Central Puget Sound

FREEWAY NETWORK USAGE AND PERFORMANCE

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FLOW Evaluation

Central Puget Sound
FREEWAY NETWORK
USAGE AND PERFORMANCE

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This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

This *summary* report presents an overview of the level of traveler usage (e.g., how many vehicles use the freeways) and travel performance (e.g., how fast they are traveling, where and how often congestion occurs) on the principal urban freeways in the central Puget Sound area for 1997. Data presented in this report were collected by the Washington State Department of Transportation's (WSDOT's) freeway surveillance system.

The project that led to this report is intended to meet two separate purposes: 1) to enhance WSDOT's ability to monitor and improve its traffic management efforts on Seattle-area highways, and 2) to provide useful information to the public and decision makers about the status of the freeway system's operational performance. This report is primarily intended to meet the second of these objectives. However, the software developed for this project and many of the graphics presented in this report are directly applicable to the first objective.

This report is one of three products resulting from this WSDOT project. In addition to this report, this project produced a set of software tools to assist in freeway data analysis, as well as a technical report describing the evaluation approach, process, and analytical tool set that were developed to analyze freeway usage and performance in the central Puget Sound region. The freeways studied in this project are managed by WSDOT using its FLOW system, a coordinated network of traffic monitoring, measuring, information dissemination, and control devices that operates on urban state and Interstate highways in the central Puget Sound region.

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Disclaimer

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Acknowledgments

A prerequisite for the type of analysis documented in this report is the availability of detailed traffic data and professional guidance from a variety of sources. This project was fortunate to have had the cooperation of numerous state and local agencies and their staff, who responded in a timely and professional manner to requests for data, as well as to follow-up questions. They also provided this project with valuable feedback regarding preliminary analytical results and offered important technical advice. This report would not have been possible without their enthusiastic support; we extend our sincere thanks to them all.

This project was made possible with the support and encouragement of the WSDOT Research Office and its director, Martin Pietz, and WSDOT's Northwest Region Traffic Systems group and its Assistant Regional Administrator, Les Jacobson. The project researchers also wish to acknowledge the ongoing technical guidance of WSDOT Northwest Region staff, with particular thanks to Mark Morse, Mark Leth, and David Berg.

This research effort was fortunate to have access to a multi-year traffic database for the central Puget Sound freeway network, which was the foundation for most of the results presented in this report. Valuable technical support for the use of this database and the associated Compact disc Data Retrieval (CDR) software was provided by WSDOT Northwest Region's Dongho Chang, Lanping Xu, Greg Leege, Michael Forbis, Mahrokh Arefi, CDR's original programmer Alan Shen, and the Traffic Systems Management Center (TSMC). Assistance with other archived traffic data was provided by Amity Trowbridge, Keith Bynum, and Paul Neel of WSDOT. In addition, transit ridership data were provided by representatives of regional transit agencies, including Joy Munkers, Jon Layzer, and Brent Russell of Community Transit; Tom Friedman, Wayne Watanabe, and David Rinearson of the King County Department of Transportation (Metro Transit); and Nathaniel Jones and George Patton of Pierce Transit. Data collection assistance was also provided by Nicholas Roach and Joel Pfundt of the Puget Sound Regional Council. Dan Dailey of the University of Washington provided technical assistance for selected performance measure algorithms used in this analysis. Vehicle occupancy and travel time data were provided by William Brown and Eldon Jacobson of the WSDOT HOV Lane Evaluation project.

Valuable suggestions were also received during presentations of preliminary project results to regional and state groups. Comments were provided by members of the Washington State Transportation Commission, as well as staff of the WSDOT Research Office, WSDOT Northwest Region Traffic and Freeway Operations group, WSDOT Office of Urban Mobility, WSDOT Transportation Data Office, WSDOT Advanced Technology Branch, Community Transit, Metro Transit, Pierce Transit, and the Puget Sound Regional Council.

The project researchers also wish to recognize the significant contributions made by the Washington State Transportation Center's technical staff. These include Duane Wright, who developed the project's analysis software tools and provided extensive computer graphics support; Stephanie MacLachlan, who contributed to the initial scoping and methodology design phase of this project; Jennifer Nee, who performed technical analyses of person volumes, HOV lane performance, and overall freeway usage; Mary Marrah, who was responsible for graphic design; and Amy O'Brien, who edited the text and supervised final document design, report layout, and integration. This report would not have been possible without their participation.

Glossary

GP Lanes	General purpose freeway lanes. GP freeway lanes can be used by any vehicle regardless of the number of occupants in the vehicle or the vehicle type.
HOV Lanes	High occupancy vehicle freeway lanes. HOV freeway lanes can be used by a) any vehicle with at least 2 occupants, including the driver (as of 1997, 3 occupants minimum on the SR 520 HOV lane), b) motorcycles, and c) transit vehicles.
Lane Occupancy	The percentage of time that a roadway sensor detects the presence of a vehicle at a particular freeway location. This value can be used to estimate different levels of traffic congestion. In the central Puget Sound area, electronic sensors embedded in individual freeway lanes are commonly used to collect these data.
Peak Hour Volume	The highest number of vehicles that pass a particular freeway location in a one-hour period during the AM hours (midnight to noon) and during the PM hours (noon to midnight).
Peak Period Volume	The total number of vehicles that pass a particular freeway location per peak period. In this report, the AM peak period is defined as 6:00 AM to 9:00 AM, and the PM peak period is 3:00 PM to 7:00 PM.
Person Volume	The estimated total number of persons passing a particular freeway location over a given time period (daily, peak period, or peak hour). Also referred to as person throughput. In this report, person volume is computed by using a combination of vehicle volume data (estimated number of vehicles) and vehicle occupancy data (estimated number of travelers per vehicle, based on data from transit agencies and field observations).
Reversible Lanes	Freeway lanes that operate in only one direction during part of the day, and the opposite direction during the rest of the day. Vehicle occupancy requirements on reversible lanes (e.g., HOVs only) vary with location and time of day. In the central Puget Sound area, reversible lanes are found on I-5 between the Seattle central business district and Northgate, and on I-90 between Seattle and the east side of Mercer Island.
Vehicle Volume	The estimated total number of vehicles passing a particular freeway location over a given time period (daily, peak period, or peak hour). In the central Puget Sound area, electronic sensors embedded in individual freeway lanes are commonly used to collect these data.
vplph	Vehicles per lane per hour. Vplph is the estimated vehicle volume at a particular freeway location, adjusted for the number of lanes at that site and the time period of the measurement. For example, if vehicle volume has been collected at each of three lanes at a location for 5 minutes, vplph is determined by adding together the 5-minute vehicle counts for the three lanes, dividing that sum by the number of lanes (three), then multiplying the result by 12 to get an equivalent hourly volume (12 X 5 minutes = 1 hour). This produces a per-lane, per-hour equivalent volume. Vplph allows measurements of vehicle volume from different locations with different numbers of lanes to be more directly compared to one another.

Section 1. Introduction

Purpose of This Report

This report presents an overview of the level of traveler usage and travel performance on the principal urban freeways in the central Puget Sound area for 1997. The freeways included in this report are managed by the Washington State Department of Transportation (WSDOT) through operation of its FLOW system, a coordinated network of traffic monitoring, measuring, information dissemination, and control devices that operates on urban state and interstate highways in the central Puget Sound region. This report is a product of a WSDOT-sponsored project whose purpose is twofold: (1) to enhance the Department's ability to monitor and improve its traffic management efforts on Seattle-area highways, and (2) to provide useful information to the public and other decision makers about the status of state traffic management activities in the area. This report is one of a planned series of periodic evaluations of the central Puget Sound urban highway network and the WSDOT FLOW system.

This is a summary report intended to provide an overview of the freeway system's usage and performance based on information collected at selected locations. Generalizing to other locations in the freeway network requires caution, as performance can vary significantly even among closely spaced sites. However, the data analysis procedures used for this project were designed to be general; they can be employed at locations other than those included in this report, provided that the appropriate data have been collected.

The analysis in this report is dependent on the availability and quality of traffic data for central Puget Sound freeways. Although the regional traffic data used for this report were generally detailed and comprehensive, data for some locations and time periods were occasionally unavailable or of variable quality because of construction activity, lack of sensor installations, or equipment problems. The analysis methods used for this report were designed to compensate for extended segments of unavailable or incomplete data as much as was practicable; nevertheless, some of the results are considered tentative because of the nature of the input data upon which they are based. The measures reported in this document are generally average values based on many days of traffic data; they do not represent a particular day of traffic performance but rather a "typical" day of representative performance. In addition, speed, congestion, and travel time values in this report are estimates based on approximate formulas. Therefore, such measures are best treated as relative, rather than absolute, values. Further information about data quality issues and the constraints and caveats of the analysis in this report are provided in the FLOW Evaluation Design Technical Report.

NOTE: This is an interim report based on 1997 data. Plans call for a more comprehensive report based on 1998 data to be produced later in 1999.

Geographic Scope

This report summarizes 1997 central Puget Sound area freeway usage and performance and includes the combined effects of all WSDOT traffic management efforts in the region. This is a "state of the system" report, and as such, it does not evaluate the individual contributions of specific traffic management system components, although the effects of some components are apparent in these aggregate results. Subsequent analysis reports will evaluate the performance of specific WSDOT Northwest Region traffic management components.

This analysis covers sections of freeway for which 1997 data were available (Figure 1).

What Is in This Report

This report summarizes general measures of **facility usage** (e.g., how many vehicles are transported on the freeway network) and **facility performance** (e.g., how fast they are traveling, where and how often congestion occurs). These measures are meant to be succinct, yet provide sufficient detail to convey a sense of the complexity of highway performance variations as a function of location, time, and other conditions. In addition, this analysis is designed to be repeatable, i.e., the report's contents can be

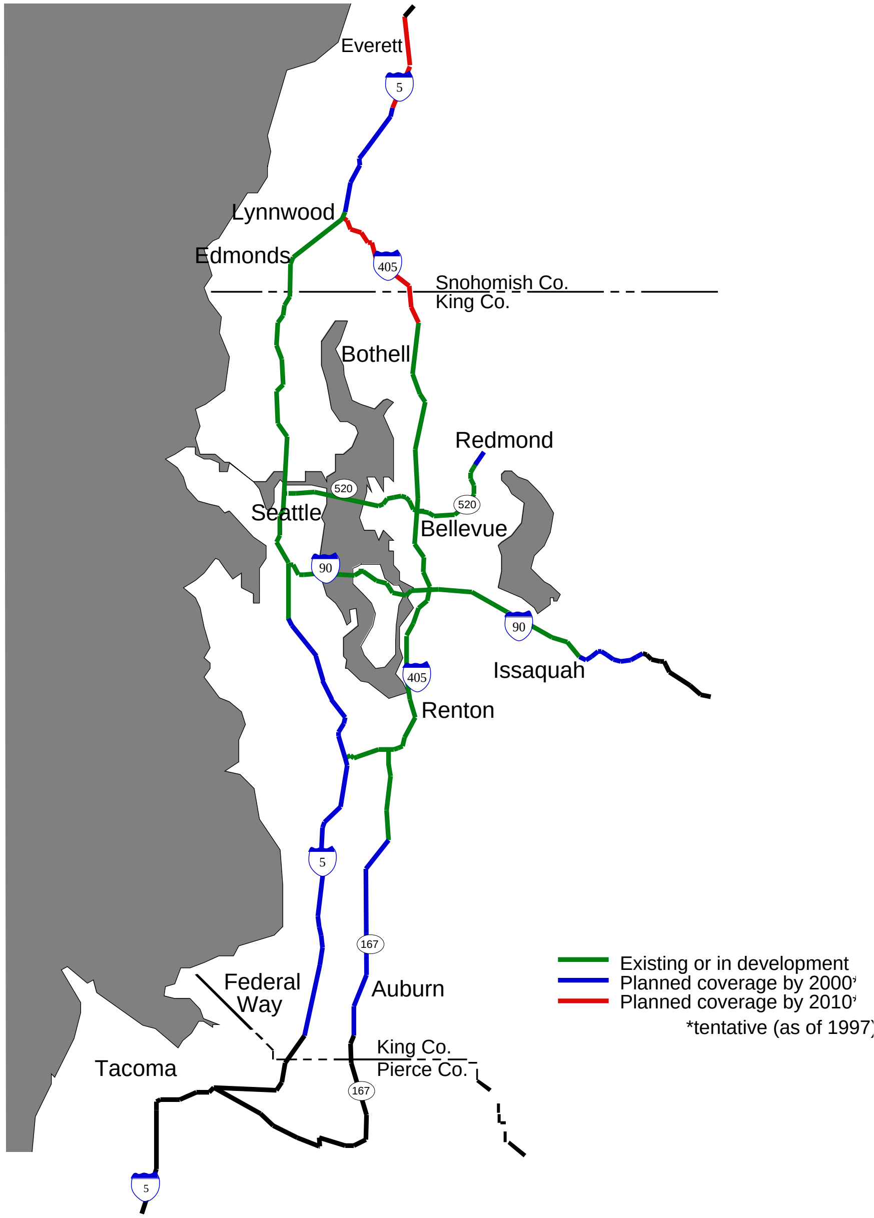


Figure 1. FLOW System Implementation on Central Puget Sound Freeways

updated periodically with a consistent set of measures, so that trends can be monitored over time. This report is divided into five additional sections:

System Usage. Average usage measures taken at selected locations summarize the level of usage of the Seattle-area highway network. Usage is measured in terms of average weekday daily, peak hour, and peak period vehicle volumes for general purpose (GP), high-occupancy vehicle (HOV), and reversible lanes.

System Performance I. The performance of the highway network along a corridor is summarized. Performance is indicated with the following measures: facility-wide traffic patterns as a function of time of day and location on the corridor; average travel times along selected routes; and variability and reliability of travel times on those routes.

System Performance II. The performance of the highway network at selected locations is summarized. Performance is indicated with the following measures: average vehicle volume; average speed; and average congestion frequency or travel reliability, all as a function of time of day.

System Performance III. Variations in the performance of the highway network as a function of different background conditions are summarized for selected locations. Selected examples are used to compare 1995 vs. 1997 trends, weekday vs. weekend performance, and GP vs. HOV usage.

HOV Lane Network. The usage and person-carrying capacity of the HOV lane network are discussed.

About This Project

This report is a product of a WSDOT-sponsored project, FLOW Evaluation Framework Design. The overall objectives of this project are to 1) develop a methodology, framework, and detailed procedures for conducting an ongoing series of evaluations of the performance and effects of the FLOW traffic management system now in operation on Puget Sound area freeways; 2) create tools for performing those evaluations; and 3) supplement earlier evaluation data with updated results by using the developed framework to evaluate selected portions of the FLOW system. This report reflects the results of work on the first two objectives and addresses the third objective.

Section 2. System Usage

This section summarizes general levels of usage of the freeway system in the central Puget Sound area. These statistics, based on 1997 data, are intended to provide an overview of freeway traffic patterns and comparative levels of use among different freeway segments.

How System Usage Was Measured

System usage was estimated in two ways for selected freeway locations in the study area:

Average Annual Weekday Vehicle Volume

The average weekday volume is a general measure of the level of usage of the freeway system at a specific location. This value equals the estimated total number of vehicles passing a given location during an average 24-hour weekday period (Monday through Friday) throughout the year. These values are based on available vehicle count data collected electronically by WSDOT for the 1997 calendar year.

Average Peak Vehicle Volume

The average peak volumes represent levels of system usage during the traditionally busiest periods of the day. Average peak vehicle volumes are estimated for four weekday time periods. These periods are

1) the morning peak period (defined as 6:00 AM to 9:00 AM)
2) the evening peak period (3:00 PM to 7:00 PM)
3) the AM peak hour (the one-hour AM period with the highest volume)
4) the PM peak hour (the one-hour PM period with the highest volume).

The peak periods represent the traditional morning and evening "rush hour" commute periods, whereas the peak hours represent the highest one-hour traffic volumes during the day. The peak-period measurements are always based on the fixed time periods noted above; the average peak-hour volumes can be based on a different one-hour period from day to day, but always represent the AM and PM hour with the highest volumes. A peak hour is normally, though not necessarily, within a peak period. Because severe congestion limits the number of vehicles that can use a freeway lane, peak volumes on congested roads can occur outside the fixed peak period.

Where System Usage Was Measured

Summary system usage statistics were estimated at 13 freeway locations throughout the central Puget Sound freeway network: five locations on I-5, four locations on I-405, and two locations each on I-90 and SR 520. (See Figure 2.) These locations were selected on the basis of their traffic significance and the availability of data, and they are intended to be descriptive of the freeway system. (Note that data were not available for I-5 south of Boeing Field in 1997.)

Note that while the measurement locations were chosen to be in some way representative of the facilities on which they were located, caution should be exercised in attempting to generalize about a corridor on the sole basis of usage measurements at a few locations. Average traffic conditions can change significantly within a short distance because of interchanges, on- and off-ramps, and other road and land-use conditions. In addition, the volumes presented in this section are vehicle volumes. Person usage of the system, and in particular the use of high-occupancy vehicle (HOV) versus general purpose (GP) lanes is discussed later in this report in section 6, "The HOV Lane Network."

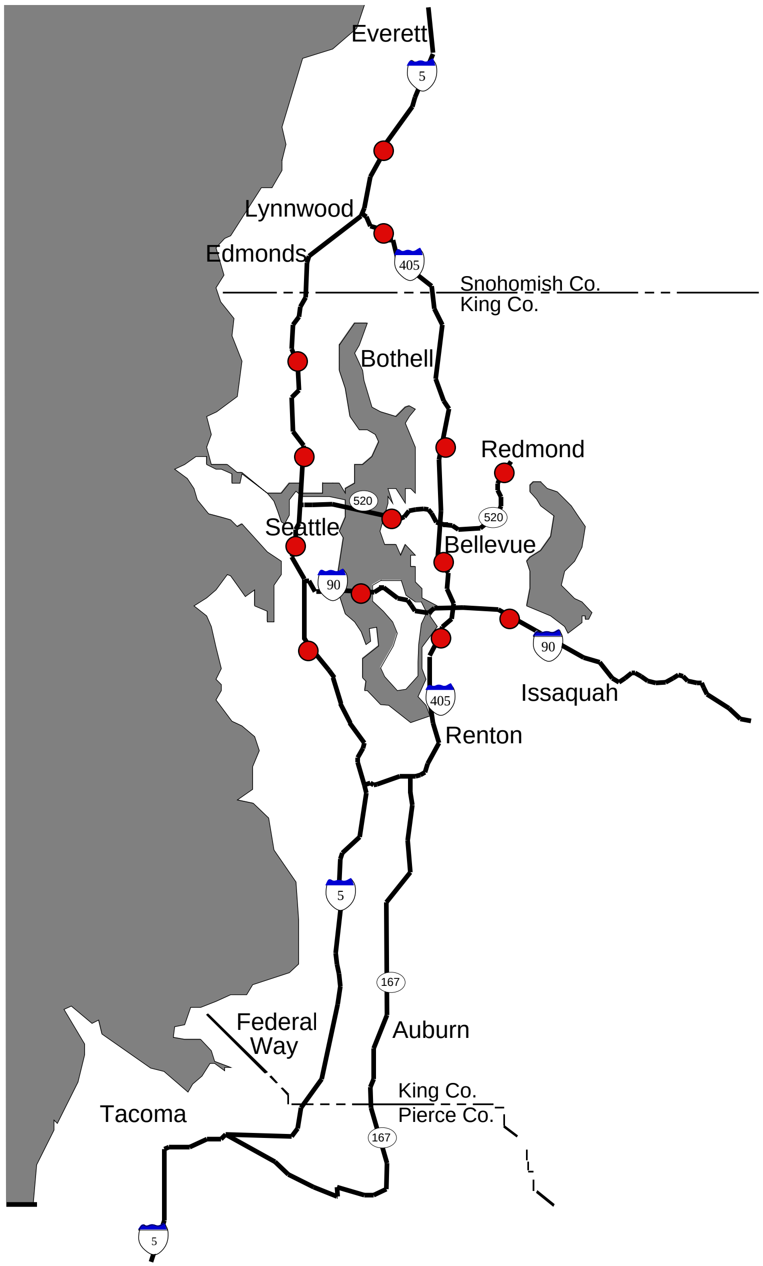


Figure 2. FLOW Evaluation Measurement Sites

Results for Selected Locations

Average Daily Vehicle Volumes

Average weekday daily vehicle volumes are summarized in Table 1a. All traffic volume estimates are based on 1997 data. The following are summaries of the vehicle volume patterns in the major corridors.

Major North-South Facilities. Interstates 5 and 405 are the principal north-south urban highway facilities in the central Puget Sound area. Interstate 5 is the dominant facility in the region in terms of number of lanes and vehicle volume. Volumes recorded at four I-5 locations within the Seattle city limits are consistently high, with the highest volumes in and north of downtown Seattle; total vehicle volumes range from 203,000 to 257,000 vehicles (both directions combined, all lanes) on an average weekday. HOV vehicle volumes (not person volumes) range from 8 percent (north of downtown Seattle) to 10 percent (south of downtown Seattle) of all traffic. Express lane volumes measured between Northgate and downtown Seattle represent about 18 percent of all traffic.

On the east side of Lake Washington, vehicle volumes recorded on Interstate 405 are also significant, with estimates that vary from 136,000 vehicles per weekday south of the Interstate 90 interchange to 213,000 vehicles per day near downtown Bellevue. Traffic volumes near Kirkland are approximately 159,000 per day, while at the north end near the junction with Interstate 5, I-405 carries over 95,000 vehicles per weekday. HOVs vary from 11 percent (Kirkland) to 23 percent (south of I-90) of total vehicle volumes.

Major East-West Facilities. The two east-west facilities are State Route 520 and Interstate 90. SR 520 includes the Governor Albert Rosellini Evergreen Point Floating Bridge, which carries over 113,000 vehicles per weekday (both directions combined). I-90 includes the Homer Hadley and Lacey Murrow (Mercer Island) floating bridges, which carry over 146,000 vehicles per weekday. Vehicle volumes on SR 520 remain high east of the bridge, with 110,000 recorded vehicles per weekday near Redmond, while on I-90 volumes drop to 82,000 vehicles east of the I-405 interchange. I-90 features more lanes in each direction than SR 520, with three GP lanes in each direction and two reversible

Table 1a. Average Weekday Vehicle Volumes at Selected Freeway Locations (1997estimates)

Location (# GP Lanes)	GP[1] Lanes Daily Vehicle Volume Direction 1	Direction 2	Total GP	HOV Lanes Daily Vehicle Volume Direction 1	Direction 2	Total HOV	Reversible[5] Lanes Daily Vehicle Volume Direction 1	Direction 2	Total REV	Total GP+HOV+REV
Interstate 5	**NB**	**SB**		**NB**	**SB**		**NB**	**SB**		
S. Pearl St.[4] (4)	**104,600**[7]	106,100	210,700	12,000	12,800	24,800			-	235,500
University St.[4] (4)	**104,400**	**116,200**	220,700	[2]	9,200[6]	9,200	18,000[6]	9,700	27,700	257,500
NE 63rd St (4)	**98,300**	**107,300**	205,600			-	25,700	19,700	45,400	251,000
NE 137th St (4)	**93,100**	**93,900**	187,000	7,900	8,700	16,600			-	203,600
128th St SW (3)	55,800	n/a[3]	n/a			n/a			n/a	n/a
Interstate 405	**NB**	**SB**		**NB**	**SB**		**NB**	**SB**		
SE 52nd St (2)	48,100	56,900	105,000	16,300	15,600	31,900			-	136,900
NE 14th St (3)	**90,800**	**86,200**	177,000	**17,800**	**18,700**	36,500			-	213,500
NE 85th St (3)	**70,000**	**70,700**	140,700	**9,300**	9,700	19,000			-	159,660
Damson Road (2)	**47,400**	**48,100**	95,500						-	95,500
SR 520	**EB**	**WB**		**EB**	**WB**		**EB**	**WB**		
76th Ave NE[4] (2)	**54,000**	**56,700**	110,600		2,700	2,700			-	113,400
NE 60th St (2)	**44,700**	66,000	110,700			-			-	110,700
Interstate 90	**EB**	**WB**		**EB**	**WB**		**EB**	**WB**		
Midspan (3)	63,900	**68,900**	132,800			-	9,100	4,800	13,900[8]	146,700
161st Ave SE (3)	**38,000**	**39,400**	77,400	2,600	2,700	5,300			-	82,700

Notes

1) GP = General Purpose, HOV = High Occupancy Vehicle
2) A blank entry indicates there is no HOV or reversible lane in that direction at that location
3) "n/a" indicates data are unavailable, because of construction of data collection problems
4) At University St. and 76th Ave NE, there is no NB or EB HOV lane, respectively. At S. Pearl, SB HOV volume is based on 3Q-4Q 1997 data
5) "REV" indicates reversible/express lanes. Reversible lane volumes are determined using 12:0 PM as transition time.
6) At University St., REV, there is one HOV lane SB AM, and no HOV lanes NB PM. University St. SB HOV volumes combine HOV SB and HOV REV SB.
7) Average weekday volumes use AASHTO aggregation method when sufficient data are available (bold). Otherwise, an average is used.
8) At I-90 midspan, Western highrise data are used for REV lanes.

center lanes; SR 520, on the other hand, has two GP lanes in each direction and a single westbound HOV lane that ends at the east approach to the bridge deck (as of 1997). Reversible lane use represents about 9 percent of all vehicle traffic on the I-90 bridge.

Average Peak Vehicle Volumes

Tables 1b (general purpose lanes) and 1c (HOV lanes) summarize average peak-period and peak-hour vehicle volumes at selected freeway locations in the central Puget Sound area. As with the daily volumes, all peak volumes are year-long weekday averages and are based on 1997 data.

Major North-South Facilities. Interstate 5's role as the dominant north-south carrier of daily traffic in the region is reflected in the peak periods. Within the Seattle city limits, weekday peak-period volumes average from 36,000 to 46,000 per three-hour morning peak period (approximately 12,000 to 15,000 vehicles per hour), and between 55,000 and 66,000 vehicles during the longer four-hour afternoon peak period (13,500 to 16,500 vehicles per hour). Measurements taken just north of the downtown Seattle area indicate that the reversible express lanes carry over 40 percent of the AM, peak-period, southbound vehicle volume and approximately 36 percent of the PM, peak-period, northbound vehicle volume.

Peak-period volumes also vary significantly at different points along Interstate 405. At the north end near Swamp Creek, I-405 carries 17,000 vehicles in the AM peak period (5,600 per hour) and 26,000 vehicles in the PM peak period (6,500 per hour). Near Kirkland, vehicle volumes increase to 30,000 vehicles in the AM peak period (10,000 per hour) and 43,000 vehicles in the PM peak period (almost 11,000 per hour). Volumes are even higher approaching downtown Bellevue, with an AM peak period average of 39,000 vehicles (13,000 per hour) and 57,000 vehicles (14,000 per hour) during the 3:00 PM to 7:00 PM peak period. Moving farther south past the I-90 interchange, volumes drop to 25,000 vehicles per AM period (8,300 per hour) and 37,000 vehicles during the PM peak period (9,000 per hour).

Major East-West Facilities. The Evergreen Point Floating Bridge on SR 520 carries approximately 20,000 vehicles during the morning peak period and approximately 29,000 vehicles during the longer afternoon peak period (approximately 6,800 AM and 7,200 PM vehicles per hour). Traffic volumes vary by direction in the AM peak period, with westbound traffic volumes higher near Redmond than at the bridge, and eastbound traffic volumes higher at the bridge than near Redmond. However, volumes at the bridge and near Redmond are very nearly equal to one another during the PM peak period. Overall, SR 520 traffic volumes (combining both directions) at the bridge are nearly the same as the volumes near Redmond, regardless of the peak period.

On Interstate 90's floating bridge, peak period volumes are roughly 53 percent higher than those of SR 520's floating bridge, at approximately 31,000 vehicles in the morning (10,400 per hour) and 44,000 vehicles in the afternoon (11,000 per hour). These volumes include bridge traffic on the reversible center lanes, which carry both HOVs and Mercer Island traffic. The reversible center lanes carry 3,700 vehicles in the morning peak period and 5,500 vehicles in the afternoon peak period. Unlike SR 520, where eastbound and westbound traffic are roughly balanced during the peak hours, the extra capacity provided by the reversible lanes contributes to traffic patterns on I-90 that favor westbound travel in the morning and eastbound travel in the evening, with approximately 5,300 more vehicles traveling in the westbound direction vs. eastbound direction in the morning peak period, and about 4,500 more vehicles traveling in the eastbound direction vs. westbound direction in the afternoon peak period. In comparison to the I-90 bridge volumes, peak period traffic levels drop by nearly 45 percent when measured near the Eastgate area east of the I-405 interchange. This is significantly different from the SR 520 corridor, where volumes remain high at each end of the facility. In fact, as one moves east on each corridor, SR 520 volumes actually become higher than I-90 volumes approaching Redmond and Eastgate, respectively.

Table 1b. Average Weekday Peak GP Vehicle Volumes at Selected Freeway Locations (1997 estimates)

Location (# Lanes)	Northbound (I-5/I-405) or Eastbound (SR 520/I-90)						Southbound (I-5/I-405) or Westbound (SR 520/I-90)						Combined GP[1] Volume	
	AM Vehicle Volume			PM Vehicle Volume			AM Vehicle Volume			PM Vehicle Volume			Both Directions	
	Peak Period (6-9 AM)	Peak Period (Per Hour)	Peak Hour	Peak Period (3-7 PM)	Peak Period (Per Hour)	Peak Hour	Peak Period (6-9 AM)	Peak Period (Per Hour)	Peak Hour	Peak Period (3-7 PM)	Peak Period (Per Hour	Peak Hour	AM Peak Period	PM Peak Period
Interstate 5														
S. Pearl St. (4)	20,500	6,833	7,500	25,100	6,275	6,800	18,700	6,233	6,900	25,900	6,475	7,100	39,200	51,000
University St. (4)	18,200	6,067	6,600	25,300	6,325	6,600	20,600	6,867	7,400	27,700	6,925	7,300	38,800	53,000
University St. REV[4] (2)			[3]	7,000	1,750	2,500	5,500	1,833	1,900				5,500	7,000
NE 63rd St (4)	13,300	4,433	5,800[5]	26,200	6,550	6,900	19,100	6,367	6,900	25,000	6,250	6,500	32,400	51,200
NE 63rd St REV (3)				14,900	3,725	4,300	13,300	4,433	5,200				13,300	14,900
NE 137th St (4)	11,600	3,867	4,500	28,400	7,100	7,400	21,100	7,033	7,400	20,600	5,150	5,400	32,700	49,000
128th St SW (3)	10,000	3,333	3,600	13,500	3,375	3,600	n/a[2]	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Interstate 405														
SE 52nd St (2)	9,300	3,100	3,400	12,700	3,175	3,400	10,100	3,367	3,600	14,500	3,625	3,700	19,400	27,200
NE 14th St (3)	14,500	4,833	5,200	26,800	6,700	7,100	18,300	6,100	6,500	21,100	5,275	5,900	32,800	47,900
NE 85th St (3)	10,200	3,400	3,700	21,200	5,300	5,700	16,500	5,500	5,700	16,100	4,025	4,500	26,700	37,300
Damson Road (2)	8,200	2,733	2,900	13,700	3,425	3,600	9,300	3,100	3,400	13,200	3,300	3,600	17,500	26,900
SR 520														
76th Ave NE (2)	10,000	3,333	3,700	13,300	3,325	3,400	10,000	3,333	3,600	14,400	3,600	3,700	20,000	27,700
NE 60th St (2)	5,700	1,900	2,300	13,800	3,450	3,800	15,000	5,000	5,300	14,700	3,675	4,300	20,700	28,500
Interstate 90														
Midspan (3)	13,100	4,367	5,400	19,000	4,750	5,300	14,600	4,867	5,600	20,100	5,025	5,400	27,700	39,100
Midspan REV[6] (2)				5,500	1,375	2,000	3,700	1,233	1,800				3,700	5,500
161st Ave SE (3)	4,700	1,567	2,000	13,400	3,350	3,900	11,100	3,700	4,300	8,700	2,175	2,300	15,800	22,100

Notes

1) GP = General Purpose traffic
2) "n/a" indicates data are unavailable, because of construction of data collection problems
3) "REV" indicates reversible/express lane volumes at that location. Blank cells in REV lane locations indicate that GP traffic is not traveling in that direction at that time of day.
4) At University St. REV, there is one GP lane SB AM, and two GP lanes NB PM.
5) Boxed peak hour values are outside the fixed peak periods (6-9 AM, 3-7 PM)
6) At I-90 midspan, Western highrise data are used for REV lanes.

Table 1c. Average Weekday Peak HOV Vehicle Volumes at Selected Freeway Locations (1997 estimates)

Location	Northbound (I-5/I-405) or Eastbound (SR 520/I-90)						Southbound (I-5/I-405) or Westbound (SR 520/I-90)						Combined HOV[1] Volume Both Directions	
	AM Vehicle Volume			PM Vehicle Volume			AM Vehicle Volume			PM Vehicle Volume				
	Peak Period (6-9 AM)	Peak Period (Per Hour)	Peak Hour	Peak Period (3-7 PM)	Peak Period (Per Hour)	Peak Hour	Peak Period (6-9 AM)	Peak Period (Per Hour)	Peak Hour	Peak Period (3-7 PM)	Peak Period (Per Hour	Peak Hour	AM Peak Period	PM Peak Period
Interstate 5														
S. Pearl St.[7]	3,220	1,073	1,380	3,650	913	1,050	1,560	520	670	4,590	1,148	1,300	4,780	8,240
University St.	[2]	-			-		460	153	310	3,070	768	910	460	3,070
University St. REV[5]	[4]						1,570	523	740				1,570	
NE 63rd St		-			-			-			-			
NE 137th St	280	93	180[6]	4,500	1,125	1,380	3,370	1,123	1,400	1,770	443	470	3,650	6,270
128th St SW		-			-		n/a[3]		n/a	n/a		n/a	n/a	n/a
Interstate 405														
SE 52nd St	3,450	1,150	1,260	4,460	1,115	1,180	2,420	807	960	5,240	1,310	1,410	5,870	9,700
NE 14th St	2,710	903	1,140	4,330	1,083	1,260	4,350	1,450	1,730	4,800	1,200	1,310	7,060	9,130
NE 85th St	750	250	430	3,630	908	1,020	2,700	900	1,130	2,420	605	650	3,450	6,050
Damson Road		-			-			-			-			
SR 520														
76th Ave NE		-			-		370	123	180	1,260	315	390	370	1,260
NE 60th St		-			-			-			-			
Interstate 90														
Midspan		-			-			-			-			
161st Ave SE	160	53	110	1,380	345	450	930	310	460	720	180	200	1,090	2,100

Notes

1) HOV = High Occupancy Vehicle traffic
2) A blank entry indicates that there is no HOV lane in that direction at that location
3) "n/a" indicates data are unavailable, because of construction of data collection problems
4) "REV" indicates reversible/express lane volumes at that location. Blank cells in REV lane locations indicate that HOV traffic is not traveling in that direction at that time of day.
5) At University St. REV, there is one HOV lane SB AM, and no HOV lanes NB PM.
6) Boxed peak hour values are outside the fixed peak periods (6-9 AM, 3-7 PM)
7) At Pearl St., SB HOV volume is based on 3Q-4Q 1997 data.

Section 3. System Performance: Freeway Corridors

The previous section described the **level of use** of freeway facilities in the urban central Puget Sound region at selected locations, presenting summary values such as average weekday volumes to provide an overall measure of comparative traffic conditions. Beginning with this section, we shift our focus to the **performance** of the system, presenting a range of measures of personal mobility that focus on the traffic conditions freeway travelers experience.

