Hexagon Transportation Consultants, Inc.

Memorandum

Date: August 13, 2020

To: Mr. Ed Shikada, City of Palo Alto
CC: Ms. Millette Litzinger, AECOM

From: Gary Black, Trisha Dudala

Subject: Churchill, Meadow and Charleston Grade Separation Traffic Analysis

Introduction

The Caltrain Electrification project will increase the frequency of trains through Palo Alto. The gate downtime at at-grade crossings is expected to be as high as 45 seconds per 3 minutes. The three at-grade crossings included in the Connecting Palo Alto study are located on Churchill Avenue, Meadow Drive, and Charleston Road. This report summarizes the findings of the traffic operations analysis that was conducted for alternatives that would provide grade separation at the three at-grade crossings. These alternatives were selected for further evaluation by the City and the XCAP.

This study analyzes traffic operations during the weekday AM (7-9) and PM (4-6) peak commute hours under existing and future (Year 2030) conditions. The analysis was conducted using the simulation software VISSIM by PTV Vision, and Synchro/SimTraffic by Trafficware. Traffic conditions at the study intersections were evaluated using level of service (LOS). Level of service is a qualitative description of operating conditions ranging from LOS A, or free-flow conditions with little or no delay, to LOS F, or jammed conditions with excessive delays. The acceptable LOS in the City of Palo Alto is LOS D or better for signalized and unsignalized intersections.

Bicycle and Pedestrian Circulation

The traffic study focuses on vehicular traffic operations at Churchill Avenue, Meadow Drive, and Charleston Road for the alternatives. However, bicycle and pedestrian circulation has been accounted for in the traffic analysis. All alternatives have been designed to be consistent with the City's safe routes to schools plan. The design drawings show all planned sidewalks and bicycle lanes/paths.

Churchill Avenue Alternatives

Existing AM and PM peak hour traffic counts and future volumes for the Alma Street/Churchill Avenue intersection were obtained from the 2018 counts and 2030 forecasts presented in the *Draft Churchill Closure* report by TJKM. A comparison of AM and PM peak hour delays at the Alma and Churchill Avenue for the three alternatives with existing traffic volumes are shown in Table 1 and with Year 2030 volumes are shown in Table 2. As shown in Table 1, the intersection of Alma and Churchill currently operates at LOS F during the AM peak hour and LOS E during the PM peak hour. With future traffic volumes (see Table 2) the intersection would operate at LOS F during both the AM and PM peak hours and with electrification, the intersection would continue to operate at

unacceptable LOS F during both the AM and PM peak hours. The electrification would increase the number of trains and the downtime at the at-grade crossing which would cause the intersection delay to increase.

Churchill Closure

This analysis scenario evaluated the impacts of the closure of Churchill Avenue across the railroad tracks. With the closure of Churchill Avenue west of the railroad tracks, Churchill Avenue would no longer provide an east-west connection for vehicles across Alma Street. Figures 1A and 1B shows the conceptual intersection layout and rendering of the intersection, developed by AECOM. As shown in Table 1 and Table 2, the intersection of Alma and Churchill Avenue would operate at an acceptable LOS C during both the AM and PM peak hours with existing and future traffic volumes with the Churchill closure. However, this alternative would cause the existing traffic using the Churchill railroad crossing to reroute to other crossings, creating traffic impacts on Embarcadero Road and on Oregon Expressway/Page Mill Road. These impacts and mitigation measures were the subject of a separate traffic study prepared by Hexagon and included in Appendix A.

Churchill Viaduct

Under this alternative, an elevated structure (viaduct) would carry the railroad tracks over Churchill Avenue, and Churchill would continue to provide an east-west connection for pedestrians, bicycles and vehicles. Figure 2 illustrates the conceptual rendering of the intersection, developed by AECOM. As shown in Table 1, the intersection of Alma and Churchill Avenue would operate at LOS D during both the AM and PM peak hours with existing traffic volumes. The improvement in LOS would be due to the train interruption being eliminated. With future traffic volumes (see Table 2), the intersection would operate at LOS D during the AM peak hour and LOS E during the PM peak hour.

The reduction in delay due to the elimination of gate down time could lead to an increase in traffic volume on Churchill Avenue. Of particular concern is the residential portion of Churchill Avenue, which is east of Alma Street. Hexagon calculated the additional intersection capacity that would result from the elimination of gate down time. The increase in capacity could result in about 100 additional vehicles per day using Churchill Avenue east of Alma Street. This represents a 5% increase in traffic. It should be noted that the additional capacity would primarily occur during the peak AM and PM commute hours. During the off-peak hours, there is much less gate down time because of many fewer trains.

Churchill Partial Underpass

This alternative proposes to separate Caltrain from Churchill Avenue but preserve access to Alma street by keeping Churchill Avenue partially open via a modified underpass. It requires lowering both Churchill and Alma to allow the western portion of Churchill to pass underneath the Caltrain tracks, while keeping the eastern portion of Churchill at grade. The most significant traffic-flow change is that no through traffic would be possible on Churchill Avenue across Alma Street. This alternative also would separate the bicycle and pedestrian traffic crossing Alma Street from vehicular traffic by providing a bridge over Churchill Avenue that connects to the bike trail next to Palo Alto High School. Figures 3A and 3B illustrates the conceptual intersection layout and renderings of the intersection, developed by AECOM.

Because through traffic and some turning movements at Churchill would not be possible, some traffic would reroute to other streets. The following traffic movements would need to reroute (see Figures 4A, 4B, 4C and 4D):

- Eastbound through traffic on Churchill – 90% of the traffic is expected to reroute to turn left on Alma and travel north to use Embarcadero Road or one of the neighborhood cross streets. 10% of the traffic is expected to turn right at Alma and use one of the neighborhood cross streets.
- Westbound through traffic on Churchill Avenue – All traffic is expected to make a right turn on Alma and travel north to use Embarcadero Road.
- Westbound left-turn traffic on Churchill Avenue – All traffic is expected to use another of the neighborhood streets to access Alma.
- Southbound left-turn traffic on Alma Street – All traffic is expected to turn left into one of the other neighborhood streets.

As shown in Table 1 and Table 2, the signalized intersection of Alma Street and Churchill Avenue would operate at acceptable LOS C or better during both the AM and PM peak hour periods with the existing and future traffic volumes.

Table 1
Alma and Churchill Grade Separation Alternatives – Existing Traffic Volumes

Traffic Operations (Existing Traffic Volumes)																
	No Improvements (No Electrification) [1]				Churchill Closure [2]				Viaduct [3]				Partial Underpass [4]			
	AM		PM		AM		PM		AM		PM		AM		PM	
	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS
Alma Street & Churchill Avenue	88.9	F	66.67	E	23.58	C	28.23	C	45.39	D	42.73	D	15.62	B	21.66	C

Notes:-

1. All turning movements permitted. Analysis assumes 8 trains per hour under existing conditions. Traffic analysis was conducted using PTV Vissim software.
2. The following turning movements would not be possible;- left-turn, right-turn and through traffic from eastbound Churchill, through traffic from westbound Churchill, northbound left-turns and southbound right-turn from Alma. Traffic analysis was conducted using PTV Vissim software.
3. All turning movements permitted. Traffic analysis was conducted using PTV Vissim software.
4. The following turning movements would not be possible;- eastbound and westbound through traffic on Churchill Avenue across Alma Street, left-turn from westbound Churhill, and left-turn from southbound Alma. Traffic analysis was conducted using SimTraffic.

Table 2
Alma and Churchill Grade Separation Alternatives – Future Traffic Volumes

Traffic Operations (Year 2030 Traffic Volumes)																		
	No Improvements (No Electrification) [1]				No Improvements (With Electrification) [2]				Churchill Closure [3]				Viaduct [4]				Partial Underpass [5]			
	AM		PM		AM		PM		AM		PM		AM		PM		AM		PM	
	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS
Alma Street & Churchill Avenue	118.5	F	90	F	173.5	F	178.5	F	25.1	C	30.6	C	48.4	D	56.77	E	15.65	B	30.97	C

Notes:-

1. All turning movements permitted. Analysis assumes 8 trains per hour with no electrification. Traffic analysis was conducted using PTV Vissim software.
2. All turning movements permitted. Analysis assumes 14 trains per hour with electrification. Traffic analysis was conducted using PTV Vissim software.
3. The following turning movements would not be possible;- left-turn, right-turn and through traffic from eastbound Churchill, through traffic from westbound Churchill, northbound left-turns and southbound right-turn from Alma. Traffic analysis was conducted using PTV Vissim software.
4. All turning movements permitted. Traffic analysis was conducted using PTV Vissim software.
5. The following turning movements would not be possible;- eastbound and westbound through traffic on Churchill Avenue across Alma Street, left-turn from westbound Churhill, and left-turn from southbound Alma. Traffic analysis was conducted using SimTraffic.

Preliminary Layout shown based on early concepts
(subject to change)

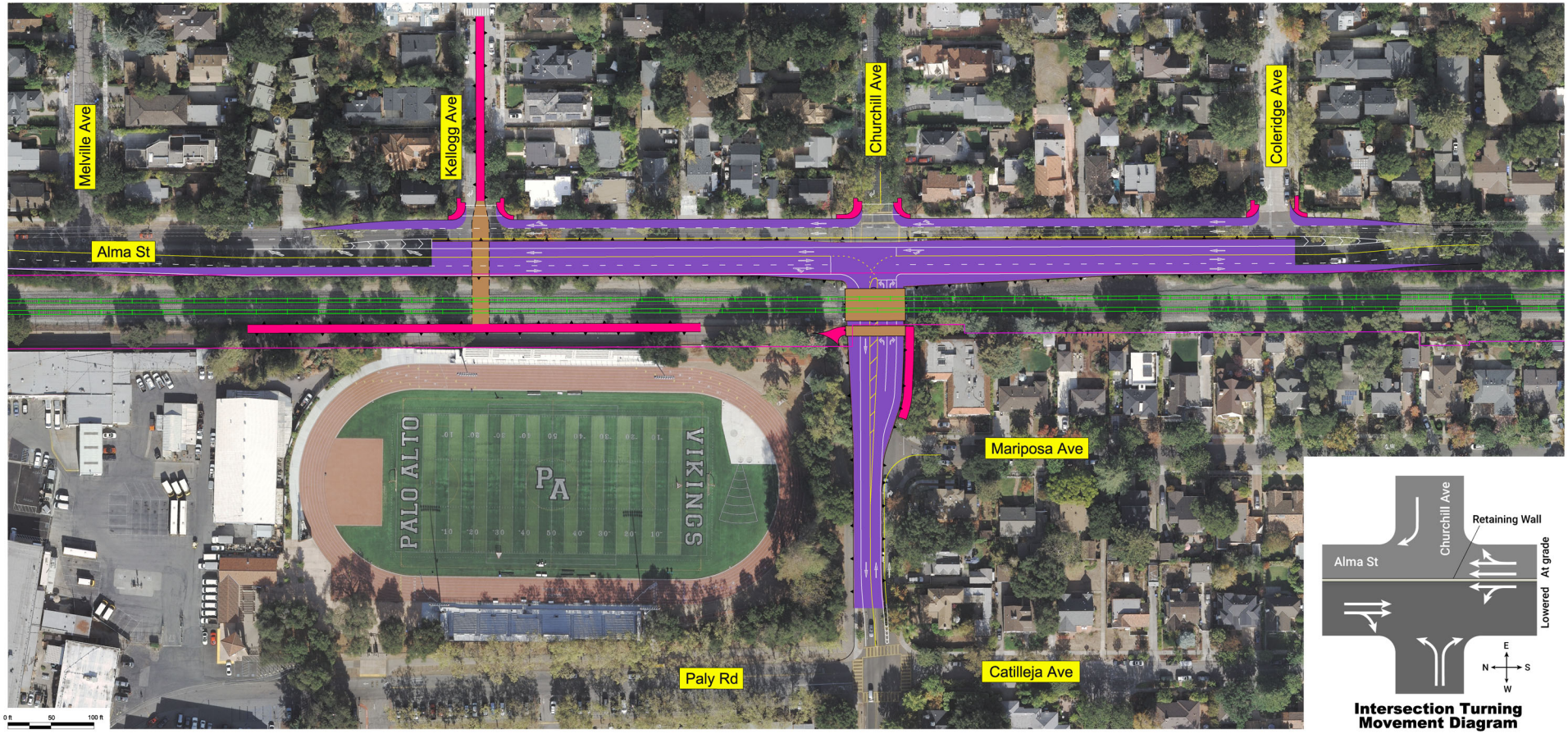
Figure 1A
Churchill Closure Rendering 1

Preliminary Layout shown based on early concepts
(subject to change)

Figure 1B
Churchill Closure Rendering 2

Preliminary Layout shown based on early concepts
(subject to change)

Figure 2
Churchill Viaduct Rendering



Preliminary Layout shown based on early concepts
(subject to change)

Figure 3A
Churchill Partial Underpass Intersection Layout

Preliminary Layout shown based on early concepts
(subject to change)

Figure 3B
Churchill Partial Underpass Rendering

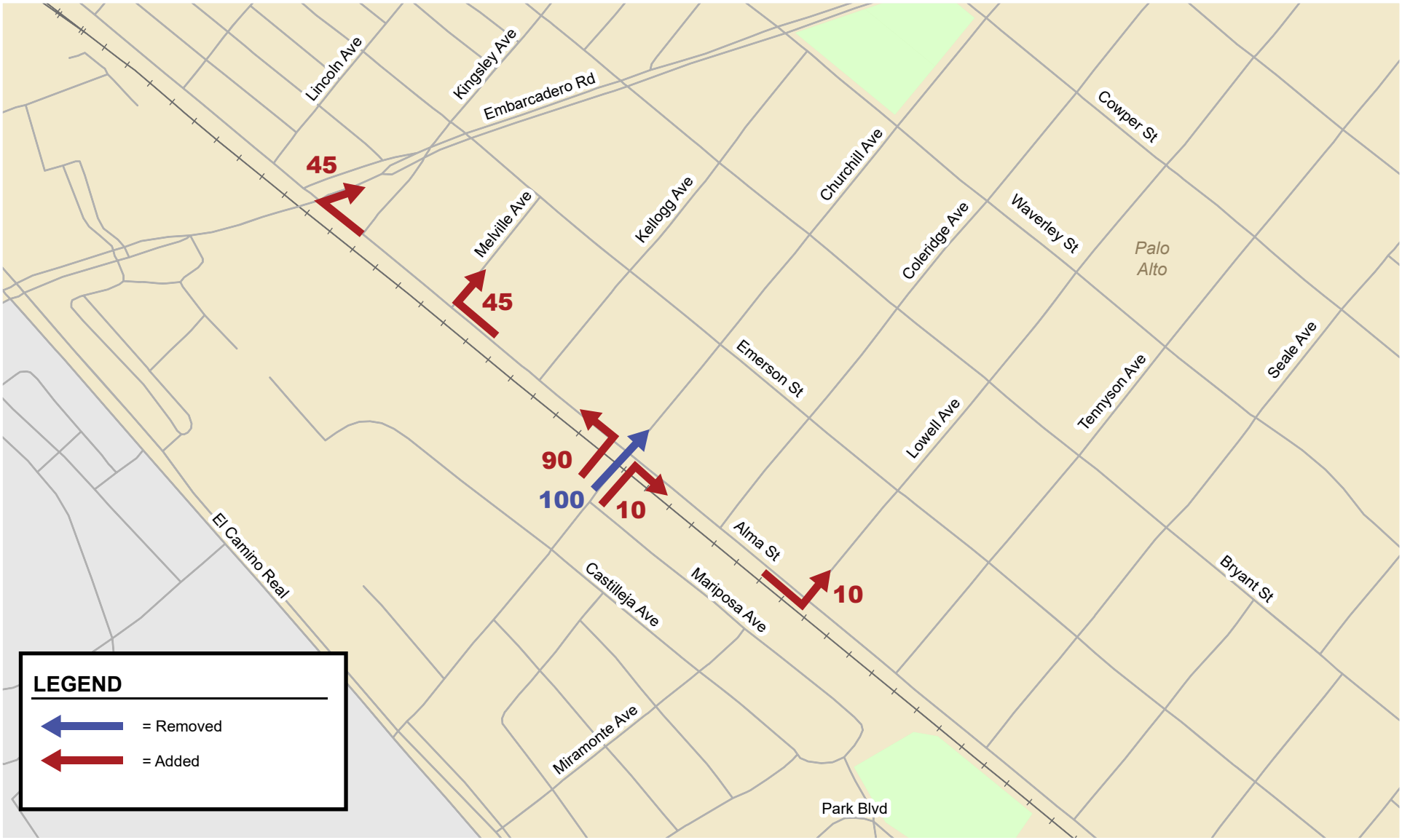


Figure 4A
Churchill Ave/Alma St AM and PM Peak-Hour Diversions (Partial Underpass Alternative)

Figure 4B
Churchill Ave/Alma St AM and PM Peak-Hour Diversions (Partial Underpass Alternative)

Figure 4C
Churchill Ave/Alma St AM and PM Peak-Hour Diversions (Partial Underpass Alternative)

Figure 4D
Churchill Ave/Alma St AM and PM Peak-Hour Diversions (Partial Underpass Alternative)

Meadow Drive and Charleston Road Alternatives

Existing AM and PM peak hour traffic counts for the Alma Street/Meadow Drive and Alma Street/Charleston Road were conducted in October 2019 (see Appendix B). Future traffic volumes for these two study intersections were obtained from the *Palo Alto Comprehensive Plan Update* prepared by Hexagon in January 2016. For the at-grade crossings at Meadow Drive and Charleston Road, two alternatives were evaluated as described below. A comparison of AM and PM peak hour delays at the Alma/Meadow and Alma/Charleston for the two alternatives with existing traffic volumes are shown in Table 3 and with future traffic volumes are shown in Table 4. As shown in Table 3, the Alma/Meadow intersection currently operates at LOS F during the AM peak hour and LOS E during the PM peak hour. The intersection of Alma/Charleston operates at LOS F during both the AM and PM peak hours. With future traffic volumes (see Table 4), the analysis shows that both the Meadow and Charleston intersections would operate at LOS F during the AM and PM peak hours. With electrification, the analysis shows that both intersections would continue to operate at unacceptable LOS F during the AM and PM peak hours with future traffic volumes.

