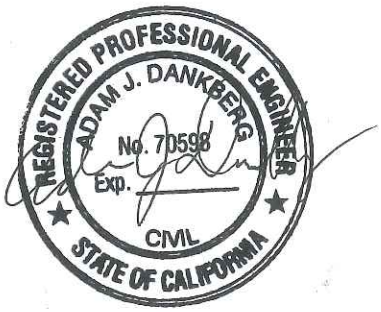
Kimley»Horn

MEMORANDUM



To:	Andrew Yi, P.E. and Cesar Romo City of Santa Clarita
From:	Jean Fares, P.E. and Adam Dankberg, P.E. Kimley-Horn and Associates, Inc.
Date:	April 30th, 2015
Subject:	Left-Turn Yellow Change Interval Study

The City of Santa Clarita retained Kimley-Horn and Associates, Inc. to assist in developing a citywide policy on establishing yellow change interval timings for left-turn phases at signalized intersections. While yellow change interval durations are governed by the *California Manual on Uniform Traffic Control Devices (2014) (CA MUTCD)*, there is limited guidance and research specifically on yellow change interval timings for left-turn movements. The 2014 version of the CA MUTCD (released subsequent to the start of this study) incorporates changes to yellow change interval guidelines, establishing a correlation between the yellow change interval and measured speeds, as opposed to posted speeds. Through this study, the City sought to achieve compliance with these recent guideline modifications and establish a scientific justification for left-turn yellow change intervals. This study used measurements of actual left-turn behavior at thirteen intersections in conjunction with a kinetics-based model to establish the left-turn yellow change interval duration that can be applied to the range of intersection conditions throughout the City. This memorandum documents the assumptions, calculations and findings of the study.

Project Background

The CA MUTCD states that "the exclusive function of the yellow change interval shall be to warn traffic of an impending change in the right-of-way assignment." The yellow change interval provides the driver with a decision – either to proceed into the intersection or to stop prior to the intersection stop bar. The interval should be set at a sufficient duration such that a driver traveling at a safe speed can choose one of the two options and avoid entering the intersection subsequent to the termination of the yellow change interval. Too large of a yellow change interval can have an adverse effect on the operational efficiency of the intersection and may result in longer cycle lengths, which would increase delay and queuing for all users. It may also encourage drivers who are capable of stopping prior to the intersection to instead decide to accelerate through the intersection. Therefore, the yellow change interval must be carefully set to achieve the objectives while not impacting roadway operations.

The 2012 CA MUTCD, and preceding versions, specified that the posted speed limit should be used in conjunction with Table 4D-102(CA) in establishing the minimum yellow change interval for the through traffic movement. It indicated that the minimum yellow change interval for protected left-turn

and right-turn movements should be 3.0 seconds. The 2012 CA MUTCD allowed for larger yellow change intervals based on field review or appropriate engineering judgment.

The City of Santa Clarita currently uses a yellow change interval of 3.5 seconds for all left-turn movements, except at a few specific locations where a yellow change interval of 4.0 or 4.5 seconds is utilized. This is in compliance with the 2012 CA MUTCD.

This study was prompted by discussions held by the California Traffic Control Devices Committee (CTCDC) in early 2014 regarding proposed modifications to the MUTCD requirements. The recommendations of this committee have since been incorporated into the 2014 CA MUTCD (released in November 2014). The standard included in the 2014 CA MUTCD, Section 4D.26 is as follows:

> The minimum yellow change interval for through traffic movement shall be determined by using the 85th percentile speed of free-flow traffic rounded up to the next 5 mph increment. Where the posted or prima facie speed limit is higher than the rounded value, use the posted or prima facie speed limit for determination of the minimum yellow change interval for the through traffic movement. See Table 4D-102(CA) sub-heading “a”.

Additional guidance is provided in paragraph 14d:

> Practitioners should exercise engineering judgment for determination of the minimum yellow change interval. Judgment should be based on numerous factors including, but not limited to, field observation of traffic behavior, intersection geometrics, downhill grade, perception-reaction time of drivers in the area, and actually driving the protected left-turn or protected right-turn movements to assess the need for longer yellow change intervals. Particular attention should be paid where setting minimum yellow change interval timing when exclusive turn lane exceeds 150 feet in length excluding the transition.

And finally, an additional option is included in paragraph 14e:

> The minimum yellow change interval for the through movement and the protected left-turn or protected right-turn may be increased based on appropriate engineering judgment.

The CA MUTCD therefore provides the City Traffic Engineer with discretion in establishing the left-turn yellow change interval and suggests and engineering study be performed to assist in that process. This study provides an engineering basis for establishing left-turn yellow change intervals throughout the City.

Study Methodology

Yellow and all-red change intervals have been studied extensively in research at the national level. National Cooperative Highway Research Program (NCHRP) Report 731: Guidelines for Timing

Yellow and All-Red Intervals at Signalized Intersections provides documentation on key factors and standard parameters when calculating appropriate yellow change intervals.

As noted above, the yellow change interval is intended to provide the driver with the option of either stopping prior to entering the intersection or entering the intersection prior to the conclusion of the yellow change interval. The driver's decision is dependent on the vehicle's speed, distance from the intersection, and driver behavior. If an insufficient yellow change interval is provided, then a dilemma zone can be created, where the driver may not be able to safely stop prior to entering the intersection but also may not be able to enter the intersection prior to the termination of the interval. In this case, the driver would necessarily enter the intersection during or after the all-red interval, resulting in the violation. Local driver behavior and vehicle characteristics influence the location of dilemma zones. Driver aggressiveness, deceleration rate, and decision time at specific locations or during certain times of day may vary from standard parameters. Thus, the calculations on dilemma zones in this analysis are approximate based on industry standards. Yellow change intervals were developed to provide for safe operation of intersections based on these industry standards.

Study Process and Calculations

This study was divided into two phases. The first phase was to analyze approach speeds for left-turn movements at 13 intersections throughout the City of Santa Clarita to identify a yellow change interval that would be consistent with the 2014 CA MUTCD guidelines. The second phase was to use this information to establish a policy for yellow change intervals for left-turn movements citywide.