This report describes system performance in two ways. In this section, summary measures of corridor-wide or facility-wide performance will be presented, including average traffic congestion patterns as a function of both time of day and location along a corridor, and average travel time, travel time variability, and frequency of congestion along a corridor. These measures provide a top-level view of freeway system performance in an effort to understand 1) how traffic conditions vary with location, and 2) how these conditions can affect a trip taken from one place to another by freeway. In section 4, traffic performance at specific locations is analyzed. The principal performance measures used to evaluate traffic performance at a location include traffic volume, average speed, and congestion frequency; each is described as a function of time of day, direction of travel, and type of lane (general purpose or HOV).

How Freeway Corridor Performance Was Measured

Four measures of freeway corridor performance were used. These are listed below and are explained more fully in example graphs presented later.

Average Traffic Congestion Levels, by Time of Day and Location

To better understand how traffic conditions change as vehicles travel from one location to another on the freeway network, the researchers measured general purpose lane congestion patterns at different points (mileposts) along the corridor. The data presented are the average of conditions measured for 261 weekdays during the year. The result is an image of the "routine" conditions in each corridor for all 24 hours of the average weekday.

Average Corridor Travel Times, by Trip Start Time

Travel times are another measure of corridor-wide freeway performance. This measure is particularly useful for conveying corridor congestion because it is in a form that is readily understood and that individual travelers can compare to their own experiences. For this report, travel times were estimated for trips that traverse the length of each corridor in the analysis. and for a range of start times. For a range of start times for each trip, the project estimated the average of general purpose lane travel times measured from 261 weekdays during the year.

90th Percentile Corridor Travel Times, by Trip Start Time

While the average travel time is a useful barometer of trip performance, it is also helpful to understand the degree to which travel times can vary from that average. For this reason, 90th percentile weekday general purpose lane travel times were estimated for a range of trip start times throughout an average 24-hour weekday. This measurement indicates that nine times out of ten (i.e., 90 percent of the time) a trip's travel time will take a certain number of minutes or less.

Frequency of Heavy Congestion, by Trip Start Time

Another useful indicator of travel variability on a given trip is the likelihood that the average trip speed will be below some level. The average and 90th percentile travel times were therefore supplemented by a measurement of the likelihood (percentage of times) that the average trip speed would be below 45 mph for a given trip start time. This measure is similar in form to the state policy standard for evaluating HOV lane performance; those standards call for an average speed of 45 mph or better, 90 percent of the time during the peak hour.

Where Freeway Corridor Performance Was Measured

Corridor performance was measured for all the corridors in the study area. This includes I-5 from the south end of Boeing Field to Lynnwood; I-405 from Tukwila to Swamp Creek; SR 520 from Seattle to Redmond; and I-90 from Seattle to Issaquah.

Results: Average Facility Traffic Patterns

Following an example of how to read the graphs (Figure 3) are descriptions of each corridor contour map shown in figures 4 through 9. Note that these maps show the estimated routine weekday congestion levels on **general purpose lanes** only. HOV lanes and express/reversible lanes are not included.

Reading the Graphs

To better understand how traffic conditions change as vehicles travel from one location to another on the freeway network, the researchers developed corridor maps showing general purpose lane congestion patterns at different points (mileposts) along the corridor during an average 24-hour weekday. (Thus, on some days conditions are much better than those illustrated, and on others they can be much worse.) Each map is presented in a contour format similar to that of a topographic or elevation map, with colors that indicate relative levels of congestion as a function of time of day and location (milepost) along a freeway corridor. Beside each graph is a map of the freeway corridor and major cross-streets to provide a rough approximation of freeway locations.

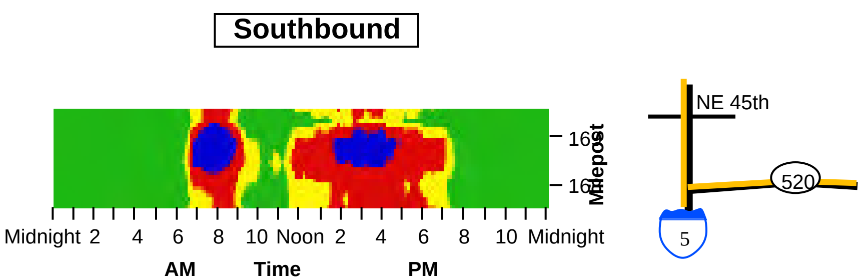


Figure 3. Traffic Profile: Southbound I-5 Ship Canal Bridge

This slice of a traffic profile (see Figure 3) shows the southbound general purpose lanes on I-5 at the Ship Canal Bridge, just north of downtown Seattle approximately (mileposts 169 to 168). Vertically, the graph represents the length of the bridge. Horizontally, the graph shows a 24-hour day, from midnight to midnight. The traffic profile represents average weekday traffic conditions. It is based on data collected every 5 minutes during approximately 261 weekdays in 1997.

The colors on the profile represent congestion as follows:

- green means that traffic generally moves at or near the speed limit under uncongested, free-flow conditions
- yellow means that travelers encounter borderline traffic conditions with more restricted movements (for example, lane changing difficulties), but still travel near the speed limit
- red is more heavily congested traffic traveling perhaps between 45 and 55 mph
- purple is extremely congested, unstable traffic that ranges from stop and go to 45 mph.

Studying this portrait of the Ship Canal Bridge (southbound) shows that, on average, from midnight to about 6:30 AM traffic flows freely. This is followed by a brief period of rapidly increasing congestion (yellow to red to purple), so that by 7:00 AM traffic is extremely congested and may well be nearly stopped.

This congestion is caused both by the increasing number of cars arriving from farther up the freeway and by cars merging onto the freeway from the 50th and 45th street on-ramps just north of the bridge. Notice that the worst traffic congestion (purple) is at the north end of the bridge near the 45th St. on-ramp, whereas at the south end of the bridge, which offers an exit to SR 520, traffic is freer. (As SR 520 traffic merges with I-5 southbound traffic, just south of where this picture ends, I-5 becomes more congested again.)

The extreme congestion lasts until about 8:45, after which traffic slowly clears out until about 10:00 AM. There is a brief period of freely flowing traffic, but the congestion build-up and slow-downs begin again about 11:30 AM. This congestion occurs continuously until about 7:00 PM or later. By 8:00 PM traffic is free flowing once again.

North I-5 (Downtown Seattle to Lynnwood)

Overall: Southbound traffic exhibits significant congestion throughout the day, while northbound traffic north of SR 520 is largely limited to the afternoon and early evening hours. (See Figure 4.) The north- and southbound approaches to the SR 520 interchange and the northbound approach to the I-405 interchange at Swamp Creek all show significant congestion.

Northbound: Northbound congestion in the morning is mostly limited to the approach to SR 520, which has moderate to significant congestion throughout the day (approximately 8:00 AM to 7:00 PM). In the afternoon congestion is extended in the PM peak period along the 12-mile stretch from downtown Seattle north to the county line. The approach to the I-405 interchange is also moderately to significantly congested during much of the afternoon and evening (approximately 2:00 PM to 7:00 PM).

Southbound: Congestion is notable in the southbound direction during the morning commute from the county line to downtown Seattle. Southbound congestion eases slightly during the mid-morning hours (approximately 10:00 AM to 12:00 PM), then builds to significant levels throughout the afternoon and into the evening, particularly between Northgate and downtown Seattle. For the most part, congestion is moderate to significant from 7:00 AM to 7:00 PM in the southbound direction from Northgate to downtown Seattle.

South I-5 (South Boeing Field to Downtown Seattle)

Overall: This is among the most routinely congested freeway segments in the metropolitan area. (See Figure 5.) (**Note:** I-5 traffic data between Tukwila and the Boeing Access Road were not available for 1997 because of construction projects and ongoing installation of vehicle sensors. In 1998, data became available for that segment of I-5. No data are yet available for I-5 south of the I-405/Southcenter interchange.)

Northbound: The data indicate moderate to significant congestion between the Boeing Access Road and downtown Seattle throughout the day (approximately 6:00 AM to 7:00 PM), with particularly heavy congestion during the peak periods.

Southbound: The data indicate moderate to significant congestion between the Boeing Access Road and downtown Seattle throughout the day (approximately 6:00 AM to 7:00 PM), with particularly heavy congestion between downtown and the exit to the West Seattle Bridge. In the afternoon, southbound traffic is congested from downtown to at least the Boeing Access Road. The peak periods show the heaviest congestion, although the yellow color (as an average condition) in the morning and midday shows that congestion occurs frequently even at those times.

North I-405 (Downtown Bellevue to Swamp Creek)

Overall: This segment of I-405 (Figure 6) is a clear example of what was formerly considered a typical commute pattern, namely a “tidal” pattern in which traffic moves predominantly in one direction in the morning and in the opposite direction in the evening. In this case, congestion builds in the southbound direction during the morning, and the northbound direction in the evening.

Northbound and Southbound: Congestion on the north part of I-405 has a strong directional pattern, with congested flow southbound toward SR 520 and downtown Bellevue in the morning, and heavy congested flow northbound toward SR 522 and Swamp Creek in the evening. Traffic bottlenecks include southbound AM traffic as it approaches the SR 520 interchange, as well as northbound PM traffic near NE 85th in Kirkland, NE 124th at Totem Lake, and the approach to SR 522. While available data suggest that congestion is also heavy between SR 522 and Swamp Creek (I-5) in both directions, analyses of that part of I-405 are tentative due to lack of data. Congestion tends to be primarily in the peak periods (AM southbound, PM northbound), but during that time it extends along nearly the entire corridor.

South I-405 (Tukwila to Downtown Bellevue)

Overall: Congestion is significant all day on I-405 from I-5 Tukwila to I-90, with another bottleneck at downtown Bellevue. (See Figure 7.) Analysis of the south part of I-405 is tentative because of a lack of data resulting from construction projects.

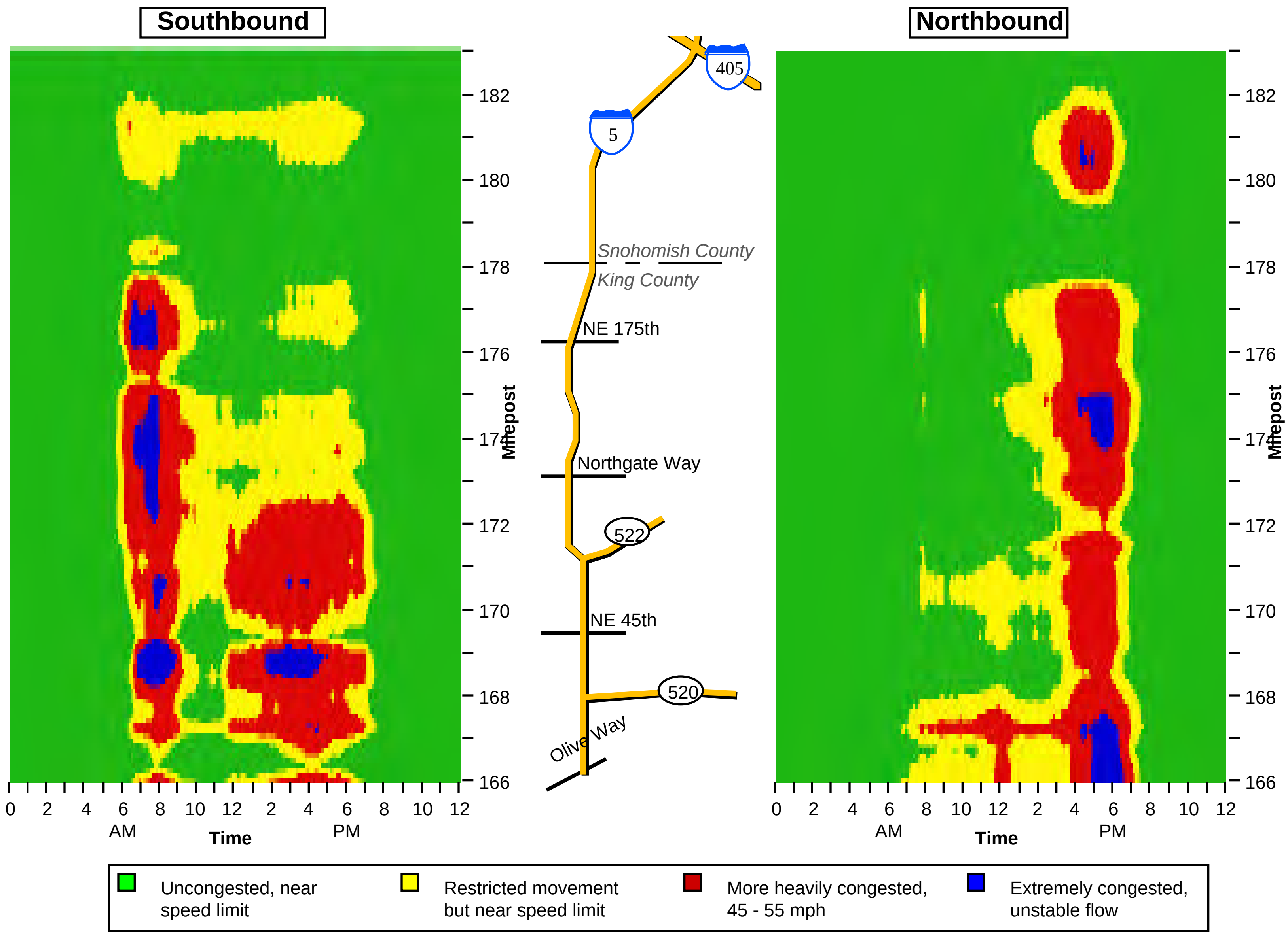
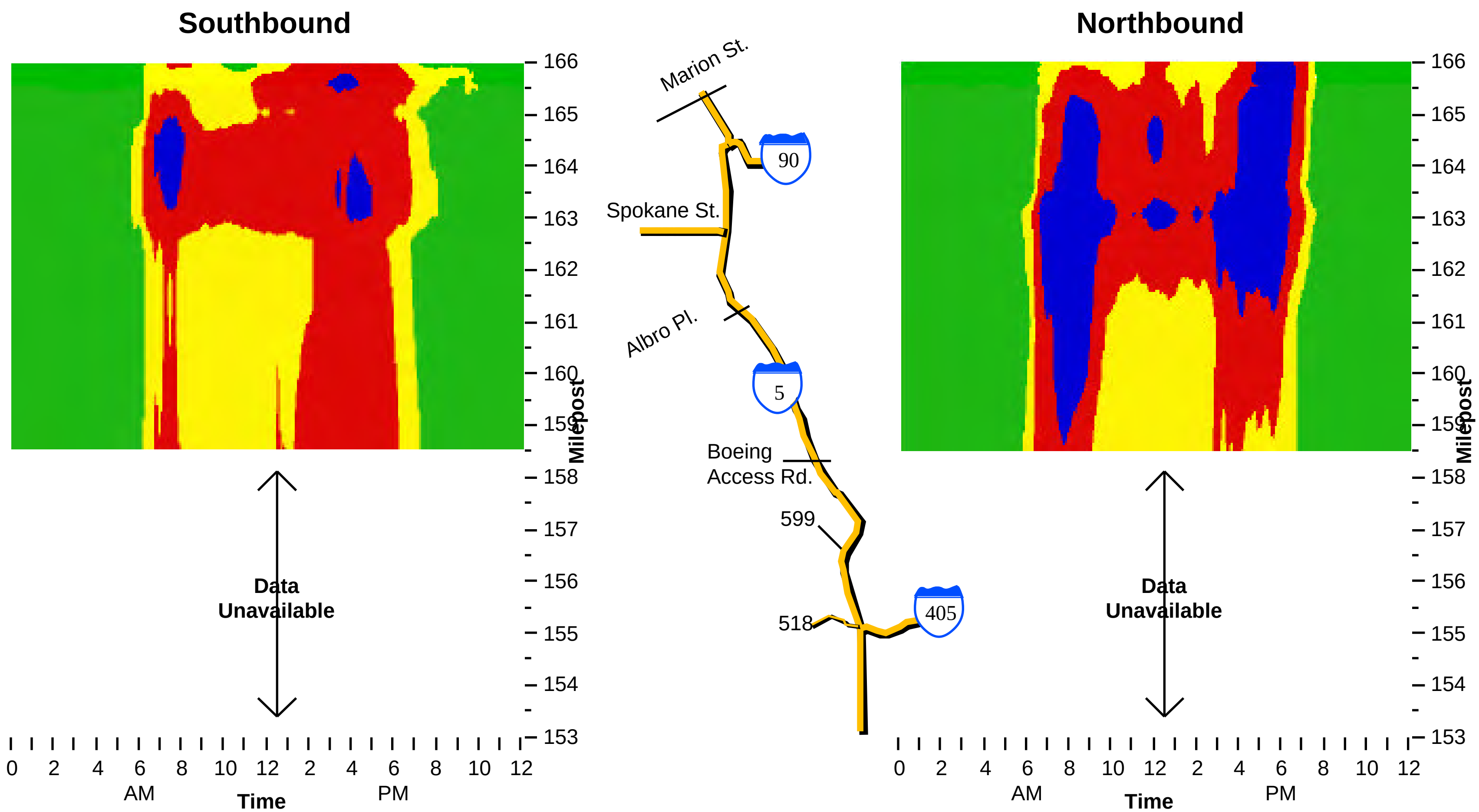


Figure 4. Interstate 5 Traffic Profile: General Purpose Lanes, 1997 Weekday Average

Interstate 5 South Traffic Profile
General Purpose Lanes
1997 Weekday Average



Uncongested, near speed limit

Restricted movement but near speed limit

More heavily congested, 45 - 55 mph

Extremely congested, unstable flow

Figure 5. Interstate 5 South Traffic Profile: General Purpose Lanes, 1997 Weekday Average

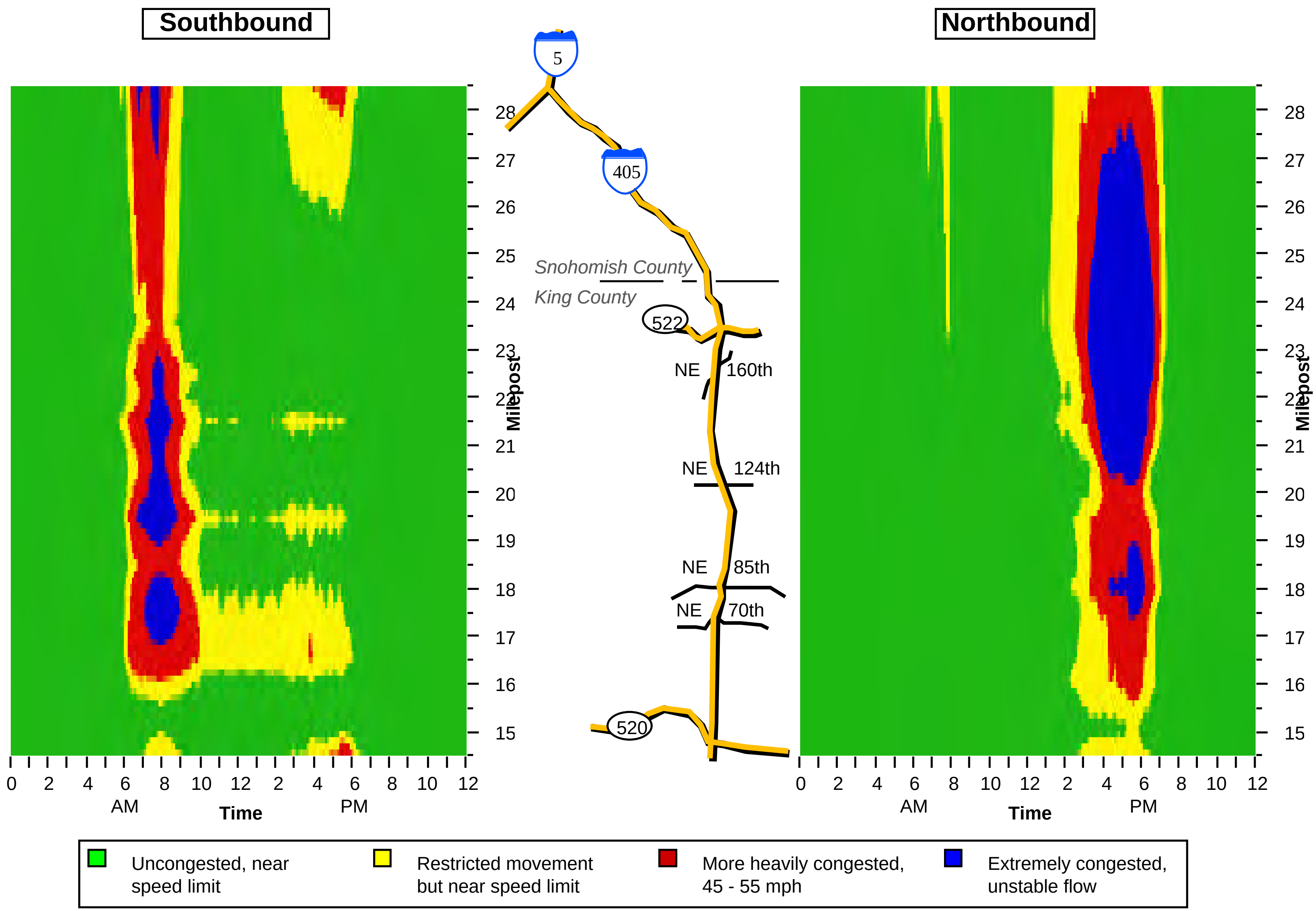


Figure 6. Interstate 405 North Traffic Profile: General Purpose Lanes, 1997 Weekday Average

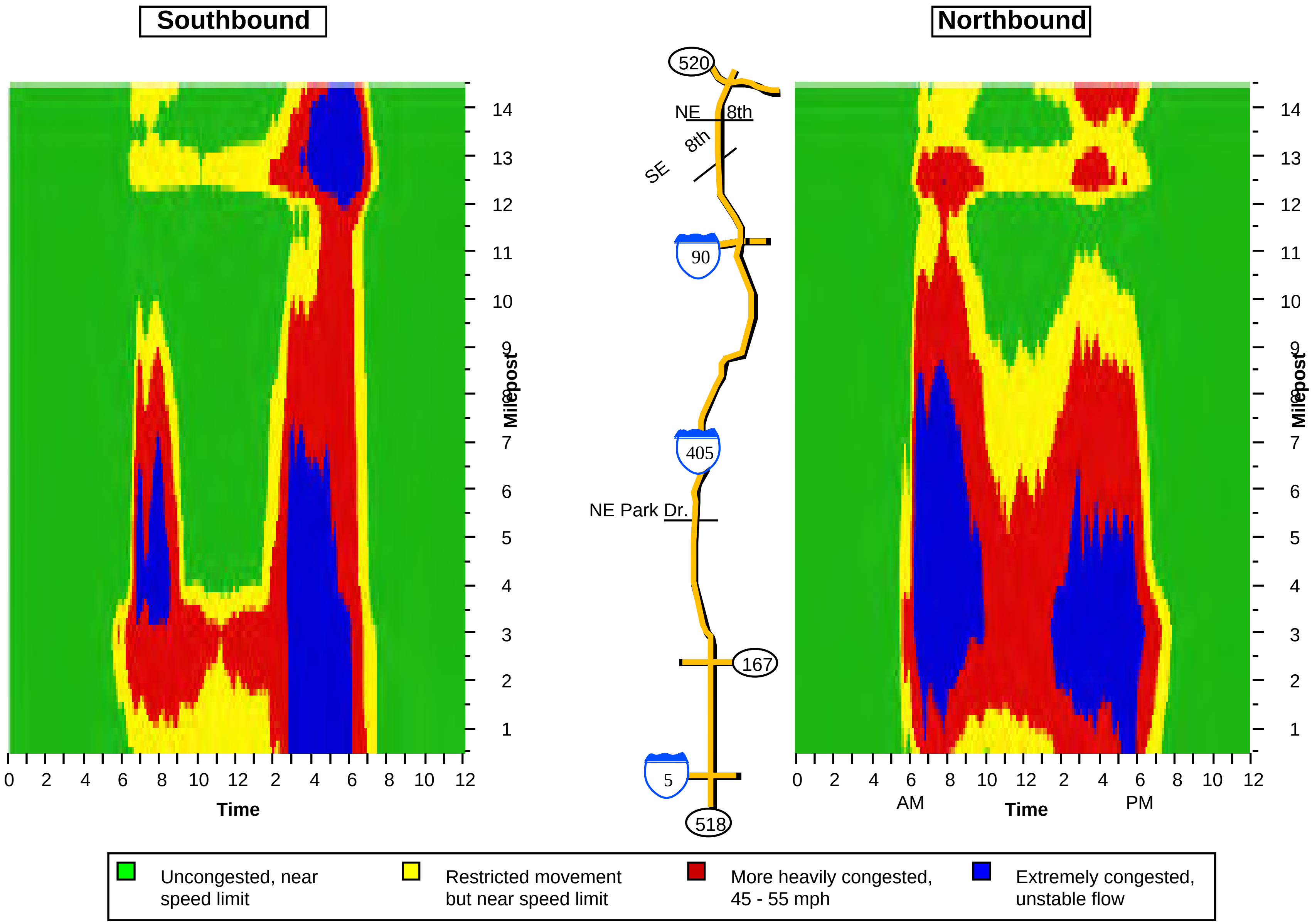


Figure 7. Interstate 405 South Traffic Profile: General Purpose Lanes, 1997 Weekday Average

Northbound: Northbound traffic conditions are routinely heavy from I-5 (at Tukwila) to nearly the I-90 interchange, with much of this segment congested from 6:00 AM to 7:00 PM. Northbound traffic is also moderately congested throughout the day near downtown Bellevue and approaching the SR 520 interchange.

Southbound: Traffic congestion is heavy during both AM and PM peak periods, with congestion extending into the midday hours between SR 900 and the I-5 Tukwila interchange. Southbound congestion is also significant in the PM peak period from the SR 520 interchange to the I-90 interchange.

SR 520 (I-5 to Redmond)

Overall: Morning and afternoon congestion levels in both directions are relatively balanced in geographic extent, particularly approaching the bridge deck, and indicate the significance of the "reverse" commute volumes on this facility. (See Figure 8.)

Eastbound: Congestion is moderate to heavy on the eastbound approach to the bridge, as well as on the bridge deck itself throughout the day (approximately 6:00 AM to 7:00 PM), with moderate to heavy day-long congestion between the bridge and NE 148th (in the Overlake area). In addition, in the evening eastbound traffic becomes heavily congested approaching Redmond.

Westbound: Congestion is heavy on the westbound approach to the bridge during the peak periods, with an extended period of westbound congestion in the afternoon from approximately 3:00 PM to 7:00 PM. In addition, congestion between NE 148th at Overlake and the bridge is moderate to heavy throughout the day (approximately 6:00 AM to 7:00 PM). The routine afternoon congestion approaching the bridge (the "reverse commute") lasts almost twice as long (5 hours) as the morning peak congestion (approximately 2.5 hours).

I-90 (I-5 to Issaquah)

Overall: There is very little off-peak congestion on I-90 (Figure 9). The duration of heavy congestion during the peak periods is also relatively small in comparison to other facilities. As with SR 520, there are notable "reverse" commute volumes on this facility, as indicated by the congestion patterns.

Eastbound and Westbound: Congestion is comparatively limited and occurs primarily during relatively narrow AM and PM peak periods. Westbound congestion extends throughout the corridor during the morning peak period, whereas eastbound congestion focuses on a segment from the bridge deck to the I-405 interchange. In the afternoon peak period, westbound congestion can back up from the bridge deck, across Mercer Island, to the I-405 interchange.

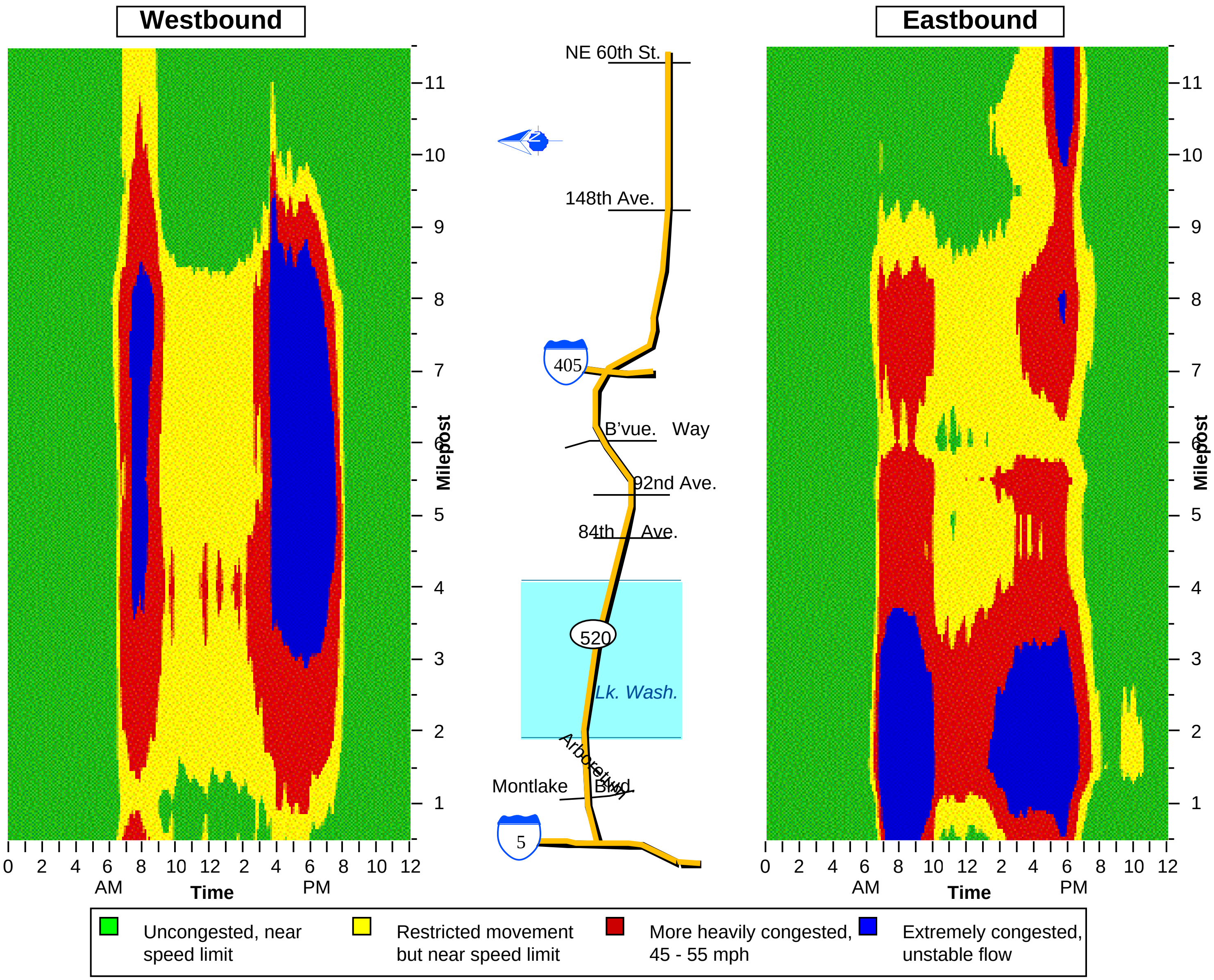


Figure 8. SR 520 Traffic Profile: General Purpose Lanes, 1997 Weekday Average

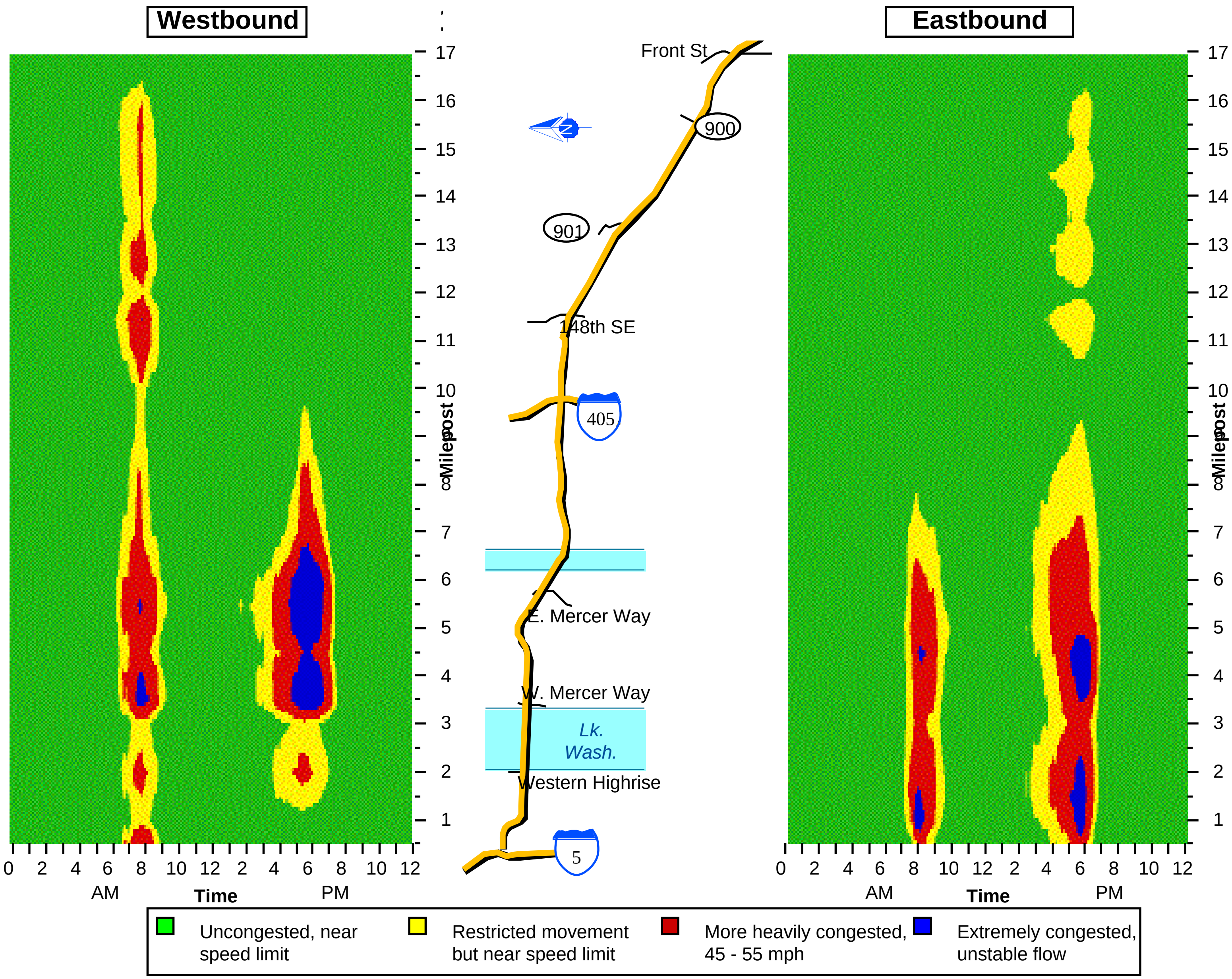


Figure 9. I-90 Traffic Profile: General Purpose Lanes, 1997 Weekday Average

Results: Average Facility Travel Times

For each of four hypothetical trip routes, three travel time measures were estimated: 1) average travel time, 2) 90th percentile travel time (i.e., a measurement that indicates that nine times out of ten—90 percent of the time—a trip's travel time will be less than a certain number of minutes), and 3) the likelihood that the average trip speed will be less than 45 mph. These measures were all summarized as a function of the trip start time and trip direction. All trips assume freeway-only routes on **general purpose lanes** during an average weekday. HOV lanes and express/reversible lanes are not included.

Note that the resulting travel time estimates are primarily for comparative purposes and reflect "average" freeway conditions on these routes at these times. A specific travel time on a given day may differ because of an individual's driving style and vehicle, as well as that day's traffic levels, congestion patterns, and weather conditions. Note also that the travel times reflect the cumulative effect of all congestion along the route. To gain a better understanding of the association between trip time and specific bottle-necks, it is useful to compare the travel time patterns with the geographic patterns of congestion seen in the traffic profile graphs (figures 4-8) because the average trip time may be affected by one large section of congestion or many small slow-downs along the way.

