Annual Weigh-in-Motion (WIM) Report

2010-2013

EXECUTIVE SUMMARY

This report served as the first attempt to publish an annual report of Minnesota's weigh-in-motion (WIM) data. Prior to this effort, the Minnesota Department of Transportation (MnDOT) had published (and continues to publish) monthly reports of WIM data[1]. This report covers WIM data collected at seventeen (17) WIMs that were in operation between 2010-2013. The amount of monthly data collected per WIM that was included in this report ranged anywhere between 10 months to up to 48 months.

Most WIMs experienced relatively similar seasonal trends in volume with a few exceptions (namely WIMs 33, 39, and 41, particularly for heavy commercial vehicles). It was also found that overweight heavy commercial vehicle (HCV) patterns typically mirrored overall HCV volume trends, suggesting that overweight trucks don't behave differently from overall HCV truck populations.

Monthly gross vehicle weight (GVW) data was also found to typically mirror monthly volume data. However, it was also found that there were some data points that did not show this relationship, which appeared to be indicative of problems in the actual classification of vehicles according to one of the 13 classes (particularly between 2010-2011, and for especially Class 1 and 13 vehicles). Due to this finding, it was suggested that future annual reports may benefit from removing 2010-2011 data to avoid added noise in future analyses.

In addition to traffic volumes and GVWs, freight information was presented per site along with information regarding directional differences in freight movement. ESALs were also discussed with the following findings: 1) 90% of all ESALs were not always distributed in the driving lanes of 4-lane, 2-direction roadways, 2) Class 9, 10, and 5 vehicles generally contributed the most to total ESALs at many sites, and 3) calculation of ESALs from overweight Class 9s and 10s indicated that these vehicle classes reduce the pavement life by no more than 5 months (if current calculation methods are correct).

Vehicle speed data was also presented in this report, which indicated very little change over the 4 years of data collection. In general, passenger vehicles (PVs) were typically found to drive at faster speeds than HCVs, and passing lane vehicles tended to drive faster than driving lane vehicles. Furthermore, there seemed to be some decrease in speed during late night/early morning hours which may be due to poorer visibility during the night time. Furthermore, there was some indication in the data that high volume sites typically showed the greatest differences in passing lane speeds from driving lane speeds with a few exceptions.

Apart from the actual analysis of data, procedures for monitoring system performance (incoming data quality) were discussed along with methods for WIM scale calibration. In particular, current methods for monitoring system performance were found to be somewhat inadequate for distinguishing hardware problems (e.g., sensors, inductive loops, WIM controller) from non-hardware problems. While this problem may never go away completely, new procedures for monitoring system performance have been proposed and implemented after 2013 that will help make this process more effortless than before (namely monitoring for qualitative differences in the Class 15 errors, as well as looking for qualitative differences in warnings that accompany vehicle records). These new procedures for monitoring system performance are also implemented more frequently as well (weekly as opposed to monthly).

[1] Monthly reports of WIM data can be found here: http://www.dot.state.mn.us/traffic/data/reports-monthly-wim.html

WIM scales are roughly calibrated twice a year, but there have been occasional challenges in keeping the system in calibration between these official twice-a-year calibrations. This report will discuss some proposed methods for keeping the system in calibration (in between these twice-a-year calibrations) that involves potential collaboration with MN State Patrol, as well as in investing in a research project that is ongoing to predict when WIM systems have gone out of calibration.

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1. WIM SYSTEM LOCATION, DESIGN, AND CLASSIFICATION SCHEME

Since October 2009, monthly reports have been published on WIM data at operational sites. Due to growing interest in an annual report of the monthly data, this paper serves as the first attempt to address those needs. This report will provide information on system performance and operation, along with descriptions of traffic characteristics at WIM sites that were in operation anywhere from January 1, 2010 to December 31, 2013. During that time frame, seventeen (17) WIM systems were in operation in Minnesota.

The following figure (Figure 1.1) shows the locations of the seventeen WIMs within Minnesota (in operation from 2010-2013) and includes the following information: site number (unique numerical identifier), the roadway on which the WIM is situated, the mile post along the roadway the WIM is located, and the month and year corresponding to the date of first publication of data at this site (date follows sometime after initial installation and calibration). According to Figure 1.1 below, each MnDOT district had between 1-3 WIM sites within the 2010-2013 period (long-term goal is to have at least two WIM sites in each of the eight MnDOT districts).

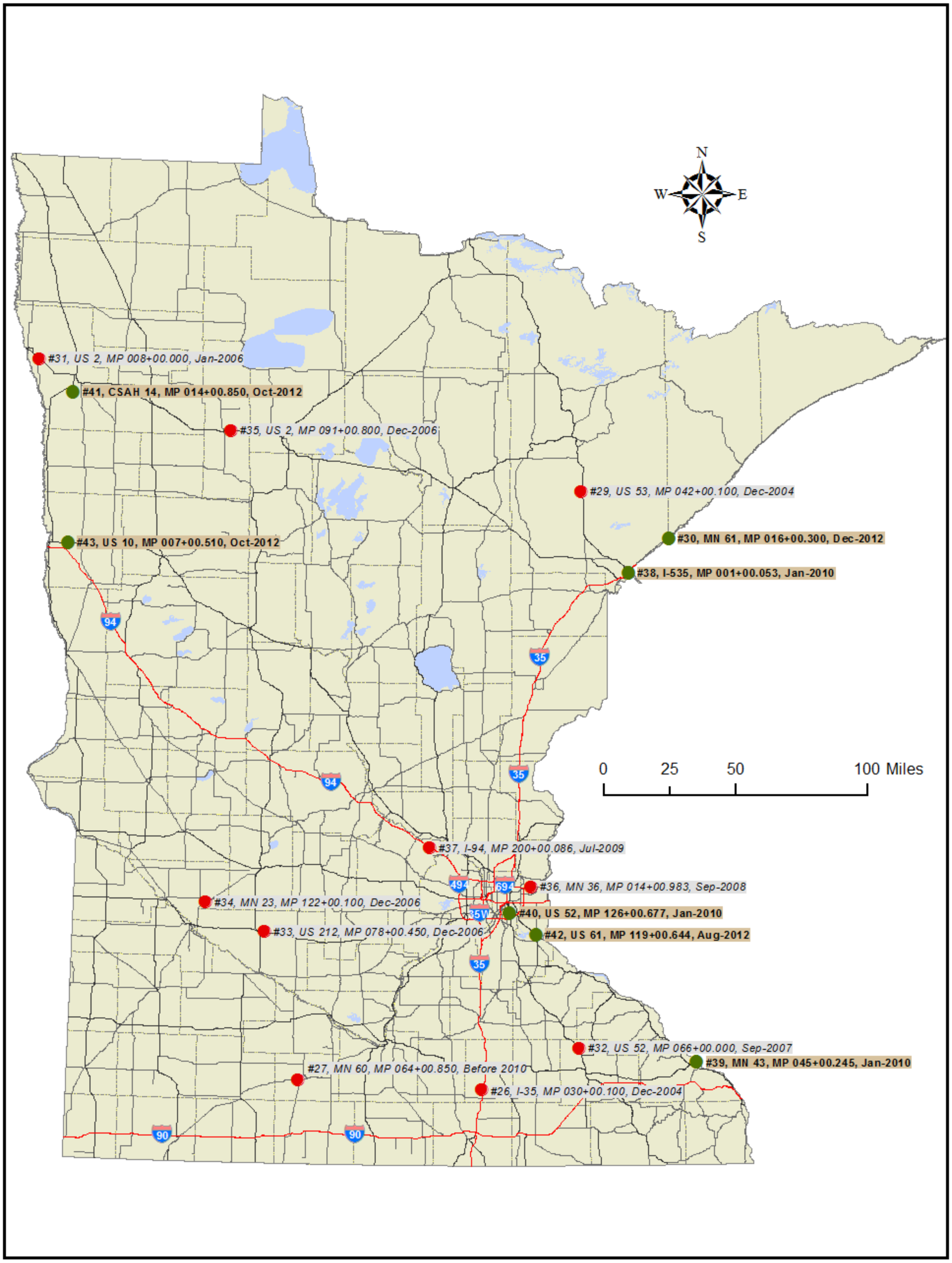


Figure 1.1. A location map of Minnesota weigh-in-motion (WIM) systems in operation from 2010-2013.

Table 1.1 provides a list of all WIM sites in operation between 2010-2013, with additional information about roadway characteristics. For example, all roadways on which the WIMs were located had speeds varying from 50-70 miles per hour (mph). In addition, all WIM sites with the exception of one happened to be located on some type of principal arterial roadway (the exception is WIM #41 (Crookston) which is located on a rural major collector).

WIM #	Roadway	Nearest City	Direction	# of Lanes	Functional Class	Speed Limit (mph)	Start of Data Collection
26	I-35	Owatonna	NB & SB	4	Rural Principal Arterial - Interstate	70	Dec-04
27[a]	MN 60	St. James	EB	2	Rural Principal Arterial-Other	65	Jan-05[b]
29	US 53	Cotton	NB & SB	4	Rural Principal Arterial-Other	65	Dec-04
30	MN 61	Two Harbors	NB & SB	4	Rural Principal Arterial-Other	65	Dec-12
31	US 2	East Grand Forks	EB & WB	4	Rural Principal Arterial-Other	65	Jan-06[c]
32	US 52	Oronoco	NB & SB	4	Rural Principal Arterial-Other	65	Sep-07
33	US 212	Olivia	EB & WB	2	Rural Principal Arterial-Other	55	Dec-06
34	MN 23	Clara City	NB & SB	2	Rural Principal Arterial-Other	60	Dec-06
35	US 2	Bagley	EB & WB	4	Rural Principal Arterial-Other	65	Dec-06
36	MN 36	Lake Elmo	EB & WB	4	Urban Other Principal Arterials	65	Sep-08
37[a]	I-94	Otsego	WB	2	Rural Principal Arterial - Interstate	70	Jul-09
38	I-535	Duluth	NB & SB	4	Urban Principal Arterial - Interstate	55	Jan-10
39	MN 43	Winona	NB & SB	2	Urban Other Principal Arterials	50	Jan-10
40	US 52	South St. Paul	NB & SB	4	Urban Principal Arterial - Other Freeways or Expressways	55	Jan-10
41	CSAH 14	Crookston	NB & SB	2	Rural Major Collector	55	Sep-10
42	US 61	Cottage Grove	NB & SB	4	Rural Principal Arterial-Other	60	Aug-12
43	US 10	Moorhead	EB & WB	4	Rural Principal Arterial-Other	65	Oct-12

[a] Data collection only occurs in one direction of travel at these WIM sites

[b] Data collection ended in October 2010

[c] Data collection ended in December 2011

Table 1.1. List of Minnesota weigh-in-motion (WIM) systems along with roadway characteristics.

Minnesota WIMs are typically configured in the following manner in each lane and in the following order. Firstly, a lead 6' x 6' induction loop is present followed by 2' to 3' gap. Following the gap is a Kistler crystalline quartz piezo-electric WIM sensor that covers both the right and left wheel path. This is subsequently followed by a second Kistler crystalline quartz piezo-electric WIM sensor covering both the right and left wheel path, which is spaced 10' to 12' after the first one. Lastly, the lag 6' x 6' induction follows 2' to 3' after the second Kistler sensor. This particular design was chosen in Minnesota to provide some redundancy in data collection and to minimize needed saw cuts. A visual sketch of this WIM system configuration is respectively provided for 2-lane and 4-lane roadways (see Figures 1.2 and 1.3 below).

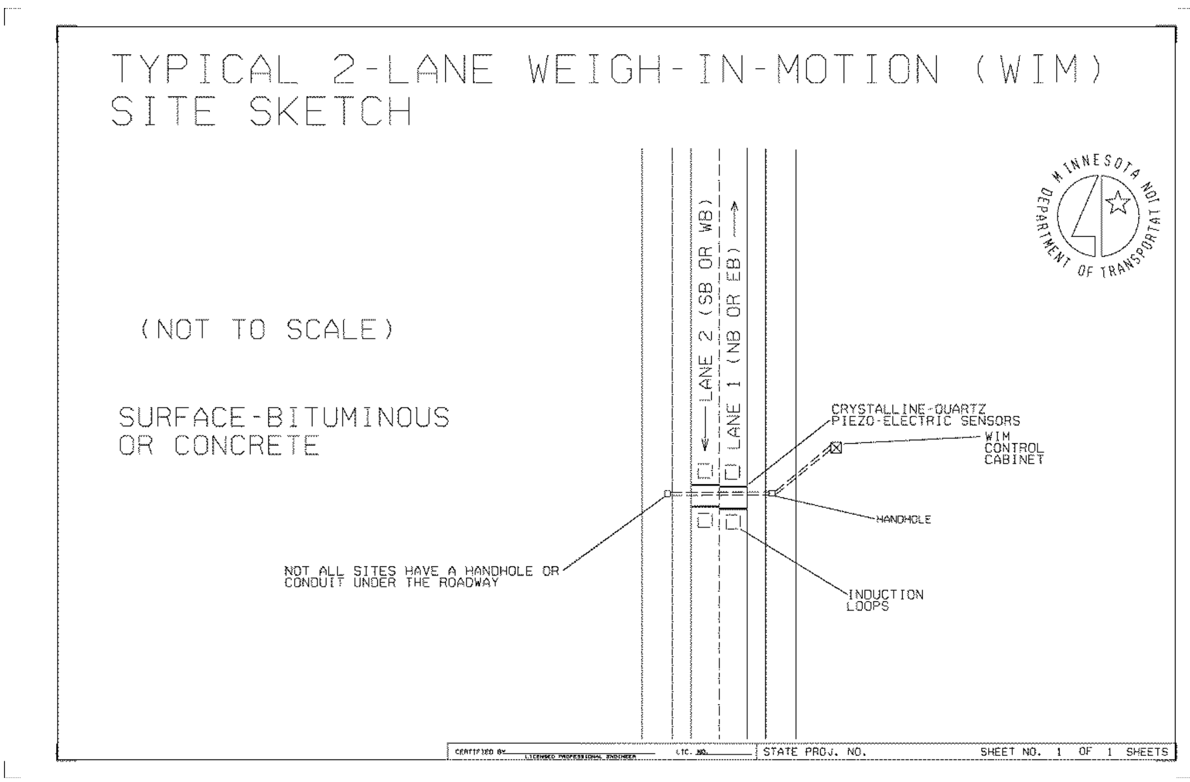


Figure 1.2. Typical sketch of a 2-lane weigh-in-motion (WIM) site.

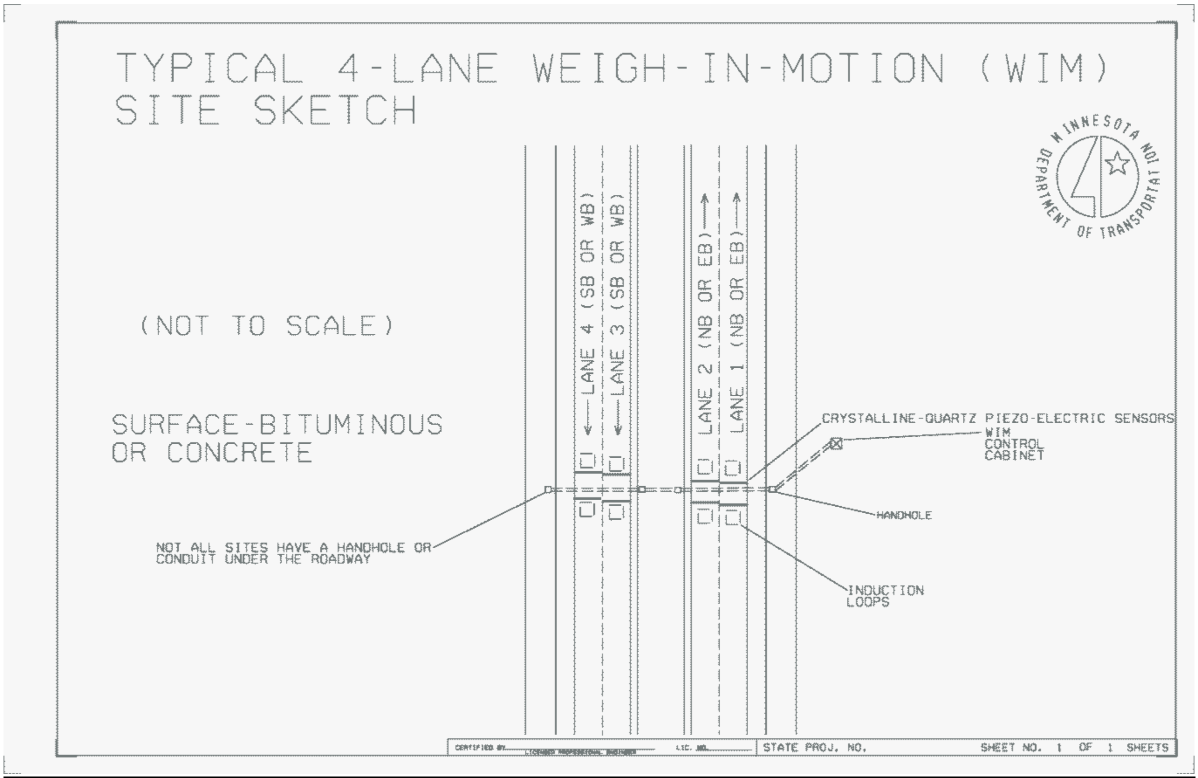


Figure 1.3. Typical sketch of a 4-lane weigh-in-motion (WIM) site.

MnDOT classifies vehicles according to the thirteen Federal Highway Administration (FHWA) vehicle classes. Of the thirteen vehicle classes, the first three (classes 1-3) are considered passenger vehicles while the rest (classes 4-13) are considered heavy commercial vehicles. Please see Figure 1.4 for a visual depiction of the thirteen vehicle classes. In addition to the thirteen vehicle classes, MnDOT also has a Class 14 and Class 15 category. Class 14s refer to vehicles that the classification algorithm was unable to classify into one of the thirteen classes (i.e., algorithm identifies sensor inputs as a vehicle but cannot identify which of the 13 classes it belongs to). Class 15s, on the other hand, refer to inputs to the WIM controller that were unsuccessfully resolved; Class 15s are often referred to as “errors”.

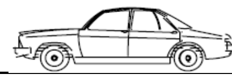
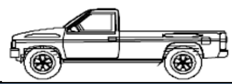
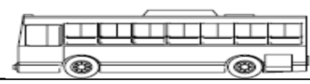
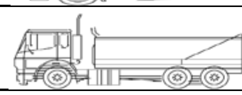
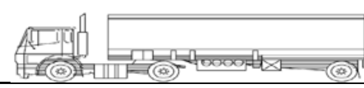
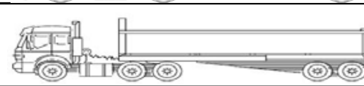
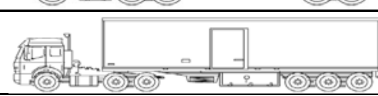
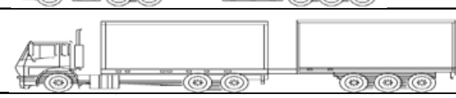
MnDOT VEHICLE CLASSIFICATION SCHEME		
CLASS	**PASSENGER VEHICLES**	
1	Motorcycle	
2	Car	
3	Truck Van	
	SINGLE UNITS	
4	Bus Truck with trailer	
5	2 Axle Single Unit	
6	3 Axle Single Unit	
7	4+ Axle Single Unit	
	COMBO UNITS	
8	3 & 4 Axle Semi	
9	5 Axle Semi	
10	6+ Axle Semi	
11, 12, 13	Twin Trailer Semi	

Figure 1.4. MnDOT’s thirteen vehicle classes.

2. SYSTEM OPERATION

One of the misconceptions about the WIMs (or any of the continuous data collection systems) is that they work continuously. In fact, WIM systems can occasionally go down due to several different factors. For example, the following are some reasons that cause WIM systems to go down: power outages, lightning strikes, extreme temperatures (e.g., extreme temperature lows), moisture that seeps into the wiring from the sensors and/or wiring from the power source, damage caused by wildlife (chewing through power cables), and occasionally, unknown causes.

Table 2.1 summarizes the percentage of time the WIM systems were in operation on a monthly basis from 2010-2013. As demonstrated in the table, the amount of time the WIM systems were in operation across years was fairly high when collapsed across months (> 90%). At an average annual level, it appears that WIM systems varied in operational status from 92.8% to 93.5% operational.

	2010	2011	2012	2013	Average All Years	Average 2010 to 2012
January	93.8%	97.6%	98.2%	97.9%	96.9%	96.5%
February	90.9%	95.3%	97.3%	97.8%	95.4%	94.5%
March	90.6%	91.0%	96.1%	99.6%	94.3%	92.6%
April	88.2%	88.7%	100.0%	99.8%	94.2%	92.3%
May	90.4%	90.9%	100.0%	100.0%	95.3%	93.8%
June	90.5%	91.5%	87.6%	99.6%	92.3%	89.9%
July	88.2%	89.8%	87.1%	90.5%	88.9%	88.4%
August	95.0%	91.7%	92.0%	99.4%	94.5%	92.9%
September	99.1%	91.5%	92.3%	94.7%	94.4%	94.3%
October	92.2%	94.2%	91.5%	63.3%	85.3%	92.6%
November	98.6%	100.0%	87.3%	84.8%	92.7%	95.3%
December	96.1%	100.0%	92.8%	91.8%	95.2%	96.3%
Annual Average =	92.8%	93.5%	93.5%	93.3%	93.3%	93.3%

Table 2.1. Overall WIM system operation (%) as a function of month and year.

Values in Table 2.1 are also graphically represented in Figure 2.1 (see below). In addition, Figure 2.2 shows the number of possible hours the WIMs systems could have hypothetically been in operation (hypothetical number of hours available if systems were 100% operational; red line) compared to actual number of hours in operation (blue-shaded line). These values are plotted against a secondary axis represented the number of WIMs in operation at a given month and year.

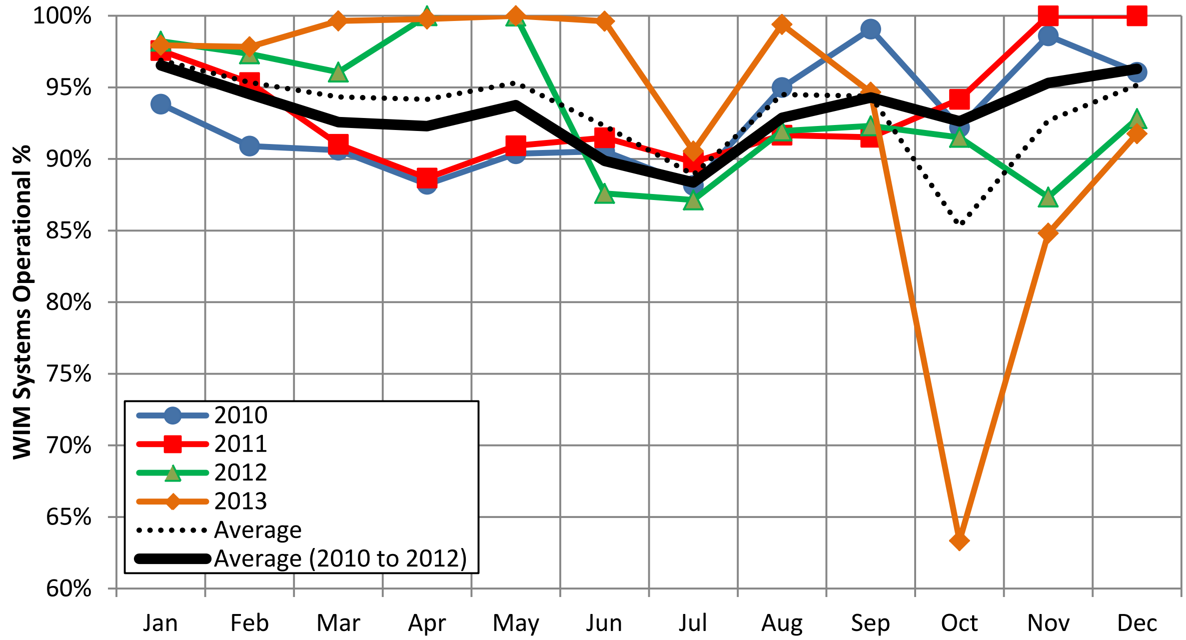


Figure 2.1. Overall WIM system operation (%) as a function of month and year.

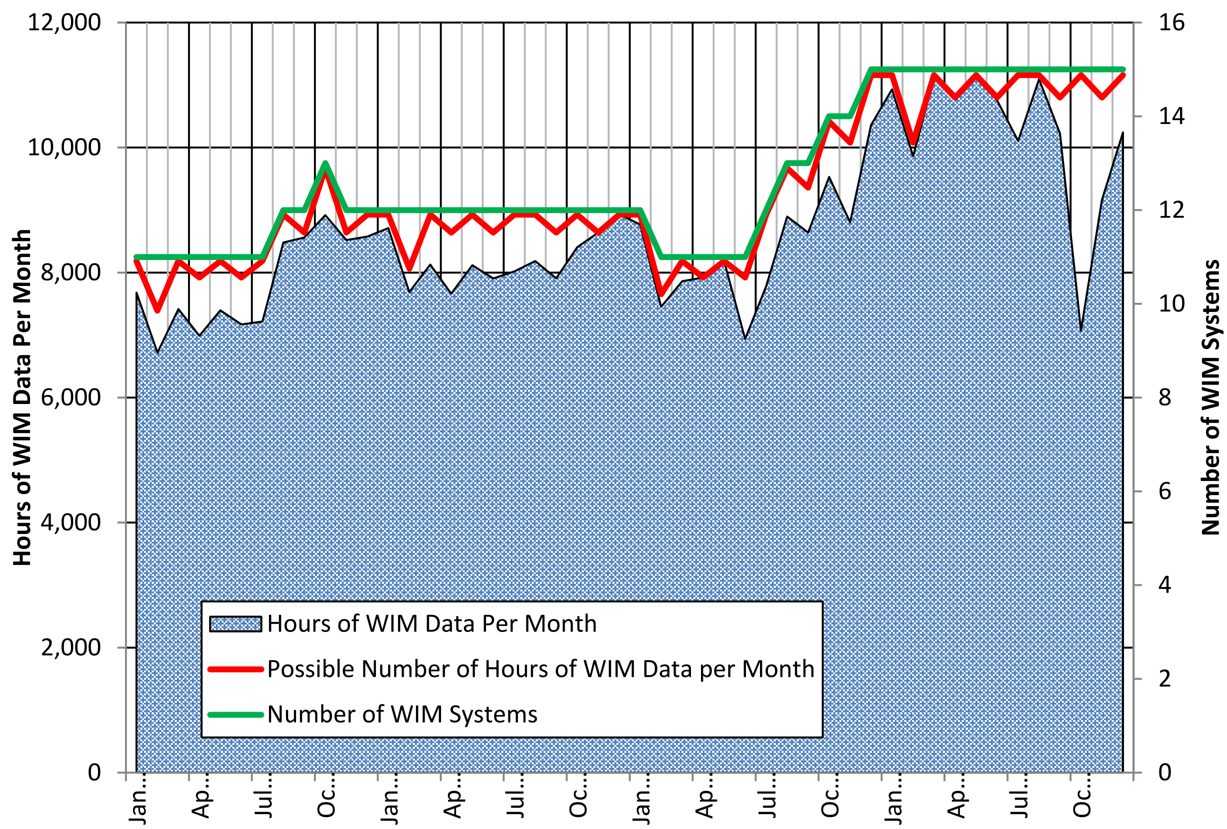


Figure 2.2. Overall hours of WIM system operation compared to total possible hours of WIM system operation.

A few things are apparent based on the results presented above. Firstly, the months with the lowest operational percentages occurred in (ascending order):

1) October
2) July
3) June

Secondly, the highest operational percentages occurred in (descending order):

1) January
2) February
3) May

If the above two analyses were performed again excluding data from 2013[2], the following can be discerned. Firstly, the months with lowest operational percentages from 2010-2012 occurred in (ascending order):

1) July
2) June
3) April

Secondly, the most with the highest operational percentages from 2010-2012 occurred in (descending order):

1) January
2) December
3) November

Data seems to indicate that the months with the least amount of operational hours generally occurred during the summer months, while the greatest amount of operational hours typically occurred during the winter months. This is an interesting finding because it was initially speculated that extremely cold temperatures may cause the most system problems. Since results are contrary to initial speculations, this suggests that priorities may need to shift toward the summer months to restoring WIMs to full operation. Traditionally, MnDOT has given priority to completing in-ground and in-pavement construction over the summer. While this high priority to summer construction is certainly justified, one suggestion may be to also consider the working conditions of the WIMs (and ATRs) at the same time to restore them to full operation.

Over the course of data collection from 2010-2013, MnDOT's procedures for data management and quality checking has evolved. For example, MnDOT has moved away from monthly quality checks in favor of weekly quality checks (weekly quality checks started in February 2014). This action was primarily implemented as a means for MnDOT staff to more quickly resolve WIM system problems as they arise (rather than a month later). For example, when cameras were installed at some of the WIM sites back in October 2013, one of the unintended consequences of that was a shortage of memory space which lead to camera data (images) overriding the WIM data. This issue was caught belatedly (a couple months after the fact). With weekly quality checks of the data, these sorts of issues will be identified more quickly. As MnDOT learns more about the WIM systems and their limitations, it is expected

[2] Data from 2013 was excluded here because there were a couple months where camera data was overwriting WIM data (mainly October 2013, but also November 2013 for some sites). Due to this unique, atypical situation, line graph data from 2013 biases the overall trends in the data.

that data management and quality checking will continue to evolve to keep the systems operating as best as possible. A future goal over the next few years is to try to increase WIM system performance from 92% to 95%. In addition, MnDOT hopes to be able to devise methods in the future to better predict sensor failure—this would help MnDOT allocate resources strategically according to likelihood of sensor failure.

3. SYSTEM CALIBRATION AND QUALITY CONTROL

System Calibration

MnDOT currently adopts a goal of calibrating the scales at each WIM site twice a year. These calibrations are conducted once in the spring (during normal weight limits and after spring load restrictions have ended) and once in the winter (during the winter load increase[3]). MnDOT's current procedure for calibration requires the known weights (gross vehicle weight (GVW) and individual axle weights) and known dimensions (overall length and axle spacings) of a test vehicle to be compared to the observed weights and dimensions recorded at the WIM site. The test vehicle has traditionally been a fully-loaded Class 9 vehicle (~80,000 lbs) with good vehicle suspension. The materials used to load the truck were also carefully chosen to be composed of solid, non-shifting material—this avoids any dynamic weight imbalances from occurring within the truck during operation.

When the test truck crosses over the WIM sensors during calibration, the raw inputs to the WIM controller[4] (the central processing unit of the WIM system) are converted into a vehicle record for that truck. Calibration factors are subsequently manually adjusted to match the observed weights from the controller to the actual weights of the calibration test truck. MnDOT's current policy for calibration is to have the observed GVW (calculated from the controller) to be within ±5% of the actual GVW of the test truck. In addition, current procedure dictates that the observed, individual axle weights should be within ±9% of actual individual axle weights. Calibration factors are manually adjusted until a total of 5 consecutive test runs come within the aforementioned tolerance ranges for GVW and individual axle weights.

Table 3.1 shows the initial WIM system installation date and calibration dates for each site. At some sites, calibration occurred more than twice a year, while in others they occurred less than twice a year.

[3] For information on seasonal load limits: http://www.mrr.dot.state.mn.us/research/seasonal_load_limits/sllindex.asp

[4] MnDOT currently uses the iSINC controller to capture vehicle data. iSINC is a product developed by International Road Dynamics, Inc. (IRD). For more information about IRD: http://www.irdinc.com/

WIM #	WIM Installation Date	CAL DATE	CAL DATE	CAL DATE	CAL DATE	CAL DATE	CAL DATE	CAL DATE	CAL DATE	CAL DATE	CAL DATE	CAL DATE
26	September 2003	1/20/11	6/1/11	1/24/12	4/30/12	5/14/12	1/29/13					
27[a]	October 2003	2/3/10	9/30/10									
29	October 2004	10/5/10	3/15/11	6/8/11	1/18/12	5/9/12	12/27/12					
30	October 2004	1/15/13	2/20/13									
31	2005 (Lanes 3-4); 2006 (Lanes 1-2)	2/11/10	9/28/10	2/23/11	1/19/12	6/21/12						
32	September 2007	4/6/10	7/14/10	10/14/10	1/25/11	5/25/11	10/18/12	1/24/13				
33	December 2006	2/3/10	9/30/10	1/27/11	5/26/11	11/30/11	5/10/12	1/17/13				
34	December 2006	2/3/10	9/30/10	1/27/11	5/26/11	5/10/12	1/17/13					
35	December 2006	2/11/10	9/28/10	2/23/11	9/21/11	1/18/12						
36	August 2008	2/10/10	10/1/10	2/2/11	6/6/11	1/25/12	5/3/12	1/25/13	9/12/13			
37[a]	June 2009	2/10/10	12/1/10	12/10/10	1/5/11	1/24/11	11/28/11	1/10/12	5/22/12	7/24/12	8/29/13	12/12/13
38	September 2009	10/5/10	2/8/11	6/8/11	1/18/12	5/9/12	12/27/12					
39	October 2009	10/14/10	1/25/11	5/25/11	1/24/12	3/8/12	3/22/12	4/4/12	4/12/12	4/30/12	11/1/12	1/24/13
40	October 2009	2/10/10	10/1/10	2/2/11	1/25/12	5/3/12	3/20/13	9/12/13				
41	June 2010	9/27/10	2/24/11	9/21/11	1/19/12	6/21/12						
42	November 2010	10/18/12	1/29/13	9/12/13								
43	September 2011	1/30/13										

[a] These sites only had sensors installed and calibrated in one direction during 2010-2013 (WIM #27: EB sensors; WIM #37: WB sensors)

Table 3.1. WIM system installation and calibration dates for all sites in operation between 2010-2013.

An important point to keep in mind is that, even after system calibration, there will generally be some measurement error on these scales. For this reason, one should be cognizant of measurement error when WIM data is used for screening vehicles for possible weight violations. It is typically estimated that WIM scales measure GVWs within 90% (within 10% error) of baseline GVW measures taken from static scales. Therefore, to account for measurement error, vehicles that exceed 10% of the legal weight limits should be considered overweight. For example, vehicles with GVWs exceeding 80,000 pounds (lbs) are considered to be legally overweight during normal weight limits. However, to account for the possibility of some measurement error on the WIM scales, it is recommended that vehicles over 10% of legal GVW should be screened for most efficient use of personnel and equipment. Here is the 10% rule applied below:

- Legal maximum GVW (during normal weight limits) = 80,000 lbs
- 10% of 80,000 lbs = 8,000 lbs
- 80,000 lbs + 8,000 lbs = 88,000 lbs

According to the example above, vehicles should be considered overweight (and are great candidates for weight screening by State Patrol) if they exceed 88,000 lbs. Using this particular value (instead of the actual legal maximum GVW value) leaves room to account for possible measurement error on the WIM scales. A similar rule applies during winter weight limits (when the legal maximum GVW is increased to 88,000 lbs): vehicles should be considered overweight when they exceed 96,800 lbs (88,000 lbs + 8,800 lbs).

To assure WIM scale performance between calibrations, MnDOT monitors the average front axle weight of Class 9 vehicles at each site on a monthly basis. For a given month at each site, the observed average Class 9 front axle weight is compared to a baseline average Class 9 front axle weight (the baseline measure is the average front axle weight calculated immediately following the most recent calibration). The front axle weight of the Class 9 is used for comparison because this particular axle weight remains relatively constant and is independent of overall vehicle weight. The observed change from the baseline front axle weight measure is calculated thusly:

$$\%\ \text{AvgFrAxWt} = \frac{(\text{Observed AvgFrAxWt} - \text{Baseline AvgFrAxWt})}{(\text{Baseline AvgFrAxWt})}$$

where:

- Observed AvgFrAxWt = average front axle weight measured over a particular month
- Baseline AvgFrAxWt = average front axle weight calculated immediately following the most recent calibration

The percentage change observed in the average front axle weight (% AvgFrAxWt) is represented over time in Figures 3.1-3.17 per lane for each site in operation between 2010-2013. According to these figures, the following sites remained within ±9% of the baseline average front axle weight measure:

- WIM #26 (all 4 lanes)
- WIM #30 (all 4 lanes except for Lane #1 from June 2013-Sept. 2013)

- WIM #32 (all 4 lanes)
- WIM #40 (all 4 lanes except 1) Lane #4 in Aug. 2012, and 2) Lane #1 in Aug. 2013)
- WIM #41 (all 2 lanes except in Lane #2 in Nov. 2010 and July 2011)
- WIM #42 (all 4 lanes except Lane #2 in Aug. 2013)
- WIM #43 (all 2 lanes)

All other sites fell outside of the ±9% tolerance range for as little as a month to – at most – 12 months (i.e., WIM #35) until a calibration could be performed.

Quality Control

One of MnDOT's traditional methods for monitoring WIM system quality has been to observe daily Class 15 records as a percentage of daily total records (# Class 15 records/(Total records falling into Classes 1-15)). Class 15s represent signal inputs that were unsuccessfully resolved by the WIM controller; Class 15s are system errors. Daily Class 15s typically contribute to a small percentage of daily total records, meaning that increases in Class 15s may indicate problems with WIM hardware (e.g., sensors, loops, WIM controller) or other factors unrelated to the hardware (e.g., weather-related effects, lane discipline (driving partially outside lane boundaries while crossing the WIM), etc.). It is important to be able to distinguish between these two sources because one of them (hardware problems) can be directly controlled by MnDOT staff. The next few paragraphs will briefly introduce Class 15 trends at all WIM sites. In addition, there will be a discussion of sites where Class 15 rates were known to be caused by hardware performance issues.

The general rule-of-thumb adopted by MnDOT is to investigate for potential quality issues when daily Class 15s contribute to more than 3% of all daily records. Figures 3.18-3.34 represent Class 15 rates by lane at each site from 2010-2013.

Data indicate that a good proportion of WIMs stayed below the 3% threshold in all lanes for the entire reporting period (i.e., 26, 27, 32, 39, 42, and 43). For WIMs that did exhibit Class 15 values above the threshold, many did not remain at those elevated levels for any extended, successive number of months (i.e., WIMs 30, 31, 33, 35, 36, 38, and 40). In some cases, those elevated Class 15s dropped spontaneously back to acceptable levels without an identifiable cause. In other cases, a specific source was able to be identified that was unrelated to WIM hardware problems. For example, driver lane disciple has been speculated to be behind the Class 15 increases at WIMs #34 and #41. Increases in Class 15s have co-occurred between the two sites for December 2010, January 2011, March 2011, July 2011, December 2012, and January 2013.

There were also some instances where elevated Class 15s were directly associated with WIM hardware performance. Lane 1 at WIM #37 started exhibiting a significant increase in Class 15s starting December 2010. Subsequent analyses determined that the Lane 1 sensor was failing with this sensor eventually being replaced on May 17, 2011. Lane 3 at WIM #29 also showed high Class 15 rates starting February 2010. In this case, the upstream inductive loop was failing in Lane 3 (upstream loop was disabled on August 18, 2014, which resolved the high Class 15 rate).

4. VOLUME AND VEHICLE CLASS

The following section summarizes the vehicle volume and vehicle class trends observed from 2010-2013. It is important to note that the amount of data available during this time frame will vary by WIM site. Factors affecting data availability during this time frame depend on multiple factors including 1) the WIM installation date and initial calibration (not all WIMs were installed and calibrated at the same time), 2) operational status of the system, and 3) the validity of the data collected (which is primarily dependent on data quality).

Vehicle classes 1, 2 and 3 shall henceforth be collectively referred to as passenger vehicles (PVs), while classes 4 through 13 shall be referred to as heavy commercial vehicles (HCVs).

There are a couple points to highlight prior to interpreting the results below. Most importantly, although some traffic patterns will remain consistent across years for a given site, there will undoubtedly be some variability in the data over time which will require some consideration when making generalizations about traffic patterns. Generally speaking, one can presume a higher level of confidence in the traffic patterns if the patterns appear consistently across time. Situations that will lead to lesser degrees of confidence may occur if 1) a relatively small number of data points were collected over time, 2) traffic patterns across time do not follow a discernible pattern such that one cannot make an educated prediction into the near future, or 3) the validity of the data comes into question, thereby increasing the probability of making erroneous conclusions from the data. Although the reader will observe situations where traffic patterns have remained relatively consistent across time, the reader will also encounter situations where a high degree of variability will limit interpretive power. The reader is encouraged to keep these in mind when referring to the results and figures/tables that follow.

WIM #26

Monthly ADT and HCADT. Average daily traffic (ADT) and heavy commercial average daily traffic (HCADT) were calculated each month, and these values are represented in Figure 4.1 from 2010-2013. Highest monthly ADT values coincided with summer months (June-August), with lowest monthly ADT values observed over the winter. Monthly HCADT values also shared a similar pattern: highest values generally occurred from May through August, with lowest values occurring during the winter. Mean values for monthly ADT and monthly HCADT were respectively at 19,569 (SD[5] = 2523) and 4,338 (SD = 334)[6].

Weekly Volume Trends. On average, traffic volumes were highest on Fridays and lowest on Tuesdays at this site. This was observed for both directions (NB and SB). See Figure 4.2.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.3). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 6.

Monthly Volume Trends for PVs and HCVs. In general, PVs reached highest volumes over the late spring (May) to early fall months (September), with lowest volumes generally

[5] Represents one standard deviation (SD) from the mean.
[6] For ease of interpretation, numerical means and standard deviations have been rounded to the nearest whole number.

observed over the winter (typically December through February). A similar volume trend was also observed across the HCVs. (See Figure 4.4). The increase in volume observed over the late spring to early fall months is thought to coincide with greater recreational travel for PVs, along with greater freight movement in the HCVs. In contrast, decreased recreational travel and freight movement is thought to explain lower volumes over the winter months.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.5). On an average 24-hour day, PVs traveling either direction (NB or SB) exhibited similar hourly volume trends. While, SB PVs reached greater traffic concentrations earlier than NB PVs, traffic volumes were at its highest around afternoon rush hour for both NB and SB directions.

HCV traffic concentrations were slightly different depending on the direction of travel. While both directions reported highest HCV concentrations around typical business hours (~ 9 am – 5 pm), SB HCVs had a more noticeable drop in the number of vehicles immediately preceding and following the peak level times.

WIM #27

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.6 from 2010. Of the ten months of available data, monthly ADT values were highest in the summer (June-August), with lowest monthly ADT values coinciding with winter (January-March). Monthly HCADT values did not show as much variation as the overall monthly ADT, but they still showed some seasonal differences: higher HCADTs in the fall (August-October), and lowest HCADTs in the winter (January-March). Mean values for monthly ADT and monthly HCADT were respectively at 2,778 (SD = 436) and 428 (SD = 34).

Weekly Volume Trends. On average, traffic volumes were highest on Fridays and lowest on Tuesdays at this site. These observations were based on traffic in the EB direction (in-pavement WIM only exists in the EB lanes at this site). See Figure 4.7.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.8). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 6.

Monthly Volume Trends for PVs and HCVs. All PVs generally reached highest volumes starting in the late spring to late summer months except for Class 1 vehicles. Although data suggests that C1 volumes were highest in the winter, these data points may not be valid—it is currently speculated that the high C1 volume may be due to some other factor (i.e., a need for refining the vehicle classification algorithm).

HCVs generally showed one of three volume patterns: a volume peak in the summer through late fall, a volume peak in the late winter (February to March), or volume peaks at both times (in the summer through late fall and again in the late winter). (See Figure 4.9).

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.10; note that data collection at this site was confined to the EB direction). On an average 24-hour day, EB PVs gradually increased in volume starting around 5 am, with peak volumes coinciding with afternoon rush hour. EB HCVs also started to rise starting from 5 am, with peak volumes occurring roughly from 11 am – 6 pm.

WIM #29

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.11 from 2010-2013. Highest monthly ADT values coincided with summer months (June-August), with lowest monthly ADT values observed over the winter. Monthly HCADT values are also suggestive of a similar pattern to that of overall ADTs: highest values generally occurring in the summer into early fall, with lowest values occurring during the winter. Although 2013 was the only year that had ADT data for summer months, all other years suggest a gradual rise in monthly ADTs leading up to a highly likely peak in the summer. Mean values for monthly ADT and monthly HCADT were respectively at 7,526 (SD = 1656) and 428 (SD = 200).

Weekly Volume Trends. On average, traffic volumes going NB were highest on Fridays and lowest on Sundays at this site. In contrast, while SB traffic volumes were also highest Fridays, lowest volumes were observed on Tuesdays. See Figure 4.12.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.13). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 10.

Monthly Volume Trends for PVs and HCVs. All PVs generally reached highest volumes starting in the late spring/early summer (June) to early fall months (September). In contrast, HCV volume trends tended to differ slightly based on the vehicle class, although many also showed a similar increase in volume coinciding with the summer months (see Figure 4.14 for specific vehicle class volume trends). The increase in volume observed over the late spring to early fall months is thought to coincide with greater recreational travel for PVs, along with greater freight movement in the HCVs. In contrast, decreased recreational travel and freight movement is thought to explain lower volumes over the winter months.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.15). On an average 24-hour day, NB PVs gradually increased in volume over the day, with peak volumes coinciding with afternoon rush hour. In contrast, SB PVs increased more rapidly in volume by the hour (compared with NB PVs), with peak volume times from 10 am – 5 pm.

WIM #30

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.16 from 2012-2013. With the limited amount of monthly data points available, data suggests higher ADTs in the summer to early fall months (June-September), with lowest ADTs observed in the winter to early spring (December-April). Monthly HCADTs showed the same pattern as monthly ADTs: highest in the summer to early fall, and lowest in the winter to early spring. Mean values for monthly ADT and monthly HCADT were respectively at 7,568 (SD = 1647) and 441 (SD = 90).

Weekly Volume Trends. On average, traffic volumes going NB were highest on Fridays and lowest on Sundays at this site. In contrast, while SB traffic volumes were also highest Fridays, lowest volumes were observed on Saturdays. See Figure 4.17.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.18). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 8.

Monthly Volume Trends for PVs and HCVs. In general, PVs reached highest volumes starting in the late spring/early summer (June) until fall (October), with Class 1s specifically having a slightly narrower summer volume peak from July to September. These trends in the PVs coincide with increased recreational travel often found in the summer months in Minnesota. HCVs also had a similar increase in volume from early summer (June) until the late fall (October/November), which is indicative of increased freight activity during those times (compared to winter months). See Figure 4.19.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.20). While NB PVs gradually increased to peak volume levels during afternoon rush hour, peak volume levels were distributed more broadly for SB PVs (extending roughly from 10 am to afternoon rush hour).

NB and SB HCV volumes showed similar yet distinct volume trends. While HCVs exhibited a clear, single peak in volumes, the time range in which this peak occurred depended on the direction of travel. NB HCV volume was greatest in the morning hours (roughly 7 am – 11 am), while SB HCV volume was greatest later in the day (12 pm – 3:30 pm).

WIM #31

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.21 from 2010-2011. Highest ADT values were generally observed over the summer and into the early fall (June-September), with lowest monthly ADTs observed over the winter (November-January). In contrast, monthly HCADT values had a slightly more delayed peak that coincided with fall months (August-October), with lowest monthly HCADTs occurring over the winter. Mean values for monthly ADT and monthly HCADT were respectively at 5,363 (SD = 764) and 491 (SD = 112).

Weekly Volume Trends. On average, traffic volumes going EB were highest on Fridays and lowest on Sundays at this site. In contrast, while WB traffic volumes were also highest Fridays, lowest volumes were observed on Saturdays. See Figure 4.22.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.23). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 10.

Monthly Volume Trends for PVs and HCVs. With the exception of Class 1s, PV volumes were highest from late spring/early summer (June) through early fall (October). Class 1 volume trends were more difficult to interpret in this report because volumes were significantly higher for Class 1s starting September 2011 and on. Prior to September 2011, monthly Class 1 volumes were reported to be relatively low (the most frequently occurring monthly value was a volume of 0). Due to the change in Class 1 volume frequency starting September 2011, any general interpretation about C1 volumes carries a greater degree of uncertainty.

HCV volume trends differed depending on vehicle class, but they typically either attained peak volume levels around the same time as the PVs (Class 2s and 3s specifically), or they peaked in the late summer (August) through early fall (October). See Figure 4.24 for monthly volume trends by vehicle class.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.25). PVs going either direction (EB or WB) showed very similar volume profiles over an average 24-hour period. Firstly, there was an observable morning rush hour for both directions, with peak morning volume levels occurring between 7 am and 8 am. Secondly, there was also an afternoon rush hour for EB and WB PVs, with peak afternoon volumes occurring roughly from 3 pm – 6:30 pm.

HCV vehicles also showed similar volume profiles regardless of direction of travel. Peak volume levels coincided with typical business hours for both directions, with EB HCVs roughly getting a one-hour head start on their WB counterparts.

WIM #32

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.26 from 2012-2013. With the limited amount of available data, monthly ADT and HCADT trends appear to most likely fit most other WIM sites. More specifically, WIM #32 showed highest ADT and HCADT values in the summer (June-August), with lowest values occurring in the winter (December-March). Mean values for monthly ADT and monthly HCADT were respectively at 26,795 (SD = 2295) and 2,438 (SD = 345).

Weekly Volume Trends. On average, traffic volumes going NB were highest on Fridays and lowest on Mondays at this site. In contrast, while SB traffic volumes were also highest Fridays, volumes on Tuesdays were marginally lower than other days during the work week. See Figure 4.27.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.28). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 6.

Monthly Volume Trends for PVs and HCVs. PVs typically reached highest volumes starting in the late spring (May) to early fall months (October), with Class 1s specifically having a slightly narrower peak range from June through September. These trends in the PVs coincide with increased recreational travel often found in the summer months in Minnesota. Similarly, HCVs generally reached peak volume levels from roughly May through October/September, with that range being somewhat more restricted or broad depending on the vehicle class (for specific details, see Figure 4.29). In general, however, HCV volume trends roughly paralleled PV volume trends at the monthly level.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.30). On an average 24-hour day, NB PVs gradually increased in volume over the day, with peak volumes coinciding with afternoon rush hour times. In contrast, SB PVs appeared to show patterns indicative of both a morning and afternoon rush hour.

HCVs in either direction showed similar volume changes over a typical 24-hour period with one exception. While the highest concentration of SB HCVs was observed over typical business hours, NB HCVs had a greater bias in traveling earlier during the day (~ 7:30 am – 10 am) with a gradual decrease in numbers over typical business hours.

WIM #33

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.31 from 2010-2013. Highest ADTs were typically found in the summer to early fall months (August-October), with lowest ADTs observed over the winter months (December-February). In contrast, monthly HCADT values were typically highest in the late summer into the fall (September-November), with lowest HCADTs occurring in the late spring to early summer (May-July). While it is not uncommon for monthly HCADTs to be highest in the late summer/early fall, WIM #33 somewhat deviates from many other WIMs in that heavy commercial vehicles tended to reach lowest daily volumes in the late spring to early summer. It would be interesting in the future to explore the possible industries that are served by the roadway on which WIM #33 is located—perhaps the type of industry may give some explanation for the lower HCADT values that were observed in the spring/early summer. Mean values for monthly ADT and monthly HCADT were respectively at 4,859 (SD = 442) and 768 (SD = 156).

Weekly Volume Trends. On average, traffic volumes were highest on Fridays and lowest on Sundays at this site. This was observed for both directions (EB and WB). See Figure 4.32.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.33). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 10.

Monthly Volume Trends for PVs and HCVs. Peak PV volume trends differed slightly across the three PV classes. While all three PV classes generally reported highest volumes in August, the volume profiles across all 12-months were not identical across the three PV classes (particularly when comparing Class 1s against the other two classes). For HCVs, volume trends varied widely as a function of vehicle class (see Figure 4.34). Generally, however, HCV volume trends fell into one of three patterns: 1) highest volumes observed during the late spring (May) to early fall (Sept), 2) peak levels observed during Minnesota's 'snowy' months (roughly November to March), or 3) a peak in volume during the late summer into fall (August to October). These generalizations, however, are somewhat limited when considering the wide variability in the data points across the years.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.35). On an average 24-hour day, EB PVs gradually increased in volume over the day, with peak congestion coinciding with afternoon rush hour. WB PVs showed a similar volume trend to EB PVs except that 1) WB PVs showed a more rapid increase in volume over the morning hours (most markedly between 5 am and 8 am), and 2) the gradual rise to afternoon peak levels (coinciding with afternoon rush hour) occurred at a slower rate of volume change compared to EB PVs.

HCVs traveling in either direction showed a very similar volume trend across the average 24-hour day; peak volume times roughly occurred from 8 am – 4 pm in both directions.

WIM #34

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.36 from 2010-2013. Highest monthly ADT values generally occurred in the late spring to summer (May-September), while lowest ADTs were observed over the winter months. Monthly HCADT patterns were relatively similar to overall ADT patterns: more of a sustained peak observed from the late spring to early fall (May-October), with lowest HCADTs recorded over the winter. Mean values for monthly ADT and monthly HCADT were respectively at 3,040 (SD = 353) and 429 (SD = 79).

Weekly Volume Trends. On average, traffic volumes going NB were highest on Fridays and lowest on Sundays at this site. In contrast, while SB traffic volumes were also highest Fridays, volumes on Tuesdays were marginally lower than other days during the work week. See Figure 4.37.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.38). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 10.

Monthly Volume Trends for PVs and HCVs. PVs typically reached highest volumes in the late spring (May) through early fall (October), with Class 1s generally having a slightly narrower peak range (June through August). HCVs generally reported higher volumes in the spring (May/June) to fall (October/November) than in the winter months with one exception. More specifically, there were a couple HCVs that exhibited two distinct volume peaks in an average 12-month period—once in the late spring, a volume decrease in the summer, and then another peak in the fall (see Classes 5 and 7). The reader, however, should keep in mind that there was noticeable variability in the monthly data when examined across years (most obvious when comparing year 2010 from the other years)—such variability over time will limit interpretive power in the data itself. See Figure 4.39.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.40). NB and SB PVs showed very similar volume changes within an average 24-hour day. After a rapid change in PV volume in the morning (~5 am – 8 am), PVs gradually increased in volume throughout the day, with peak volumes coinciding with afternoon rush hour.

HCV volume trends, in contrast, differed according to direction of travel. While HCV volumes were lowest during overnight hours (as is typical of all current roadways with WIMs), SB HCVs increased in volume more rapidly from 2 am – 4 am leading to higher concentrations of SB HCVs earlier in the day compared to NB HCVs. NB HCVs, while increasing slowly over the day, didn't reach peak volume levels until afternoon rush hour times. This contrasts with SB HCVs that peaked earlier (~8 am - 11 am), maintained volume levels during midday, and declined in the middle of rush hour (after 4 pm).

WIM #35

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.41 from 2010-2013. Highest ADT values were observed over the summer months (June-September), with lowest ADTs reported during the winter months. Monthly HCADTs were somewhat more variable across years and did not show a pronounced peak or trough in HCADT values across the months. However, HCADTs were generally highest in the late summer to fall (August-October). Determining the lows in HCADTs were somewhat more challenging due to the variability observed across years. Generally speaking, HCADT values were relatively similar from November through May (but lower than the summer/early fall peak discussed above). Mean values for monthly ADT and monthly HCADT were respectively at 5,560 (SD = 653) and 450 (SD = 62).

Weekly Volume Trends. On average, traffic volumes going EB were highest on Fridays and lowest on Sundays at this site. In contrast, while WB traffic volumes were also highest Fridays, lowest volumes were reported on Saturdays. See Figure 4.42.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.43). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 10.

Monthly Volume Trends for PVs and HCVs. PV volumes consistently appeared to reach highest levels over the summer months (June – August), with lowest volumes observed over the winter months. This is attributed to increased recreational travel often found in the summer months in Minnesota (whereas, poorer roadway conditions in the winter are more likely to discourage excessive travel than when necessary or desired). HCVs similarly exhibited a general volume peak over the summer months, with this peak sometimes extending into early fall (October). The only exception to this rule may be Classes 5 and 10. Class 5s generally had a more uniform distribution across all months, while Class 10s reached peak volume levels in the winter months (January and February). See Figure 4.44. Due to overall variability in the monthly volumes across the years, it will be important to collect further data to increase the representativeness of the underlying traffic patterns.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.45). EB and WB PVs shared the following similarities: 1) both showed a rapid rise in volume concentrations between 5 am and 8 am, and 2) both attained peak volume levels during afternoon rush hour. The main difference between EB and WB PVs was in their volume patterns during midday. While the amount of vehicles had significantly increased by 8 am in both directions (compared to the overnight hours), WB PV volumes decreased for a couple hours followed by a gradual increase up through afternoon rush hour times. In contrast, EB PVs generally continued to rise after 8 am and up through afternoon rush hour times (the only exception being from 1 pm – 2 pm).

For HCVs, those going EB generally reached highest concentrations later in the day compared to WB HCVs—between 11 am and 4 pm. In contrast, WB HCVs peaked a little earlier in the day, roughly between 8 am and 1 pm. This is somewhat to be expected since WB HCVs reached greater concentrations earlier in the day overall.

WIM #36

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.46 from 2010-2013. Due to greater variability in monthly ADT and HCADT values across the years (especially between the months of July through December), it is somewhat difficult to ascertain the true, underlying volume patterns during those several months. While earlier years (2010-2011) suggested peak ADT values in the summer to early fall (June-October), this pattern did not emerge as clearly in later years (2012-2013). A similar statement can be made for monthly HCADT values; high HCADT variability across the years limits understanding the true, underlying traffic patterns at this site. However, one statement that can be made about this site is that winter months (December-March) generally have lower monthly ADTs and HCADTs than other months of the year. Mean values for monthly ADT and monthly HCADT were respectively at 37,330 (SD = 3611) and 1,005 (SD = 195).

Weekly Volume Trends. On average, traffic volumes were highest on Fridays and lowest on Sundays at this site. This was observed for both directions (EB and WB). See Figure 4.47.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.48). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 5, 9, and 6.

Monthly Volume Trends for PVs and HCVs. PVs generally reached peak volume levels in the late spring (May) to late summer months (August), with lowest volumes reported over the winter months (December through February). HCVs also showed the same pattern—highest in the late spring to late summer months, with lowest volumes observed over the winter. These trends make intuitive sense in that these numbers reflect greater recreational travel around the summer time, with decreased travel over the winter (due to poorer roadway conditions (i.e., ice, snow)). See Figure 4.49.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.50). On an average 24-hour day, EB PVs gradually increased in volume over the day, with peak volumes coinciding with afternoon rush hour times. WB PVs on the other hand displayed two distinct volume peaks—one coinciding with morning rush hour (6 am – 9 am), and the other with afternoon rush hour (2 pm – 6 pm).

EB and WB HCVs had similar volume profiles over an average 24-hour day at this site. However, peak HCV volume times differed slightly in that EB HCVs peaked slightly earlier and for a shorter period (8 am – 12 pm), while WB HCVs peaked a little later but for a slightly longer period of time (9 am – 3 pm).

WIM #37

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.51 from 2010-2013. Highest ADTs were generally coincided with late spring to early fall months (May-September), with lowest monthly ADTs observed during winter months (December-February). Monthly HCADT patterns were relatively similar to those observed with overall ADTs: peak levels observed from summer to early fall (June-October), with lowest values observed over the winter (December-February). Mean values for monthly ADT and monthly HCADT were respectively at 27,525 (SD = 2965) and 3,578 (SD = 391).

Weekly Volume Trends. On average, traffic volumes were highest on Fridays and lowest on Sundays at this site. These observations were based on traffic in the WB direction (in-pavement WIM only exists in the WB lanes at this site). See Figure 4.52.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.53). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 6.

Monthly Volume Trends for PVs and HCVs. In general, PVs reached peak volume levels in the late spring (May) to late summer months (August), with lowest volumes coinciding with winter months (December through February). HCV classes generally followed one of two volume patterns: one that mirrored the PV volume trends (a late spring to late summer volume peak), or a more delayed volume peak that typically went from the middle of summer (July) to late fall (October). Of the HCVs, there were a couple classes that did not fit either of these two patterns—most noticeably in Classes 10 and 11. While these two classes showed a fall peak, there also was another volume peak in the late winter (March) to late spring/early summer (June), with a decrease between the two volume peaks (decrease over the summer months). See Figure 4.54. Due to the monthly variability in volume across the years, it will be important to collect further data to better understand underlying traffic patterns.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.55; note that data collection at this site was confined to the WB direction). WB PVs gradually increased in volume over the day, with highest numbers coinciding with afternoon rush hour times. WB HCVs, in contrast, tended to peak earlier during midday (~10 am – 3 pm).

WIM #38

[Prior to discussing monthly trends at WIM #38, the reader should be aware that there was construction nearby on I-35 during the summer of 2010 and 2011. In addition, bridge painting occurred on the Blatnik Bridge (near which the WIM is located) in the summer of 2012, which also significantly affect traffic volumes. Volume data coinciding with these time frames, while valid, were not considered into the interpretation of trends discussed below.]

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.56 from 2010-2013. Highest monthly ADTs were generally observed from spring to early fall (May-September), with lowest monthly ADTs coinciding with winter months. In contrast, monthly HCADT values were highest a little later in the season, typically from summer to fall (July-October). Lastly, monthly HCADT lows generally extended from the winter into early spring (December-April). Mean values for monthly ADT and monthly HCADT were respectively at 26,285 (SD = 4458) and 1,620 (SD = 218).

Weekly Volume Trends. On average, traffic volumes were highest on Fridays and lowest on Sundays at this site. This was observed for both directions (NB and SB). See Figure 4.57.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.58). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 6.

Monthly Volume Trends for PVs and HCVs. Monthly trends for PVs and HCVs were somewhat more difficult to ascertain with a high degree of confidence. When one ignores the data from summer 2010, many of the generalizations made about the monthly trends are made based on two yearly data points per month (see Figure 4.59). In addition, the months that only contained the two yearly data points happened to coincide with the summer and fall months—the time period when one is most likely to observe the highest volume concentrations over a calendar year (if such a pattern were to truly exist at this particular site). To further complicate the matter, the months that have two remaining data points do not always show similar numerical values across the two years, which reduces interpretive power even more. Despite these limitations, there does seem to be some indication of an increase in PVs over the summer months (June through September), with some attenuation of PV volume over the winter (based on the average of 2-3 data points per month, excluding summer 2010 data). Some HCV classes also showed a similar volume peak in the summer months (June through September) like the PVs, while other HCV classes (due to wider variability in data points within a given month) showed a more uniformly distributed volume profile across all months. Further data collection is warranted to better understand underlying monthly patterns at this site.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.60). NB and SB PVs had similar volume profiles over a typical 24-hour day. A rapid increase in PV volumes coincided with morning rush hour times as well as with afternoon rush hour times.

HCVs traveling in either direction had similar volume profiles over a typical 24-hour period with the following exception: NB HCVs tended to peak earlier but for a shorter period of time (8 am – 12 pm), while SB HCVs peaked a little later but for a more sustained period of time (9 am – 3 pm).

WIM #39

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.61 from 2010-2013. Highest monthly ADT values were observed generally from late spring to early fall (May-October), with lowest ADTs observed over the winter months (December-February). Monthly HCADT values, in contrast, showed a unique pattern of its own—something quite different from overall ADT patterns. Monthly HCADT patterns showed two distinct HCADT peaks—one in the spring (April-June) and the other in the fall (October-November). Therefore, monthly HCADT patterns at this site appear to differ considerably from most other WIM sites. One industry that is known to heavily use the roadway in which this WIM is situated is the frac sand mining industry. Perhaps some of the unique patterns shown in the monthly HCADT patterns are a reflection of the activities found in that industry within Minnesota. Mean values for monthly ADT and monthly HCADT were respectively at 10,610 (SD = 1015) and 617 (SD = 143).

Weekly Volume Trends. On average, traffic volumes were highest on Fridays and lowest on Sundays at this site. This was observed for both directions (NB and SB). See Figure 4.62.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.63). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 6.

Monthly Volume Trends for PVs and HCVs. PVs, particularly Class 2s and 3s, reached highest volumes between spring (May) and the fall (October), with lowest volumes reported over the winter months (December through February). In contrast, monthly trends were more difficult to ascertain with Class 1s due to high variability and low reliability in the data across the 4 years' worth of data collection. While this variability in the Class 1 data may reflect the true underlying traffic patterns at this site, current speculation leans toward a need to better refine the classification algorithm to better capture Class 1s.

HCVs typically showed one of three different volume trends in a typical calendar year: 1) a general volume peak extending roughly from spring (May) to fall (November), with lowest volumes observed over the winter (December through February), 2) a twice-yearly volume peak (specifically Class 9s and, to a lesser extent, the Class 10s)—once in the spring (April) to early summer (June), with the next peak occurring in the fall (October through November), or 3) some HCV classes that showed less variation in numerical volume across the calendar year. See Figure 4.64.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.65). On an average 24-hour day, NB PVs typically increased in volume over the day, with peak volume times coinciding with afternoon rush hour times. SB PVs, however, reached peak volumes during morning rush hour, with PV volumes leveling off for the remainder of a typical business day.

HCVs traveling in either direction exhibited a very similar volume trend over a typical 24-hour day, with peak volume levels occurring from 9 am – 3 pm.

WIM #40

[Prior to discussing WIM #40 data, the reader should keep in mind that most of the data included here coincides with construction of the new Lafayette Bridge (project is scheduled from 2011-2015). It is expected that the bridge construction will have affected commuter route volumes and truck volumes (due to truck length restrictions) on US 52). While volume data may not necessarily look atypical during these years (due to volume imputation procedures), other types of data may show some atypicality due to the construction (e.g., weight data).]

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.66 from 2010-2013. Monthly ADT values were relatively similar across all months except for the winter. While monthly ADT values varied little from spring to mid-fall (March-November), ADT values were slightly lower in the winter (December-February). HCADT patterns also varied little across months. However, highest HCADT values were observed in the late summer to mid-fall (August-November), with lowest HCADTs observed over the winter (December-February). Mean values for monthly ADT and monthly HCADT were respectively at 53,541 (SD = 4971) and 3,454 (SD = 801).

Weekly Volume Trends. On average, traffic volumes were highest on Fridays and lowest on Sundays at this site. This was observed for both directions (NB and SB). See Figure 4.67.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.68). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 6.

Monthly Volume Trends for PVs and HCVs. PVs with the exception of Class 1s tended to show an increase in volume starting around late winter/early spring (March), with volumes significantly dropping in the fall (October/November). This contrasts with other WIM sites in that most other sites start to significantly rise in volume a little later (generally mid to late spring at the earliest). However, it should be noted that the monthly numerical volumes at this site were not consistent over time, which currently limits interpretive power. Class 1 volumes showed trends indicative of a significant increase in the spring (May/June) and up through August—a more restricted peak range than the other two PV classes. See Figure 4.69.

HCV vehicle classes widely varied when examining volume trends at the monthly level. In some HCV classes, they showed a noticeable increase in volume starting the spring (anywhere between March and June), which was generally sustained through the fall (October). For some other HCV classes, there didn't necessarily seem to be a seasonal change in volume—rather, volume peaks and troughs cycled more quickly over a 12-month period (i.e., Classes 8 and 9). These conclusions are based on averaged monthly volume levels, meaning that these estimations are susceptible to variability in the data.

Hourly Volume Trends for PVs and HCVs. PV and HCV volumes were investigated at an hourly level (see Figure 4.70). On an average 24-hour day, NB PVs reached peak volume levels at morning rush hour, with another (smaller) volume peak coinciding with afternoon rush hour times. SB PVs, however, typically increased in volume over the day, with peak volumes coinciding with afternoon rush hour.

HCVs traveling in either direction exhibited nearly identical volume trends over a typical 24-hour day, with peak volume levels occurring from 8 am – 1 pm.

WIM #41

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.71 from 2010-2013. The roadway on which WIM #41 is situated is heavily used by a sugar beet factory located north of the WIM, particularly in October of each year. Therefore, it is not surprising to see that ADT values have been consistently at highest levels in the month of October each year (months flanking October also show some elevation in traffic activity that is probably related to the sugar beet industry as well). The same pattern is reflected in the monthly HCADT numbers as well (highest in October). Mean values for monthly ADT and monthly HCADT were respectively at 488 (SD = 221) and 123 (SD = 164).

Weekly Volume Trends. On average, traffic volumes were highest on Wednesdays and lowest on Sundays at this site. This was observed for both directions (NB and SB). See Figure 4.72. These weekly volume patterns deviate from all other sites, most likely due to the high traffic volumes that occur for the sugar beet harvest in October of each year—these volumes may be high enough to shift the mean to conform to patterns most often observed during the sugar beet harvest.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.73). Interestingly, although Class 2s and Class 3s contributed the most to total volume, this is the only site in which the number of Class 3s exceeds the number of Class 2s. Following those two classes, the next highest contributors to total volume are HCVs belonging to Classes 9, 10, and 5.

Monthly Volume Trends for PVs and HCVs. PVs (particularly Class 2s and 3s) generally reached highest volumes in the late summer (August) through fall (October). Class 1 volume patterns were slightly different in that a moderate volume increase started in the spring (May), with peak volume levels occurring in September.

Sugar beet farming is very big in the fall around Crookston, particularly in October of each year. With WIM #41 being on a roadway heavily used for transporting sugar beets, it directly impacts the amount of HCVs that pass through during that time. More specifically, the following HCV classes showed a significant increase in volume during October: Classes 4, 6, 7, 9, and 10. This suggests that these particular vehicle classes are most heavily involved in the transportation associated with the sugar beet industry (i.e., the actual movement of sugar beets from one location to another, the movement of equipment and personnel associated with the sugar beet harvest, etc.). The other, remaining HCV classes (except for Class 13s) generally showed a volume increase that started in the summer and lasting into the fall. Class 13s, on the other hand, generally started to increase in volume during the fall and maintain those elevated levels through winter (the particular industry that influences the movement of Class 13s here is unclear). See Figure 4.74.

Hourly Volume Trends for PVs and HCVs. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.75). NB PVs reached peak volumes during morning rush hour, with PV volumes leveling off for the remainder of the business day. In contrast, SB PVs generally increased in volume over the day, with peak volume levels coinciding with afternoon rush hour.

HCVs traveling in either direction exhibited very similar volume trends over a typical 24-hour day, with peak volume times generally occurring during typical business hours (~9 am – 5 pm).

WIM #42

Monthly ADT and HCADT. [Note: WIM #42, along with WIM #43, came into existence last out of all of the WIMs from 2010 - 2013. Therefore, the amount of data that is available to draw inferences from is more limited compared to most other WIMs. The inferences that are drawn at the monthly-level are generally limited to one data point per month.]

ADT and HCADT were calculated each month, and these values are represented in Figure 4.76 from 2012-2013. Although neither year (2012 or 2013) has a complete set of traffic data over a calendar year, trends from the two years suggest that highest ADT levels occur in the spring to summer months (May-August), with lowest ADTs observed in the winter. This trend is mirrored in the HCADT data: highest HCADT values in the spring through summer, and lowest in the winter. Mean values for monthly ADT and monthly HCADT were respectively at 29,102 (SD = 2524) and 1,355 (SD = 180).

Weekly Volume Trends. On average, traffic volumes were highest on Fridays and lowest on Sundays at this site. This was observed for both directions (NB and SB). See Figure 4.77.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.78). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 6.

Monthly Volume Trends for PVs and HCVs. Monthly trends at this site are based on available data from 2012 and 2013, as well as knowledge from other sites that share similar characteristics with WIM #42. Since WIM #42 is 1) a relatively high volume site, 2) within the metropolitan area, and 3) a suburb that contains a good number of residential neighborhoods, we may be able to draw further inferences from other WIMs that share such characteristics (high traffic volume, in metro area, a suburb).

Based on available data (see Figure 4.79), PVs generally started showing an increase in volume starting in the spring (May). Assuming that WIM #42 is somewhat similar to other high volume, urban sites, it is probable that that increase is generally maintained through the middle of summer (July), with available data suggesting a decline in volume starting in the fall (October/November).

For HCVs, available data suggests that this site experiences an increase in volume in the spring (May). If WIM #42 exhibits similar traffic patterns as other high volume, in-metro sites, the volume increase in spring may generally also be maintained through at least the middle of summer (July), with available data at WIM #42 possibly suggesting a decline in volume starting around the fall (November). It should be mentioned that the inferences drawn about volume trends in the late summer to early fall were complicated by the fact that 2012 and 2013 data weren't always consistent during those times (roughly August to December).

Hourly Volume Trends for PVs and HCVs. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.80). On an average 24-hour day, NB PVs showed two time periods in which traffic volumes were highest, the first occurring during morning rush hour and the latter occurring during afternoon rush hour. In contrast, SB PVs generally increased in volume over the day, with peak volume levels coinciding with afternoon rush hour.

NB and SB HCVs generally had relatively similar volume profiles over an average 24-hour day except on a few minor points. While HCV volumes were lowest during overnight hours (as is typical of all current roadways with WIMs), NB HCVs increased in volume more rapidly in the early morning (especially from 5 am – 7 am) compared to SB HCVs. Furthermore, NB HCVs generally maintained peak volume levels for a slightly longer period of time (9 am – 3 pm) compared to SB HCVs (peak volume times from 9 am – 1 pm). Overall, any differences in HCV volume trends were relatively minimal between the NB and SB directions.

WIM #43

Monthly ADT and HCADT. ADT and HCADT were calculated each month, and these values are represented in Figure 4.81 from 2012-2013. Assuming that 2013 data is a representative sample of the true, underlying traffic patterns at this site, highest ADT values are observed in the spring to early fall (May-September), with lowest ADTs observed during the winter (December-March). A similar pattern is observed with monthly HCADTs: highest in the spring to fall (May-October), with lowest HCADTs observed in the winter months. Mean values for monthly ADT and monthly HCADT were respectively at 15,333 (SD = 2330) and 1,336 (SD = 344).

Weekly Volume Trends. On average, traffic volumes going EB were highest on Fridays and lowest on Sundays at this site. In contrast, while WB traffic volumes were also highest Fridays, lowest volumes were reported on Saturdays. See Figure 4.82.

Vehicle Class Composition. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.83). On average, Class 2s and Class 3s contributed the most to total volume, followed by HCVs belonging to Classes 9, 5, and 10.

Monthly Volume Trends for PVs and HCVs. Data collection at WIM #43 began later in the 2010 -2013 period, with a total of 15 monthly data points collected over this time period. Therefore, similar to the challenges posed in interpreting monthly trends at WIM #42, the same issues exist here (i.e., making inferences about the site based on 1-2 monthly data points).

According to available data, PVs generally increased in volume between the spring (May) to late summer/early fall (September), with Class 1s specifically showing a more restricted peak during this time (generally from June through August). PV volumes were lowest in the winter (December through February). See Figure 4.84.

HCVs typically showed one of two different trends across the calendar year: 1) a volume peak between spring (May) and fall (October), or 2) a similar pattern as the first except that it also contained a more drastic volume increase in November.

Hourly Volume Trends for PVs and HCVs. Vehicle classes were examined by their overall contribution to total volume (see Figure 4.85). Over a typical 24-hour day, EB PVs gradually increased in volume over the day, with peak volume levels coinciding with afternoon rush hour. In contrast, WB PVs reached peak volume times during morning rush hour, with PV volumes leveling off for the remainder of the business day.

EB and WB HCVs generally exhibited similar volume trends for a typical 24-hour period, with highest volume concentrations generally coinciding with typical business hours (~8 am – 5/6 pm). Of the two HCV distributions, EB HCV numbers tended to decrease more rapidly over the tail-end of business hours.

Conclusions

Monthly ADT and HCADT

Monthly patterns in ADTs and HCADTs generally mirrored each other for many of the WIM sites (this is expected due to the fact that monthly calculations of ADT include heavy commercial traffic). In addition, many WIM sites exhibited similar seasonal changes in ADT and HCADT. More specifically, the monthly highs in ADTs and HCADTs often coincided with the summer months, with these highs occasionally starting in mid-spring (typically May) and/or extending into the fall (typically into September or October). A few sites more noticeably deviated from this common pattern, however, particularly in the analysis of the HCADT data. These sites were WIMs #33, #39, and #41.

Atypical HCADT patterns. WIMs #33, #39, and #41 had atypical HCADT patterns that deviated from the more typical high-summer/low-winter HCADT pattern. Furthermore, none of these three sites shared the same monthly HCADT pattern—they were uniquely different from each other. WIM #33 deviated from the more common high-summer/low-winter pattern because, while seasonal HCADT values were highest in the fall (September-November), the seasonal HCADT lows occurred during the spring to early summer months (May-July). In other words, HCADT values were typically higher in the winter months than in the spring/early summer. This may be tied to the type of industry utilizing the roadway on which WIM #33 is located (agriculture, particularly corn and corn-based products). WIM #39, on the other hand, had two distinct HCADT volume highs— one coinciding with early-to-mid spring (April-June) and the other in the fall (October-November). Some of this HCADT pattern at WIM #39 may be tied to the frac sand mining industry as well as the river barge shipping patterns in Winona, MN. Lastly, WIM #41 showed a sharp HCADT increase in October which coincided with the sugar beet harvest occurring at that time. Overall, this highlights a need to better identify the industries utilizing the roadways on which all WIMs are situated. Achieving such a goal would allow traffic data analysts to identify whether particular industries have a specific pattern of traffic movement. Such knowledge would allow analysts to potentially be able to predict the type of industries utilizing 'new' roadway segments based on traffic patterns (e.g., monthly HCADT patterns).

Weekly Volume Trends

Weekly volume trends did not vary widely from site to site. For example, 16 out of 17 WIMs had highest weekly volumes falling on Fridays. The only site that did not follow this pattern was WIM #41 (weekly high fell on Wednesdays). However, on account of how the average weekly volume trends are derived, it is possible that the patterns derived from the averaging process may have conformed to times of the year when volumes were significantly higher (it is well known that means are highly sensitive to outliers in data). For example, volumes significantly increase during the sugar beet harvest—so much so that volumes during this time (particularly in October of each year) could be said to be an outlier compared to other data points from the remainder of the calendar year. This potential issue draws attention to the fact that it will be important in the future to compute weekly volume trends by season rather than at annual level.

Vehicle Class Composition

While total traffic volumes varied across site, a few consistent things emerged regardless of site when examined at the level of vehicle class. For example, Classes 2 and 3 consistently appeared to contribute the most to total volume. One interesting finding amongst this trend was that, while all WIMs reported more Class 2s than Class 3s, WIM #41 showed the opposite pattern. After the Class 2s and 3s, HCV classes were the next biggest contributors to total volume.

Out of all HCV classes, Class 9 vehicles consistently contributed the most to total volume at all WIMs (except WIM #36). In addition, when determining the top 3 HCV classes that contributed to total volume, the majority of the WIMs fell into one of two categories—either a top 3 of Classes 9, 5, and 6, or a top 3 of Classes 9, 5, and 10 (see Table 4.1).

Top 3 HCV Classes Contributing to Total Volume (From Most to Least)	# of WIMs (out of 17)
9, 5, 6	8
9, 5, 10	6
9, 5, 8	1
9, 10, 5	1
5, 9, 6	1

Table 4.1. A categorical list of the top 3 HCV classes contributing to total volume, with the number of WIMs that fall into each category.

Distribution of HCVs in Driving and Passing Lanes (4-Lane, 2-Direction Sites)

The distribution of HCVs in the driving and passing lanes was explored as a function of WIM location (urban vs. rural areas). Data showed that a greater percentage of HCVs utilize the driving lanes in rural areas[7] compared to urban areas[8]. While, approximately 87.0% of HCVs occupy the driving lanes (13.0% in passing lanes) in rural areas, 76.5% of HCVs occupy the driving lanes (23.5% in passing lanes) in urban areas. These findings may, in part, be explained by the amount of traffic passing through these roadways at the WIMs. HCVs may be more likely to utilize the passing lanes to a greater degree on roadways with greater traffic volumes (typically urban sites). In the future, it may be interesting to observe dynamic changes in the distribution of HCVs in the driving and passing lanes over a 24-hour day.

It should also be noted that the HCV lane usage disparity (greater usage of driving lanes than passing lanes) is not as pronounced at WIM #38 compared to other WIMs. This is because the traffic characteristics in the NB direction are somewhat unique at the location of the WIM itself. As vehicles travel NB into Minnesota from Wisconsin on I-535, the drivers have to make a decision about whether they are heading into Duluth or towards Minneapolis/St. Paul. By the time the vehicles are passing the WIM, most vehicles have strategically aligned themselves in either the NB driving lane or passing lane—the former of which leads into Duluth, with the latter becoming the exit to head towards Minneapolis/St. Paul.

For site-specific information on the distributions of HCVs in driving and passing lanes, refer to Table 4.2.

[7] The following WIMs are in rural areas: 26, 27, 29, 30, 31, 32, 35, 37, and 43.
[8] The following WIMs are in urban areas: 36, 38, 40, and 42.

WIM #	Roadway	Nearest City	Year	Heavy Commercial Vehicles in Driving Lane (%)	Heavy Commercial Vehicles in Passing Lane (%)
26	I-35	Owatonna	2010	88.7%	11.3%
			2011	90.7%	9.3%
			2012	90.8%	9.2%
			2013	90.4%	9.6%
27[a]	MN 60 (EB)	St. James	2010	88.2%	11.8%
29	US 53	Cotton	2010	90.9%	9.1%
			2011	90.8%	9.2%
			2012	91.0%	9.0%
			2013	91.3%	8.7%
30	MN 61	Two Harbors	2012	94.0%	6.0%
			2013	90.1%	9.9%
31	US 2	East Grand Forks	2010	92.0%	8.0%
			2011	91.4%	8.6%
			2012	92.7%	7.3%
32	US 52	Oronoco	2012	77.8%	22.2%
			2013	82.8%	17.2%
35	US 2	Bagley	2010	89.7%	10.3%
			2011	78.2%	21.8%
			2012	90.5%	9.5%
			2013	81.3%	18.7%
36	MN 36	Lake Elmo	2010	73.0%	27.0%
			2011	71.4%	28.6%
			2012	73.4%	26.6%
			2013	74.1%	25.9%
37[a]	I-94 (WB)	MnROAD	2010	77.9%	22.1%
			2011	77.4%	22.6%
			2012	78.7%	21.3%
			2013	78.1%	21.9%

[a] Data collection only occurs in one direction of travel at these WIM sites

Table 4.2. Percentage of heavy commercial vehicles in driving and passing lanes at 4-lane, 2-direction WIM sites.

WIM #	Roadway	Nearest City	Year	Heavy Commercial Vehicles in Driving Lane (%)	Heavy Commercial Vehicles in Passing Lane (%)
38	I-535	Duluth	2010	58.0%	42.0%
			2011	67.4%	32.6%
			2012	57.6%	42.4%
			2013	54.5%	45.5%
40	US 52	South St. Paul	2010	78.9%	21.1%
			2011	82.3%	17.7%
			2012	80.7%	19.3%
			2013	81.5%	18.5%
42	US 61	Cottage Grove	2012	74.5%	25.5%
			2013	74.9%	25.1%
43	US 10	Moorhead	2012	88.4%	11.6%
			2013	87.4%	12.6%

Table 4.2 (cont.). Percentage of heavy commercial vehicles in driving and passing lanes at 4-lane, 2-direction WIM sites.

Monthly Volume Trends for PVs and HCVs

When monthly volumes were examined for seasonal trends across a calendar year, a few general patterns emerged. For example, volumes were generally highest over the spring to fall months, with each site showing some variation in the length of those volume peaks within that time range. Lowest volumes, on the other hand, were generally demonstrated over the winter months (generally December through February). The increase in volume observed over the late spring to early fall months is thought to coincide with greater recreational travel for PVs, along with greater freight movement in the HCVs. In contrast, decreased recreational travel and freight movement is thought to explain lower volumes over the winter months. Despite these general trends, it is also important to highlight some cases that made monthly interpretations more difficult. Two such cases are highlighted below.

First, it should be mentioned that there was a significant increase in monthly Class 1 volumes starting from September 2011 and on (the reader will find visual evidence of this change when looking at the monthly volume figures). This observation was noted after compiling all monthly, numerical volume data that was available at each site. While the cause of this increase in Class 1s in unknown, it most likely is a better representation of Class 1 volumes than before September 2011. On any future annual reports, it may be advisable to not include Class 1 data prior to September 2011 to avoid introducing statistical noise into future analyses and interpretation of the data.

Secondly (and most importantly), there is the issue of variability in the data, particularly when the goal is to examine data at the *monthly* level. At most, any one month can only have up to 4 data points to draw conclusions from (one data point per month for each year of observation). When one of the goals is to look for monthly/seasonal trends across the years, a high degree of variability in the data significantly reduces interpretive power. To reduce such problems with data interpretation, the following suggestions are proposed. Firstly, greater attempts must be made to control for the quality of the data. Secondly, once better quality checking methods are implemented, increasing the sample size will help with more accurate interpretations of time series data. Thirdly, if there are any concerns with the vehicle classification algorithm, the algorithm itself should be refined to better capture vehicles into their respective classes. Lastly, certain data points—while valid—may benefit from a discussion on whether they should be discarded prior to any analysis of the data itself. A good example of this is data that is affected by roadway construction. Volume data will show atypical patterns when construction is underway. While this data is valid, it can introduce noise in interpreting the true, underlying traffic patterns at a given site. Whether to remove atypical/abnormal data points may depend on objectives of the analysis itself. If the goal is to understand typical traffic patterns at a site, then removing atypical data points will better capture the true traffic patterns. In contrast, keeping these atypical data points in the analysis can provide some measure of residual error (particularly if used for modeling purposes).

Hourly Volume Trends for PVs and HCVs

Although there were some hourly differences in traffic patterns across the different WIMs, a few different types of patterns tended to emerge independent of site. Firstly, in many of the sites capturing data from two directions (e.g., NB and SB or EB and WB), at least one of the directions tended to have a very distinct, sharp volume increase that coincided with afternoon rush hour times. If this was observed in one direction, the other direction often showed one of two things 1) increased volume levels coinciding with morning and afternoon rush hour times, or

2) a volume peak that was more widely distributed over typical business hours. In either case, one direction generally tended to have a highly-defined afternoon rush hour peak. It would be interesting to explore in the future whether there are any underlying factors contributing to one type of hourly trend over another. HCV hourly volume trends appeared to be less varied than PV hourly volume trends. Generally speaking, HCVs tended to reach peak volume levels during typical business hours.

5. GROSS VEHICLE WEIGHT

This section summarizes the gross vehicle weight (GVW) trends observed from 2010-2013, with the amount of data available during this time varying by site. MnDOT measures GVWs in kips (1 kip = 1,000 pounds). Factors affecting data availability during this time frame depend on multiple factors including 1) the WIM installation date and initial calibration (not all WIMs were installed and calibrated at the same time), 2) operational status of the system, and 3) the validity of the data collected (which is primarily dependent on data quality).

One particular point should be introduced prior to the discussion of GVW data for each WIM. It can generally be assumed that monthly GVWs will be higher for months that also experienced higher traffic volumes (each vehicle carries some weight—the more vehicles there are traveling in a month, the higher the monthly total GVW should generally be). This assumption should roughly apply to all vehicle classes, meaning that there should be a positive correlation between monthly volumes and monthly GVWs. While this assumption has been confirmed for all WIMs[9] (discussed within the "Monthly Trends" subsection; results from Pearson product-moment correlations), there are a small number of cases in which this assumption was unsupported (cases in which increases in monthly volume were not associated with increases or decreases in monthly GVWs). Such an analysis, when performed separately for each vehicle class, is potentially interesting because a lack of a positive correlation (between monthly volumes and GVWs) may indicate a need to further examine the vehicles included in that vehicle class (i.e., investigate whether vehicles are being classified correctly into their respective vehicle class). It could also be an indication that not all monthly data points included in the analysis are valid, meaning that considerable noise may have been included in the analysis.

WIM #26

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.1). Out of all vehicle classes, Class 9s contributed the most to total GVW (64.5%) followed by Class 2s (13.1%) and Class 3s (10.0%). The remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. PVs typically reached peak GVWs during late spring (May) to early fall (September), with lowest GVWs observed over the winter (December through February). A similar GVW trend was also observed across the HCVs—highest between late spring to early fall, and lowest GVWs over the winter. See Figures 5.2a-5.14a for monthly GVW data.

Pearson product-moment correlations were conducted to address whether there is a relationship between monthly volumes and monthly GVWs. Results suggested that monthly changes in GVWs were positively correlated with monthly changes in volume (see scatterplots in Figures 5.2b-5.14b). As traffic volumes increased, GVWs generally increased as well.

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[9] Pearson product-moment correlations were conducted separately for each vehicle class between monthly traffic volumes and monthly GVWs (α-level = .05). Scatterplots representing the relationship between monthly volumes and GVWs are included in the figures for each vehicle class, with data points color-coded by season (fall, spring, summer, and winter). "Season", as defined in these scatterplots, is based on professional judgment of traffic patterns in Minnesota (as opposed to seasonal boundaries set by the Gregorian calendar).

WIM #27

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.15). Out of all vehicle classes, Class 9 vehicles contributed the most to total GVW (56.0%) followed by Class 2s (18.6%) and Class 3s (14.2%). The remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. PVs typically reached highest GVW levels starting in the spring (May) and until early fall (October). On the other hand, GVWs for HCVs tended to vary by vehicle class. Many HCV classes showed GVW peaks from spring to early fall, with some peaking at highest levels in October. See Figures 5.16a-5.28a.

Due to the relative sparsity of monthly data points (n=8), correlational tests were not performed to ascertain the relationship between monthly volumes and GVWs. However, many of the vehicle class scatterplots (see Figures 5.16b-5.28b) seem to indicate that a positive relationship may exist between monthly volumes and GVWs. Some exceptions to that may be Classes 1 and 12. The scatterplot of Class 1 data (see Figure 5.16b) suggests issues with data validity. For example, several data points are reflective of little-to-no monthly volume while still also reporting GVWs in the several thousand kips. It is quite possible that some of these data points are capturing something other than (or in addition to) Class 1s. Additionally, Class 12s don't appear to show much of a relationship between monthly volumes and GVWs (see Figure 5.27b)—further examination will be warranted after further data collection.

WIM #29

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.29). Out of all vehicle types, Class 9 vehicles contributed the most to total GVW (32.0%) followed by Class 2s (25.4%) and Class 3s (20.8%). The next highest GVW contributors were the Class 10s (10.5%) and Class 5s (5.9%). All other, remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. All PVs generally reached highest volumes starting in the late spring/early summer (June) to early fall months (September). In contrast, HCV volume trends tended to differ slightly based on the vehicle class, although many also showed a similar increase in volume coinciding with the summer months (see Figures 5.30a-5.42a).

Pearson product-moment correlations were conducted to address whether there is a relationship between monthly volumes and monthly GVWs. Results suggested that monthly changes in GVWs were positively correlated with monthly changes in volume (see scatterplots in Figures 5.30b-5.42b) for all vehicle classes with the possible exception of Class 11s. In other words, increases in monthly volume were typically associated with increases in GVWs for all vehicle classes except for Class 11s. If the lack of a positive relationship persists with more data collection, it will be interesting to examine reasons underlying this non-relationship at this specific site (i.e., better examination of Class 11 data).

WIM #30

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.43). Out of all vehicle classes, Class 2 vehicles contributed the most to total GVW (37.2%) followed by Class 3s (29.2%) and Class 9s (19.0%). The remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. Based on roughly one year's worth of data collection from 2010-2013, PVs reached highest GVWs in the late spring/early summer (June) to fall (October). The majority of the HCVs also exhibited a similar GVW trend as the PVs except for Classes 10, 12, and 13. Class 10s generally stayed within a relatively narrow GVW range for most of the calendar year except from April to May (significant drop in GVWs during those two months). In contrast, Classes 12 and 13 exhibited a sharp rise in GVWs in July. See Figures 5.44a-5.56a.

Due to the relative sparsity of monthly data points (n=13), correlational tests were not performed to ascertain the relationship between monthly volumes and GVWs. However, all of the vehicle class scatterplots (see Figures 5.44b-5.56b) seem to visually indicate that a positive relationship may exist between monthly volumes and GVWs; further data collection should help to address this question in the future.

WIM #31

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.57). Out of all vehicle classes, Class 2 vehicles contributed the most to total GVW (36.4%) followed by Class 3s (24.6%) and Class 9s (20.5%). The next highest GVW contributor was the Class 10s (8.7%). All other, remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. [Monthly data at this site showed one unusual data point that is most likely anomalous, specifically June 2010 GVW data (see Figures 5.58a-5.70a; some vehicle classes clearly show the atypicality of June 2010 data). Any statements that follow regarding monthly GVW trends at this site will not include June 2010 into consideration (although the data point will still remain in the figures.]

PVs generally attained peak GVWs from the spring (May) until the fall (October), with Class 1s showing a narrower peak range within that time frame. While HCV classes varied in monthly trends, many HCV classes also showed similar GVW peaks occurring within the same general time range as the PVs—highest from spring (May) through fall (October). See Figures 5.58a-5.70a.

Due to the relative sparsity of monthly data points (n=24), correlational tests were not performed to ascertain the relationship between monthly volumes and GVWs. However, the majority of the vehicle class scatterplots (see Figures 5.58b-5.70b) seem to visually indicate that a positive relationship may exist between monthly volumes and GVWs. Therefore, increases in monthly GVWs were associated with increases in monthly traffic volumes.

WIM #32

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.71). Out of all vehicle classes, Class 9 vehicles contributed the most to total GVW (41.1%) followed by Class 2s (29.9%) and Class 3s (17.4%). The remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. Based on 16-months' worth of data collection from 2010-2013, PVs generally reached peak GVW levels between late spring (May/June) to late summer/early fall (September). Although HCVs were somewhat more varied than PVs, HCVs generally also reached peak GVW levels within that same time frame. See Figures 5.72a-5.84a.

Due to the relative sparsity of monthly data points (n=16), correlational tests were not performed to ascertain the relationship between monthly volumes and GVWs. However, all of the vehicle class scatterplots (see Figures 5.44b-5.56b) seem to visually indicate that a positive relationship may exist between monthly volumes and GVWs; further data collection should help to address this question in the future.

WIM #33

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.85). Out of all vehicle classes, Class 9 vehicles contributed the most to total GVW (41.2%) followed by Class 2s (18.7%) and Class 3s (17.2%). The next highest GVW contributor was the Class 10s (13.8%). All other, remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. GVW trends differed slightly across the three PV classes. While all three PV classes generally reported highest GVWs in August, the GVW profiles across all 12-months were not identical across the three PV classes (particularly when comparing Class 1s against the other two classes). See Figures 5.86a-5.98a. For HCVs, GVW trends varied widely as a function of vehicle class (see Figure 4.20). Generally, however, HCV GVW trends fell into one of three patterns: 1) highest GVWs observed during the late spring (May) to early fall (Sept), 2) peak levels observed during the fall through winter (roughly September to March, which coincides with peak times for sugar beet processing around this region. West of Olivia is Danube, MN which is home to the Southwest Minnesota Sugar Beet Cooperative), or 3) a peak in GVWs during the late summer into fall (August to October). These generalizations, however, are somewhat limited when considering the wide variability in the data points across the years.

Pearson product-moment correlations were conducted to address whether there is a relationship between monthly volumes and monthly GVWs. Results suggested that monthly changes in GVWs were positively correlated with monthly changes in volume (see scatterplots in Figures 5.86b-5.98b) for all vehicle classes with the possible exception of Class 13s. In other words, increases in monthly volume were generally associated with increases in GVWs for all vehicle classes except for Class 13s. The Class 13 scatterplot (Figure 5.98b) clearly shows no relationship between monthly volumes and GVWs; increases in GVW are not associated with increasing numbers of Class 13 vehicles. This suggests a potential need to further examine the vehicles that were categorized as Class 13 vehicles, at least at this site.

WIM #34

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.99). Out of all vehicle classes, Class 9 vehicles contributed the most to total GVW (44.3%) followed by Class 2s (19.8%) and Class 3s (19.5%). The next highest GVW contributor was the Class 10s (5.4%). All other, remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. PVs typically reached highest GVWs in the late spring (May) through early fall (October). HCVs generally reported higher GVWs in the spring (May/June) to fall (October/November) than in the winter months, with some variation in GVW trends within that time frame. See Figures 5.100a-5.112a.

Pearson product-moment correlations were conducted to address whether there is a relationship between monthly volumes and monthly GVWs. Results suggested that monthly changes in GVWs were positively correlated with monthly changes in volume (see scatterplots in Figures 5.100b-5.112b) for all vehicle classes. As traffic volumes increased, GVWs generally increased as well—this was observed in all vehicle classes.

WIM #35

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.113). Out of all vehicle classes, Class 2 vehicles contributed the most to total GVW (30.1%) followed by Class 3s (29.3%) and Class 9s (23.8%). The next highest GVW contributor was the Class 5s (6.1%). All other, remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. GVWs for PVs consistently appeared to reach highest levels over the summer months (between May - September), with lowest volumes observed over the winter months. Although GVW trends varied by HCV class, many HCV classes also showed a similar GVW peak over the summer months, with this peak oftentimes extending into the early fall. See Figures 5.114a-5.126a.

Pearson product-moment correlations were conducted to address whether there is a relationship between monthly volumes and monthly GVWs. Results suggested that monthly changes in GVWs were positively correlated with monthly changes in volume (see scatterplots in Figures 5.114b-5.126b) for all vehicle classes. As traffic volumes increased, GVWs generally increased as well—this was observed in all vehicle classes.

WIM #36

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.127). Out of all vehicle classes, Class 2 vehicles contributed the most to total GVW (55.7%) followed by Class 3s (28.1%) and Class 5s (5.1%). The remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. PVs typically reached peak GVW levels from late spring (May) through summer (August), with lowest GVWs over the winter. HCVs also showed the same GVW trends—highest from late spring through the summer months, with lowest GVWs over the winter. See Figures 5.128a-5.140a.

Pearson product-moment correlations were conducted to address whether there is a relationship between monthly volumes and monthly GVWs. Results suggested that monthly changes in GVWs were positively correlated with monthly changes in volume (see scatterplots in Figures 5.128b-5.140b) for all vehicle classes. Increases in GVWs were generally observed with increases in traffic volumes—this was observed in all vehicle classes.

WIM #37

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.141). Out of all vehicle classes, Class 9 vehicles contributed the most to total GVW (52.4%) followed by Class 2s (21.8%) and Class 3s (13.7%). The remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. With the exception of Class 1s (which showed atypical GVW trends), PVs generally reached peak GVW levels between May and August (summer months). HCV classes showed some variability in GVW trends across months within a calendar year, although many showed some semblance of a summer GVW peak like the PVs. See Figures 5.142a-5.154a.

Pearson product-moment correlations were conducted to address whether there is a relationship between monthly volumes and monthly GVWs. Results suggested that monthly changes in GVWs were positively correlated with monthly changes in volume (see scatterplots in Figures 5.142b-5.154b) for all vehicle classes except Class 13s. In other words, apart from Class 13s, months with higher GVWs were associated with months that also had higher monthly traffic volumes. The lack of a relationship between monthly Class 13 volumes and GVWs suggests a need to further examine the vehicles that were categorized into that vehicle class.

WIM #38

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.155). Out of all vehicle classes, Class 2 vehicles contributed the most to total GVW (36.3%) followed by Class 9s (27.5%) and Class 3s (22.0%). The remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. Apart from Class 1s, PVs generally peaked in GVWs starting around spring (May) until the early fall (September/October) with GVWs roughly staying relatively consistent across the remaining other months. Class 1s showed peak GVW levels starting in the late spring/early summer (June) through early fall (September). Some HCV classes also showed a similar GVW peak in the summer months as the PVs (roughly June through October), while other HCV classes (due to wider variability in data points within a given month) showed a more uniformly distributed GVW profile across all months. See Figures 5.156a-5.168a.

Pearson product-moment correlations were conducted to address whether there is a relationship between monthly volumes and monthly GVWs. With the exception of Class 2s and Class 3s, results suggested that monthly changes in GVWs were positively correlated with monthly changes in volume (see scatterplots in Figures 5.156b-5.168b). Scatterplots for Classes 2 and 3 (see Figures 5.157b-5.158b) both clearly showed a few outliers from 2010 which, if removed from the correlational test, actually shows that Class 2s and 3s both show a positive correlation between monthly volumes and GVWs. Therefore, all vehicle classes at this site effectively appear to show a positive association between monthly volumes and GVWs—increases in GVWs generally coincided with increases in traffic volumes.

WIM #39

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.169). Out of all vehicle classes, Class 2 vehicles contributed the most to total GVW (39.0%) followed by Class 3s (25.5%) and Class 9s (25.3%). The remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. PVs generally showed peak GVW levels starting late winter/early spring (March) to the fall (October/November), with C1s showing a more restricted GVW peak within that time range. Lowest GVW levels for PVs were generally observed over the winter months (December-February). Monthly GVWs of HCVs tended to vary depending on the vehicle class. Some HCVs showed a similar monthly GVW pattern as the PVs, while another group of HCVs tended to have two GVW peaks—one around April/May, the other around October. Finally, another group of HCVs tended to show a more restricted GVW range across all months in a calendar year. See Figures 5.170a-5.182a.

Pearson product-moment correlations were conducted to address whether there is a relationship between monthly volumes and monthly GVWs. With the exception of Class 13s, results suggested that monthly changes in GVWs were positively correlated with monthly changes in volume (see scatterplots in Figures 5.170b-5.182b). While increases in GVWs were generally observed with increases in traffic volumes, this was not the case for Class 13s. Results suggest a possible need to further examine Class 13 vehicle compositions.

WIM #40

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.183). Out of all vehicle classes, Class 2 vehicles contributed the most to total GVW (44.1%) followed by Class 9s (22.7%) and Class 3s (16.6%). The next highest GVW contributor was the Class 5s (5.6%). All other, remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. With the exception of Class 1s, PVs tended to show little variability in monthly GVWs over a calendar year. From March through December, GVWs generally stayed within a restricted numerical range, with slightly lower GVW numbers observed in January and February. Class 1s observed a different monthly pattern—peak GVWs recorded in the spring (May) to early fall (September), with lowest values occurring in the winter. HCVs tended to vary depending on vehicle class. Some HCV classes showed a similar trend as PVs (Class 2s and 3s)—low variation in monthly GVWs over a calendar year with the exception of January and February (when GVWs were slightly lower than the remaining months). Other HCV classes showed greatest GVW levels over the late summer (August) into early fall months (November). See Figures 5.184a-5.196a.

Pearson product-moment correlations were conducted to address whether there is a relationship between monthly volumes and monthly GVWs. Results suggested that monthly changes in GVWs were positively correlated with monthly changes in volume (see scatterplots in Figures 5.184b-5.196b) for all vehicle classes. Increases in GVWs were generally observed with increases in traffic volumes—this was observed in all vehicle classes.

WIM #41

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.197). Out of all vehicle classes, Class 3 vehicles contributed the most to total GVW (28.1%) followed by Class 10s (24.1%) and Class 9s (19.9%). The next highest GVW contributors were the Class 2s (12.7%) and Class 6s (5.3%). All other, remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. Except for Class 1s, PVs generally showed highest GVW levels in the late summer (August) to the fall (October). Class 1 monthly GVW trends were somewhat similar to the other PV classes except that peak GVW levels were attained roughly a month earlier (July to September). Due to the sugar beet industry in this area, several HCV classes showed peak GVW levels in the month of October (historically coincides with greatest sugar beet harvesting activity in this area). Other HCV classes that did not show this pattern (generally those classes that appear to not be heavily utilized for the sugar beet harvest season) typically attained peaked GVW levels between mid-summer (July) and fall (October). See Figures 5.198a-5.210a.

Pearson product-moment correlations were conducted to address whether there is a relationship between monthly volumes and monthly GVWs. With the exception of Class 13s, results suggested that monthly changes in GVWs were positively correlated with monthly changes in volume (see scatterplots in Figures 5.198b-5.210b). While increases in GVWs were generally observed with increases in traffic volumes, this was not the case for Class 13s. Results suggest a possible need to further examine Class 13 vehicle compositions in order to understand whether the non-relationship (between monthly volumes and GVWs) is valid.

WIM #42

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.211). Out of all vehicle classes, Class 2 vehicles contributed the most to total GVW (45.1%) followed by Class 3s (27.3%) and Class 9s (16.8%). The remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. PVs generally reached peak GVW levels starting in the late spring/early summer months (May/June) with levels starting to decline starting the fall (October/November). For HCV classes, available data is indicative of a general peak in GVW levels starting in the spring (May) and lasting until start of fall (September). [Note that part of the statements made in the above paragraph was based on some interpolation due to a limited number of data points]. See Figures 5.212a-5.224a.

Due to the relative sparsity of monthly data points (n=14), correlational tests were not performed to ascertain the relationship between monthly volumes and GVWs. However, many of the vehicle class scatterplots (see Figures 5.212b-5.224b) seem to indicate that a positive relationship may exist between monthly volumes and GVWs—with the possible exception of Class 13s. The scatterplot of Class 13 data (see Figure 5.224b) suggests that a further examination may be needed for this particular HCV class to ensure the validity in the data (e.g., verify whether the current vehicle classification algorithm for Class 13s is accurately capturing these vehicles).

WIM #43

GVW by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total GVW (see Figure 5.225). Out of all vehicle classes, Class 2 vehicles contributed the most to total GVW (29.4%) followed by Class 3s (25.9%) and Class 9s (24.6%). The next highest GVW contributor was the Class 10s (10.2%). All other, remaining vehicle classes contributed a negligible amount to total GVW (less than 5% each).

Monthly Trends. Based on available data, PVs showed peak GVW levels starting in the spring (May) until the fall (October), with lowest GVWs observed over the winter months. Monthly GVW trends differed more widely among the HCV classes, but many of them showed similar GVW trends as the PVs—highest levels starting in the spring (May) until mid-fall (October). See Figures 5.226a-5.238a.

Due to the relative sparsity of monthly data points (n=15), correlational tests were not performed to ascertain the relationship between monthly volumes and GVWs. However, many of the vehicle class scatterplots (see Figures 5.226b-5.238b) seem to indicate that a positive relationship may exist between monthly volumes and GVWs—with the possible exception of Class 13s. The scatterplot of Class 13 data (see Figure 5.238b) suggests that a further examination may be needed for this particular HCV class to ensure the validity in the data (e.g., verify whether the current vehicle classification algorithm for Class 13s is accurately capturing these vehicles).

Conclusions

GVW by Vehicle Class

Examination of GVW data across all sites suggests that, on average, the top 3 vehicle classes contributing the most to total GVW make up 84.2% of total GVW. This means that the remaining 10 vehicle classes combined to contribute approximately 15.8% of total GVW. Table 5.1 shows the top 3 vehicle classes that contributed the most to total gross vehicle weight, with 1) information on the number of WIMs that fall into each top 3 category and 2) the average, combined contribution of the top 3 towards total gross vehicle weight.

Top 3 Vehicle Classes Contributing to Total GVW (From Most to Least)	# of WIMs (out of 17)	Mean Combined Contribution of the Top 3 to Total GVW
9, 2, 3	7	84.5%
2, 3, 9	6	84.8%
2, 9, 3	2	84.6%
2, 3, 5	1	88.9%
3, 10, 9	1	72.1%

Table 5.1. A categorical list of the top 3 vehicle classes contributing to total volume, with the number of WIMs that fall into each category and their mean combined contribution to total gross vehicle weight (GVW).

Information from Table 5.1 suggests that the majority of WIM sites (15 out of 17 sites) have the same 3 vehicle classes contributing the most to total volume: Classes 2, 3, and 9. Table 5.1 also indicates that, for vehicle classes that did not make up the top 3 (the remaining 10 vehicle classes at each site), their combined contribution toward total GVW was very small in comparison—typically less than 20%. In fact, apart from 3-4 vehicle classes at each WIM site, the other remaining 9-10 vehicle classes each contributed less than 5% to total GVW.

Monthly Trends

As discussed in the introduction of this section (2nd paragraph of introduction), monthly GVW trends at each site should generally mirror monthly volume trends at that site—this should be true for all vehicle classes. If vehicles – as weight-bearing objects – cross a WIM site, it should generally follow that more of these vehicles traveling in a month should also mean that more weight will have passed through the roadway during that month. Correlational tests were subsequently performed on monthly traffic volumes and monthly GVWs at each site, which overwhelmingly supported this position—increases in monthly traffic volume were associated with increases in monthly GVW values. However, although there was overwhelming support for this position, there were a rare number of cases that did not show this relationship between traffic volumes and GVW. Of the small handful of cases that showed a lack of a positive relationship between monthly volumes and GVWs, the majority of them were Class 1s and Class 13s. Figure 5.239 represents typical scatterplots of Class 1 and Class 13 data (note: although scatterplots specifically depict WIM #33 (Olivia) data, these scatterplots are highly representative of data patterns found at many other WIM sites for Class 1 and Class 13 data).

