Six-Month Bike Box Evaluation

Tiburon Boulevard (SR 131) / Blackfield Drive / Greenwood Cove Drive

September 2017

Prepared for:

Town of Tiburon

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TRANSPORTATION CONSULTING

Table of Contents

1.Introduction

The intersection of Tiburon Boulevard / Blackfield Drive / Greenwood Cove Drive is an important crossing for students attending Bel Aire Elementary School and Del Mar Intermediate School; There is an active community of dozens of students that bicycle to Bel Aire Elementary School with a "biking student school bus", and older students that ride alone or in groups. Most of these student bicyclists travel in the north-south direction across Tiburon Boulevard.

The intersection is also an important junction for many recreational bicyclists riding through the Tiburon Peninsula. Westbound recreational bicyclists typically make a northbound left turn from Greenwood Cove Drive onto westbound Tiburon Boulevard. Anecdotally, there are dozens of recreational bicyclists passing through this intersection during weekdays, and hundreds during weekend days.

Prior to October 2016, however, both the northbound southbound approaches lacked signage or pavement markings to indicate a preferred alignment for bicyclists through the intersection. Although there were no reported bicycle-involved collisions, there were observed bicycle-related conditions or behaviors that included intersection crowding, wrong-way and/or sidewalk riding, and near-collisions with vehicle traffic. Figure 1 depicts the condition of the Greenwood Cove approach at Tiburon Boulevard in Spring 2015.

Figure 1. Pre-implementation conditions, northbound Greenwood Cove Drive at Tiburon Boulevard (SR 131).

EXPERIMENTAL MEASURES

The Town of Tiburon, working with Parisi Transportation Consulting, submitted a Request for Experimentation to the Federal Highway Administration (FHWA) and the California Traffic Control Devices Committee (CTCDC) to install bike boxes at the Blackfield Drive and Greenwood Cove Drive approaches to the intersection in Fall 2015. The request for experimentation was approved In December 2015. The objective of the experiment is to evaluate the effectiveness of the bike boxes for positioning bicyclists when approaching and queued at the intersection, in combination with the following improvements (Figure 2):

- Bike lanes from Cecilia Way to Greenwood Cove Drive,
- Bicycle traffic signal detection at Blackfield Drive and Greenwood Cove Drive,
- Dashed green pavement markings at conflict areas,
- Bicycle lane extension markings through the intersection, and
- Leading pedestrian / bicycle interval at Blackfield / Greenwood Cove signal phases.

The scope of the study focused on elementary and middle school-age bicyclists' movements through the intersection and the observation periods were selected to occur during the periods before the school morning bell and after the school afternoon bell. A crossing guard was present at the study intersection during both the morning and afternoon study periods in both the pre and post-implementation periods.

Figure 2. Tiburon Boulevard (SR 131) / Blackfield Drive / Greenwood Cove Drive Bike Box Improvements

EVALUATION METHODOLOGY

Pre-implementation data was collected in August 24, 2016 and the first round of post-implementation data was collected on May 10, 2017 (Bike to School Day). For both days, bicyclist and motorist activity was observed from 7:30-8:30 AM and 1:30-2:30 PM, which encompass the drop-off and pick-up periods of nearby schools (Wednesday schedule). The following metrics were observed and documented:

1. Bicycle positioning approaching each bike box,
2. Bicycle positioning queued at the intersection,
3. Vehicle positioning approaching the intersection,
4. Vehicle positioning queued at the intersection,
5. Bicycle and vehicle traffic counts,
6. Collision data,
7. Bicyclist and motorist conflict, e.g., incidents requiring an avoidance maneuver, and
8. Potential bicyclist and motorist conflict, e.g., incidents of unsafe behavior, but not resulting in an avoidance maneuver.

Pre- and post-implementation evaluation intervals were recorded with a video camera at each intersection approach (Figure 3). The videos were analyzed by an engineer for each of the metrics listed above.

Blackfield Drive at Tiburon Boulevard *Greenwood Cove Drive at Tiburon Boulevard*

Figure 3. Video Observation Screencap

2. Experimentation Results

The following sections describe the pre- and post-implementation results for the bike boxes based on bicycle positioning, vehicle positioning, bicycle and vehicle counts, collision records, and incidents of conflict.