NCHRP Report 731 provides guidance on the calculation of the presence and length of dilemma zones. It is governed by standard kinetic equations that account for the vehicle's ability to decelerate upon perceiving a change in the traffic signal indication. Factors affecting the dilemma zone for left-turn movements include the vehicle's deceleration rate, the driver's reaction time, the speed at which the left-turn is executed at, the approach speed, and the yellow change interval.

The approach speed was measured in the field at each of the study locations through the use of radar. Only those vehicles traveling at "free-flow" speed were measured. In this case, "free-flow" is defined as occurring when a green left-turn indication is shown and the left-turn queue, if any, does not result in vehicle deceleration. This represents a worst-case scenario as the vehicle will be approaching the intersection at a higher speed than in other conditions, such as when a red light or a long queue are present. It should be noted that "free-flow" conditions are experienced by only a small fraction of vehicles approaching a left-turn movement. A red light indication is displayed for the majority of the signal cycle (generally 75 percent or more for left-turn movements) and, at many locations, queued vehicles at the start of the left-turn phase require approaching vehicles to decelerate below free-flow speed as they enter or travel within the left-turn pocket. As a result, the approach speed measured in this study is reflective of only the most conservative scenario where a vehicle can maintain a higher approach speed until required to decelerate in order to conduct the left-turn maneuver at a safe speed. In all other conditions, the vehicle approach speed would be less. A lower approach speed allows the vehicle to more easily stop prior to the stop bar if the signal indication changes to yellow, and thus would require a shorter yellow change interval.

The vehicle turning speed was calculated based on the left-turn radius and Table 3-13b from the American Association of State Highway and Transportation Officials (AASHTO) A Policy on Geometric Design of Highways and Streets, 6th Edition (2011).

The existing yellow change interval was provided by the City of Santa Clarita.

Consistent with the *Draft ITE Proposed Recommended Practice: Guidelines for Determining Traffic Signal Change and Clearance Intervals (March 2015)*, a vehicle deceleration speed of 10 feet per second and a driver reaction time of 0.6 seconds were utilized.

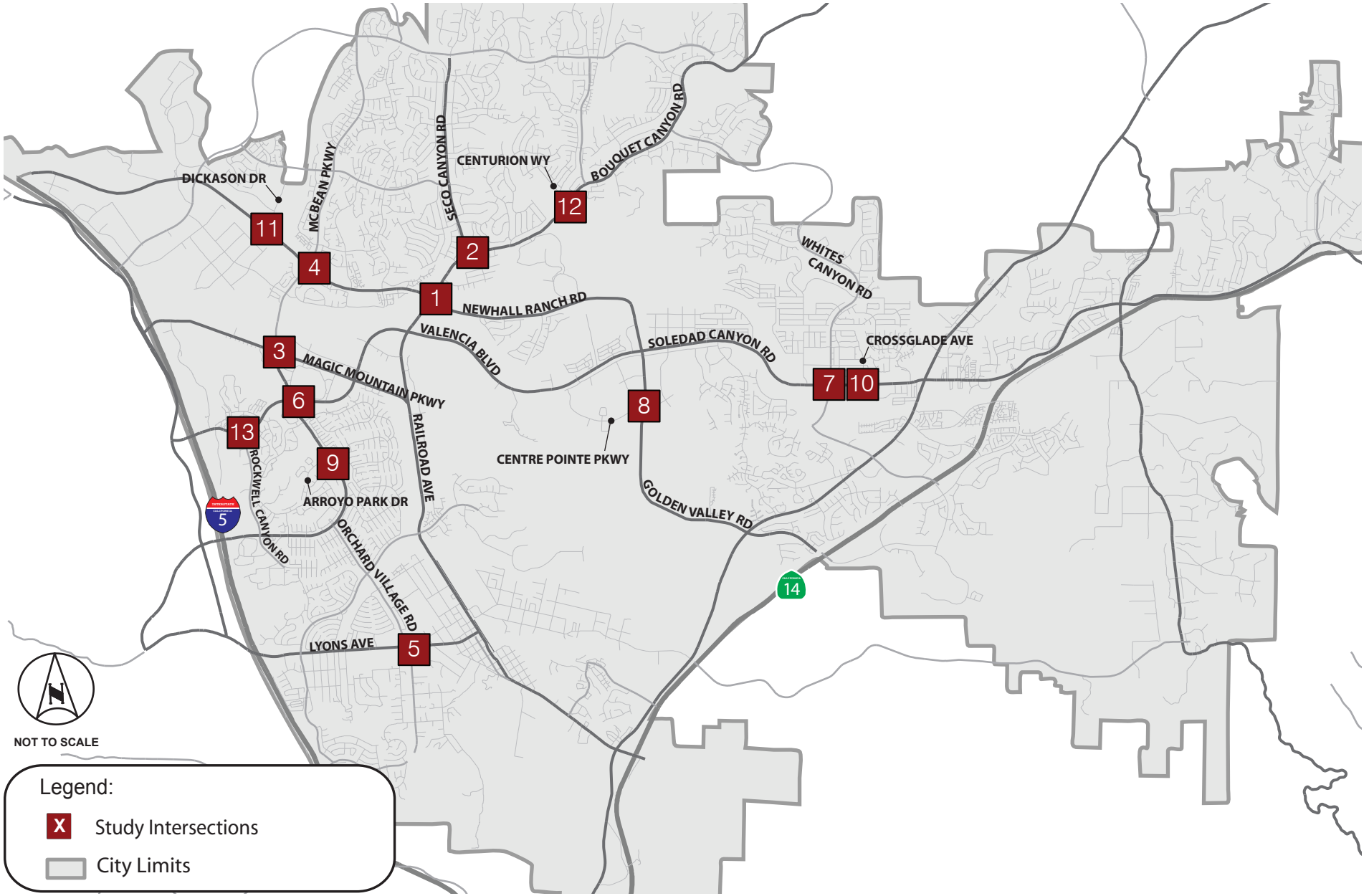
Based on these parameters and measurements, the dilemma zone, if any, was calculated as was the yellow change interval required to avoid the creation of a dilemma zone for each left-turn study location.

In the second phase of the study, the yellow change intervals required to avoid a dilemma zone for each study location were tabulated and compared to identify trends. A number of potential factors were evaluated for their effects on the required left-turn yellow change interval. These included left-turn pocket length, speed limit, intersection geometry, and measured adjacent through speed. A regression analysis was performed for each potential factor and those factors deemed to have the greatest influence on required yellow change interval were identified and utilized in the proposed policy.

