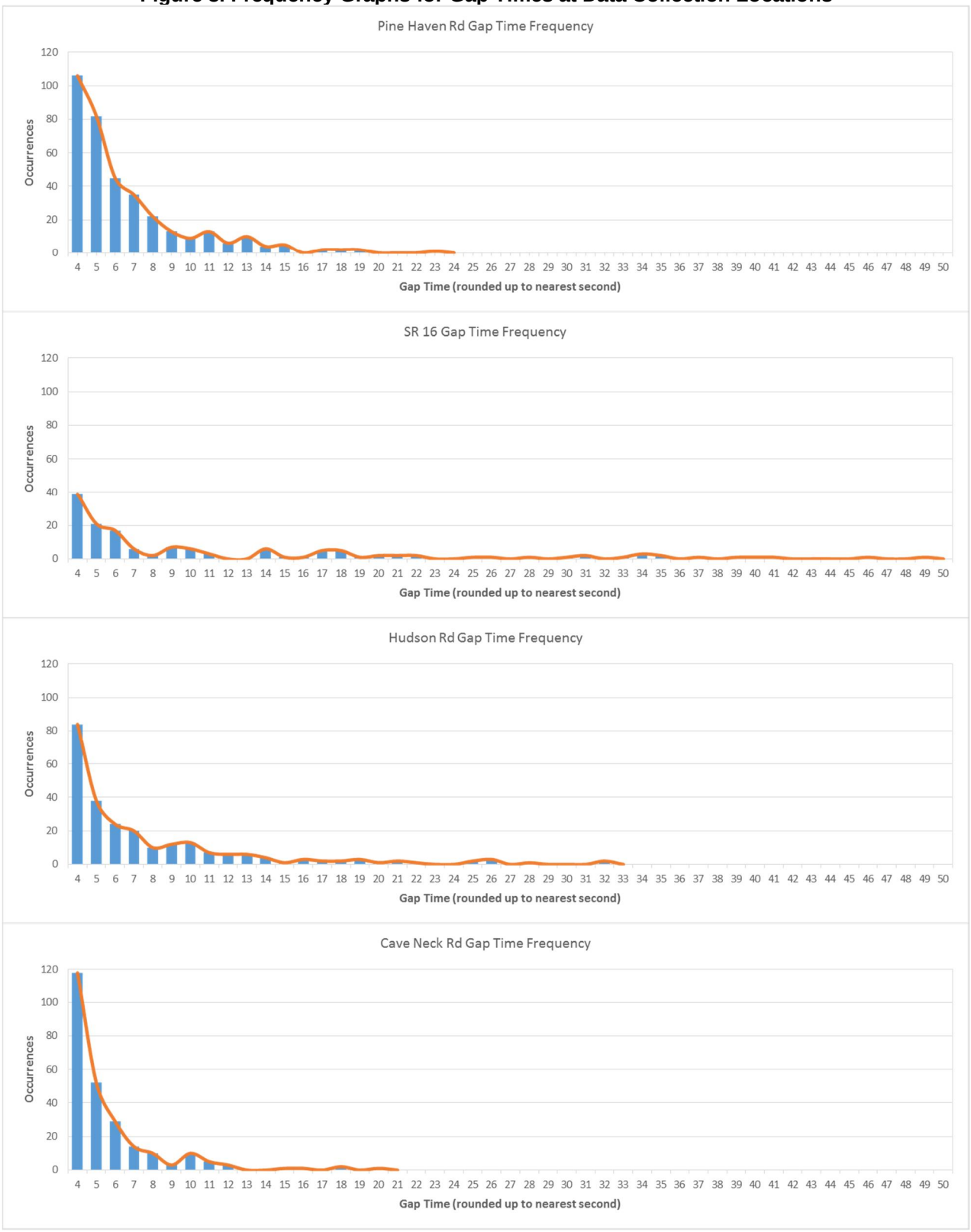


Figure 3A. Frequency Graphs for Gap Times at Data Collection Locations (2019)