BICYCLE POSITION APPROACHING THE INTERSECTION

Figure 4 presents a summary of bicyclists' position approaching Tiburon Boulevard from Blackfield Drive and Greenwood Cove Drive before and after project implementation.

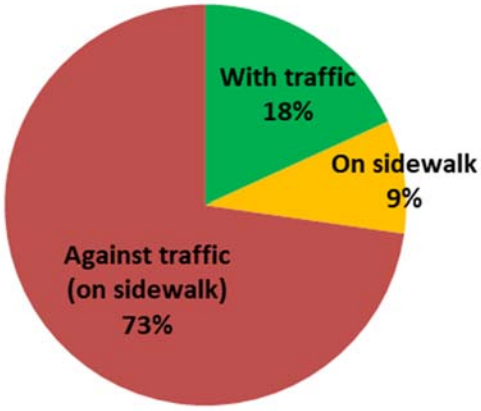
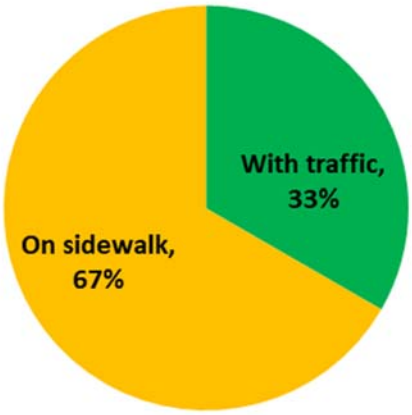
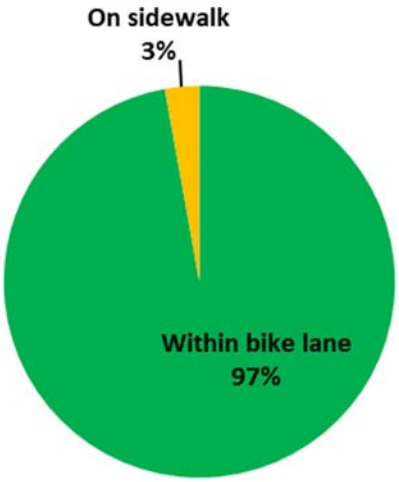
During the pre-implementation observations, 73 percent of students seen travelling southbound on Blackfield Drive came from Bel Aire Elementary School via a path accessed from Cecilia Way; the path terminates at the Cove Shopping Center. These students then typically rode through the shopping center and approached the intersection on the east sidewalk, opposite northbound traffic, and then crossed against traffic in the east crosswalk. Student bicyclists then typically rode south on Greenwood Cove Drive on the sidewalk or against traffic. Students that were accompanied by an adult on southbound Blackfield Drive typically road with traffic in the street.

In the post-implementation observations, many more students approached the Blackfield Drive intersection via the southbound bike lane (69 percent). All students that rode with an adult escort as part of a bicycle school bus approached the intersection via the bike lane, as did several groups of unaccompanied student bicyclists. The students that continued to ride through the Cove Shopping Center and that crossed in the east crosswalk were not accompanied by an adult.

Prior to project implementation in the northbound direction at Greenwood Cove Drive, most students approached the intersection via the east sidewalk. When bicyclists positioned themselves at southeast corner curb ramp, the large corner radius made it difficult to see for oncoming northbound traffic; there were several incidents where a right-turning driver braked suddenly to avoid hitting a bicyclist or pedestrian crossing in the crosswalk.

In the post-implementation observations, nearly all bicyclists approached the intersection the bike lane rather than the sidewalk, and aligned themselves in the bike box. Incidences of sidewalk riding were greatly reduced and drivers also appeared to be more cautious in making the right turn across the green-dashed conflict zone.

Figure 4. Bicycle Position Approaching the Bike Box

Pre-implementation, Aug. 24, 2016 *7-9 AM, 1-3 PM*	*Post-implementation, May 10, 2017* *(Bike to School Day), 7-9 AM, 1-3 PM*
BLACKFIELD DRIVE (SOUTHBOUND)	
N=33	***N=138***
	