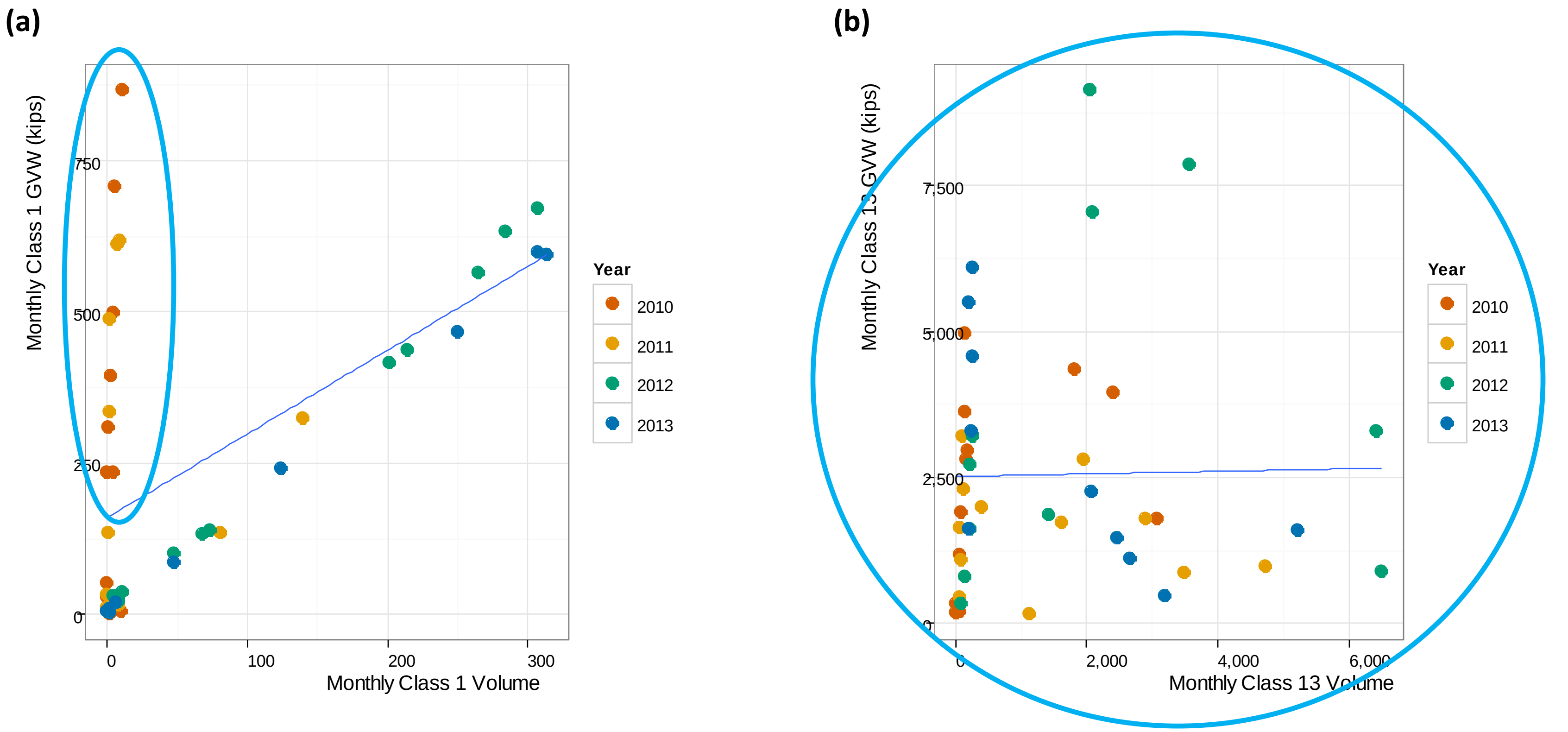

Figure 5.239. Data from WIM #33, US 212, Olivia. (a) A representative scatterplot of Class 1s depicting the relationship between monthly volumes and monthly gross vehicle weights (GVWs). Blue circled area shows data points that highly suggest vehicle classification issues that primarily occurred from 2010-2011 (note that a positive relationship may still exist between monthly Class 1 volumes and monthly Class 1 GVWs at some WIM sites regardless of the presence of 'problem' data points). Note the large variance in GVWs for months that had little-to-no recorded traffic volume. (b) A representative scatterplot of Class 13s depicting the relationship between monthly volumes and monthly gross vehicle weights. Blue circled area shows 1) a similar problem with GVWs as was depicted in the Class 1 scatterplot—large variance in GVWs for months with little-to-no recorded traffic volume, and 2) a need to more carefully examine the composition of vehicles categorized as Class 13s due to a non-existent relationship between volume and GVW.

These scatterplots (for Class 1s and Class 13s) clearly show data points that are highly unlikely to reflect real traffic patterns at these sites. For example, the Class 1 and Class 13 scatterplots both show a high degree of variance in monthly GVW observations for months that had little-to-no traffic volumes. These particular data points are, in fact, impossible based on knowledge of GVWs for both Class 1s and 13s. Rather, these data points are suggestive of a potential issue with the classification algorithm or some other factor leading to problems with accurate data collection during these months (e.g., sensor performance issues, software configuration, etc.). One interesting observation of Classes 1 and 13 scatterplot data is that the 'impossible' data points for Class 1s were primarily restricted to data from 2010-2011 for WIM sites exhibiting this problem. In contrast, the 'impossible' data points for Class 13s did not always appear to be tied to any particular year at the WIM sites showing this problem. In future annual report publications, it is recommended that these 'impossible' data points be removed prior to analysis so as to reduce statistical noise.

6. OVERWEIGHT VEHICLES[10]

The following section summarizes the overweight vehicle trends[10] observed from 2010-2013, with the amount of data available during this time varying by site. Factors affecting data availability during this time frame depend on multiple factors including 1) the WIM installation date and initial calibration (not all WIMs were installed and calibrated at the same time), 2) operational status of the system, and 3) the validity of the data collected (which is primarily dependent on data quality).

WIM #26

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 10s, and Class 6s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.1). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 9 am to 5 pm.

Violations by Direction of Travel. The amount of overweight vehicles traveling in either direction has varied from year to year. While there were more overweight vehicles traveling SB than NB in 2010 and 2012, there were more overweight vehicles going NB than SB in 2011 and 2013 (see Figure 6.2). Hour of the day information is also included in the figure, and it shows no distinct volume difference between the two directions, probably because the site does not experience a morning or evening rush hour with overweight vehicles. The peak volume times for overweight vehicles appeared to occur during normal business hours, 9 am to 5 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.3).

Monthly and Annual Trends. Overweight vehicles typically reached highest numbers in the summer to early fall (June-September), with lowest volumes observed during winter months (December-February). See Figure 6.4. In addition, it appears that years 2011 and 2012 had greater numbers of overweight vehicles than what was observed in 2013 (2010 was not included in this comparison because it did not have close to a full year's worth of data).

WIM #27

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 5s, and Class 10s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.5). Data suggests that, during business hours, overweight vehicles typically reached highest volume concentrations between 8 am to 1 pm.

Violations by Direction of Travel. No conclusions could be drawn about any directional differences in overweight vehicle volumes at this site (sensors are only installed in the EB lanes).

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[10] The term "overweight vehicles" in this report refers to the number of HCVs that had at least one weight violation (e.g., weight violations of any axle configuration, violations at the gross vehicle weight level, etc.). Therefore, even if a single HCV had multiple weight violations, a single HCV is represented once in this data as being overweight.

Day-of-the-Week Trends. Overweight vehicle volumes were highest during the weekdays (Monday through Fridays; peak observed on Thursdays), with volumes dropping over the weekends (see Figure 6.6).

Monthly and Annual Trends. Due to a limited amount of data at this site, monthly/annual trends are only based on available data. According to available data, overweight vehicles tended to be highest in late winter (February). The other months from March through September have relatively similar levels of overweight vehicles, with lowest volumes observed in January. See Figure 6.7.

WIM #29

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 10s, and Class 6s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.8). Data suggests that, during business hours, overweight vehicles typically reached highest volume concentrations between 8 am to 3 pm.

Violations by Direction of Travel. The amount of overweight vehicles traveling in either direction has varied somewhat by year. While more overweight vehicles traveled NB than SB from 2010-2012, more overweight vehicles traveled SB than NB in 2013 (see Figure 6.9). Hour of the day information is also included in the figure, and it shows no distinct volume difference between the two directions, probably because the site does not experience a morning or evening rush hour with overweight vehicles. The peak volume times for overweight vehicles appeared to occur during normal business hours, 8 am to 3 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.10).

Monthly and Annual Trends. Deciphering monthly/annual patterns for overweight vehicles was somewhat complicated by the wide variability observed in the data points between the different years as well as when investigated from a seasonal standpoint (see Figure 6.11). However, the following pattern emerges when data points are averaged by month, collapsed across all years: overweight vehicle volumes were highest in the spring, with lowest overweight volumes observed in the late fall through winter (November-January). Due to some persistent sensor problems in Lane 3 at this site (see last paragraph of "System Calibration and Quality Control" section), it will be important to collect further data to better understand traffic patterns at this site—particularly after August 2014 and beyond (Lane 3 sensor was replaced in August 2014).

WIM #30

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 10s, and Class 5s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.12). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 8 am to 4 pm.

Violations by Direction of Travel. The amount of overweight vehicles traveling NB and SB was relatively close across all years of data collection. The number of overweight vehicles traveling SB was marginally greater than those going NB in 2012, while the reverse was true in 2013 (marginally greater numbers going NB than SB; see Figure 6.13). Hour of the day information is also included in the figure, and it shows no distinct volume difference between the two directions, probably because the site does not experience a morning or evening rush hour with overweight vehicles. The peak volume times for overweight vehicles appeared to occur during normal business hours, 8 am to 4 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.14).

Monthly and Annual Trends. Based on 2013 data, overweight volumes were typically highest from the summer to fall (June-October; see Figure 6.15). All other months observed lower, but relatively similar overweight vehicle volumes. Lowest volumes were observed in April 2013.

WIM #31

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 10s, and Class 13s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.16). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 8 am to 5 pm.

Violations by Direction of Travel. Directional differences in overweight vehicle volumes were consistent from year to year. From 2010 to 2012, more overweight vehicles traveled WB than EB (see Figure 6.17). Hour of the day information is also included in the figure, and it shows no distinct volume difference between the two directions, probably because the site does not experience a morning or evening rush hour with overweight vehicles. The peak volume times for overweight vehicles appeared to occur during normal business hours, 8 am to 5 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.18).

Monthly and Annual Trends. The number of overweight vehicles observed between 2010 and 2011 varied considerably (see Figure 6.19). In particular, 2010 had significantly less overweight vehicles than 2011 across most months in a calendar year. If data points were averaged across these years within each month, data suggests that overweight vehicles are highest in the spring to fall (May-October, with lowest volumes observed in the late fall through winter (November-February).

WIM #32

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 10s, and Class 7s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.20). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 8 am to 5 pm.

Violations by Direction of Travel. Directional differences in overweight vehicle volumes were consistent from year to year. From 2012 to 2013, more overweight vehicles traveled SB than NB (see Figure 6.21). Hour of the day information is also included in the figure, and it shows no distinct volume difference between the two directions, probably because the site does not experience a morning or evening rush hour with overweight vehicles. The peak volume times for overweight vehicles appeared to occur during normal business hours, 8 am to 5 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.22).

Monthly and Annual Trends. Overweight vehicles were generally highest in the spring to early fall (June-September), with lowest overweight volumes occurring in the winter (December-February). See Figure 6.23.

WIM #33

Overweight Vehicles by Class. Directional differences in overweight vehicle volumes were consistent from year to year. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 13s, and Class 10s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.24). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 9 am to 4 pm.

Violations by Direction of Travel. Directional differences in overweight vehicle volumes were consistent from year to year. For 2010 to 2013, more overweight vehicles traveled WB than EB (see Figure 6.25). Hour of the day information is also included in the figure, and it shows no distinct volume difference between the two directions, probably because the site does not experience a morning or evening rush hour with overweight vehicles. The peak volume times for overweight vehicles appeared to occur during normal business hours, 9 am to 4 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.26).

Monthly and Annual Trends. As was observed with heavy commercial average daily traffic (HCADT) patterns (see “Volume and Vehicle Class” section on WIM #33), overweight volume patterns tended to deviate from most sites. More specifically, lowest volumes of overweight vehicles were observed in the spring to mid-summer (April-July). In addition, this site seems to experience possible two distinct peaks in overweight volumes—once in the fall (September-November) and once centered late winter/early spring (March). See Figure 6.27.

WIM #34

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 10s, and Class 13s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.28). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 8 am to 5 pm.

Violations by Direction of Travel. The amount of overweight vehicles traveling NB and SB varied from year to year. While a marginally greater number of overweight vehicles traveled SB than NB from 2010 to 2012, more overweight vehicles traveled NB than SB in 2013 (see Figure 6.29). Hour of the day information is also included in the figure, and it shows no distinct volume difference between the two directions, probably because the site does not experience a morning or evening rush hour with overweight vehicles. The peak volume times for overweight vehicles appeared to occur during normal business hours, 8 am to 5 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.30).

Monthly and Annual Trends. Overweight vehicle volumes tended to peak spring to early fall (May-September), with lowest volumes occurring in the winter (December-February). See Figure 6.31.

WIM #35

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 10s, and Class 6s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.32). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 9 am to 5 pm.

Violations by Direction of Travel. The amount of overweight vehicles traveling EB and WB varied from year to year. While a greater number of overweight vehicles traveled EB than WB in 2011, more overweight vehicles traveled WB than EB in 2010, 2012, and 2013 (see Figure 6.33). Hour of the day information is also included in the figure, and it shows no distinct volume difference between the two directions, probably because the site does not experience a morning or evening rush hour with overweight vehicles. The peak volume times for overweight vehicles appeared to occur during normal business hours, 9 am to 5 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.34).

Monthly and Annual Trends. There were some emerging patterns in overweight volumes at WIM #35. Firstly, overweight volumes from 2010 and 2011 were quite similar to each other, while overweight volumes from 2012 and 2013 were similar to each other (see Figure 6.35). More specifically, overweight vehicle volumes in 2012 and 2013 were significantly higher in many cases compared to 2010 and 2011. Secondly, the seasonal trends observed between these two patterns (2010/2011 vs. 2012/2013) were markedly different—2010/2011 data showed that overweight vehicle volumes were highest in the winter through early spring (December-March), while the 2012/2013 data showed that overweight vehicles reached peak levels in the spring to early fall (May-September). Due to this variability, it is somewhat unclear which pattern will closely match subsequent overweight traffic patterns. Further data collection is suggested.

WIM #36

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 10s, and Class 6s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.36). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 8 am to 4 pm.

Violations by Direction of Travel. The amount of overweight vehicles traveling EB and WB varied from year to year. While a greater number of overweight vehicles traveled WB than EB in 2012, more overweight vehicles traveled EB than WB in 2010, 2011, and 2013 (see Figure 6.37). EB overweight vehicles showed a noticeable rise in volume a little earlier in the morning (6 am) than WB overweight vehicles (8 am), but both directional volumes started to decline after

5 pm. Overall, the peak volume times for overweight vehicles appeared to occur during normal business hours, 8 am to 4 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.38).

Monthly and Annual Trends. Overweight vehicle volumes tended to be highest in the spring to early fall (May-August), with lowest volumes occurring in the winter months (December-February). See Figure 6.39.

WIM #37

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 10s, and Class 13s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.40). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 9 am to 5 pm.

Violations by Direction of Travel. Overweight vehicle characteristics were observed in the WB lanes (no sensors are installed in the EB lanes). From 2010-2013, approximately 82% to 88% of overweight vehicles traveled in the WB driving lane. Peak overweight vehicle concentrations occurring during normal business hours, 9 am to 5 pm (see Figure 6.41).

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.42).

Monthly and Annual Trends. Overweight vehicle volumes varied widely from year to year at WIM #37 (see Figure 6.43). For example, overweight volumes were more noticeably different between 2013 compared to the other three years (2010-2012), particularly when examining data over the spring to summer (May-August). Data from 2013 suggests that overweight vehicles roughly followed typical high summer/low winter volume patterns. This contrasts from 2010-2012 data which shows peak overweight vehicle volumes coinciding with the spring (March-May).

One interesting finding regarding the overweight vehicle volumes is that these numbers did not always mirror HCADT patterns (see Figure 4.51 for HCADT data at WIM #37)—this was particularly true for 2010 and 2012 (differences were particularly noticeable during summer months). This may suggest one of two things: 1) overweight vehicles may have not been captured properly by WIM equipment (either through hardware issues that were not identified at that time or through more intentional means of evading the WIM sensors), or 2) overweight vehicles at WIM #37 were particularly compliant on legal weight restrictions (and therefore, data accurately captured traffic characteristics during the time in question). Based on typical relationships between HCADTs and overweight volumes, the former scenario is more likely but is unconfirmed.

WIM #38

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 10s, and Class 6s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.44). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 9 am to 4 pm.

Violations by Direction of Travel. The amount of overweight vehicles traveling NB and SB varied from year to year. While a greater number of overweight vehicles traveled SB than NB in 2011, more overweight vehicles traveled NB than SB in 2010, 2012, and 2013 (see Figure 6.45). Hour of the day information is also included in the figure, and it shows no distinct volume difference between the two directions, probably because the site does not experience a morning or evening rush hour with overweight vehicles. The peak volume times for overweight vehicles appeared to occur during normal business hours, 9 am to 4 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.46).

Monthly and Annual Trends. As discussed previously (see "Volume and Vehicle Class" section), interpreting underlying traffic characteristics at WIM #38 is somewhat complicated by construction that took place in 2010 and 2012. However, based on remaining data, overweight vehicles at this site suggest a volume peak in the summer to early fall (June-September), with lowest volumes occurring in the winter (December-March). See Figure 6.47.

WIM #39

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 10s, and Class 6s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.48). While overweight vehicles typically reached highest volume concentrations during normal business hours, the hours in which they occurred were slightly earlier than other sites—from 7 am to 3 pm.

Violations by Direction of Travel. The amount of overweight vehicles traveling NB and SB varied from year to year. While a greater number of overweight vehicles traveled NB than SB in 2010 and 2012, more overweight vehicles traveled SB than NB in 2011 and 2013 (see Figure 6.49). NB overweight vehicles showed a noticeable rise in volume a little earlier in the morning (6 am) than SB overweight vehicles (8 am), but both directional volumes started to decline after 5 pm. Overall, the peak volume times for overweight vehicles appeared to occur during normal business hours, 7 am to 3 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.50).

Monthly and Annual Trends. Overweight vehicle volumes exhibited a bimodal peak—one centered in the spring (April-June) and the other in the fall (October-November). See Figure 6.51.

WIM #40

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 7s, and Class 10s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.52). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 7 am to 4 pm.

Violations by Direction of Travel. The amount of overweight vehicles traveling NB and SB varied from year to year. While a greater number of overweight vehicles traveled NB than SB in 2010, more overweight vehicles traveled SB than NB from 2011-2013 (see Figure

6.53). Hour of the day information is also included in the figure, with peak volume times typically occurring during normal business hours, 7 am to 4 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.54).

Monthly and Annual Trends. Overweight vehicle volumes typically reached highest volumes in the summer to fall (June-October). See Figure 6.55. The construction of the nearby Lafayette Bridge on US 52 appeared to significantly decrease traffic on this road (decreases in ADT and HCADT were observed during construction during spring/summer/fall 2013)—this decrease is also observed in the overweight vehicle volumes.

WIM #41

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 13s, Class 9s, and Class 10s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.56). While data suggests that overweight vehicles reached highest volume concentrations during normal business hours (9 am to 6 pm), those trends are somewhat obscured in the figure due to increased HCV activity during the sugar beet harvest in October of each year. During the sugar beet harvest in October, HCV volumes increase dramatically compared to other months of the year. Furthermore, those HCVs tend to travel non-stop (24 hours/day).

Violations by Direction of Travel. A significantly larger amount of overweight vehicles traveled in the NB than SB (this remained true when removing months highly associated with the sugar beet harvest). See Figure 6.57. Hour of the day information is also included in the figure, and it shows no distinct volume difference between the two directions, probably because the site does not experience a morning or evening rush hour with overweight vehicles. The peak volume times for overweight vehicles appeared to occur during normal business hours, 9 am to 6 pm.

Day-of-the-Week Trends. Unlike other sites that typically show a high weekday/low weekend pattern for overweight vehicles, this site had different volume patterns depending on direction of travel. While the typical volume of overweight vehicles was slim-to-none going SB, NB overweight vehicles showed higher numbers traveling in the latter half of the week (roughly Wednesday through Saturday). See Figure 6.58.

Monthly and Annual Trends. Overweight vehicle volumes were highest in October of each year of data collection. This particular pattern is consistent with overall heavy commercial vehicle volumes (see HCADT data in "Volume and Vehicle Class" section) due to the sugar beet harvest during that time frame. All other times of the year have significantly lower overweight vehicle volumes compared to October. See Figure 6.59.

WIM #42

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 10s, and Class 6s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.60). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 8 am to 4 pm.

Violations by Direction of Travel. The amount of overweight vehicles traveling NB and SB has varied between 2012 and 2013. A greater number of overweight vehicles traveled

NB than SB in 2012, while more overweight vehicles traveled SB than NB in 2013 (see Figure 6.61). Some of these volume patterns were most likely influenced by the nearby, new Hastings Bridge construction. Construction of the bridge was fully completed in summer 2014, meaning that overweight vehicle patterns after that time may be more reflective of true traffic patterns at this site. Hour of the day information is also included in the figure, with peak volume times typically occurring during normal business hours, 8 am to 4 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.62).

Monthly and Annual Trends. Overweight vehicle volumes were typically highest from the spring to summer (May-August). The volume peak may extend beyond August, but it is difficult to ascertain due to the limited number of data points. See Figure 6.63.

WIM #43

Overweight Vehicles by Class. The top three vehicle classes that were overweight were, in descending order, Class 9s, Class 13s, and Class 10s (see Table 6.1 for percentages). The volume of overweight vehicles was also examined over a typical 24-hour day and as a function of vehicle class (see Figure 6.64). Data suggests that overweight vehicles generally reached highest volume concentrations during normal business hours: 7 am to 6 pm.

Violations by Direction of Travel. Directional trends in overweight vehicle volumes were the same across all years of data collection. There were more overweight vehicles going WB than EB from 2012-2013 (see Figure 6.65). Hour of the day information is also included in the figure, and it shows no distinct volume difference between the two directions, probably because the site does not experience a morning or evening rush hour with overweight vehicles. The peak volume times for overweight vehicles appeared to occur during normal business hours, 7 am to 6 pm.

Day-of-the-Week Trends. Overweight vehicle volumes were relatively similar across weekdays (Monday through Friday), with volumes dropping over the weekends (see Figure 6.66).

Monthly and Annual Trends. Overweight vehicle volumes were highest from spring to mid-fall (May-November), with lowest volumes occurring in the winter months (December-February). See Figure 6.67.

Conclusions

Overweight Vehicles by Class

For sixteen out of seventeen WIM sites, the greatest proportion of overweight vehicles came from Class 9s. For twelve of the seventeen sites, the second largest proportion of overweight vehicles came from Class 10s. Overall, the top three overweight vehicle classes accounted for 61.6% to 94.5% of the overweight vehicles. Table 6.1 shows the top three overweight vehicle classes at each WIM. Lastly, overweight vehicles were shown to typically travel during normal business hours (with highest volume concentrations occurring in late morning to mid-afternoon).

WIM #	Year	Top Three Classes of Overweight Vehicles	Percentage of Largest Class of Overweight Vehicles	Percentage 2nd Largest Class of Overweight Vehicles	Percentage 3rd Largest Class of Overweight Vehicles	Total of Top Three Classes of Overweight Vehicles
26	2010-2013	9, 10, 6	87.6%	3.9%	3.0%	94.5%
27	2010	9, 5, 10	80.5%	4.9%	4.8%	90.2%
29	2010-2013	9, 10, 6	55.7%	33.8%	3.0%	92.5%
30	2012-2013	9, 10, 5	59.1%	18.4%	6.2%	83.7%
31	2010-2011	9, 10, 13	47.8%	26.9%	8.1%	82.8%
32	2012-2013	9, 10, 7	77.0%	7.2%	4.8%	89.0%
33	2010-2013	9, 13, 10	60.3%	20.0%	13.3%	93.6%
34	2010-2013	9, 10, 13	71.0%	14.2%	3.3%	88.5%
35	2010-2013	9, 10, 6	54.8%	22.2%	5.2%	82.2%
36	2010-2013	9, 10, 6	23.5%	19.5%	18.6%	61.6%
37	2010-2013	9, 10, 13	83.1%	6.3%	2.9%	92.3%
38	2010-2013	9, 10, 6	62.5%	10.4%	8.2%	81.1%
39	2010-2013	9, 10, 7	73.6%	8.8%	6.1%	88.5%
40	2010-2013	9, 7, 10	53.6%	11.4%	11.2%	76.2%
41	2010-2013	13, 9, 10	24.9%	24.4%	23.4%	72.7%
42	2012-2013	9, 10, 6	68.1%	8.0%	6.8%	82.9%
43	2012-2013	9, 13, 10	41.6%	24.5%	20.2%	86.3%

Table 6.1. Top 3 overweight vehicle classes at each WIM site.

Violations by Direction of Travel

Overweight volumes have sometimes varied by direction of travel or have remained consistently higher/lower in a particular direction from year to year—these findings are site-specific, and the reader is encouraged to refer to specific WIMs of interest in the above subsections for further information.

Day of the Week Trends

With the exception of WIM #41, all other sites consistently reported lower numbers of overweight vehicles during the weekend compared to the weekdays (Monday-Friday).

While the day-of-week trends presented here may have some usefulness in interpreting when to anticipate greater/lesser numbers of overweight vehicles over the week, there are some limitations as well. In particular, averaging overweight volumes across years has the effect of obscuring any seasonal differences that might appear in day-of-week trends (this may only be true for sites that have *significantly* different volume patterns during one part of the year compared to others like WIM #41). In the future, it may be worthwhile to explore for seasonal differences in day-of-week trends before determining whether averaging across all seasons/years is appropriate.

Lane Trends

For WIM sites on 4-lane, 2-direction roadways, data was examined to determine the percentage of overweight vehicles traveling on the driving lanes and passing lanes. For WIMs in rural areas[11], approximately 88.6% of overweight vehicles traveled in the driving lanes while 11.4% of overweight vehicles traveled on the passing lanes. In urban areas[12], 82.3% of overweight vehicles typically occupied the driving lanes while 17.7% traveled on the passing lanes. See Table 6.2.

[11] The following WIMs are in rural areas: 26, 27, 29, 30, 31, 32, 35, 37, and 43.
[12] The following WIMs are in urban areas: 36, 38, 40, and 42.

WIM #	Roadway	Nearest City	Year	Overweight Vehicles in Driving Lane (%)	Overweight Vehicles in Passing Lane (%)
26	I-35	Owatonna	2010	86.2%	13.8%
			2011	94.0%	6.0%
			2012	92.6%	7.4%
			2013	87.3%	12.7%
27[a]	MN 60 (EB)	St. James	2010	80.2%	19.8%
29	US 53	Cotton	2010	92.0%	8.0%
			2011	88.3%	11.7%
			2012	94.0%	6.0%
			2013	78.4%	21.6%
30	MN 61	Two Harbors	2012	97.3%	2.7%
			2013	91.9%	8.1%
31	US 2	East Grand Forks	2010	91.2%	8.8%
			2011	92.6%	7.4%
			2012	94.0%	6.0%
32	US 52	Oronoco	2012	74.8%	25.2%
			2013	77.8%	22.2%
35	US 2	Bagley	2010	93.4%	6.6%
			2011	85.1%	14.9%
			2012	94.9%	5.1%
			2013	87.4%	12.6%
36	MN 36	Lake Elmo	2010	85.1%	14.9%
			2011	82.8%	17.2%
			2012	82.2%	17.8%
			2013	82.5%	17.5%
37[a]	I-94 (WB)	MnROAD	2010	82.3%	17.7%
			2011	86.9%	13.1%
			2012	88.2%	11.8%
			2013	83.3%	16.7%

[a] Data collection only occurs in one direction of travel at these WIM sites

Table 6.2. Percentage of overweight heavy commercial vehicles in driving and passing lanes at 4-lane, 2-direction WIM sites.

WIM #	Roadway	Nearest City	Year	Overweight Vehicles in Driving Lane (%)	Overweight Vehicles in Passing Lane (%)
38	I-535	Duluth	2010	45.5%	54.5%
			2011	74.7%	25.3%
			2012	55.3%	44.7%
			2013	45.9%	54.1%
40	US 52	South St. Paul	2010	82.7%	17.3%
			2011	81.2%	18.8%
			2012	78.4%	21.6%
			2013	73.4%	26.6%
42	US 61	Cottage Grove	2012	86.2%	13.8%
			2013	88.0%	12.0%
43	US 10	Moorhead	2012	95.5%	4.5%
			2013	94.7%	5.3%

Table 6.2 (cont.). Percentage of overweight heavy commercial vehicles in driving and passing lanes at 4-lane, 2-direction WIM sites.

In an effort to reduce WIM system costs, there have been previous discussions on whether WIM sensors are necessary in the passing lanes (or whether less expensive sensors could be installed which have vehicle classification capabilities only). Data suggests that up to 18% of overweight vehicles may not be detected if WIM sensors are no longer installed in the passing lanes. This number may be useful in any future discussions on WIM system costs and determining whether this value is considered large enough to keep WIM sensors in the passing lanes.

Time Between Overweight Vehicles

To compute the average time between overweight vehicles at each site, the total hours of system operation were divided by the total number of overweight violations reported at each WIM. Results are provided in Table 6.4 and may be of some use to MN State Patrol. In the future, these times may be further refined by request to more accurately capture times between overweight vehicles during time periods most often staffed by State Patrol for weight enforcement.

WIM #	Roadway	Nearest City	Time Between Overweight Vehicles	
			Minutes	**Seconds**
26	I-35	Owatonna	2	8
27	MN 60	St. James	59	10
29	US 53	Cotton	13	58
30	MN 61	Two Harbors	19	16
31	US 2	East Grand Forks	18	52
32	US 52	Oronoco	4	4
33	US 212	Olivia	6	35
34	MN 23	Clara City	18	47
35	US 2	Bagley	34	53
36	MN 36	Lake Elmo	14	43
37	I-94	MnROAD	2	44
38	I-535	Duluth	9	25
39	MN 43	Winona	16	53
40	US 52	South St. Paul	4	51
41	CSAH 14	Crookston	31	38
42	US 61	Cottage Grove	9	16
43	US 10	Moorhead	5	17

Table 6.3. Average amount of time between overweight vehicles at each WIM site.

Monthly and Annual Trends

The following observation was made across all WIMs: month-to-month patterns in the overweight vehicle volumes typically followed similar month-to-month patterns in heavy commercial average daily traffic (HCADT) volumes. This is to be expected given that there is no a-priori reason to believe that overweight vehicle traffic (which is a subset of the heavy commercial vehicles) should behave differently from weight-compliant heavy commercial vehicles. It is also important to address within this section that there was a fair amount of variability in overweight vehicle volumes across the years for many sites—this effectively complicates efforts in isolating out the true, underlying overweight vehicle traffic patterns. While it will be important to continue with data collection at these sites, it will also be important to adapt more stringent methods for both quality checking and data validation. Lastly, since changes in overweight violations are most likely associated with changes in traffic volumes, future analyses should control for traffic volumes as a covariate prior to analyzing changes in overweight vehicle volumes.

Annual numbers of overweight violations are included below for each site along with system operation (see Table 6.5).

WIM #	Roadway	Nearest City	Year	Annual Total of Overweight Violations	WIM System Operational (%)
26	I-35	Owatonna	2010	56,996	41.9%
			2011	321,088	100.0%
			2012	279,131	100.0%
			2013	137,133	90.3%
27	MN 60	St. James	2010	4,322	78.5%
29	US 53	Cotton	2010	10,494	43.7%
			2011	32,771	88.8%
			2012	23,403	41.5%
			2013	20,653	97.0%
30	MN 61	Two Harbors	2012	1,450	8.5%
			2013	28,164	100.0%
31	US 2	East Grand Forks	2010	12,829	98.2%
			2011	40,026	100.0%
32	US 52	Oronoco	2012	60,033	50.2%
			2013	112,982	90.9%
33	US 212	Olivia	2010	77,075	100.0%
			2011	63,214	99.3%
			2012	81,362	100.0%
			2013	76,462	92.7%
34	MN 23	Clara City	2010	32,788	100.0%
			2011	19,751	77.9%
			2012	24,937	87.7%
			2013	22,035	99.7%
35	US 2	Bagley	2010	11,218	100.0%
			2011	11,093	99.7%
			2012	17,767	99.7%
			2013	18,745	99.2%
36	MN 36	Lake Elmo	2010	37,406	95.1%
			2011	23,645	90.9%
			2012	23,363	98.7%
			2013	38,395	74.5%

Table 6.5. Annual totals for overweight HCV violations. Total percentages of WIM system operation are provided to give context for interpreting annual violations.

WIM #	Roadway	Nearest City	Year	Annual Total of Overweight Violations	WIM System Operational (%)
37	I-94	MnROAD	2010	146,479	94.8%
			2011	82,614	66.7%
			2012	174,597	100.0%
			2013	221,064	91.6%
38	I-535	Duluth	2010	42,044	98.0%
			2011	53,319	100.0%
			2012	36,294	100.0%
			2013	57,257	90.1%
39	MN 43	Winona	2010	32,095	94.1%
			2011	34,831	98.7%
			2012	23,987	100.0%
			2013	31,286	99.7%
40	US 52	South St. Paul	2010	172,211	99.4%
			2011	113,695	100.0%
			2012	62,759	90.8%
			2013	26,792	85.6%
41	CSAH 14	Crookston	2010	10,460	25.2%
			2011	13,214	100.0%
			2012	13,750	100.0%
			2013	15,290	99.6%
42	US 61	Cottage Grove	2012	23,353	41.8%
			2013	41,963	87.7%
43	US 10	Moorhead	2012	23,177	24.9%
			2013	100,668	99.7%

Table 6.5 (cont.). Annual totals for overweight HCV violations. Total percentages of WIM system operation are provided to give context for interpreting annual violations.

7. PAVEMENT CONSIDERATIONS

The following section summarizes the equivalent single axle-load (ESAL) trends observed from 2010-2013. It is important to note that the amount of data available during this time frame will vary by WIM site. Factors affecting data availability during this time frame depend on multiple factors including 1) the WIM installation date and initial calibration (not all WIMs were installed and calibrated at the same time), 2) operational status of the system, and 3) the validity of the data collected (which is primarily dependent on data quality).

Conceptually, ESAL calculations are directly used as a tool for designing pavement. Indirectly, ESAL calculations are sometimes used to estimate how much earlier a pavement's design life may decrease due to traffic patterns at a particular site. In this particular instance, ESALs can be estimated from data gathered at WIM sites intersecting specific roadways (see Figure 1.1 for specific locations of the WIMs in Minnesota).

ESAL calculations are computed and reported using iAnalyze, a reporting software developed for traffic reporting by International Road Dynamics, Inc. Calculation of ESALs in iAnalyze is set up to reflect the American Association of State Highway and Transportation Officials' (AASHTO) tables with a terminal serviceability of 2.5 and a structural number of 5[13].

This section will discuss the following information based on data collected at each WIM site in operation from 2010-2013: 1) which vehicle classes contributed the most (%) to total ESALs at each WIM site, 2) the distribution of ESALs (%) across the lanes, and 3) annual ESALs at each site, along with an estimation on how much the overweight HCVs are decreasing the pavement's 20-year life.

WIM #26

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (84.9%) followed by Class 11s (4.9%) and Class 10s (2.1%). The remaining vehicle classes contributed a negligible amount to total ESALs (less than 2% each). See Figure 7.1.

WIM #27

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (84.6%) followed by Class 5s (5.8%) and Class 10s (2.5%). The remaining vehicle classes contributed a negligible amount to total ESALs (less than 3% each). See Figure 7.2.

WIM #29

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (63.1%) followed by Class 10s (20.6%) and Class

[13] Parameters reflect calculation of flexible ESALs. Parameter selection is based on MnDOT's Pavement Design Manual (2007; Chapter 4, pg. 45). For more information: http://www.dot.state.mn.us/materials/pvmtdesign/docs/2007manual/Chapter_4.pdf

5s (5.6%). The remaining vehicle classes contributed a negligible amount to total ESALs (less than 4% each). See Figure 7.3.

WIM #30

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (56.2%) followed by Class 10s (14.7%) and Class 5s (10.6%). The next highest ESAL contributors were the Class 6s (6.0%) and Class 8s (5.2%). All other, remaining vehicle classes contributed a negligible amount to total ESALs (less than 3% each). See Figure 7.4.

WIM #31

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (56.1%) followed by Class 10s (20.4%) and Class 5s (7.7%). The remaining vehicle classes contributed a negligible amount to total ESALs (less than 5% each). See Figure 7.5.

WIM #32

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (77.8%) followed by Class 5s (4.7%) and Class 10s (4.3%). The remaining vehicle classes contributed a negligible amount to total ESALs (less than 4% each). See Figure 7.6.

WIM #33

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (69.6%) followed by Class 10s (17.1%) and Class 5s (5.0%). The remaining vehicle classes contributed a negligible amount to total ESALs (less than 3% each). See Figure 7.7.

WIM #34

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (75.7%) followed by Class 10s (7.7%) and Class 5s (5.9%). The remaining vehicle classes contributed a negligible amount to total ESALs (less than 4% each). See Figure 7.8.

WIM #35

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (62.0%) followed by Class 10s (12.2%) and Class 5s (8.3%). The remaining vehicle classes contributed a negligible amount to total ESALs (less than 5% each). See Figure 7.9.

WIM #36

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (25.8%) followed by Class 5s (22.9%) and Class 6s (19.5%). The next highest ESAL contributors were the Class 8s (8.1%) and Class 10s (7.7%). All other, remaining vehicle classes contributed a negligible amount to total ESALs (less than 5% each). See Figure 7.10.

WIM #37

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (83.0%) followed by Class 10s (4.0%) and Class 11s (2.7%). The remaining vehicle classes contributed a negligible amount to total ESALs (less than 3% each). See Figure 7.11.

WIM #38

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (67.0%) followed by Class 5s (8.0%) and Class 6s (7.8%). The next highest ESAL contributor was the Class 10s (5.7%). All other, remaining vehicle classes contributed a negligible amount to total ESALs (less than 4% each). See Figure 7.12.

WIM #39

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (73.6%) followed by Class 5s (5.4%) and Class 10s (5.2%). The remaining vehicle classes contributed a negligible amount to total ESALs (less than 5% each). See Figure 7.13.

WIM #40

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (53.2%) followed by Class 5s (12.9%) and Class 6s (10.0%). The next highest ESAL contributors were the Class 7s (6.0%), Class 10s (5.7%), and Class 8s (5.6%). All other, remaining vehicle classes contributed a negligible amount to total ESALs (less than 2% each). See Figure 7.14.

WIM #41

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (41.5%) followed by Class 10s (31.0%) and Class 6s (10.7%). The next highest ESAL contributor was the Class 5s (6.1%). All other, remaining vehicle classes contributed a negligible amount to total ESALs (less than 4% each). See Figure 7.15.

WIM #42

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (62.4%) followed by Class 5s (11.1%) and Class 6s (8.5%). The remaining vehicle classes contributed a negligible amount to total ESALs (less than 5% each). See Figure 7.16.

WIM #43

ESALs by Vehicle Class. Vehicle classes were examined by their average monthly contribution to total ESALs (mean monthly percent of total ESALs). Out of all vehicle classes, Class 9s contributed the most to total ESALs (57.7%) followed by Class 10s (20.4%) and Class 5s (6.0%). The next highest ESAL contributor was the Class 6s (5.7%). All other, remaining vehicle classes contributed a negligible amount to total ESALs (less than 3% each). See Figure 7.17.

ESALs by Lane

The next few paragraphs will explore the distribution of ESALs across all lanes at each of the WIM sites. Table 7.1 and Table 7.2 respectively provide information on the percent of ESALs that were encountered in each lane (out of total ESALs) for 2-lane, 2-direction sites and 4-lane, 2-direction sites.

Table 7.1 shows that ESALs on 2-lane, 2-direction sites were fairly well distributed between directions of travel with the exception of WIM #41 (Crookston). The bigger disparity in ESAL distributions between the two lanes at WIM #41 is ultimately driven by the significant increase in northbound (NB; Lane 1) traffic volumes (particularly HCVs) that is experienced during the fall sugar beet harvest. Information from Table 7.1 can also help pavement designers decide which lane to designate as the design lane (typical method is to default to the lane with the greatest percentage of observed ESALs).

Table 7.2 presents the distribution of ESALs on 4-lane, 2-direction sites according to direction of travel. Within each direction of travel, ESALs are further divided by driving and passing lanes. The data shows that the distribution of ESALs was more heavily biased toward the driving lanes than passing lanes for all sites except for the NB direction at WIM #38 (Duluth). In fact, ESALs observed in the NB passing lane was higher than those observed in the NB driving lane. This can easily be explained by WIM #38's location on I-535, which serves as a major route connecting Wisconsin and Minnesota. A greater number of vehicles entering Minnesota (via NB I-535) are heading south (towards Minneapolis/St. Paul) than Duluth. Since the exit lane to south on I-35 is located in the NB passing lane, it is natural for the number of ESALs observed in this lane to be higher than that of the NB driving lane.

Current procedure at MnDOT for designing pavement at 4-lane, 2-direction roadways is to assume that 90% of all ESALs experienced on a roadway is concentrated on the driving lanes (roughly a 45:45 split between driving lanes for each direction). Table 7.2 clearly shows that this is not always the case. While there are several sites that fit close to this assumption, there are also many that do not (e.g., WIM # 38 (Duluth), WIM #32 (Oronoco), WIM #40 (South St. Paul)). One recommendation to enhance financial effectiveness would be to consider the possibly of adjusting pavement design procedures for sites that clearly fall below the 90% assumption.

Percent (%) of Total ESALs:
2-Lane, 2-Direction Roadways

WIM #	Direction	Lane 1	Lane 2
33	EB & WB	47.3	52.7
34	NB & SB	49.4	50.6
39	NB & SB	48.8	51.2
41	NB & SB	84.6	15.4

Table 7.1. A list of 2-lane, 2-direction roadways along with each lane's equivalent single axle load (ESAL) contribution (%) to total ESALs experienced on the roadway.

Percent (%) of Total ESALs: 4-Lane, 2-Direction Roadways

WIM #	Direction	Lane 1 - Driving Lane (%)	Lane 2 - Driving Lane (%)	Lane 3 - Driving Lane (%)	Lane 4 - Driving Lane (%)	Combined Driving Lane Contribution (%) to Total ESALs
26	NB & SB	47.7	3.5	4.5	44.3	92.0
27[a]	EB	74.0	26.0	--	--	--
29	NB & SB	45.6	6.8	4.2	43.4	89.0
30	NB & SB	50.4	4.6	3.2	41.8	92.2
31	EB & WB	35.2	3.3	5.0	56.5	91.7
32	NB & SB	38.6	10.1	9.9	41.4	80.0
35	EB & WB	39.0	6.4	6.1	48.6	87.6
36	EB & WB	43.4	12.0	6.3	38.3	81.8
37[a]	WB	84.3	15.7	--	--	--
38	NB & SB	14.8	36.9	5.3	43.1	57.8
40	NB & SB	34.1	11.0	9.0	45.9	80.0
42	NB & SB	46.7	3.3	13.4	36.6	83.3
43	EB & WB	40.5	5.7	2.4	51.3	91.9

[a] Sites collecting WIM data in only one direction of a 4-lane, 2-direction roadway

Table 7.2. A list of 4-lane, 2-direction roadways along with each lane's equivalent single axle load (ESAL) contribution (%) to total ESALs experienced on the roadway. Right-most column indicates the combined driving lane contributions (Lanes 1 and 4) to total ESALs.

Effects of Overweight Vehicles on Pavement Life

Monthly ESAL estimations from Class 9s and 10s were summated for each calendar year of available data to derive annual ESALs in the design lane (missing months within a given year were substituted for the same month from a different year or were averaged across the same month across multiple years). These annual ESAL estimates were subsequently averaged across all available years (e.g., if annual ESAL estimates were available for years 2010-2013, the mean annual ESAL estimate was calculated across those years). These mean annual ESAL estimates for the design lane are presented in Table 7.3 below (see third column).

The next two adjacent columns (columns 4 and 5) in Table 7.3 represent mean annual ESALs from Class 9s and 10s that are estimated to be observed over the 20-year pavement life of the design lane (column 4), as well as those estimates if overweight trucks were loaded to legal weight limits (i.e., hypothetically not overweight; column 5). Column 6 gives estimations on how much earlier (in months) the pavement life is expected to decrease due to overweight Class 9s and 10s (annual ESALs x 20 years x [1+(20 years x (GrowthFactor ÷ 100))]). According to these values, the damage that may be caused by overweight Class 9s and 10s translates into relatively minimal decreases in the pavement life (less than 5 months). These numbers – if accurate – are reassuring that pavement appears to be designed to last close to 20 years. However, it is unclear whether the method chosen to calculate these numbers is the best measure for accurately capturing the amount of damage the overweight trucks are causing to these roadways. For example, if all of the *monthly* pavement life decrease estimates were averaged together for a particular site, those values suggest significantly higher estimates in pavement life decrease than what is presented in Table 7.3 (up to 47.7 months earlier). To better reconcile varying methods for calculating pavement life decrease, it is crucial for each of these methods to be compared alongside actual observations of road conditions (e.g., ride quality index, observations from pavement survey crew, etc.).

One point to keep in mind regarding Table 7.3 is that data are based on Class 9 and 10 data only. A next point of discussion might be to decide 1) whether other HCV classes should be included when determining pavement life decreases due to overweight vehicles, and 2) whether the additive effects of the other HCV classes contribute any meaningful amount of degradation in pavement conditions (and hence, pavement life). The WIM unit (in the Traffic Data and Analysis section within the Office of Transportation System Management) plans to work with the Pavement Design unit within the Office of Materials and Road Research to help address these questions.

WIM #	Year	Design Lane[1]	Total Annual Design Lane ESALs	20-Year Design Lane ESALs with Overweight Trucks	20-Year Design Lane ESALs without Overweight Trucks	Pavement Life Decrease in Months
30	2013	Lane 1	68,293	1,611,712	1,275,773	4.92
41	2011-2013	Lane 1	34,830	905,585	741,875	4.62
33	2010-2013	Lane 2	167,300	4,416,722	3,751,739	4.05
37	2010-2013	Lane 1	1,022,015	32,295,659	28,377,428	3.68
29	2010-2013	Lane 1	107,926	2,460,714	2,149,331	2.87
31	2010-2011	Lane 4	60,424	1,329,336	1,179,469	2.02
34	2010-2013	Lane 2	72,598	1,858,512	1,711,126	2.02
39	2010-2013	Lane 2	80,077	1,953,879	1,812,400	1.79
36	2010-2013	Lane 1	81,414	1,856,243	1,704,904	1.62
42	2013	Lane 1	135,986	3,372,455	3,161,435	1.55
43	2013	Lane 4	189,057	4,537,368	4,252,673	1.51
26	2010-2013	Lane 1	770,259	23,107,770	22,158,246	1.23
35	2010-2013	Lane 4	49,399	1,284,384	1,236,517	0.91
32	2013	Lane 4	323,484	7,504,838	7,242,435	0.81
40	2010-2013	Lane 4	320,015	7,936,365	7,679,749	0.76
38	2010-2013	Lane 4	190,973	4,277,800	4,193,676	0.43

[1] Refers to the lane that consistently had the highest number of ESALs every year (or the majority of the years, or on average across the years)

Note: WIM #27 data is not included in the table due to having less than a year's worth of data.

Table 7.3. All WIM sites are identified by their pavement design lane ("Design Lane") along with calculations of the following based on design lane characteristics: 1) mean number of ESALs observed in a year, 2) mean number of ESALs observed within a 20-year design life *with* overweight vehicles, 3) mean number of ESALs observed within a 20-year design life *without* overweight vehicles, and 4) the estimated decrease that is anticipated to occur (in months) to the pavement life on account of the overweight vehicles. "Year" column depicts the years that were averaged together to calculate means of the aforementioned data. WIM sites are rank-ordered in descending order by pavement life decrease.

Conclusions

ESALs by Vehicle Class

The majority of the WIM sites had the same three vehicle classes that generated the most ESALs. These vehicles classes are: Classes 9, 10, and 5. This is generally not surprising given the fact that Class 9 and 10 vehicle volumes were generally highest for combination-unit trucks. In addition, for single-unit trucks, Class 5s generally produced the highest volumes. To look at the distribution of ESALs across vehicle classes at all WIM sites, the reader is encouraged to look at Figures 7.1-7.17.

An important point to highlight is the fact that the relative distribution of ESALs is site-specific. For example, while some sites are Class 9 heavy in ESALs and not much else (e.g., Class 9s generate close to 87% of all ESALs at WIM #33), other sites show greater representation of ESALs coming from additional vehicle classes in addition to Class 9s (e.g., WIM #36). These particular nuances may reflect particular vehicle and roadway characteristics that may interact with geographical location and other factors.

ESALs by Lane

Although there was some variation in the distribution of ESALs across the lanes at each site, they generally followed a similar pattern with few exceptions. Firstly, the percentage of ESALs observed between lanes in a 2-lane, 2-direction site was relatively well-balanced between directions of travel except at WIM #41 (see WIM #41 subsection for details). Secondly, at 4-lane, 2-direction sites, the driving lanes typically accumulated a greater proportion of ESALs than those in the passing lanes. The only exception to this finding was in the NB lanes at WIM #38 on account of the NB passing lane serving as the exit lane towards Minneapolis/St. Paul—greater ESALs were observed in the NB passing lane than NB driving lane. Lastly, it was observed that not all 4-lane, 2-direction sites experienced 90% of the ESALs in the driving lanes (45:45 by direction of travel). Since current pavement design procedures assume this distribution in the driving lanes of 4-lane, 2-direction sites, the results presented here can be used to adjust pavement design policy to further enhance financial effectiveness.

Effects of Overweight Vehicles on Pavement Life

Deriving estimates on pavement life decrease (a numerical value to capture how much earlier the pavement is expected to reach its pavement life due to overweight vehicles) for all WIMs were somewhat complicated by the fact that calculation methods can vary. When mean *annual* ESAL values from Class 9s and 10s are used to estimate pavement life decreases, numbers suggested relatively minimal effects of overweight vehicles on pavement life (less than 5 months decrease in pavement life due to overweight Class 9 and Class 10 vehicles). However, when mean *monthly* ESAL values from Class 9s and Class 10s are used to estimate pavement life decreases, those estimates tended to be significantly higher (up to 48 months decrease in pavement life due to overweight C9s and C10s). Due to potential disparity in the results, it may be worthwhile in the future to compare these estimates alongside direct measures of pavement life decrease (e.g., ride quality index, direct surveying of pavement conditions, etc.). The WIM unit (in the Traffic Data and Analysis section within the Office of Transportation System Management) plans to work with the Pavement Design unit within the Office of Materials and Road Research to help address these questions.

Lastly, it should be noted that estimates on pavement life decrease are only calculated based on Class 9 and Class 10 traffic patterns in this report. To more accurately capture numerical measures of pavement life decrease, it may be advisable to consider whether other vehicle classes (particularly HCVs) should be included in this analysis.

8. FREIGHT

This section summarizes the freight trends of heavy commercial vehicles (HCVs) observed from 2010-2013, with the amount of data available during this time varying by site. MnDOT measures freight tonnage in short tons (US metric for ton; 1 ton = 2,000 pounds). Factors affecting data availability during this time frame depend on multiple factors including 1) the WIM installation date and initial calibration (not all WIMs were installed and calibrated at the same time), 2) operational status of the system, and 3) the validity of the data collected (which is primarily dependent on data quality).

Summary of Directional Freight Movement

One of the questions addressed in this section is whether there were any differences in the amount of HCV freight traveling between directions of roadways on which the WIMs were situated. It is important to note that this question was addressed in two different ways. If interest lies solely in the amount of freight that traveled between directions, then monthly freight totals can be analyzed for any statistical differences between travel directions. If, on the other hand, the desire is to explore that same question after having equated for traffic volumes between travel directions, then additional steps are necessary prior to analyzing the dataset. To address both interpretations of this question, two separate analyses were performed:

1) Analysis to capture sheer freight total differences between directions[14]
2) Analysis to capture freight total differences *after* controlling for volume differences between directions of travel[15].

Table 8.1 provides a summary of the results that addresses 1) whether there were any differences in the amount of HCV freight that traveled in one direction compared to the other for each WIM, and 2) whether – after controlling for differences in HCV traffic volumes between directions of travel – there were any differences in the amount of HCV freight traveling in one direction compared to the other at each WIM. It is entirely possible that freight trends will not always be the same between the two different analyses, and it is up to the readers of this report to decide which type of information is most useful for them.

For the sake of understanding how to interpret the results from the two analyses (see Table 8.1), let us pretend that there is a WIM ("WIM Z") on an EB/WB roadway in which analyses suggested that more freight traveled WB than EB (EB < WB)—this is a straightforward interpretation of the first analysis. However, let us suppose that the second analysis suggests that the same amount of freight traveled EB and WB (EB = WB). This second analysis can be interpreted thusly: when HCV volumes are equated between the two directions at WIM Z, there is no difference in the amount of freight traveling in either direction (the same amount of freight travels between the two directions when traffic volumes are equated to be the same). In the

[14] For each WIM, a paired-samples t-test was performed on monthly HCV freight totals (collected between 2010-2013) by direction of travel.

[15] An initial residual analysis was performed for each WIM with monthly HCV freight totals regressed on monthly HCV volumes. A paired-samples t-test was subsequently performed on the residuals of the linear model fitted to each WIM's data.

following section, the discussion of freight trends at each WIM site will include further discourse into the directional trends than what is provided in Table 8.1.

WIM #	# of Months Included in Analysis	Freight Quantity (tons) by Direction	Freight Quantity (tons) by Direction After Controlling for Directional Volume Differences
26	39	NB > SB	NB < SB
27*	--	--	--
29	27	NB > SB	NB = SB
30	13	NB = SB	NB < SB
31	24	EB = WB	EB < WB
32	16	NB = SB	NB < SB[1]
33	45	EB < WB	EB < WB
34	43	NB < SB	NB < SB
35	47	EB < WB	EB < WB
36	43	EB > WB	EB > WB
37*	--	--	--
38	41	NB = SB	NB > SB
39	48	NB < SB	NB < SB
40	42	NB = SB	NB > SB
41	38	NB > SB	NB > SB
42	14	NB = SB	NB = SB
43	15	EB < WB	EB < WB

* Data collection only occurs in one direction at these WIM sites

[1] Freight movement was marginally greater ($p < .10$) going SB than NB

Table 8.1. A summary of the amount of freight (tons) traveling between directions at each WIM operating between 2010-2013. Results in the third column depict differences in freight quantity traveling between directions *without* controlling for traffic volume differences between those directions. Results in the fourth column depict differences in freight quantity traveling between directions *after* having controlled for traffic volume differences between those directions. Assignment of mathematical symbols (>, <, and =) are based on results of paired-samples t-tests with $\alpha = .05$.

WIM #26

Monthly Freight Trends. Monthly freight totals were generally highest between spring through fall (May-October), with lowest freight movement typically observed during the winter (December-February). See Figure 8.1.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2010-2013 was greater in the NB direction than SB direction. However, if HCV traffic volumes are equalized between directions, analyses showed that SB HCVs actually carried more freight than those going NB. Refer to Table 8.1.

WIM #27

Monthly Freight Trends. Monthly freight totals in the EB direction were highest in October and lowest in April of 2010. Information at this site is limited to less than a full year's worth of data. Therefore, it is important to keep in mind that any freight conclusions here are drawn from this limited dataset. See Figure 8.2.

WIM #29

Monthly Freight Trends. Monthly freight trends are somewhat more difficult to ascertain at this WIM site from 2010-2013 for a few reasons. Firstly, at least two of the years (specifically data from 2010 and 2012) do not have spring/summer freight data. Since many sites tend to exhibit increases in freight totals during that time frame (spring/summer months), the lack of data from those months makes any seasonal interpretations of freight trends more difficult just based on 2010 and 2012 data alone. Secondly, there were intermittent problems with Lane 3 (SB passing lane) that affected the validity of the data. Problems in Lane 3 started to occur in March 2012 and continued intermittently until August 2014[16]. Therefore, statements on monthly freight trends made here will primarily rely on freight patterns observed in 2011. If the true underlying freight trends mirror what was observed in 2011, then freight totals were generally highest from spring to fall (May-September) compared to other months of the year. Lowest freight volumes occur in the winter to early spring (January-April; according to 2011 data). See Figure 8.3.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2010-2013 was greater in the NB direction than SB direction. However, if HCV traffic volumes are equalized between directions, analyses showed that NB HCVs generally carried the same amount of freight as those going SB. Refer to Table 8.1. These conclusions are drawn in spite of the issues outlined above (see WIM #29's "Monthly Freight Trends" subsection above). A future goal should be to redo these same analyses at WIM #29 with subsequent years' worth of data (2014 data and on), while having enforced higher standards for data quality.

WIM #30

Monthly Freight Trends. Monthly freight totals were highest from summer to fall (June-October), with lowest volumes occurring in winter through mid-spring (December-May). These observations are based on data available in 2013. In the future, it will be interesting to see whether the 2013 freight trends are mirrored in subsequently years. See Figure 8.4.

[16] The Lane 3 problems that started in March 2012 were resolved when the inductive loops and sensors were replaced immediately following a nearby bridge replacement (replacement of loops and sensors occurred on September 26, 2012). However, problems in Lane 3 started again (in March 2013), which was subsequently identified as a problem with the upstream loop (upstream loop was disabled in August 2014).

Directional Freight Movement. The overall amount of HCV freight that traveled from 2012-2013 was roughly the same between NB and SB directions. However, if HCV traffic volumes are equalized between directions, analyses showed that SB HCVs actually carried more freight than those going NB. Refer to Table 8.1.

WIM #31

Monthly Freight Trends. Monthly freight trends are based on data from 2010-2011. Both years showed some similarities in freight patterns but also some differences. While lowest freight volumes were similarly observed in winter (December-February) across both years, peak freight movement patterns were different between the two years. Whereas 2010 showed peak freight volumes in the late summer to fall (August-October), year 2011 showed something closer to a bimodal peak—one centered around May, and the other around October. See Figure 8.5.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2010-2011 was roughly the same between EB and WB directions (based on a relatively small number of available months included in the analysis). However, if HCV traffic volumes are equalized between directions, analyses showed that WB HCVs actually carried more freight than those going EB. Refer to Table 8.1.

WIM #32

Monthly Freight Trends. Monthly freight trends are based on data from 2012-2013. However, since there is no data for half of 2012, inferences on monthly freight trends are based on data from 2013 only. Based on 2013 data, this site experiences highest freight movement in the summer to early fall (June-September), with lowest volumes reported in the winter (December-February). See Figure 8.6.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2012-2013 was roughly the same between NB and SB directions (based on a relatively small number of available months included in the analysis). However, if HCV traffic volumes are equalized between directions, analyses showed that SB HCVs marginally carried more freight than those going NB. Refer to Table 8.1.

WIM #33

Monthly Freight Trends. Monthly freight trends at this site suggest two distinct peaks in freight movement—one roughly coinciding with the fall (September-November), and the other (more variable) peak coinciding with the winter months (particularly January and March). These suggest specific patterns of freight movement that may be dependent on the type of industry utilizing the road on which the WIM site is located. See Figure 8.7.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2010-2013 was greater in the WB direction than EB direction. This finding remained the same even when controlling for volume differences between directions—when HCV traffic volumes are equalized between directions, analyses showed that WB HCVs carried more freight than those going EB. Refer to Table 8.1.

WIM #34

Monthly Freight Trends. Monthly freight totals typically reached peak levels in the spring to fall (May-October), with lowest freight movement observed in the winter (December-February). See Figure 8.8.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2010-2013 was greater in the SB direction than NB direction. This finding remained the same even when controlling for volume differences between directions—when HCV traffic volumes are equalized between directions, analyses showed that SB HCVs carried more freight than those going NB. Refer to Table 8.1.

WIM #35

Monthly Freight Trends. Monthly freight trends tended to vary year by year. However, if freight totals are averaged across years by month, results suggest two potential freight peaks occurring at this site—one from summer to fall (June-October), and another one briefly in the winter (January-February). Lowest volumes occurred in the late winter (particularly March). It will be interesting in the future to investigate whether these two distinct freight total peaks are from two distinct industries or are from the same industry. See Figure 8.9.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2010-2013 was greater in the WB direction than EB direction. This finding remained the same even when controlling for volume differences between directions—when HCV traffic volumes are equalized between directions, analyses showed that WB HCVs carried more freight than those going EB. Refer to Table 8.1.

WIM #36

Monthly Freight Trends. Monthly freight totals generally peaked in the spring to early fall (May-September), with lowest volumes occurring in the winter months (December-February). WIM #36 is somewhat interesting in the fact that a couple of the years exhibited a sharp increase in freight during the month of August while other years did not—whether those differences are a reflection of specific characteristics in traffic patterns during those years is unclear. See Figure 8.10.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2010-2013 was greater in the EB direction than WB direction. This finding remained the same even when controlling for volume differences between directions—when HCV traffic volumes are equalized between directions, analyses showed that EB HCVs carried more freight than those going WB. Refer to Table 8.1.

WIM #37

Monthly Freight Trends. Monthly freight trends tended to vary year by year. However, if freight totals are averaged across years by month, results suggest that monthly freight totals are highest from early spring to fall (March-October). However, due to some known construction projects at this site (e.g., 2013 concrete rehabilitation project), it is advisable that valid but atypical data points from such events be removed from analyses (or imputed) to get more accurate representations of true underlying traffic patterns at this site. See Figure 8.11.

WIM #38

Monthly Freight Trends. Monthly freight trends suggest relatively low variability across all years except 2013. However, it should be noted that construction projects were observed during the spring/summer months in both 2010 and 2012, which attenuated traffic patterns during that time frame for those two years. For this reason, data from 2011 and 2013 are only used to interpret monthly freight trends at this site. If data from 2011 and 2013 are close reflections of the true underlying traffic patterns at this site, then data suggests that freight trends are highest in the summer to fall (June-October). According to an authority on the Duluth port, lots of different types of freight (via Lake Superior) move to truck and rail each year, particularly from April through the third week of December. Commodities distributed to trucks include some of the following: pulp (to make paper) and paper, clay, pipeline pipe, aggregate (limestone), construction material, and lumber. As of now, it is unclear whether any of the listed commodities move across WIM #38 on I-535, but this question may be explored in the future. Lowest freight activity generally occurring during winter months (December-February), which also happens to coincide with decreased activity on the Lake Superior ports. See Figure 8.12.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2010-2013 was roughly the same between NB and SB directions. However, if HCV traffic volumes are equalized between directions, analyses showed that NB HCVs actually carried more freight than those going SB. Refer to Table 8.1.

WIM #39

Monthly Freight Trends. Monthly freight totals tended to have two separate peaks—once typically around spring to early summer (April-June), and another peak in the late fall (October-November). In contrast, lowest amounts of freight were typically observed in the winter (December-March). These interpretations were based on averaging monthly data across all years, but it is clear from Figure 8.13 that the two peaks in freight volume tended to vary slightly per year. Perhaps these slight differences are due to the timing of certain industry activities that occur every year. For example, the frac sand mining industry is fairly large within this region and may be tied to the monthly freight trends observed in this report. In addition, there may be some interactions between port activity near Winona (on Mississippi River) and freight moving across WIM #39 (trucks bring commodities to the port or leave with commodities from the port). According to an authority on Winona port activity, port activity is busiest in May, October, and November with the majority of this activity attributed to grain transportation. Other common commodities that are seen through the port (either inbound or outbound) are: corn, salt, fertilizer, gypsum, and coal. The port typically opens in April and closes around Thanksgiving (late November). See Figure 8.13.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2010-2013 was greater in the SB direction than NB direction. This finding remained the same even when controlling for volume differences between directions—when HCV traffic volumes are equalized between directions, analyses showed that SB HCVs carried more freight than those going NB. Refer to Table 8.1.

WIM #40

Monthly Freight Trends. Traffic volumes (particularly HCV traffic) were significantly lower on US-52 (specifically as recorded at the WIM site) from roughly March 2013 through the end of the year, which also subsequently affected the amount of freight recorded that year. Although there were no immediately-surrounding events that would explain the noticeable decrease in volume (and hence, freight), it is speculated that HCVs may have taken alternative routes to avoid construction upstream at the Lafayette Bridge on US-52. For this reason, statements on monthly freight trends will be based on data available from 2010-2012 only. Based on data from 2010-2012, monthly freight totals were generally highest from summer to fall (June-October), with lowest volumes occurring in the winter (December-February). See Figure 8.14.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2010-2013 was roughly the same between NB and SB directions. However, if HCV traffic volumes are equalized between directions, analyses showed that NB HCVs actually carried more freight than those going SB. Refer to Table 8.1.

WIM #41

Monthly Freight Trends. Monthly freight totals generally showed a consistent peak in October, which coincides with the sugar beet harvest that occurs in western Minnesota. All other months had relatively small but consistent monthly values in freight totals with some variation within each year. See Figure 8.15.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2010-2013 was greater in the NB direction than SB direction. This finding remained the same even when controlling for volume differences between directions—when HCV traffic volumes are equalized between directions, analyses showed that NB HCVs carried more freight than those going SB. Refer to Table 8.1.

WIM #42

Monthly Freight Trends. Monthly freight trends are based on data from 2012-2013. Although both years did not have a complete years' worth of data, the available monthly data are similar enough across years to make some inferences about the freight patterns at this site. Monthly freight total appear to be highest starting in the spring through fall (May-October), with lowest volumes observed in the winter (particularly February-March). To better understand the underlying freight trends at this site, further data collection is warranted. See Figure 8.16.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2012-2013 was roughly the same between NB and SB directions (based on a relatively small number of available months included in the analysis). This finding remained the same even when controlling for volume differences between directions—when HCV traffic volumes are equalized between directions, analyses showed that NB HCVs generally carried the same amount of freight as those going SB. Refer to Table 8.1.

WIM #43

Monthly Freight Trends. Monthly freight trends are based on data from 2012-2013. However, since data collection did not start at this site until the last quarter of 2012, inferences on monthly freight trends are based on data from 2013 only. Based on 2013 data, monthly freight totals are generally highest in the summer to late fall (July-November), with lowest amounts of freight movement overlapping with winter months (December-February). To better understand the underlying freight trends at this site, further data collection is warranted. See Figure 8.17.

Directional Freight Movement. The overall amount of HCV freight that traveled from 2012-2013 was greater in the WB direction than EB direction (based on a relatively small number of available months included in the analysis). This finding remained the same even when controlling for volume differences between directions—when HCV traffic volumes are equalized between directions, analyses showed that WB HCVs carried more freight than those going EB. Refer to Table 8.1.

Conclusions

Monthly Freight Trends

Monthly HCV freight trends showed some seasonal variability when examined at an annual level. In particular, many of the WIM sites exhibited greater freight movement in the summer (with this peak frequently having started in the late spring and/or extending into the fall), with lowest freight movement coinciding with winter months (most often December through February). These observations generally mirror the annual volume and GVW patterns discussed earlier in this report. A few sites, however, appeared to more noticeably deviate from this high-summer/low-winter pattern in freight movement, specifically WIMs #33 (Olivia), #35 (Bagley), #39 (Winona), and #41 (Crookston). In addition, these four atypical sites were all uniquely different from each other in freight movement patterns. For example, 3 out of 4 of these sites (WIMs #33, #35, and #39) appeared to show bimodal peaks in freight movement, although not necessarily encompassing the same months of the year. WIM #33 experienced a freight movement peak centered around two time frames—once in the fall (September-November) and also in the winter (January-March). WIM #35 had bimodal freight peaks centered around the summer through fall (June-October), along with a shorter freight peak in winter (January-February). In contrast, WIM #39 showed bimodal freight peaks in the spring through early summer (April-June), with the second freight peak occurring in the winter (December-March). Lastly, WIM #41 was different from all other WIMs in that a sharp increase in freight movement was centered around October (peak time for the sugar beet harvest and staging operations occurring in this area). With the exception of WIM #35, the other three sites with atypical freight patterns were also previously discussed for their atypical HCV volume patterns (see Section 4; Volume and Vehicle Class). This further suggests that there might be unique characteristics in the HCV populations at these sites compared to what is observed at most other sites (e.g., type of industry or goods relying on HCV transport in these regions at different times of the year).

Directional Freight Movement

In this section, directional freight movement of HCVs was collected at the monthly level from 2010-2013. This dataset was explored in two ways. Firstly, a direct comparison of monthly freight totals was conducted by direction of travel, and results are presented in the third column in Table 8.1. The same analysis was performed a second time but with the following important modification: HCV volumes were controlled for prior to analysis. By performing these two analyses, the following questions were able to be addressed: 1) whether there were any differences in the amount of freight traveling between directions, and 2) whether any of those differences remain after controlling for volume differences. The former analysis (presented in Table 8.1, 3rd column) can tell the reader what actual freight movement patterns were like at a given site. The latter case, on the other hand, can tell the reader whether vehicles traveling in one direction tended to carry more freight on average compared to the vehicles traveling in the other direction (Table 8.1, 4th column). Both questions are equally important and have been addressed in this section.

9. VEHICLE SPEEDS

The following section summarizes speed trends (miles per hour; mph) observed from 2010-2013, with the amount of data available during this time varying by site. Factors affecting data availability during this time frame depend on multiple factors including 1) the WIM installation date and initial calibration (not all WIMs were installed and calibrated on the same day), 2) operational status of the system, and 3) the validity of the data collected (which is primarily dependent on data quality).

Vehicle classes 1, 2 and 3 shall henceforth be collectively referred to as passenger vehicles (PVs), while classes 4 through 13 shall be referred to as heavy commercial vehicles (HCVs). Traffic lane directions shall be abbreviated as NB, SB, EB, or WB to respectively represent northbound, southbound, eastbound, or westbound directions of travel.

WIM #26

Speed By Month. The speed limit on I-35 at the WIM site is 70 mph. The average monthly vehicle speed was 72.3 mph, with monthly speeds varying between 70.4 and 73.1 mph (2.8 mph difference). Although speeds generally remained relatively similar across months, lower speeds were generally observed over the winter months (December-February), which can be attributed to poorer road conditions during that time frame (i.e., ice, snow, etc.). See Figure 9.1.

Speed By Lane. Speed was analyzed as a function of lane (driving lanes vs. passing lanes). On average, vehicles in the passing lanes travelled 4.5 mph faster than those in the driving lanes. See Figure 9.2.

WIM #27

Speed By Month. The speed limit on MN 60 at the WIM site is 65 mph. The average monthly vehicle speed was 63.9 mph, with monthly speeds varying between 61.1 and 65.1 mph (4.0 mph difference). Although speeds generally remained relatively similar across months, lower speeds were typically observed over the winter months (January-February), which can be attributed to poorer road conditions during that time frame (i.e., ice, snow, etc.). See Figure 9.3.

Speed By Lane. Speed was analyzed as a function of lane (EB driving vs. EB passing). While vehicles in passing lanes are typically faster than those in driving lanes, data at this site suggests no significant difference in vehicle speeds between the two lanes. See Figure 9.4.

WIM #29

Speed By Month. The speed limit on TH 53 at the WIM site is 65 mph. The average monthly vehicle speed was 67.5 mph, with monthly speeds varying between 66.1 and 68.9 mph (2.9 mph difference). Although speeds generally remained relatively similar across months, lower speeds were typically observed over the winter months (December-February), which can be attributed to poorer road conditions during that time frame (i.e., ice, snow, etc.). See Figure 9.5.

Speed By Lane. Speed was analyzed as a function of lane (driving lanes vs. passing lanes). On average, vehicles in the passing lanes travelled 3.6 mph faster than those in the driving lanes. See Figure 9.6.

WIM #30

Speed By Month. The speed limit on MN 61 at the WIM site is 65 mph. The average monthly vehicle speed was 66.2 mph, with monthly speeds varying between 63.0 and 67.5 mph (4.5 mph difference). Although speeds generally remained relatively similar across months, lower speeds were typically observed over the winter months and into early spring (December-April). While many sites do exhibit this attenuation in speeds during the winter (December-February), it is less common to see these attenuations continuing into the early spring (through April). This may reflect particular road conditions within this region during those specific months (December-April). WIM #30 isn't too far inland from the shores of Lake Superior—the chilly air from the lake may extend cold weather conditions for a longer period of time compared to other sites. See Figure 9.7.

Speed By Direction and Hour. Speed was analyzed as a function of lane (driving lanes vs. passing lanes). The average speed of the vehicles in the passing lanes was marginally faster (1.6 mph faster) than that of those in the driving lanes. See Figure 9.8.

WIM #31

Speed By Month. The speed limit on US 2 at the WIM site is 65 mph. The average monthly vehicle speed was 65.9 mph, with monthly speeds varying between 64.5 and 66.7 mph (2.2 mph difference). Overall monthly speeds remained relatively consistent throughout the observation period. See Figure 9.9.

Speed By Lane. Speed was analyzed as a function of lane (driving lanes vs. passing lanes). The average speed of the vehicles in the passing lanes was marginally faster (1.9 mph faster) than that of those in the driving lanes. See Figure 9.10.

WIM #32

Speed By Month. The speed limit on US 52 at the WIM site is 65 mph. The average monthly vehicle speed was 68.4 mph, with monthly speeds varying between 66.4 and 70.2 mph (3.8 mph difference). In at least two of the years of data collection, there were lane closures due to summer construction projects in the area. This may account for the lower-than-expected overall speeds for the summer months (July and August), extending into early fall (September). See Figure 9.11.

Speed By Lane. Speed was analyzed as a function of lane (driving lanes vs. passing lanes). The average speed of the vehicles in the passing lanes was marginally faster (1.7 mph faster) than that of those in the driving lanes. See Figure 9.12.

WIM #33

Speed By Month. The speed limit on US 212 at the WIM site is 55 mph. The average monthly vehicle speed was 57.9 mph, with monthly speeds varying between 56.4 and 59.2 mph (2.8 mph difference). Overall monthly speeds remained relatively consistent throughout the observation period. See Figure 9.13.

Speed By Lane. Speed was analyzed as a function of lane (EB vs. WB lane). On average, vehicles in the EB and WB lanes traveled at roughly the same speeds. See Figure 9.14.

WIM #34

Speed By Month. The speed limit on MN 23 at the WIM site is 60 mph. The average monthly vehicle speed was 61.5 mph, with monthly speeds varying between 59.9 and 62.4 mph (2.5 mph difference). Overall monthly speeds remained relatively consistent throughout the observation period. See Figure 9.15.

Speed By Lane. Speed was analyzed as a function of lane (NB vs. SB lane). Overall, vehicles in the NB and SB lanes traveled at roughly the same speeds. See Figure 9.16.

WIM #35

Speed By Month. The speed limit on US 2 at the WIM site is 65 mph. The average monthly vehicle speed was 66.1 mph, with monthly speeds varying between 64.2 and 67.1 mph (3.0 mph difference). Overall monthly speeds remained relatively consistent throughout the observation period. See Figure 9.17.

Speed By Lane. Speed was analyzed as a function of lane (driving lanes vs. passing lanes). On average, vehicles in the passing lanes travelled 2.8 mph faster than those in the driving lanes. See Figure 9.18.

WIM #36

Speed By Month. The speed limit on MN 36 at the WIM site is 65 mph. The average monthly vehicle speed was 65.4 mph, with monthly speeds varying between 64.5 and 65.8 mph (1.3 mph difference). Overall monthly speeds remained relatively consistent throughout the observation period. See Figure 9.19.

Speed By Lane. Speed was analyzed as a function of lane (driving lanes vs. passing lanes). On average, vehicles in the passing lanes travelled 2.9 mph faster than those in the driving lanes. See Figure 9.20.

WIM #37

Speed By Month. The speed limit on I-94 at the WIM site is 70 mph. The average monthly vehicle speed was 69.4 mph, with monthly speeds varying between 67.1 and 70.6 mph (3.5 mph difference). In at least two of the years of data collection, there were lane closures due to summer construction projects in the area. This may account for the lower-than-expected overall speeds for the summer months (July and August; see Figure 9.21). Furthermore, this particular roadway going WB is a popular route for recreational travel during the summer months, where typical rush hour slow-downs are exacerbated by these recreational trips towards the northwest via I-94.

Speed By Lane. Speed was analyzed as a function of lane (WB driving vs. WB passing). The vehicles in the passing lane travelled an average of 4.5 mph faster than those in the driving lane. See Figure 9.22.

WIM #38

Speed By Month. The speed limit on I-535 at the WIM site is 55 mph. The average monthly vehicle speed was 56.8 mph, with monthly speeds varying between 55.5 and 57.5 mph (2.0 mph difference). Overall monthly speeds remained relatively consistent throughout the observation period. See Figure 9.23.

Speed By Lane. Speed was analyzed as a function of lane (driving lanes vs. passing lanes). The average speed of the vehicles in the passing lanes was marginally faster (1.1 mph faster) than that of those in the driving lanes. See Figure 9.24.

WIM #39

Speed By Month. The speed limit on MN 43 has not been the same from 2010-2013. While the speed limit going SB has always been 50 mph from 2010-2013, the NB side went from 40 mph to 50 mph some time in 2012 or early 2013. The average monthly vehicle speed at WIM #39 was 48.7 mph, with monthly speeds varying between 47.8 and 49.1 mph (1.3 mph difference). Overall monthly speeds remained relatively consistent throughout the observation period. See Figure 9.25.

Speed By Lane. Speed was analyzed as a function of lane (NB vs. SB lane). Overall, vehicles in the NB and SB lanes traveled at roughly the same speeds. See Figure 9.26.

WIM #40

Speed By Month. The speed limit on US 52 at the WIM site is 55 mph. The average monthly vehicle speed was 60.1 mph, with monthly speeds varying between 59.4 and 61.5 mph (2.1 mph difference). Overall monthly speeds remained relatively consistent throughout the observation period. See Figure 9.27.

Speed By Lane. Speed was analyzed as a function of lane (driving lanes vs. passing lanes). On average, vehicles in the passing lanes travelled 4.9 mph faster than those in the driving lanes. See Figure 9.28.

WIM #41

Speed By Month. The speed limit on CSAH 14 at the WIM site is 55 mph. The average monthly vehicle speed was 60.4 mph, with monthly speeds varying between 59.0 and 61.6 mph (2.0 mph difference). Overall, monthly speeds remained relatively consistent throughout the observation period, with the lowest average speeds observed in the late fall through winter (October-March). See Figure 9.29.

Speed By Lane. Speed was analyzed as a function of lane (NB vs. SB lane). Overall, vehicles in the NB and SB lanes traveled at roughly the same speeds. See Figure 9.30.

WIM #42

Speed By Month. The speed limit on US 61 at the WIM site is 60 mph. The average monthly vehicle speed was 61.2 mph, with monthly speeds varying between 59.7 and 62.2 mph (2.4 mph difference). Overall monthly speeds remained relatively consistent throughout the observation period. See Figure 9.31.

Speed By Lane. Speed was analyzed as a function of lane (driving lanes vs. passing lanes). Overall, vehicles in the passing lanes travelled 3.0 mph faster than those in the driving lanes. See Figure 9.32.

WIM #43

Speed By Month. The speed limit on US 10 at the WIM site is 65 mph. The average monthly vehicle speed was 66.4 mph, with monthly speeds varying between 63.4 and 67.8 mph (4.4 mph difference). Speeds typically began climbing in April, and remained at a relatively consistent peak from May through November. The lower speeds observed over the winter months (December-February) can generally be attributed to poorer road conditions during that time frame (i.e., ice, snow, etc.). See Figure 9.33.

Speed By Lane. Speed was analyzed as a function of lane (driving lanes vs. passing lanes). Overall, vehicles in the passing lanes travelled 3.4 mph faster than those in the driving lanes. See Figure 9.34.

Conclusions

Speed By Month

In general, speed analyzed as a function of month suggests that speed remained relatively consistent throughout the months of each year at all WIMs. In fact, the average difference between the highest and lowest monthly speeds across all WIM sites was only 2.8 mph. At some WIM sites (i.e., WIMs 26, 27, and 29), speeds were lower over the winter months (December, January, and February), which may be attributed to poorer road conditions during that time frame (i.e., ice, snow, etc.). In some cases, decreased speeds were extended into the spring months of March or April, which may have been due to prolonged winter weather conditions.

Speed By Lane

As expected, vehicles in passing lanes were typically faster than vehicles in driving lanes across 4-lane, 2-direction and 2-lane, 1 direction sites. The only exception to this was at WIM #27, where no speed differences were observed between driving and passing lanes.

One of the interesting findings in the data was that many of the high volume WIM sites had a higher vehicle speed difference between driving and passing lane vehicles (2.9 mph to 4.9 mph difference), specifically WIMs #40, #37, #42, and #36. Of these four WIMs, the ones with the lowest speed difference (2.9 to 3.0 mph difference; WIMs #36 and #42) were those that have stoplights. Those without stoplights (WIMs #40 and #37) had the higher speed difference between driving and passing lane vehicles (4.5 mph to 4.9 mph).

While the above statement was generally true (high volume WIM sites having a greater speed difference between driving and passing lanes), there were two high volume sites that did not show this effect. These sites were specifically WIMs #32 and #38, where the passing/driving lane speed difference was not as pronounced (respectively 1.7 mph and 1.1 mph difference). However, there may be some specific reasons that may explain the pattern observed at these two sites. For example, due to some construction events in 2012 and 2013 (the only years in which WIM #32 was in operation), it is difficult to ascertain whether the small speed difference between lanes is due to the construction events or is actually reflective of true speed patterns at WIM #32. More data collection at WIM #32 should be able to resolve this question in the future. WIM #38, on the other hand, does not behave like a typical 4-lane, 2-direction site (and therefore should not be expected to necessarily have traffic characteristics like other 4-lane, 2-direction sites). The location of WIM #38 is unique in that NB drivers must make an important decision a half mile up from the WIM. NB drivers wanting to exit towards Minneapolis/St. Paul must do so from the NB passing lane, while NB drivers heading to Duluth must do so from the NB driving lane. This effectively makes (NB) driving patterns to behave differently from other WIMs. While lane choice (driving vs. passing) is more highly independent of destination at other WIMs, this is not the case at WIM #38—the lane one chooses going NB near WIM #38 is highly dependent on destination (head south on I-35 towards Minneapolis/St. Paul vs. heading towards Duluth).

In analyzing speed as a function of hour, it is apparent that speeds were marginally lower during overnight/early morning hours (1:00 am to 4:00 am), presumably because of the decreased visibility at that time of night. WIM #42 recorded speeds that seemed to buck this trend, with 4:00 pm to 6:00 pm consistently showing the lowest speeds for all lanes in both directions. This speed decrease most likely reflects traffic congestion during the evening rush hour at that WIM site.

10. CONCLUSIONS AND RECOMMENDATIONS

This report summarizes data collected from Minnesota weigh-in-motion (WIM) sites between 2010-2013. Seventeen (17) WIMs were in operation during this time period with systems operating, on average, 93% of the time. Results suggested that times of system non-operation typically coincided with summer months, with winter months generally showing highest rates of system operation.

System Performance

Since this data collection period (after 2013), MnDOT has refined data-checking procedures for better documentation of system operation and performance/quality checking. This effectively means that MnDOT has implemented procedures to 1) check data more frequently (every week as opposed to every month), and 2) monitor multiple measures that indicate how well a system is performing while in operation. As previously discussed in this report, monitoring WIM system performance is complicated by the difficulty in distinguishing between hardware issues (e.g., WIM sensor, loop, controller, problems, etc.) from non-hardware issues (e.g., weather-related events, lane discipline—factors outside of MnDOT's control). Prior to 2014, MnDOT traditionally monitored Class 15s (system inputs that were unsuccessfully resolved by the WIM controller; a.k.a "errors") as a measure of system performance[17]. However, since hardware problems and non-hardware problems can both cause increases in Class 15 errors, this measure alone still provided some difficulty in distinguishing one from the other. Furthermore, the way that Class 15 rates were monitored prior to 2014 was to combine those Class 15 rates across lanes into one Class 15 value per day. This method effectively masked any lane-specific problems that may have occurred, which means that MnDOT personnel may have been less sensitive to identifying system problems. Now that MnDOT is more aware of these limitations in monitoring for system operation and performance, new procedures have been adopted starting February 2014.

The new procedures for monitoring system performance include documenting Class 15s in all lanes of data collection. This refinement on how to collect Class 15 data (errors) allows for MnDOT personnel to detect potential system problems in specific lanes more effortlessly than before. In addition, one new procedure that has been adopted starting 2014 has been to monitor and document the *quality* of 1) Class 15 errors and 2) warnings that are observed in the data. Class 15s have been primarily discussed as a numerical value in this report, but it is important to highlight that these errors can differ qualitatively. For example, a Class 15 error can be generated when an upstream/downstream inductive loop is triggered in the absence of actual stimulation of the WIM sensors ("upstream loop only" error, "downstream loop only" error). While qualitative in nature, this type of information adds an additional dimension to Class 15s that can help MnDOT personnel identify system problems more easily (e.g., whether the upstream loop in a particular lane is failing, etc.). Warnings, on the other hand, are information that can accompany any vehicle record (Class 1-13 vehicles) that gives additional characteristics about the vehicle or conditions that were experienced as the vehicle crossed the WIM (e.g.,

[17] It should be mentioned that Class 14s (vehicles that failed to be classified into one of the 13 vehicle classes) are also collected along with Class 15s. Although Class 14s are also monitored as a measure of system performance, they are not discussed here because Class 15s are typically a better measure of system performance.

“significant weight difference” warning, “unequal axle count on sensors” warning, etc.). Incorporating a warnings check can add additional information to help MnDOT personnel more easily distinguish between hardware problems from non-hardware problems.

System Calibration

MnDOT’s current procedure has been to calibrate the WIM scales twice a year—once in the spring (after spring load restrictions have ended) and once in the winter (during the winter load increase). According to data collected from 2010-2013, this goal has been roughly met at some sites but not at others (some were calibrated once a year, others more than twice a year). Some of this variability may be attributed to staffing/scheduling issues and/or construction work occurring on roadways near or at the WIM sites. Additionally, there were occasionally instances where the site was still in calibration meaning that a recalibration was not necessary. Upcoming sensor replacements may have also affected the timing of calibrations—in this case, a scheduled calibration may have been delayed until after the upcoming sensor replacement took place. In any case, MnDOT doesn’t have any current plans for changing the frequency of calibrations from roughly twice a year at all WIMs.

Since the first WIMs were installed in Minnesota, there has been continued discussion for ways to keep the WIM sites in calibration in between the twice-a-year calibrations. Two potential solutions have been proposed since then, including: 1) encouraging MN State Patrol to provide feedback to MnDOT on WIM scale measurements compared to static scale measurements, and 2) conducting a quantitative research project to detect when the WIM scales are drifting out of calibration. These two potential solutions are discussed in the next two paragraphs.

Firstly, MnDOT has provided training for MN State Patrol to use real-time data from the WIM sites for weight screening. While State Patrol cannot rely on WIM weight data to distribute tickets to weight violators, it has great potential for use as a screening tool to identify likely weight violators from non-violators. Potential violators (identified by WIM data) may then be brought to a static WIM scale for official weigh-in. MnDOT has encouraged State Patrol to provide feedback if the WIM scales are significantly off from static weight scale measurements. Both departments hope to mutually benefit by encouraging this collaboration. For example, if State Patrol provides MnDOT with discrepancies in weight data, MnDOT can adjust calibration factors on the WIM scales to more accurately measure vehicle weights. This should increase State Patrol’s confidence in the WIM data to continue their use for weight screening purposes.

Secondly, besides encouraging State Patrol to provide weight data to MnDOT, MnDOT has entered into a contract with an external researcher to mathematically investigate if and when WIM systems went out of calibration. This project is currently ongoing, but it is expected that an actual product will be developed for MnDOT to use in the future to identify times when sites went out of calibration and to adjust accordingly (this is contingent on actual performance of the product itself).

Traffic Data

Volume data generally showed similar patterns across all WIMs. Volumes were generally highest over the spring to fall months, with each site showing some variation in the length of those volume peaks within that time range. Lowest volumes, on the other hand, were generally demonstrated over the winter months (typically December through February). The increase in volume observed over the late spring to early fall months is thought to coincide with greater recreational travel for passenger vehicles (PVs), along with greater freight movement in the heavy commercial vehicles (HCVs). In contrast, decreased recreational travel and freight movement is thought to explain lower volumes over the winter months. Lastly, overweight HCVs typically followed the same overall HCV volume patterns observed at each site; this is not surprising given that there is no a priori reason to expect overweight HCVs to behave differently from overall HCV patterns.

A few WIM sites did not follow the high summer/low winter volume trends, particularly with respect to HCVs. These particular sites were: WIMs 33, 39, and 41. These three sites may have some unique characteristics (some that are currently known, some that are unknown) that may contribute to the different HCV volume patterns than typically observed. To better understand all of the WIM sites, it may be worthwhile in the future to identify particular characteristics that can explain their annual traffic patterns (particularly for HCVs). For example, certain industries may rely more heavily on roadways (on which the WIMs are located) as a means for transporting their goods at certain times of the year than others. By having a better understanding of these volume-industry relationships, MnDOT may be able to make better inferences on the roadways on which future WIMs may be installed.

Data showed greater variability in the distribution of PVs than HCVs over a 24-hour period. HCV volume distributions varied little in that highest volume concentrations coincided with typical business hours. PVs, on the other hand, showed greater variability in volume distributions over time but in fairly predictable ways. For example, many sites exhibited a noticeable afternoon rush hour in volumes in at least one direction of travel if not both. Some sites also appeared to have a pronounced morning rush hour, while in some cases the distribution of PVs more closely followed HCV patterns (highest concentrations during typical business hours).

Gross vehicle weights (GVWs) were also investigated in this annual report. Data suggested that the top three vehicle classes contributing the most to overall GVWs were typically Classes 9, 2, and 3. As discussed in the GVW section of the report, correlational tests were performed between monthly volumes in and monthly GVWs. Results suggested that, while there was a linear relationship between the two variables in the majority of cases, there was also evidence of potential problems with vehicle classification that occasionally lead to a non-significant relationship between vehicle class and volumes (particularly Classes 1 and 13; see GVW section for specific information). These problems were specifically tied to data collected from 2010-2011 in some instances, suggesting that rates of successful vehicle classification may have increased after 2011. In the future, it may be advisable to remove 2010-2011 data in any subsequent annual reports to reduce noise within the data.

HCV freight data was explored across years with the primary goals of understanding whether any directional differences existed in freight movement. This question was explored in two different ways--once involving actual freight differences between directions of travel, and the other controlling for HCV traffic volume prior to analyzing for freight differences. Both analyses are useful in different ways (see discussion within the Freight section), and the reader is encouraged to look at these results according to their own particular aims.

ESAL information was provided on the pavements at each WIM site. According to the data, the vehicle classes contributing the most to overall ESALs were Classes 9, 10, and 5. These results were not surprising given the fact that Class 9 and 10 vehicle volumes were generally highest for combination-unit trucks at many sites. Furthermore, Class 5 trucks generally produce the highest volumes out of all single-unit trucks. It should also be mentioned that, while these three classes contributed the most to total ESALs at most sites, the proportion they contributed to each site's ESALs varied considerably (e.g., some sites were heavily Class 9 biased and nothing else, while other sites did not show as heavy of a bias). Data also showed that some roads might be over-designed based on the distribution of ESALs across the driving lanes. It may be worth discussing these results to pavement designers in the future; alternative methods might be proposed in how to design pavement in such a way to maximize MnDOT's financial effectiveness.

Overweight HCVs were also a concern when considering how much they might decrease a pavement's design life at each WIM site. According to overweight Class 9 and 10 data, these vehicles appear to decrease the pavement design life in minimal ways (a decrease in pavement life by less than 5 months). However, it is unclear how much the numbers generated here align with actual conditions observed in the pavement itself. In order to assess the accuracy of these numbers, the WIM unit plans to work more closely with the Pavement Design unit to verify the accuracy of the estimations reported here. It may also be important to compare these values to actual measures of pavement conditions at these WIMs (i.e., gathering ride quality index measures, observational surveying of road conditions, etc.).

Lastly, vehicle speeds were collected from 2010-2013 at all WIM sites. A few observations were made regarding the data that generally mirrored monthly reports on speed. Firstly, vehicles in the passing lanes were typically faster than vehicles in the driving lanes. Secondly, PVs were generally faster than HCVs. Thirdly, there were marginal decreases in speed during the late night/early morning hours, presumably due to poorer visibility during the night time (although this is unconfirmed). Due to minimal monthly and annual variations in the speed data, the WIM unit (within the Office of Transportation System Management) will no longer be publishing speed data in the monthly reports. [Note: speed data will still be collected regularly at all WIM sites—they will just not be included in the monthly WIM reports. The WIM unit will, however, fulfill any data and analysis requests of speed data]

Summary

This concludes the first attempt to generate an annual report of Minnesota's WIM data between 2010-2013. The amount of monthly data collected per WIM that was included in this analysis ranged anywhere between 10 months to up to 48 months. The amount of data included in this report varied per site and was dependent on initial WIM installation and calibration, as well as the operational status of the WIM systems during the 4 years of data collection. During this time frame, seventeen WIMs were in operation. Most of these WIMs showed similar seasonal traffic patterns over time with a few exceptions. As the number of WIM sites expand, it is expected that the current procedures for documenting and monitoring for system performance will continue to evolve.

MnDOT expects to increase the number of WIMs over time, with the eventual goal of having at least two WIMs within each MnDOT district. Furthermore, MnDOT hopes to eventually cover all interstates within the state with a WIM system. For example, MnDOT currently lacks a WIM in the eastbound direction of I-94 near MnROAD, one north of the Twin Cities along I-35, and one east of the Twin Cities along I-94. These particular roadways, among others, serve as major routes that carry high traffic volumes on a daily basis—they may serve as ideal locations for future WIM locations.

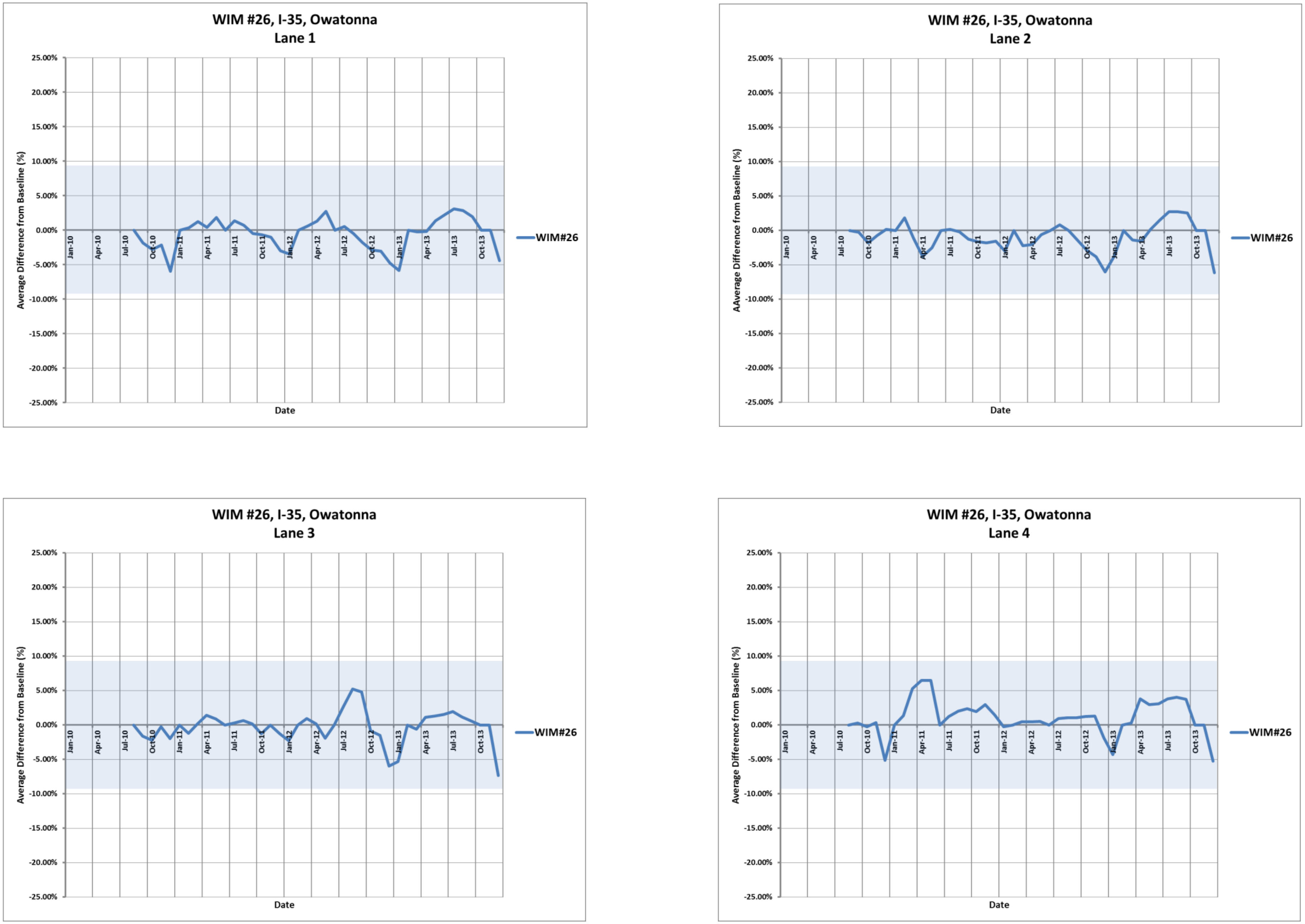
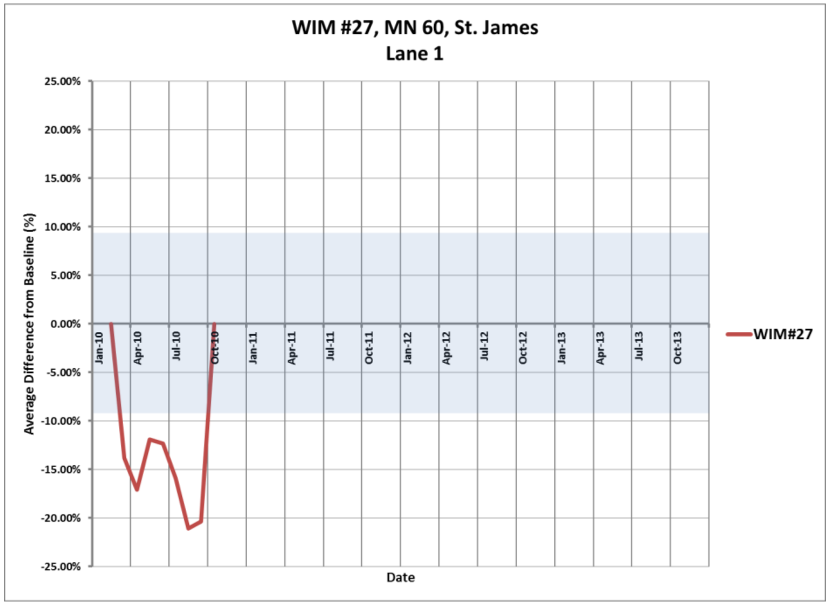


Figure 3.1. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.