Below is an example of how to read the travel time analysis graphs (Figure 10), followed by descriptions of the travel time analysis in each corridor (figures 11 through 18).

Reading the Graphs

This 8-hour slice of travel time graph (see Figure 10) is for westbound SR 520 general purpose lanes, Redmond Way to I-5. In this corridor, estimated average travel time depends on the time of day the traveler leaves, shown along the horizontal axis. The green line represents the average travel time, measured with the left vertical axis, which varies from about 12 to 15 minutes for a person leaving Redmond at midday to about 25 minutes during the evening commute.

The red line represents the 90th percentile travel time, which in this example can reach about 38 minutes in the evening peak, meaning that nine times out of ten (i.e., 90 percent of the time) the trip's travel time will be 38 minutes or less. The degree to which a trip's 90th percentile travel time differs from its average travel time indicates the variability of travel times for that trip. For someone leaving Redmond at 5:00 PM the trip ranges from 25 minutes, on average, to 38 minutes or less 90 percent of the time.

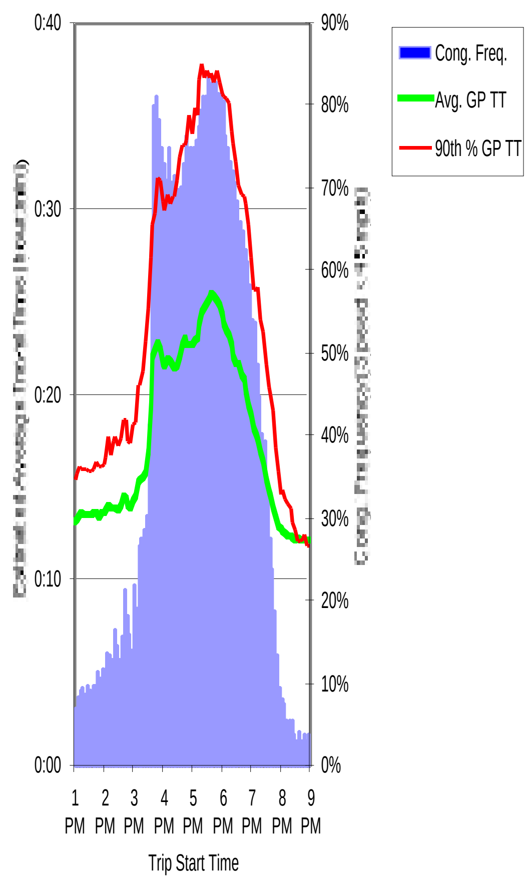


Figure 10. Estimated Average Weekday Travel Time (1997): Westbound SR 520, General Purpose Lanes, Redmond Way to I-5 (12.3 mi)

Superimposed on the travel time lines is a column graph, measured along the right vertical axis, that illustrates the frequency of congestion on a given trip or route. Congestion frequency is measured by the likelihood that the average trip speed will be below 45 mph for a given trip start time. On westbound SR 520, the congestion frequency of 80 percent at 5:30 PM indicates an 80 percent chance that the average trip speed will be less than 45 mph when the trip starts at 5:30 PM.

I-5 (between Boeing Field and Lynnwood: 25.4 miles)

Overall: The contour map analysis indicates the principal areas of northbound congestion that would affect travel times are between Boeing Field and downtown Seattle during the AM peak period, while in the PM period, most of I-5 from Boeing Field north to the county line is congested. Traveling southbound, most of I-5 south of the Snohomish county line is congested throughout the day, particularly the area from the county line south to the West Seattle bridge in the AM peak period, and the segment from Northgate south to Boeing Field in the afternoon and evening. Even during midday, the chance of averaging less than 45 mph usually ranges from 10 to 30 percent in both directions.

Northbound: Northbound travel times begin to increase at approximately 5:30 AM, and that remain higher than trip times during uncongested conditions until approximately 7:30 PM. (See Figure 11.) The AM peak period experiences about a 40 percent increase in trip time, whereas PM peak period travel times are about 60 percent higher than uncongested travel times. Midday travel times are about 20 percent higher than uncongested travel times. The 90th percentile travel times indicate additional 5-minute to 15-minute variability in travel times, depending on time of day. The congestion frequency measure suggests that slowdowns are likely during the peak period, but even at midday there is potential for highly variable trip times.

Southbound: Southbound travel times (Figure 12) begin to grow around 6:00 AM, and do not return to freeflow travel times until approximately 7:00 PM. During the AM peak, average trip times increase by 70 percent, while in the PM peak period, trips are about 50 percent higher than at uncongested times. Midday trip times are about 20 percent higher than trip times during uncongested periods. The 90th percentile times suggest considerable variability in trip times, ranging from an additional 3 minutes during the midday to 15 minutes during the AM peak. The likelihood of a slower trip (i.e., average speed less than 45 mph) is somewhat higher in the AM peak period (50 to 55 percent) than in the PM peak period (40 to 50 percent).

I-405 (between Tukwila and Swamp Creek: 28.8 miles)

Overall: The contour map analysis indicates that in the northbound direction, the principal congestion areas during the AM peak period are between Tukwila and downtown Bellevue, with virtually no morning congestion north of Bellevue. The lack of congestion on half of this route has a significant effect on northbound travel times during the AM peak relative to travel during off-peak hours. During the PM period, however, nearly the entire corridor in the northbound direction is congested, except for some moderate letup between I-90 and SR 520, so the effect on travel times is corridor-wide, not restricted to the south end. Traveling southbound in the AM, most of the corridor is congested, with somewhat less congestion approaching I-90, while in the evening, congestion is principally south of I-90. In both directions, this trip has significant peak period travel times and travel time variability, but with considerable midday improvement. **Note:** Because of the significant variability of peak period travel times for these trips, the I-405 travel time graphs have a vertical (travel time) scale that ranges from zero to 1 hour 20 minutes; all other travel time graphs have a 1-hour maximum.

Northbound: Northbound travel times exceed uncongested trip time levels from about 6:00 AM to 7:00 PM. (See Figure 13.) Average travel times increase strongly in the peak period, with AM peak period trip times about 30 percent higher and PM peak period times over 100 percent higher than uncongested trip times. Midday average trip times are only about 10 percent higher than uncongested trip times. The 90th percentile times indicate moderate to high variability during the day, ranging from an additional 7 to 8 minutes during the AM peak and midday periods, to over 15 minutes during the height of the PM peak period. The likelihood of a slower trip is moderate during the morning (about 50 percent) and high during the afternoon peak (about 85 percent).

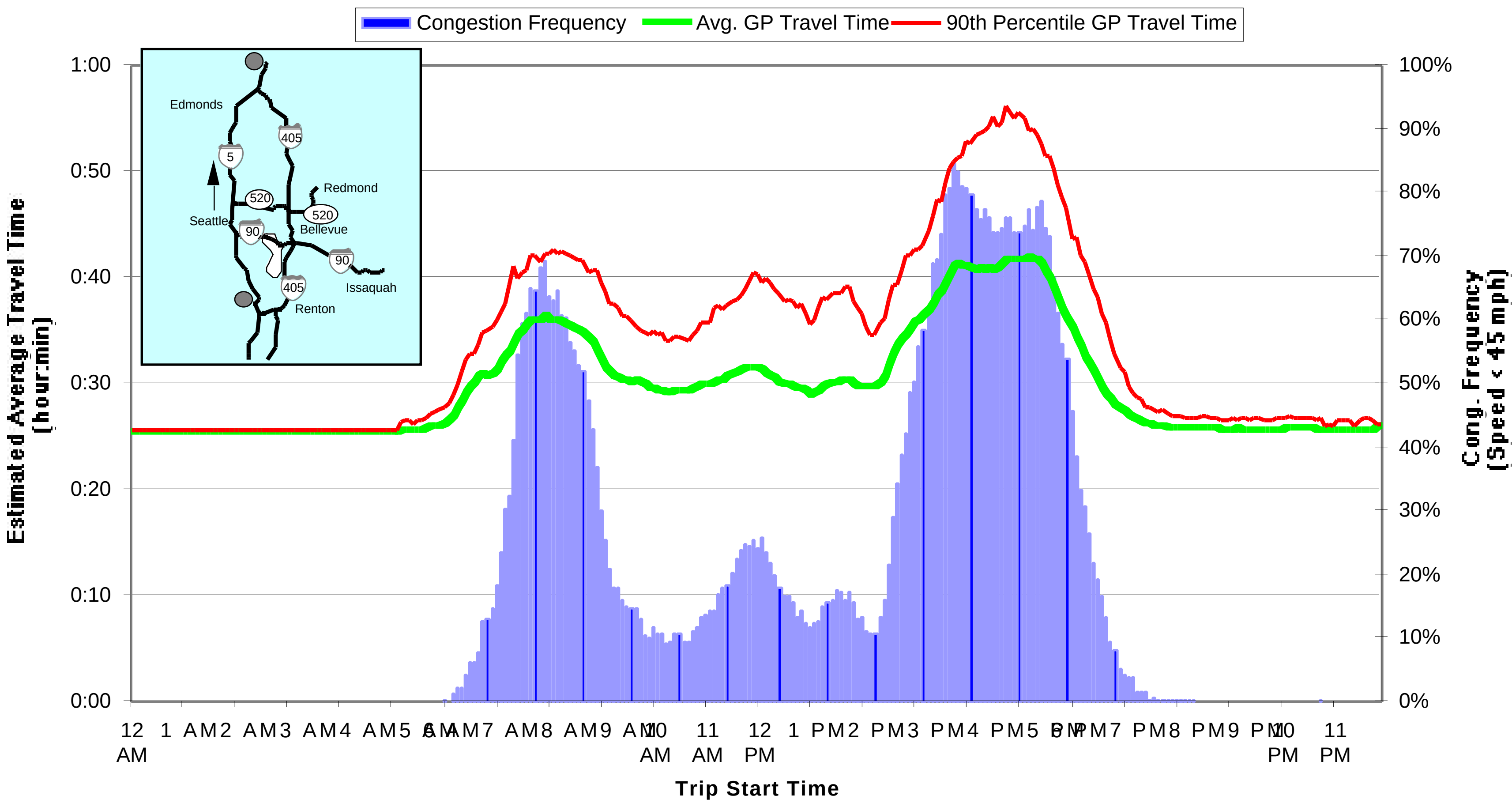


Figure 11. Estimated Average Weekday Travel Time (1997): Northbound Interstate 5 General Purpose Lanes, Boeing Field to Lynnwood (25.4 mi)

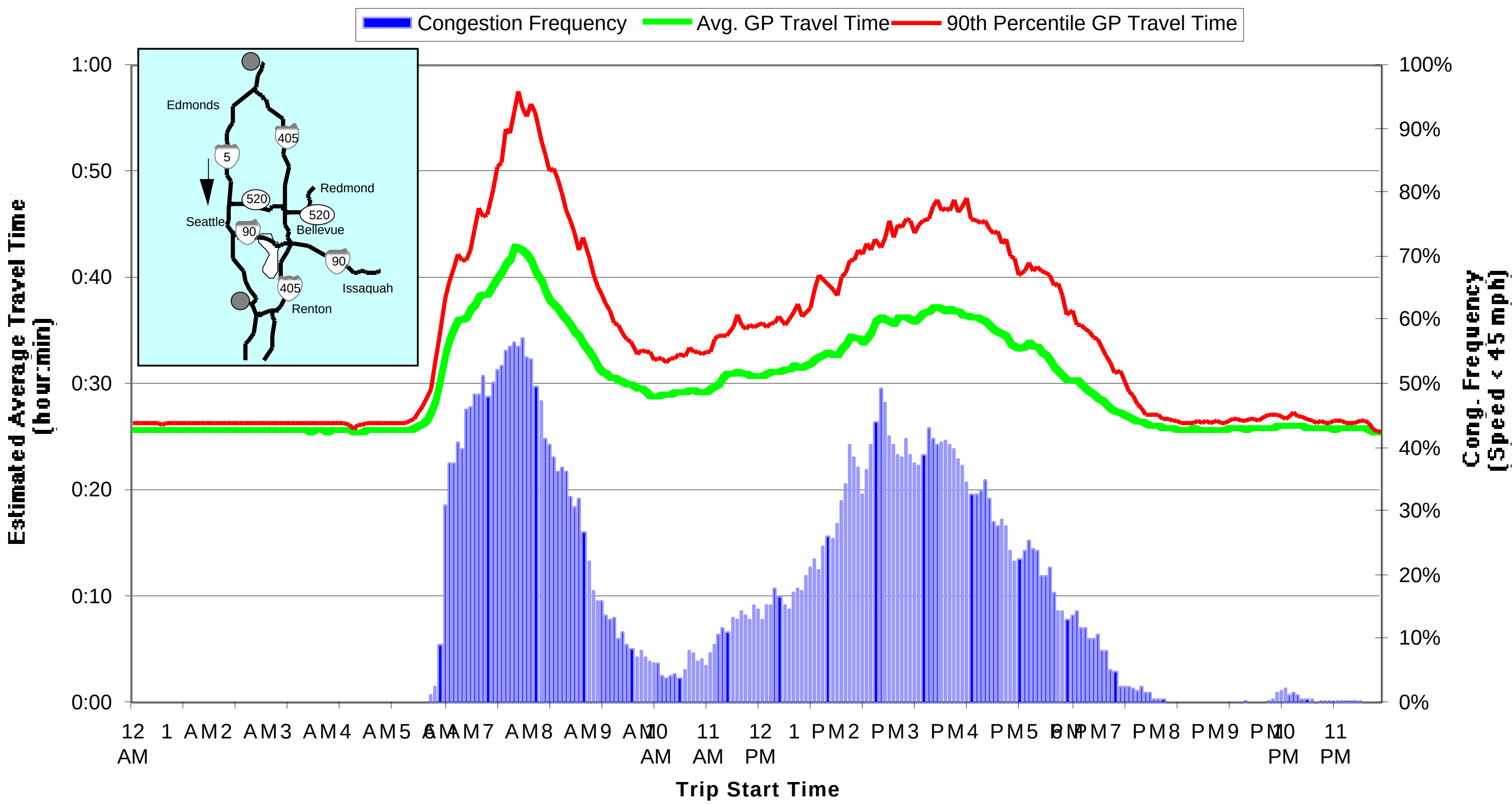


Figure 12. Estimated Average Weekday Travel Time (1997): Southbound Interstate 5 General Purpose Lanes, Lynnwood to Boeing Field (25.4 mi)

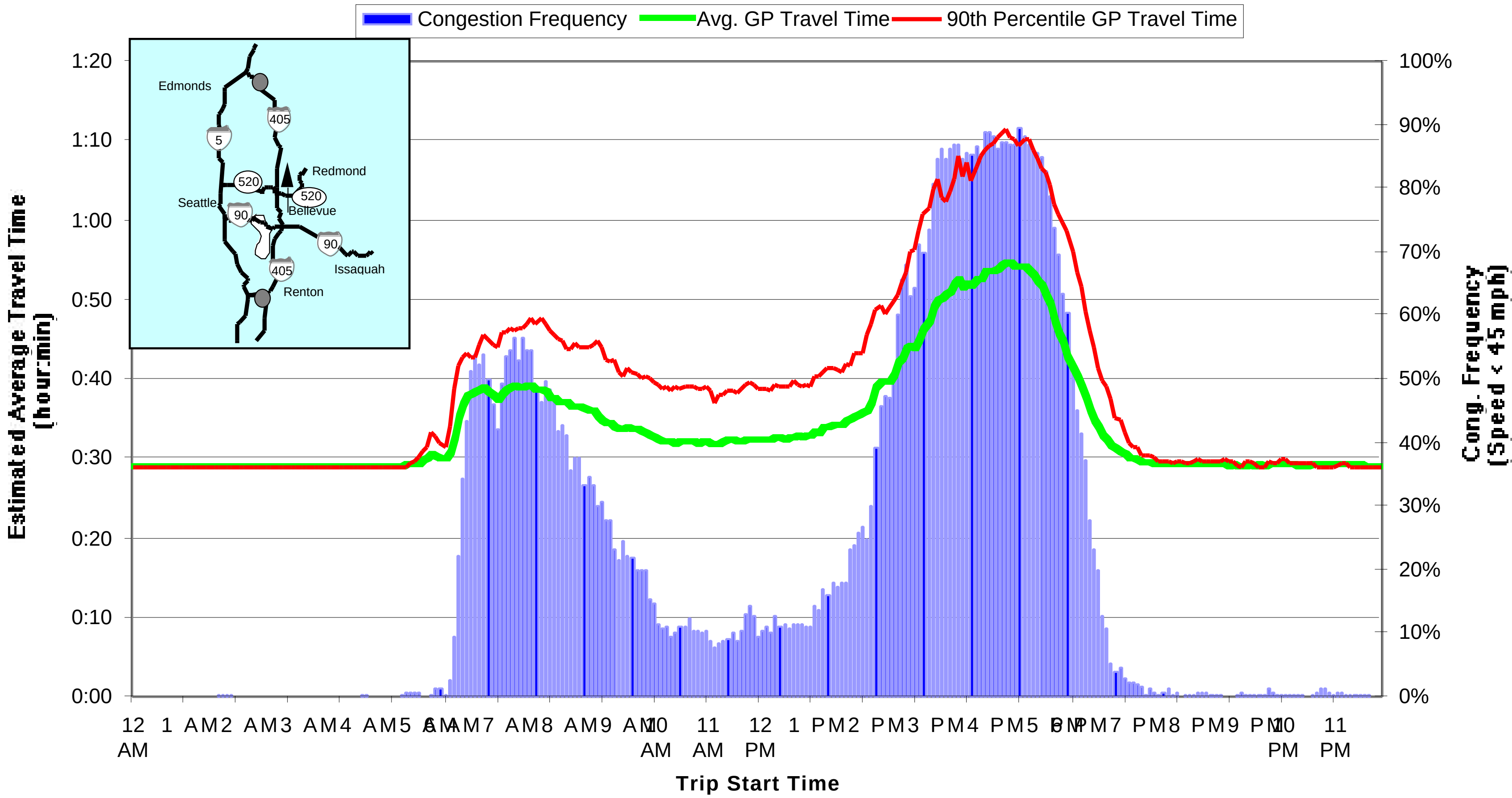


Figure 13. Estimated Average Weekday Travel Time (1997): Northbound Interstate 405 General Purpose Lanes, Tukwila to Damson Road (28.8 mi)

Southbound: Southbound trip times (Figure 14) exceed uncongested trip time levels from about 5:30 AM to 7:00 PM. As with the northbound direction, average travel times during the peak periods increase greatly; both AM and PM peak period trip times are about 50 percent higher than uncongested trip times. Midday average trip times are close to uncongested trip times. The 90th percentile times suggest that there is an additional variability of 10 to 12 minutes during the peak periods and relatively small variability during the midday. The likelihood of a slower trip is moderate to high during both the morning peak and the afternoon peak.

SR 520 (between I-5 and Redmond: 12.3 miles)

Overall: The contour map analysis indicates that there is significant peak period congestion between I-5 and the bridge headed eastbound, and 148th Avenue NE to the bridge in the westbound direction. Eastbound traffic is also congested approaching Redmond. A notable aspect of westbound trip times in the afternoon is the combination of a significant trip time increase, highly variable trip times, and a high likelihood of slow trips. This is a reflection of a significant "reverse" commute pattern and associated congestion.

Eastbound: Eastbound travel times begin to increase around 6:00 AM and return to near-uncongested trip time levels around 7:30 PM. (See Figure 15) Both AM and PM peak period average trip times are approximately double the uncongested trip times, with midday times about 30 percent higher than uncongested levels. Travel time variability is about 3 to 7 minutes throughout the day. However, the likelihood of a slower trip is very high during the peak periods, (approaching 90 percent[1]), and although that likelihood drops significantly during the midday, it begins to grow again in the early afternoon.

Westbound: Westbound trip times (Figure 16) start to increase around 6:30 AM and return to uncongested levels around 8:00 PM. Peak period times nearly double in the AM period and more than double in the PM period. Midday times, however, are near uncongested levels. Variability of travel times is between 8 to 12 minutes, with greater variability during the PM period. The likelihood of a slower trip is relatively high during the peak periods, but low during the midday.

I-90 (between I-5 and Issaquah: 16.5 miles)

Overall: Congestion is focused on peak period hours (approximately 2 hours in the morning, 3 hours in the afternoon); midday conditions are uncongested, unlike most other corridors in the region. The contour map analyses indicate that during peak periods, eastbound congestion is principally on the bridge and Mercer Island (more so in the morning than the evening). Westbound, traffic backs up approaching the bridge (much more so in the afternoon), although there is occasional congestion at Eastgate and further east. A notable travel time pattern occurs during afternoon westbound travel, which shows higher travel time variability than at other times. In addition, the frequency of slower trips is highest in the eastbound direction during the AM peak (approaching 50 percent). These two patterns suggest the so-called reverse commute pattern (eastbound in the morning, westbound in the evening), though not nearly to the extent seen in the SR 520 corridor.

Eastbound and Westbound: Average trip times increase only during relatively narrow peak periods (both AM and PM), during which they are approximately 35 to 40 percent higher than uncongested times. (See figures 17 and 18.) Variability is 5 to 8 minutes, except during the westbound afternoon peak period, when the 90th percentile time is over 15 minutes higher than the average time. The frequency of slower trips in the AM peak is 20 percent eastbound and 50 percent westbound, and in the PM peak the frequency of slower trips is 35 to 40 percent in both directions. On average, midday trips between 10:00 AM and 3:00 PM are uncongested in both directions.

[1] Average weekday traffic conditions in this report were based on all 261 weekdays in 1997 (subject to data availability). Therefore, weekday holidays (when one would expect lighter traffic) were also included. It is thus reasonable to expect that the congestion frequencies for the average <u>non-holiday</u> weekday would be higher than those shown in this report.

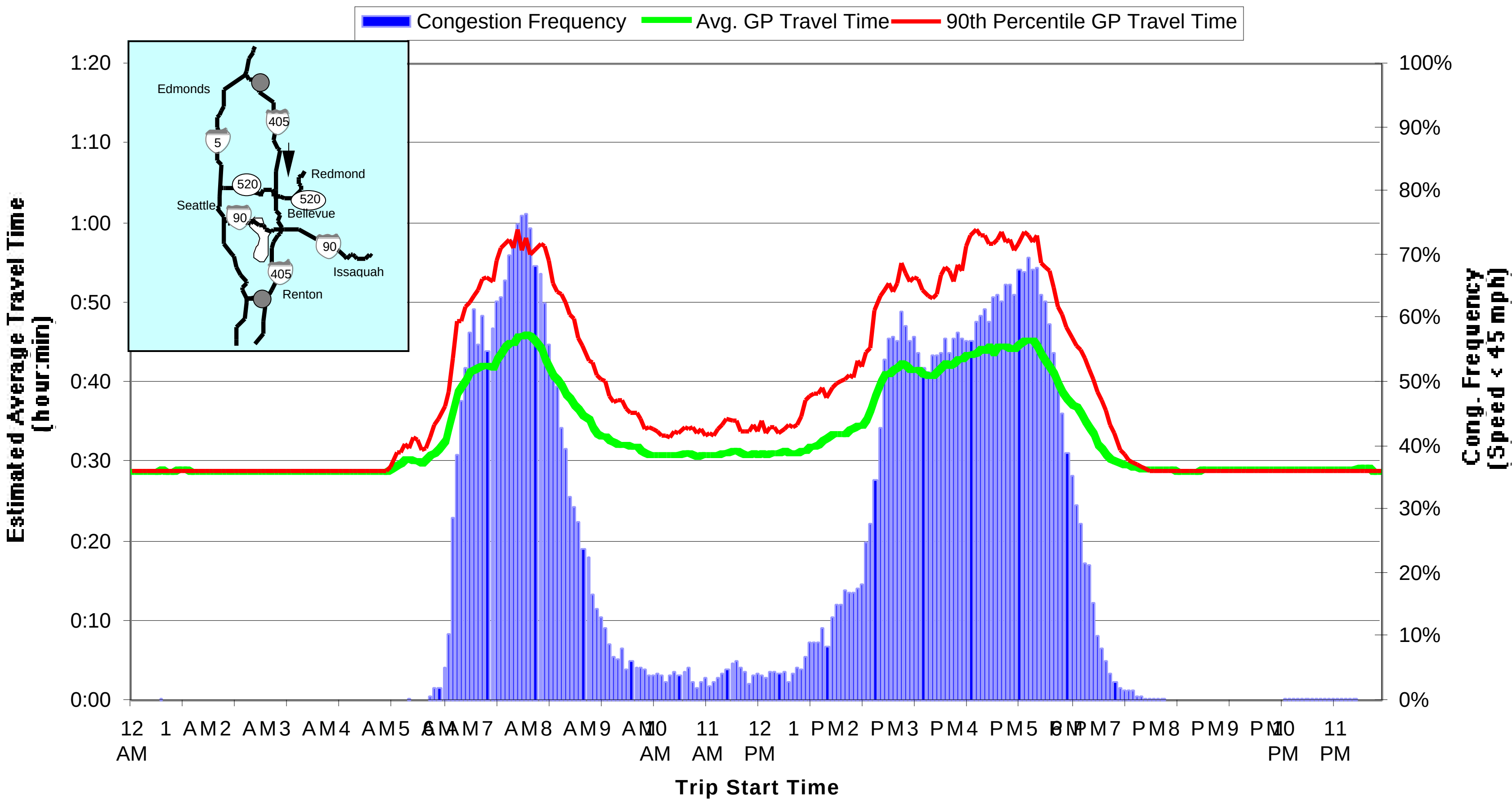


Figure 14. Estimated Average Weekday Travel Time (1997): Southbound Interstate 405 General Purpose Lanes, Damson Road to Tukwila (28.8 mi)

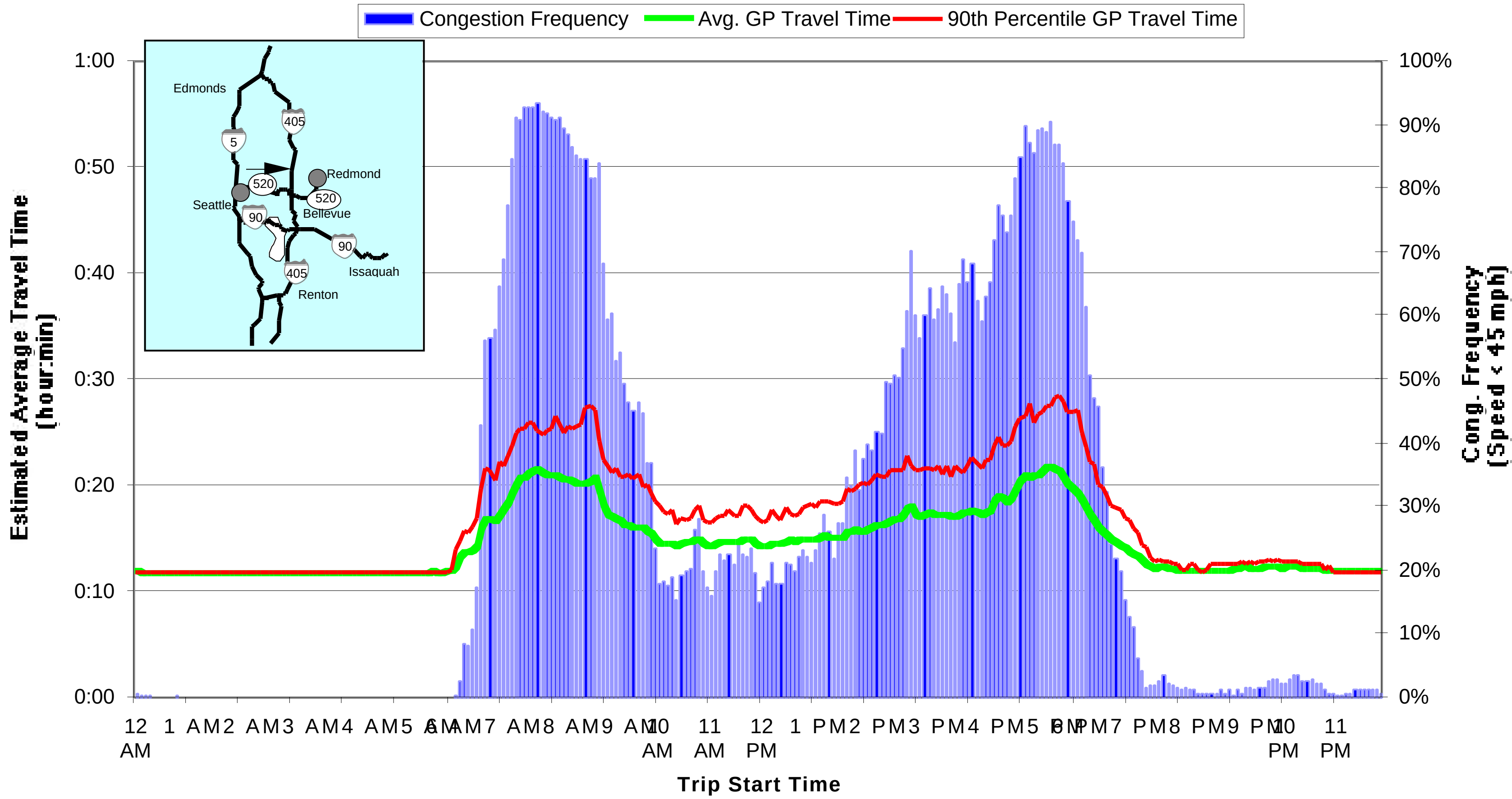


Figure 15. Estimated Average Weekday Travel Time (1997): Eastbound SR 520 General Purpose Lanes, I-5 to Redmond Way (12.3 mi)

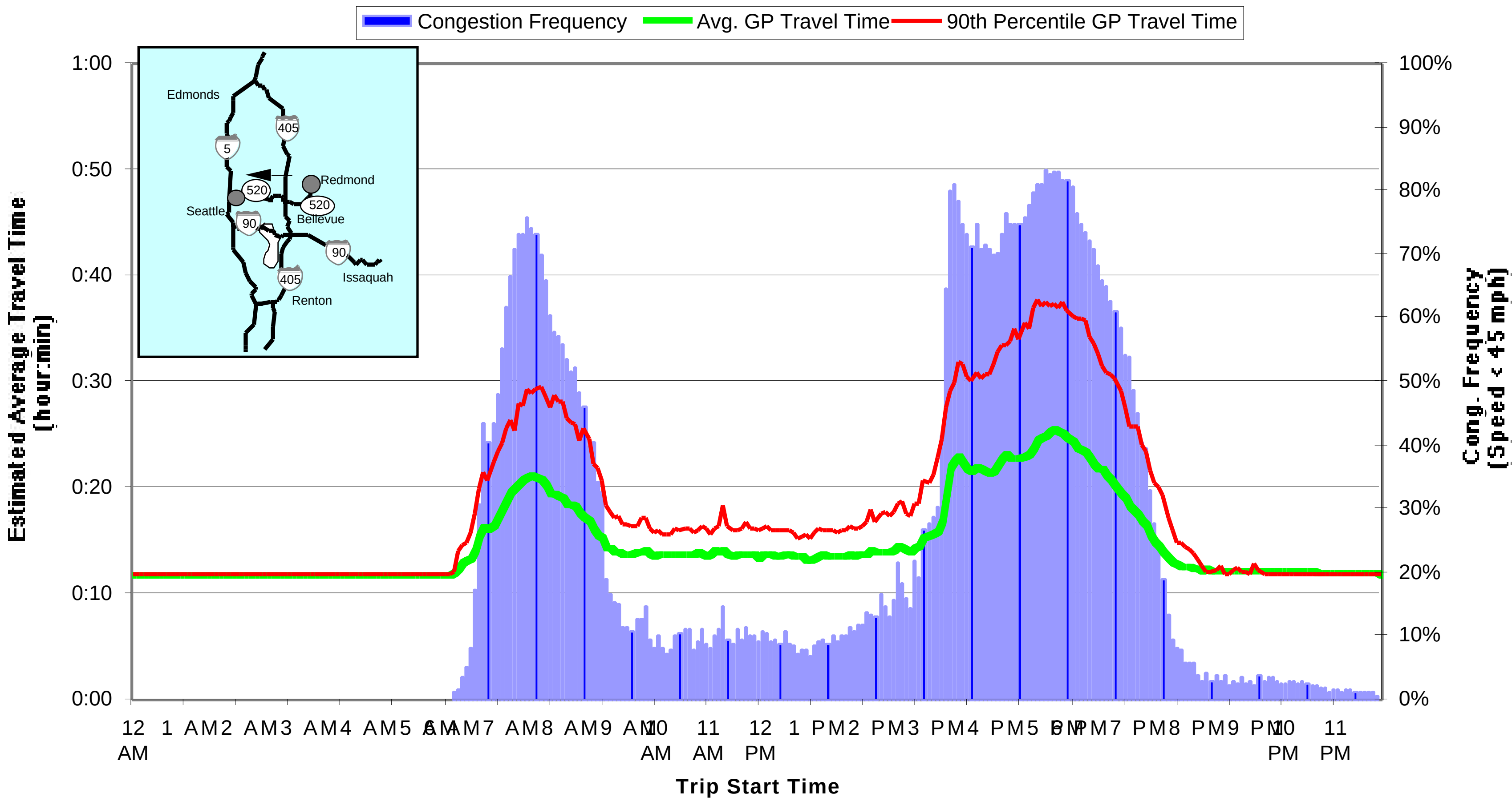


Figure 16. Estimated Average Weekday Travel Time (1997): Westbound SR 520 General Purpose Lanes, Redmond Way to I-5 (12.3 mi)

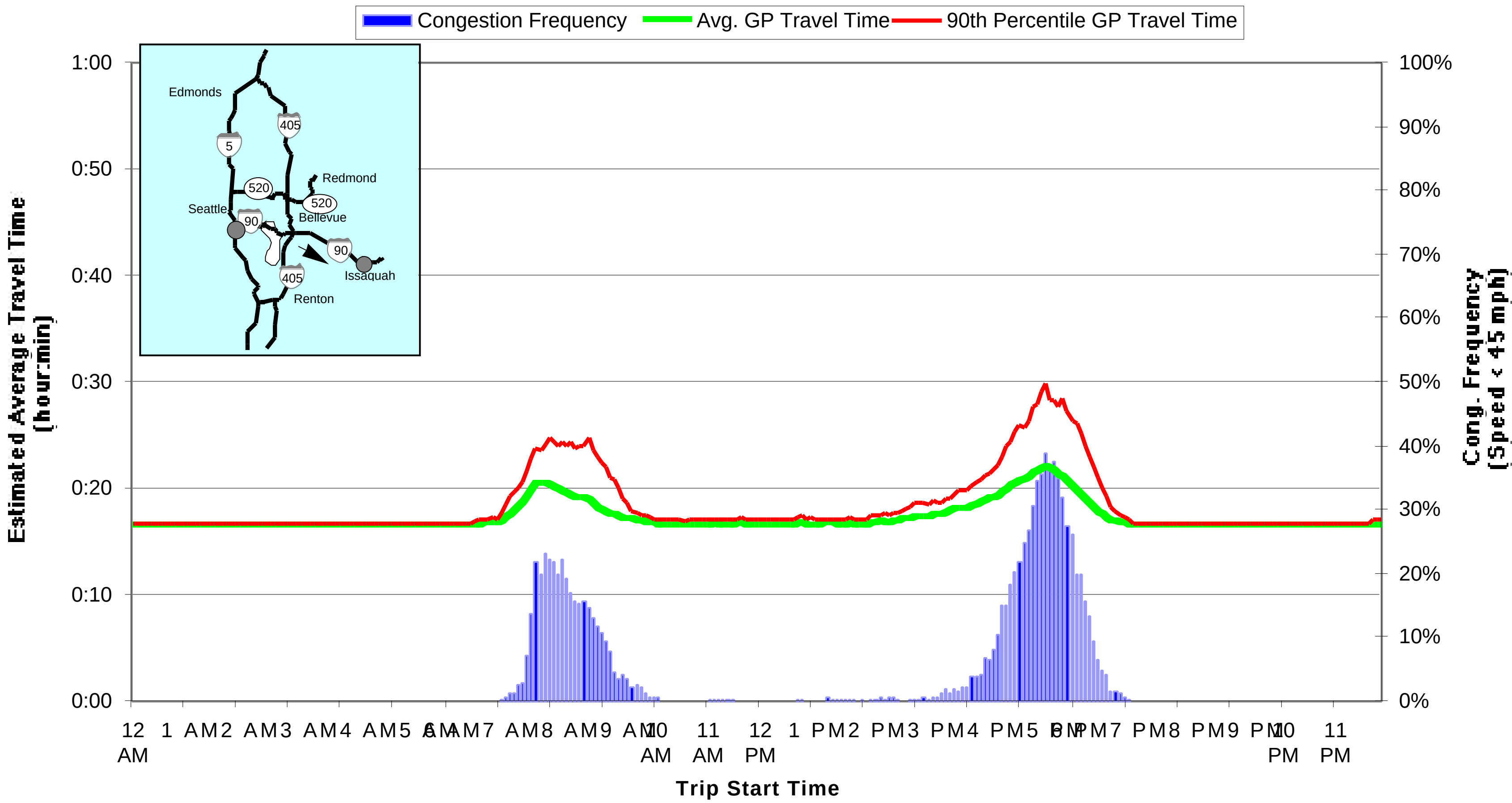


Figure 17. Estimated Average Weekday Travel Time (1997): Eastbound Interstate 90 General Purpose Lanes, I-5 to Issaquah (16.5 mi)