GREENWOOD COVE DRIVE (NORTHBOUND)	
N=46	***N=141***
	

BICYCLE POSITION QUEUED AT THE INTERSECTION

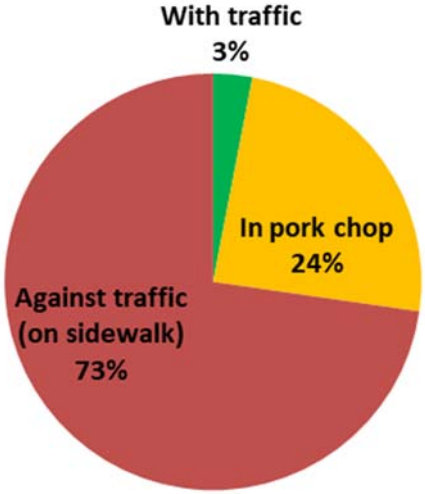
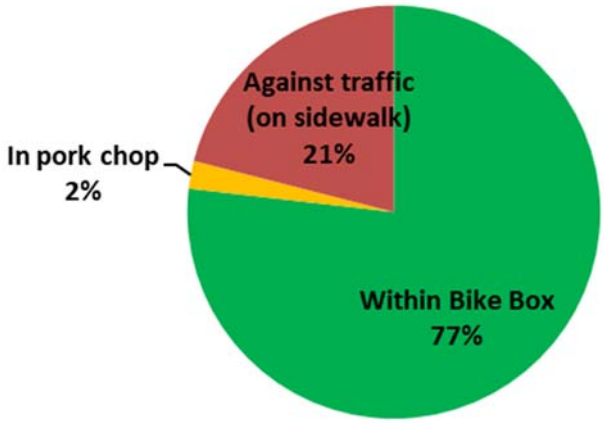
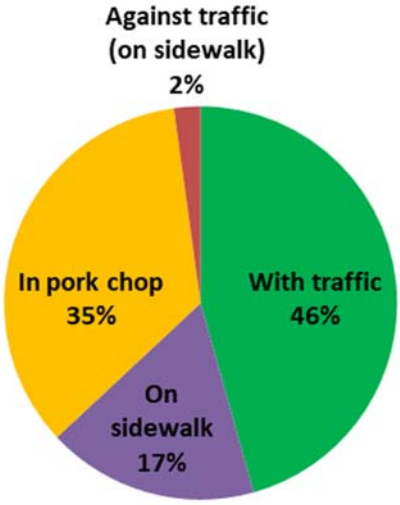
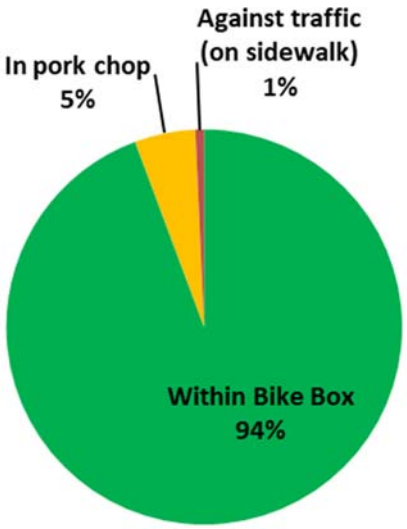
Figure 5 presents a summary of bicyclists' position when queued or passing through the Blackfield Drive and Greenwood Cove Drive.

At the southbound Blackfield Drive approach, the queuing position before implementation largely matched students' approach position, with many waiting at the northeast corner to cross Tiburon Boulevard in the east crosswalk. Students that approached with traffic or on the sidewalk tended to then move to right turn island, or "pork chop", when queued at the traffic signal.

After project implementation, most bicyclists queued in the new bike box. Although some students continued to approach Tiburon Boulevard from the Cove Shopping Center, several students moved to queue at the bike box with assistance from the school crossing guard. Students that moved to the bike box with the crossing guard's assistance were counted as queued within the bike box. Positioning these students in the bike box helped reduce the number of the students riding southbound against traffic on Greenwood Cove Drive after passing through the intersection.

Before project implementation at the northbound Greenwood Cove Drive approach, bicyclists were varied in their queuing position at the intersection. Most either positioned with the vehicular lane (46 percent) or on either side of the pork chop (35 percent). After project implementation, bicyclists were nearly uniform in queuing in the bike box (94 percent). Groups of bicyclists proceeding through the intersection tended to align themselves on the right side of the bike box, rather than using the entire width of the bike box. This occasionally resulted in bicyclist queuing that spilled back into the dashed green conflict area.