Study Area

The City of Santa Clarita selected 13 signalized intersections located throughout the City for inclusion in the analysis. These intersections, depicted in **Figure 1**, were carefully selected to provide a cross-section of intersection types commonly found in the City. The locations represent a wide variety of intersection and approach configurations, including single-left turn lanes, dual left-turns, trap lanes, raised medians, positive and negative grades, T-intersections, and horizontal curves. Turn pocket lengths ranged from less than 100 feet to over 500 feet. The intersection approaches have a wide range of speed limits, ranging from 25 to 55 miles per hour. In total, speed data was collected and the required yellow change interval analyzed for 40 intersection approaches at the 13 intersections. All approaches with red light camera enforcement were included in the study.

A table summarizing the characteristics for each of the study intersections is included in **Appendix A**.



Kimley»Horn

FIGURE 1

STUDY INTERSECTIONS

K:\OAK_TPTO\099167031 - Santa Clarita Yellow Time\Illustrator\Study Area Map_Yellow Time.ai

Data Collection

Vehicle speed measurements were taken over a two-hour period between 9 AM and 3 PM at each of the 40 intersection approaches. The data was collected between July and November 2014 in good weather conditions. The number of measurements collected at each location varied depending on traffic volumes and the frequency of vehicles approaching the intersection at "free-flow" speed within the left-turn lane. Up to 93 speed measurements were taken at each approach, with a total of 444 speed measurements obtained for all locations combined. The speed data collected is provided in **Appendix B**.

The vehicle approach speed was measured at a location after the vehicle had entered the left-turn pocket and at a distance from the intersection conservatively assumed to be the earliest possible start of the dilemma zone, based on the posted speed limit. The 85th percentile of the "free-flow" speed was calculated for each left-turn movement. Note that this does not represent the overall 85th percentile speed of left-turning vehicles, but rather the 85th percentile speed of those vehicles approaching the intersection on a green arrow without being affected by a vehicle queue.

A field visit was performed at each study intersection. Physical elements such as grades and curves, signal operations such as phasing and timing, and driver behavior were all observed and noted for their potential effect on vehicle turning speeds.

Additional Data Provided by City

The City provided 85th percentile through speeds and speed limits for each of the intersection approaches, and a database indicating the turn pocket properties for each left-turn lane. The City also provided additional left-turn approach speed data from a Wavetronix speed detection machine that was placed at a couple of the studied intersection approaches. The Wavetronix machine collected data over a complete 24-hour period. At four turning movement locations that data was compared against the manual speed data collected at all study locations to verify consistency. The manually-collected data was determined to be consistent with the machine-collected data at all overlapping locations.

Analysis of Left-turn Approach Speeds

Using the data collected for the approach speed of "free-flow" left-turn vehicles, the 85th percentile approach speed of the left-turn movement was calculated. This represents a very conservative approach, as is it reflects the 85th percentile speed of only those vehicles approaching during "free-flow" conditions. The majority of vehicles approaching a left-turn movement will not do so in "free-flow" conditions and would thus have a lower speed. The 85th percentile speed for vehicles approaching in "free-flow" conditions was then compared against the speed limit and the measured speed of the adjacent through traffic, as provided by the City of Santa Clarita. This information is tabulated in **Table 1**.

Table 1: Summary of Left-Turn Approach Speeds

Intersection		Movement	Road Speed Limit	Left-Turn Approach Speed (mph)	Speed Limit - Left-Turn Approach (mph)	Adjacent Through Speed (mph)	Adjacent Through Speed - Left-Turn Approach (mph)
1	Bouquet Canyon Rd & Newhall Ranch Rd	NB Left	45	40	5	48	8
		SB Left	45	35	10	48	13
		EB Left	50	41	9	51	10
		WB Left	55	37	18	55	18
2	Seco Canyon Rd & Bouquet Canyon Rd	EB Left	45	37	8	48	11
3	McBean Pkwy & Magic Mountain Pkwy	NB Left	45	31	14	44	13
		SB Left	50	35	15	51	16
		EB Left	50	36	14	53	17
		WB Left	45	29	16	47	18
4	McBean Pkwy & Newhall Ranch Rd	NB Left	50	35	15	51	16
		SB Left	50	31	19	53	22
		EB Left	50	31	19	53	22
		WB Left	50	41	9	51	10
5	Orchard Village Rd & Lyons Ave	SB Left	45	34	11	45	11
6	McBean Pkwy & Valencia Blvd	EB Left	50	37	13	55	18
		WB Left	45	31	14	45	14
7	Whites Canyon Rd & Soledad Canyon Rd	NB Left	50	39	11	50	11
		SB Left	45	34	11	48	14
		EB Left	40	36	4	40	4
		WB Left	40	37	3	40	3
8	Golden Valley Road & Centre Point Pkwy	NB Left	50	34	16	53	19
		SB Left	50	26	24	52	26
		EB Left	40	32	8	N/A	N/A
		WB Left	35	34	1	N/A	N/A
9	McBean Pkwy & Arroyo Park Dr	NB Left	45	27	18	49	22
		SB Left	45	28	17	49	21
		EB Left	35	25	10	N/A	N/A
		WB Left	35	23	12	N/A	N/A
10	Crossglade Ave & Soledad Canyon Rd	NB Left	25	17	8	N/A	N/A
		SB Left	25	26	-1	N/A	N/A
		EB Left	40	19	21	40	21
		WB Left	40	26	14	40	14
11	Dickason Drive & Newhall Ranch Rd	NB Left	45	38	7	N/A	N/A
		SB Left	40	18	22	N/A	N/A
		EB Left	50	37	13	53	16
		WB Left	50	36	14	53	17
12	Centurion Way & Bouquet Canyon Rd	SB Left	25	31	-6	N/A	N/A
		EB Left	50	29	21	50	21
13	Rockwell Canyon Rd & Valencia Blvd	NB Left	45	25	20	N/A	N/A
		WB Left	50	27	23	50	23

Note: N/A indicates that adjacent through speed was not available

Of the 40 left-turn movements measured, the average 85th percentile left-turn approach speed was 32 miles per hour. The 85th percentile left-turn approach speed, on average, was 12.5 miles per hour below the posted speed limit and 15.7 miles per hour below the measured adjacent through movement.