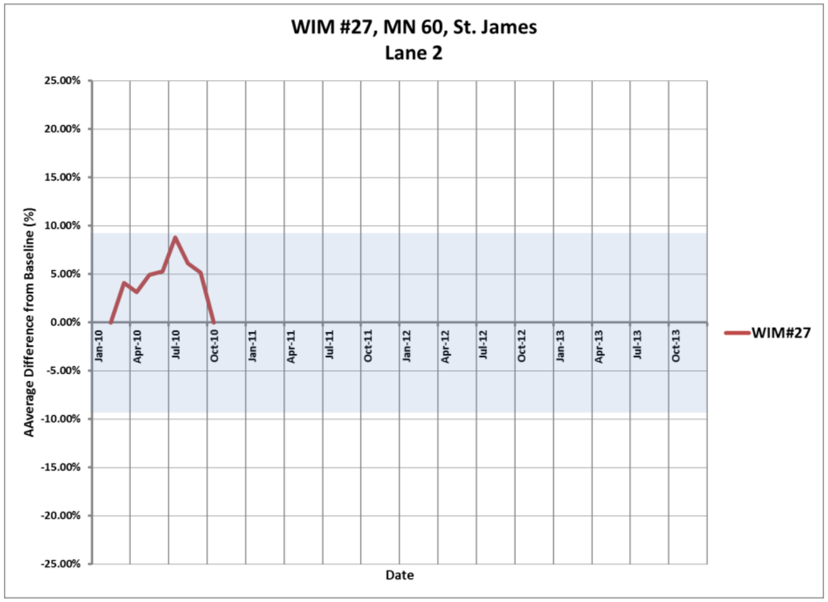


Figure 3.2. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

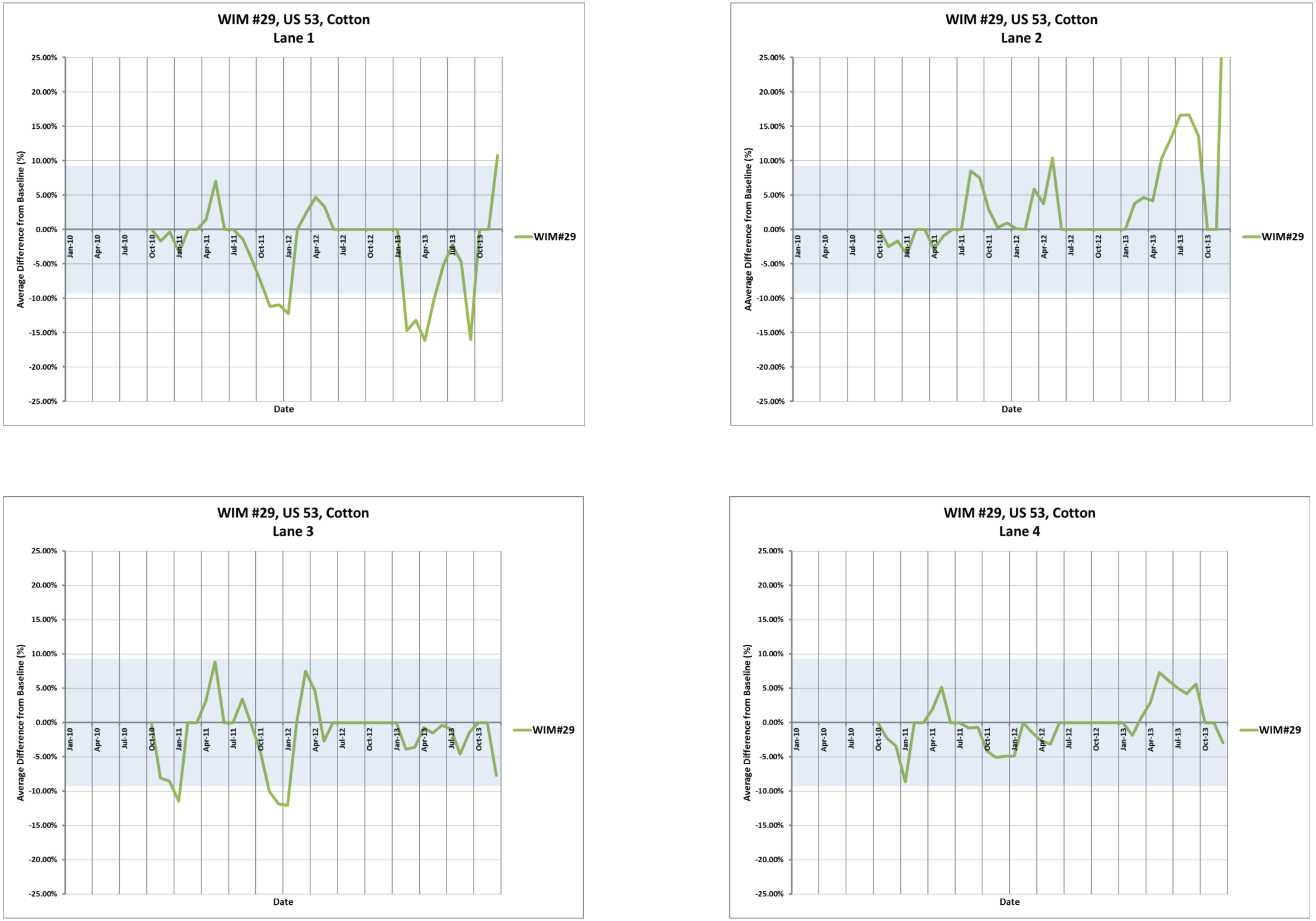


Figure 3.3. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

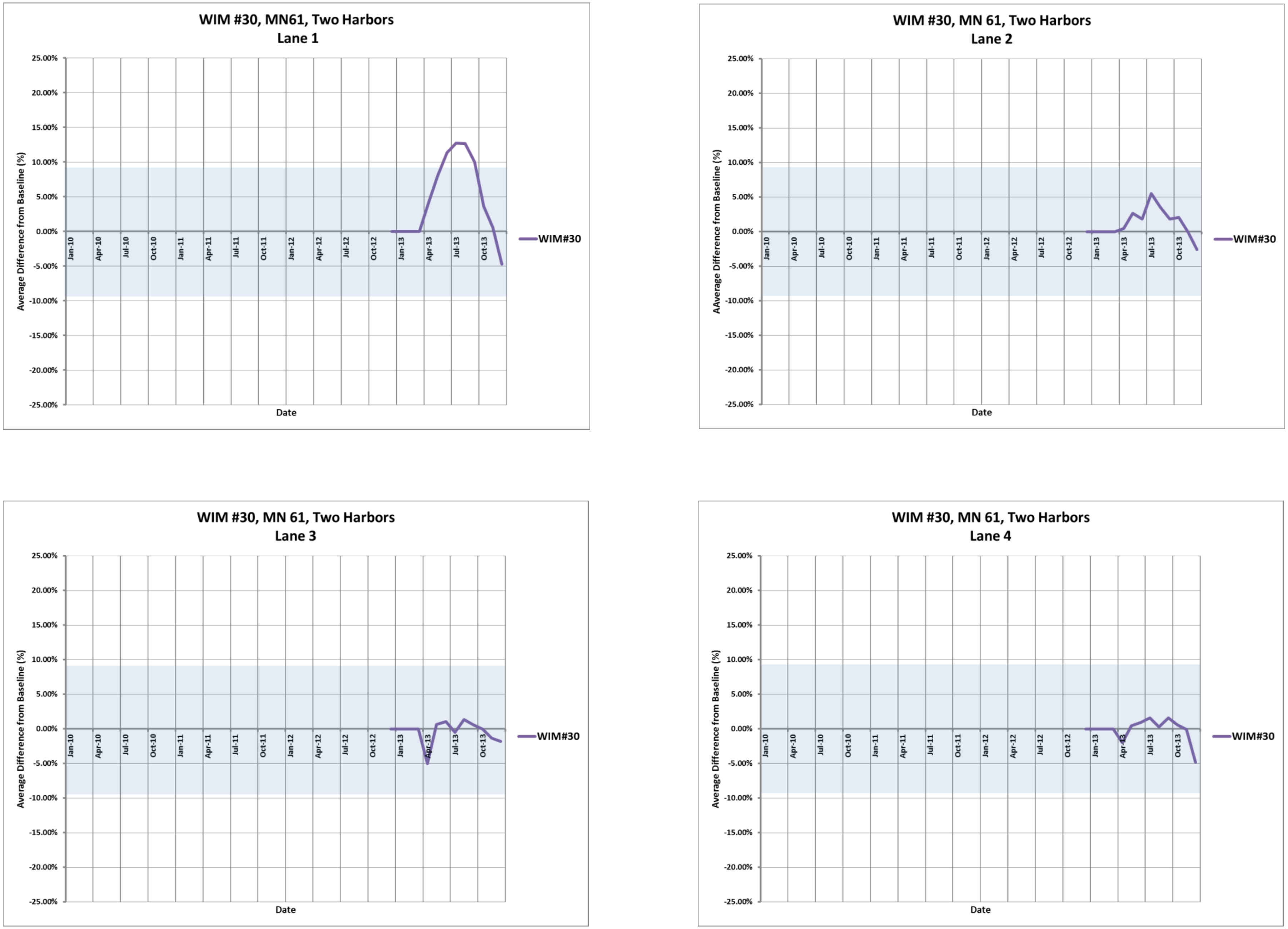


Figure 3.4. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

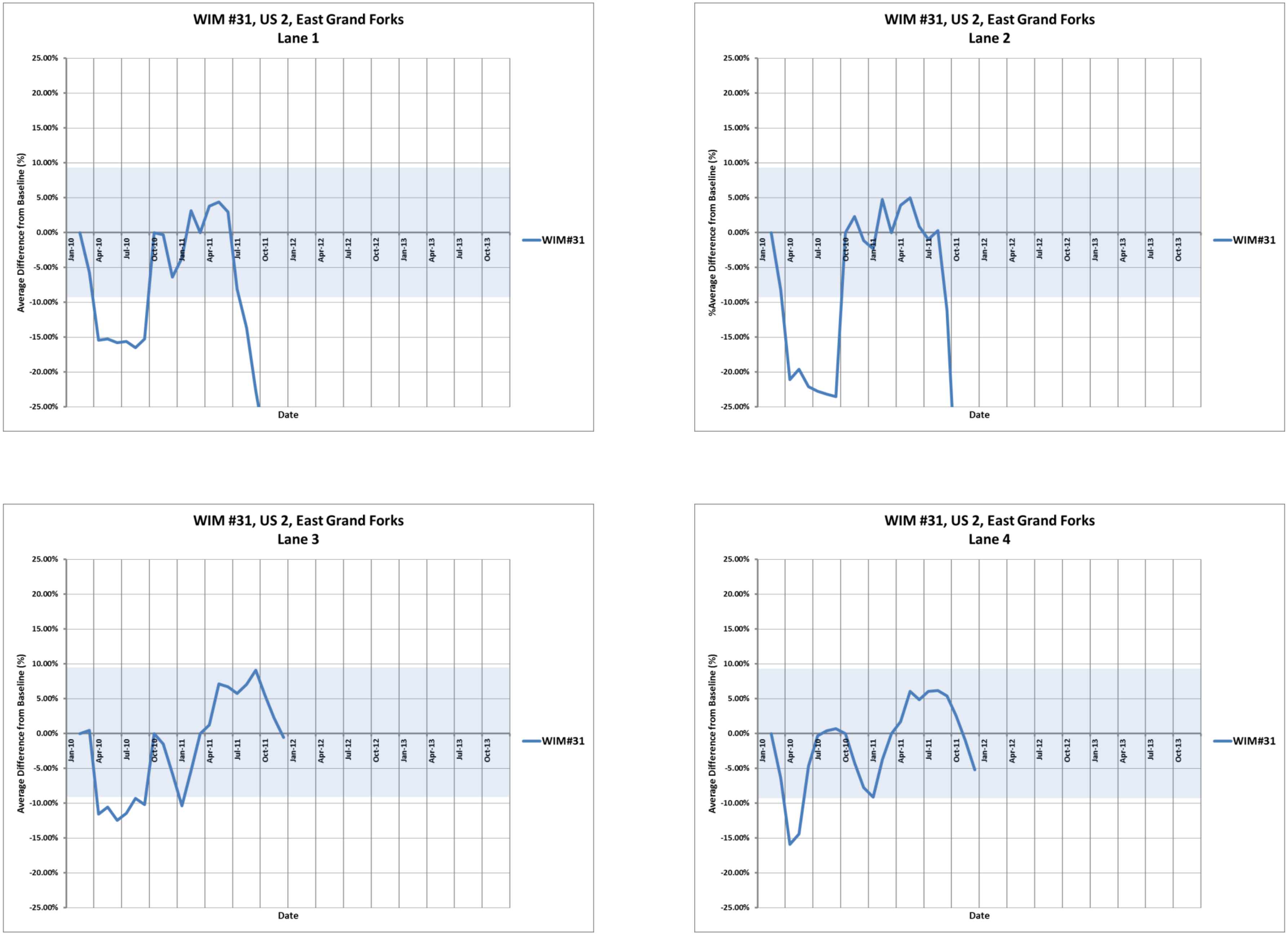


Figure 3.5. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

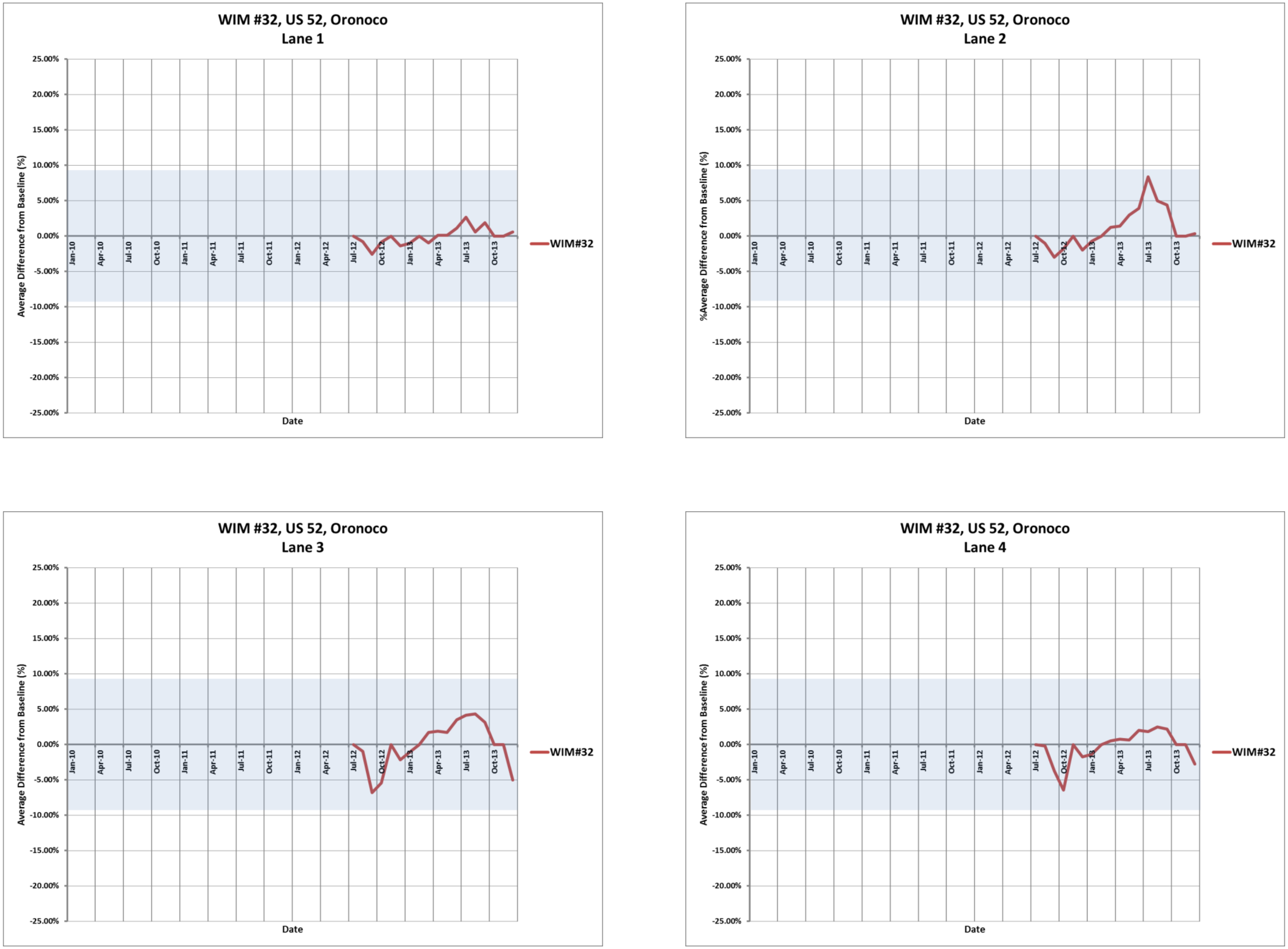
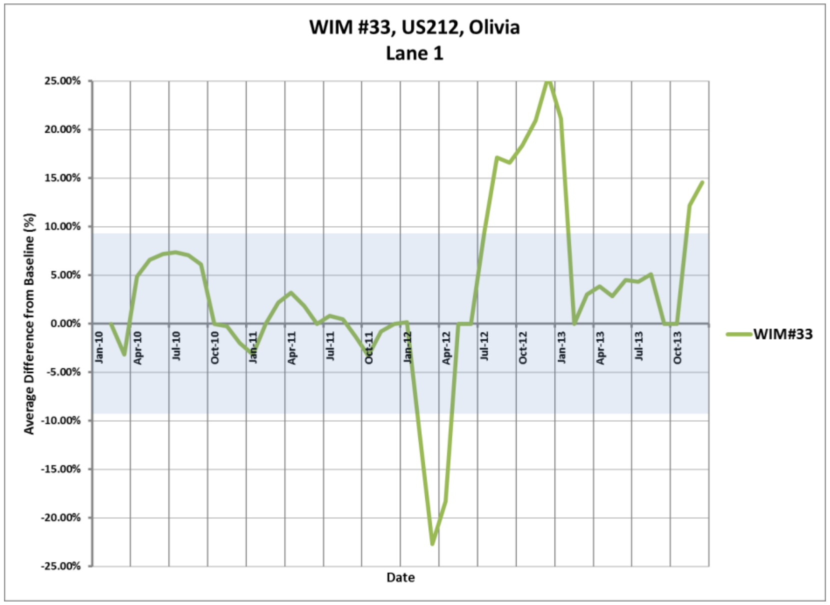


Figure 3.6. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.



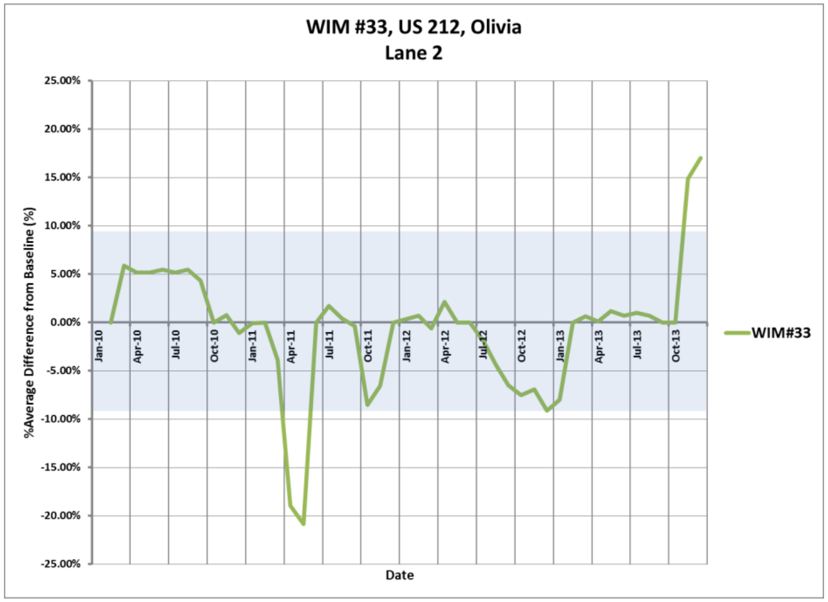


Figure 3.7. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

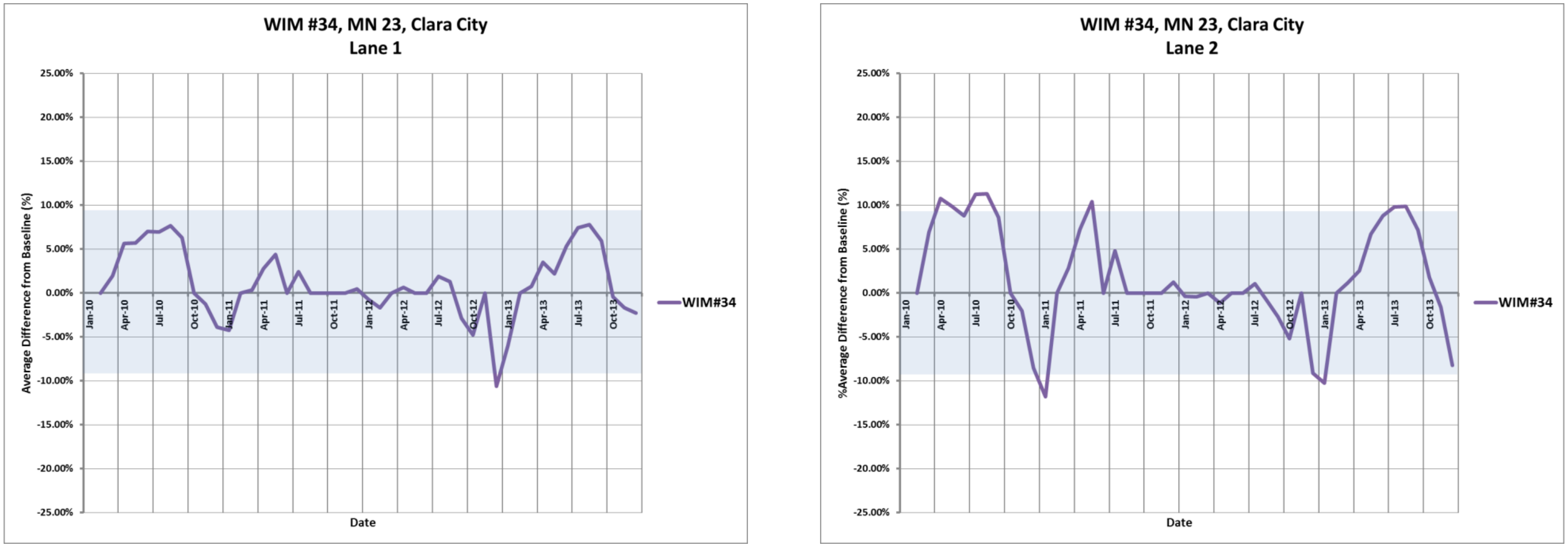


Figure 3.8. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

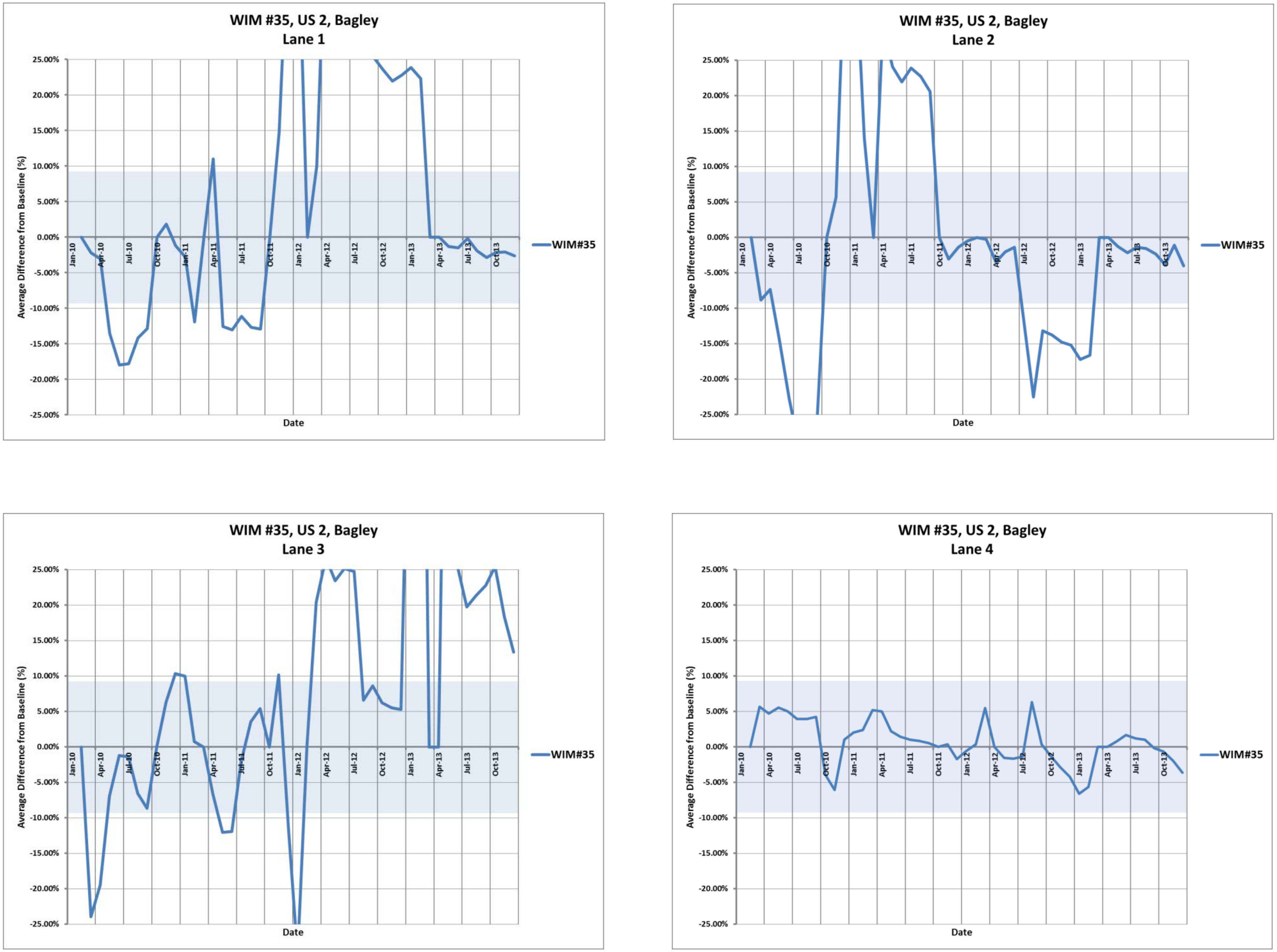


Figure 3.9. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

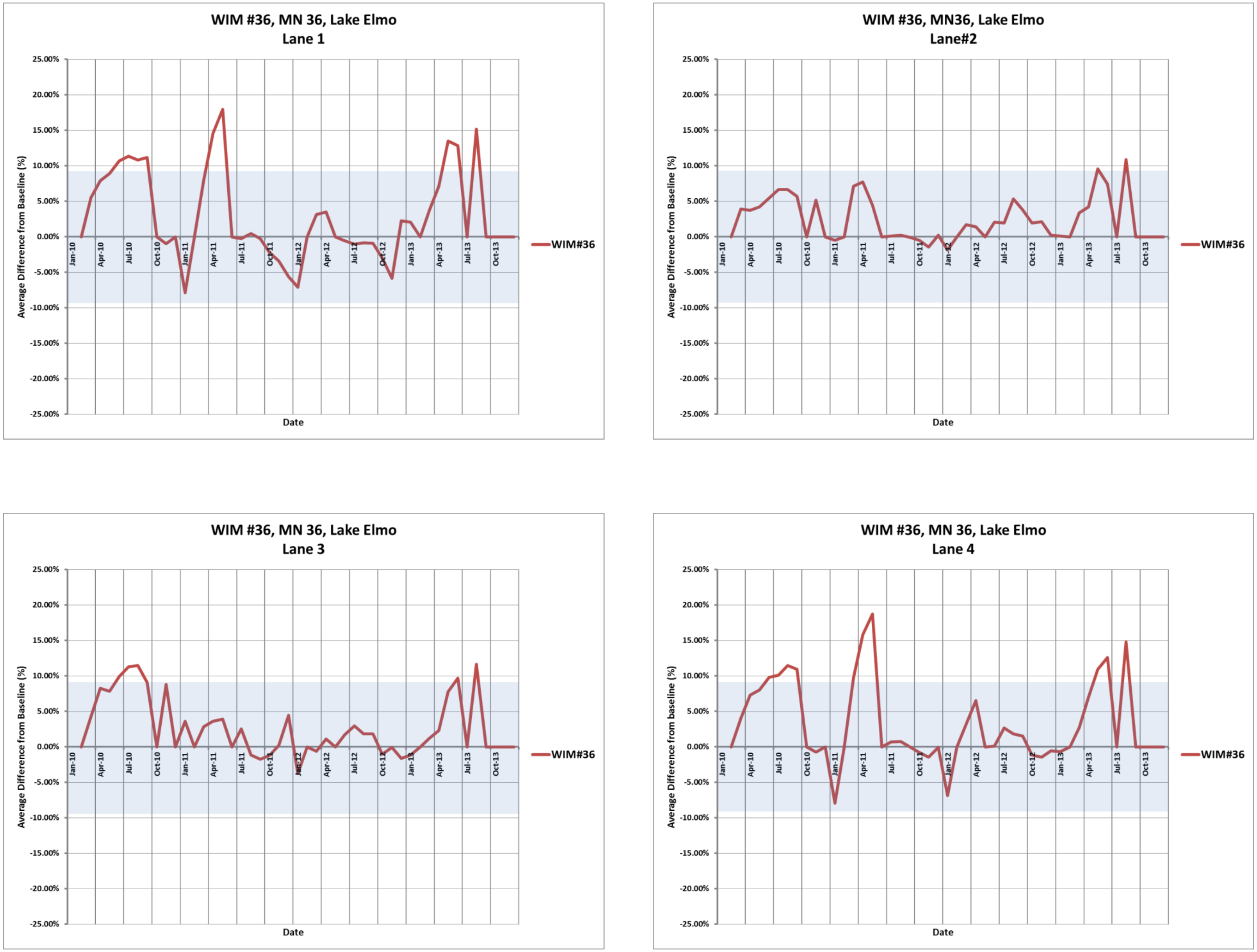


Figure 3.10. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

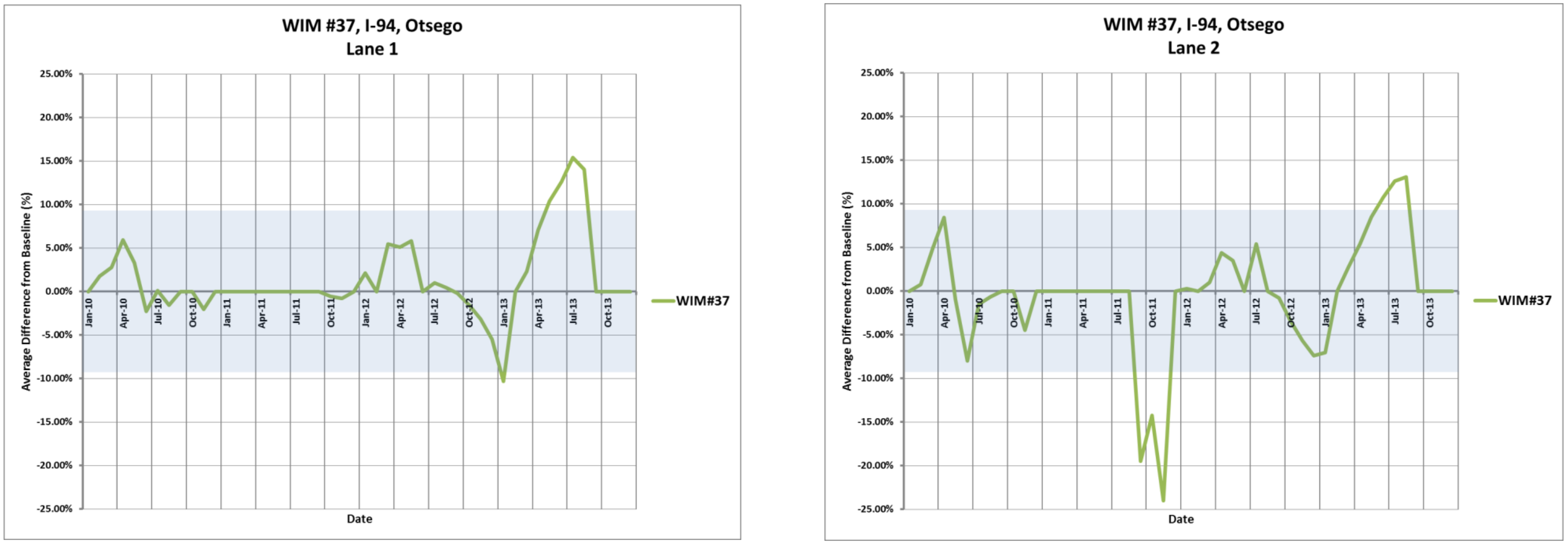


Figure 3.11. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

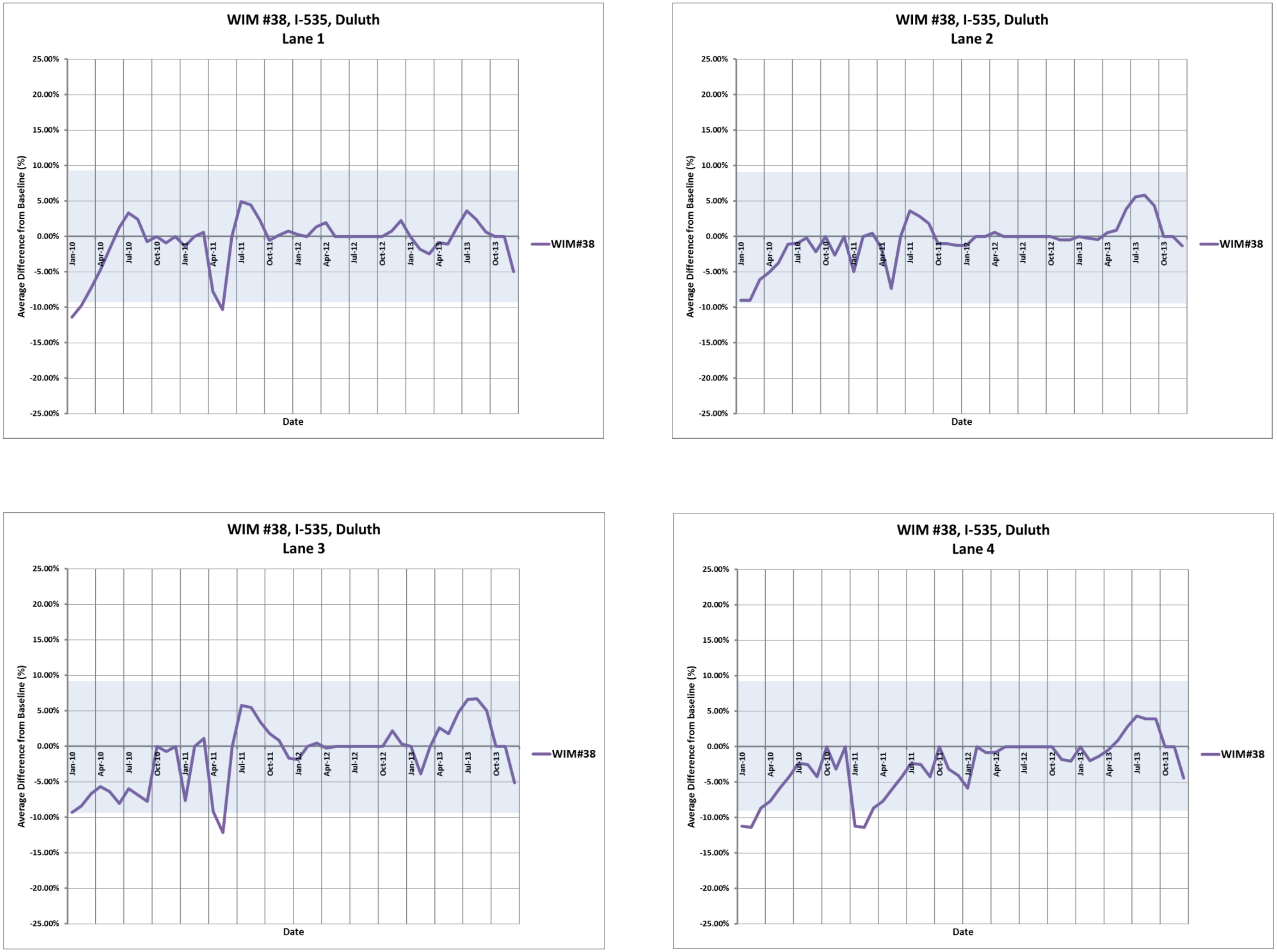
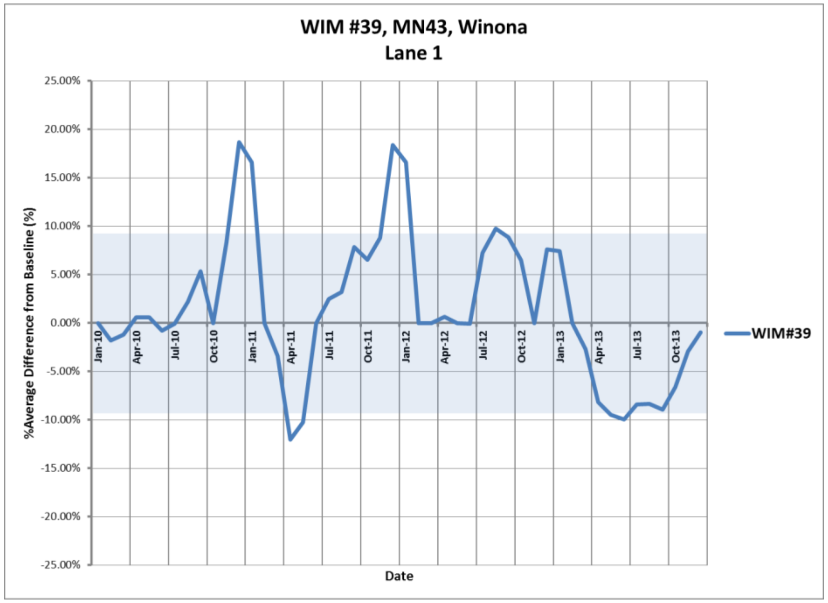


Figure 3.12. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.



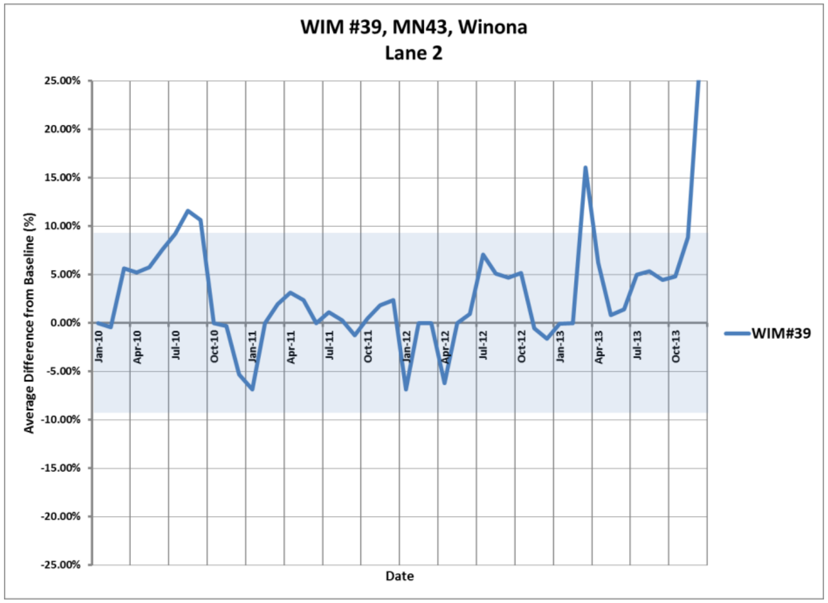


Figure 3.13. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

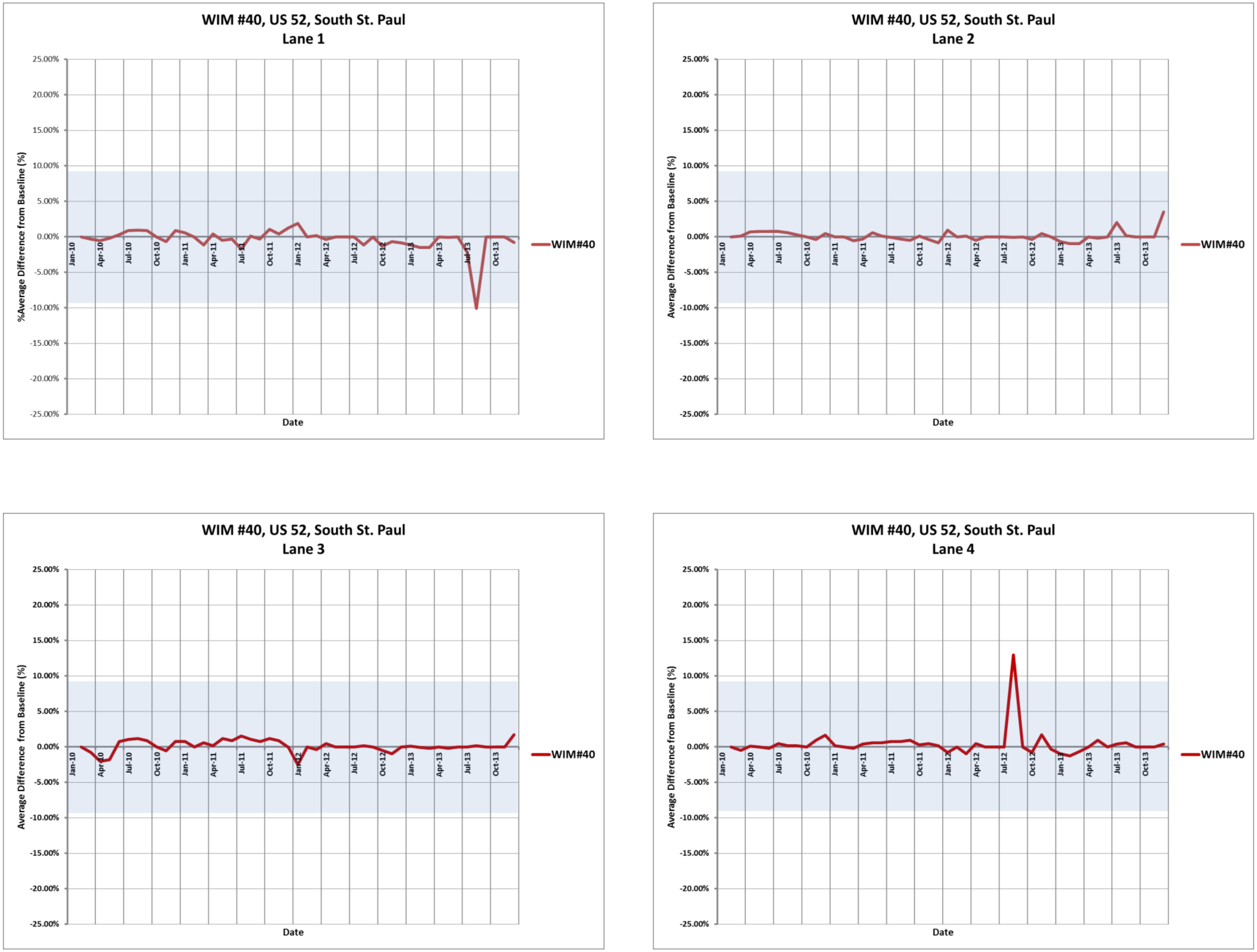
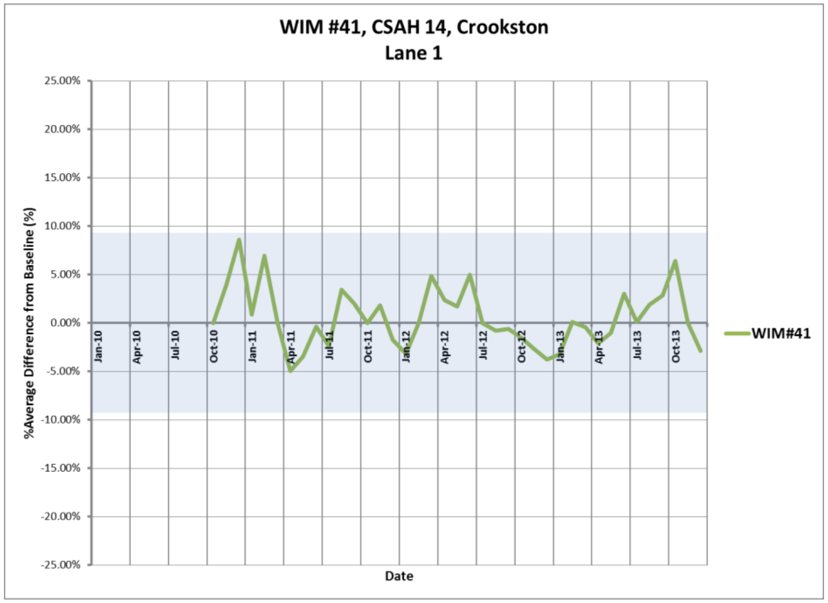


Figure 3.14. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.



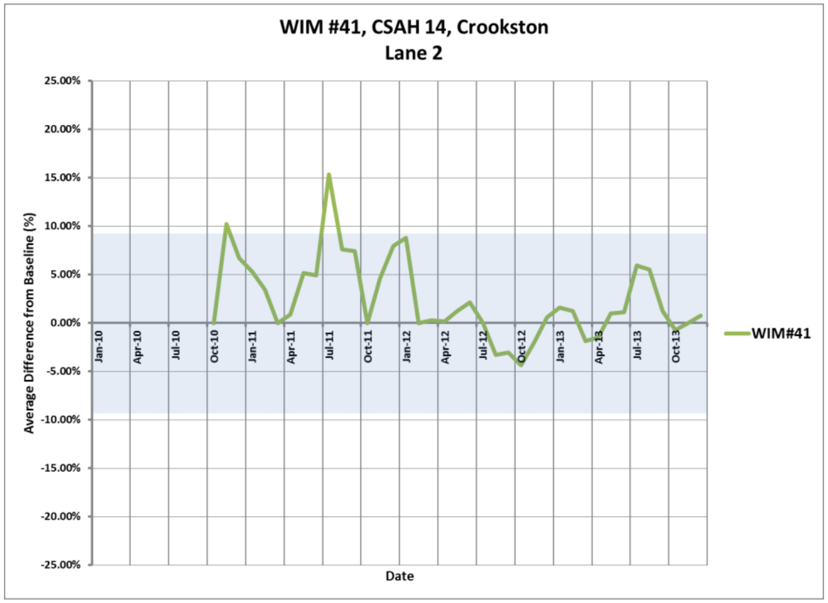


Figure 3.15. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

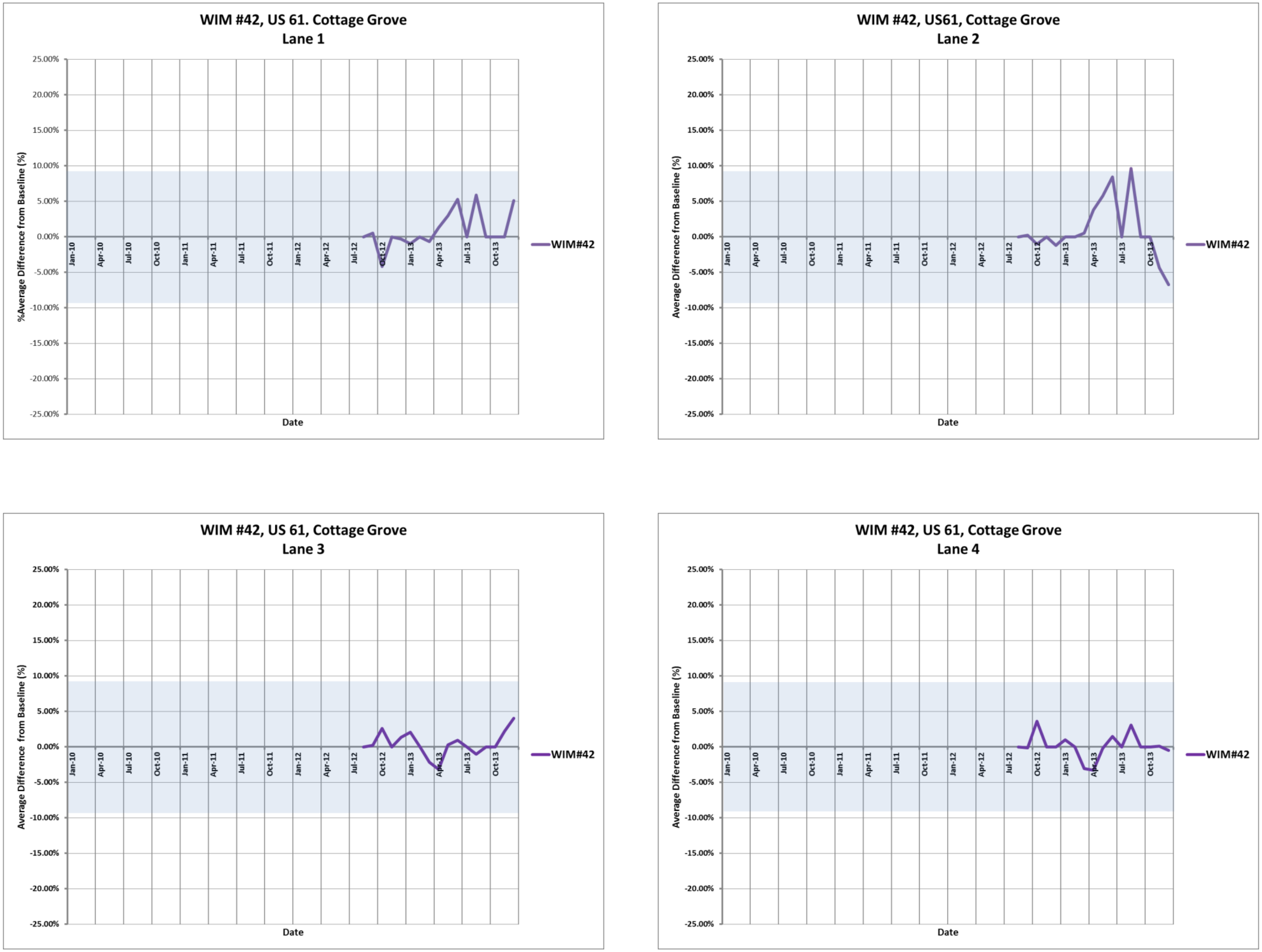


Figure 3.16. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

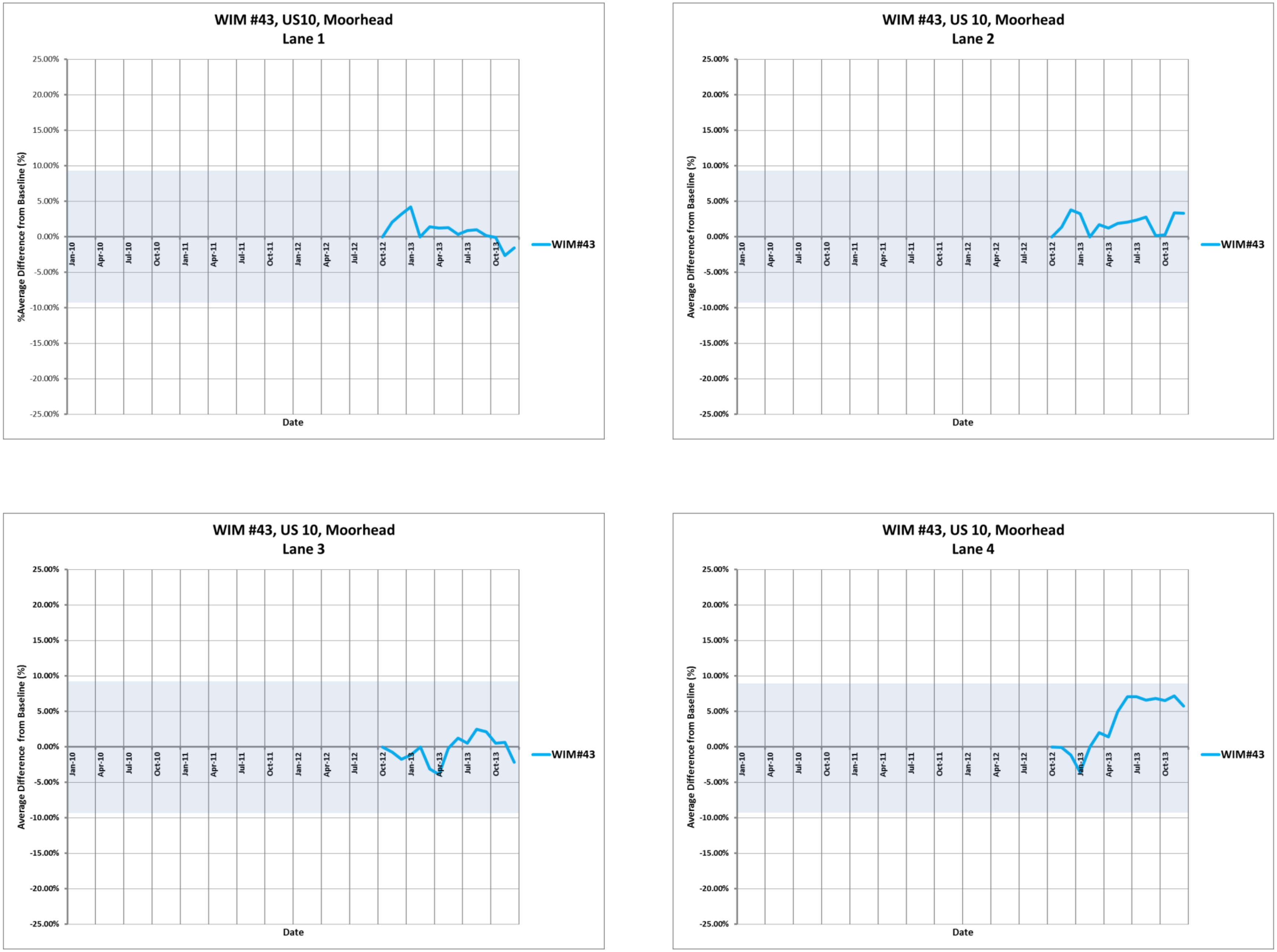


Figure 3.17. The numerical change (%) in average front axle weights over time compared to those at calibration (baseline). Blue shaded area represents the currently used criterion (+/- 9% of baseline values) for acceptable front axle weights.

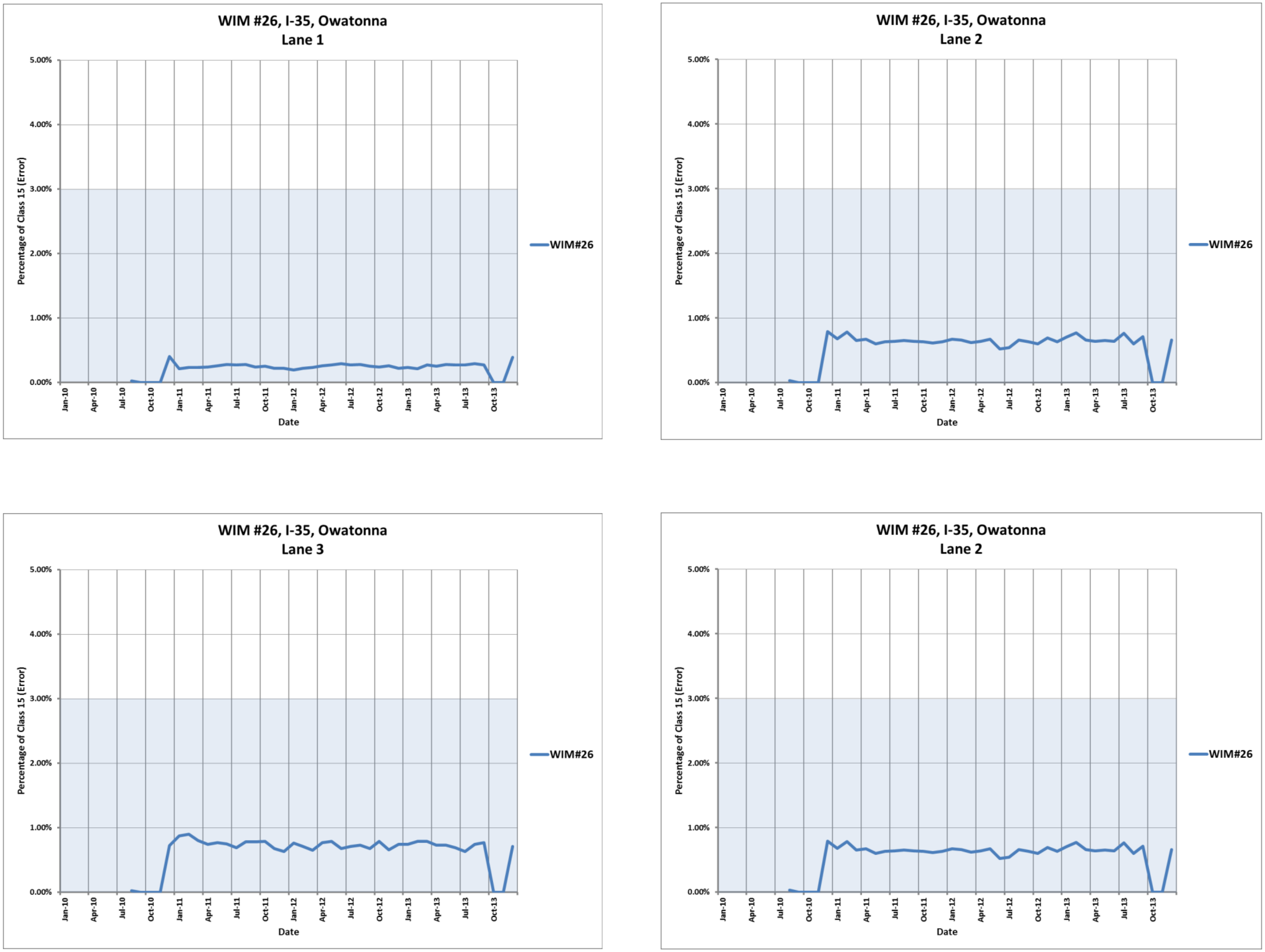
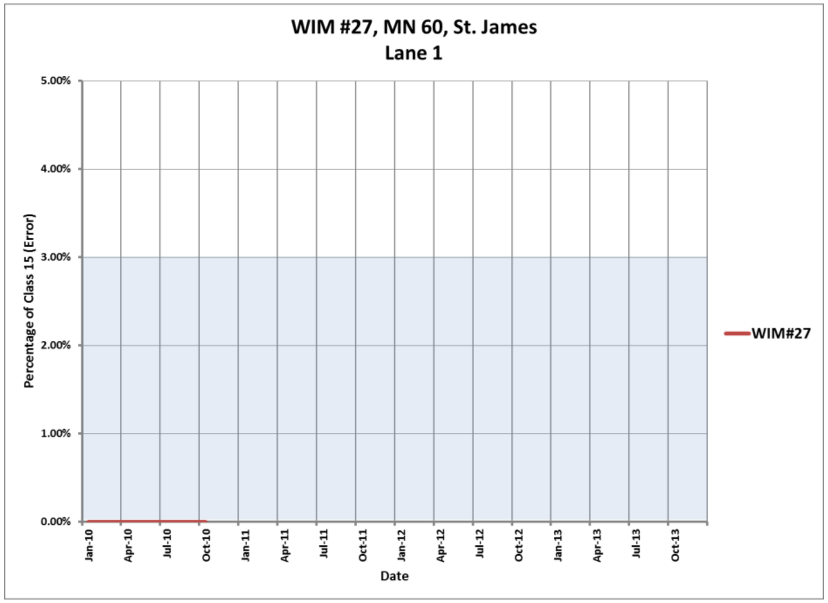


Figure 3.18. Percent of Class 15s (errors) observed over time in Lanes 1-4. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).



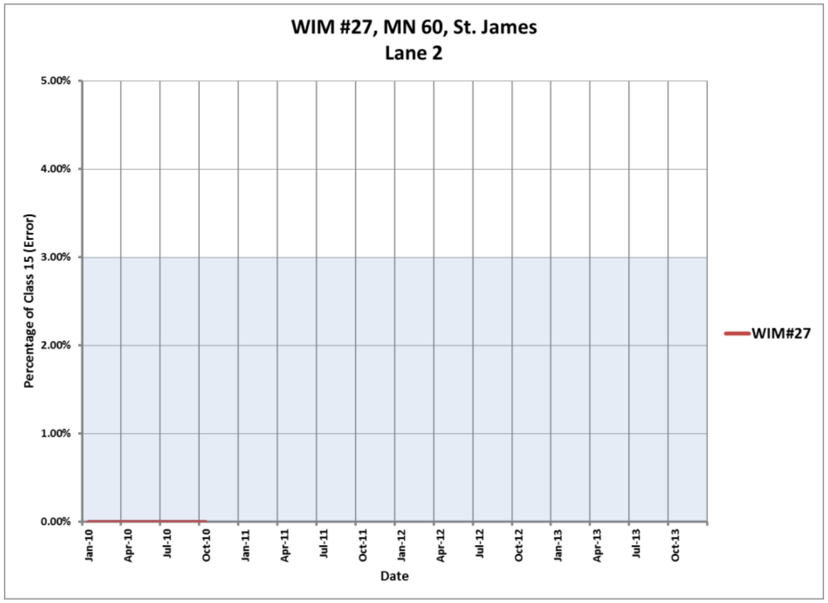


Figure 3.19. Percent of Class 15s (errors) observed over time in Lanes 1-2. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).

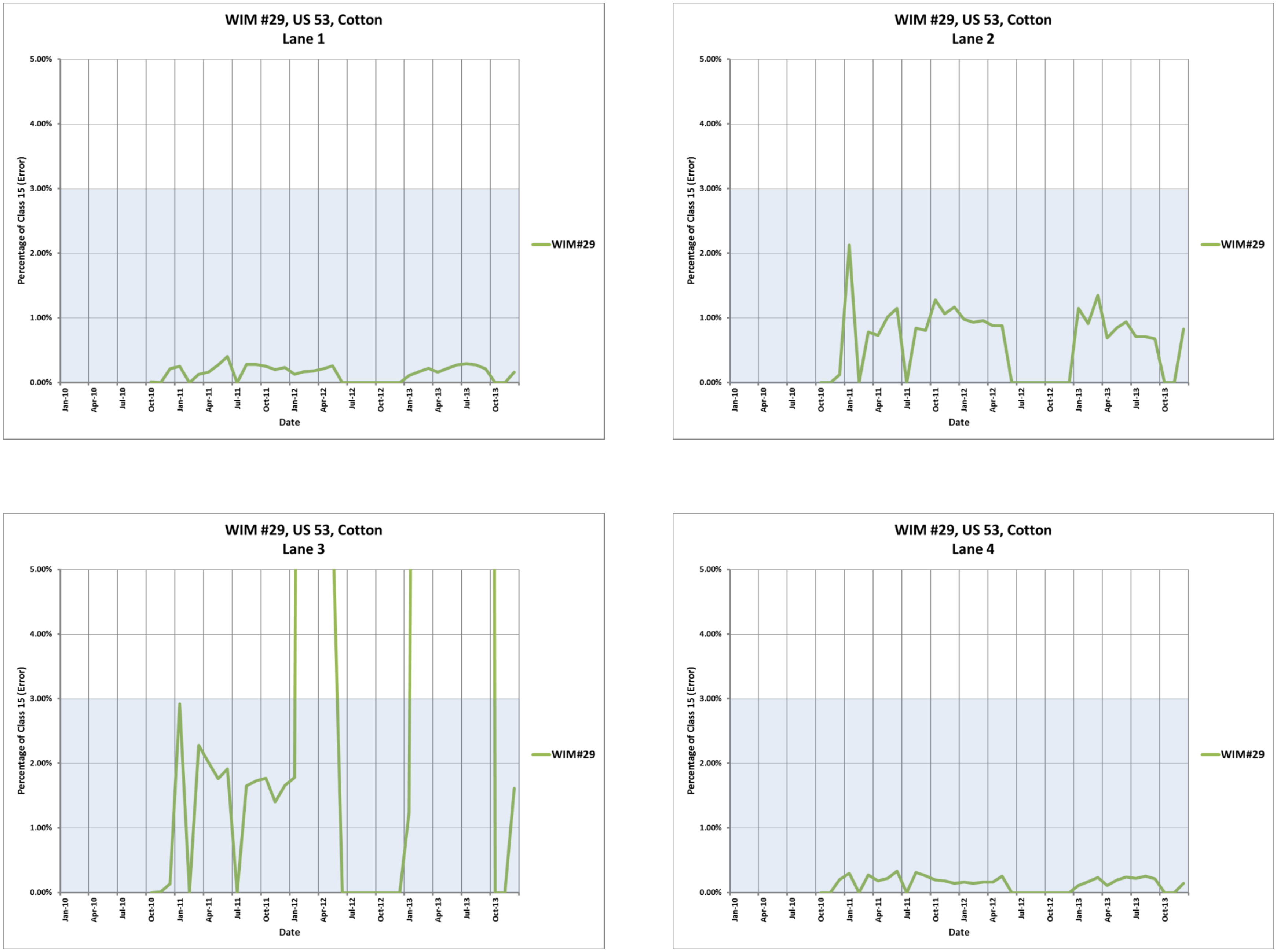


Figure 3.20. Percent of Class 15s (errors) observed over time in Lanes 1-4. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).

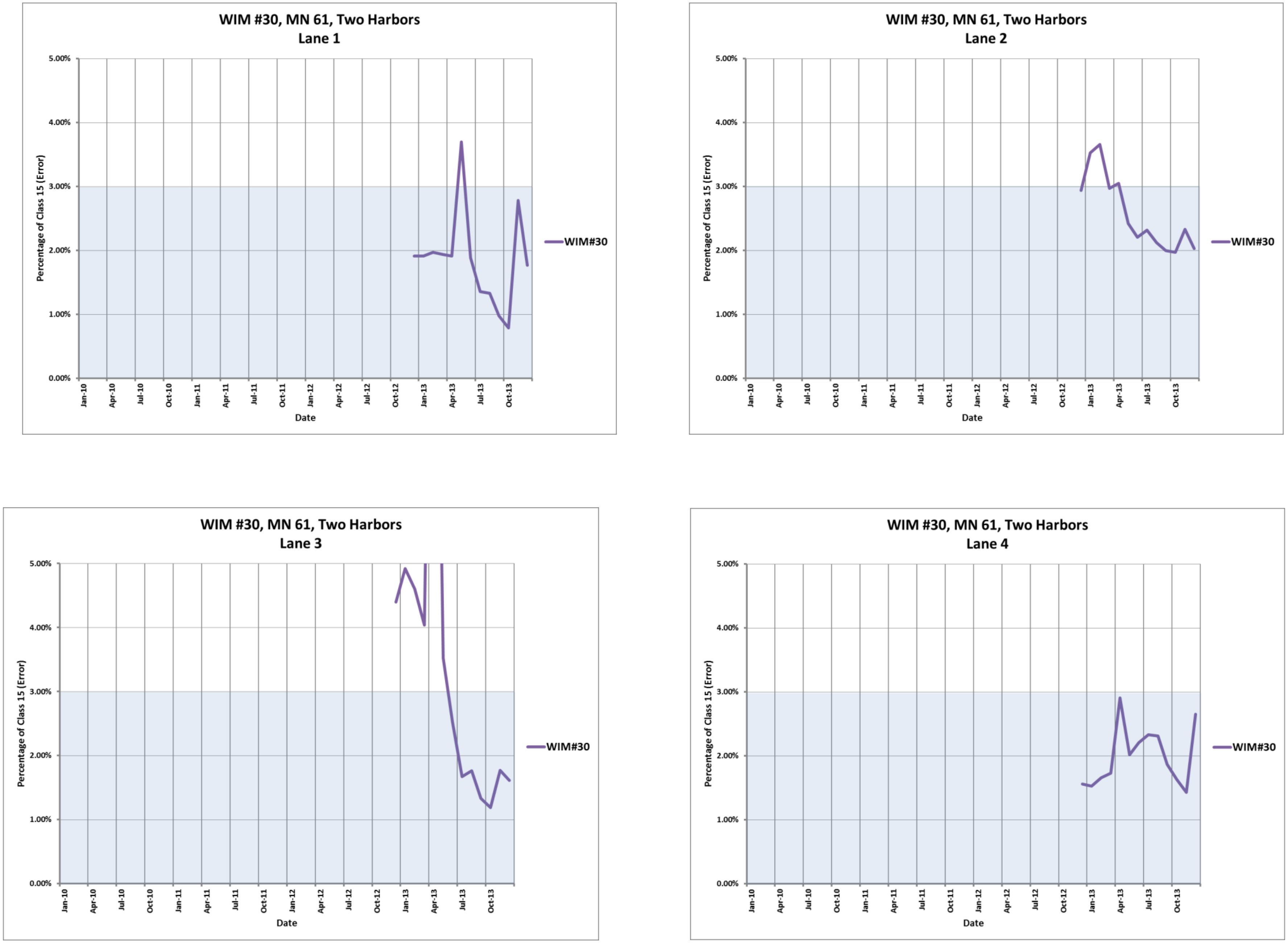


Figure 3.21. Percent of Class 15s (errors) observed over time in Lanes 1-4. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).

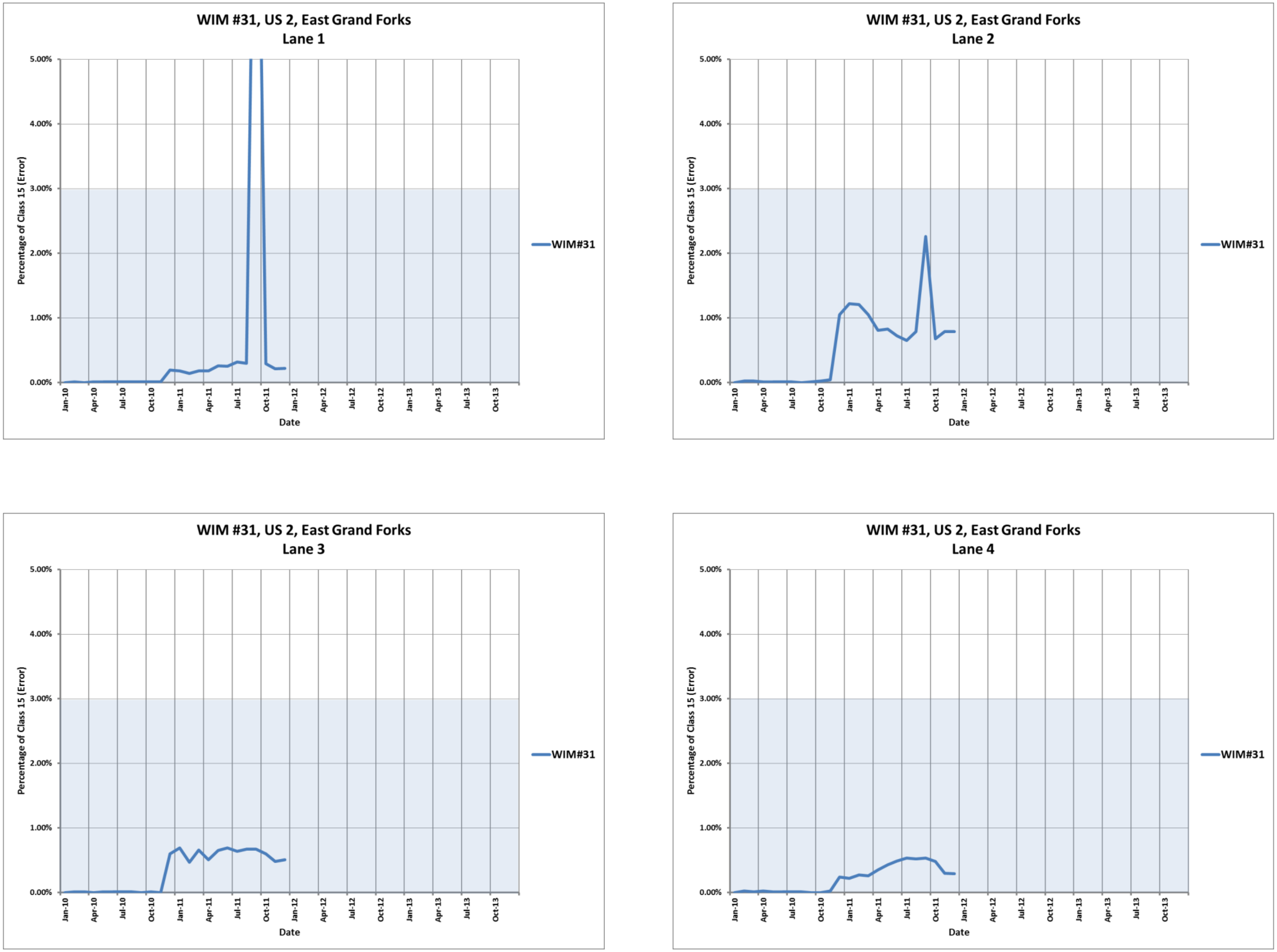


Figure 3.22. Percent of Class 15s (errors) observed over time in Lanes 1-4. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).

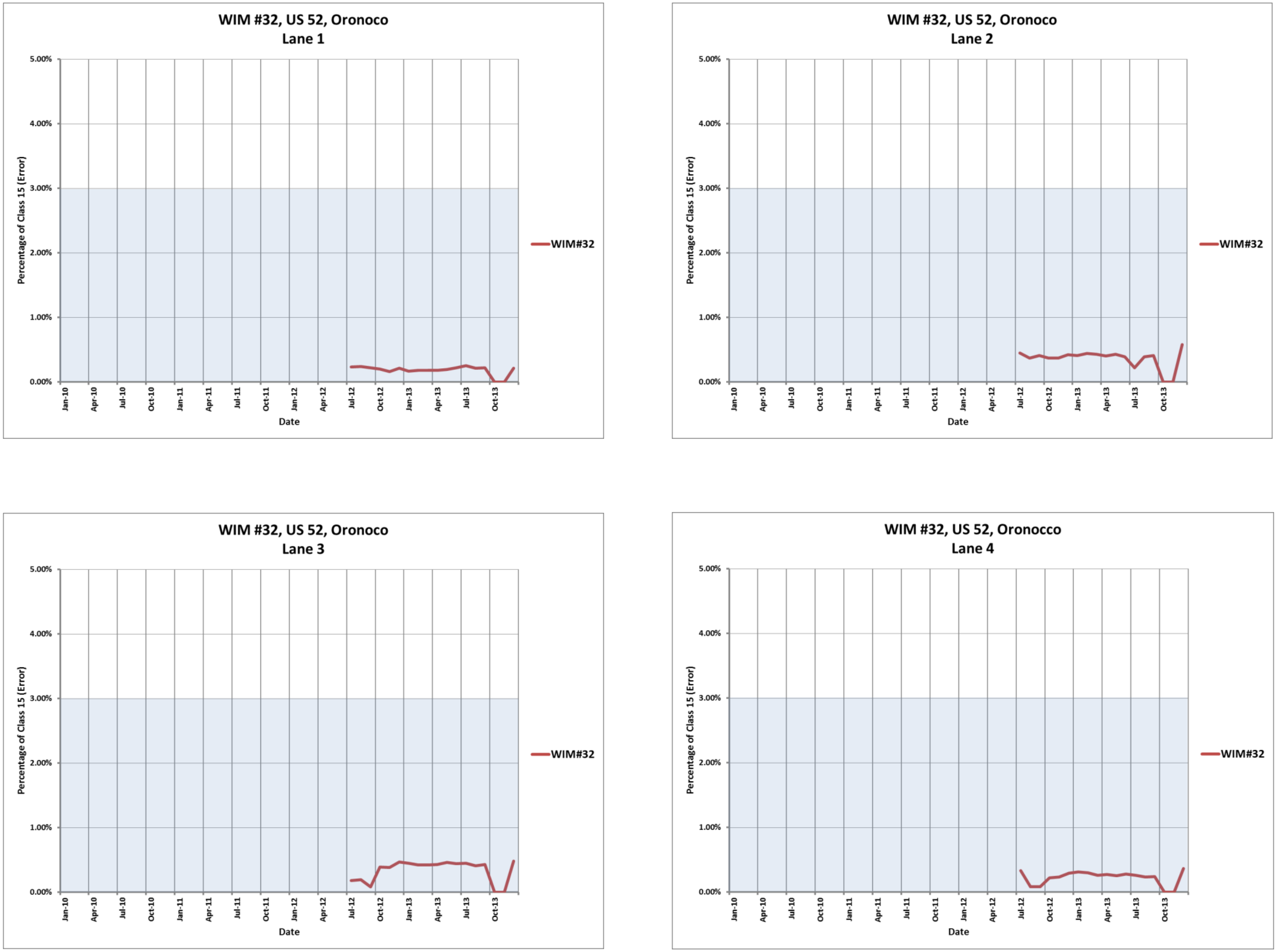
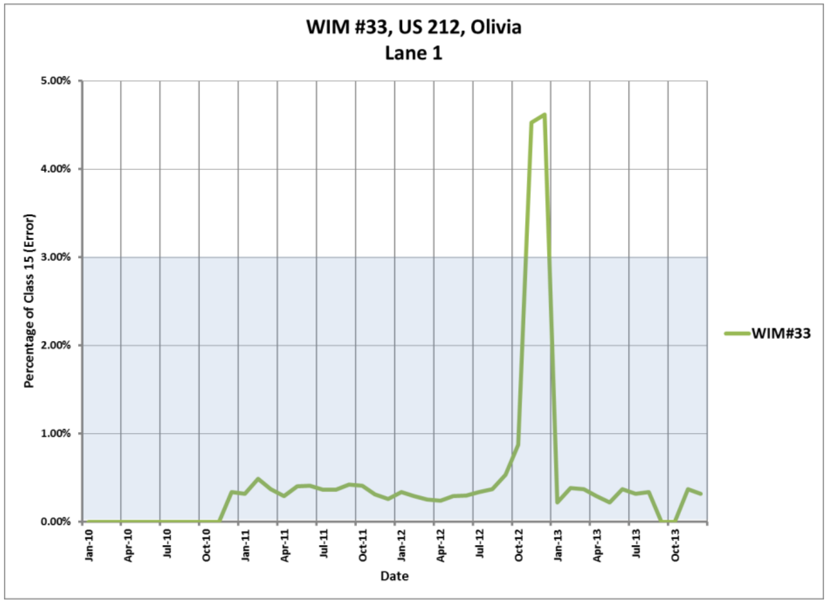


Figure 3.23. Percent of Class 15s (errors) observed over time in Lanes 1-4. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).



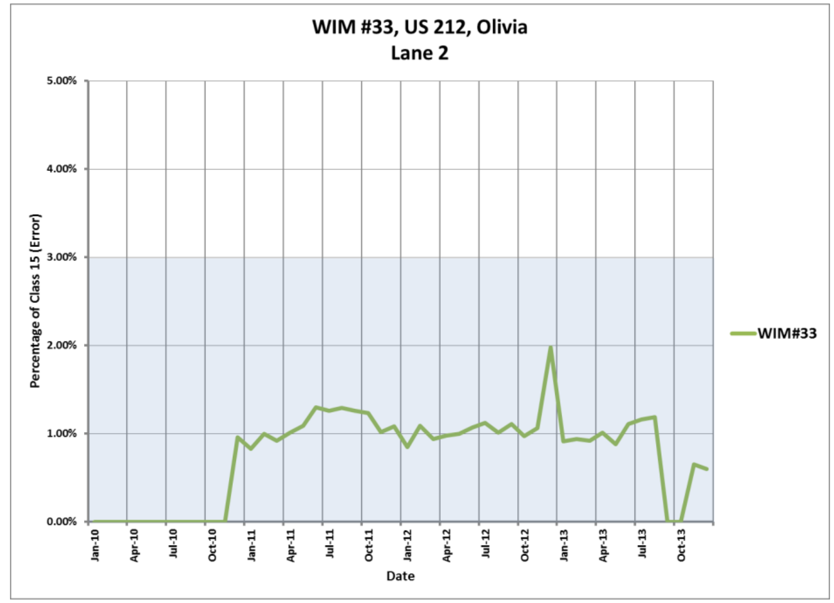
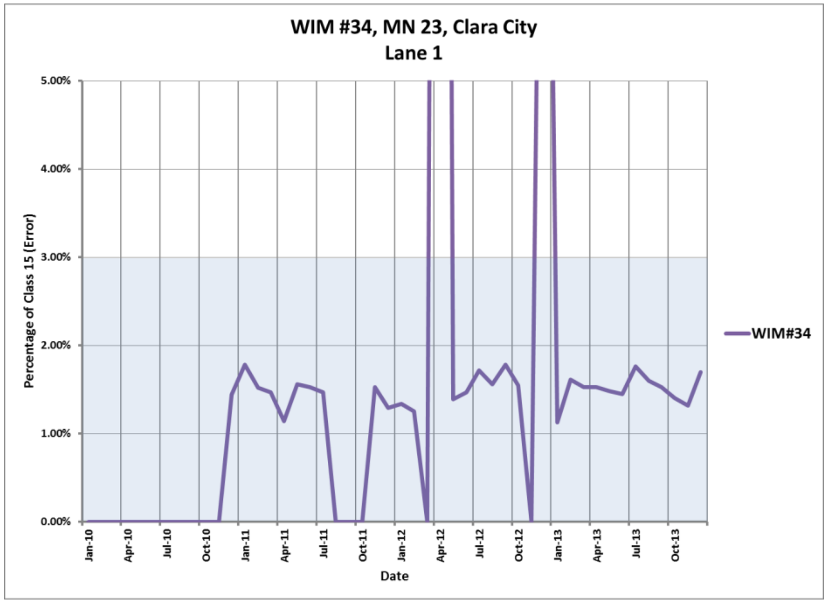


Figure 3.24. Percent of Class 15s (errors) observed over time in Lanes 1-2. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).



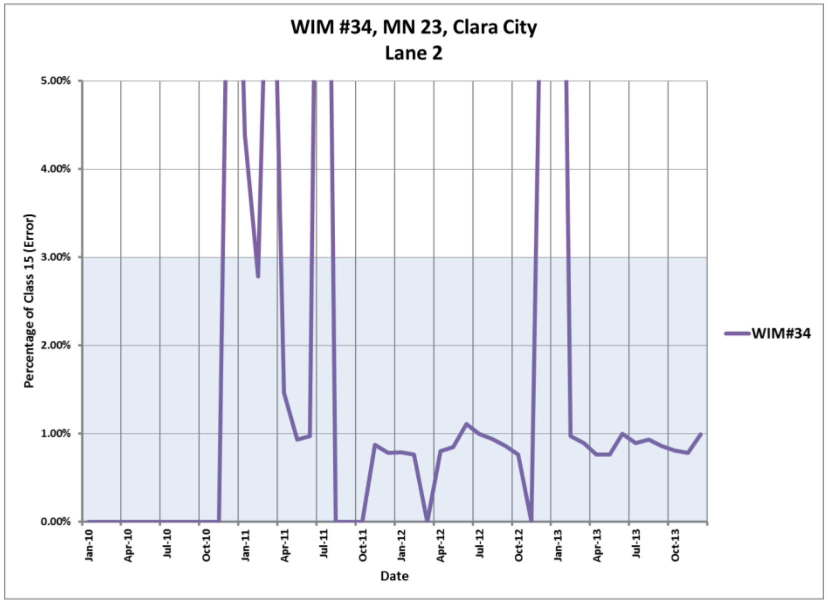


Figure 3.25. Percent of Class 15s (errors) observed over time in Lanes 1-2. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).

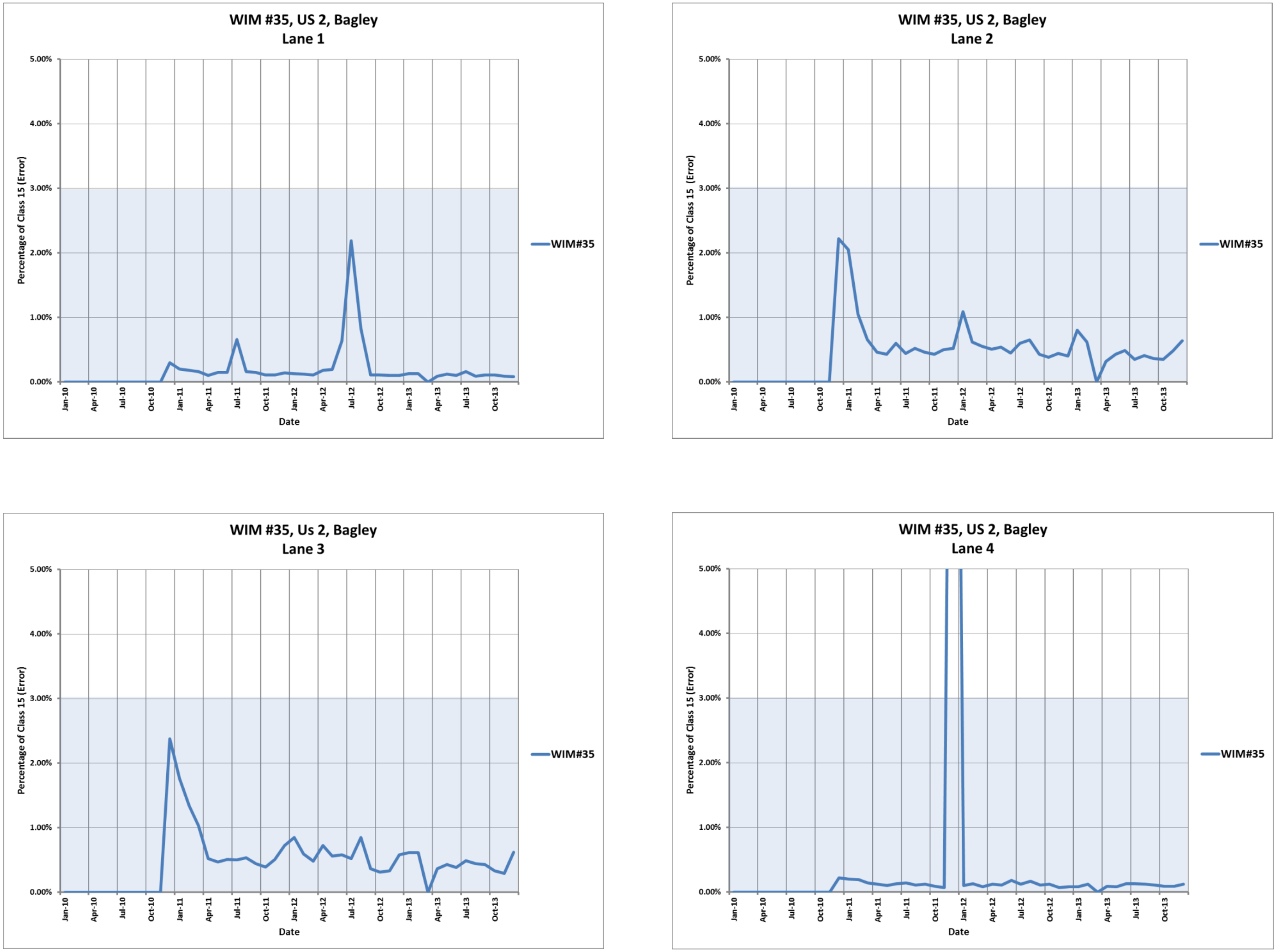


Figure 3.26. Percent of Class 15s (errors) observed over time in Lanes 1-4. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).

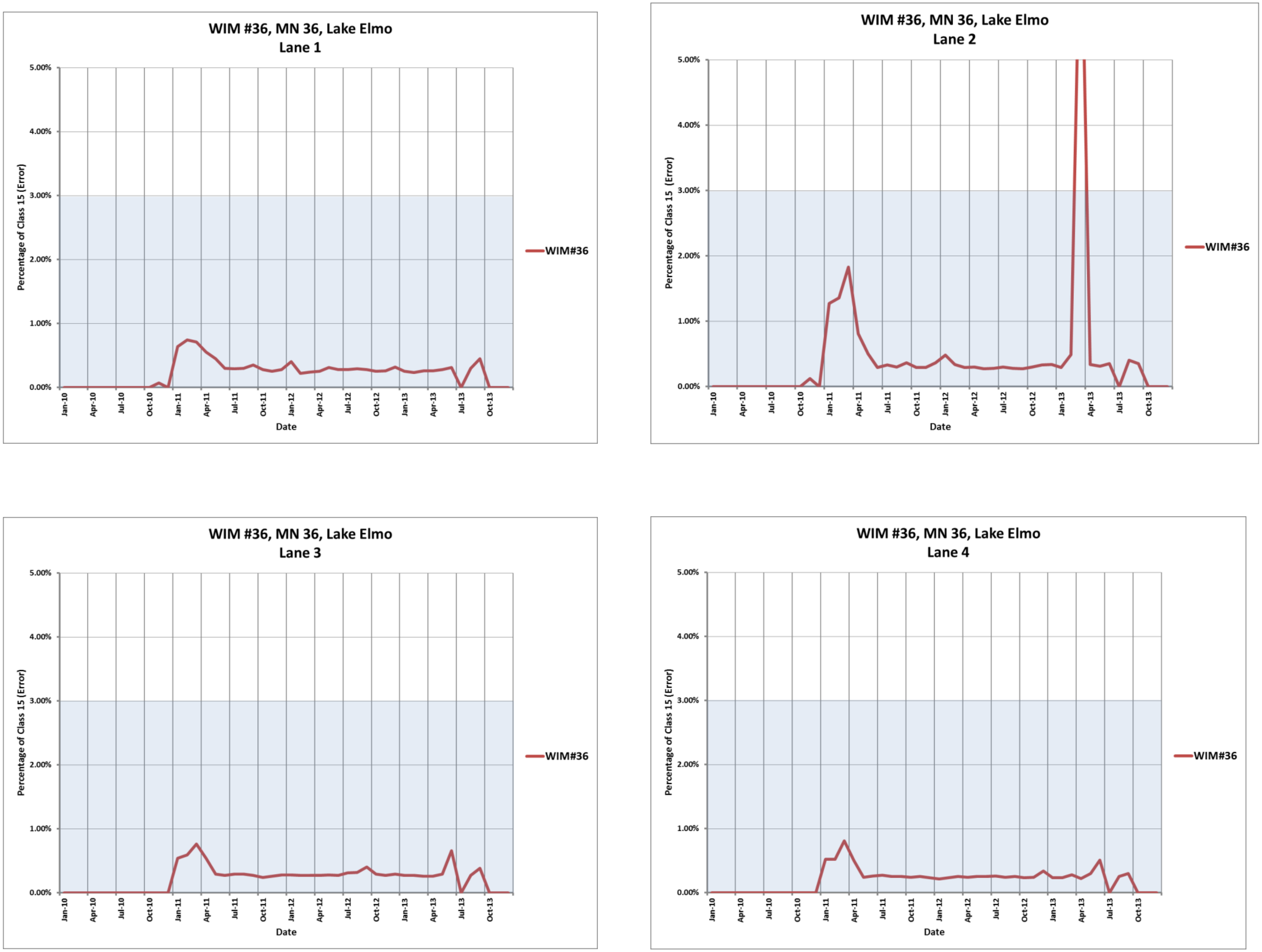
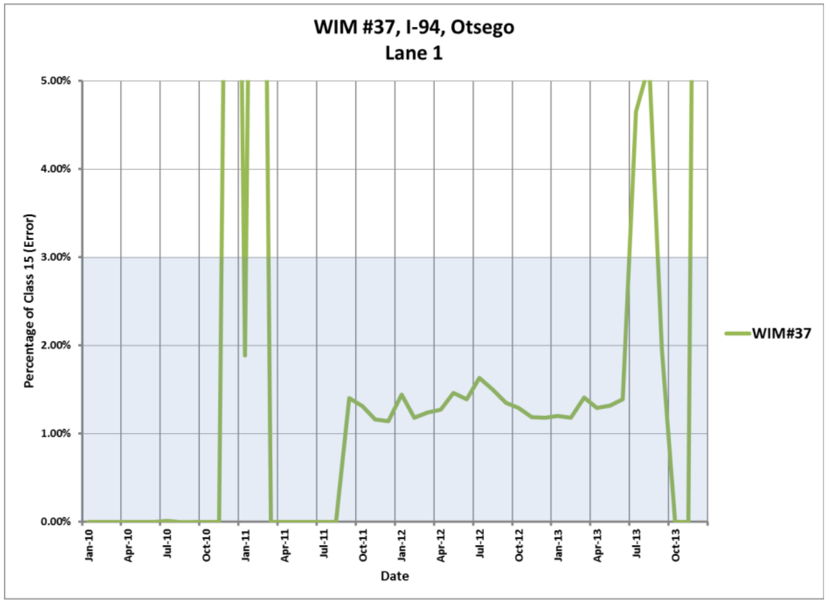


Figure 3.27. Percent of Class 15s (errors) observed over time in Lanes 1-4. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).



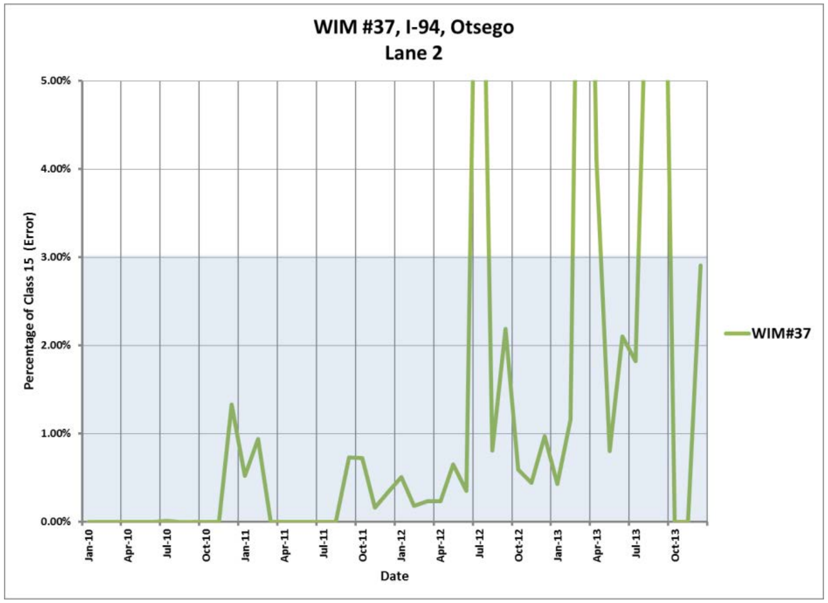


Figure 3.28. Percent of Class 15s (errors) observed over time in Lanes 1-2. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).

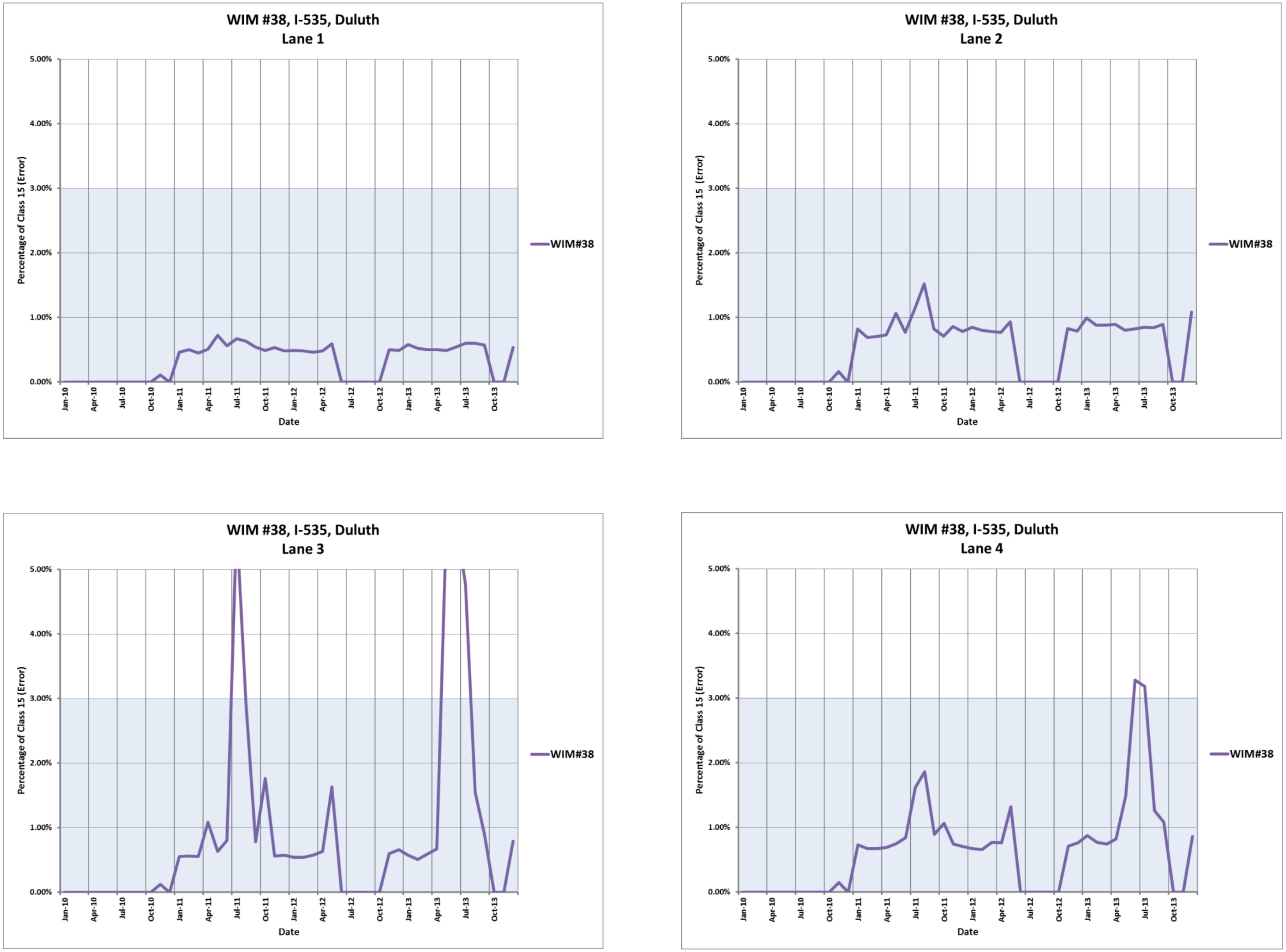
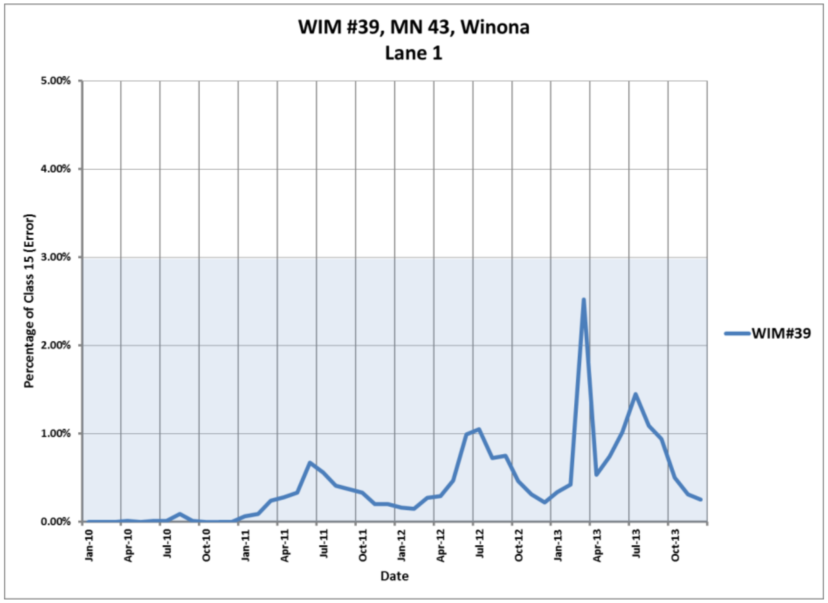


Figure 3.29. Percent of Class 15s (errors) observed over time in Lanes 1-4. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).



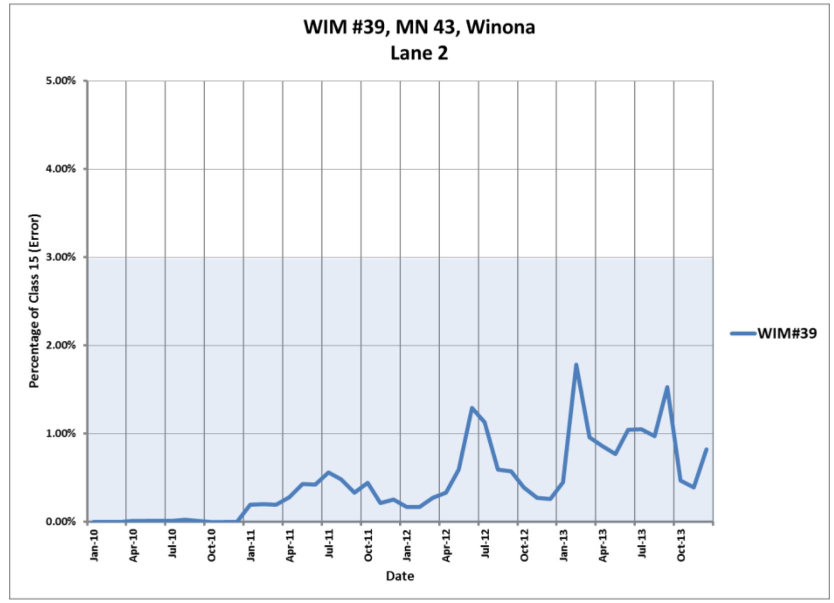


Figure 3.30. Percent of Class 15s (errors) observed over time in Lanes 1-2. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).

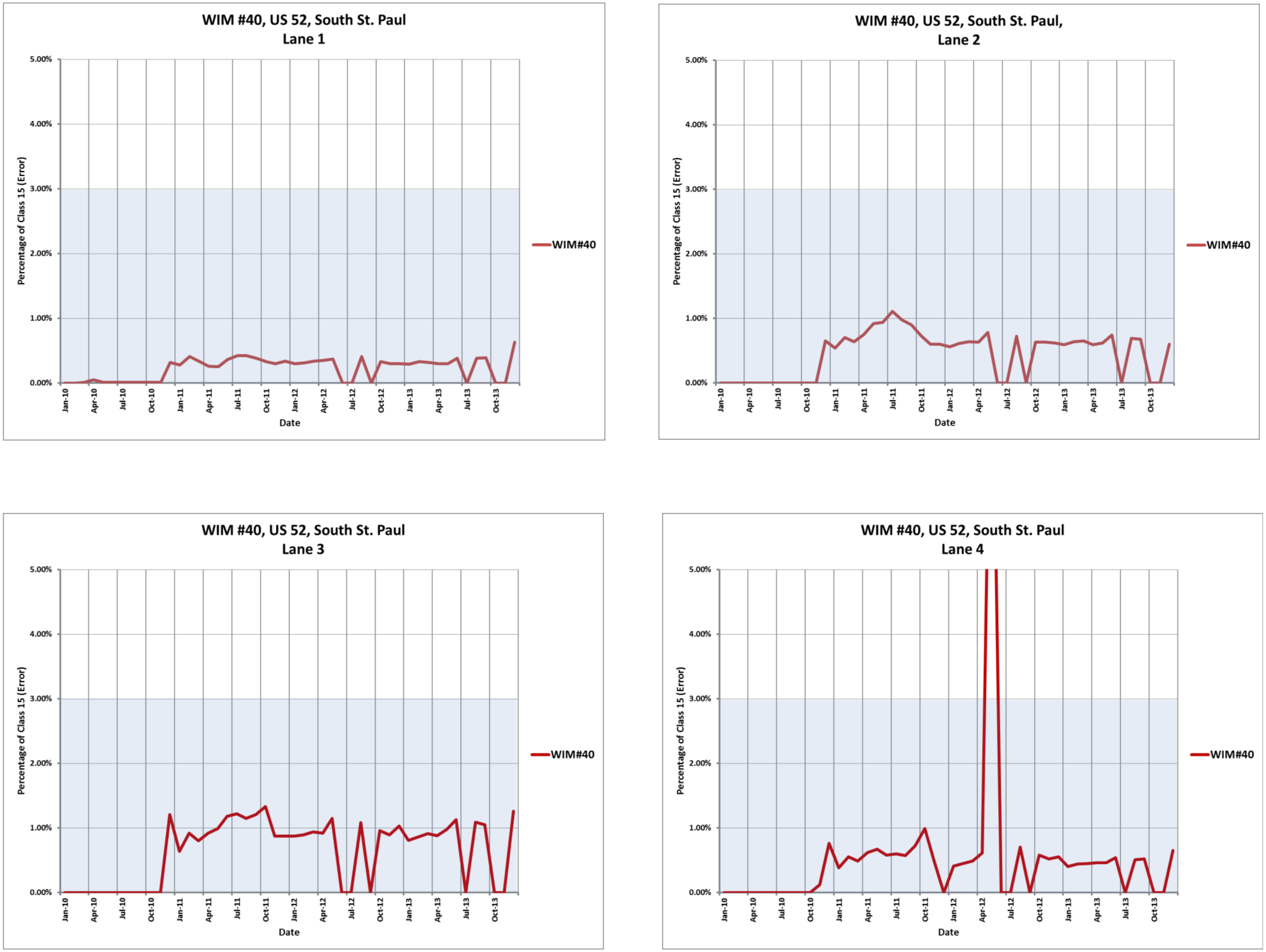
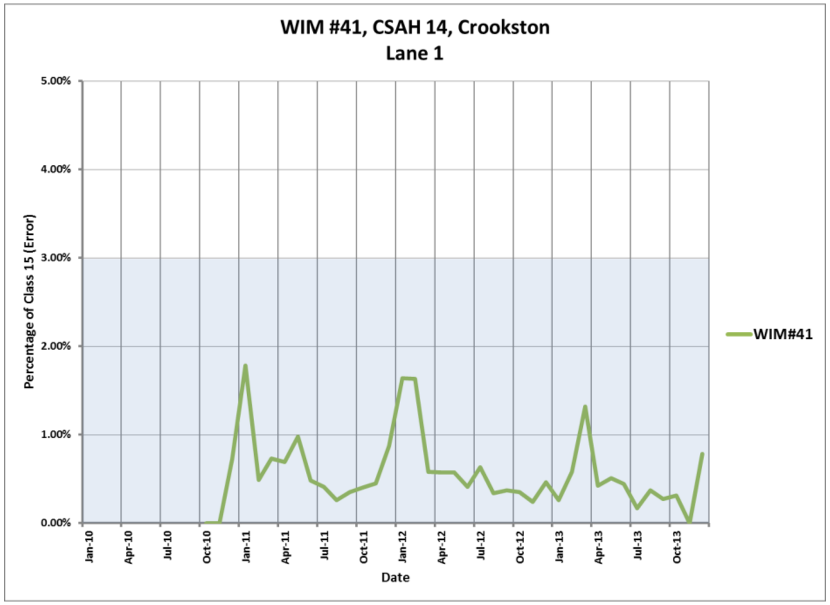


Figure 3.31. Percent of Class 15s (errors) observed over time in Lanes 1-4. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).



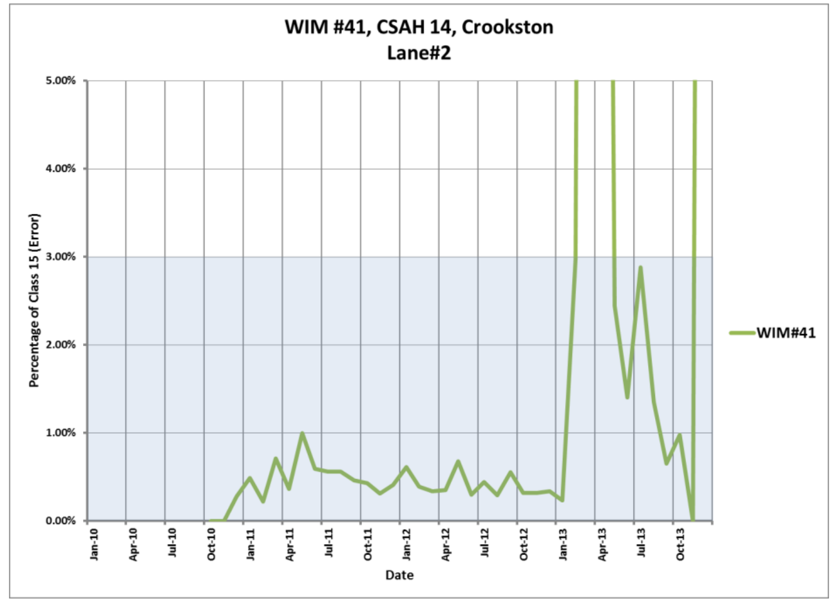


Figure 3.32. Percent of Class 15s (errors) observed over time in Lanes 1-2. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).

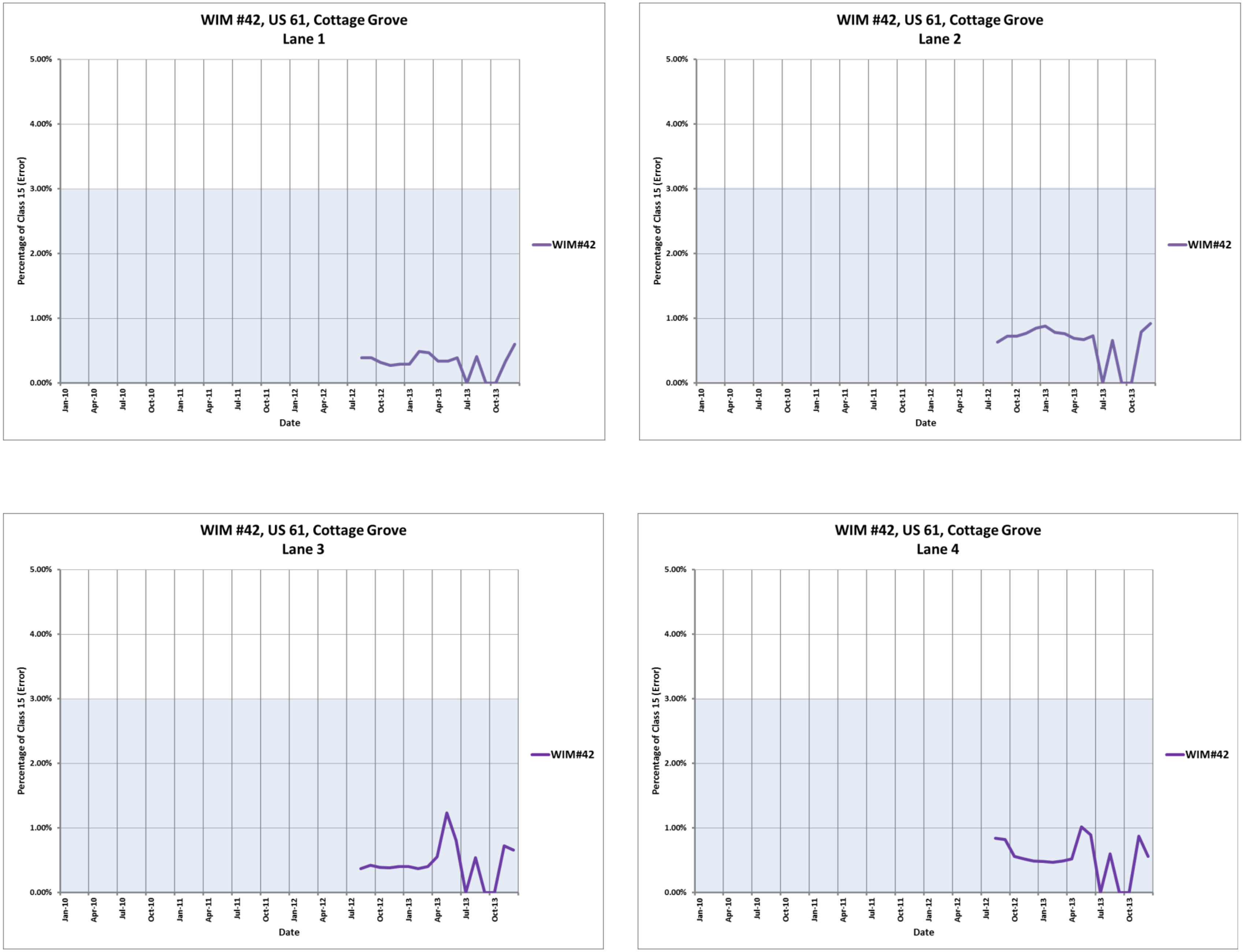


Figure 3.33. Percent of Class 15s (errors) observed over time in Lanes 1-4. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).

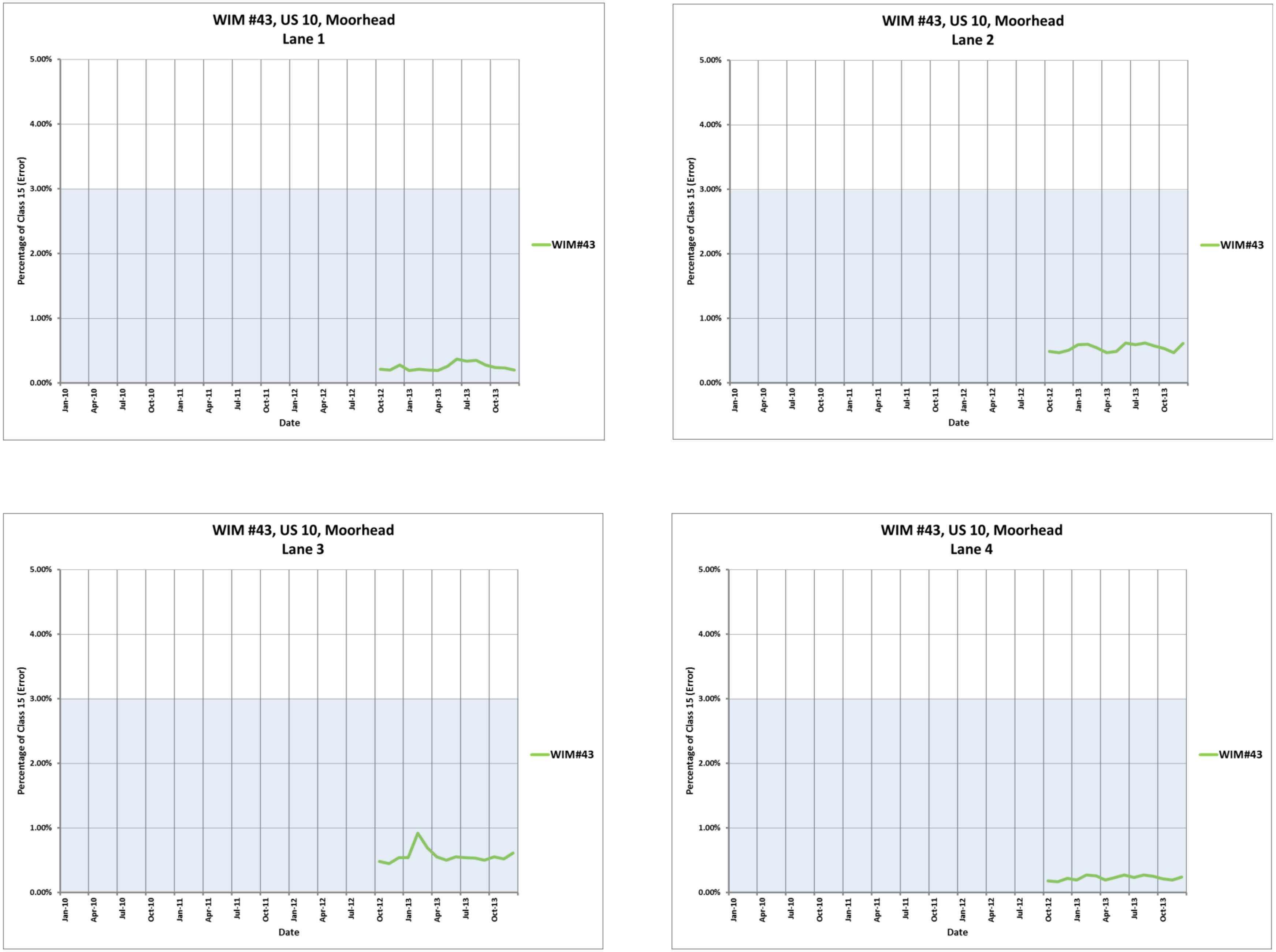


Figure 3.34. Percent of Class 15s (errors) observed over time in Lanes 1-4. Blue shaded area represents the currently accepted range in which Class 15s should fall (<3% of total records).