Figure 5. Bicycle Position Queued at the Intersection

Pre-implementation, Aug. 24, 2016 7:30-8:30 AM, 1:30-2:30 PM	*Post-implementation, May 10, 2017 (Bike to School Day), 7:30-8:30 AM, 1:30-2:30 PM*
BLACKFIELD DRIVE (SOUTHBOUND)	
N=33	***N=138***
	
GREENWOOD COVE DRIVE (NORTHBOUND)	
N=46	***N=141***
	

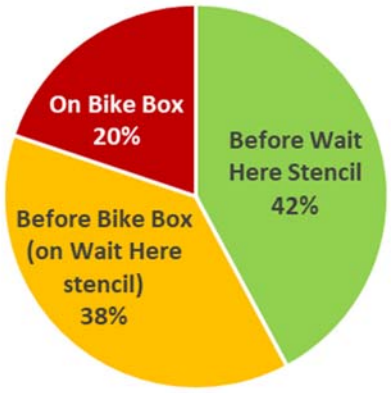
VEHICLE APPROACH AND POSITIONING

Figure 6 presents the observed vehicle compliance with the bike box and "Wait Here" markings. There was 20 to 25 percent violation rate of the bike box markings. Many vehicles positioned themselves on top of the "Wait Here" stencil, but avoided encroaching beyond the painted stop bar.

Figure 6. Vehicle Position Queued at the Intersection (post-implementation only)

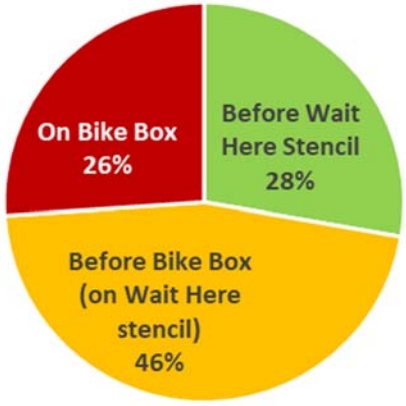
BLACKFIELD DRIVE

N=76



GREENWOOD COVE DRIVE

N=74



Motor vehicle right-turn movements through the marked conflict area (dashed green boxes) were qualitatively evaluated during the morning and school peak hours. Vehicles tended to approach the conflict area with slower speeds after project implementation, which is likely due to several factors: the presence of a marked bike lane approaching the intersection, the dashed green boxes in the conflict area, and the greater number of bicyclists riding in the bike lane and queuing at the bike box. We hypothesize that beyond the benefit of providing a queuing area, the green bike box serves as a visual reminder to drivers that bicyclists are present at the intersection approach.

BICYCLE AND VEHICLE COUNTS

Table 1 presents the total bicycles and motor vehicles counted at the project site before and after project implementation. The number of vehicles is roughly the same before and after project implementation. There is a large increase in bicycles counted, but this is likely due to the August 2016 count taking place early in the school year, and the May 2017 count taking place on Bike to School Day.

The Bike Box and associated improvements did not appear to have a measurable effect on vehicular demand or capacity.

Table 1. Bicycle and Vehicle Counts (7:30-8:30 AM, 1:30-2:30 PM)

Location	Pre-Implementation August 24, 2016		Post-Implementation May 10, 2017	
	Vehicles	Bicycles	Vehicles	Bicycles
Blackfield Drive	686	33	779	138
Greenwood Cove Drive	242	46	271	141

CRASH ANALYSIS

There have not been any bicycle or pedestrian-involved collisions at the project location since 2015. Between January 1, 2015 to September 31, 2016, there was one recorded broadside collision between two motor vehicles at the intersection of SR 131 Tiburon Boulevard and Blackfield / Greenwood Cove.[1] There was one rear-end collision on Tiburon Boulevard at the intersection after the project was installed in October 2016.[2] The California Statewide Integrated Traffic Records System (SWITRS) does not have collision data for 2017 and the Tiburon Police Department reported that there have not been any other traffic collisions at the study intersection in 2017.

[1]SWITRS Case ID 90025771.

[2]SWITRS Case ID 90360511.

CONFLICT / POTENTIAL CONFLICT BETWEEN BICYCLISTS AND MOTORISTS

Within the evaluation methodology, **conflicts** between bicyclists and motorists were defined as:

> Incidents of behaviors where an avoidance maneuver was required to avoid a collision.

