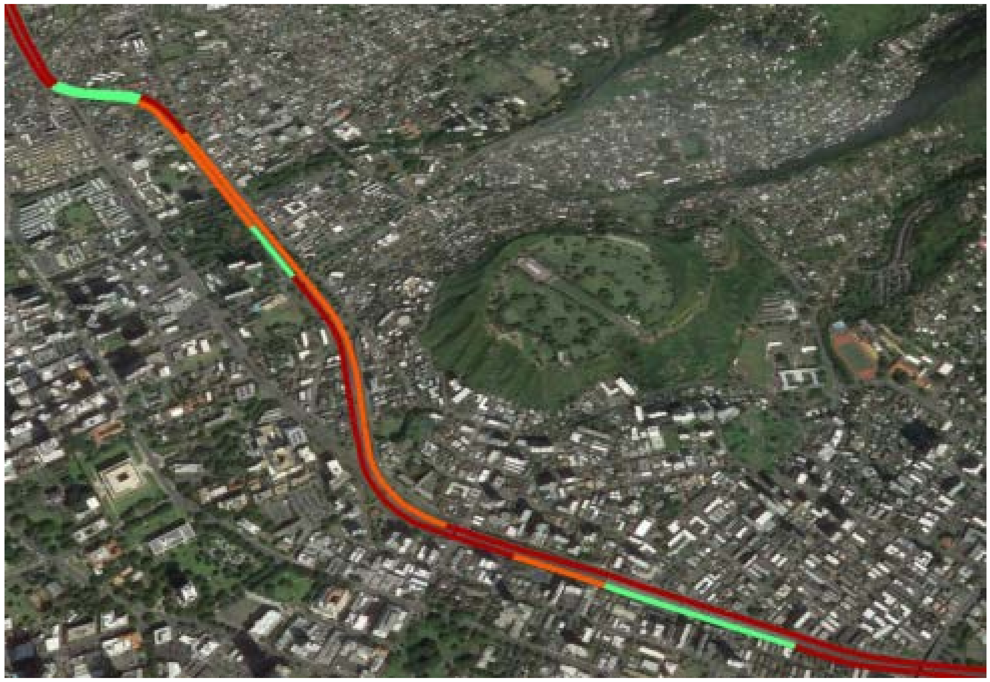
TNM NOISE ANALYSIS OF CENTRAL H-1 FREEWAY



FINAL REPORT PREPARED IN COOPERATION WITH:

State of Hawaii, Department of Transportation, Highways Division

and U.S. Department of Transportation, Federal Highway Administration

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4.4.14

Technical Report Documentation Page

1. Report No. FHWA/HI-14/HWY-L--2006-01	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle TNM NOISE ANALYSIS OF CENTRAL H-1 FREEWAY		5. Report Date April 4, 2014
		6. Performing Organization Code
7. Author(s) Panos D. Prevedouros. Ph.D.		8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Civil and Environmental Engineering University of Hawaii at Manoa		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. 55145
12. Sponsoring Agency Name and Address Hawaii State Department of Transportation Highways Division		13. Type of Report and Period Covered 6/11 to 3/14
		14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

The purpose of this project was to provide a comprehensive first-time assessment of noise levels along the central part of the H-1 Freeway. The noise analysis tool used was FHWA's Traffic Noise Model (TNM, version 2.5). Analyses of both existing (year 2012) conditions and with a 10 ft. noise barrier were conducted for three time periods: 6:00-7:00 AM was selected to represent worse noise conditions during the AM peak period; 5:00-6:00 PM was selected to represent worse noise conditions during the PM peak period; and 7:00-8:00 PM was selected to represent worse night time noise conditions. The latter period has relatively high volumes and high speeds. After 8 PM speeds are high but volume becomes low, thus estimates of noise are lower in magnitude. The 7-8 PM hour is the preferred period for assessing annoyance from highway noise along this corridor.

Results: 17% of the segments or 1.08 out of 7.66 miles of central H-1 Freeway examined in this analysis have traffic noise levels below the NAC, that is, below the level that requires noise abatement; 48% or 3.83 miles have a noise level above the NAC that can be mitigated using 10 ft. noise barriers; 31% or 2.44 miles have a noise level above the NAC that cannot be mitigated using 10 ft. noise barriers because the receptors are located at an elevation over 10 ft. above the roadway; and, 3% or 0.32 miles have a major traffic noise problem that would require tall barriers (well over 10 ft.) to mitigate.

In mid-2014 a large portion of the subject freeway from Middle St. to Punahou St. was widened from 3 to 4 lanes per direction rendering most of the results herein approximate, at best.

17. Key Words Traffic Noise TNM Freeway Hawaii	18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	76	

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EXECUTIVE SUMMARY

The purpose of this project was to provide a comprehensive first-time assessment of noise levels along the central part of the H-1 Freeway. The noise analysis tool used was FHWA's Traffic Noise Model (TNM, version 2.5). Analyses of both existing (year 2012) conditions and with a 10 ft. noise barrier were conducted for three time periods: 6:00-7:00 AM was selected to represent worse noise conditions during the AM peak period; 5:00-6:00 PM was selected to represent worse noise conditions during the PM peak period; and 7:00-8:00 PM was selected to represent worse night time noise conditions. The latter period has relatively high volumes and high speeds. After 8 PM speeds are high but volume becomes low, thus estimates of noise are lower in magnitude. The 7-8 PM hour is the preferred period for assessing annoyance from highway noise along this corridor.

About 17% of the segments or 1.08 out of 7.66 miles of central H-1 Freeway examined in this analysis have traffic noise levels below the NAC, that is, below the level that requires noise abatement. A near-majority portion of 48% or 3.83 miles have a noise level above the NAC that can be mitigated using 10 ft. noise barriers. About one third (31%) or 2.44 miles have a noise level above the NAC that cannot be mitigated using 10 ft. noise barriers because the receptors are located at an elevation over 10 ft. above the roadway. A very small portion of 3% or 0.32 miles have a major traffic noise problem that would require tall barriers (well over 10 ft.) to mitigate.

According to HDOT's ***Highway Noise Policy and Abatement Guidelines***, the highway noise results from either field surveys or TNM must be subjected to feasibility and reasonableness analysis to assess whether the potential installation of noise barriers for abatement is appropriate. Using a 2007 estimate by HDOT's design section updated to 2013, a 10 ft. concrete wall may cost approximately $800 per linear foot including design, construction engineering and administration. Based on this and the lengths examined herein for which such a wall would be suitable abatement, the installation of 10 ft. noise barriers may cost about $32 million for the central H-1 Freeway.

There are 597 residential and similar land use units along segments where noise barriers can reduce the noise level by at least 5 dBA, and exceed the stated 75% design goal for 7 dBA noise reduction for front row receptors. The approximate estimate of $32,000,000 for 597 units yields a cost of $53,600 per unit. Therefore the provision of traffic noise abatement along the identified segments is both feasible and reasonable. Notably "feasible" in this context is based on noise analysis and evaluation only. Some of these barriers may not be structurally feasible, or they may not be wanted by the adjacent property owners; other localized issues may also be applicable. The 2011 ***Guidelines*** cited above detail additional investigations that need to take place for area-specific deployment of noise abatement.

Open-graded rubberized asphalt concrete (also known as quiet pavement) should be considered for several segments where noise barriers are infeasible or undesirable. NCHRP Report 738 (TRB, 2013) provides useful guidance for pavement/barrier combinations for noise abatement, including cost tradeoffs.

Most of the main results of this study for all 29 north (mauka) side and 29 south (makai) side segments of the H-1 Freeway are available for agency and public viewing as *Google Earth* files with color coded results by segment, and pop-up tables of noise estimates for each representative receptor by time period examined, as follows:

1. **H-1.Receptors.kmz**: Displays every receptor using a yellow ear. Includes the coordinates of each receptor.
2. **H-1.Segmentation.kmz**: H-1 Freeway segments of analysis are demarcated by white markers. Includes the length of each segment.
3. **H-1.Noise.Results.kmz**: By clicking on the yellow ear next to the receptor label, a mini table pops up to display TNM-derived noise level without and with a barrier in the AM peak, PM peak and night periods.
4. **H-1.AM.color.kmz**: Color coded noise level results for existing conditions in 6:00 - 7:00 AM period. In **green** sections the noise level is 62.4 dBA or below. In **orange** sections the noise level is between 62.5 dBA and 69.4 dBA. In **red** sections the noise level is 69.5 or above.
5. **H-1.PM.color. kmz**: Color coded noise level results for existing conditions in 5:00 - 6:00 PM. (Same ranges as above.)
6. **H-1.Night.color. kmz**: Color coded noise level results for existing conditions in 7:00 - 8:00 PM. (Same ranges as above.) Part of the display of this file is shown on this report's cover.

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1. Study Purpose

The University of Hawaii Department of Civil Engineering collaborated with the Hawaii State Department of Transportation (HDOT) and the Federal Highway Administration (FHWA) to update HDOT's 1997 Highway Noise Guidelines and develop the current policy titled ***Highway Noise Policy and Abatement Guidelines*** (August 2011).

As an extension to that project, a noise analysis study of the H-1 Freeway was conducted for its central section between Middle St. and Kahala Mall, the total length of which is 7.66 miles. The noise analysis tool used was FHWA's Traffic Noise Model (TNM version 2.5). Based on both FHWA and HDOT policy, TNM is the required model for predicting noise levels of highways. We used TNM to estimate the noise level for about 30 segments of the H-1 freeway forming the aforementioned 7.66 mile section. For each segment, noise estimates were obtained separately for the north (mauka) and south (makai) sides of the freeway (front row of adjacent land uses) and for two scenarios: Existing conditions and with a 10 ft. high noise barrier.

The purpose of this project was to provide a comprehensive first-time assessment of noise levels along the central part of the H-1 Freeway. The analysis was designed to reveal areas with potentially substantial highway noise impacts and assess the feasibility and reasonableness of providing noise abatement in the form of noise barrier. However, it is not the intent of this study to be the final determination of specific areas for noise barrier deployment. HDOT should consider the results produced by this study and then deploy area-specific noise analysis as well as other engineering and community-based analysis to determine the final efficacy and desirability for providing noise barriers or other noise mitigation such as quiet pavement on specific freeway segments.

This report is organized as follows. Chapters 2, 3 and 4 detail the TNM inputs. Chapter 2 describes the fundamental features such as the segmentation of the freeway and the selection of time periods of analysis. Chapter 3 describes the geometry of each segment in TNM, e.g., the (x,y,z) coordinates and height of each receptor by land use type. Chapter 4 describes the traffic data of each segment in TNM, e.g., volumes and speeds by lane. Chapter 5 summarizes the voluminous results by segment, location and land use of receptors, time of day and presence or absence of a noise barrier. It also presents the *Google Earth* materials prepared as part of this study. Chapter 6 relies on the specifications of HDOT's ***Highway Noise Policy and Abatement Guidelines*** to conduct a reasonableness analysis and a summary assessment. Chapter 7 is a summary of recommendations.

2. Fundamental Features: Segments, Time Periods

The proper application of TNM requires its application of uniform or homogeneous segments of a highway facility. During a given time period, a highway segment is homogeneous if its traffic volume and speed are fairly constant along the entire length. Once a large change occurs (e.g., over ±10% in volume and over ±20% in speed) then a new segment needs to be created. Typically the merging and diverging points of on- and off-ramps dictate the borders between segments. The analyst has to be careful to combine both directions of the highway. Often ramps on the sides of a highway do not align closely, which results in more homogeneous segments having to be created for reliable noise estimates with TNM. Additional reasons for segmentation include large elevation differences such as the beginning and end of a viaduct section of a freeway. Tunnels, lane additions and drops are also reasons for further segmentation.

The subject segment of the H-1 Freeway between the Middle St. overpass and Kahala Mall was divided into segments based on both geometric features and traffic characteristics, such as grade, topography, side slopes, volume, and speed. The peak periods were chosen based on HDOT's ***Highway Noise Policy and Abatement Guidelines*** which specifies to conduct analysis "… when the highest noise levels are expected. The period with the highest levels may not be at the peak traffic hour, but a period when traffic volumes may be lower but the overall percentage of trucks or vehicle speeds are higher." Unlike a traffic simulation model that analyzes congestion and queues based on the diurnal patterns of traffic flow, time of day traffic volume and demand does not correlate with high noise levels, therefore various times were selected because of the varied traffic flow characteristics. Based on 2012 data, the following three periods were identified:

- 6:00-7:00 AM was selected to represent worse noise conditions during the AM peak period, because this period has high volumes and relatively high speeds. After 7 AM the flow is too congested and speeds are low.
- 5:00-6:00 PM was selected to represent worse noise conditions during the PM peak period for similar reasons as above. Specifically volumes are not as high in the hour before and the hour after as the selected one, whereas congested conditions (speeds) are similar during the 4:00 to 7:00 PM period.
- 7:00-8:00 PM was selected to represent worse night time noise conditions. This period has relatively high volumes and high speeds. After 8 PM speeds are high but volume becomes low, thus estimates of noise are lower in magnitude. This is the preferred period for assessing annoyance from highway noise along this corridor.

The segmentation was carried on images from *Google Earth* and the main noise results were also summarized on *Google Earth* digital maps of the subject H-1 Freeway segment. An altitude of 2,000 ft. was selected for generating images, but the user can zoom in and out at will. Each homogeneous segment has identical speed, volume and elevation. The procedures of segmentation are as follows:

- The 1st round of segmentation was based on speeds from four continuous count stations on H-1 Freeway. Using 2012 data, cut lines (refer to Appendix A) were placed at the borders of speed change; they correspond to major on- or off-ramps that cause speed changes to the mainline.
- The 2nd round of segmentation was based on all the on- and off-ramps. Cut lines were placed at merging and diverging points of ramps that cause a greater than ±10% in volume. Most ramps meet this condition.
- The 3rd round of segmentation was based on the elevation of the road, i.e. whether the freeway centerline is level, elevated or depressed.

This resulted in 30 mauka and 30 makai sections forming 60 segments along the H-1 Freeway, with uniform geometric and traffic features, as shown in Figure 2.1. Data were not readily available for the section between Kahala Mall and Ainakoa St., so the noise analysis was limited to 29 sections (58 segments), from Middle St. to Kahala Mall.

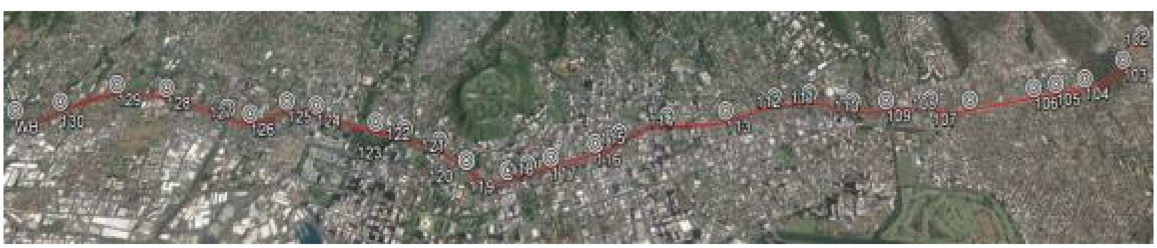


Figure 2.1. Segmentation of H-1 Freeway in homogeneous segments.

3. Segment Geometry

For each segment, geometric data are the X, Y, Z coordinates of the lanes and median, the receptors, and the terrain lines.

The absolute elevation is not particularly useful in noise analysis. The elevation difference between the road and the receptor is critical. As a result, the road surface of the freeway was set to Z=0. TNM allows importing DXF files to obtain X and Y coordinates, which is suitable for localized applications. However, using detailed DXF files to model several miles of freeway with the accompanying frequent volume, speed and lane changes is too tedious. Although importing DXF files to TNM was attempted initially, it quickly became unworkable due to practical limitations: It simply took too long on a fast computer to scroll over each segment and enter its data because all the details of a 7.66 mile section of freeway were in memory. Instead, the freeway was modeled with straight lines representing each of the 29 sections. Most of the 29 sections are relatively short, so they are indeed approximately straight. TNM is not sensitive to curvature. TNM is not sensitive to interactions among segments (i.e., it analyzes one segment at a time). Both of our simplifications have no impact to the noise estimations.

Three important geometric inputs are roadway geometry, receptor locations and terrain lines, as detailed below.

3.1. Roadway Geometry

The orientation of the subject H-1 Freeway section is approximately east – west. The centerline of the freeway was modeled as a 3 ft. high barrier extended from the east to the west. This barrier represents the median and is used as the X coordinate axis. Its east point is X=0, and west point is X=L. L was the length of each segment measured in *Google Earth*. Lanes, located on the north and south side of the centerline (the median), were placed parallel to the centerline. Lanes have positive Y coordinates on the north side of the centerline, and negative Y coordinates on the south side. All points on the roadway have an elevation (Z) of zero and each receptor has an appropriate elevation (Z) and height (H).

3.2. Representative Receptors

The FHWA Noise Abatement Criteria (NAC) specify land use categories and their corresponding allowable noise levels, as shown in Table 3.1. Three land use types of front row receptors are found along the H-1 Freeway: B, C, and E. This project used HDOT's ***Highway Noise Policy and Abatement Guidelines*** criteria which is 1 dBA less than the NAC based on Leq(h).

Table 3.1. FHWA NAC by Land Use

TABLE 1 TO PART 772—NOISE ABATEMENT CRITERIA

[Hourly A–Weighted Sound Level_decibels (dB(A)) [1]]

Activity category	Activity Leq(h)	Criteria [2] L10(h)	Evaluation location	Activity description
A	57	60	Exterior	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B [3]	67	70	Exterior	Residential.
C [3]	67	70	Exterior	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings.
D	52	55	Interior	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios.
E [3]	72	75	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A–D or F.
F				Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing.
G				Undeveloped lands that are not permitted.

[1] Either Leq(h) or L10(h) (but not both) may be used on a project.
[2] The Leq(h) and L10(h) Activity Criteria values are for impact determination only, and are not design standards for noise abatement measures.
[3] Includes undeveloped lands permitted for this activity category.

Representative receptors were selected from each type of receptor in each segment. The data needed for a representative receptor are: The number of units it represents, its coordinates (X, Y, Z), and its H value.

Count: All receptors, located along the front row within 300 ft. from the centerline of the road (noise sensitive region) were considered for noise modeling. Using the "street view" option on *Google Earth*, all buildings within the sensitive zone were identified, marked and counted. The unit closest to the centerline was chosen as the representative receptor for each NAC land use type.

Receptor type B represents residential units, including all houses and apartment buildings. The orange triangle in each segment in Figure 3.1 identifies the receptor B which represents all the type B receptors on the same side of a segment. A representative receptor B was marked on each direction of a segment, except for segments 121 and 130, which do not have buildings for residential use on the south side. The total number of front-row and nearest-to-centerline type B units along the modeled section of the freeway is 1,054.

Receptor type C represents sports areas, playgrounds, day care centers, hospitals, libraries, medical facilities, schools, parks, churches, recreational areas. Over one third of the segments have buildings that are used for activities such as those mentioned above; they were marked using purple triangles. The count of type C receptors on both sides is 41.

<u>Receptor type E</u> represents office buildings. Only a few type E receptors are located along this section of the H-1 Freeway; they were all marked using blue triangles. The count of type E receptors is 5 on the south side and 22 on the north side.

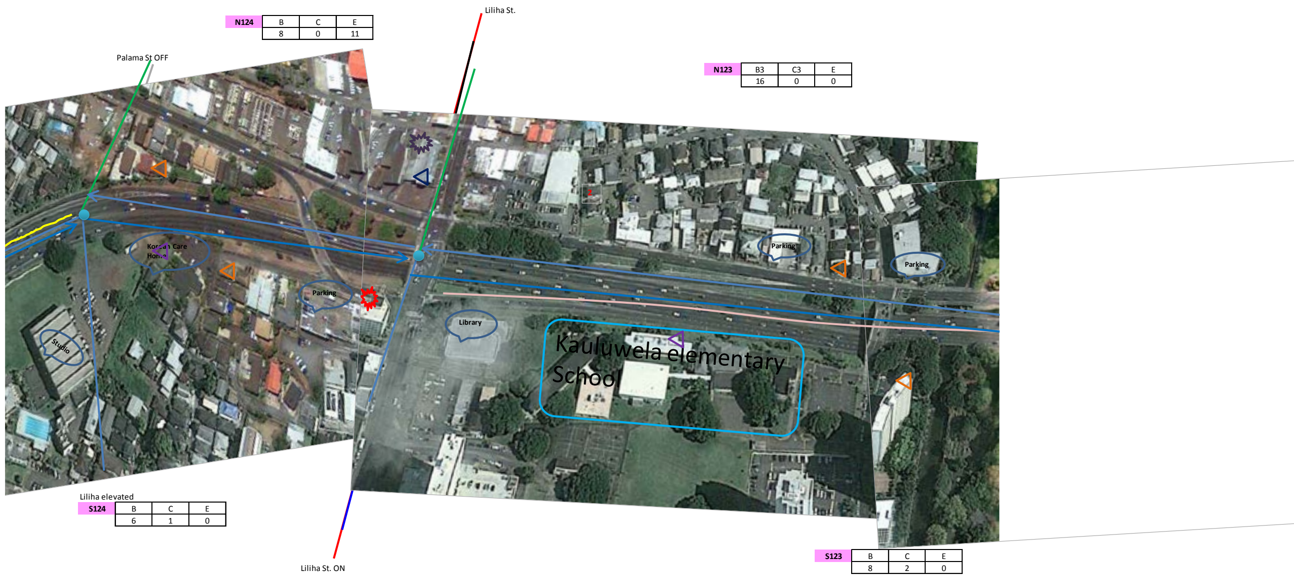


Figure 3.1. Count of representative receptors.

All the representative receptors were marked and labeled in a *Google Earth* file. The number of receptors that a representative receptor represents was counted and recorded as detailed in Appendix A and summarized in Table 3.2. This was a painstaking and tedious task, and team of three double checked the work. Nevertheless, small variances as to the exact number of front row receptors are likely because we cannot always know how many separate housing units a row of windows in a building fronting the highway might contain. A similar uncertainty is present for office building. Buildings, not individual offices are reflected in the count. Even if all offices are counted in a detailed survey, office occupancy is typically a portion of the set (e.g., 70% occupancy).

Coordinates X, Y, Z and H: X and Y coordinates were measured by the ruler tool of *Google Earth*. The horizontal position to the centerline is X, and the vertical position is Y. The Z coordinate is the elevation difference between the freeway centerline and the receptor. A positive Z indicates that the receptor is above the roadway, and a negative value indicates that the receptor is under it. Measure H represents the height of the ear of a typical person above Z; H was uniformly set equal to 5 ft.

Table 3.2 displays a small sample of the geometric data of six segments 130, 129 and 128 and their receptors (prefix **N** for mauka and **S** for makai side segments). The full data set is included in Appendix B.

Table 3.2. Representative Receptors of Land Use Types B, C and E

Segment	B				C				E				Length (ft)
	No.	X	Y	Z	No.	X	Y	Z[1]	No.	X	Y	Z	
N130	13	1,303	122	10	2	233	177	20	0				1,471
N129	18	113	93	5	1	1,197	199	14	0				1,826
N128	4	200	102	0	2	953	80	10	0				1,696
……													

Notes	1	Z over 10 ft. = freeway is depressed / z under -10 ft. = freeway is elevated

Segment	B				C				E				Length (ft)
	No.	X	Y	Z	No.	X	Y	Z[1]	No.	X	Y	Z	
S130	0				1	772	-83	10	0				1,471
S129	14	1154	-85	12	2	1673	-160	14	0				1,826
S128	7	105	-71	10	0				1	1497	-90	0	1,696
……													

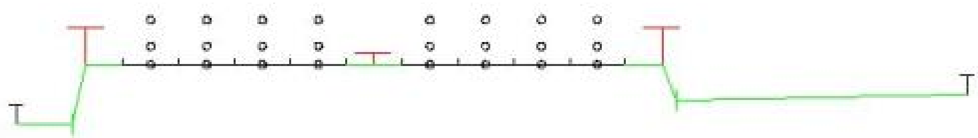
Notes	1	Z over 10 ft. = freeway is depressed / z under -10 ft. = freeway is elevated

3.3. Terrain Lines

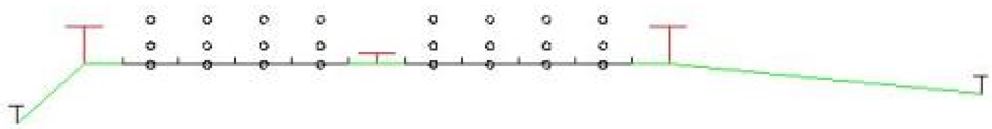
A terrain line can be added to define the topography in places where the highway is elevated or depressed while at the same time, a gradual slope is not present. In other words, without a user-input terrain line, TNM assumes a direct slope to the nearest receptor if the receptor is located higher or lower than the road. As shown in Figure 3.2, TNM will generate higher traffic noise in (a.2) and (b.2), when the receptors are located on a gradually sloping land. In the case of natural rock or retaining wall structures as (a.1) and (b.1) show, the terrain line at shields the receptors like a natural barrier and at least partially reduces the noise level. Terrain lines inform TNM of such sharp changes at the edge of the roadway and they need to be input, if applicable, in order to obtain realistic estimates of noise levels.

(a.1)

(a.2)



(b.1)



(b.2)

Figure 3.2. User input of applicable terrain lines versus TNM gradual slope assumption for (a) depressed highway, and (b) elevated highway.

The inputs of terrain lines include X, Y, and Z coordinates. The Z value of a terrain line is the elevation difference with the roadway. X and Y coordinates are determined by the length of the terrain and the distance to the roadway centerline.

4. Segment Traffic Data

4.1. Overview

Volume, speed and vehicle classification are the traffic data needed for modeling. Speed and volume data for the most recent full year (2012) were downloaded from an intranet HDOT site. Four stations in the database contain both volume and speed data: SL15 (at Kalihi St.), SL23 (at Kapalama Stream Bridge), 724A (at McCully St.), and SL58 (at Manoa/Palolo Drainage Canal). Six days of data were selected, avoiding weekends and holidays. The data from these stations are detailed in Appendix C.

The days selected for data extraction were Tuesday, Wednesday, and Thursday in the first week of May and the last week of September, all which were normal school days. These data were used to adjust comprehensive 1996 to 1998 ramp-by-ramp data collected for a freeway analysis project conducted for HDOT by Dr. P. Prevedouros. The 2012 data were used to (a) define speeds, (b) to adjust the 1996 to 1998 volume data, and (c) to generate mainline volume splits by lane, as required by TNM. Also Dr. A. R. Archilla’s pavement project for HDOT provided us with a comprehensive table with vehicle classification data.

4.2. Volume Adjustments and Volume/hour/lane

TNM needs hourly volume of each segment being modeled, separately for each lane of the subject highway. Year 2012 data at four locations were used to adjust the volumes on H-1 Freeway taken in the late 1990s. It was observed that no adjustment was necessary for the 6 AM to 7 AM TNM modeling period. A +34% adjustment was necessary for the 5 PM to 6 PM TNM modeling period and a +51% adjustment was necessary for the 7 PM to 8 PM TNM modeling period. These data suggest roughly 15 years later, traffic on the H-1 freeway is expanding on hours surrounding the traditional peaks. As Figure 4.1 indicates the 2012 volume data were consistent.

Volume/hour/lane data were generated by using the volume split per lane observed at the four stations with 2012. Table 4.1 shows the percentage of volume by lane was derived from the 2012 data sets, which was adjusted based on each segment’s location and experience.

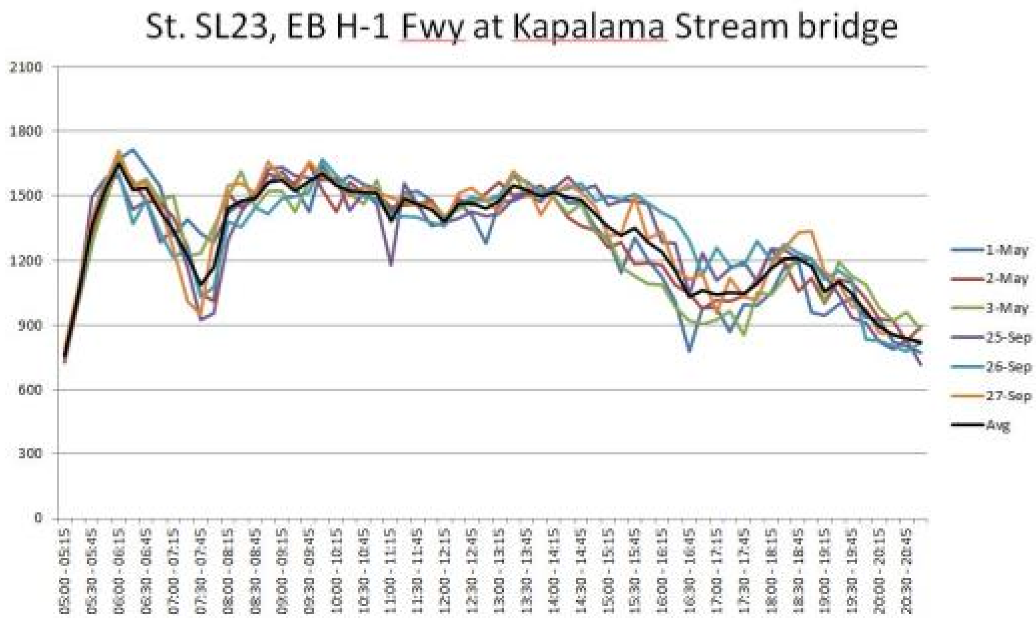


Figure 4.1. Sample 2012 volume data of station SL.23 – color lines represent the volume/hour/direction, and the black line represents the average of the six days.

Table 4.1. Percentage of Volume by Lane

Westbound	L1[1]	L2	L3	L4
6:00-7:00 AM				
Kalihi St. to Middle St.	**30%**	**30%**	**40%**	
Vineyard on to Kalihi St.	**30%**	**28%**	**30%**	**12%**
Pali to Vineyard on	**35%**	**33%**	**32%**	
Punahou St. to Pali off	**28%**	**25%**	**28%**	**19%**
Kapiolani off to Punahou St.	**35%**	**33%**	**32%**	
Kahala to Kapiolani off	**30%**	**28%**	**30%**	**12%**
5:00-6:00 PM				
Kalihi St. to Middle St.	**30%**	**30%**	**40%**	
Vineyard on to Kalihi St.	**28%**	**25%**	**28%**	**19%**
Pali to Vineyard on	**33%**	**35%**	**32%**	
Punahou St. to Pali off	**28%**	**25%**	**28%**	**19%**
Kapiolani off to Punahou St.	**35%**	**33%**	**32%**	
Kahala to Kapiolani off	**32%**	**30%**	**32%**	**6%**
7:00-8:00 PM				
Kalihi St. to Middle St.	**33%**	**33%**	**34%**	
Vineyard on to Kalihi St.	**30%**	**30%**	**30%**	**10%**
Pali to Vineyard on	**30%**	**40%**	**30%**	
Punahou St. to Pali off	**28%**	**25%**	**28%**	**19%**
Kapiolani off to Punahou St.	**30%**	**40%**	**30%**	
Kahala to Kapiolani off	**32%**	**30%**	**32%**	**6%**

Eastbound	L1	L2	L3	L4
6:00-7:00 AM				
Middle St. to Vineyard off	**30%**	**30%**	**27%**	**13%**
Vineyard off to Vineyard on	**25%**	**35%**	**40%**	
Vineyard on to Punahou St.	**28%**	**25%**	**25%**	**22%**
Punahou St. to Kapiolani on	**25%**	**35%**	**40%**	
Kapiolani on to Kahala	**25%**	**25%**	**25%**	**25%**
5:00-6:00 PM				
Middle St. to Vineyard off	**28%**	**25%**	**25%**	**22%**
Vineyard off to Vineyard on	**33%**	**33%**	**34%**	
Vineyard on to Punahou St.	**28%**	**25%**	**25%**	**22%**
Punahou St. to Kapiolani on	**33%**	**33%**	**34%**	
Kapiolani on to Kahala	**25%**	**25%**	**25%**	**25%**
7:00-8:00 PM				
Middle St. to Vineyard off	**25%**	**33%**	**30%**	**12%**
Vineyard off to Vineyard on	**35%**	**35%**	**30%**	
Vineyard on to Punahou St.	**25%**	**33%**	**30%**	**12%**
Punahou St. to Kapiolani on	**35%**	**35%**	**30%**	
Kapiolani on to Kahala	**25%**	**25%**	**25%**	**25%**

([1]) L1 is the median lane,L4 is the shoulder lane.