Meadow and Charleston Viaduct

Under this alternative, an elevated structure (viaduct) would carry the railroad over both Meadow Drive and Charleston Road. Meadow and Charleston would continue to provide east-west connections for pedestrians, bicycles and vehicles. Figure 5 illustrates the conceptual rendering of the Meadow Drive viaduct and Figure 6 illustrates the conceptual rendering of the Charleston Road viaduct.

Alma Street and Meadow Drive Intersection

As shown in Tables 3 and 4, the intersection of Alma and Meadow would operate at LOS D during both the AM and PM peak hours with existing traffic volumes. With future traffic volumes, this intersection would operate at LOS E during the AM peak hour and LOS F during the PM peak hour with the viaduct.

Alma Street and Charleston Road Intersection

The analysis shows that the intersection of Alma and Charleston would operate at LOS E during the AM peak hour and LOS D during the PM peak hour with existing traffic volumes (see Table 3). With future traffic volumes, this intersection would operate at LOS F during both the AM and PM peak hours with the viaduct (see Table 4).

There are no feasible improvements that would mitigate the traffic operations under future traffic volumes to acceptable levels.

Meadow and Charleston Trench

Under this alternative, the railroad tracks would be fully lowered in a trench, and the roadways would remain at grade. Meadow and Charleston would continue to provide east-west connections for pedestrians, bicycles, and vehicles. The traffic impacts for this alternative would be similar to the viaduct alternative.

Table 3
Meadow and Charleston Grade Separation Alternatives – Existing Traffic Volumes

Traffic Operations (Existing Traffic Volumes)									
		No Improvements (No Electrification) [1]				Viaduct [2]			
		AM		PM		AM		PM	
	Traffic Control	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS
Meadow Drive									
Alma Street & Meadow Drive	Signal	81.34	F	64.43	E	52.00	D	47.36	D
Charleston Road									
Alma Street & Charleston Road	Signal	123.06	F	101.40	F	60.93	E	51.59	D

Notes:-

1. All turning movements permitted. Analysis assumes 8 trains per hour under existing conditions. Traffic analysis was conducted using SimTraffic.
2. All turning movements permitted. Traffic analysis was conducted using SimTraffic.

Table 4
Meadow and Charleston Grade Separation Alternatives – Future Traffic Volumes

Traffic Operations (Year 2030 Traffic Volumes)													
		No Improvements (No Electrification) [1]				No Improvements (With Electrification) [2]				Viaduct [3]			
		AM		PM		AM		PM		AM		PM	
	Traffic Control	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS	Delay (secs)	LOS
Meadow Drive													
Alma Street & Meadow Drive	Signal	215.03	F	318.96	F	318.39	F	502.87	F	68.93	E	238.26	F
Charleston Road													
Alma Street & Charleston Road	Signal	330.72	F	330.31	F	421.58	F	535.47	F	114.94	F	274.50	F

Notes:-

1. All turning movements permitted. Analysis assumes 8 trains per hour with no electrification. Traffic analysis was conducted using SimTraffic.
2. All turning movements permitted. Analysis assumes 14 trains per hour with electrification. Traffic analysis was conducted using SimTraffic.
3. All turning movements permitted. Traffic analysis was conducted using SimTraffic.

Preliminary Layout shown based on early concepts
(subject to change)

Figure 5
Meadow Drive Viaduct Rendering

Preliminary Layout shown based on early concepts
(subject to change)

Figure 6
Charleston Road Viaduct Rendering

Meadow and Charleston Hybrid

Under this alternative, the railroad track would be slightly raised, and the roadway would be slightly lowered. Meadow and Charleston would continue to provide east-west connections for pedestrians, bicycles, and vehicles. The traffic impacts for this alternative would be similar to the viaduct alternative.

South Palo Alto Tunnel – Passenger and Freight

Under this alternative, both the passenger trains and the freight trains would be accommodated within an underground tunnel. The traffic impacts for this alternative would be similar to the viaduct alternative.

South Palo Alto Tunnel – At-Grade Freight

Under this alternative, the passenger trains would use an underground tunnel and the freight trains would continue to operate at grade. Also, Alma Street would be reduced to one lane in each direction between approximately El Dorado-Loma Verde and Charleston-Greenmeadow Way. As a result, the traffic impacts under this alternative would be worse than the viaduct, trench, hybrid and tunnel (with passenger and freight) alternatives.

Meadow and Charleston Partial Underpass – With U-Turn at Alma Village Circle

This alternative proposes to keep the Caltrain tracks at grade and lower Meadow Drive and Charleston Road to go under the tracks and under Alma Road. Figures 7A and 7B illustrates the conceptual intersection layout and rendering of the Meadow Drive partial underpass and Figures 8A and 8B illustrates the conceptual intersection layout and rendering of the Charleston Road partial underpass. This alternative was analyzed only for future conditions (see Table 5).

Alma Street and Alma Village Circle

A U-turn lane would be constructed on northbound Alma at the existing signalized intersection of Alma Street and Alma Village Circle. Alma Village Circle is located approximately 600 feet to the north of Meadow Drive. The U-turn lane would allow northbound traffic on Alma Street to access Meadow Drive by making a U-turn at the Alma Village Circle and using the proposed southbound Alma Street off-ramp to Meadow Drive. Due to the close spacing between the proposed Alma Street on-ramp from Meadow Drive and Alma Village Circle, traffic from westbound Meadow would not be able to access the U-turn lane to go southbound on Alma.

Alma Street and Meadow Drive Intersection

For the most part, this alternative has Meadow Drive passing under Alma Street, with a couple of connections. Southbound left-turns and right-turns from Alma to Meadow Drive will be accommodated by an off-ramp from Alma Street to Meadow Drive with a traffic signal. Also, westbound right-turns from Meadow Drive to northbound Alma Street would be accommodate by a ramp. A U-turn lane would be constructed on northbound Alma at the existing signalized intersection of Alma Street and Alma Village Circle to facilitate turning movements from northbound Alma to Meadow Drive. Alma Village Circle is located approximately 600 feet to the north of Meadow Drive. The U-turn lane would allow northbound traffic on Alma Street to access Meadow Drive by making a U-turn at the Alma Village Circle and using the proposed southbound Alma Street off-ramp to Meadow Drive. Due to the close spacing between the proposed Alma Street on-ramp from Meadow Drive and Alma Village Circle, traffic from westbound Meadow would not be able to access the U-turn lane to go southbound on Alma. Westbound left-turns and eastbound

right-turns from Meadow to southbound Alma would reroute to other locations (see Figures 9A and 9B).

Three options as described below were analyzed for the northbound and southbound ramp intersections at Meadow Drive (see Table 5).

- Option 1 – Traffic signal at the Alma southbound off-ramp and no control at the Alma northbound off-ramp. Left-turning traffic from eastbound Meadow would have to find gaps in the uncontrolled traffic flow on westbound Meadow.
- Option 2 – Traffic signal at the Alma southbound off-ramp and an all-way stop control at the Alma northbound on-ramp.
- Option 3 – Traffic signals at both the southbound off-ramp and northbound on-ramp.

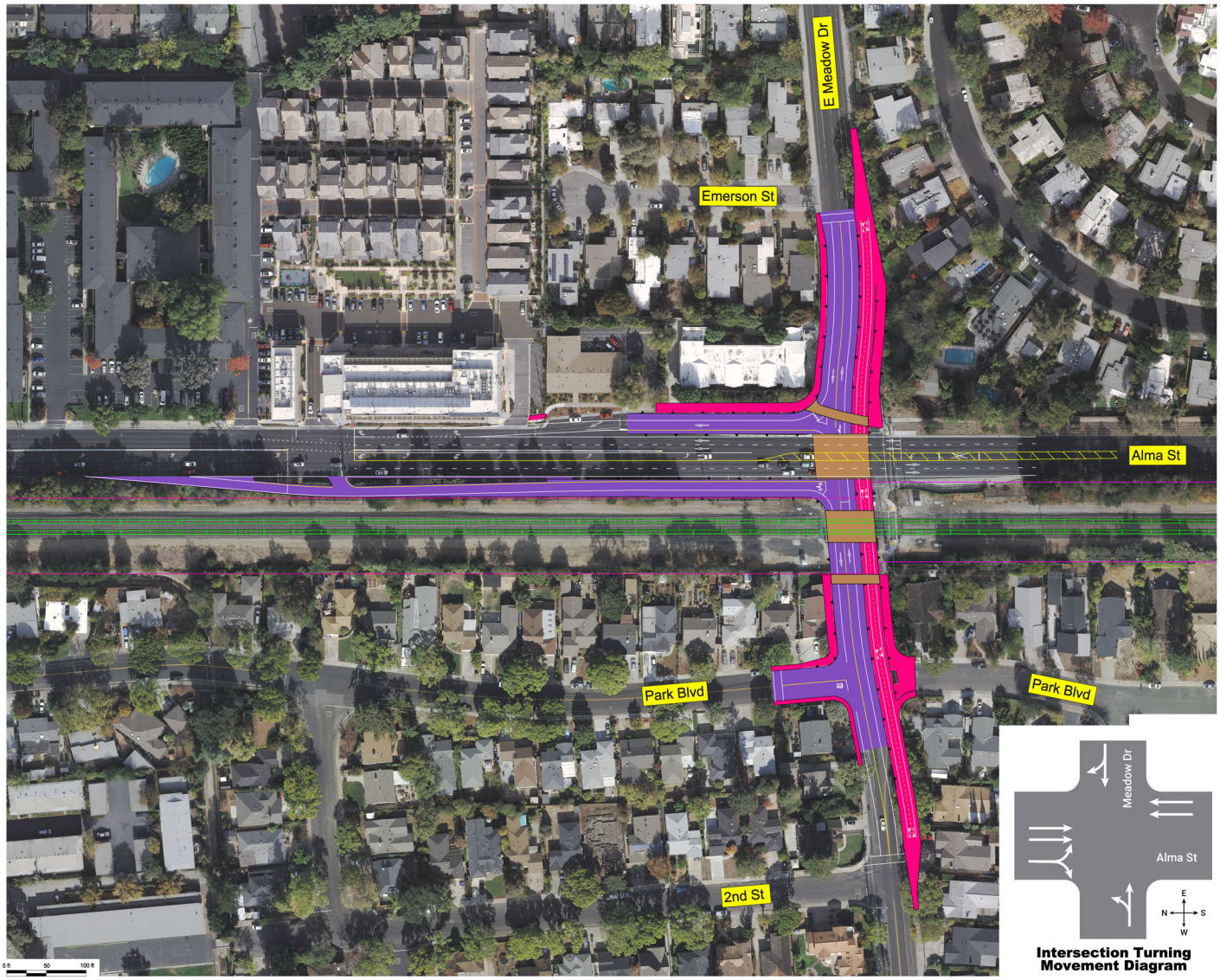
Alma Street and Charleston Road Intersection

At the Alma/Charleston intersection, some turning movements would be cut off at the intersection itself but would be accommodated via a two-lane roundabout that would be provided on Charleston Road at Mumford Place, east of Alma Street (see Figures 10A, 10B and 10C). Two ramps and two traffic signals would be provided to connect Charleston Road to Alma Street. The signal to the north would facilitate turning movements from westbound Charleston to northbound and southbound Alma Street. The signal to the south would facilitate southbound left-turns and northbound right turns from Alma Street to eastbound Charleston Road. The design also includes a ramp connection from eastbound Charleston to southbound Alma Street.

As shown in Table 5, the analysis shows that the intersection of Alma Street and Alma Village Circle would operate at acceptable LOS B during both the AM and PM peak hours with future traffic volumes.

At the Alma/Meadow intersection, the analysis shows that both the ramps from southbound Alma to Meadow and from Meadow to northbound Alma would operate at acceptable LOS B or better during the AM and PM peak hours with future traffic volumes. Where the northbound on-ramp would merge onto Alma Street, the analysis shows that the on-ramp approach would operate at LOS E during the AM peak hour, as traffic merging onto Alma Street would have to find gaps in the uncontrolled traffic flow on northbound Alma, which is the peak direction.

The analysis shows that the two signalized intersections at Alma/Charleston would operate at LOS C or better during both the AM and PM peak hours under future conditions. Where the on-ramp from eastbound Charleston would merge onto southbound Alma Street, the analysis shows that the on-ramp approach would operate at LOS E during the PM peak hour under future traffic conditions, as traffic merging onto Alma Street would have to find gaps in the uncontrolled traffic flow on southbound Alma, which is the peak direction. The analysis shows that the two-lane roundabout at Charleston/Mumford would operate at acceptable levels of service during both the AM and PM peak hours under existing and future conditions.