Potential conflicts were defined as:

> Instances of unsafe behaviors that did not require a direct avoidance behavior, but increased the likelihood for a potential conflict (e.g., riding against traffic and crossing outside a marked crossing), or encroached on the right-of-way of another mode (e.g., left turning vehicles encroaching into the intersection against oncoming pedestrian and bicycle traffic.)

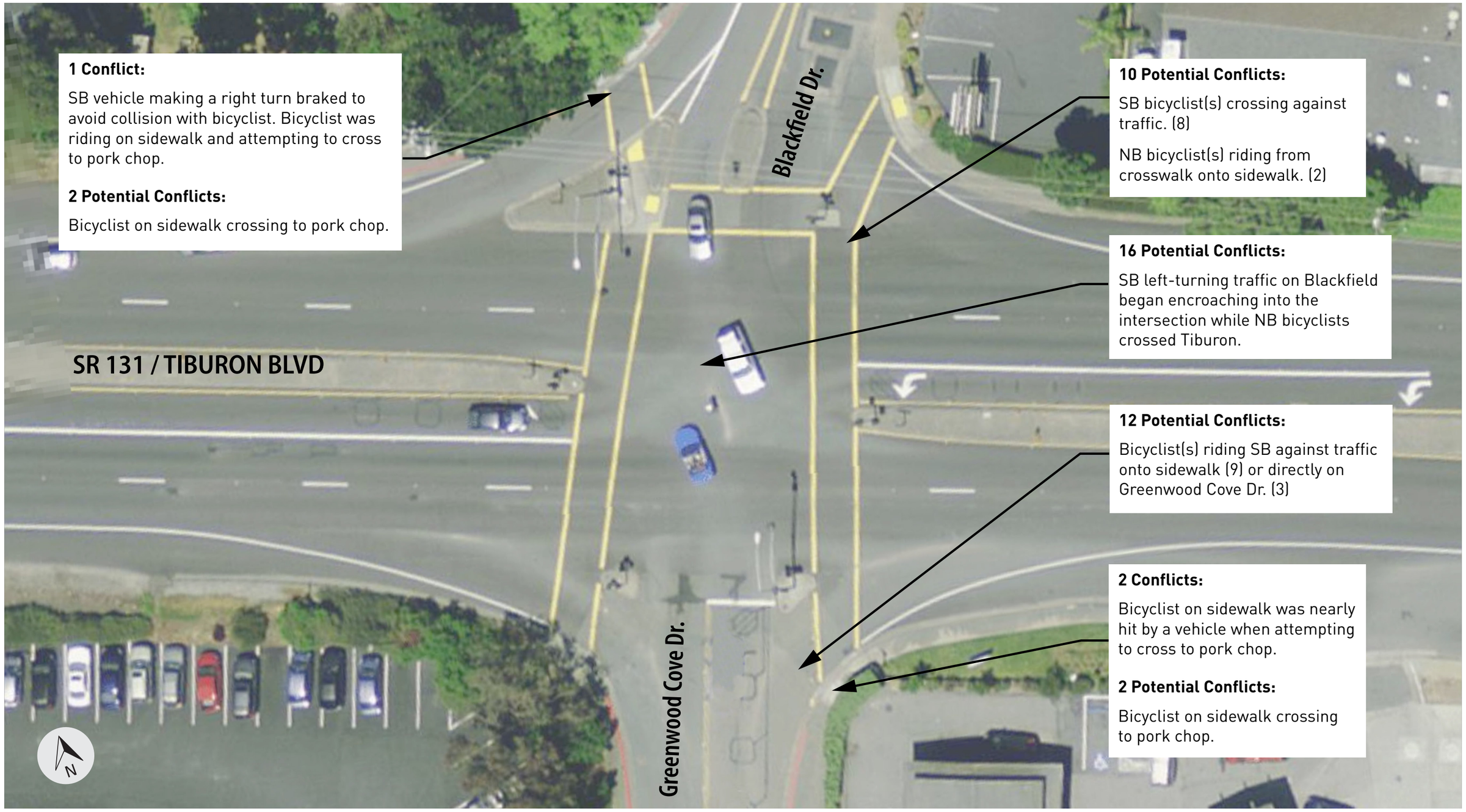
The count of conflicts and potential conflicts before and after project implementation is presented in Table 2. The conflict locations are indicated in Figure 7 and Figure 8.