4.3. Speed

The speed of each segment was derived directly from four HDOT continuous data stations using six days in 2012. The detailed data from the four stations, one of which is shown in Figure 4.2 (top) formed the basis along with experience to derive the applicable speed data for uniform sections by time of day, a sample of which is shown in Figure 4.2 (bottom). The traffic data of each segment for each of the three periods are listed in Table 4.2. Detailed speed data are included in Appendix D. The corresponding volume data are in Appendix E.

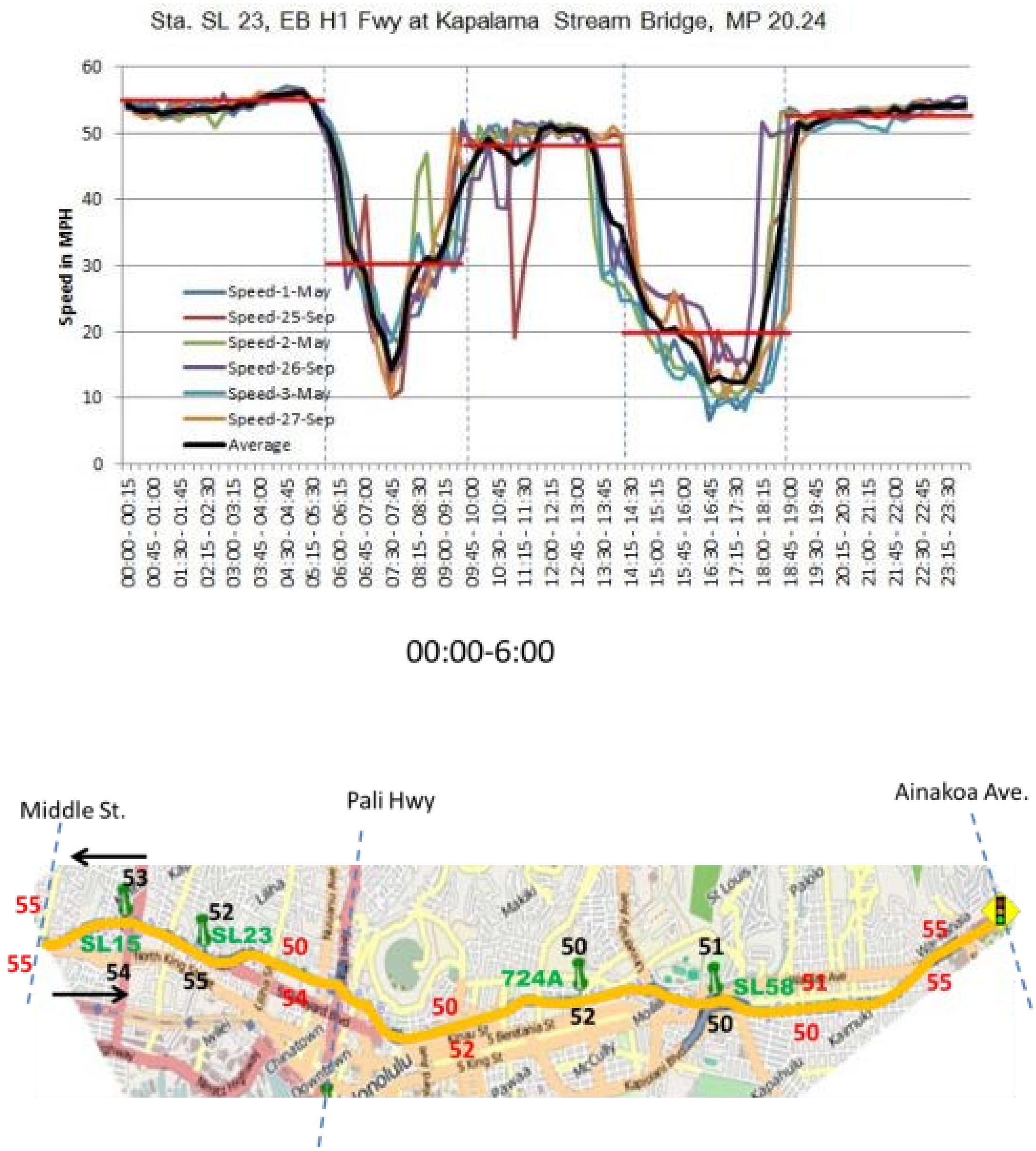


Figure 4.2. Sample 2012 speed data from station SL.23 (top) and sectional average speeds along the H-1 Freeway (bottom).

Table 4.2. Summary of Traffic Data of All Segments

(a) Traffic Data – Eastbound Segments

	6:00 -7:00 AM					5:00 - 6:00 PM					7:00 - 8:00 PM				
Segment	Speed	L1	L2	L3	L4	Speed	L1	L2	L3	L4	Speed	L1	L2	L3	L4
S102	55	232	232	232	232	55	969	969	969	969	55	618	618	618	618
S103	50	268	268	268	268	50	1,154	1,154	1,154	1,154	50	625	625	625	625
S104	50	268	268	268	268	50	1,154	1,154	1,154	1,154	50	625	625	625	625
S105	50	378	378	378	378	50	1,452	1,452	1,452	1,452	50	783	783	783	783
S106	50	378	378	378	378	50	1,452	1,452	1,452	1,452	50	783	783	783	783
S107	50	552	552	552	552	50	1,766	1,766	1,766	1,766	50	983	983	983	983
S108	50	552	772	883		50	2,331	2,331	2,401		50	1,377	1,377	1,180	
S109	50	463	648	740		50	1,588	1,588	1,636		50	969	969	830	
S110	50	702	982	1,122		50	1,909	1,909	1,967		50	1,229	1,229	1,053	
S111	52	844	1,182	1,351		52	2,058	2,058	2,120		52	1,321	1,321	1,133	
S112	52	815	1,141	1,304		52	1,887	1,887	1,944		52	1,208	1,208	1,035	
S113	30	966	1,352	1,545		30	2,091	2,091	2,154		52	1,370	1,370	1,174	
S114	30	1,082	966	966	850	30	1,774	1,584	1,584	1,394	52	979	1,292	1,174	470
S115	30	1,545	1,379	1,379	1,214	30	2,176	1,943	1,943	1,710	52	1,342	1,772	1,611	644
S116	30	1,487	1,328	1,328	1,169	30	1,925	1,719	1,719	1,513	52	1,221	1,612	1,466	586
S117	30	1,487	1,328	1,328	1,169	30	1,925	1,719	1,719	1,513	52	1,221	1,612	1,466	586
S118	30	1,414	1,262	1,262	1,111	30	1,702	1,520	1,520	1,337	52	1,065	1,405	1,277	511
S119	30	1,166	1,633	1,866		30	1,559	1,559	1,606		52	1,189	1,189	1,019	
S120	30	1,588	2,223	2,541		30	1,987	1,987	2,047		52	1,547	1,547	1,326	
S121	30	1,221	1,709	1,953		30	1,557	1,557	1,604		53	1,264	1,264	1,083	
S122	30	1,391	1,947	2,225		30	1,643	1,643	1,693		53	1,359	1,359	1,165	
S123	30	1,614	2,259	2,582		30	1,934	1,934	1,993		53	1,610	1,610	1,380	
S124	30	1,423	1,992	2,276		30	1,637	1,637	1,686		53	1,403	1,403	1,203	
S125	30	1,423	1,992	2,276		20	1,637	1,637	1,686		53	1,403	1,403	1,203	
S126	30	1,423	1,992	2,276		20	1,637	1,637	1,686		53	1,403	1,403	1,203	
S127	30	2,069	2,069	1,862	897	20	1,747	1,560	1,560	1,373	53	1,134	1,497	1,361	544
S128	20	2,069	2,069	1,862	897	20	1,747	1,560	1,560	1,373	52	1,134	1,497	1,361	544
S129	20	1,709	1,709	1,538	740	20	1,673	1,494	1,494	1,314	52	1,036	1,368	1,244	497
S130	20	1,709	1,709	1,538	740	20	1,673	1,494	1,494	1,314	55	1,036	1,368	1,244	497

(b) Traffic Data – Westbound Segments

	6:00 -7:00 AM					5:00 - 6:00 PM					7:00 - 8:00 PM				
Segment	Speed	L1	L2	L3	L4	Speed	L1	L2	L3	L4	Speed	L1	L2	L3	L4
N102	55	1,410	1,316	1,410	564	55	1,021	957	1,021	191	55	744	698	744	140
N103	30	1,410	1,316	1,410	564	52	1,021	957	1,021	191	52	744	698	744	140
N104	30	1,410	1,316	1,410	564	52	1,021	957	1,021	191	52	744	698	744	140
N105	30	1,410	1,316	1,410	564	52	1,021	957	1,021	191	52	744	698	744	140
N106	30	1,410	1,316	1,410	564	52	1,021	957	1,021	191	52	744	698	744	140
N107	30	1,577	1,471	1,577	631	52	1,192	1,118	1,192	224	52	863	809	863	162
N108	30	1,839	1,734	1,682		52	1,304	1,230	1,192		52	809	1,079	809	
N109	20	1,435	1,353	1,312		30	977	921	893		52	624	832	624	
N110	20	1,792	1,690	1,639		30	1,418	1,337	1,296		52	911	1,215	911	
N111	20	1,886	1,778	1,724		30	1,555	1,467	1,422		52	1,030	1,373	1,030	
N112	18	1,742	1,642	1,593		30	1,406	1,326	1,286		47	947	1,263	947	
N113	18	1,990	1,876	1,819		30	1,756	1,656	1,606		47	1,247	1,663	1,247	
N114	18	1,762	1,573	1,762	1,196	30	1,563	1,396	1,563	1,061	47	1,304	1,164	1,304	885
N115	18	1,618	1,445	1,618	1,098	30	1,403	1,252	1,403	952	47	1,141	1,019	1,141	774
N116	20	1,618	1,445	1,618	1,098	32	1,403	1,252	1,403	952	47	1,141	1,019	1,141	774
N117	20	1,618	1,445	1,618	1,098	32	1,403	1,252	1,403	952	47	1,141	1,019	1,141	774
N118	20	1,960	1,750	1,960	1,330	32	1,863	1,663	1,863	1,264	47	1,543	1,378	1,543	1,047
N119	20	1,608	1,435	1,608	1,091	32	1,643	1,467	1,643	1,115	47	1,376	1,229	1,376	934
N120	20	1,608	1,435	1,608	1,091	32	1,643	1,467	1,643	1,115	47	1,376	1,229	1,376	934
N121	20	1,832	1,728	1,675		32	1,537	1,630	1,490		47	1,198	1,597	1,198	
N122	40	1,959	1,847	1,791		35	1,834	1,945	1,778		47	1,402	1,869	1,402	
N123	40	1,843	1,738	1,685		35	1,733	1,838	1,680		47	1,321	1,761	1,321	
N124	40	2,278	2,147	2,082		35	2,162	2,293	2,096		47	1,571	2,095	1,571	
N125	40	2,234	2,107	2,043		35	2,115	2,243	2,051		47	1,534	2,046	1,534	
N126	40	1,915	1,788	1,915	766	36	1,795	1,602	1,795	1,218	47	1,534	1,534	1,534	511
N127	40	1,873	1,748	1,873	749	36	2,099	1,874	2,099	1,424	47	1,654	1,654	1,654	551
N128	40	1,765	1,765	2,353		36	1,975	1,975	2,633		47	1,563	1,563	1,610	
N129	45	2,165	2,165	2,887		45	2,240	2,240	2,986		51	1,801	1,801	1,856	
N130	55	2,091	2,091	2,789		55	2,175	2,175	2,900		55	1,752	1,752	1,805	

4.4. Vehicle Classification

TNM models five vehicle types: Light duty vehicles (cars, vans and pickup trucks), medium trucks, heavy trucks, buses, and motorcycles. A pavement analysis data set for the Middle St. cross section provided by Dr. A. R. Archilla was used to derive representative classification data. The percentage of each vehicle type used in this TNM analysis was as follows:

- Automobiles: 94.6%
- Medium trucks: 4.3%
- Heavy trucks: 0.3%
- Buses: 0.4%
- Motorcycles: 0.4%

5. Results

A noise barrier analysis was conducted with TNM for **existing conditions** (representing average workday 2012 conditions) and with a uniform **10 ft. high noise barrier** applied on both sides to all segments in the analysis. Tables 5.1, 5.2, and 5.3 summarize the predicted sound level results for the three periods (6-7 AM, 5-6 PM, and 7-8 PM periods). Each table shows the noise levels of the representative receptor on each segment (numbered 102 to 130) along the mauka and makai sides of the freeway. The noise level, existing (orange columns) and with barriers (white columns), is displayed side by side for land use B and C type of receptors.[1] The **blue** numbers indicate that the noise level estimates are **below** the Noise Abatement Criterion of 66 dBA.

The morning period results are shown in Table 5.1. They indicate that for land use B on the mauka side 11 segments are below NAC and 18 segments are at or above NAC, whereas on the makai side 10 segments are below NAC and 17 segments are at or above NAC. For land use C on the mauka side two segments are below NAC and 10 segments are at or above NAC, whereas on the makai side five segments are below NAC and seven segments are at or above NAC. The lowest noise level of 54.3 dBA is estimated on segment 119 on the makai side (at Queens Medical Center). The highest noise level of 73.7 dBA is estimated on segment 112 on the makai side (downstream the eastbound Bingham St. off-ramp in Moiliili).

The morning period results improve substantially with 10 ft. high noise barriers. On both directions, 47 segments are estimated to be below NAC and 11 segments are at or above NAC. The highest noise level of 72.8 dBA with a 10 ft. wall is estimated on segment 128 because a 10-12 ft. wall is present there (e.g., makai retaining wall, Gullick St. to Kalihi St. bridge). Obviously locations where a 10 ft. or taller wall is presently there for structural reason do not see a noise level improvement if a 10 ft. noise wall is modeled.

The afternoon period results are shown in Table 5.2. They indicate that for land use B on the mauka side seven segments are below NAC and 22 segments are at or above NAC, whereas on the makai side seven segments are below NAC and 20 segments are at or above NAC. For land use C on the mauka side three segments are below NAC and nine segments are at or above NAC, whereas on the makai side four segments are below NAC and eight segments are at or above NAC. The lowest noise level of 55.7 dBA is estimated on segment 119 on the makai side (at Queens Medical Center). The highest noise level of 78.5 dBA is estimated on segment 107 on the makai side (near 3rd Ave).

[1] The corresponding results of **land use type E** are presented in Appendix F.

The afternoon period results improve substantially with 10ft. high barriers. On both directions, 42 segments are estimated to be below NAC and 16 segments are at or above NAC. The highest noise level of 76.8 dBA is estimated on segment 103 on the north side (near 13th Ave.). These receptors are located on rocky elevated terrain that is over 10 ft. above the freeway roadbed. A noise wall treatment would have to employ 16 - 20 ft. high noise walls in order to be effective at this location.

The night period results are shown in Table 5.3. They indicate that for land use B on the mauka side four segments are below NAC and 25 segments are at or above NAC, whereas on the makai side five segments are below NAC and 22 segments are at or above NAC. For land use C on the mauka side three segments are below NAC and nine segments are at or above NAC, whereas on the makai side two segments are below NAC and ten segments are at or above NAC. The lowest noise level of 59 dBA is estimated on segment 119 on the makai side (at Queens Medical Center). The highest noise level of 78.6 dBA is estimated on segment 115 on the makai side (located between the Keeaumoku St. overpass and Liholiho St. in Makiki).

The night period results improve substantially with 10 ft. high barriers. On both directions, 38 segments are estimated to be below NAC and 20 segments are at or above NAC. The highest noise level of 76 dBA is estimated on segment 114 (near Makiki St.); at this location the receptor is only about 20 ft. from the nearest lane.

Sample noise contours of section 112 in Moiliili (between westbound Wilder Ave. off-ramp and the McCully St. overpass) are shown in Figures 5.1 to 5.3. They display the estimated contours for a distance of 250 ft. around the center line under both existing conditions and with 10 ft. noise barriers.

Table 5.1. TNM Results of Receptors Type B & C, 6-7 AM

	Baseline dBA[2] (hourly L_{eq})				L_{eq} dBA with 10 ft. barrier[3]			
	North (mauka)				South (makai)			
Segment[1]	B		C		B		C	
102	67.9	67.9			69.6	69.6		
103	71.4	71.4	66.5	66.5	68.0	68.0		
104	70.7	59.6	66.4	62.9	64.3	55.7		
105	64.2	56.1	66.1	55.9	59.9	54.8		
106	72.0	58.5			71.1	59.2		
107	72.0	61.1			73.6	61.6		
108	63.7	56.4			70.0	58.9	65.6	56.9
109	67.2	56.2			67.9	57.3		
110	70.8	59.6			72.5	60.8		
111	69.9	61.6	69.8	63.5	73.1	61.0	64.8	54.9
112	72.3	61.3			73.7	62.0		
113	70.0	60.2			69.1	63.0	63.2	62.7
114	70.7	59.1	66.2	66.2	71.2	69.3	68.4	59.9
115	69.1	59.4			72.6	59.2		
116	69.4	59.8			57.1	54.3		
117	66.6	66.5			58.8	55.0	69.6	59.3
118	64.9	64.9	60.8	60.8	65.4	65.4		
119	64.4	64.4			65.8	64.7	54.3	54.2
120	63.6	63.4			72.3	61.1		
121	58.5	57.8					67.7	59.0
122	60.5	60.5			59.1	58.9		
123	63.3	63.3			65.4	59.3	70.7	63.5
124	73.4	63.9			64.6	64.1	68.8	64.2
125	64.9	58.5	66.7	57.6	64.6	57.1		
126	70.4	59.7	71.8	60.7	70.0	59.3		
127	69.7	60.1	71.1	61.1	71.2	61.9	67.0	59.1
128	72.4	61.3	73.0	68.7	72.8	72.8		
129	63.9	63.2	70.0	62.4	72.7	72.7	62.9	62.9
130	61.0	61.0	63.2	62.8			69.6	68.3

Notes		
	1	102= Kahala Mall, 130 = Middle St.
	2	Based on 2012 sample volumes and speeds
	3	Located on the edge of each shoulder, nearest to the affected receptors
	60.2	L_{eq} estimate is below NAC

Table 5.2. TNM Results of Receptors Type B & C, 5-6 PM

	Baseline dBA[2] (hourly L_{eq})				L_{eq} dBA with 10 ft. barrier[3]			
	North (mauka)				South (makai)			
Segment[1]	B		C		B		C	
102	70.0	70.0			73.2	73.1		
103	76.8	76.8	72.1	72.1	67.5	67.5		
104	75.6	63.9	71.6	68.6	70.5	61.2		
105	67.7	59.9	71.0	60.1	65.5	59.9		
106	76.9	62.4			76.7	64.4		
107	76.8	65.2			78.5	66.2		
108	68.0	60.3			74.8	63.5	70.2	61.3
109	70.1	58.8			71.6	60.9		
110	72.3	60.8			73.9	62.1		
111	72.4	63.6	72.2	65.6	75.6	63.5	67.2	57.2
112	74.7	63.3			76.0	64.2		
113	72.5	61.9			71.2	65.1	65.4	65.0
114	73.3	61.0	68.3	68.3	73.4	71.6	70.6	60.7
115	71.4	60.9			74.1	60.6		
116	71.7	61.4			58.3	55.4		
117	68.6	68.5			59.9	56.2	71.0	60.5
118	66.3	66.3	62.4	62.4	67.8	67.8		
119	65.0	65.0			67.7	67.1	55.7	55.7
120	64.2	63.8			72.4	61.5		
121	59.0	57.8					68.4	59.9
122	59.6	59.6			58.1	57.9		
123	62.5	62.4			64.4	58.5	69.9	62.7
124	72.1	62.9			63.6	63.1	67.8	63.3
125	63.6	57.3	65.3	56.3	62.3	55.4		
126	69.1	58.6	70.5	59.5	67.7	57.8		
127	69.4	59.8	70.4	60.6	69.9	61.1	65.7	58.2
128	71.8	60.9	72.4	68.4	72.0	72.0		
129	64.0	63.3	70.1	62.6	72.6	72.6	63.0	63.0
130	66.8	66.1	62.8	62.8			69.8	69.6

Notes		
	1	102= Kahala Mall, 130 = Middle St.
	2	Based on 2012 sample volumes and speeds
	3	Located on the edge of each shoulder, nearest to the affected receptors
	60.2	L_{eq} estimate is below NAC

Table 5.3. TNM Results of Receptors Type B & C, 7-8 PM

	Baseline dBA[2] (hourly L_{eq})				L_{eq} dBA with 10 ft. barrier[3]			
	North (mauka)				South (makai)			
Segment[1]	B		C		B		C	
102	68.2	68.2			71.4	71.3		
103	74.9	74.9	69.9	69.9	65.4	65.4		
104	74.0	62.0	69.7	66.2	67.9	58.7		
105	66.0	58.1	69.8	57.9	62.7	57.5		
106	75.2	60.6			74.1	62.0		
107	75.2	63.3			76.1	64.0		
108	66.5	58.4			72.4	61.3	67.7	59.1
109	71.8	59.0			69.3	59.2		
110	74.5	61.5			72.7	61.6		
111	74.3	63.7	73.7	65.1	74.0	62.6	66.0	56.6
112	76.6	63.8			74.4	63.0		
113	76.7	64.9			75.4	68.6	69.2	68.7
114	77.5	64.3	72.3	72.3	77.5	76.0	74.7	63.6
115	75.5	64.2			78.6	63.8		
116	75.5	64.4			61.6	58.1		
117	72.5	72.5			63.1	59.1	75.5	63.6
118	70.7	70.7	65.9	65.9	72.0	71.9		
119	69.4	69.4			71.7	70.9	59.0	58.9
120	68.1	67.3			77.1	64.8		
121	63.0	62.0					73.1	63.4
122	63.1	63.1			61.2	61.0		
123	66.5	66.5			68.5	61.3	74.4	65.7
124	75.0	65.5			67.0	66.2	72.2	66.6
125	59.7	59.5	59.3	59.0	59.3	59.1		
126	72.1	61.2	73.4	62.2	73.5	61.1		
127	71.2	61.5	73.2	62.9	74.9	64.0	70.8	61.5
128	74.4	63.4	75.7	73.3	77.4	77.4		
129	65.2	64.7	71.8	65.0	75.9	75.9	64.5	64.5
130	68.6	68.0	64.6	64.6			69.7	68.3

Notes		
	1	102= Kahala Mall, 130 = Middle St.
	2	Based on 2012 sample volumes and speeds
	3	Located on the edge of each shoulder, nearest to the affected receptors
	60.2	L_{eq} estimate is below NAC

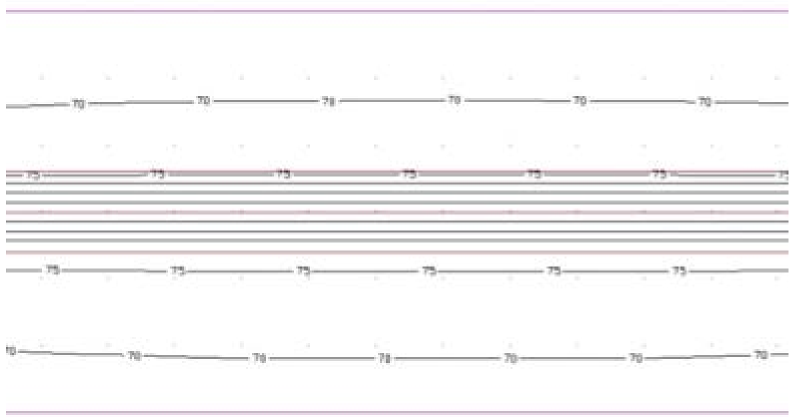


Figure 5.1.a. Contour analysis of segment 112, 6-7 AM, with existing conditions.

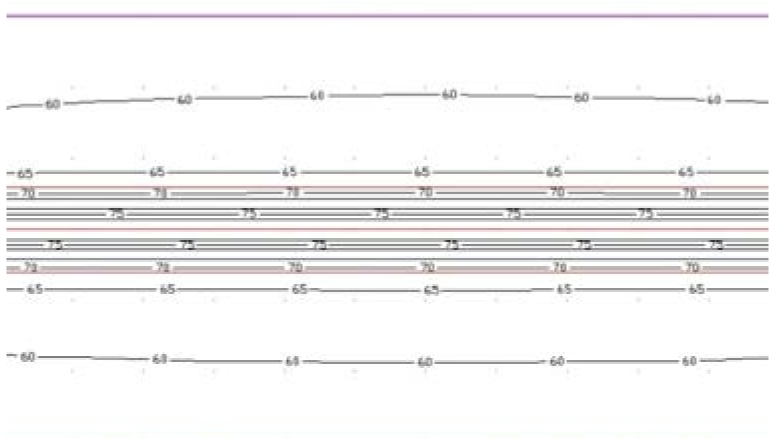


Figure 5.1.b. Contour analysis of segment 112, 6-7 AM, with 10 ft. barrier.

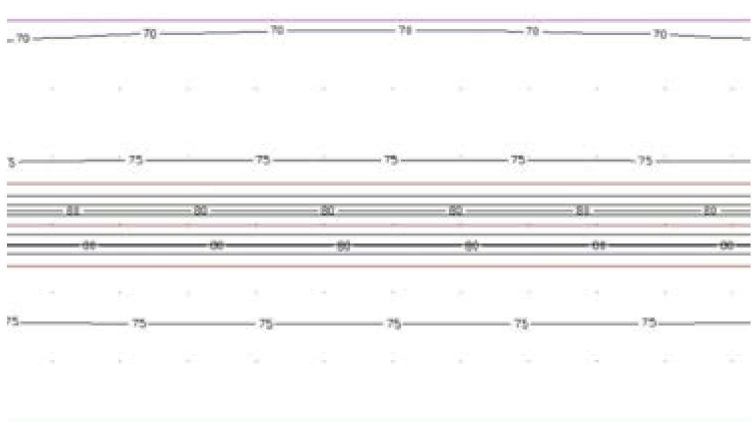


Figure 5.2.a. Contour analysis of segment 112, 5-6 PM, with existing conditions.

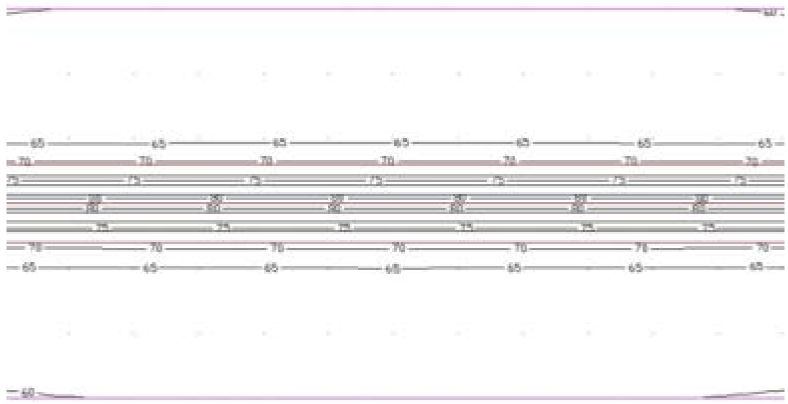


Figure 5.2.b. Contour analysis of segment 112, 5-6 PM, with 10 ft. barrier.

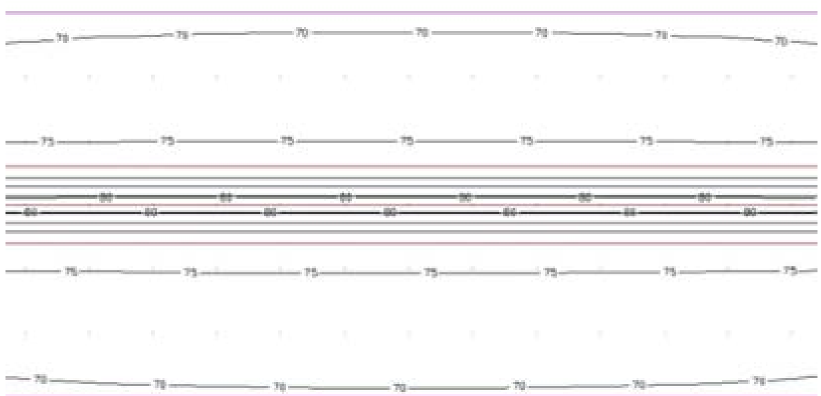


Figure 5.3.a. Contour analysis of segment 112, 7-8 PM, with existing conditions.

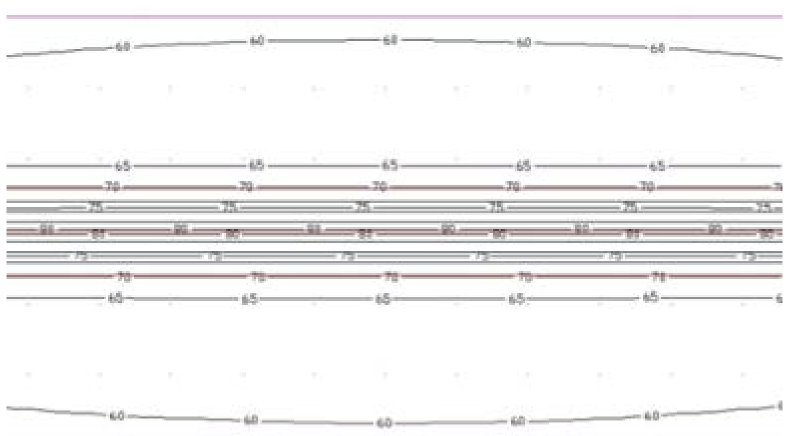


Figure 5.3.b. Contour analysis of segment 112, 7-8 PM, with 10 ft. barrier.

The main results of this study for all 29 north (mauka) side and 29 south (makai) side segments of the H-1 Freeway were encoded into *Google Earth* files that combine *Google Maps*. Color coded results by segment and pop-up tables of noise estimates for each representative receptor by time period examined facilitate agency and public viewing. The six files developed as part of this project are listed below:

1. **H-1.Receptors.kmz**: Displays every receptor using a yellow ear. Includes the coordinates of each receptor.
2. **H-1.Segmentation.kmz**: H-1 Freeway segments of analysis are demarcated by white markers. Includes the length of each segment.
3. **H-1.Noise.Results.kmz**: By clicking on the yellow ear next to the receptor label, a mini table pops up to display TNM-derived noise level without and with a barrier in the AM peak, PM peak and night periods.
4. **H-1.AM.color.kmz**: Color coded noise level results for existing conditions in 6:00 - 7:00 AM period. In **green** sections the noise level is 62.4 dBA or below. In **orange** sections the noise level is between 62.5 dBA and 69.4 dBA. In **red** sections the noise level is 69.5 or above.[2]
5. **H-1.PM.color. kmz**: Color coded noise level results for existing conditions in 5:00 - 6:00 PM. (Same ranges as above.)
6. **H-1.Night.color. kmz**: Color coded noise level results for existing conditions in 7:00 - 8:00 PM. (Same ranges as above.)

The first time user is suggested to open the third file first (**3.H-1.Noise.Results.kmz**) to identify the freeway and all the representative receptors used in this study as well as the results for each receptor. The view on the computer monitor should look similar to Figure 5.4 (top screen).

Then click off or remove the contents of this file and open the last file (**6.H-1.Night.color.kmz**) for a colorful overview of the results in the critical 7 PM to 8 PM time period. (Click off the

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[2] The logic behind the 3-class sorting of the results begins with the NAC standard of 66 dBA in the ***Highway Noise Policy and Abatement Guidelines***. The NAC in both FHWA and HDOT policies is stated as a integer which means that decimals need to be truncated.

On the lower side, 65.5 truncates to 66 dBA. A fundamental element of noise perception by humans is that they cannot discern a noise that is up to 3 dBA louder or quieter than a reference noise. So 65.5-3= 62.5 dBA established the lower cutoff point. On the upper side, 66.4 truncates to 66 dBA. So 66.5+3=69.5 dBA established the upper cut off point. The lower and upper cutoff points define the low, moderate and high noise ranges:

- A noise estimate below 62.5 dBA is well below the NAC (low noise range, marked **green**).
- A noise estimate between 62.5 and 69.4 dBA is ±3 dBA human noise perception range around the HDOT NAC (moderate noise range, marked **orange**).
- A noise estimate above 69.5 perceptibly exceeds the HDOT NAC (high noise range, marked **red**).