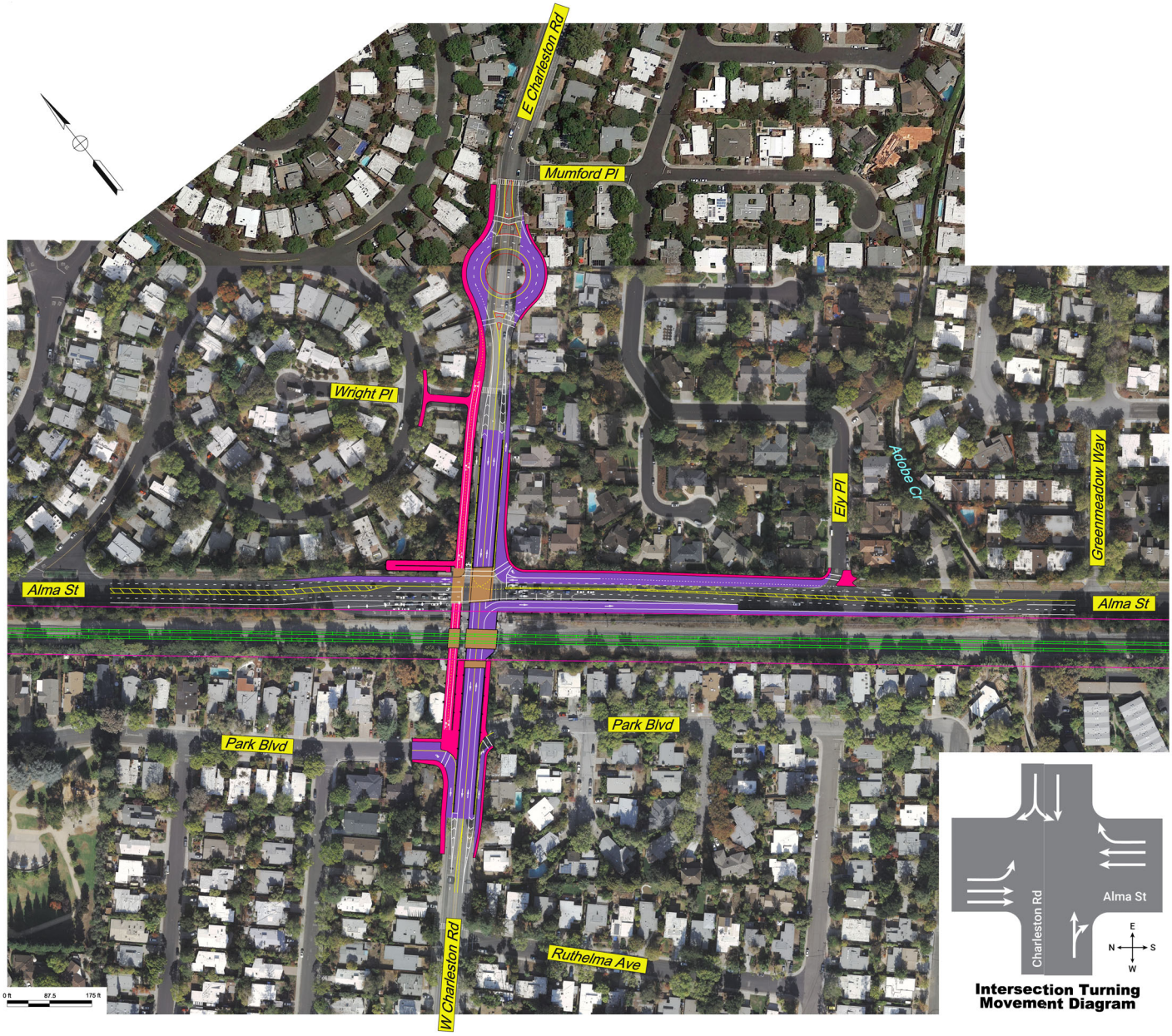


Preliminary Layout shown based on early concepts
(subject to change)

Figure 7A
Meadow Drive Partial Underpass Intersection Layout

Preliminary Layout shown based on early concepts
(subject to change)

Figure 7B
Meadow Drive Partial Underpass Rendering



Preliminary Layout shown based on early concepts
(subject to change)

Figure 8A
Charleston Road Partial Underpass Intersection Layout

Preliminary Layout shown based on early concepts
(subject to change)

Figure 8B
Charleston Road Partial Underpass Rendering

Table 5
Meadow and Charleston Partial Underpass with U-Turn at Alma Village Circle – Future Traffic Volumes

Traffic Operations (Year 2030 Traffic Volumes) - Partial Underpass															
	Option 1					Option 2					Option 3				
		AM		PM			AM		PM			AM		PM	
	Traffic Control	Delay (secs)	LOS	Delay (secs)	LOS	Traffic Control	Delay (secs)	LOS	Delay (secs)	LOS	Traffic Control	Delay (secs)	LOS	Delay (secs)	LOS
Alma Village Circle	Signal	18.84	B	19.37	B	Signal	18.38	B	20.1	B	Signal	18.86	B	20.7	B
Meadow Drive															
Alma Street SB Off-Ramp & Meadow Drive	Signal	10.92	B	11.94	B	Signal	12.11	B	14.91	B	Signal	13.47	B	14.43	B
Alma Street On-Ramp & Meadow Drive	Uncontrolled	5.10	A	5.10	A	AWSC	7.90	A	7.90	A	Signal	9.50	A	9.90	B
Meadow to NB Alma (On-Ramp)	Yield	35.80	E	27.00	D	Yield	35.10	E	28.20	D	Yield	37.30	E	28.60	D
Charleston Road															
Alma Street & Charleston Road (N)	Signal	13.61	B	25.97	C	Signal	18.23	B	26.36	C	Signal	14.90	B	27.40	C
Alma Street & Charleston Road (S)	Signal	20.75	C	19.24	B	Signal	20.25	C	19.61	C	Signal	21.24	C	19.30	C
EB Charleston to SB Alma (On-Ramp)	Yield	8.60	A	38.90	E	Yield	9.80	A	38.40	E	Yield	9.00	A	38.50	E
Mumford Place & Charleston Road	Roundabout	6.08	A	9.71	A	Roundabout	6.15	A	11.94	B	Roundabout	5.88	A	11.11	B

Notes:-

AWSC - All Way Stop Controlled

1. Option 1 - At the Medow Dr and Alma NB-On Ramp intersection, analysis assumes through traffic on Medow does not stop. Left-turns from Meadow to Alma northbound would yield to westbound traffic on Meadow. The delay for the eastbound left-turns is shown in the table.
2. Option 2 - At the Meadow Dr and Alma NB-On Ramp intersection, analysis assumes an all-way stop control.
3. Option 3 - At the Meadow Dr and Alma NB-On Ramp intersection, anaysis assumes a traffic signal.
4. The following turning movements are restricted at Alma/Meadow and Alma/Charleston due to the partial underpass.
   - Alma/Meadows - right-turn from eastbound Meadow, left-turn from westbound Meadow, left-turn and right-turn from northbound Alma.
   - Alma/Charleston - left-turn from eastbound Charleston, left-turn from northbound Alma, right-turn from southbound Alma.
5. The analysis assumes a northbound U-turn lane at Alma/Alma Village Circle signal to allow northbound traffic on Alma Street to make a U-turn and use the southbound off-ramp to Meadow Drive.

Figure 9A
E Meadow Dr/Alma St AM and PM Peak-Hour Diversions (Partial Underpass Alternative)

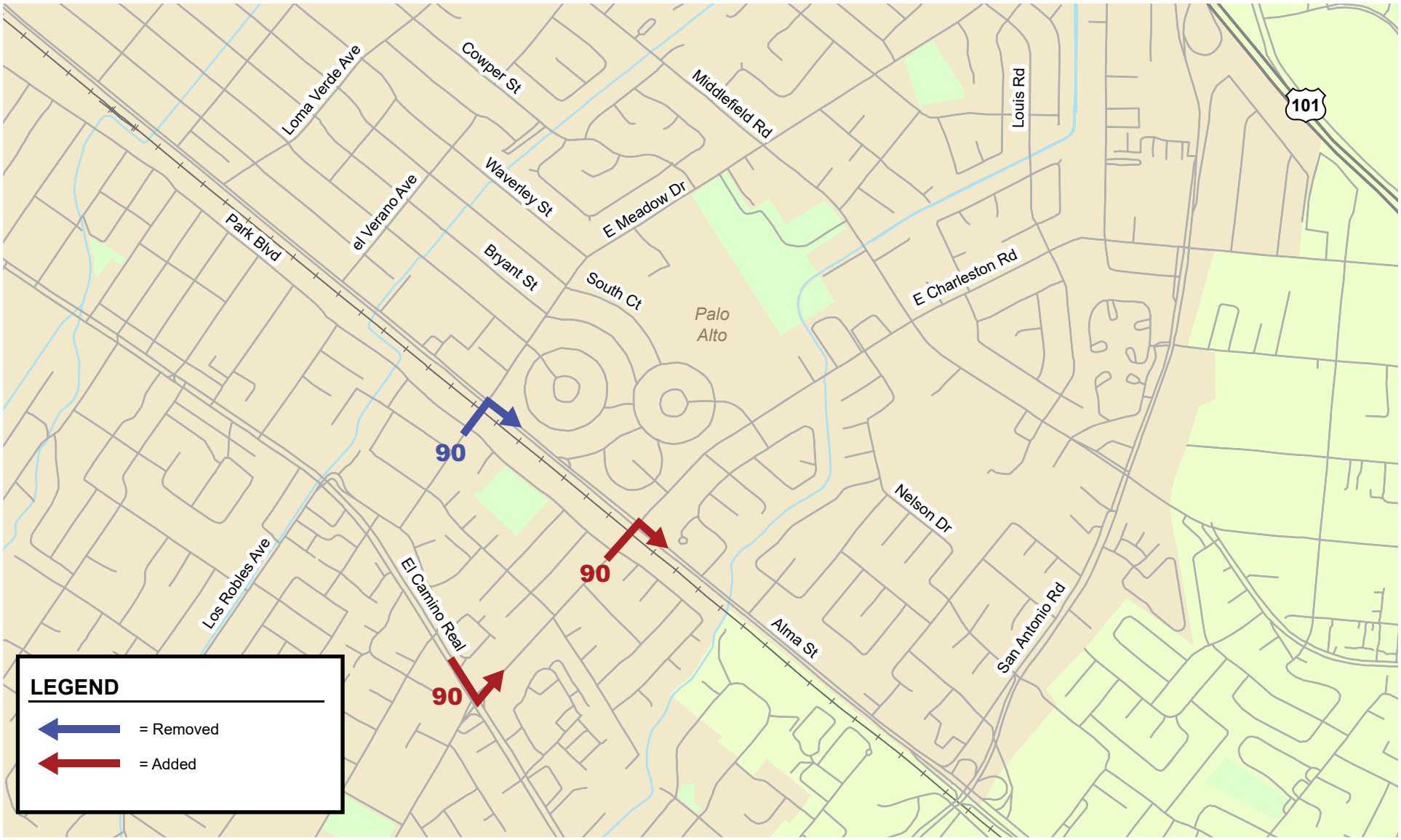


Figure 9B
E Meadow Dr/Alma St AM and PM Peak-Hour Diversions (Partial Underpass Alternative)

Figure 10A
Charleston Rd/Alma St Turning Movements Via Roundabout (Partial Underpass Alternative)

Figure 10B
Charleston Rd/Alma St Turning Movements Via Roundabout (Partial Underpass Alternative)

Figure 10C
Charleston Rd/Alma St Turning Movements Via Roundabout (Partial Underpass Alternative)

Appendices

Appendix A – Churchill Closure Traffic Study
Appendix B – Meadow and Charleston Traffic Counts
Appendix C – Synchro Existing and Future Traffic Volumes

Appendix A
Churchill Closure Traffic Study

HEXAGON TRANSPORTATION CONSULTANTS, INC.

Memorandum

Date: November 26, 2019

To: City of Palo Alto
CC: Ms. Millette Litzinger, AECOM

From: Gary Black, Trisha Dudala

Subject: Traffic Analysis of Potential Closure of Churchill Avenue at Alma Street

Summary

The Caltrain Electrification project will increase the frequency of trains through Palo Alto. As a result, the City of Palo Alto is considering closing the Churchill Avenue railroad crossing as part of the Connecting Palo Alto grade separation study. This report describes the results of the traffic impact analysis for the "Do Nothing" alternative and closure of Churchill Avenue at the railroad crossing. The study looked at traffic impacts during the weekday AM (7-9) and PM (4-6) peak commute hours. It is during these hours that the roadways generally experience the most traffic congestion. The analysis was conducted using the simulation software VISSIM by PTV Vision, which has the ability to analyze signal pre-emption.

The analysis of the "Do Nothing" alternative for the at-grade rail crossing at the Alma Street and Churchill Avenue intersection showed that the delays incurred by certain turning movements would be significantly high resulting in longer vehicular queues during the AM peak hour and PM peak hours under existing and Year 2030 conditions with the increase in frequency of trains attributed to the proposed Caltrain electrification.

The analysis of the potential Churchill Avenue closure at the railroad tracks showed that the diverted vehicular traffic volumes from Churchill Avenue would cause significant impacts to six intersections in the study area. Mitigations were identified for all six intersections, and with the implementation of these mitigation measures, the analysis showed that traffic impacts from the potential Churchill closure would be adequately mitigated during both the AM and PM peak hours under existing and Year 2030 traffic conditions.

A report was prepared by TJKM (*Draft Traffic Impact Study Report, Churchill Avenue Closure*, August 7, 2019) that analyzed the closure of Churchill Avenue (included in the appendix). The study determined that several intersections in the study area would have significant traffic operational impacts. The analysis discussed in this report uses much of the data from the TJKM report. However, this report identifies alternative mitigation for the potential impacts at the Embarcadero & Alma interchange.

Alma Street and Churchill Avenue Intersection – Traffic Analysis

Existing Conditions Analysis

The existing conditions analysis was conducted based on existing peak hour traffic volumes, existing lane geometries, existing signal timings, and the number of trains during the peak hours as described below.

Existing Lane Geometry and Traffic Volumes

Separate left turn lanes are provided on Alma Street in both the northbound and southbound directions to Churchill Avenue (see Figure 1). In addition, there is a southbound right turn lane on Alma Street to westbound Churchill Avenue (toward the high school). Eastbound Churchill Avenue has a separate right turn lane and a shared through/left turn lane at Alma Street. Westbound Churchill Avenue at Alma Street has one all-movement lane and another lane that allows on-street parking. Parking is prohibited from 7-8 AM, and through traffic is prohibited 7:45 to 8:30 AM Monday through Friday. Therefore, during the peak school time in the morning, westbound Churchill Avenue essentially has one left turn lane and one right turn lane. Churchill Avenue operates with split phase signal timing.

AM and PM peak hour turning movement counts for vehicles, pedestrians, and bicycles were conducted at the Alma/Churchill intersection in December 2018 when schools were in session. These counts are shown on Figure 1. As shown on Figure 1, a total of 2,592 vehicles and approximately 400 bicycles and pedestrians were counted during the AM peak hour and a total of 3,312 vehicles and approximately 80 bicycles and pedestrians were counted during the PM peak hour.

These counts were verified with more recent counts conducted on October 1st, 2019 (see Table 1). As shown in Table 1, the December 2018 counts were found to be 5% and 10% higher during the AM and PM peak hours, respectively. Therefore, these counts were used for the analysis of the Churchill closure.

Table 1
Alma Street and Churchill Avenue – Existing Volume Comparison

	AM Peak Hour				PM Peak Hour			
	Thursday 12/6/18 Counts	Tuesday 10/1/2019 Counts	Difference	% Difference	Thursday 12/6/18 Counts	Tuesday 10/1/2019 Counts	Difference	% Difference
Total	**2,592**	**2,474**	**-118**	**-5%**	**3312**	**2973**	**-339**	**-10%**

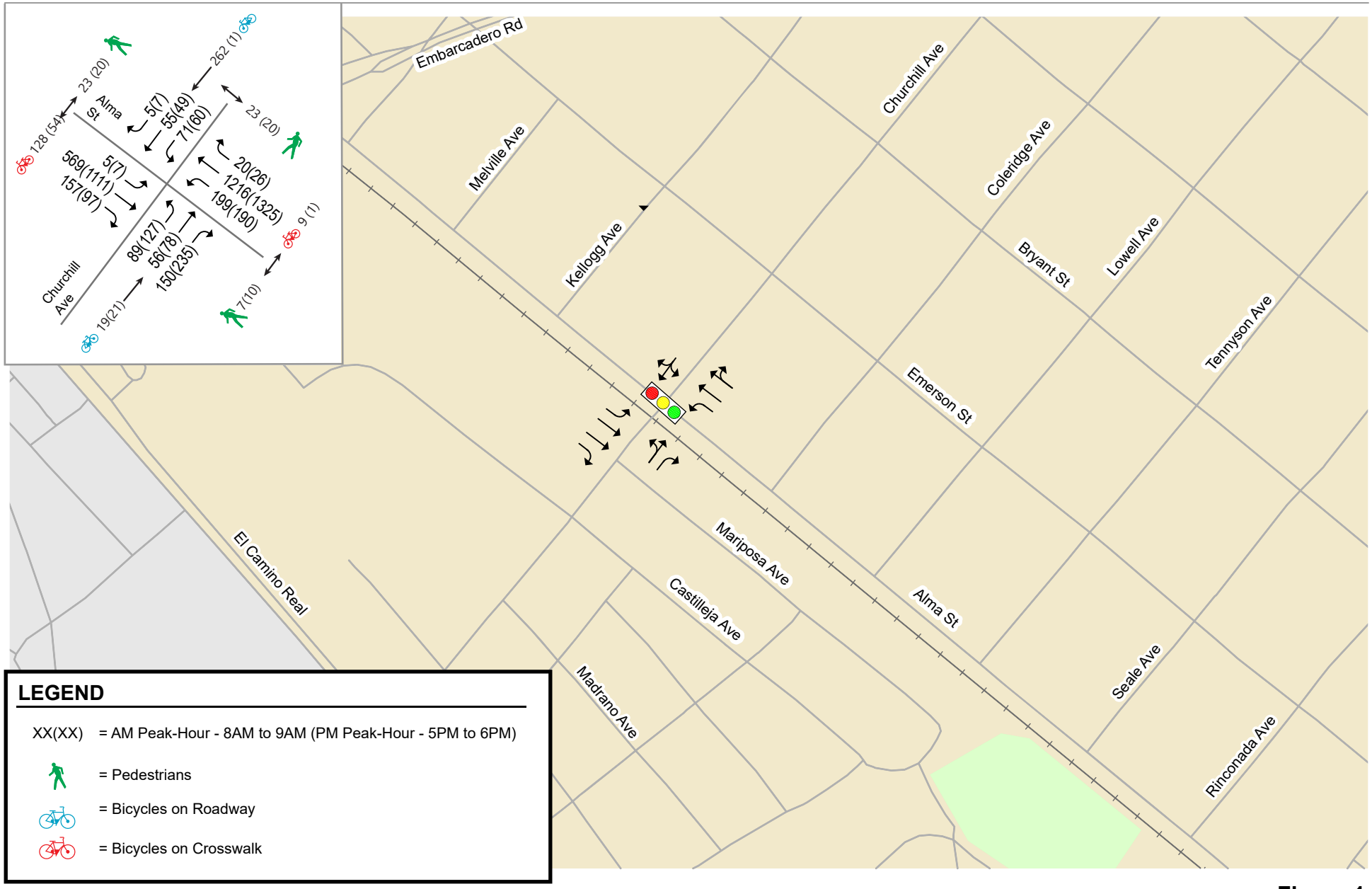


Figure 1
Alma Street and Churchill Avenue Existing Lane Geometry and Traffic Volumes

Signal Timings

The existing signal timing data at the Alma and Churchill intersection were obtained from the City of Palo Alto. Additional information regarding turn restrictions during certain time periods was obtained from field observations. The Alma and Churchill intersection currently operates at 150- second (2 ½ minutes) and 180- second (3 minutes) cycle lengths during the AM and PM peak hours, respectively. Also, through traffic on westbound Churchill is prohibited (via signage installed at the intersection) during the morning school peak hour that occurs between 7:45 – 8:30 AM.