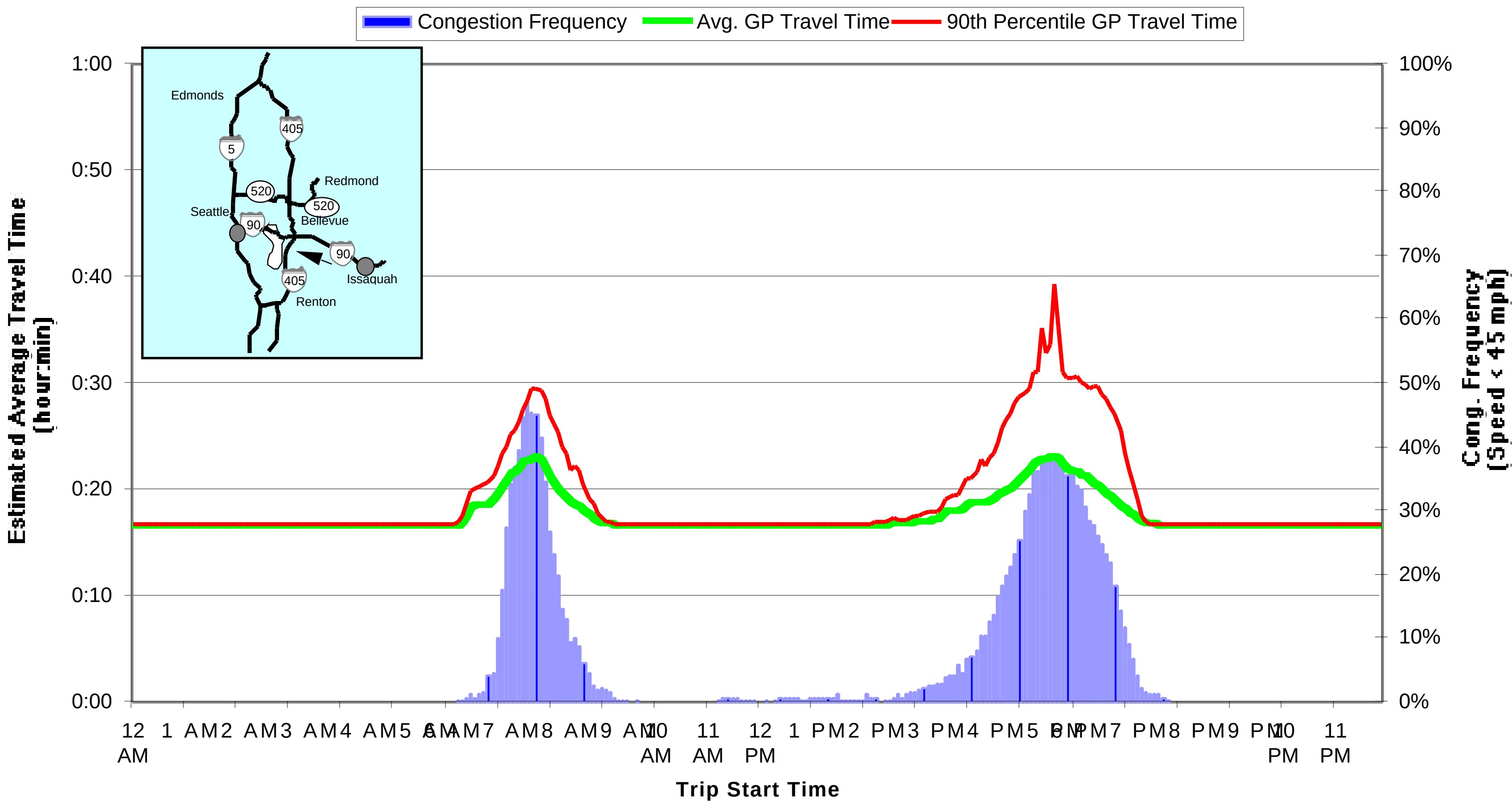


Figure 18. Estimated Average Weekday Travel Time (1997): Westbound Interstate 90 General Purpose Lanes, Issaquah to I-5 (16.5 mi)

Section 4. System Performance: Selected Freeway Sites

The previous section described corridor-wide or facility-wide performance, including average traffic congestion patterns as a function of both time of day and location along a corridor, and average travel time, travel time variability, and congestion frequency on a corridor. While these measures provide a top-level overview of system performance, they do not provide much detail about performance at any specific site. In this section, traffic performance at specific locations is analyzed. The principal measures used to evaluate traffic performance at a particular site include traffic volume, average speed, and congestion frequency; each is analyzed as a function of time of day, direction of travel, and type of lane (general purpose or HOV).

How Site-Specific Freeway Performance Was Measured

Three measures of system performance were used at selected freeway locations. They include the following:

Average Traffic Volume Profile at a Location, by Time of Day

Average traffic conditions at a site vary significantly over the course of a day. In the past, the typical weekday 24-hour volume "profile" was usually thought to be a pattern of high vehicle volumes during the morning and evening "rush hour" peak periods, and significantly lower volumes during non-peak hours. This pattern is changing as peak demand extends into the "shoulders" of traditional peak periods (i.e., the beginning and end of the peak period). In addition, the more congested the facility, the "flatter" the mid-day traffic volume profile, i.e., there is less of a dropoff in volume during the time between the AM and PM peak periods. People traveling in the peak shoulders might have preferred to travel during the traditional peak period, but traffic conditions caused them to shift the timing of their trip to avoid congestion as much as possible.

Because the magnitude and timing of volumes during the day are important considerations in trying to understand freeway performance, an average 24-hour weekday traffic profile was estimated at selected freeway sites. Vehicle volumes were estimated at 5-minute intervals over an average 24-hour weekday at a given site; these volumes were then adjusted to a "per lane" hourly rate (vehicles per lane per hour, or **vplph**) to allow direct comparisons between sites with different numbers of lanes.

Average Speed at a Location, by Time of Day

Because traffic volumes are affected by the speed that vehicles can travel (and vice versa), average speeds were also estimated for the selected sites throughout the day.

Frequency of Heavy Congestion at a Location, by Time of Day

Average conditions do not represent the condition that always occurs. Some days traffic speeds will be much lower than average, and on other days conditions will be better. To describe how often a facility experiences "bad" traffic conditions, the researchers also estimated the frequency of congestion at the selected locations. Congestion frequency is measured by the likelihood that significantly congested traffic will be encountered at a given time of day. For example, a measure of 75 percent at 5:00 PM indicates a 75 percent chance of encountering congested conditions at a particular location in that direction of travel at 5:00 PM. This measure is an excellent way to determine how "reliable" a given facility is. The more frequent the congestion, the less reliable a trip using that facility becomes.

Where Site-Specific Freeway Performance Was Measured

Volume graphs for a core set of four central freeway measurement locations in the Seattle area "rectangle," bounded by I-5, SR 520, I-405, and I-90, are presented below. While those sites are not representative of all freeway sections, they provide considerable insight into the freeway system's performance. Software tools developed for WSDOT allow the creation of these graphs wherever data are available. The locations selected for this report are downtown Seattle on I-5 at University Street, downtown Bellevue on I-405 at NE 14th Street, SR 520 at the east end of the bridge, and I-90 at the midspan of the bridge.

Results

Following an example of how to read the freeway performance graphs (Figure 19) are descriptions of volume, speed, and congestion frequency conditions (for 1997 data) for general purpose as well as HOV and/or reversible lanes (where they exist) presented by vehicle travel direction for each location (see figures 20-34).

Reading the Graphs

This freeway performance graph (see Figure 19) is for westbound SR 520 general purpose lanes at 76th Ave NE from 6:00 AM to 8:00 PM. The horizontal axis represents time of day, from midnight to midnight. The shape of the line shows volume patterns, measured along the left vertical axis in vehicles per lane per hour, by time of day. In the "traditional" commute pattern, volumes are heavy during the morning and afternoon peak hours but decrease substantially at midday. At this site, however, volumes remain fairly steady all day long, from before 7:00 AM to nearly 8:00 PM.

The volume line is further enhanced by color coding to reflect the approximate speed of vehicles on the average day:

- green indicates that traffic moves at or near the speed limit (55 mph and above)
- yellow represents speeds somewhat under the speed limit (approximately 45 to 55 mph)
- red represents traffic traveling slower than 45 mph.

At this location, travelers can count on moving at less than 45 mph for the entire morning and evening peak periods, from about 6:45 AM to 9:00 AM and from about 3:00 PM to 7:30 PM. Even at midday, speeds may slow to 45 mph.

Superimposed on the volume line is a column graph, measured along the right vertical axis, that illustrates the frequency of congestion to describe how often a site experiences "bad" traffic conditions. Congestion frequency is measured by the likelihood that a traveler will encounter significantly congested traffic at a given time of day. At this location on westbound SR 520, for example, congestion frequency measures nearly 90 percent at 5:30 PM, indicating a 90 percent chance that commuters will experience congested conditions at 5:30 PM. From about 9:00 AM to 2:00 PM, however, travelers have only a 10 percent chance of encountering significant congestion. Thus, at this

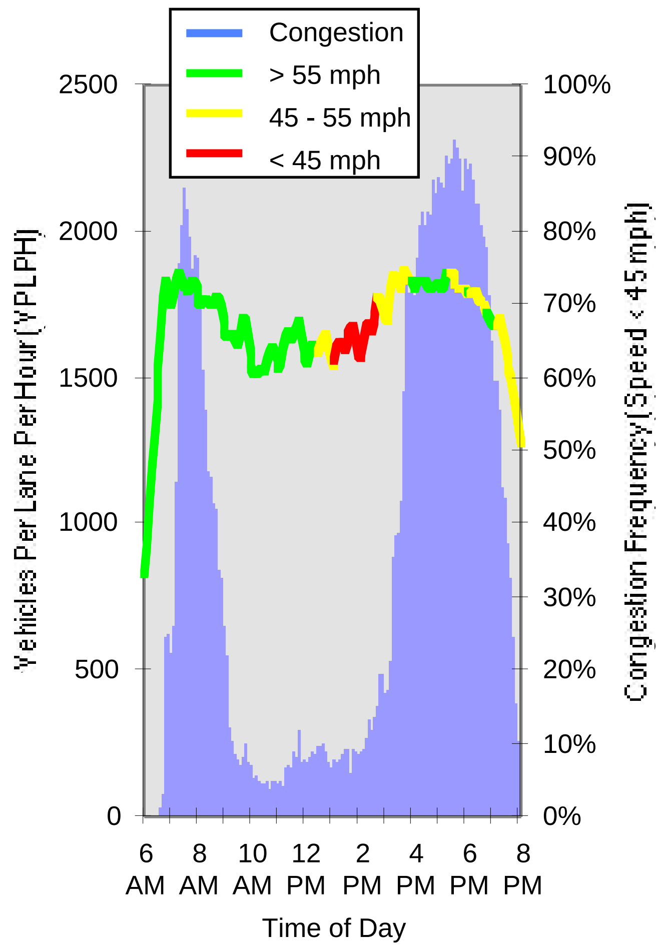


Figure 19. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Westbound SR 520, 76th Ave. NE, General Purpose Lanes

site, the occurrence of congestion varies greatly, and speeds vary with it, even though volumes remain consistently high.

Downtown Seattle (I-5 at University Street)

Overall: This location includes southbound traffic from north Seattle, Snohomish County, and westbound SR 520, as well as northbound traffic heading to and through downtown Seattle. Peak period volumes in both directions in the AM and PM peak periods are high, with little drop-off in volume during the midday hours. Overall, SB GP volumes during the day are slightly higher than NB GP volumes, though SB traffic has less frequent heavy congestion in the PM peak period.

Southbound HOV volumes are low in the morning, but steadily increase in the afternoon. This is to be expected at this location, which is just south of several major downtown on- and off-ramps. Lower AM volumes would be expected given that much of the southbound I-5 HOV traffic in the morning is destined for downtown Seattle and therefore exits I-5 before reaching this location (therefore, lower volumes are recorded). In the afternoon, however, one would expect the HOV lane to be more heavily used as it serves southbound HOV traffic starting from Seattle and heading south, as well as traffic from north of downtown that passes through the city.

GP Northbound: Significant volumes (1,500+ vplph) occur throughout the day (7:00 AM to 8:00 PM), with little drop-off in volumes during the midday. (See Figure 20.) Congestion is moderate in the early afternoon and heavier during the PM peak period from 5:00 PM to 7:00 PM, as traffic travels northbound away from downtown. The frequency of heavy congestion peaks sharply during the PM peak period.

GP Southbound: Significant volumes (1,500+ vplph) occur throughout the day (6:00 AM to 7:00 PM). (See Figure 21.) Uniformly high volumes persist throughout much of the day, with a slight drop from 9:00 AM to 12:00 PM. Congestion is moderate throughout the day, with some reduction in the later morning hours and heavier congestion during the early PM peak (approximately 3:00 PM to 4:00 PM) as traffic moves southbound through downtown Seattle. The frequency of heavy congestion peaks during the mid-afternoon.

HOV Northbound: There is no mainline northbound HOV lane at this location.

HOV Southbound: Volumes build throughout the day to a significant (1,000 vplph) peak in the mid- to late afternoon (approximately 4:00 PM) as traffic moves through and away from downtown. (See Figure 22.) There is almost no heavy congestion in this HOV lane. (Note that the southbound HOV lane basically starts at this location, as there is no HOV lane on the mainline between Northgate and the Seattle central business district.)

Reversible GP: Volumes peak prominently in the AM and PM, as would be expected on this reversible facility, which is closed to traffic at midday to reverse the direction of travel (Figure 23). The AM peak traffic experiences significant congestion as it moves southbound toward downtown, whereas the PM peak traffic has little congestion as it moves northbound away from downtown. During the southbound AM peak period from 6:30 AM to 8:30 AM, the frequency of heavy congestion is very high. Peak vehicle volumes are significant in both peak periods (1,400 to 2,000 vplph). Much of the southbound congestion on this facility is caused by the loss of reversible lanes further south. Similarly, northbound congestion here is minimal because additional capacity (lanes) is added for vehicles entering the reversible facility.

Reversible HOV: Peak AM volumes are significant (750+ vplph), with little or no congestion (Figure 24). The reversible HOV lane becomes a GP lane in the northbound PM hours.

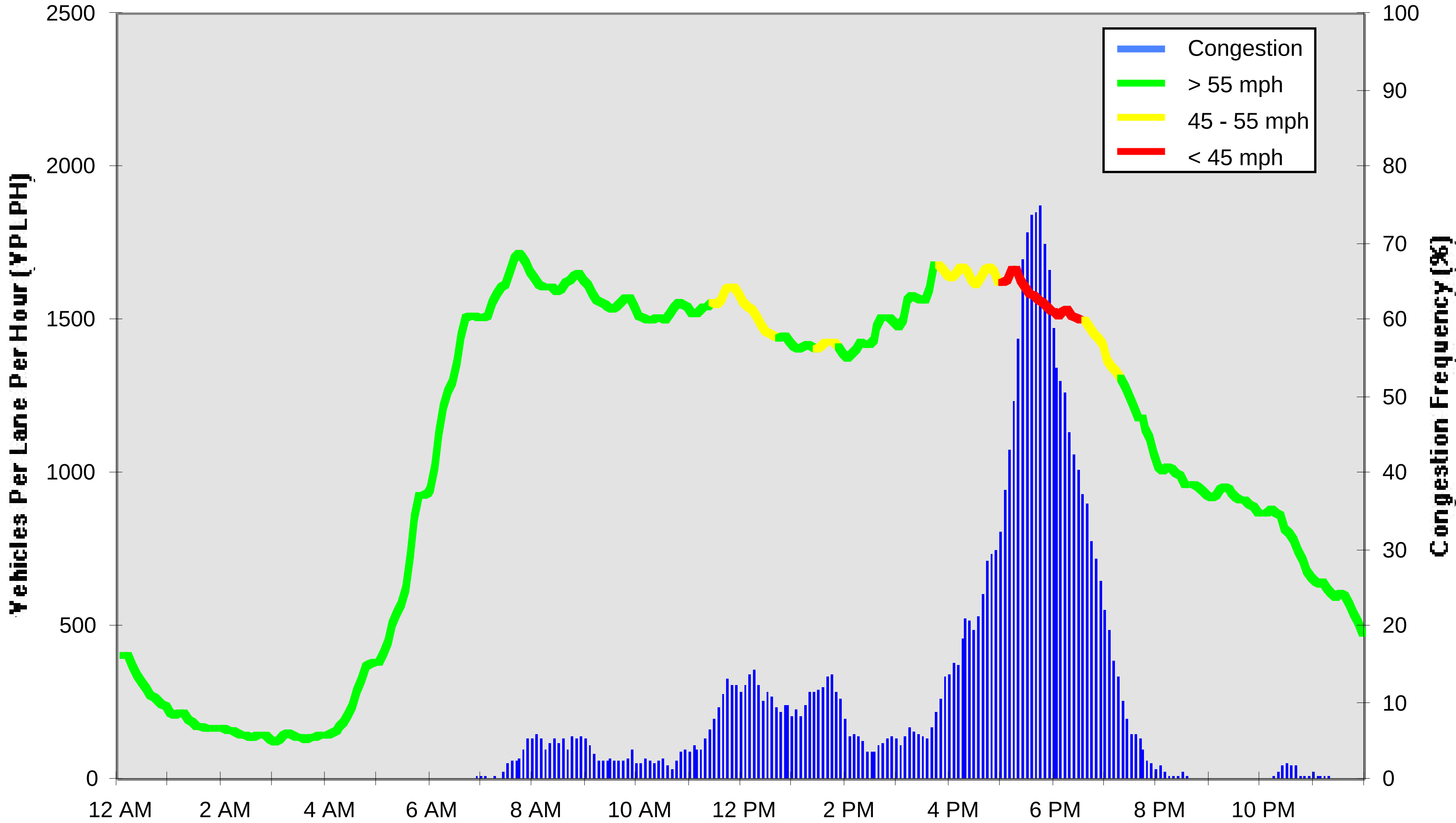


Figure 20. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Northbound I-5, University St, General Purpose Lanes

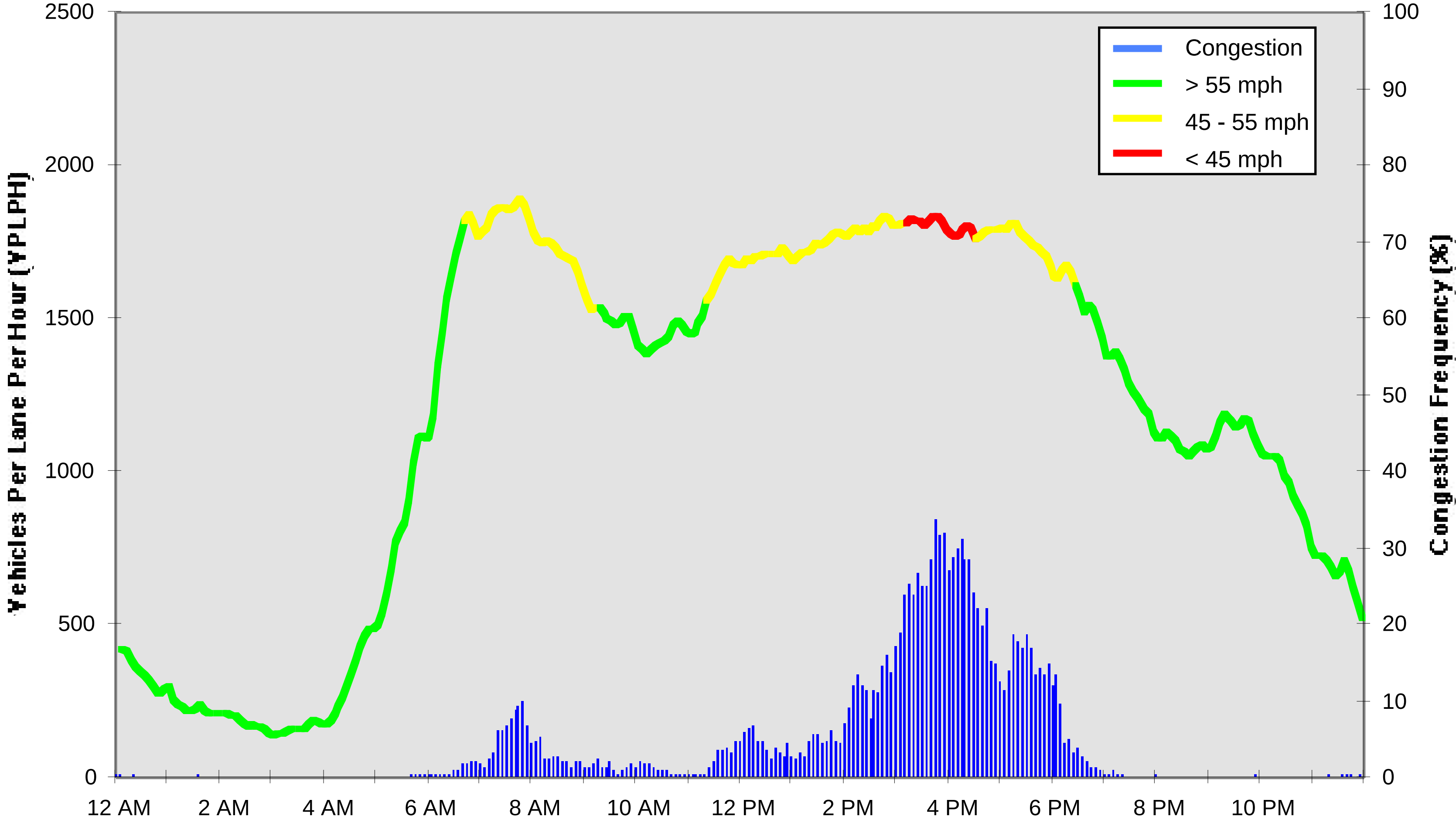


Figure 21. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Southbound I-5, University St, General Purpose Lanes

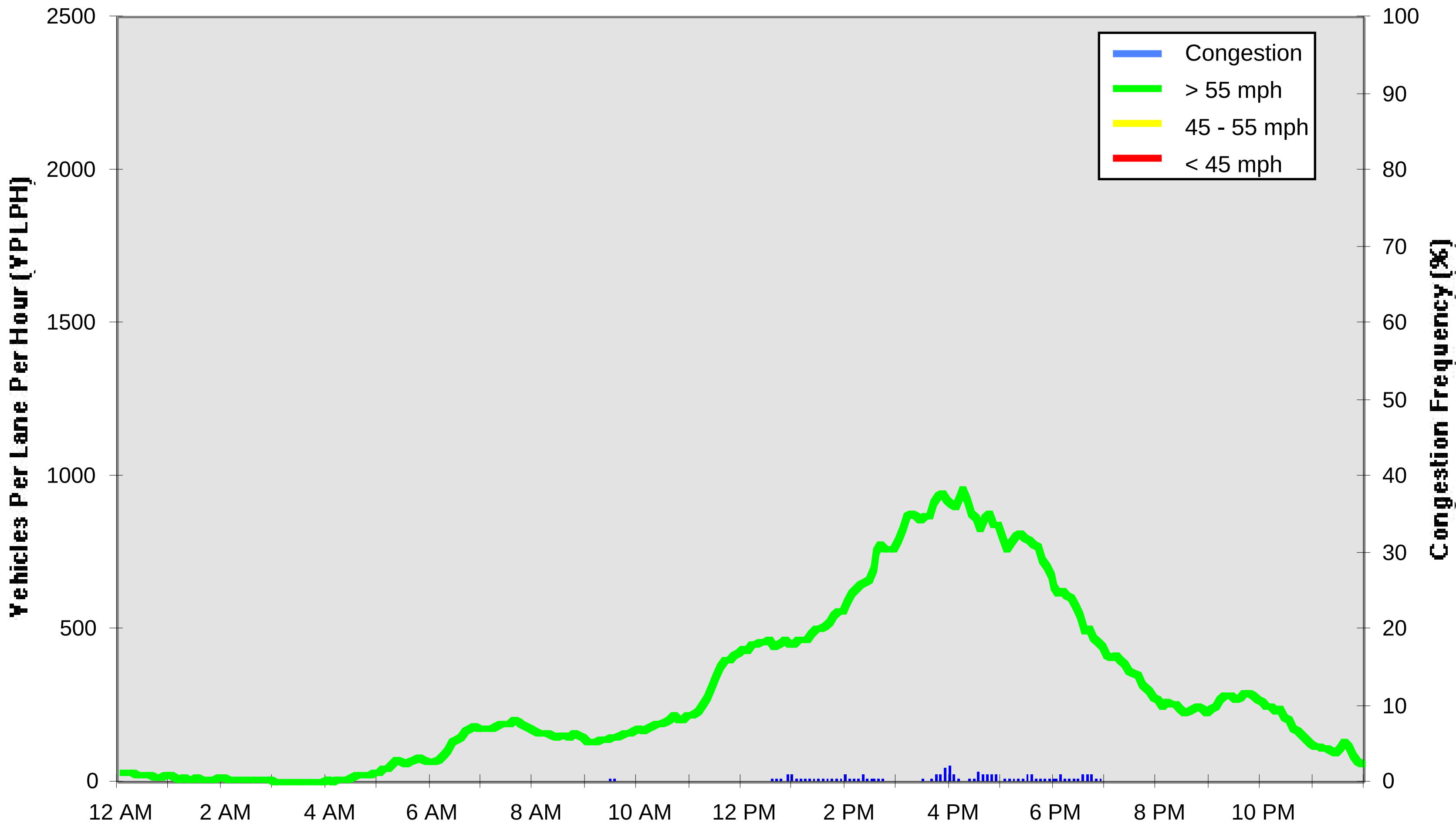


Figure 22. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Southbound I-5, University St, HOV Lanes

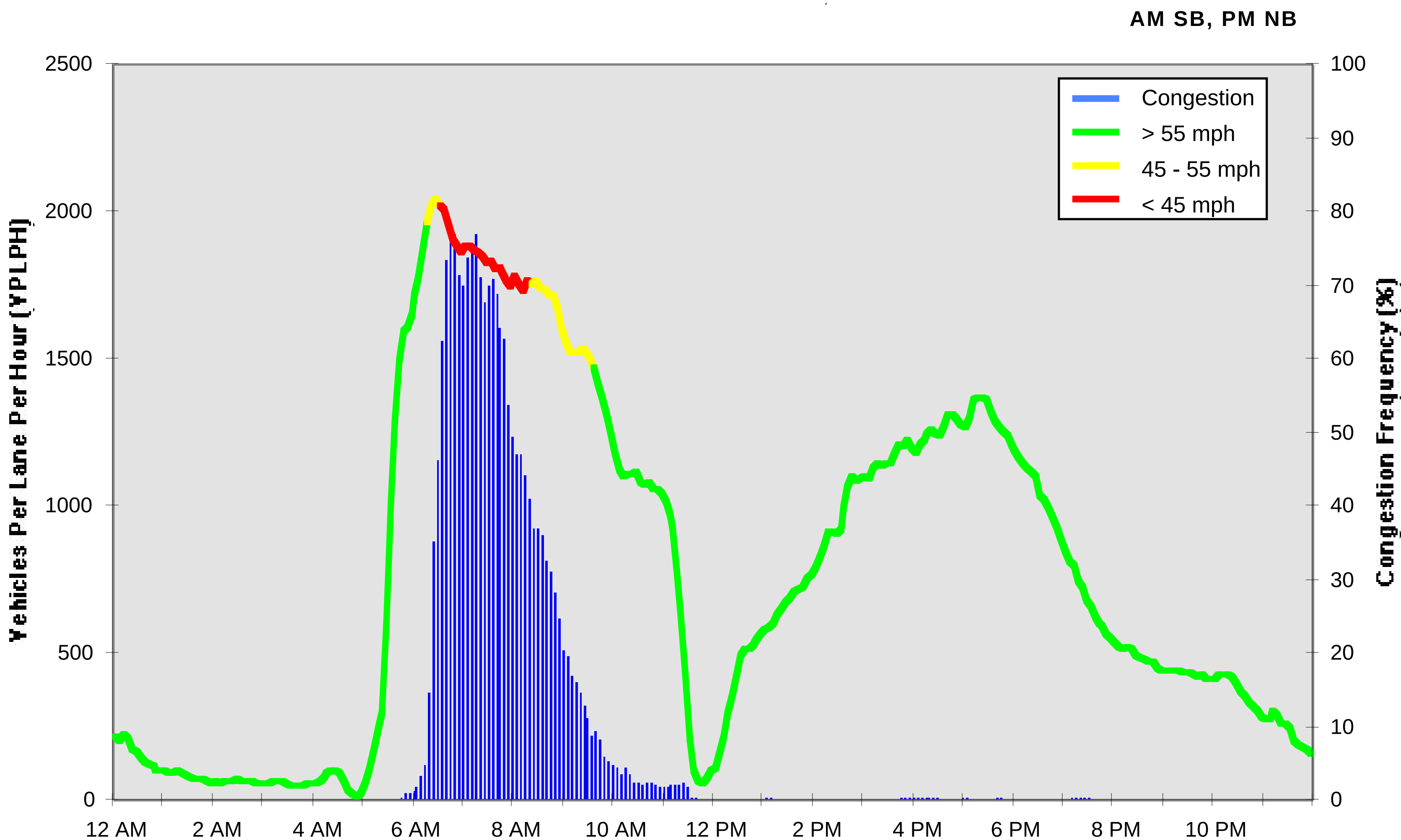


Figure 23. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): I-5, University St, General Purpose Reversible Lanes

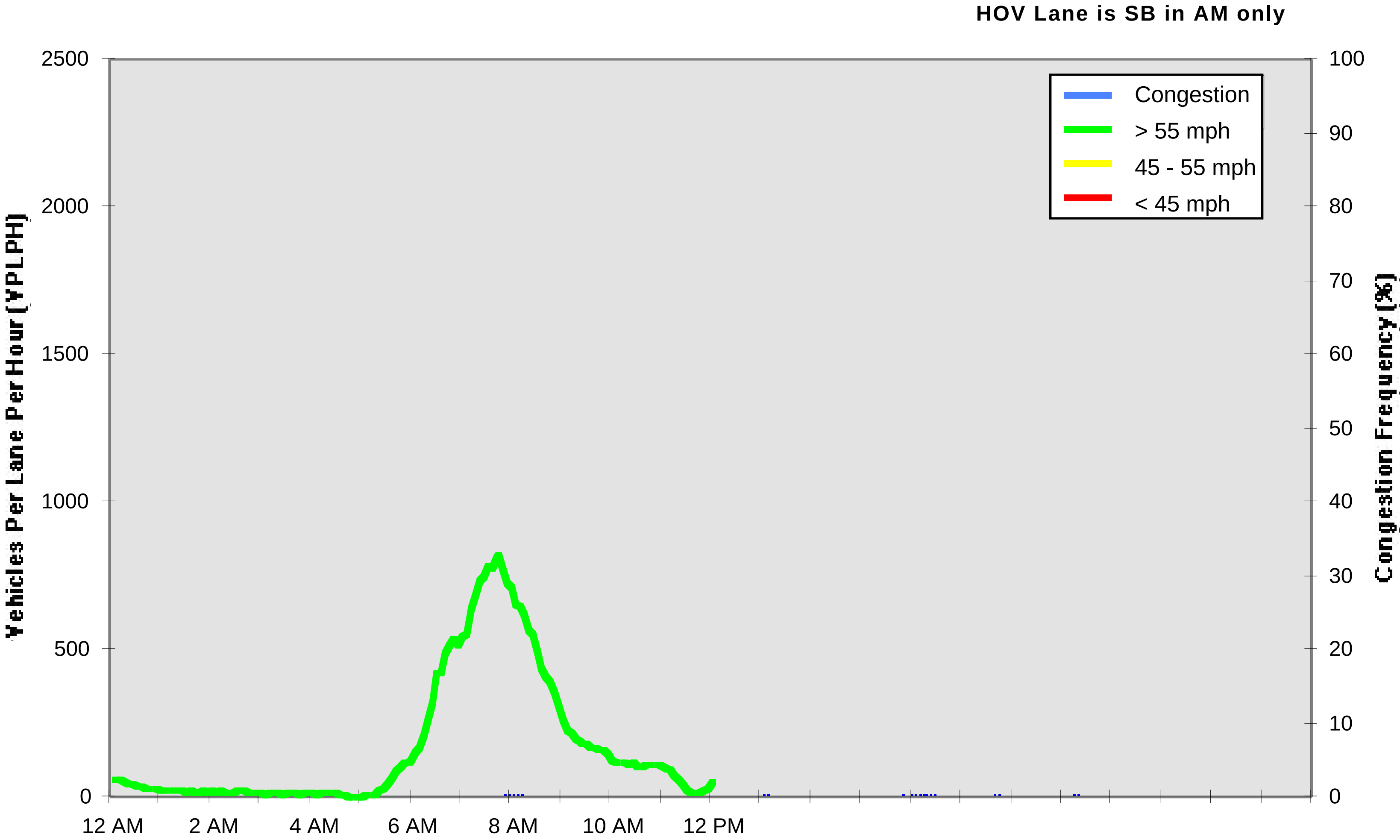


Figure 24. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): I-5, University St, HOV Reversible Lanes

Downtown Bellevue (I-405 at NE 14th Street)

Overall: This location includes traffic heading to and from Kirkland, SR 520, and other parts of northeast King County, as well as traffic heading northbound past Bellevue. Volumes remain high throughout the day. The HOV lane volumes are very high at this location, although this could be at least partly attributable to the fact that in 1997 the HOV lane was on the outside (far right) mainline lane alongside on- and off-ramp lanes; conditions measured on the HOV lane could therefore reflect not only HOV traffic but vehicles weaving across that lane as they enter or exit I-405. (Please see the HOV Lane Network discussion in section 6 for more information.)