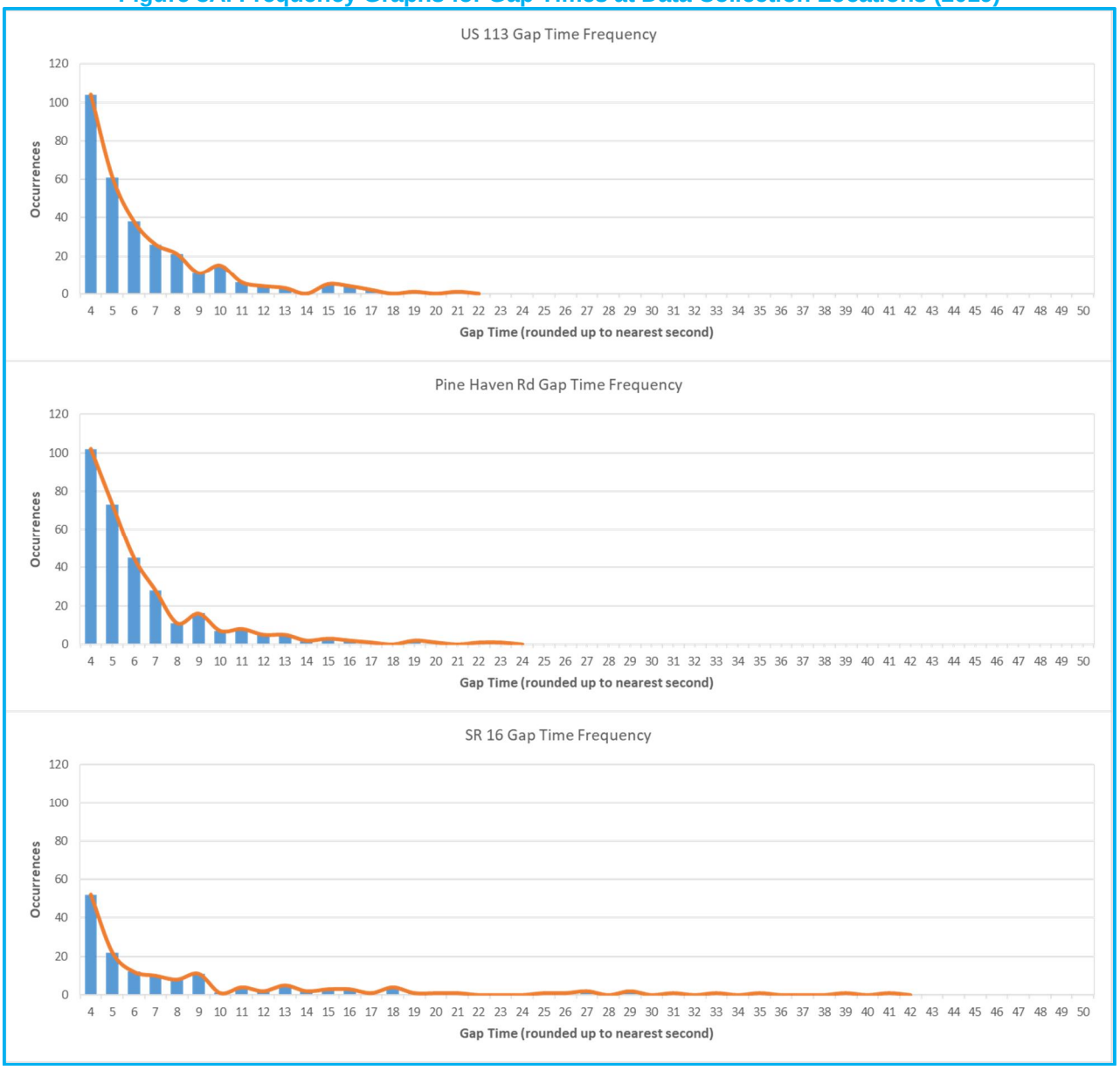
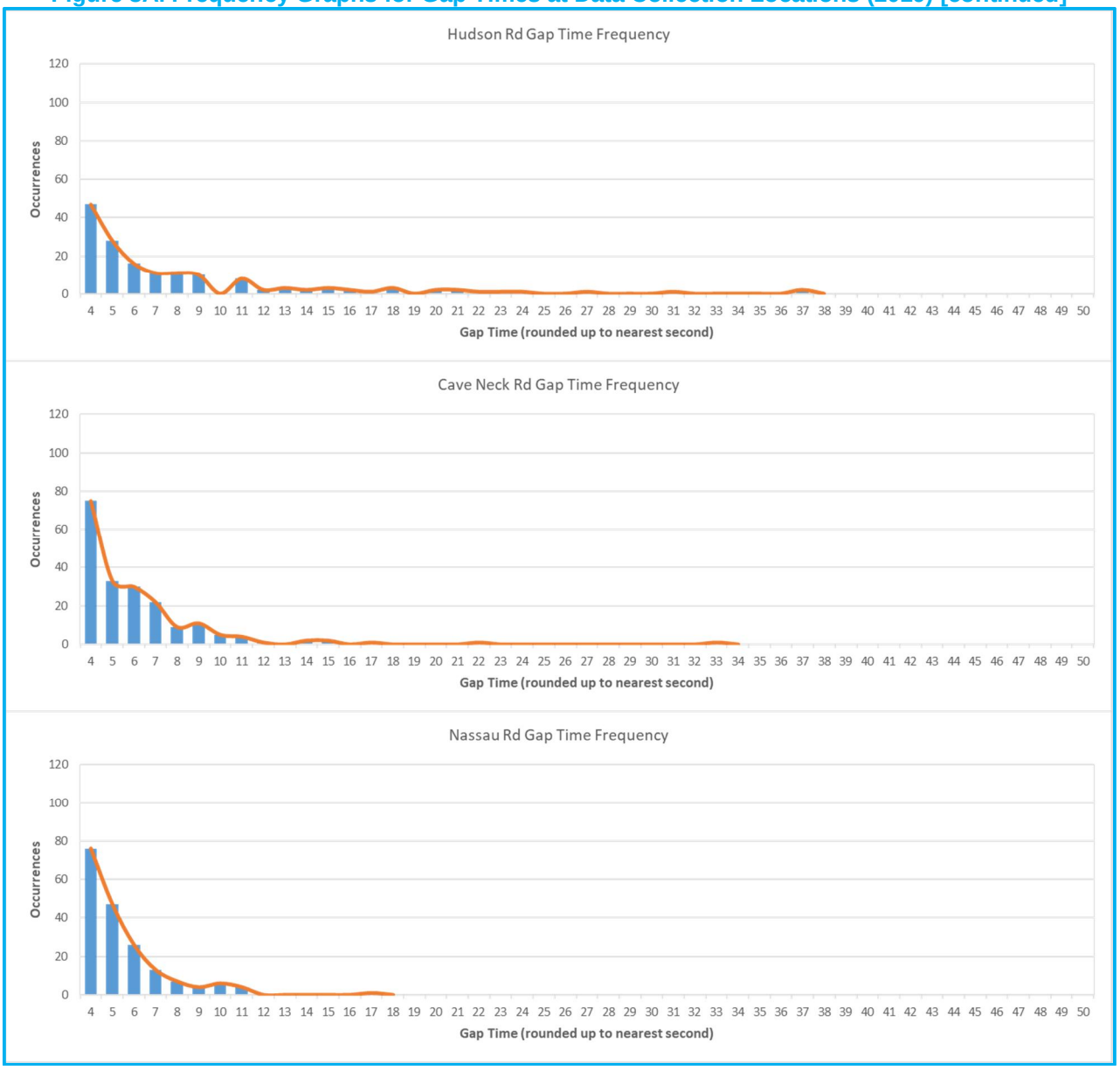