Based on the measured left-turn approach speeds, and using the methodology outlined earlier in this memo, the required yellow change interval was calculated for each movement. As noted earlier in this report, the calculated yellow change interval is based on the 85th percentile approach speed of vehicles experiencing "free-flow" conditions. For vehicles arriving at times other than "free-flow" conditions, the approach speed, and thus the calculated yellow time, would be much less. Therefore, this is a conservative calculation. In compliance with the 2012 CA MUTCD, the City of Santa Clarita currently uses a yellow change interval for left-turn movements of 3.5 seconds citywide, except at a few specific locations using 4.0 or 4.5 seconds. To obtain compliance with the new guidelines included in the 2014 CA MUTCD and based on the conservative measurements obtained in this study, additional yellow time is proposed at 11 of the 40 study locations. The existing and the calculated yellow change intervals at the study locations are shown in **Table 2**.

Table 2: Calculated Yellow Change Intervals

Intersection		Movement	Existing Yellow Time (sec)	Calculated Yellow Time
1	Bouquet Canyon Rd and Newhall Ranch Rd	NB Left Turn	3.5	4.2
		SB Left Turn	3.5	3.6
		EB Left Turn	3.5	4.3
		WB Left Turn	3.5	3.8
2	Seco Canyon Rd and Bouquet Canyon Road	EB Left Turn	3.5	3.9
3	McBean Pkwy and Magic Mountain Pkwy	NB Left Turn	3.5	3.0
		SB Left Turn	3.5	3.4
		EB Left Turn	3.5	4.0
		WB Left Turn	3.5	3.0
4	McBean Pkwy and Newhall Ranch Rd	NB Left Turn	4.0	3.7
		SB Left Turn	4.0	3.2
		EB Left Turn	4.0	3.2
		WB Left Turn	4.0	4.5
5	Orchard Village Rd and Lyons Ave	SB Left Turn	3.5	3.4
6	McBean Pkwy and Valencia Blvd	EB Left Turn	4.5	4.0
		WB Left Turn	4.5	3.3

Table 2: Calculated Yellow Change Intervals

Intersection		Movement	Existing Yellow Time (sec)	Calculated Yellow Time
7	Whites Canyon Rd & Soledad Canyon Rd	NB Left Turn	3.5	4.2
		SB Left Turn	3.5	3.6
		EB Left Turn	3.5	3.9
		WB Left Turn	3.5	3.9
8	Golden Valley Road and Centre Point Pkwy	NB Left Turn	4.0	3.7
		SB Left Turn	4.0	3.0
		EB Left Turn	3.5	3.3
		WB Left Turn	3.5	3.6
9	McBean Pkwy and Arroyo Park Dr	NB Left Turn	4.0	3.0
		SB Left Turn	4.0	3.0
		EB Left Turn	3.5	3.0
		WB Left Turn	3.5	3.0
10	Crossglade Ave and Soledad Canyon Rd	NB Left Turn	3.5	3.0
		SB Left Turn	3.5	3.0
		EB Left Turn	3.5	3.0
		WB Left Turn	3.5	3.0
11	Dickason Drive and Newhall Ranch Rd	NB Left Turn	4.0	3.8
		SB Left Turn	4.0	3.0
		EB Left Turn	4.0	3.7
		WB Left Turn	4.0	3.9
12	Centurion Way and Bouquet Canyon Rd	SB Left Turn	3.5	3.4
		EB Left Turn	3.5	3.1
13	Rockwell Canyon Rd and Valencia Blvd	NB Left Turn	4.0	3.0
		WB Left Turn	3.5	3.0

Assessment of Determining Factors

In order to develop a yellow change interval policy that can be utilized citywide, the factors that influence the approach speed and the corresponding calculated yellow change interval were examined.

Relationship to Posted or Actual Speed

One factor that was assumed to likely affect the left-turn approach speed (which in turn affects the calculated yellow change interval) is the speed of the roadway. The posted speed is generally associated with the design speed of the roadway. The actual measured through speed is affected by how drivers interact with that geometry and the effectiveness of speed limit enforcement. Both factors would likely affect the required yellow change interval by influencing the initial vehicle speed and the speed at which the vehicle enters the turn pocket.

The calculated yellow change intervals were charted against both the posted speed and the adjacent through speed at each location and a linear regression line was fit for each dataset. This chart is shown in **Figure 2**. As shown in the figure, the relationship between the calculated yellow time and the speed limit is much stronger than the relationship between the left-turn approach speed and the adjacent through speed.

Relationship to Turn Pocket Length

Another key factor in determining the required yellow change interval is the length of the turn pocket. A longer turn pocket will allow vehicles to maintain higher speeds for a longer distance approaching the left-turn movement and bypass queues that may be present for the through movement.

The calculated yellow times were charted against the turn pocket length at each location and a linear regression was fit for each dataset. This chart is shown in **Figure 3**. As shown in the figure, there is a measureable relationship between the calculated yellow time and the turn pocket length, particularly for longer and shorter pockets.

Other Factors

The influence of other factors was analyzed for their effects on left-turn approach speeds and calculated yellow times. These factors included grades, trap lanes, horizontal curves, and intersection skew. No substantial trends were observed to result from these factors. While there may be some influence on speeds from these elements, that influence was insignificant compared to the effects of measured or posted roadway speed and turn pocket length.

Figure 2
Calculated Yellow Times by Speed (Speed Limit and Measured)