Signal Pre-emption and Number of Trains

As the Churchill Avenue railroad crossing is located only 25 feet to the west of Alma Street, the intersection of Alma Street and Churchill Avenue is equipped to receive a traffic preemption signal when there is a train detection. This is a special control mode in the traffic signal controller designed to start up and clear any vehicular traffic on the roadway approach crossing the railroad tracks. Before the train approaches the intersection, eastbound vehicular queues on Churchill Avenue between the railroad gate and Alma street are cleared. Only through traffic on Alma street, which does not conflict with the railroad movement, receives a green light for the duration of the train movement. A gate closure time of 45 seconds was assumed based on field observations. This calculates to an effective gate closure time of 360 seconds (6 minutes) during the peak hours, which is 10% of the peak hours.

Based on the number of gate closures observed during the field visit, the existing conditions analysis assumed a total of 8 trains (4 northbound and 4 southbound) during each of the AM and PM peak hours. Based on the current Caltrain schedule, there can be up to 10 trains in the peak hour. Because the actual train spacing varies daily, the analysis assumed a constant time interval between consecutive trains, which calculates to one train every 7 ½ minutes. This represents average conditions. Occasionally trains arrive closer together, which creates longer delays, or more spread out, which creates shorter delays.

Field Observations

AM Peak Hour

During the AM peak, long vehicular queues were observed for the northbound left-turn movement on Alma Street and also on westbound Churchill Avenue. Vehicles in the northbound left-turn lane frequently extended out of the left-turn pocket, into the adjacent through lane, because of signal preemption and because of the school traffic. Palo Alto High School is located on the northwest quadrant of Alma Street and Churchill Avenue, and during the school peak hour, which starts around 8 AM, it was observed that vehicular queues from Palo Alto High School frequently extended up to Alma Street. As a result, during some cycles, the northbound left-turning vehicles could not turn on green. After pre-emption, vehicles in the north-bound left-turn lane have to wait for approximately two minutes before receiving the green signal. As a result, queues for the northbound left-turn movement frequently extended past Tennyson Avenue and did not clear in one signal cycle. Vehicular queues on westbound Churchill frequently extended past Emerson Street. No turn lanes are provided on westbound Churchill Avenue. Although through traffic is restricted during the AM school peak hour, the right turning traffic has to yield to a high number of bicycles and pedestrians crossing the north leg of this intersection, resulting in long vehicular queues.

PM Peak Hour

During the PM peak hour, long vehicular queues were observed on eastbound Churchill Avenue. Queues frequently extended past Madrono Avenue due to signal preemption. Vehicular queues on eastbound Churchill Avenue could not clear in one signal cycle.

Caltrain Electrification Under "Do Nothing" Alternative

This analysis scenario describes the impact of the proposed electrification on existing traffic conditions at Alma Street and Churchill Avenue. As Caltrain begins to modernize, it is expected that the number of trains will increase from 8 trains to 12 trains during both the AM and PM peak hours (based on the Caltrain Electrification EIR). This calculates to one train every five minutes. With a gate closure time of 45 seconds for every train crossing, a total gate closure time of 540 seconds (9 minutes) during peak hours is expected with electrification, which is 15% of the peak hour time. Table 2 below summarizes AM and PM peak hour intersection delays and levels of service at the Alma Street and Churchill Avenue intersection under existing conditions and with the proposed electrification with Churchill open.

Table 2
Alma and Churchill Intersection Delay and Levels of Service – Existing Conditions

	Alma/Churchill - Delay (LOS) Existing Conditions									
	AM					PM				
	Existing		Electrification			Existing		Electrification		
	Delay (Secs)	LOS	Delay (Secs)	LOS	% Increase	Delay (Secs)	LOS	Delay (Secs)	LOS	% Increase
Average Intersection Delay	88.9	F	127.86	F	44%	66.67	E	92.44	F	39%

Notes -
Existing Conditions - 8 trains in AM peak hour and 8 trains during the PM peak hour
Caltrain Electrification - 12 trains during the AM and PM peak hours.

As shown in Table 2, the analysis shows that under existing conditions the intersection of Alma Street and Churchill Avenue currently operates at an unacceptable LOS F during the AM peak hour and LOS E during the PM peak hour. With the proposed Caltrain electrification, the analysis shows that the delay would increase by 44% during the AM peak hour and by 39% during the PM peak hour. The intersection would operate at LOS F during both the AM and PM peak hours with the proposed electrification.

Table 3 summarizes AM and PM peak hour intersection delays and levels of service at the Alma and Churchill intersection under Year 2030 traffic conditions without and with the electrification. Year 2030 traffic volumes were obtained from the Palo Alto Travel Demand Forecasting Model.

Table 3
Alma and Churchill Intersection Delay and Levels of Service – Year 2030 conditions

	Alma/Churchill - Delay (LOS) Year 2030 Conditions									
	AM					PM				
	No Electrification		Electrification			No Electrification		Electrification		
	Delay (Secs)	LOS	Delay (Secs)	LOS	% Increase	Delay (Secs)	LOS	Delay (Secs)	LOS	% Increase
Average Intersection Delay	118.5	F	157.27	F	33%	89.99	F	110.02	F	22%

Notes -
No Electrification Conditions - 8 trains in AM peak hour and 8 trains during the PM peak hour
Caltrain Electrification - 12 trains during the AM and PM peak hours.

As shown in Table 3, under Year 2030 traffic conditions, the intersection of Alma and Churchill Avenue would continue to operate at unacceptable LOS F during both the AM and PM peak hours without the electrification. The analysis shows that the delays would be 25% to 30% higher than existing conditions. With the proposed electrification, the delays are expected to increase by an additional 20% to 30%.

Figure 2 and Figure 3 show a comparison of vehicular queues under existing conditions and with the proposed electrification (with existing traffic volumes) during the AM and PM peak hours, respectively.

As shown on Figure 2, the analysis shows that during the AM peak hour, the northbound left-turn movement would be significantly impacted with the increase in the frequency of trains with the proposed electrification. The analysis shows that the average queue would increase by approximately 25 vehicles and queues would frequently extend past Rinconada Avenue. It would take approximately four to five signal cycles (10 to 12 minutes) for the northbound left-turn to clear.

As shown on Figure 3, during the PM peak hour, the analysis shows that the increase in the frequency of trains would cause the vehicular queue on eastbound Churchill Avenue to extend beyond El Camino Real and potentially affect traffic operations at the El Camino Real and Churchill Avenue intersection. As a result, the analysis shows that it would take 3 to 5 signal cycles for traffic to clear on eastbound Churchill Avenue.

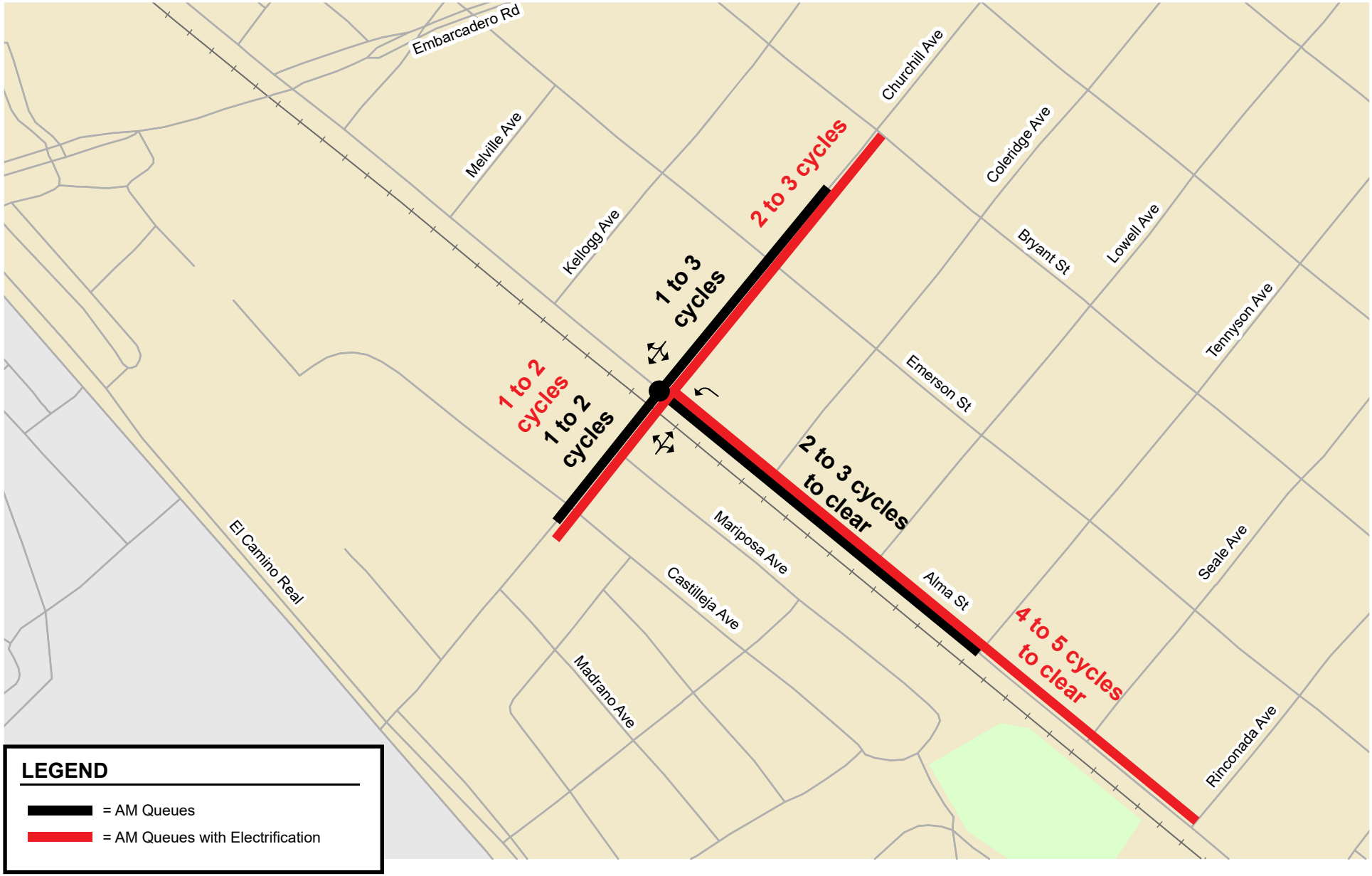


Figure 2

Alma Street and Churchill Avenue Vehicular Queues - Existing and "Do Nothing" Alternative (AM Peak-Hour)

Figure 3

Alma Street and Churchill Avenue Vehicular Queues - Existing and "Do Nothing" Alternative (PM Peak-Hour)

Complete Churchill Closure

This analysis scenario describes the impacts of the closure of Churchill Avenue near the railroad tracks and the impact on the surrounding roadway system. With the closure of Churchill Avenue, the intersection geometry of Alma Street/Churchill Avenue is proposed to undergo the following changes: the northbound left-turn lane is proposed to be removed, the southbound left-turn lane and southbound right-turn lane are also proposed to be removed, and the left most through lane is to be converted to a shared left-through lane. Pedestrian and bicycle connections would be maintained with an undercrossing. A pedestrian/bicycle overcrossing would be undesirable because the bottom of the overcrossing would need to be 24'6" above the track, resulting in approaches that would be extensively long. Figures 4, 5, and 6 illustrate the conceptual intersection layout and renderings of the intersection, all developed by AECOM.

Origin-Destination Analysis

In order to evaluate existing trip patterns that currently use Churchill Avenue, an origin-destination (O-D) analysis was conducted within the study area by TJKM. The objective of this task was to determine how traffic would be rerouted with Churchill closed. Data for a typical Tuesday, Wednesday, and Thursday for the morning and afternoon hours during 2017 while schools in Palo Alto were in session (using the Street Light Data platform) was used for evaluating trip patterns through the Alma Street and Churchill Avenue intersection. StreetLight data represent movements tracking cell phones. Cell phone companies supply anonymized data about the origins, destinations, and routes of people using cell phones. Any time a geo-based app on the phone is enabled, the movement of that phone is tracked. While not all people have cell phones or have apps running, the data are aggregated from thousands of users over time and provide a good representation of travel patterns.

Redistribution of Trips

As a result of the proposed Churchill closure, existing trips that are currently using the Churchill railroad crossing would use alternative roadways in the study area. Based on existing traffic counts, there are approximately 706 vehicles in the AM peak hour and 776 vehicles in the PM peak hour that would be rerouted. These trips were rerouted to alternative roadways based on the O-D study. Figure 7A illustrates the redistribution of eastbound Churchill trips, and Figure 7B illustrates the redistribution of westbound Churchill trips in the study area.

Intersection Impacts

The TJKM study analyzed the impact of Churchill Avenue closure on the surrounding roadway network. A total of 24 intersections were analyzed. Note that the intersection of the Town & Country driveway with Embarcadero Road was not included in the study. The operation of that section of Embarcadero Road is controlled by the intersection with El Camino Real. The driveway intersection, which also serves Palo Alto High School, has relatively light traffic compared to El Camino Real.

Traffic conditions at the study intersections were evaluated using level of service (LOS). Level of service is a qualitative description of operating conditions ranging from LOS A, or free-flow conditions with little or no delay, to LOS F, or jammed conditions with excessive delays. The acceptable LOS in the City of Palo Alto is LOS D or better for non-CMP signalized intersections. The City has adopted LOS E as the acceptable standard for Congestion Management Program (CMP) intersections, consistent with VTA guidelines. The City does not have an official standard for unsignalized but typically identifies impacts if a project would increase delay by at least 4 seconds and the intersection meets the peak-hour volume signal warrant.