Figure 3A. Frequency Graphs for Gap Times at Data Collection Locations (2019) [continued]



In summary and in response to the specific questions posed at the public workshop:

(1) *How will this project affect traffic signal congestion on SR 1 at points farther to the south, such as at the intersection of SR 1 and US 9/SR 404 (Five Points)?*

The recently collected summer peak traffic data clearly shows that the effects of the signal at SR 16 are lost well before traffic arrives at Five Points, 6.7 miles south of SR 16. Additionally, southbound volumes are shown to increase from north of the signal to south of the signal at SR 16; further suggesting that, despite queuing and delays, significant amounts of traffic are being processed by the signal and even more volume is added from side roads south of the signal. For these reasons, **it is unlikely that significant traffic impacts will be noticeable at Five Points and points farther south once the SR 1 at SR 16 grade-separated intersection is constructed.**

(2) *What impact will the removal of the existing signal have on turning movements for cross streets/median crossovers downstream of the intersection (specifically SR 1 at Hudson Road, which is located approximately 2.2 miles south of SR 1 at SR 16)?*

Because the southbound platooning effects of the SR 16 signal are not completely dissipated until approximately three to four miles downstream, cross streets and median crossovers north of that range will likely experience fewer acceptable gaps and/or gaps that are generally shorter in duration than the current gaps resulting from the upstream signal. However, the anticipated gaps will be significantly longer than the (lack of) gaps when the dense signalized through-traffic platoons from SR 16 traverse the downstream influence area. Impacts to delays and queuing at these cross streets and median crossovers will depend greatly on the specific movements and side-street traffic volumes at the given location. However, because Hudson Road already exhibits noticeable delay and queuing on both side-street approaches during peak periods, these issues may be exacerbated when the signal at SR 16 is removed. Similarly, because Hudson Road (affected by SR 16 platooning) and Cave Neck Road (unaffected by SR 16 platooning) both have angle crash histories, changes to SR 1 arrival characteristics may also lead to additional safety concerns. For these reasons, **further studies at the impacted median crossovers are recommended prior to the SR 16 interchange project and safety/operations should be closely monitored after the project.**

Update: November 1, 2019

The summer 2019 data supports the conclusions reached during the 2016 study. There is no significant change in the findings from the 2016 analysis, despite three fewer signals between Dover and Milford and a slight upward trend in volumes year-to-year. Travel time data collected for the Five Points Working Group meeting indicates that there is no "carmageddon" at SR 16 and/or Five Points. The platooning behavior remains virtually unchanged – random arrivals approaching the SR 16 signal, followed by pronounced platooning and longer gaps downstream of the signal, but returning almost completely to a random arrival pattern once reaching the area of Cave Neck Road. Gaps in traffic are "lost" primarily due to:

- platoons naturally spacing out (e.g., SR 16 to Cave Neck Road has similar volumes, but significantly fewer and shorter gaps), and
- volume increases from "fill-in" traffic (e.g., Pine Haven Road to Nassau Road, where traffic is similarly unaffected by signals, but higher volumes result in the virtual elimination of acceptable gaps)

It is recommended that the SR 1 and SR 16 Grade Separated Intersection (GSI) proceed as scheduled, as no significant changes are expected to traffic patterns or delays at Five Points. However, the gap availability will be reduced along SR 1 approximately 3-4 miles downstream of the GSI and is already a concern at many unsignalized crossovers along SR 1. To address these safety concerns, nine crossover projects are planned in the short term, and GSI projects (Minos Conaway Road and Cave Neck Road) are presently in design concurrently with the SR 1 and SR 16 GSI.