GP Northbound: Moderate to significant volumes persist throughout the day, beginning with moderate volumes (1,000 to 1,300 vplph) and moderate-to-heavy congestion in the morning (approximately 7:00 AM to 10:00 AM). (See Figure 25.) At this location, AM congestion is usually produced by backups on the off-ramps leading to SR 520, rather than high vehicle volumes traveling north on I-405. Volumes slightly taper off later in the morning, then begin building to the highest volumes of the day in the PM peak (1,700+ vplph) accompanied by heavy congestion (vehicles are traveling north from downtown Bellevue). The frequency of heavy congestion is highest during the PM peak period at approximately 5:30 PM to 6:00 PM. Evening congestion can be caused by backups from the SR 520 ramps, as well as heavy vehicle volumes on I-405 itself.

GP Southbound: Moderate to significant volumes (1,200 to 1,500 vplph) persist throughout the day (Figure 26). The highest volumes of the day are in the AM peak, but with little or no congestion. However, moderate to significant congestion occurs during the PM peak (traveling toward downtown Bellevue) as vehicles merging from downtown Bellevue add to significant vehicle volumes on I-405. This is accompanied by a moderate frequency of heavy congestion in the 5:30 PM to 6:00 PM period.

HOV Northbound: HOV volumes are significant (1000+ vplph) throughout the day (approximately 7:00 AM to 7:00 PM), with intermittent moderate congestion during the AM peak and mid-afternoon. (See Figure 27.) The volumes are relatively constant throughout the day and extend into the evening hours, with volumes of approximately 750 vplph well into the evening (up to 9:00 PM). (Note: In 1997 HOV lanes on I-405 were on the outside (far right) lane; because of the heavy ramp volumes at this location, the HOV volumes recorded are likely to include vehicles moving into or out of the HOV lane.)

HOV Southbound: HOV volumes are very high during the AM peak period (traffic moving toward downtown Bellevue), exceeding 1,700 vplph at around 8:00 AM. (See Figure 28.) During the rest of the day volumes are significant, at 1,000 vplph or more, until approximately 6:00 PM, when they start to drop. Congestion during the PM peak period is moderate. (As with the northbound HOV lane, the placement of the southbound HOV lane on the outside lane during 1997 means that HOV volumes were affected by the heavy merging and exiting volumes.)

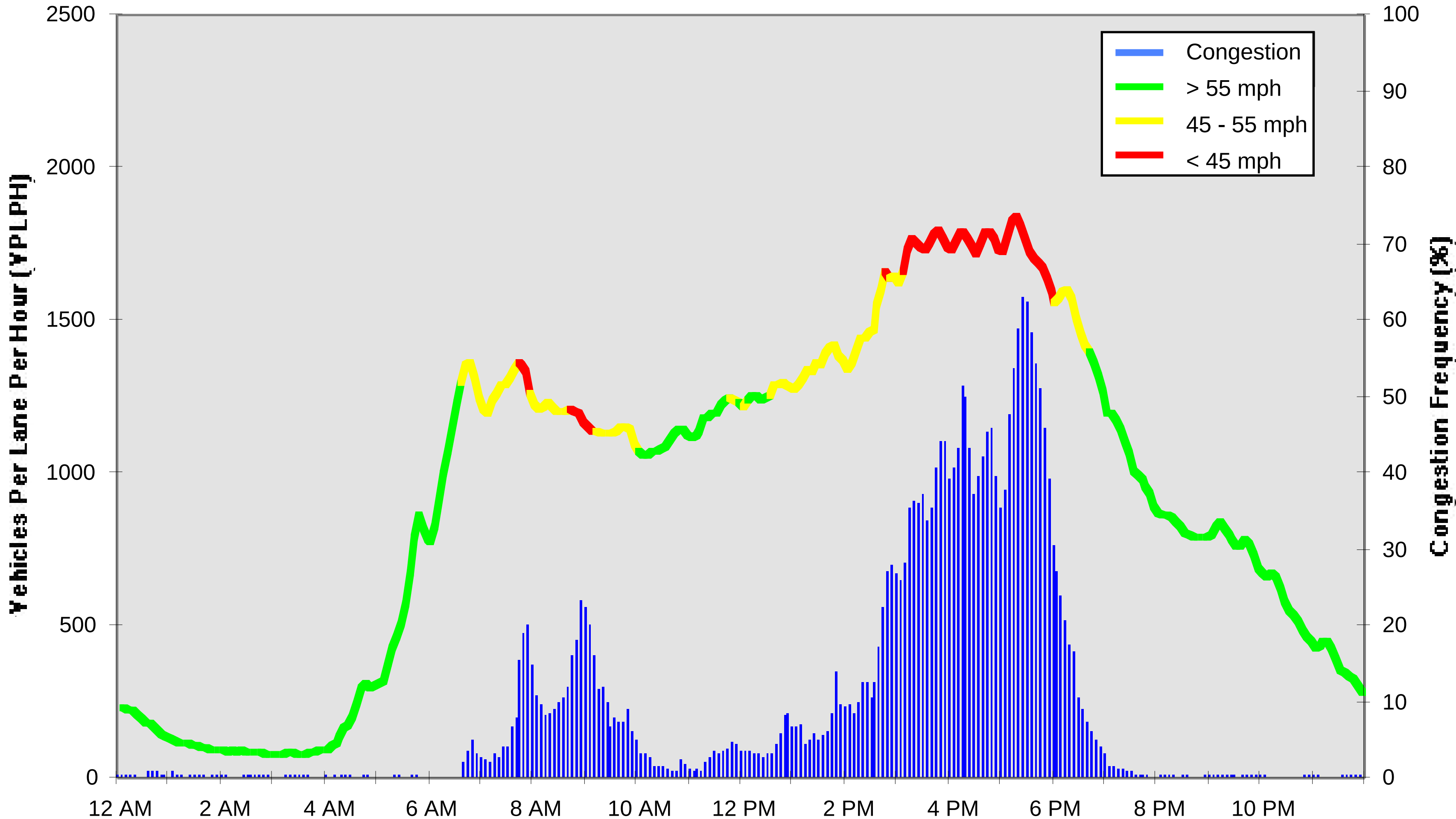


Figure 25. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Northbound I-405, NE 14th St, General Purpose Lanes

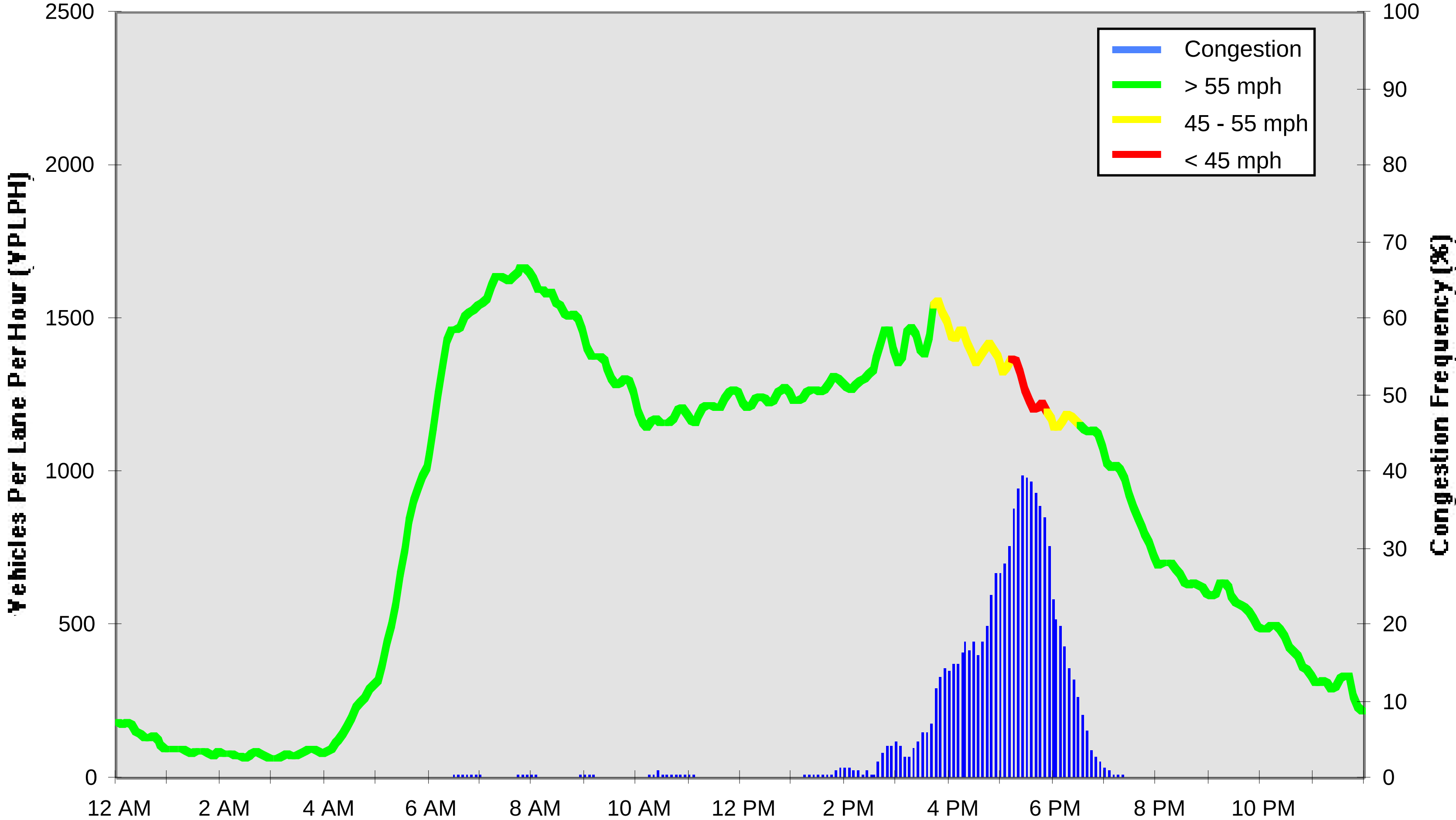


Figure 26. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Southbound I-405, NE 14th St, General Purpose Lanes

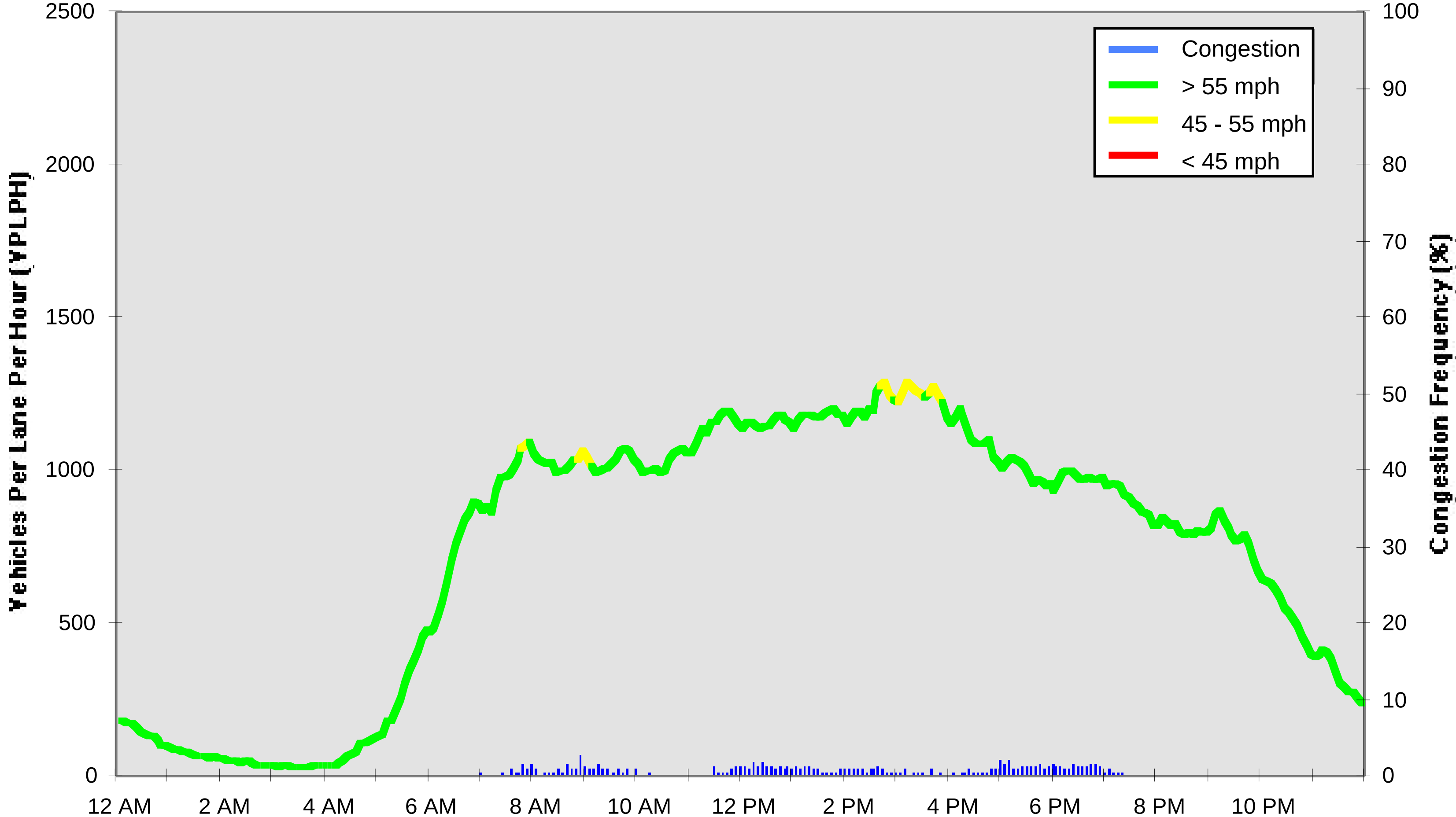


Figure 27. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Northbound I-405, NE 14th St, HOV Lanes

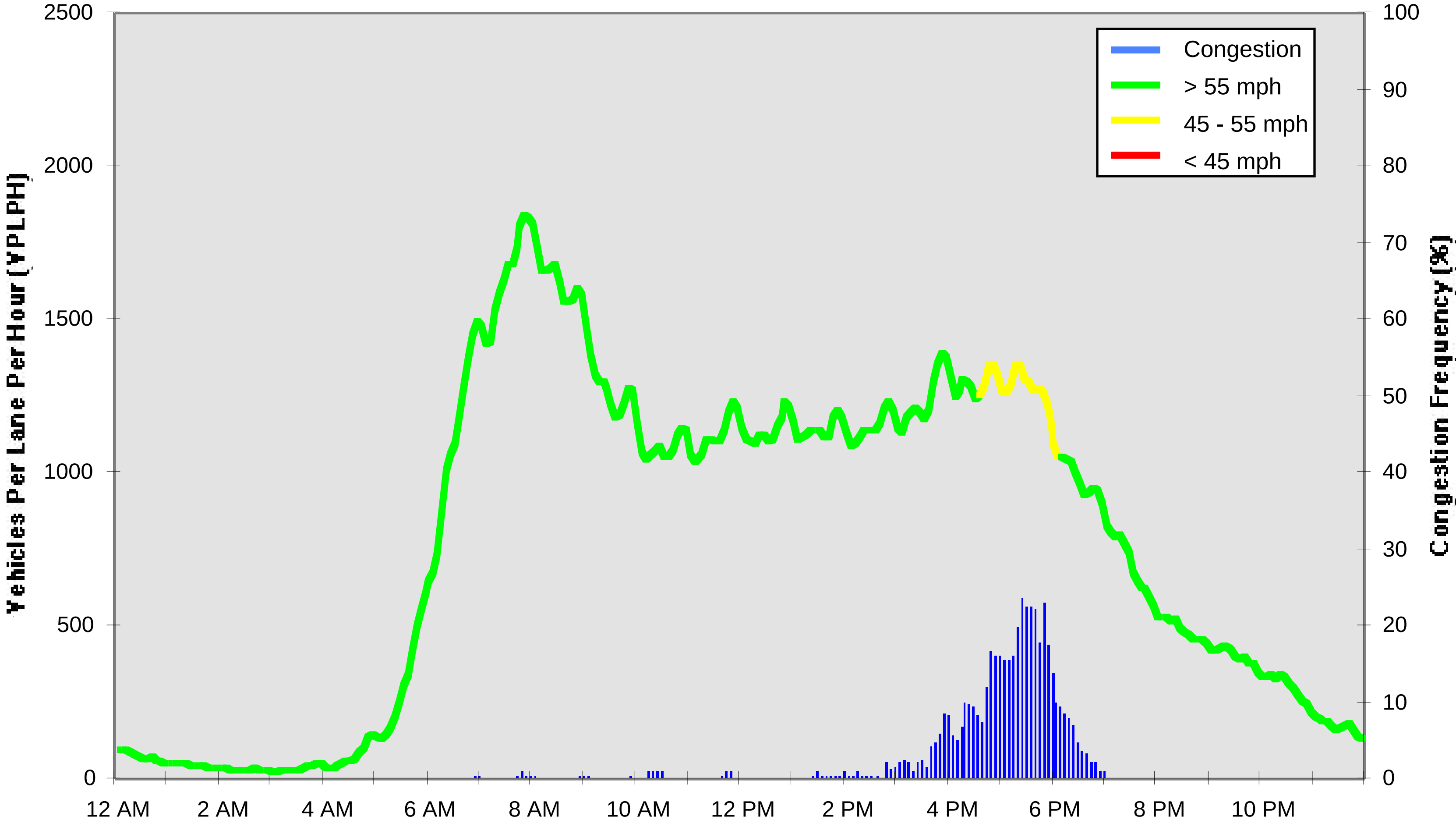


Figure 28. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Southbound I-405, NE 14th St, HOV Lanes

SR 520 (Evergreen Point) Floating Bridge (at NE 76th/NE 84th, just east of the bridge)

Overall: This location includes all SR 520 traffic that is approaching or has crossed the bridge span. GP volumes remain very high throughout the day and are comparable to the per-lane volumes carried during peak periods on I-5. Westbound GP congestion frequency at this site is the highest of the locations measured in this analysis. The significance of what used to be referred to as the "reverse" commute—i.e., Seattle to the Eastside in the morning, and Eastside to Seattle in the evening—is evident in the GP volume profiles; volumes are approximately the same in both directions in the morning and evening. The HOV lane is on the outside (right lane) in a converted shoulder and requires 3+ occupants. The westbound HOV lane ends just east of NE 76th, requiring HOVs to merge into general purpose traffic and contributing to congestion in the GP lane.

GP Eastbound: Volumes are routinely high (1,500 to 1,800 vplph) throughout the day at this location (eastbound just after crossing the bridge), with little drop-off at midday (Figure 29). Light to moderate congestion occurs during the AM peak period from about 7:00 AM to 10:00 AM and during the PM peak period from about 3:00 PM to 6:30 PM. Note that significant congestion does occur on eastbound SR 520, but it occurs west of this measurement location (typically from the the ramps at Lake Washington and Montlake boulevards to midspan). By the time vehicles reach the east high rise of the bridge near this measurement location, however, they have normally broken free of significant congestion.

GP Westbound: Volumes are high throughout the day (1,700 vplph, with only a slight drop in volume at midday) as westbound traffic approaches the bridge, with heavy congestion during both peak periods, and persistent high volumes and moderate congestion throughout the midday. (See Figure 30.) The frequency of heavy congestion is very high during both peak periods, with the PM peak period congestion extending from 4:00 PM to nearly 8:00 PM. Note that congestion in the so-called "reverse commute" direction (westbound to Seattle in the evening) is more frequent, for a longer period, than the traditional AM commute into Seattle.

HOV Eastbound: There is no EB HOV lane at this site.

HOV Westbound: Volumes are low to moderate (up to about 350 vplph) throughout the day for westbound HOV traffic approaching the bridge, with volumes peaking during the peak periods (Figure 31). There is occasional moderate congestion in the PM peak period. PM peak volumes are somewhat higher than AM peak period volumes; this reflects the high usage of buses in the morning due to better Seattle-bound AM transit service, as well as higher westbound PM carpool usage that may be in part a reflection of the relative lack of afternoon transit service. Note also that the lower HOV volumes (in comparison to I-405, for example) reflect in part the more stringent 3+ carpool requirement on SR 520.

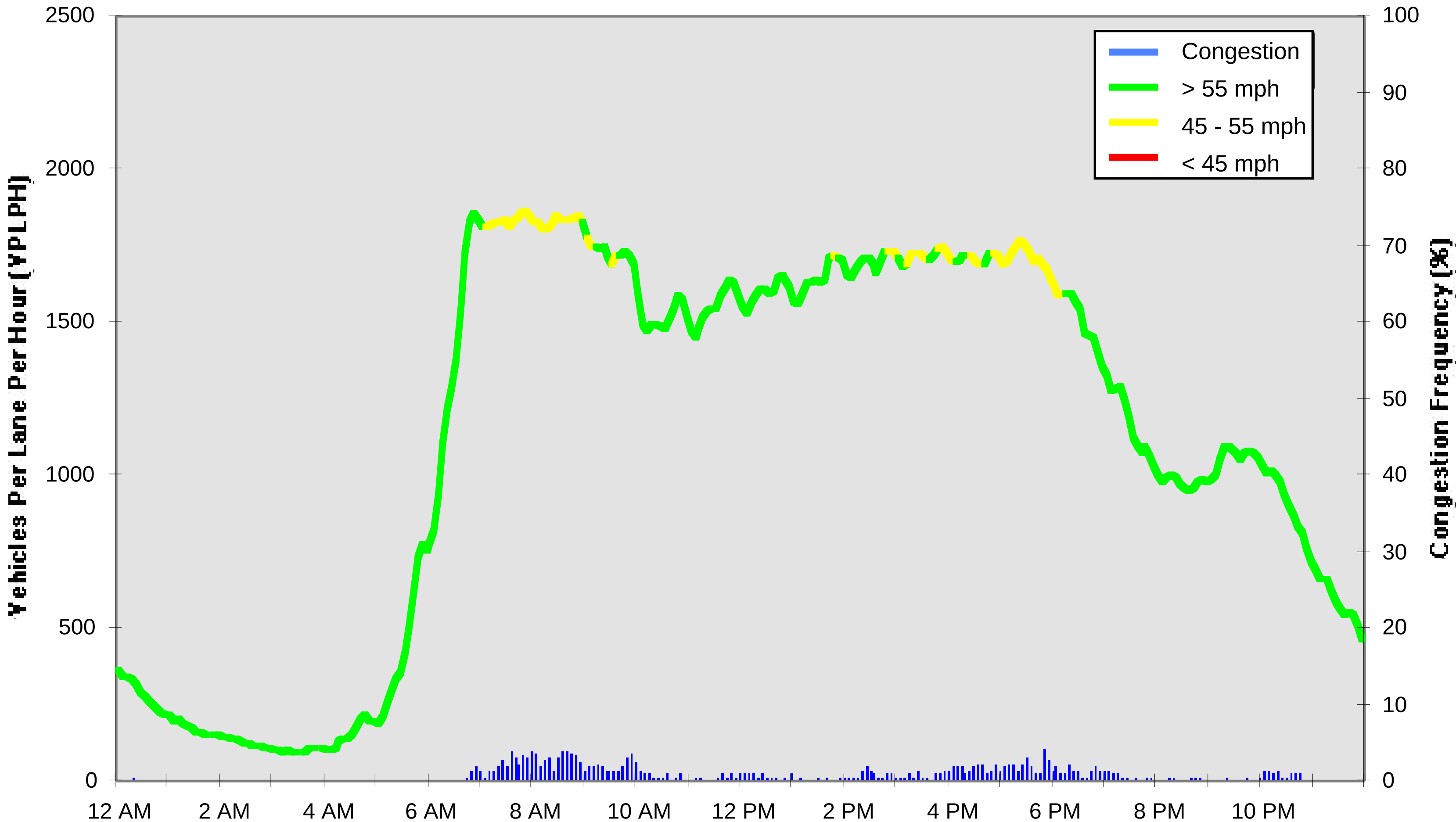


Figure 29. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Eastbound SR 520, 76th Ave NE, General Purpose Lanes

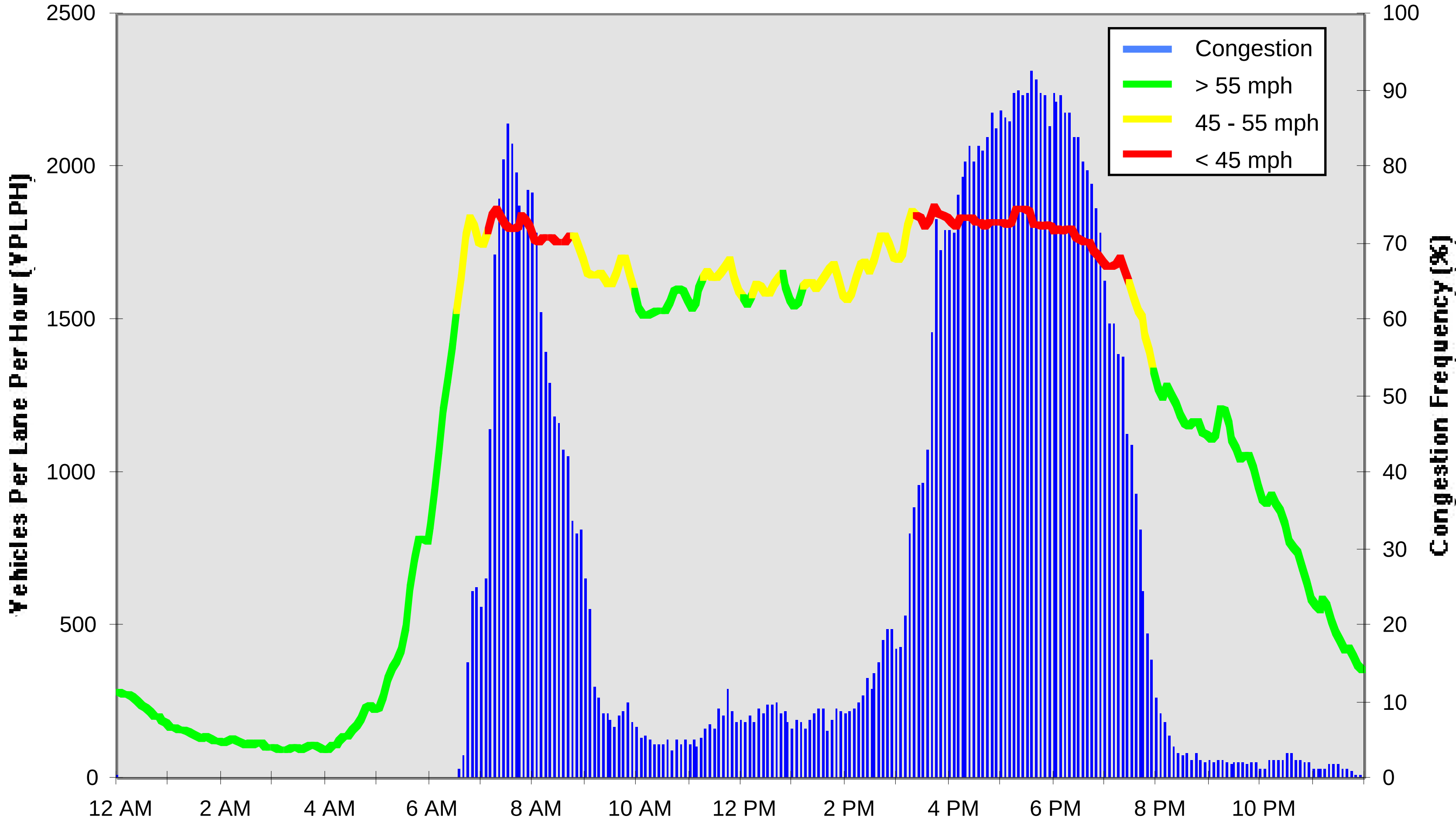


Figure 30. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Westbound SR 520, 76th Ave NE, General Purpose Lanes

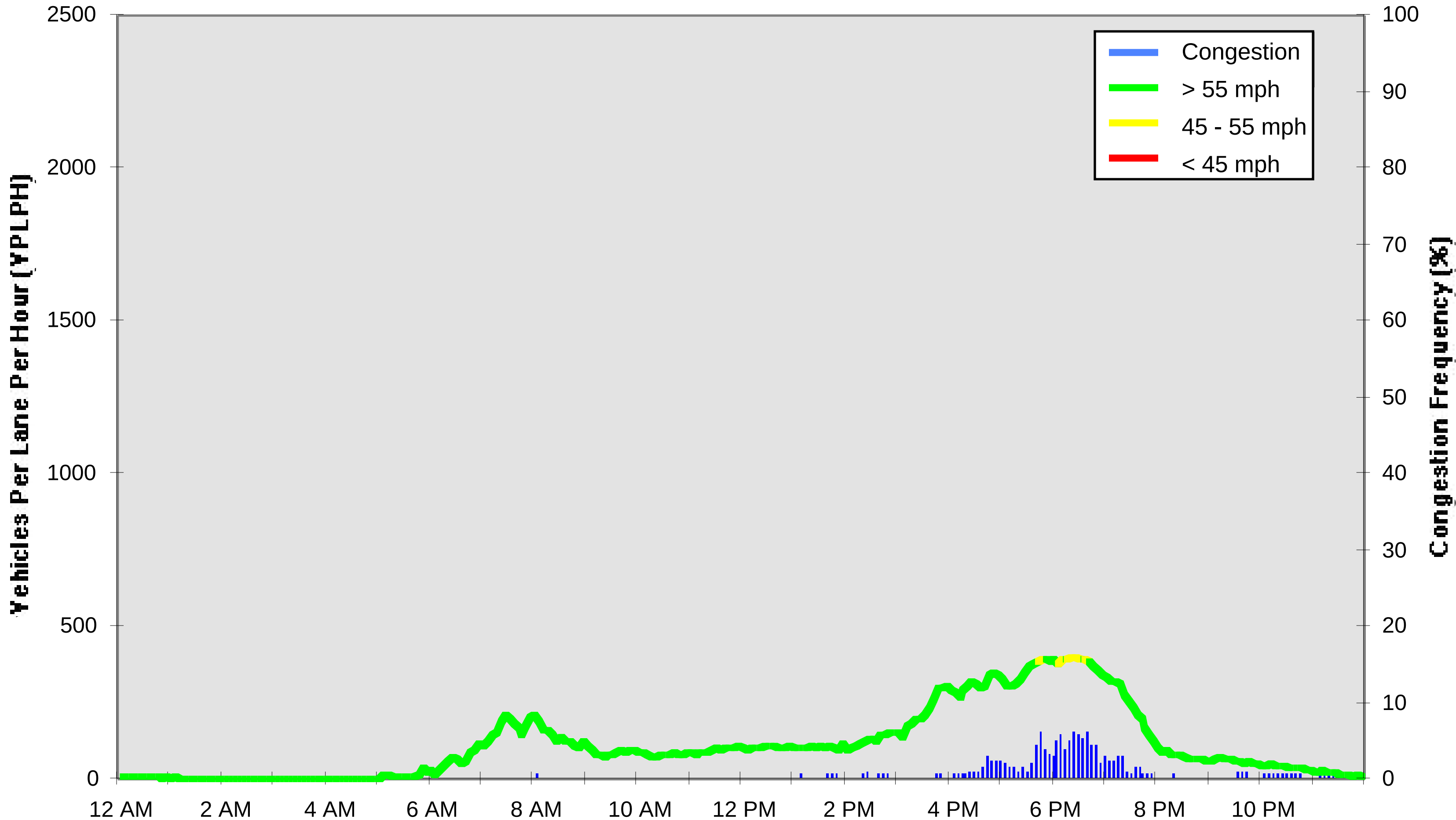


Figure 31. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Westbound SR 520, 84th Ave NE, HOV Lanes

I-90 (Mercer Island) Floating Bridge (Midspan)

Overall: The I-90 bridge has three general purpose lanes in each direction and two peak-direction reversible lanes (whereas the other east-west corridor, SR 520, has two GP lanes per direction and one westbound HOV lane). The reversible lanes operate westbound in the morning, and eastbound in the afternoon and evening. This location still illustrates what was formerly considered a common pattern: high volumes in the peak period and significantly lower volumes during the midday. However, as with SR 520, these traffic profiles also show the significance of what was formerly considered the relatively minor "reverse" commute, i.e., Seattle to the Eastside in the morning, and Eastside to Seattle in the evening. In fact, volumes on the GP lanes are very similar in both directions in the morning and evening. As with the eastbound SR 520 graph, this location (in both directions) does not show the primary congestion locations on I-90. A better image of the congestion on this route can be found on the traffic profile for I-90 (Figure 8).

GP Eastbound and Westbound: Both directions feature two prominent volume peaks (one AM, one PM), with peak levels of 1,500 to 1,700 vplph and significantly reduced midday volumes (about 1,000 vplph). (See Figure 32.) Congestion is moderate during the peaks (approximately 7:30 AM to 9:00 AM, and 5:00 PM to 7:00 PM).

HOV Eastbound and Westbound: There are no exclusive HOV lanes at the midspan of the I-90 bridge; reversible lanes are open to HOVs and Mercer Island traffic. (See Figure 33.)

Reversible GP and HOV: There are two prominent peak volumes (Figure 34), about 1,000 vplph at 8:00 AM (westbound traffic) and approximately 1,100 vplph at 5:30 PM (eastbound traffic). There is no significant congestion. While the reversible lane volume is moderately high during the peak commute hours, the vehicle count includes vehicles traveling between Seattle and Mercer Island, which are not subject to a minimum vehicle occupancy requirement.