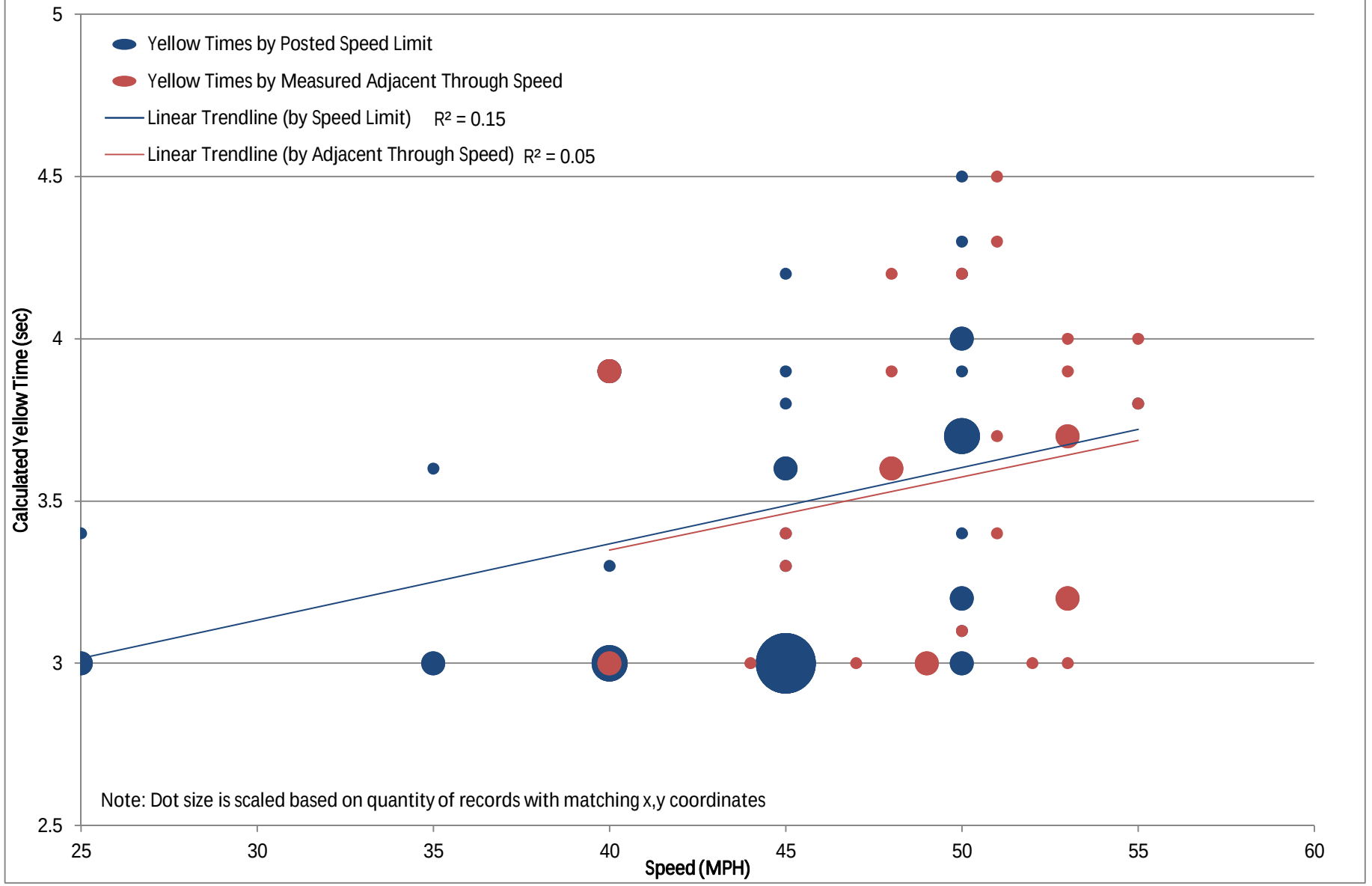
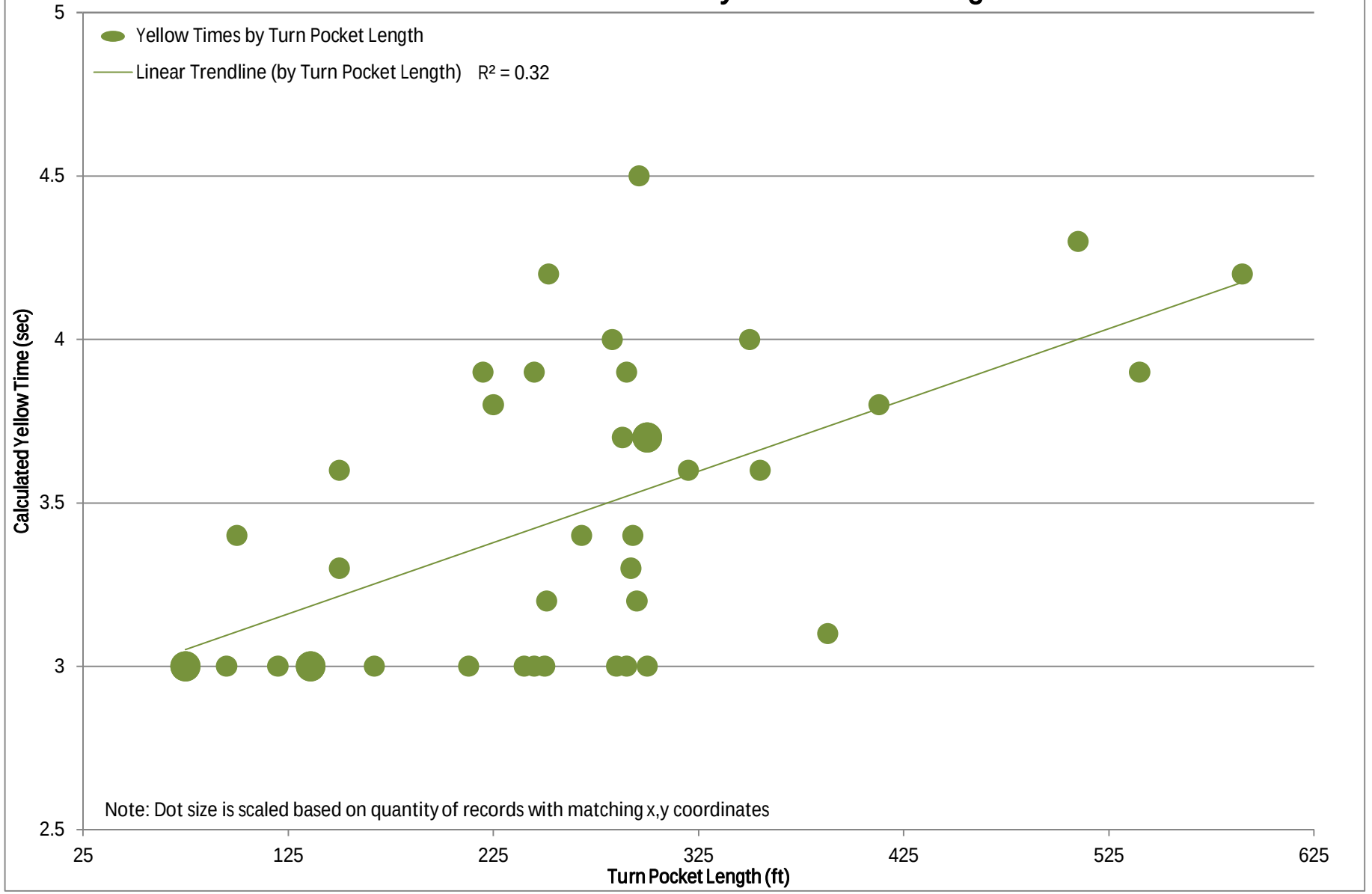