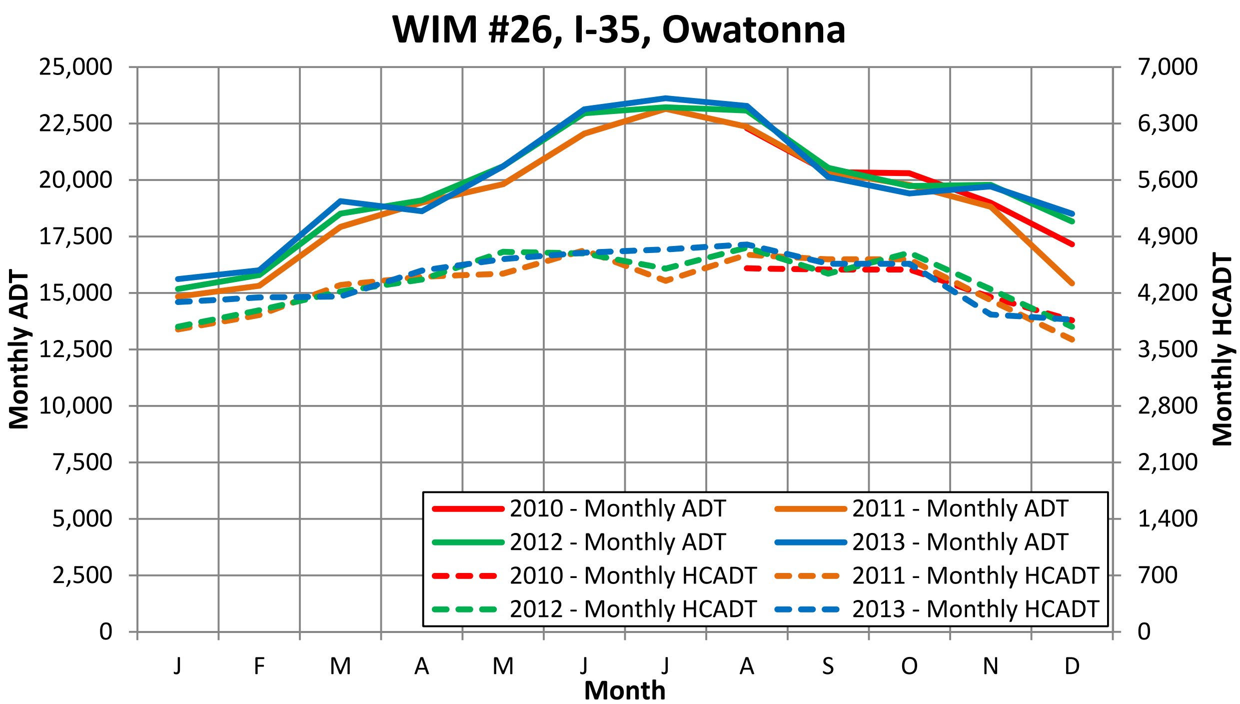


Figure 4.1. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

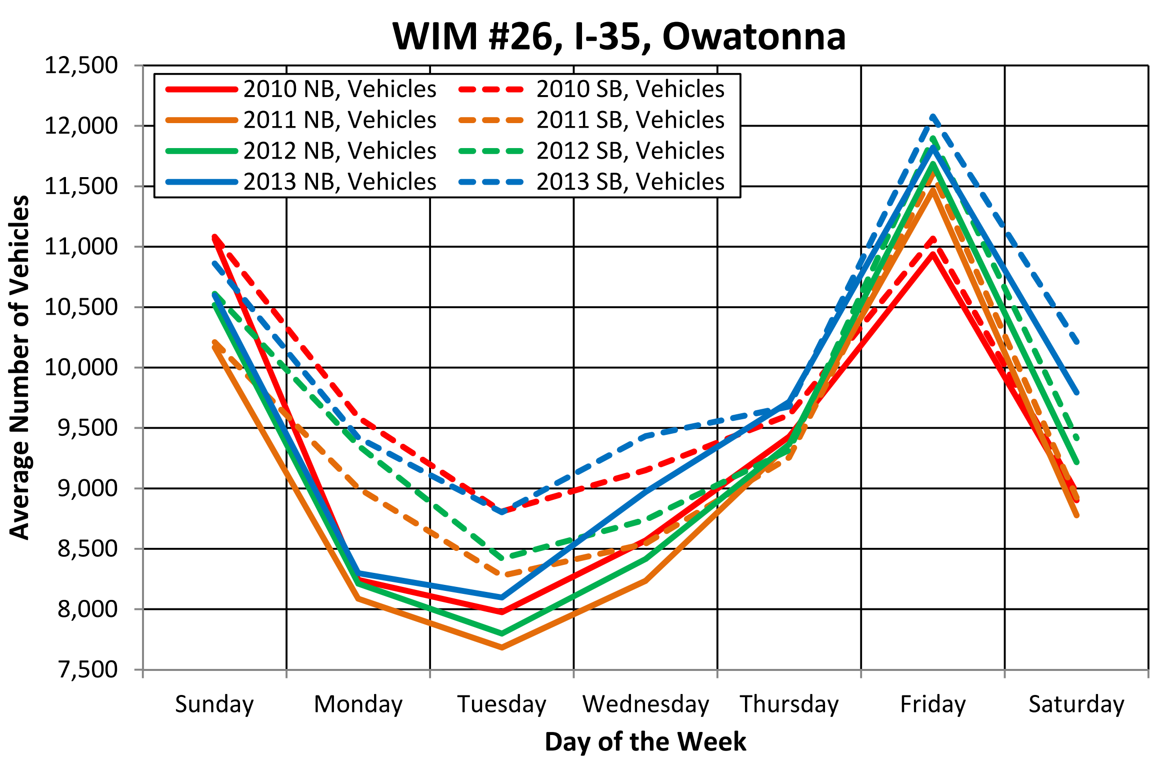


Figure 4.2. Mean number of vehicles by day of week, observed as a function of year and direction (northbound vs. southbound; NB vs. SB).

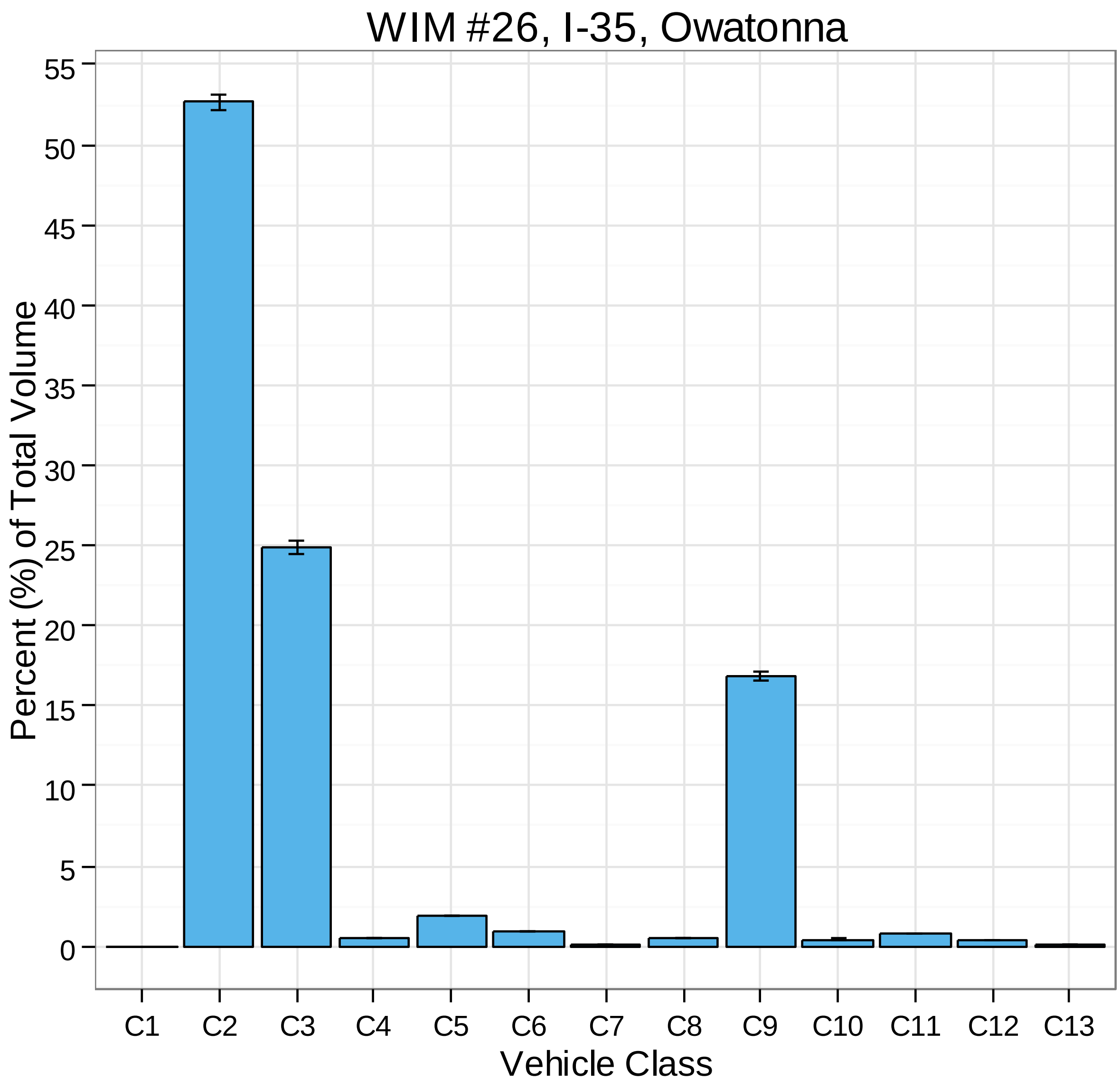


Figure 4.3. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

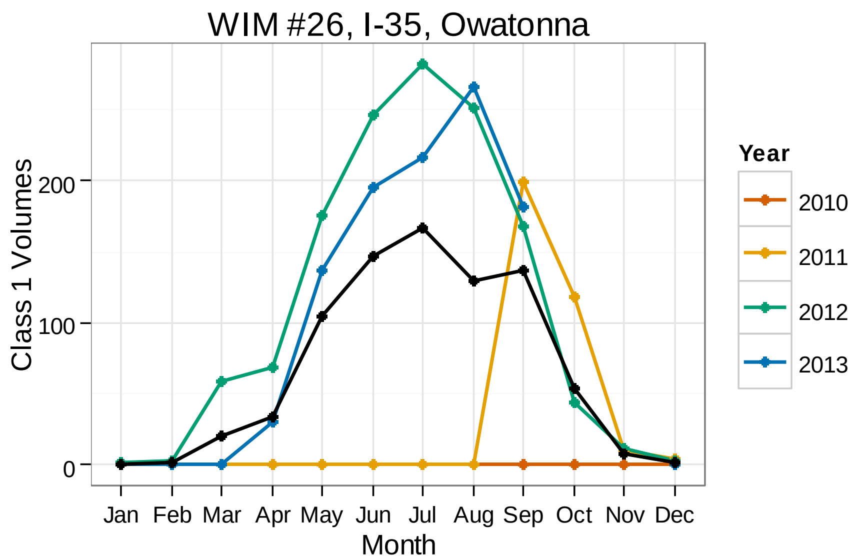


Figure 4.4a. Class 1 volume as a function of month and year. Black line represents the average volume within each month across all years.

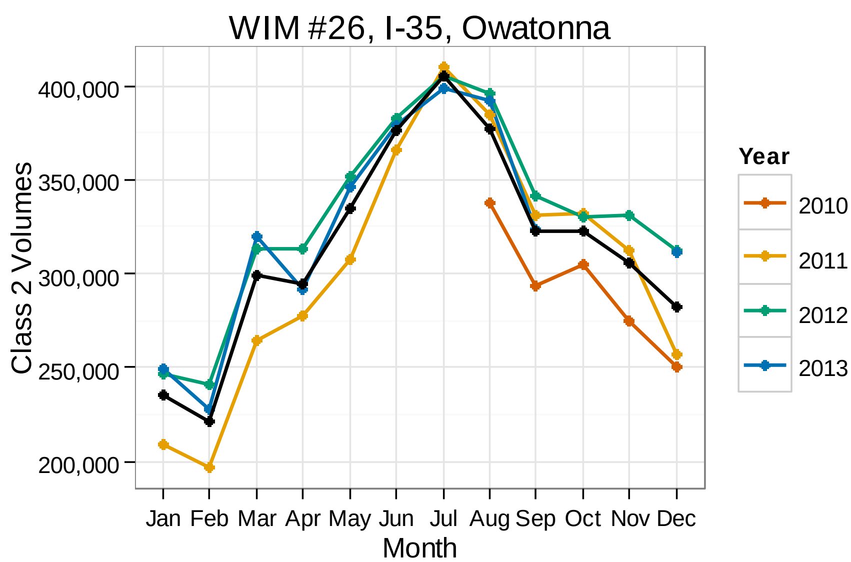


Figure 4.4b. Class 2 volume as a function of month and year. Black line represents the average volume within each month across all years.

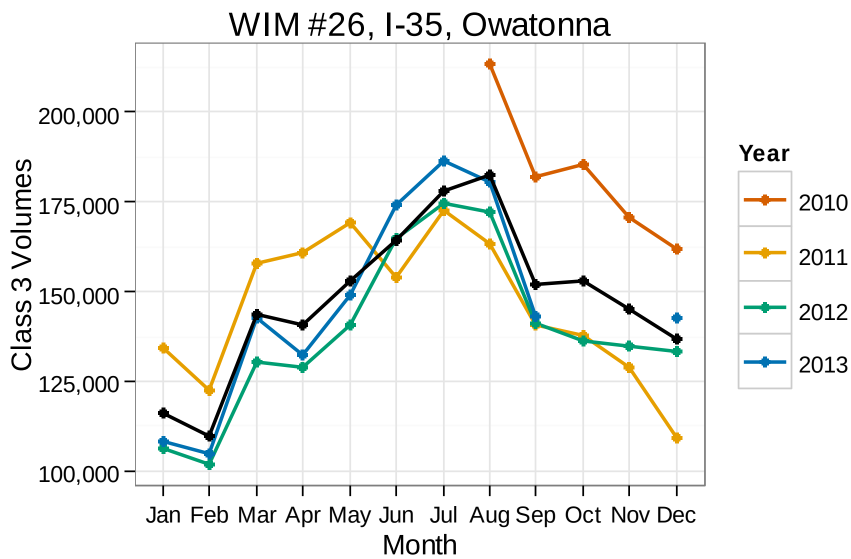


Figure 4.4c. Class 3 volume as a function of month and year. Black line represents the average volume within each month across all years.

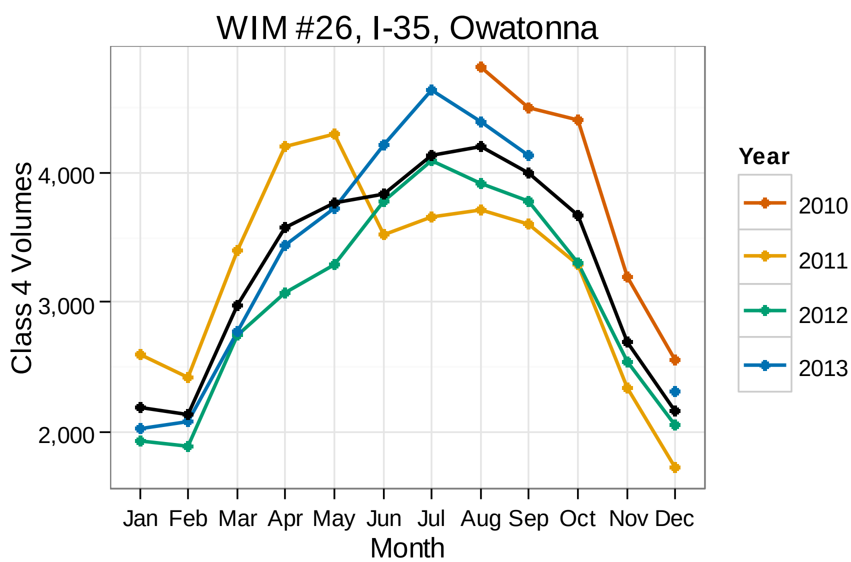


Figure 4.4d. Class 4 volume as a function of month and year. Black line represents the average volume within each month across all years.

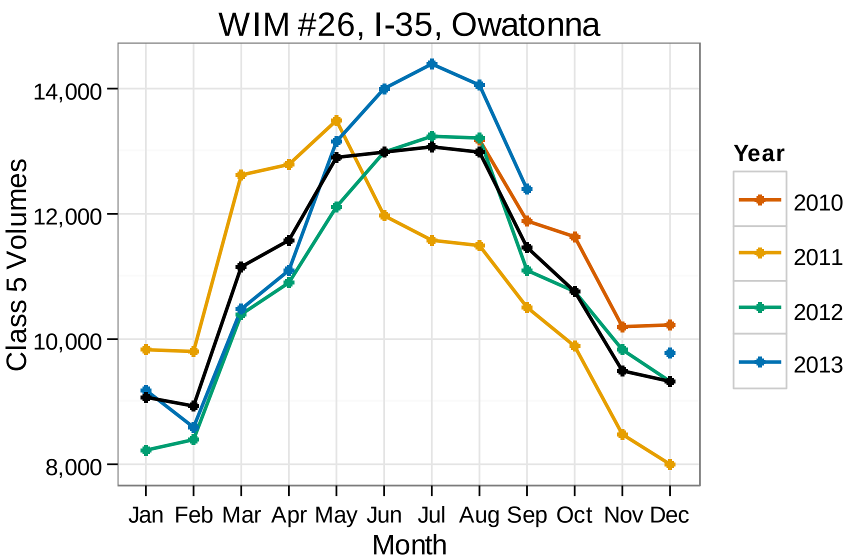


Figure 4.4e. Class 5 volume as a function of month and year. Black line represents the average volume within each month across all years.

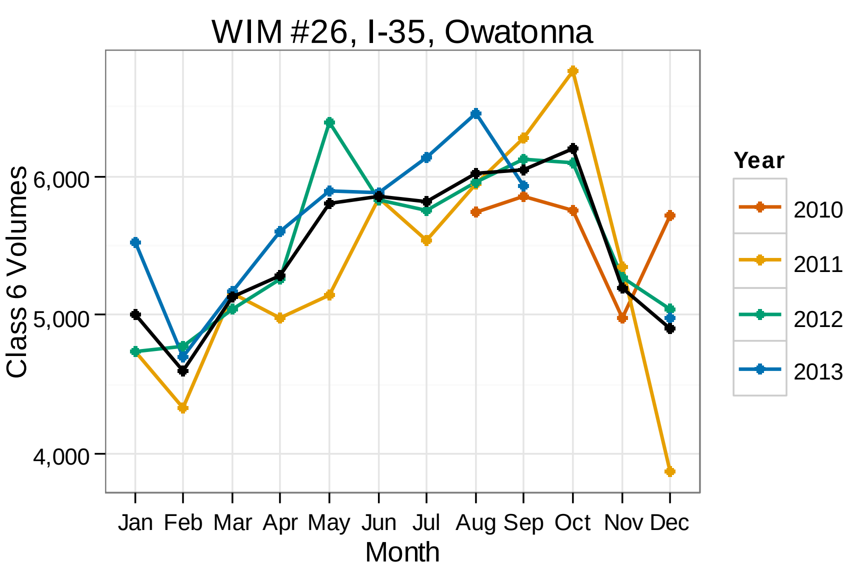


Figure 4.4f. Class 6 volume as a function of month and year. Black line represents the average volume within each month across all years.

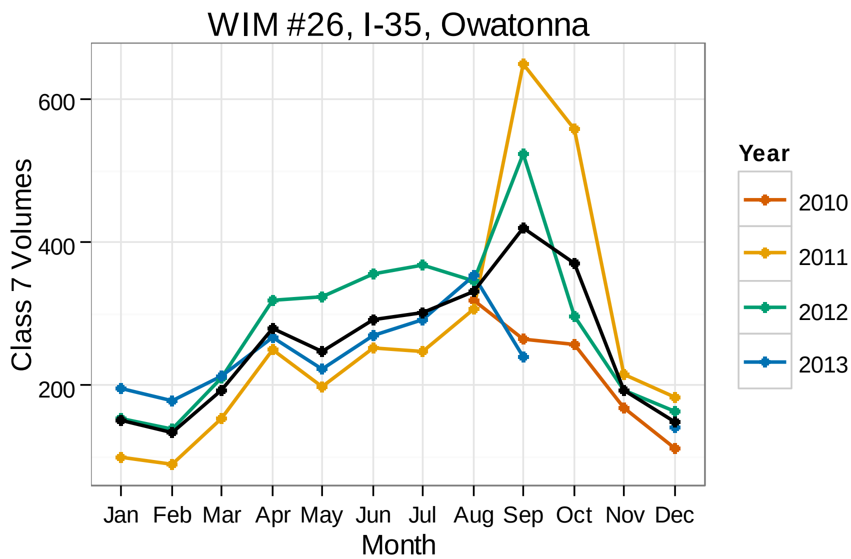


Figure 4.4g. Class 7 volume as a function of month and year. Black line represents the average volume within each month across all years.

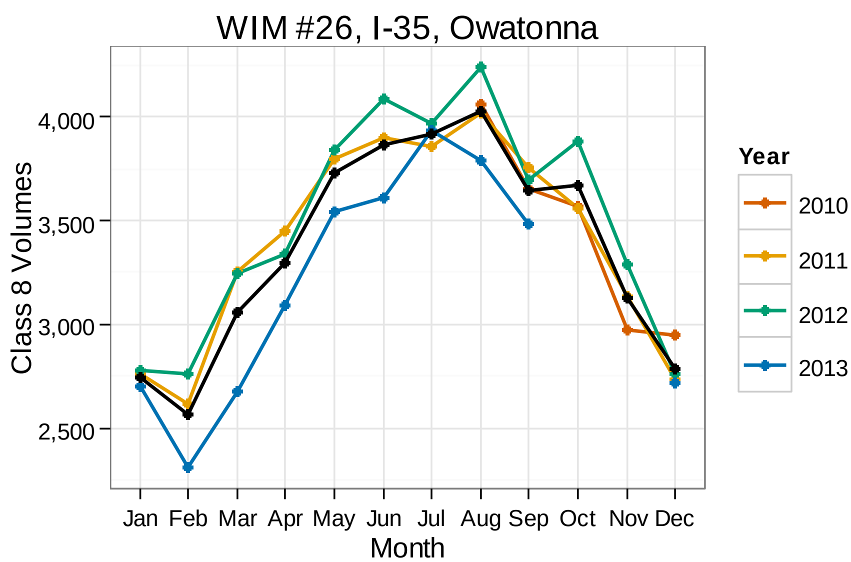


Figure 4.4h. Class 8 volume as a function of month and year. Black line represents the average volume within each month across all years.

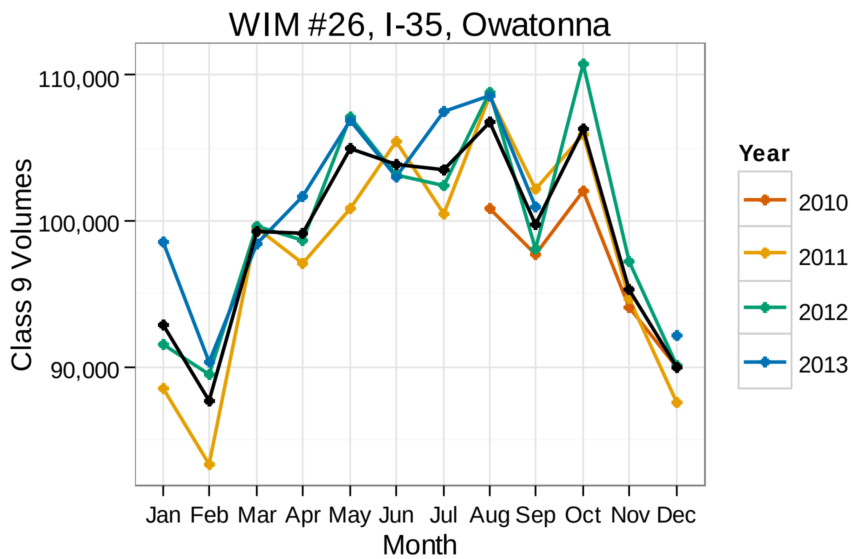


Figure 4.4i. Class 9 volume as a function of month and year. Black line represents the average volume within each month across all years.

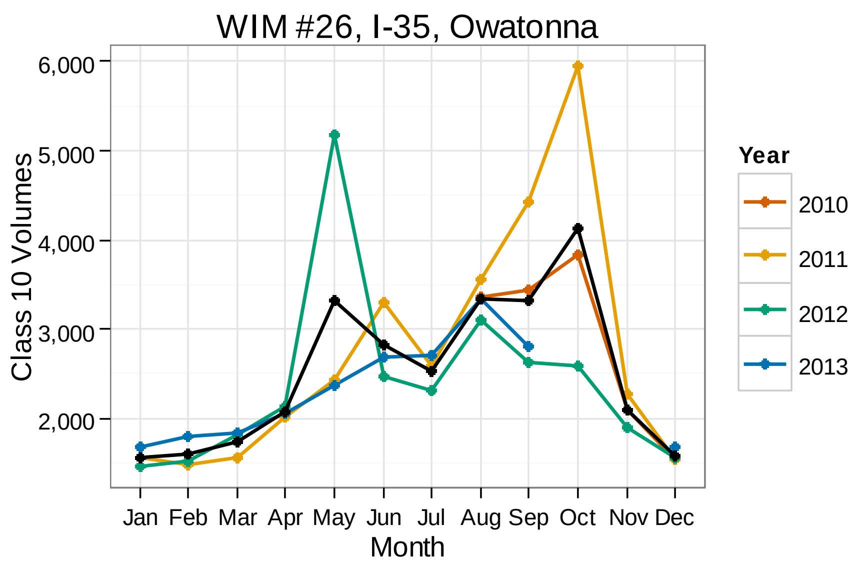


Figure 4.4j. Class 10 volume as a function of month and year. Black line represents the average volume within each month across all years.

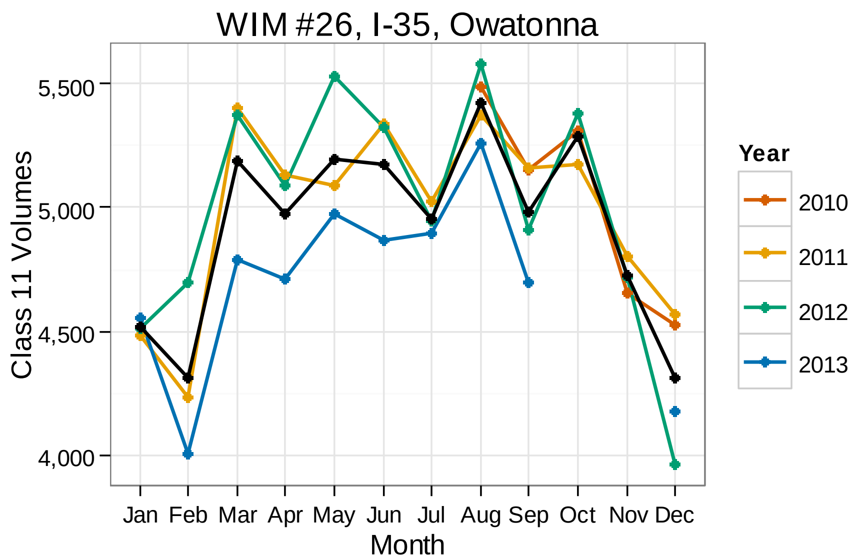


Figure 4.4k. Class 11 volume as a function of month and year. Black line represents the average volume within each month across all years.

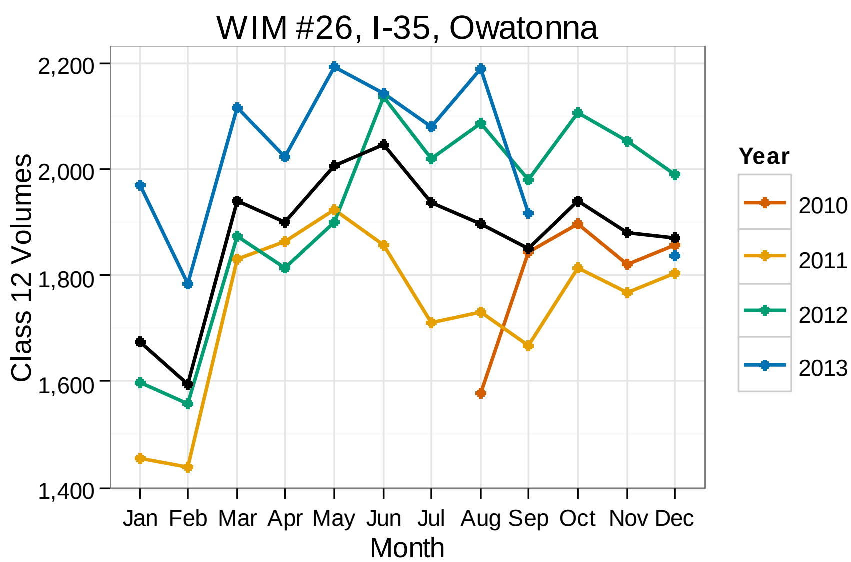


Figure 4.4l. Class 12 volume as a function of month and year. Black line represents the average volume within each month across all years.

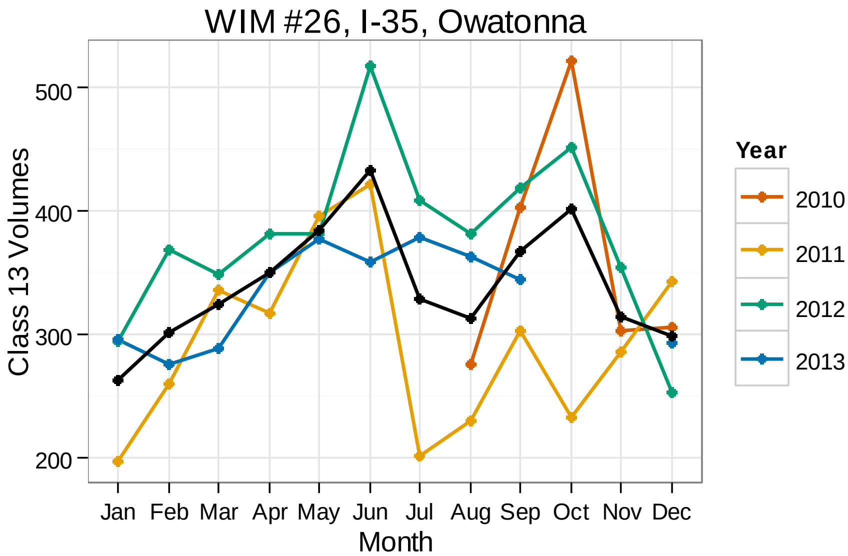


Figure 4.4m. Class 13 volume as a function of month and year. Black line represents the average volume within each month across all years.

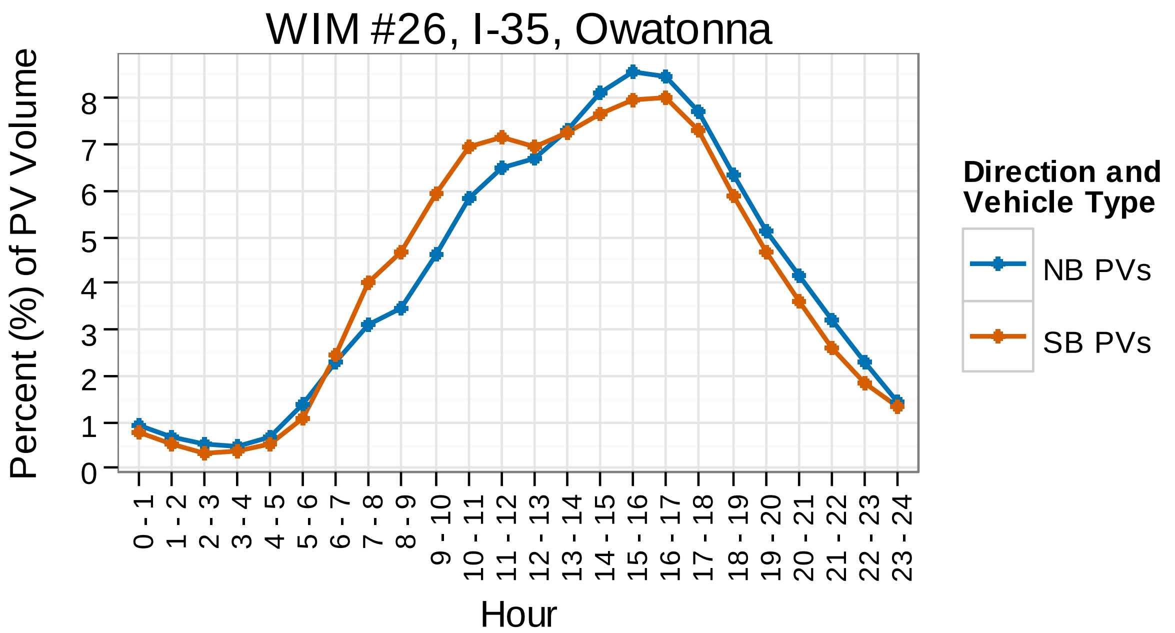


Figure 4.5a. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for passenger vehicles (PVs).

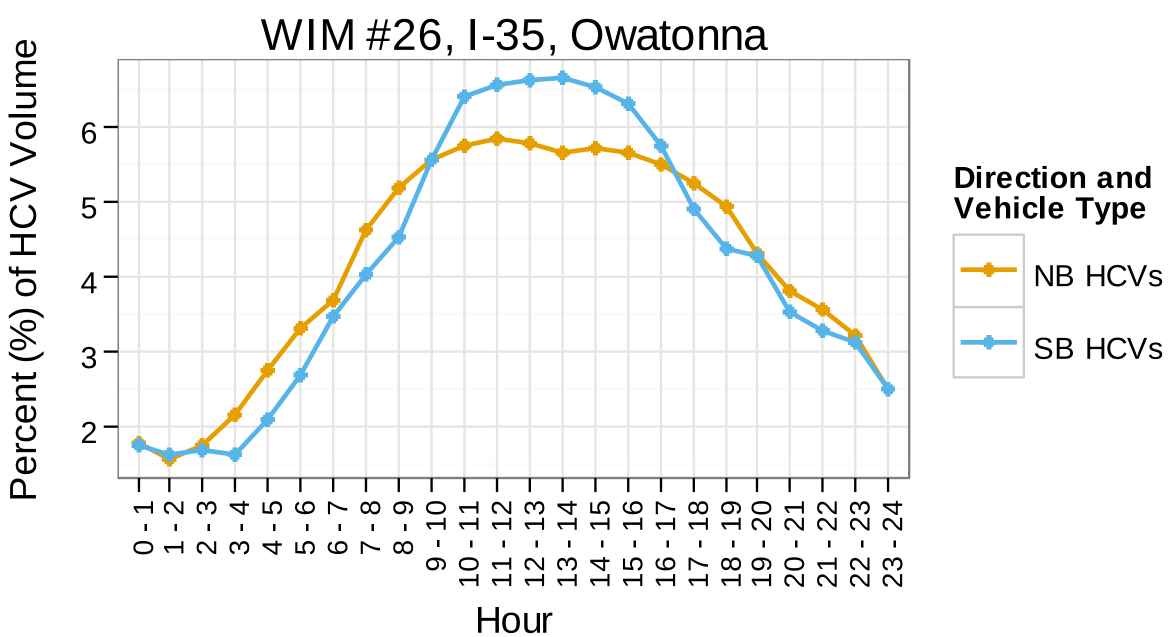


Figure 4.5b. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for heavy commercial vehicles (HCVs).

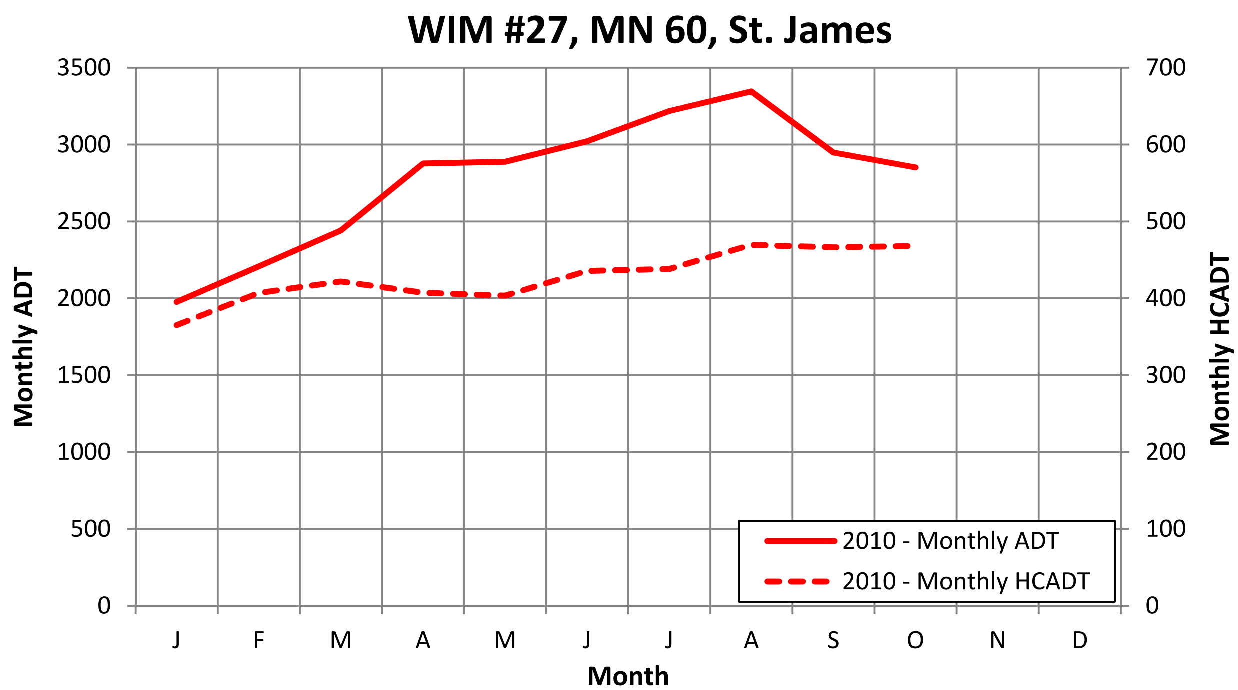


Figure 4.6. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

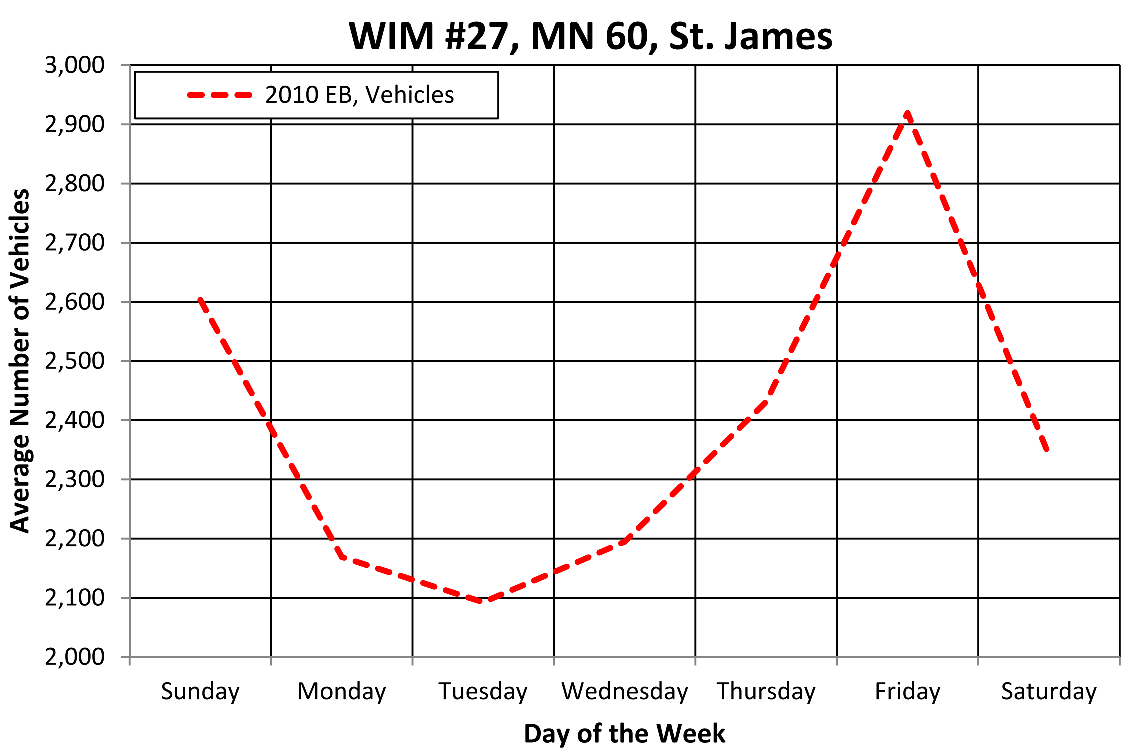


Figure 4.7. Mean number of vehicles by day of week, observed as a function of year and direction (eastbound; EB). [In-pavement WIM scale only exists in the EB lane at this site]

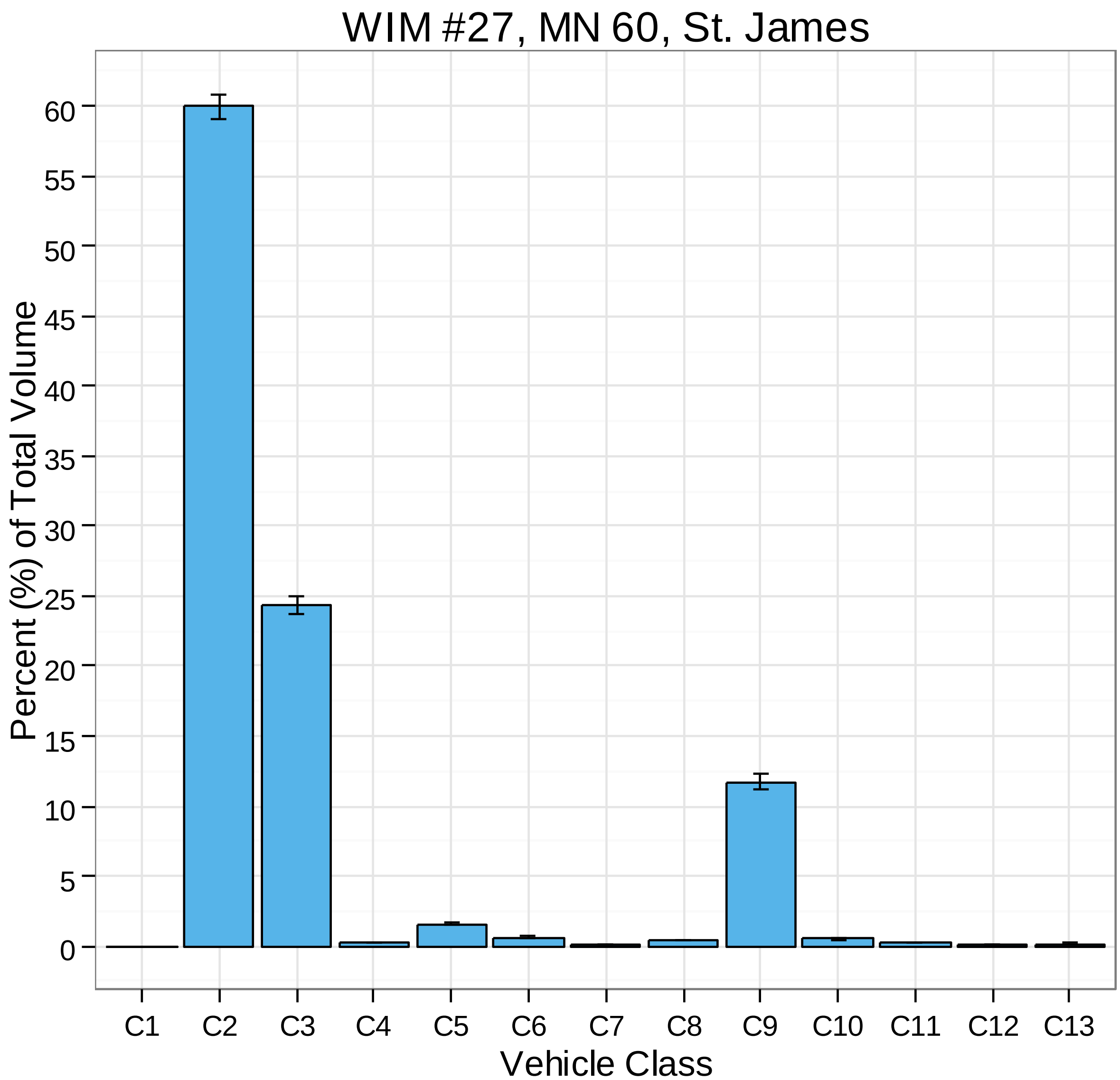


Figure 4.8. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

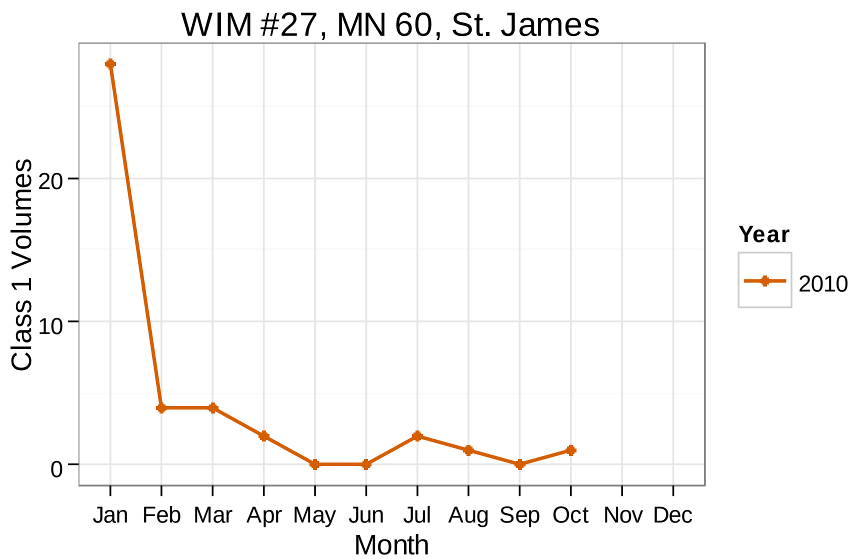


Figure 4.9a. Class 1 volume as a function of month and year.

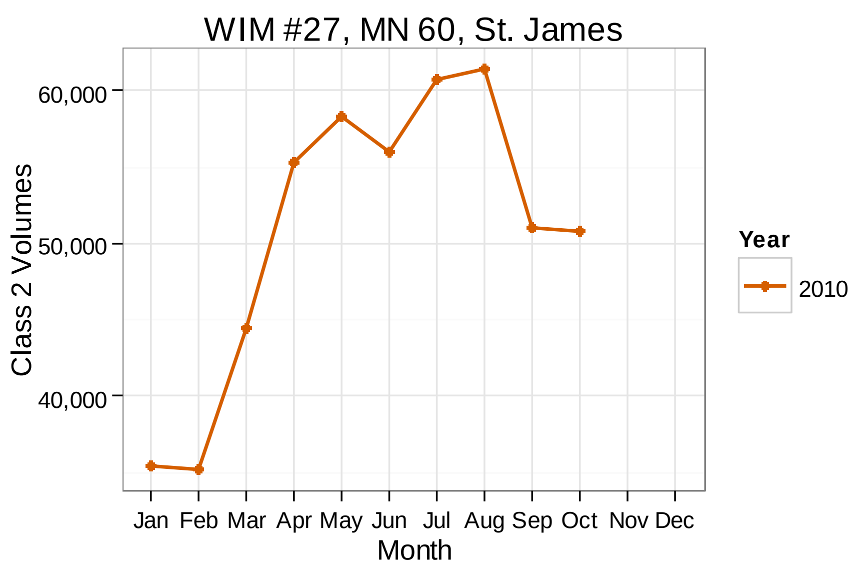


Figure 4.9b. Class 2 volume as a function of month and year.

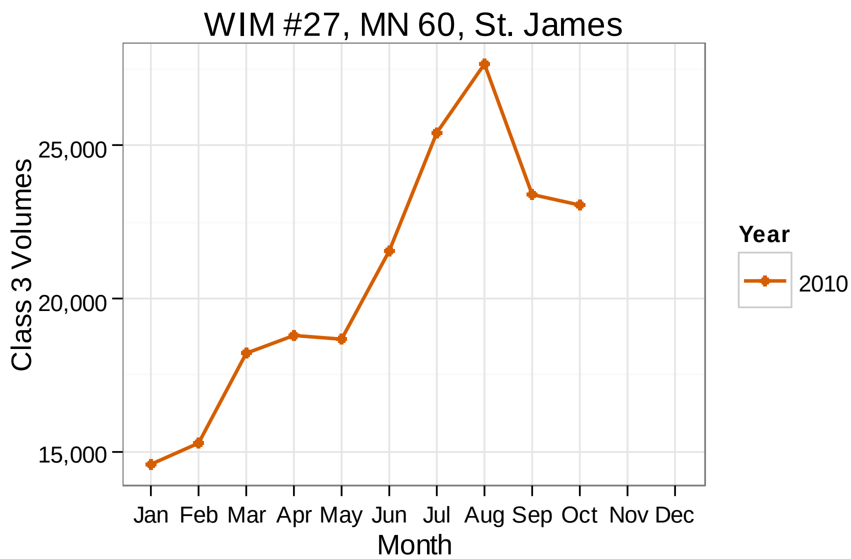


Figure 4.9c. Class 3 volume as a function of month and year.

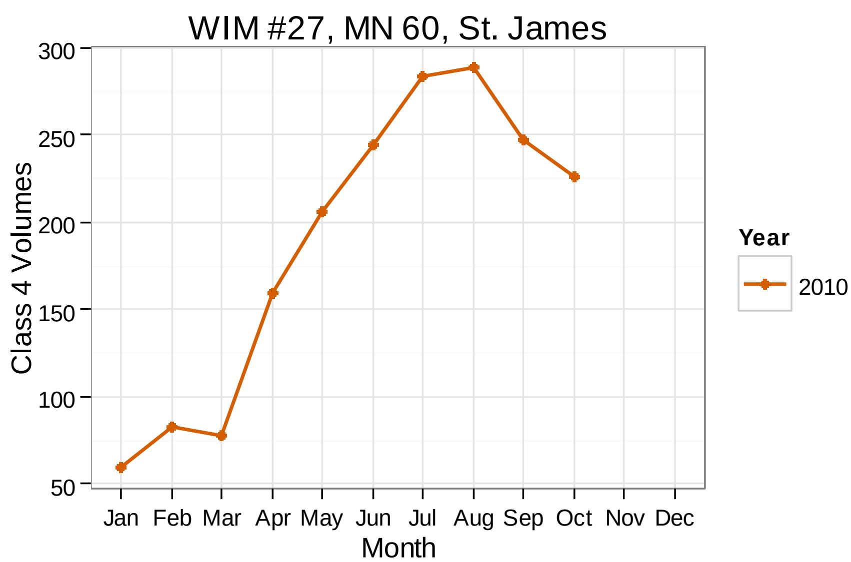


Figure 4.9d. Class 4 volume as a function of month and year.

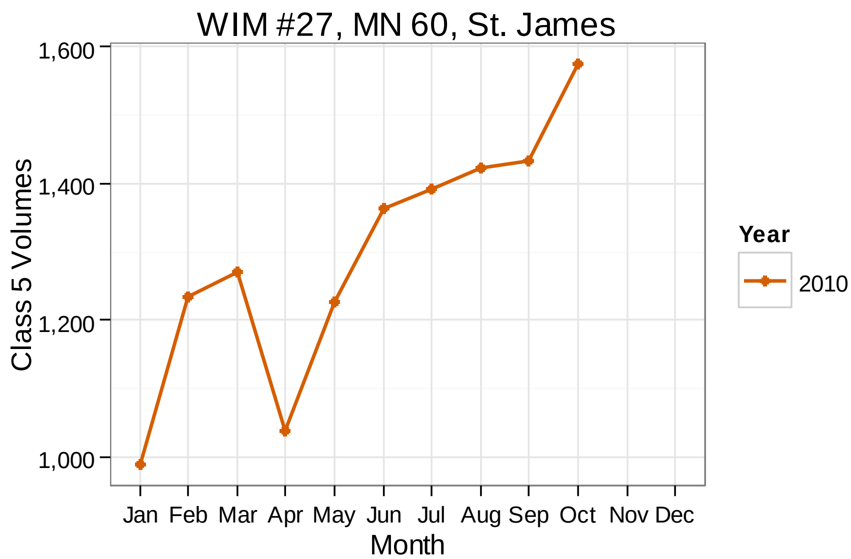


Figure 4.9e. Class 5 volume as a function of month and year.

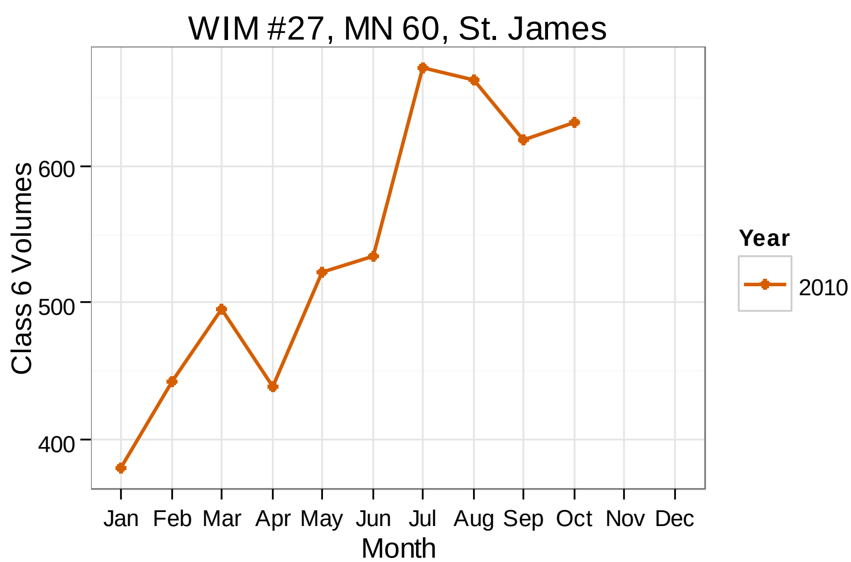


Figure 4.9f. Class 6 volume as a function of month and year.

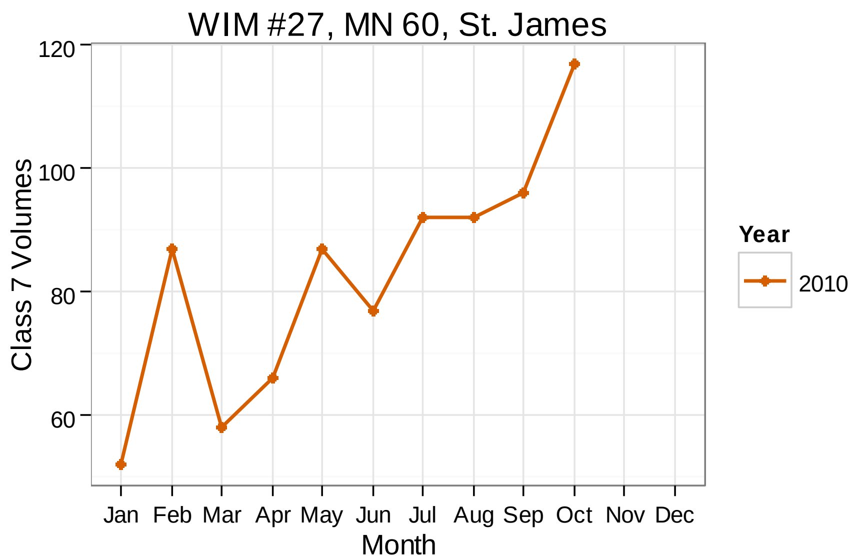


Figure 4.9g. Class 7 volume as a function of month and year.

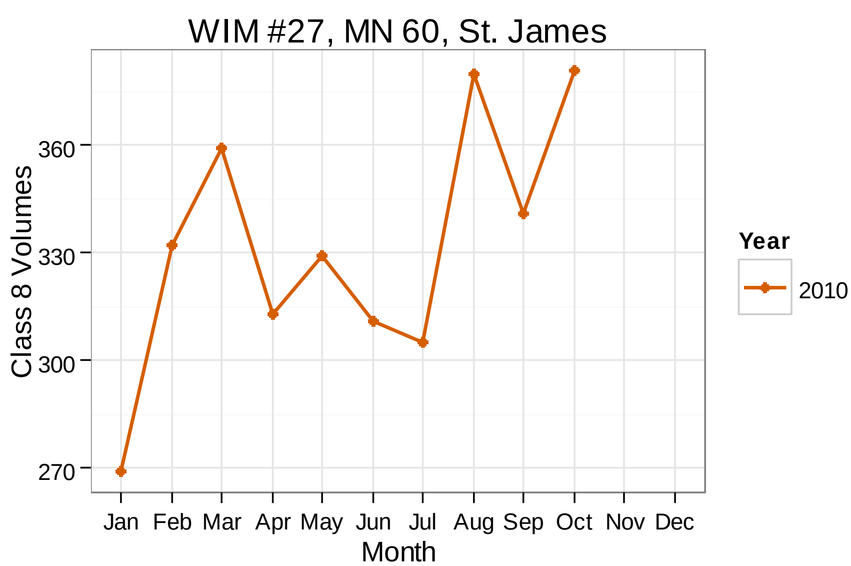


Figure 4.9h. Class 8 volume as a function of month and year.

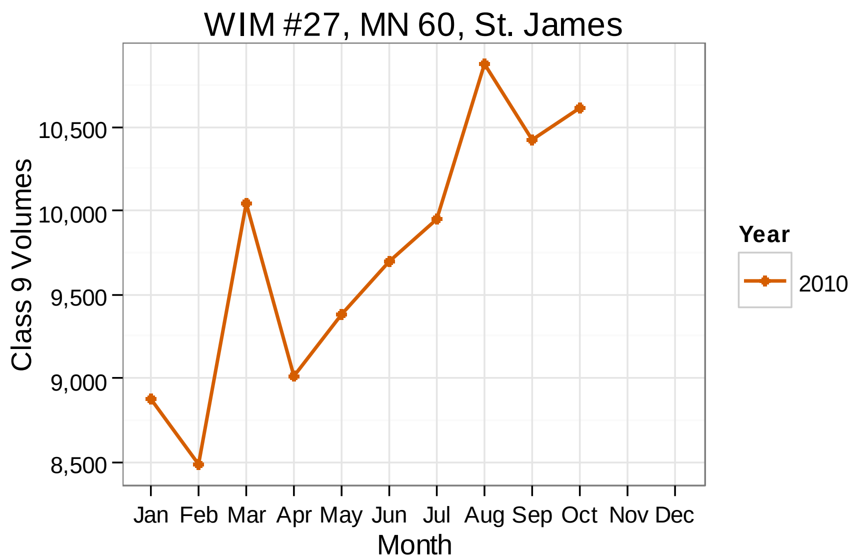


Figure 4.9i. Class 9 volume as a function of month and year.

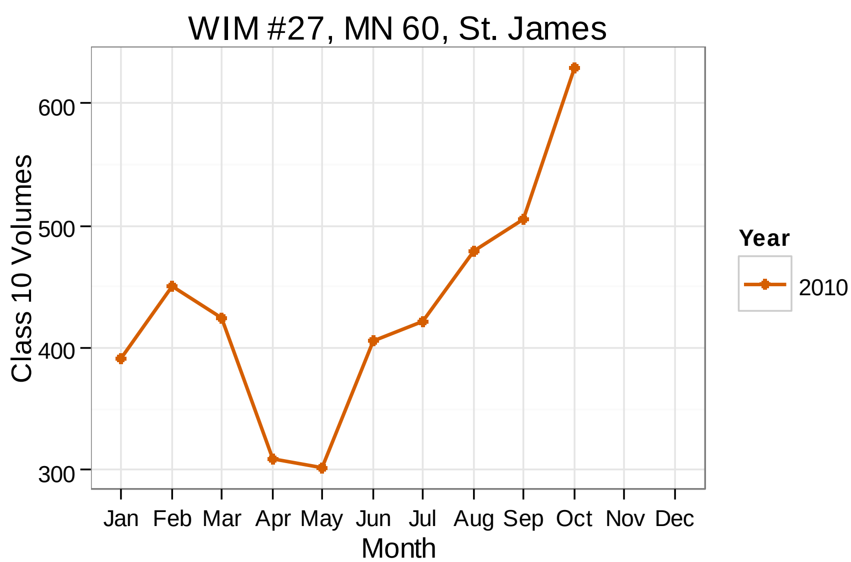


Figure 4.9j. Class 10 volume as a function of month and year.

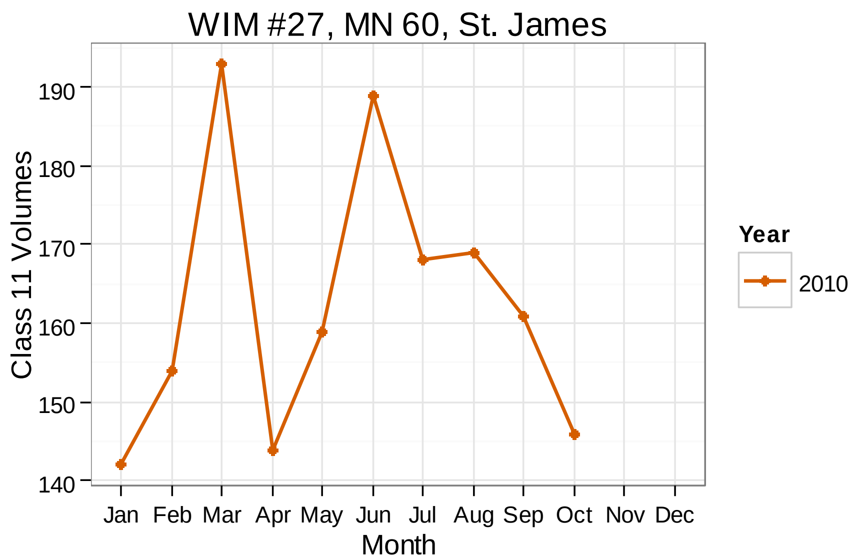


Figure 4.9k. Class 11 volume as a function of month and year.

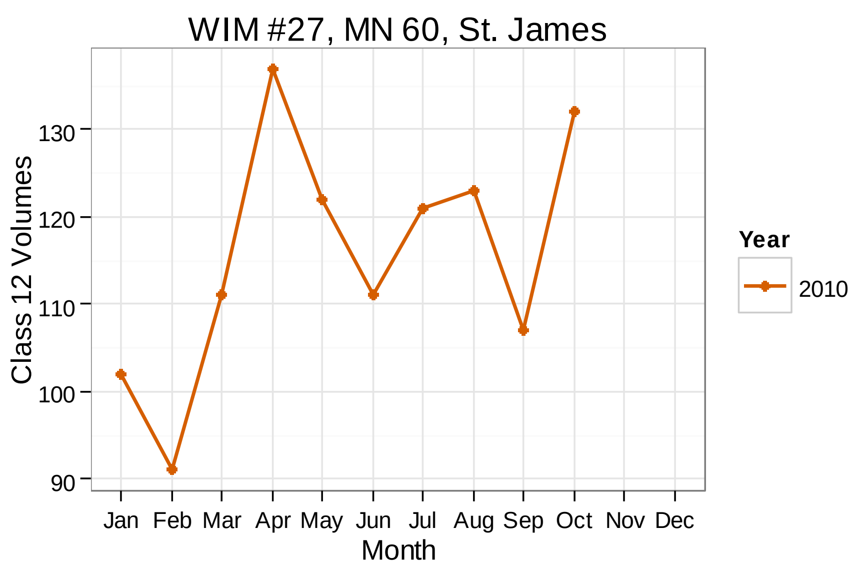


Figure 4.9l. Class 12 volume as a function of month and year.

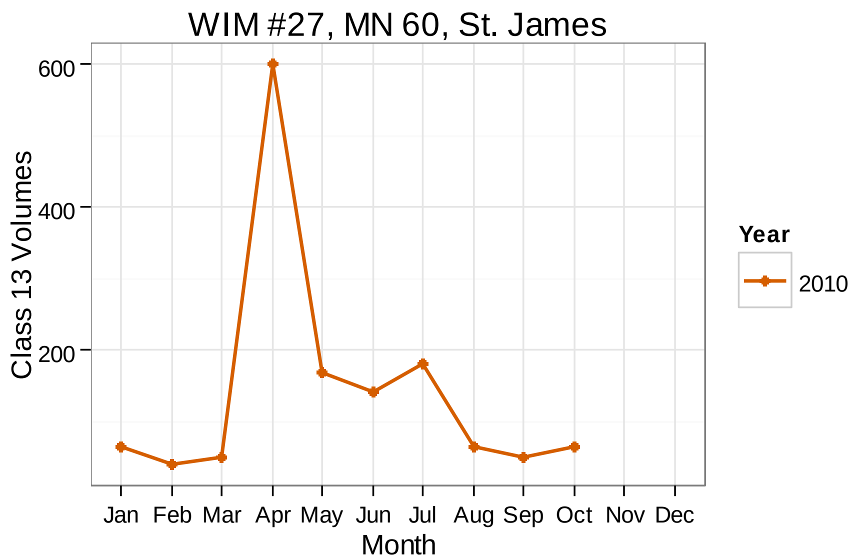


Figure 4.9m. Class 13 volume as a function of month and year.

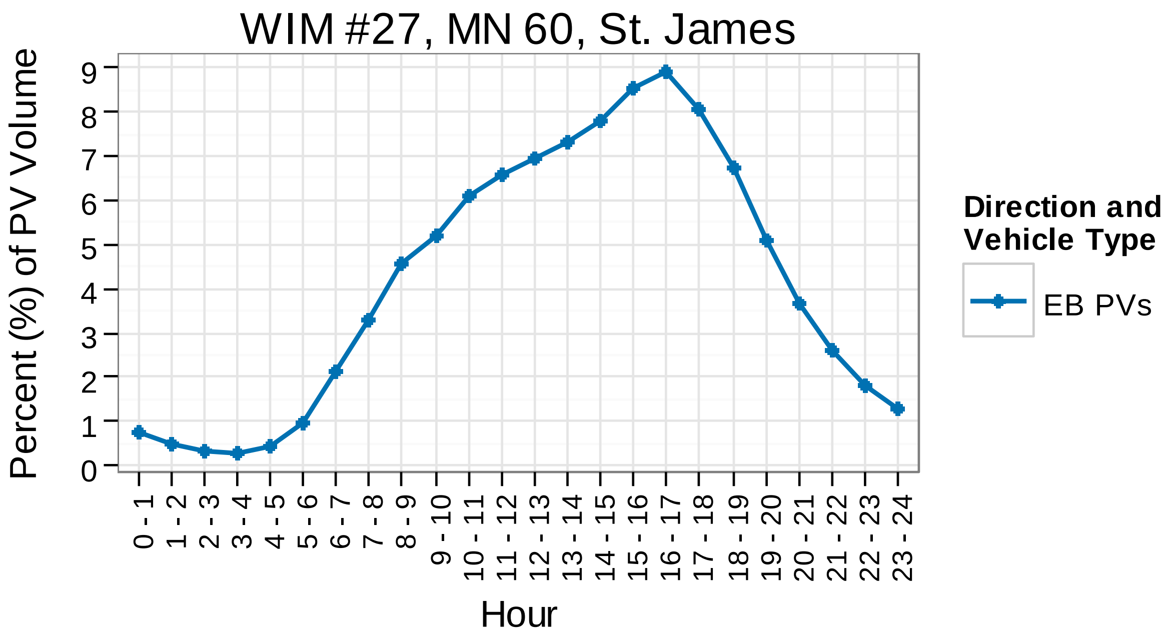


Figure 4.10a. Amount of traffic (% of volume) observed at an hourly basis in the eastbound (EB) direction for passenger vehicles (PVs).

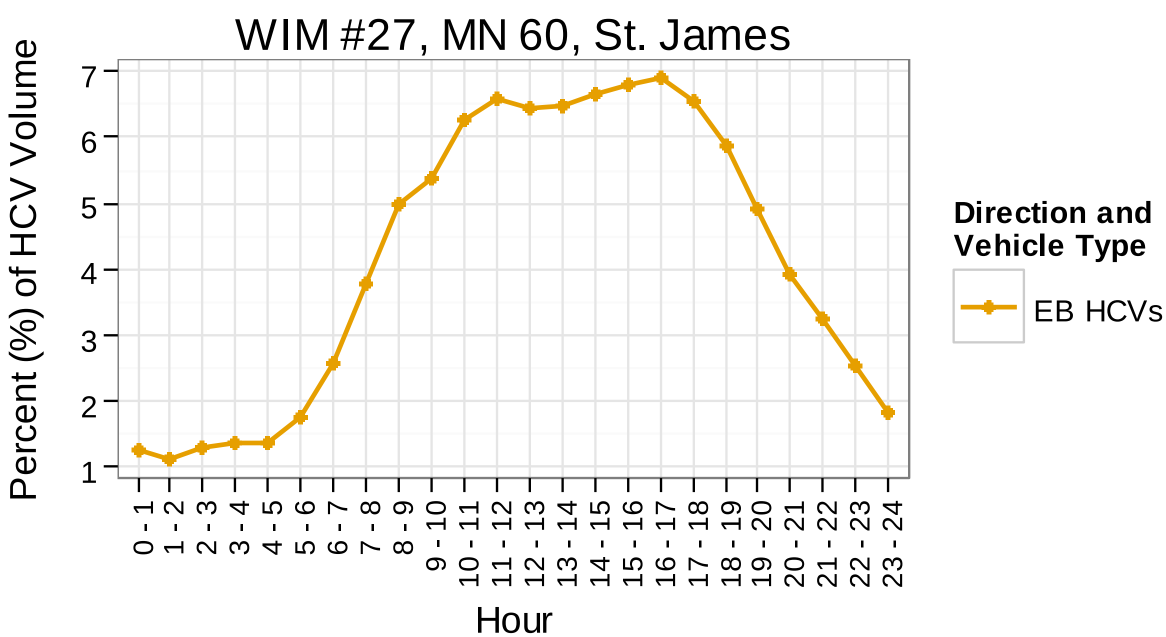


Figure 4.10b. Amount of traffic (% of volume) observed at an hourly basis in the eastbound (EB) direction for heavy commercial vehicles (HCVs).

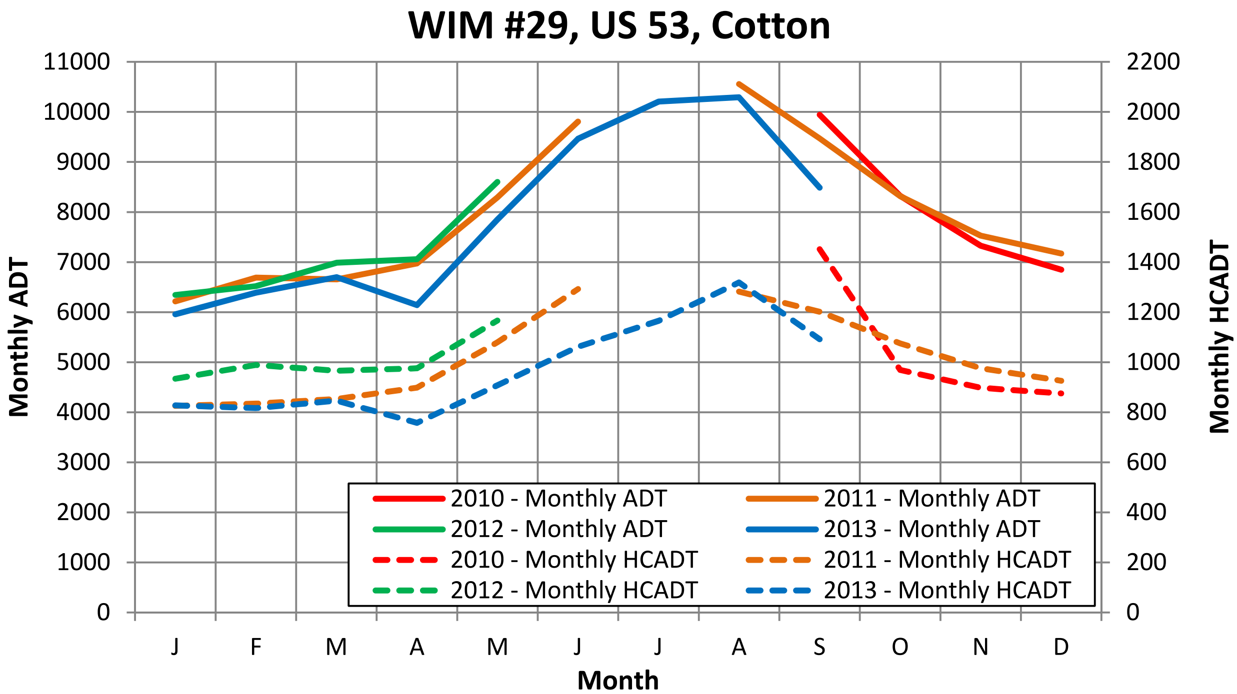


Figure 4.11. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

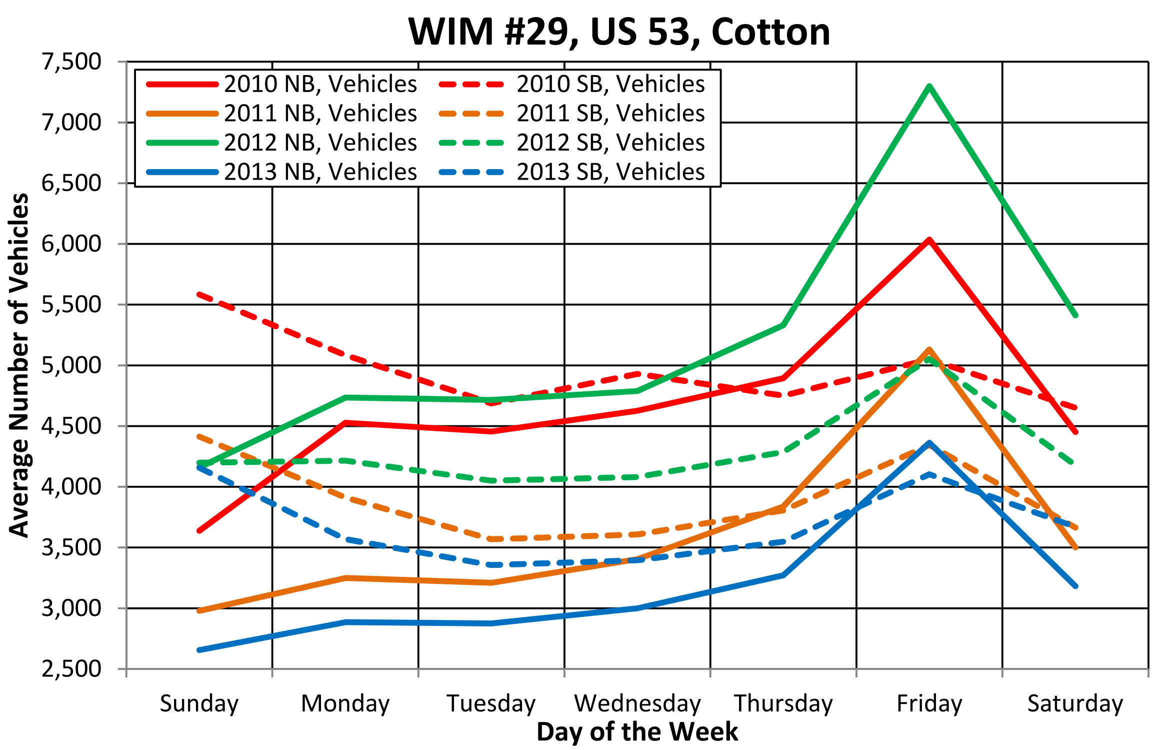


Figure 4.12. Mean number of vehicles by day of week, observed as a function of year and direction (northbound vs. southbound; NB vs. SB).

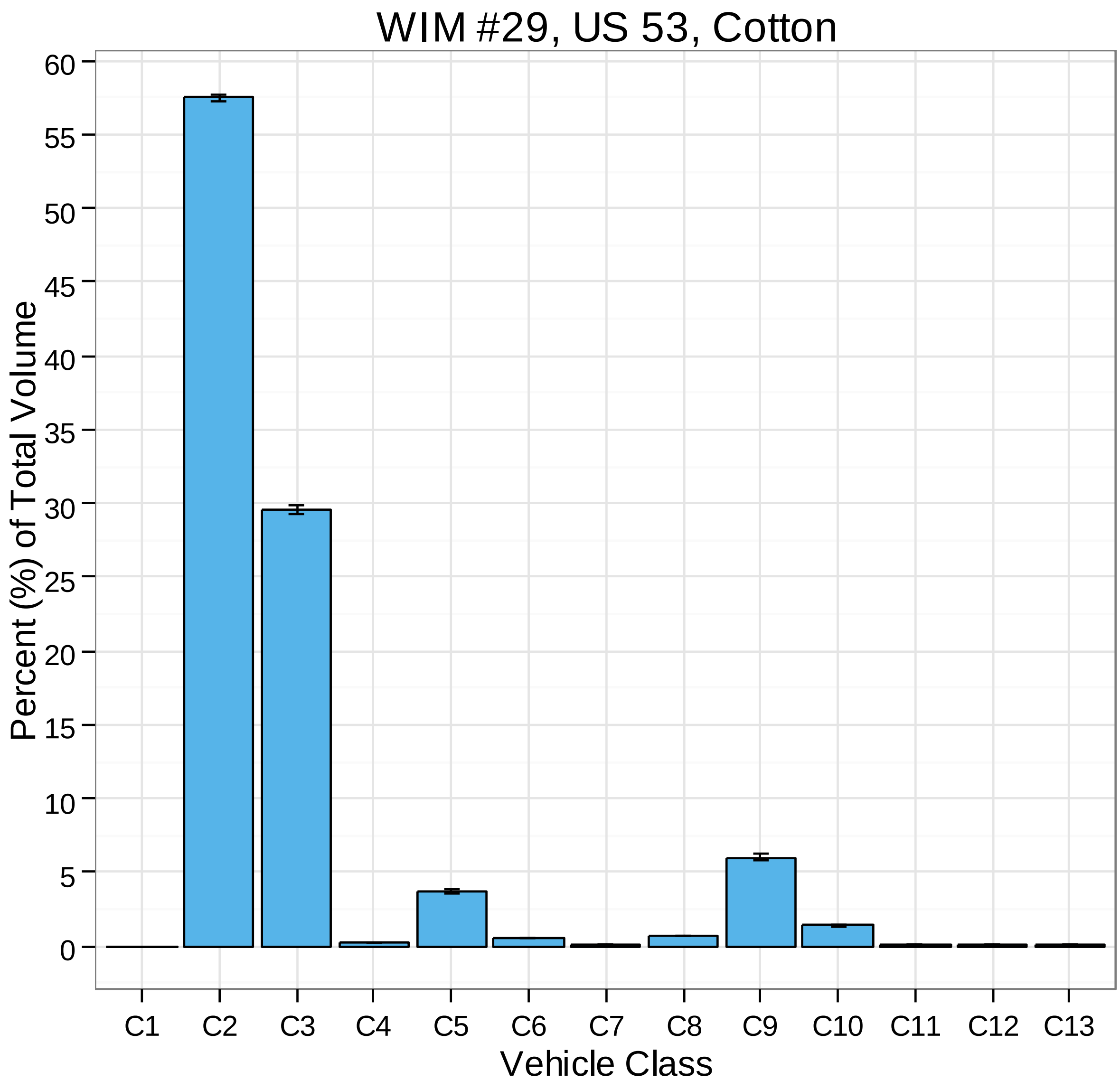


Figure 4.13. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

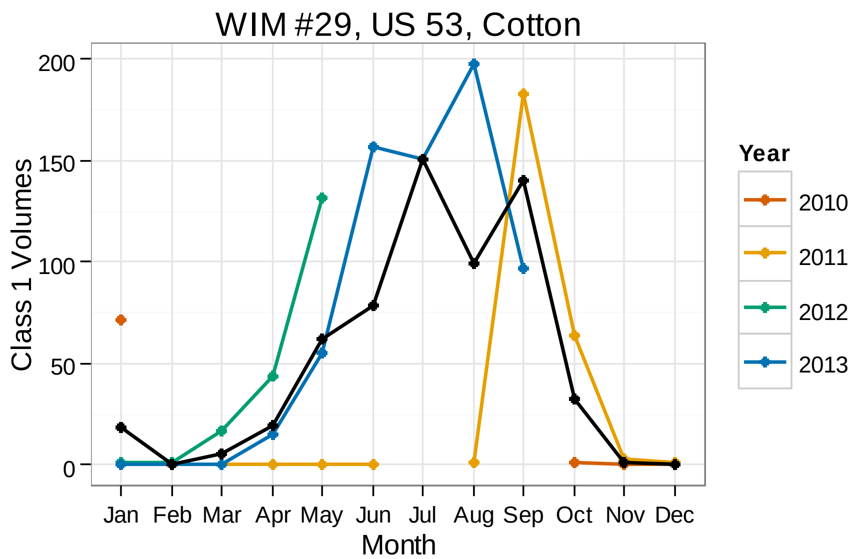


Figure 4.14a. Class 1 volume as a function of month and year. Black line represents the average volume within each month across all years.

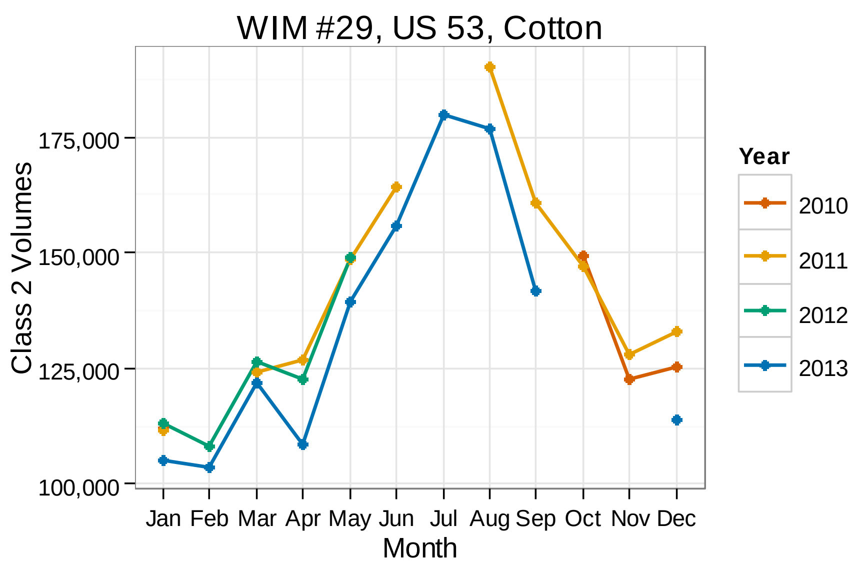


Figure 4.14b. Class 2 volume as a function of month and year.

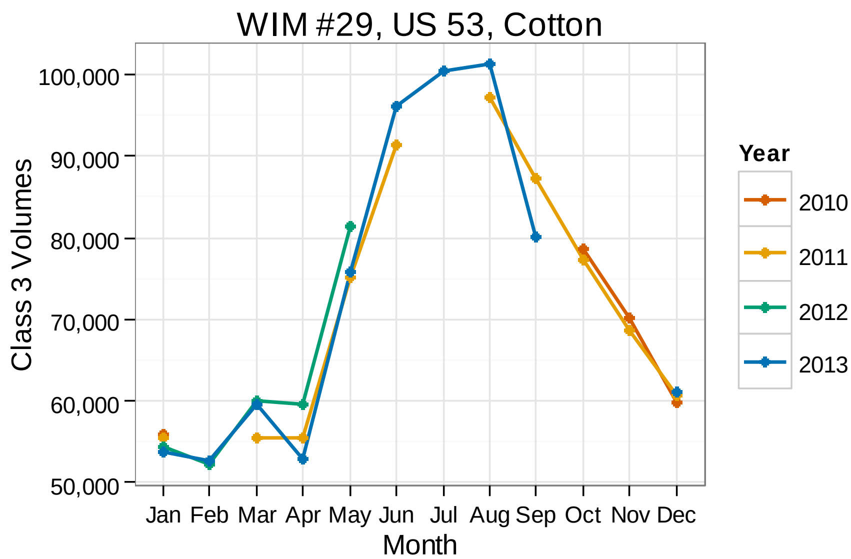


Figure 4.14c. Class 3 volume as a function of month and year.

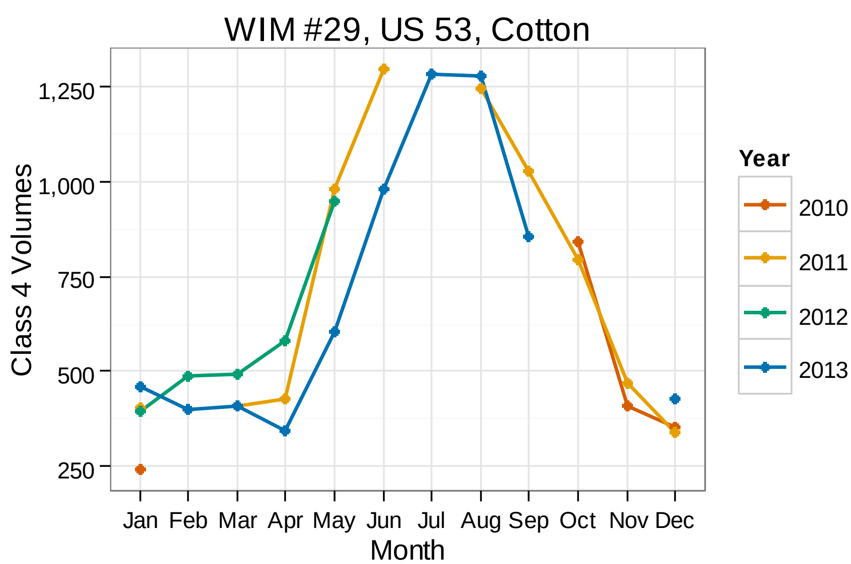


Figure 4.14d. Class 4 volume as a function of month and year.

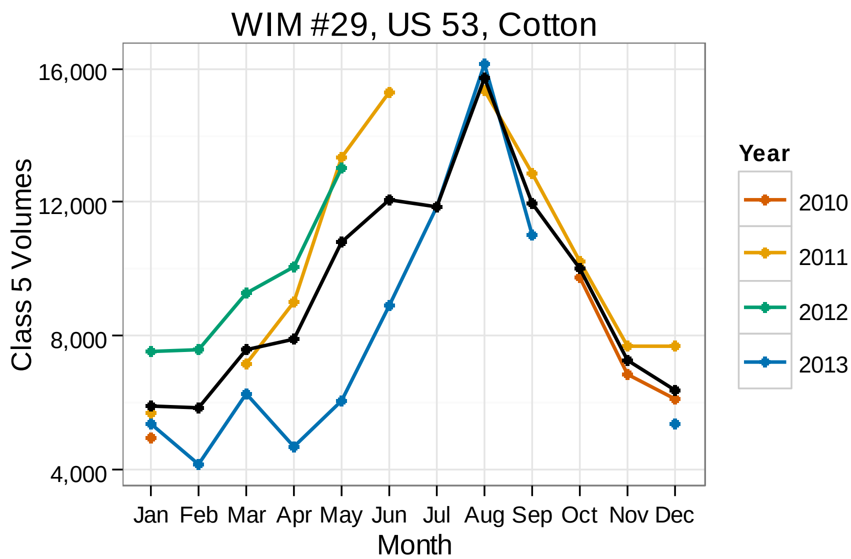


Figure 4.14e. Class 5 volume as a function of month and year. Black line represents the average volume within each month across all years.

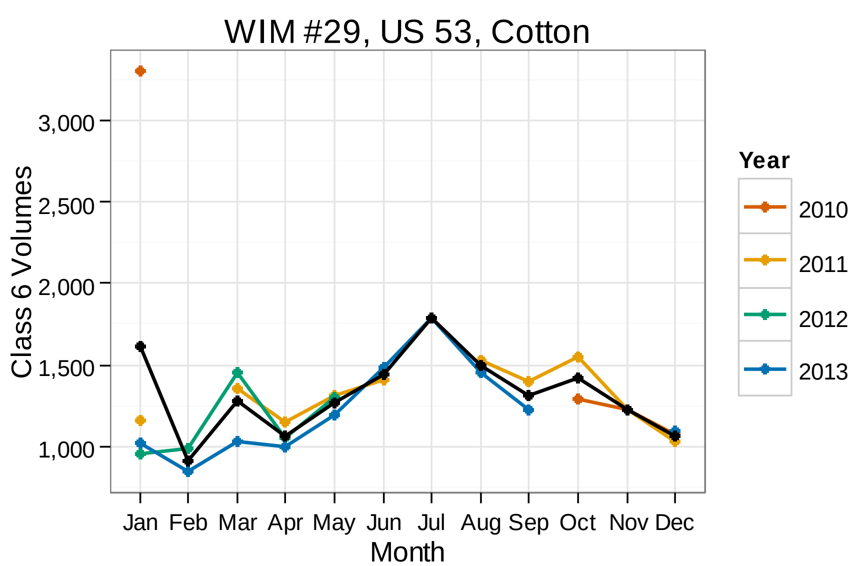


Figure 4.14f. Class 6 volume as a function of month and year. Black line represents the average volume within each month across all years.

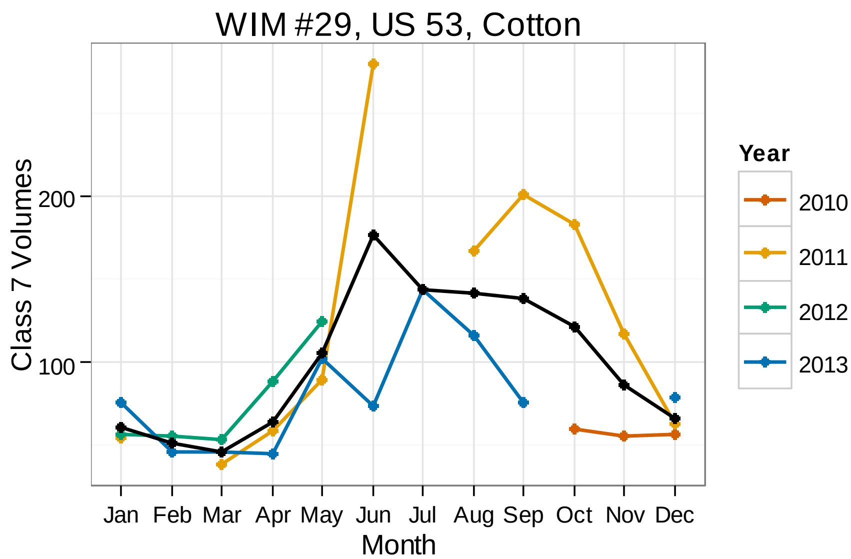


Figure 4.14g. Class 7 volume as a function of month and year. Black line represents the average volume within each month across all years.

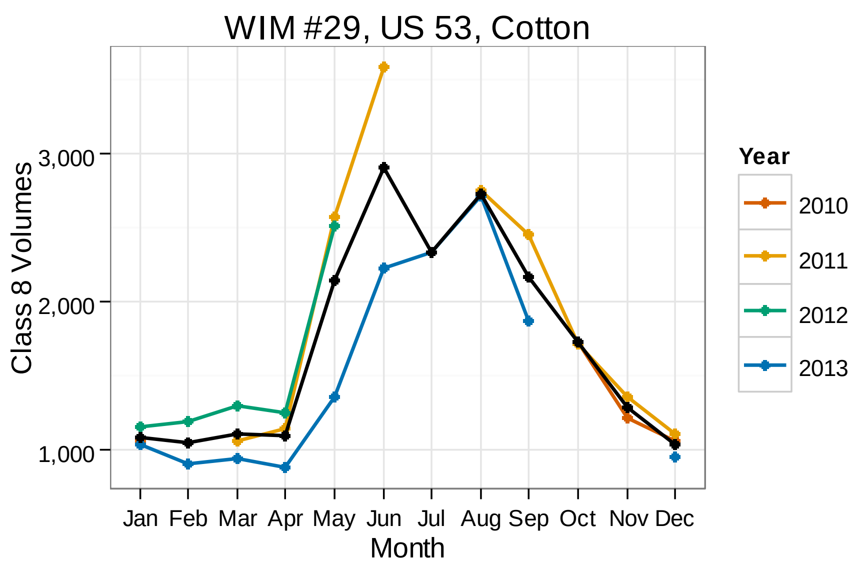


Figure 4.14h. Class 8 volume as a function of month and year. Black line represents the average volume within each month across all years.

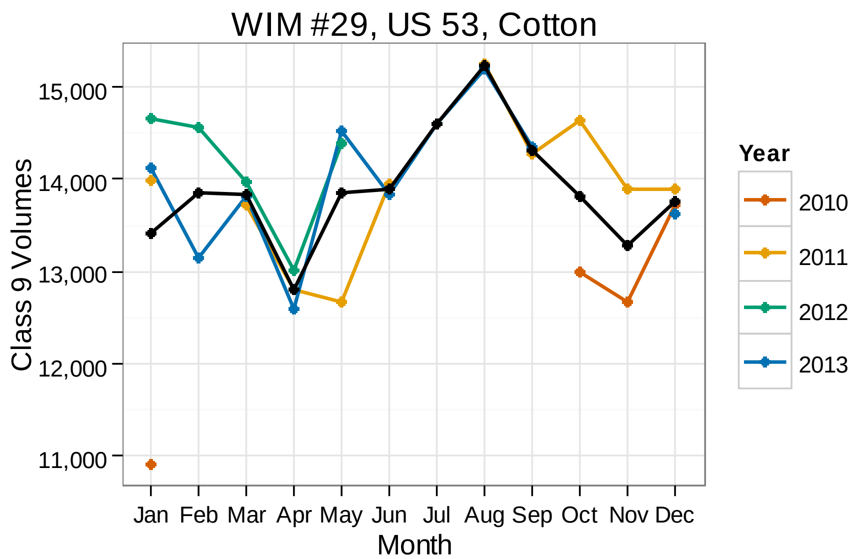


Figure 4.14i. Class 9 volume as a function of month and year. Black line represents the average volume within each month across all years.

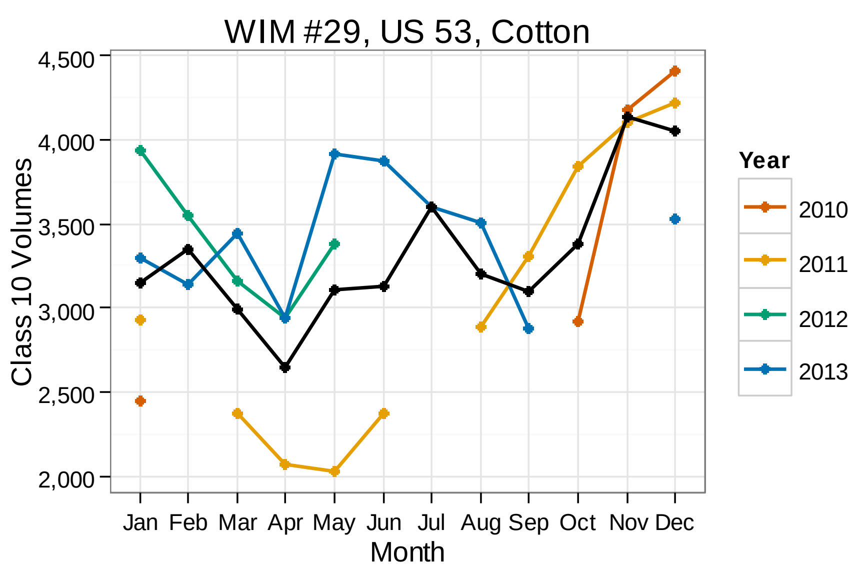


Figure 4.14j. Class 10 volume as a function of month and year. Black line represents the average volume within each month across all years.

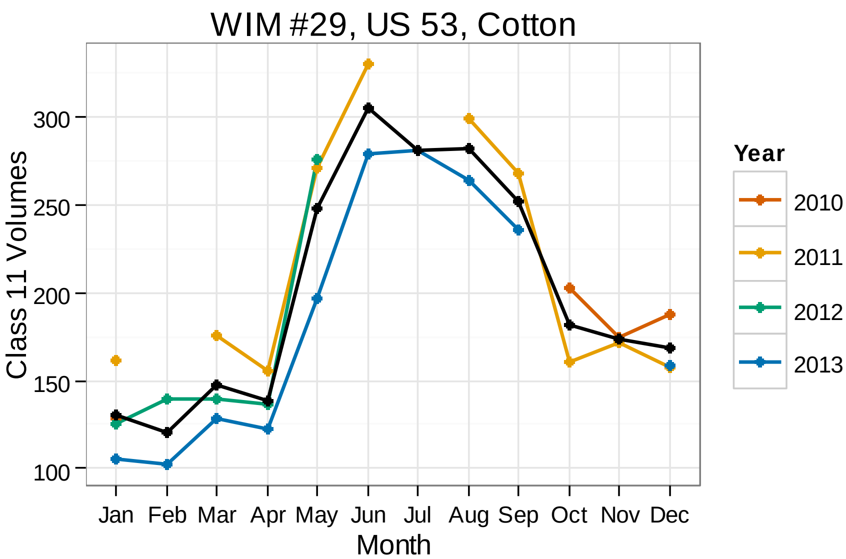


Figure 4.14k. Class 11 volume as a function of month and year. Black line represents the average volume within each month across all years.

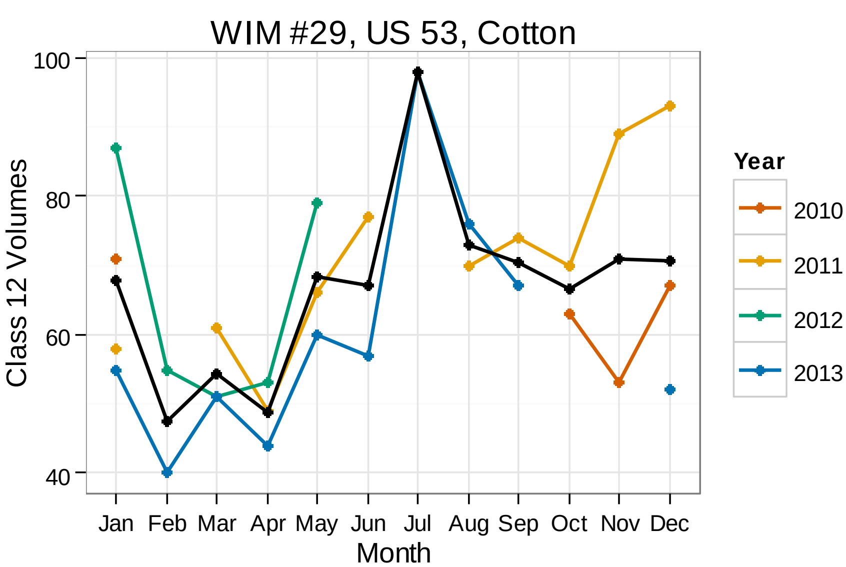


Figure 4.14l. Class 12 volume as a function of month and year. Black line represents the average volume within each month across all years.

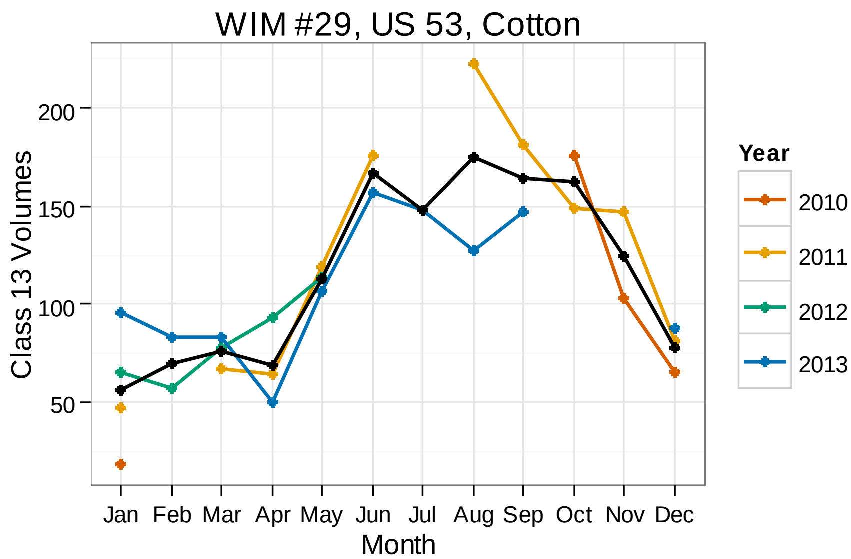


Figure 4.14m. Class 13 volume as a function of month and year. Black line represents the average volume within each month across all years.

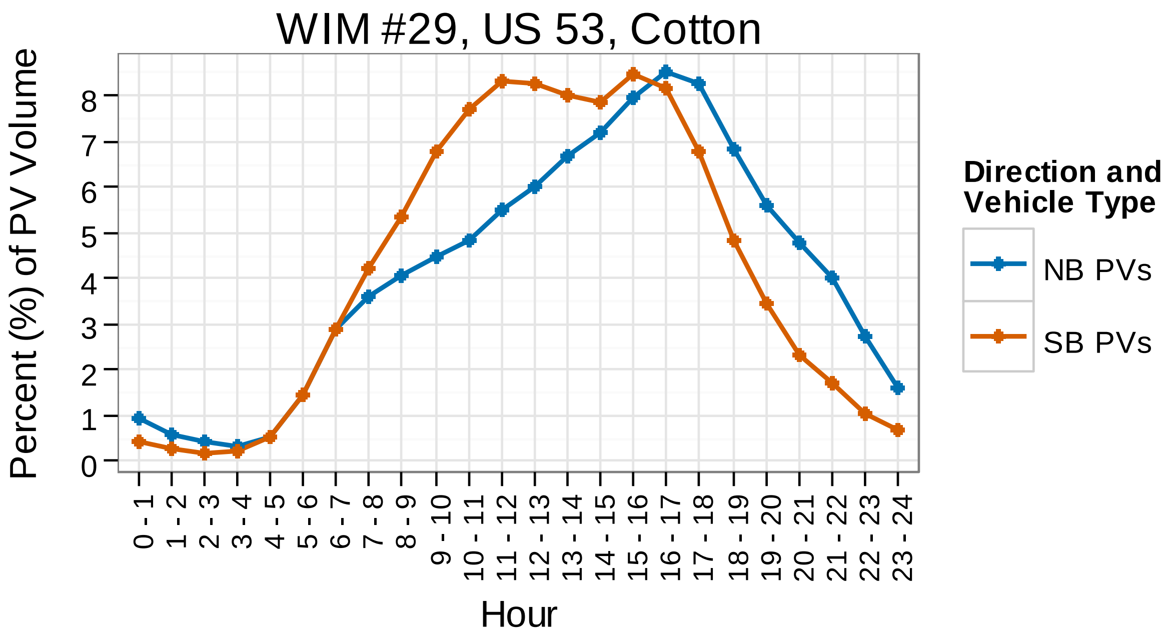


Figure 4.15a. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for passenger vehicles (PVs).

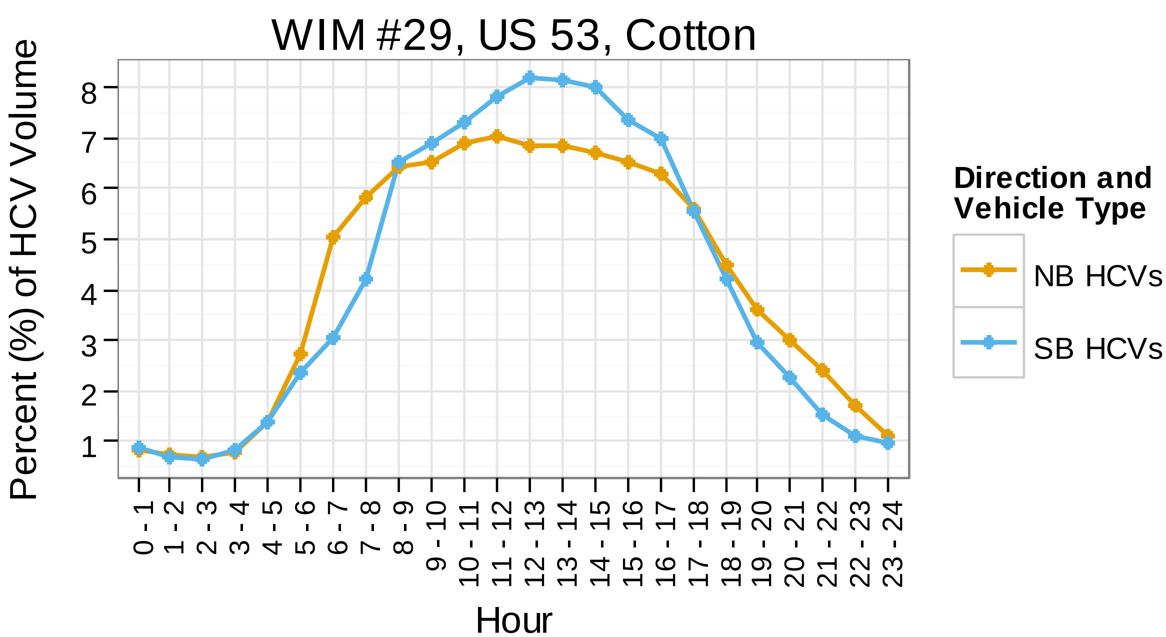


Figure 4.15b. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for heavy commercial vehicles (HCVs).