"sketch_cutting points" option for best viewing.) The view on the computer monitor should look similar to Figure 5.4 (bottom screen).

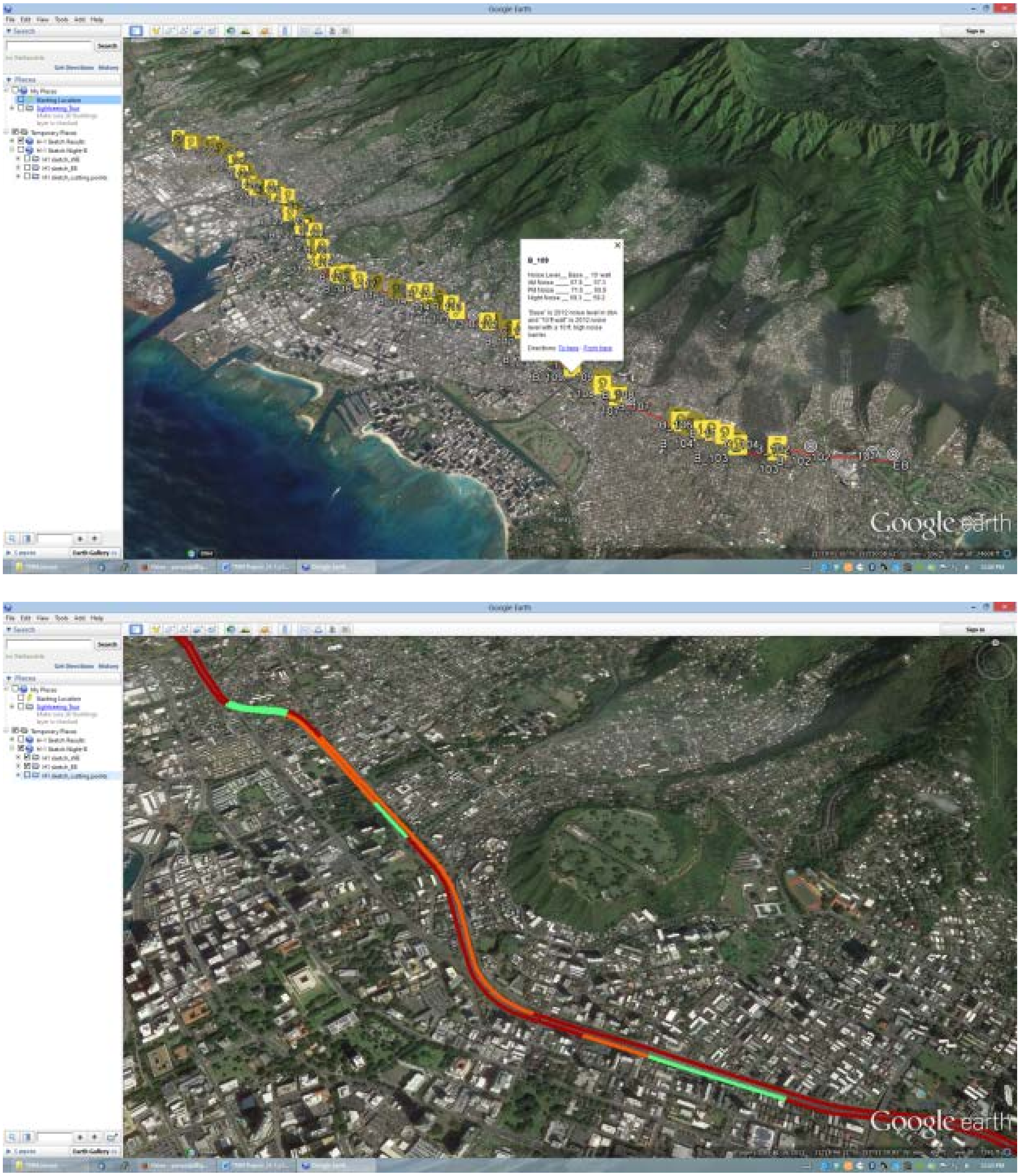

Figure 5.4. Google Earth results: depiction of receptors and sample results for receptor B 109 (top); and color coded results for weekday night time operations (bottom).

6. Assessment

According to ***Highway Noise Policy and Abatement Guidelines***, the highway noise results from either field surveys or TNM must be subjected to feasibility and reasonableness analysis to assess whether the potential installation of noise barriers for noise abatement is appropriate. Feasibility analysis is defined as achievement of at least a 5 dBA highway traffic noise reduction. Reasonableness of the potential installation of noise barriers for noise abatement is defined as achievement of a noise reduction design goal of 7 dBA for 75% of the benefiting front-row receptors along the modeled freeway. The 75% goal was calculated as the sum-product of noise reduction and number of units affected in each type of receptors per section, then divided by the amount of receptors in that section.

The assessment results were grouped into four outcome categories:

- **N** is the worst case outcome: the 10 ft. barriers cannot yield a noise reduction of at least 5 dBA and the noise reduction does not meet the 75% design goal.
- **N,↑** represents a special case: the barriers cannot yield a noise reduction of at least 5 dBA traffic noise or the noise reduction does not fulfill the 75% design goal, because receptors are located on elevated terrain, therefore the 10 ft. barrier is ineffective.
- **Y** represents a promising outcome: the 10 ft. barriers can yield a noise reduction of at least 5 dBA and the noise reduction fulfills the 75% design goal.
- **below NAC** represents the best case: traffic noise is below 66 dBA without any barrier other than any naturally occurring differences in elevation.

Table 6.1 summarizes the assessment results in terms of freeway segments and length. It shows that the morning peak hour is the quietest one among the three periods examined, which is also a reflection of slow traffic flow during that time. The night hour 7:00 to 8:00 PM is the noisiest time in a day. There is an obvious reduction in numbers of **Y** and **below NAC,** and an increase in **N** and **N**,**↑** outcomes. Although the traffic flow during the night hour is lower compared to the peak hours in the morning and the afternoon, average speeds are high due to the free flow conditions, which in turn creates more noise. Tables 6.1, 6.2 and 6.3 detail the feasibility and reasonableness analysis outcomes.

The final assessment in Table 6.1, 7-8 PM conditions, suggest that about 17% of the segments or 1.08 out of 7.66 miles of central H-1 Freeway have traffic noise levels below the NAC, that is below the level that requires noise abatement. A near majority portion of 48% or 3.83 out of 7.66 miles have a noise level above the NAC that can be mitigated using 10 ft. noise barriers. About one third (31%) or 2.44 out of 7.66 miles have a noise level above the NAC that cannot be mitigated using 10 ft. noise barriers because the receptors are located above 10 ft. from the roadway. A very small portion of 3% or 0.32 out of 7.66 miles have a major traffic noise problem that would require tall barriers (well over 10 ft.) to mitigate.

Using a 2007 estimate by HDOT's design section updated to 2013, a 10 ft. wall may cost approximately $800 per linear foot including design, construction engineering and administration. Based on this and the lengths examined herein, abatement using 10 ft. noise barriers may cost about $32 million for segments **Y**.

Table 6.1. Summary of Feasibility and Reasonableness Analysis by Segments and Length

(a) Affected Number of Segments

	Percent of Segments		
Type of Assessment Results	6:00-7:00 AM	5:00-6:00 PM	7:00-8:00 PM
N	3%	3%	3%
N,↑	17%	28%	31%
Y	52%	55%	48%
below NAC	28%	14%	17%

(b) Affected Freeway Length (miles)

	Affected Length of H-1 (miles)		
Type of Assessment Results	6:00-7:00 AM	5:00-6:00 PM	7:00-8:00 PM
N	0.32	0.32	0.32
N,↑	1.43	2.10	2.44
Y	4.04	4.18	3.83
below NAC	1.88	1.06	1.08

The ***Highway Noise Policy and Abatement Guidelines*** specify that "Abatement costing up to $60,000 per benefitted receptor is deemed to be reasonable for cost." There are 597 Land Use B first floor units fronting the examined length of the H-1 Freeway. The approximate estimate of $32,000,000 divided by 597 yields a per-unit cost of $53,600, therefore the provision of traffic noise abatement on these segments is reasonable for cost.

These 597 units are located along **Y** segments 104 near Kokohead Ave., 106 to 113 (11th Avenue to Punahou St.), 115 to 116 (Lunalilo St. off-ramp to Lunalilo St. on-ramp), 124 (Liliha St. to Palama St.), 126 to 127 (Palama St. to Houghtailing off-ramp), where the freeway is at grade, elevated or the receivers are located slightly above the road (less than 10 ft.). Along these segments, noise barriers can reduce the noise level by at least 5 dBA, and exceed the stated 75% for the 7 dBA noise reduction design goal for front row receptors.

Table 6.2. Feasibility and Reasonableness of Noise Abatement for Receptors Type B & C, 6-7 AM

	Land Use B		Land Use C	
Segment[1]	At least 5 dBA noise reduction?	Meets [2] 75% goal?	At least 5 dBA noise reduction?	Meets 75% goal?
102	N,↑	na	na	na
103	N,↑	na	N,↑	na
104	Y	100%	N,↑	na
105	below NAC	na	Y	100%
106	Y	100%	na	na
107	Y	100%	na	na
108	Y	100%	below NAC	na
109	Y	100%	na	na
110	Y	100%	na	na
111	Y	100%	Y	100%
112	Y	100%	na	na
113	Y	100%	below NAC	na
114	N	83%	N,↑	na
115	Y	100%	na	na
116	Y	93%	na	na
117	N,↑	na	Y	100%
118	below NAC	na	below NAC	na
119	below NAC	na	below NAC	na
120	Y	80%	na	na
121	below NAC	na	Y	100%
122	below NAC	na	na	na
123	below NAC	na	Y	100%
124	Y	81%	N	66%
125	below NAC	na	Y	100%
126	Y	100%	Y	100%
127	Y	100%	Y	100%
128	N,↑	na	N	61%
129	N,↑	na	Y	36%
130	below NAC	na	N,↑	na

Notes		
	1	102= Kahala Mall, 130 = Middle St.
	2	Achieve the noise reduction design goal of 7 dBA for 75% of front-row receptors?
	↑	An up arrow indicates that the receiver is higher than the noise barrier, so a 10 ft. barrier is ineffective

Table 6.3. Feasibility and Reasonableness of Noise Abatement for Receptors Type B & C, 5-6 PM

	Land Use B		Land Use C	
Segment[1]	At least 5 dBA noise reduction?	Meets [2] 75% goal?	At least 5 dBA noise reduction?	Meets 75% goal?
102	N,↑	na	na	na
103	N,↑	na	N,↑	na
104	Y	100%	N,↑	na
105	Y	91%	Y	100%
106	Y	100%	na	na
107	Y	100%	na	na
108	Y	100%	Y	100%
109	Y	100%	na	na
110	Y	100%	na	na
111	Y	100%	Y	100%
112	Y	100%	na	na
113	Y	100%	below NAC	na
114	N	86%	Y	100%
115	Y	100%	na	na
116	Y	99%	na	na
117	N,↑	na	Y	100%
118	N,↑	na	below NAC	na
119	N,↑	na	below NAC	na
120	Y	79%	na	na
121	below NAC	na	Y	100%
122	below NAC	na	na	na
123	below NAC	na	Y	100%
124	Y	78%	N	64%
125	below NAC	na	below NAC	na
126	Y	100%	Y	100%
127	Y	100%	Y	100%
128	N,↑	na	N	57%
129	N,↑	na	Y	36%
130	N,↑	na	N,↑	na

Notes		
	1	102= Kahala Mall, 130 = Middle St.
	2	Achieve the noise reduction design goal of 7 dBA for 75% of front-row receptors?
	↑	An up arrow indicates that the receiver is higher than the noise barrier, so a 10 ft. barrier is ineffective

Table 6.4. Feasibility and Reasonableness of Noise Abatement for Receptors Type B & C, 7-8 PM

	Land Use B		Land Use C	
Segment[1]	At least 5 dBA noise reduction?	Meets [2] 75% goal?	At least 5 dBA noise reduction?	Meets 75% goal?
102	N,↑	na	na	na
103	N,↑	na	N,↑	na
104	Y	100%	N,↑	na
105	below NAC	na	Y	100%
106	Y	100%	na	na
107	Y	100%	na	na
108	Y	100%	Y	100%
109	Y	100%	na	na
110	Y	100%	na	na
111	Y	100%	Y	100%
112	Y	100%	na	na
113	Y	100%	N	7%
114	N	88%	N,↑	na
115	Y	100%	na	na
116	Y	100%	na	na
117	N,↑	na	Y	100%
118	N,↑	na	below NAC	na
119	N,↑	na	below NAC	na
120	N,↑	na	na	na
121	below NAC	na	Y	100%
122	below NAC	na	na	na
123	N,↑	na	Y	100%
124	Y	82%	N	80%
125	below NAC	na	below NAC	na
126	Y	100%	Y	100%
127	Y	100%	Y	100%
128	N,↑	na	N	34%
129	N,↑	na	Y	32%
130	below NAC	na	N,↑	na

Notes		
	1	102= Kahala Mall, 130 = Middle St.
	2	Achieve the noise reduction design goal of 7 dBA for 75% of front-row receptors?
	↑	An up arrow indicates that the receiver is higher than the noise barrier, so a 10 ft. barrier is ineffective

7. Recommendations

The purpose of this project was to provide a comprehensive first-time assessment of noise levels along the central part of the H-1 Freeway. The estimation of exact locations and types of abatement was not a goal of this project and more detailed analysis is necessary prior to the deployment of abatement at selected sections of the subject freeway. In addition it is important to acknowledge a recent report of the National Cooperative Highway Research Program titled ***Evaluating Pavement Strategies and Barriers for Noise Mitigation***[3] (TRB, 2013). The report presents interesting findings of providing highway noise mitigation by (a) barriers, (b) quiet pavement and (c) = (a) + (b). Case studies include examples of combining RAC(O) with 8, 10 and 12 ft. high noise barriers. RAC(O) stands for open-graded rubberized asphalt concrete.

One sample example in NCHRP 738 suggests that RAC(O) provides a lower noise reduction for a lower cost. Specifically RAC(O) achieved a reduction from 74 dBA to 69 dBA at a cost of $346,000. On the same section, a 10 ft. noise barrier installation achieved a reduction from 74 dBA to 66 dBA at a cost of $637,000.[4]

Given past problems of proposing noise barriers along the H-1 freeway in Moiliili, RAC(O) and low height noise barriers (8 ft.) may be appropriate for segments with noise levels substantially above the state highway noise standard. Based on the feasibility and reasonableness assessment, the following general recommendations are made for the four types of outcomes:

- **N** substantial non-attainment of the noise standard even with 10 ft. high noise barriers. These segments will require a combination of taller barriers (12 to 20 ft.) and quiet pavement such as RAC(O) should be investigated along these segments.
- **N,↑** represents noise non-attainment receptors located on elevated terrain which renders barriers ineffective. RAC(O) is a practical option for abatement.
- **Y** represents segments where 10 ft. barriers can yield a noise reduction of at least 5 dBA and this reduction fulfills the 75% design goal. These locations have the option of deploying either barrier or RAC(O) abatement, or a combination of both.
- **below NAC** represents attainment of the federal and state highway noise standard without any barrier other than any naturally occurring differences in elevation. These segments do not require any noise abatement in the near future.

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[3] Full report: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_738.pdf

[4] Massachusetts location and costs. Project along a 6-lane highway with a 1,140 ft. length for the segment examined in the case study.

Appendices

A: H-1 Freeway Sketch for TNM Analysis: Middle Street to Kahala Mall

B: Summary of Geometric Data for Representative Receptors, FHWA Land Use Types B, C and E

C: Speed and volume at Four HDOT Stations

D: 2012 Station and Sectional Speeds

E: 2012 HDOT Volume Analysis

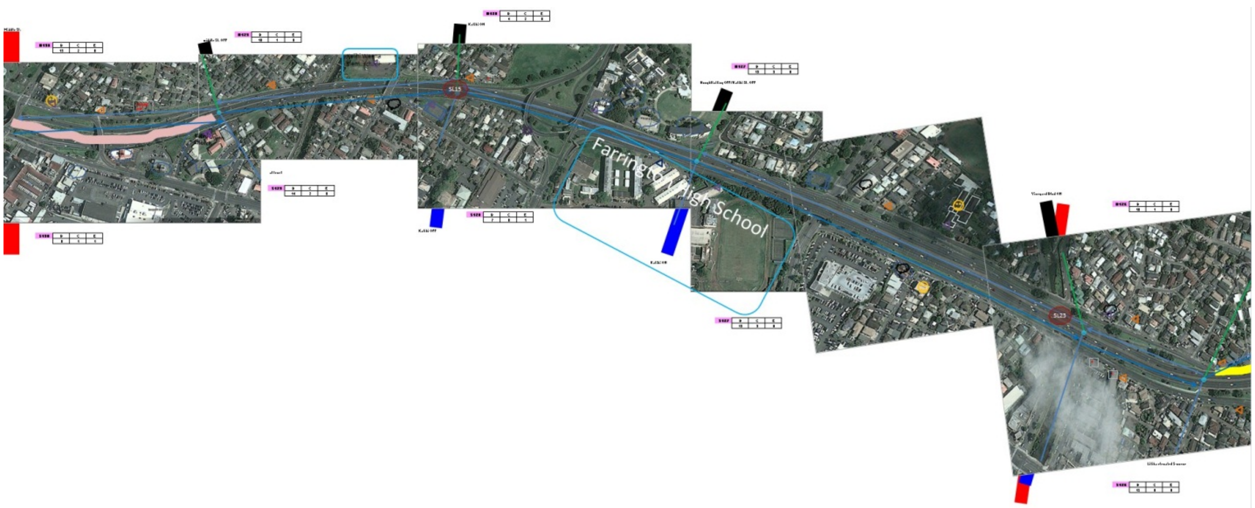
F: TNM Results of Receptor Type E

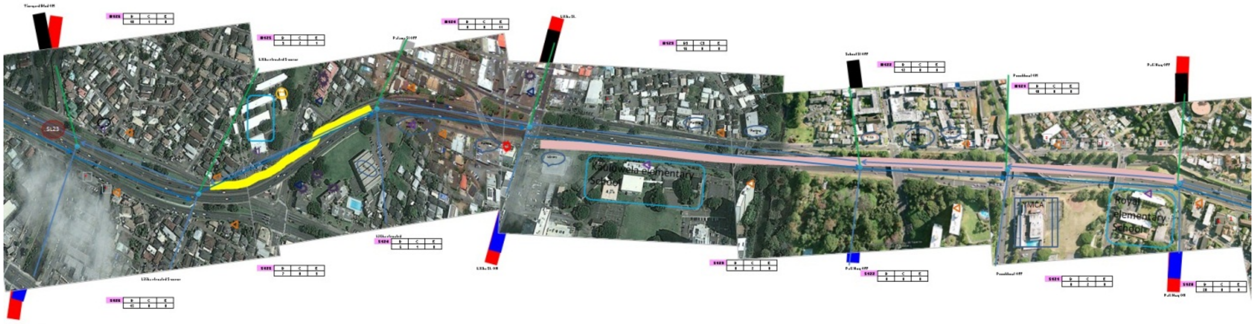
G: Color Coded Results of TNM, 17:00-18:00

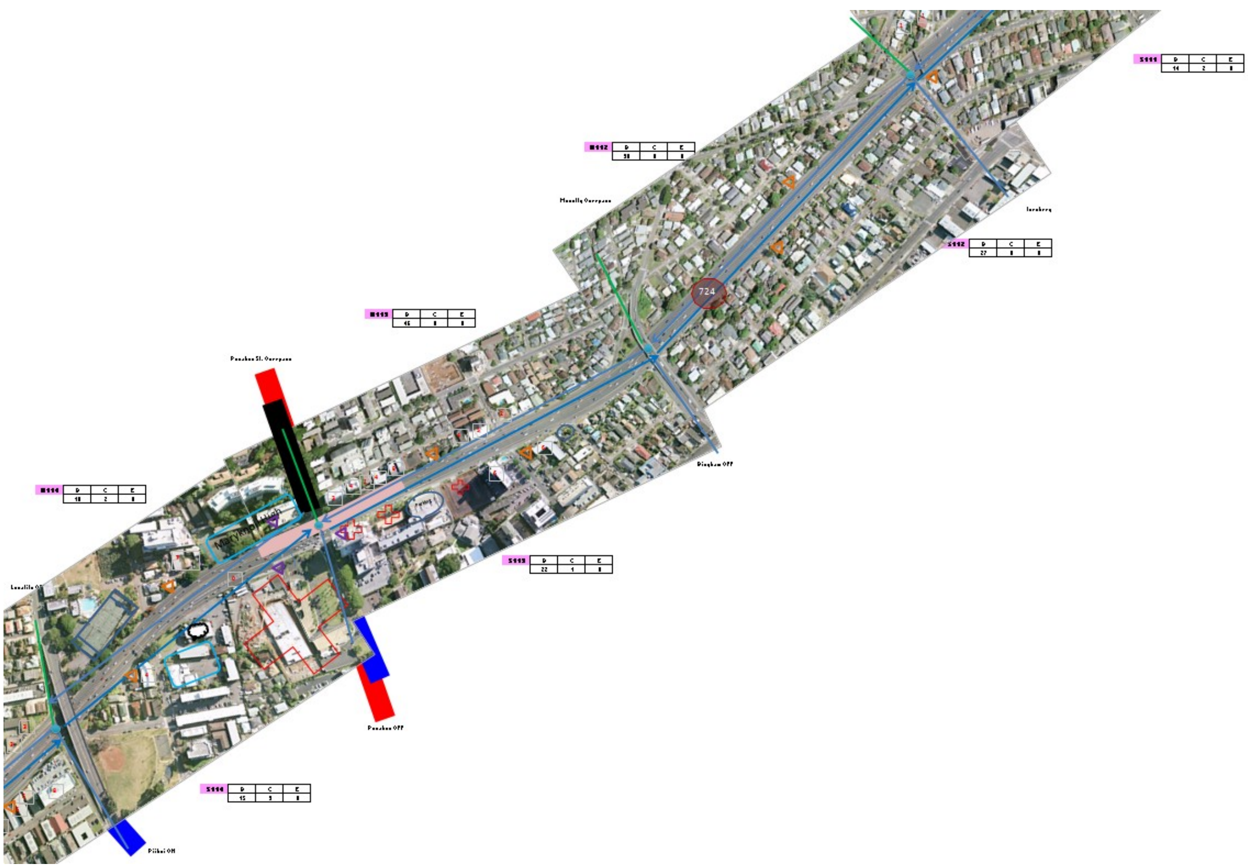
Appendix A

H-1 Freeway Sketch for TNM Analysis:

Middle Street to Kahala Mall



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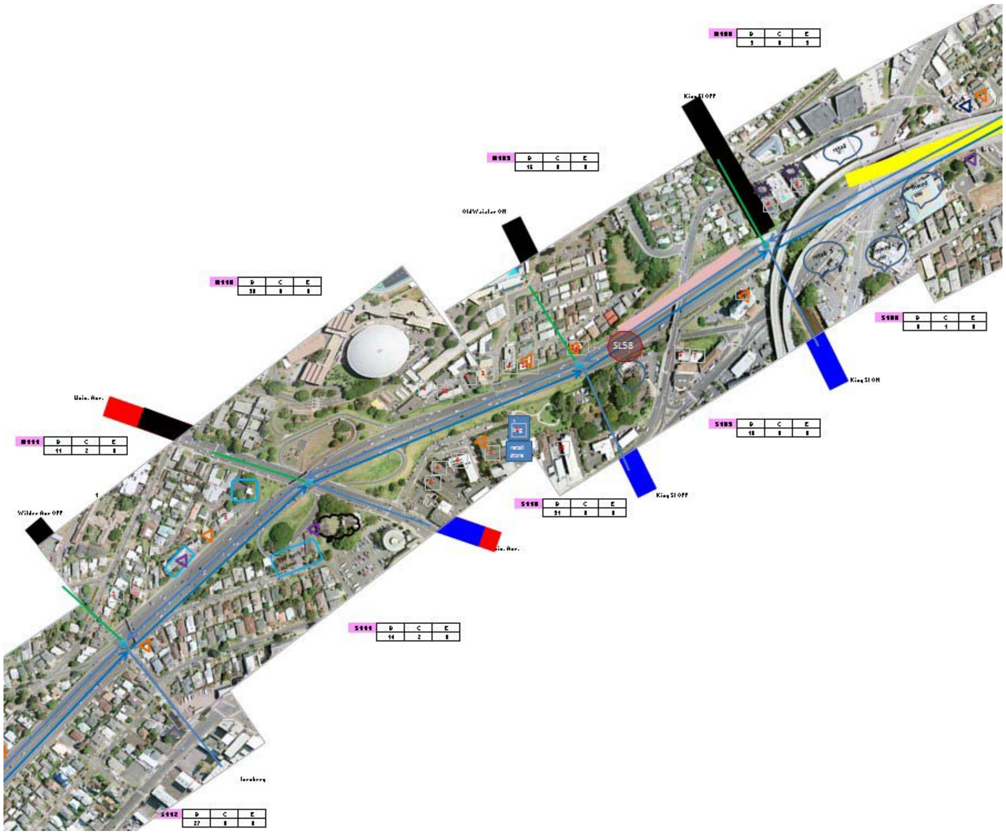

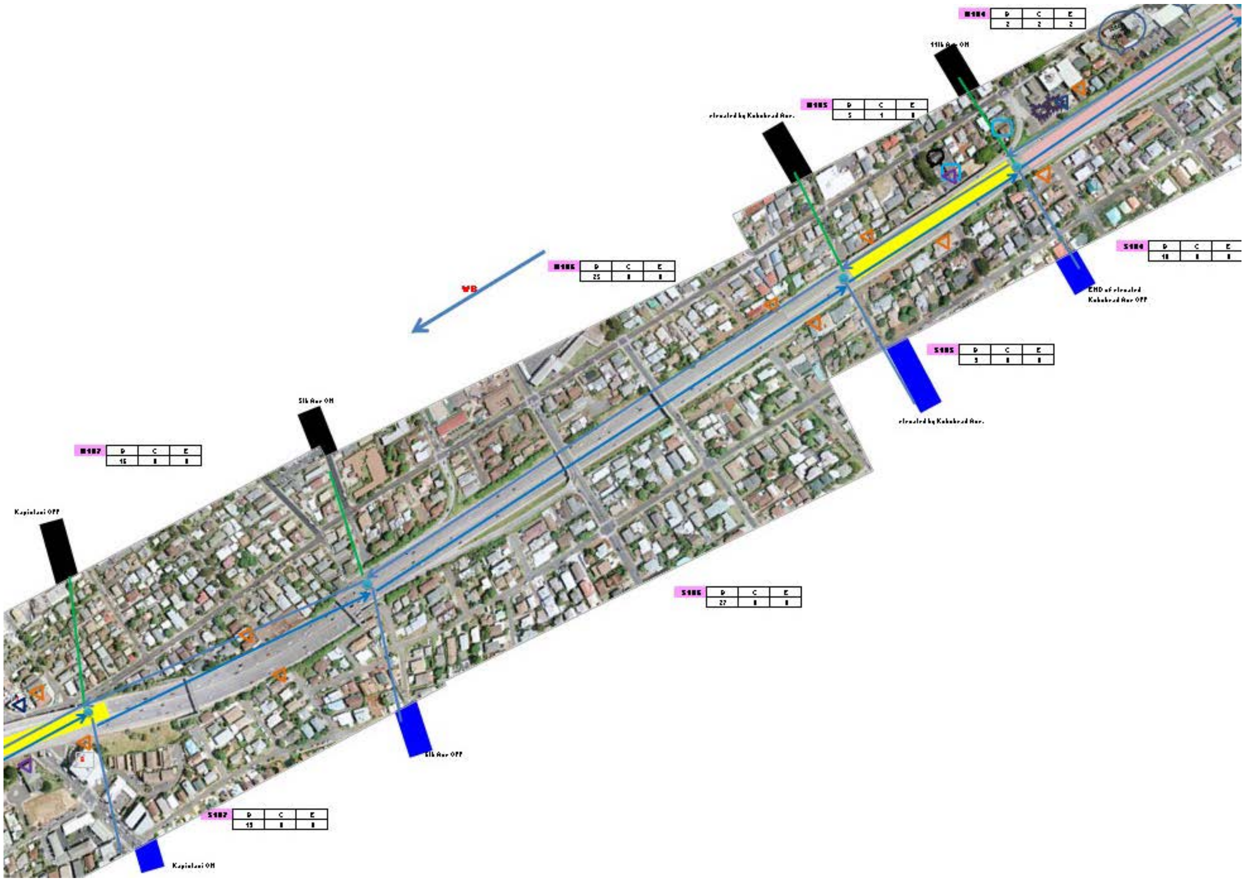
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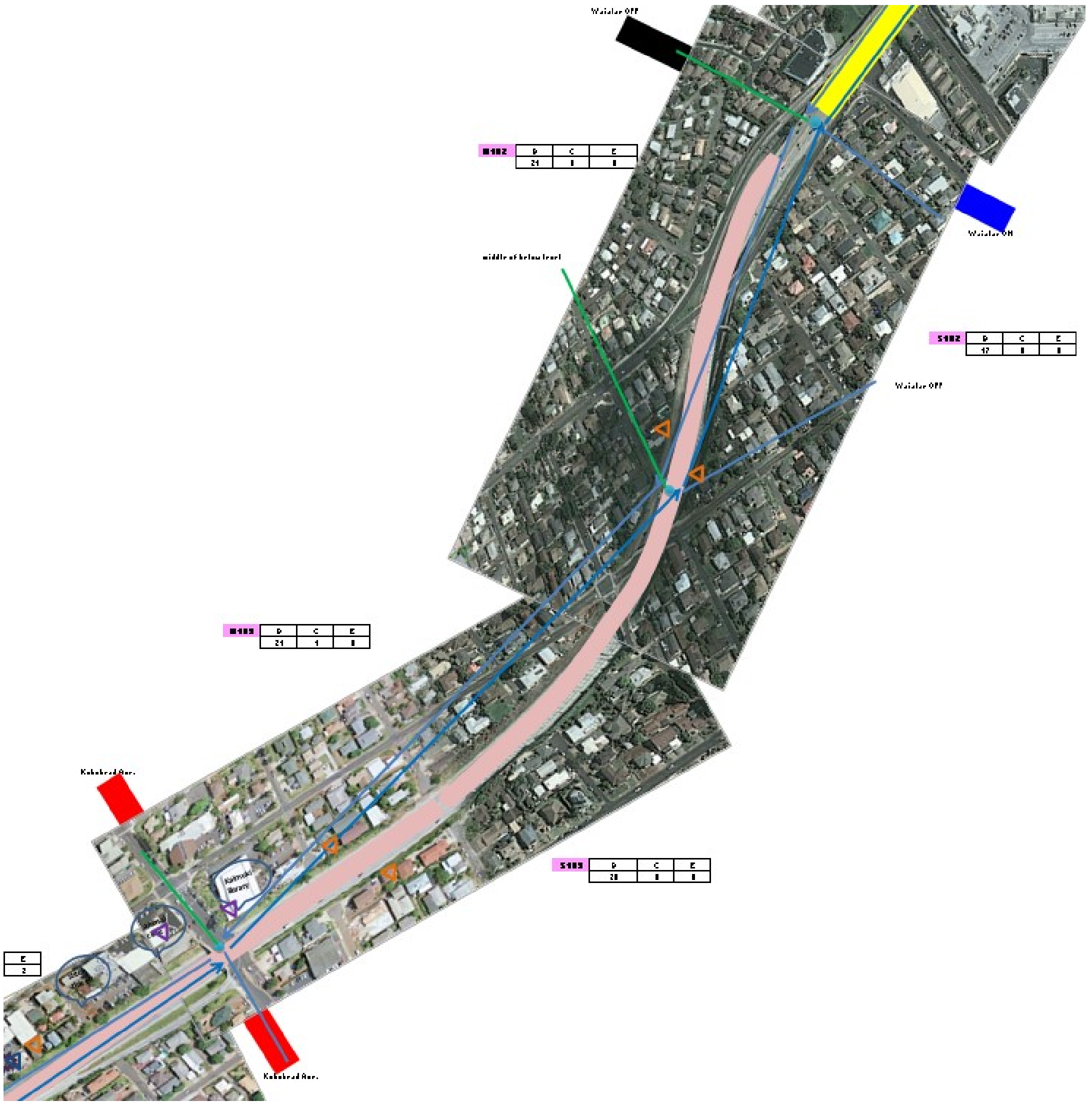
Kapiolani ON