Figure 3
Calculated Yellow Times by Turn Pocket Length



Proposed Policy

A yellow change interval that can be utilized citywide needs to be easily calculable for a wide variety of locations and geometries, but also sufficiently accurate to provide the needed yellow change interval without being overly conservative. The two most influential factors in determining the required yellow change interval for left-turn movements are the roadway speed limit and the turn pocket length.

A variety of policies frameworks were evaluated at the study locations to identify those that best aligned with the calculated yellow times determined from field measurements. Based on that analysis, a policy that was based on the speed limit, with adjustments related to turn pocket length, was found to result in yellow times that most closely matched the individual calculated yellow times. The 85th percentile yellow time amongst the studied left-turn movements with a given roadway speed limit was calculated and used to represent the yellow time associated with each speed limit value. The turn pocket adjustment factor was developed in a similar manner by focusing on those studied left-turn movements with long or short pockets. It was observed that turn pocket lengths had a significant effect on calculated yellow time when the pockets exceeded 500 feet or were less than 200 feet in length.

The proposed yellow change interval policy is as follows:

1. Establish the yellow change interval based on the speed limit of the roadway with the left-turn movement, using **Table 3**.

Table 3: Proposed Yellow Change Interval by Speed Limit

Speed Limit	Yellow Change Interval
50 to 55 MPH	4.0 seconds
40 to 45 MPH	3.8 seconds
35 MPH	3.6 seconds

2. Adjust the proposed yellow change interval using the turn pocket length adjustment shown in **Table 4**.

Table 4: Proposed Yellow Change Interval Adjustment by Turn Pocket Length

Turn Pocket Length	Yellow Change Interval Adjustment
≥ 500 ft	+0.4 seconds
≥ 200 ft and < 500 ft	No Adjustment
<200 ft	set to 3.5 seconds

Insufficient data points were available to set a proposed yellow change interval for roadways with speed limits less than 35 miles per hour.

Effects of the Proposed Policy

In compliance with the 2012 CA MUTCD, the City currently predominately uses a yellow change interval of 3.5 seconds for left-turn movements, with some movements at red light camera enforcement locations using a yellow change interval of 4.0 or 4.5 seconds. To achieve compliance with the new MUTCD guidelines, the yellow change interval will be increased at 43 percent of the study locations.

In accordance with the guidelines in the 2014 CA MUTCD, yellow change intervals at some locations will increase to as much as 4.4 seconds, which would increase yellow change intervals from existing conditions by as much as 0.9 seconds. Amongst the study locations, seven locations would see a reduction in yellow change interval, 14 locations would see the same yellow change interval, and the remaining 16 locations would see an increase in yellow change interval. The yellow times at the study locations with implementation of the proposed policy are shown in **Table 5**.

Table 5: Yellow Change Intervals at Study Locations with Proposed Policy

Intersection		Movement	Existing Yellow Time (sec)	Proposed Yellow Time (sec)	Change in Yellow Time (sec)
1	Bouquet Canyon Rd and Newhall Ranch Rd	NB Left Turn	3.5	4.2	0.7
		SB Left Turn	3.5	3.8	0.3
		EB Left Turn	3.5	4.4	0.9
		WB Left Turn	3.5	4.0	0.5
2	Seco Canyon Rd and Bouquet Canyon Road	EB Left Turn	3.5	4.2	0.7
3	McBean Pkwy and Magic Mountain Pkwy	NB Left Turn	3.5	3.5	0.0
		SB Left Turn	3.5	4.0	0.5
		EB Left Turn	3.5	4.0	0.5
		WB Left Turn	3.5	3.8	0.3

Table 5: Yellow Change Intervals at Study Locations with Proposed Policy

Intersection		Movement	Existing Yellow Time (sec)	Proposed Yellow Time (sec)	Change in Yellow Time (sec)
4	McBean Pkwy and Newhall Ranch Rd	NB Left Turn	4.0	4.0	0.0
		SB Left Turn	4.0	4.0	0.0
		EB Left Turn	4.0	4.0	0.0
		WB Left Turn	4.0	4.0	0.0
5	Orchard Village Rd and Lyons Ave	SB Left Turn	3.5	3.8	0.3
6	McBean Pkwy and Valencia Blvd	EB Left Turn	4.5	4.0	-0.5
		WB Left Turn	4.5	3.8	-0.7
7	Whites Canyon Rd & Soledad Canyon Rd	NB Left Turn	3.5	4.0	0.5
		SB Left Turn	3.5	3.8	0.3
		EB Left Turn	3.5	3.8	0.3
		WB Left Turn	3.5	3.8	0.3
8	Golden Valley Road and Centre Point Pkwy	NB Left Turn	4.0	4.0	0.0
		SB Left Turn	4.0	4.0	0.0
		EB Left Turn	3.5	3.5	0.0
		WB Left Turn	3.5	3.6	0.1
9	McBean Pkwy and Arroyo Park Dr	NB Left Turn	4.0	3.8	-0.2
		SB Left Turn	4.0	3.8	-0.2
		EB Left Turn	3.5	3.5	0.0
		WB Left Turn	3.5	3.5	0.0
10	Crossglade Ave and Soledad Canyon Rd	NB Left Turn	3.5	N/A	N/A
		SB Left Turn	3.5	N/A	N/A
		EB Left Turn	3.5	3.5	0.0
		WB Left Turn	3.5	3.5	0.0
11	Dickason Drive and Newhall Ranch Rd	NB Left Turn	4.0	3.8	-0.2
		SB Left Turn	4.0	3.8	-0.2
		EB Left Turn	4.0	4.0	0.0
		WB Left Turn	4.0	4.0	0.0
12	Centurion Way and Bouquet Canyon Rd	SB Left Turn	3.5	N/A	N/A
		EB Left Turn	3.5	4.0	0.5
13	Rockwell Canyon Rd and Valencia Blvd	NB Left Turn	4.0	3.8	-0.2
		WB Left Turn	3.5	4.0	0.5

Note:
The proposed policy does not apply to locations with a speed limit of 25 MPH.