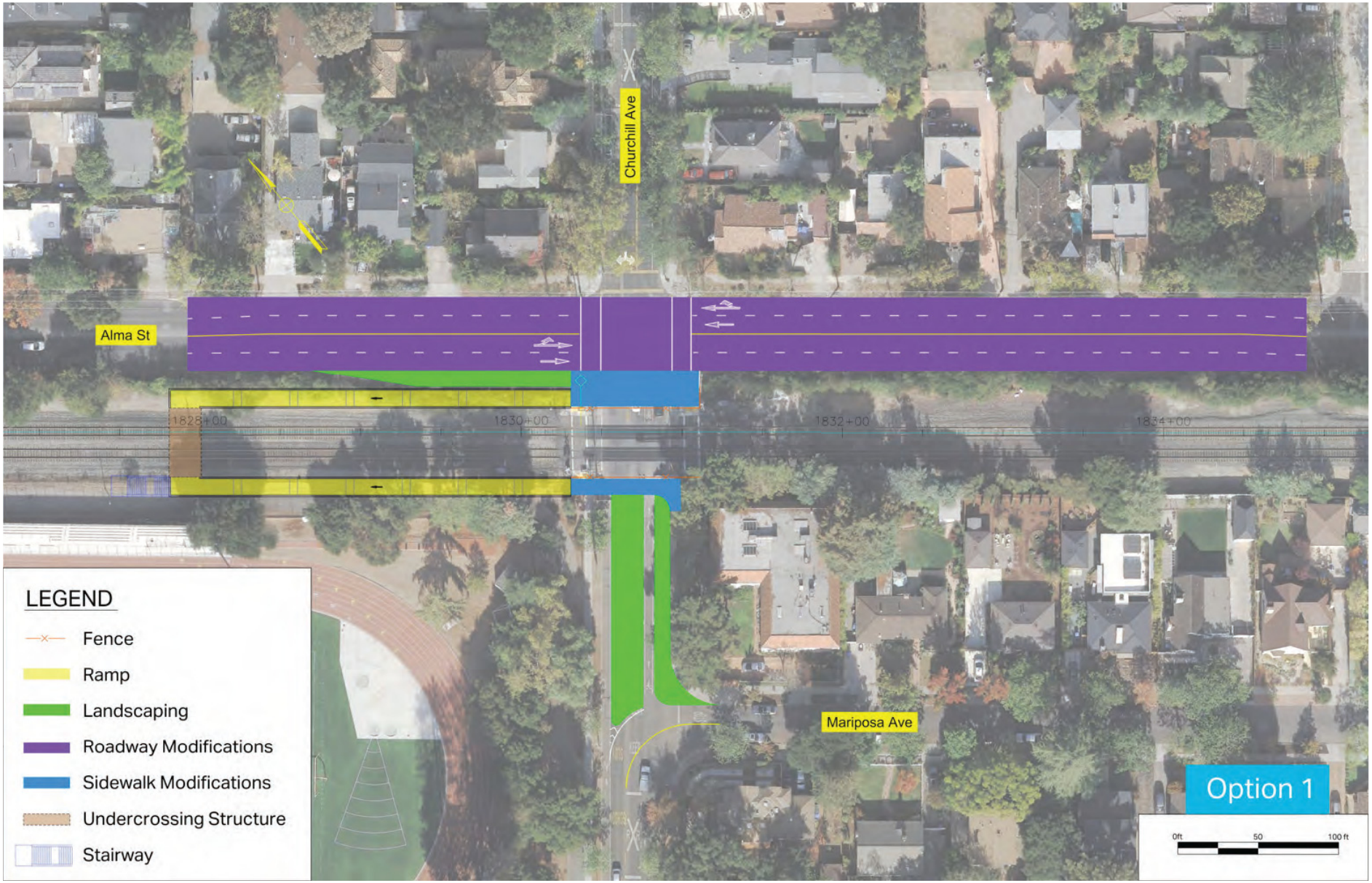


Figure 4
Alma Street and Churchill Avenue - Conceptual Layout

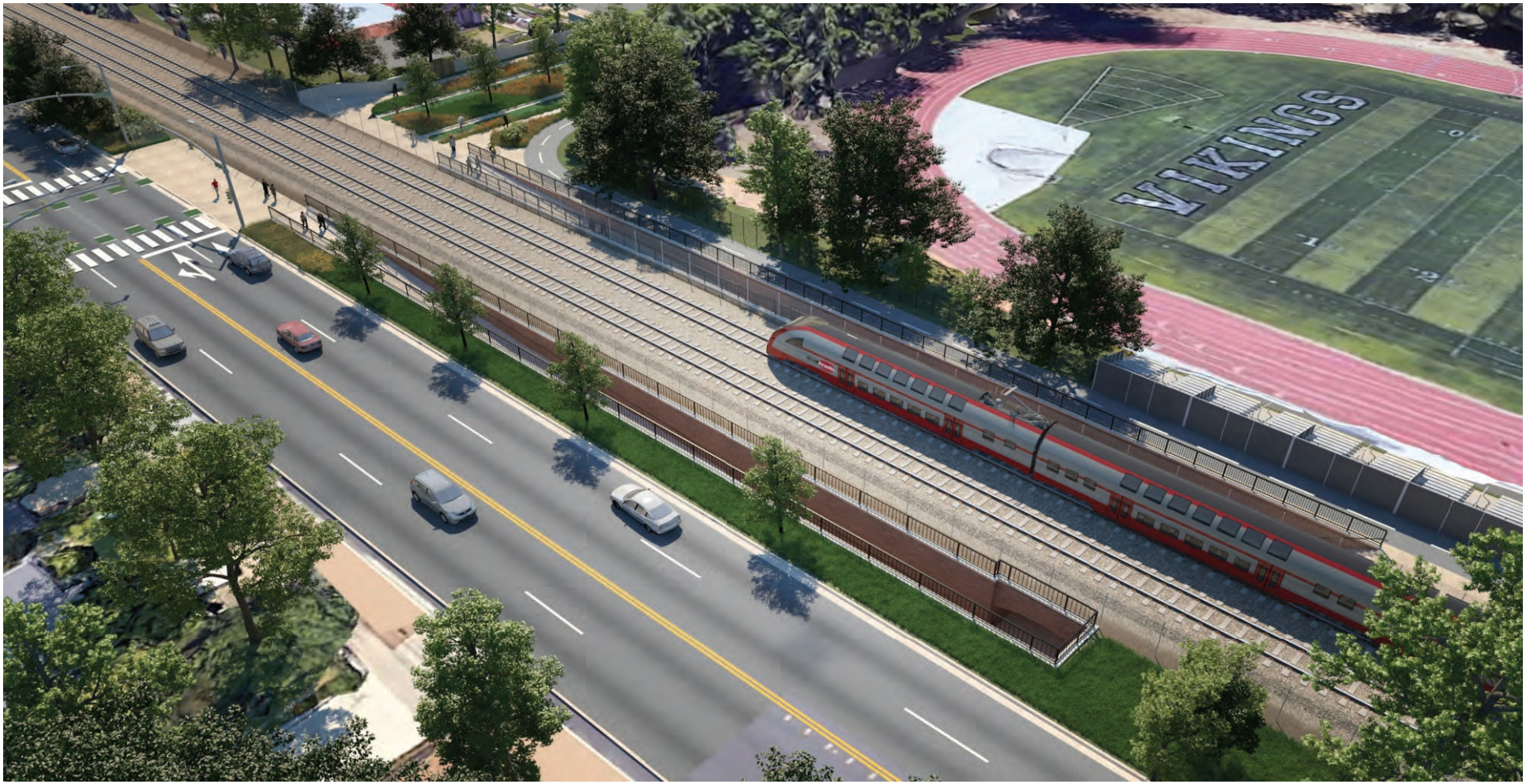
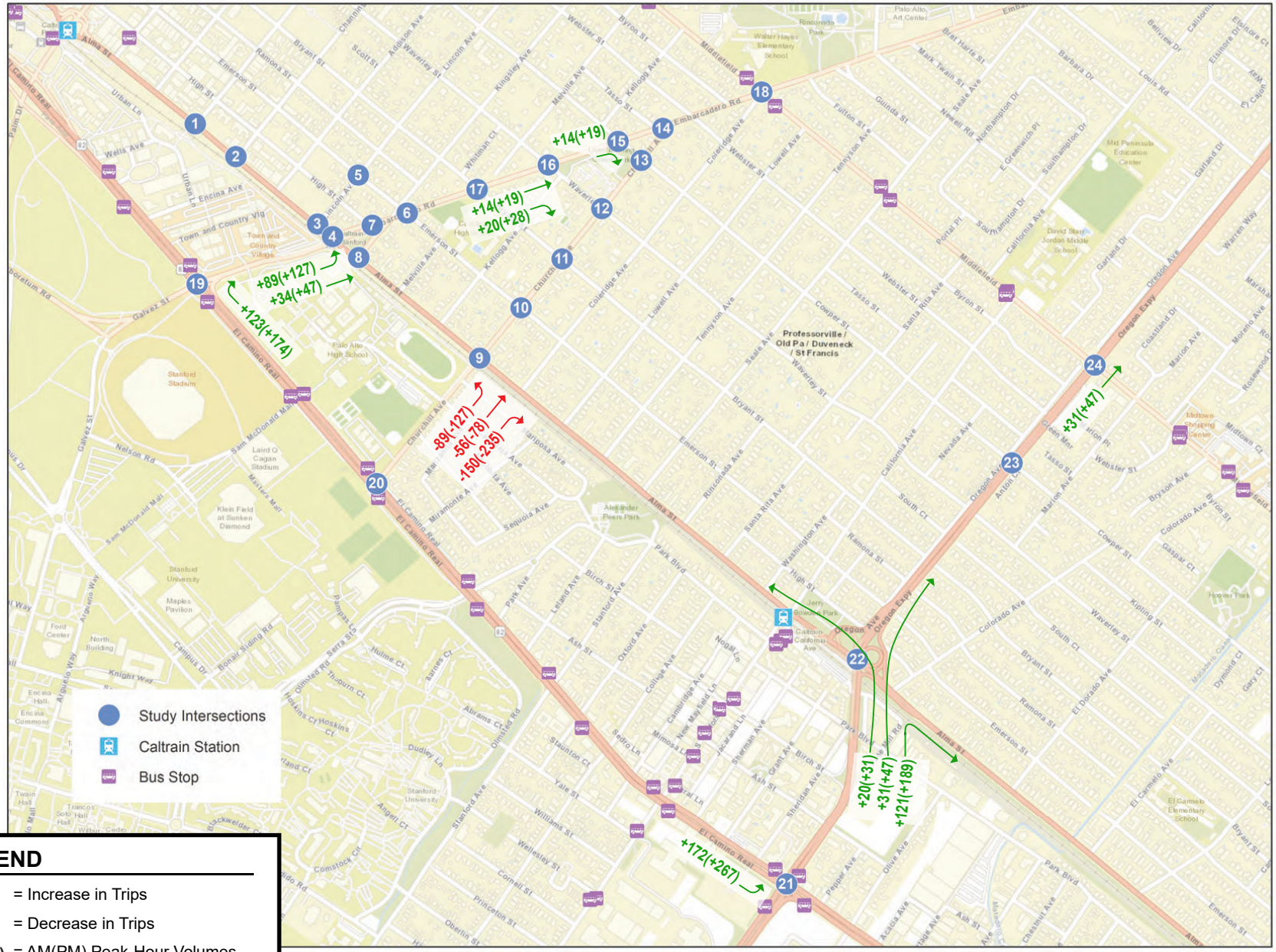


Figure 5
Alma Street and Churchill Avenue - Conceptual Rendering 1

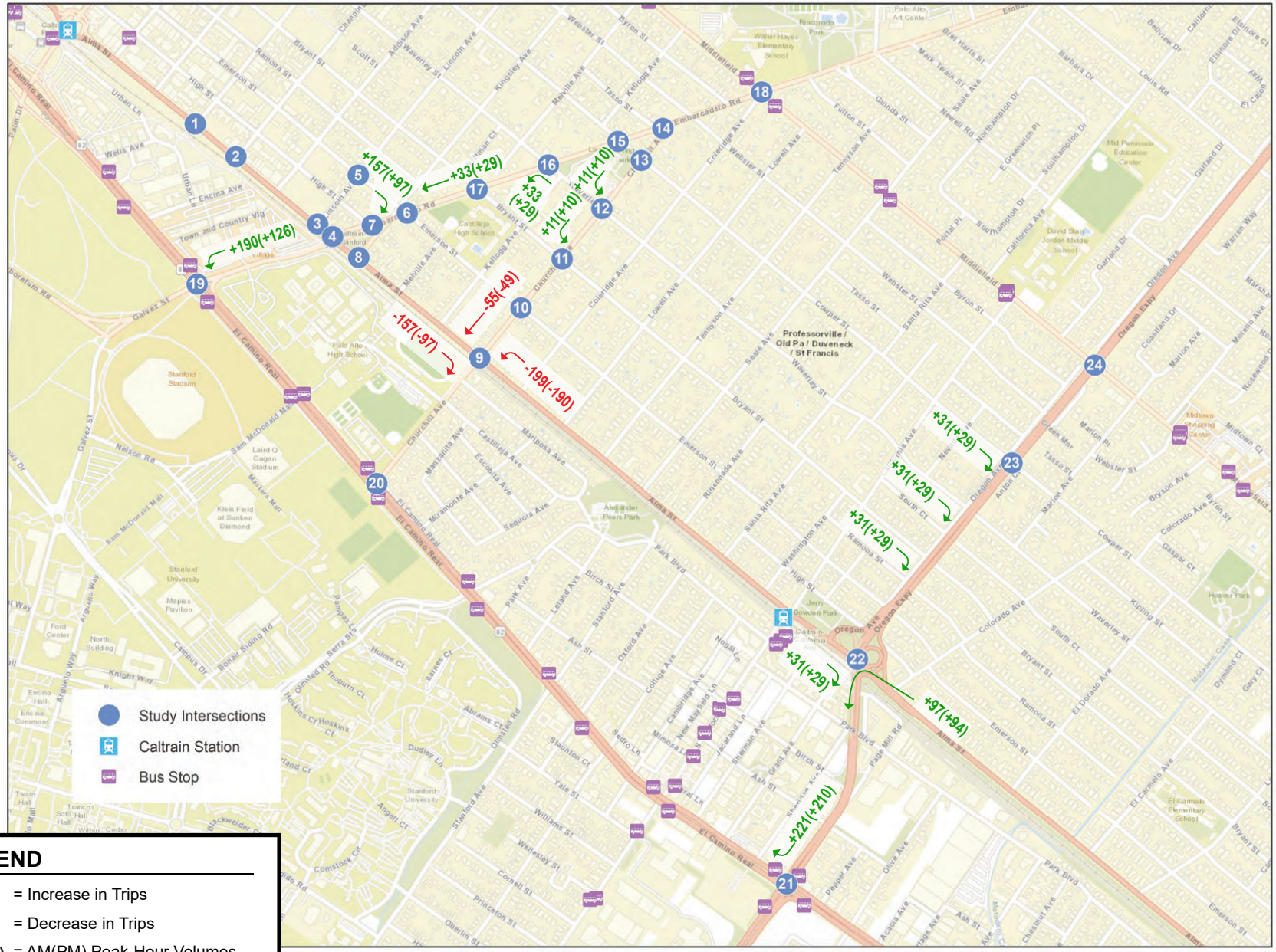
Figure 6
Alma Street and Churchill Avenue - Conceptual Rendering 2



LEGEND

+XX	= Increase in Trips
-XX	= Decrease in Trips
XX(XX)	= AM(PM) Peak-Hour Volumes

Figure 7A
Redistribution of Eastbound Churchill Avenue Trips



LEGEND

+XX	= Increase in Trips
-XX	= Decrease in Trips
XX(XX)	= AM(PM) Peak-Hour Volumes

Figure 7B
Redistribution of Westbound Churchill Avenue Trips

The TJKM study determined that the closure of the Churchill Avenue railroad crossing would create significant impacts at eight of the study intersections. Hexagon disagrees with two of the impacts, but agrees that the following six intersections and would experience unacceptable levels of service as a result of the reassigned traffic under existing conditions and under future year 2030 traffic conditions (see Table 4):

1. Alma Street/Lincoln Avenue
2. Alma Street/Embarcadero Road
3. Alma Street/Kingsley Avenue
4. El Camino Real/Embarcadero Road (CMP)
5. El Camino Real/Oregon Expressway-Page Mill Road (CMP)
6. Alma Street/Oregon Expressway

Table 4
Churchill Closure – Impacted Intersection Levels of Service

						Churchill Closure			
						Existing		Year 2030	
#	Intersection	Peak Hour	Traffic Control	Existing Avg. Delay (sec.)	LOS	Avg. Delay (sec.)	LOS	Avg. Delay (sec.)	LOS
1	Alma St & Lincoln Ave	AM	One-Way	**>=50**	**F**	**>=50**	**F**	**>=50**	**F**
		PM	Stop	**>=50**	**F**	**>=50**	**F**	**>=50**	**F**
2	Alma St & Embarcadero Rd	AM	One-Way	**>=50**	**F**	**>=50**	**F**	**>=50**	**F**
		PM	Stop	**>=50**	**F**	**>=50**	**F**	**>=50**	**F**
3	Alma St & Kingsley Ave	AM	One-Way	**>=50**	**F**	**>=50**	**F**	**>=50**	**F**
		PM	Stop	**>=50**	**F**	**>=50**	**F**	**>=50**	**F**
4	El Camino Real/Embarcadero Rd*	AM	Signal	60.3	E	**>80**	**F**	**>80**	**F**
		PM		67.0	E	**>80**	**F**	**>80**	**F**
5	El Camino Real/Oregon Expwy-Page Mill Rd*	AM	Signal	72.9	E	**>80**	**F**	**>80**	**F**
		PM		66.4	E	**>80**	**F**	**>80**	**F**
6A	Alma St & Oregon Expwy WB Off Ramp (Oregon Av	AM	One-Way	**>=50**	**F**	**>=50**	**F**	**>=50**	**F**
		PM	Stop	**>=50**	**F**	**>=50**	**F**	**>=50**	**F**
6B	Alma St & Oregon Expwy EB Off Ramp	AM	One-Way	**>=50**	**F**	**>=50**	**F**	**>=50**	**F**
		PM	Stop	**>=50**	**F**	**>=50**	**F**	**>=50**	**F**

Notes:
1. *CMP Intersection.
2. Average delay is reported for the worst approach at one-way stop intersections.
3. Bold indicates substandard intersection level of service.