Waialae OFF
Waialae ON
Waialae OFF
D C E
E
2

Appendix B

Summary of Geometric Data for Representative Receptors, FHWA Land Use Types B, C and E

Table B.1. Summary of Geometric Data for Receptors, Type B, C, and E on the North Side of H-1 Freeway

Segment	B					C					E				
	No.	X	Y	Z	H	No.	X	Y	Z	H	No.	X	Y	Z	H
N102	21	118	98	16	5	0					0				
N103	21	354	75	16	5	1	94	87	16	5	0				
N104	2	349	82	0	5	2	875	156	16	5	2	287	105	-2	5
N105	5	145	80	-10	5	1	515	128	-8	5	0				
N106	25	2,027	75	-4	5	0					0				
N107	16	817	80	0	5	0					0				
N108	3	1,322	116	-16	5	0					9	1,227	129	-8	5
N109	16	56	93	-4	5	0					0				
N110	38	1,301	87	-4	5	0					0				
N111	13	655	105	2	5	2	493	118	8	5	0				
N112	30	963	59	0	5	0					0				
N113	46	834	68	0	5	0					0				
N114	10	886	70	0	5	2	1,572	83	16	5	0				
N115	33	341	87	0	5	0					0				
N116	56	901	90	0	5	0					0				
N117	29	93	117	16	21	0					0				
N118	5	286	124	16	13	3	536	121	12	5	0				
N119	22	363	130	16	13	0					0				
N120	29	505	139	10	5	0					0				
N121	18	340	194	20	13	0					0				
N122	12	567	150	16	5	0					0				
N123	16	1,175	139	16	9	0					0				
N124	8	273	83	3	5	0					11	978	220	16	13
N125	9	129	67	-16	5	2	424	159	-16	5	1	915	189	-16	5
N126	10	45	128	0	5	1	157	124	0	5	0				
N127	19	103	87	-8	5	3	1,357	167	0	5	0				
N128	4	200	102	0	5	2	953	80	10	5	0				
N129	18	113	93	5	5	1	1,197	199	14	5	0				
N130	13	1,303	122	10	5	2	233	177	20	5	0				

Table B.2. Summary of Geometric Data for Receptors, Type B, C, and E on the South Side of H-1 Freeway

Segment	B					C					E				
	No.	X	Y	Z	H	No.	X	Y	Z	H	No.	X	Y	Z	H
S102	17	74	-99	16	5	0					0				
S103	20	445	-84	16	5	0					0				
S104	10	85	-76	-8	5	0					0				
S105	9	359	-78	-16	5	0					0				
S106	27	2,222	-82	0	5	0					0				
S107	13	845	-82	0	5	0					0				
S108	8	1,481	-83	0	5	1	1,239	-112	-16	5	0				
S109	18	1,041	-64	-8	5	0					0				
S110	31	842	-134	0	5	0					0				
S111	14	82	-96	0	5	2	1,121	-188	-16	5	0				
S112	27	733	-100	0	5	0					0				
S113	22	1,190	-92	8	5	1	166	-89	16	5	0				
S114	15	488	-67	8	5	3	1,361	-107	0	5	0				
S115	32	463	-73	-3	5	0					0				
S116	46	39	-72	-16	5	0					0				
S117	13	689	-82	-16	5	1	181	-100	0	5	0				
S118	25	333	-121	12	13	0					0				
S119	42	110	-82	10	13	1	360	-219	16	5	0				
S120	28	182	-72	0	5	0					0				
S121	0					2	995	-120	8	5	0				
S122	8	687	-236	12	13	0					0				
S123	8	1,442	-275	6	5	2	700	-102	4	5	0				
S124	6	513	-120	12	5	2	310	-84	6	5	0				
S125	7	203	-139	-16	5	0					3	579	-121	-8	5
S126	15	365	-132	-4	5	0					0				
S127	13	1,484	-128	0	5	3	163	-101	-10	5	0				
S128	7	105	-71	10	13	0					1	1,497	-90	0	5
S129	14	1,154	-85	12	5	2	1,673	-160	14	5	0				
S130	0					1	1,446	-117	10	5	1	772	-83	10	5

Appendix C

Speed and Volume at Four HDOT Stations

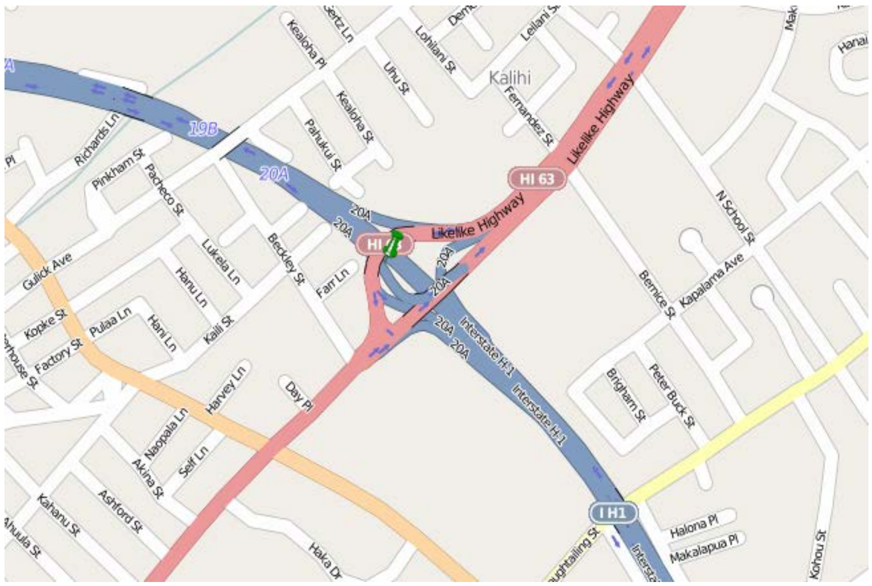


Figure C.1. Sta.SL15 MP19.27.

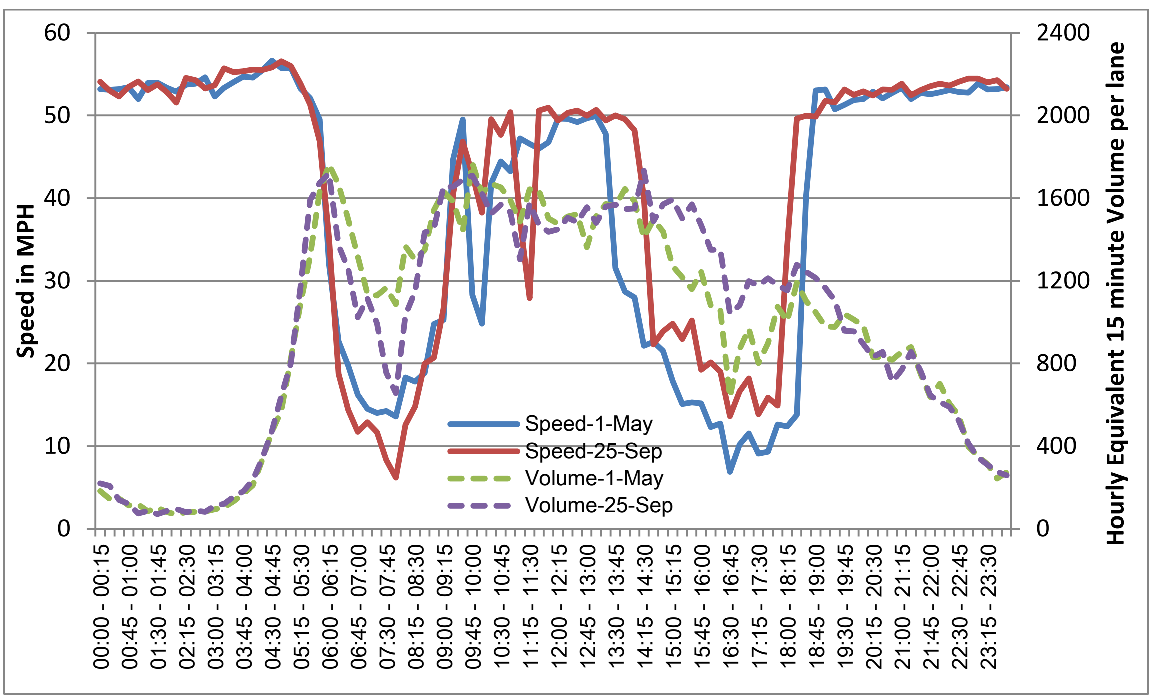


Figure C.2. Sta. SL15, EB H1 Fwy. at Kalihi IC, MP19.27 (Tuesday, 2012).

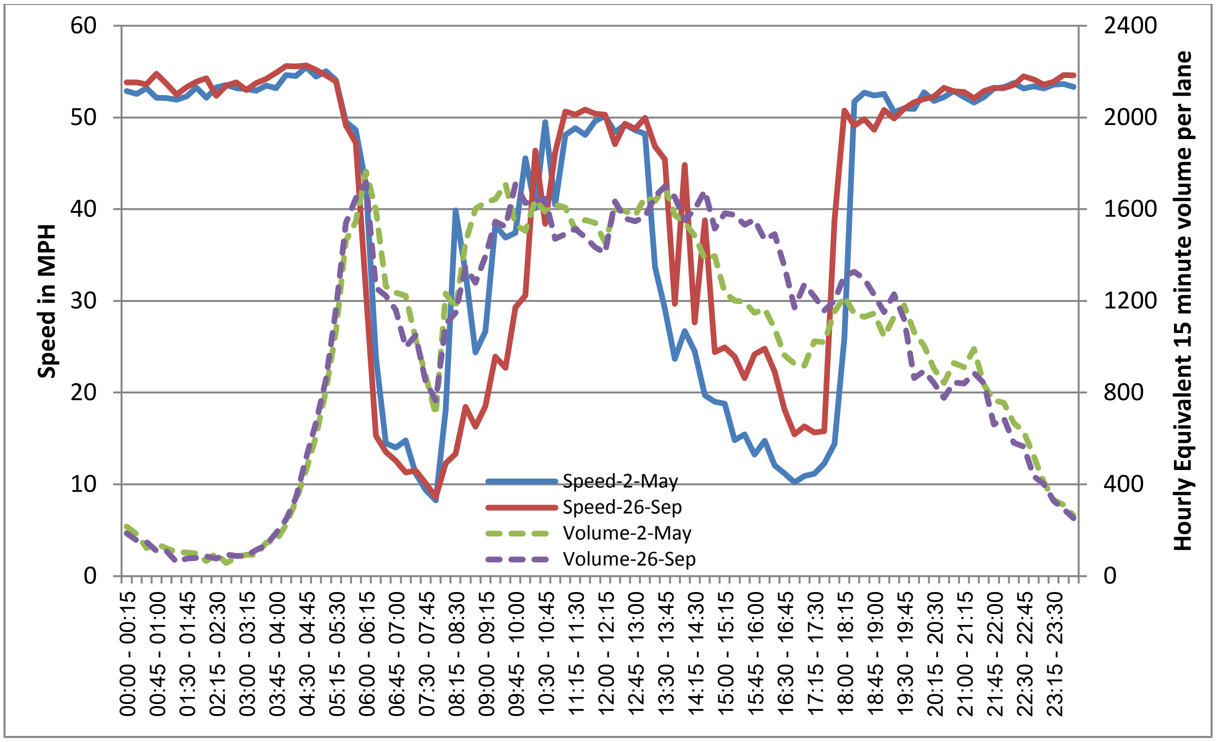


Figure C.3. Sta. SL15, EB H1 Fwy. at Kalihi IC, MP19.27 (Wednesday, 2012) .

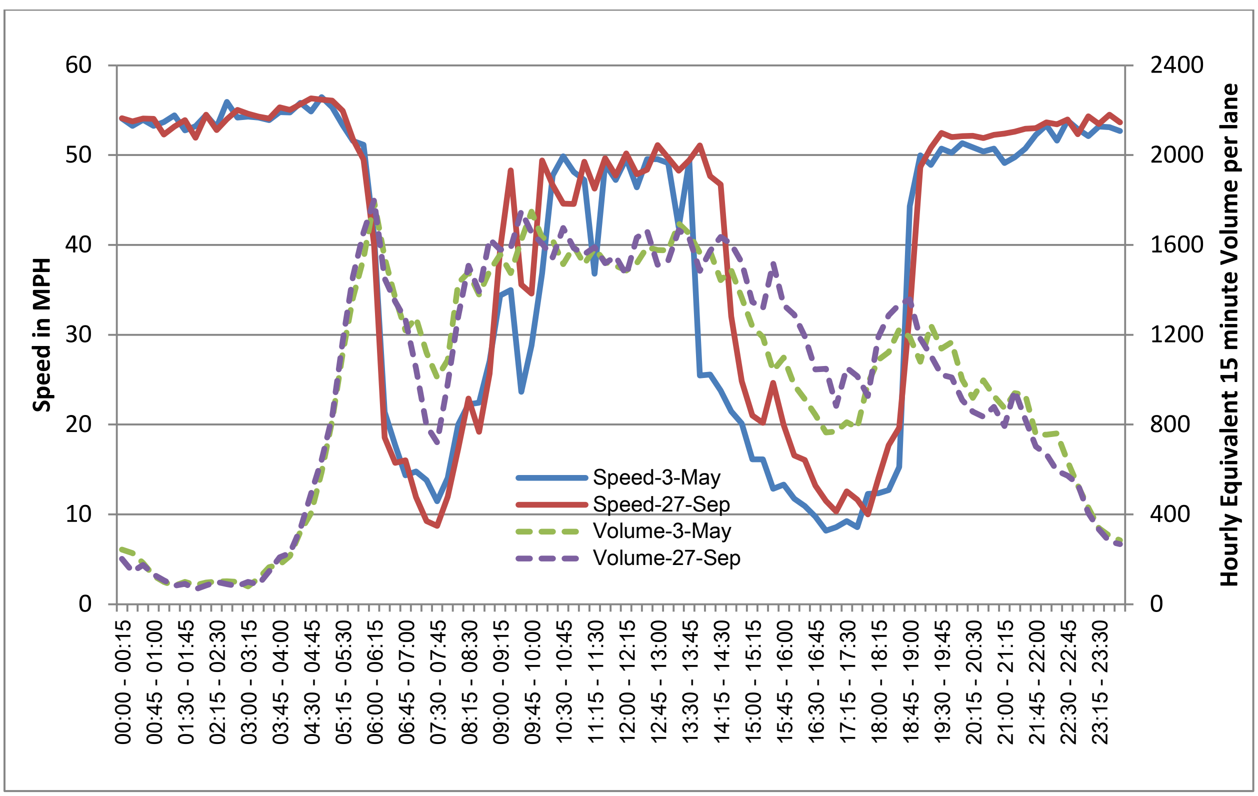


Figure C.4. Sta. SL15, EB H1 Fwy. at Kalihi IC, MP 19.27 (Thursday, 2012).

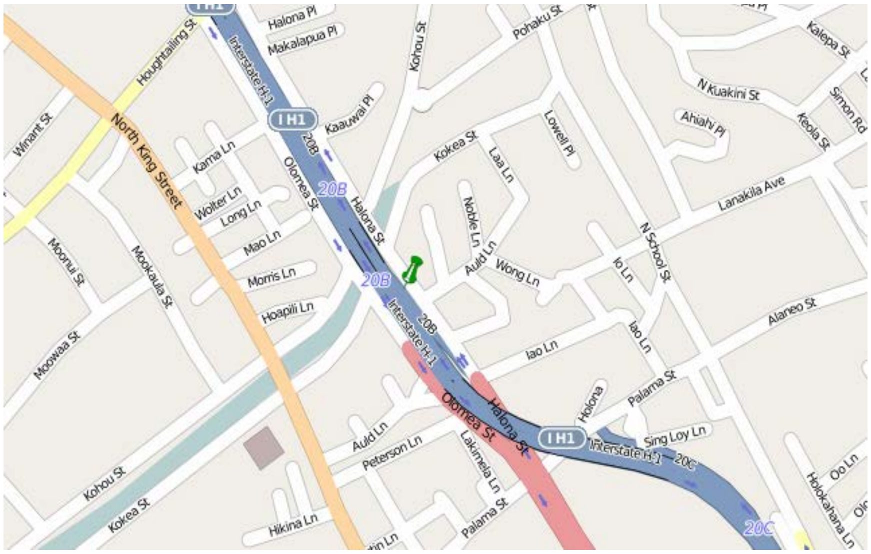


Figure C.5. Sta.SL23 MP20.24.

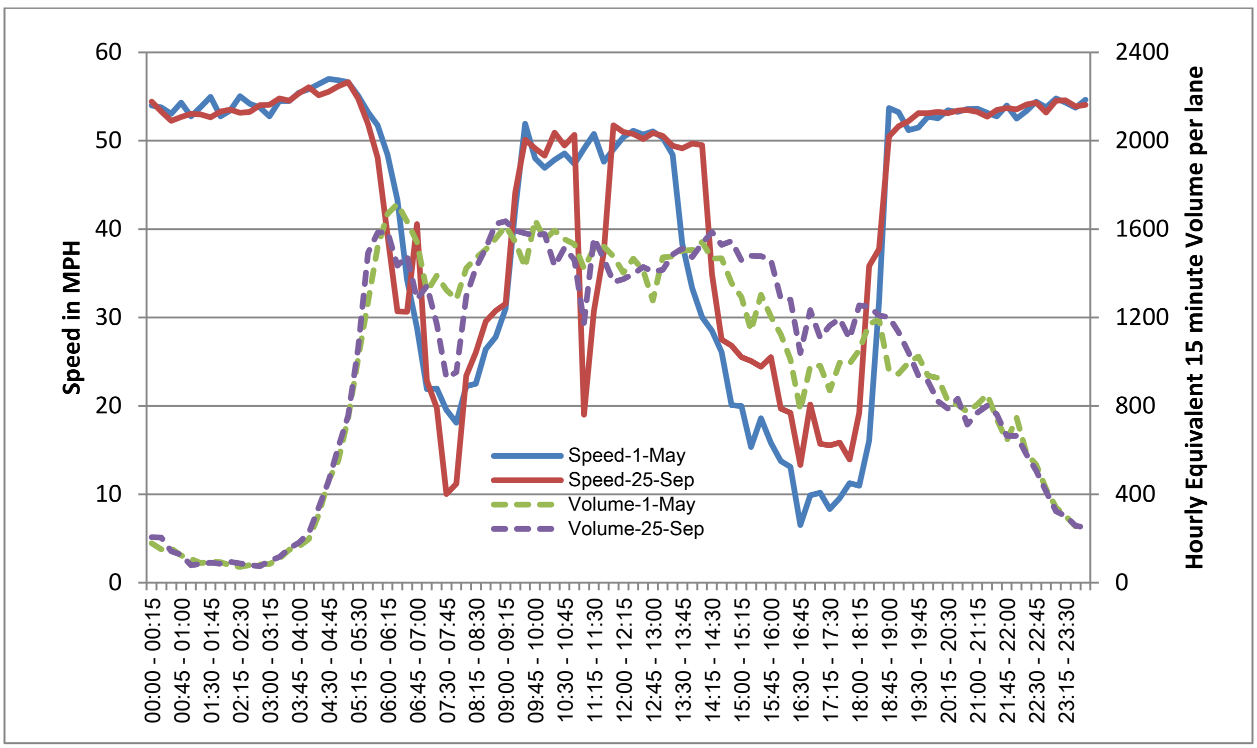


Figure C.6. Sta.SL23, EB H1 Fwy. at Kapalama Stream Bridge, MP20.24 (Tuesday,2012).

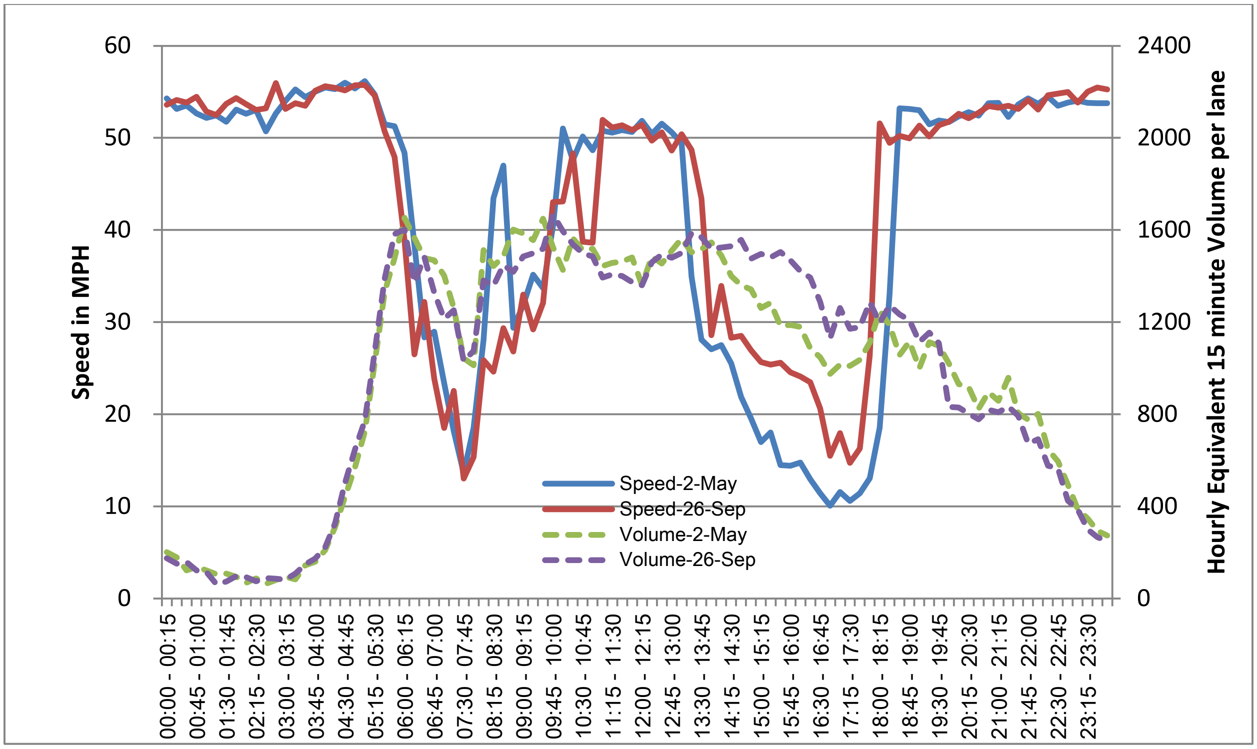


Figure C.7. Sta.SL23, EB H1 Fwy. at Kapalama Stream Bridge, MP 20.24 (Wednesday, 2012).

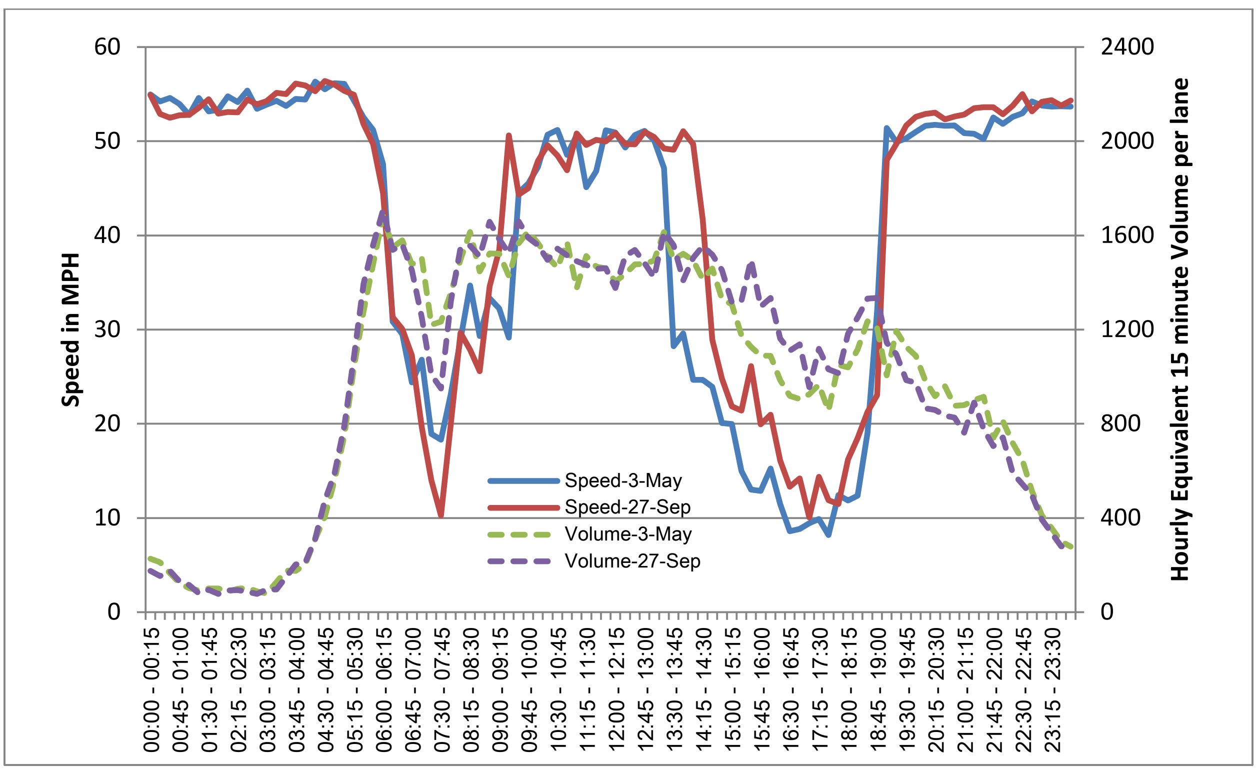


Figure C.8. Sta. SL23, EB H1 Fwy. at Kapalama Stream Bridge, MP 20.24 (Thursday, 2012).

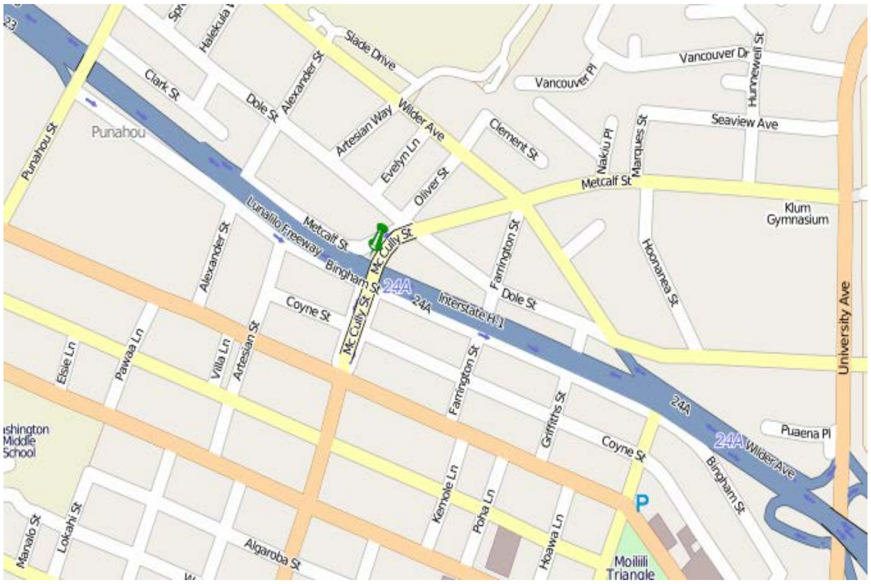


Figure C.9. Sta.724A MP23.55.

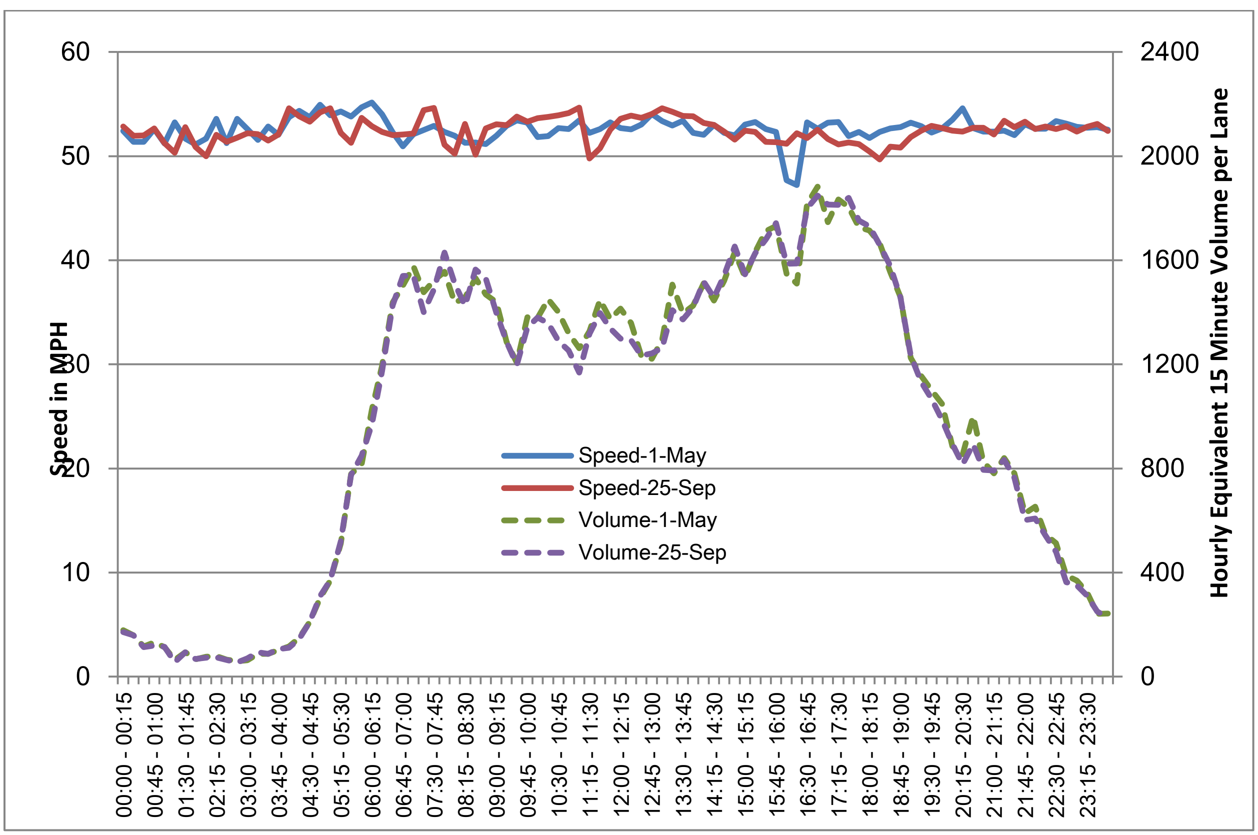


Figure C.10. Sta. 724 A, EB H1 Fwy. at McCully St., MP 23.55 (Tuesday, 2012).