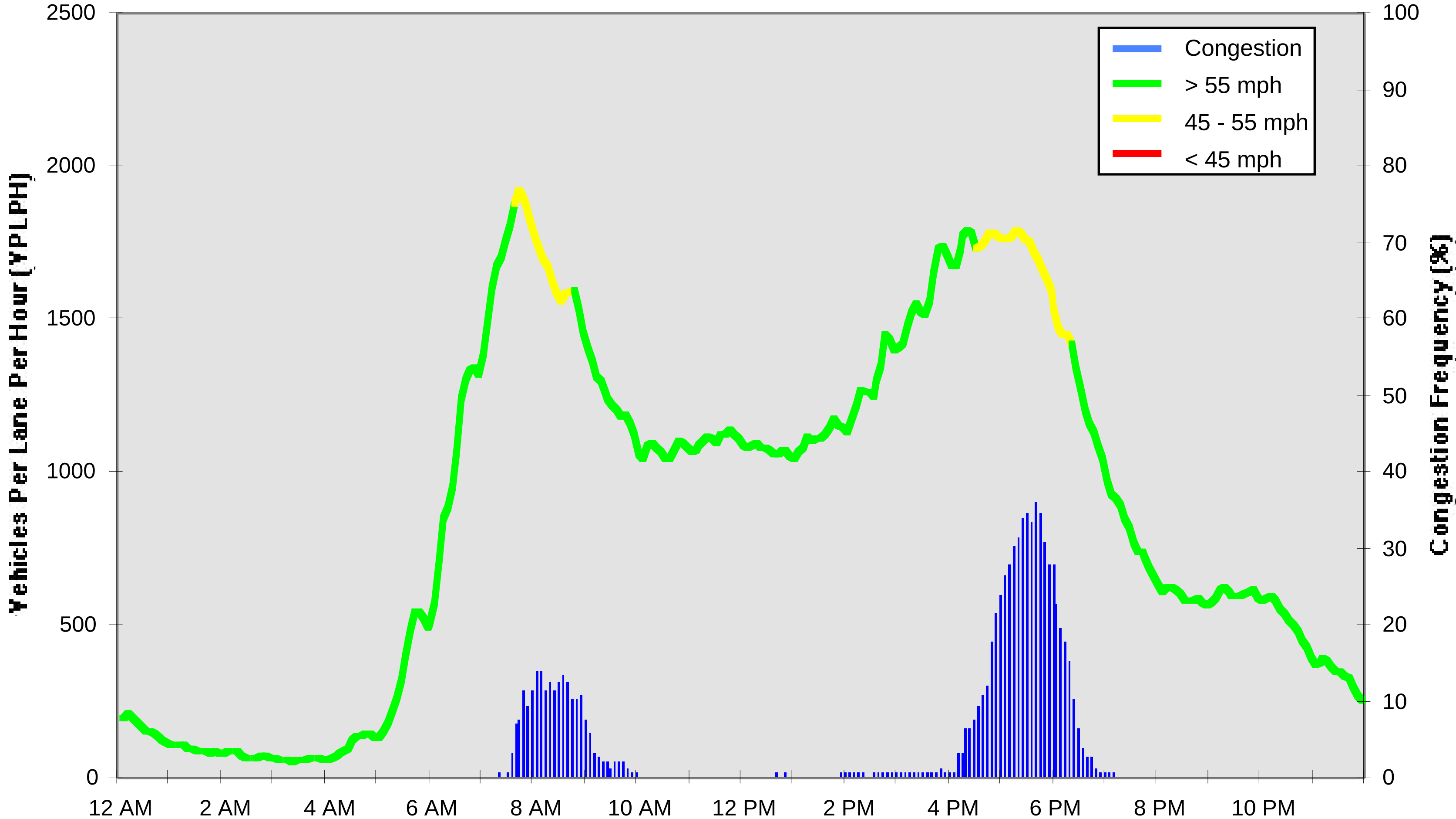


Figure 32. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Eastbound I-90, Midspan, General Purpose Lanes

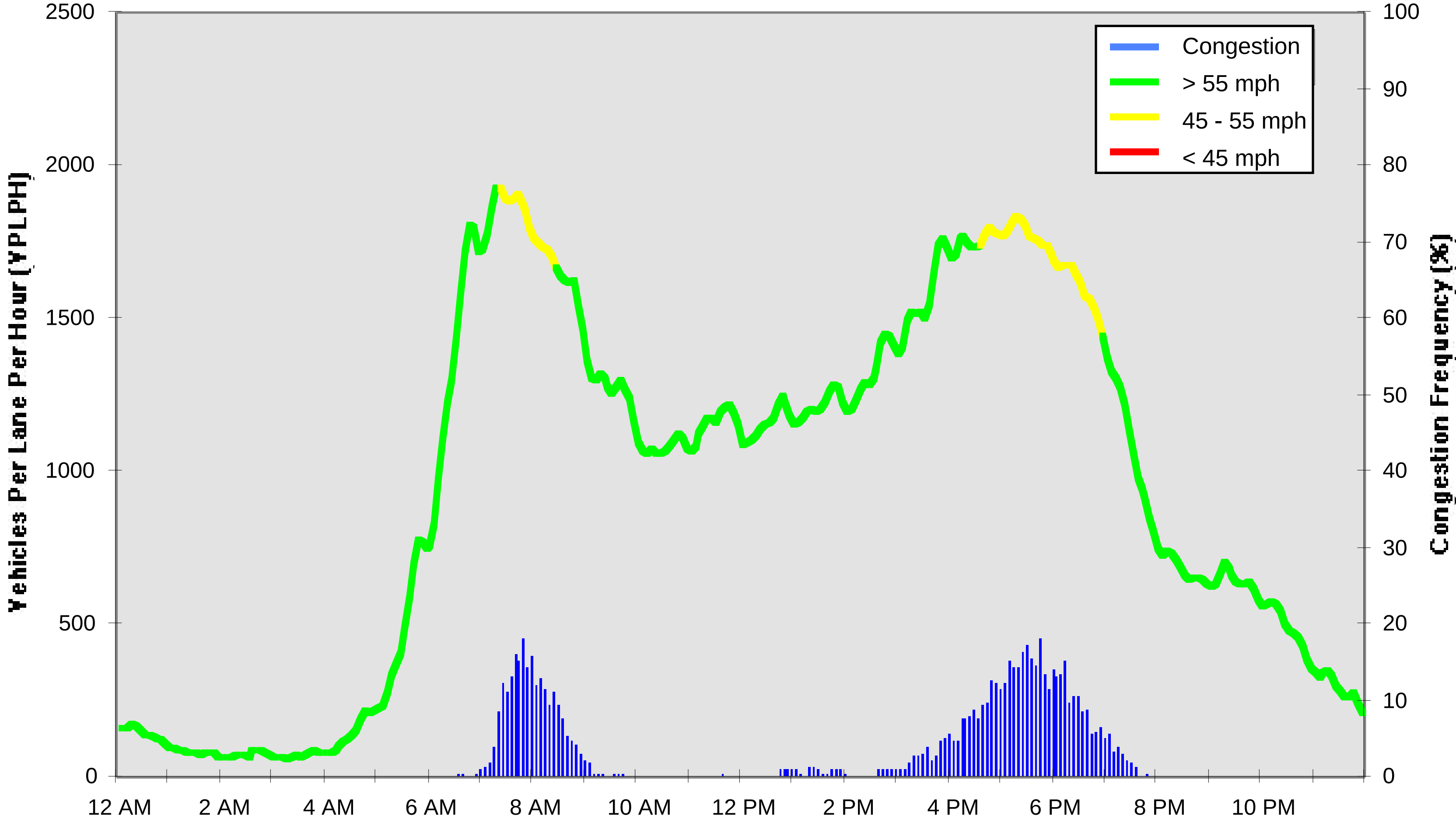


Figure 33. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): Westbound I-90, Midspan, General Purpose Lanes

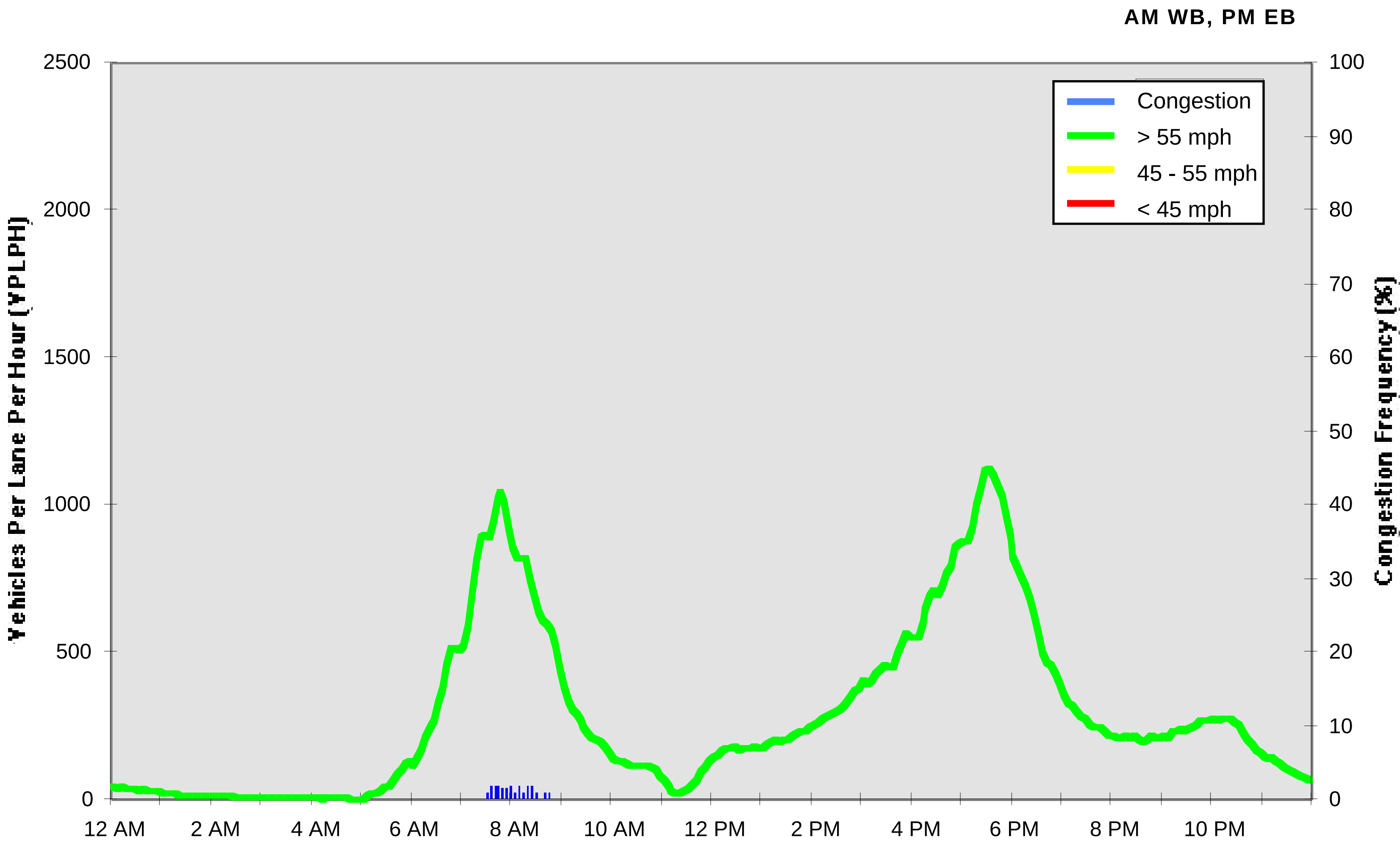


Figure 34. Estimated Weekday Volume, Speed, and Reliability Conditions (1997): I-90, West Highrise, General Purpose Reversible Lanes

Section 5. System Performance: Performance Variations

Each performance measure described in sections 3 and 4 varies with conditions such as time of day, lane type, direction of travel, location, or year. One of the benefits of the analytical tools used for this report is their ability to help better describe the nature of those linkages. This section looks in more detail at the link between freeway performance and other conditions. Examples of freeway performance changes as a function of year, day of the week (weekday vs. weekend), and facility type (general purpose vs. HOV) are described for selected locations.

Where Freeway Performance Comparisons Were Measured

The comparisons in this section were performed on a core set of four central freeway locations in the Seattle area "rectangle" bounded by I-5, SR 520, I-405, and I-90, with each freeway represented by a site. Those locations are downtown Seattle on I-5 at University Street, downtown Bellevue on I-405 at NE 4th Street, SR 520 just east of the bridge, and I-90 at Shorewood Drive (east of Island Crest Way) on Mercer Island. (The I-405 and I-90 locations were modified from those used in section 4 to illustrate specific GP vs. HOV comparisons.) Selected additional freeway locations were also analyzed to point out notable traffic performance characteristics at those sites.

Results: Daily Averages

Table 2 summarizes the average total daily weekday and weekend volumes for selected sites in 1995 and 1997. The comparison suggests the upward trend in freeway usage, as well as the significance of weekend traffic volumes.

1995 vs. 1997

A comparison of 1995 and 1997 weekday and weekend daily volumes at selected locations indicates that in nearly every case, volumes increased during the two-year period. At the east-west sites (on SR 520 and I-90), general purpose volume changes varied from -2.3 percent to +7.6 percent, while HOV volume changes varied from +7.9 percent to +27.4 percent. On north-south sites (I-5 and I-405), GP volume changes varied from +6.3 percent to +14.1 percent, while on HOV lanes, volume changes varied from +8.9 percent to +58.6 percent.

Weekday vs. Weekend

A check of weekday and weekend daily volumes at selected locations indicates that weekend volumes are significant and in some cases exceed their weekday counterparts at some times of the day. Measuring 1997 average weekend volumes as a percentage of 1997 average weekday volumes, the average general purpose weekend volume is 74 percent of the corresponding weekday volume, while the average HOV weekend volume is 107 percent of the corresponding weekday volume. Figure 35 shows the weekend volume as a percentage of weekday volume at selected sites.

Table 2. Average Vehicle Volumes at Selected Freeway Locations (1995 and 1997, Weekday and Weekend)

East-West Facilities	1995				1997				1997 vs. 1995 (% change)			
	EB GP	WB GP	EB HOV	WB HOV	EB GP	WB GP	EB HOV	WB HOV	EB GP	WB GP	EB HOV	WB HOV
SR 520 @ 76th/84th Ave NE												
Weekday	53,800	55,200		2,500	54,000	56,700		2,700	0%	3%		8%
Weekend	38,500	38,400		1,900	41,000	41,300		2,500	6%	8%		32%
Weekend as % of weekday	71.6%	69.6%		76.0%	75.9%	72.8%		92.6%				
I-90 @ Shorewood Dr.												
Weekday	66,000	64,600	5,200	2,100	68,100	69,200	6,100	2,500	3%	7%	17%	19%
Weekend	45,000	45,000	6,500		43,900	47,600	7,800		-2%	6%	20%	
Weekend as % of weekday	68%	70%	125%		64%	69%	128%					

North-South Facilities	1995				1997				1997 vs. 1995 (% change)			
	NB GP	SB GP	NB HOV	SB HOV	NB GP	SB GP	NB HOV	SB HOV	NB GP	SB GP	NB HOV	SB HOV
I-5 @ University St.												
Weekday	91,500	109,400		6,200	104,400	116,200		7,100	14%	6%		15%
Weekend	73,900	92,200		8,200	82,000	98,700		8,900	11%	7%		9%
Weekend as % of weekday	81%	84%		132%	79%	85%		125%				
I-405 @ NE 4th St												
Weekday	61,400	61,300	6,800	4,000	66,600	67,800	8,500	6,300	8%	11%	25%	58%
Weekend	42,000	45,300	7,800	3,900	47,600	51,400	8,900	5,400	13%	13%	14%	38%
Weekend as % of weekday	68%	74%	115%	98%	71%	76%	105%	86%				

GP = General Purpose, HOV = High Occupancy Vehicle

indicates no HOV lane at that location in that direction

Site	Description
SR 520 @ 76th/84th Ave NE	East end of the bridge
I-90 @ Shorewood Drive	Mercer Island, east of Island Crest Way (reversible lanes not included)
I-5 @ University Street	Downtown Seattle (reversible lanes not included)
I-405 @ NE 4th Street	Downtown Bellevue

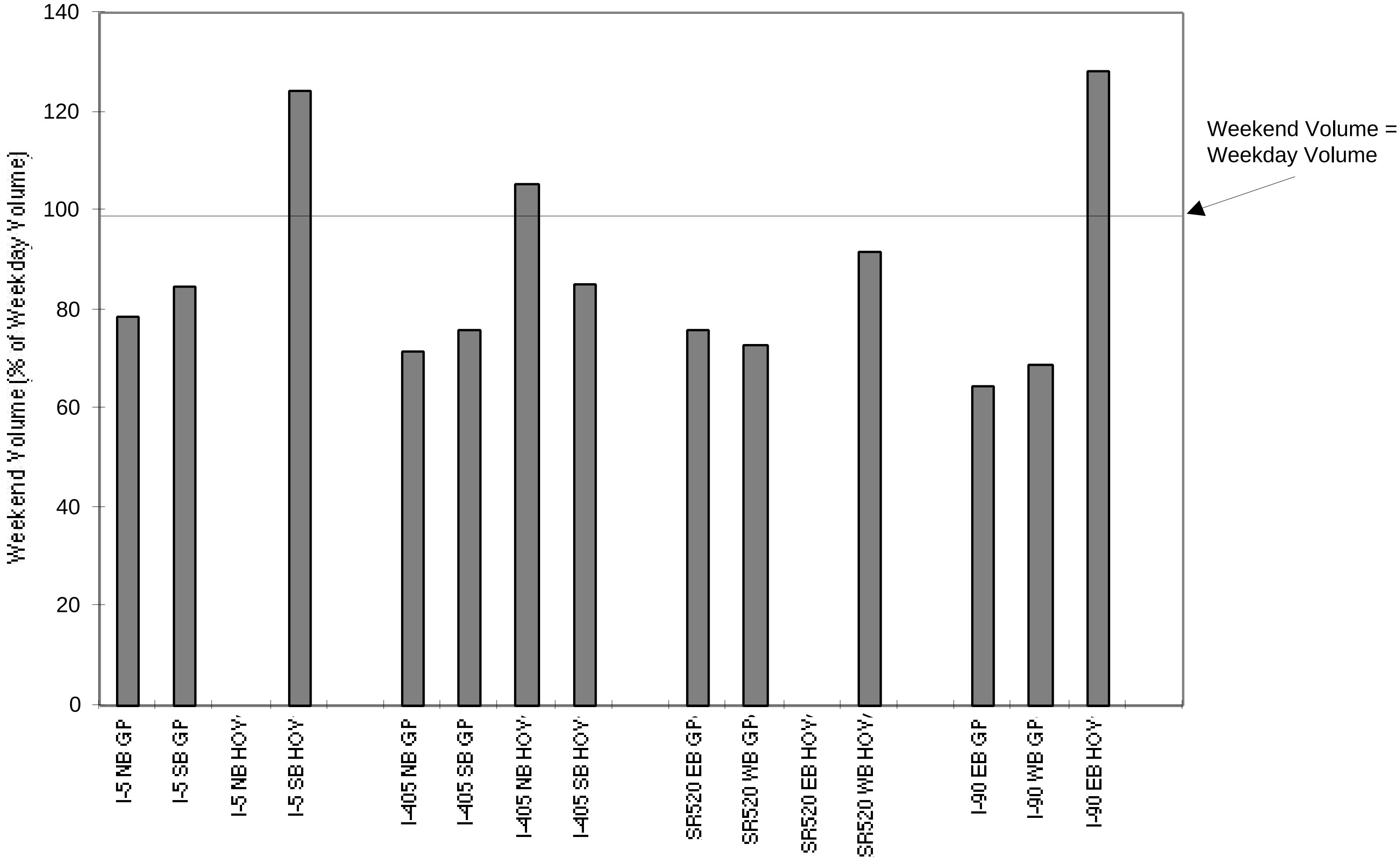


Figure 35. Average Weekend Daily Volume as a Percentage of Weekday Volume (1997)

Results: 24-Hour Volume Profiles

The following discussion analyzes weekday and weekend volume comparisons for selected sites in 1995 and 1997. To reduce the size of this report, only selected locations are included.

1995 vs. 1997

Figures 36 and 37 show 1995 vs. 1997 weekday volume profiles for selected sites. Overall, both GP and HOV volumes increased from 1995 to 1997, sometimes to a significant degree. Furthermore, those increases were often outside of the peak periods.

Downtown Seattle (I-5 at University Street). Volumes went up for both directions of travel and for both GP and HOV lanes. The increases were not limited to peak periods, but were noticeable for nearly the entire 24-hour period. Northbound GP volumes went up significantly during the peak periods.

Downtown Bellevue (I-405 at NE 4th Street). Volumes went up for both directions of travel and for both GP and HOV lanes. The increases were not limited to peak periods, but were noticeable for nearly the entire 24-hour period. HOV volumes went up significantly during the peak periods and midday hours.

SR 520 at 76th Ave. NE. As with downtown Seattle, volumes stayed nearly the same for both directions of travel and for both GP and HOV lanes, although there were slight HOV increases, as well as some off-peak increases in the GP lanes. This suggests that vehicle volumes are reaching the maximum that the facility can support, with the off-peak increases indicating a "peak-spreading" phenomenon. Figure 38 shows the change in travel reliability (i.e., the difference between histograms) from 1995 to 1997 on the westbound approach to the bridge (see Figure 27 for the 1997 reliability graph). The figure shows that while total volumes may not have changed significantly, congestion frequency has increased significantly in the afternoon peak (the "reverse" commute). Furthermore, that increase is occurring not just during the traditional evening "commute" period, but earlier in the afternoon and later in the evening, again illustrating the effects of peak-spreading. (Note that some improvement in reliability on westbound SR 520 has occurred in the morning peak.)

I-90 at Shorewood Drive (east of Island Crest Way). Volumes went up for both directions of travel and for both GP and HOV lanes. The increases were not limited to peak periods but were noticeable for most times of the day.

Weekday vs. Weekend

Figures 39 and 40 show 1997 weekday vs. weekend volume profiles for selected sites. While weekend volumes are usually not as high as weekday volumes, particularly during peak periods, they often approach weekday volume levels during the midday and afternoon hours. On occasion, weekend volumes can exceed weekday volumes, particularly in the HOV lane.

Downtown Seattle (I-5 at University Street). In the general purpose lanes, weekend volumes are significantly lower than corresponding weekday volumes in the morning, reflecting the absence of AM commute traffic. By midday, however, volumes have grown to levels approaching, though not equaling, weekday traffic. In the HOV lane, weekend volumes actually exceed weekday volumes during much of the day, with the exception of the afternoon peak period when weekday commute trips normally take place.

Downtown Bellevue (I-405 at NE 4th Street). In the general purpose lanes, weekend volumes are significantly lower than corresponding weekday volumes during both peak periods, reflecting the absence of commute traffic. Midday volumes are at levels approaching, though not equaling, weekday traffic. In the HOV lane, weekend volumes actually exceed weekday volumes at midday but are lower during peak periods when weekday commute trips normally take place.

SR 520 at 76th Ave. NE. As with the I-5 site, the general purpose weekend volumes are significantly lower than corresponding weekday volumes in the morning, reflecting the absence of AM commute traffic. By midday, however, volumes are at levels approaching weekday traffic. In the HOV lane, weekend volumes exceed weekday volumes at midday but are lower during the peak periods when weekday commute trips normally take place.

I-90 at Shorewood Drive (east of Island Crest Way). In the general purpose lanes, weekend volumes are significantly lower than corresponding weekday volumes during both peak periods, reflecting the absence of commute traffic. Midday volumes are at levels approaching weekday traffic. In the HOV lanes, weekend volumes actually exceed weekday volumes at midday but are lower during peak periods when weekday commute trips normally take place. Note, however, that during the weekends the center (HOV) lanes are open eastbound only throughout the day, unlike the weekdays when HOV lanes operate westbound in the morning and eastbound in the afternoon and evening.

General Purpose vs. HOV

Figures 41 and 42 show 1997 GP vs. HOV vehicle volume profiles for selected sites. On a per-lane basis, HOV lanes can carry a significant number of vehicles in comparison to their GP counterparts. (This becomes more significant when the person-carrying capacity of the vehicles is measured; see section 6 for additional discussions of HOV lane usage.)

Downtown Seattle (I-5 at University Street). SB HOV volumes are approximately 50 percent of SB GP volumes (on a per-lane basis) during the afternoon peak period.

Downtown Bellevue (I-405 at NE 4th Street). HOV volumes are significant in comparison to GP volumes, particularly during peak periods. HOV volumes can approach 40 to 50 percent of corresponding GP volumes (on a per-lane basis) during the afternoon peak period.

SR 520 at 76th Ave. NE. HOV volumes are relatively low at this location, reflecting in part the road geometry (the HOV lane is a converted shoulder) and the strict occupancy requirement (3+ occupants per vehicle, in comparison to a 2-person minimum on all other HOV lanes in the region).

I-90 at Shorewood Drive (east of Island Crest Way). HOV volumes have prominent peak values during peak periods. Peak period HOV volumes can approach 25 to 35 percent of corresponding GP volumes (on a per-lane basis).

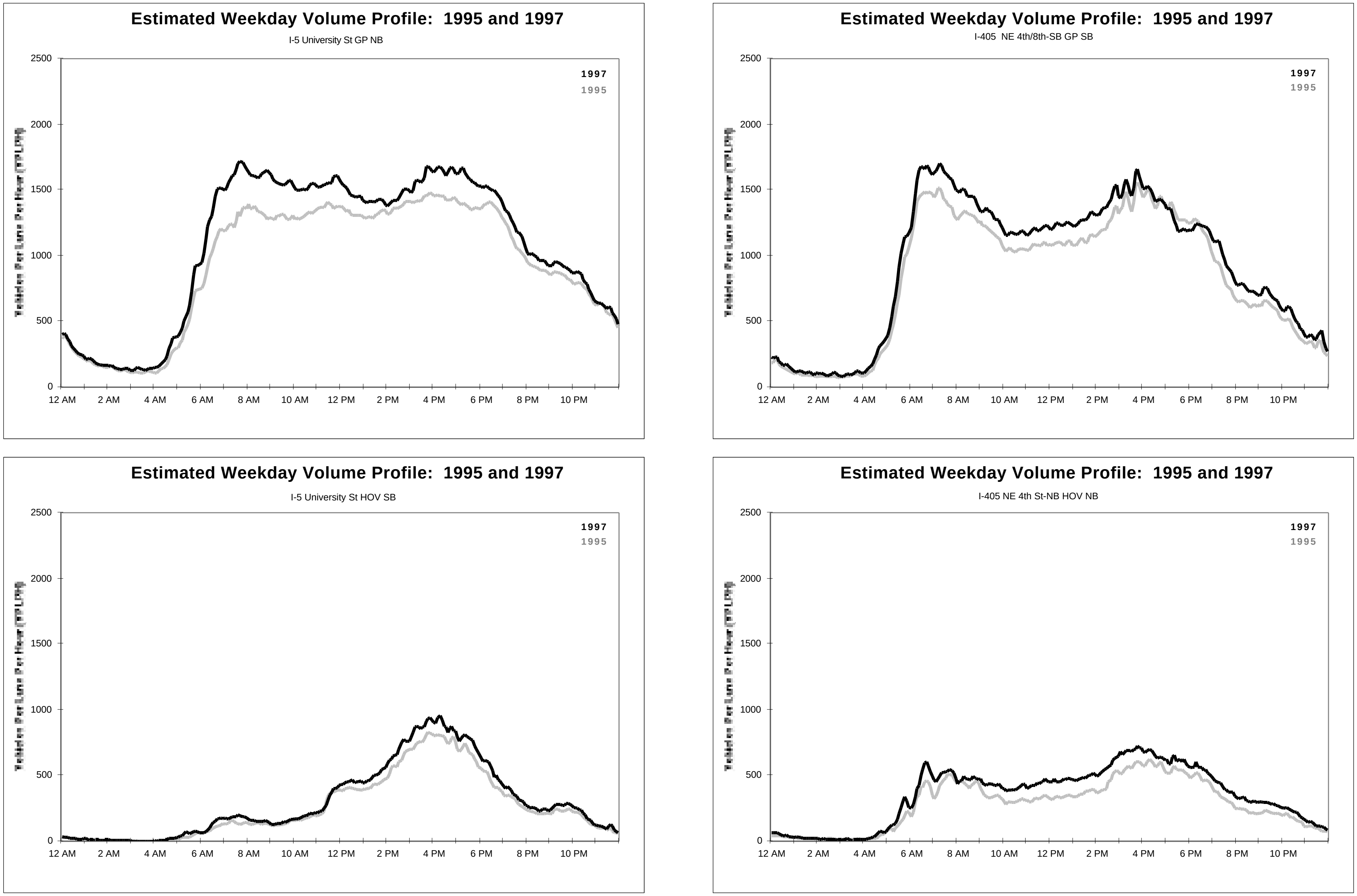


Figure 36. 1995 vs. 1997 Weekday Volume Profiles for Selected Sites

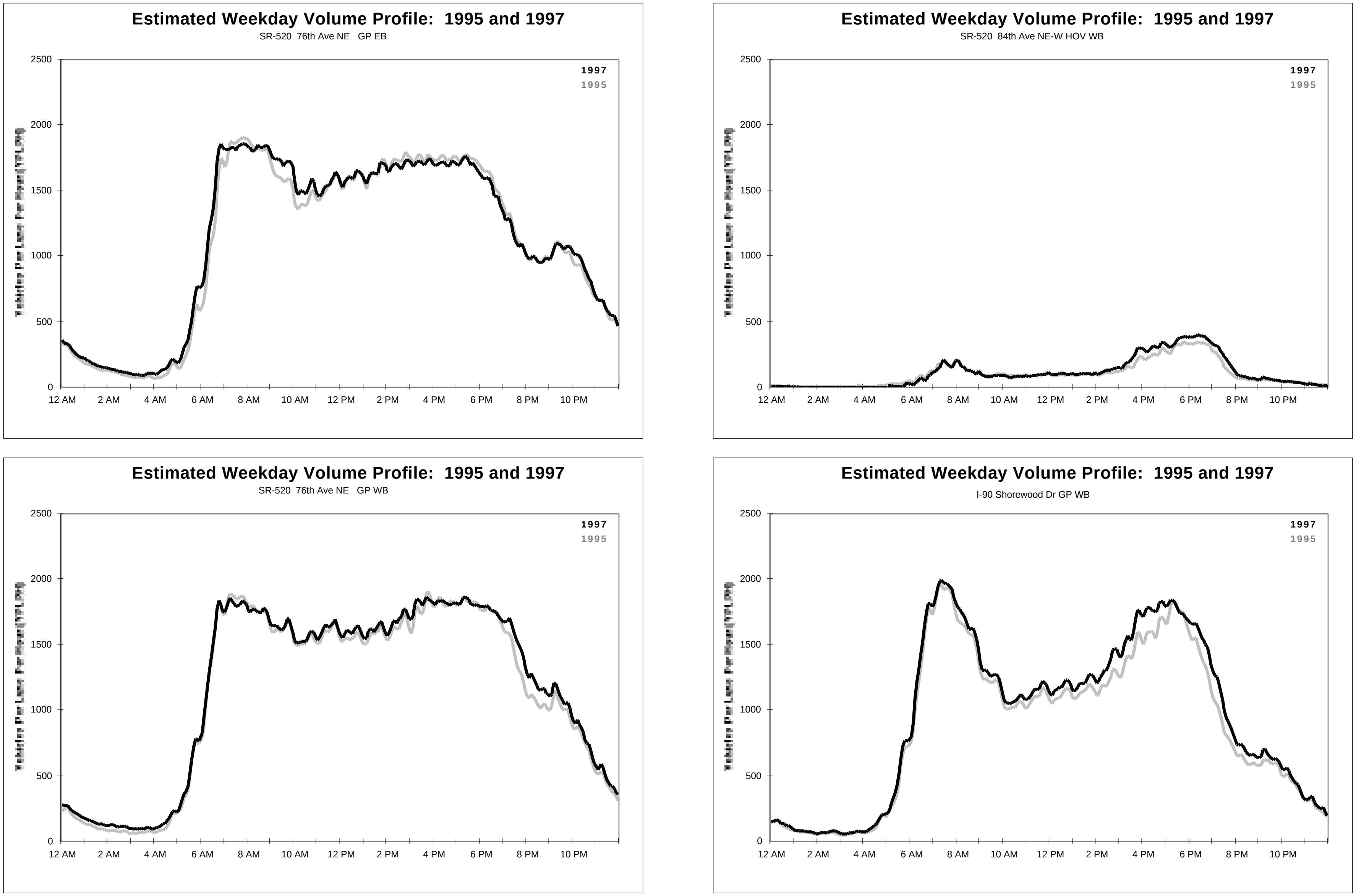


Figure 37. 1995 vs. 1997 Weekday Volume Profiles for Selected Sites

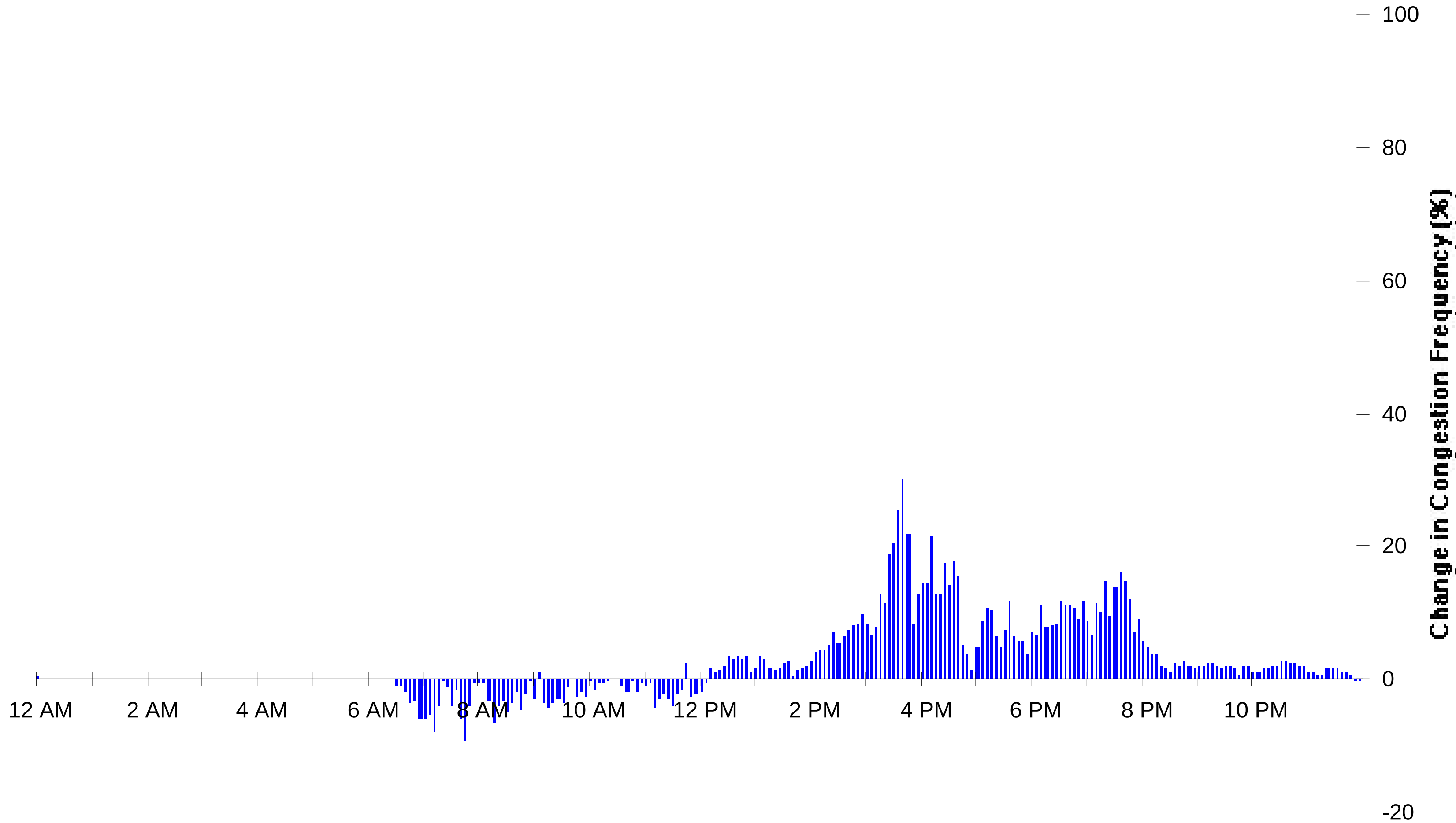


Figure 38. Estimated Change in Travel Reliability Conditions (1997 vs. 1995), Westbound SR 520, 76th Ave NE, General Purpose Lanes