Mitigation Measures

Potential mitigation measures were identified for the intersections that were shown to be impacted as described below.

Alma Street Intersections (# 1, 2 and 3)

With the closure of Churchill Avenue, some traffic would be rerouted to Embarcadero Road. However, the connections for some of the turning movements between Alma Street and Embarcadero Road are circuitous. Traffic from Alma Street that wants to head west on Embarcadero Road must use Lincoln Avenue to Emerson Street. The amount of traffic going "around the block" to access Embarcadero from Alma would increase by 157 vehicles during the AM peak hour and 97 vehicles during the PM peak hour. Due to the close spacing, intersections 1, 2 and 3 could be mitigated as a group with the following recommendations (see Figures 8). These improvements are different from the mitigations identified in the TJKM report.

- Restrict the intersection of Alma Street/Lincoln Street to right-in/right-out only movements.

- Divert left-turning traffic off of Lincoln Avenue by adding a left-turn lane to the Embarcadero Road slip ramp to facilitate left-turns onto Alma Street.
- Install traffic signals at the Alma Street/Embarcadero Road slip ramp and Alma Street/Kingsley Avenue with one controller.
- Install a traffic signal at the Embarcadero Road/Kingsley Avenue intersection to allow left-turns from Kingsley Street onto westbound Embarcadero Road.
- Provide a 75 to 100-foot left-turn pocket on southbound Alma Street at Kingsley Avenue.
- Provide two northbound travel lanes on northbound Alma Street at Kingsley Avenue.

Providing two northbound travel lanes on Alma Street at Kingsley Avenue would require widening of the Alma Street bridge over Embarcadero Road, as the existing width of the bridge can only accommodate three travel lanes on Alma Street. Widening would require extensive modification or potential replacement of the existing bridge structure. No additional right-of-way is needed on Alma Street, south of Embarcadero Road.

These improvements would provide a direct connection between Alma Street and Embarcadero Road. Diverted traffic from southbound Alma Street (157 AM peak hour trips and 97 PM peak hour trips) would not have to use local streets to access Embarcadero Road. In addition, existing traffic on northbound Alma Street (approximately 70 vehicles during the AM peak hour and 75 vehicles during the PM peak hour) would no longer have to go around the block (Lincoln to Emerson) to travel west on Embarcadero. This traffic on Alma would make a right-turn at Kingsley and a left-turn at the proposed traffic signal at Embarcadero Road.

With the proposed improvements, the analysis shows that intersections 1, 2 and 3 would operate at acceptable levels of service during the AM and PM peak hours under existing (see Table 5) and Year 2030 traffic volumes (see Table 6).

Note that Figure 8 show a conceptual design of potential improvements at the Embarcadero Road and Alma Street interchange. If this project were to be pursued, many design details would need to be worked out with regard to maintaining access to existing residential driveways on Embarcadero Road, Kingsley Street, High Street, and the Embarcadero slip ramp.

El Camino Real & Embarcadero Road (Intersection 4)

The analysis showed that at the CMP intersection of El Camino Real/Embarcadero Road, significant traffic impacts would occur due to reassigned traffic. It is recommended that an additional westbound left-turn lane and a northbound right-turn lane be provided along with signal optimization at this intersection (see Figure 9). With these improvements, the intersection of El Camino Real and Embarcadero Road would operate at acceptable LOS E during both peak hours under existing and Year 2030 traffic volumes.

El Camino Real & Page Mill Road/Oregon Expressway (Intersection 5)

At the CMP intersection of El Camino Real/Oregon Expressway-Page Mill Road, the traffic analysis identified significant traffic impacts due to reassigned traffic. The report recommended a westbound right-turn lane from Oregon Expressway to northbound El Camino Real along with optimizing the signal timing (see Figure 10). With these improvements, the intersection would operate at acceptable levels of service during the AM and PM peak hours under existing conditions. Under Year 2030 traffic conditions, the analysis shows that the intersection would continue to operate at unacceptable LOS F with the proposed improvements. However, the intersection delay during both

the AM and PM peak hours is projected to be lower than the intersection delay without these improvements.

Alma Street & Oregon Expressway (Intersections 6A and 6B)

The traffic analysis identified significant impacts to the intersections of Alma Street/Oregon Expressway with the reassignment. The analysis determined that these intersections currently meet the peak hour signal warrant and recommends traffic signals at both the on and off ramps (see Figure 11). With the proposed traffic signals at both the ramp locations, the intersections of Alma Street and Oregon Expressway are projected to operate at acceptable LOS C or better during both peak hours under existing and Year 2030 traffic conditions.

Table 5
Churchill Closure – Mitigated Intersection Levels of Service under Existing Conditions

			Churchill Closure - Existing Conditions					
			No Improvements			With Improvements		
#	Intersection	Peak Hour	Traffic Control	Avg. Delay (sec.)	LOS	Traffic Control	Avg. Delay (sec.)	LOS
1	Alma Street & Lincoln Avenue	AM	One-Way	**>=50**	**F**	One-Way	5.7	A
		PM	Stop	**>=50**	**F**	Stop	21.1	C
2	Alma Street & Embarcadero Road	AM	One-Way	**>=50**	**F**	Signal	4.8	A
		PM	Stop	**>=50**	**F**		3.0	A
3	Alma Street & Kingsley Avenue	AM	One-Way	**>=50**	**F**	Signal	13.3	B
		PM	Stop	**>=50**	**F**		18.3	B
4	El Camino Real/Embarcadero Rd*	AM	Signal	**>80**	**F**	Signal	67.1	E
		PM		**>80**	**F**		61.1	E
5	El Camino Real/Oregon Expwy-Page Mill Rd*	AM	Signal	**>80**	**F**	Signal	72.5	E
		PM		**>80**	**F**		73.5	E
6A	Alma St & Oregon Expwy WB Off Ramp (Oregon Ave)	AM	One-Way	**>=50**	**F**	Signal	6	A
		PM	Stop	**>=50**	**F**		6.7	A
6B	Alma St & Oregon Expwy EB Off Ramp	AM	One-Way	**>=50**	**F**	Signal	17.9	B
		PM	Stop	**>=50**	**F**		16.0	B

Notes:
1. Average delay is reported for the worst approach at one-way stop intersections.
2. Bold indicates substandard intersection level of service.

Table 6
Churchill Closure – Mitigated Intersection Levels of Service under Year 2030 Conditions

			Churchill Closure - Year 2030 Conditions					
			No Improvements			With Improvements		
#	Intersection	Peak Hour	Traffic Control	Avg. Delay (sec.)	LOS	Traffic Control	Avg. Delay (sec.)	LOS
1	Alma Street & Lincoln Avenue	AM	One-Way Stop	**>=50**	**F**	One-Way Stop	14.4	B
		PM		**>=50**	**F**		15.2	C
2	Alma Street & Embarcadero Road	AM	One-Way Stop	**>=50**	**F**	Signal	4	A
		PM		**>=50**	**F**		3.6	A
3	Alma Street & Kingsley Avenue	AM	One-Way Stop	**>=50**	**F**	Signal	13.0	B
		PM		**>=50**	**F**		14.8	B
4	El Camino Real/Embarcadero Rd*	AM	Signal	**>80**	**F**	Signal	73.6	E
		PM		**>80**	**F**		76.2	E
5	El Camino Real/Oregon Expwy-Page Mill Rd*	AM	Signal	**>80 (120.3)**	**F**	Signal	**>80 (91.8)**	**F**
		PM		**>80 (108.4)**	**F**		**>80 (92.7)**	**F**
6A	Alma St & Oregon Expwy WB Off Ramp (Oregon Ave)	AM	One-Way Stop	**>=50**	**F**	Signal	7.8	A
		PM		**>=50**	**F**		9.1	A
6B	Alma St & Oregon Expwy EB Off Ramp	AM	One-Way Stop	**>=50**	**F**	Signal	24.9	C
		PM		**>=50**	**F**		21.5	C

Notes:
1. Average delay is reported for the worst approach at one-way stop intersections.
2. Bold indicates substandard intersection level of service.

Impacts to University Avenue

University Avenue is located approximately one mile north of the Alma Street and Churchill Avenue intersection. During the peak hours, University Avenue is more congested than the parallel arterials of Embarcadero Road and Oregon Expressway. Figure 12 shows that University Avenue at Woodland Avenue typically is operating at LOS F during the PM peak hour compared to LOS E on Oregon Expressway and LOS D/E on Embarcadero Road near to US101. Due to the existing congestion on University Avenue, trips from the potential Churchill closure much more likely would be rerouted to Embarcadero Road or Oregon Expressway. The potential Churchill Avenue closure is not likely to impact traffic operations along University Avenue.

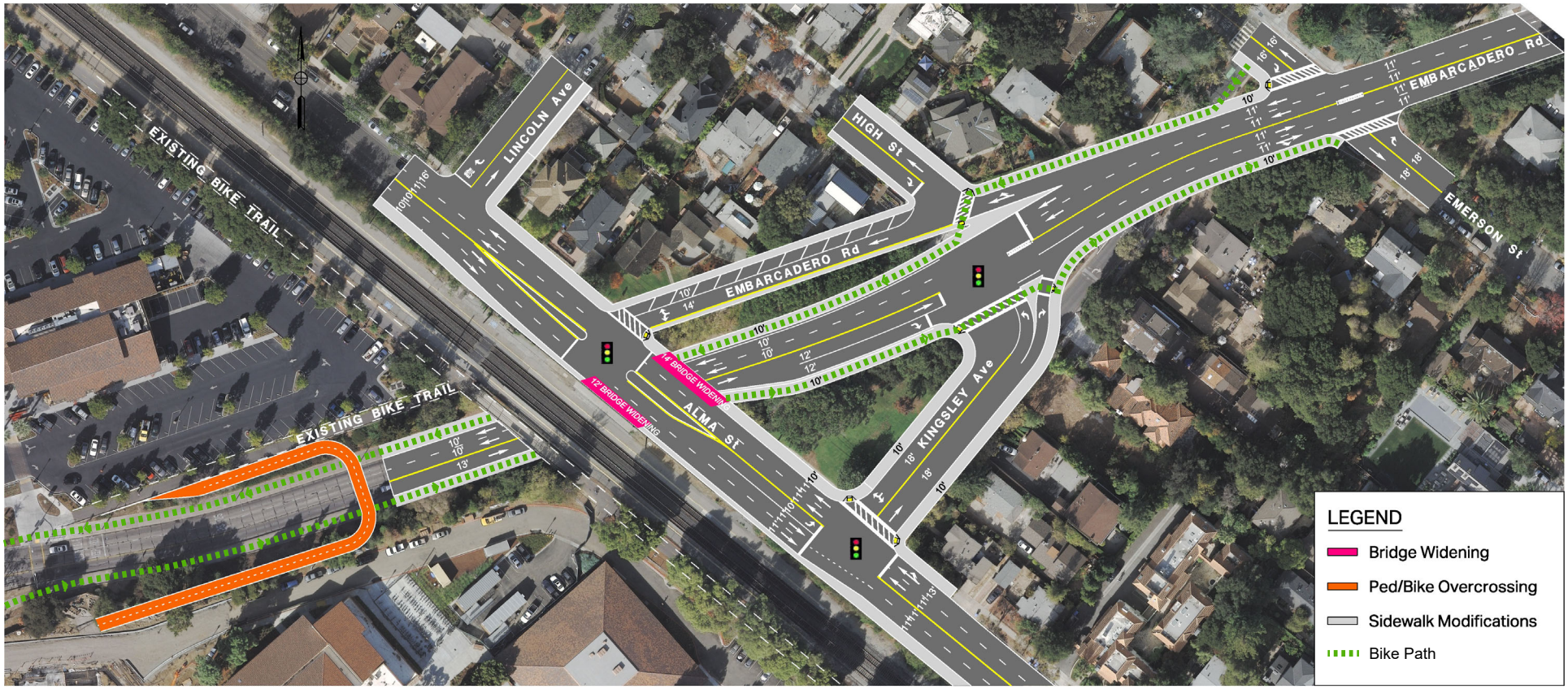
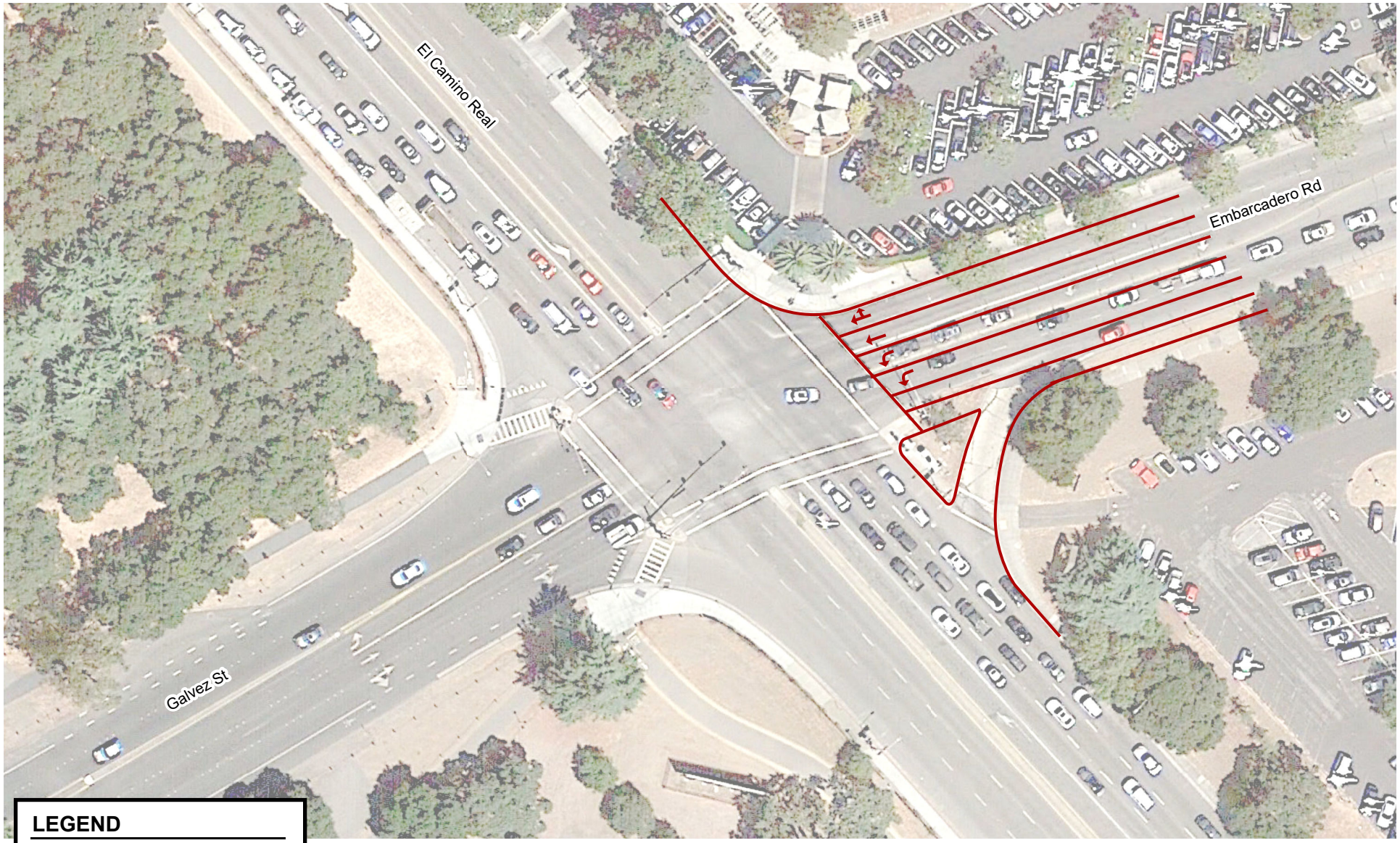