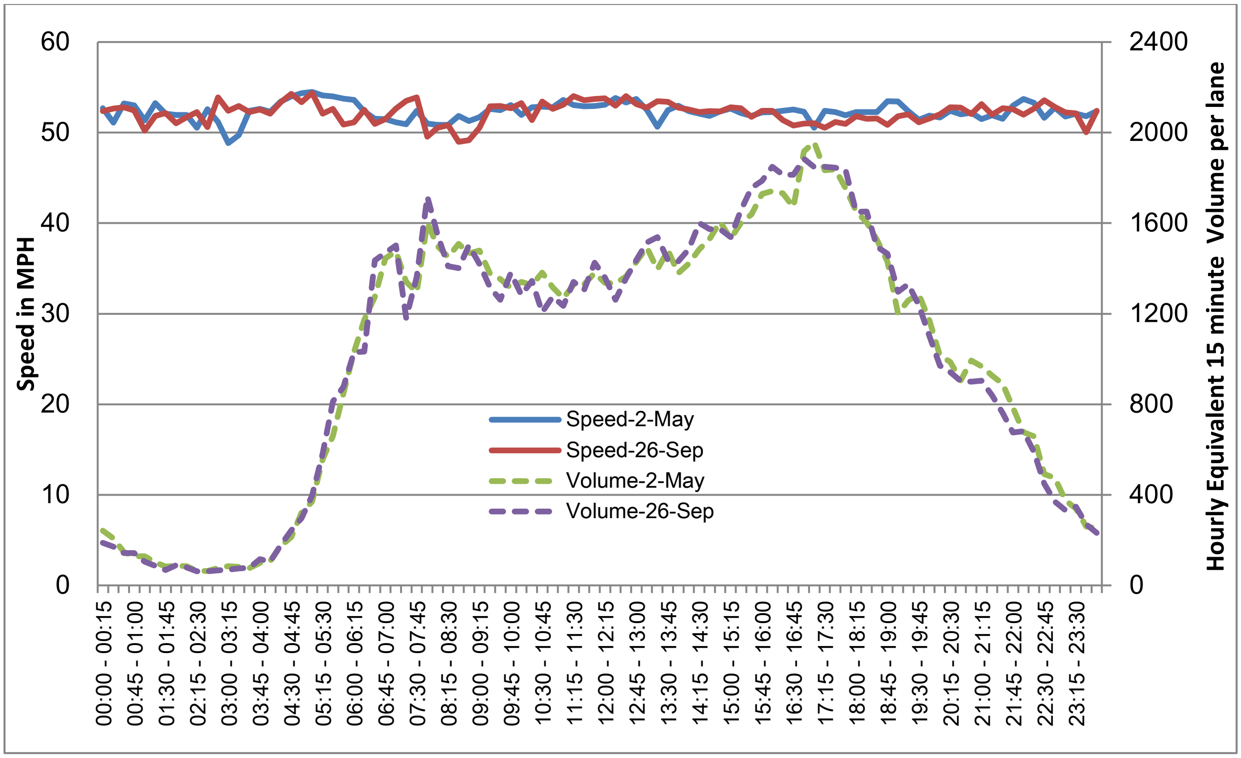


Figure C.11. Sta. 724 A, EB H1 Fwy. at McCully St., MP23.55 (Wednesday, 2012).

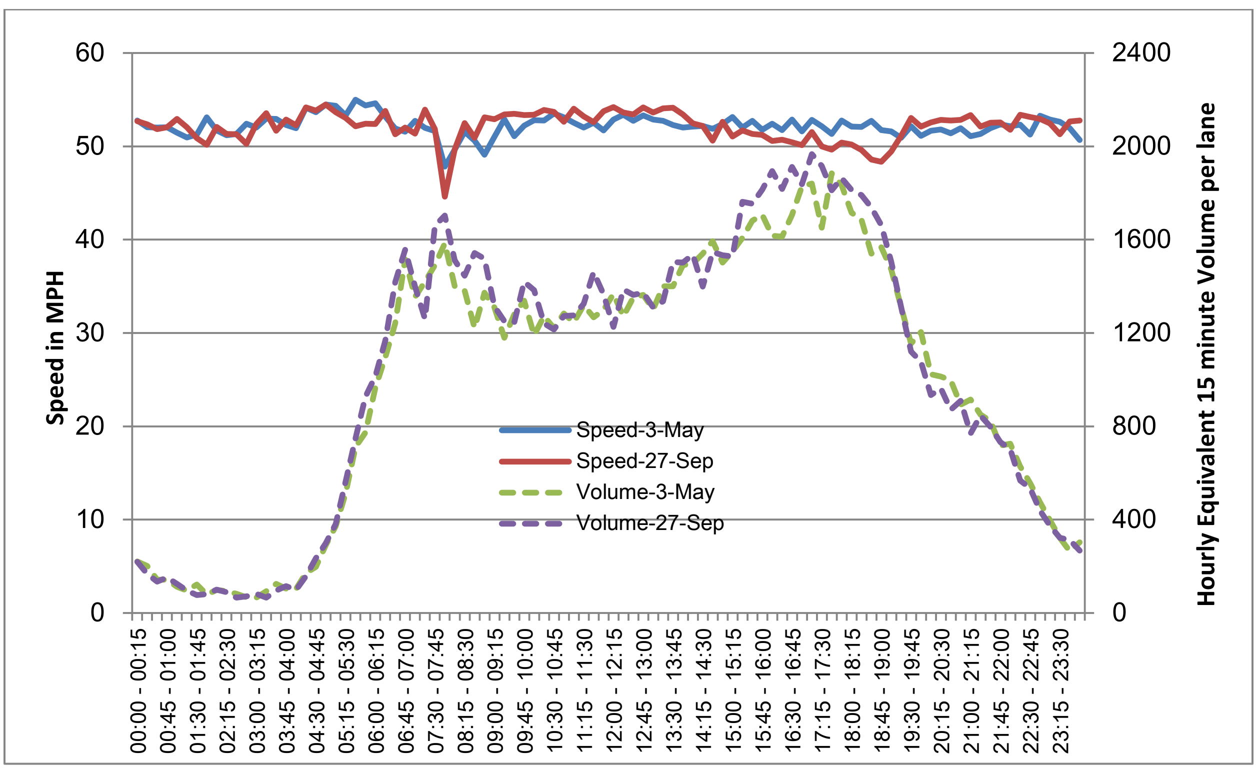


Figure C.12. Sta.724 A, EB H1 Fwy. at McCully St., MP23.55 (Thursday, 2012).

Figure C.13. Sta.SL58 MP24.85.

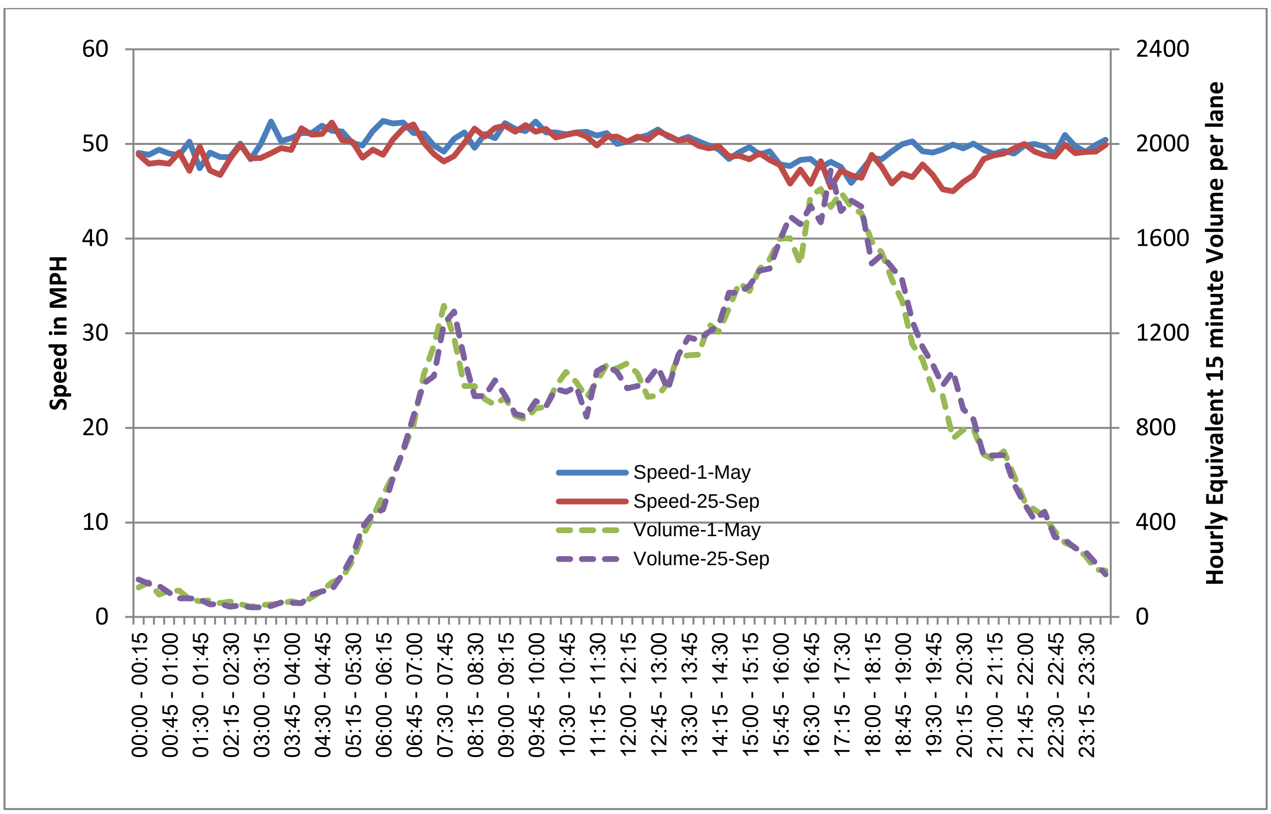


Figure C.14. Sta.SL58, EB H1 Fwy. at Manoa/Palolo Drainage Canal, MP 24.85 (Tuesday, 2012).

Figure C.15. Sta.SL58, EB H1 Fwy. at Manoa/Palolo Drainage Canal, MP 24.85 (Wednesday, 2012).

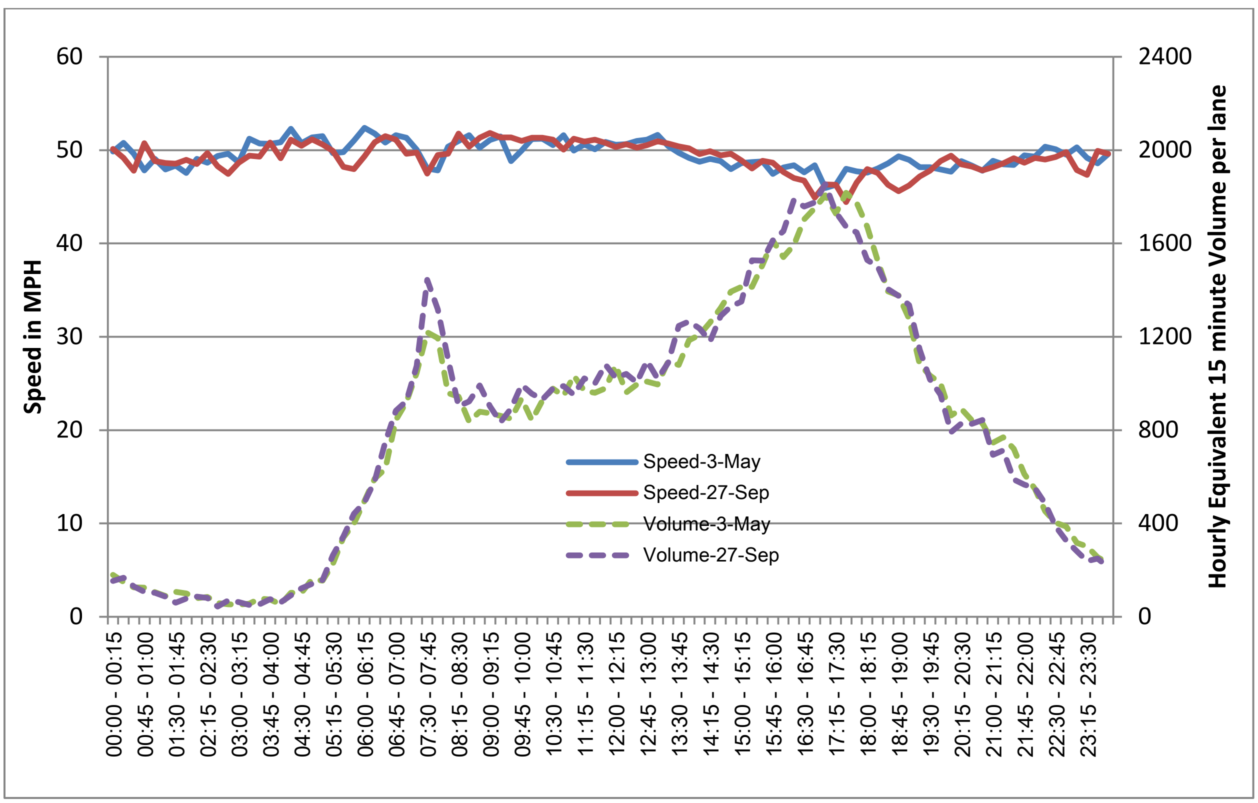


Figure C.16. Sta.SL58, EB H1 Fwy at Manoa/Palolo Drainage Canal, MP 24.85 (Thursday, 2012).

Figure C.17. Sta.SL58 MP24.85.

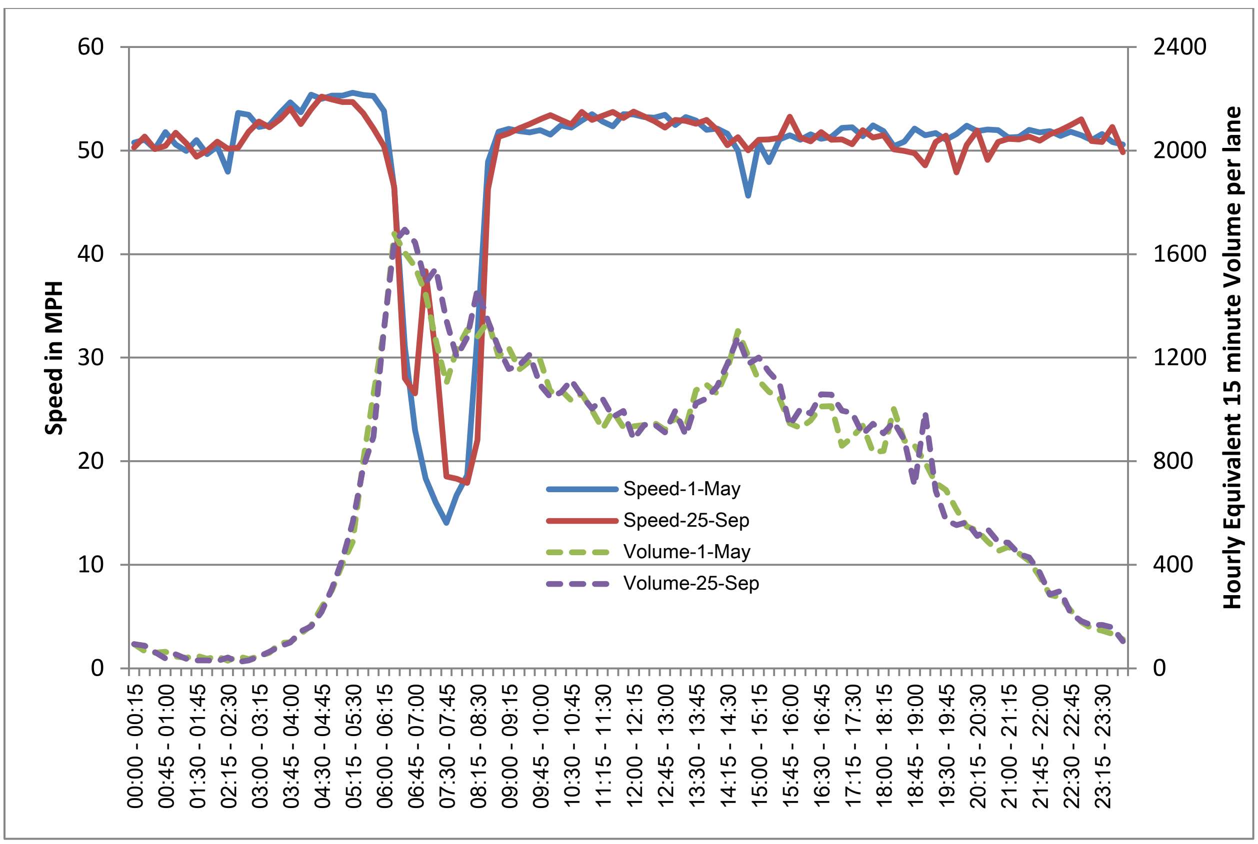


Figure C.18. Sta.SL 58, WB H1 Fwy. at Manoa/Palolo Drainage Canal, MP 24.55 (Tuesday, 2012).

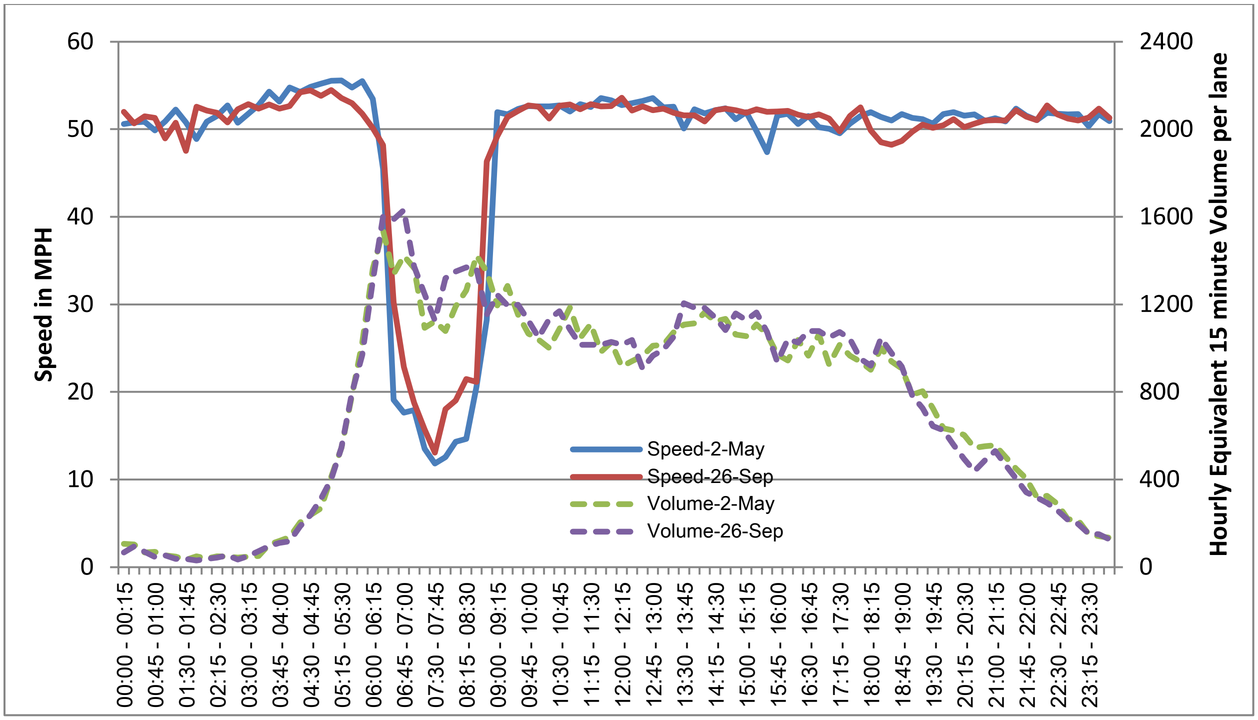


Figure C.19. Sta. SL58, WB H1 Fwy. at Manoa/Palolo Drainage Canal, MP 24.55 (Wednesday, 2012).

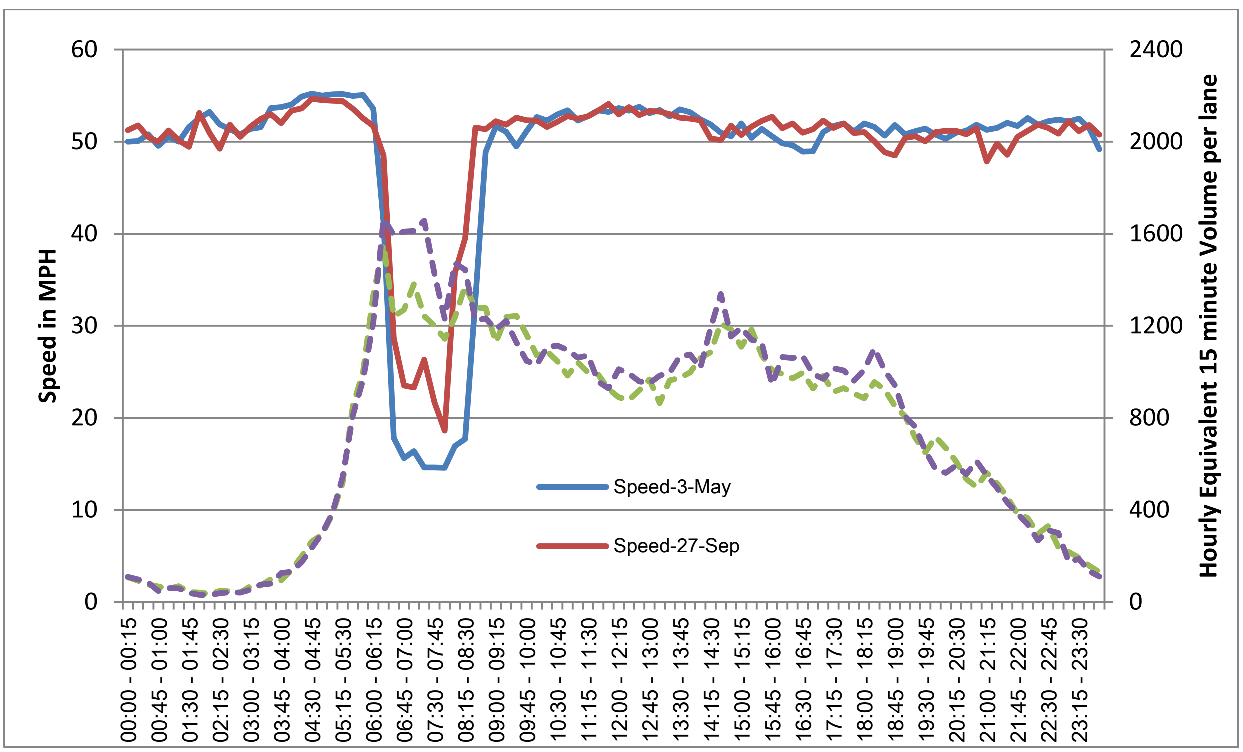


Figure C.20. Sta. SL58, WB H1 Fwy. at Manoa/Palolo Drainage Canal, MP 24.55 (Thursday, 2012).

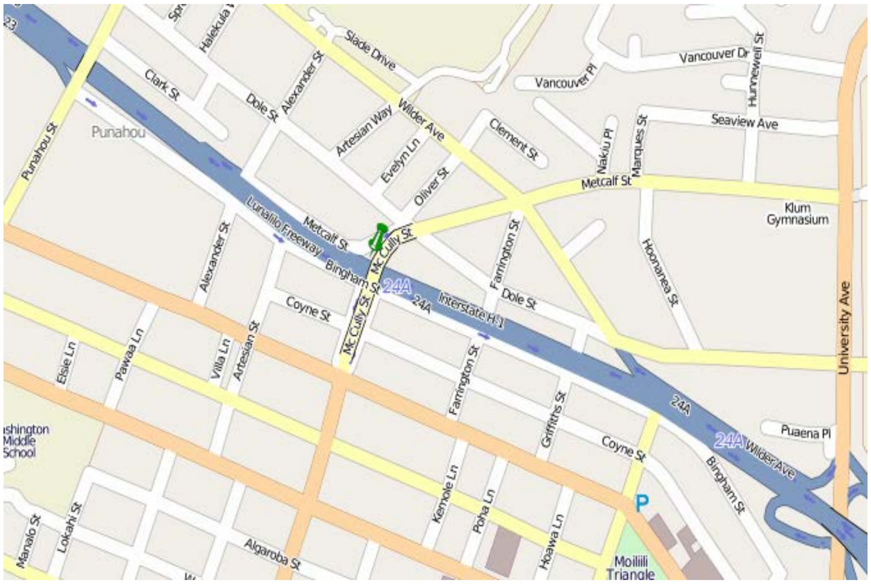


Figure C.21. Sta.724A MP23.55.

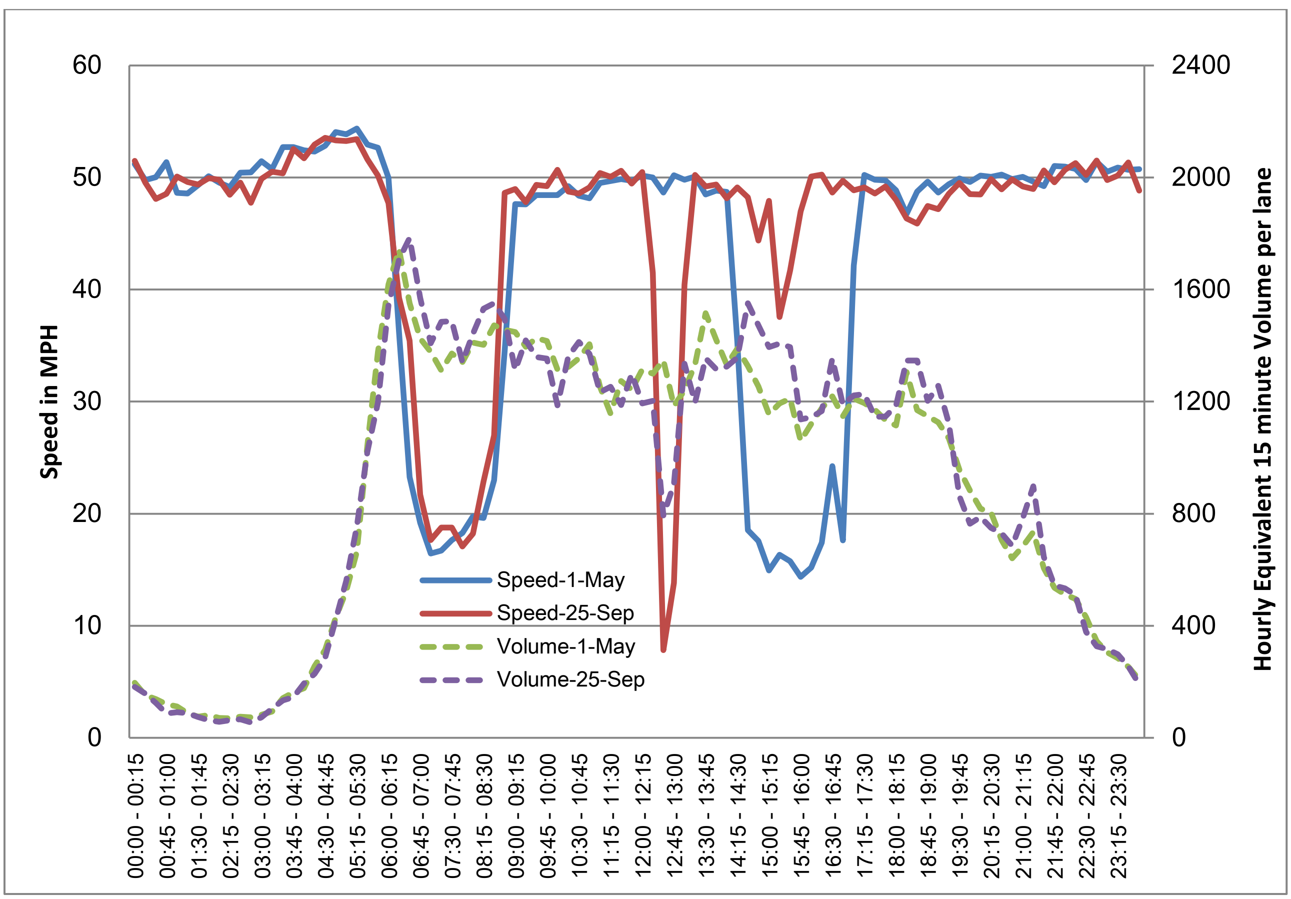


Figure C.22. Sta.724 A, WB H1 Fwy. at McCully St., MP 23.55 (Tuesday, 2012).

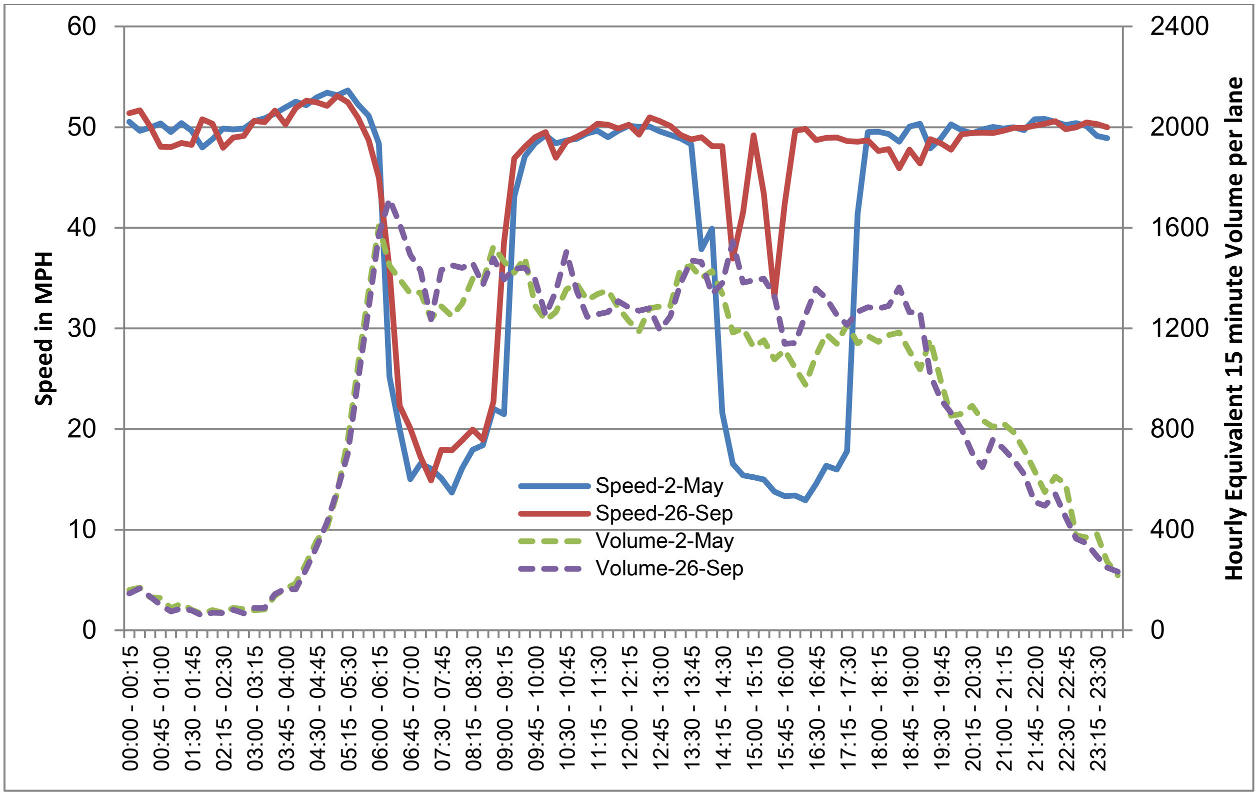


Figure C.23. Sta. 724A, WB H1 Fwy. West at McCully St., MP 23.55 (Wednesday, 2012).

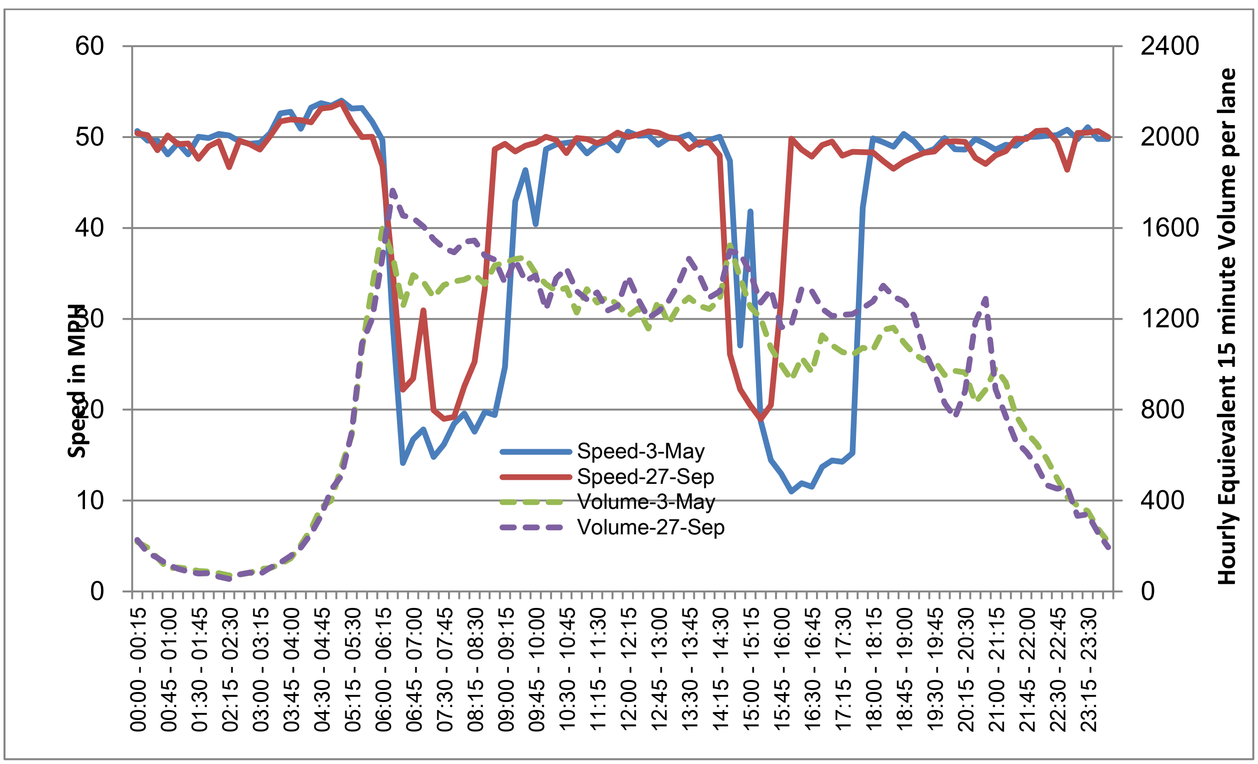


Figure C.24. Sta.724 A, WB H1 Fwy. at McCully St., MP 23.55 (Thursday, 2012).