Table 2. Conflict Summary

	Pre-Implementation August 24, 2016		Post-Implementation May 10, 2017	
Approach	Conflicts	Potential Conflict	Conflicts	Potential Conflict
Blackfield Drive (SB)	1	28	0	10
Bikes on sidewalk crossing to pork chop (west Xwalk)	1	2	0	0
Bikes crossing SB in east Xwalk	0	8	0	7
Vehicle SBL encroaching into intersection	0	16	0	3
NB bikes in east Xwalk riding to sidewalk	0	2	0	0
Greenwood Cove Drive (NB)	2	14	1	9
Bikes riding NB on sidewalk to pork chop (east Xwalk)	2	2	0	1
Bikes riding SB on sidewalk	0	9	0	5
Bikes riding SB against traffic on Greenwood Cove Dr.	0	3	1	3

SBL – southbound left turn
NB / SB – northbound / southbound

The reduction in bicyclist- initiated conflicts or potential conflicts on a per rider basis is noteworthy. In the pre-implementation observations, there were 29 incidents, not counting vehicular encroachment, observed out of 79 bicyclists (37 percent incidence rate). After implementation, there were 17 incidents, not counting vehicular encroachment, observed out of 279 bicyclists (seven percent incidence rate).



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SR 131 Tiburon Boulevard / Blackfield Drive / Greenwood Cove Drive Bike Box Evaluation Study

Pre-Implementation Conflict Diagram

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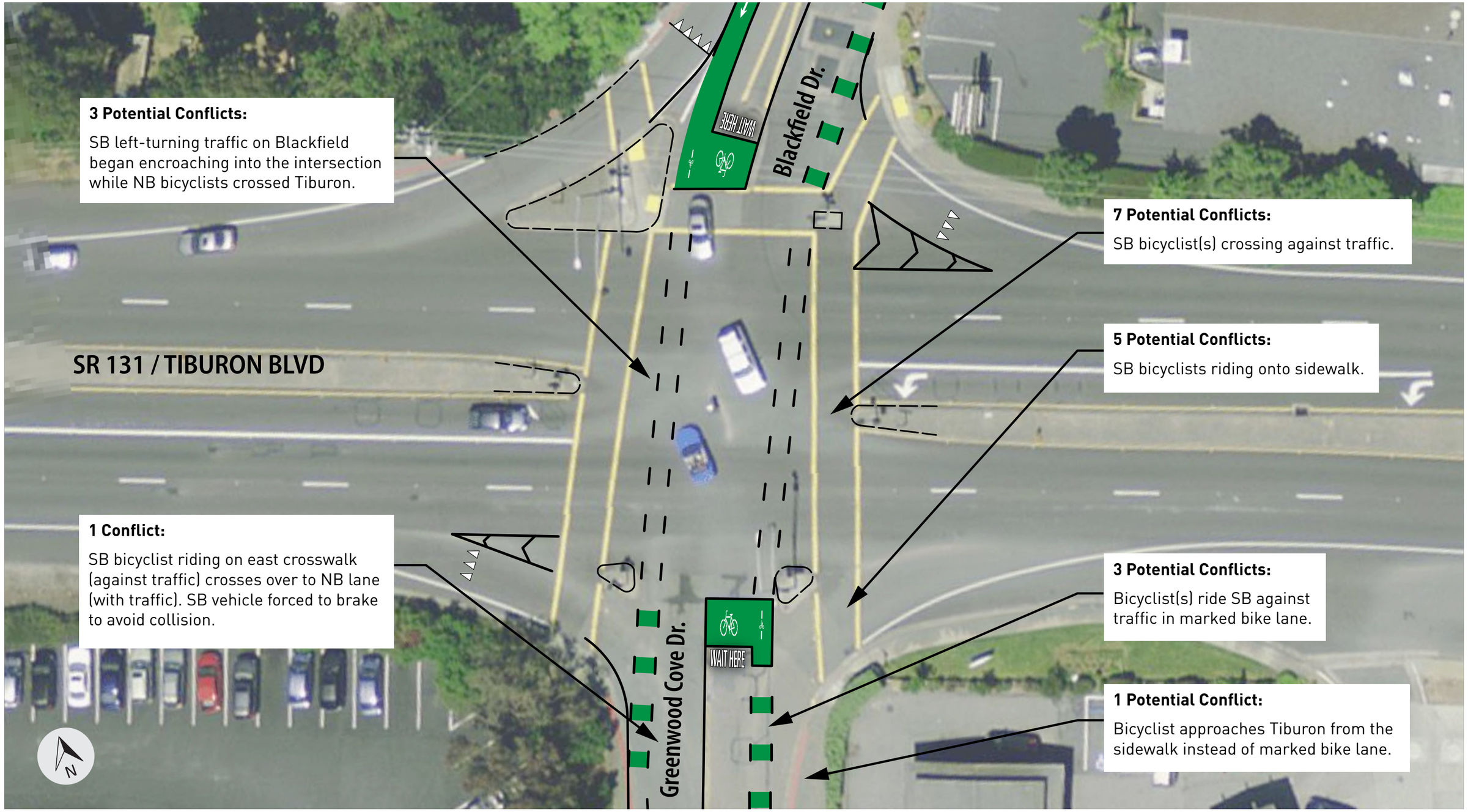