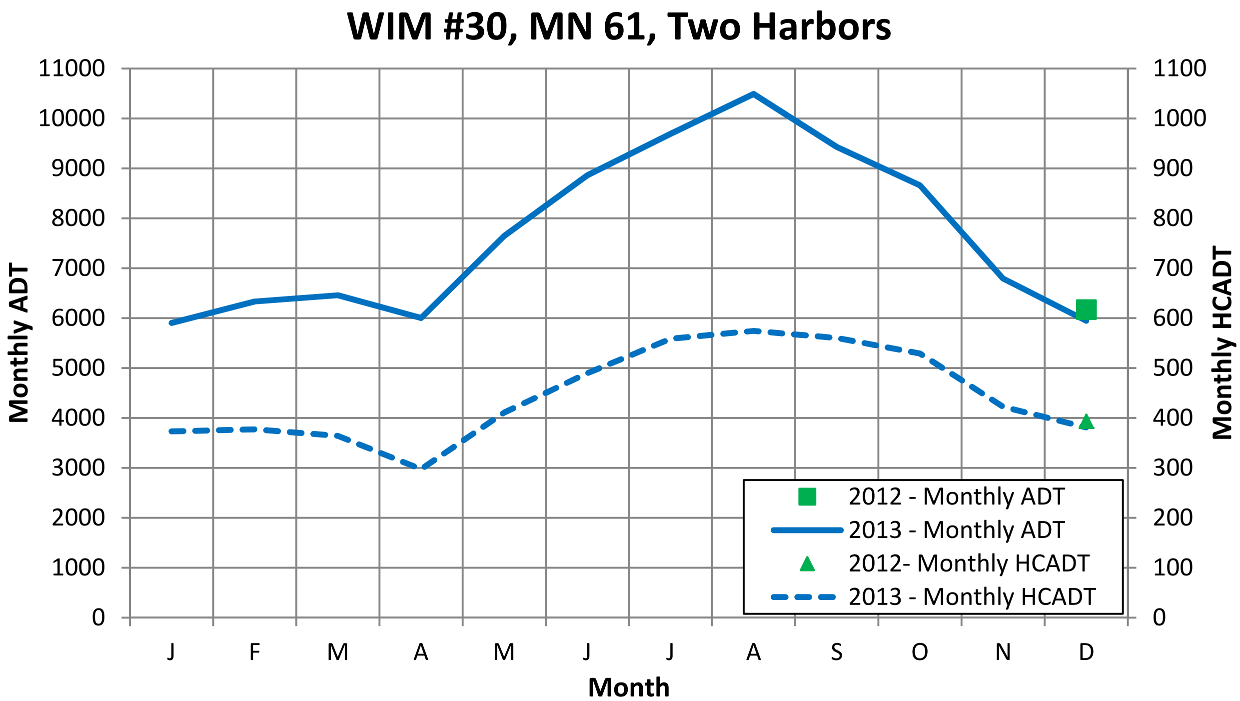


Figure 4.16. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

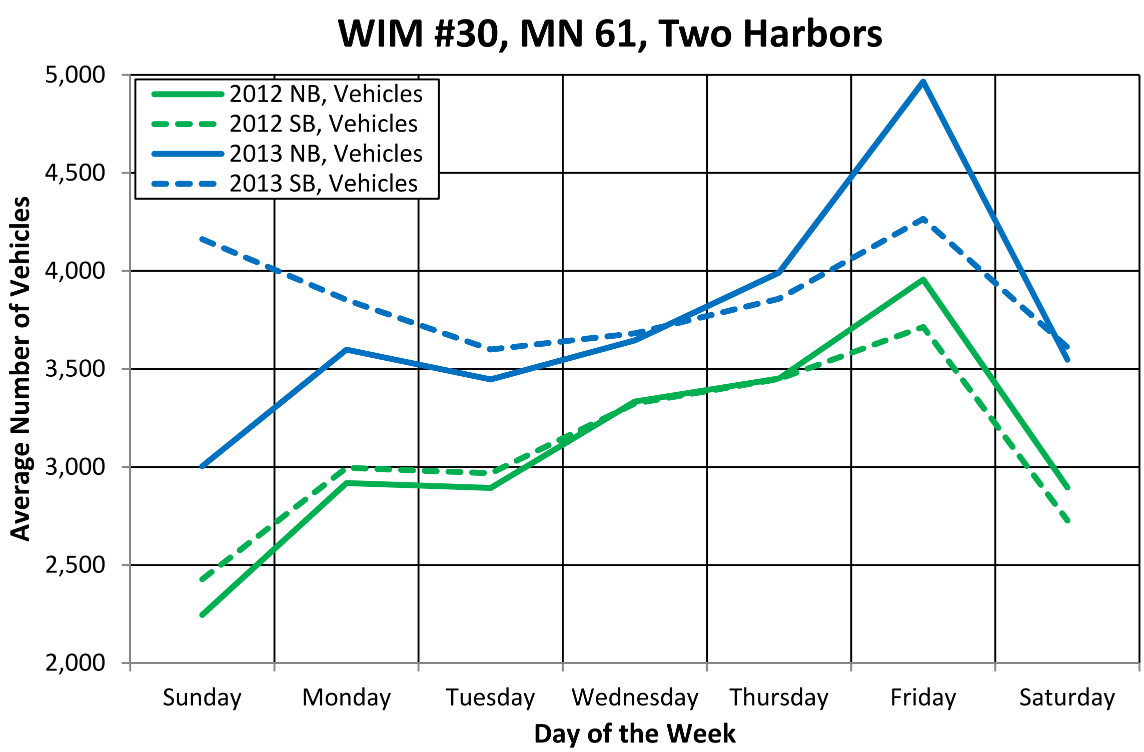


Figure 4.17. Mean number of vehicles by day of week, observed as a function of year and direction (northbound vs. southbound; NB vs. SB).

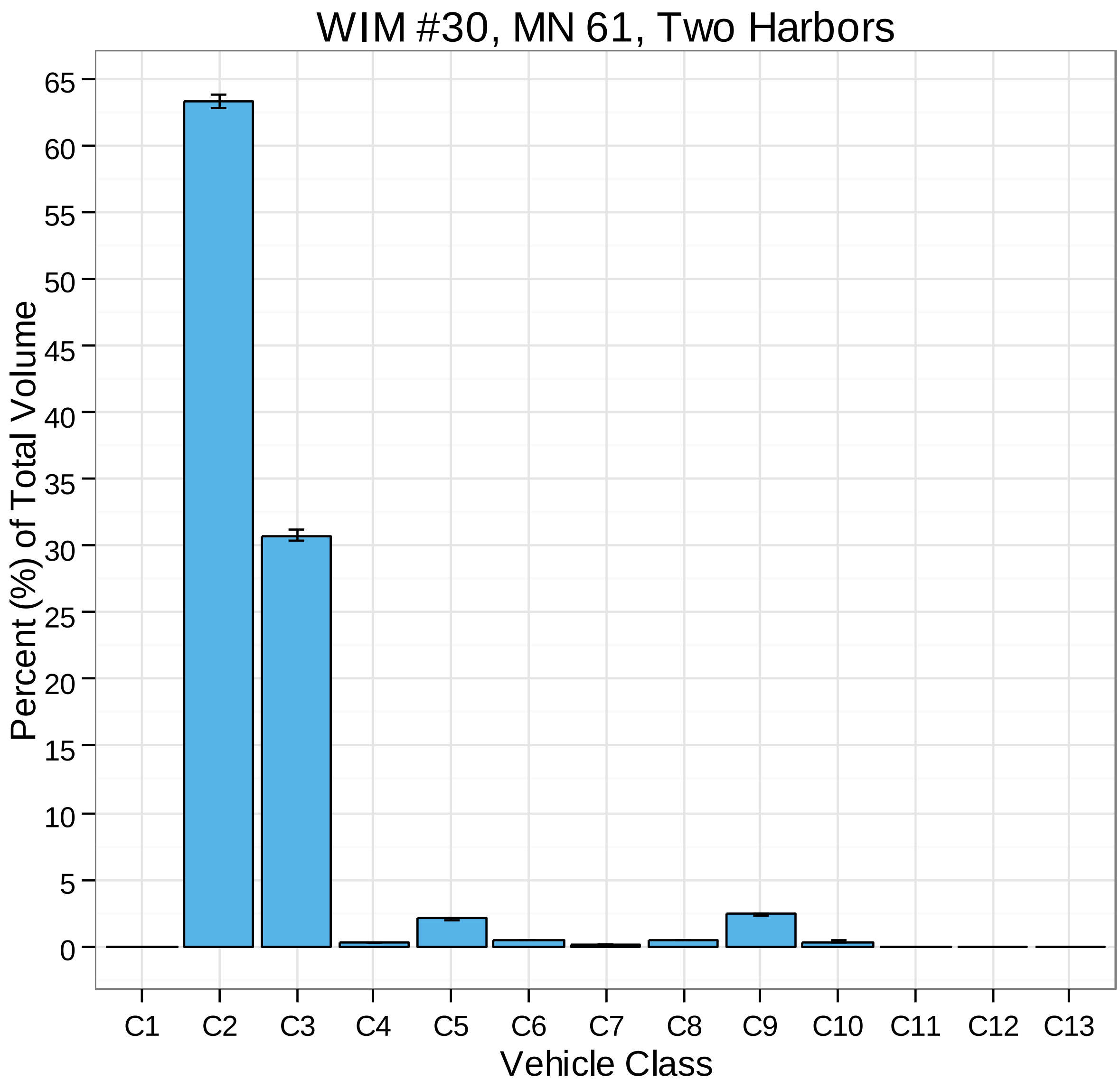


Figure 4.18. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

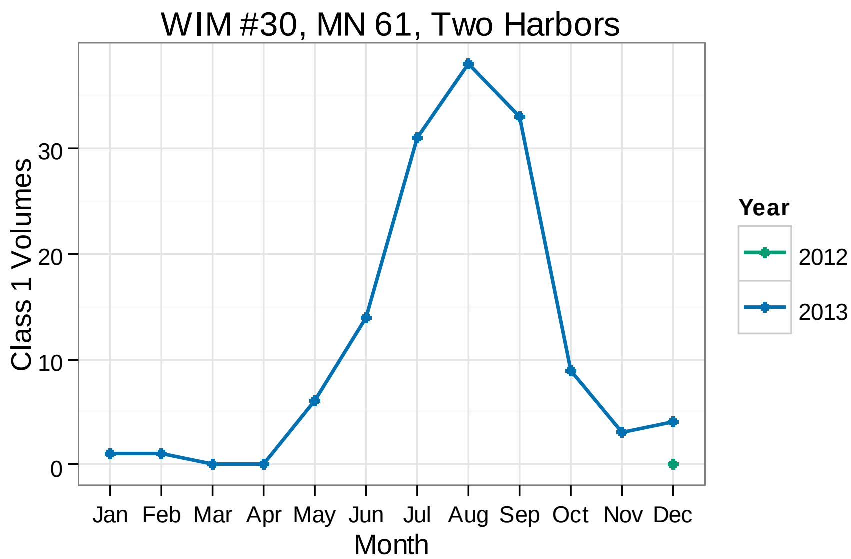


Figure 4.19a. Class 1 volume as a function of month and year.

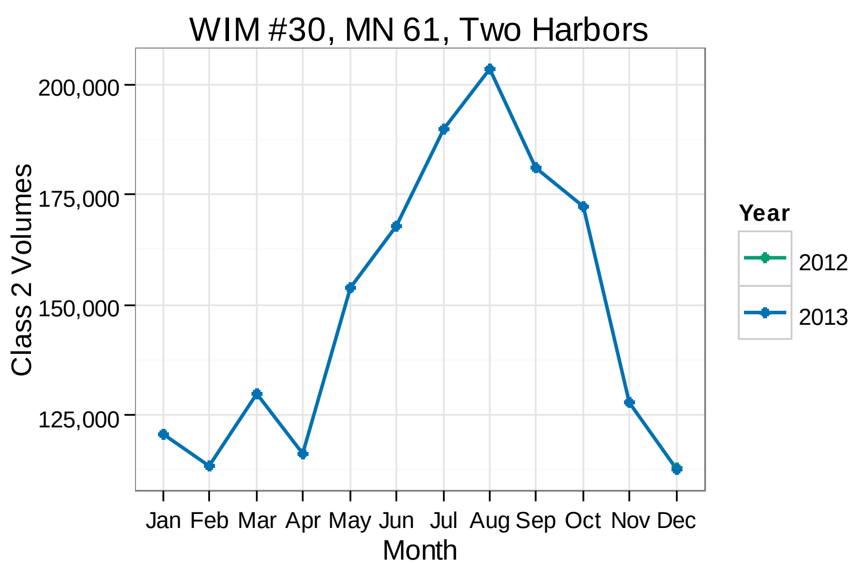


Figure 4.19b. Class 2 volume as a function of month and year.

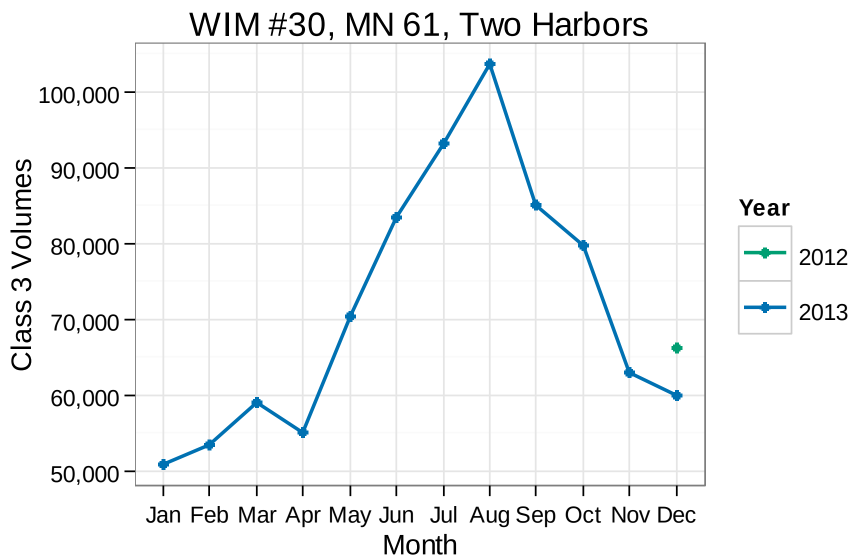


Figure 4.19c. Class 3 volume as a function of month and year.

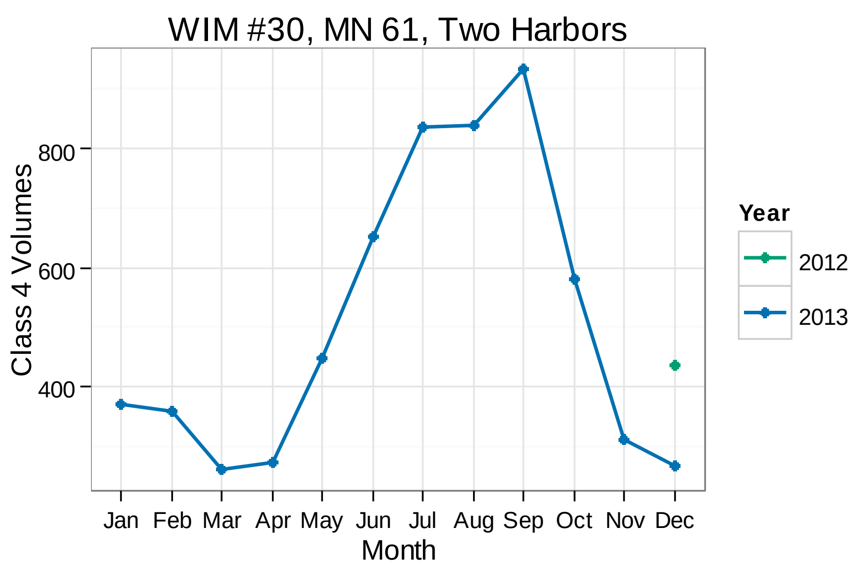


Figure 4.19d. Class 4 volume as a function of month and year.

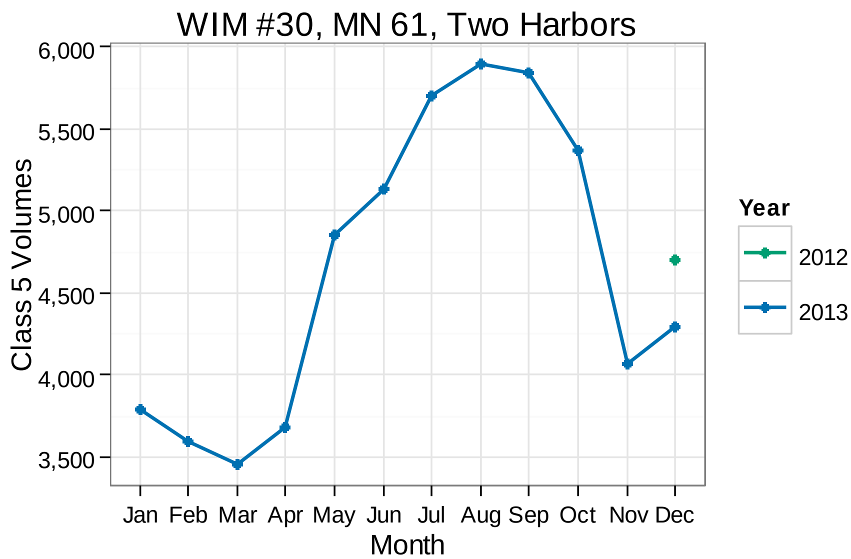


Figure 4.19e. Class 5 volume as a function of month and year.

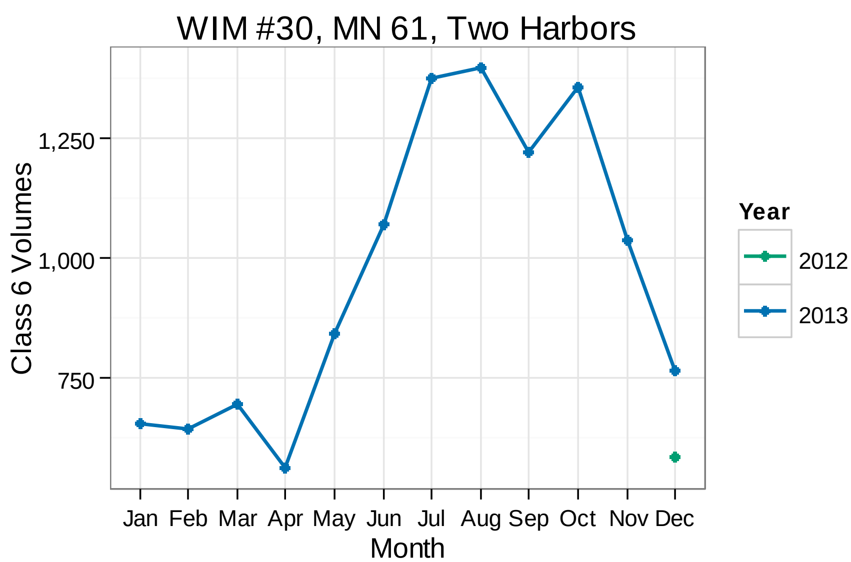


Figure 4.19f. Class 6 volume as a function of month and year.

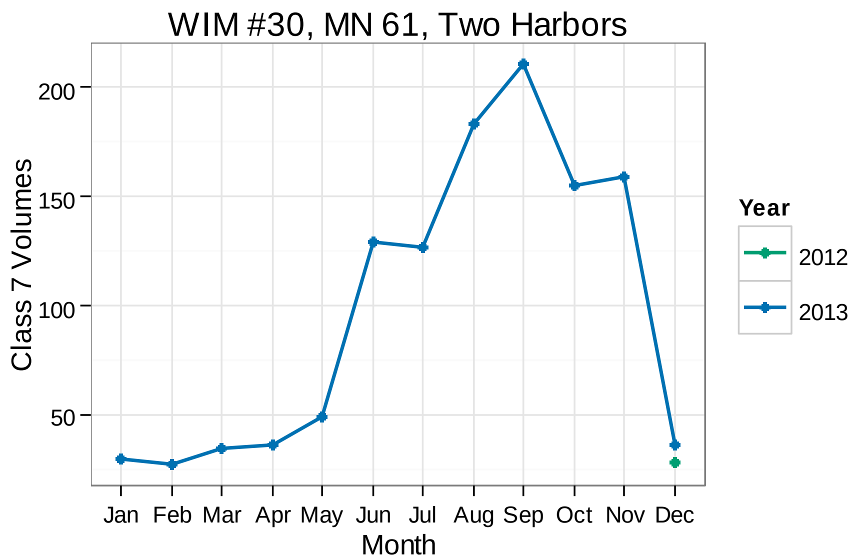


Figure 4.19g. Class 7 volume as a function of month and year.

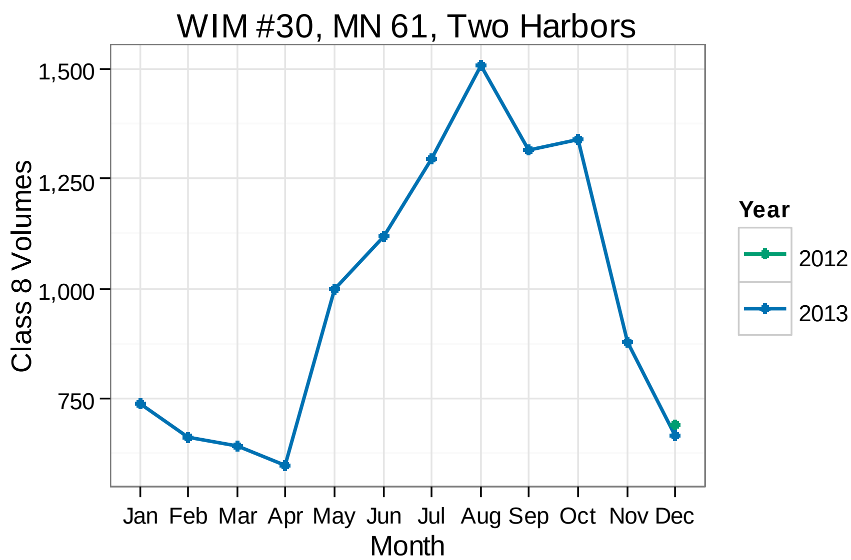


Figure 4.19h. Class 8 volume as a function of month and year.

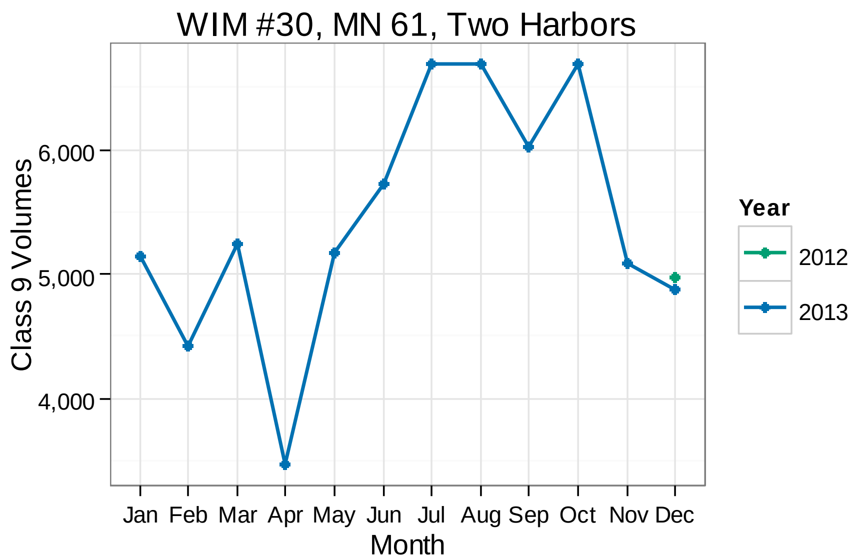


Figure 4.19i. Class 9 volume as a function of month and year.

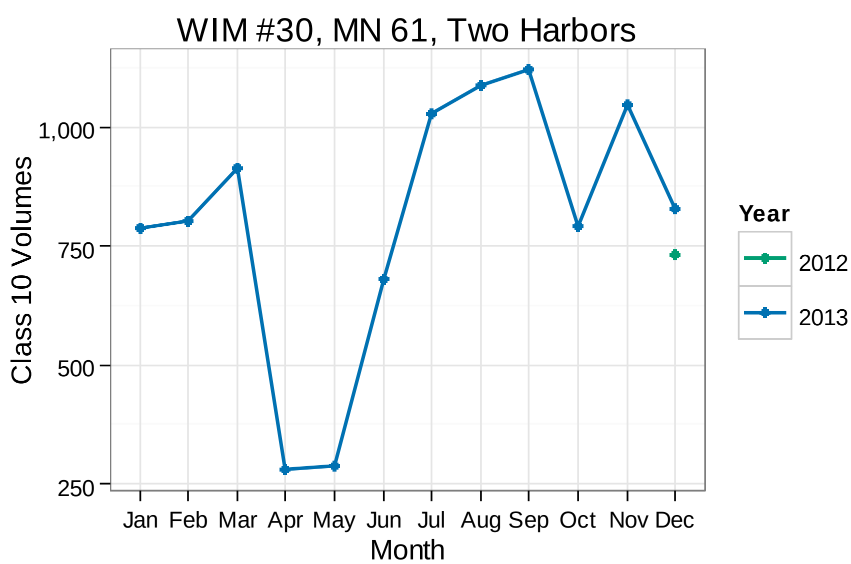


Figure 4.19j. Class 10 volume as a function of month and year.

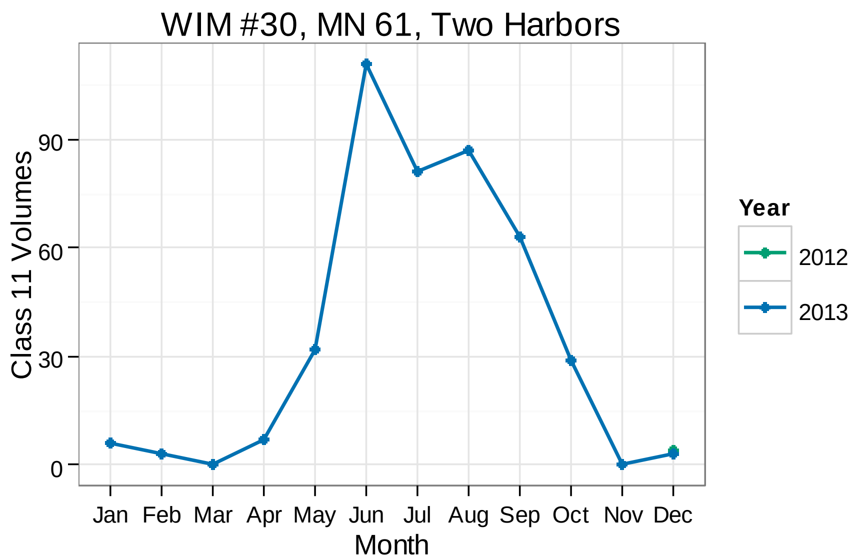


Figure 4.19k. Class 11 volume as a function of month and year.

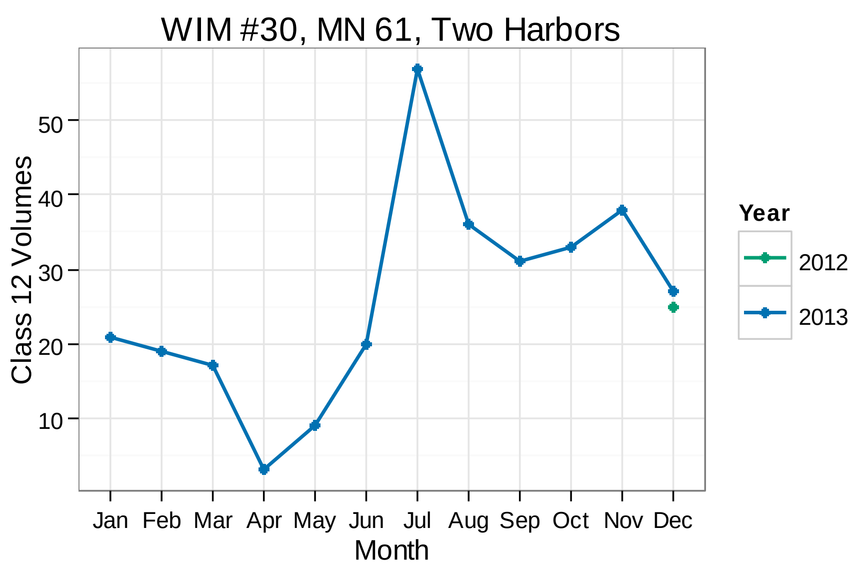


Figure 4.19l. Class 12 volume as a function of month and year.

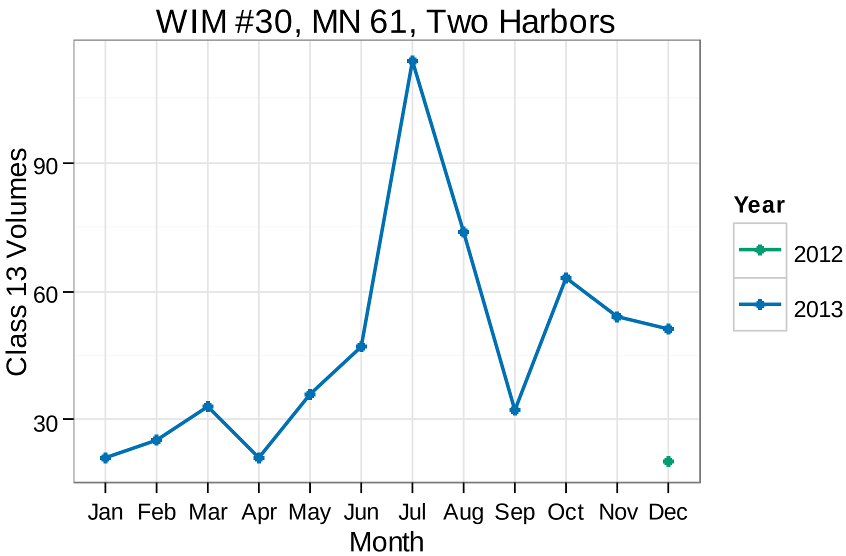


Figure 4.19m. Class 13 volume as a function of month and year.

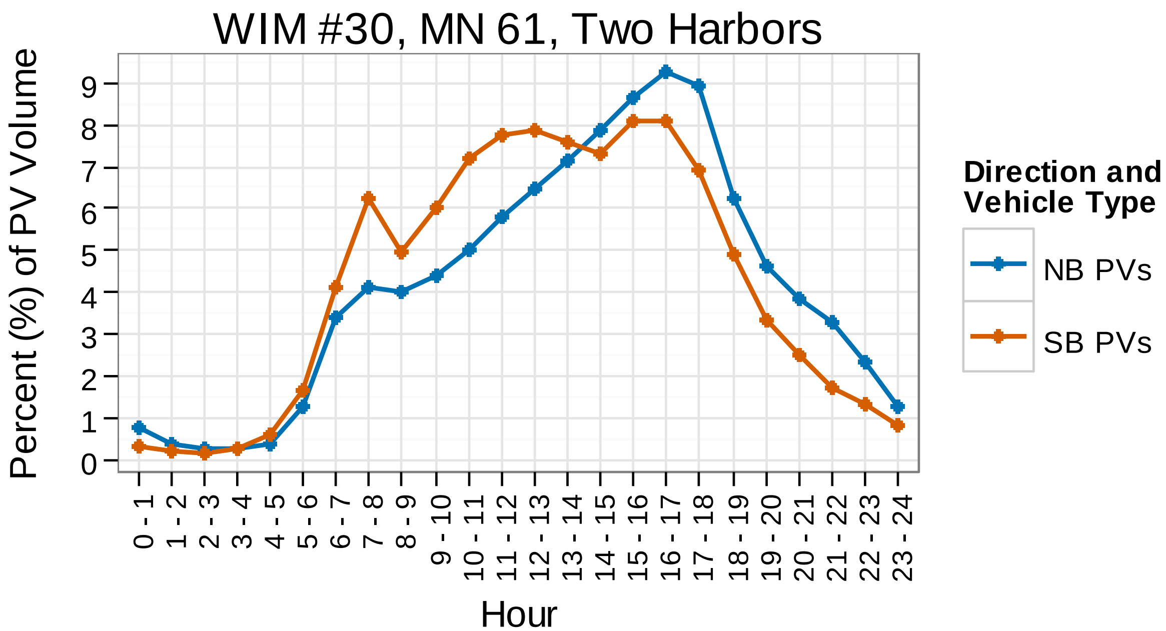


Figure 4.20a. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for passenger vehicles (PVs).

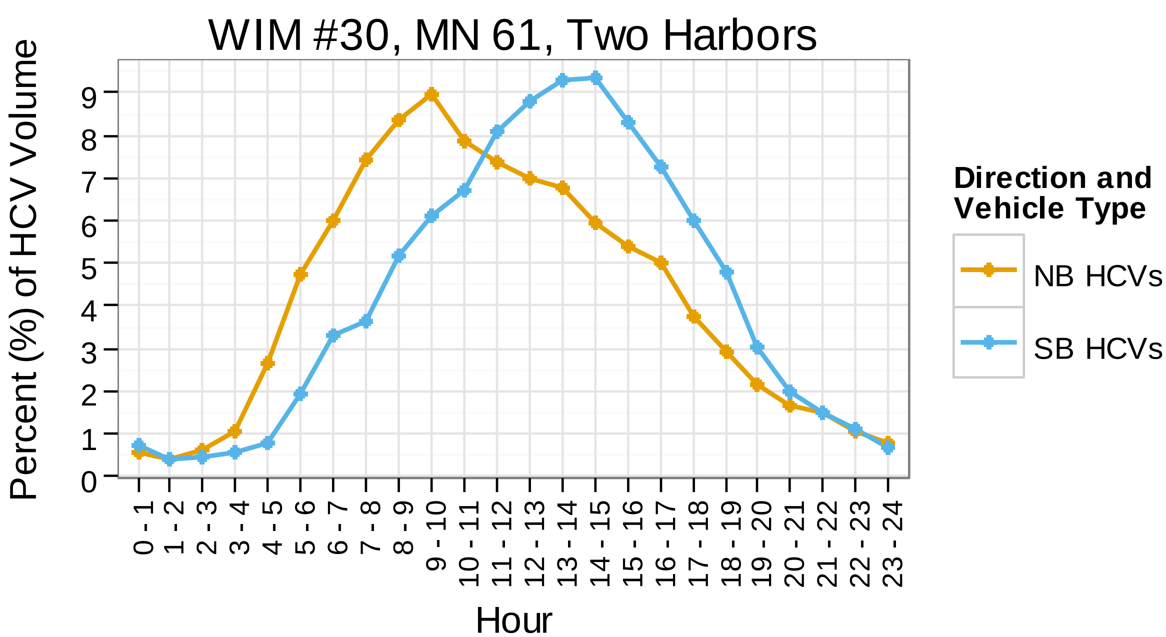


Figure 4.20b. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for heavy commercial vehicles (HCVs).

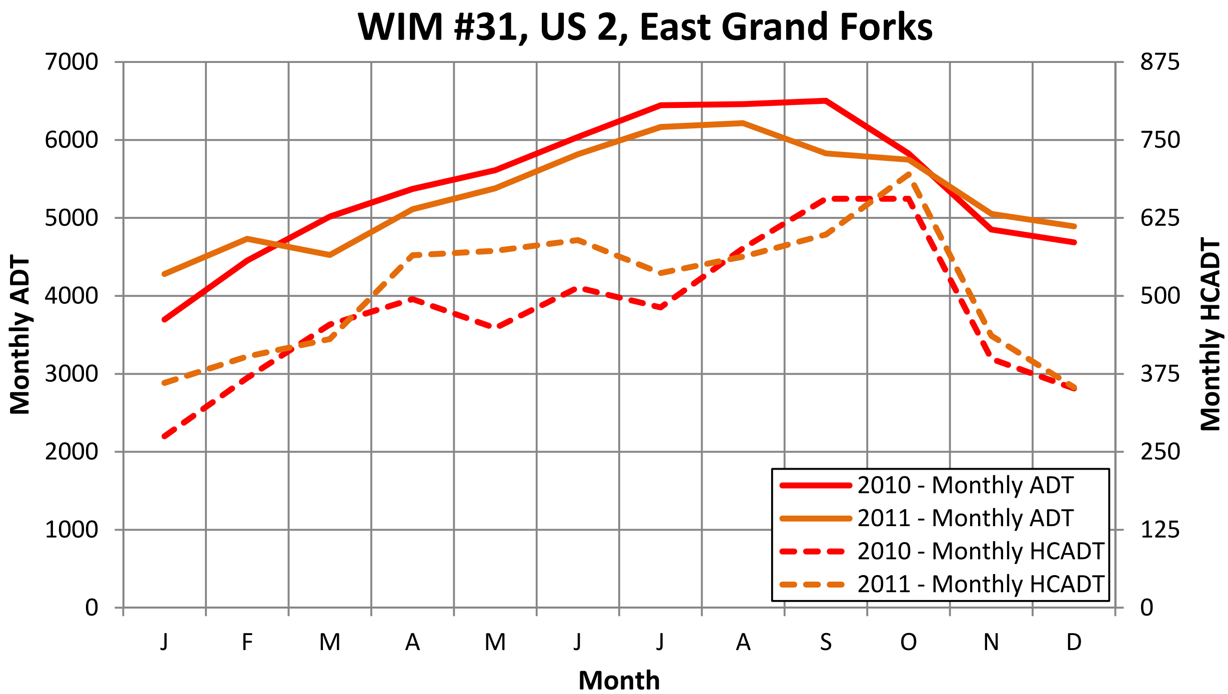


Figure 4.21. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

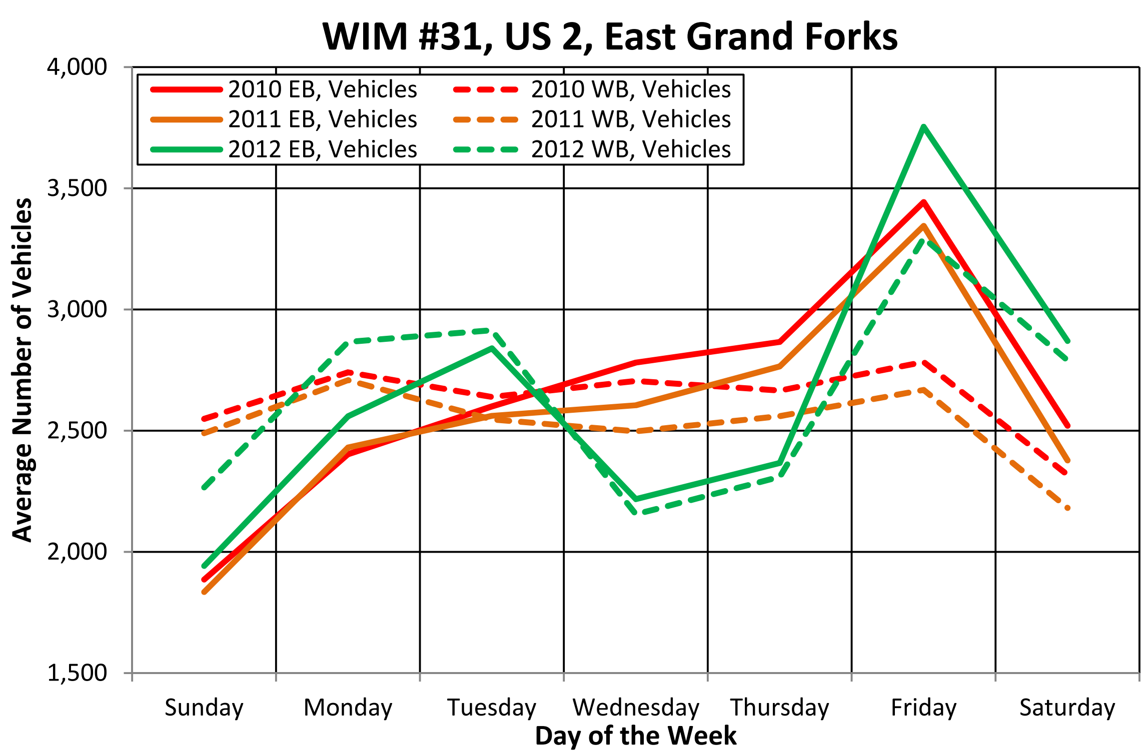


Figure 4.22. Mean number of vehicles by day of week, observed as a function of year and direction (northbound vs. southbound; NB vs. SB).

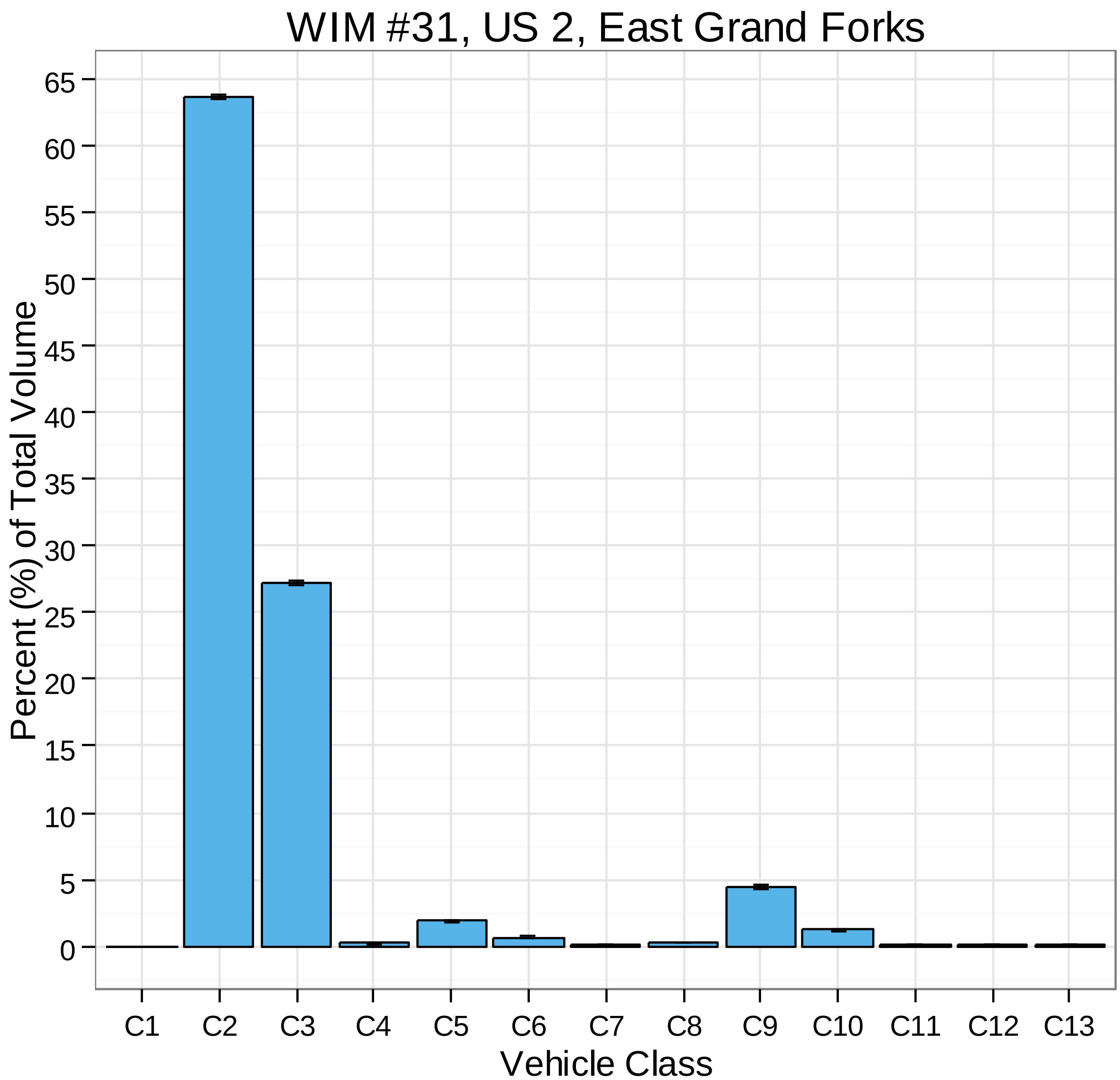


Figure 4.23. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

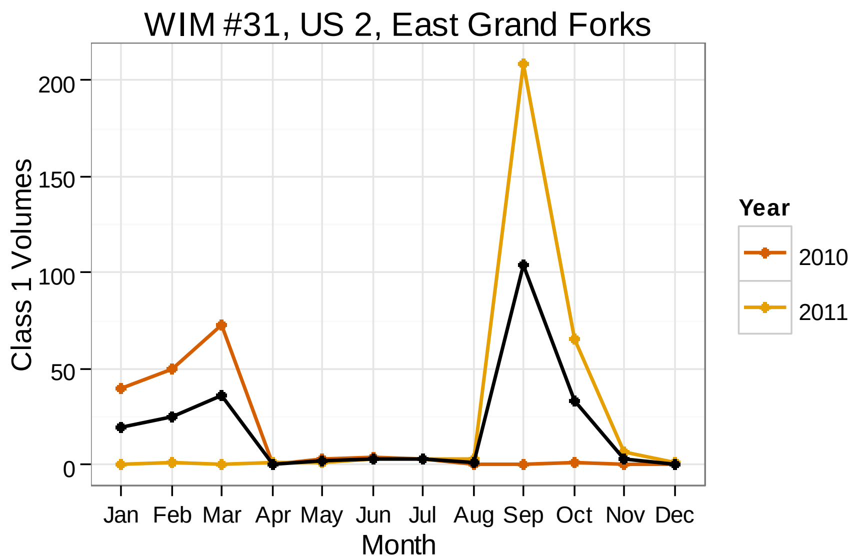


Figure 4.24a. Class 1 volume as a function of month and year. Black line represents the average volume within each month across all years.

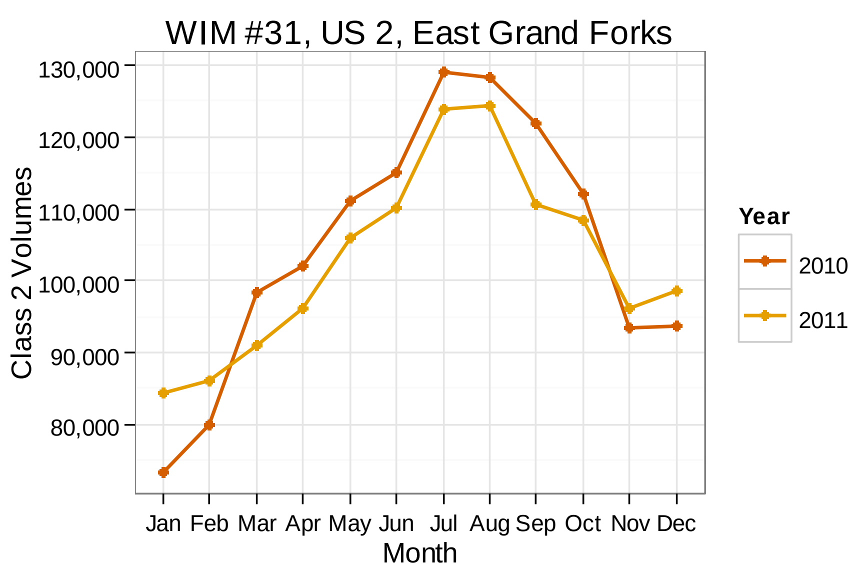


Figure 4.24b. Class 2 volume as a function of month and year.

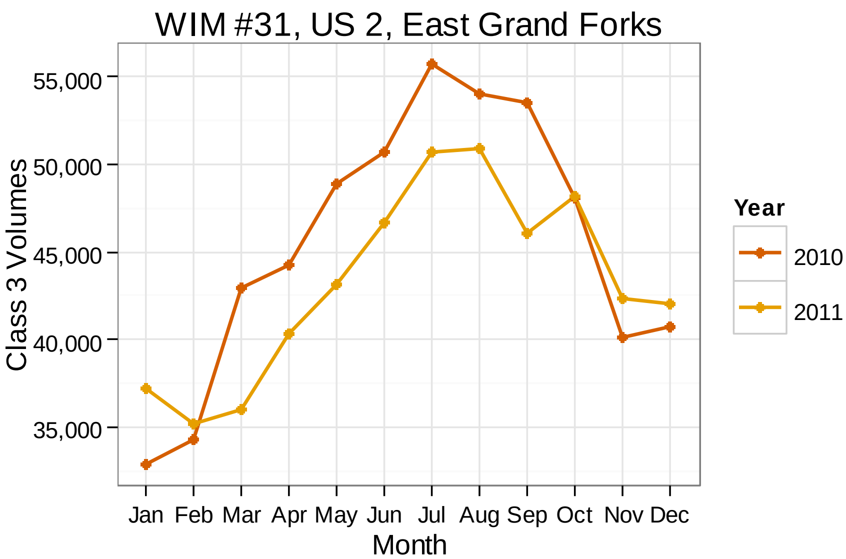


Figure 4.24c. Class 3 volume as a function of month and year.

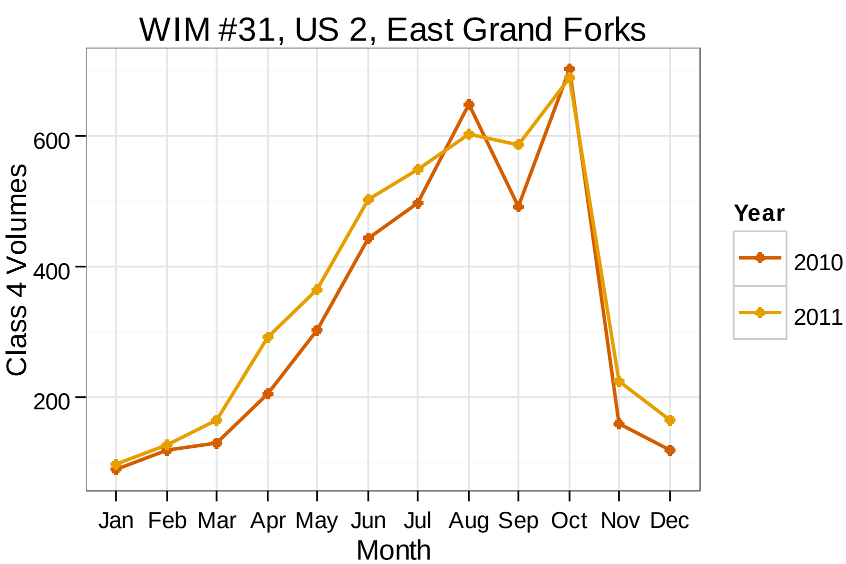


Figure 4.24d. Class 4 volume as a function of month and year.

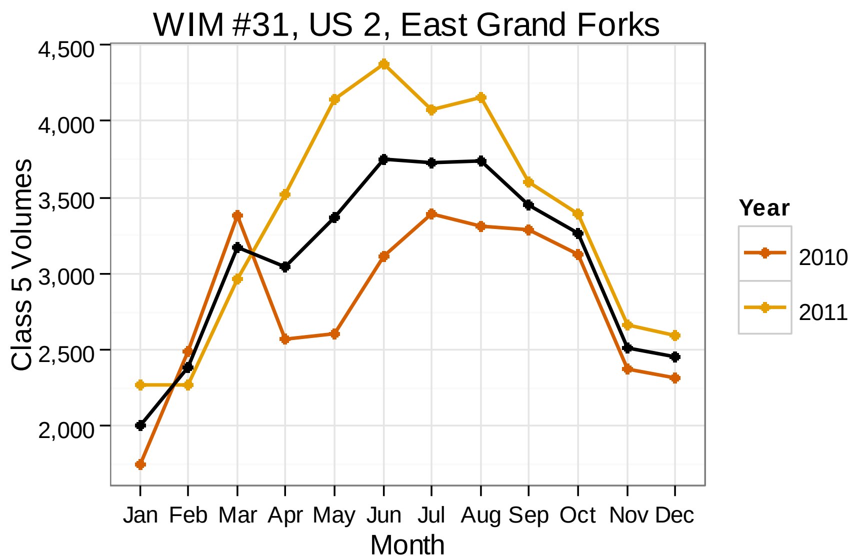


Figure 4.24e. Class 5 volume as a function of month and year. Black line represents the average volume within each month across all years.

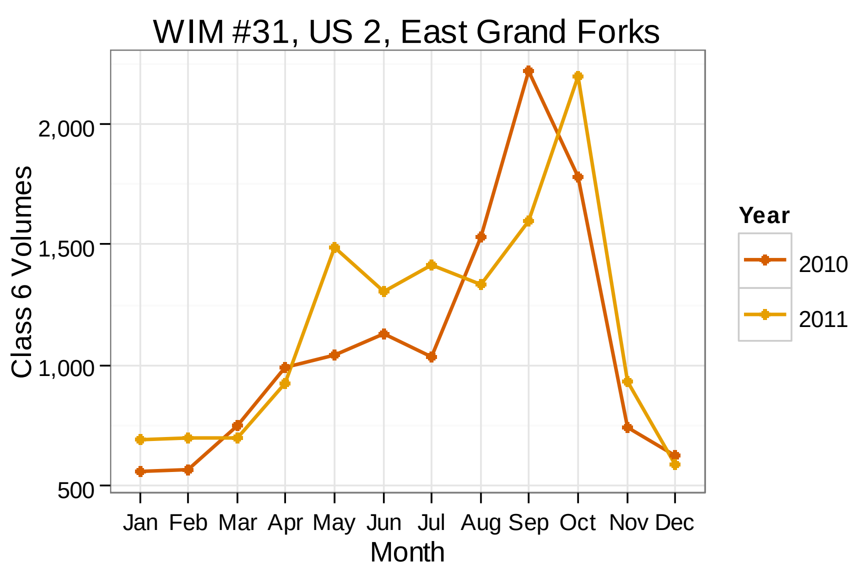


Figure 4.24f. Class 6 volume as a function of month and year.

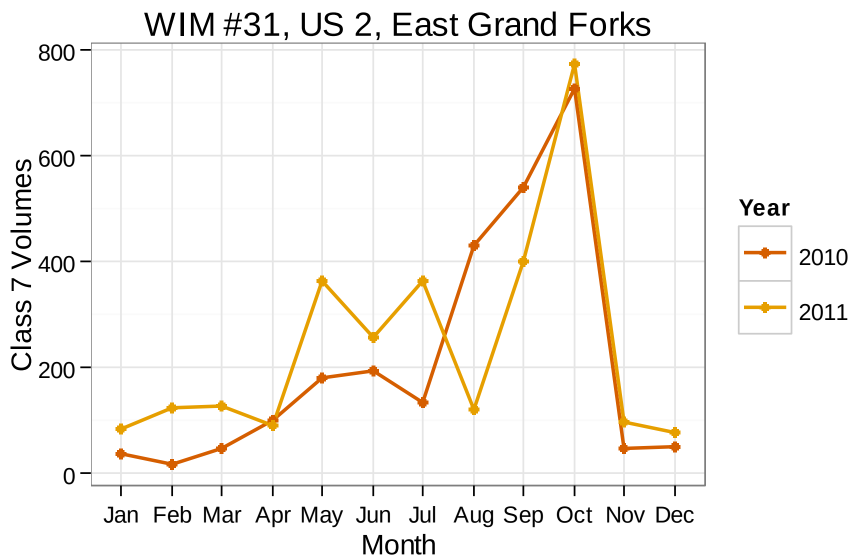


Figure 4.24g. Class 7 volume as a function of month and year.

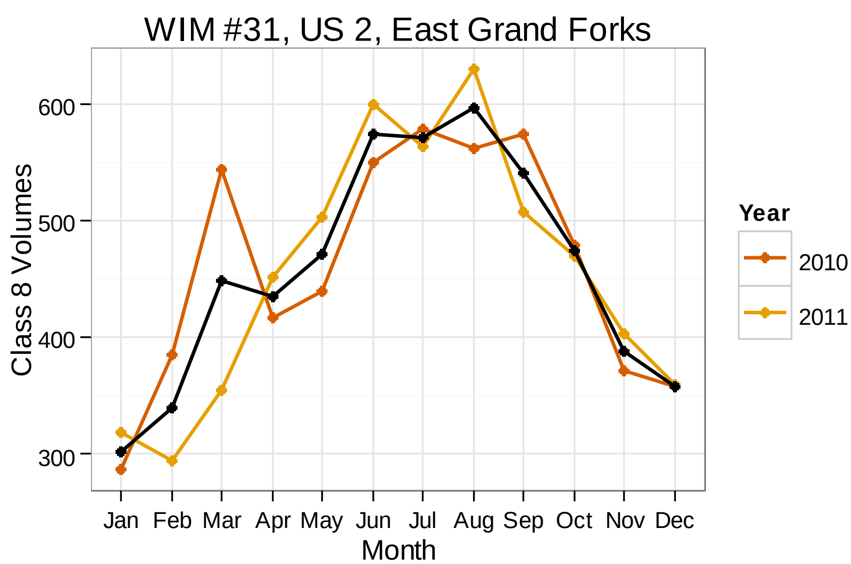


Figure 4.24h. Class 8 volume as a function of month and year. Black line represents the average volume within each month across all years.

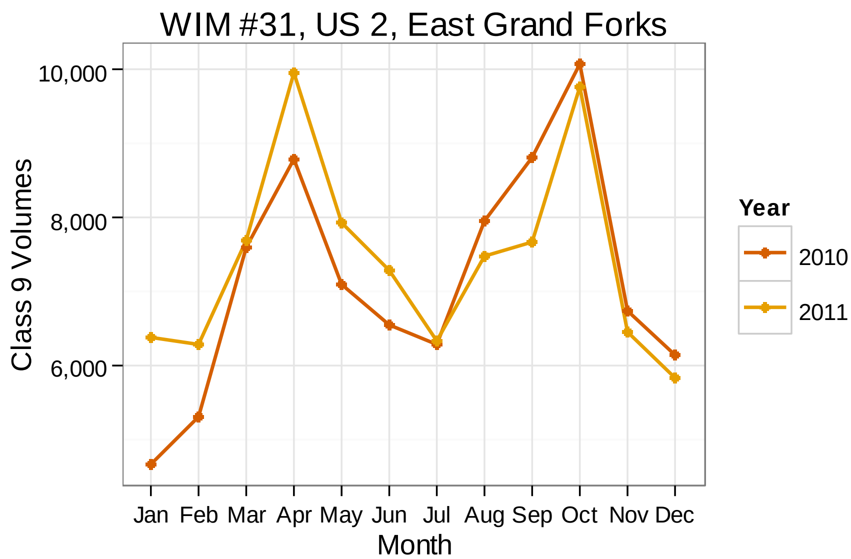


Figure 4.24i. Class 9 volume as a function of month and year.

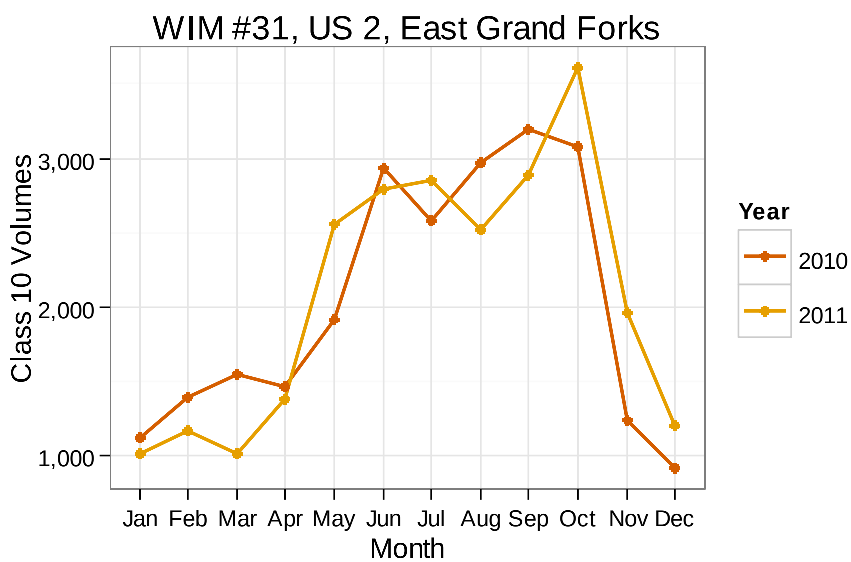


Figure 4.24j. Class 10 volume as a function of month and year.

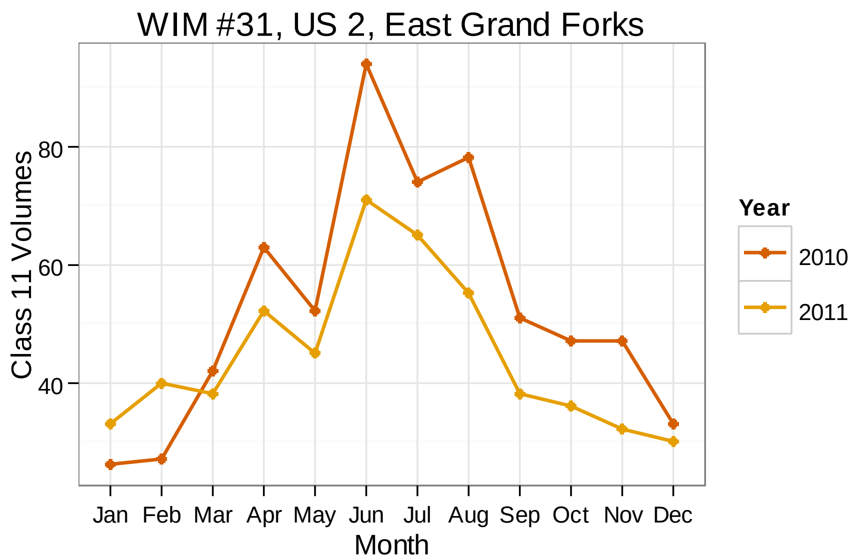


Figure 4.24k. Class 11 volume as a function of month and year.

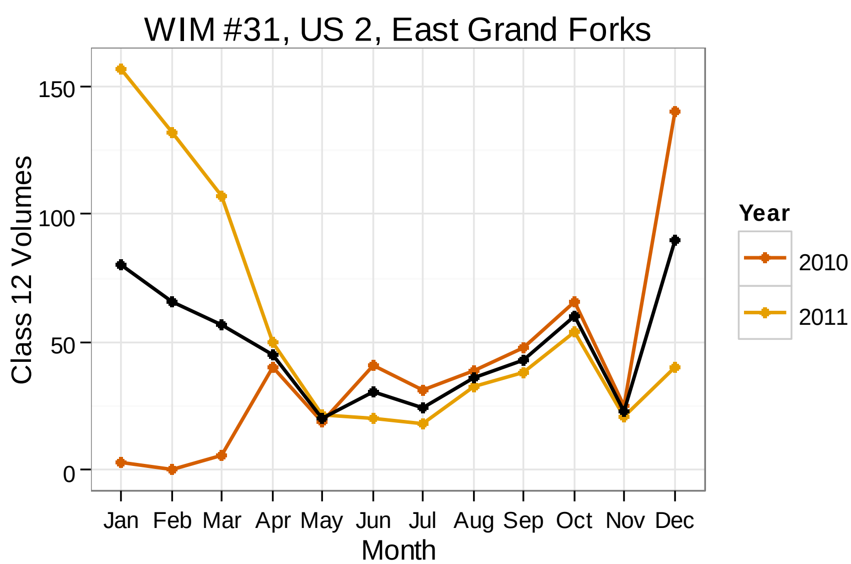


Figure 4.24l. Class 12 volume as a function of month and year. Black line represents the average volume within each month across all years.

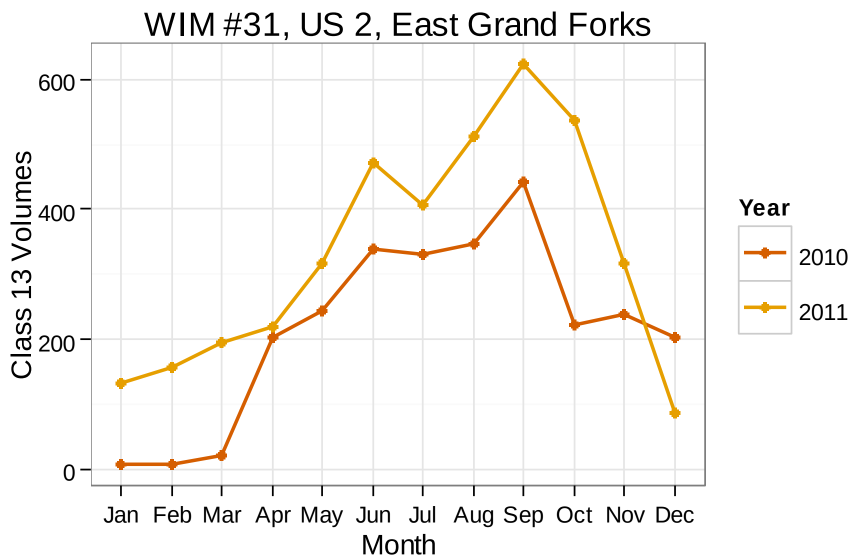


Figure 4.24m. Class 13 volume as a function of month and year.

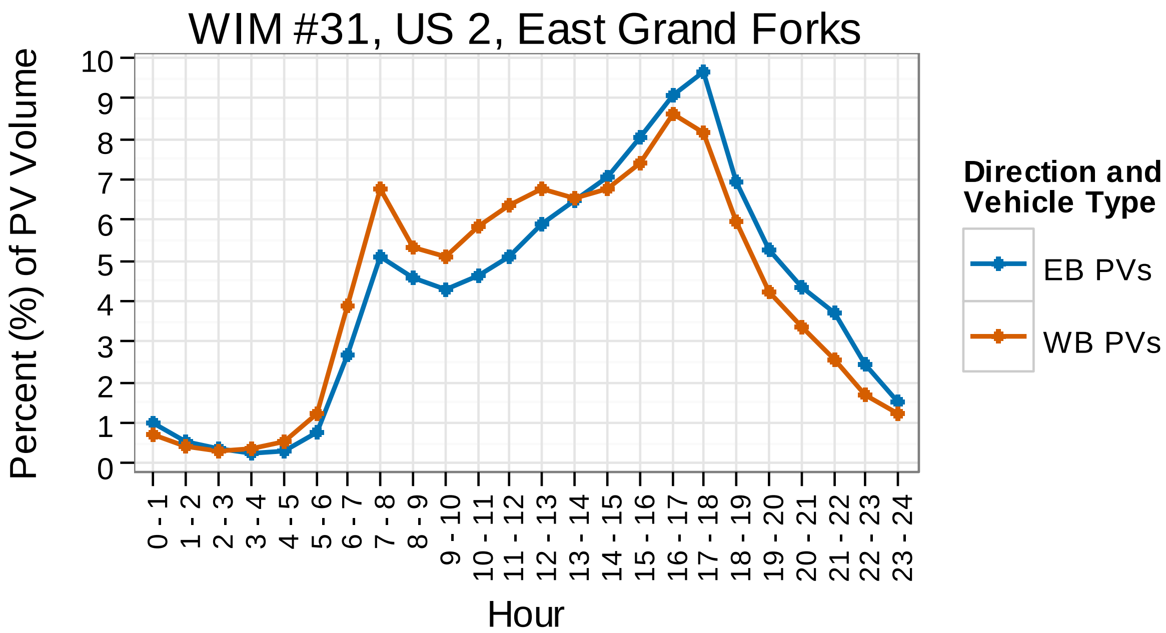


Figure 4.25a. Amount of traffic (% of volume) observed at an hourly basis for each direction (eastbound; EB vs. westbound; WB) for passenger vehicles (PVs).

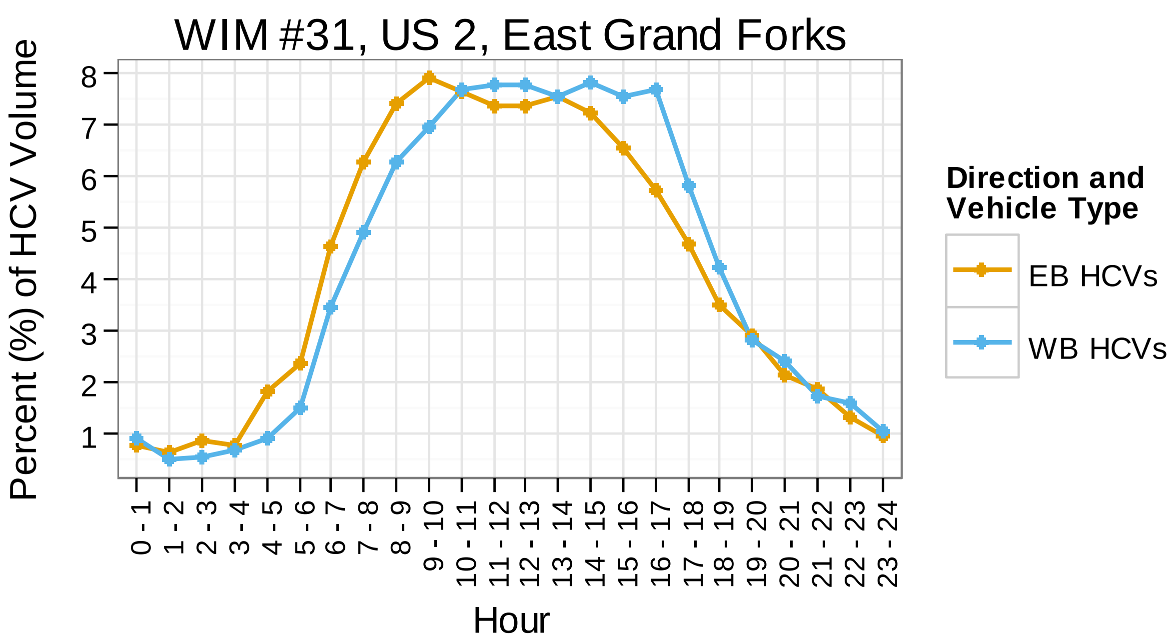


Figure 4.25b. Amount of traffic (% of volume) observed at an hourly basis for each direction (eastbound; EB vs. westbound; WB) for heavy commercial vehicles (HCVs).

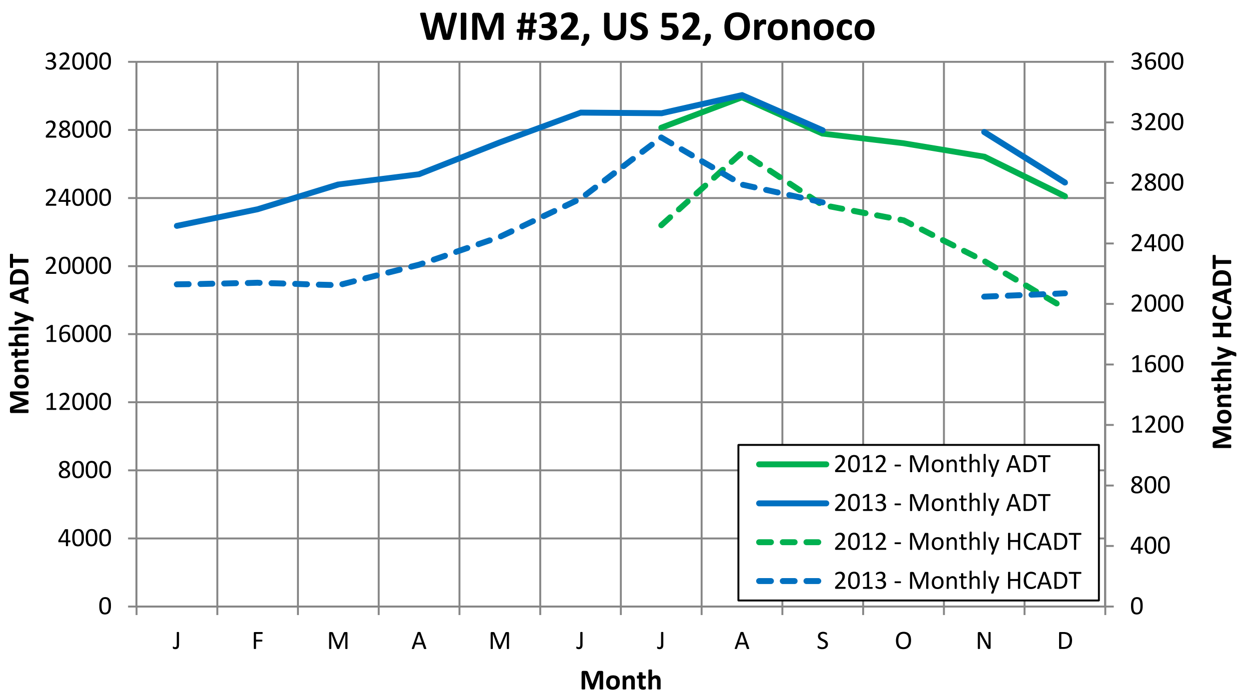


Figure 4.26. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

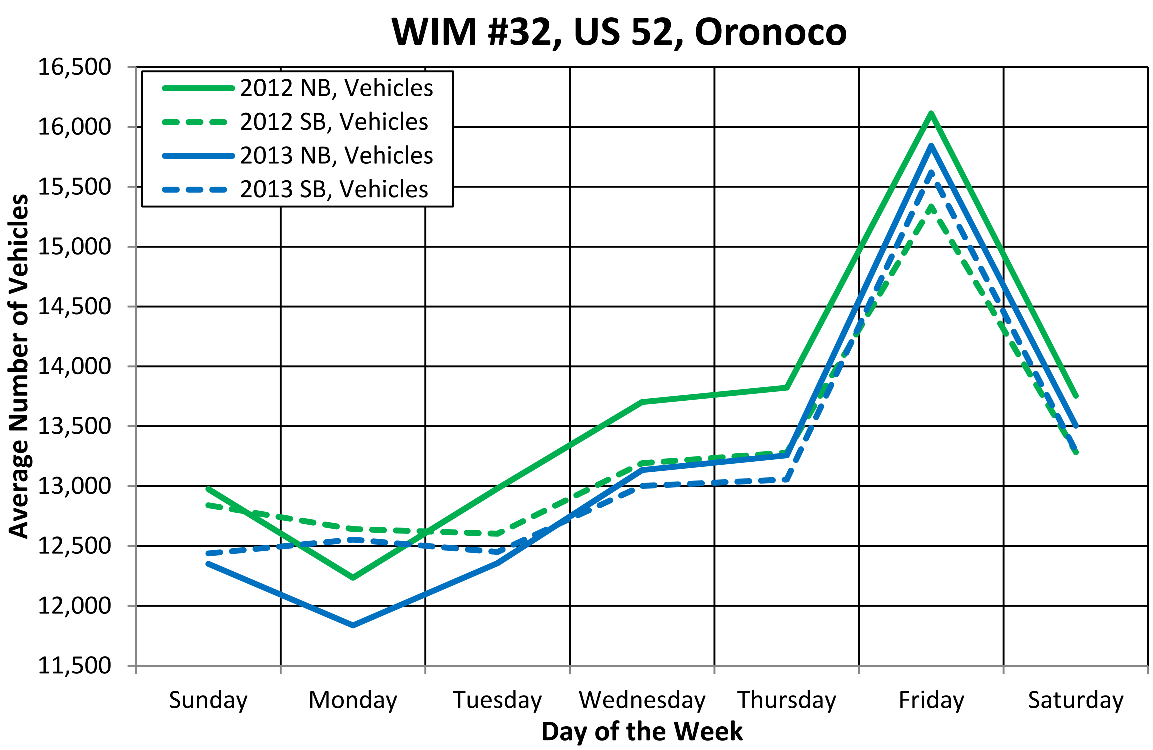


Figure 4.27. Mean number of vehicles by day of week, observed as a function of year and direction (northbound vs. southbound; NB vs. SB).

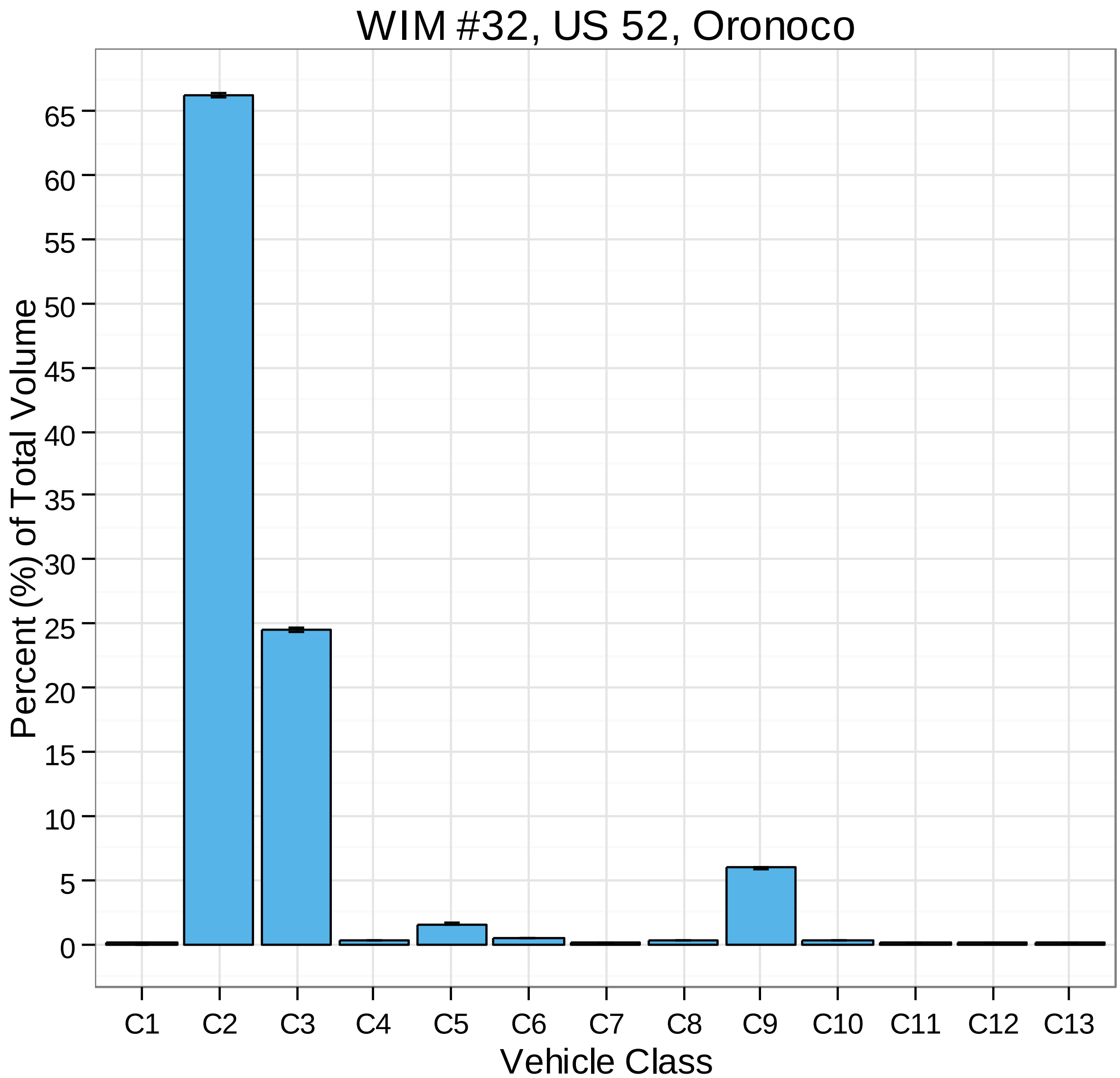


Figure 4.28. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

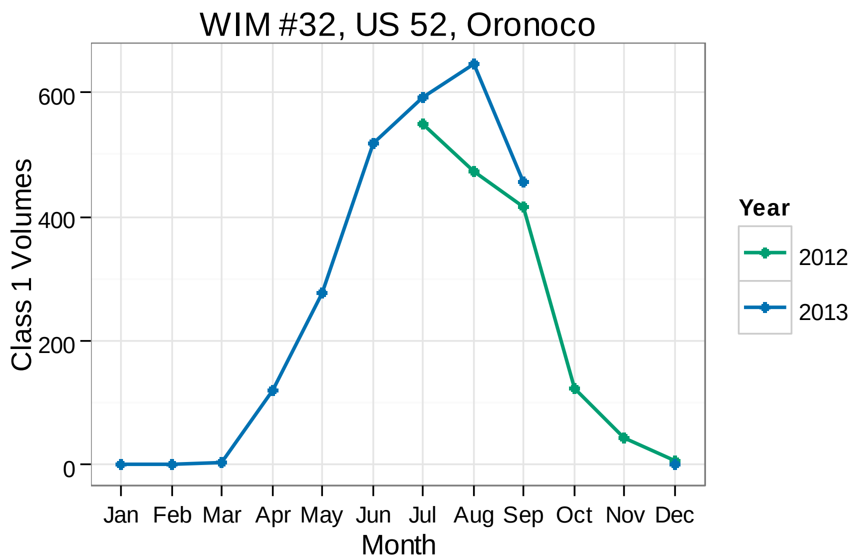


Figure 4.29a. Class 1 volume as a function of month and year.

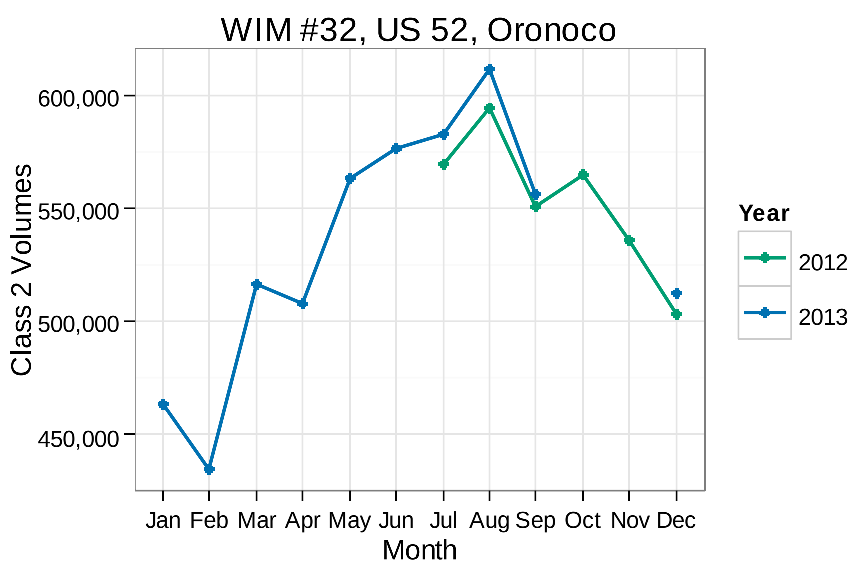


Figure 4.29b. Class 2 volume as a function of month and year.

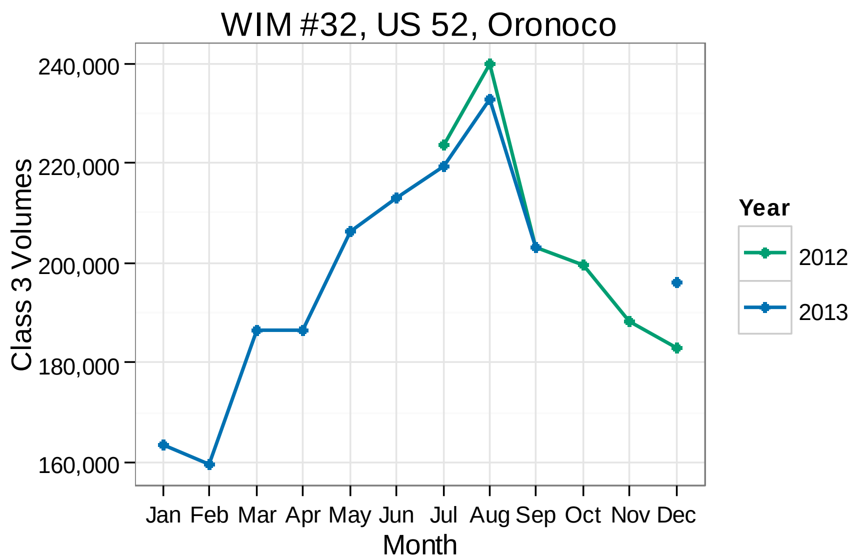


Figure 4.29c. Class 3 volume as a function of month and year.

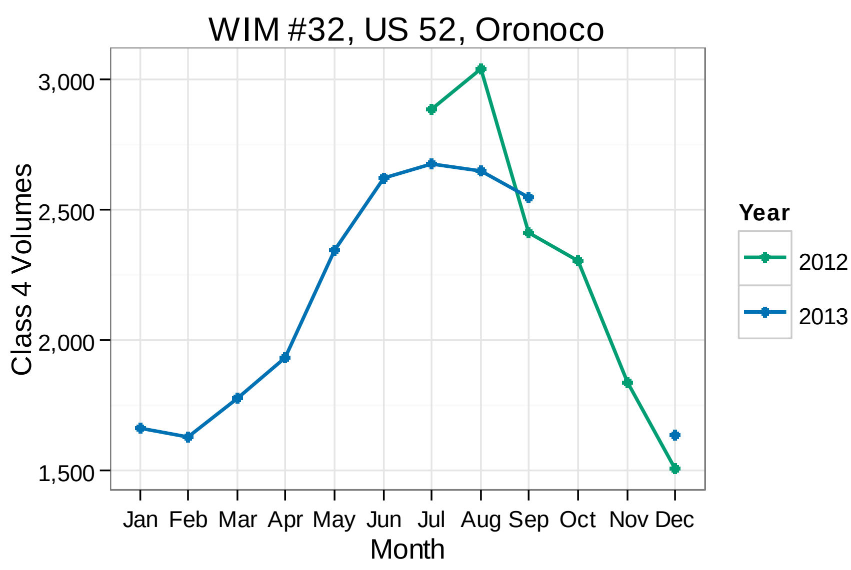


Figure 4.29d. Class 4 volume as a function of month and year.

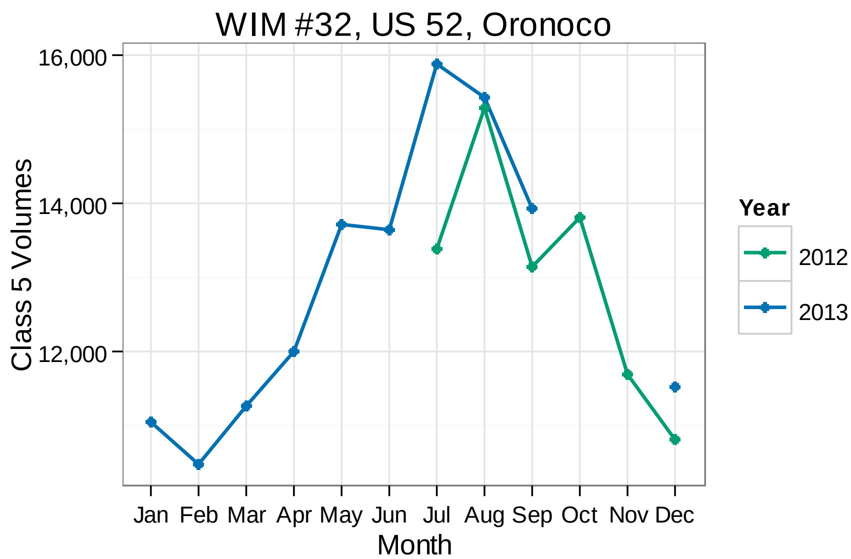


Figure 4.29e. Class 5 volume as a function of month and year.

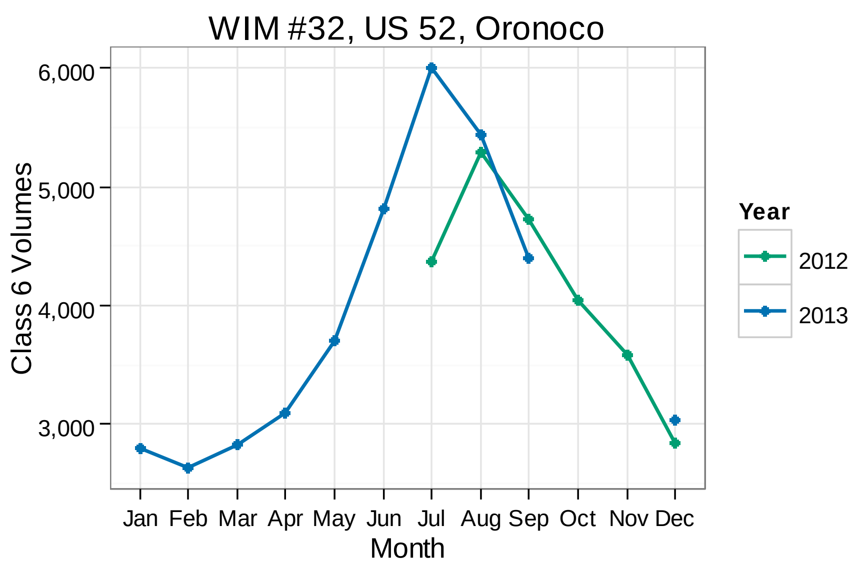


Figure 4.29f. Class 6 volume as a function of month and year.

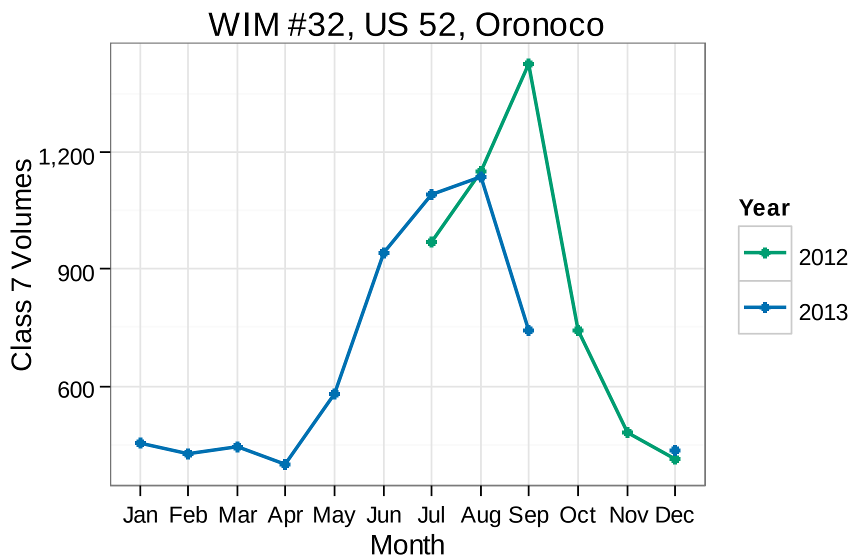


Figure 4.29g. Class 7 volume as a function of month and year.

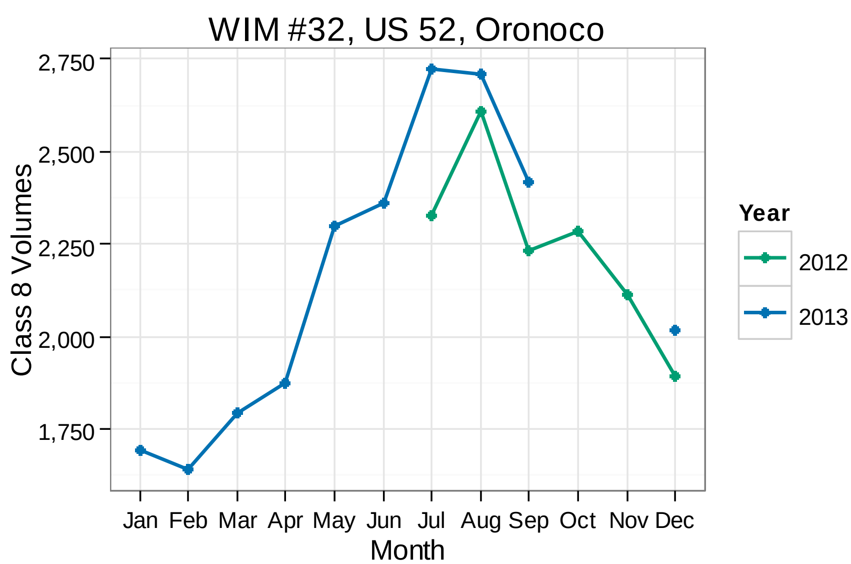


Figure 4.29h. Class 8 volume as a function of month and year.

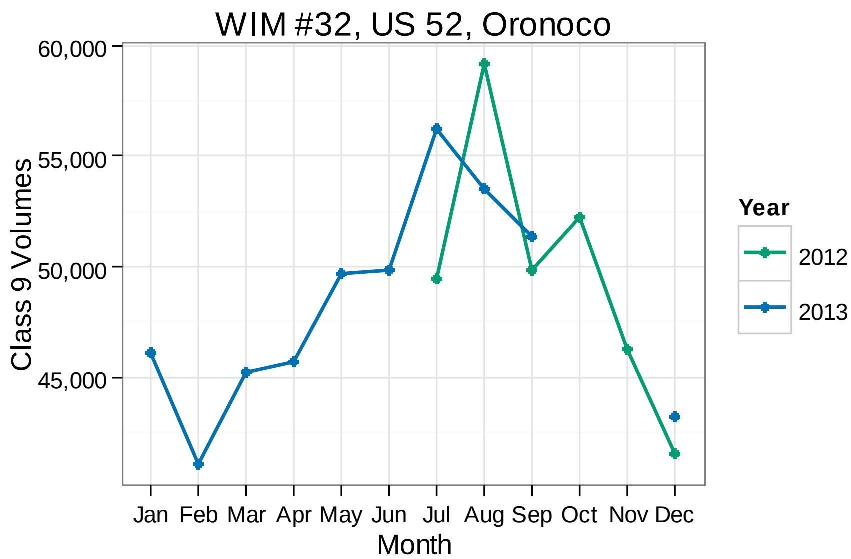


Figure 4.29i. Class 9 volume as a function of month and year.

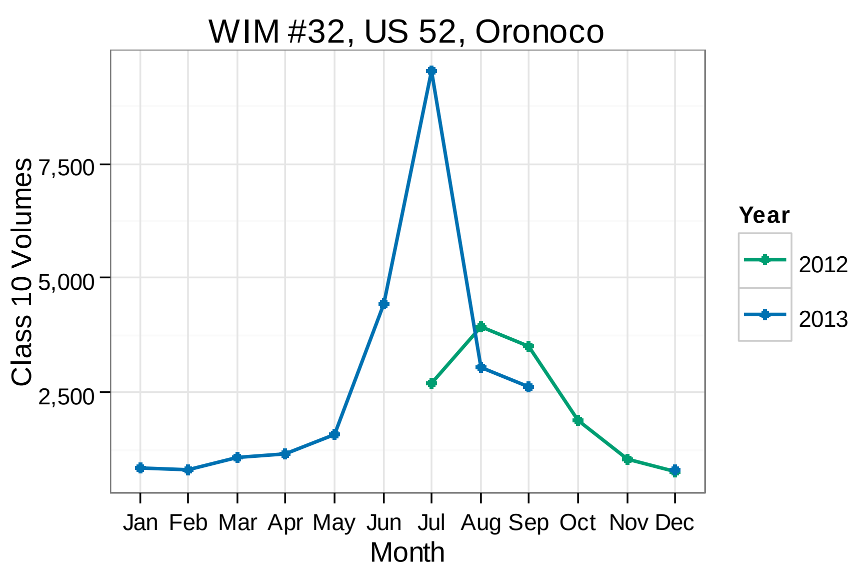


Figure 4.29j. Class 10 volume as a function of month and year.

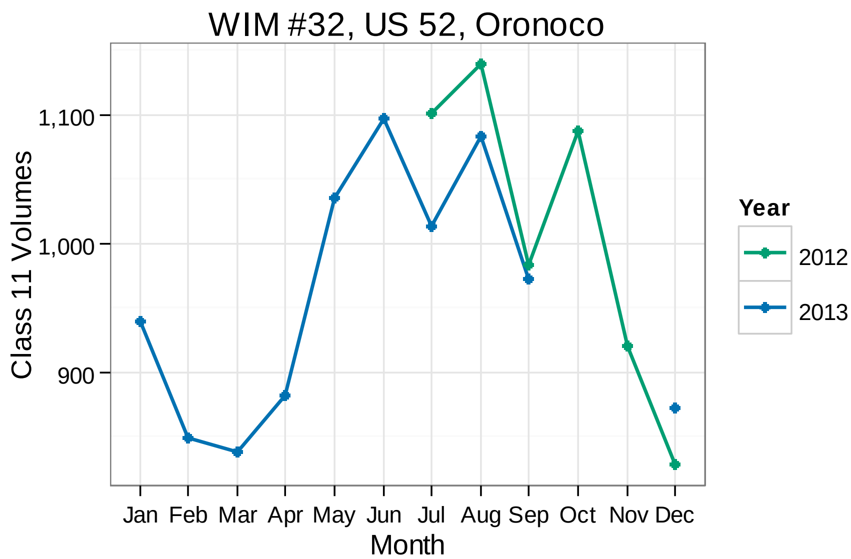


Figure 4.29k. Class 11 volume as a function of month and year.

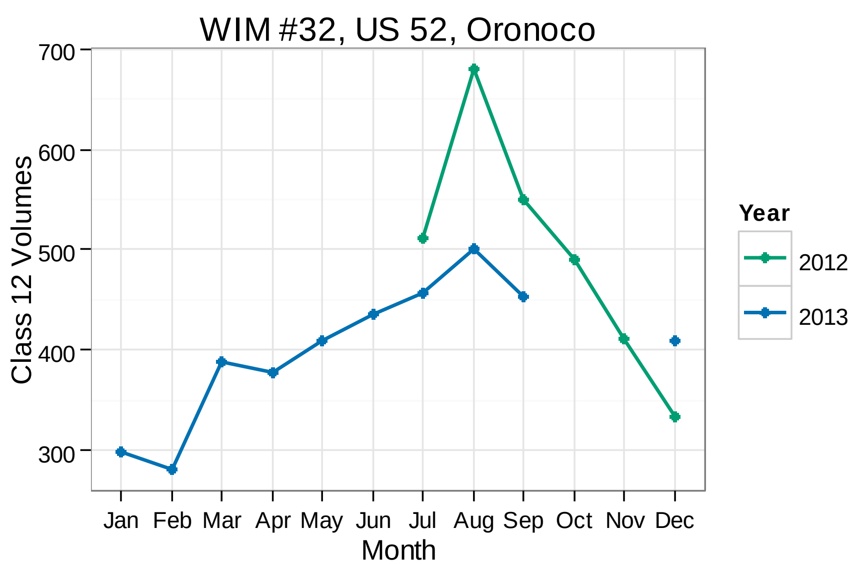


Figure 4.29l. Class 12 volume as a function of month and year.

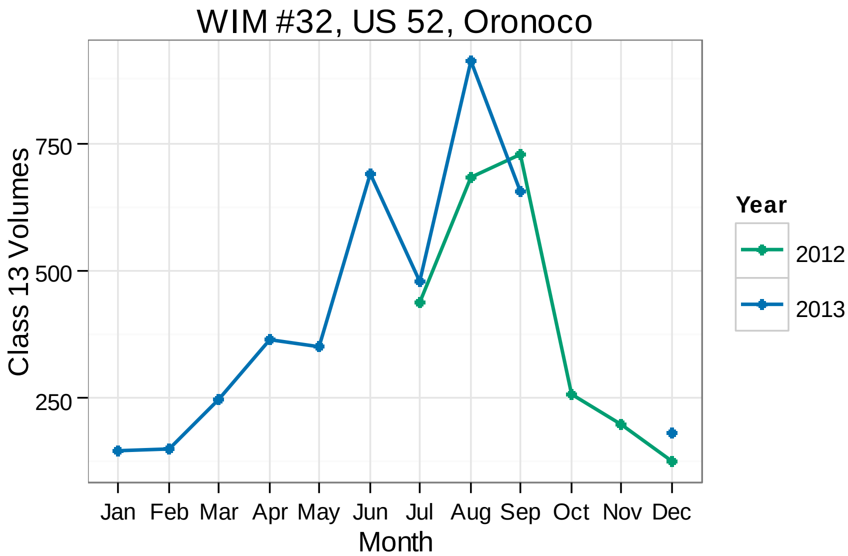


Figure 4.29m. Class 13 volume as a function of month and year.

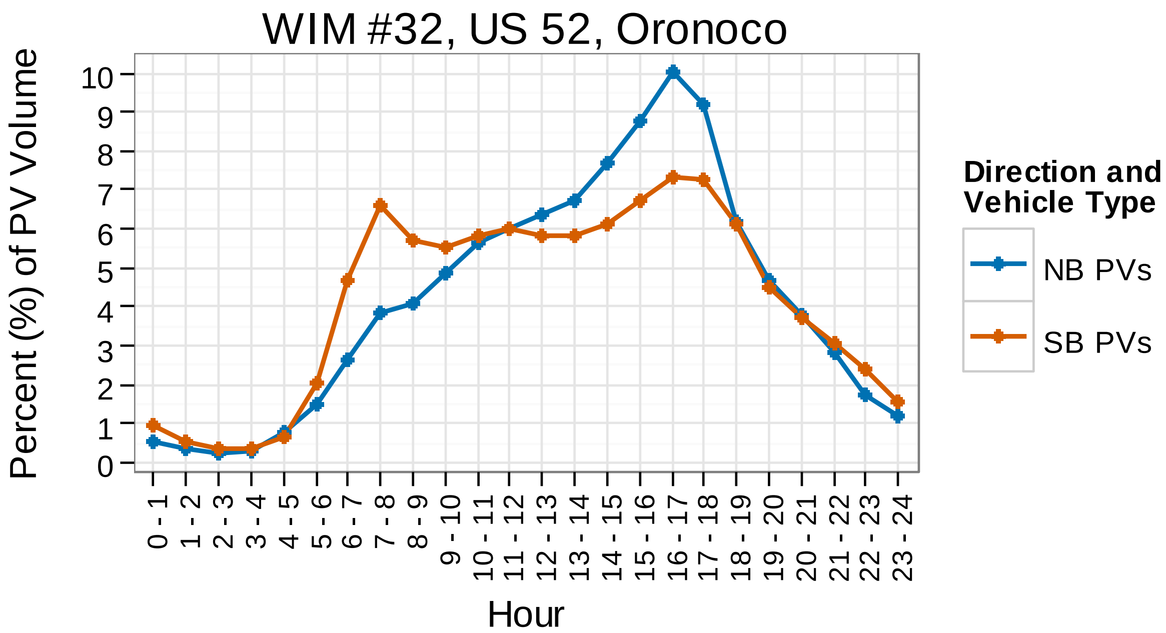


Figure 4.30a. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for passenger vehicles (PVs).

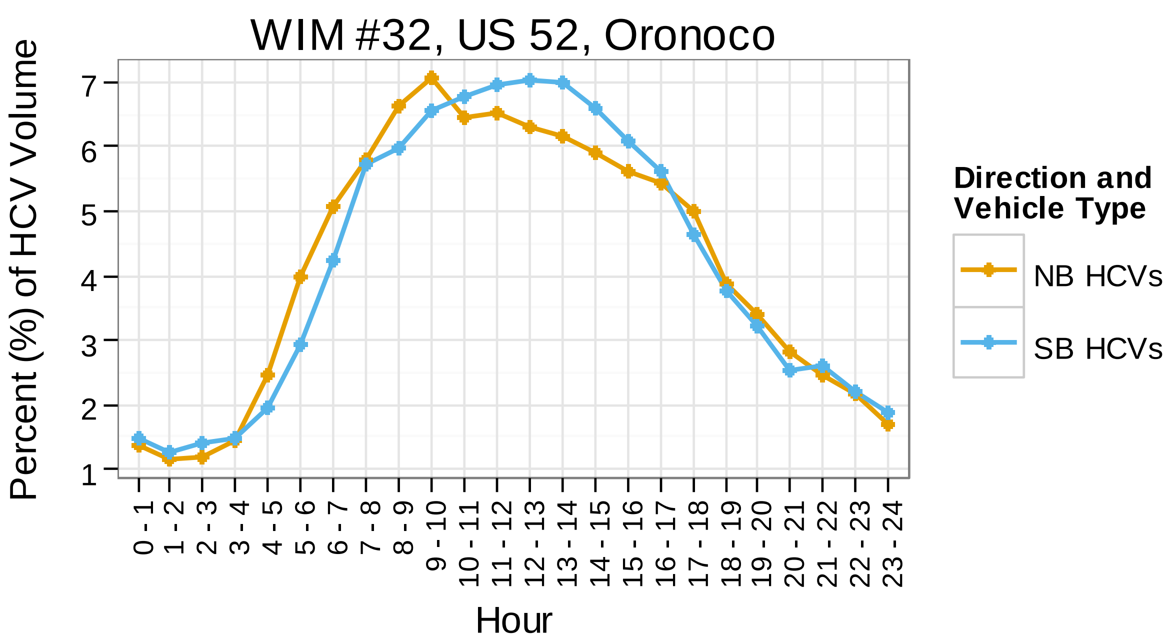


Figure 4.30b. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for heavy commercial vehicles (HCVs).

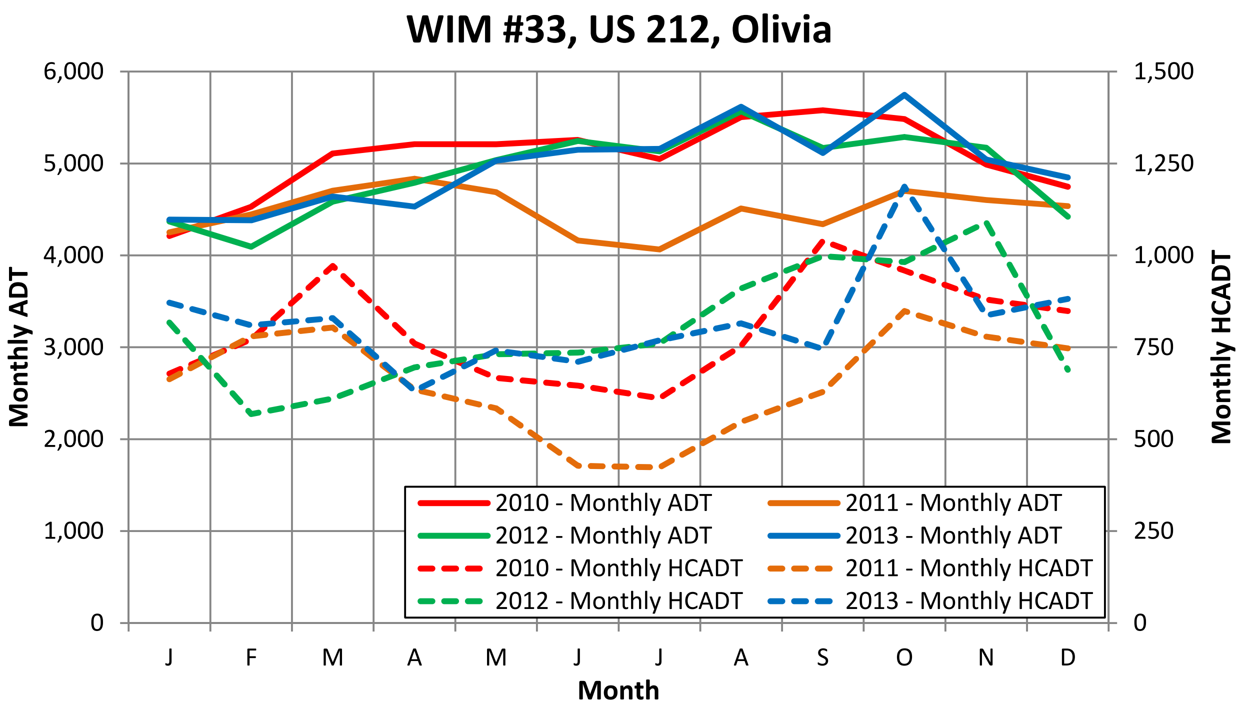


Figure 4.31. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

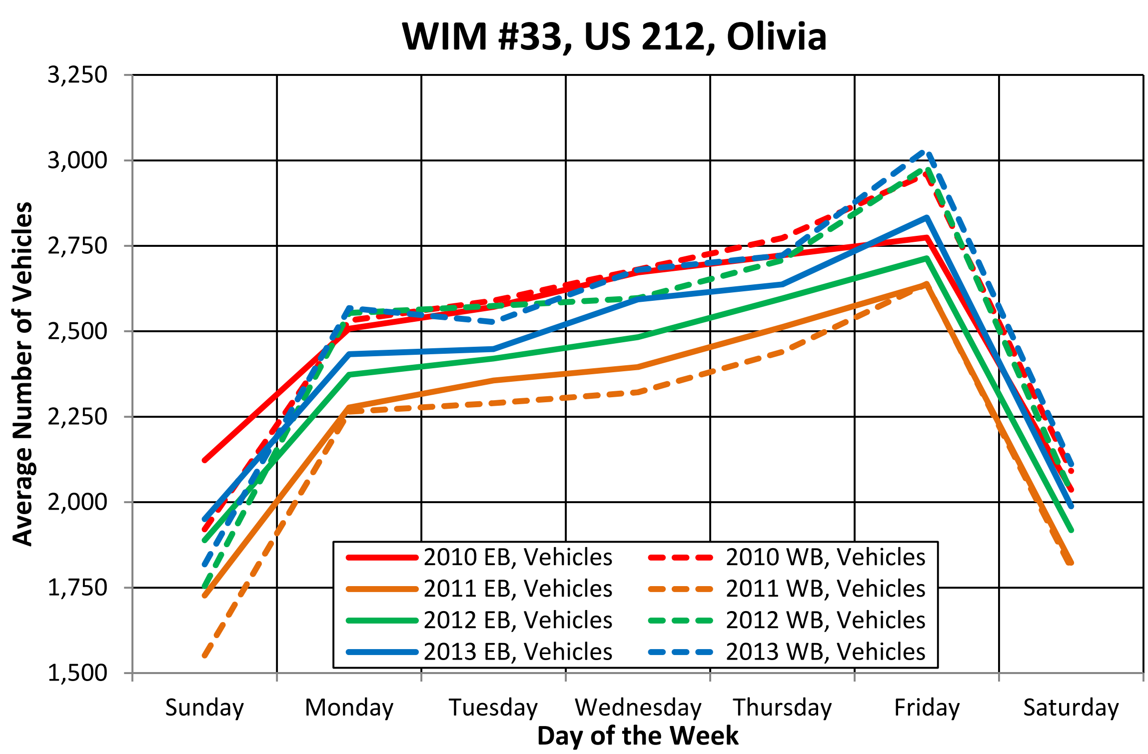


Figure 4.32. Mean number of vehicles by day of week, observed as a function of year and direction (eastbound vs. westbound; EB vs. WB).