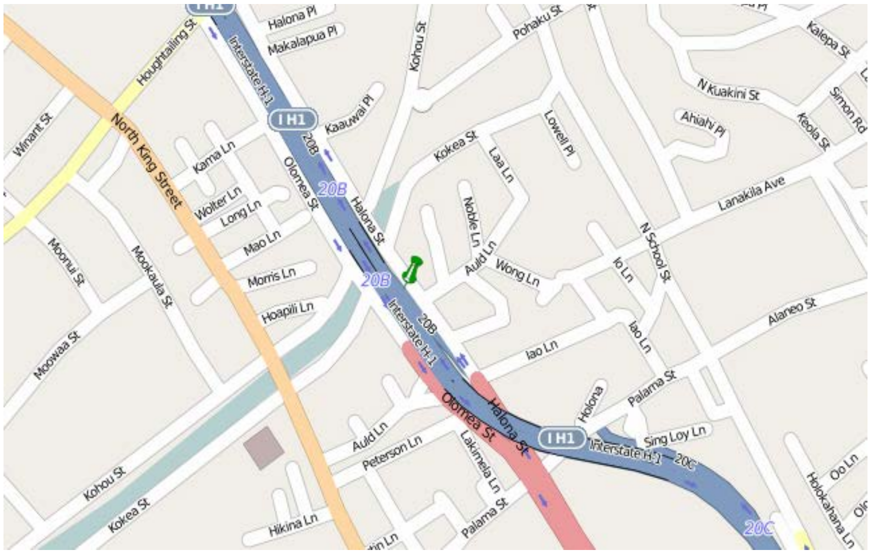


Figure C.25. Sta.SL23   MP20.24.

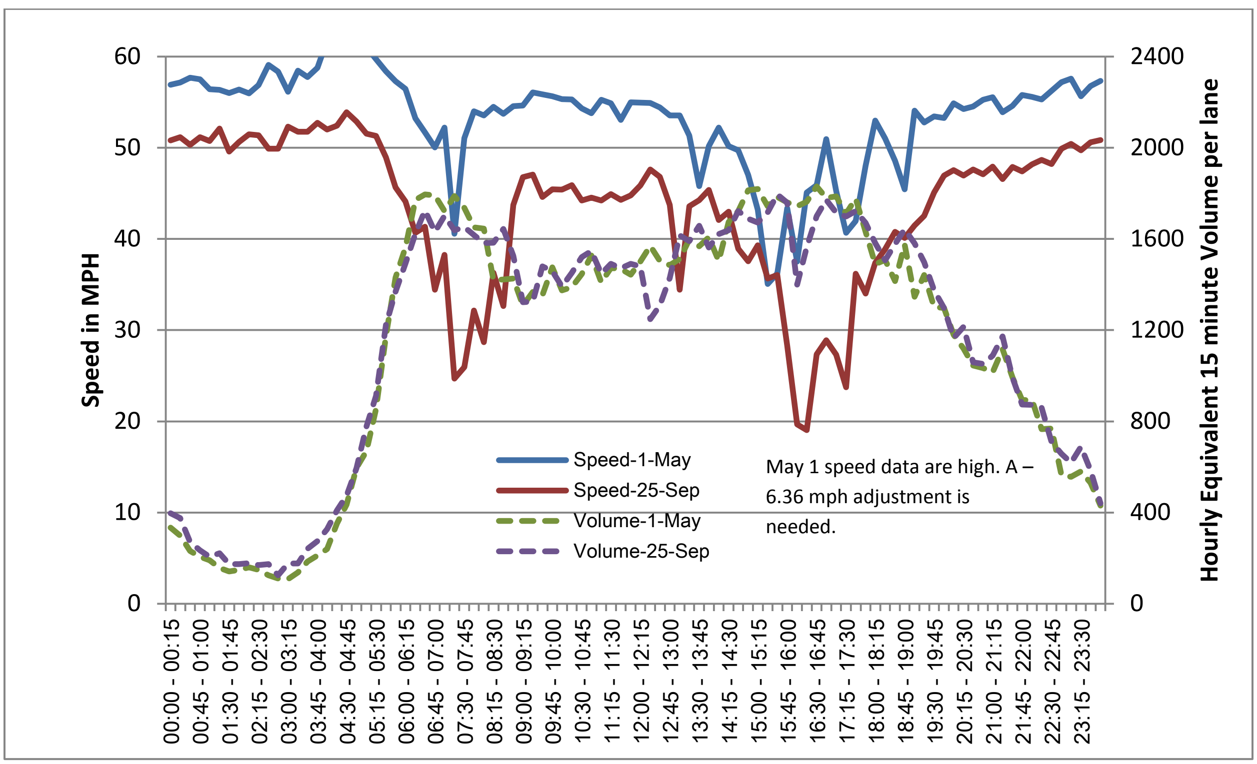


Figure C.26. Sta. SL23, WB H1 Fwy. at Kapalama Stream Bridge, MP20.24 (Tuesday, 2012).

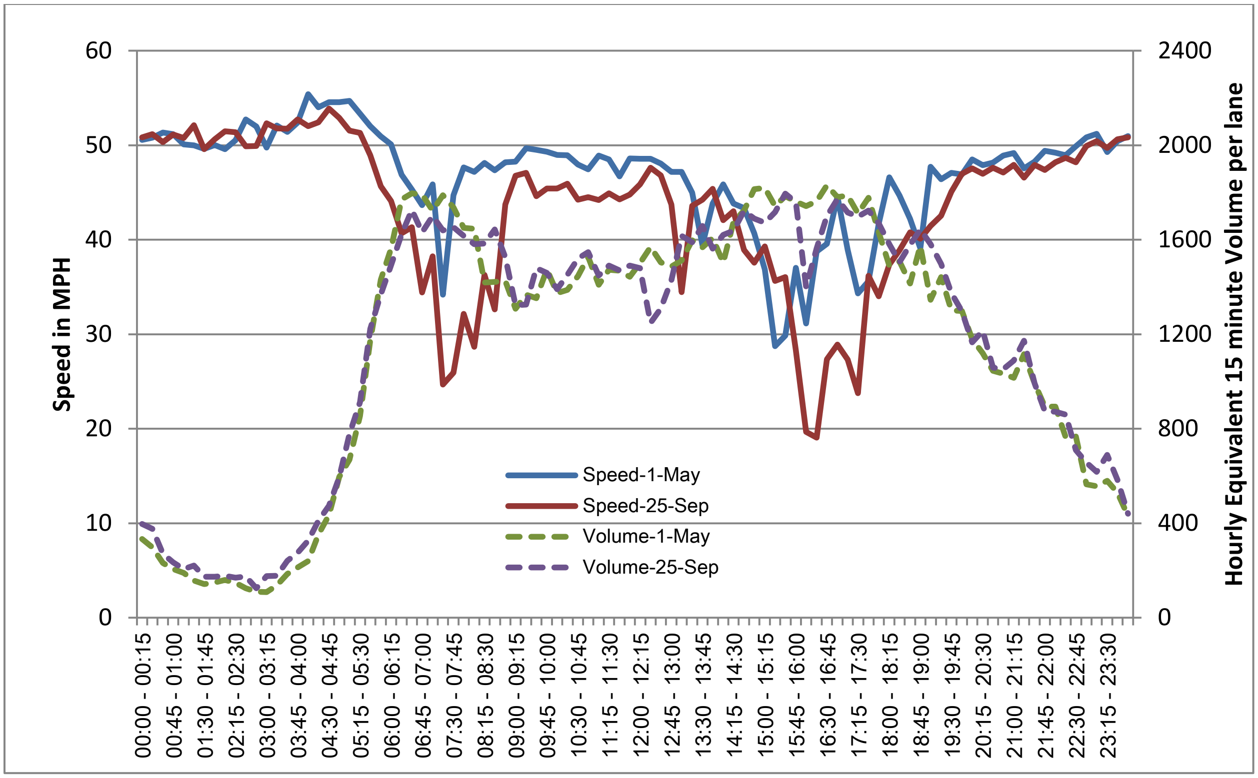


Figure C.26. Sta. SL23, WB H1 Fwy. at Kapalama Stream Bridge, MP 20.24 (Tuesday, 2012).

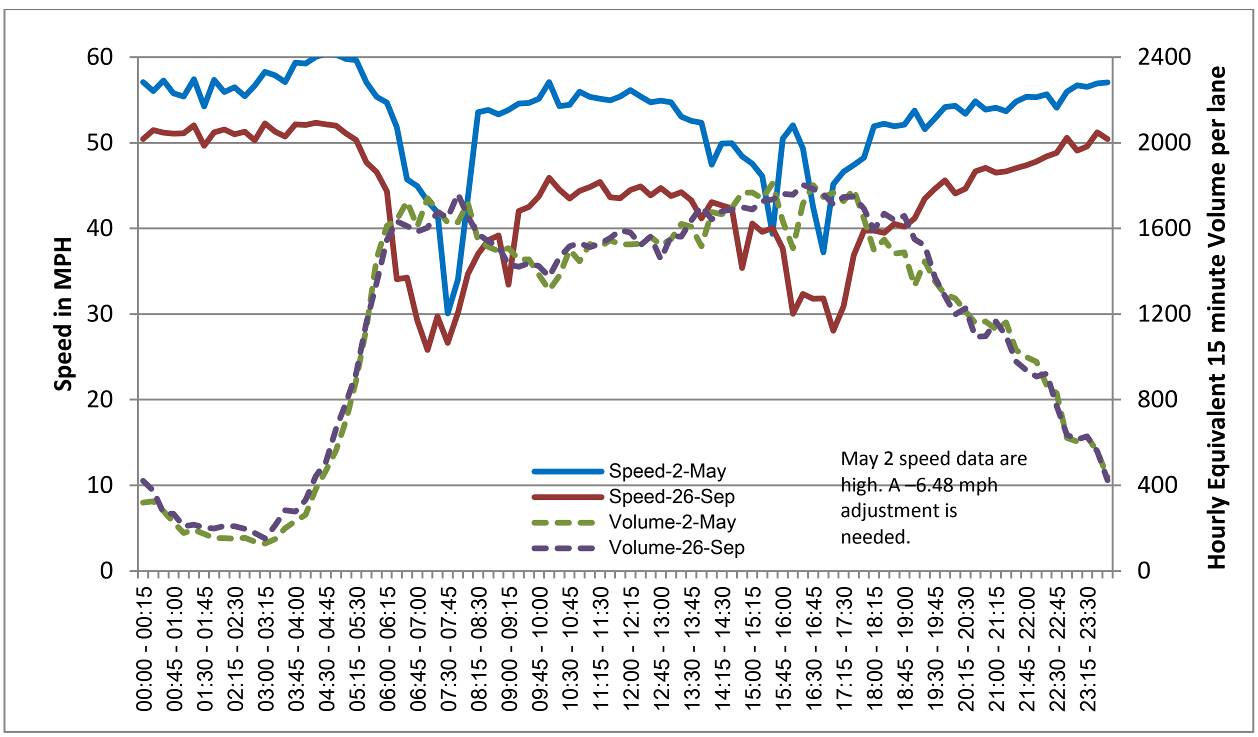


Figure C.27. Sta.SL23, WB H1 Fwy. at Kapalama Stream Bridge, MP 20.24 (Wednesday, 2012).

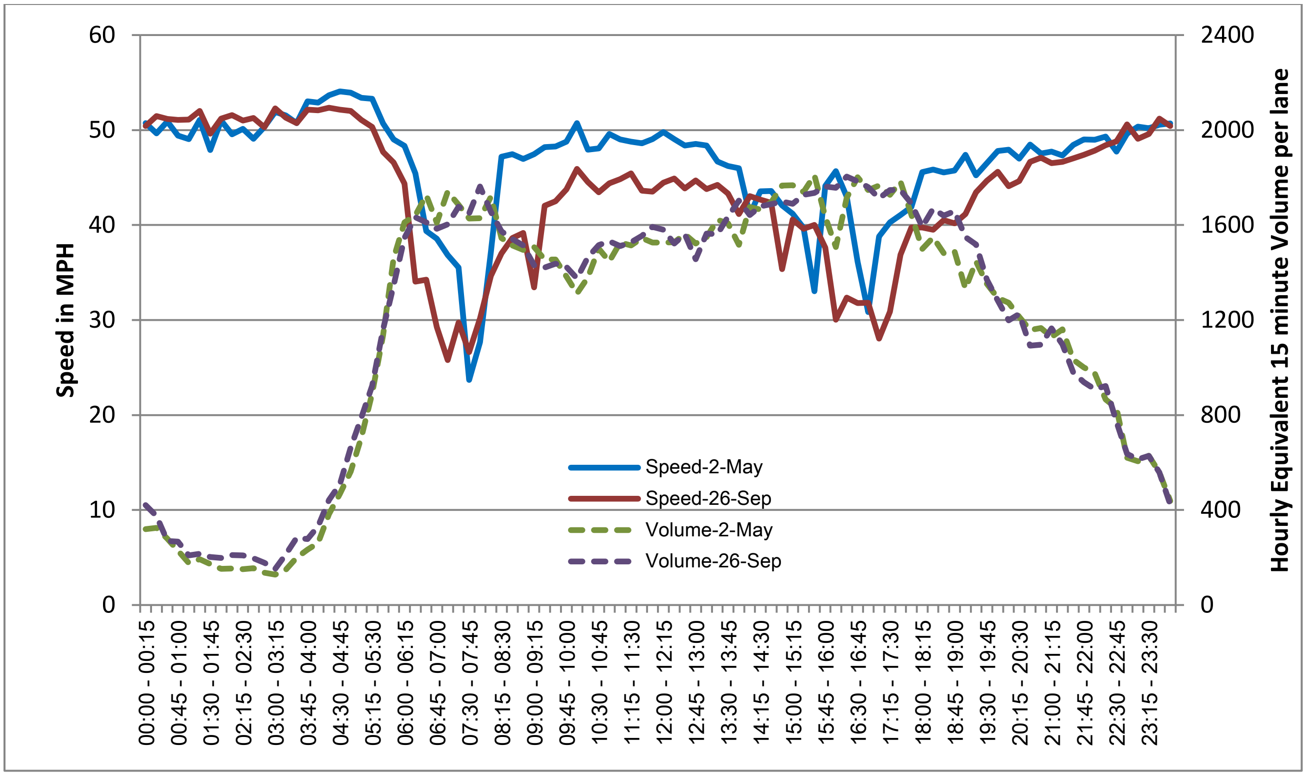


Figure C.27. Sta.SL23, WB H1 Fwy. at Kapalama Stream Bridge , MP 20.24 (Wednesday, 2012).

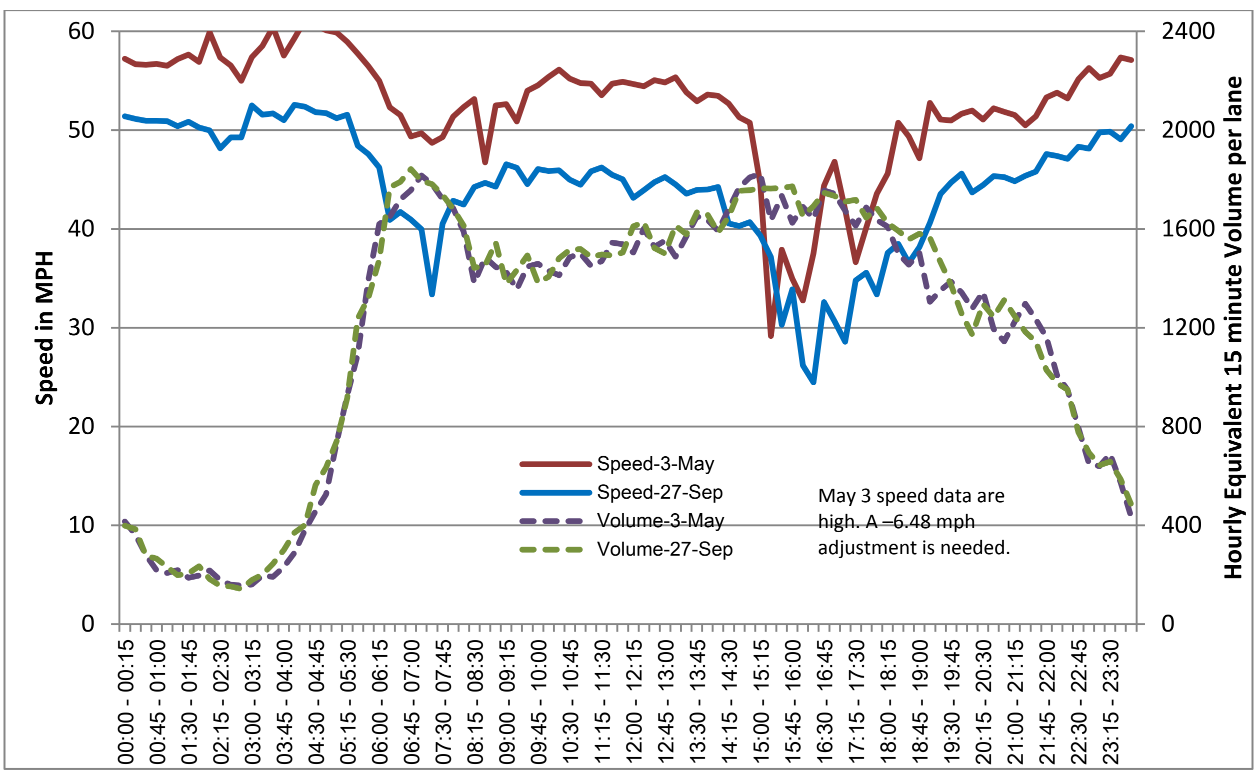


Figure C.28. Sta.SL23, WB H1 Fwy. at Kapalama Stream Bridge, MP 20.24 (Thursday, 2012).

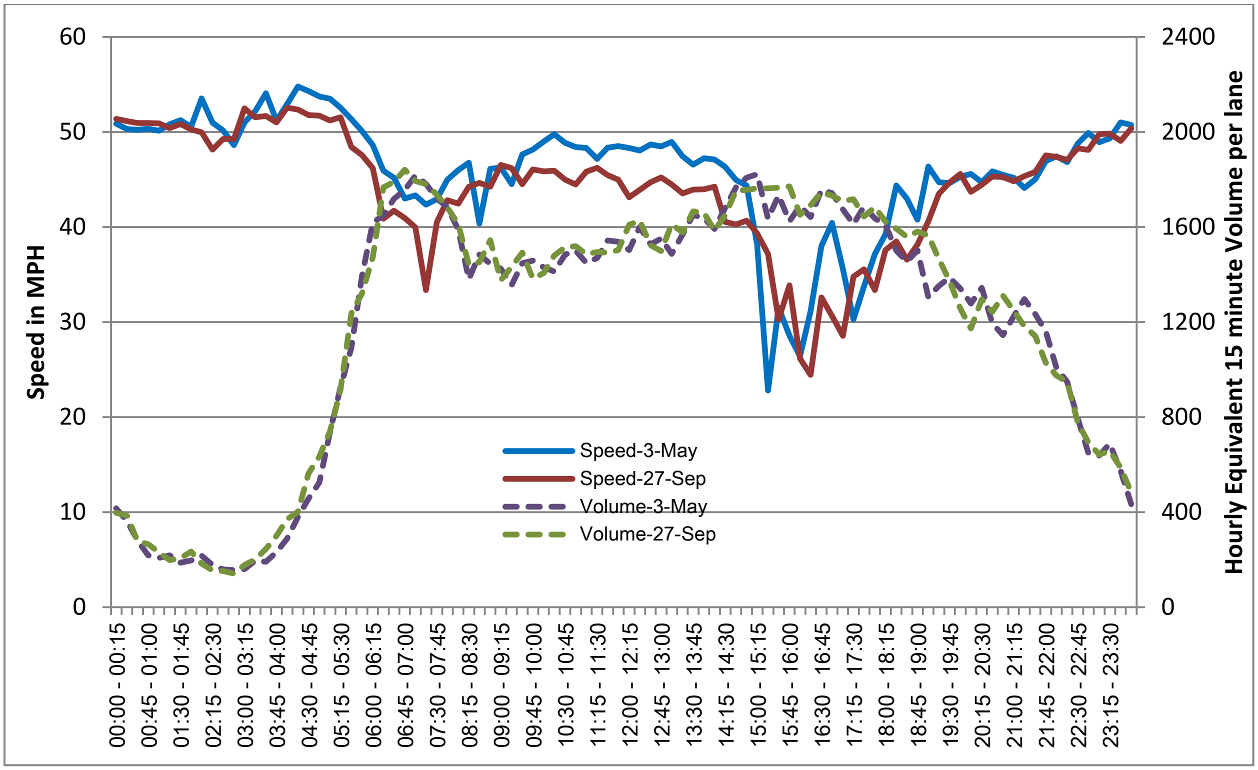


Figure C.28. Sta.SL23, WB H1 Fwy. at Kapalama Stream Bridge, MP 20.24 (Thursday, 2012).

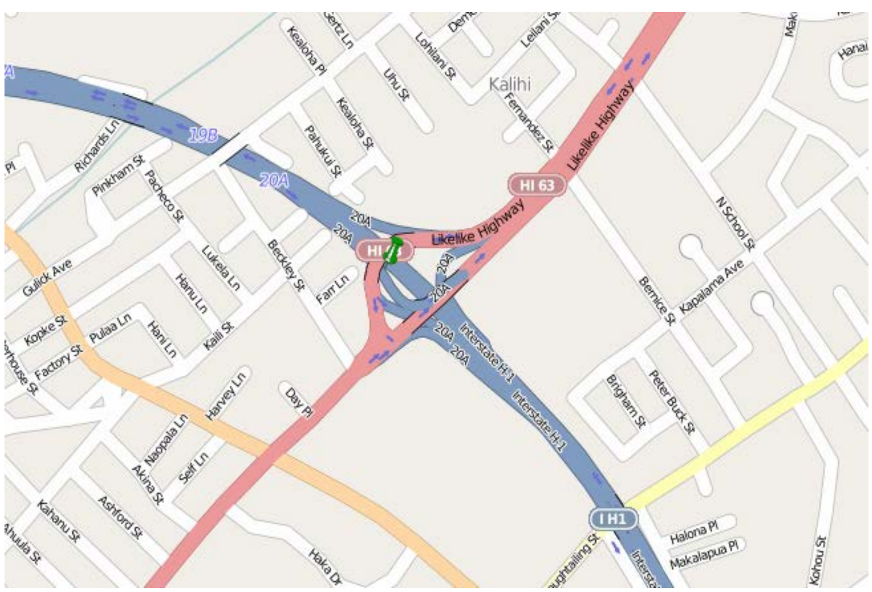


Figure C.29. Sta.SL15 MP19.27 (2012).

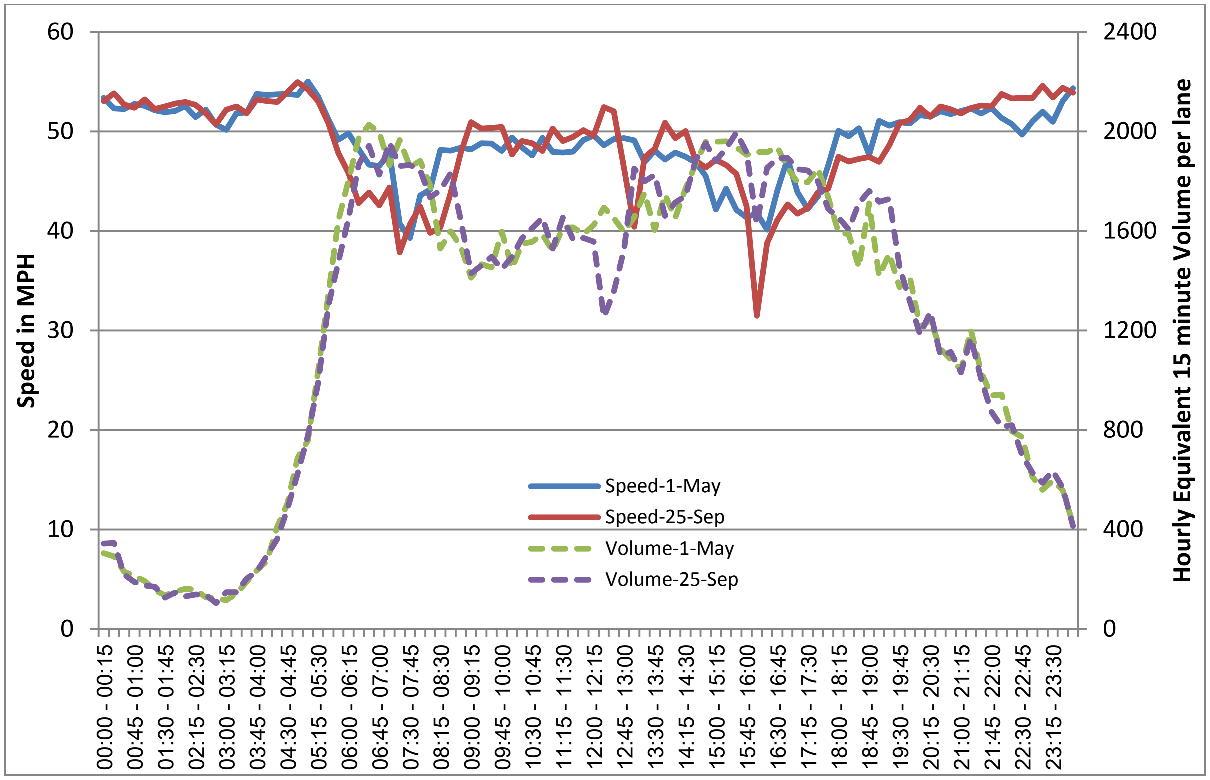


Figure C.30. Sta.SL15, WB H1 Fwy. at Kahily IC, MP19.27 (Tuesday, 2012).

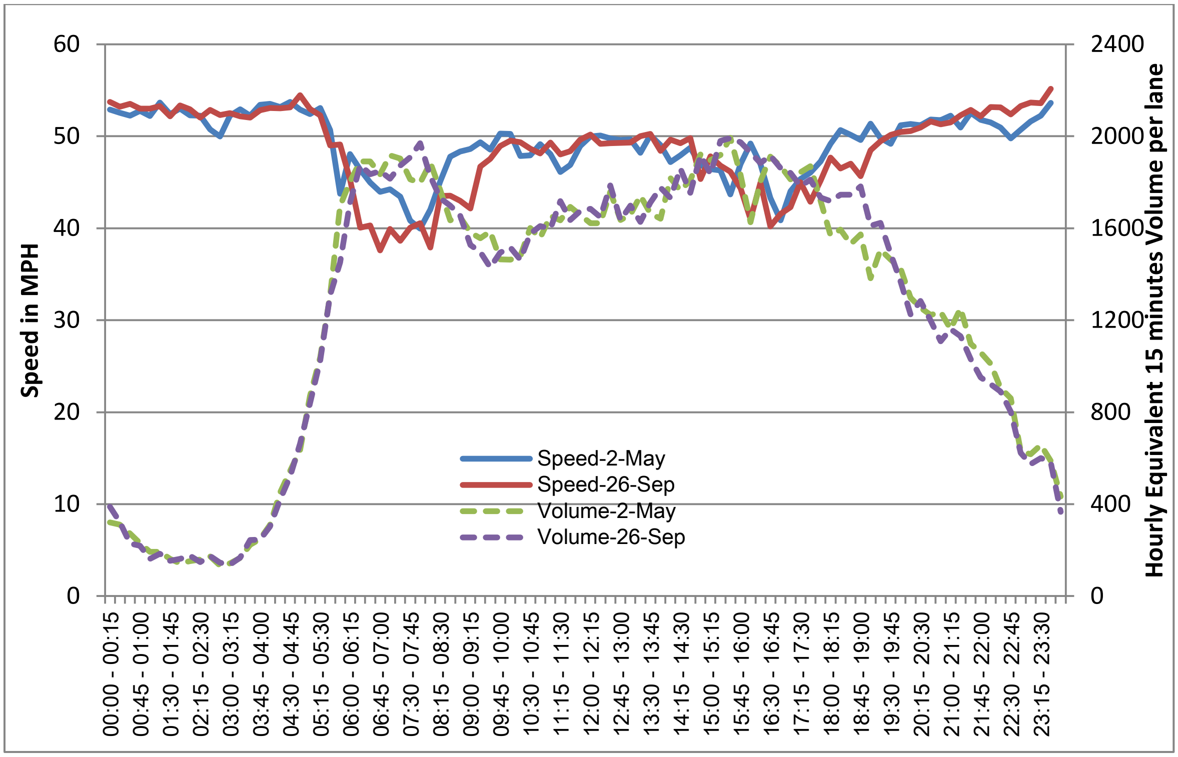


Figure C.31. Sta. SL15, WB H1 Fwy. at Kalihi IC, MP19.27 (Wednesday, 2012).

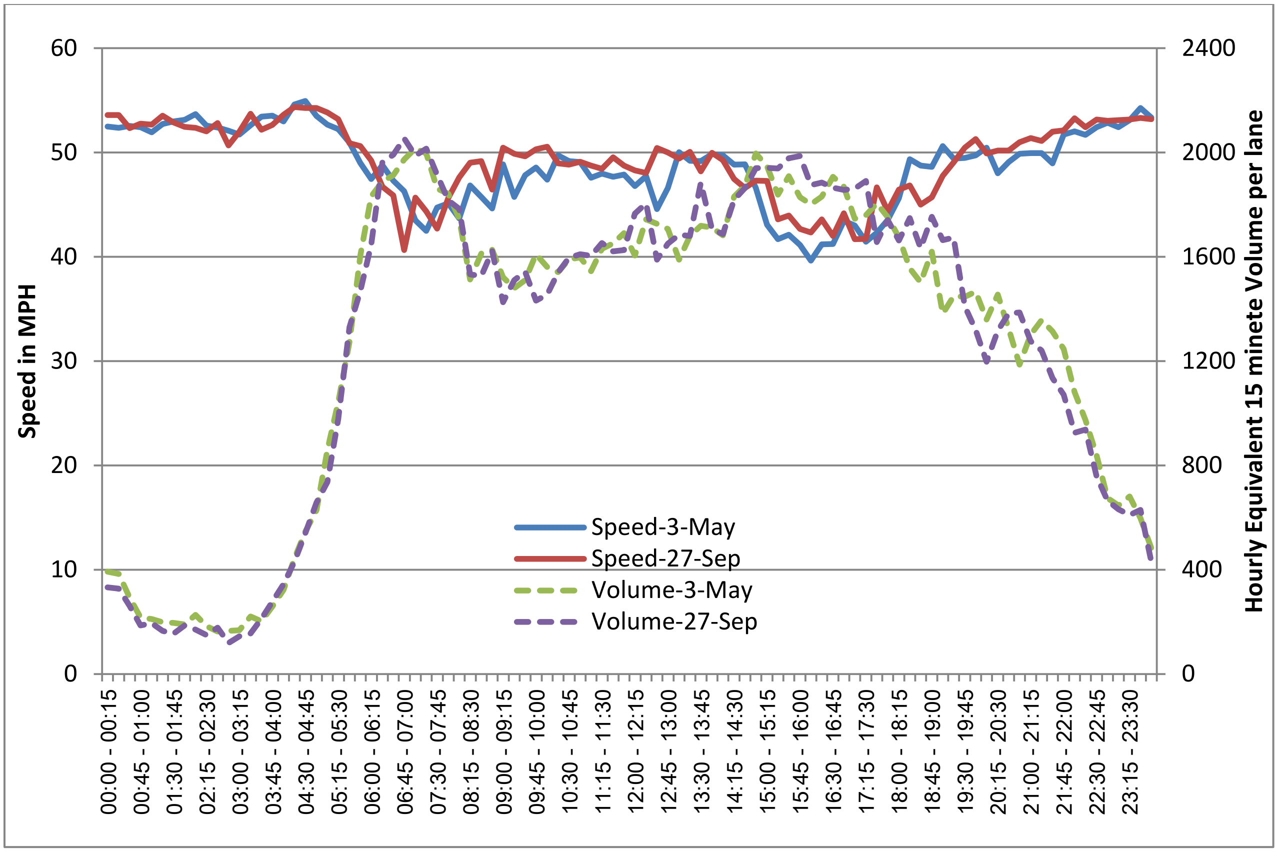


Figure C.32. Sta. SL15, WB H1 Fwy. at Kalihi IC, MP 19.27 (Thursday, 2012).