The yellow change interval at all City intersections will be recalculated using the policy described in this report to meet the 2014 CA MUTCD guidelines. At many intersections, the change in yellow change interval for each left-turn movement will be 0.5 seconds or less. This will result in a total increase in the intersection loss time of 1.0 second or less. Loss time represents time during which the intersection is not serving vehicle traffic, and results in inefficiency in signal operations.

At some larger intersections, the increase in yellow change interval for one or more left-turn movement would range from 0.5 to 0.9 seconds with implementation of the proposed policy. The intersection of Bouquet Canyon Road and Newhall Ranch Road will be the most affected of those analyzed in this study. At that location, the total intersection loss time will increase by 1.6 seconds with implementation of the proposed policy. If the signal cycle length is desired to remain unchanged, this would result in reduced vehicle green time and reduced capacity of the intersection. The coordinated cycle length throughout the City is 132 seconds. Of the 132 seconds, 22.5 seconds are already dedicated to yellow and all-red time. Thus, the increase in lost time will result in a 1.5 percent reduction in intersection green time and intersection capacity. The intersection's pedestrian timings, minimum green times, yellow times and all-red times currently sum to 126.5 seconds. Therefore, there is little flexibility in adjusting the existing timing to meet the increased yellow time requirements. Further analysis would be required to identify the impact of the increased yellow time on vehicle delay and whether a small increase in the cycle length would be required.

At other locations, the effect on intersection capacity and pressure on the existing cycle length would be somewhat less. However, at all locations where the loss time increases, intersection control delay would increase marginally, resulting in some level of increased vehicle delay.

Summary

The recent 2014 update to the CA MUTCD changes the methodology by which yellow change intervals are calculated at signalized intersections. It also provides cities the option of further analyzing the yellow change intervals of protected left-turn movements at signalized intersections. As the result of this change, the City of Santa Clarita commissioned this study to examine yellow change intervals for left-turn movements at key locations within the City and to develop a left-turn change interval policy that could be implemented citywide that would comply with the new guidelines.

Based on data collected at 40 left-turn locations throughout the City, this study is recommending a yellow change interval policy for protected left-turn movements throughout the City. The policy is as follows:

1. Establish the yellow change interval based on the speed limit of the roadway with the left-turn movement, using **Table 6**.

Table 6: Proposed Yellow Change Interval by Speed Limit

Speed Limit	Yellow Change Interval
50 to 55 MPH	4.0 seconds
40 to 45 MPH	3.8 seconds
35 MPH	3.6 seconds

2. Adjust the proposed yellow change interval using the turn pocket length adjustment shown in **Table 7**.

Table 7: Proposed Yellow Change Interval Adjustment by Turn Pocket Length

Turn Pocket Length	Yellow Change Interval Adjustment
≥ 500 ft	+0.4 seconds
≥ 200 ft and < 500 ft	No Adjustment
<200 ft	set to 3.5 seconds

With the implementation of this policy, the yellow change interval at all signalized intersections in the City will be recalculated. At many locations this will result in an increase in the yellow change interval. The proposed policy could increase average vehicle delay at some locations where it is implemented due to the increase in intersection loss time associated with a longer yellow change interval.

The proposed policy is consistent with the 2014 CA MUTCD. It specifies yellow change intervals in exceed of the required minimums based on an engineering study and the actual speed of drivers making left-turn movements. It also provides for longer yellow change intervals for movements with longer left-turn pockets.

Attachments:

Appendix A – Study Intersection Characteristics

Appendix B – Left-turn Approach Speed Data

Appendix A
City of Santa Clarita
Study Intersection Characteristics

Intersection	North Approach							South Approach						
	Lanes	Trap	Speed	Taper Length	Pocket Length	Grade	Skew	Lanes	Trap	Speed	Taper Length	Pocket Length	Grade	Skew
Bouquet Canyon Road at Newhall Ranch Road	2	N	45	#1LT 60'	355'	N	N	2	N	45	60'	590'	N	N
Bouquet Canyon Road at Seco Canyon Road	1	N	45	75'	91'	N	Y	No Roadway						
Magic Mountain Parkway at McBean Parkway	2	N	50	90'	293'	N	Y	2	N	45	90'	167'	N	Y
McBean Parkway at Newhall Ranch Road	2	N	50	90'	251'	N	N	2	N	50	90'	300'	N	N
Lyons Avenue at Orchard Village Road	2	Y	45	120' #1LT	268'/454'	N	Y	1	N	35	60'	137'	N	Y
Valencia Boulevard at McBean Parkway	2	N	45	120'	198'	N	Y	2	N	45	75'	145'	N	Y
Soledad Canyon Road at Whites Canyon Road	2	Y	45	90'	320'	N	N	2	N	50	90'	252'	Y	N
Golden Valley Road at Centre Pointe Parkway	1	N	50	120'	240'	Y	Y	1	N	50	120'	300'	Y	Y
McBean Parkway at Arroyo Park Drive	1	N	45	120'	300'	N	N	1	N	45	75'	250'	N	N
Soledad Canyon Road at Crossglade Avenue	Minor Street: Permissive w/ 75' left turn pocket							Minor Street: Permissive w/ 75' left turn pocket						
Newhall Ranch Road at Avenue Tibbitts-Dickason	2	N	40	90'	245'	Y	N	2	N	45	105'	225'	Y	N
Bouquet Canyon Road at Centurion Way	Minor Street: Permissive left turn pocket							No Roadway						
Valencia Boulevard at Rockwell Canyon Road	No Roadway							2	Y	45	75'	285'	N	Y