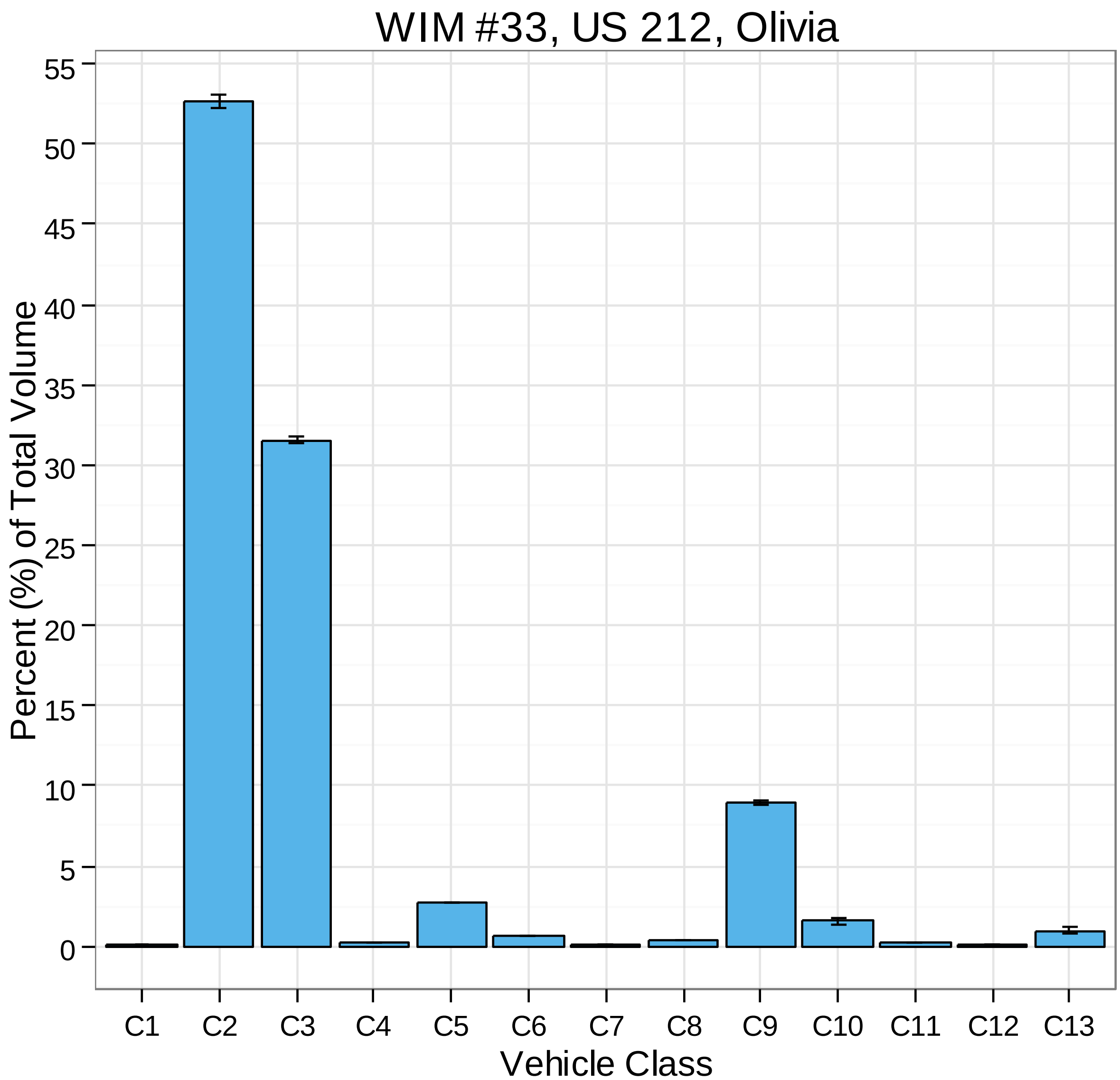


Figure 4.33. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

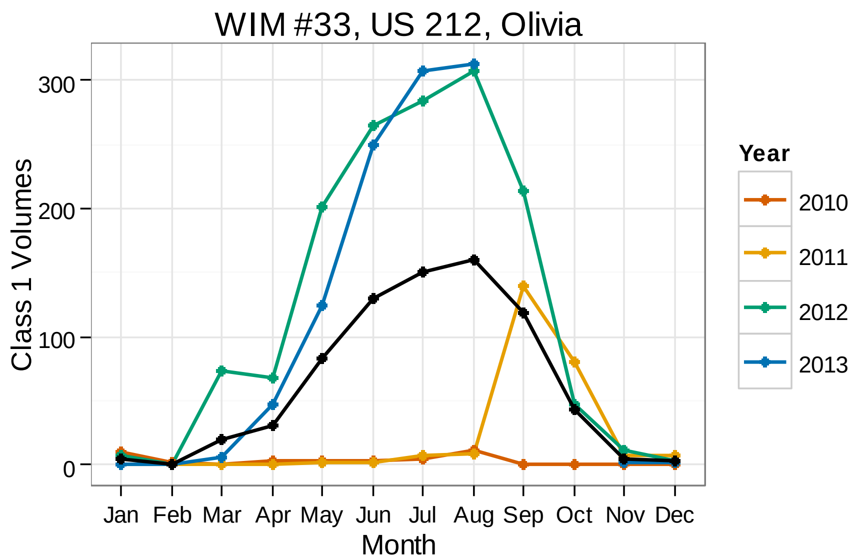


Figure 4.34a. Class 1 volume as a function of month and year. Black line represents the average volume within each month across all years.

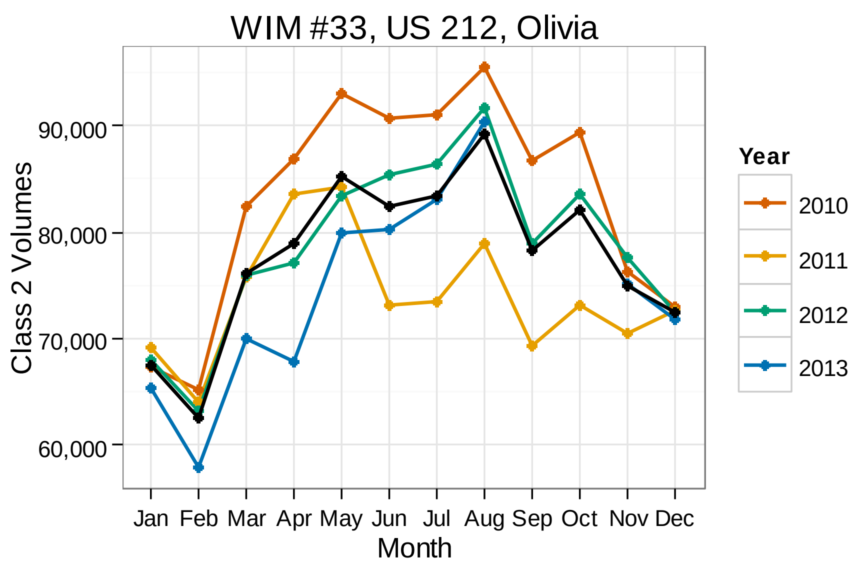


Figure 4.34b. Class 2 volume as a function of month and year. Black line represents the average volume within each month across all years.

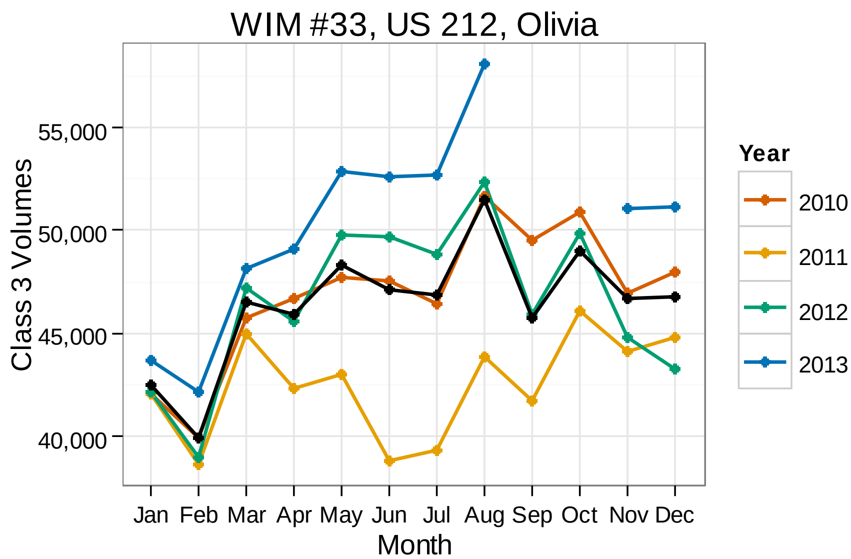


Figure 4.34c. Class 3 volume as a function of month and year. Black line represents the average volume within each month across all years.

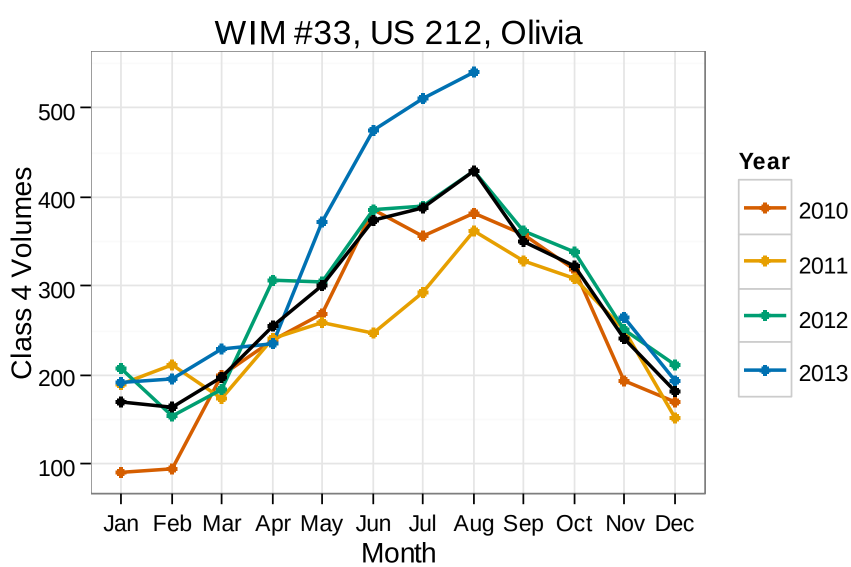


Figure 4.34d. Class 4 volume as a function of month and year. Black line represents the average volume within each month across all years.

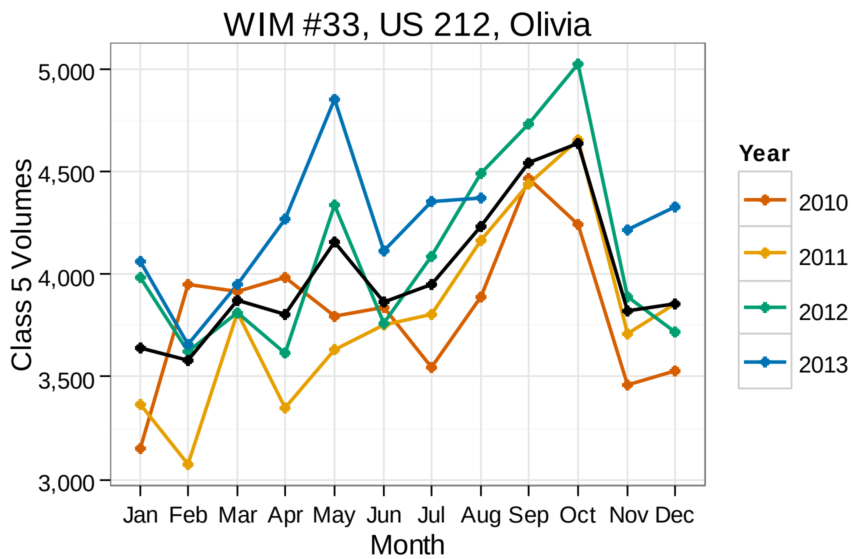


Figure 4.34e. Class 5 volume as a function of month and year. Black line represents the average volume within each month across all years.

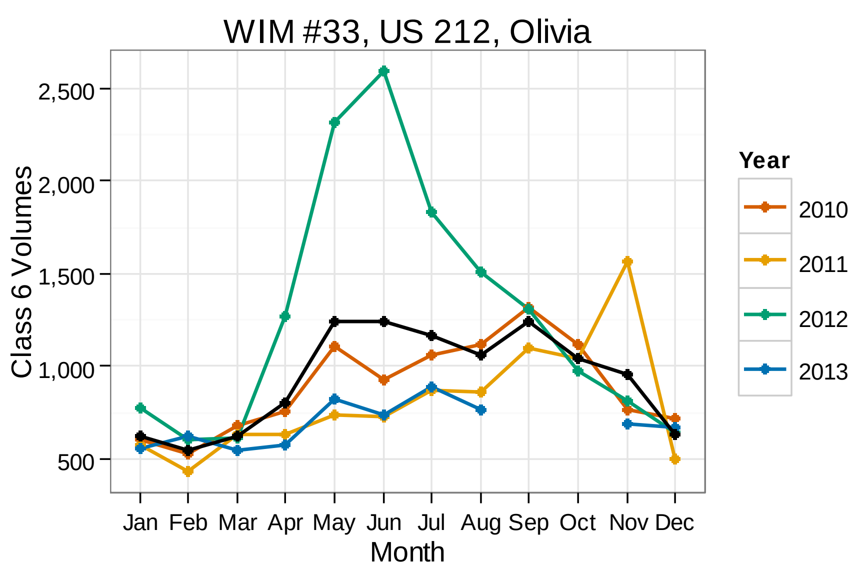


Figure 4.34f. Class 6 volume as a function of month and year. Black line represents the average volume within each month across all years.

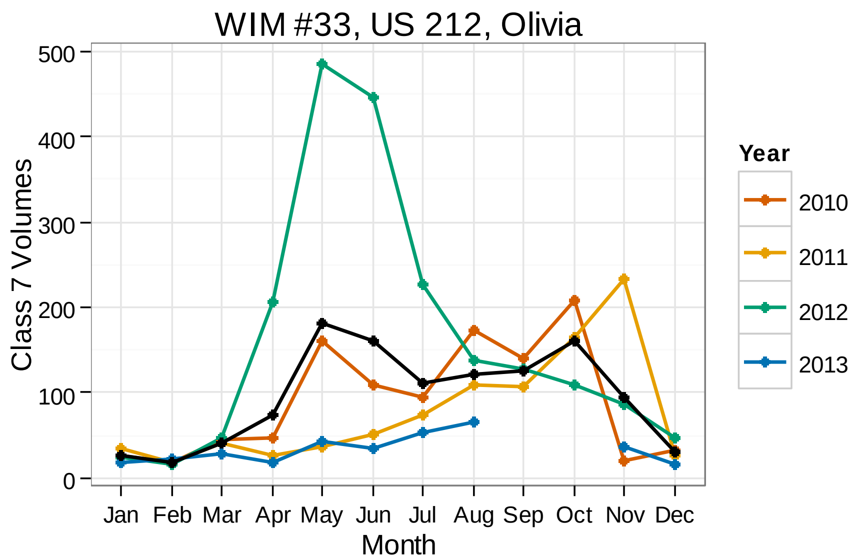


Figure 4.34g. Class 7 volume as a function of month and year. Black line represents the average volume within each month across all years.

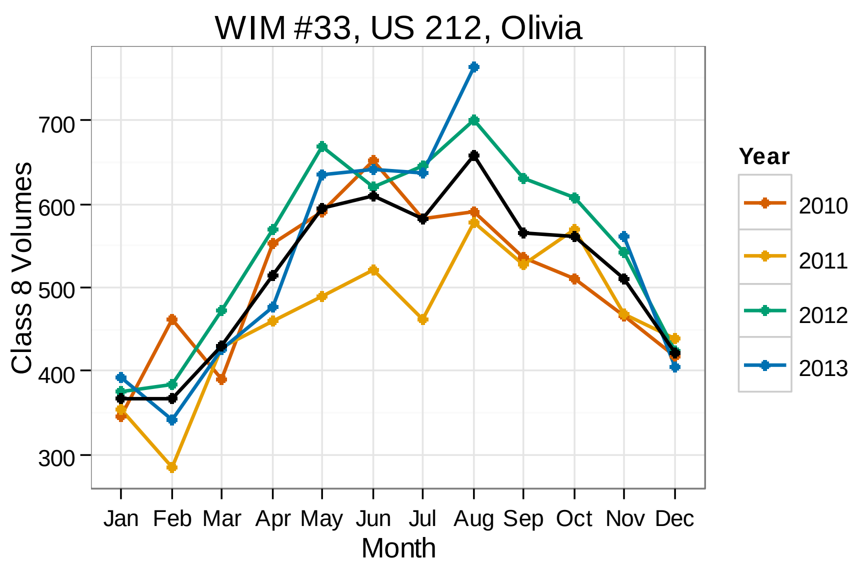


Figure 4.34h. Class 8 volume as a function of month and year. Black line represents the average volume within each month across all years.

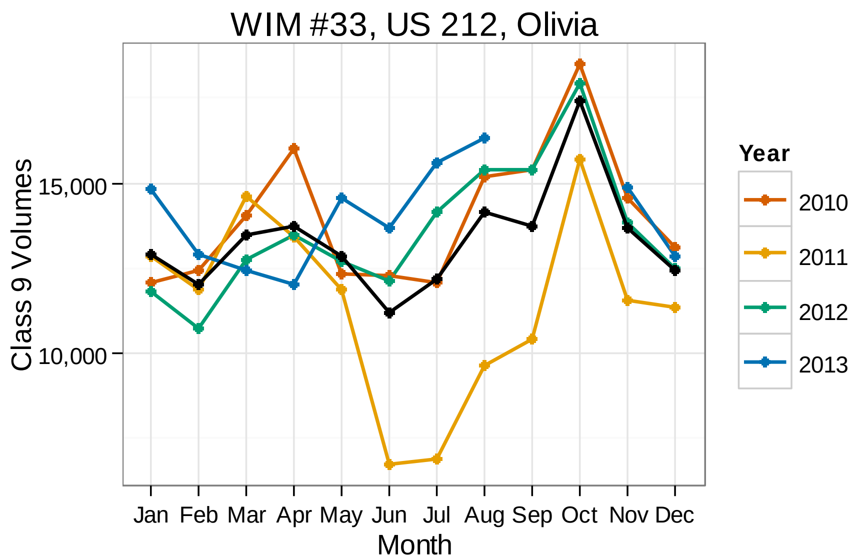


Figure 4.34i. Class 9 volume as a function of month and year. Black line represents the average volume within each month across all years.

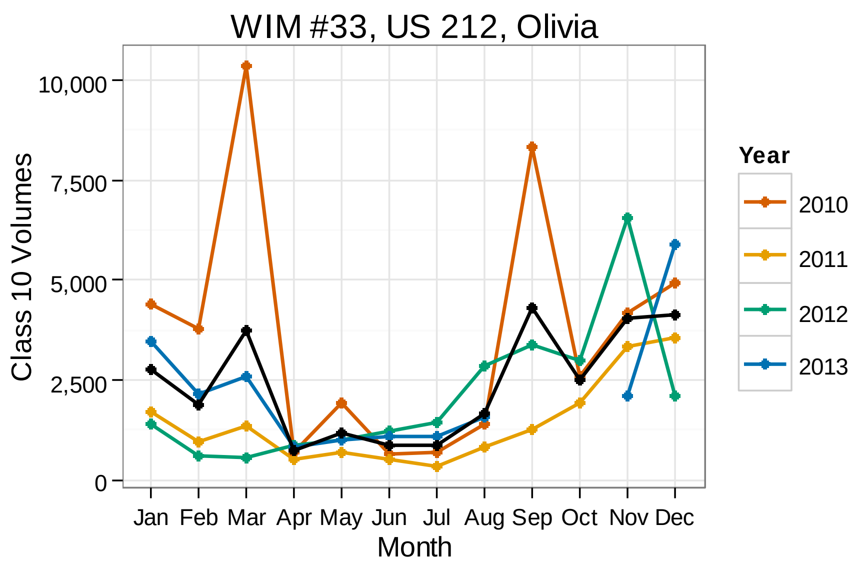


Figure 4.34j. Class 10 volume as a function of month and year. Black line represents the average volume within each month across all years.

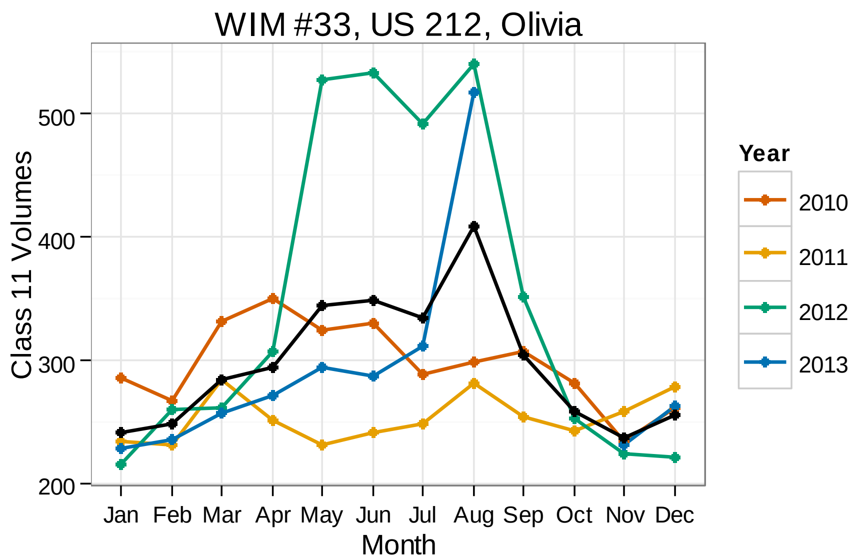


Figure 4.34k. Class 11 volume as a function of month and year. Black line represents the average volume within each month across all years.

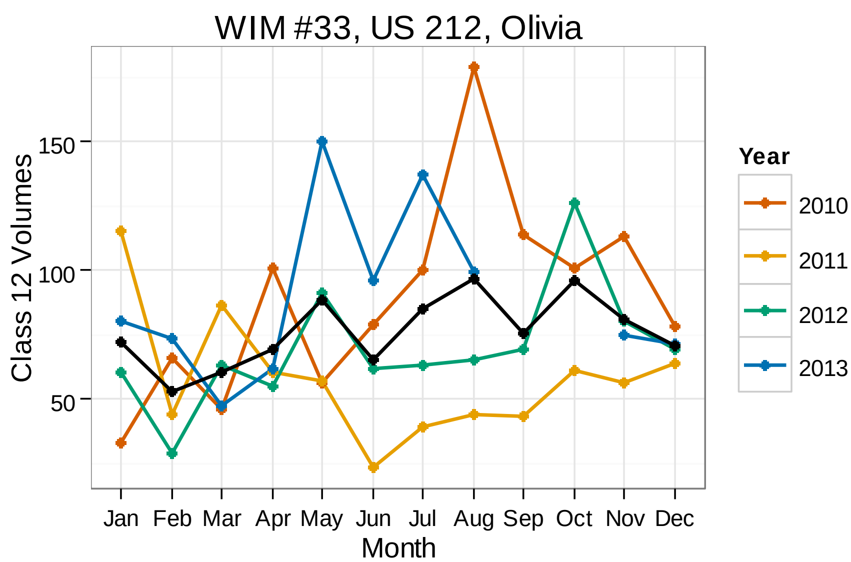


Figure 4.34l. Class 12 volume as a function of month and year. Black line represents the average volume within each month across all years.

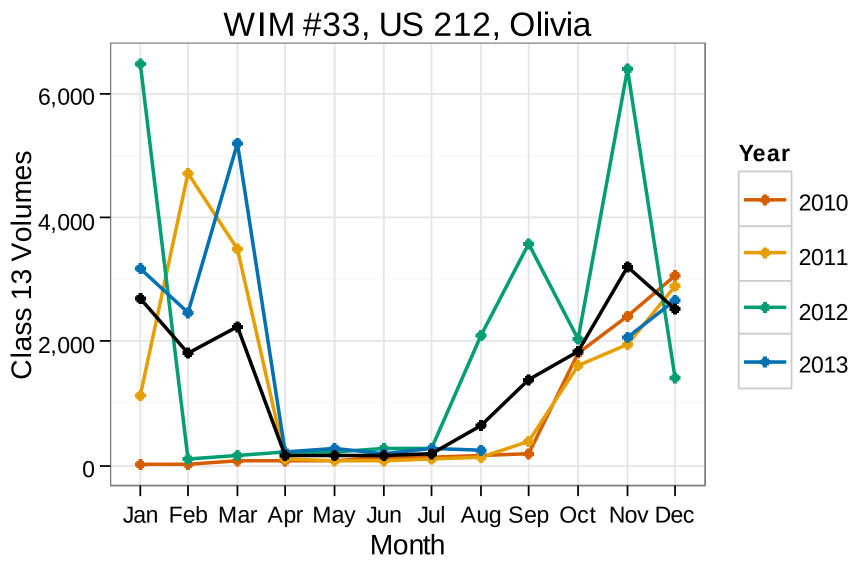


Figure 4.34m. Class 13 volume as a function of month and year. Black line represents the average volume within each month across all years.

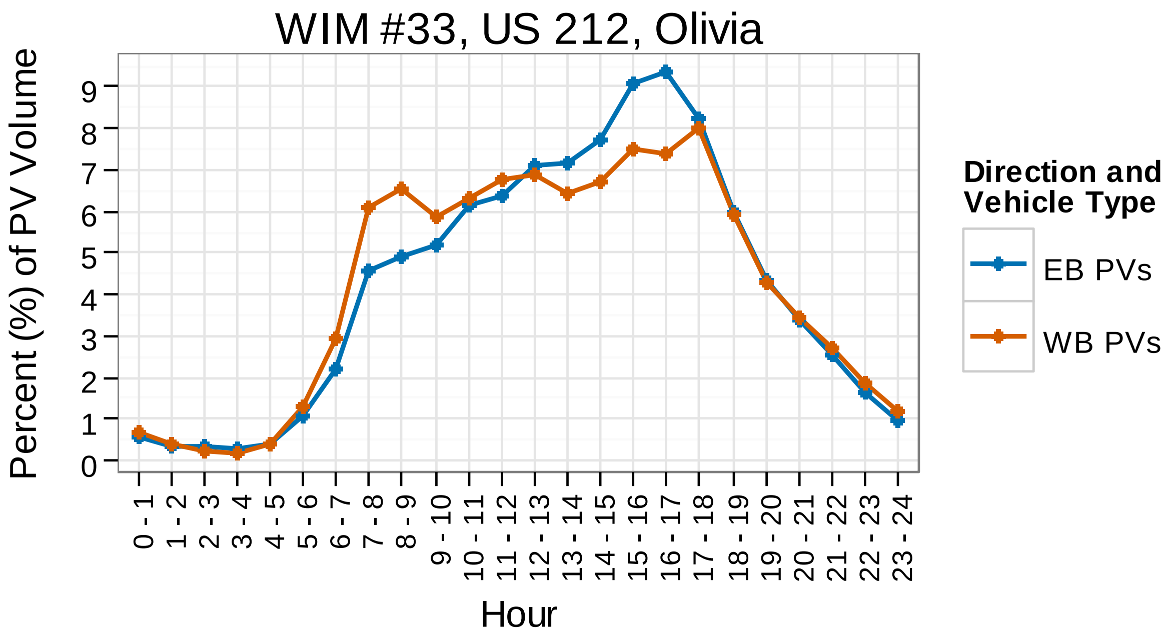


Figure 4.35a. Amount of traffic (% of volume) observed at an hourly basis for each direction (eastbound; EB vs. westbound; WB) for passenger vehicles (PVs).

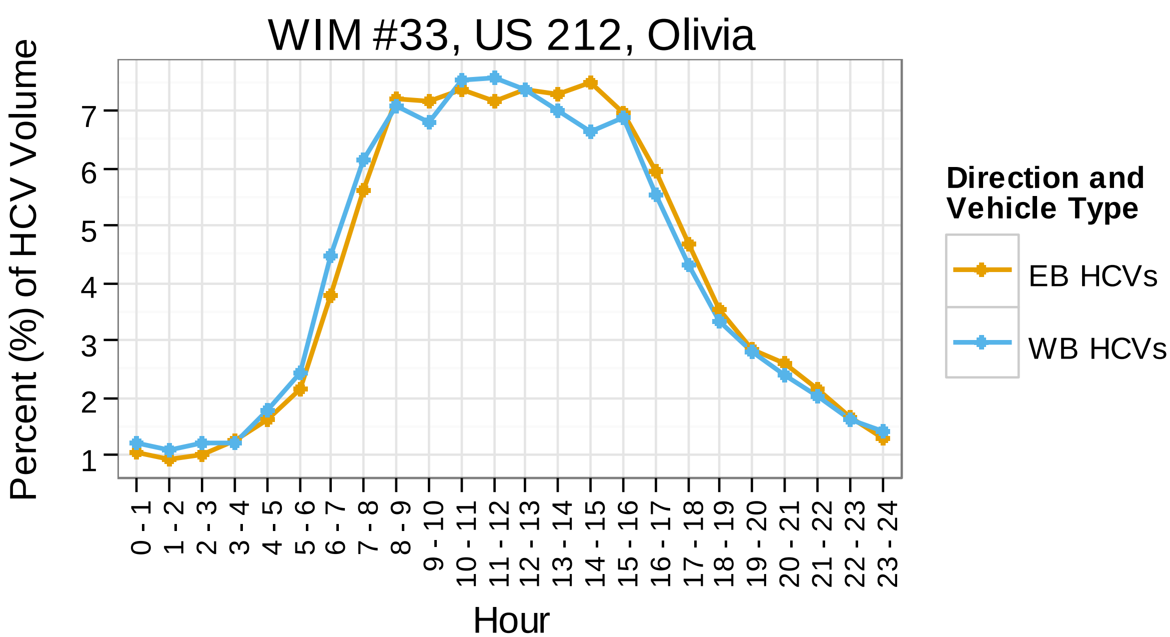


Figure 4.35b. Amount of traffic (% of volume) observed at an hourly basis for each direction (eastbound; EB vs. westbound; WB) for heavy commercial vehicles (HCVs).

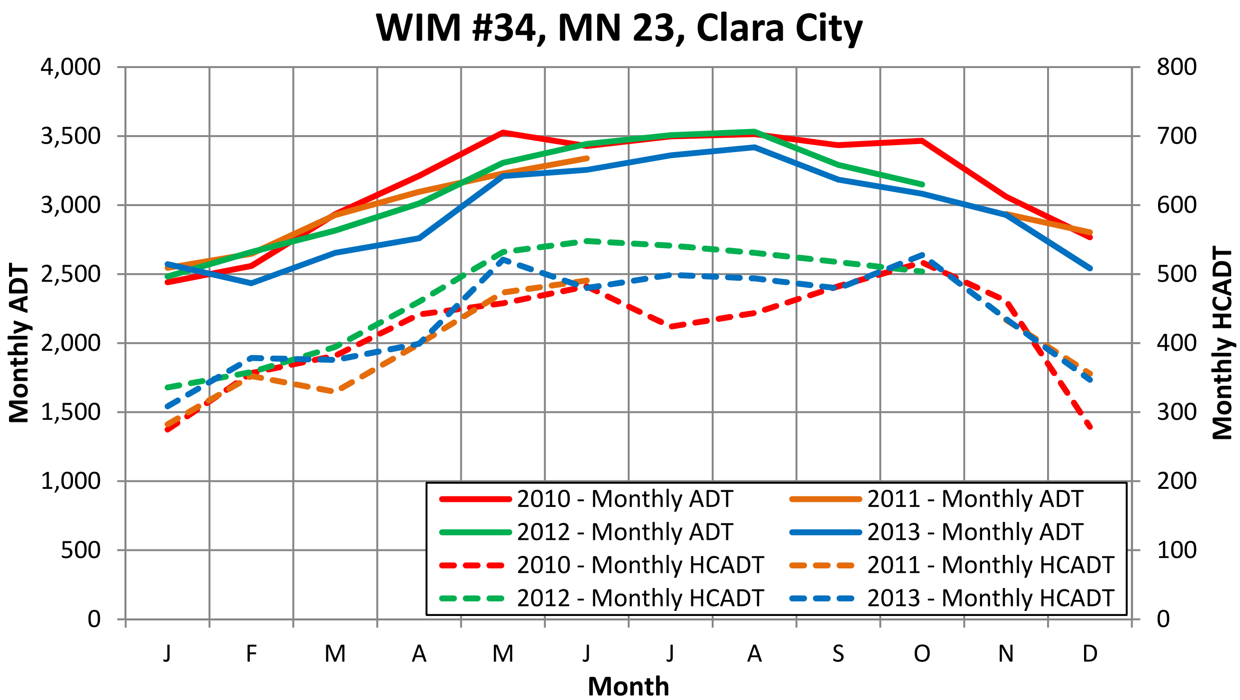


Figure 4.36. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

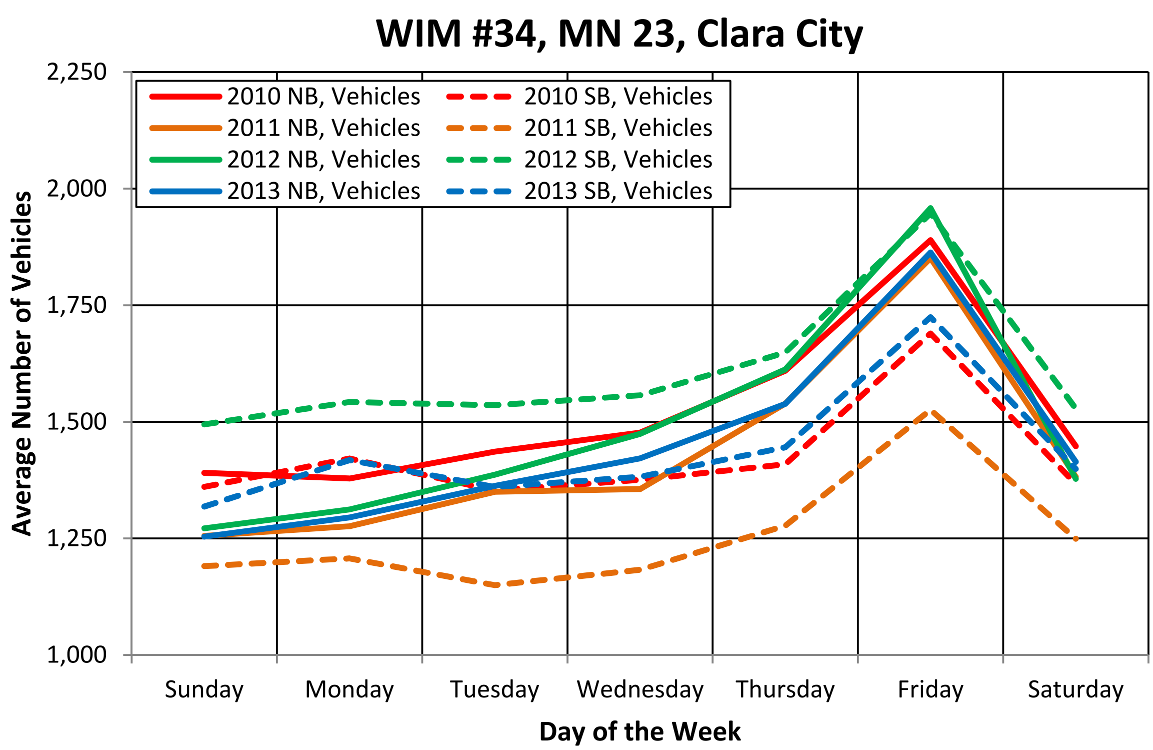


Figure 4.37. Mean number of vehicles by day of week, observed as a function of year and direction (northbound vs. southbound; NB vs. SB).

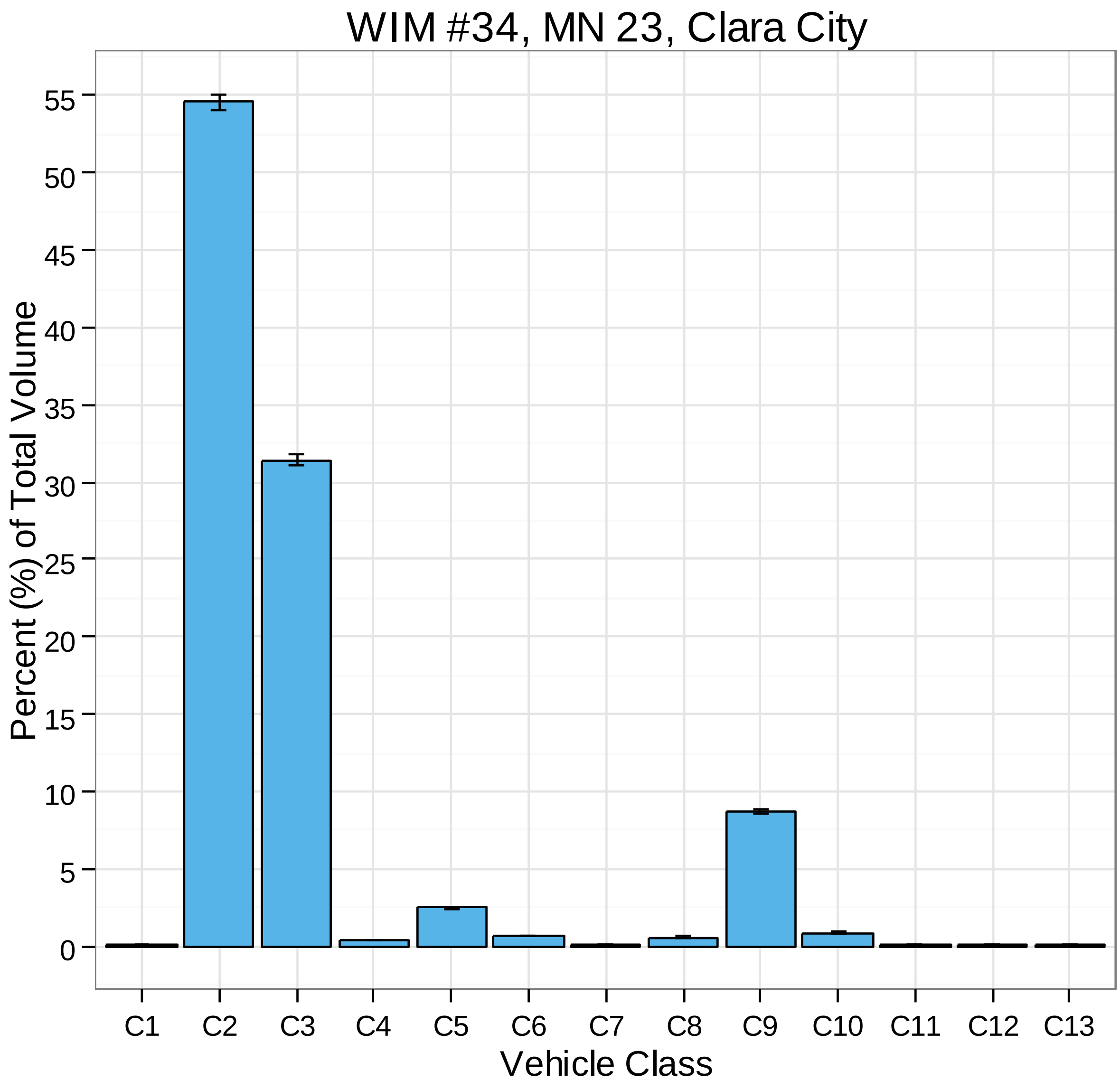


Figure 4.38. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

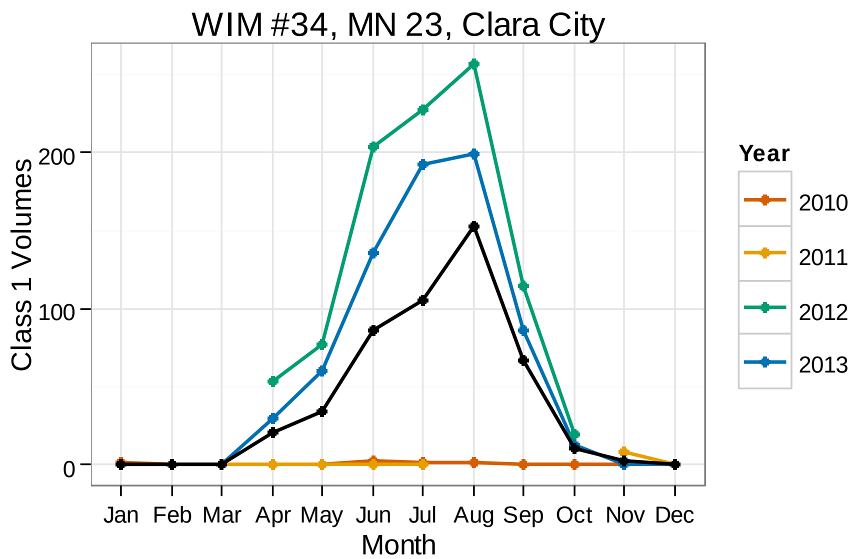


Figure 4.39a. Class 1 volume as a function of month and year. Black line represents the average volume within each month across all years.

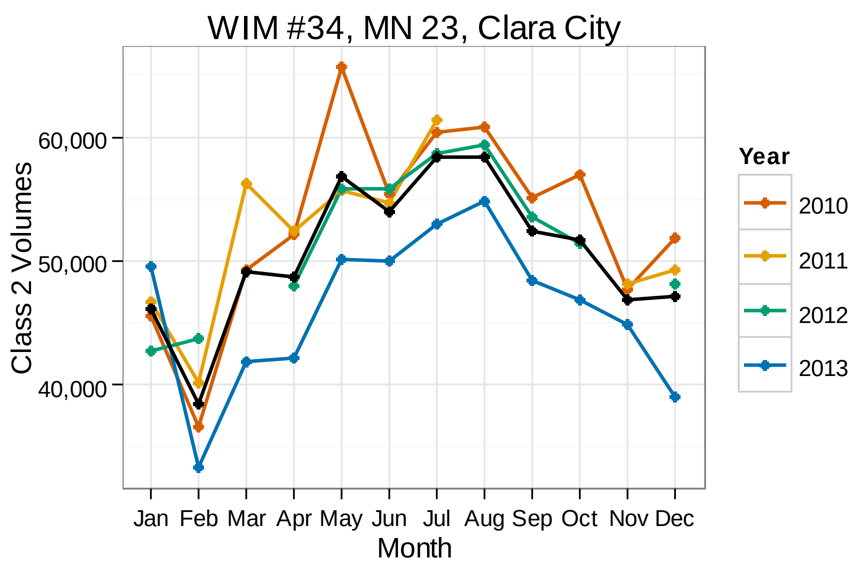


Figure 4.39b. Class 2 volume as a function of month and year. Black line represents the average volume within each month across all years.

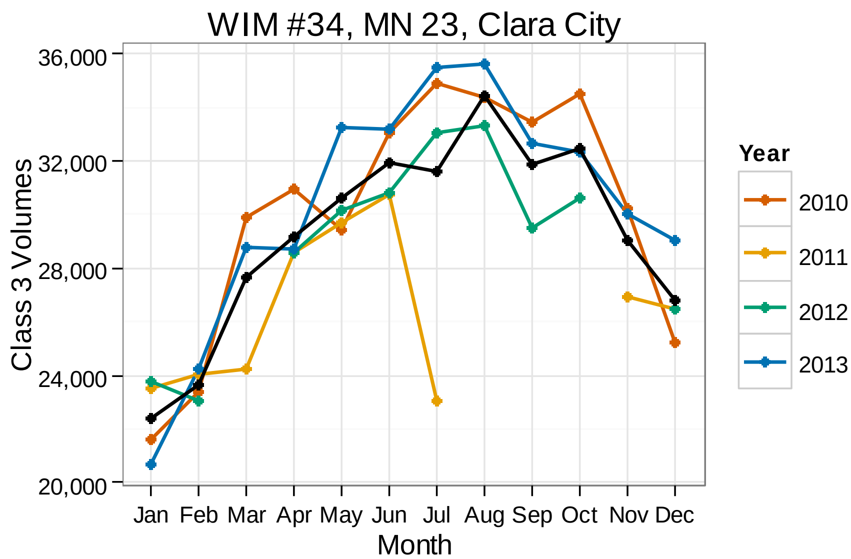


Figure 4.39c. Class 3 volume as a function of month and year. Black line represents the average volume within each month across all years.

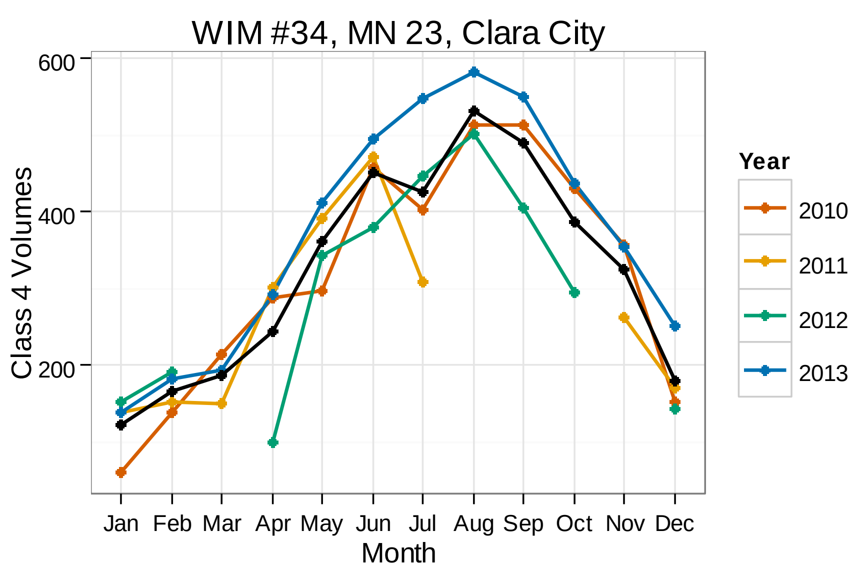


Figure 4.39d. Class 4 volume as a function of month and year. Black line represents the average volume within each month across all years.

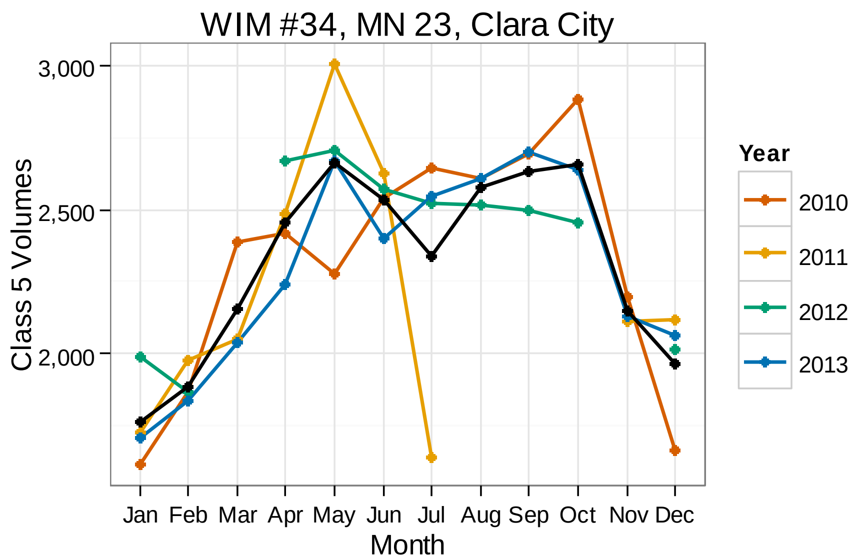


Figure 4.39e. Class 5 volume as a function of month and year. Black line represents the average volume within each month across all years.

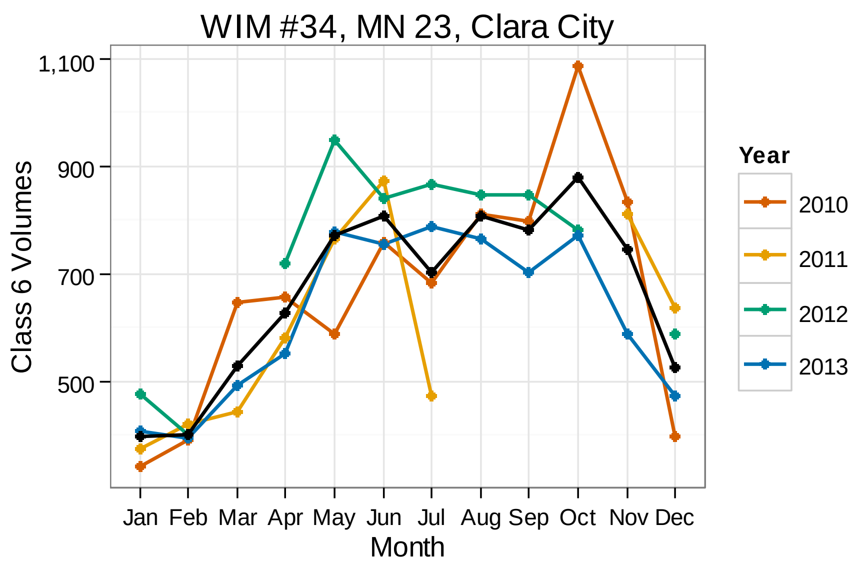


Figure 4.39f. Class 6 volume as a function of month and year. Black line represents the average volume within each month across all years.

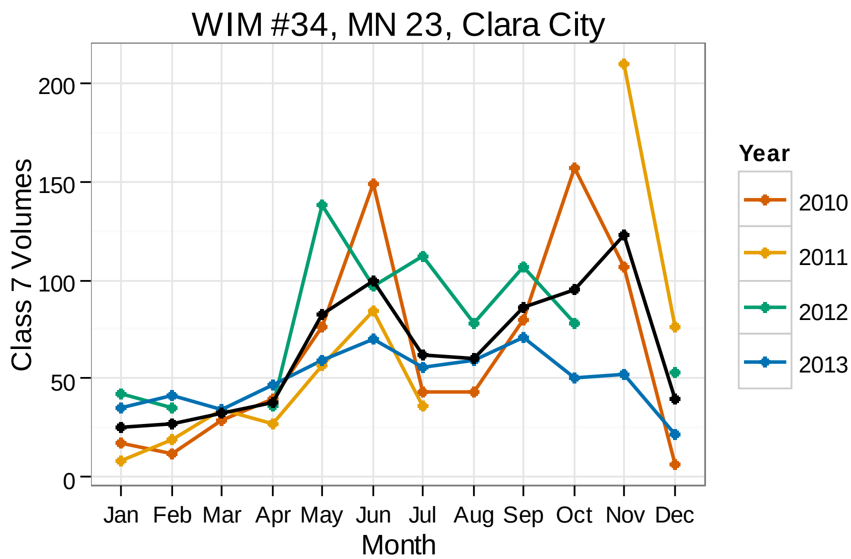


Figure 4.39g. Class 7 volume as a function of month and year. Black line represents the average volume within each month across all years.

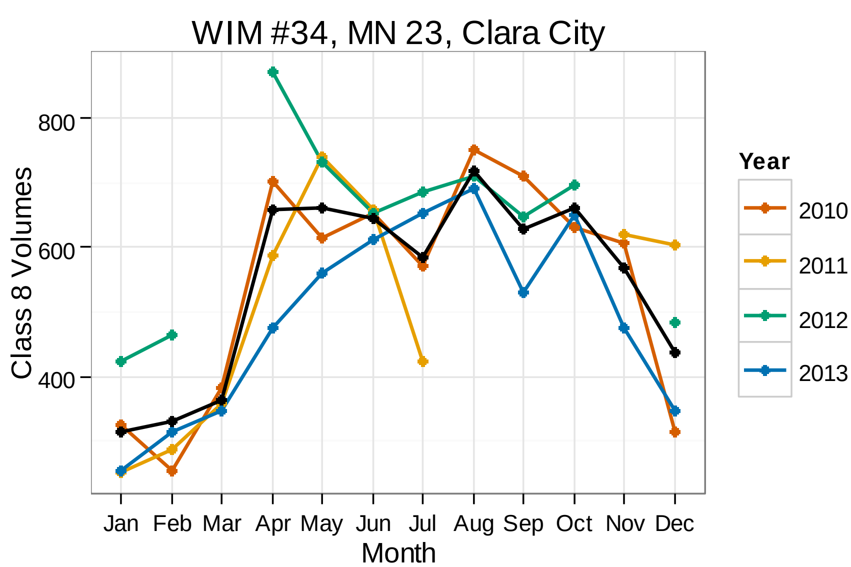


Figure 4.39h. Class 8 volume as a function of month and year. Black line represents the average volume within each month across all years.

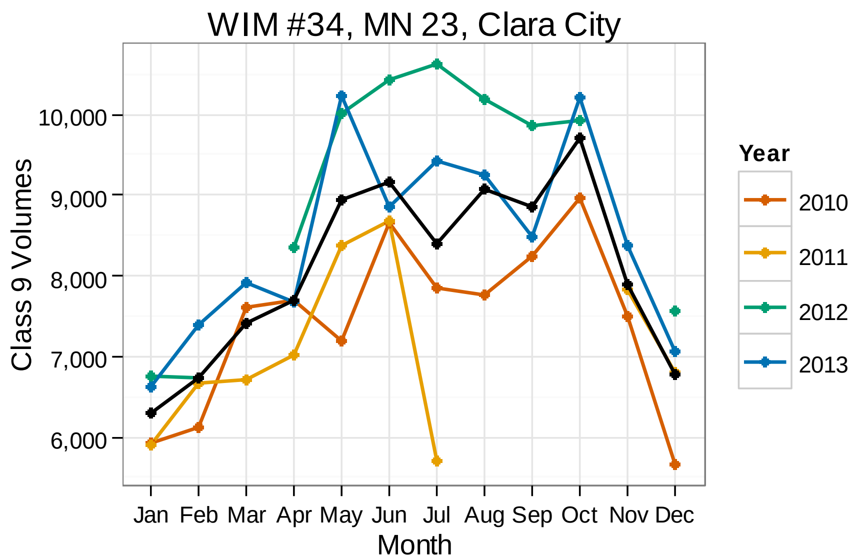


Figure 4.39i. Class 9 volume as a function of month and year. Black line represents the average volume within each month across all years.

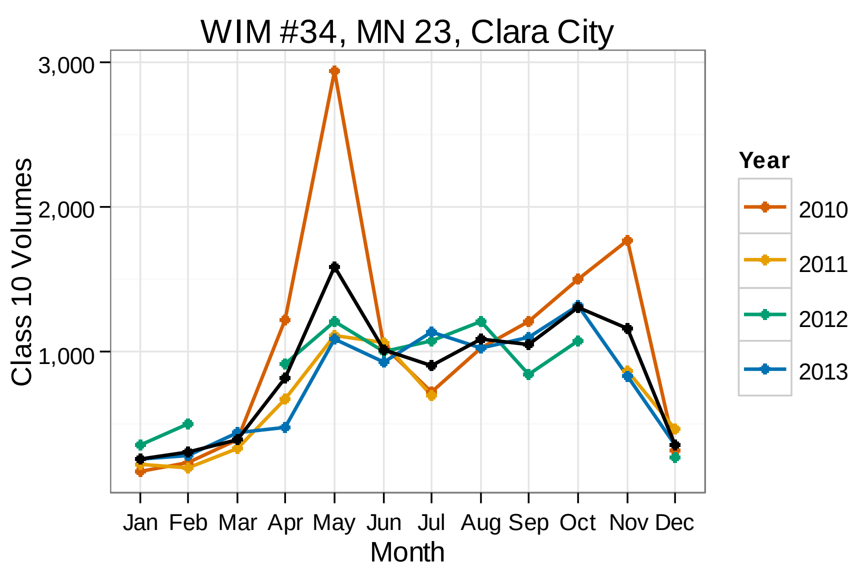


Figure 4.39j. Class 10 volume as a function of month and year. Black line represents the average volume within each month across all years.

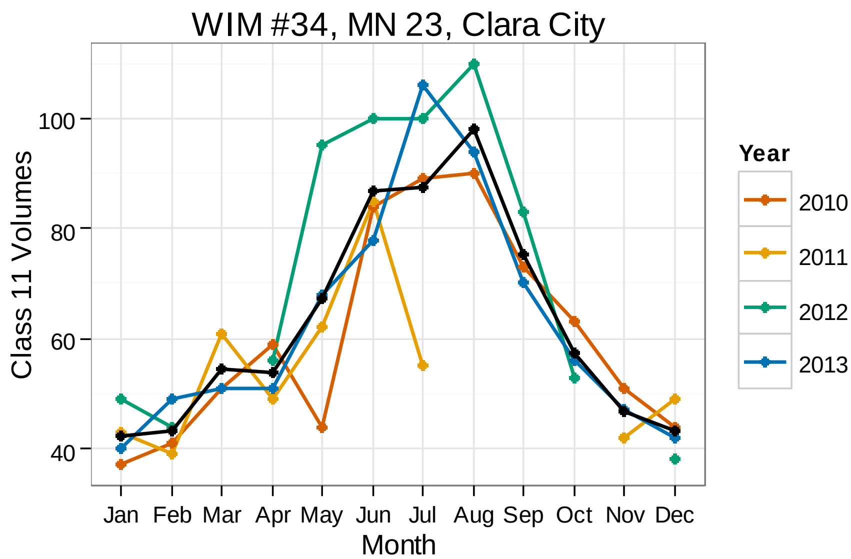


Figure 4.39k. Class 11 volume as a function of month and year. Black line represents the average volume within each month across all years.

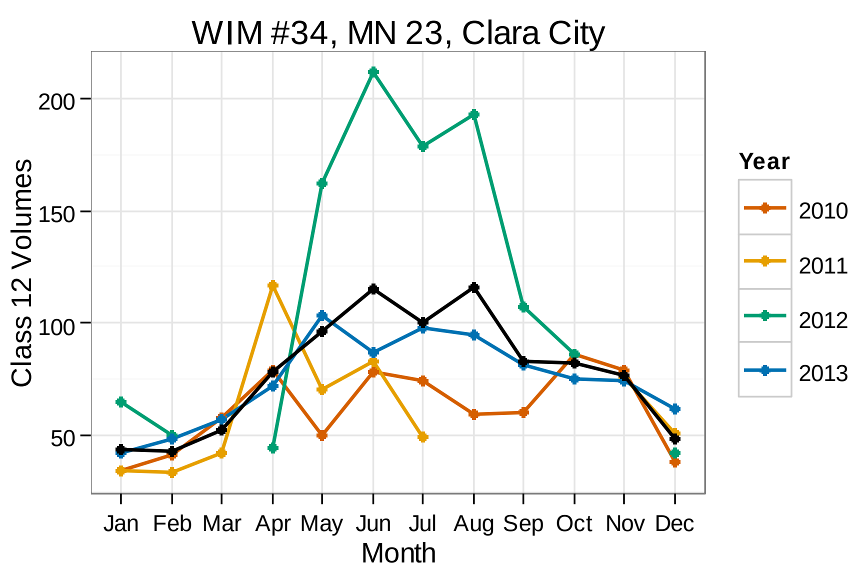


Figure 4.39l. Class 12 volume as a function of month and year. Black line represents the average volume within each month across all years.

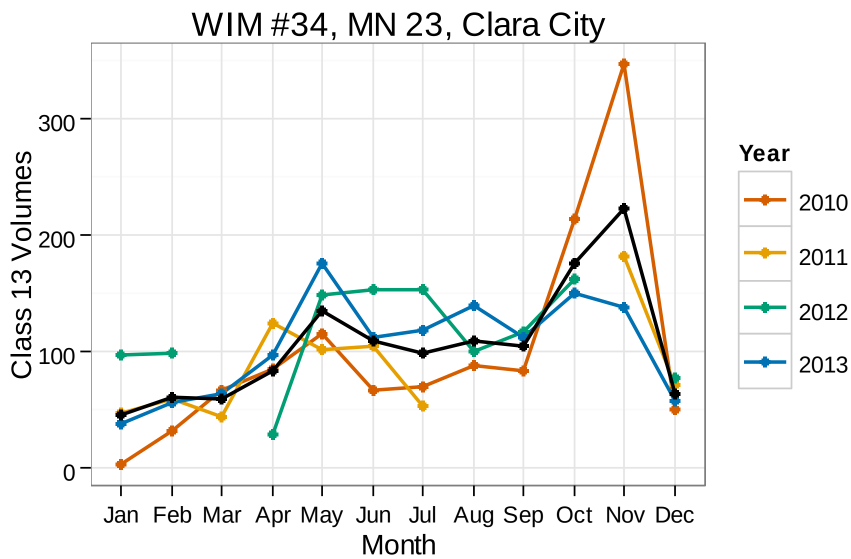


Figure 4.39m. Class 13 volume as a function of month and year. Black line represents the average volume within each month across all years.

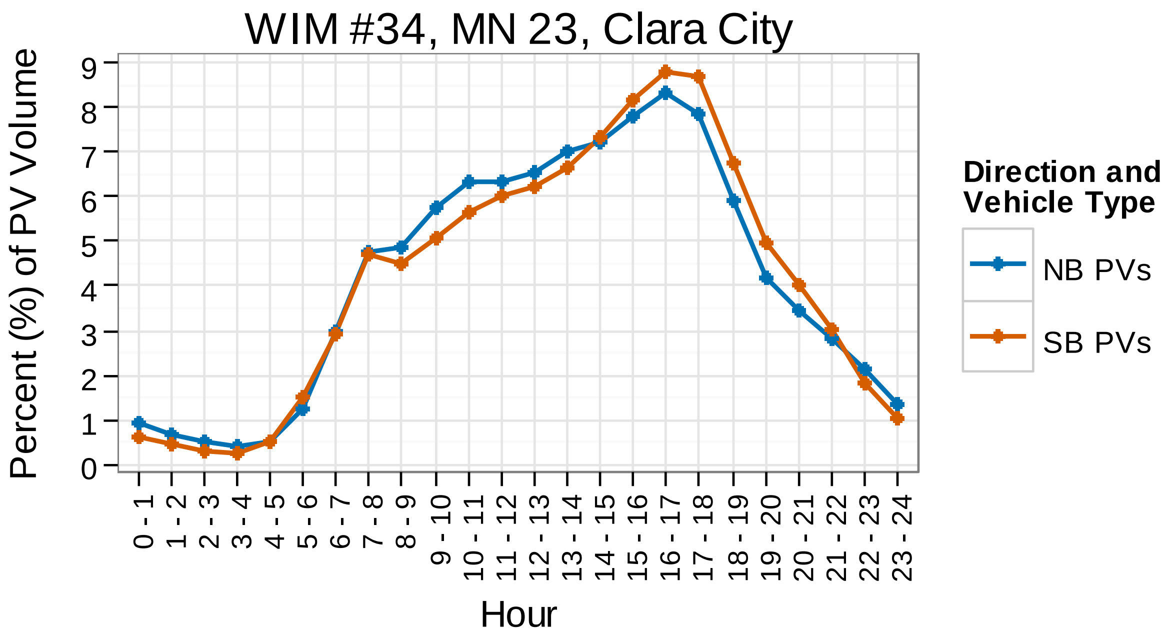


Figure 4.40a. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for passenger vehicles (PVs).

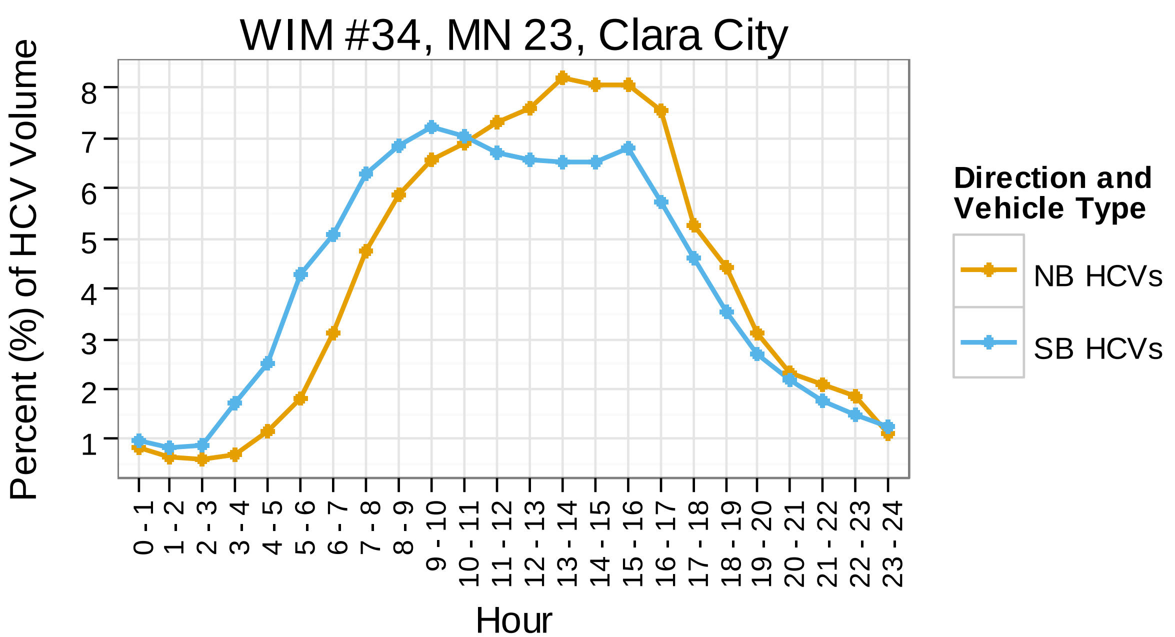


Figure 4.40b. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for heavy commercial vehicles (HCVs).

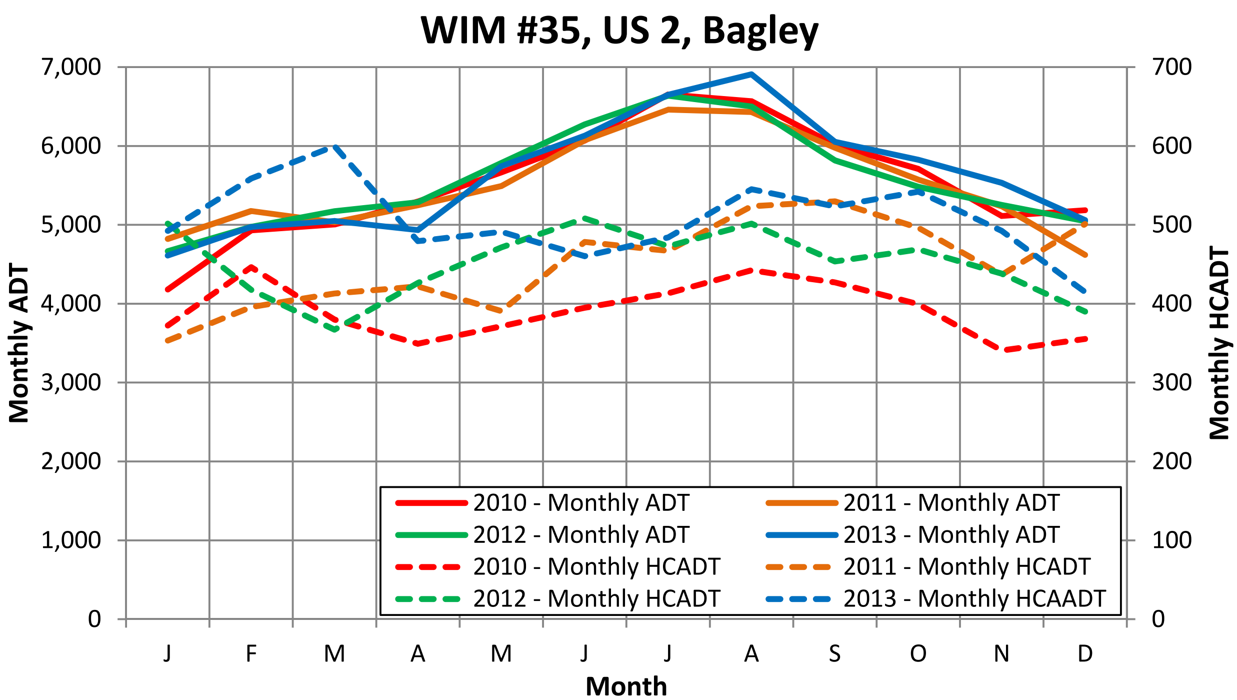


Figure 4.41. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

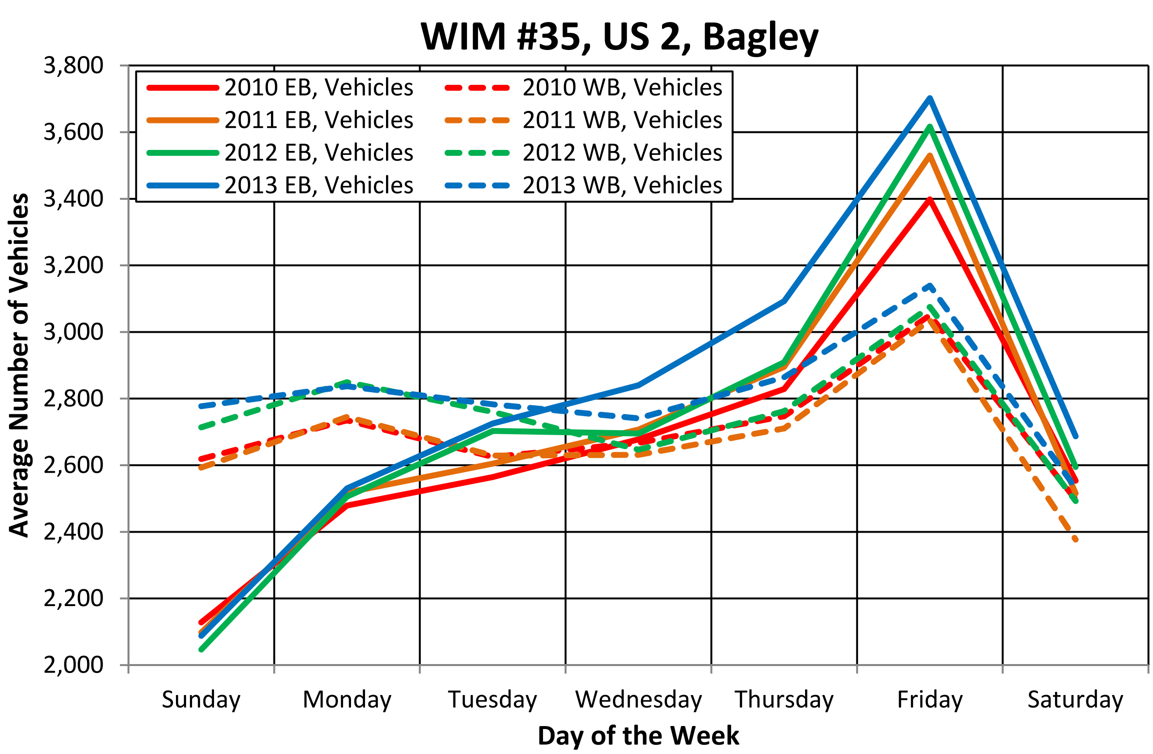


Figure 4.42. Mean number of vehicles by day of week, observed as a function of year and direction (eastbound vs. westbound; EB vs. WB).

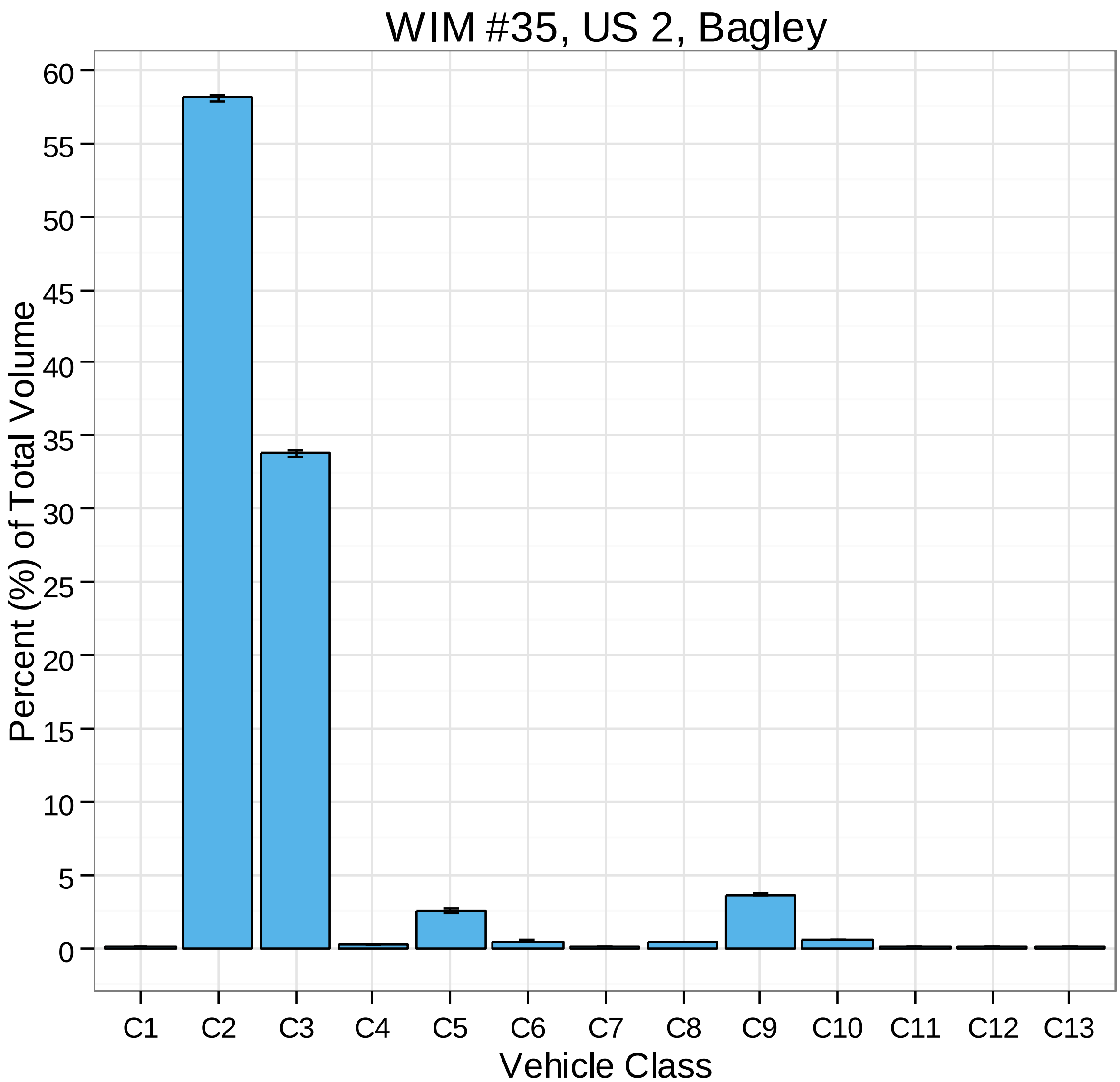


Figure 4.43. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

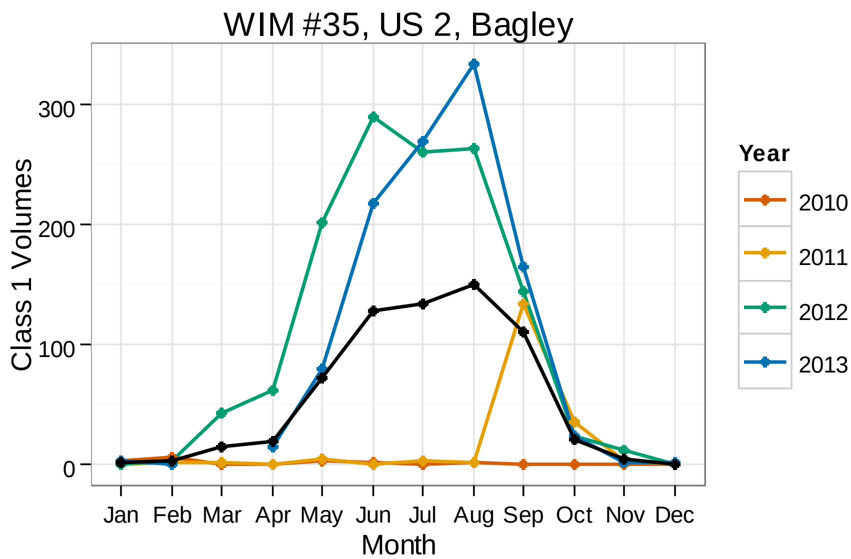


Figure 4.44a. Class 1 volume as a function of month and year. Black line represents the average volume within each month across all years.

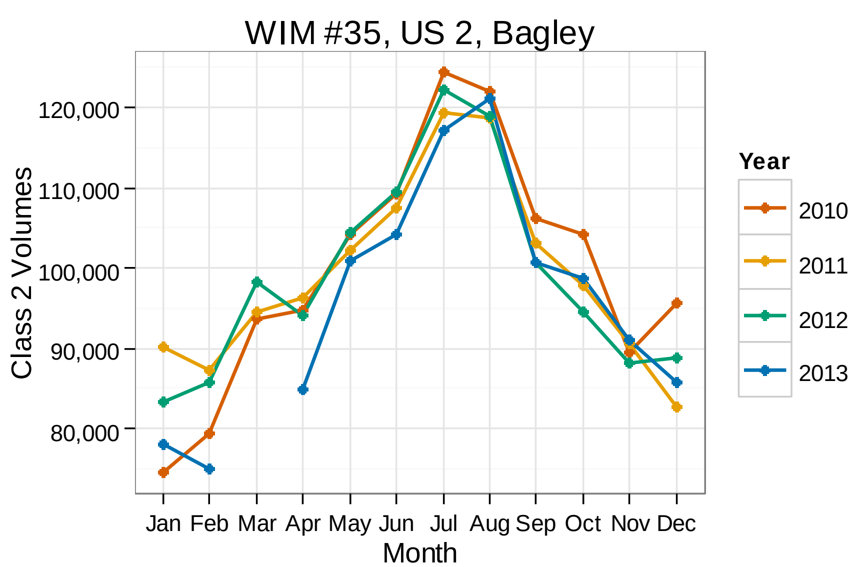


Figure 4.44b. Class 2 volume as a function of month and year.

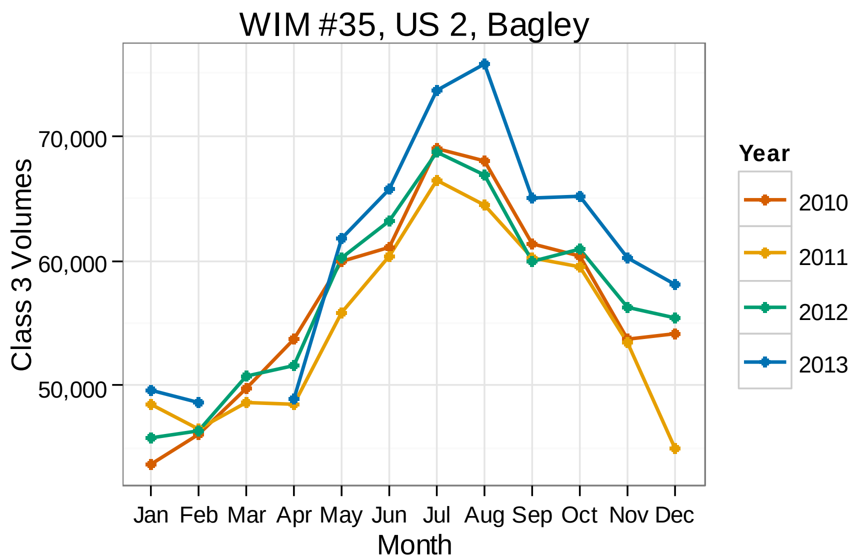


Figure 4.44c. Class 3 volume as a function of month and year.

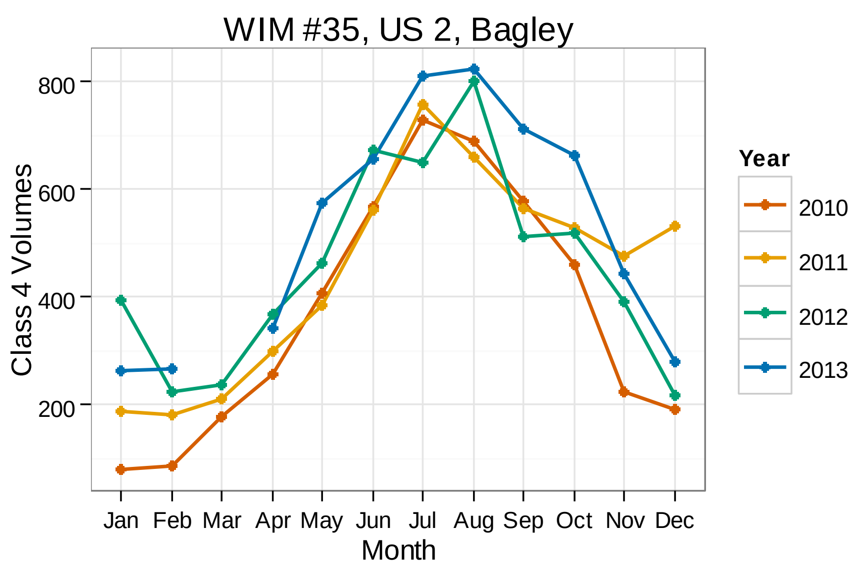


Figure 4.44d. Class 4 volume as a function of month and year.

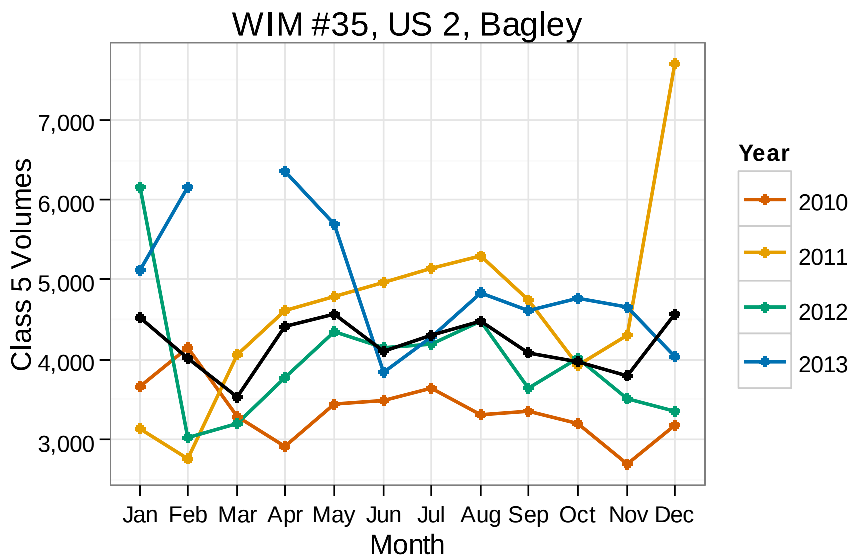


Figure 4.44e. Class 5 volume as a function of month and year. Black line represents the average volume within each month across all years.

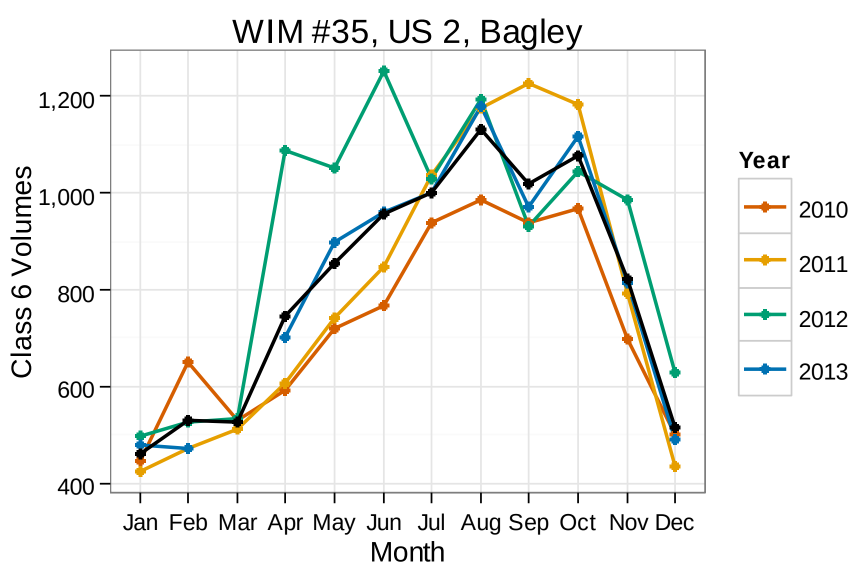


Figure 4.44f. Class 6 volume as a function of month and year. Black line represents the average volume within each month across all years.

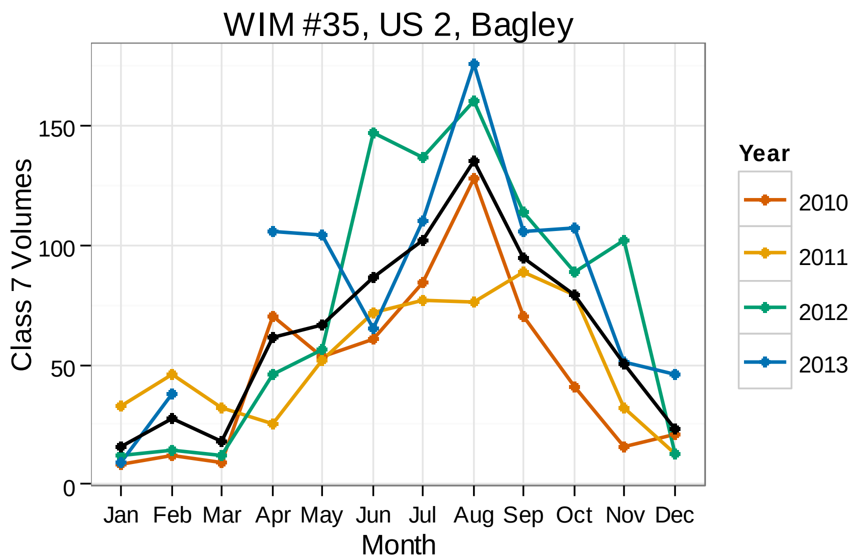


Figure 4.44g. Class 7 volume as a function of month and year. Black line represents the average volume within each month across all years.

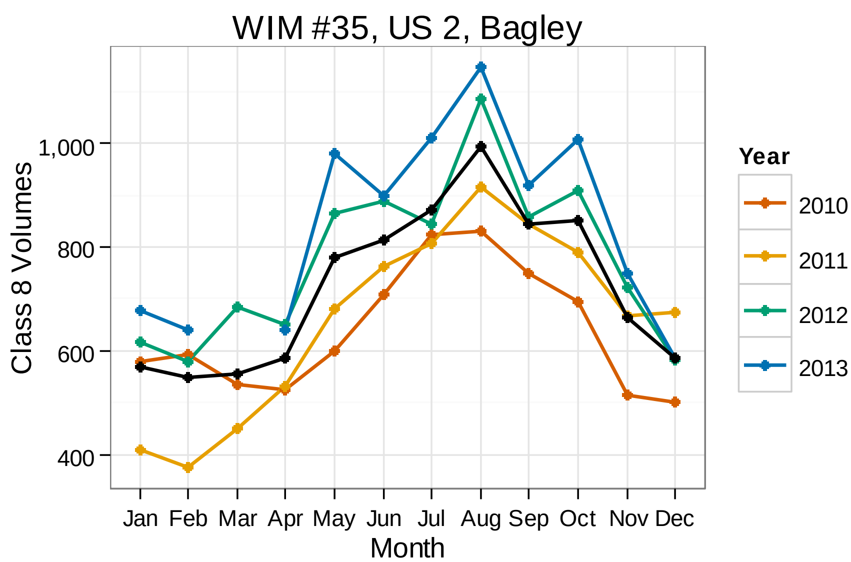


Figure 4.44h. Class 8 volume as a function of month and year. Black line represents the average volume within each month across all years.

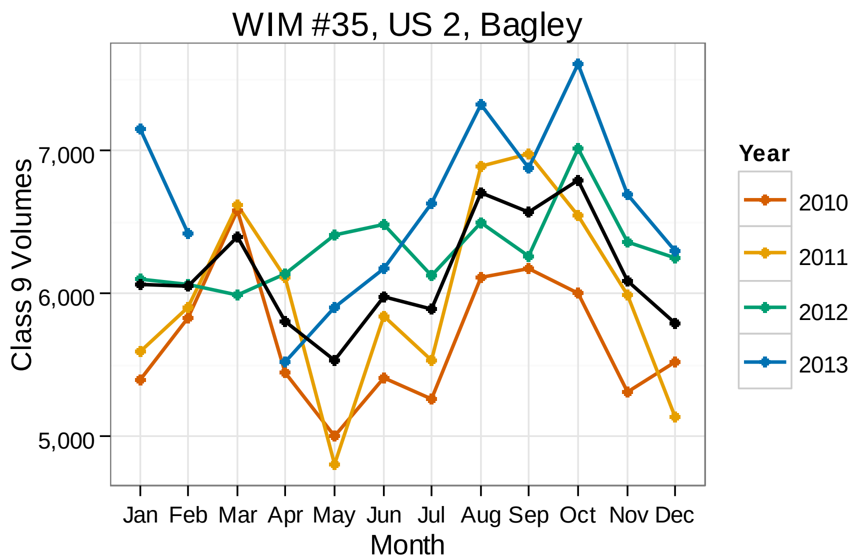


Figure 4.44i. Class 9 volume as a function of month and year. Black line represents the average volume within each month across all years.

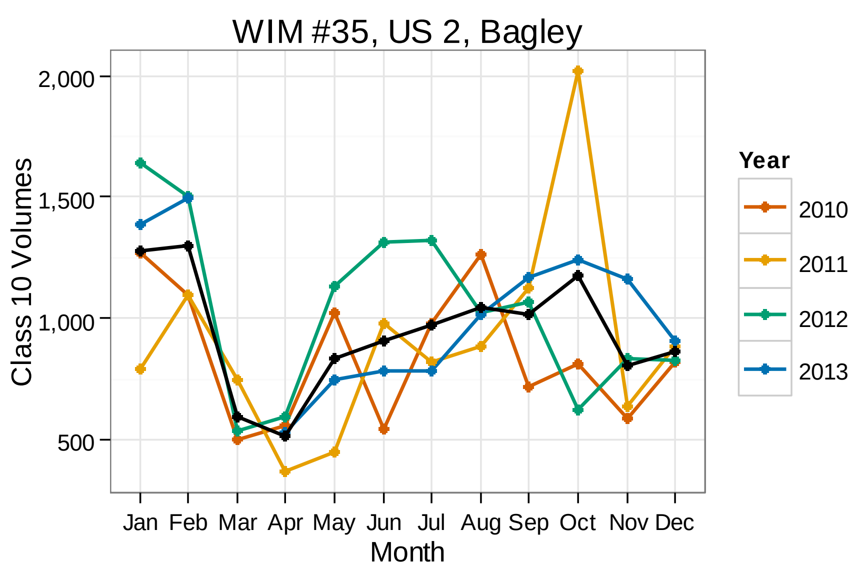


Figure 4.44j. Class 10 volume as a function of month and year. Black line represents the average volume within each month across all years.

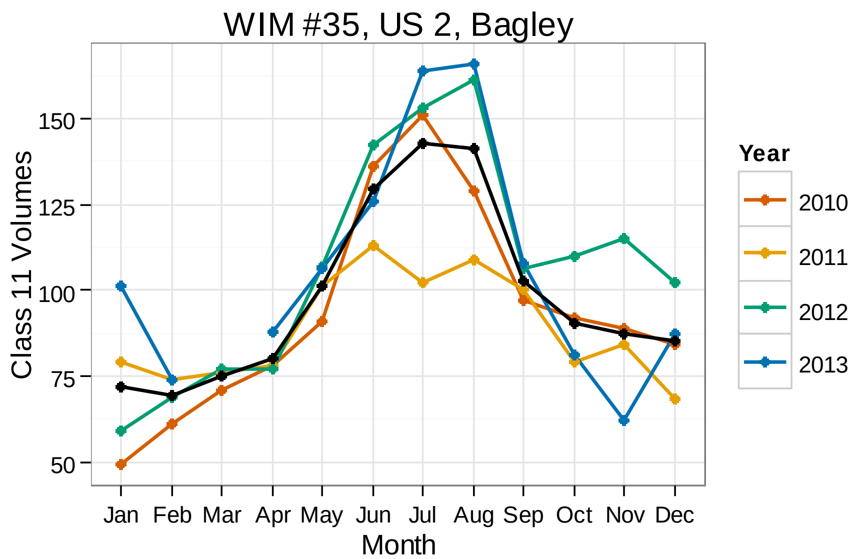


Figure 4.44k. Class 11 volume as a function of month and year. Black line represents the average volume within each month across all years.

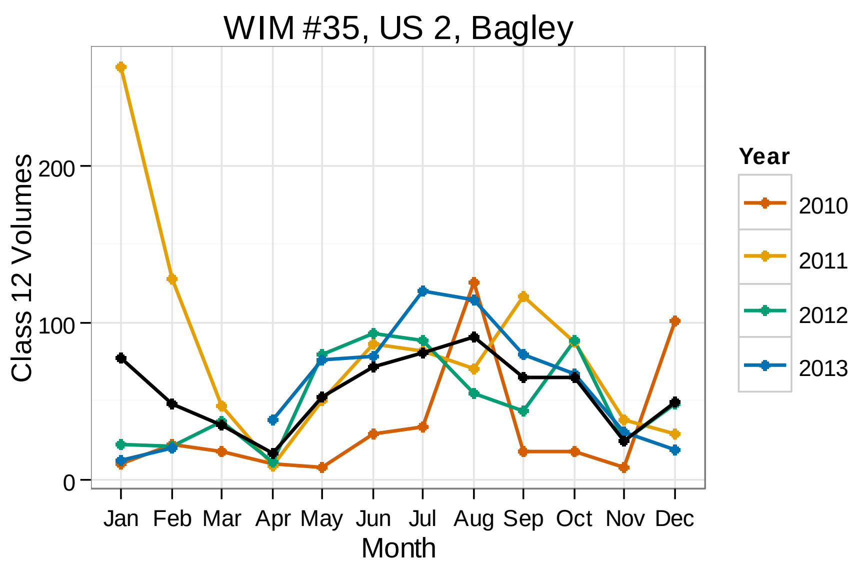


Figure 4.44l. Class 12 volume as a function of month and year. Black line represents the average volume within each month across all years.

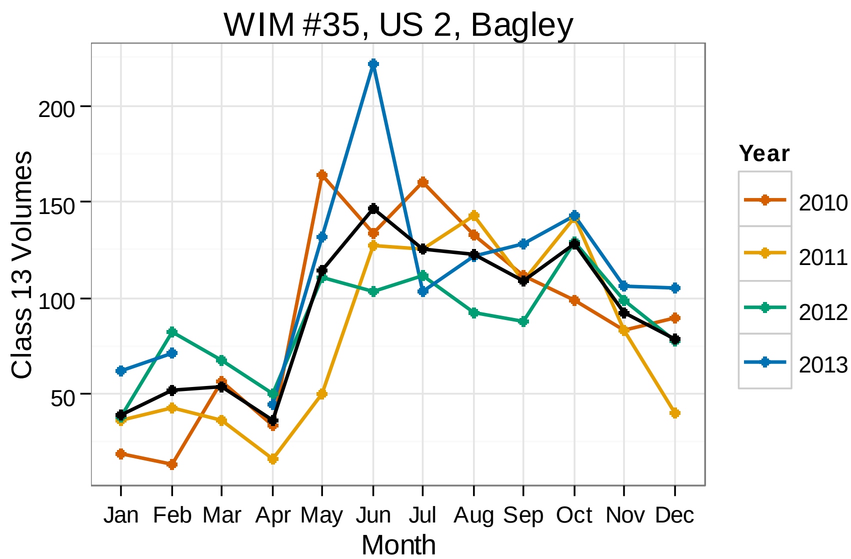


Figure 4.44m. Class 13 volume as a function of month and year. Black line represents the average volume within each month across all years.

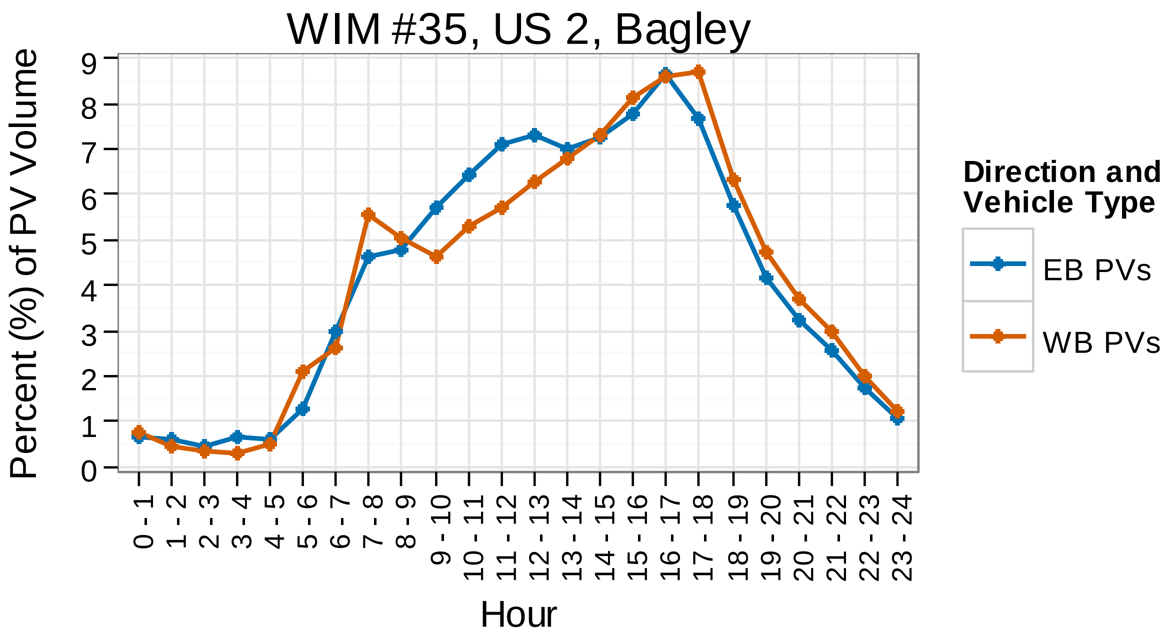


Figure 4.45a. Amount of traffic (% of volume) observed at an hourly basis for each direction (eastbound; EB vs. westbound; WB) for passenger vehicles (PVs).

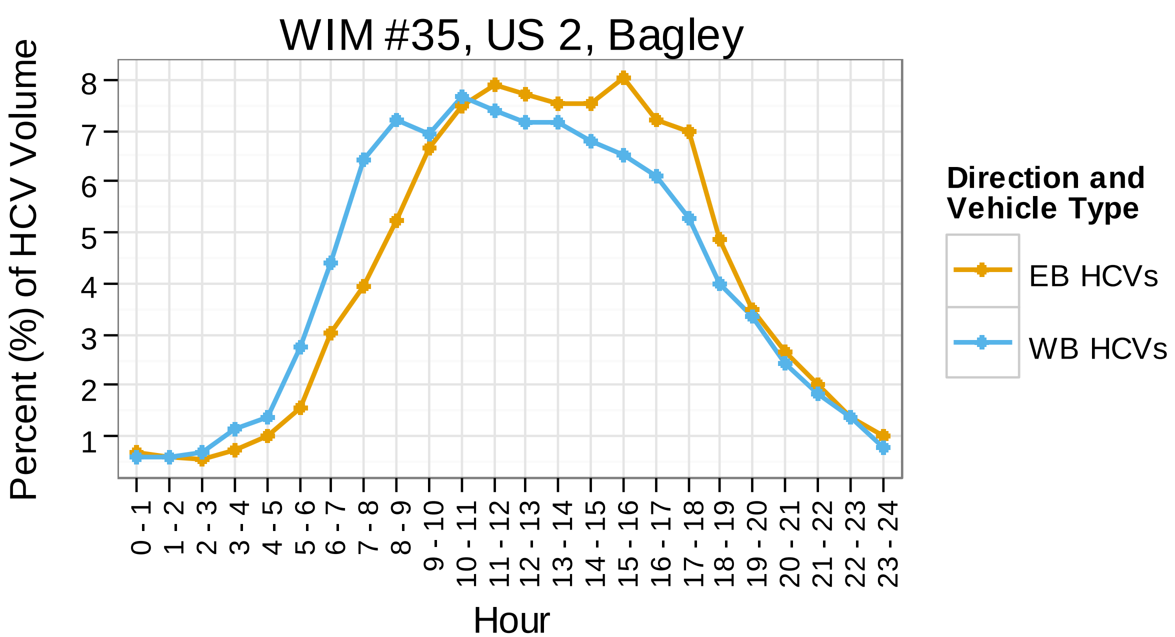


Figure 4.45b. Amount of traffic (% of volume) observed at an hourly basis for each direction (eastbound; EB vs. westbound; WB) for heavy commercial vehicles (HCVs).

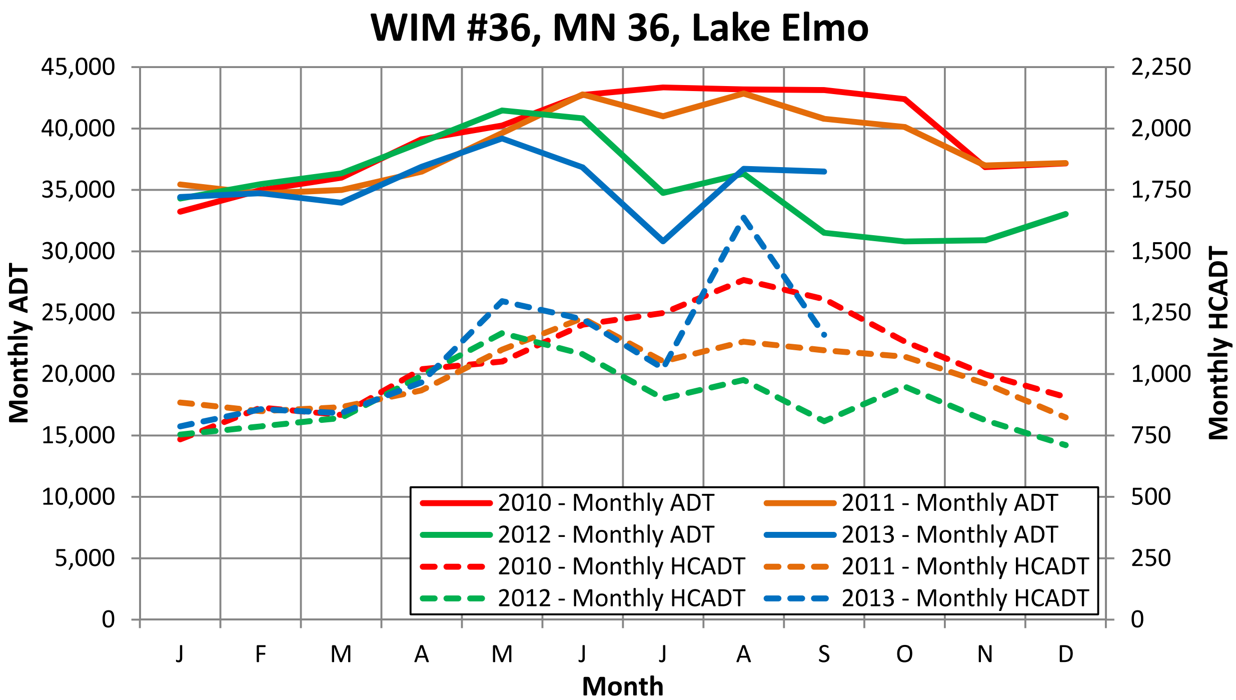


Figure 4.46. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

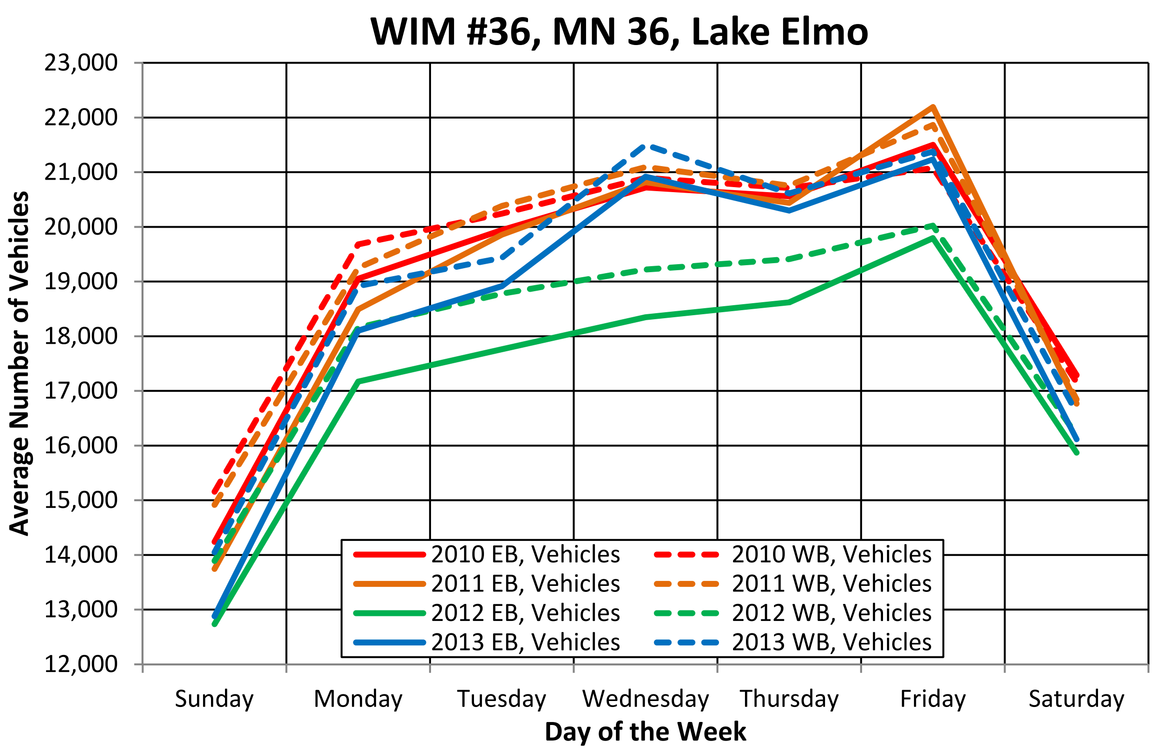


Figure 4.47. Mean number of vehicles by day of week, observed as a function of year and direction (eastbound vs. westbound; EB vs. WB).