Appendix D

2012 Station and Sectional Speeds

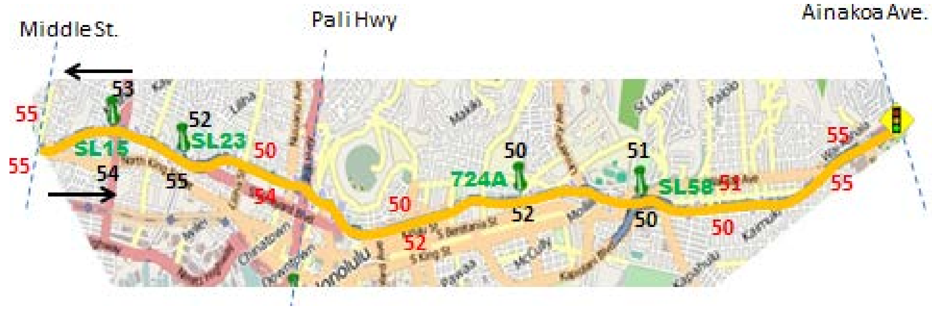


Figure D.1. Speed along H-1 Fwy. 00:00-6:00.

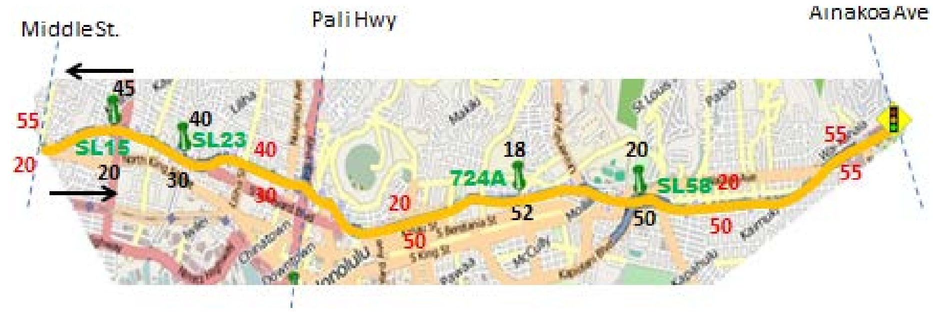


Figure D.2. Speed along H-1 Fwy. 06:00-10:00.

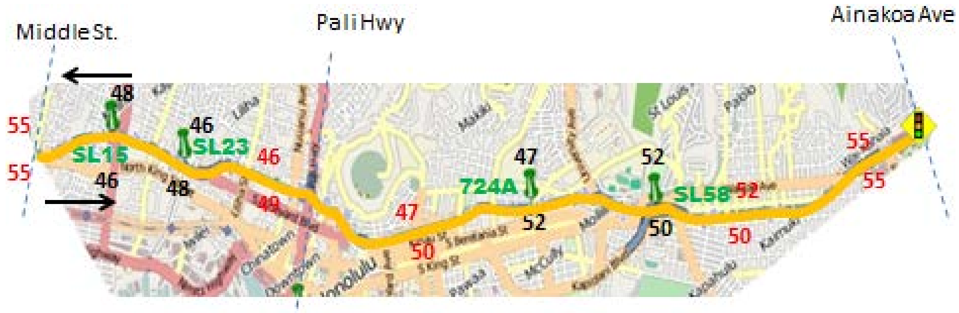


Figure D.3. Speed along H-1 Fwy. 10:00-14:30.

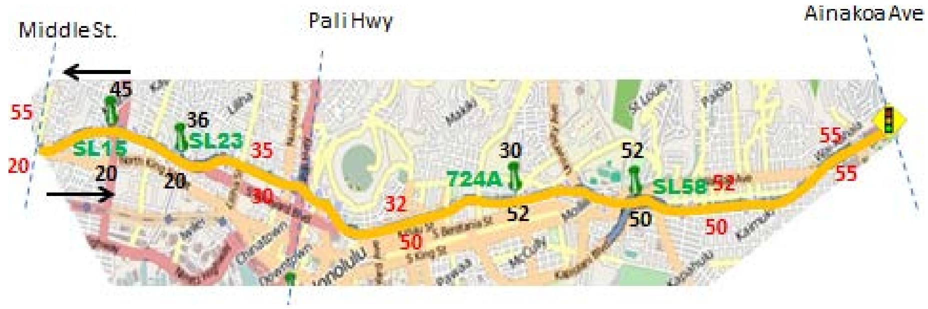


Figure D.4. Speed along H-1 Fwy. 14:30-19:00.

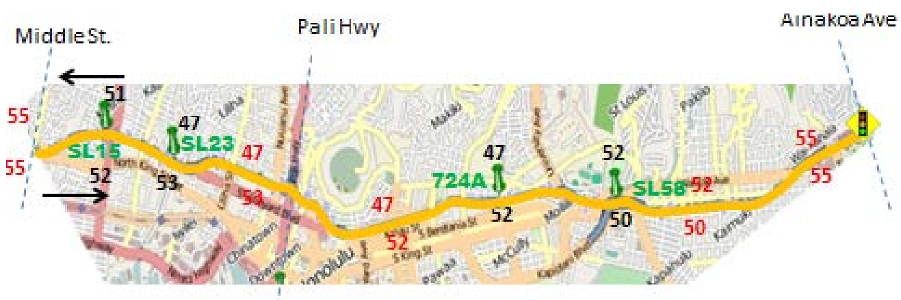


Figure D.5. Speed along H-1 Fwy. 19:00-24:00.

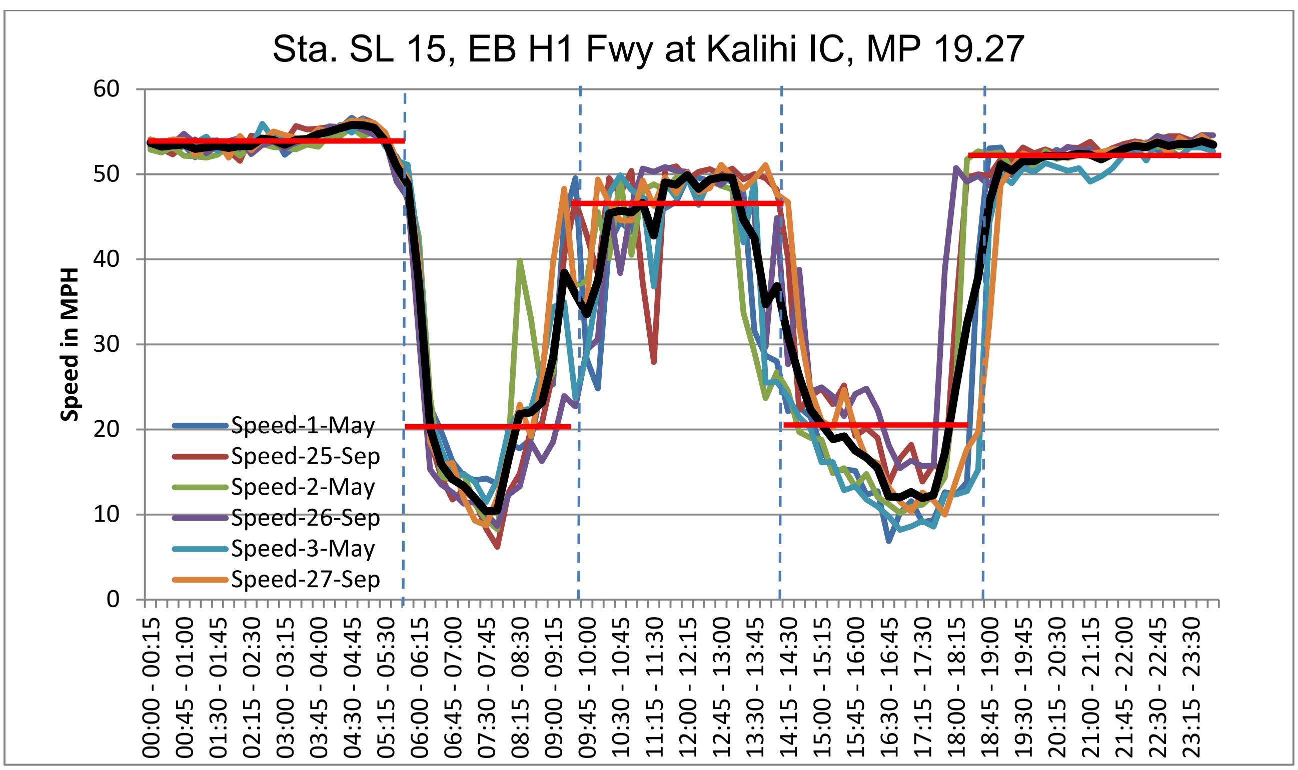


Figure D.6. Sample average speed from Sta. SL 15, EB.

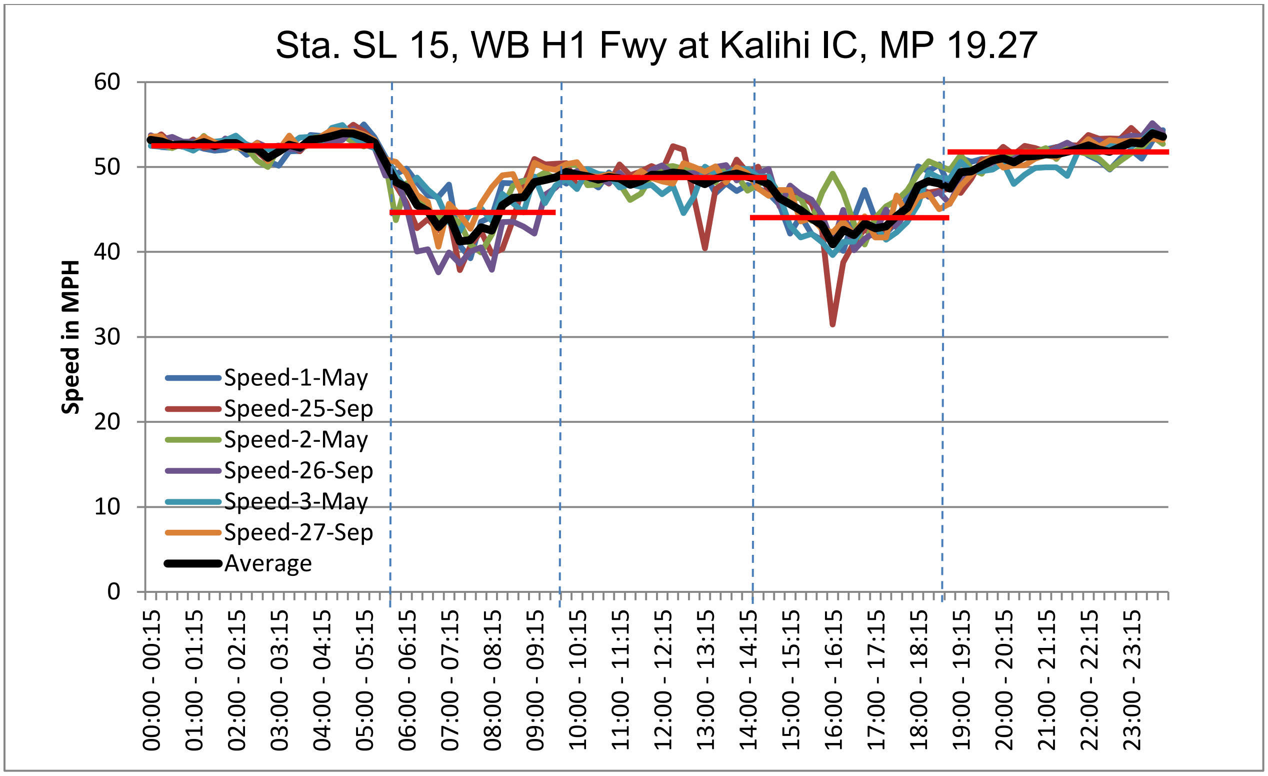


Figure D.7. Sample average speed from Sta. SL 15, WB.

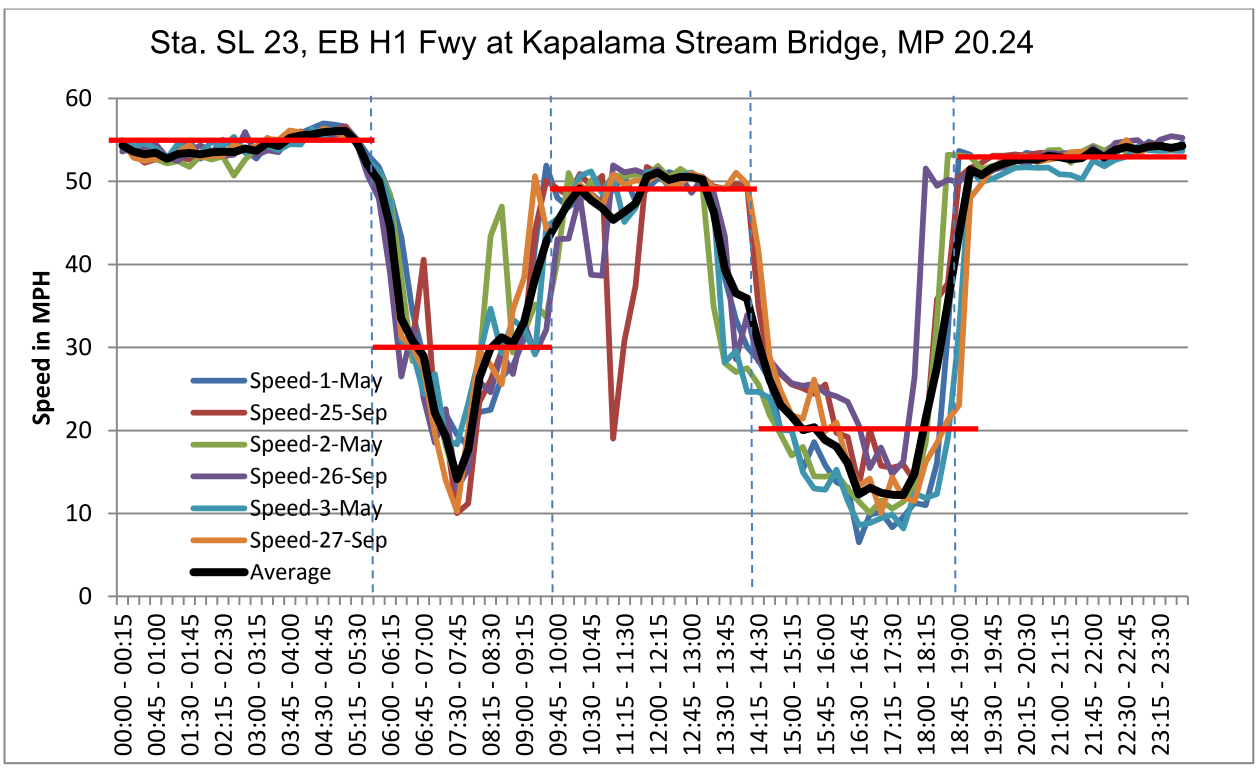


Figure D.8. Sample average speed from Sta. SL 23, EB.

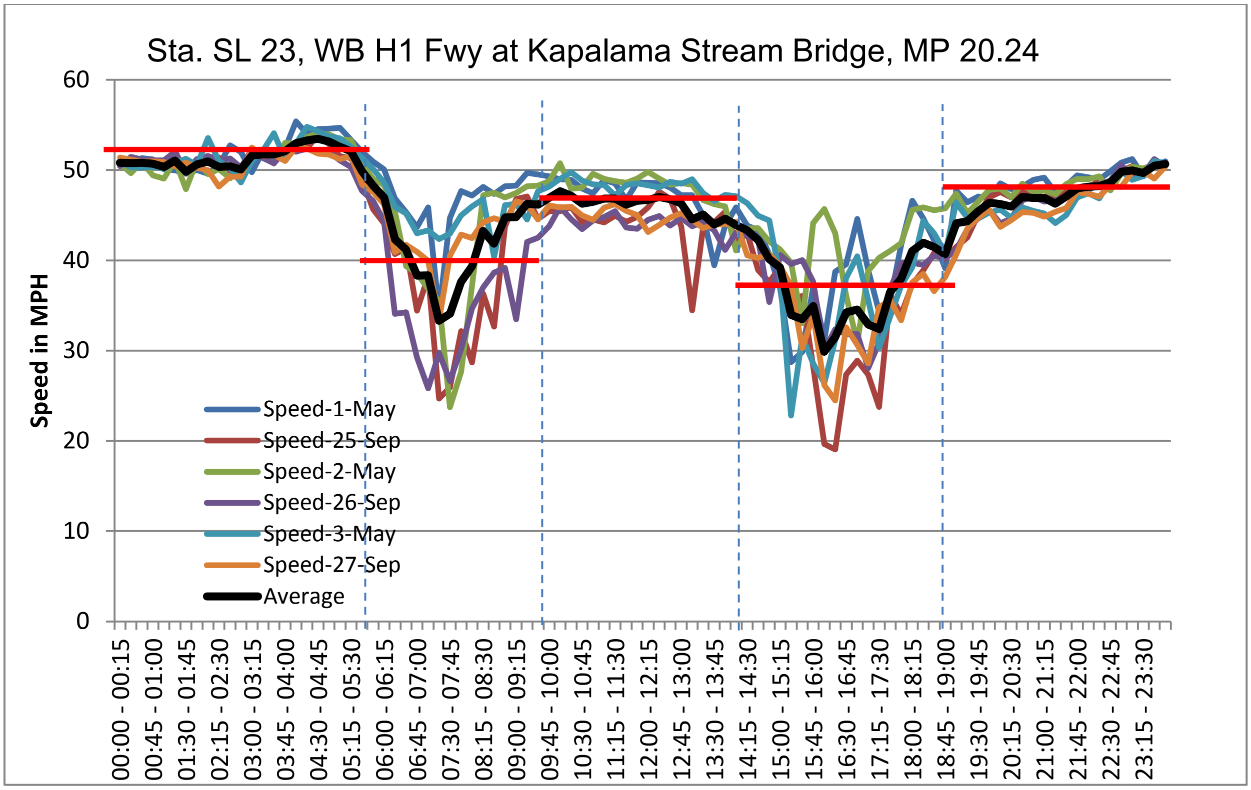


Figure D.9. Sample average speed from Sta. SL 23, WB.

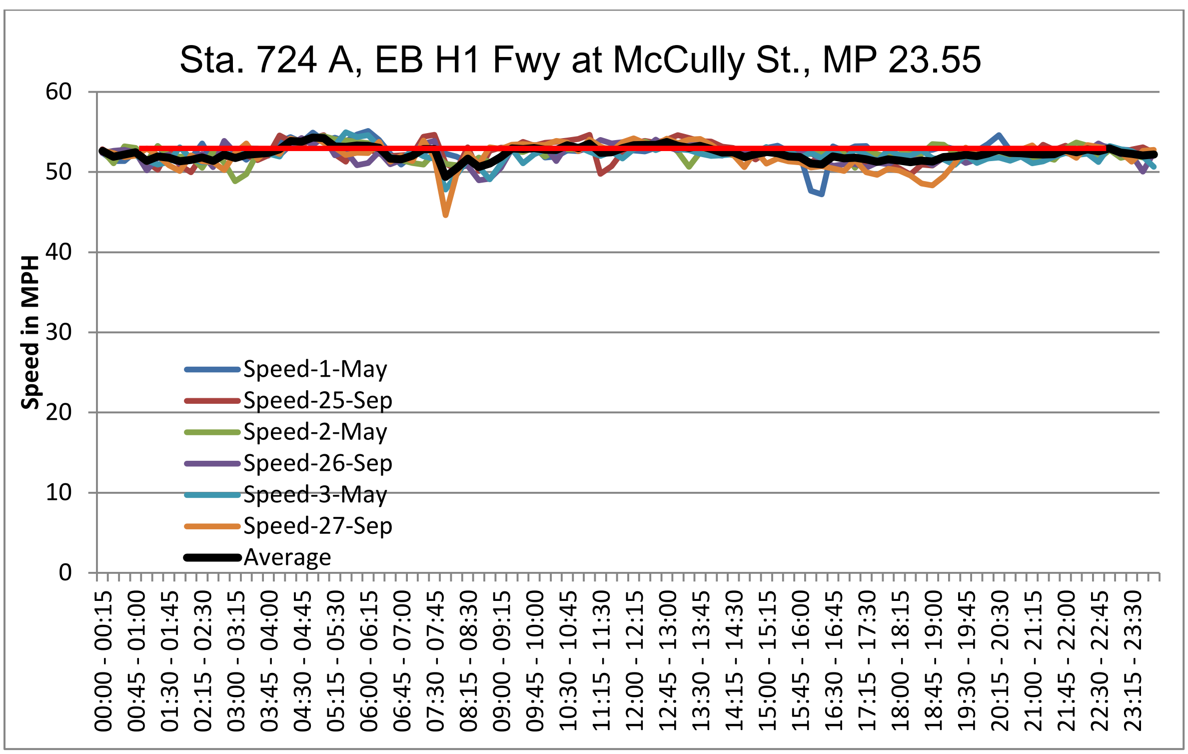


Figure D.10. Sample average speed from Sta. 724A, EB.

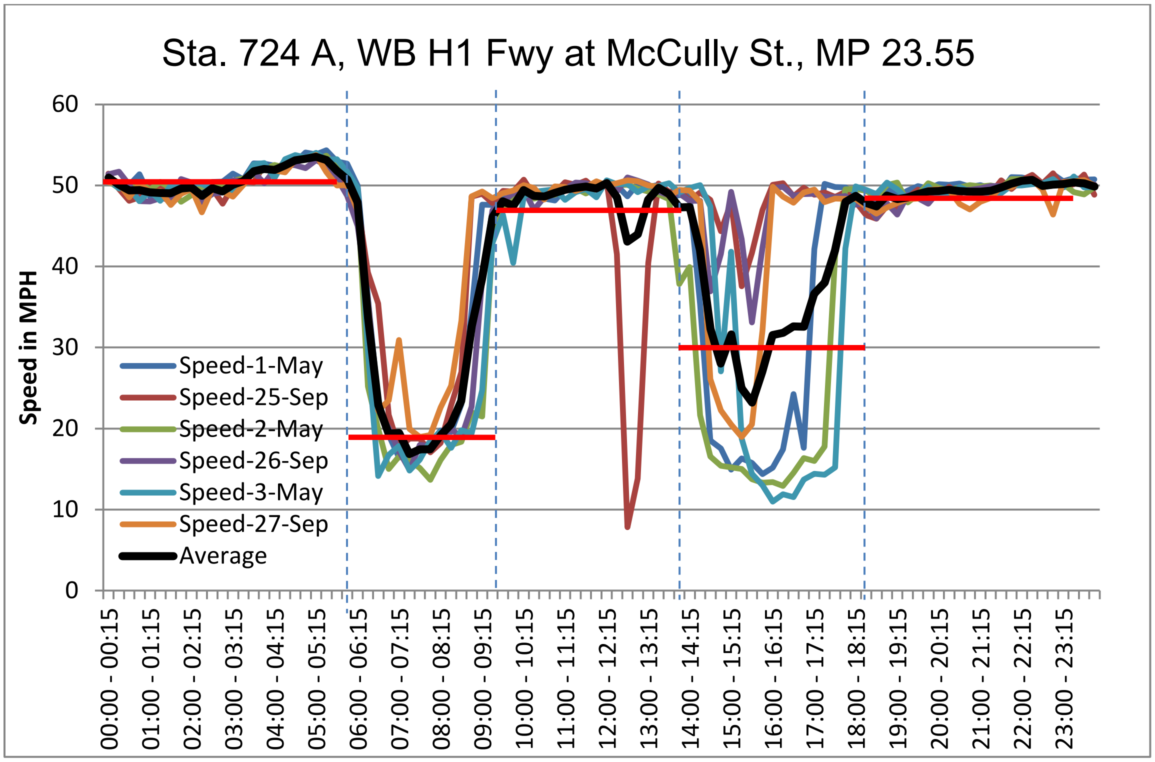


Figure D.11. Sample average speed from Sta. 724A, WB.

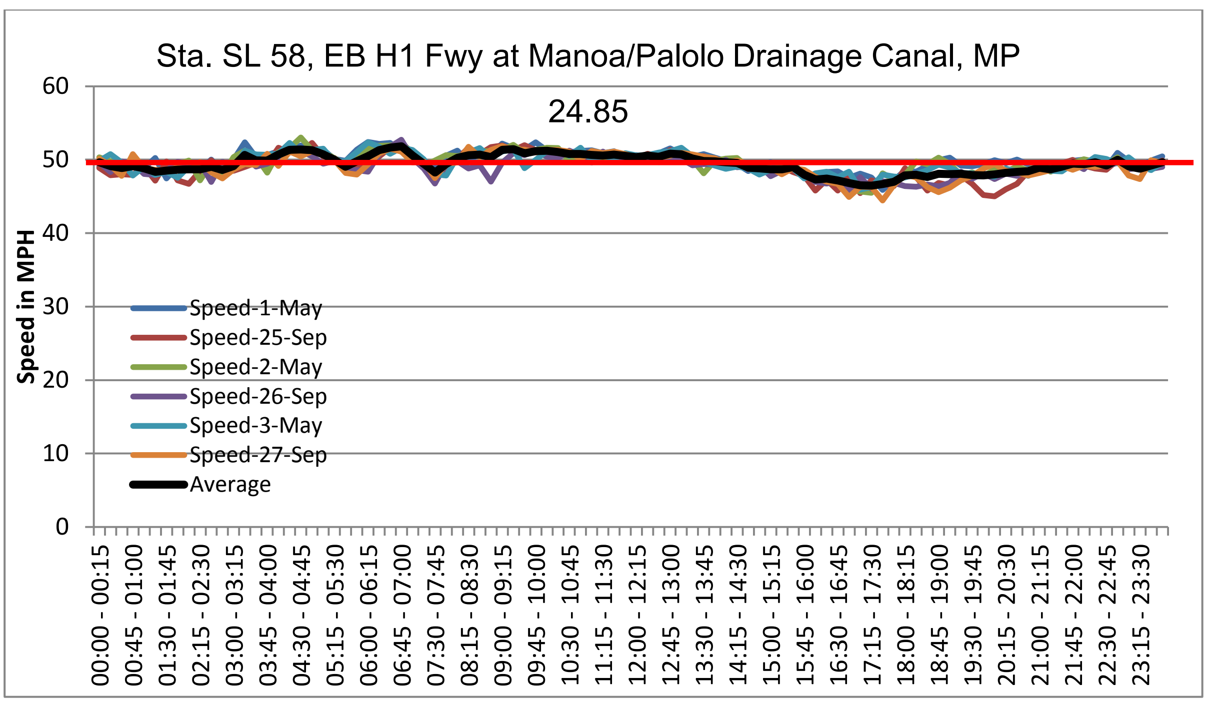


Figure D.12. Sample average speed from Sta.SL 58, EB.

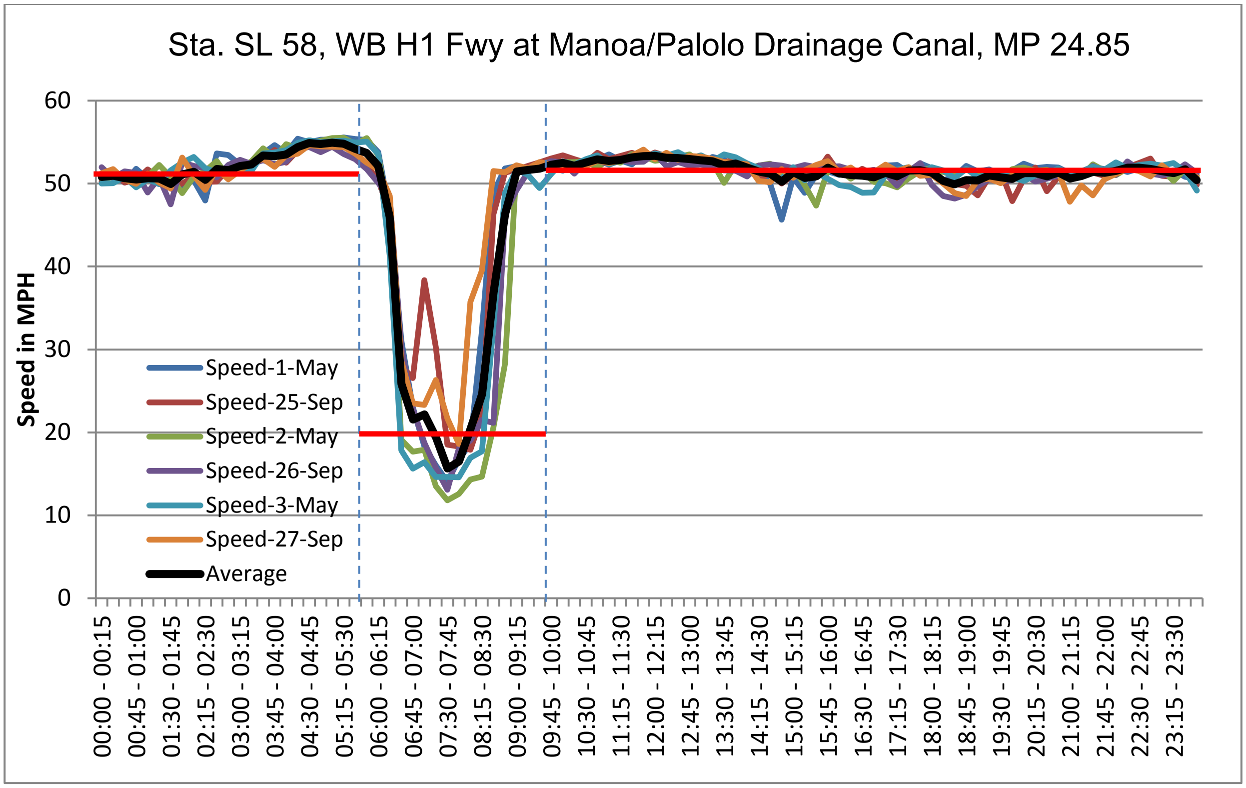


Figure D.13. Sample average speed from Sta.SL 58, WB.