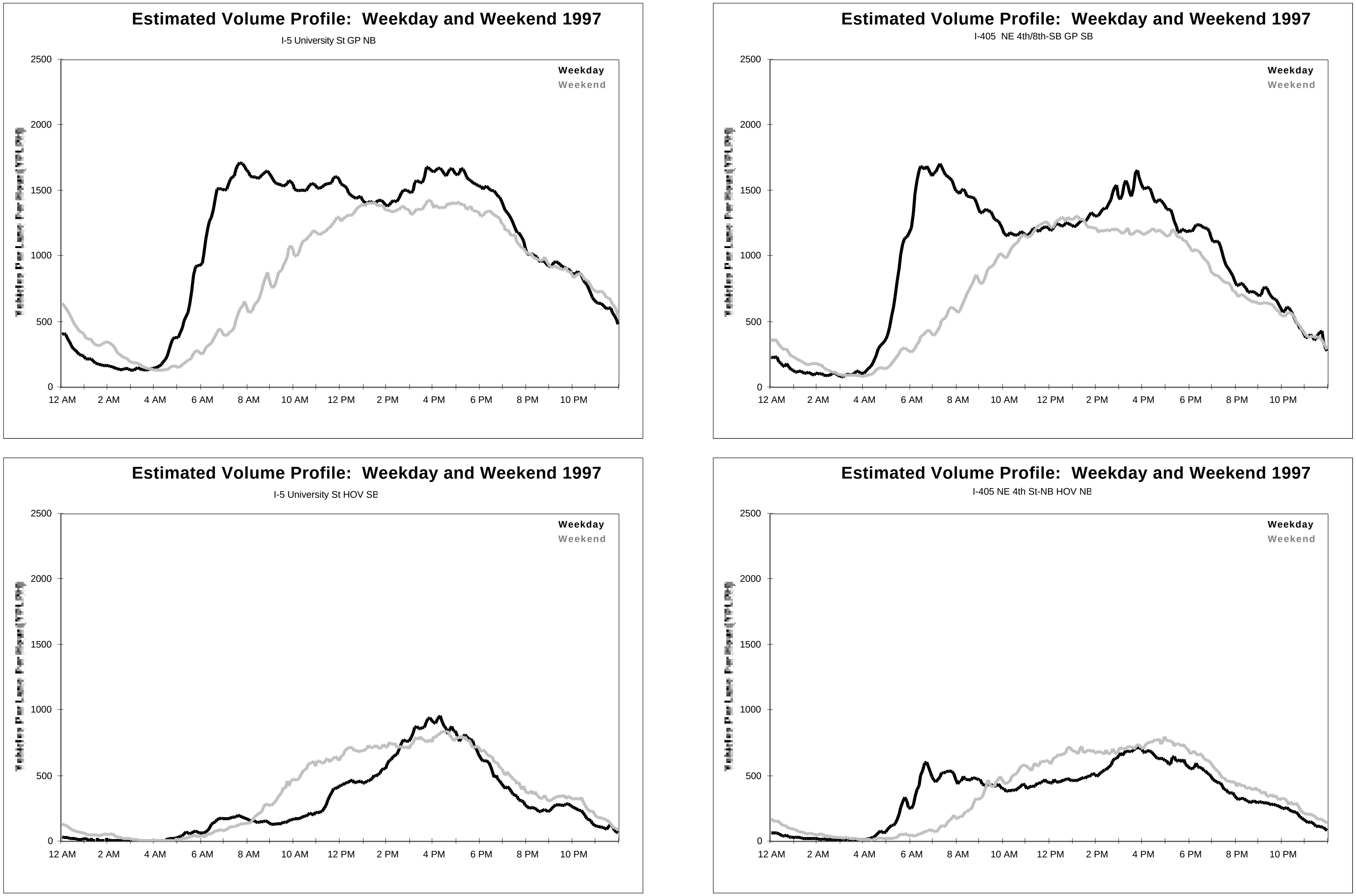


Figure 39. 1997 Weekday vs. Weekend Estimated Volume Profiles for Selected Sites

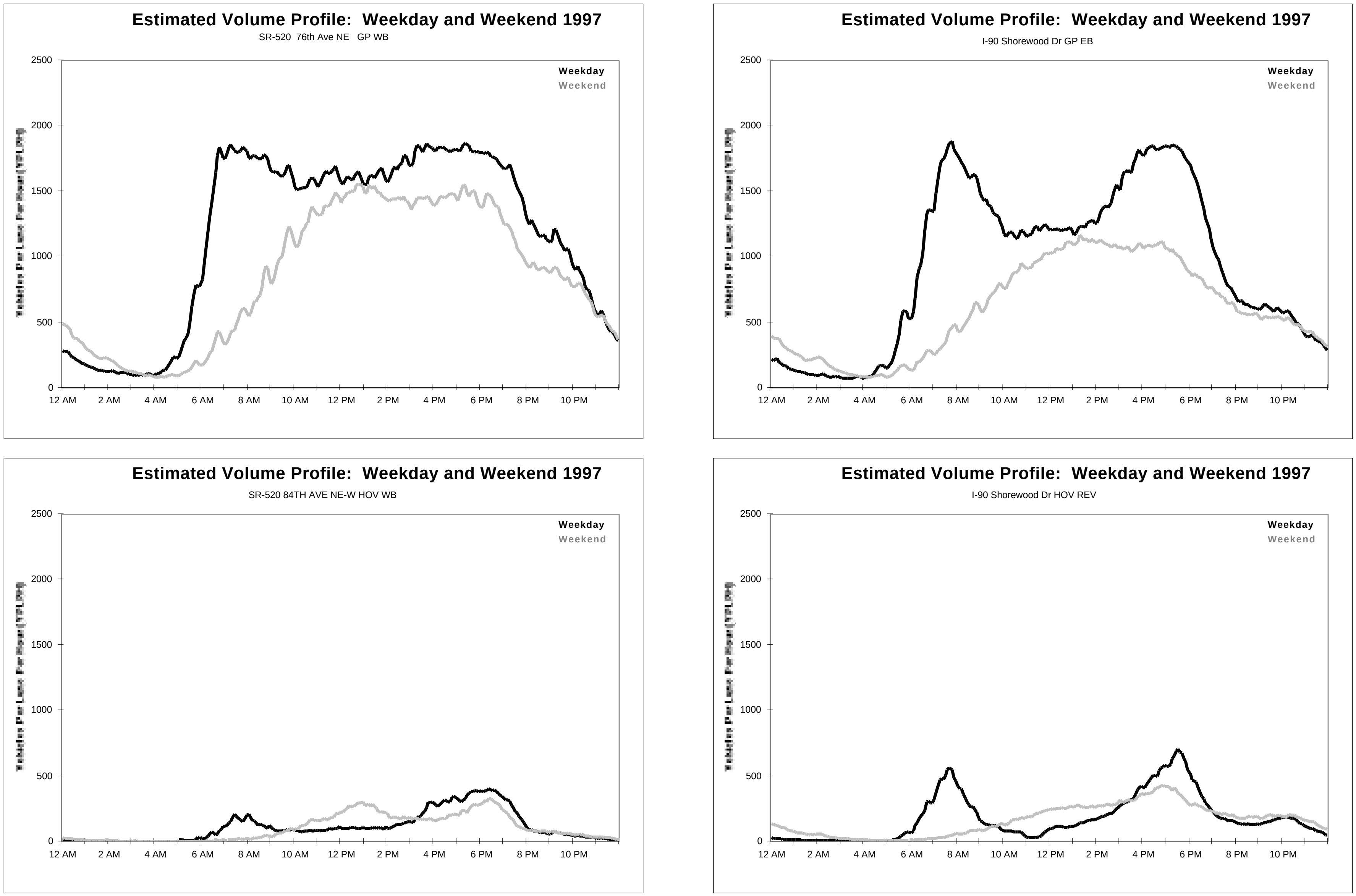
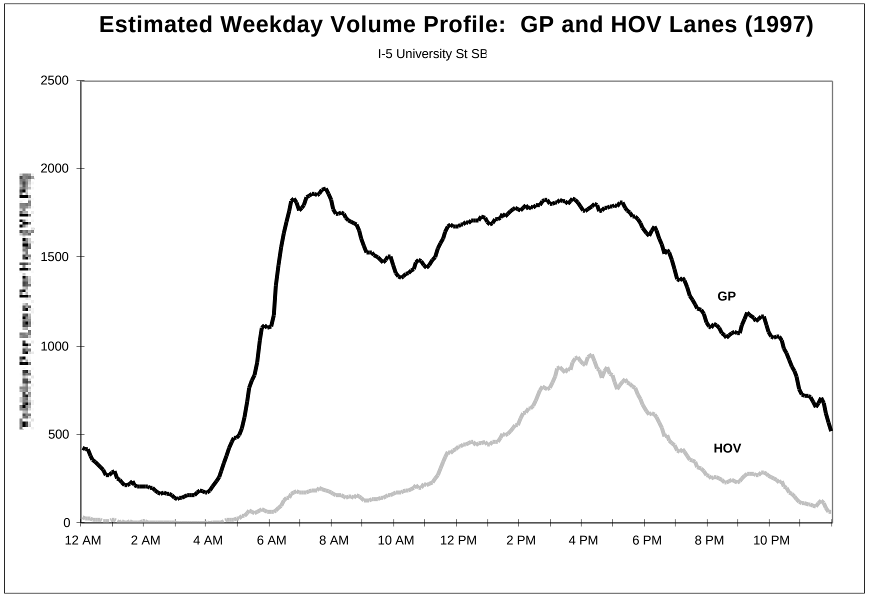


Figure 40. 1997 Weekday vs. Weekend Estimated Volume Profiles for Selected Sites



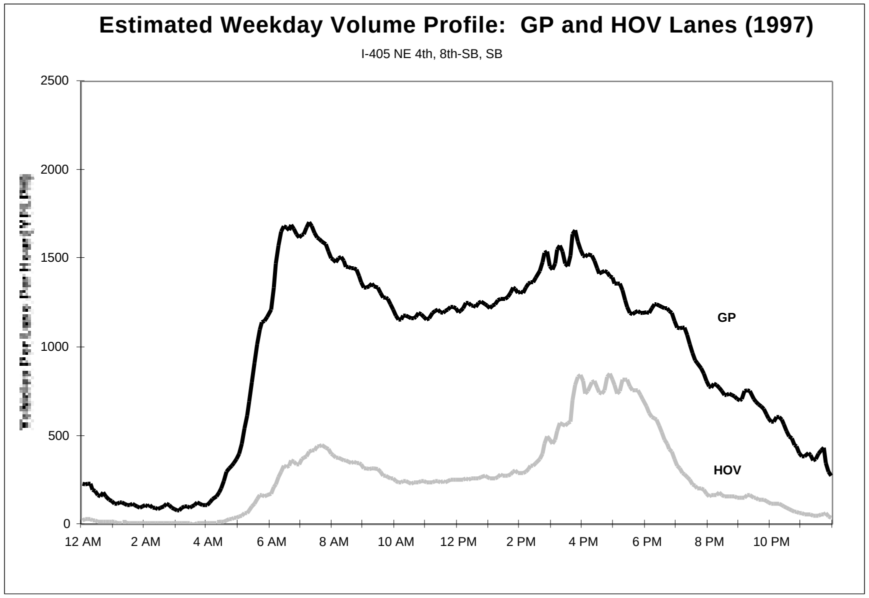
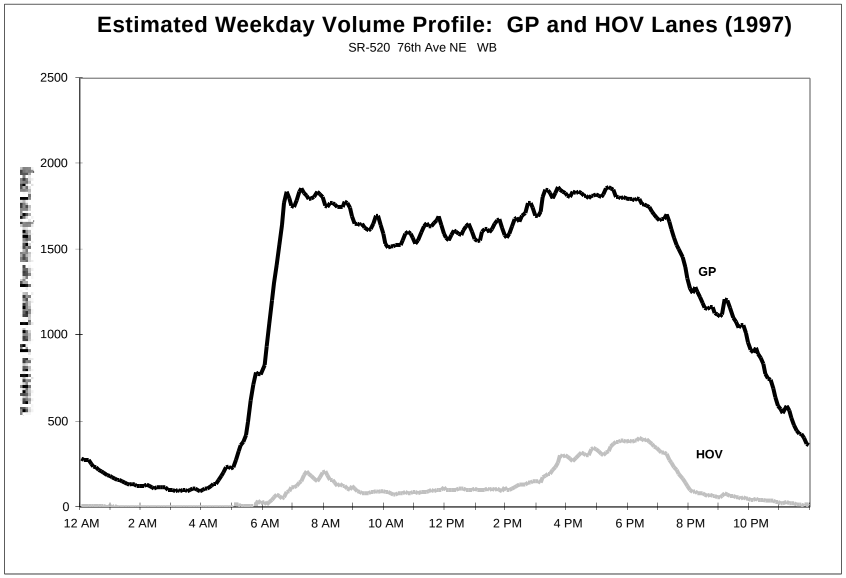
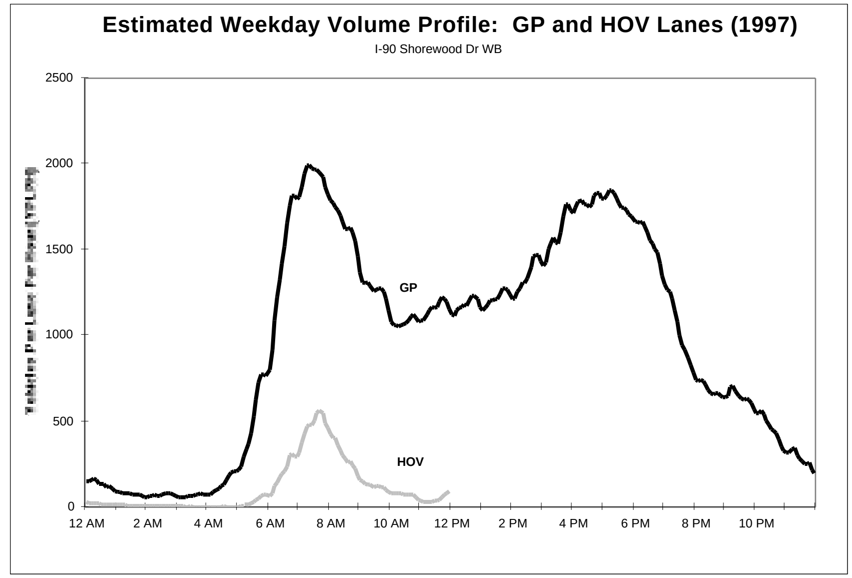


Figure 41. 1997 General Purpose vs. HOV Lane Estimated Volume Profiles for Selected Sites





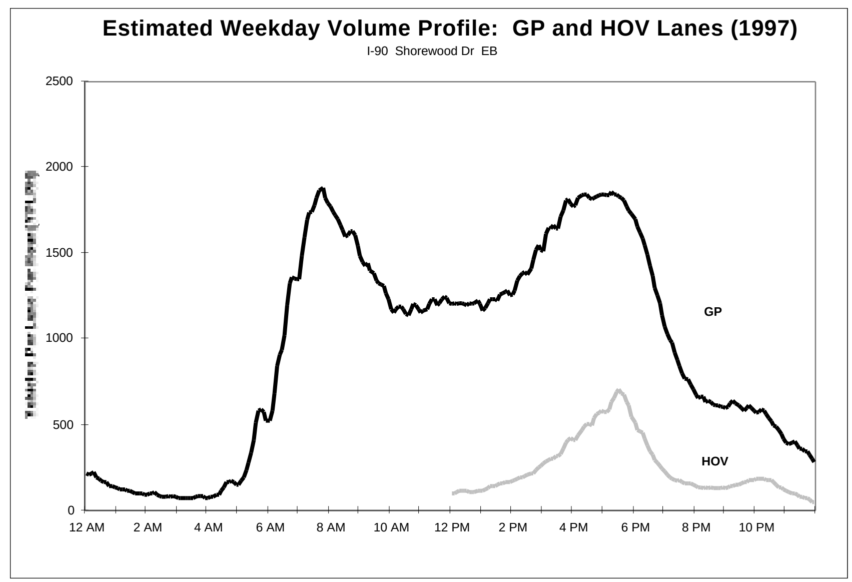


Figure 42. 1997 General Purpose vs. HOV Lane Estimated Volume Profiles for Selected Sites

Section 6. The HOV Lane Network

An important component of the WSDOT FLOW system is the HOV lane network. The following discussion summarizes the objectives and operation of this system and discusses its effect on traveler mobility.

The HOV Lane Network

HOV freeway lanes are designated for use by vehicles that satisfy a requirement for a minimum number of passengers, including the driver. These lanes, also known as carpool lanes or diamond lanes, are not restricted to formal multi-passenger vehicles such as buses and organized vanpools but are open to any vehicle that meets occupancy requirements. The occupancy requirement for all HOV lanes on the Seattle metropolitan freeway system is at least 2 passengers (including the driver), except for the SR 520 westbound lanes, which have a 3+ passenger requirement because of safety and other considerations. The only exceptions to the occupancy rule are motorcyclists, who can travel on any HOV lane, and SOVs traveling on the I-90 reversible lanes between Mercer Island and Seattle.

HOV lanes are designed to improve the people-carrying capacity of the system by encouraging informal and formal carpooling and the use of public transportation. This philosophy is formalized in Washington State's transportation policy, which notes that the HOV lane network plays an important role in increasing the movement of people, as opposed to simply the movement of vehicles. The HOV lane network is intended to enhance the people-moving capability of the freeway system by providing HOV lane users with a time benefit and a travel reliability advantage in comparison to travelers on general purpose lanes. This is particularly important for transit, for which travel time savings and reliability both translate directly into cost savings and increased ridership. For transit agencies, HOV lanes help enhance the level of transit service and reduce transit service cost by reducing transit route travel times and improving schedule reliability.

Washington state has established a policy standard regarding the desired speed and reliability of an HOV lane. This standard calls for an average speed of 45 mph or better, 90 percent of the time during the peak hour. (Note: As of February 1999, the specifics of this standard are being reviewed by the PSRC regional HOV policy committee for Puget Sound area HOV lanes.)

How Freeway Corridor Performance Was Measured

A full evaluation of HOV lane effectiveness using these measures is now under way in conjunction with the WSDOT HOV Lane Evaluation Project, a separate but related project to study and quantify HOV lane use in the Puget Sound area. The HOV Lane Evaluation project will supply complete results on HOV lane performance. The report produced by that project will reflect enhancements to the analytical techniques that produced the freeway performance graphics presented earlier in this report. Because these enhancements are still under development at this time, this report will provide only preliminary test results.

Two measures are used to analyze HOV lane performance:

Number of Vehicles (GP and HOV)

The number of vehicles traveling per lane per hour (vplph), as a function of time, on GP and HOV lanes are measured at selected locations along the corridor.

Number of Persons (GP and HOV)

The number of persons traveling per lane per hour, during the peak periods, on GP and HOV lanes are measured at selected locations along the corridor.

A third measure, corridor travel time performance and reliability, will be discussed in later versions of this report. (See section 5 for an example of this approach.) This statistic is not currently available for HOV lanes, as the software modifications and procedures needed to perform this analysis are still under development.

The purpose of these three measures is to 1) determine whether and to what extent an HOV lane is being used; 2) determine whether the HOV lane is enhancing person-carrying capacity of the system; 3) determine whether a measurable travel time and trip reliability benefit accrues from the use of the HOV lane.

Results: HOV Use at Selected Locations

Number of Vehicles

Like general purpose traffic volumes, HOV lane use varies by time of day and location. In general, the more congestion an HOV lane can bypass, the greater incentive there is to use the HOV lane, and therefore the more people will use it. Similarly, the better the transit service, the higher the number of people using transit in the HOV lane, which translates to higher person volumes in the HOV lane. As a result, HOV vehicle volumes are at their peak during the traditional peak commute periods. However, HOV vehicle volumes on almost all HOV lanes remain reasonably strong throughout the day. Most HOV lanes average 400 to 1,500 vehicles per hour from 6:30 AM to 7:30 PM, with the highest use occurring near major employment centers during the peaks of the commute periods, and the lowest use occurring at the endpoints of HOV facilities during the beginning of the morning commute and the end of the evening commute.

Number of Persons

Figures 43 through 49 present summary information on peak period HOV use at selected locations along each corridor analyzed in the central Puget Sound region. The top graphs compare overall HOV and GP lane person throughput, as well as overall HOV and GP lane vehicle throughput. As would be expected, both person and vehicle throughput are higher for the combined GP lanes than for the HOV lanes, but at selected locations on I-5 and I-405, HOV person throughput is an extremely high percentage of total throughput.

The lower graphs compare person and vehicle throughput per lane. The percentages in the HOV columns indicate the percentage of people or vehicles carried in the HOV lane in relation to those in a single GP lane. AVO_{HOV} and AVO_{GP} are the average number of people per vehicle in an HOV or GP lane, respectively.

These graphs show that, in most cases, the HOV lane carries more people than any individual GP lane next to it. As an example, the HOV lane on I-5 near Northgate (Figure 43) carries over twice as many people during the peak period than the average GP lane next to it. In fact, among the selected locations, only the I-90 and SR 520 HOV facilities carry fewer people than the adjacent GP lanes during the peak periods. (Note that the peak <u>period</u> differs from the peak <u>hour</u>. The SR 520 HOV lane does carry more people than the average adjacent general purpose lane during the peak hour of the commute, but not during the peak period.) HOV use is more limited on I-90 because of the reduced extent of congestion on this facility in comparison to the other freeways studied. On SR 520, HOV use is constrained by the three-person occupancy requirement, which makes it harder for travelers to form and maintain carpools.

Example: HOV Use on I-405

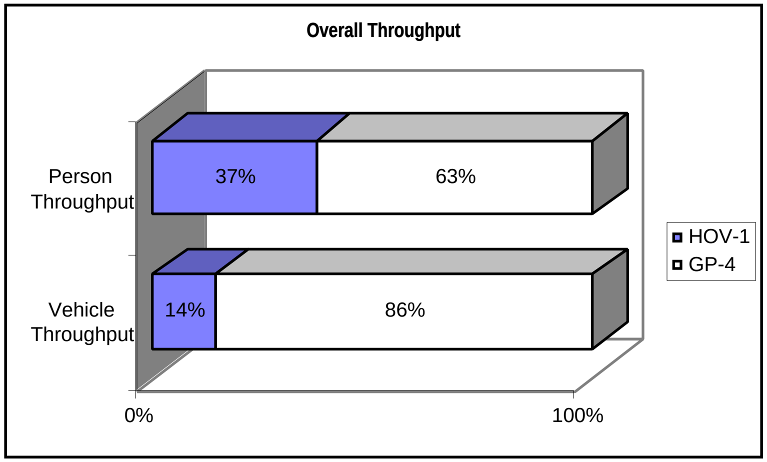
To examine the variation in HOV use along a particular facility, figures 50 through 52 show average weekday HOV and general purpose lane use (presented as vehicle volume per lane per hour) as a function of time of day at selected locations of I-405. Because HOV lanes on I-405 north of I-90 switched from an outside (right) configuration to an inside (left lane) configuration in September 1998, with a potentially significant impact on HOV lane operations, this analysis presents data for November 1998. These figures show that traffic volumes in the HOV lanes can approach 1500 vehicles per hour, a very high rate even for GP lanes. In fact, at some locations and times of day, HOV volumes actually match or even exceed GP volumes on a per-lane basis. For example, at selected locations on I-405 between SR 900 and downtown Bellevue, HOV vehicle volumes approach or exceed GP volumes in the morning peak (northbound) and the evening peak (southbound). Similarly, HOV vehicle volumes are high in the evening peak period for traffic heading northbound from downtown Bellevue. Times and locations of high HOV use typically coincide with high congestion in the GP lanes. In terms of person volumes, partial data on the I-405 corridor suggest that the HOV lane carries a significant share of all travelers using the corridor. A limited sample of sites on I-405 just south of I-90 and near Kirkland indicates that while the single HOV lane carries 14 to 28 percent of all vehicles on the corridor, that HOV lane actually carries 28 to 45 percent of all travelers. On a per-lane basis, the HOV lane carries more people than the average GP lane at all of these sites.

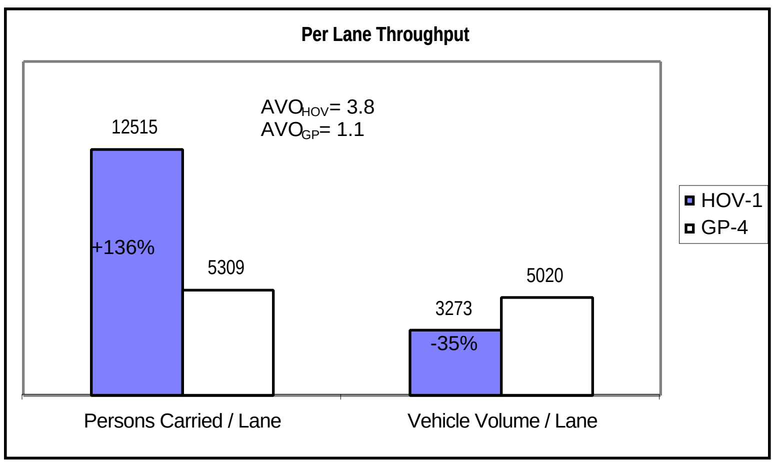
High HOV lane vehicle use, combined with a higher per-vehicle traveler occupancy on HOV lanes, results in higher person volumes on HOV lanes in comparison to general purpose lanes, on a per-lane basis. Furthermore, if the HOV lane also offers a performance and reliability benefit in the form of faster speeds and more reliable travel times relative to the adjacent GP lanes, the combined result is that more travelers are enjoying a faster and more reliable trip on the HOV lane network than on the general purpose lane network.

Other HOV Lane Considerations: Lane Placement

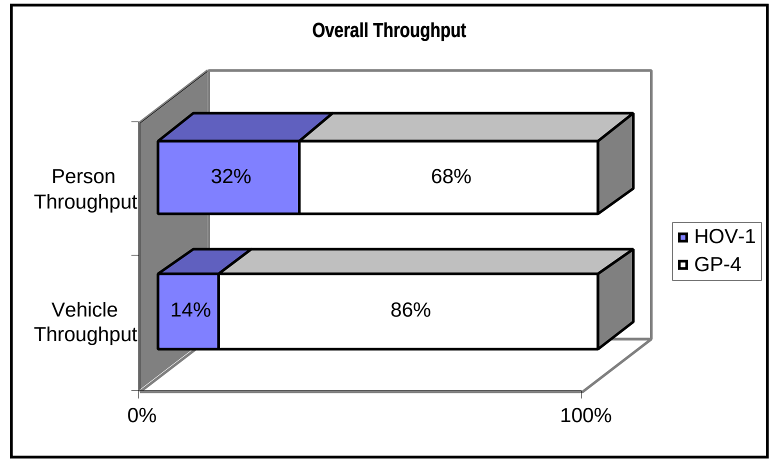
In the autumn of 1998, HOV lanes on I-405 north of I-90 were moved from the outside lane (far right) to the inside lane (far left). Before that time, HOV lane measurements near on- and off-ramps were complicated by the presence of potentially slower-moving vehicles (both HOV and SOV) entering and exiting the freeway. Because the HOV lane was on the right side, it was difficult to determine whether patterns of congestion in the HOV lane were the result of high HOV volumes and associated congestion, or the weaving patterns of entering and exiting traffic. An example of such an area is northbound I-405 near downtown Bellevue, where an on-ramp from SE 8th is immediately followed by off-ramps to NE 4th and NE 8th. Figure 53 compares the traffic patterns in the HOV lane in 1997, when the HOV lane was on the outside, with the traffic patterns at that location in November 1998, after the HOV lane was moved to the inside. The results indicate that significant performance improvements occurred in the HOV lane.

I-5 SB @ NE 137th St.
During AM Peak Period





I-5 NB @ NE 137th St.
During PM Peak Period



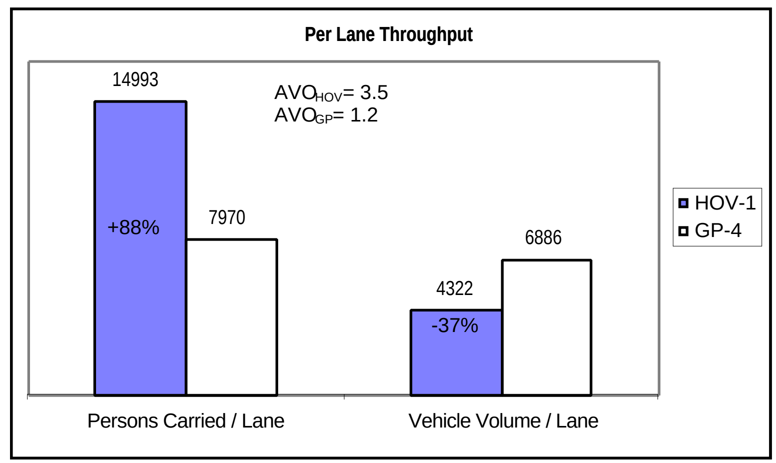
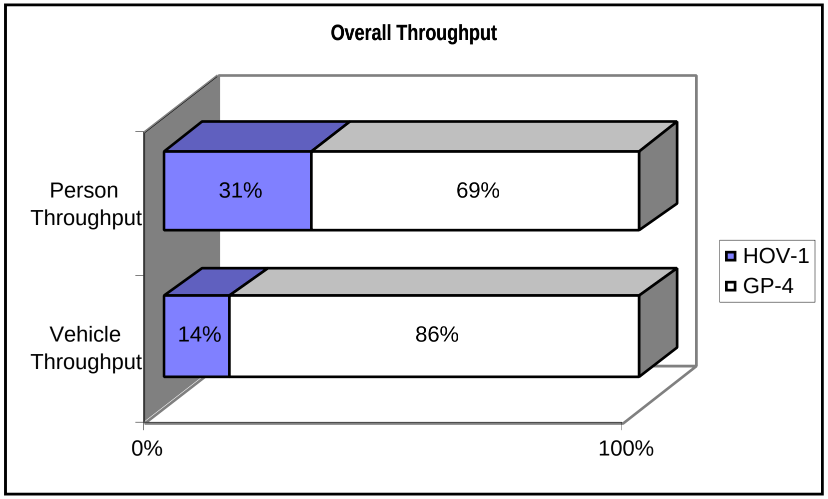
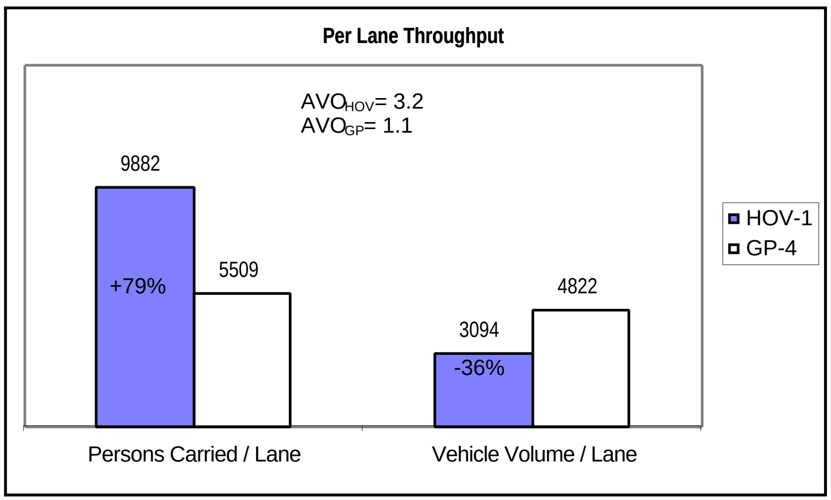


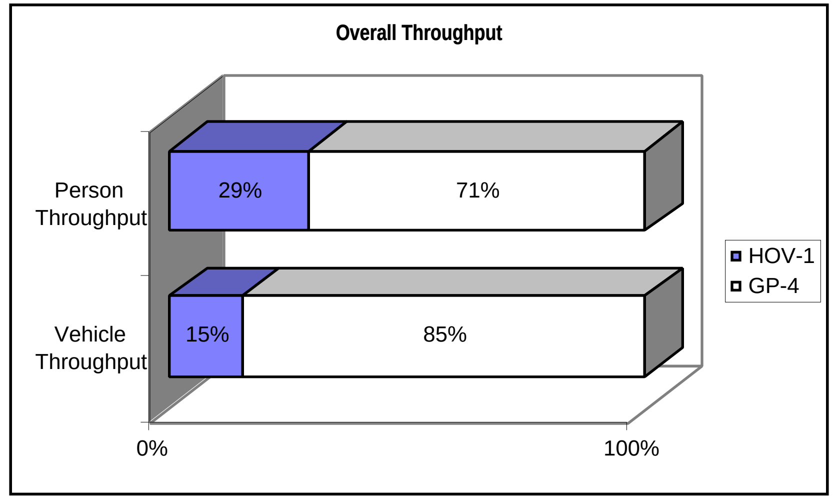
Figure 43. Peak Period Vehicle and Person Throughput Comparisons (I-5 @ NE 137th St.)

I-5 NB @ Albro Place
During AM Peak Perio





I-5 SB @ Albro Place
During PM Peak Period



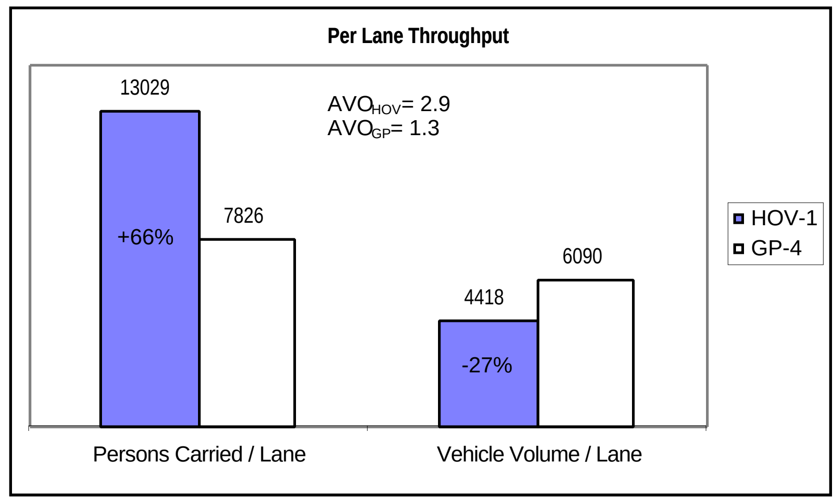


Figure 44. Peak Period Vehicle and Person Throughput Comparisons (I-5 @ NE Albro Place)

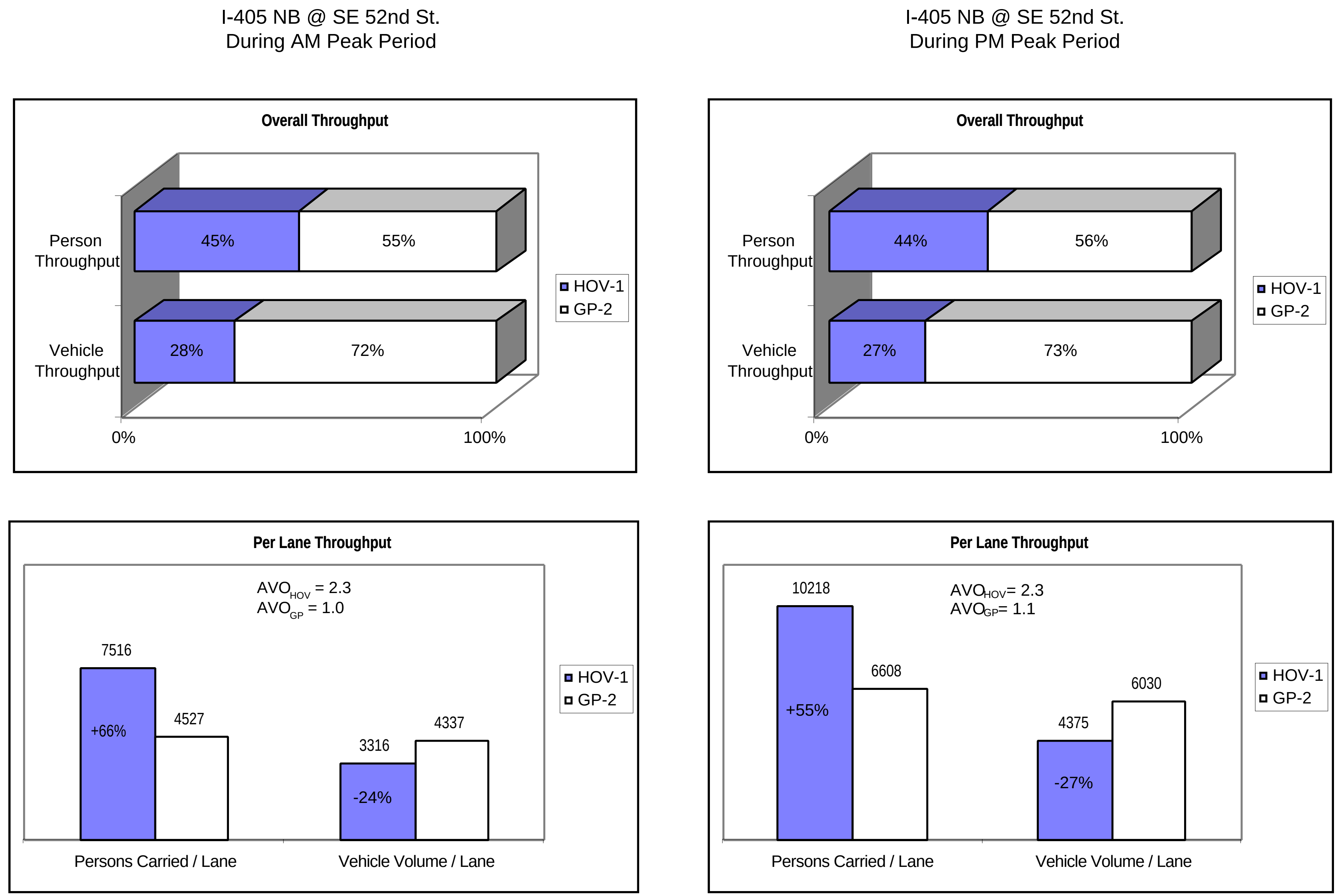


Figure 45. Peak Period Vehicle and Person Throughput Comparisons (I-405 Northbound @ SE 52nd St.)