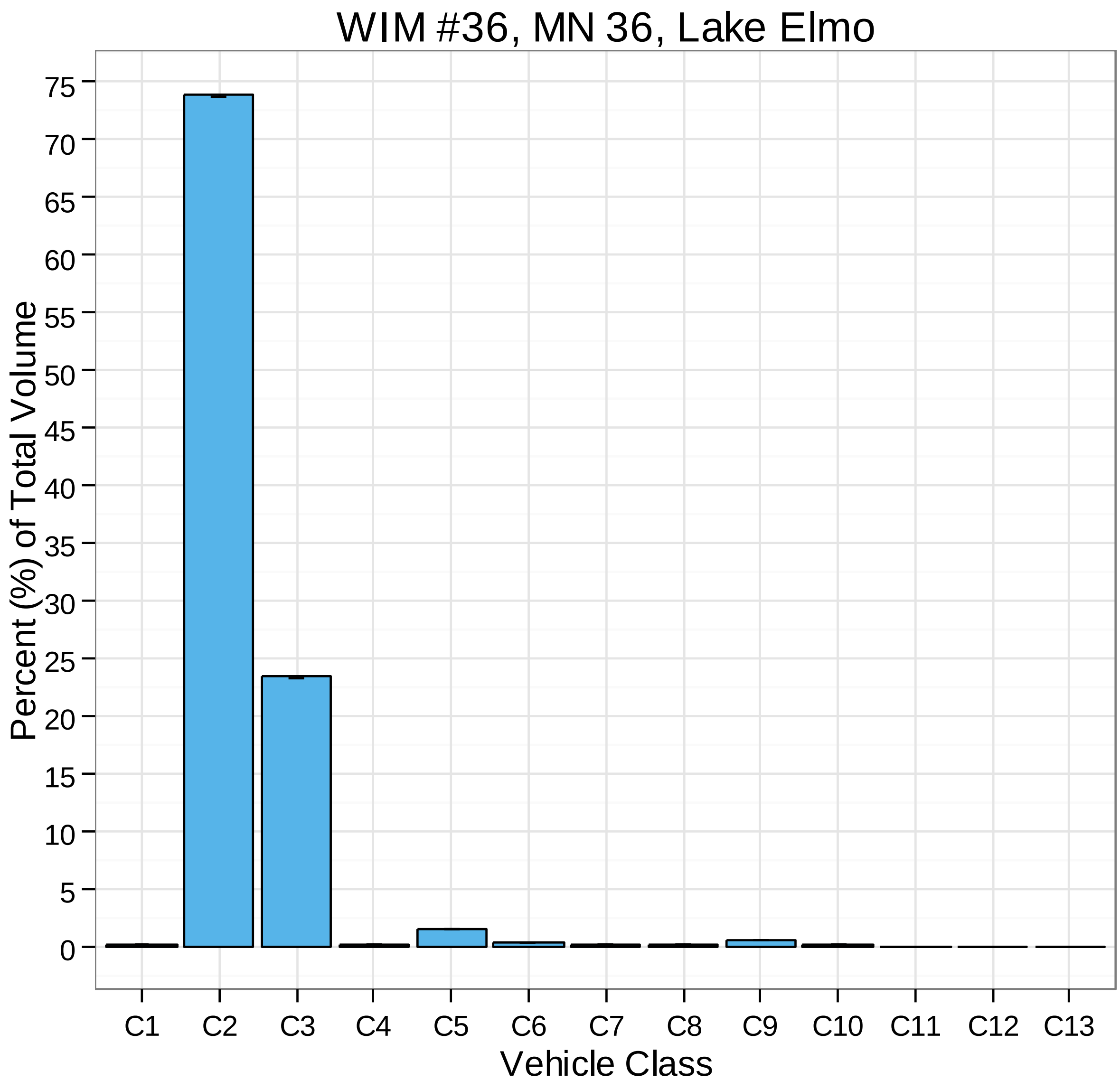


Figure 4.48. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

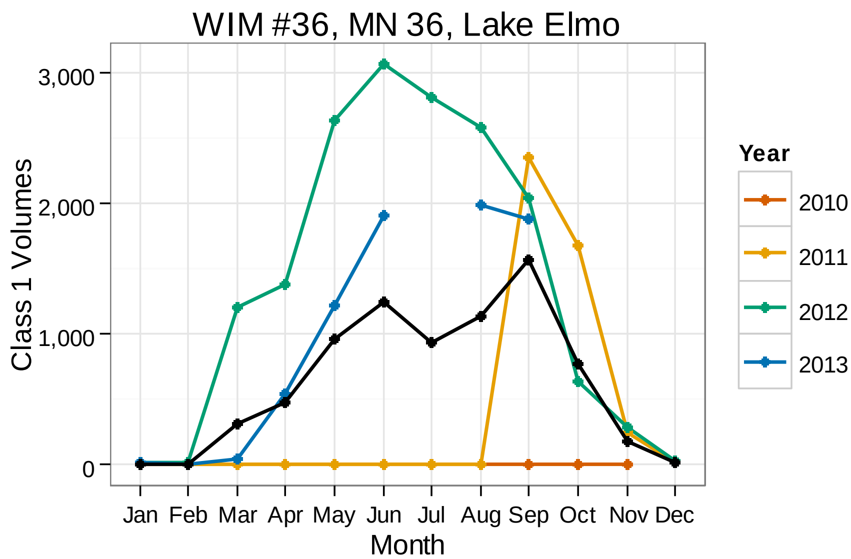


Figure 4.49a. Class 1 volume as a function of month and year. Black line represents the average volume within each month across all years.

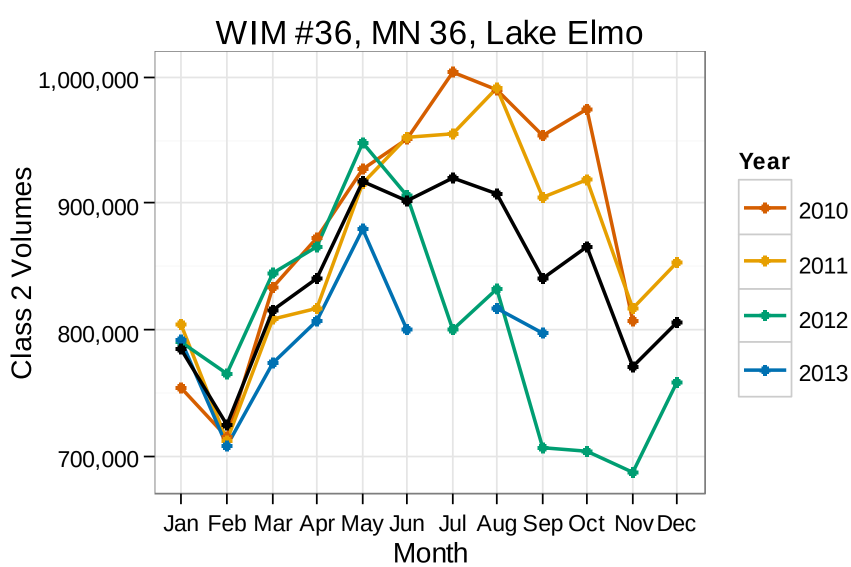


Figure 4.49b. Class 2 volume as a function of month and year. Black line represents the average volume within each month across all years.

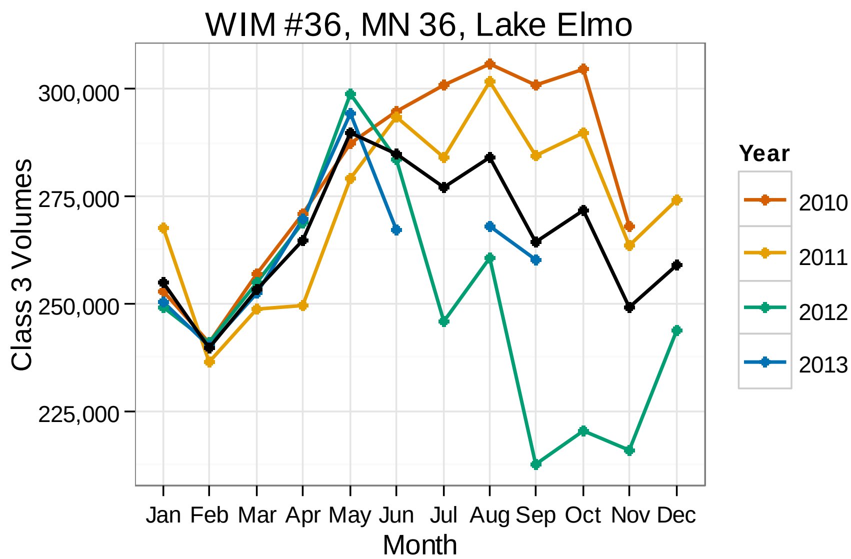


Figure 4.49c. Class 3 volume as a function of month and year. Black line represents the average volume within each month across all years.

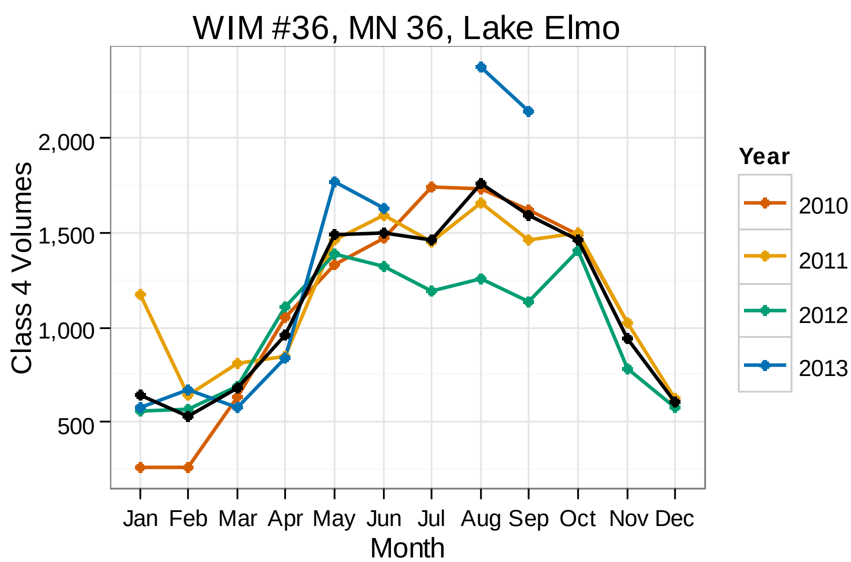


Figure 4.49d. Class 4 volume as a function of month and year. Black line represents the average volume within each month across all years.

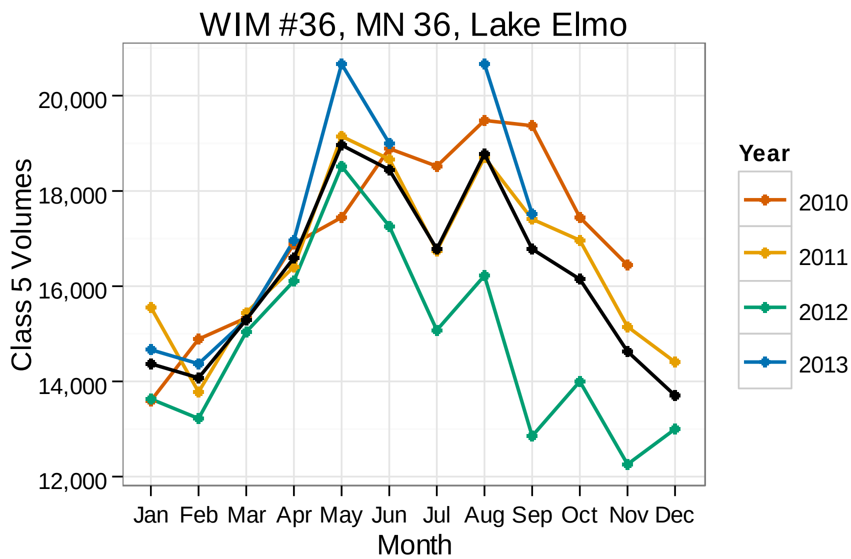


Figure 4.49e. Class 5 volume as a function of month and year. Black line represents the average volume within each month across all years.

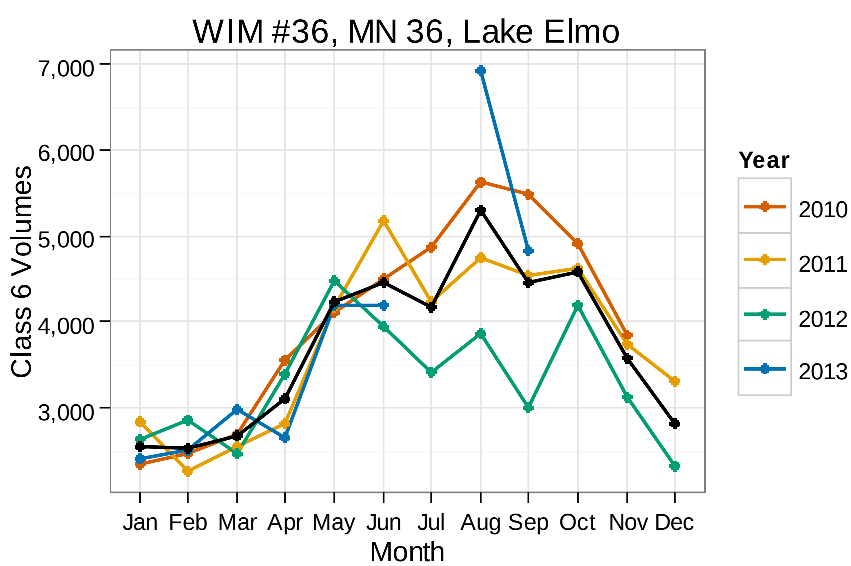


Figure 4.49f. Class 6 volume as a function of month and year. Black line represents the average volume within each month across all years.

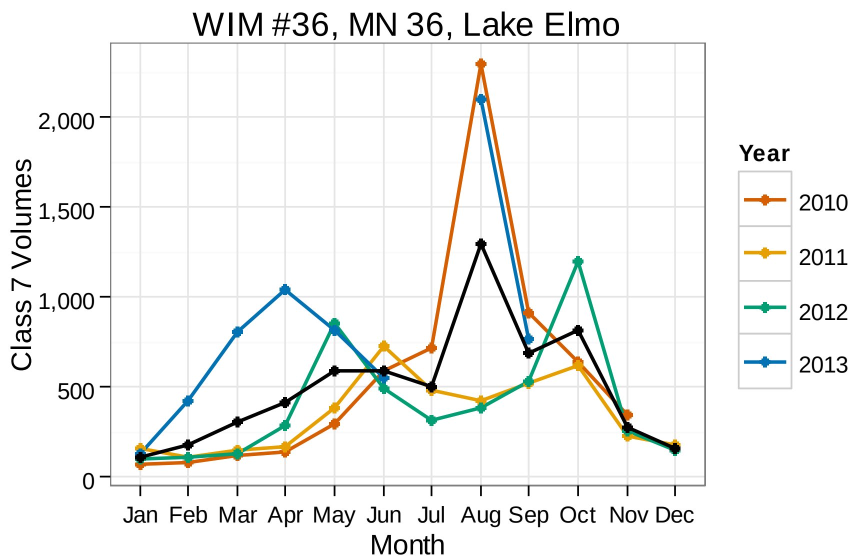


Figure 4.49g. Class 7 volume as a function of month and year. Black line represents the average volume within each month across all years.

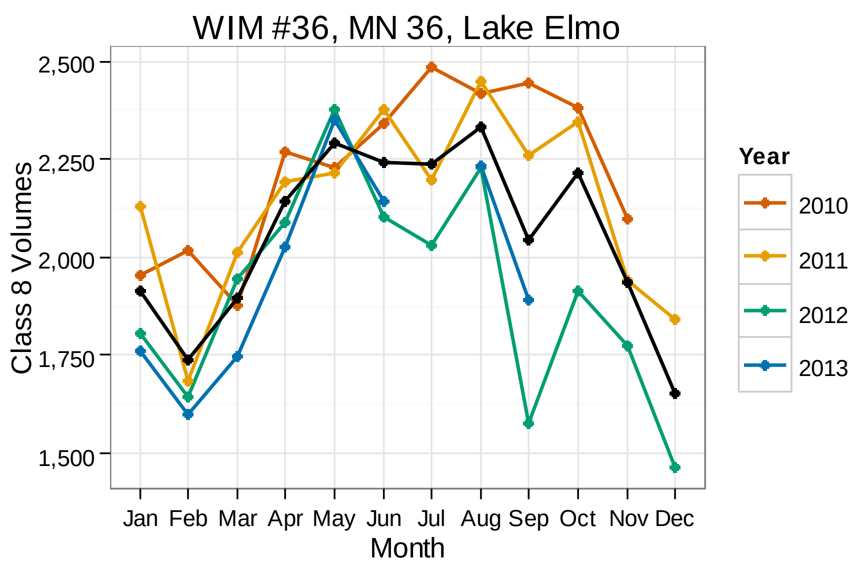


Figure 4.49h. Class 8 volume as a function of month and year. Black line represents the average volume within each month across all years.

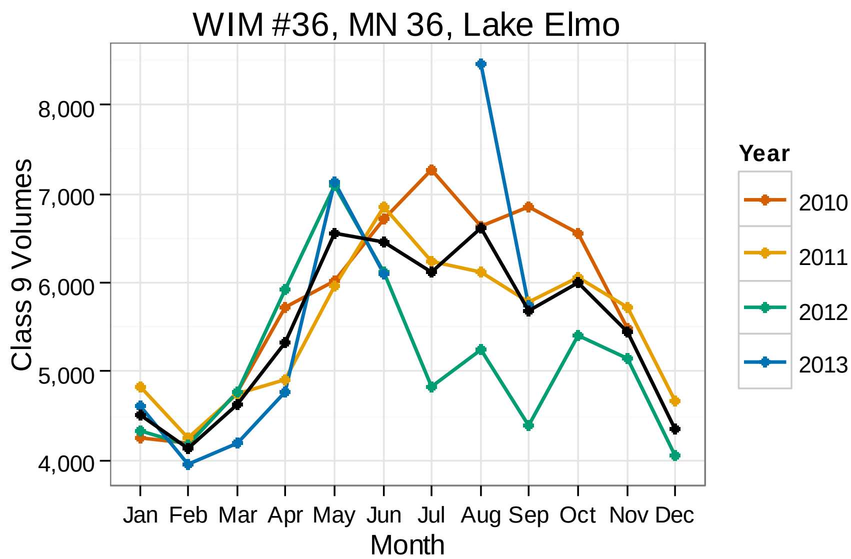


Figure 4.49i. Class 9 volume as a function of month and year. Black line represents the average volume within each month across all years.

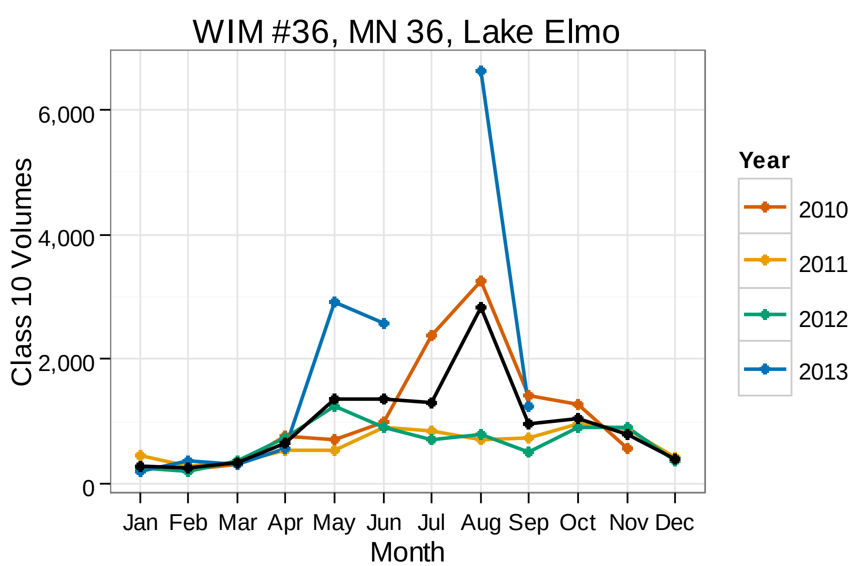


Figure 4.49j. Class 10 volume as a function of month and year. Black line represents the average volume within each month across all years.

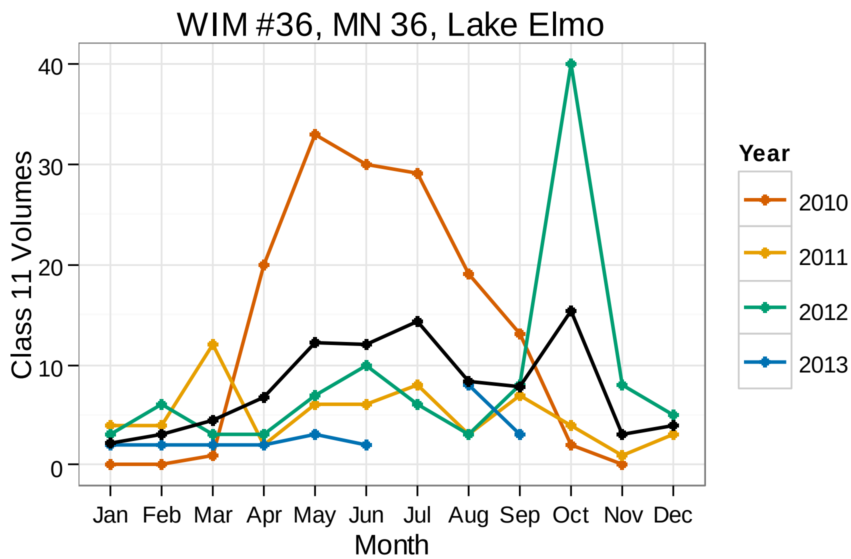


Figure 4.49k. Class 11 volume as a function of month and year. Black line represents the average volume within each month across all years.

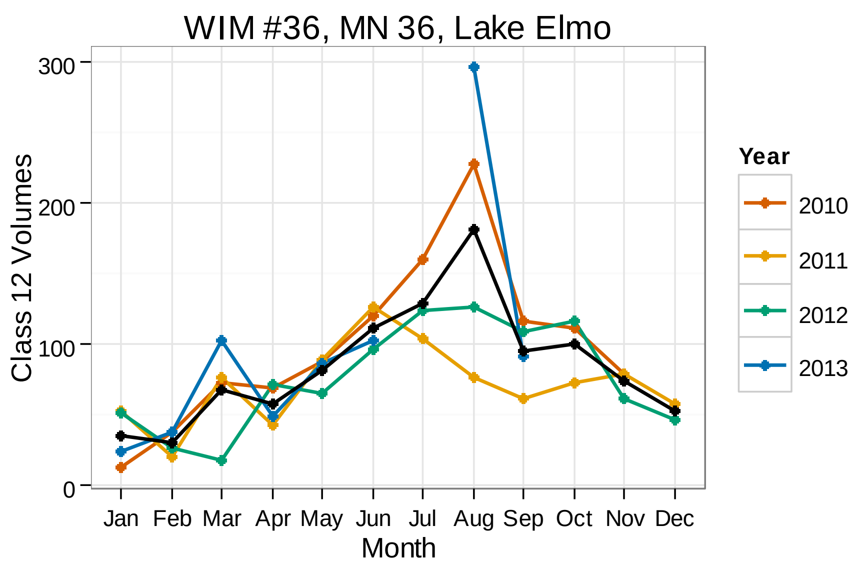


Figure 4.49l. Class 12 volume as a function of month and year. Black line represents the average volume within each month across all years.

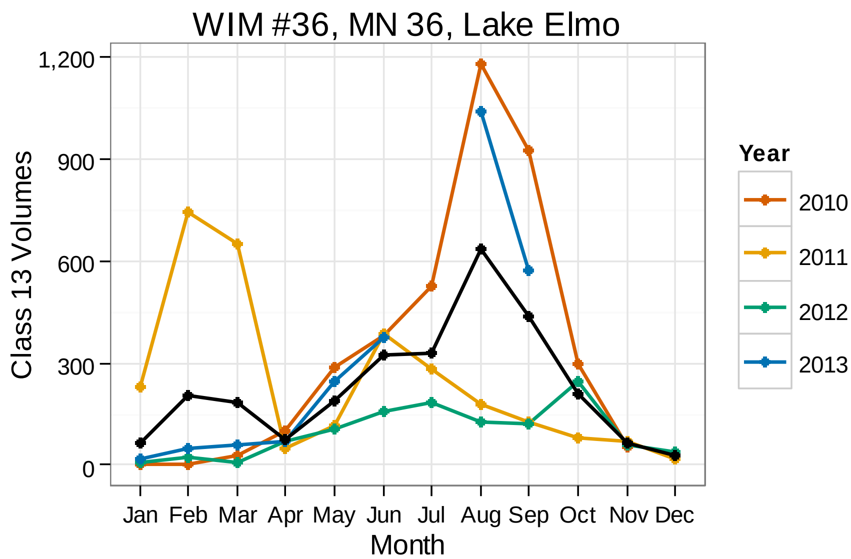


Figure 4.49m. Class 13 volume as a function of month and year. Black line represents the average volume within each month across all years.

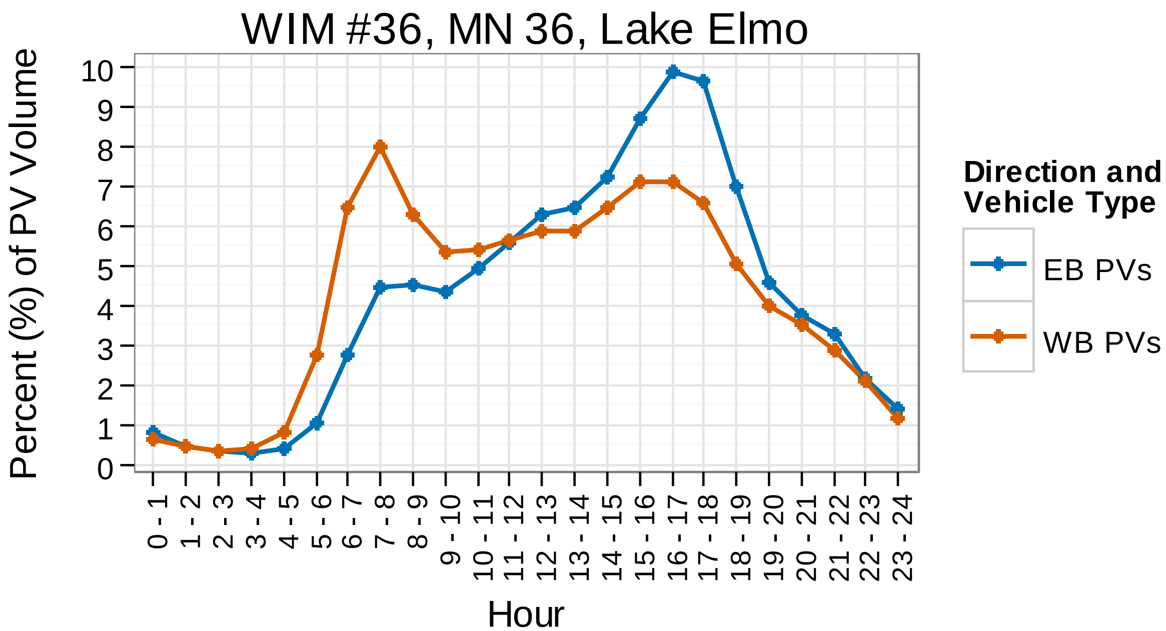


Figure 4.50a. Amount of traffic (% of volume) observed at an hourly basis for each direction (eastbound; EB vs. westbound; WB) for passenger vehicles (PVs).

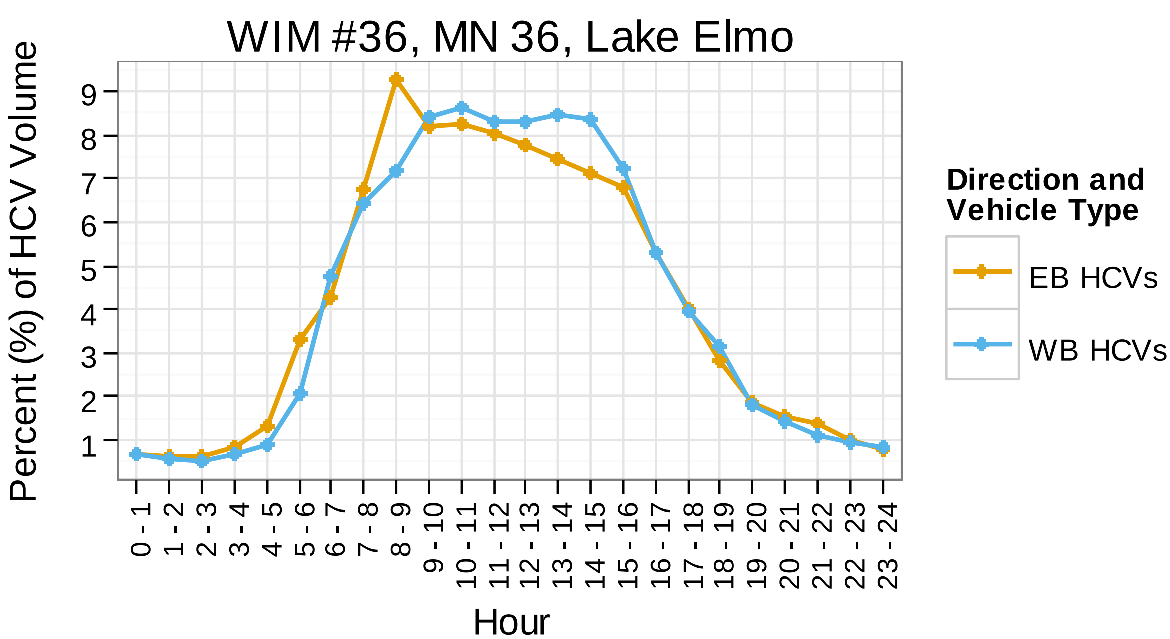


Figure 4.50b. Amount of traffic (% of volume) observed at an hourly basis for each direction (eastbound; EB vs. westbound; WB) for heavy commercial vehicles (HCVs).

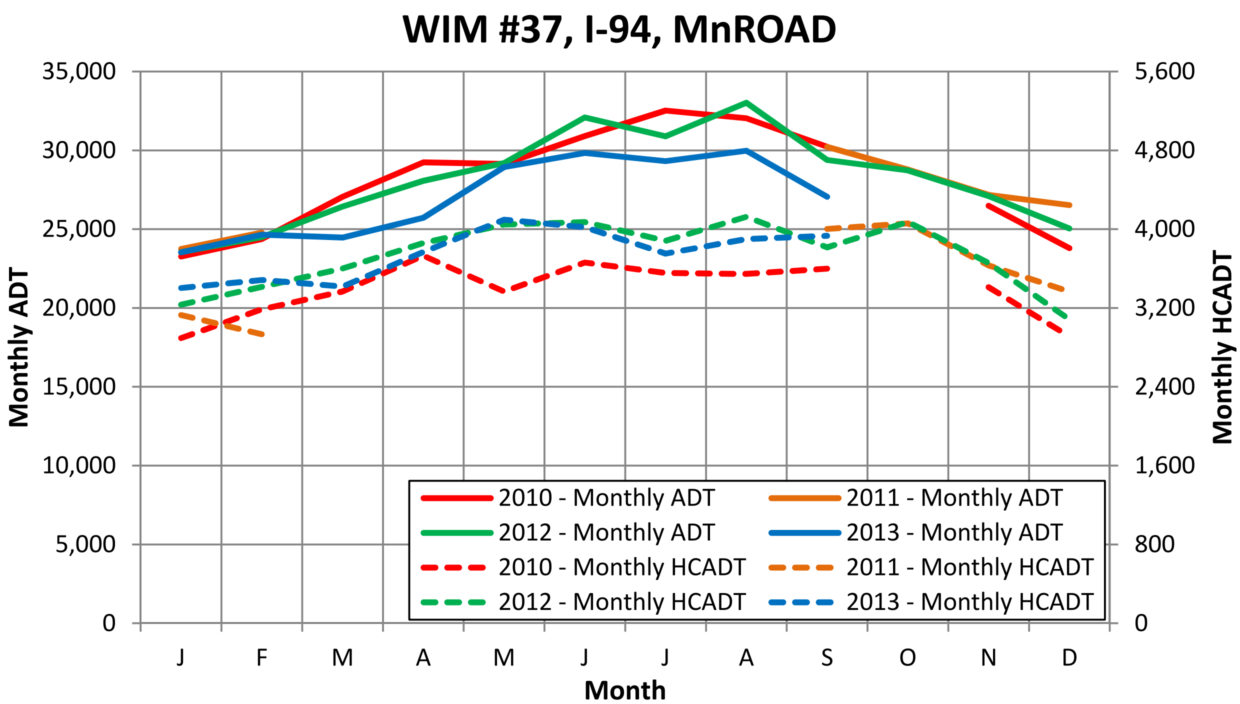


Figure 4.51. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

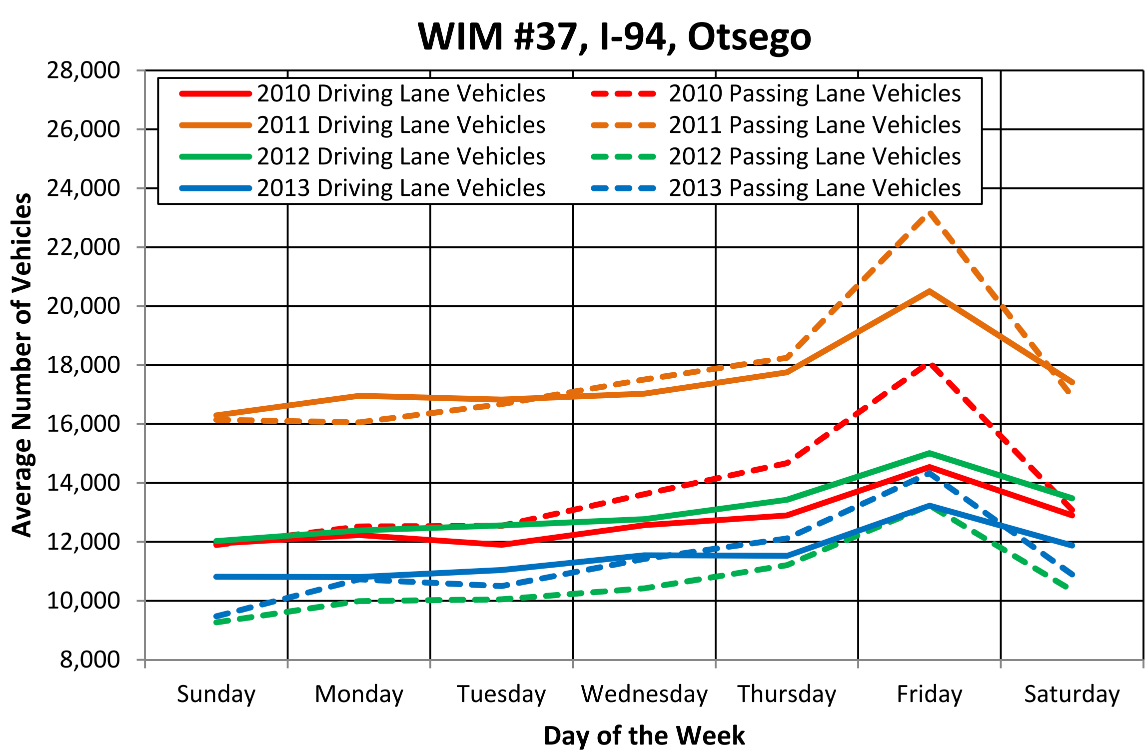


Figure 4.52. Mean number of vehicles by day of week, observed as a function of year and direction (westbound; WB). [In-pavement WIM scale only exists in the WB lane at this site]

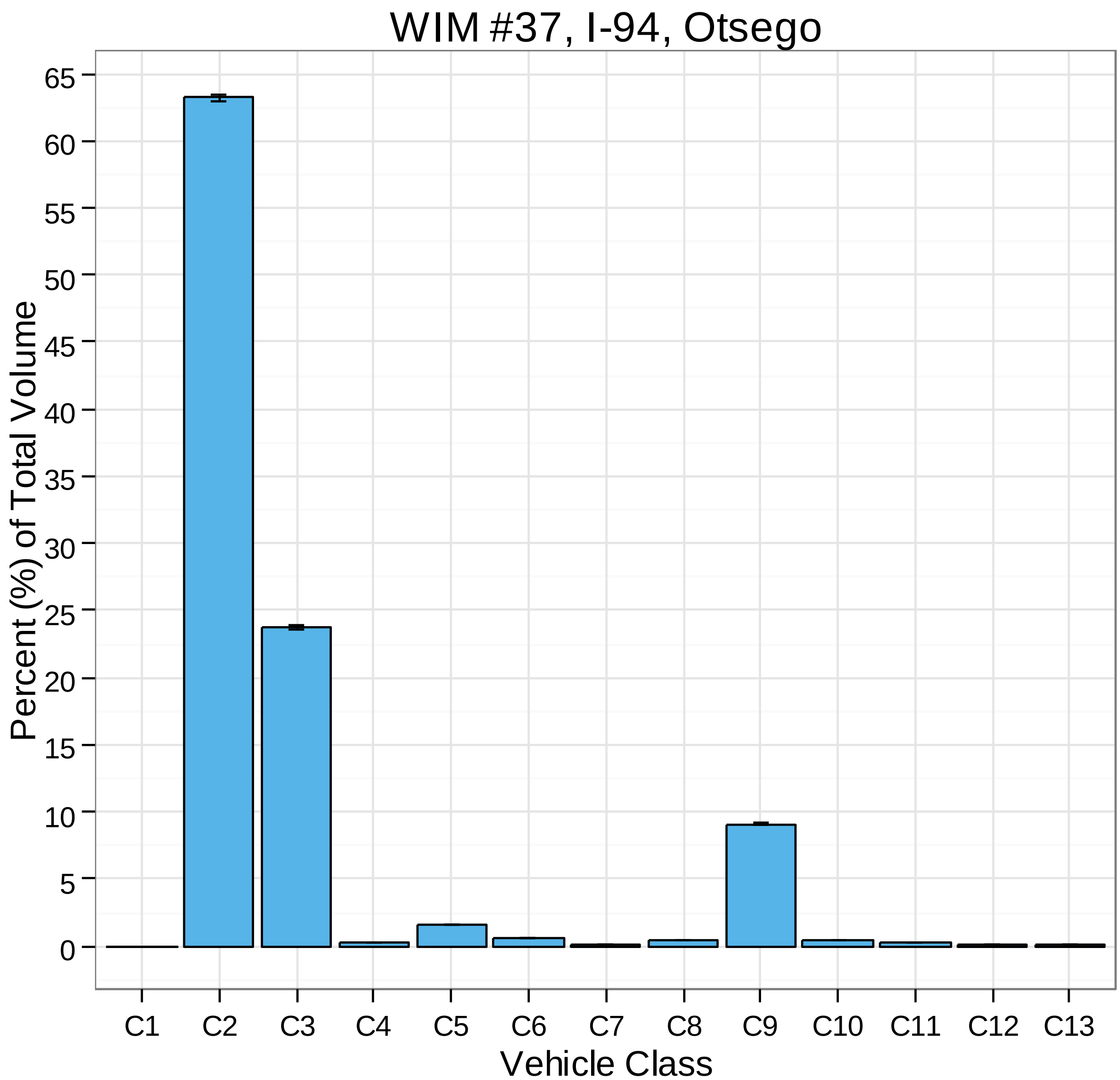


Figure 4.53. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

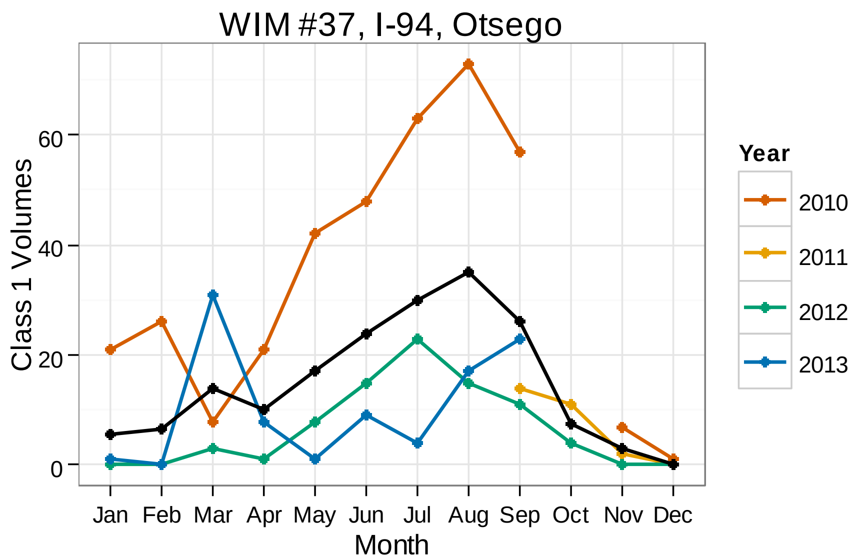


Figure 4.54a. Class 1 volume as a function of month and year. Black line represents the average volume within each month across all years.

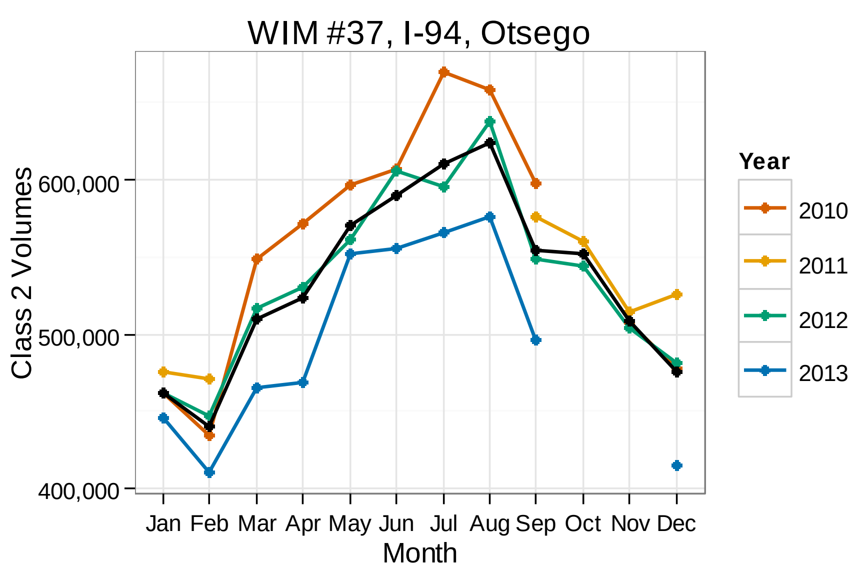


Figure 4.54b. Class 2 volume as a function of month and year. Black line represents the average volume within each month across all years.

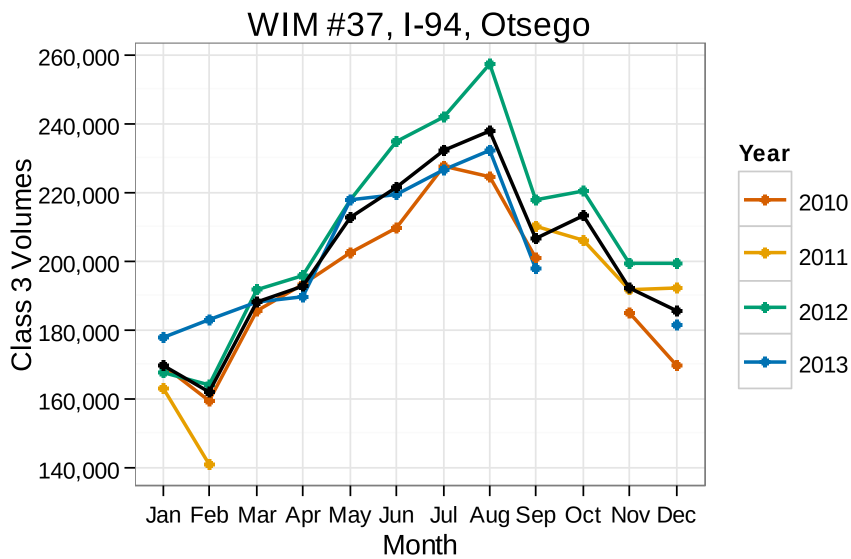


Figure 4.54c. Class 3 volume as a function of month and year. Black line represents the average volume within each month across all years.

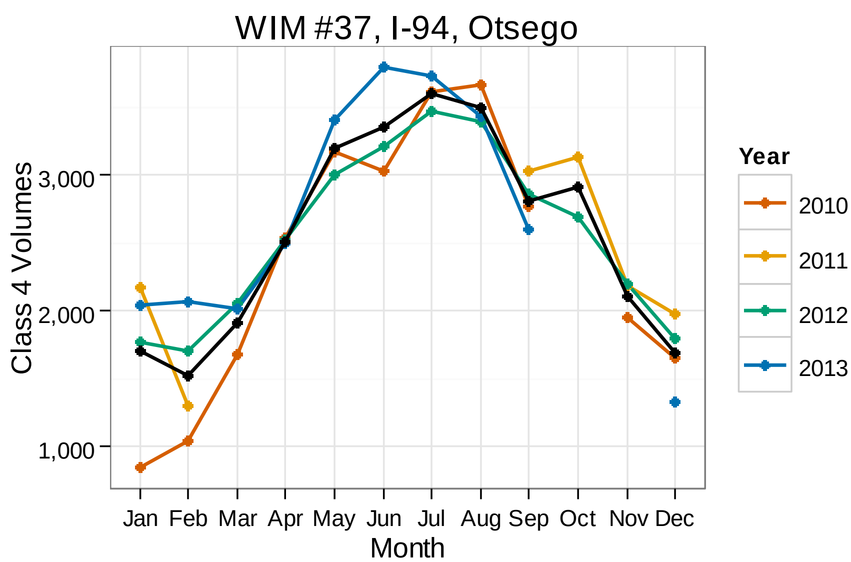


Figure 4.54d. Class 4 volume as a function of month and year. Black line represents the average volume within each month across all years.

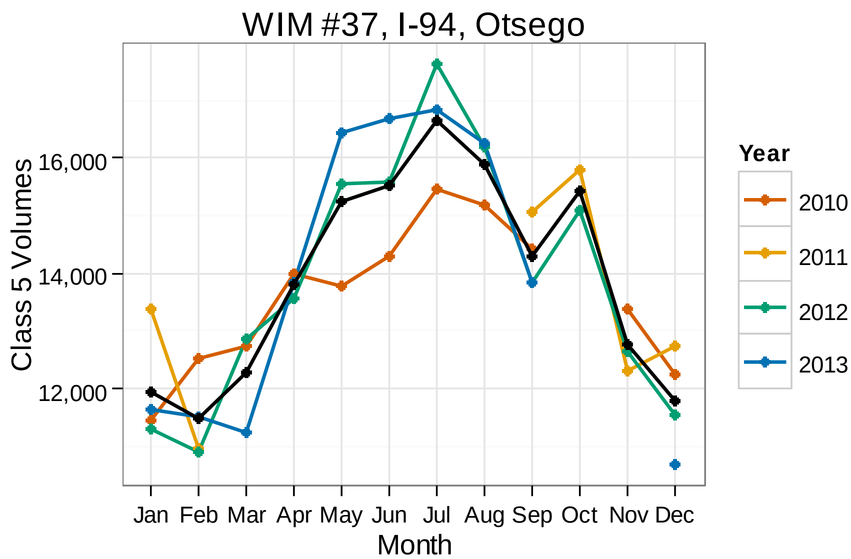


Figure 4.54e. Class 5 volume as a function of month and year. Black line represents the average volume within each month across all years.

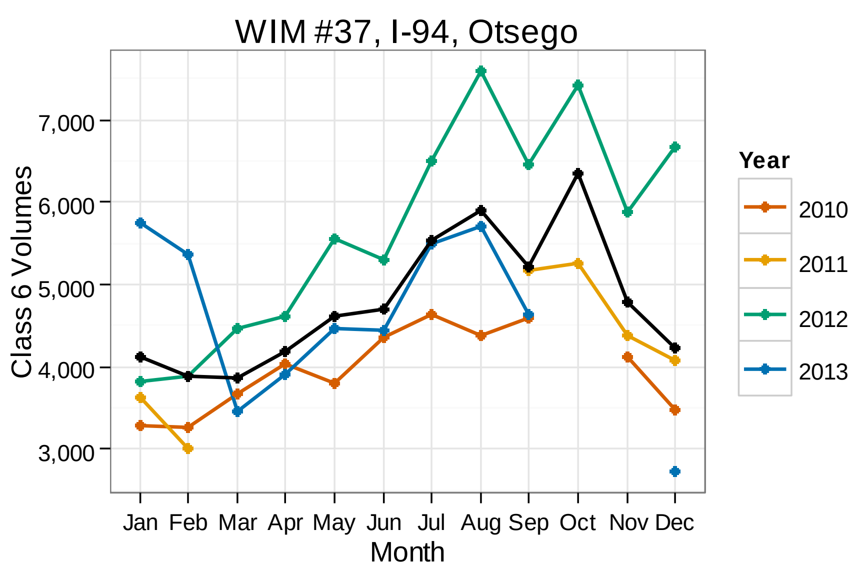


Figure 4.54f. Class 6 volume as a function of month and year. Black line represents the average volume within each month across all years.

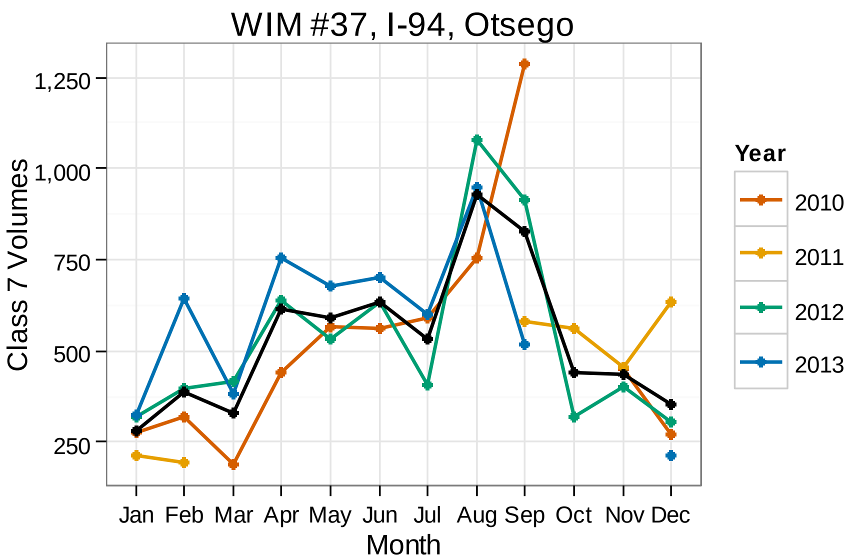


Figure 4.54g. Class 7 volume as a function of month and year. Black line represents the average volume within each month across all years.

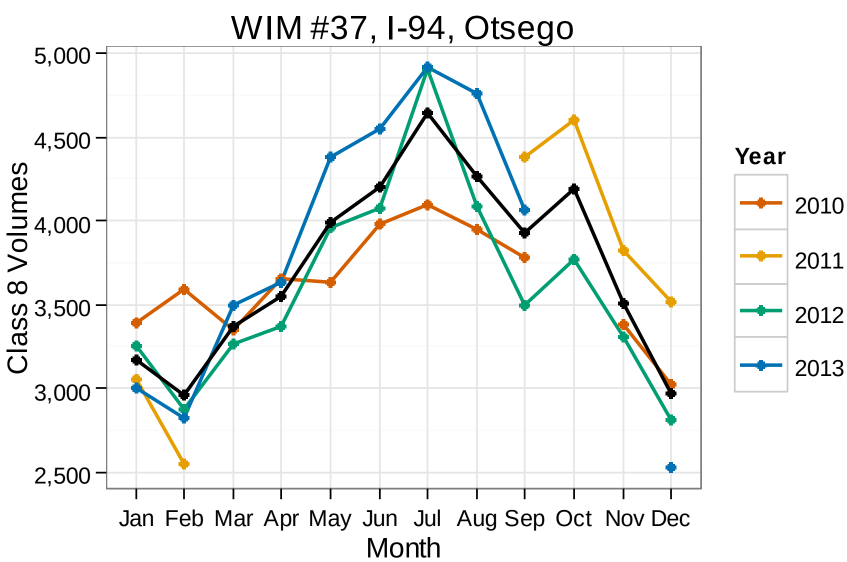


Figure 4.54h. Class 8 volume as a function of month and year. Black line represents the average volume within each month across all years.

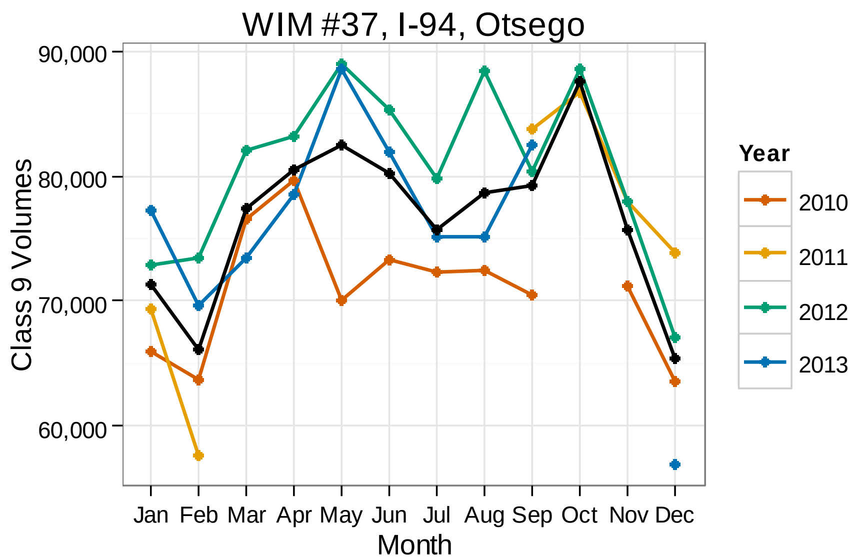


Figure 4.54i. Class 9 volume as a function of month and year. Black line represents the average volume within each month across all years.

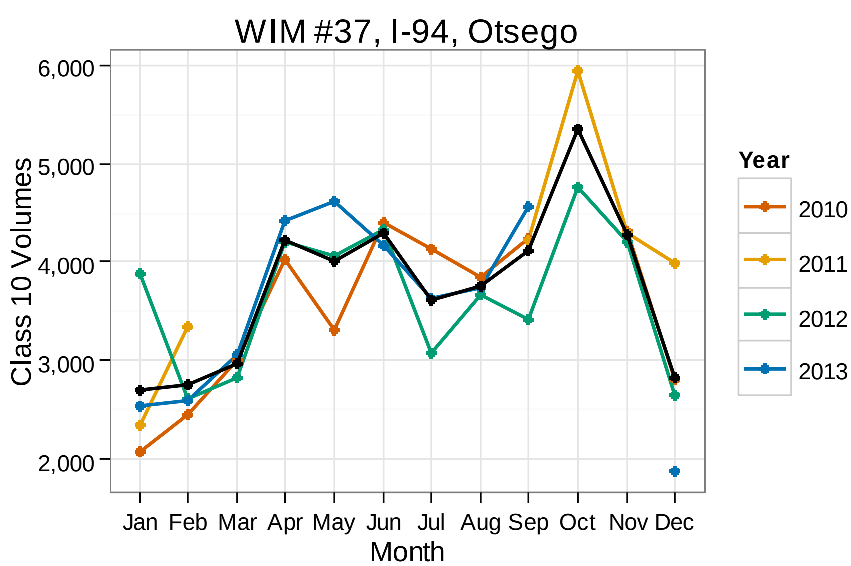


Figure 4.54j. Class 10 volume as a function of month and year. Black line represents the average volume within each month across all years.

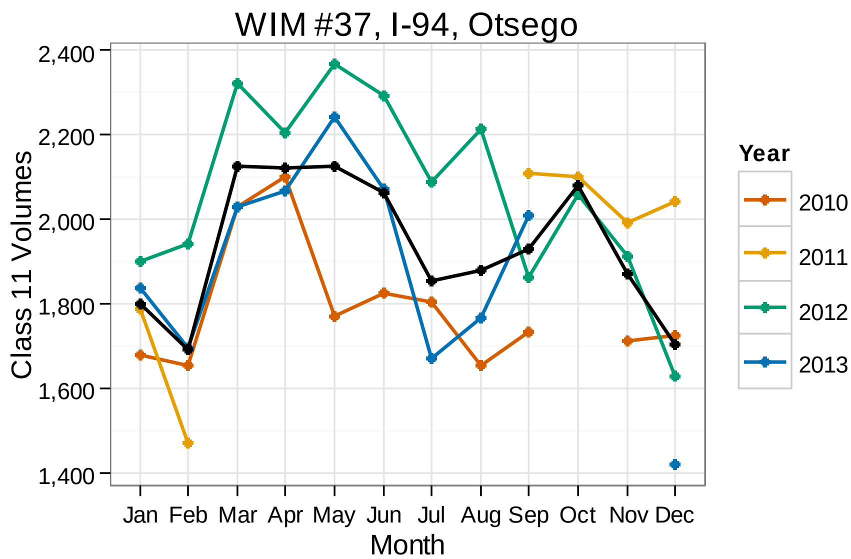


Figure 4.54k. Class 11 volume as a function of month and year. Black line represents the average volume within each month across all years.

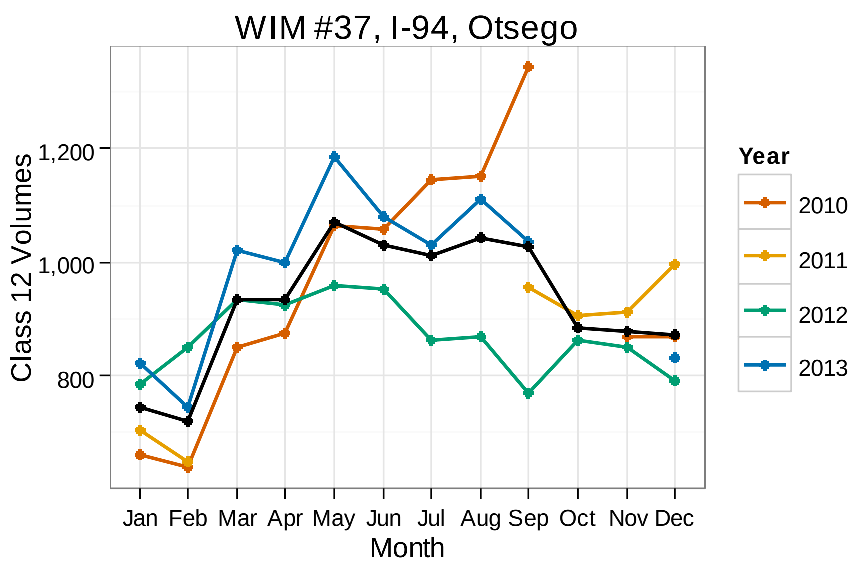


Figure 4.54l. Class 12 volume as a function of month and year. Black line represents the average volume within each month across all years.

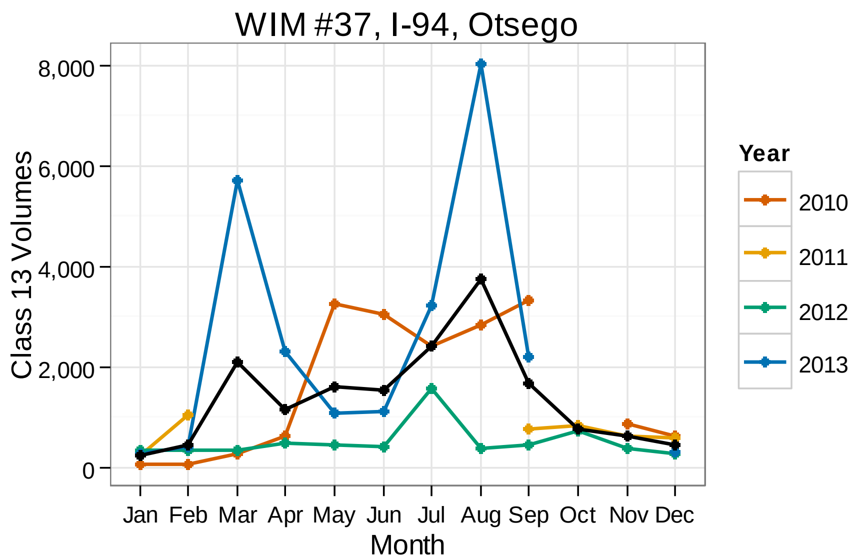


Figure 4.54m. Class 13 volume as a function of month and year. Black line represents the average volume within each month across all years.

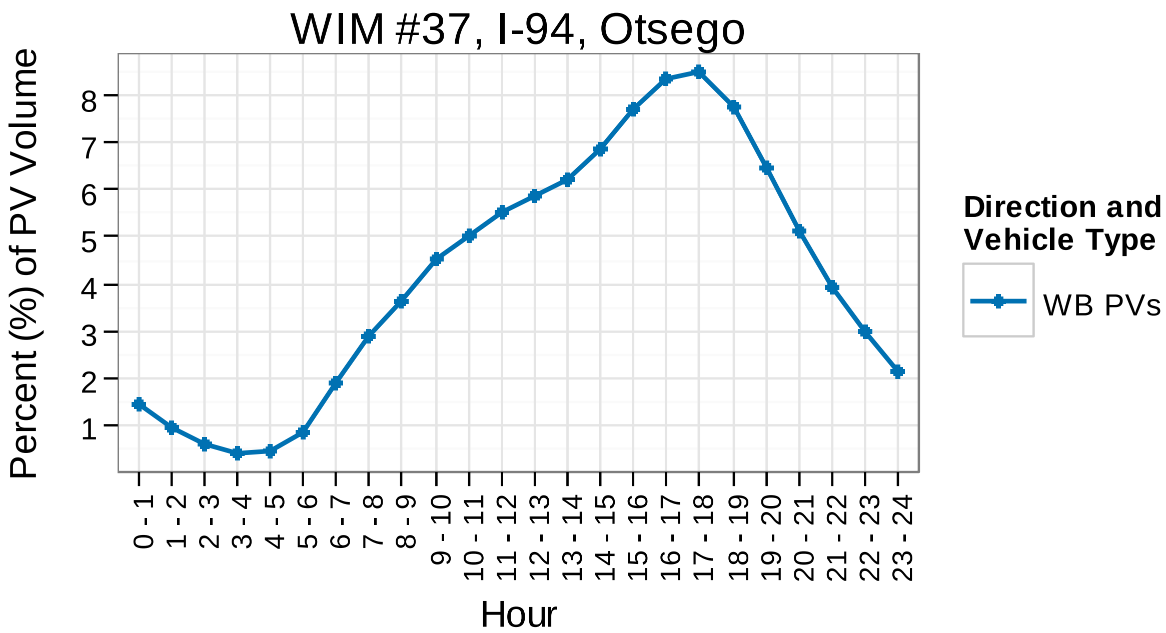


Figure 4.55a. Amount of traffic (% of volume) observed at an hourly basis in the westbound (WB) direction for passenger vehicles (PVs).

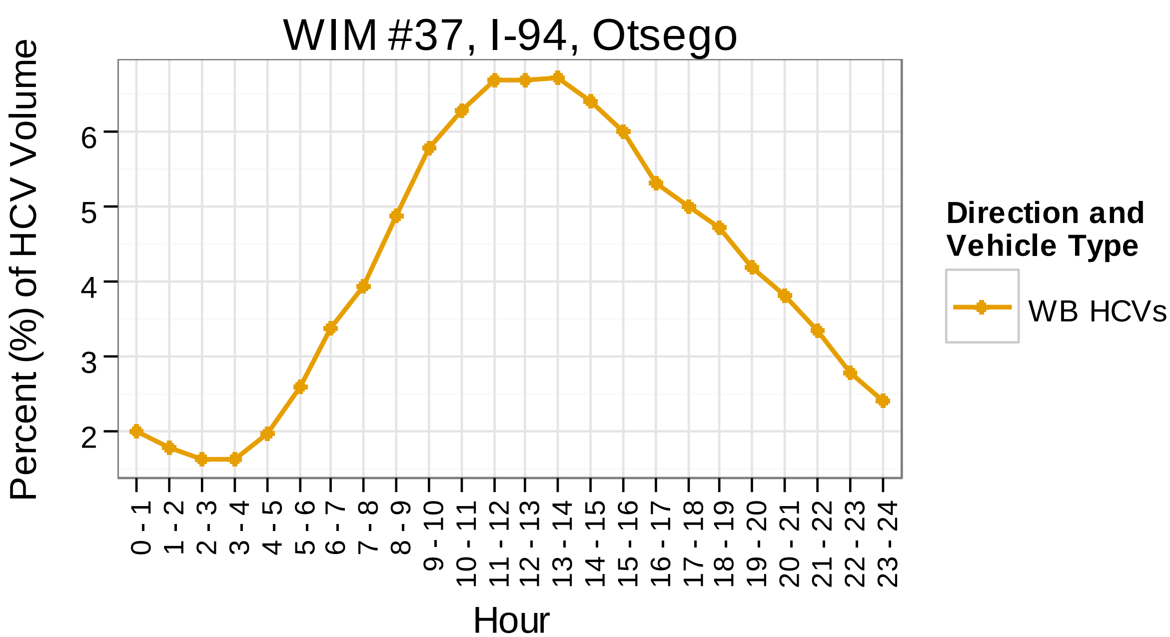


Figure 4.55b. Amount of traffic (% of volume) observed at an hourly basis in the westbound (WB) direction for heavy commercial vehicles (HCVs).

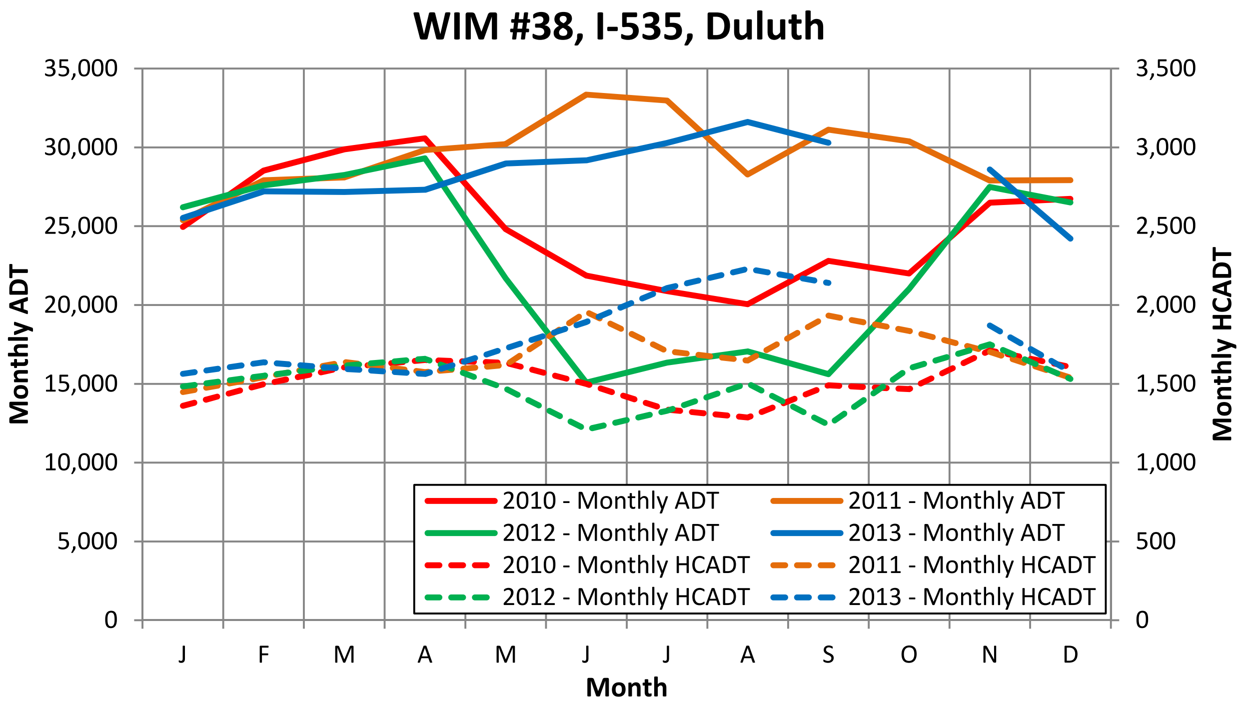


Figure 4.56. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

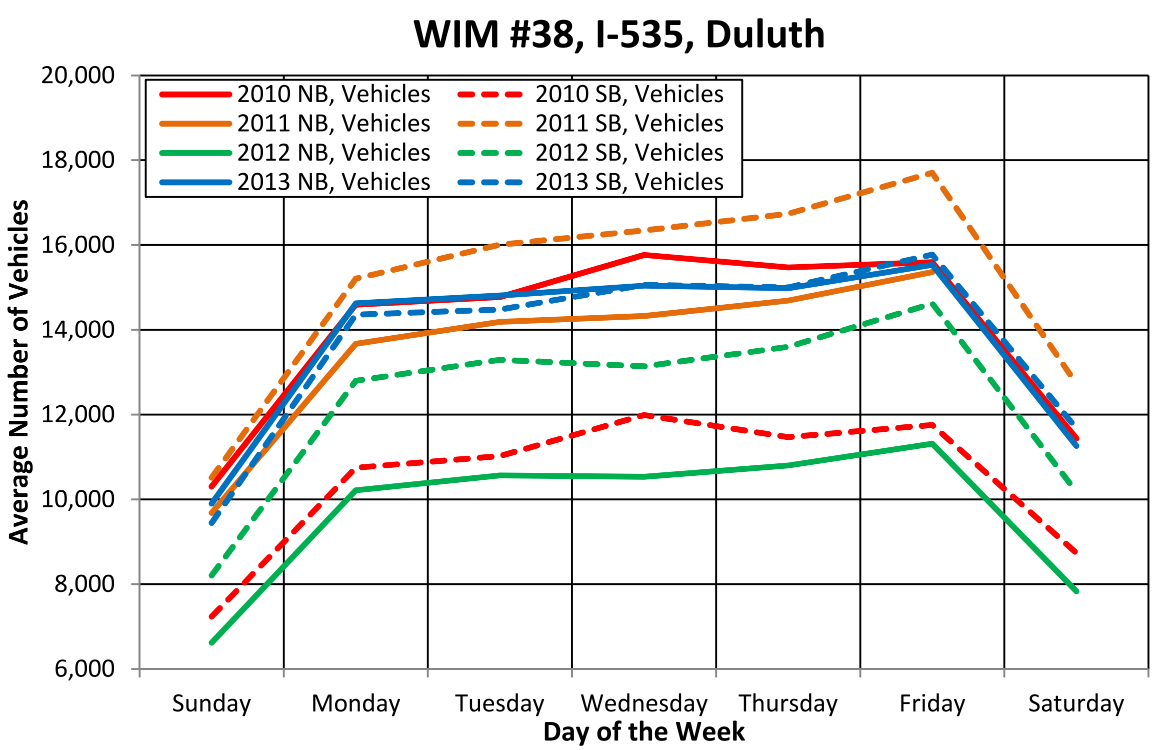


Figure 4.57. Mean number of vehicles by day of week, observed as a function of year and direction (northbound vs. southbound; NB vs. SB).

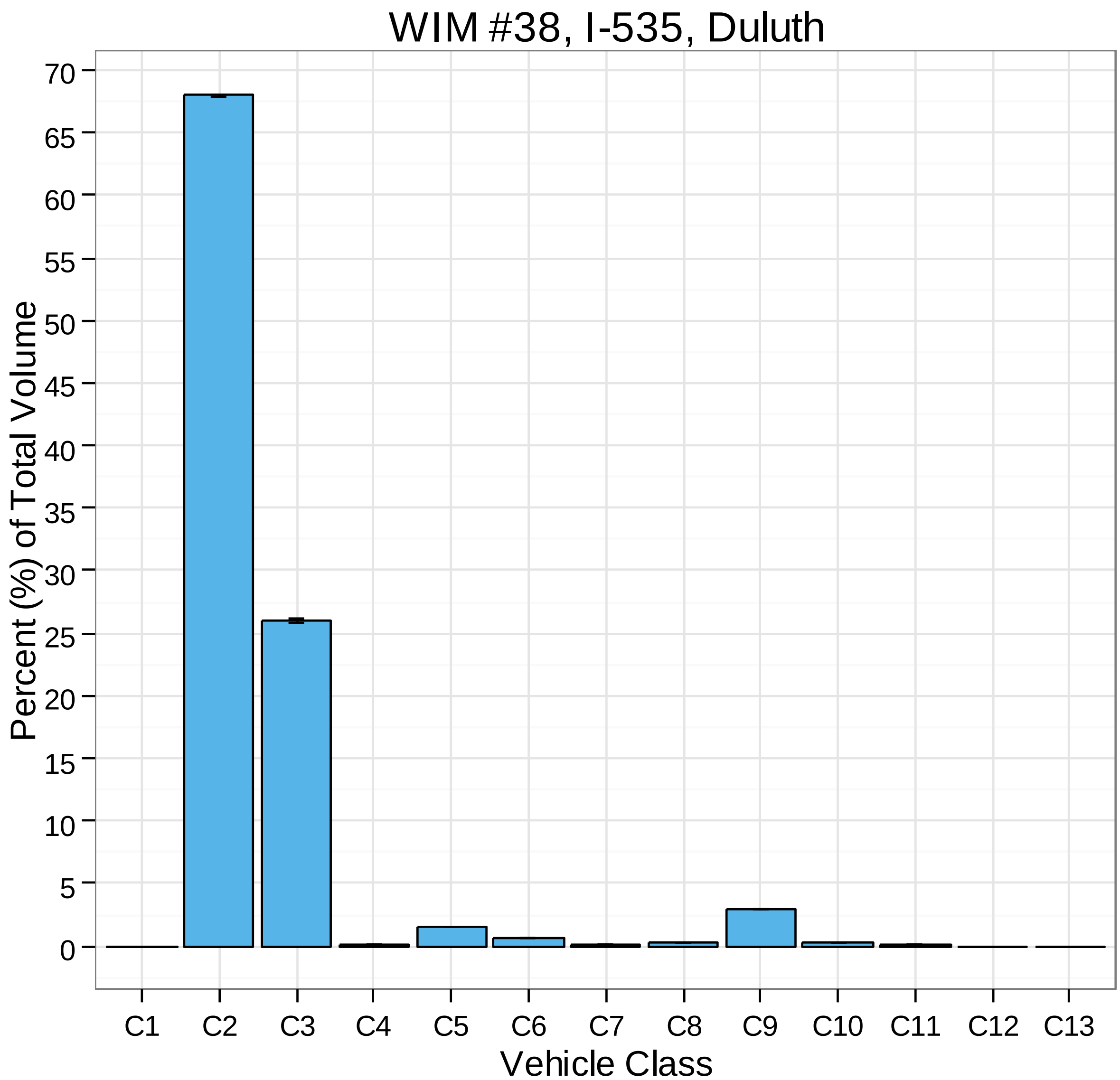


Figure 4.58. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

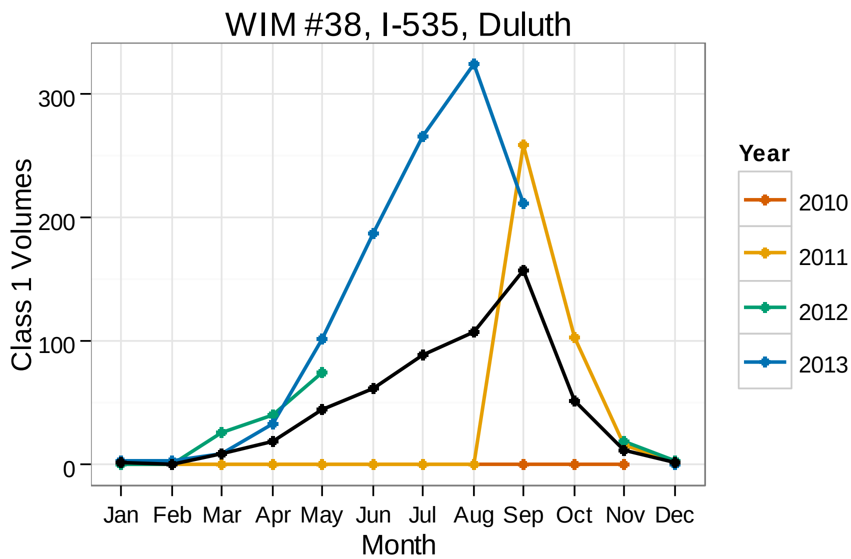


Figure 4.59a. Class 1 volume as a function of month and year. Black line represents the average volume within each month across all years.

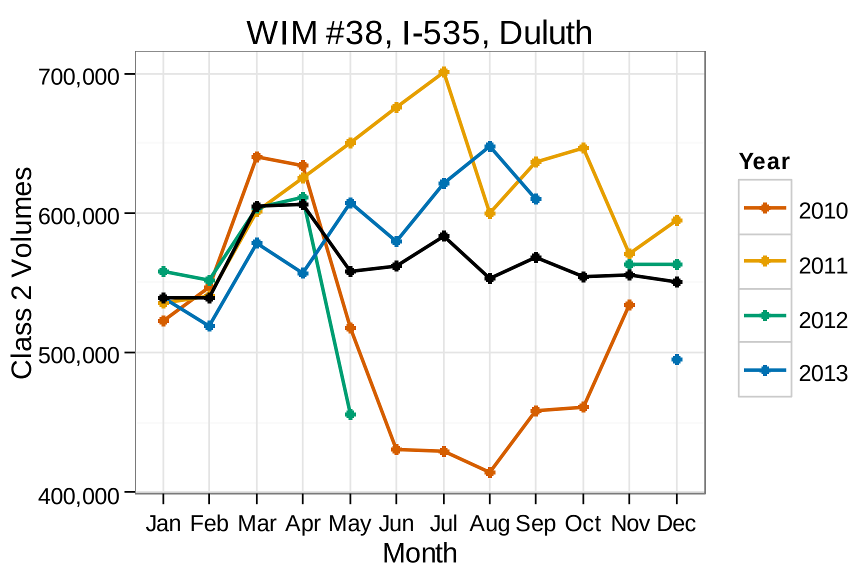


Figure 4.59b. Class 2 volume as a function of month and year. Black line represents the average volume within each month across all years.

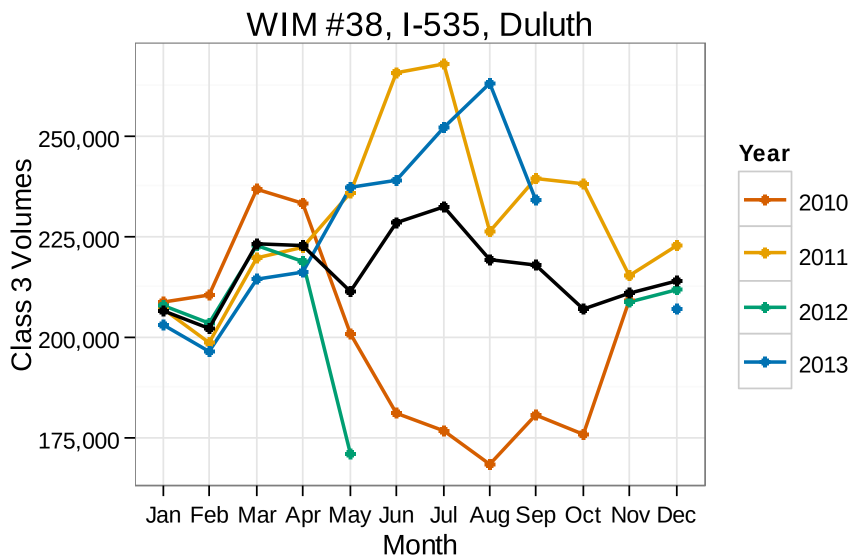


Figure 4.59c. Class 3 volume as a function of month and year. Black line represents the average volume within each month across all years.

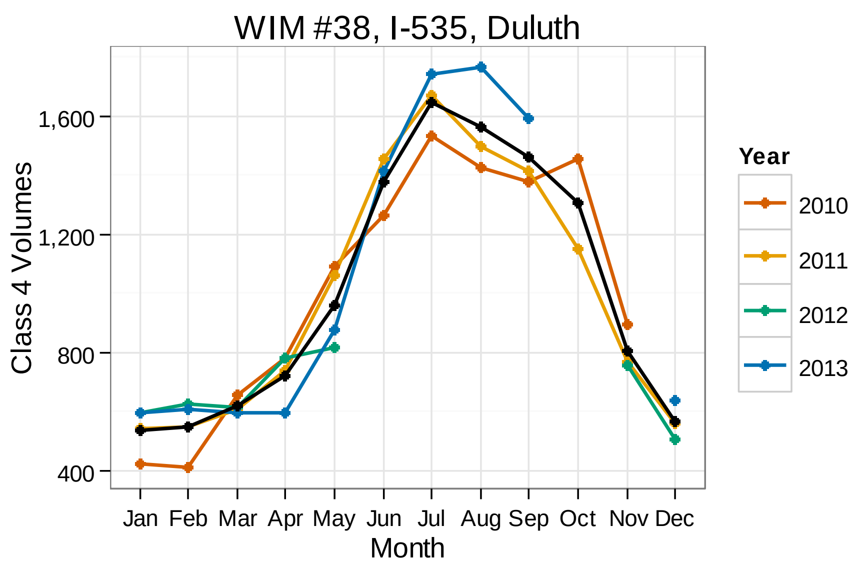


Figure 4.59d. Class 4 volume as a function of month and year. Black line represents the average volume within each month across all years.

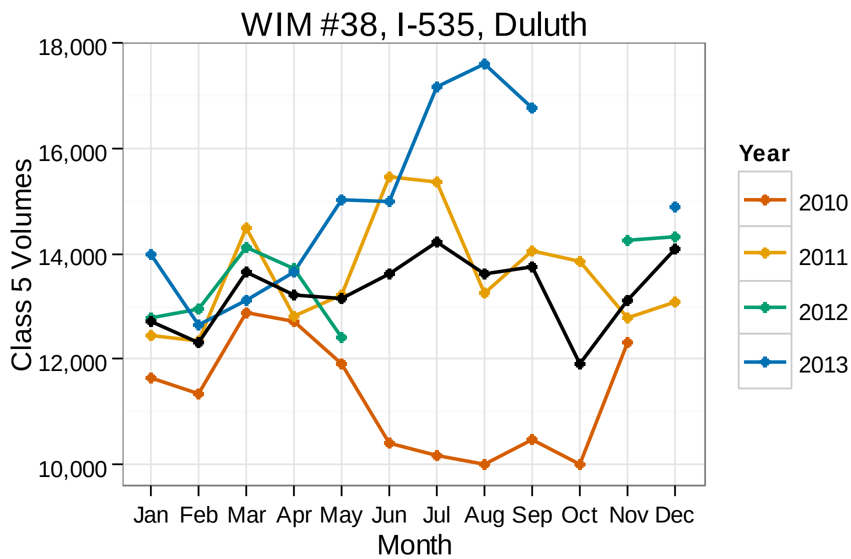


Figure 4.59e. Class 5 volume as a function of month and year. Black line represents the average volume within each month across all years.

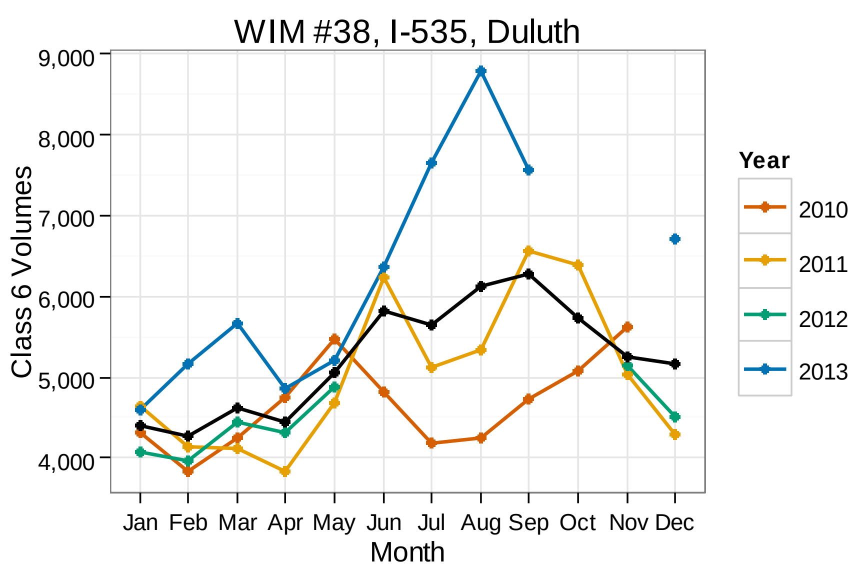


Figure 4.59f. Class 6 volume as a function of month and year. Black line represents the average volume within each month across all years.

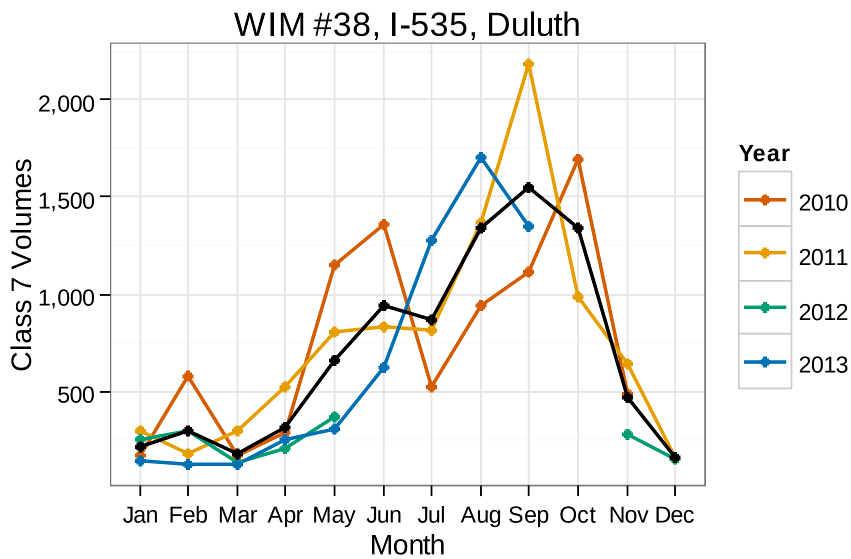


Figure 4.59g. Class 7 volume as a function of month and year. Black line represents the average volume within each month across all years.

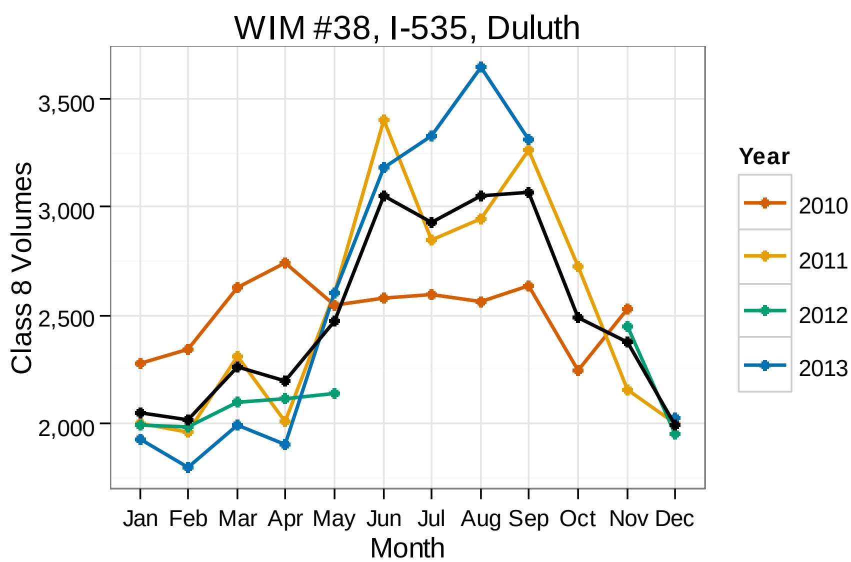


Figure 4.59h. Class 8 volume as a function of month and year. Black line represents the average volume within each month across all years.

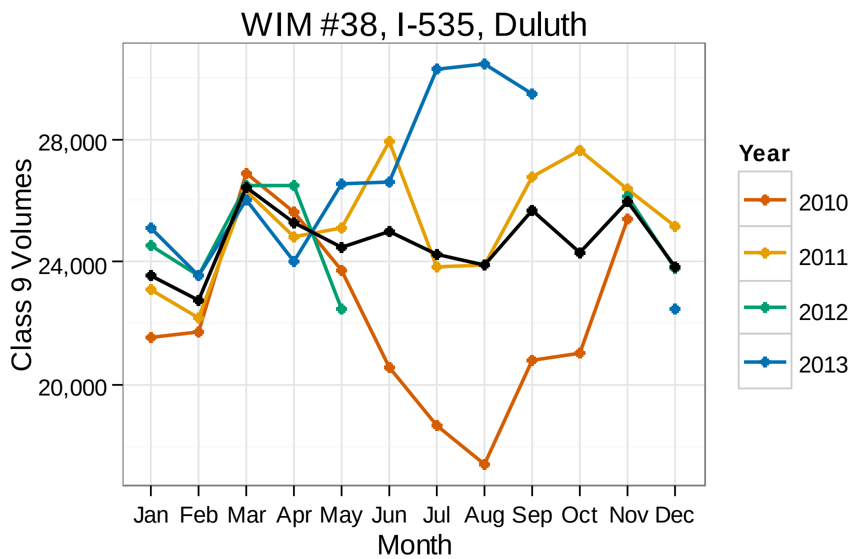


Figure 4.59i. Class 9 volume as a function of month and year. Black line represents the average volume within each month across all years.

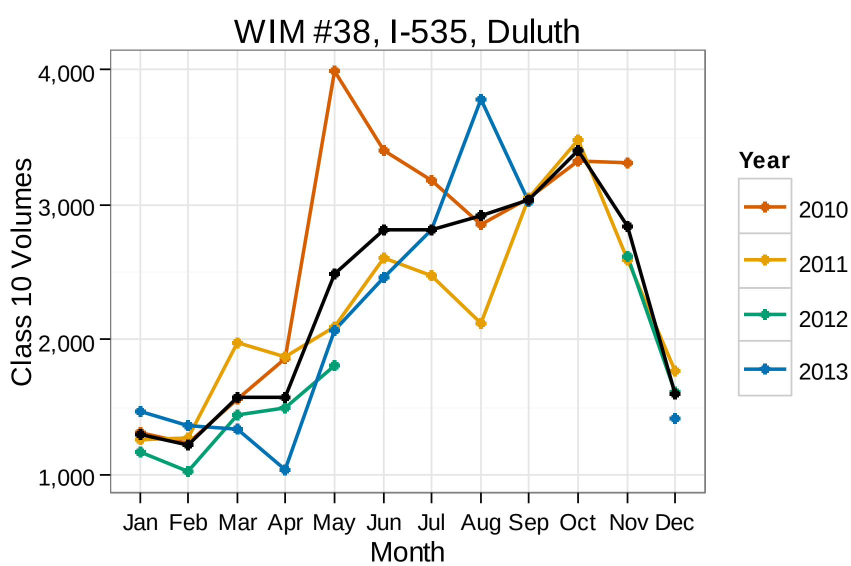


Figure 4.59j. Class 10 volume as a function of month and year. Black line represents the average volume within each month across all years.

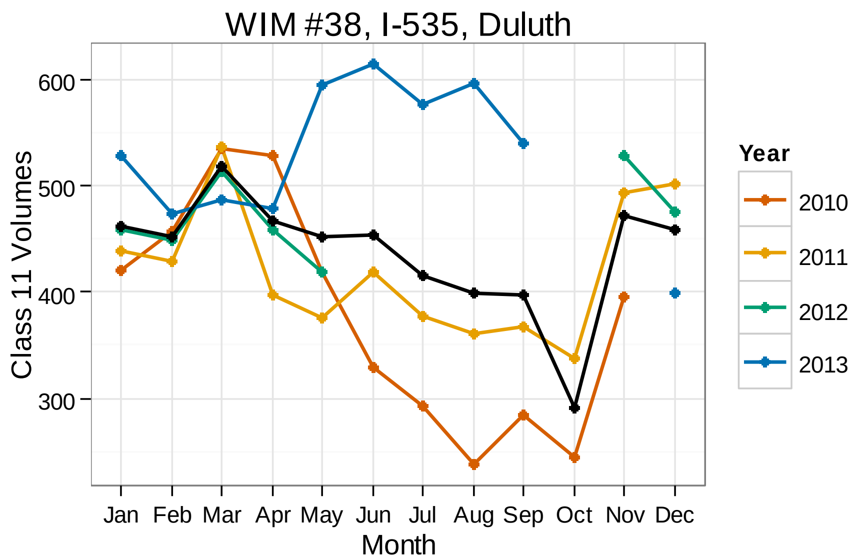


Figure 4.59k. Class 11 volume as a function of month and year. Black line represents the average volume within each month across all years.

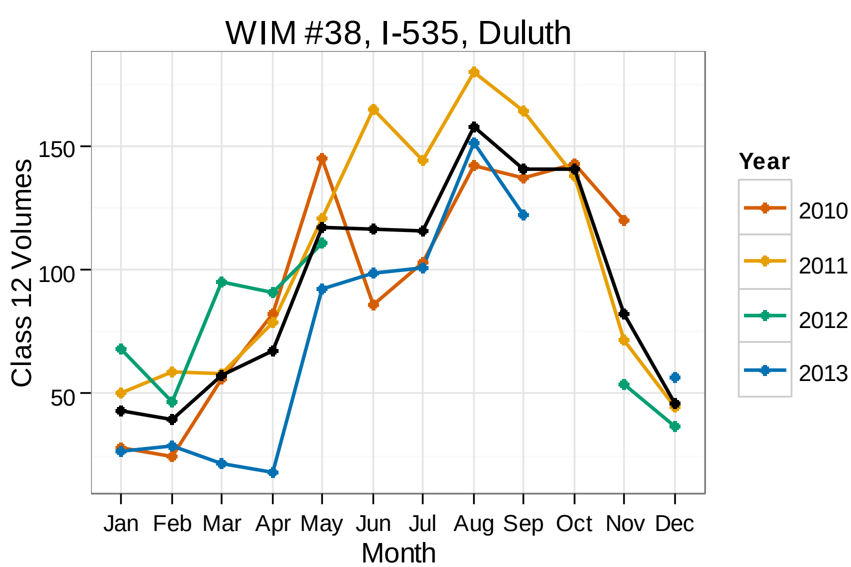


Figure 4.59l. Class 12 volume as a function of month and year. Black line represents the average volume within each month across all years.

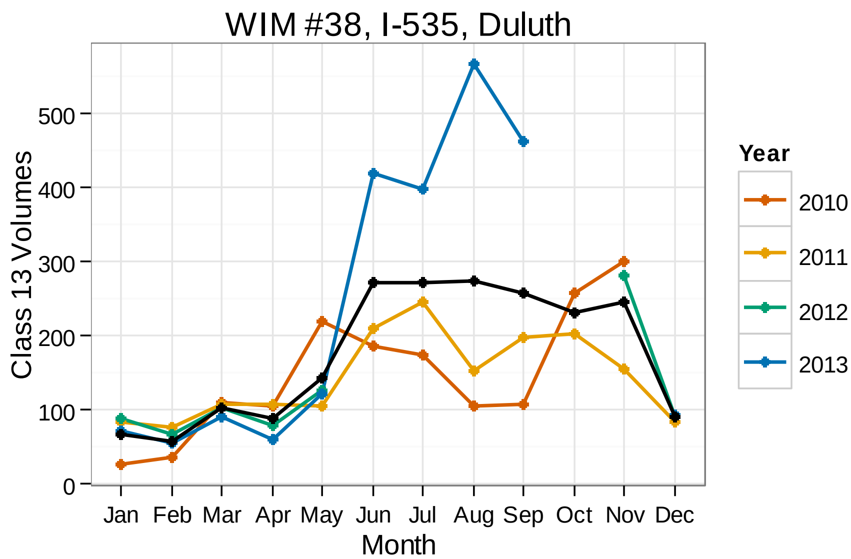


Figure 4.59m. Class 13 volume as a function of month and year. Black line represents the average volume within each month across all years.

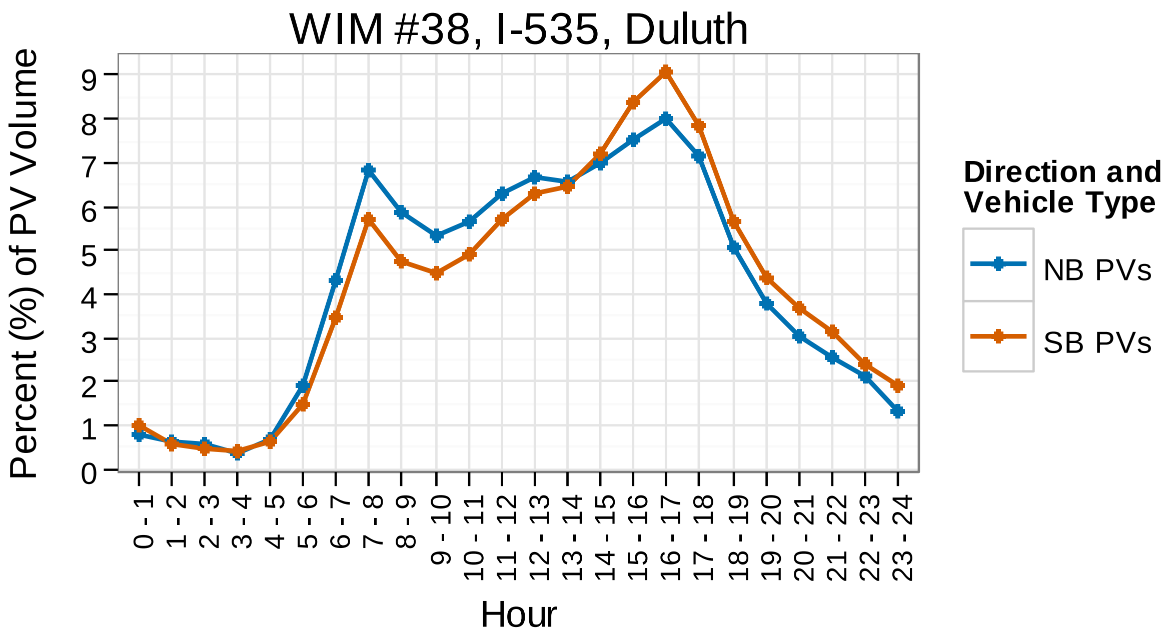


Figure 4.60a. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for passenger vehicles (PVs).

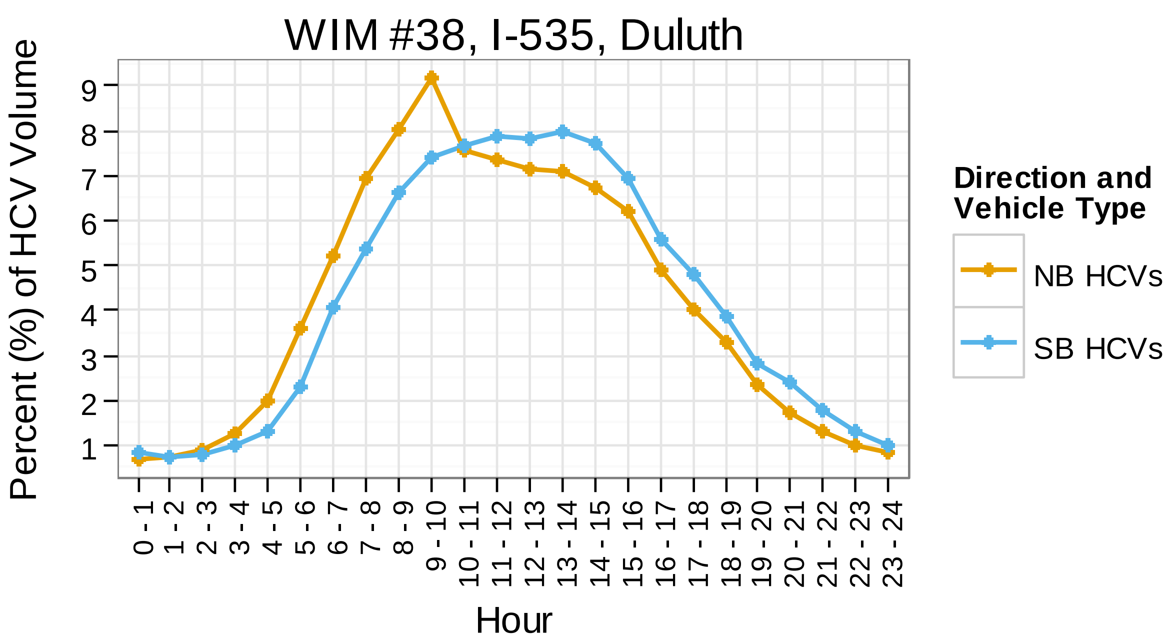


Figure 4.60b. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for heavy commercial vehicles (HCVs).

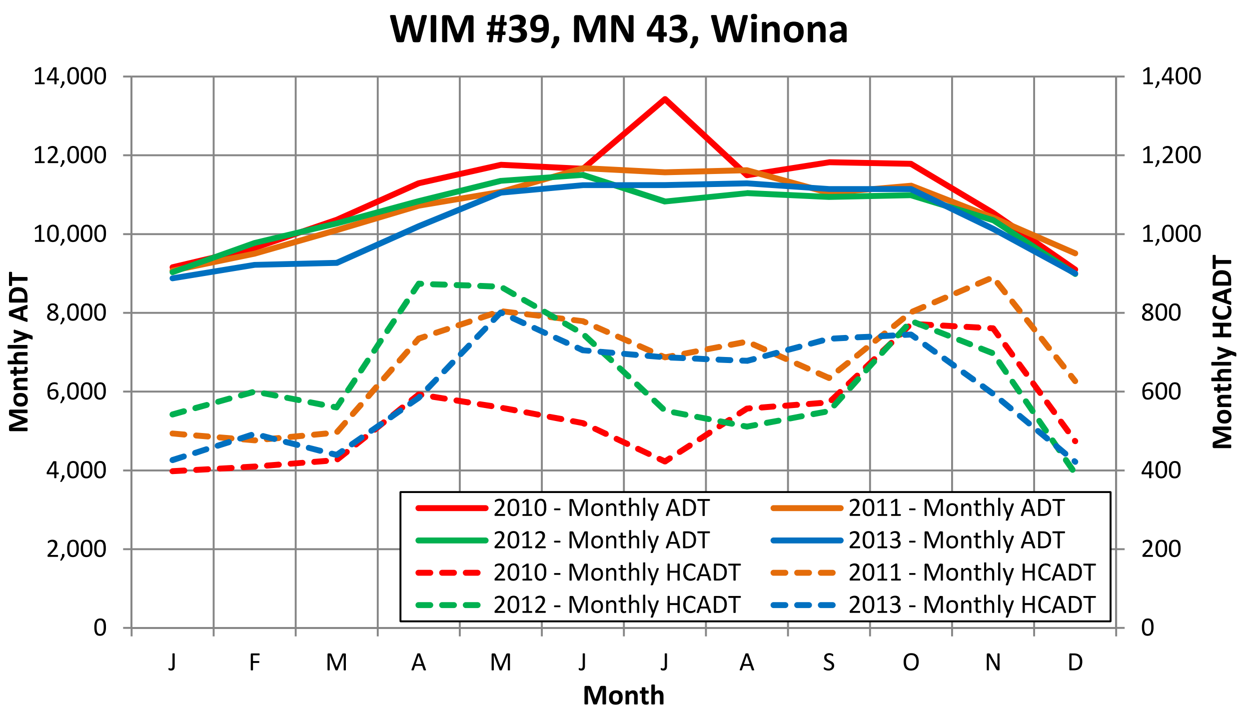


Figure 4.61. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

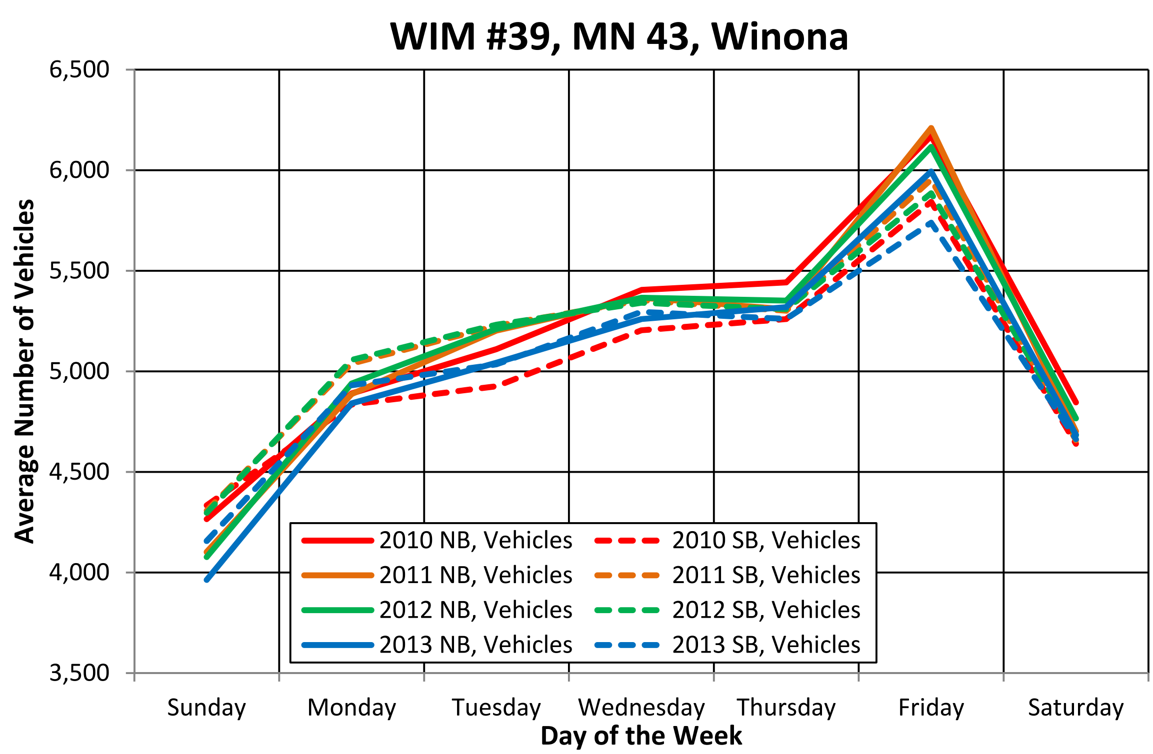


Figure 4.62. Mean number of vehicles by day of week, observed as a function of year and direction (northbound vs. southbound; NB vs. SB).

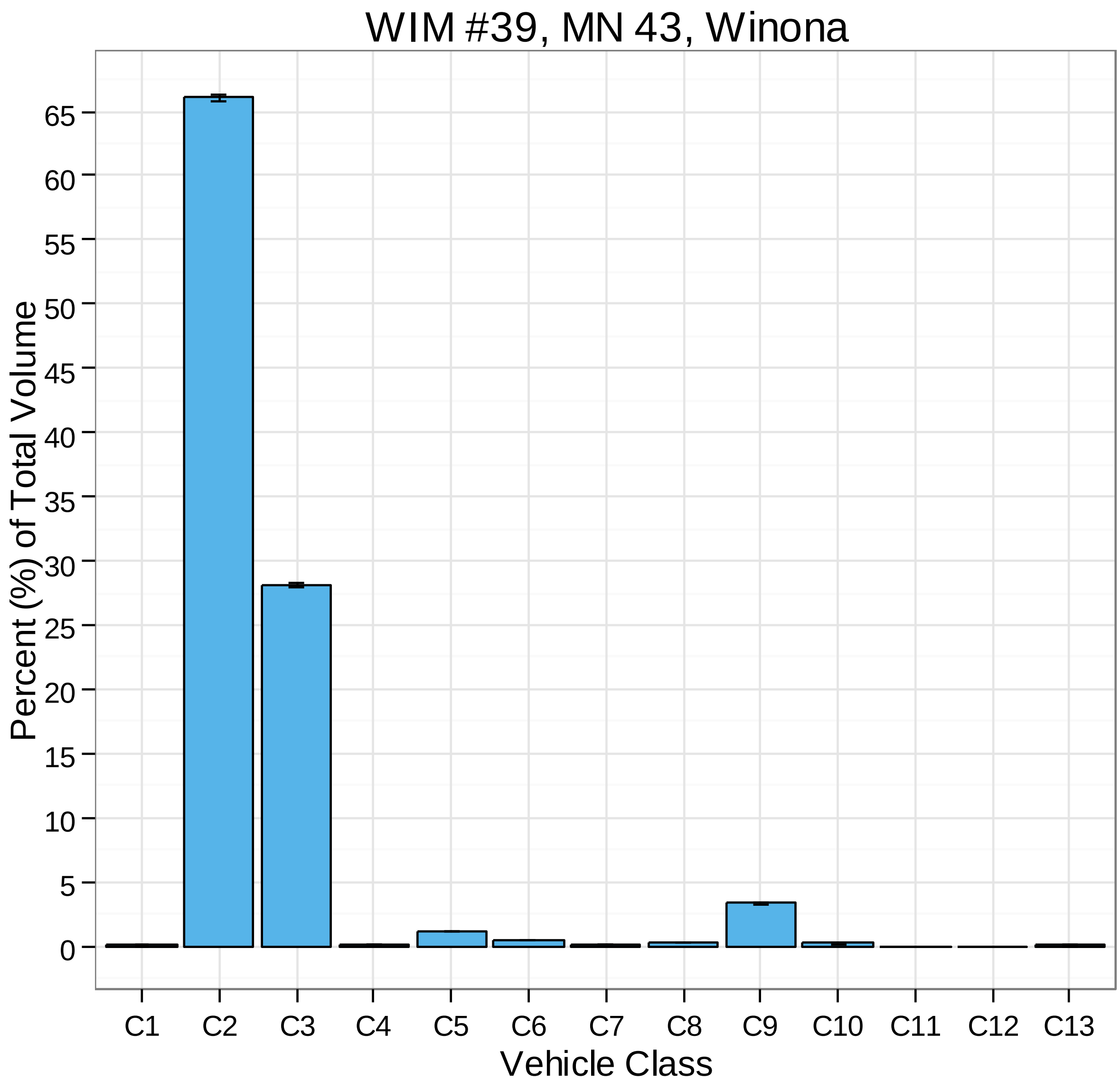


Figure 4.63. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

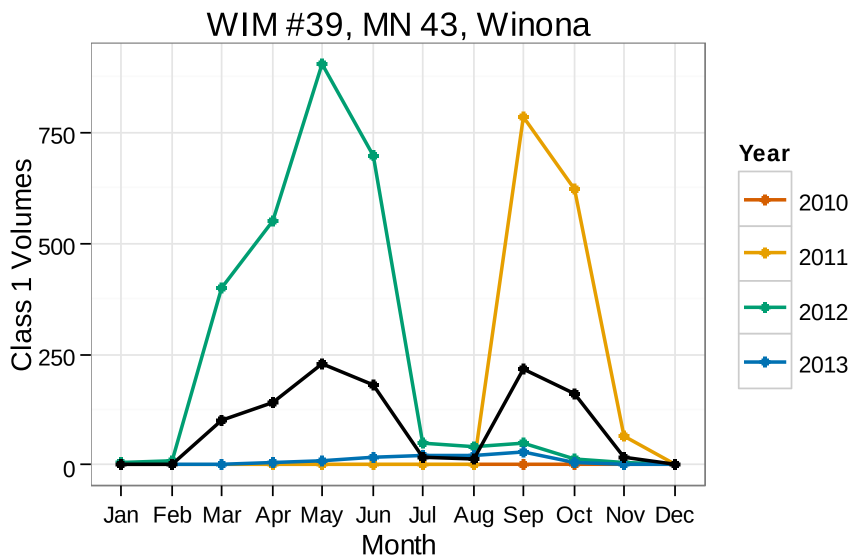


Figure 4.64a. Class 1 volume as a function of month and year. Black line represents the average volume within each month across all years.