Appendix E

2012 HDOT Volume Analysis

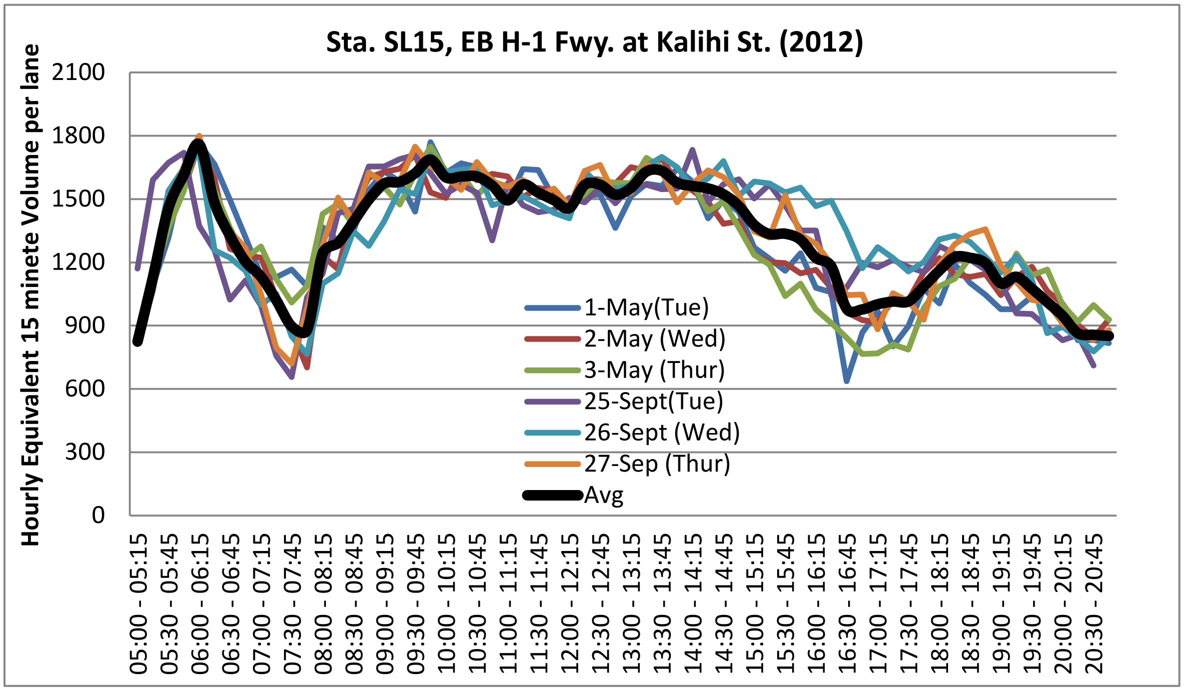


Figure E.1. Sample average volume from Sta. SL 15, EB.

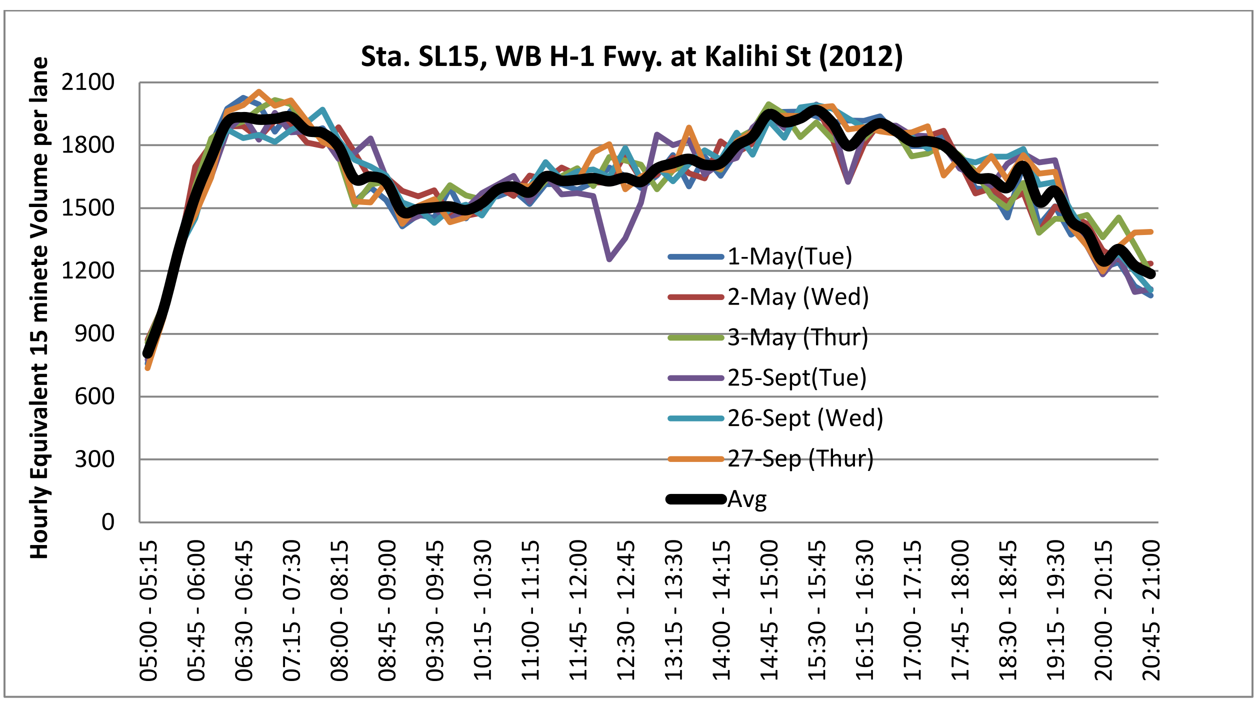


Figure E.2. Sample average volume from Sta. SL 15, WB.

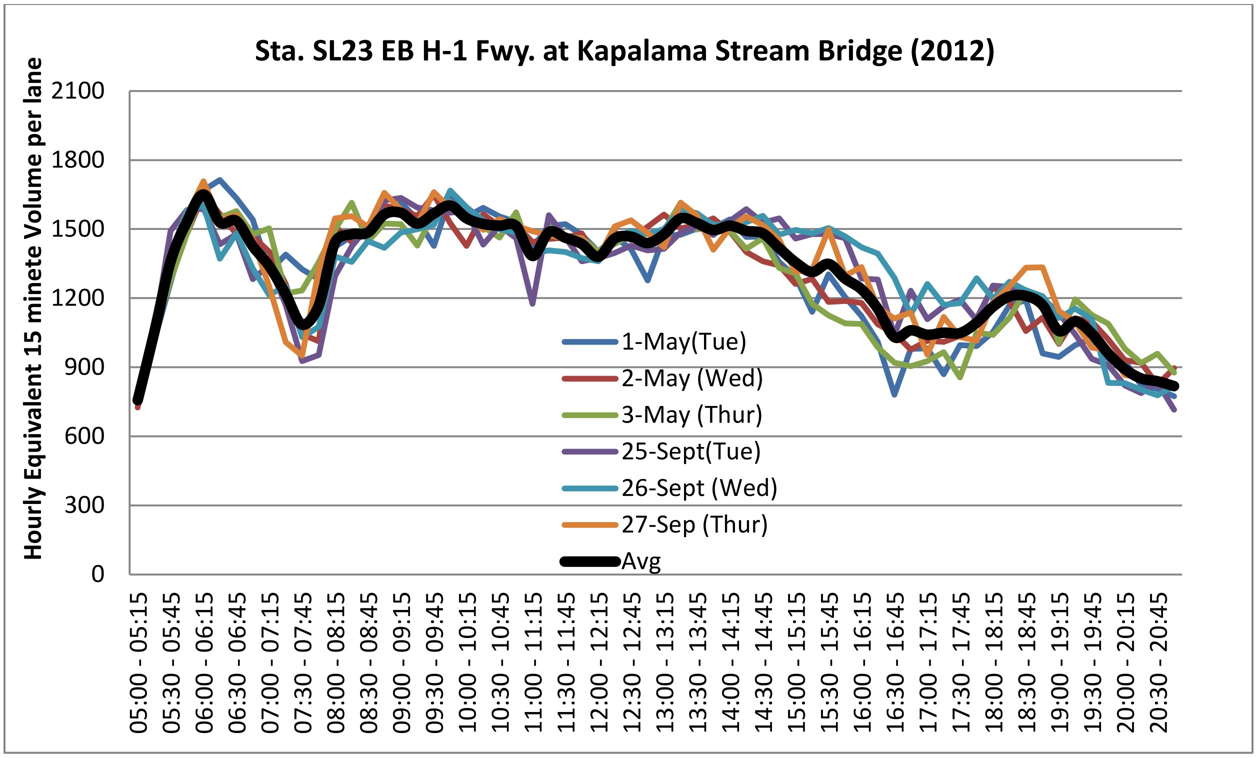


Figure E.3. Sample average volume from Sta. SL 23, EB.

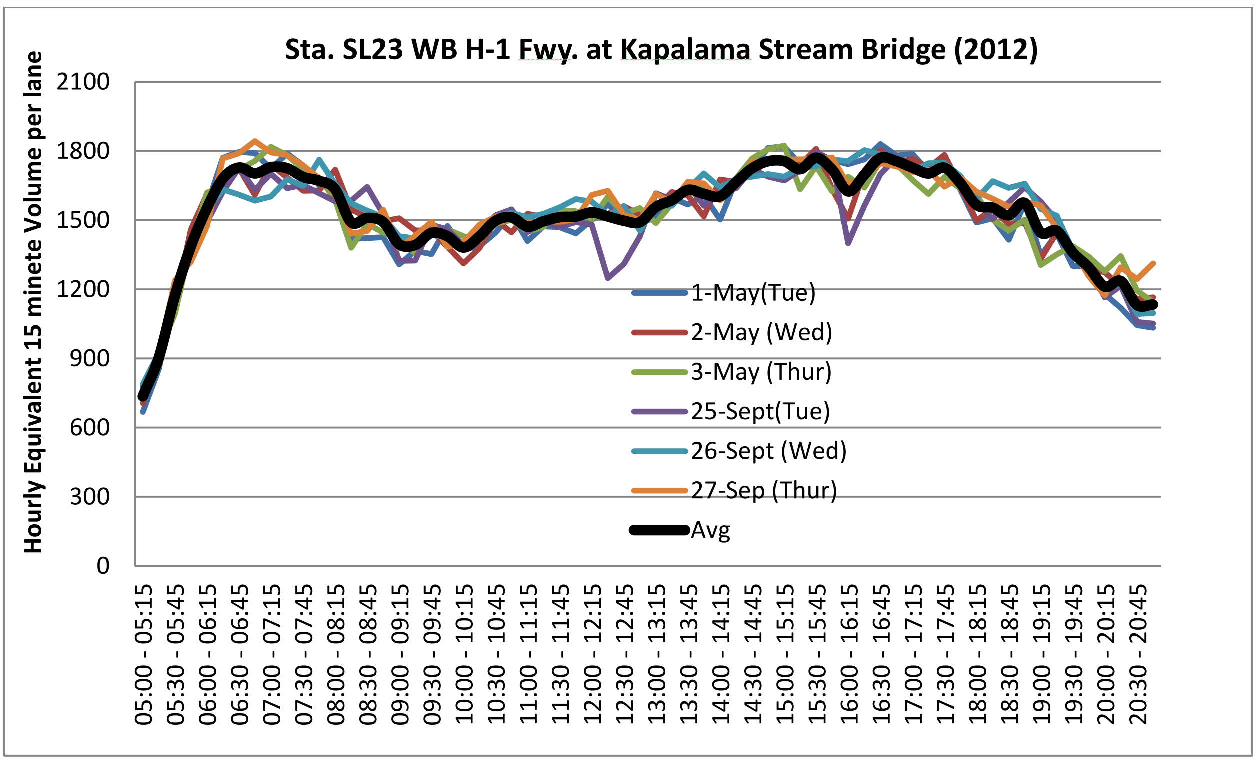


Figure E.4. Sample average volume from Sta. SL 23, WB.

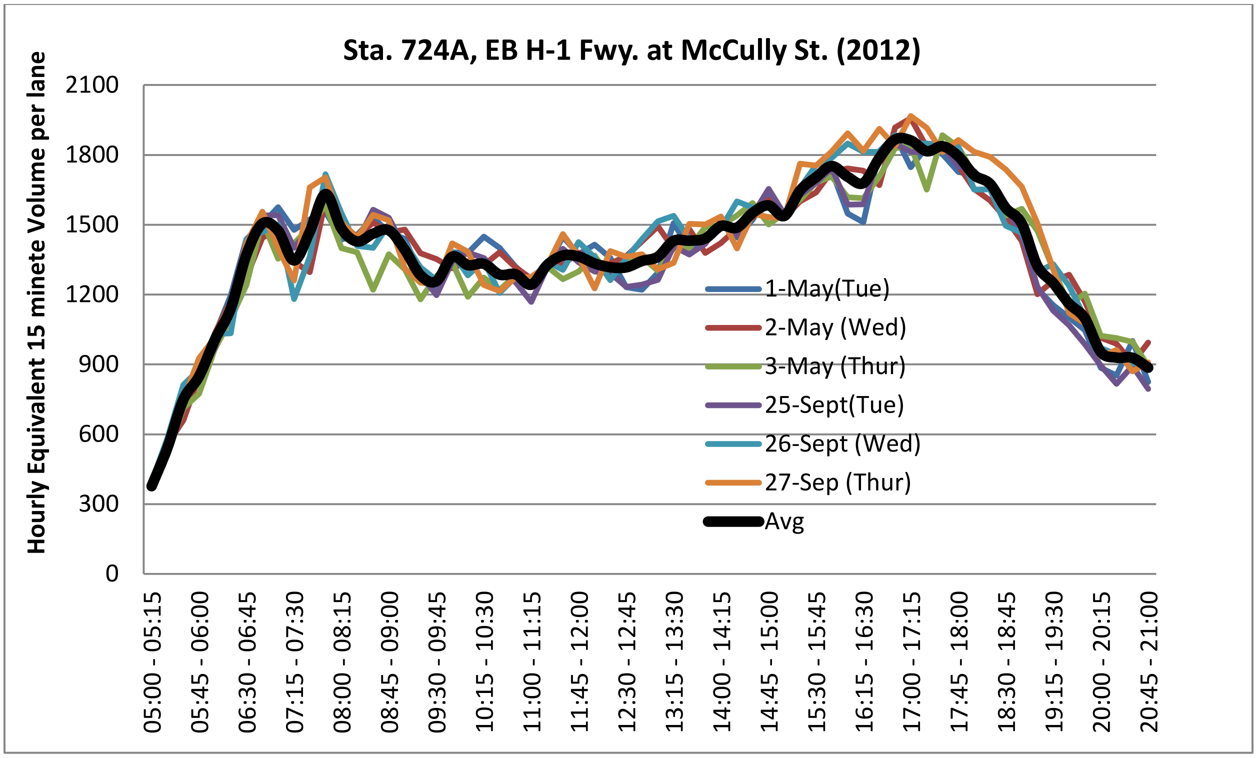


Figure E.5. Sample average volume from Sta. 724A, EB.

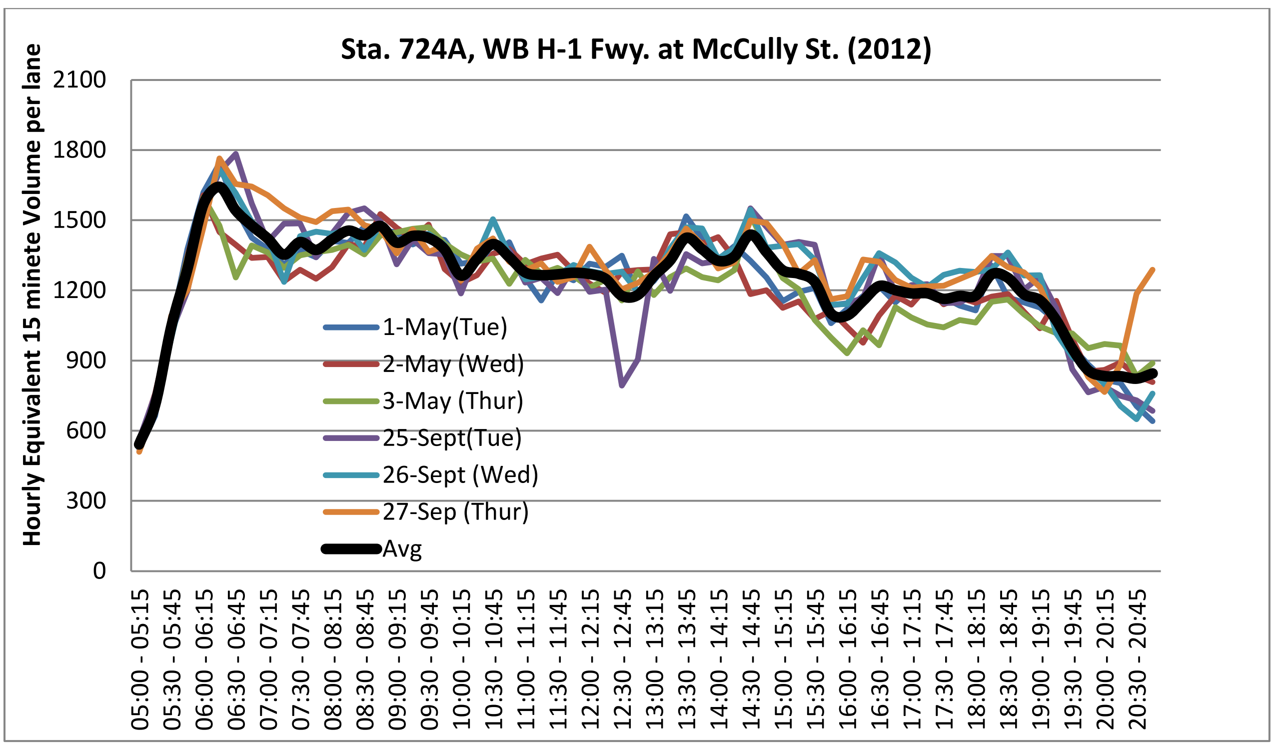


Figure E.6. Sample average volume from Sta. 724A, WB.

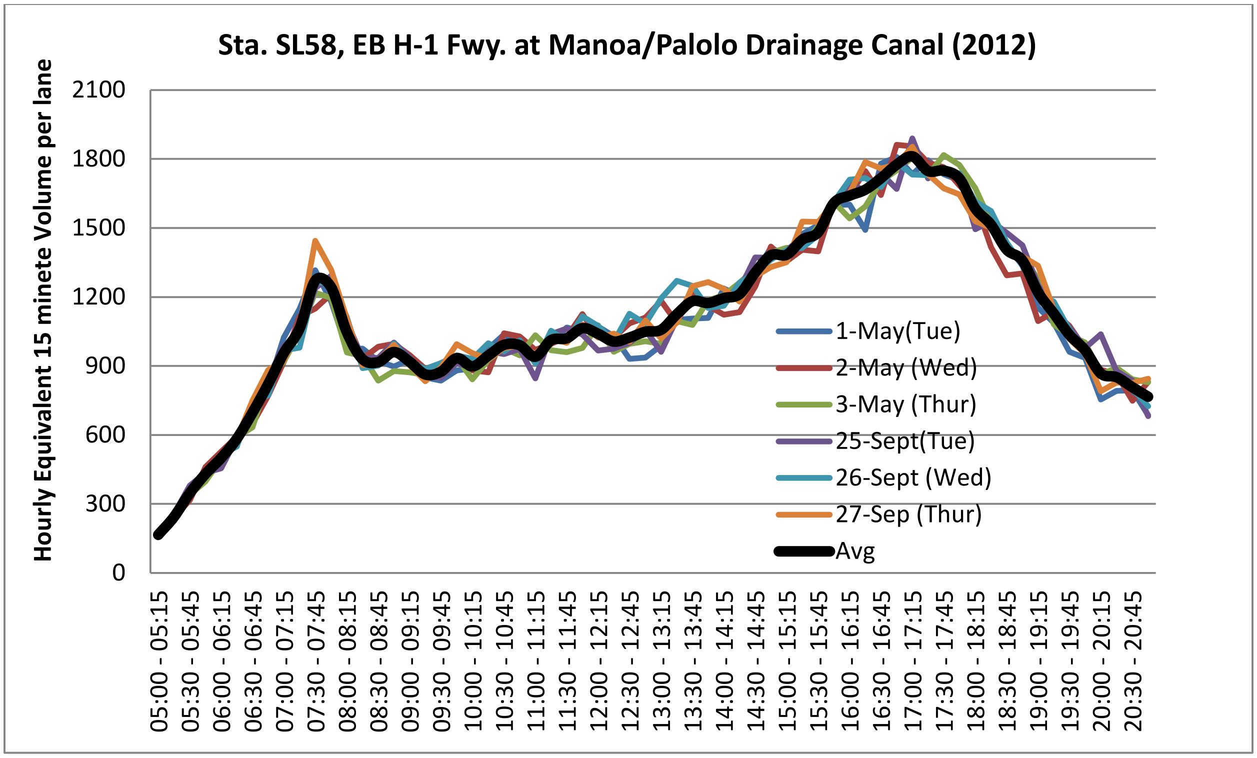


Figure E.7. Sample average volume from Sta. SL 58, EB.

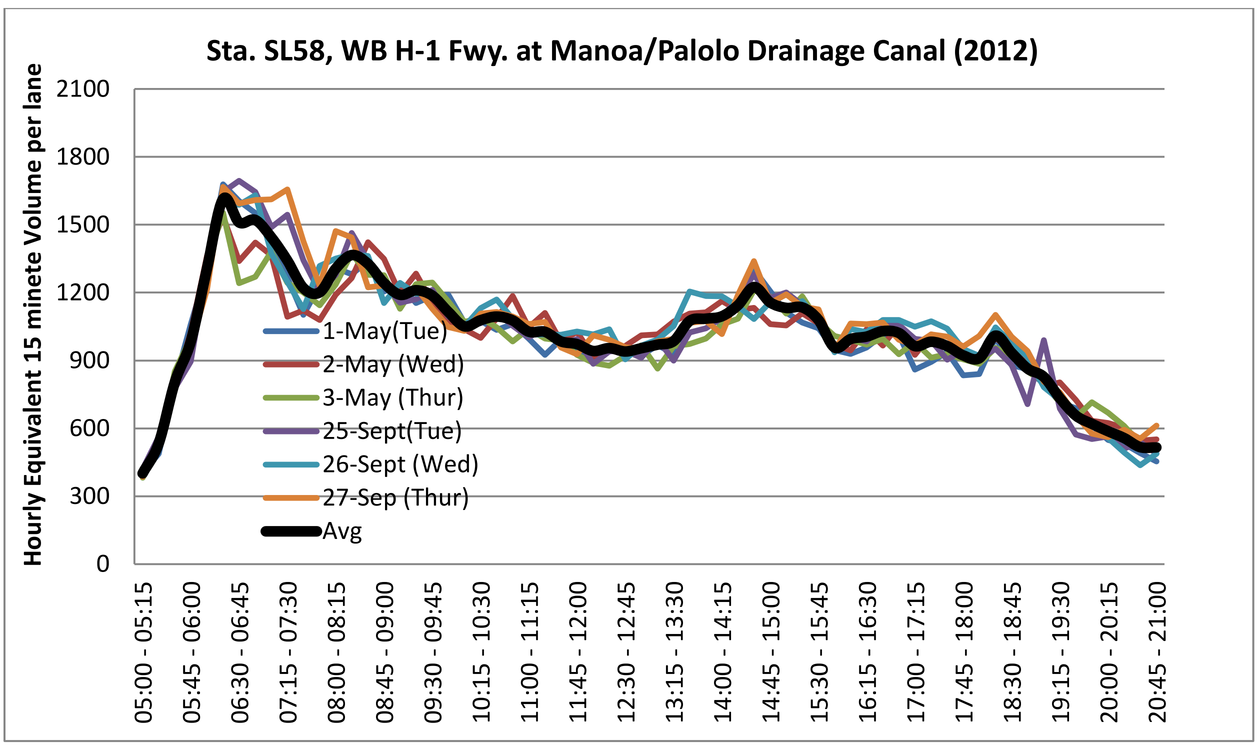


Figure E.8. Sample average volume from Sta. SL 58, WB.

Appendix F

TNM Results of Receptor Type E

Table F.1. TNM Results Summary, Feasibility and Reasonableness of Noise Abatement, Receptor Type E, 6:00-7:00

	Side of H-1 Freeway				Hawaii DOT NAC criterion[3] (dBA)	Baseline dBA[4] (hourly L_{eq})		L_{eq} dBA with 10 ft. barrier[5]		Land Use E	
	North (mauka)		South (makai)			North (mauka)	North (mauka)	South (makai)	South (makai)	At least 5 dBA noise reduction?	Meets[6] 75% goal?
	No. of Affected Units by NAC Land Use and their Elevation (z)[2]										
Segment[1]	E	z	E	z		E		E			
102					71					na	na
103					71					na	na
104	5	-2			71	69.2	58			below NAC	na
105					71					na	na
106					71					na	na
107					71					na	na
108	8	-8			71	67.9	57.6			below NAC	na
109					71					na	na
110					71					na	na
111					71					na	na
112					71					na	na
113					71					na	na
114					71					na	na
115					71					na	na
116					71					na	na
117					71					na	na
118					71					na	na
119					71					na	na
120					71					na	na
121					71					na	na
122					71					na	na
123					71					na	na
124	11	16			71	60.1	59.3			below NAC	na
125	1	-16	3	-8	71	66.1	56.8	68.8	58	below NAC	na
126					71					na	na
127					71					na	na
128			1	0	71			70.6	61.2	below NAC	na
129					71					na	na
130			1	10	71			**74.7**	**74.4**	N,↑	na

Notes		
	1	102 = Kahala Mall, 130 = Middle St.
	2	z over 10 ft. = freeway is depressed / z under -10 ft. = freeway is elevated
	3	Same for land uses B (single and multi-family residences) and C (campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, recreation areas, Section 4(f) sites, schools, ...)
	4	Based on 2012 sample volumes and speeds
	5	Located on the edge of each shoulder, nearest to the affected receptors
	6	Achieve the noise reduction design goal of 7 dBA for 75% of front-row receptors?
	↑	An up arrow indicates that the receiver is higher than the noise barrier, so a 10 ft. barrier is ineffective
	60.2	Leq estimate is below NAC

Table F.2. TNM Results Summary, Feasibility and Reasonableness of Noise Abatement, Receptor Type E, 17:00-18:00

	Side of H-1 Freeway				Hawaii DOT NAC criterion[3] (dBA)	Baseline dBA[4] (hourly L_{eq})		L_{eq} dBA with 10 ft. barrier[5]		Land Use E	
	North (mauka)		South (makai)								
	No. of Affected Units by NAC Land Use and their Elevation (z)[2]					North (mauka)	North (mauka)	South (makai)	South (makai)	At least 5 dBA noise reduction?	Meets[6] 75% goal?
Segment[1]	E	z	E	z		E		E			
102					71					na	na
103					71					na	na
104	5	16			71	74.2	62.3			Y	100%
105					71					na	na
106					71					na	na
107					71					na	na
108	8	-8			71	72.6	61.6			Y	100%
109					71					na	na
110					71					na	na
111					71					na	na
112					71					na	na
113					71					na	na
114					71					na	na
115					71					na	na
116					71					na	na
117					71					na	na
118					71					na	na
119					71					na	na
120					71					na	na
121					71					na	na
122					71					na	na
123					71					na	na
124	11	16			71	59.1	58.3			below NAC	na
125	1	-16	3	-8	71	64.6	55.4	66.7	56.2	below NAC	na
126					71					na	na
127					71					na	na
128			1	0	71			70.2	60.8	below NAC	na
129					71					na	na
130			1	10	71			74.8	74.5	N,↑	na

Notes		
	1	102 = Kahala Mall, 130 = Middle St.
	2	z over 10 ft. = freeway is depressed / z under -10 ft. = freeway is elevated
	3	Same for land uses B (single and multi-family residences) and C (campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, recreation areas, Section 4(f) sites, schools, ...)
	4	Based on 2012 sample volumes and speeds
	5	Located on the edge of each shoulder, nearest to the affected receptors
	6	Achieve the noise reduction design goal of 7 dBA for 75% of front-row receptors?
	↑	An up arrow indicates that the receiver is higher than the noise barrier, so a 10 ft. barrier is ineffective
	60.2	Leq estimate is below NAC

Table F.3. TNM Results Summary, Feasibility and Reasonableness of Noise Abatement, Receptor Type E, 19:00-20:00

	Side of H-1 Freeway				Hawaii DOT NAC criterion[3] (dBA)	Baseline dBA[4] (hourly L_{eq})		L_{eq} dBA with 10 ft. barrier[5]		Land Use E	
	North (mauka)		South (makai)			North (mauka)	North (mauka)	South (makai)	South (makai)	At least 5 dBA noise reduction?	Meets[6] 75% goal?
	No. of Affected Units by NAC Land Use and their Elevation (z)[2]										
Segment[1]	E	z	E	z		E		E			
102					71					na	na
103					71					na	na
104	5	16			71	72.5	60.4			Y	100%
105					71					na	na
106					71					na	na
107					71					na	na
108	8	-8			71	70.7	59.6			Y	100%
109					71					na	na
110					71					na	na
111					71					na	na
112					71					na	na
113					71					na	na
114					71					na	na
115					71					na	na
116					71					na	na
117					71					na	na
118					71					na	na
119					71					na	na
120					71					na	na
121					71					na	na
122					71					na	na
123					71					na	na
124	11	16			71	62.8	62.2			below NAC	na
125	1	-16	3	-8	71	58.5	58.2	60.5	60.3	below NAC	na
126					71					na	na
127					71					na	na
128			1	0	71			76.1	64.5	Y	100%
129					71					na	na
130			1	10	71			77.7	76	N,↑	na

Notes		
	1	102 = Kahala Mall, 130 = Middle St.
	2	z over 10 ft. = freeway is depressed / z under -10 ft. = freeway is elevated
	3	Same for land uses B (single and multi-family residences) and C (campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, recreation areas, Section 4(f) sites, schools, ...)
	4	Based on 2012 sample volumes and speeds
	5	Located on the edge of each shoulder, nearest to the affercted receptors
	6	Achieve the noise reduction design goal of 7 dBA for 75% of front-row receptors?
	↑	An up arrow indicates that the receiver is higher than the noise barrier, so a 10 ft. barrier is ineffective
	60.2	Leq estimate is below NAC

Appendix G

Color Coded Results of TNM, 17:00-18:00

Below 62.5, 62.5 to 69.4[5], 69.5 and above in dBA

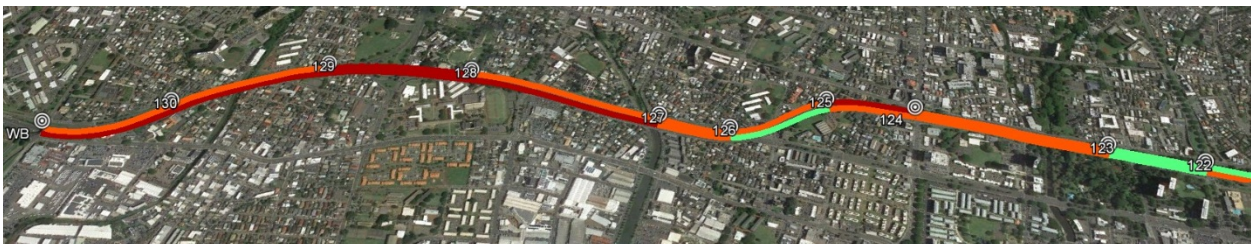


Figure G.1. H-1 Freeway segments 130 to 122: from Middle St. to Kalihi.

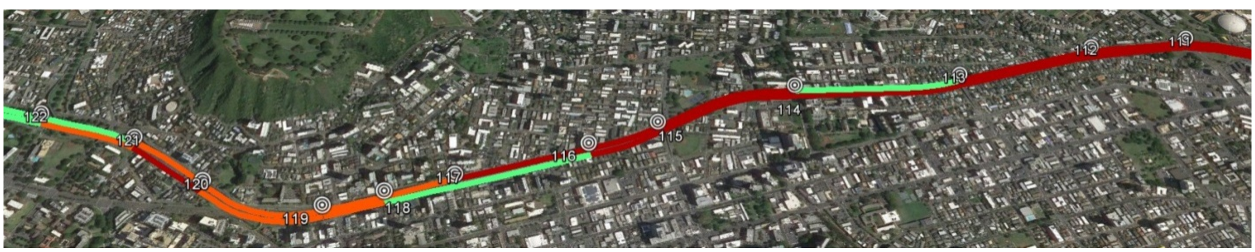


Figure G.2. H-1 Freeway segments 122 to 111: from Kalihi to UH-Manoa.

Figure G.3. H-1 Freeway segments 111 to 102: from UH-Manoa to Kahala Mall.

[5] This is ±3 dBA around the 66 dBA NAC for receptors type B and C. This yields a range of 63 to 69 dBA, but 62.5 rounds up to 66 and 69.4 rounds down to 69 so the effective range used was 62.5 to 69.4 dBA.