Figure 8
Embarcadero/High/Kingsley Improvements



LEGEND

= Proposed Layout

Figure 9
El Camino Real and Embarcadero Road Improvements

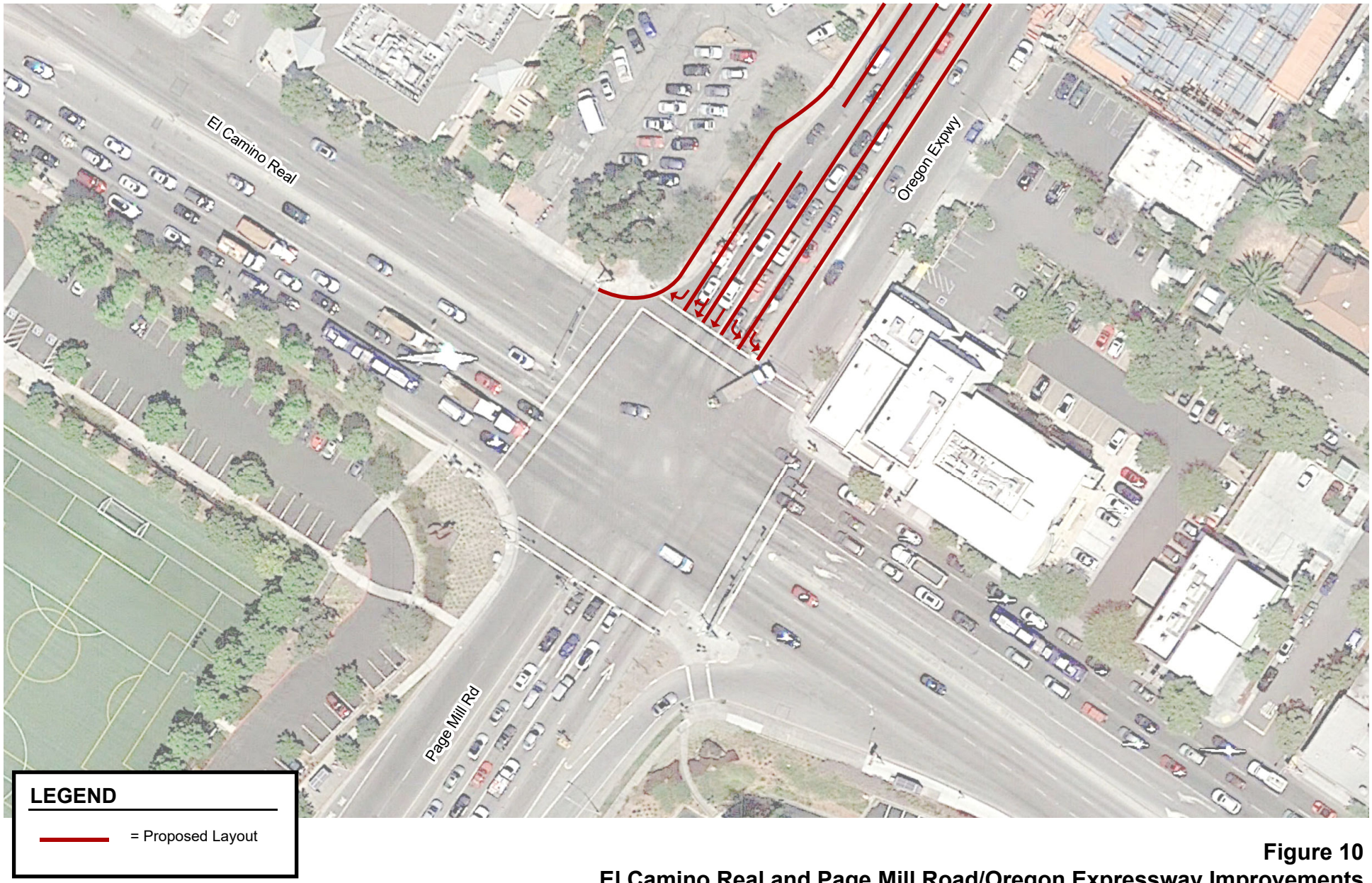


Figure 10
El Camino Real and Page Mill Road/Oregon Expressway Improvements

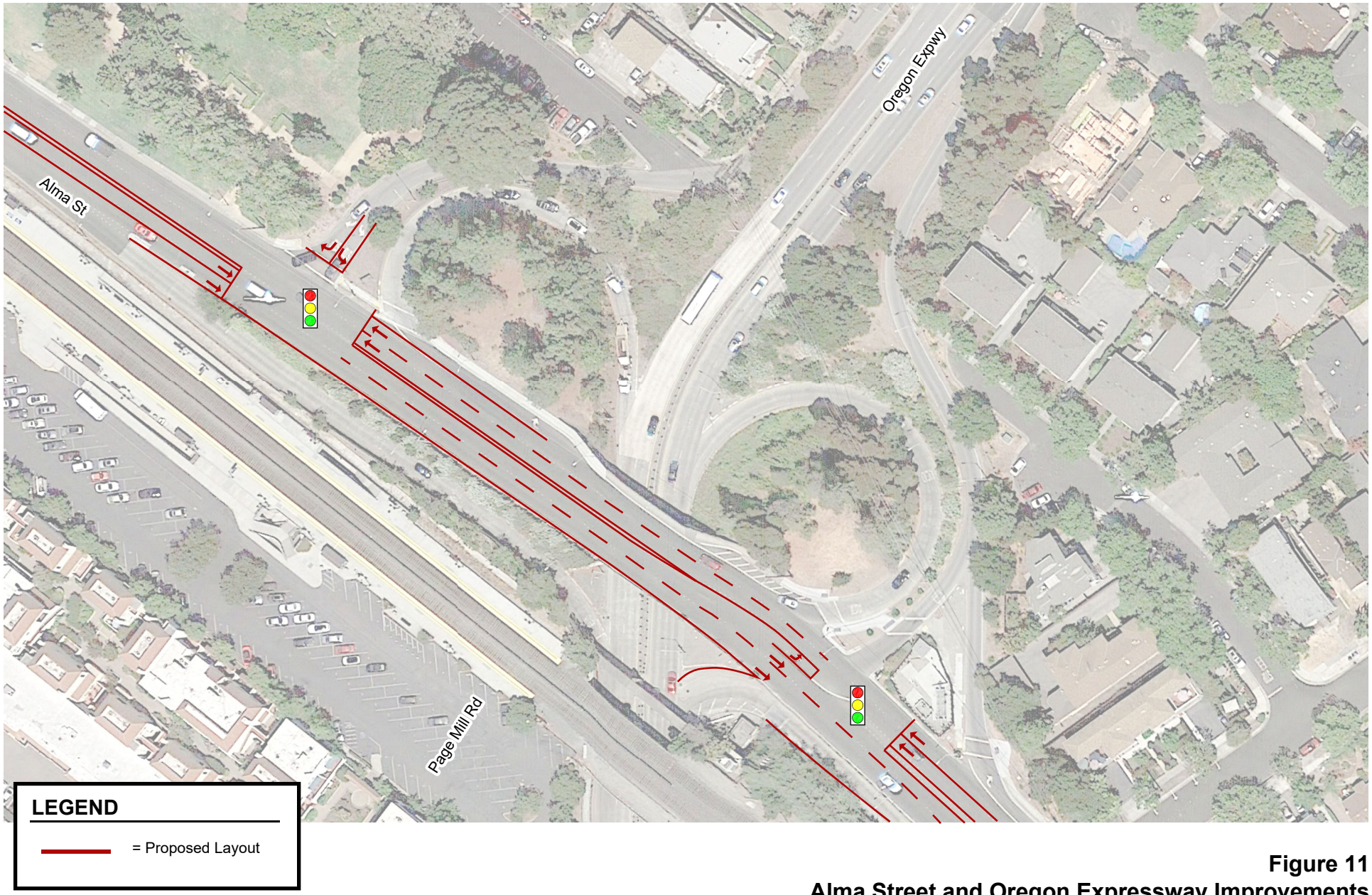


Figure 11
Alma Street and Oregon Expressway Improvements

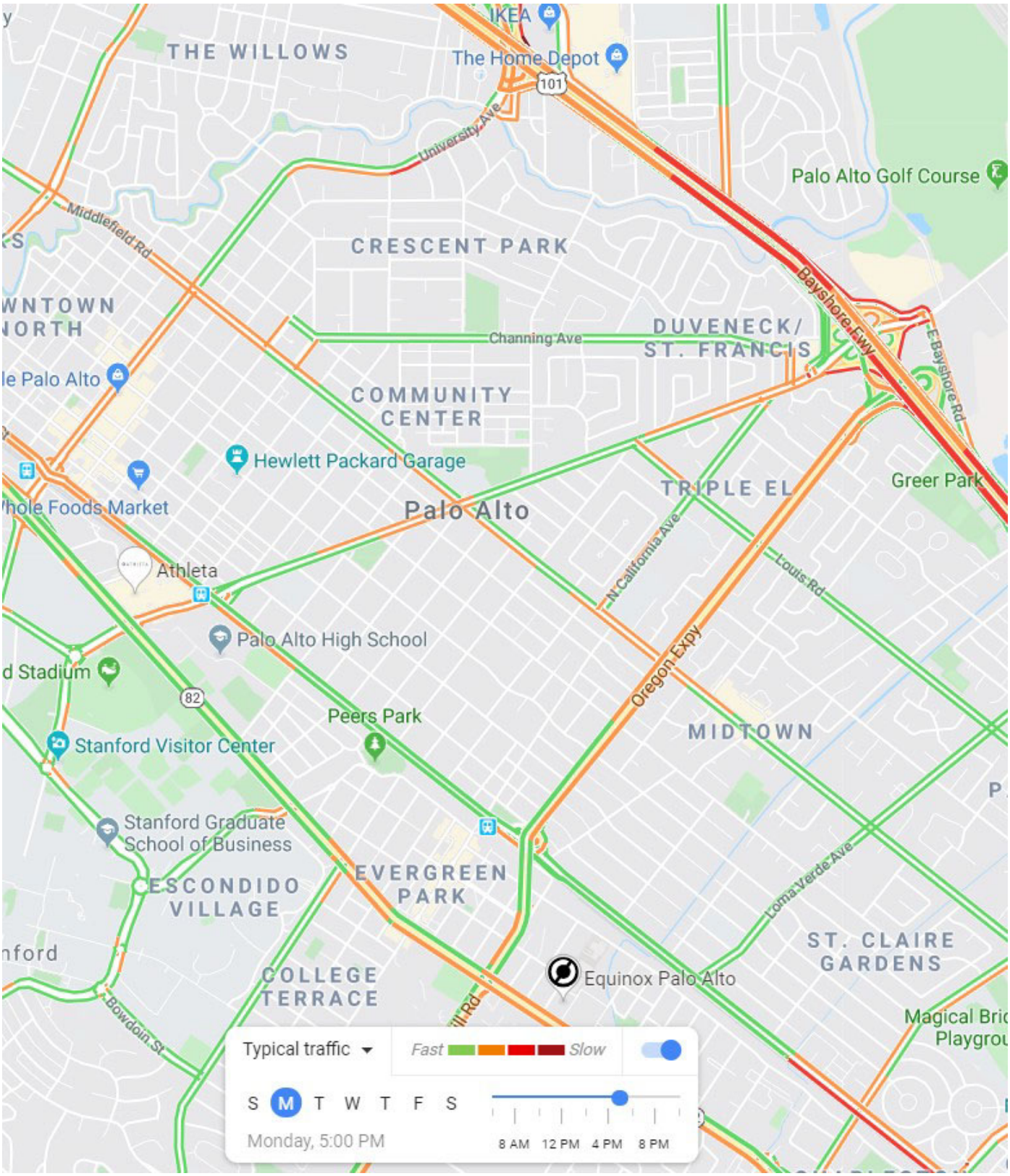


Figure 12
Typical 5PM Traffic

Potential Closure of E. Meadow Drive

A qualitative analysis was conducted for the potential closure of E. Meadow Drive at the railroad tracks. It is estimated that E. Meadow Drive has a volume of approximately 1,000 vehicles crossing the tracks during the weekday AM and PM peak hours (based on a 2013 peak hour traffic count of 800-900 vehicles). With the closure of E. Meadow Drive, vehicular traffic would be diverted onto the Charleston Road railroad crossing. According to traffic studies conducted in 2013, the intersections of El Camino Real/Charleston Road and Alma Street/Charleston Road were operating at high LOS D. It is likely that operations have degraded since then. The additional traffic on Charleston Road from the proposed closure of E. Meadow Drive would cause these intersections to operate at unacceptable levels of service. Therefore, closure of the E. Meadow Drive railroad crossing is not recommended.

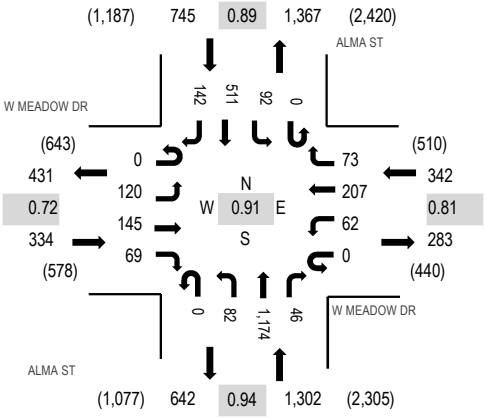
Appendix B
Meadow and Charleston Traffic Counts

All Traffic Data Services Inc.

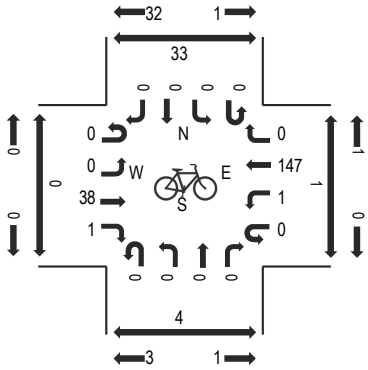
(303) 216-2439
www.alltrafficdata.net

Location: 5 ALMA ST & W MEADOW DR AM
Date: Tuesday, January 28, 2020
Peak Hour: 07:45 AM - 08:45 AM
Peak 15-Minutes: 08:00 AM - 08:15 AM

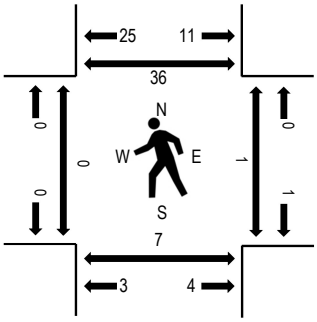
Peak Hour - Motorized Vehicles



Peak Hour - Bicycles



Peak Hour - Pedestrians



Note: Total study counts contained in parentheses.