TOWN OF TIBURON

SR 131 Tiburon Boulevard / Blackfield Drive / Greenwood Cove Drive Bike Box Evaluation Study

Post-Implementation Conflict Diagram

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There was one conflict and 28 potential conflicts observed at Blackfield Drive before project implementation. The one conflict involved a southbound vehicle and a bicyclist riding southbound on the west sidewalk. The bicyclist began crossing in the marked crosswalk from the sidewalk to the pork chop as the vehicle began making a right turn, but because the geometry of the corner curb radius makes it difficult to see people at the curb ramp, the driver needed to brake sharply to avoid colliding with the bicyclist. There were two other instances of this behavior that did not result in a direct conflict because there was no oncoming traffic (potential conflict).

Among the potential conflicts on the east side of the Blackfield Drive approach, there were eight instances of southbound bicyclists crossing in the east crosswalk, 16 instances where southbound left turning vehicles began encroaching into the intersection while northbound bicyclists were crossing the intersection, and two instances of bicyclists riding in the east crosswalk onto the sidewalk. There were two conflicts and 14 potential conflicts observed at Greenwood Cove Drive before project implementation. The two conflicts occurred at the southeast corner curb ramp, where a bicyclist riding on the sidewalk was nearly hit by a vehicle when biking to the pork chop, and two other instances of the same behavior without oncoming traffic (potential conflict). There were nine instances of bicyclists riding southbound against traffic from the east crosswalk onto the sidewalk, and three instances of bicyclists riding southbound against traffic directly on Greenwood Cove Drive.

After project implementation, there were no instances of conflicts at Blackfield Drive, and 10 potential conflicts. There were seven instances of southbound bicyclists crossing in the east crosswalk against traffic, and three occurrences of southbound left turning vehicles encroaching into the intersection while northbound bicyclists were crossing the intersection. The number of bicyclists crossing in the east crosswalk against traffic was reduced by the actions of the school crossing guard, who directed bicyclists staged at the northeast corner to cross to the bike box during the Tiburon Boulevard traffic phase. His / her actions reduced the number of bicyclists riding against traffic on Greenwood Cove Drive after passing through the intersection.

The number of instances where traffic encroached into the intersection while bicyclists were crossing was reduced with the project implementation of a leading bicyclist / pedestrian interval (LPI). With the LPI, bicyclists could get a four second head start into the intersection upon receiving the pedestrian walk signal. Most bicyclists correctly initiated the crossing with the pedestrian walk signal and did not wait for the vehicular signal. Motorists were consequently less inclined to attempt an immediate left turn upon seeing the green light. Most drivers tended to queue near the stop bar, rather in the middle of the intersection, while waiting for bicyclists to cross.

After implementation, there was one conflict and nine potential conflicts observed at Greenwood Cove Drive. The one conflict occurred when a southbound bicyclist riding in the

east crosswalk crossed over the opposing northbound lane to merge onto southbound Greenwood Cove Drive; an oncoming southbound vehicle needed to brake to avoid a collision. There were five potential conflicts with southbound bicyclists riding from the east crosswalk onto the sidewalk, and another three instances where one or more bicyclists rode southbound against traffic on Greenwood Cove Drive in the marked bike lane. There was one bicyclist that approached Tiburon Boulevard from the sidewalk.