I-405 SB @ SE 52nd St.
During AM Peak Period

I-405 SB @ SE 52nd St.
During PM Peak Period

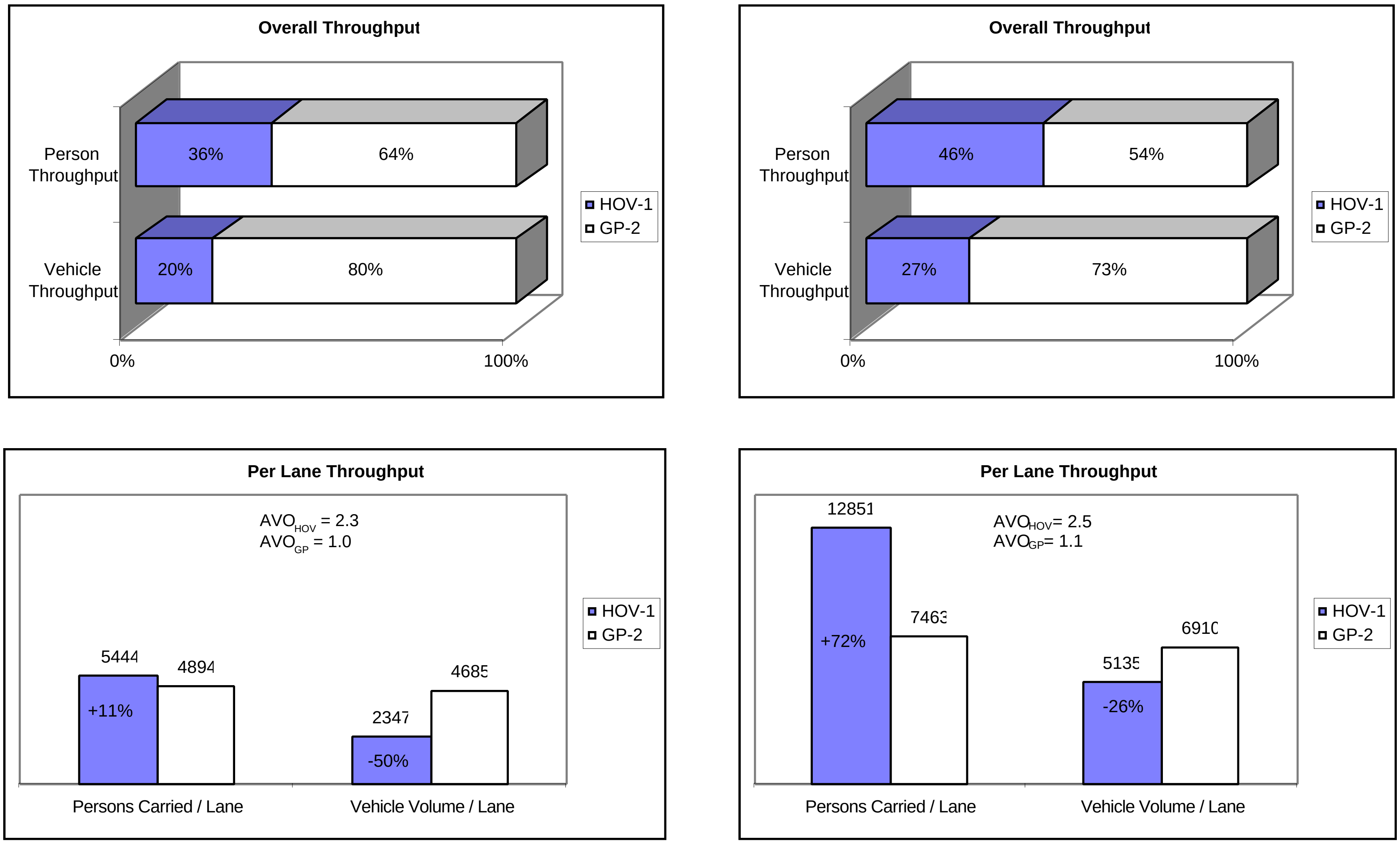


Figure 46. Peak Period Vehicle and Person Throughput Comparisons (I-405 Southbound @ SE 52nd St.)

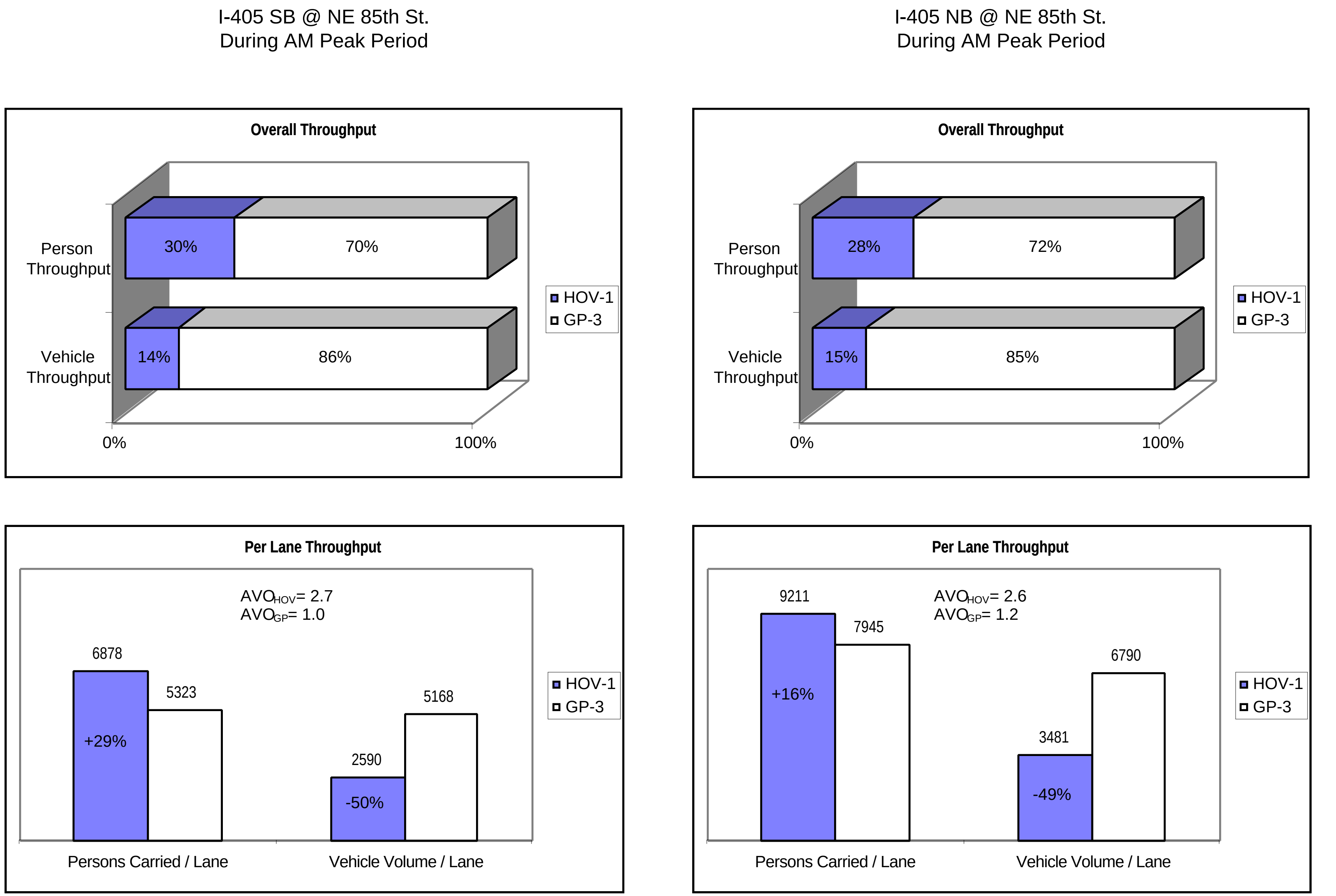
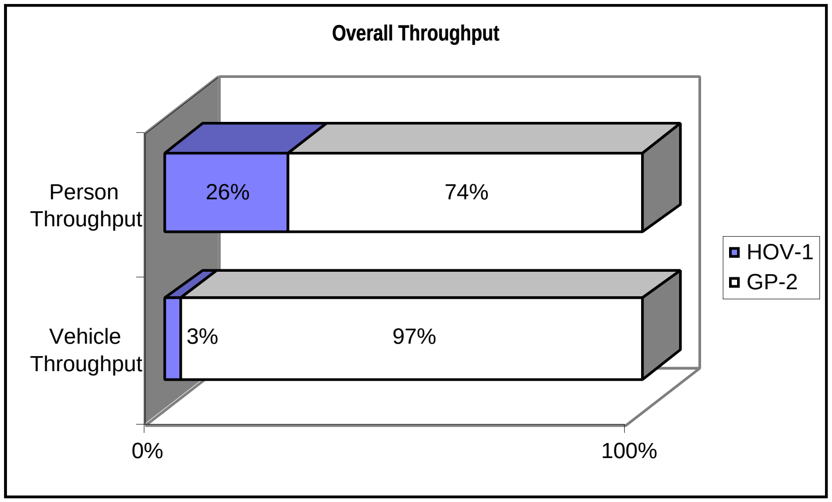
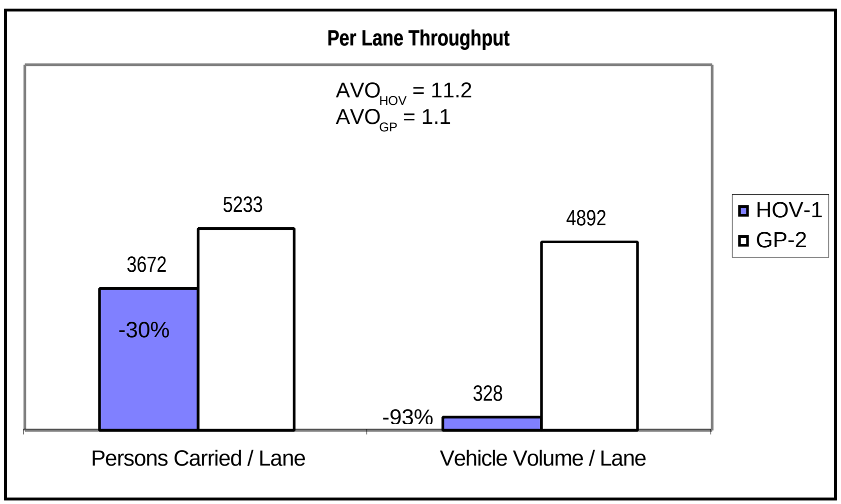


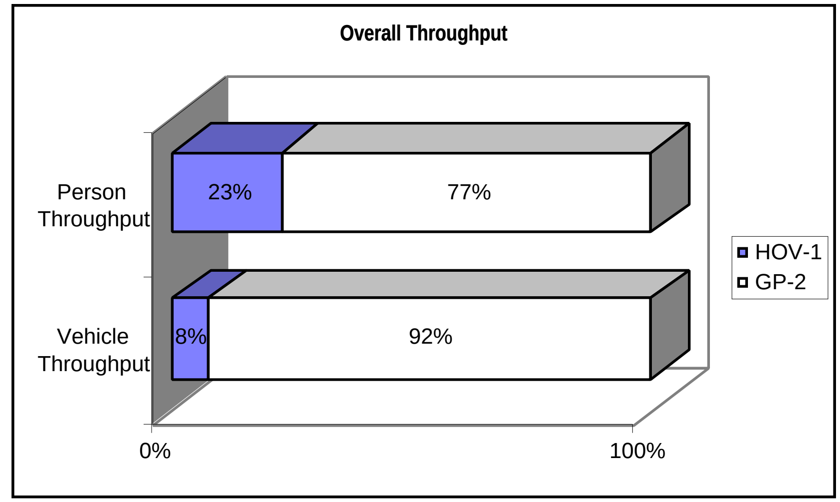
Figure 47. Peak Period Vehicle and Person Throughput Comparisons (I-405 @ NE 85th St.)

SR 520 WB @ 84th Ave. NE
During AM Peak Period





SR 520 WB @ 84th Ave. NE
During AM Peak Period



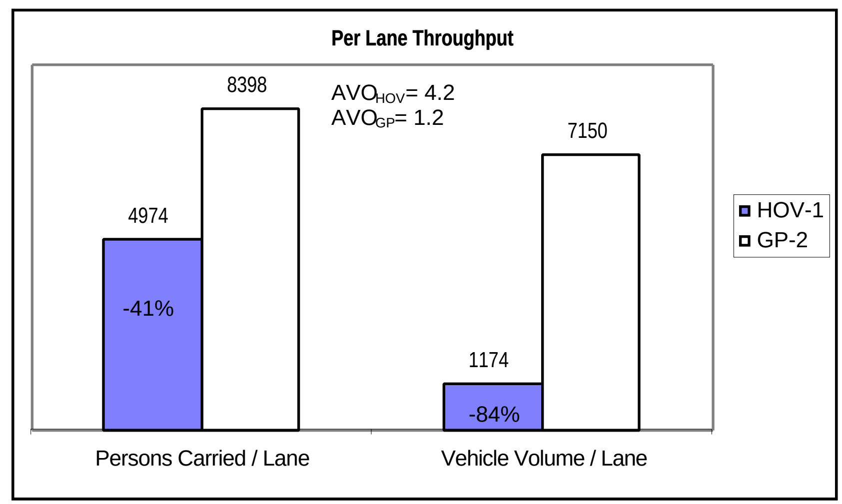


Figure 48. Peak Period Vehicle and Person Throughput Comparisons (SR 520 Westbound @ 84th Ave. NE)

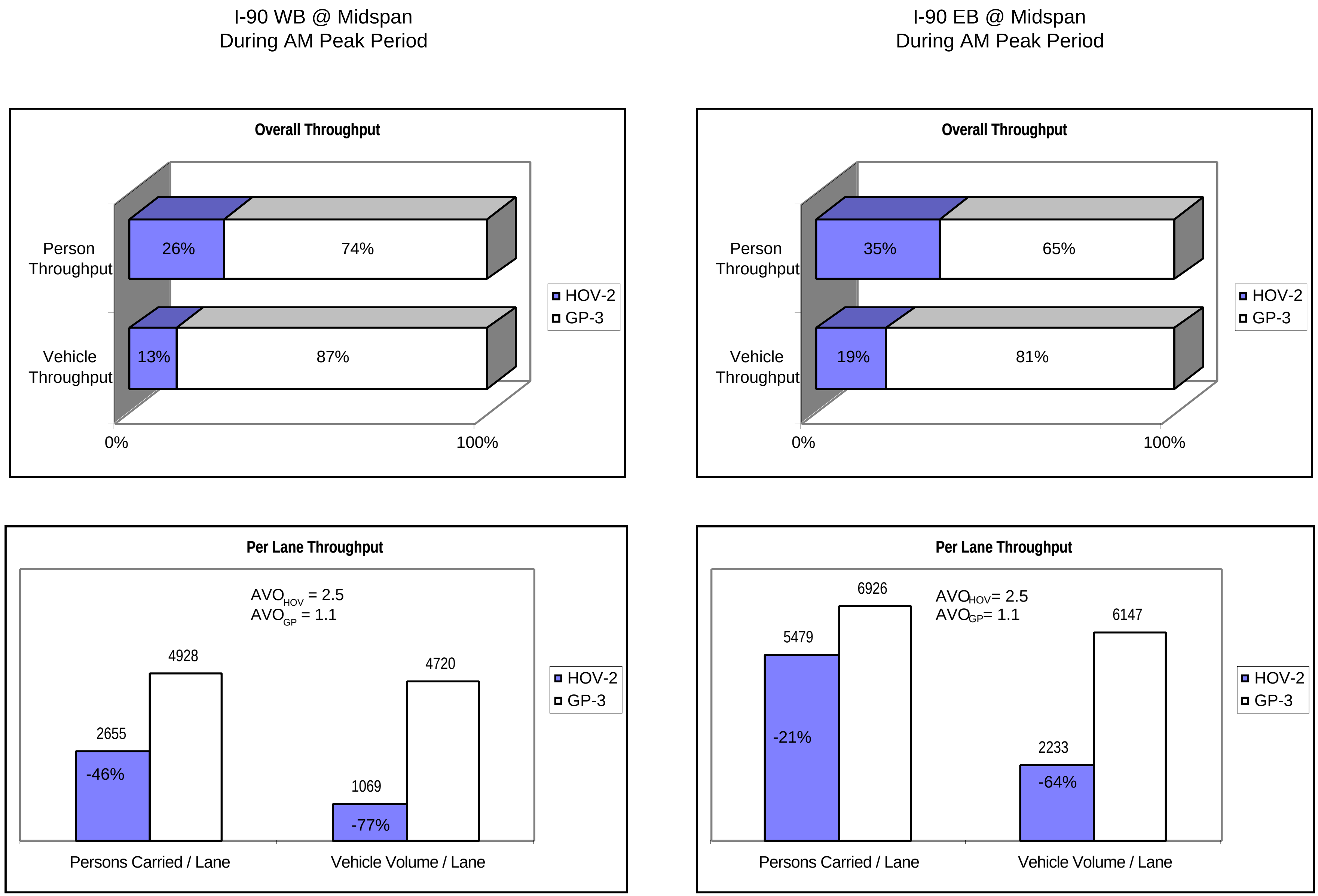


Figure 49. Peak Period Vehicle and Person Throughput Comparisons (I-90 Westbound @ Midspan)

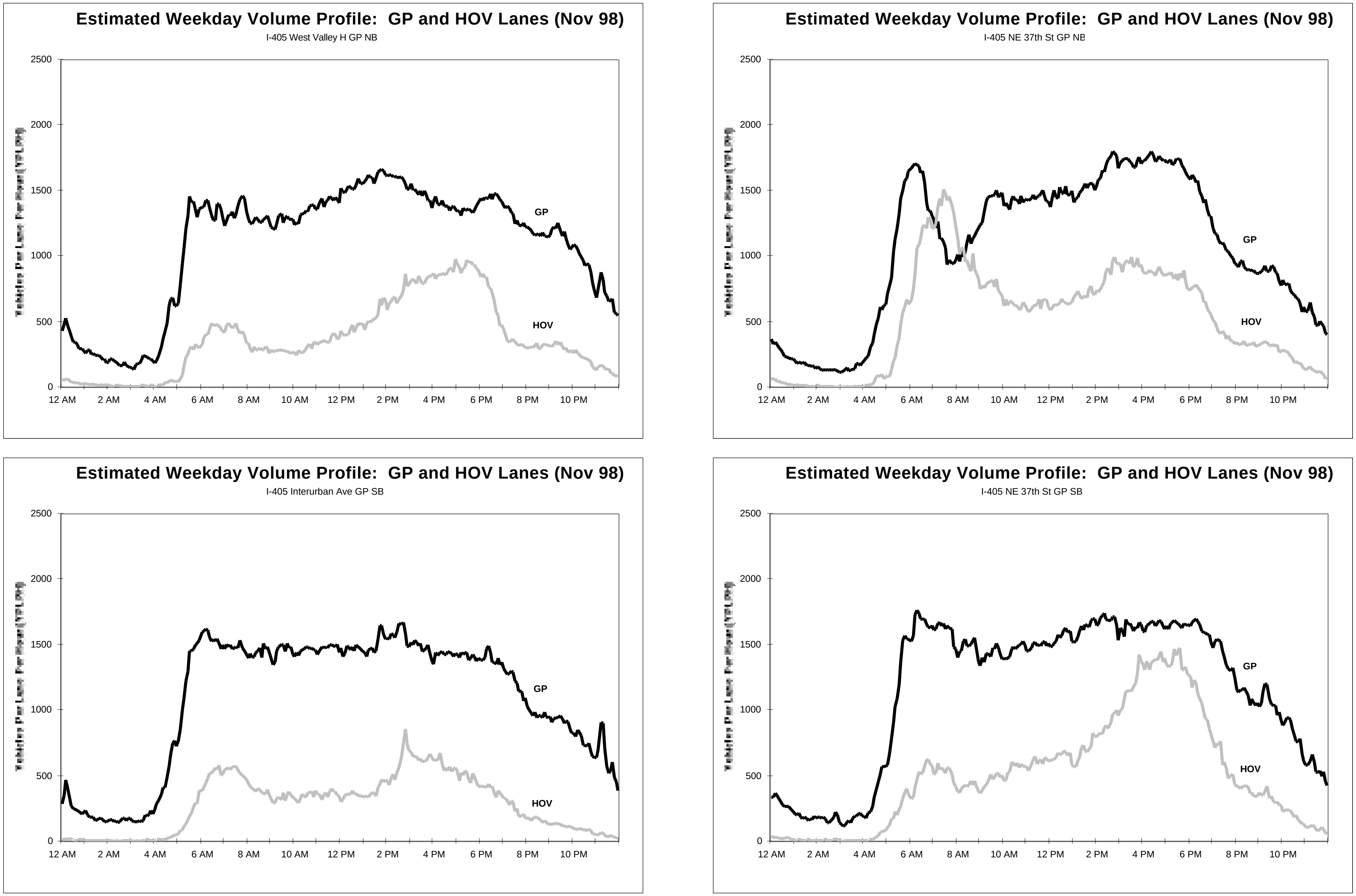
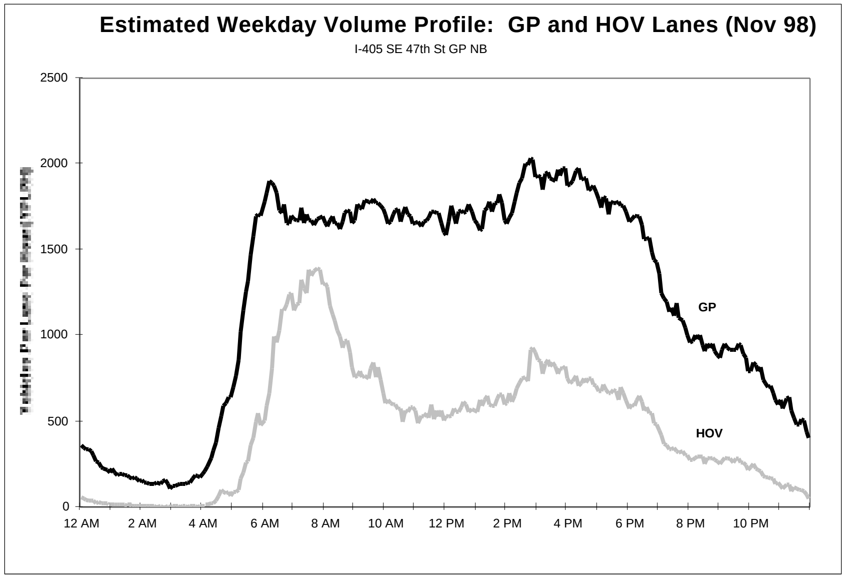
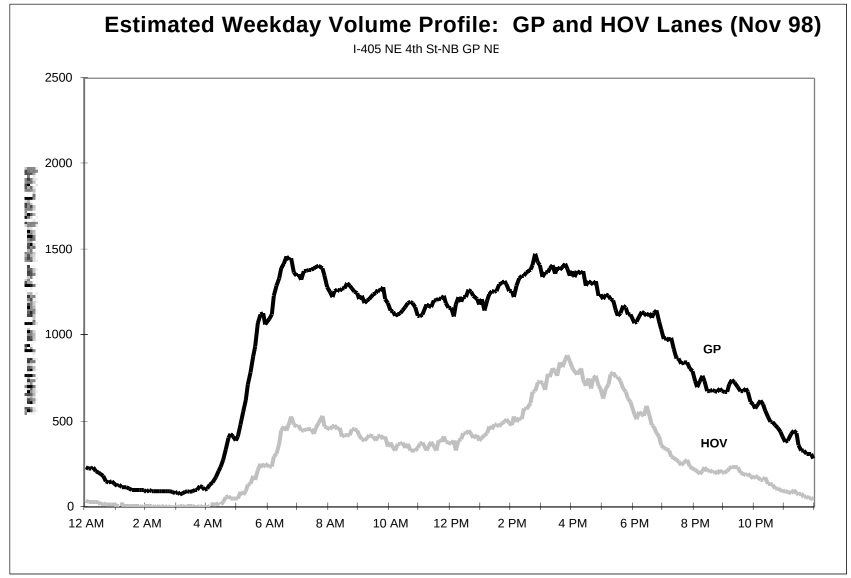
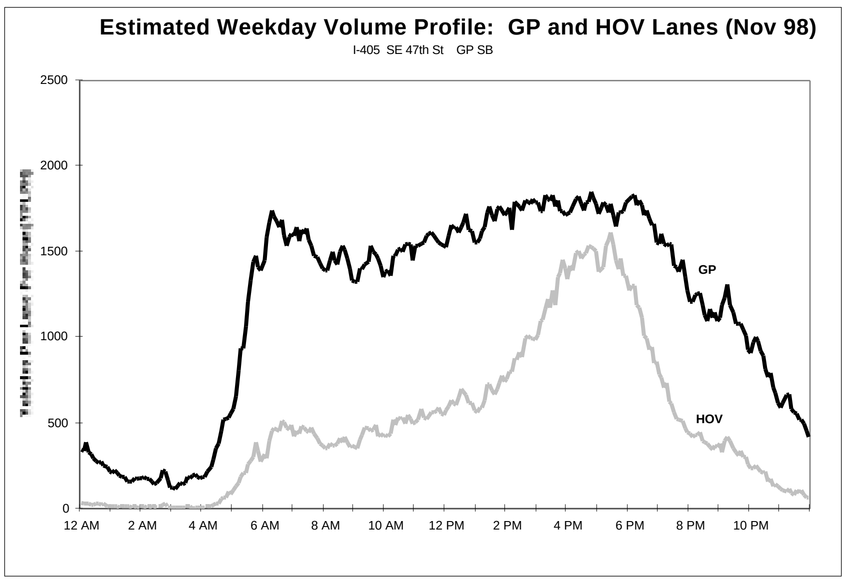


Figure 50. Estimated Weekday Volume Profiles for Selected I-405 Locations







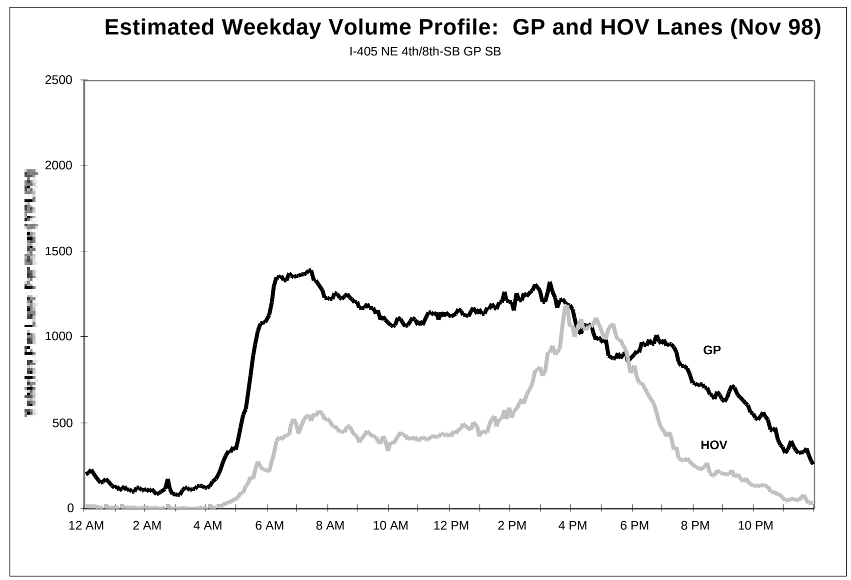


Figure 51. Estimated Weekday Volume Profiles for Selected I-405 Locations

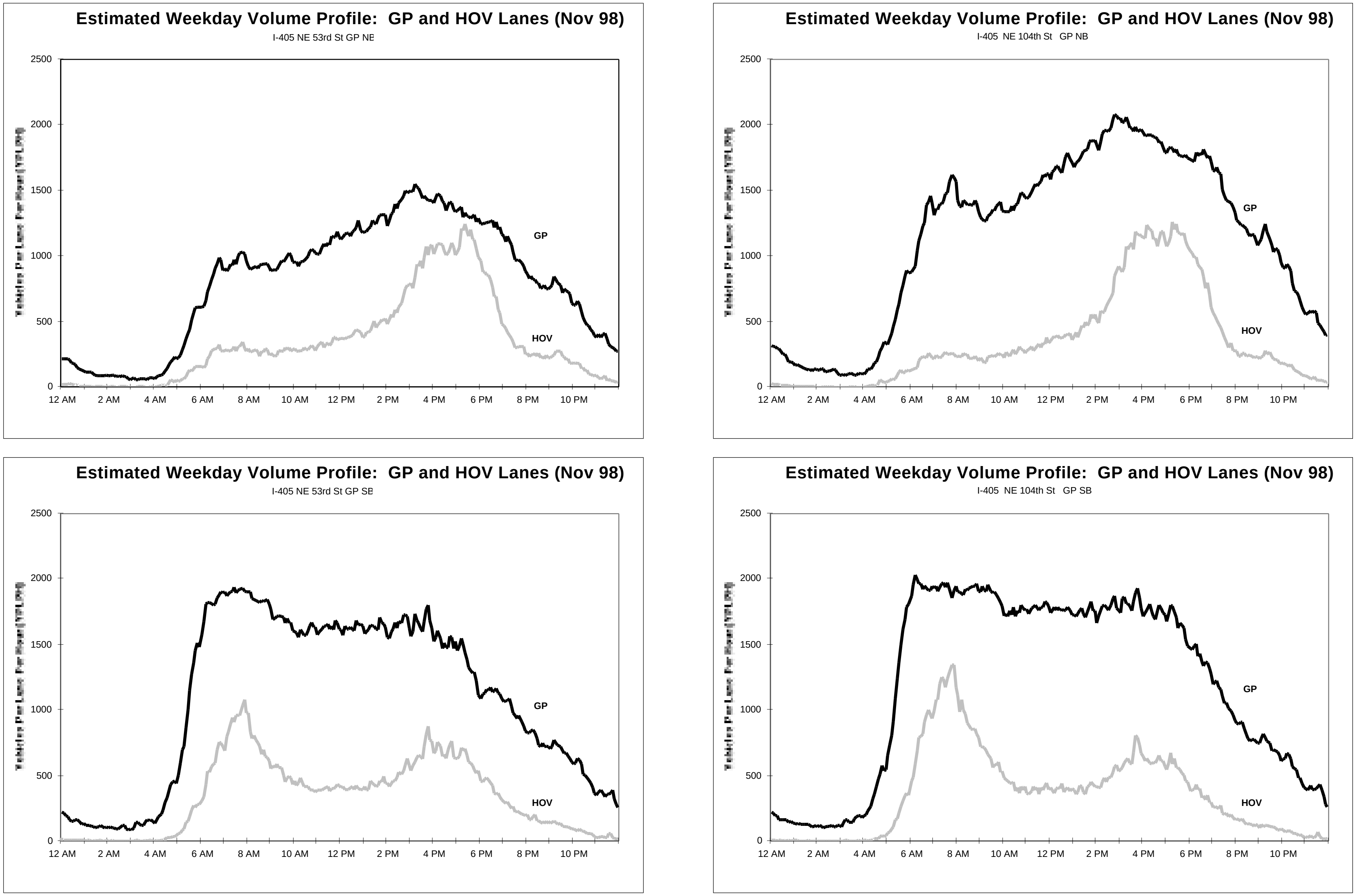
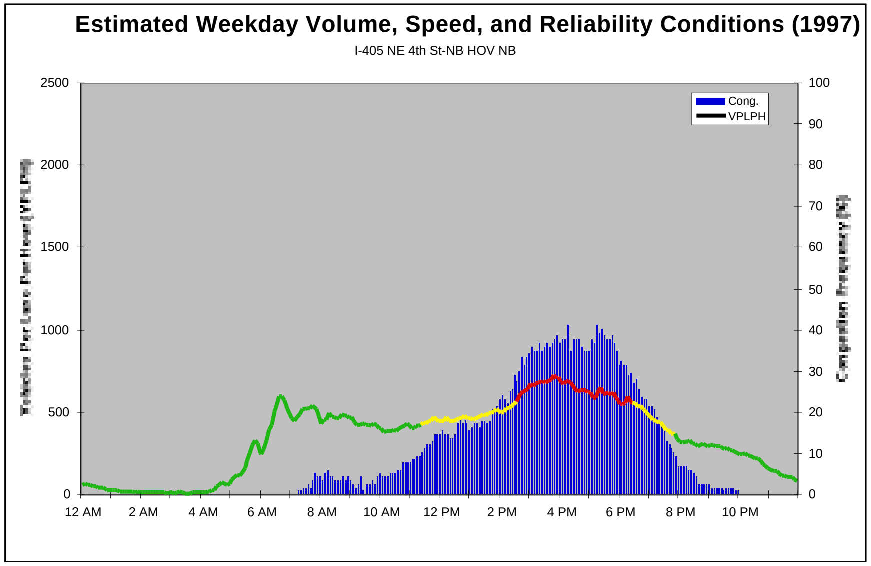


Figure 52. Estimated Weekday Volume Profiles for Selected I-405 Locations



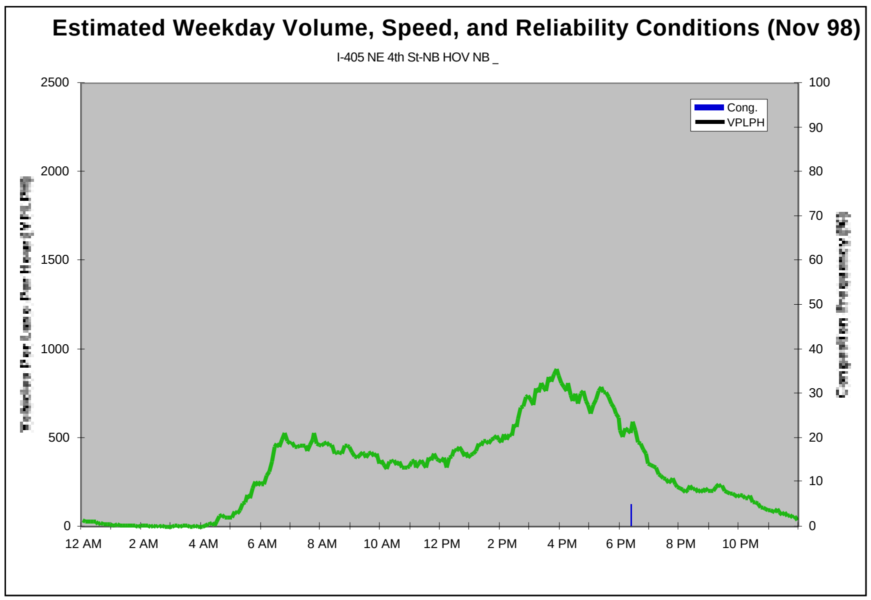


Figure 53. Comparison of Estimated Weekday Volume, Speed and Reliability Conditions for Northbound I-405 HOV Lane, 1997 and 1998.