Traffic Counts - Motorized Vehicles

Interval Start Time	W MEADOW DR Eastbound				W MEADOW DR Westbound				ALMA ST Northbound				ALMA ST Southbound				Total	Rolling Hour	Pedestrian Crossings			
	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right			West	East	South	North
7:00 AM	0	16	17	7	0	9	7	5	0	16	159	6	0	4	46	14	306	1,877	0	0	0	0
7:15 AM	0	18	15	12	0	11	10	11	0	12	217	7	0	6	55	8	382	2,322	0	1	0	0
7:30 AM	0	25	11	22	0	9	28	14	0	15	272	6	0	18	86	14	520	2,568	0	1	1	4
7:45 AM	0	41	53	22	0	13	37	11	0	17	288	9	0	35	107	36	669	2,723	0	0	1	19
8:00 AM	0	38	37	14	0	11	76	20	0	29	297	15	0	31	135	48	751	2,703	0	0	3	10
8:15 AM	0	21	30	13	0	18	47	16	0	17	271	13	0	13	132	37	628		0	0	1	6
8:30 AM	0	20	25	20	0	20	47	26	0	19	318	9	0	13	137	21	675		0	1	2	1
8:45 AM	0	39	41	21	0	9	42	13	0	21	264	8	0	18	148	25	649		0	1	1	2

Peak Rolling Hour Flow Rates

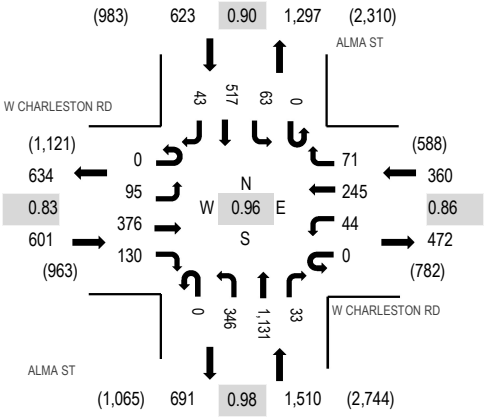
Vehicle Type	Eastbound				Westbound				Northbound				Southbound				Total
	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	
Articulated Trucks	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0	4
Lights	0	118	145	67	0	62	199	70	0	82	1,138	46	0	92	499	141	2,659
Mediums	0	2	0	2	0	0	8	3	0	0	34	0	0	0	10	1	60
Total	0	120	145	69	0	62	207	73	0	82	1,174	46	0	92	511	142	2,723

All Traffic Data Services Inc.

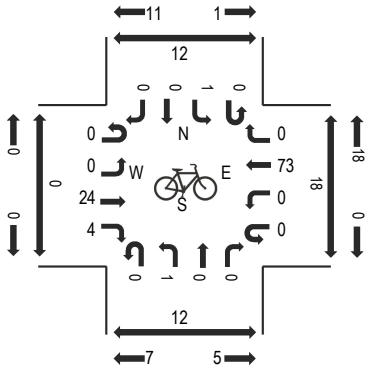
(303) 216-2439
www.alltrafficdata.net

Location: 9 ALMA ST & W CHARLESTON RD AM
Date: Tuesday, January 28, 2020
Peak Hour: 08:00 AM - 09:00 AM
Peak 15-Minutes: 08:45 AM - 09:00 AM

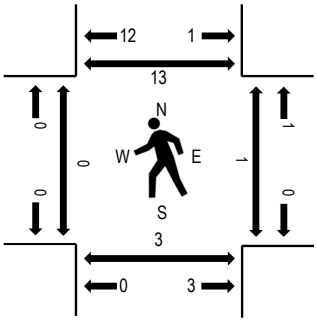
Peak Hour - Motorized Vehicles



Peak Hour - Bicycles



Peak Hour - Pedestrians



Note: Total study counts contained in parentheses.

Traffic Counts - Motorized Vehicles

Interval Start Time	W CHARLESTON RD Eastbound				W CHARLESTON RD Westbound				ALMA ST Northbound				ALMA ST Southbound				Total	Rolling Hour	Pedestrian Crossings			
	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right			West	East	South	North
7:00 AM	0	6	35	10	0	1	31	10	0	63	180	6	0	8	42	3	395	2,184	0	0	1	1
7:15 AM	0	15	49	12	0	2	34	9	0	69	198	7	0	12	67	4	478	2,593	0	3	2	0
7:30 AM	0	12	59	24	0	3	42	18	0	89	261	6	0	14	91	10	629	2,839	0	1	2	5
7:45 AM	0	19	96	25	0	10	51	17	0	81	268	6	0	12	87	10	682	2,971	0	4	1	9
8:00 AM	0	19	95	42	0	13	74	18	0	105	280	2	0	9	140	7	804	3,094	0	0	0	9
8:15 AM	0	28	70	28	0	13	53	26	0	72	296	7	0	12	111	8	724		0	0	1	1
8:30 AM	0	21	88	28	0	6	52	17	0	77	285	13	0	21	138	15	761		0	1	1	2
8:45 AM	0	27	123	32	0	12	66	10	0	92	270	11	0	21	128	13	805		0	0	1	1

Peak Rolling Hour Flow Rates

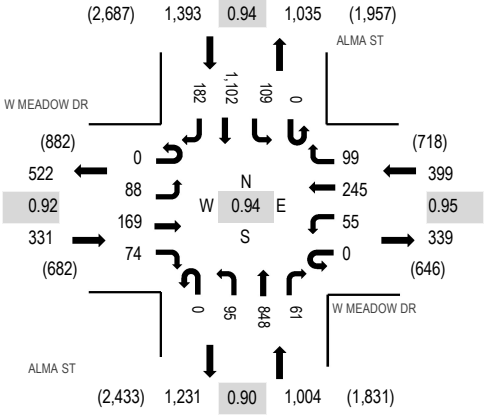
Vehicle Type	Eastbound				Westbound				Northbound				Southbound				Total
	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	
Articulated Trucks	0	0	2	0	0	0	2	1	0	0	2	0	0	1	3	0	11
Lights	0	94	363	127	0	44	231	64	0	338	1,109	32	0	61	505	43	3,011
Mediums	0	1	11	3	0	0	12	6	0	8	20	1	0	1	9	0	72
Total	0	95	376	130	0	44	245	71	0	346	1,131	33	0	63	517	43	3,094

All Traffic Data Services Inc.

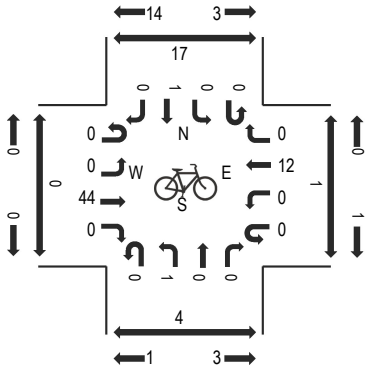
(303) 216-2439
www.alltrafficdata.net

Location: 5 ALMA ST & W MEADOW DR PM
Date: Tuesday, January 28, 2020
Peak Hour: 05:00 PM - 06:00 PM
Peak 15-Minutes: 05:15 PM - 05:30 PM

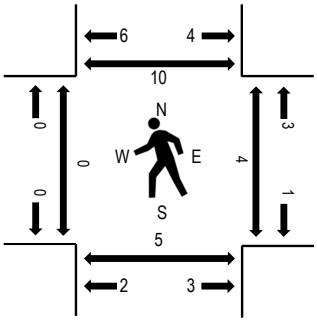
Peak Hour - Motorized Vehicles



Peak Hour - Bicycles



Peak Hour - Pedestrians



Note: Total study counts contained in parentheses.

Traffic Counts - Motorized Vehicles

Interval Start Time	W MEADOW DR Eastbound				W MEADOW DR Westbound				ALMA ST Northbound				ALMA ST Southbound				Total	Rolling Hour	Pedestrian Crossings			
	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right			West	East	South	North
4:00 PM	0	33	46	15	0	17	36	18	0	9	152	10	0	26	267	30	659	2,791	0	0	4	4
4:15 PM	0	31	41	18	0	14	44	26	0	17	194	17	0	25	300	36	763	2,851	0	1	2	7
4:30 PM	0	25	25	22	0	11	52	22	0	15	190	9	0	24	255	35	685	2,923	0	0	0	4
4:45 PM	0	28	41	26	0	14	48	17	0	12	186	16	0	27	243	26	684	3,049	0	0	1	3
5:00 PM	0	19	32	20	0	15	50	26	0	19	174	13	0	31	274	46	719	3,127	0	1	2	1
5:15 PM	0	16	46	18	0	13	72	20	0	22	240	18	0	36	278	56	835		0	0	0	4
5:30 PM	0	26	52	18	0	16	54	28	0	30	229	18	0	17	286	37	811		0	2	0	1
5:45 PM	0	27	39	18	0	11	69	25	0	24	205	12	0	25	264	43	762		0	1	3	4

Peak Rolling Hour Flow Rates

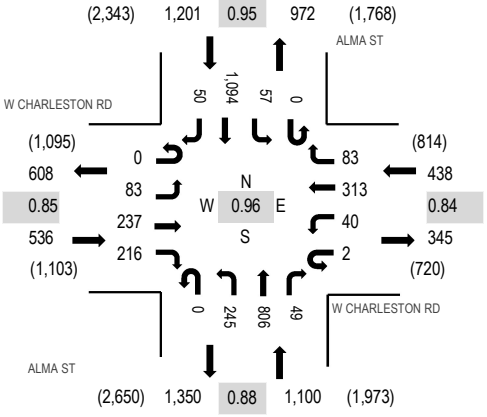
Vehicle Type	Eastbound				Westbound				Northbound				Southbound				Total
	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	
Articulated Trucks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lights	0	88	169	74	0	55	245	99	0	95	847	61	0	107	1,096	182	3,118
Mediums	0	0	0	0	0	0	0	0	0	0	1	0	0	2	6	0	9
Total	0	88	169	74	0	55	245	99	0	95	848	61	0	109	1,102	182	3,127

All Traffic Data Services Inc.

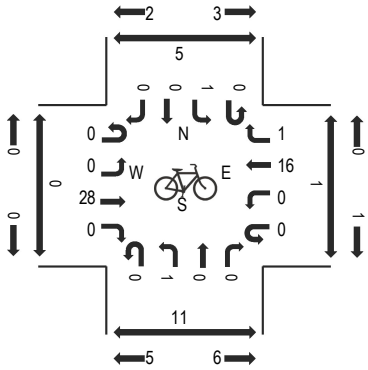
(303) 216-2439
www.alltrafficdata.net

Location: 9 ALMA ST & W CHARLESTON RD PM
Date: Tuesday, January 28, 2020
Peak Hour: 05:00 PM - 06:00 PM
Peak 15-Minutes: 05:45 PM - 06:00 PM

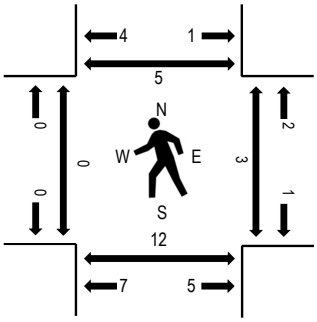
Peak Hour - Motorized Vehicles



Peak Hour - Bicycles



Peak Hour - Pedestrians



Note: Total study counts contained in parentheses.

Traffic Counts - Motorized Vehicles

Interval Start Time	W CHARLESTON RD Eastbound				W CHARLESTON RD Westbound				ALMA ST Northbound				ALMA ST Southbound				Total	Rolling Hour	Pedestrian Crossings			
	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right			West	East	South	North
4:00 PM	0	11	55	36	0	11	49	14	0	59	168	9	0	11	286	7	716	2,958	0	0	0	6
4:15 PM	0	20	94	61	0	14	88	29	0	44	145	13	0	21	209	8	746	3,007	0	1	0	1
4:30 PM	0	24	51	51	0	9	55	17	0	37	161	3	0	16	294	10	728	3,109	0	0	0	3
4:45 PM	0	18	76	70	0	1	78	11	0	46	178	10	0	16	258	6	768	3,194	0	0	3	1
5:00 PM	0	18	56	56	2	9	80	21	0	42	176	8	0	14	277	6	765	3,275	0	1	0	3
5:15 PM	0	16	62	50	0	8	59	23	0	51	246	17	0	9	297	10	848		0	1	3	1
5:30 PM	0	25	60	62	0	13	90	27	0	85	177	11	0	12	234	17	813		0	0	1	0
5:45 PM	0	24	59	48	0	10	84	12	0	67	207	13	0	22	286	17	849		0	1	8	1

Peak Rolling Hour Flow Rates

Vehicle Type	Eastbound				Westbound				Northbound				Southbound				Total
	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	U-Turn	Left	Thru	Right	
Articulated Trucks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lights	0	83	233	214	2	40	310	83	0	241	805	49	0	57	1,090	49	3,256
Mediums	0	0	4	2	0	0	3	0	0	4	1	0	0	0	4	1	19
Total	0	83	237	216	2	40	313	83	0	245	806	49	0	57	1,094	50	3,275

Appendix C
Synchro Existing and Future Traffic Volumes

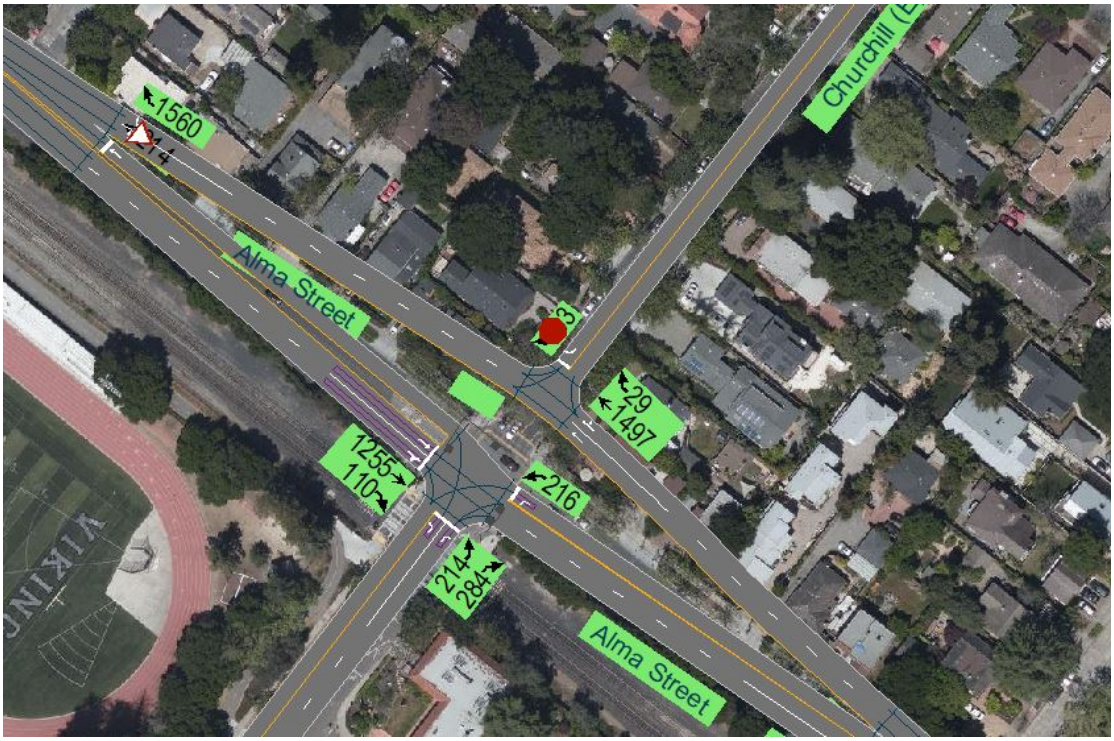
Churchill Underpass Existing AM Volumes

Churchill Underpass Existing PM Volumes

Note: - These exhibits are to show traffic volume only and are not accurate for the geometric design.

Churchill Underpass 2030 AM Volumes

Churchill Underpass 2030 PM Volumes



Note: - These exhibits are to show traffic volume only and are not accurate for the geometric design.

Meadows Drive Viaduct Existing AM Volumes

Meadows Drive Viaduct Existing PM Volumes

Note: - These exhibits are to show traffic volume only and are not accurate for the geometric design.

Meadows Drive Viaduct 2030 AM Volumes

Meadows Drive Viaduct 2030 PM Volumes

Note: - These exhibits are to show traffic volume only and are not accurate for the geometric design.

Charleston Road Viaduct Existing AM Volumes

Charleston Road Viaduct Existing PM Volumes

Note: - These exhibits are to show traffic volume only and are not accurate for the geometric design.

Charleston Road Viaduct 2030 AM Volumes

Charleston Road Viaduct 2030 PM Volumes

Note: - These exhibits are to show traffic volume only and are not accurate for the geometric design.

Meadows Drive & Alma Village Pkwy Partial Underpass 2030 AM Volumes

Note: - These exhibits are to show traffic volume only and are not accurate for the geometric design.

Meadows Drive & Alma Village Pkwy Partial Underpass 2030 PM Volumes

Note: - These exhibits are to show traffic volume only and are not accurate for the geometric design.

Charleston Rd Partial Underpass with U-Turn at Alma Village Pkwy 2030 AM Volumes

Charleston Rd Partial Underpass with U-Turn at Alma Village Pkwy 2030 PM Volumes

Note: - These exhibits are to show traffic volume only and are not accurate for the geometric design.