Intersection	West Approach							East Approach						
	Lanes	Trap	Speed	Taper Length	Pocket Length	Grade	Skew	Lanes	Trap	Speed	Taper Length	Pocket Length	Grade	Skew
Bouquet Canyon Road at Newhall Ranch Road	3	Y	50	120'#1LT	510'	N	N	2	N	55	120'	413'	Y	N
Bouquet Canyon Road at Seco Canyon Road	2	Y	45	60' #1 LT	540'	N	Y	No Left Turn Pocket						
Magic Mountain Parkway at McBean Parkway	2	N	50	90'	350'	N	Y	2	N	45	90'	213'	N	Y
McBean Parkway at Newhall Ranch Road	2	N	50	90'	295'	N	N	2	N	50	90'	296'	N	N
Lyons Avenue at Orchard Village Road	2	N	35	90'	178'	N	Y	1	N	35	90'	185'	N	Y
Valencia Boulevard at McBean Parkway	2	N	50	90'	283'	Y	Y	2	N	45	90'	292'	N	Y
Soledad Canyon Road at Whites Canyon Road	2	N	40	120'	290'	N	N	2	N	40	N/A	220'	N	N
Golden Valley Road at Centre Pointe Parkway	1	N	40	60'	150'	Y	Y	2	Y	35	60' #1	150'/243'	N	Y
McBean Parkway at Arroyo Park Drive	1	N	35	75'	120'	N	N	1	N	35	60'	95'	N	N
Soledad Canyon Road at Crossglade Avenue	1	N	40	75'	136'	Y	N	1	N	40	75'	136'	Y	N
Newhall Ranch Road at Avenue Tibbitts-Dickason	2	N	50	120'	288'	N	N	2	N	50	105'	245'	N	N
Bouquet Canyon Road at Centurion Way	1	N	50	60'	388'	N	Y	No Left Turn Pocket						
Valencia Boulevard at Rockwell Canyon Road	No Left Turn Pocket							2	N	50	135'	290'	Y	Y

Appendix B
Santa Clarita Yellow Time Study
Measured Travel Speed in Left-turn Pocket

	1				2	3				4				5	6		7			
	Bouquet Canyon Rd and Newhall Ranch Rd				Seco Canyon Rd and Bouquet Canyon Road	McBean Pkwy and Magic Mountain Pkwy				McBean Pkwy and Newhall Ranch Rd				Orchard Village Rd and Lyons Ave	McBean Pkwy and Valencia Blvd		Whites Canyon Rd & Soledad Canyon Rd			
Speed mph	NB Left Turn	SB Left Turn	EB Left Turn	WB Left Turn	EB Left Turn	NB Left Turn	SB Left Turn	EB Left Turn	WB Left Turn	NB Left Turn	SB Left Turn	EB Left Turn	WB Left Turn	SB Left Turn	EB Left Turn	WB Left Turn	NB Left Turn	SB Left Turn	EB Left Turn	WB Left Turn
<=10																				
11																				
12																				
13																				
14																				
15																				
16									1											
17																				
18									1											
19									1											
20		1							1	1										
21		1								2				4						
22	1					1	2		3	1	1									
23	1						2	2			2					1				
24	2	2				1			1	2	2			1					1	
25	2	4					1		1	3	3	1	1	5	2	3				
26	3						2	1	1		5			2				2		
27	1			1	1				1	2	1	2		1	3	3		1		
28	3	2			2	1	1	2	1	1	3		2		3	2		1	1	
29	3	1	1	2	4			1	3	2	3	1	5	2	7	2	1	3		
30	5	3		2	8			1		2	3	2	2	2	4	1	1	5	1	
31	6	3	5		4	1	1	2		1	5	2	1	1	2	2	3	6	2	
32	14	1	2	5	4					1	2			3	3	1	2	3	7	
33	8	4	1		6		1			1			6	3	2	1		2	5	1
34	6		1	1	6		1	1		2	2		10	2	1		3	2	1	2
35	2	1	5		5		1	1		5			8	1	1		1	1	2	3
36	6	1	6	2	4			1	1				6	1	5		1	2	2	3
37	5		2	1	8		1			2		1	7		3			1	1	3
38	5	1	3										5		1		2			2
39	5		2		2					1			2	1	2		3		1	
40	6				1								5		1		2		1	
41	3	1	2		2								3							
42	5				1					1			5							
43			1	1	2			1					2		1					
44	1		2	1	1															
45		1																		
46													1							
47																				
48															1					

Appendix B
Santa Clarita Yellow Time Study
Measured Travel Speed in Left-turn Pocket

	8				9				10				11				12		13	
	Golden Valley Road and Centre Point Pkwy				McBean Pkwy and Arroyo Park Dr				Crossglade Ave and Soledad Canyon Rd				Dickason Drive and Newhall Ranch Rd				Centurion Way and Bouquet Canyon Rd		Rockwell Canyon Rd and Valencia Blvd	
Speed mph	NB Left Turn	SB Left Turn	EB Left Turn	WB Left Turn	NB Left Turn	SB Left Turn	EB Left Turn	WB Left Turn	NB Left Turn	SB Left Turn	EB Left Turn	WB Left Turn	NB Left Turn	SB Left Turn	EB Left Turn	WB Left Turn	SB Left Turn	EB Left Turn	NB Left Turn	WB Left Turn
<=10	1	2				3														
11		2									1			3					1	
12	1	1				1					1									1
13		1						1	1		1			8				1	2	
14		2						1	2					9					2	
15	2	3				2								5					1	
16	1	3						1	3					8			1			
17	1								1					9				1	1	2
18		3		1		1	1	2			2			7				1	1	1
19	1				1	4	3	1		2	1			1				1	1	
20	1			1	1	2	4	2		1				1				4	2	3
21	4	2		1	1	1		1	1	2	1		1					2	2	1
22	2					5	1	1		1		1		1					1	3
23		1		2		2	1	2									2	5	1	1
24	4	1		2		6	1			1		1	2				1	3	2	4
25		1	2	1		4	3			1		1			1			3	2	5
26	1	3	1	2		2	1			2		2	1				1	2		1
27	2		1	1	1	8												2		2
28	1	1	1	1		2				1								2		
29	2		2			1		1							2			2		1
30		1				1										1			1	1
31	1					1							2		2		1	1	1	1
32	2		1	1		1							1		1	2		1		
33	1		1	1		2							1							
34	3			1		1									3	1		1		
35	2			1									1			2				
36				1											3	2		1		
37	1														1					
38	1												1		1					
39																		1		
40																				
41													1							
42																				
43															1					
44	1																			
45																				
46																				
47																				
48																				