3. Findings and Conclusions

The bike boxes and associated improvements after six months appear to result in more consistent bicyclist behavior and positioning at the project study intersection. Bicyclists are more likely to approach the intersection positioned within the marked bike lane, compared to a larger percentage of bicyclists riding on the sidewalk before the project. Bicyclists are more likely to queue aligned with traffic in the bike boxes, rather than at the pork chop or on the sidewalk. The number of wrong way riders and vehicular conflicts was reduced with more bicyclists using the bike lane to approach the intersection. The Leading Pedestrian Interval (LPI) was effective in reducing vehicular encroachment into the intersection while bicyclists and pedestrians were crossing Tiburon Boulevard.

Student bicyclists approaching Blackfield Drive from the Cove Shopping Center remain an issue. Student bicyclists that are not repositioned to the bike box by the crossing guard will consequently ride against traffic on Greenwood Cove Drive, either on the sidewalk or on the street. Further bicycle education should emphasize to student bicyclists to use Blackfield Drive when traveling southbound, rather than using the Cecilia Way path that terminates at the Cove Shopping Center.

The data show a high level of compliance among drivers approaching the bike box, with 75 to 80 percent compliance with the stop bar and green painted area. Motorists tended to stop on top of the Wait Here markings; future installations may consider foregoing this feature. The vehicular count and collision data shows no conclusive change between the pre- and post-implementation periods of the bike box.

In summary, the implementation of the bike boxes, marked bike lanes and green dashed conflict zones appear to benefit bicyclists and motorists in clarifying proper positioning at the intersection and resolving intermodal conflicts. There was a substantial number of students bicycling through this intersection in the post-implementation observations, and the investment in bicycle infrastructure is expected to continue fostering regular bicycling to and from school.

The FHWA issued an interim approval for the optional use of intersection bike boxes in October 2016 without the need for an experimental treatment application.[3] The interim approval includes provisions for the bike box design, with which the installation at Tiburon Boulevard / Blackfield Drive / Greenwood Cove Drive is fully compliant.[4] Caltrans and the CTCDC requested and

[3] http://www.dot.ca.gov/trafficops/camutcd/interim.html, IA-18.

[4] https://mutcd.fhwa.dot.gov/resources/interim_approval/ia18/index.htm.
Conditions of Interim Approval, 2. Design of Intersection Bicycle Boxes.

received approval for bike boxes to be used on a blanket basis statewide, which eliminates the need for individual agencies to seek FHWA approval. The installation at Tiburon Boulevard / Blackfield Drive / Greenwood Cove Drive conforms to the provisions of the interim approval as follows:

Table 3. FHWA Interim Approval IA-18 Design Provisions and Project Conformity

Design Provisions	Tiburon Boulevard / Blackfield Drive / Greenwood Cove Drive Design
A bicycle box shall be formed by an advance stop line placed at least 10 feet in advance of the intersection stop line.	Project conforms to Interim Approval standard.
At least one bicycle symbol shall be placed within a bicycle box (see Attachments IA-18-1 and IA-18-2 for placement details).	Project conforms to Interim Approval standard.
Where a bicycle box is provided across multiple lanes of an approach, countdown pedestrian signals (see Section 4E.07 of the 2009 MUTCD) shall be provided for the crosswalk across the approach on which the bicycle box is located.	Project conforms to Interim Approval standard.
Turns on red shall be prohibited from the approach where a bicycle box is placed using a NO TURN ON RED (R10-11 series) sign.	Not applicable to project.
At least 50 feet of bicycle lane should be provided on the approach to a bicycle box so bicyclists will not need to ride between lanes to enter the bicycle box.	Project conforms to Interim Approval guidance.
A STOP HERE ON RED (R10-6 or R10-6a) sign should be provided at the advance stop line defining the bicycle box with an EXCEPT BICYCLES (R3-7bP) word legend plaque below.	Project conforms to Interim Approval guidance with STOP HERE pavement markings in advance of the advance stop line.
Green-colored pavement (see Interim Approval No. 14) may be used within a bicycle box and the approach bicycle lane, where one is provided.	Project conforms to Interim Approval option.

https://mutcd.fhwa.dot.gov/resources/interim_approval/ia18/index.htm