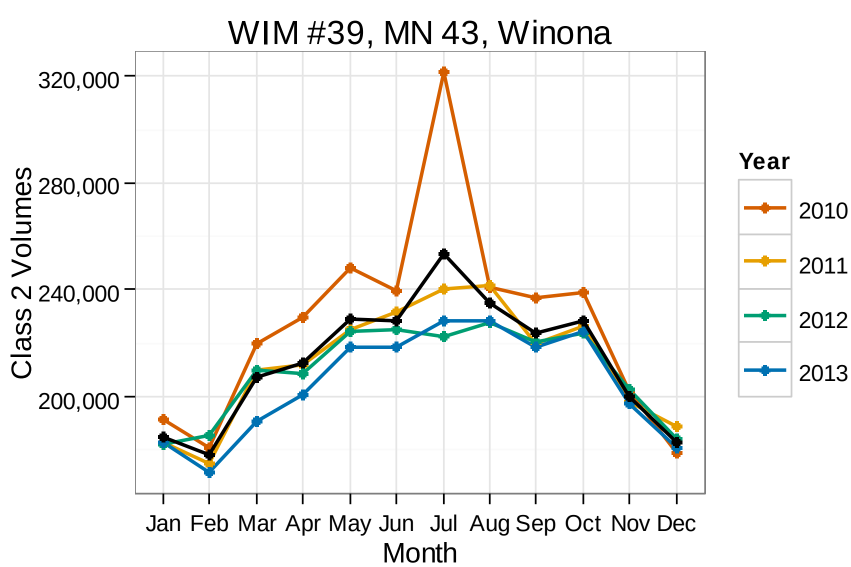


Figure 4.64b. Class 2 volume as a function of month and year. Black line represents the average volume within each month across all years.

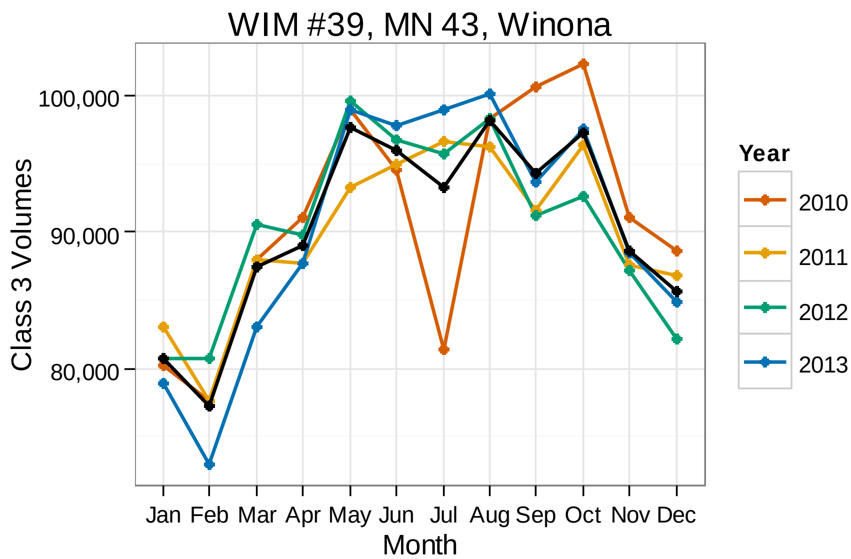


Figure 4.64c. Class 3 volume as a function of month and year. Black line represents the average volume within each month across all years.

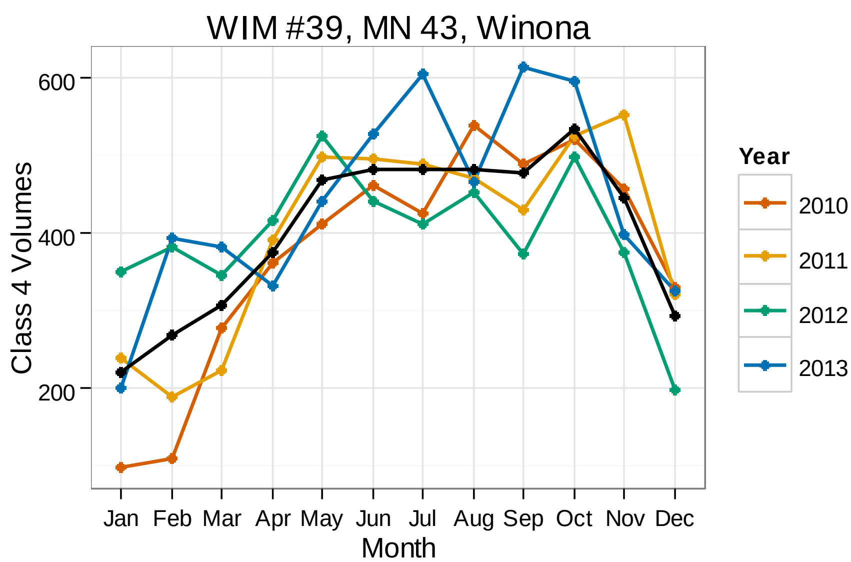


Figure 4.64d. Class 4 volume as a function of month and year. Black line represents the average volume within each month across all years.

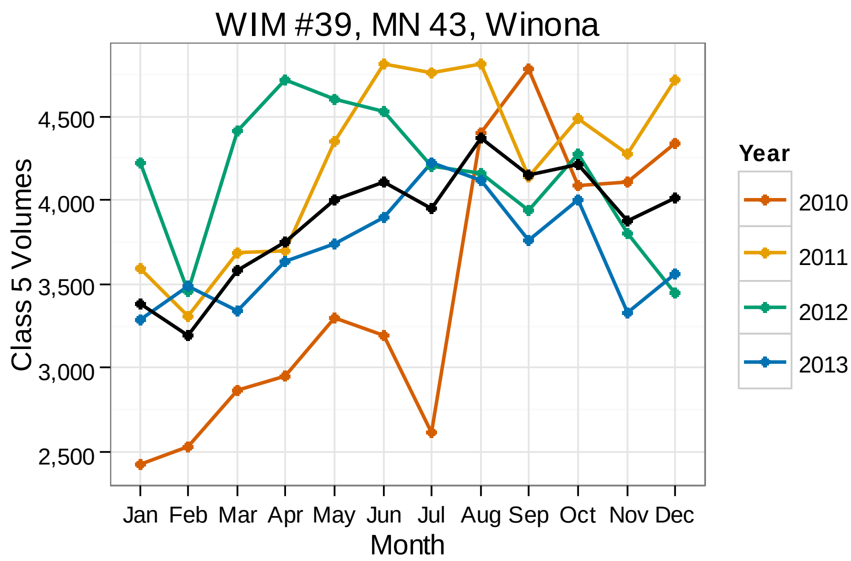


Figure 4.64e. Class 5 volume as a function of month and year. Black line represents the average volume within each month across all years.

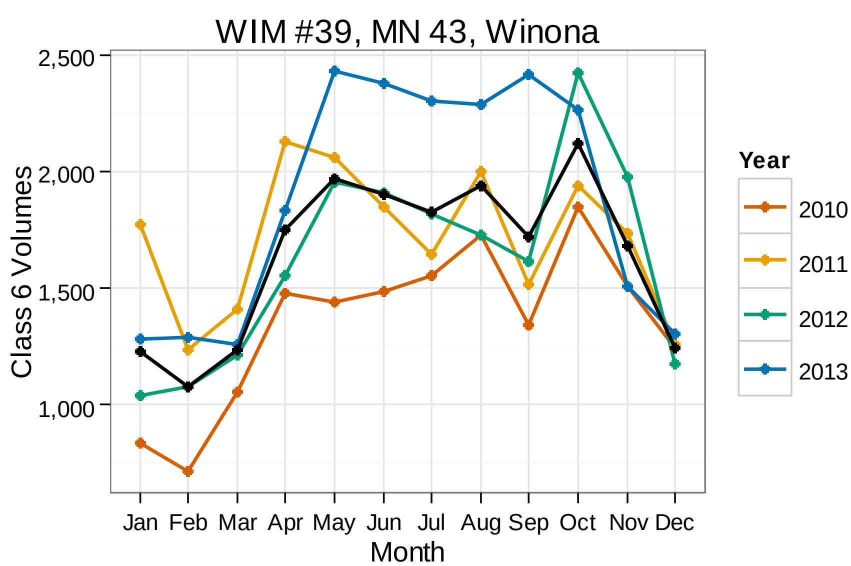


Figure 4.64f. Class 6 volume as a function of month and year. Black line represents the average volume within each month across all years.

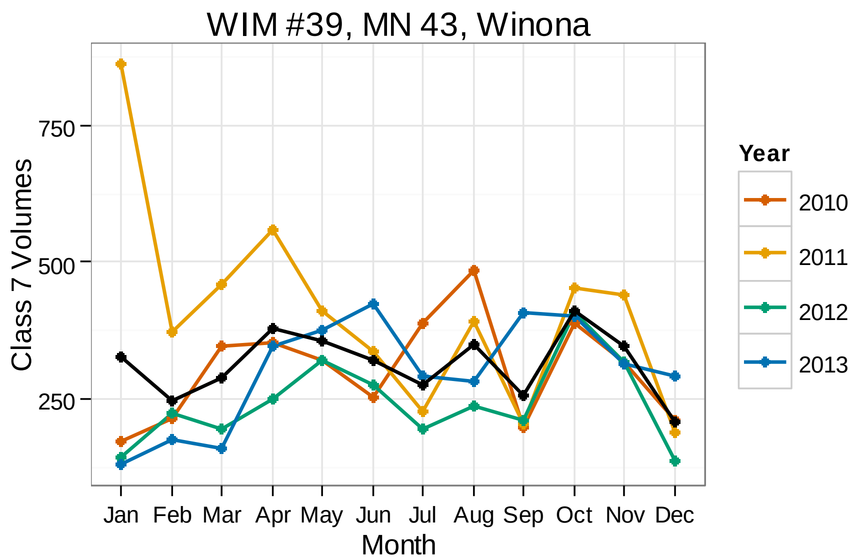


Figure 4.64g. Class 7 volume as a function of month and year. Black line represents the average volume within each month across all years.

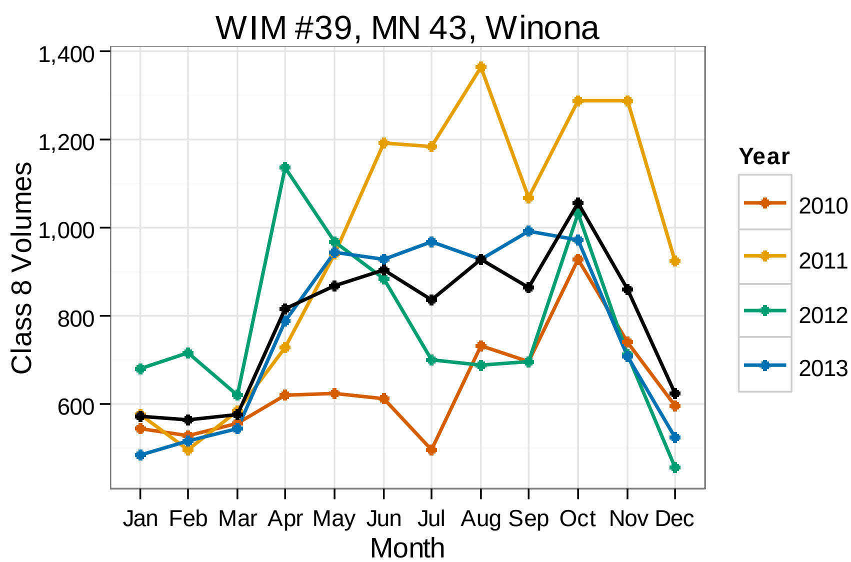


Figure 4.64h. Class 8 volume as a function of month and year. Black line represents the average volume within each month across all years.

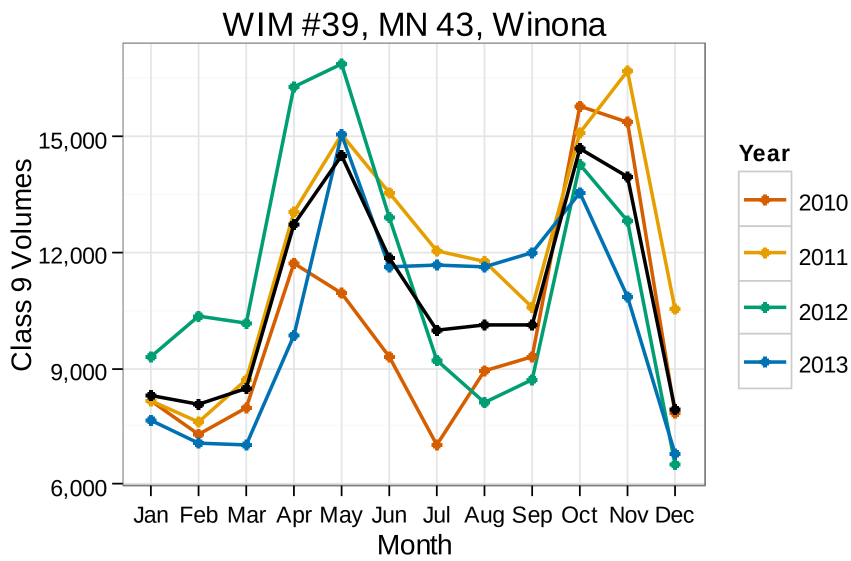


Figure 4.64i. Class 9 volume as a function of month and year. Black line represents the average volume within each month across all years.

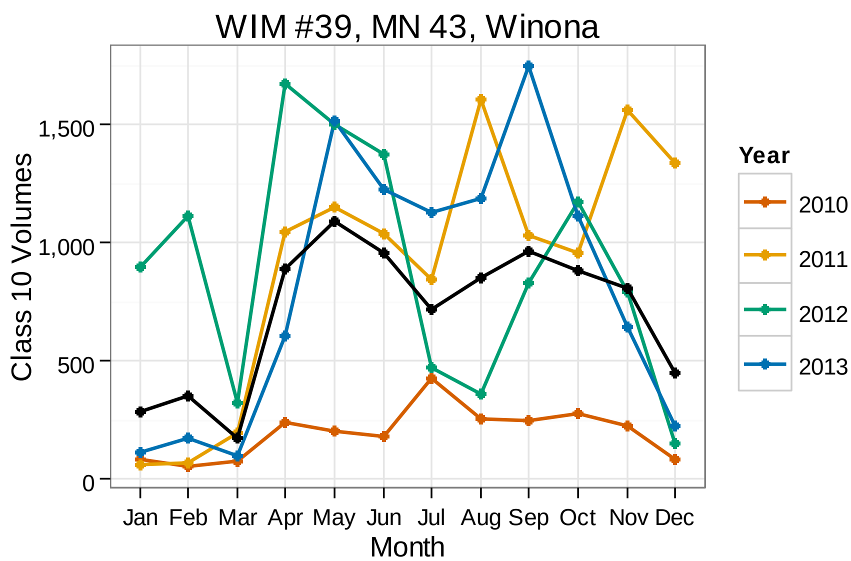


Figure 4.64j. Class 10 volume as a function of month and year. Black line represents the average volume within each month across all years.

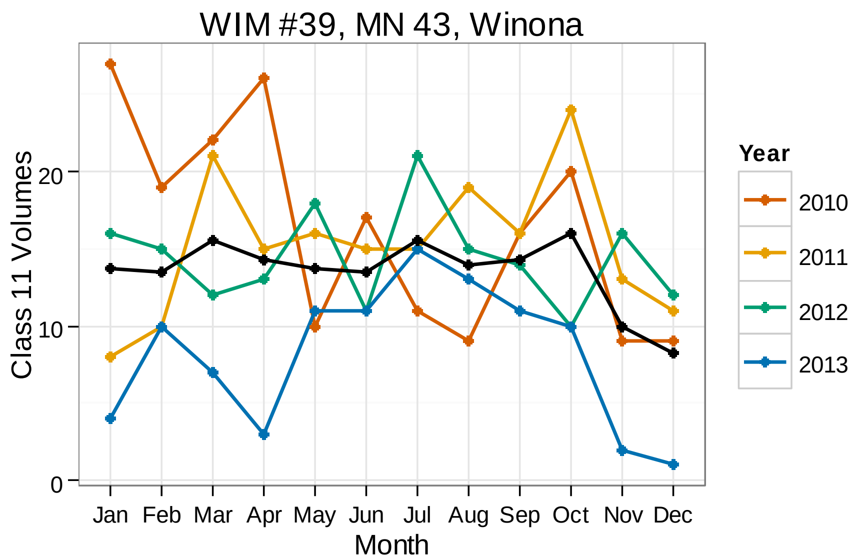


Figure 4.64k. Class 11 volume as a function of month and year. Black line represents the average volume within each month across all years.

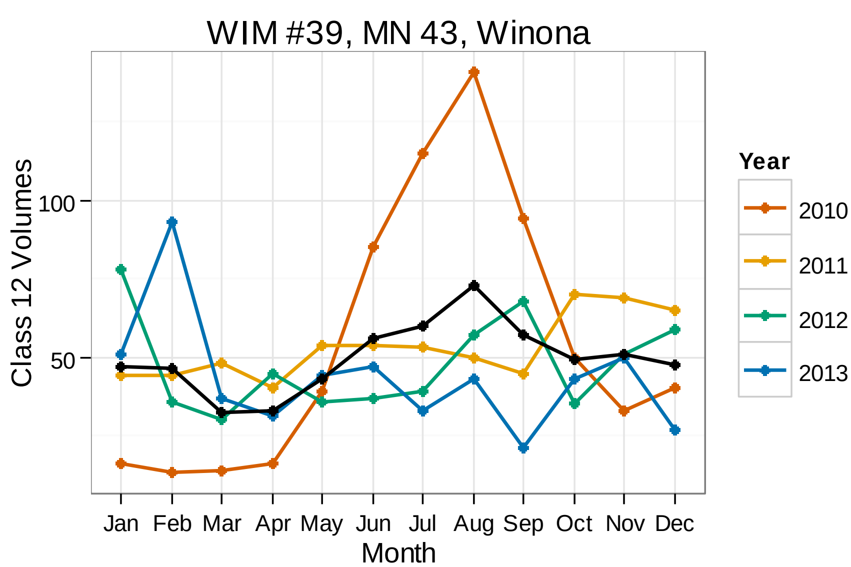


Figure 4.64l. Class 12 volume as a function of month and year. Black line represents the average volume within each month across all years.

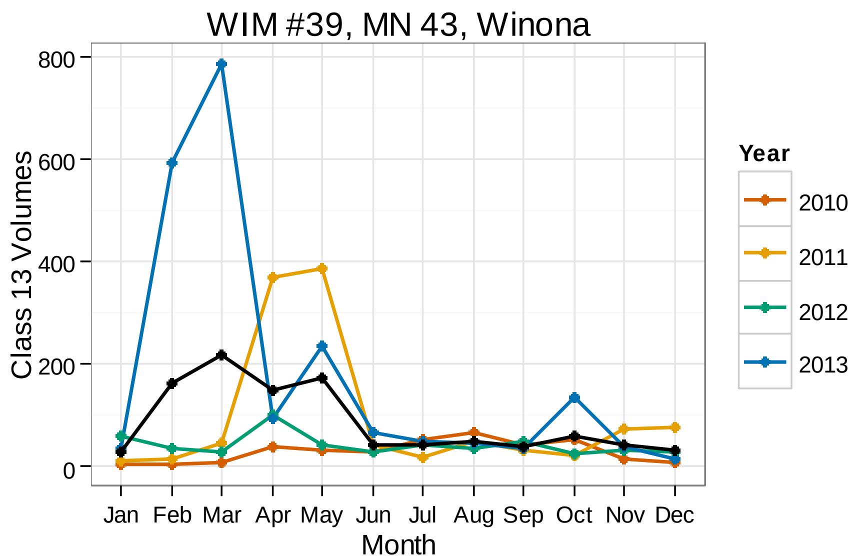


Figure 4.64m. Class 13 volume as a function of month and year. Black line represents the average volume within each month across all years.

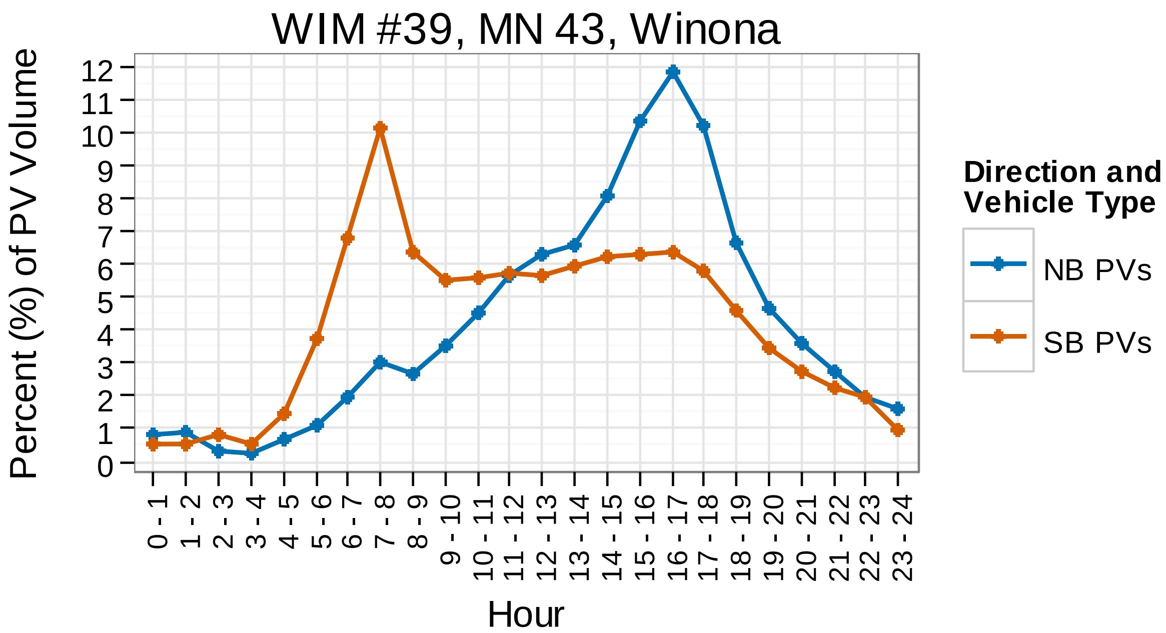


Figure 4.65a. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for passenger vehicles (PVs).

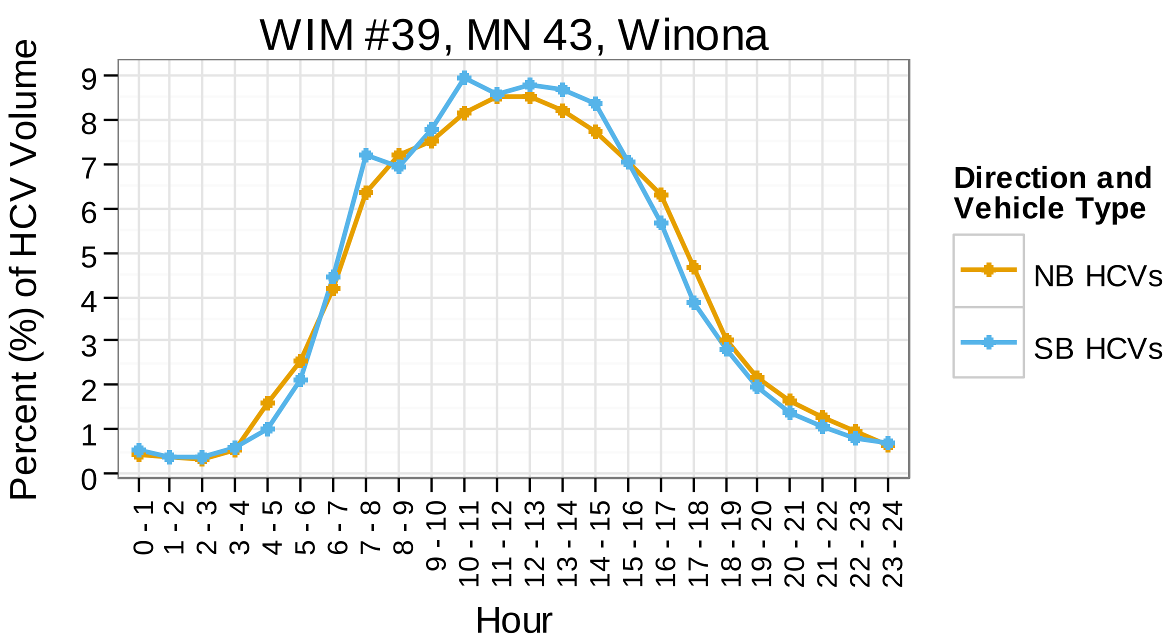


Figure 4.65b. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for heavy commercial vehicles (HCVs).

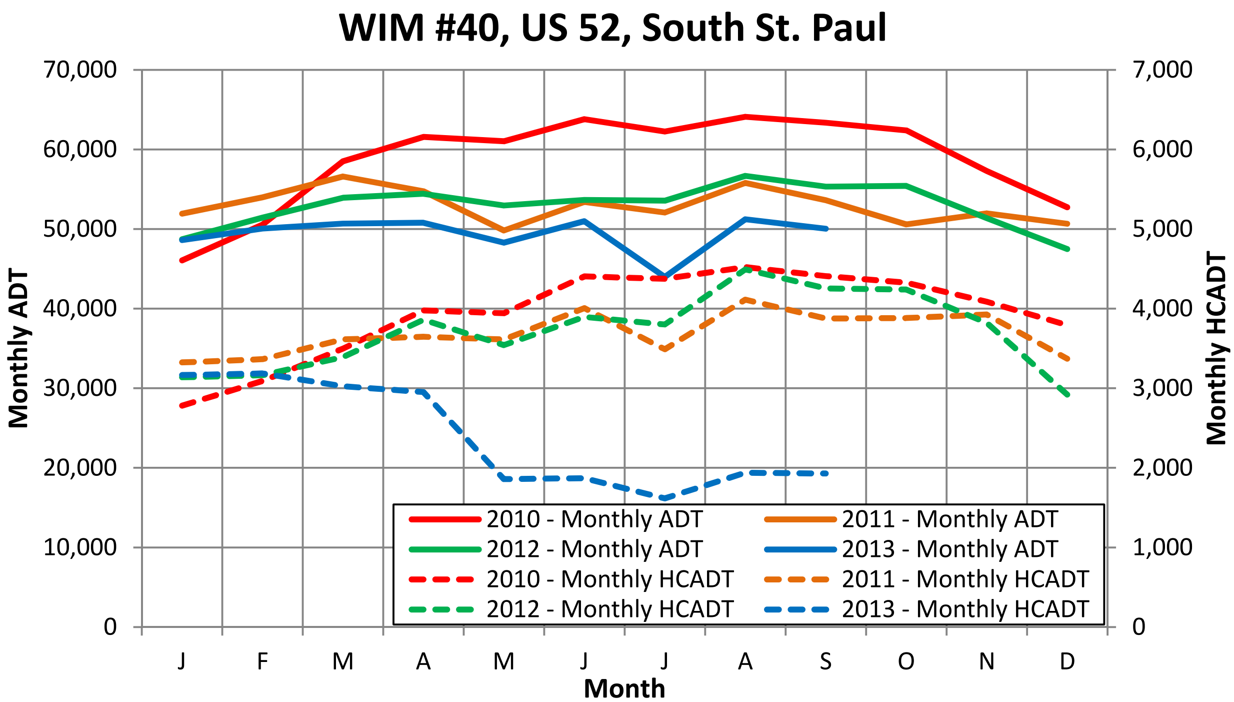


Figure 4.66. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

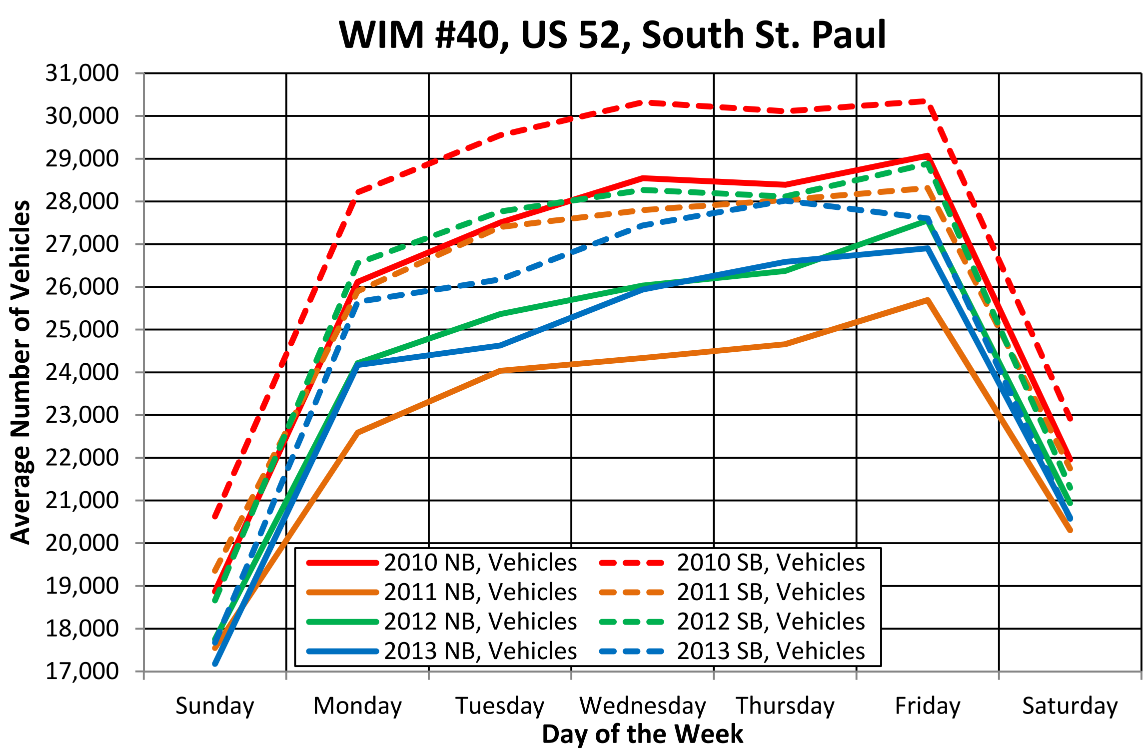


Figure 4.67. Mean number of vehicles by day of week, observed as a function of year and direction (northbound vs. southbound; NB vs. SB).

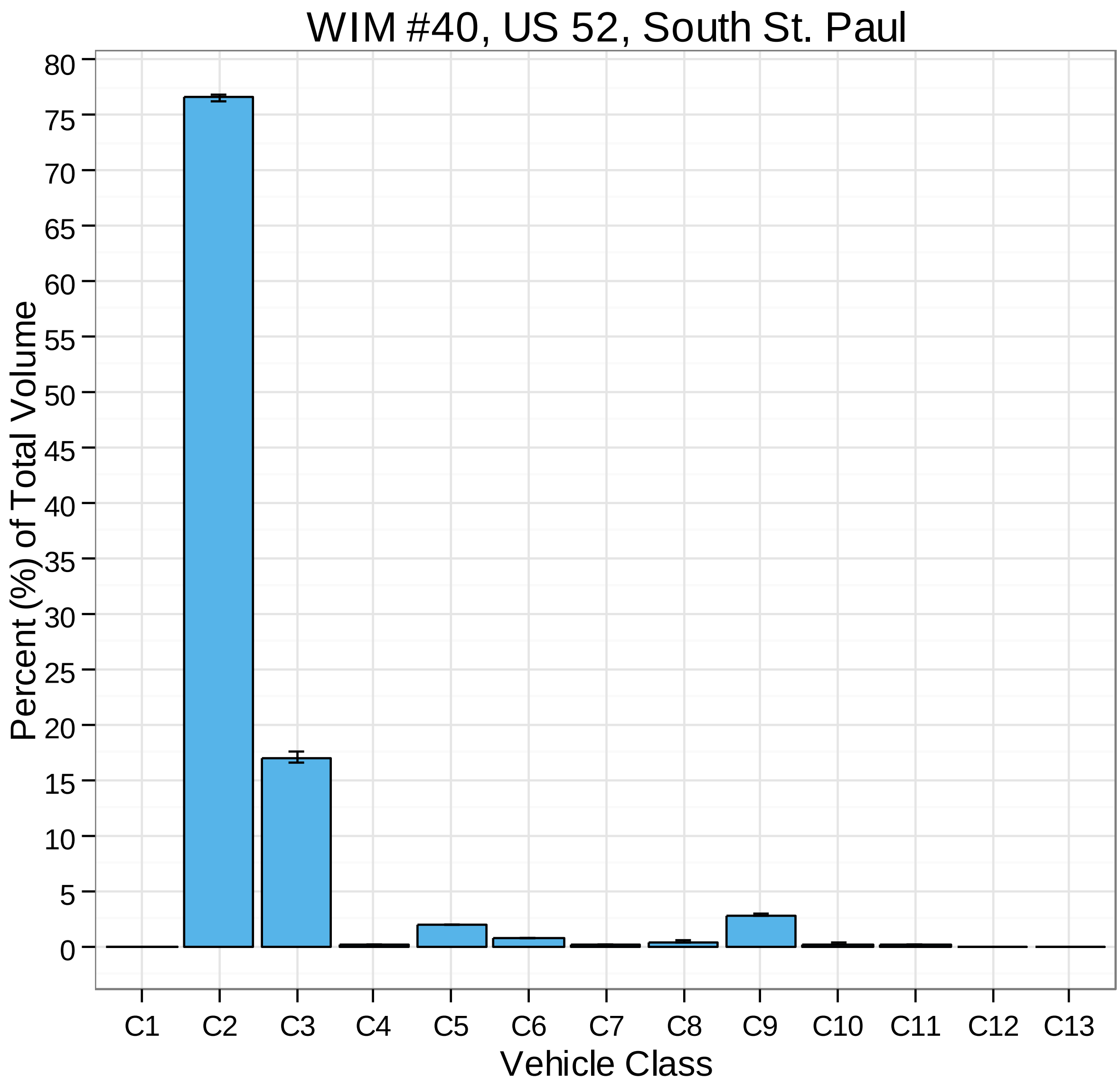


Figure 4.68. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

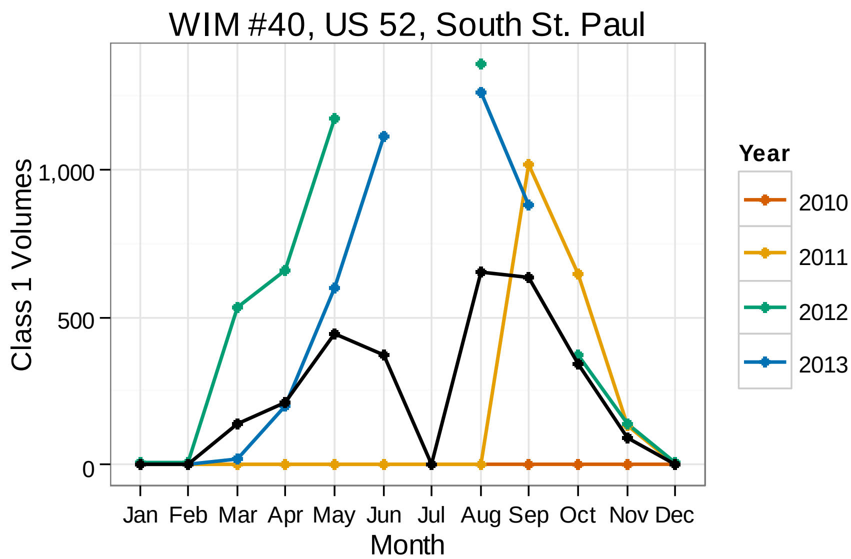


Figure 4.69a. Class 1 volume as a function of month and year. Black line represents the average volume within each month across all years.

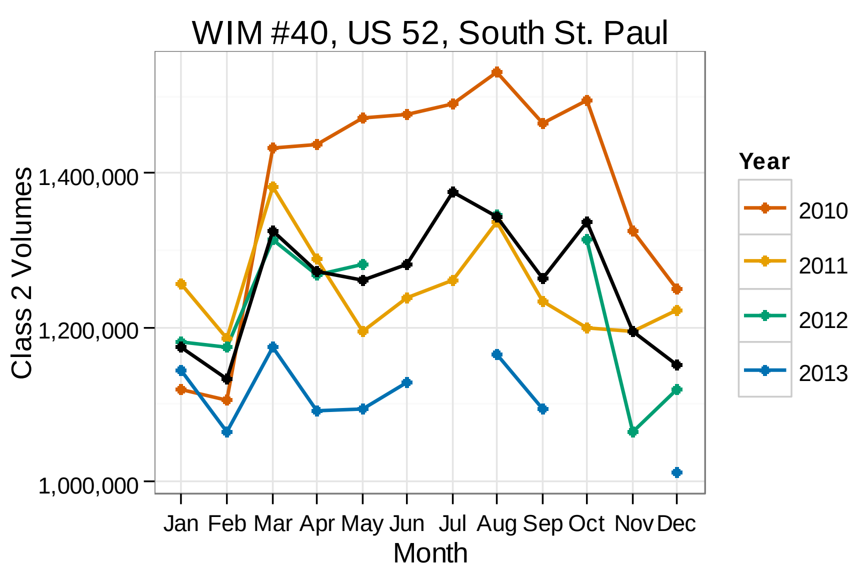


Figure 4.69b. Class 2 volume as a function of month and year. Black line represents the average volume within each month across all years.

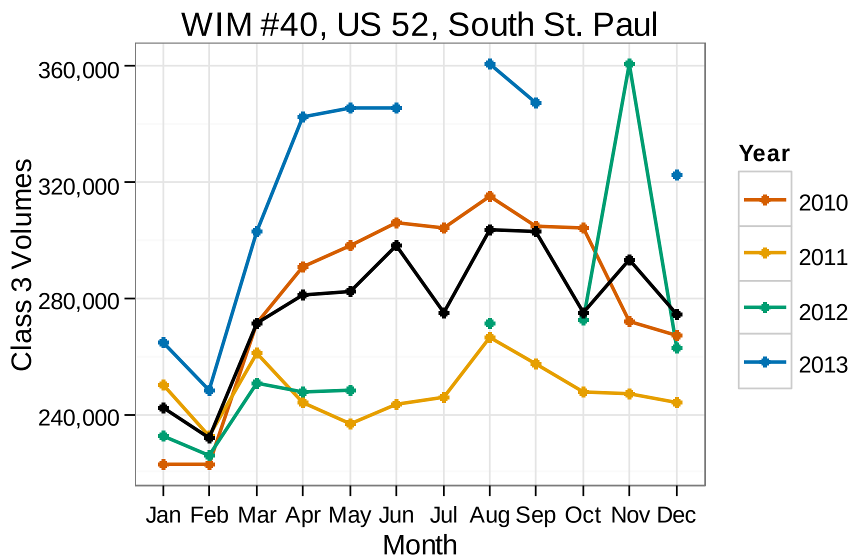


Figure 4.69c. Class 3 volume as a function of month and year. Black line represents the average volume within each month across all years.

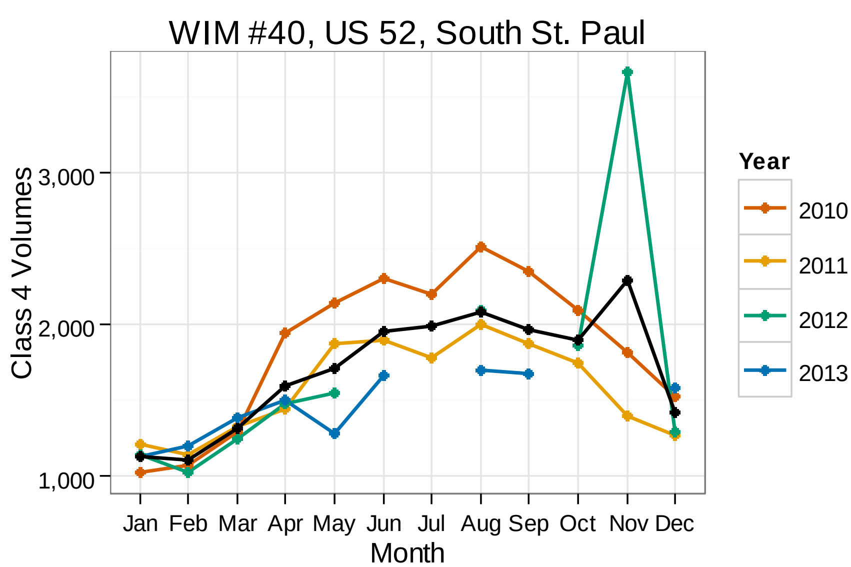


Figure 4.69d. Class 4 volume as a function of month and year. Black line represents the average volume within each month across all years.

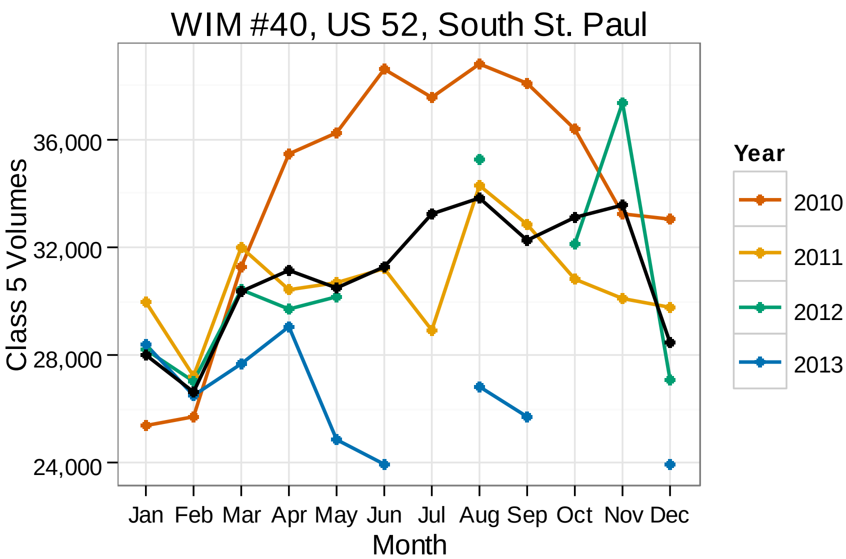


Figure 4.69e. Class 5 volume as a function of month and year. Black line represents the average volume within each month across all years.

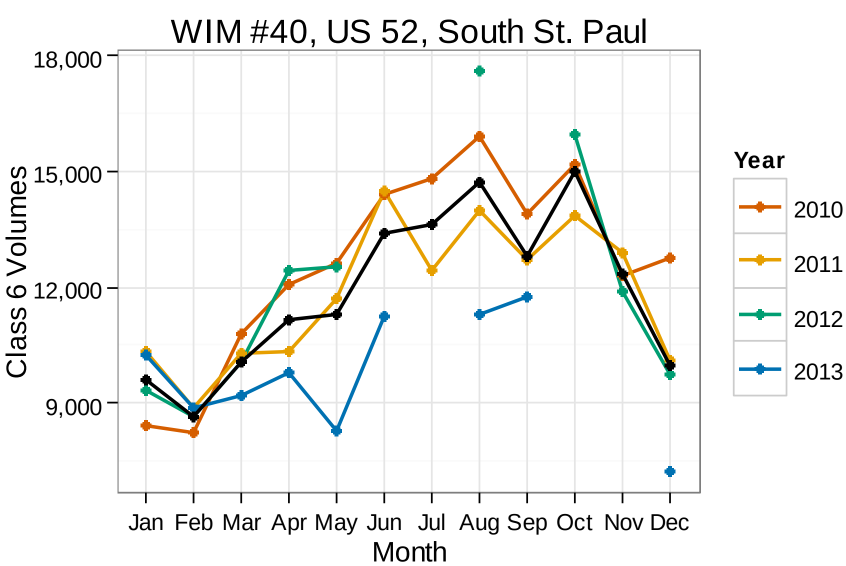


Figure 4.69f. Class 6 volume as a function of month and year. Black line represents the average volume within each month across all years.

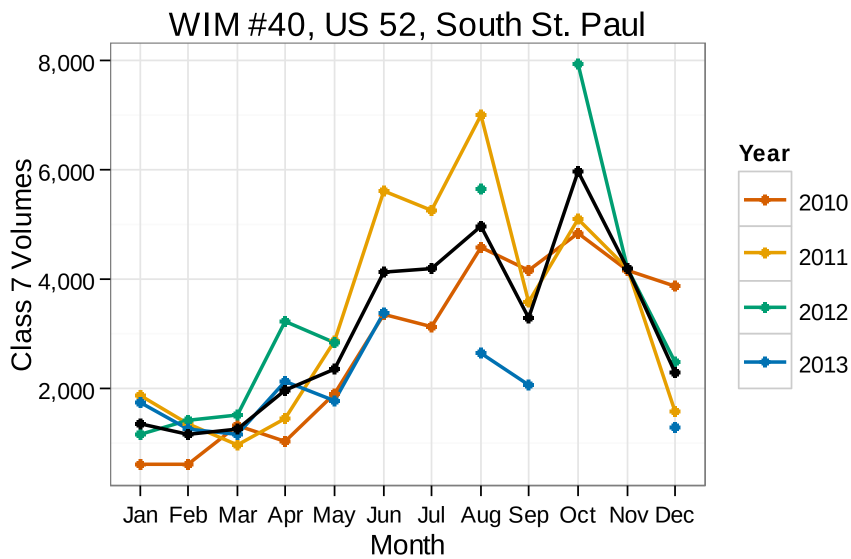


Figure 4.69g. Class 7 volume as a function of month and year. Black line represents the average volume within each month across all years.

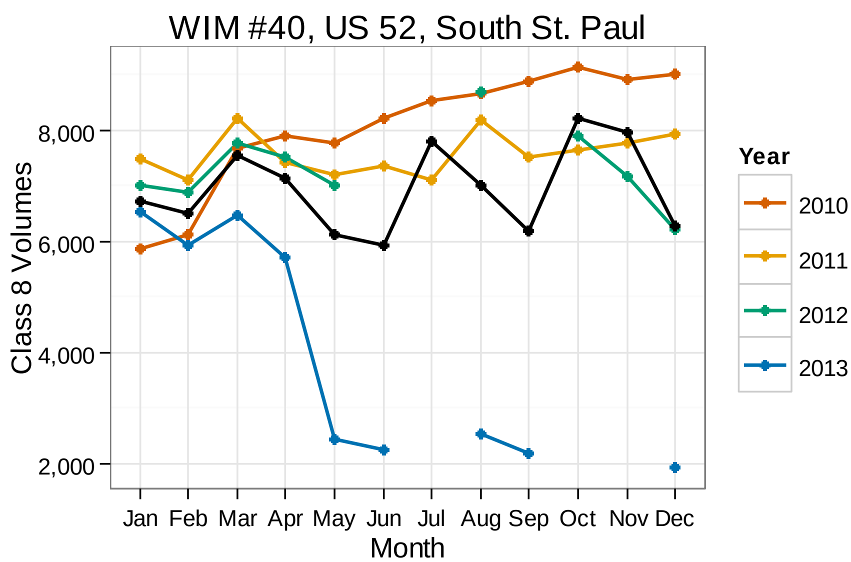


Figure 4.69h. Class 8 volume as a function of month and year. Black line represents the average volume within each month across all years.

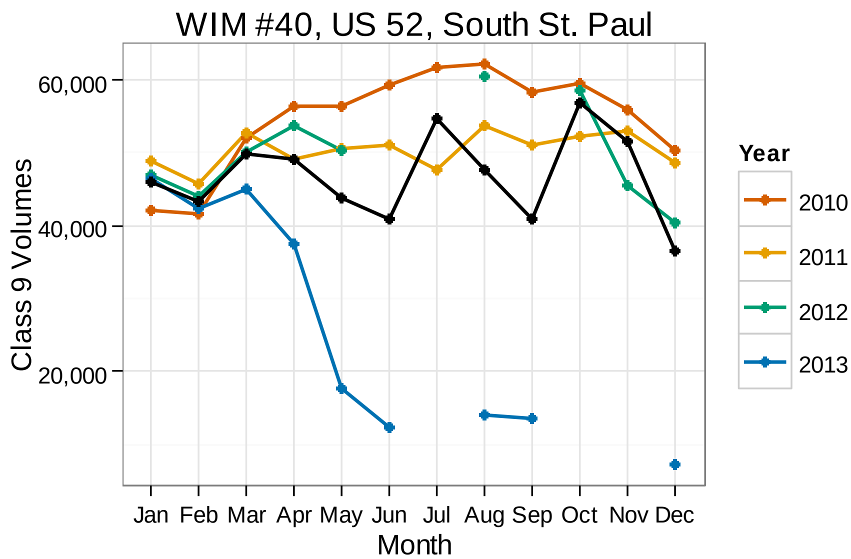


Figure 4.69i. Class 9 volume as a function of month and year. Black line represents the average volume within each month across all years.

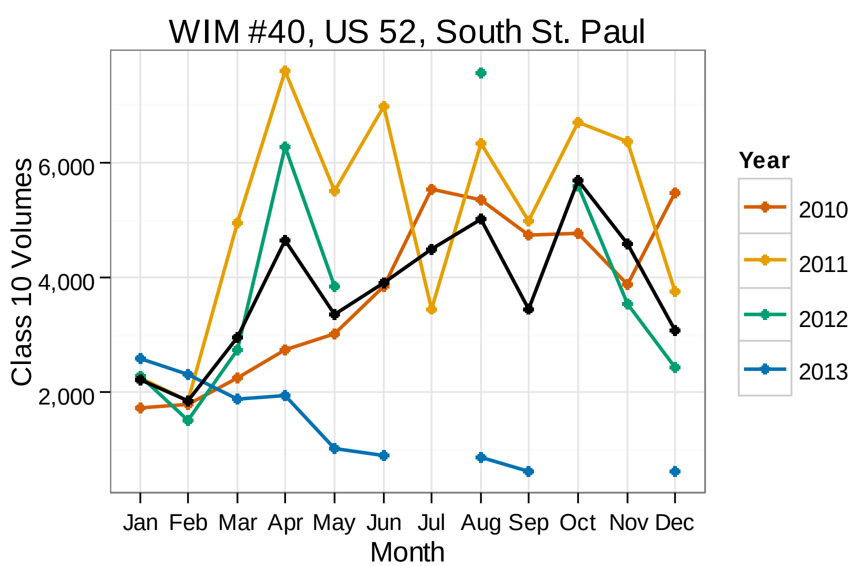


Figure 4.69j. Class 10 volume as a function of month and year. Black line represents the average volume within each month across all years.

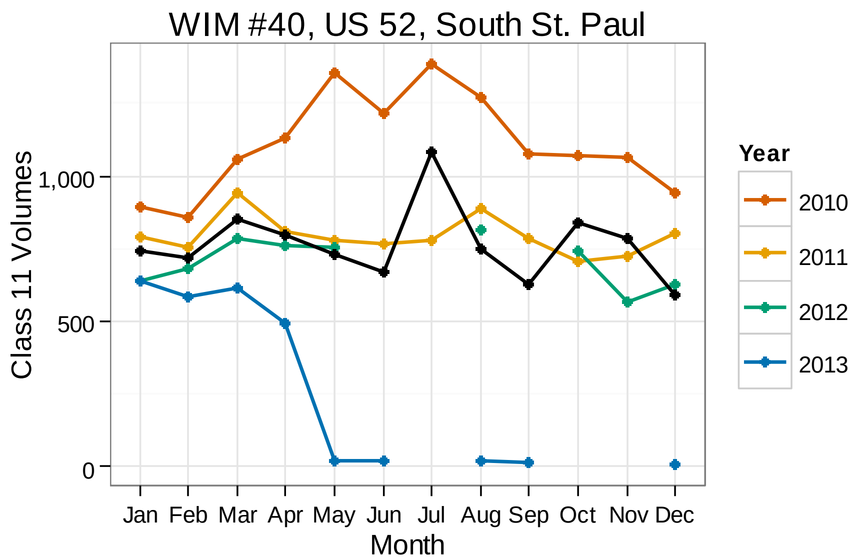


Figure 4.69k. Class 11 volume as a function of month and year. Black line represents the average volume within each month across all years.

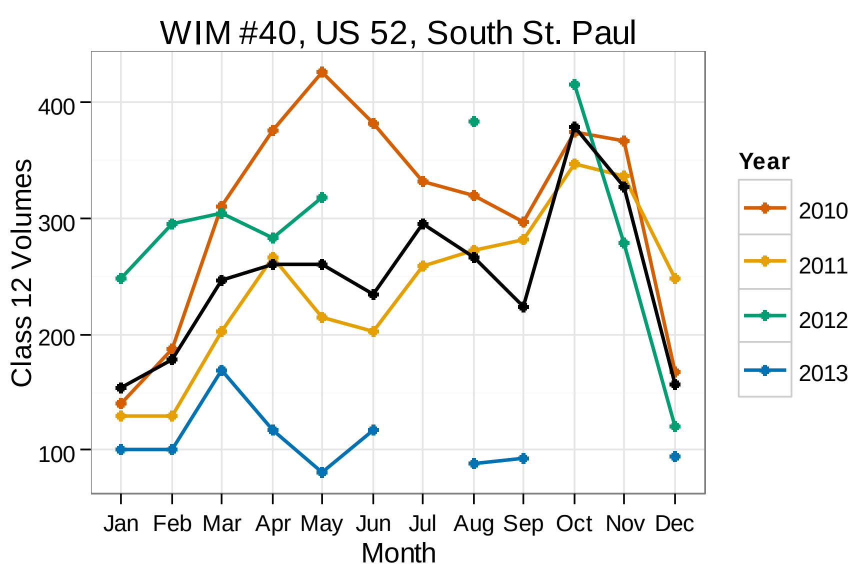


Figure 4.69l. Class 12 volume as a function of month and year. Black line represents the average volume within each month across all years.

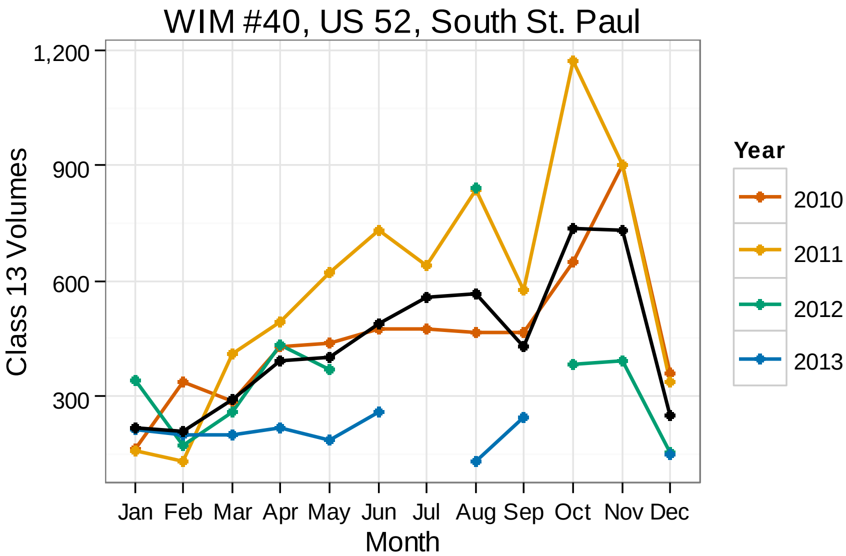


Figure 4.69m. Class 13 volume as a function of month and year. Black line represents the average volume within each month across all years.

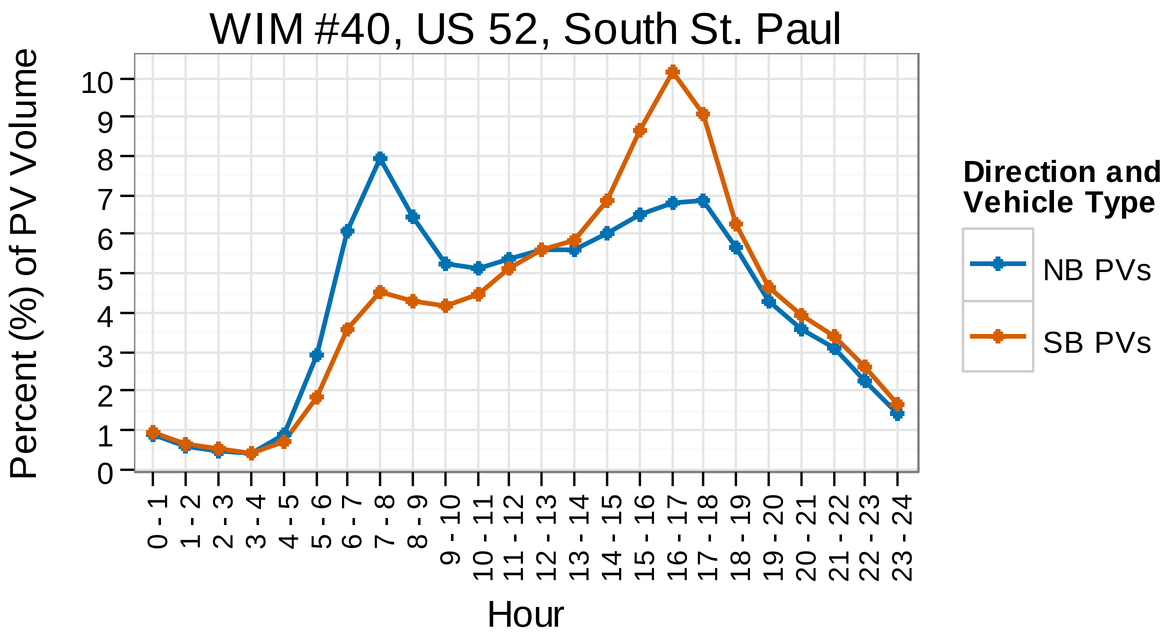


Figure 4.70a. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for passenger vehicles (PVs).

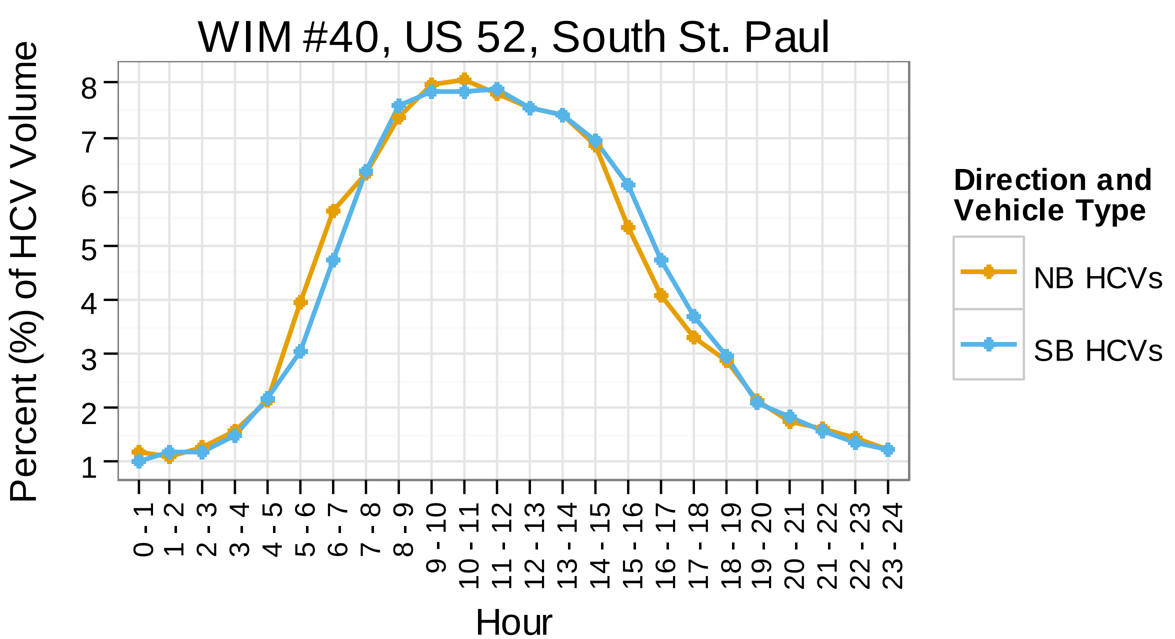


Figure 4.70b. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for heavy commercial vehicles (HCVs).

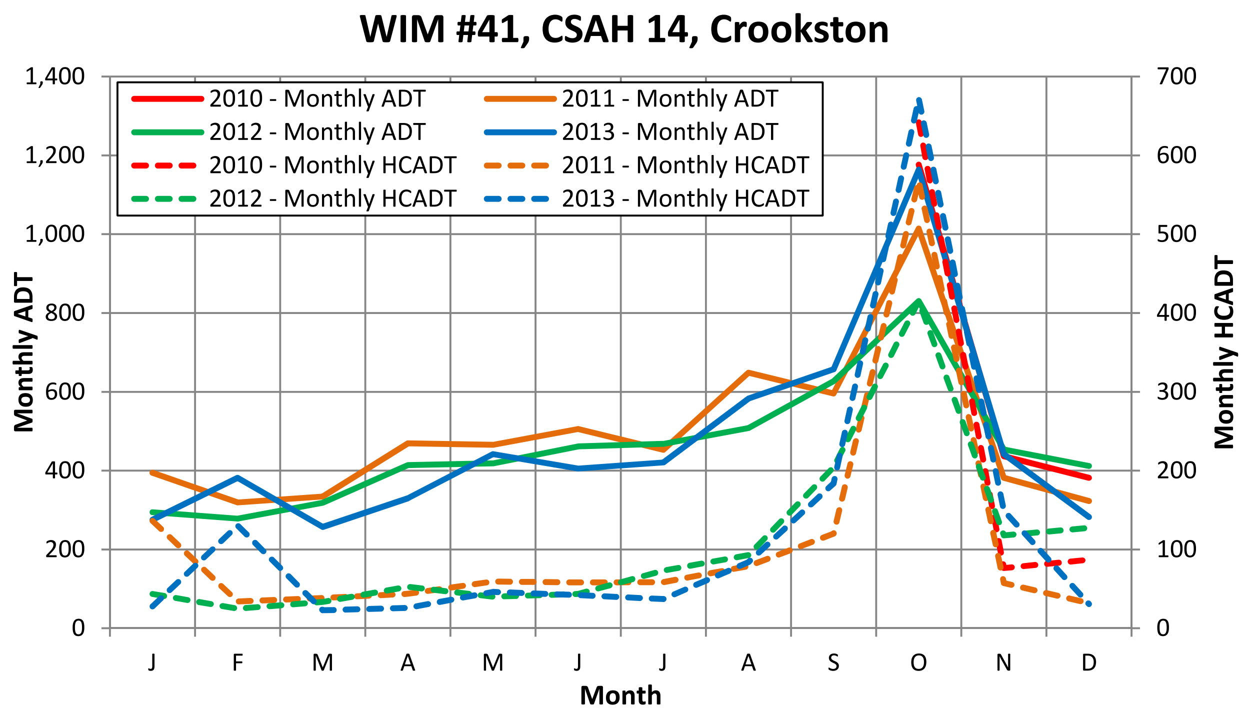


Figure 4.71. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

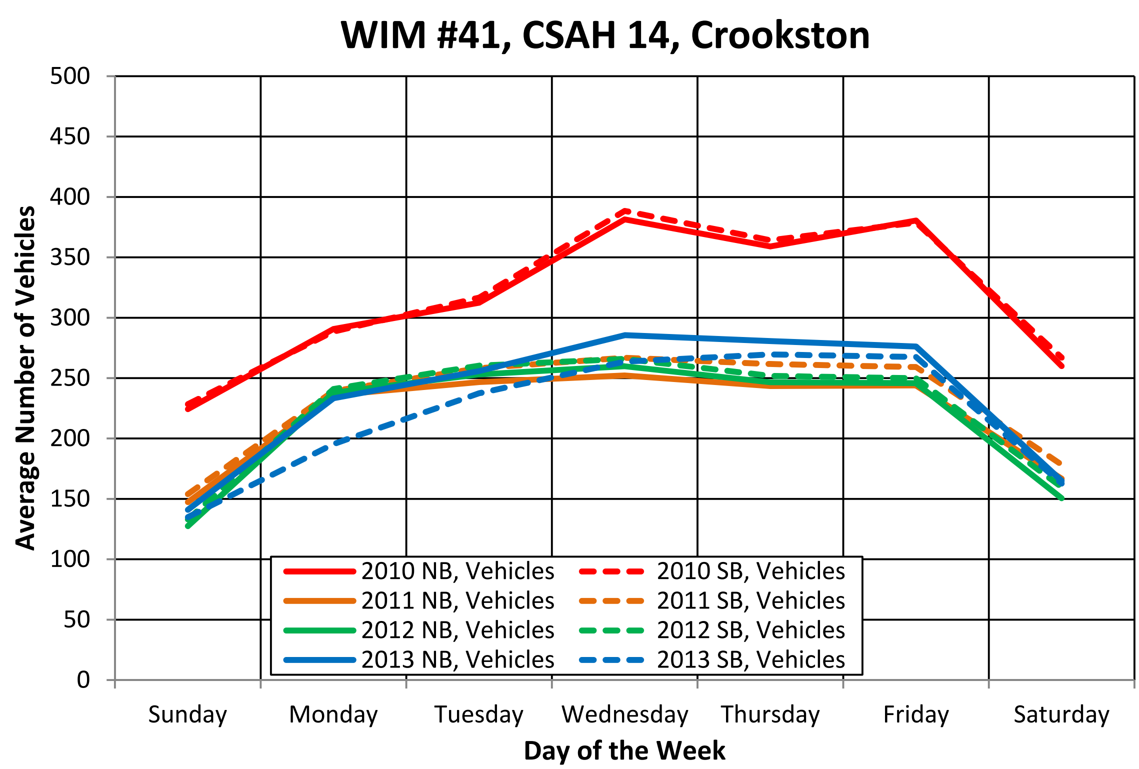


Figure 4.72. Mean number of vehicles by day of week, observed as a function of year and direction (northbound vs. southbound; NB vs. SB).

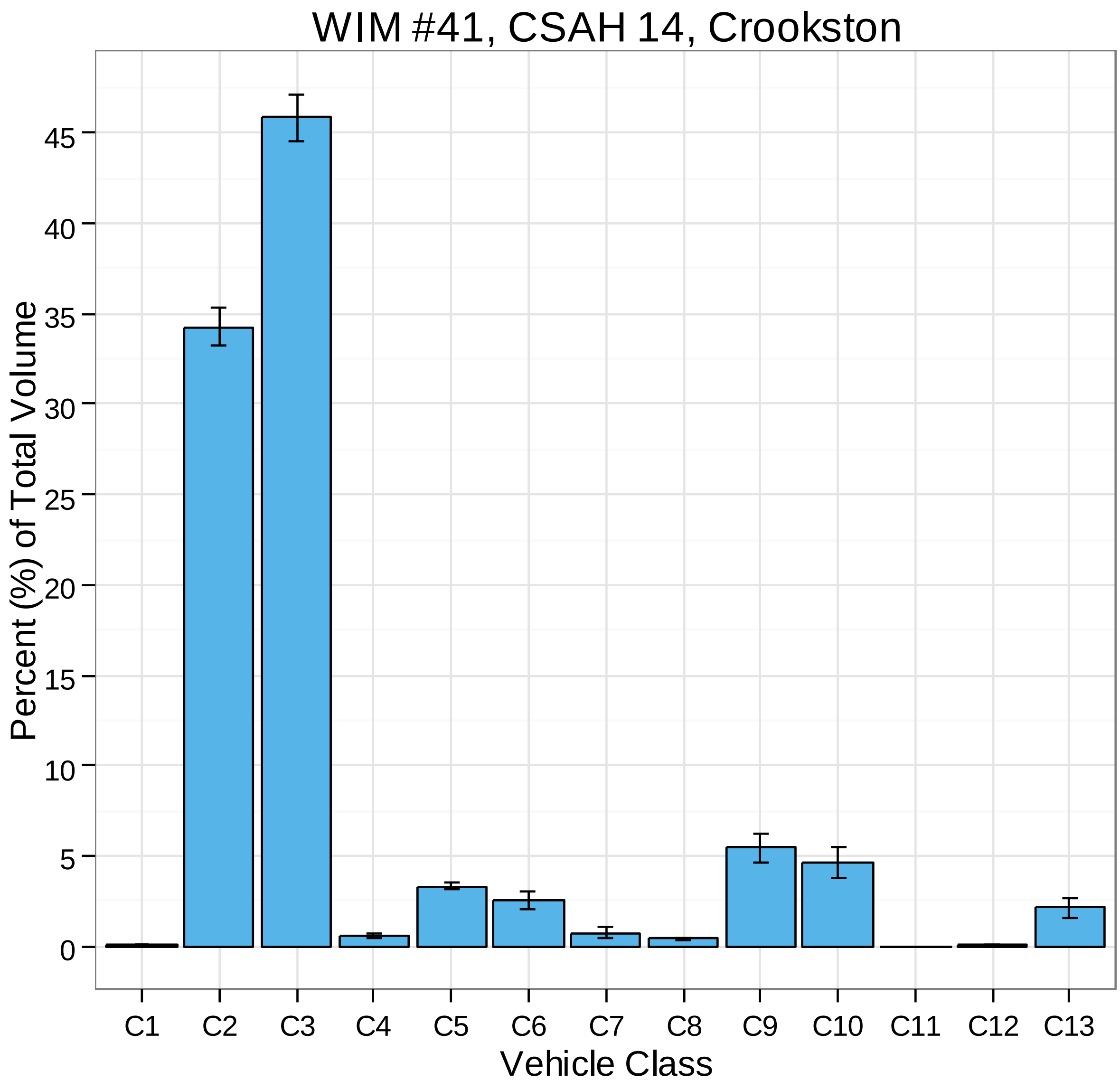


Figure 4.73. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

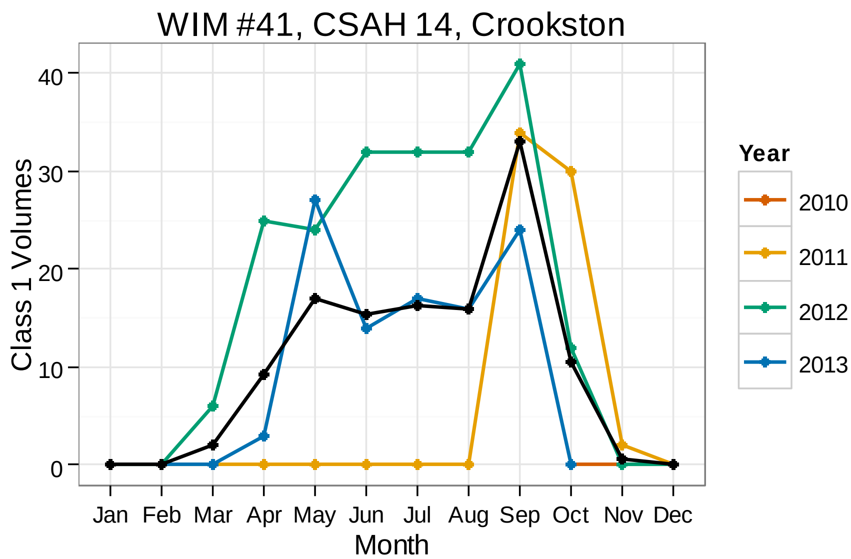


Figure 4.74a. Class 1 volume as a function of month and year. Black line represents the average volume within each month across all years.

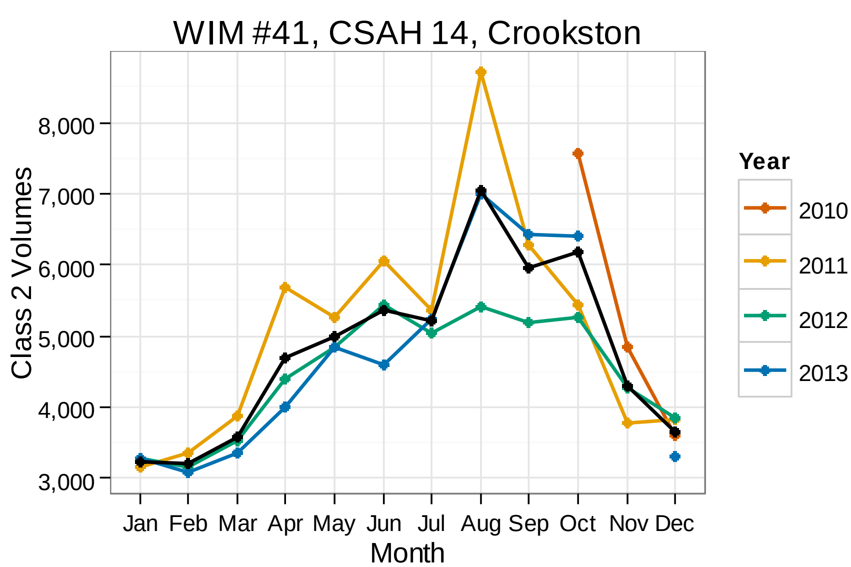


Figure 4.74b. Class 2 volume as a function of month and year. Black line represents the average volume within each month across all years.

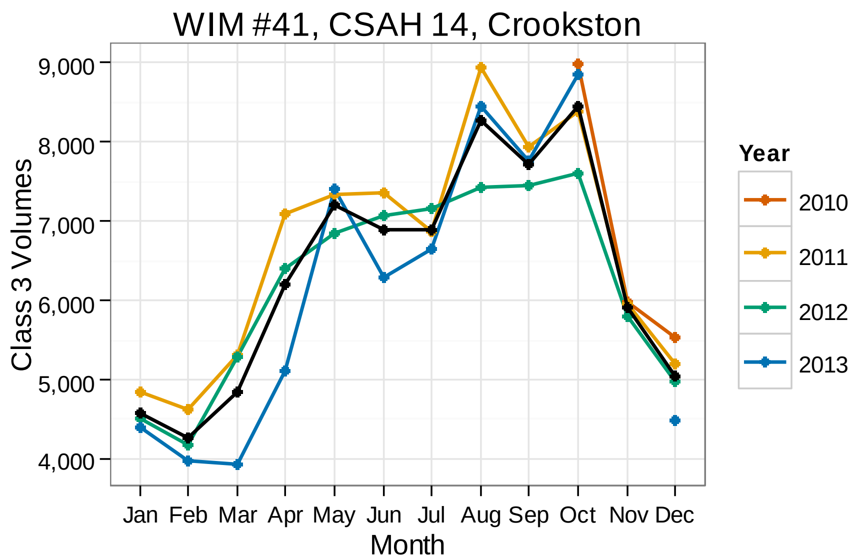


Figure 4.74c. Class 3 volume as a function of month and year. Black line represents the average volume within each month across all years.

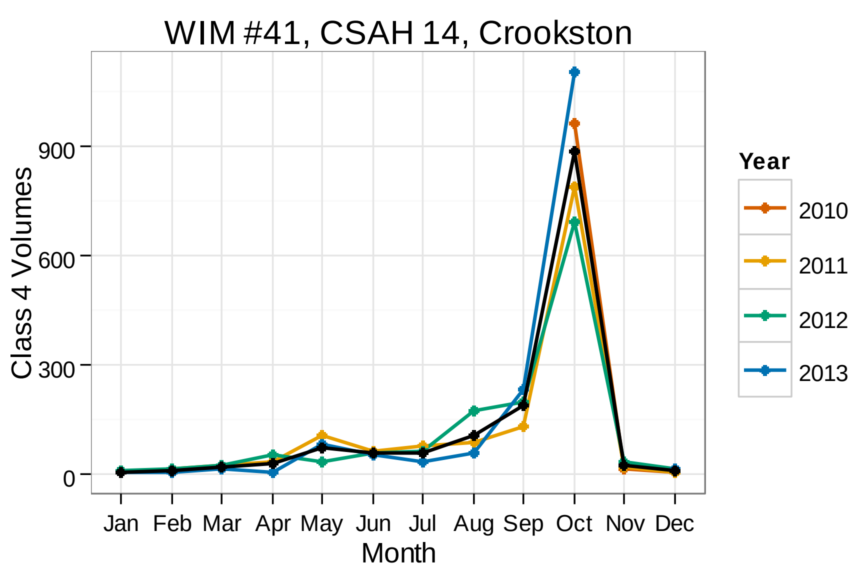


Figure 4.74d. Class 4 volume as a function of month and year. Black line represents the average volume within each month across all years.

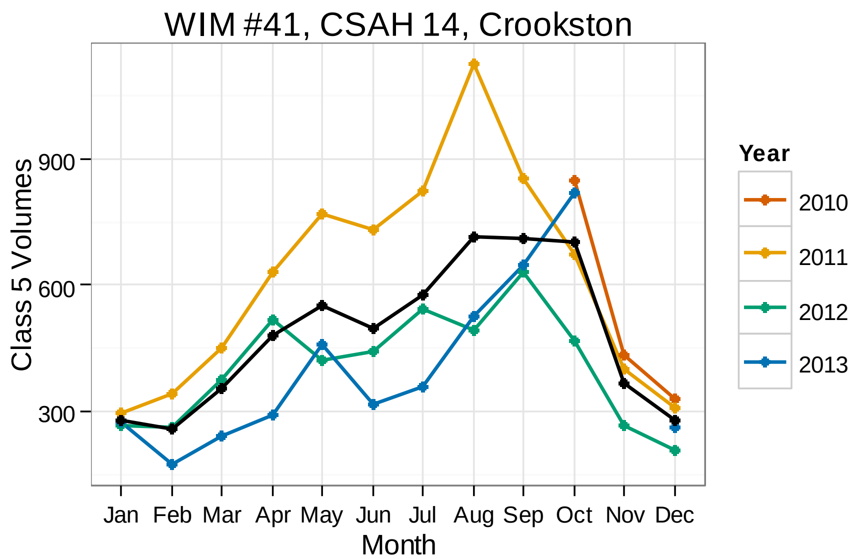


Figure 4.74e. Class 5 volume as a function of month and year. Black line represents the average volume within each month across all years.

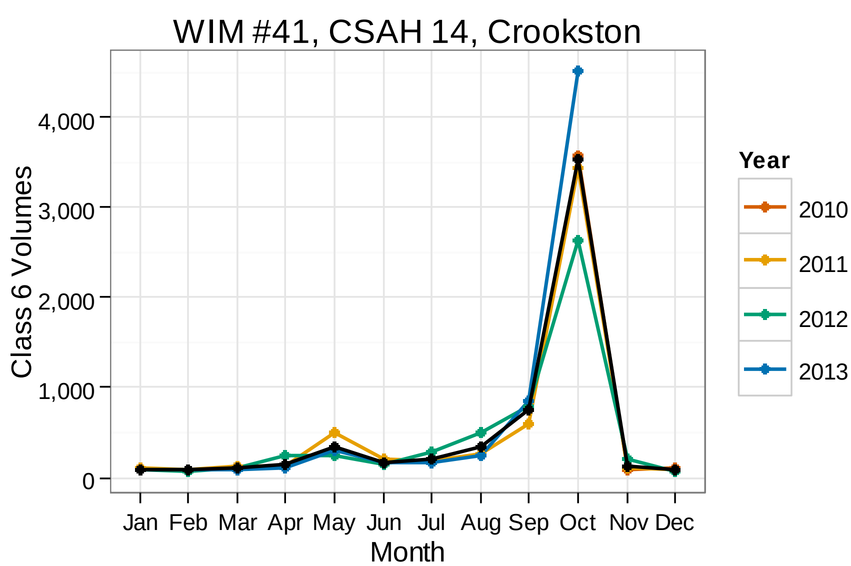


Figure 4.74f. Class 6 volume as a function of month and year. Black line represents the average volume within each month across all years.

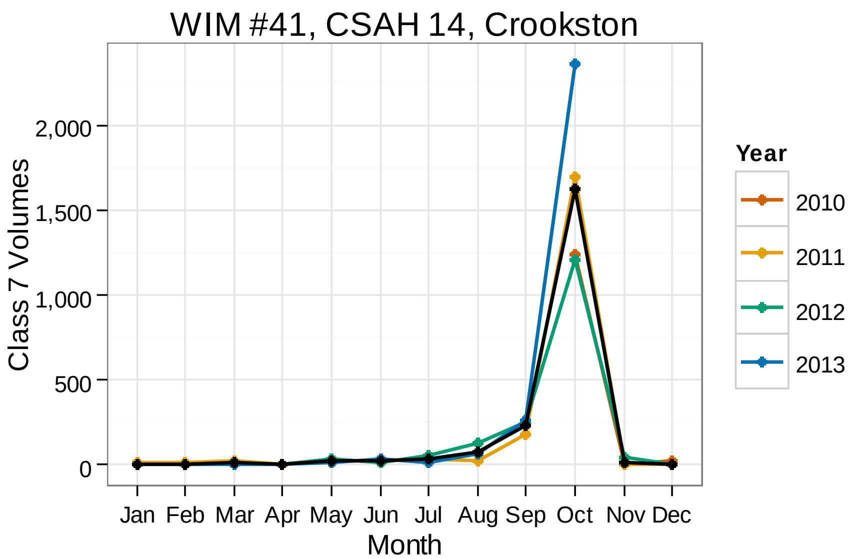


Figure 4.74g. Class 7 volume as a function of month and year. Black line represents the average volume within each month across all years.

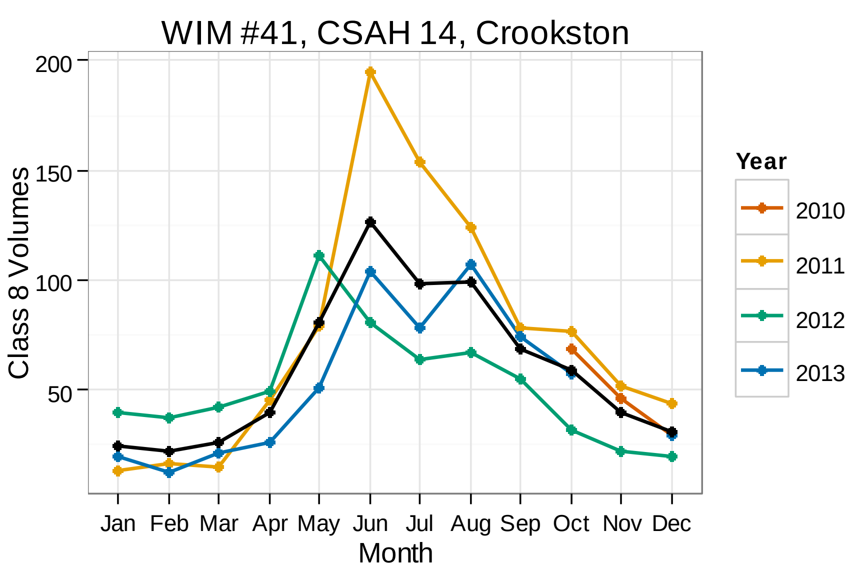


Figure 4.74h. Class 8 volume as a function of month and year. Black line represents the average volume within each month across all years.

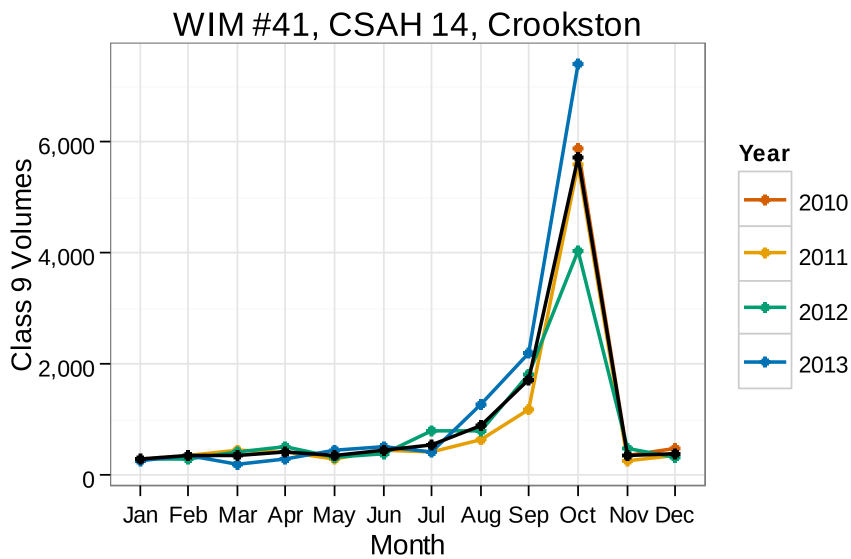


Figure 4.74i. Class 9 volume as a function of month and year. Black line represents the average volume within each month across all years.

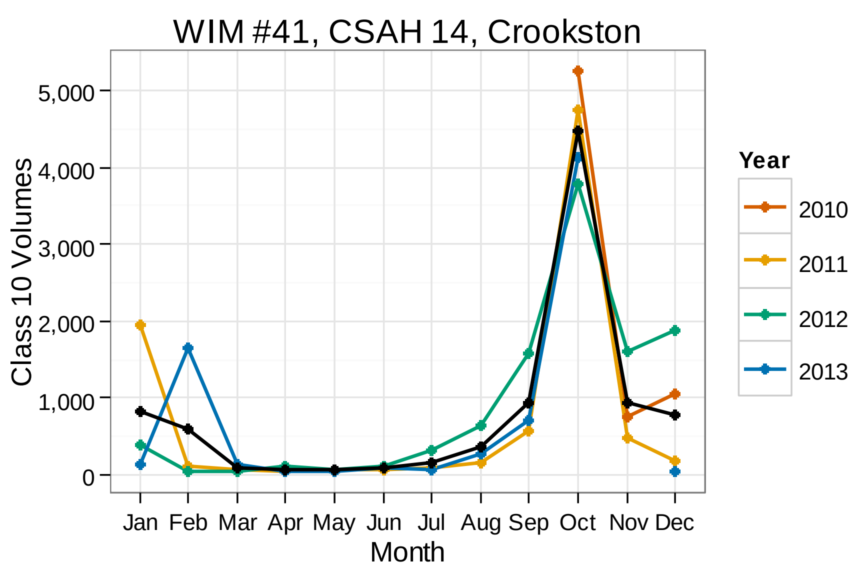


Figure 4.74j. Class 10 volume as a function of month and year. Black line represents the average volume within each month across all years.

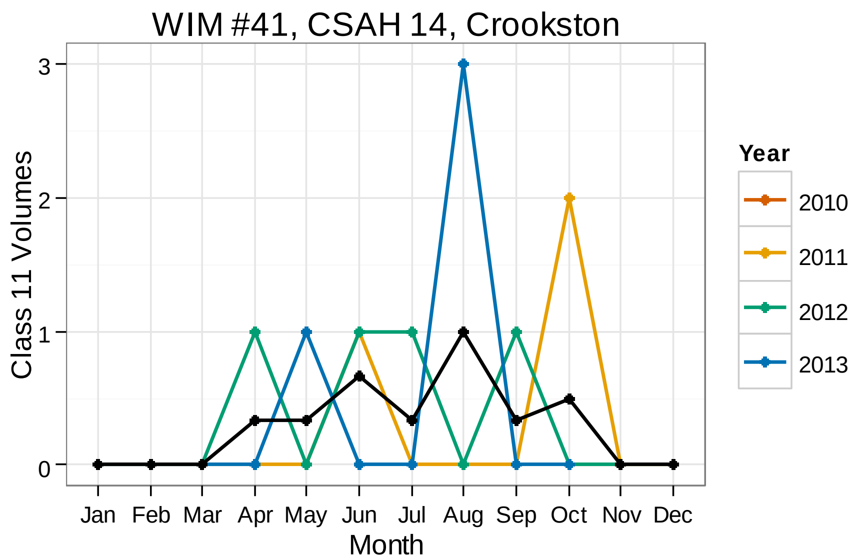


Figure 4.74k. Class 11 volume as a function of month and year. Black line represents the average volume within each month across all years.

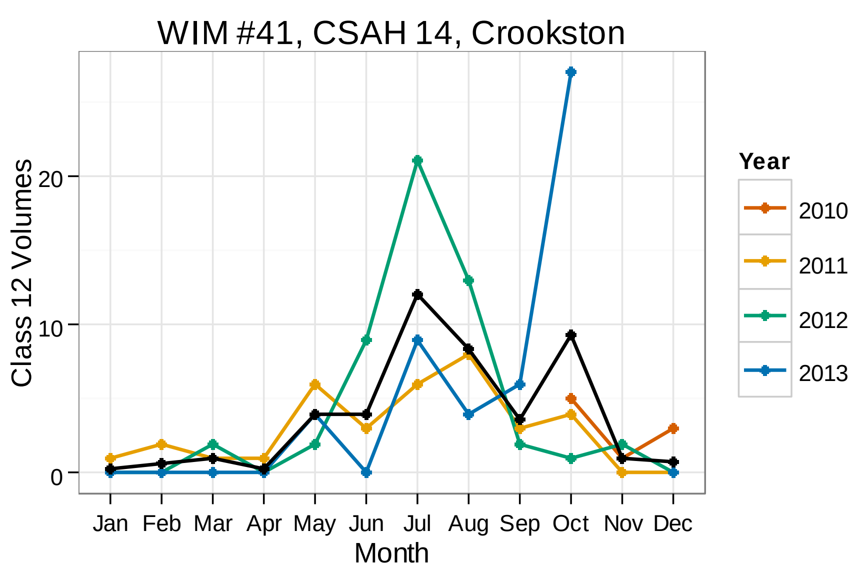


Figure 4.74l. Class 12 volume as a function of month and year. Black line represents the average volume within each month across all years.

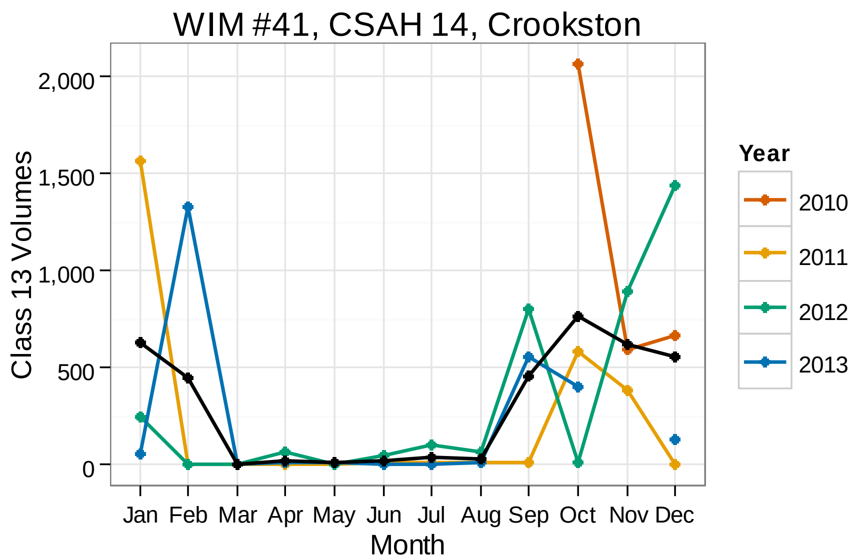


Figure 4.74m. Class 13 volume as a function of month and year. Black line represents the average volume within each month across all years.

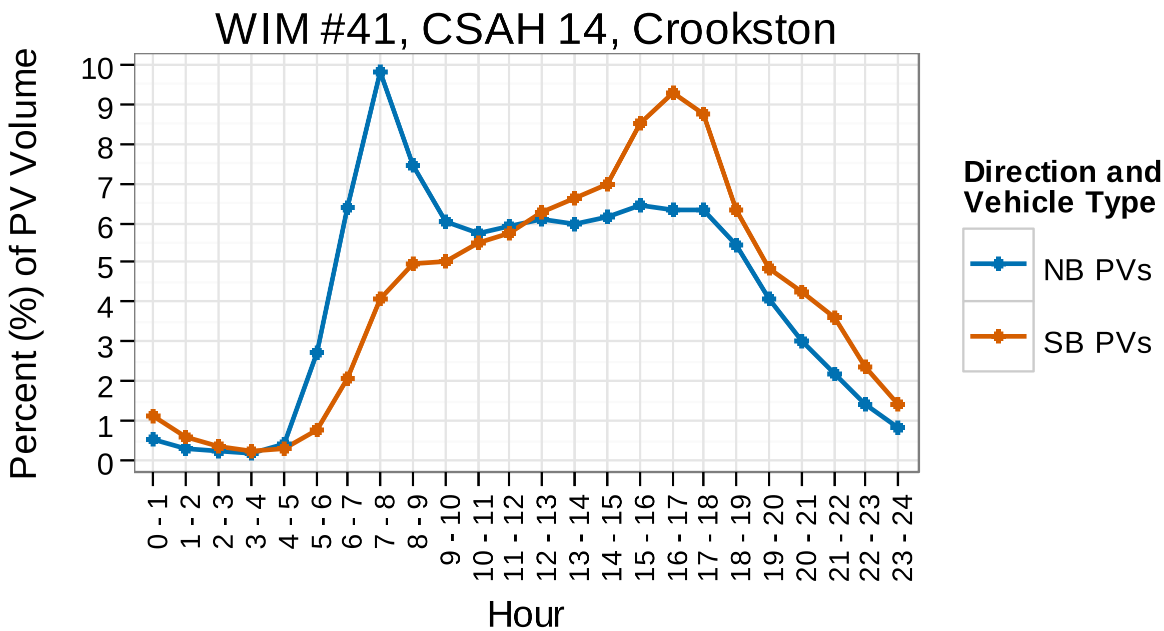


Figure 4.75a. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for passenger vehicles (PVs).

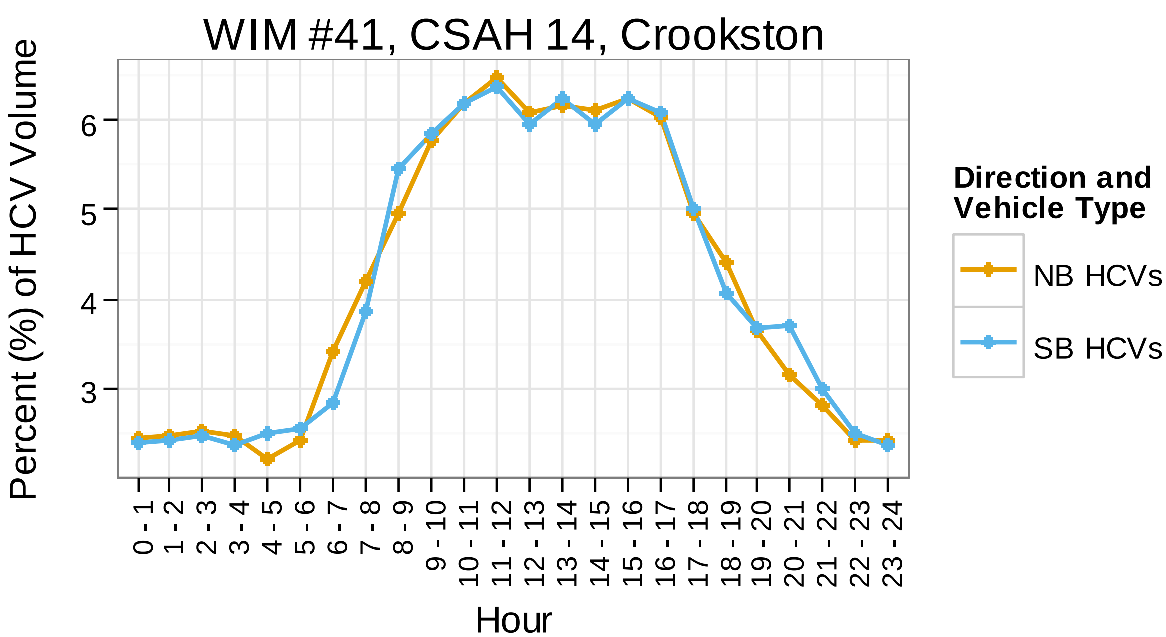


Figure 4.75b. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for heavy commercial vehicles (HCVs).

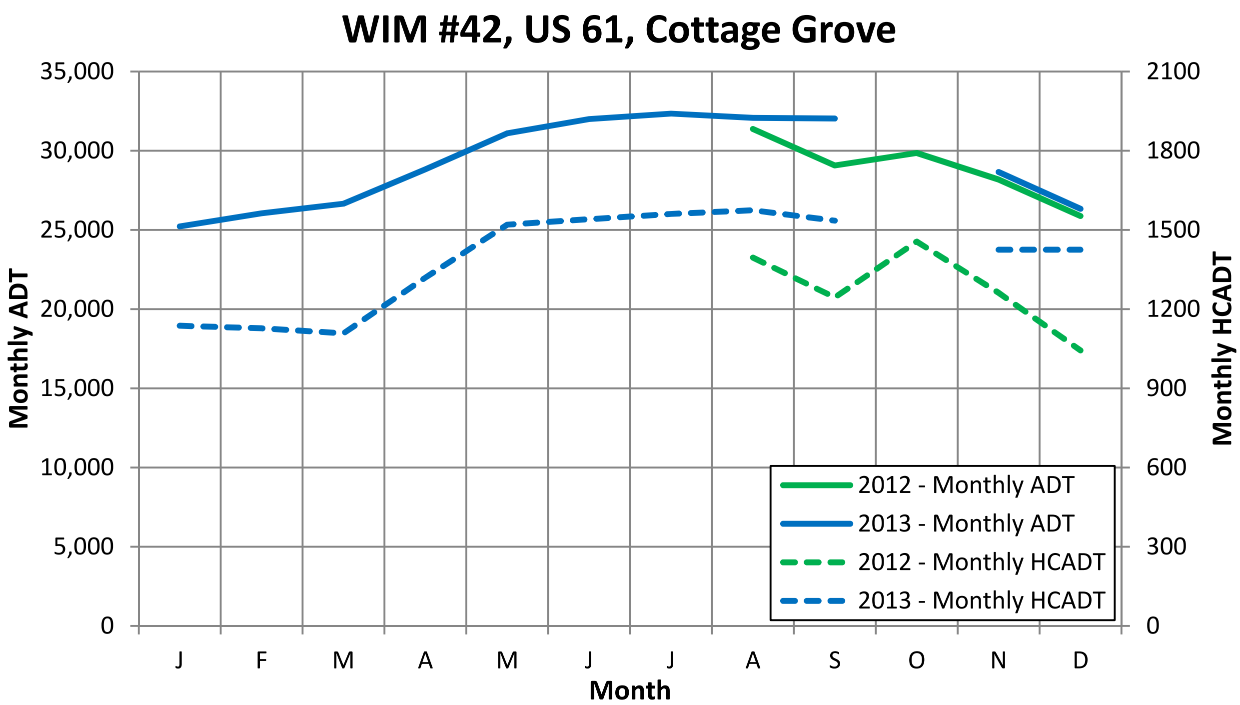


Figure 4.76. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

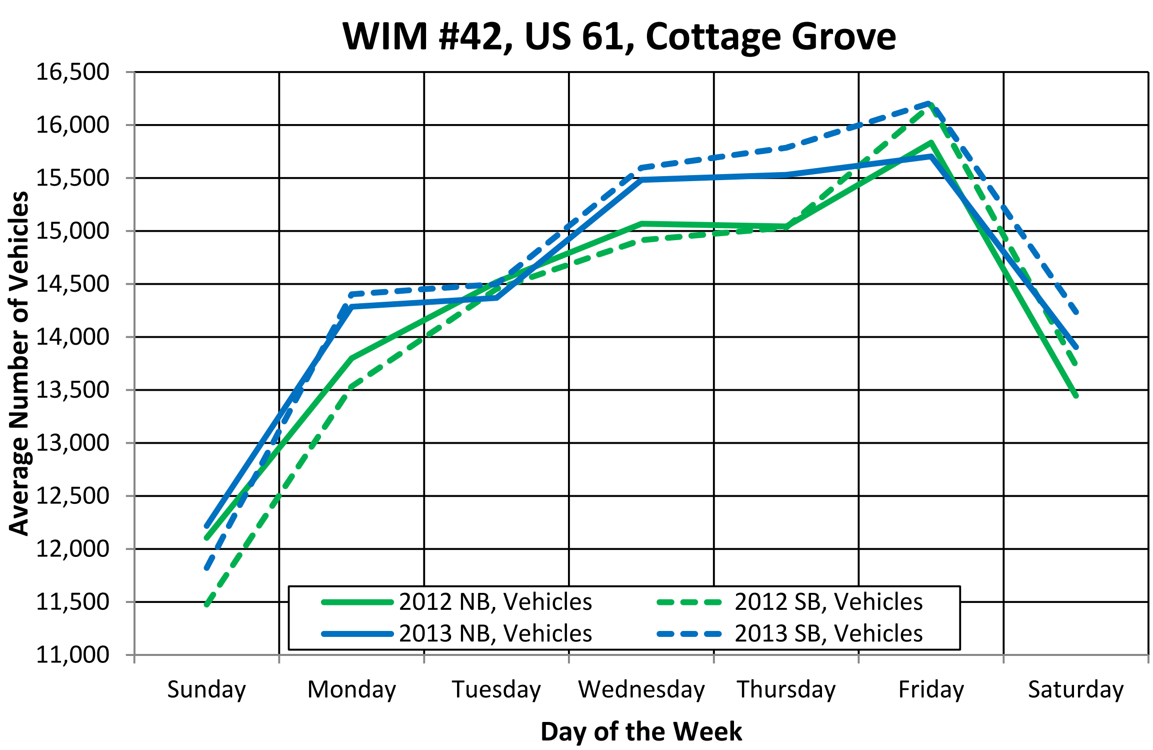


Figure 4.77. Mean number of vehicles by day of week, observed as a function of year and direction (northbound vs. southbound; NB vs. SB).

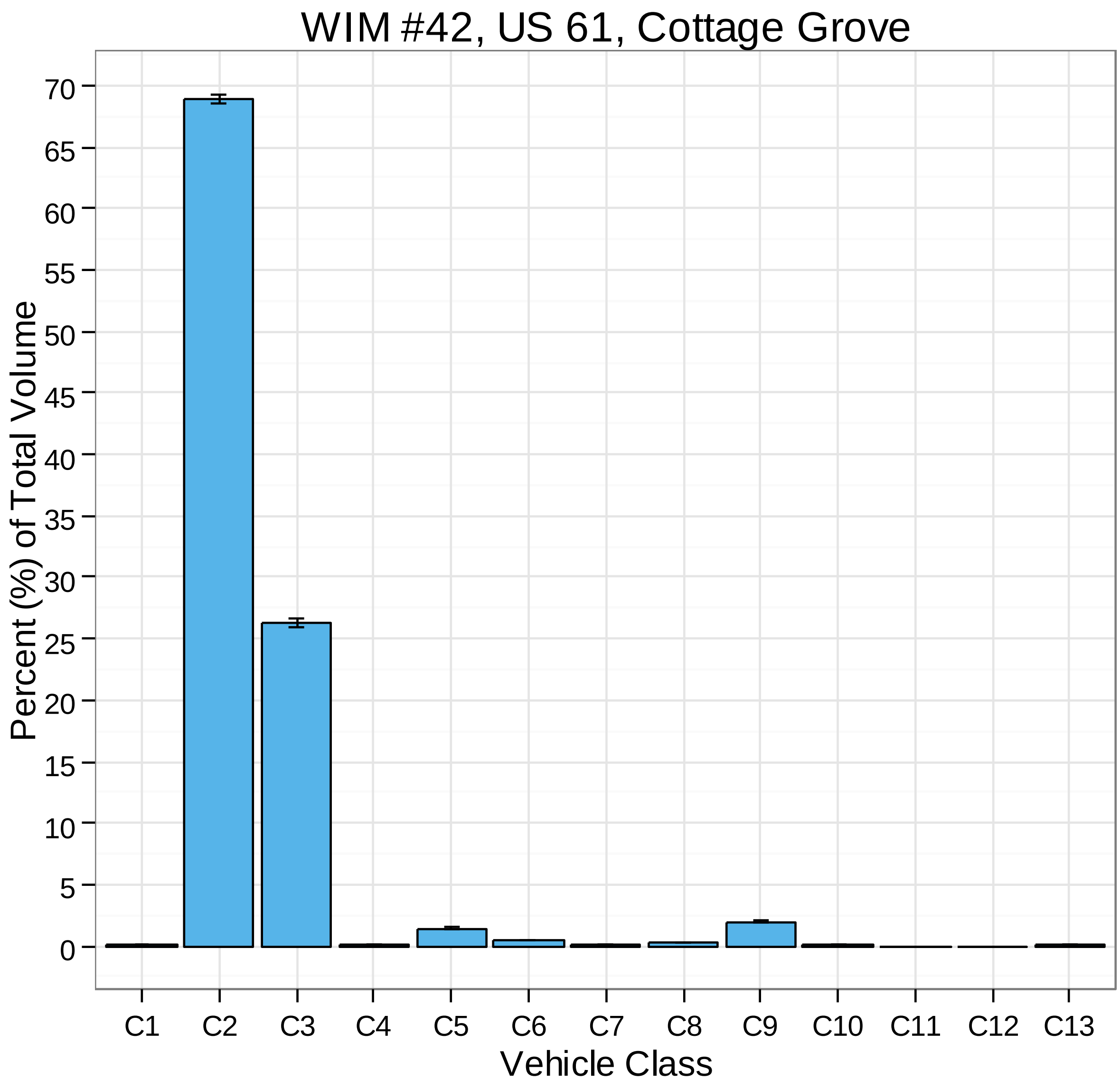


Figure 4.78. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

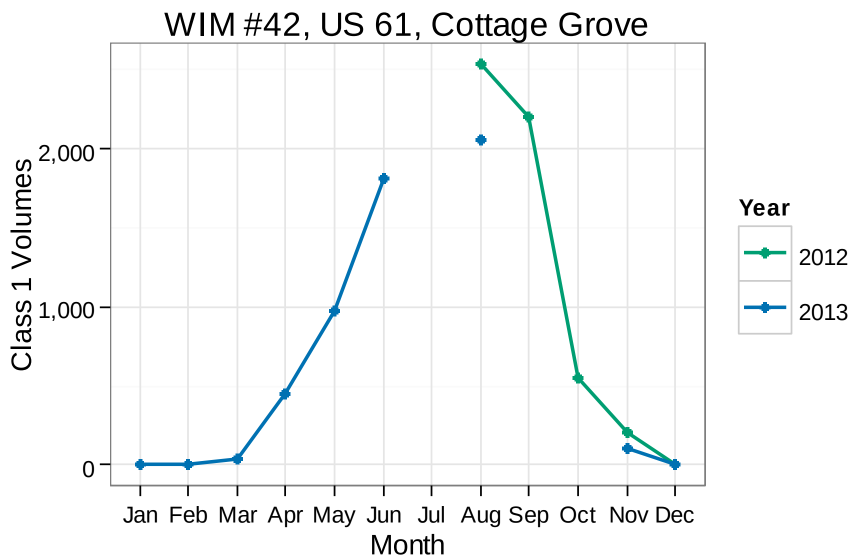


Figure 4.79a. Class 1 volume as a function of month and year.

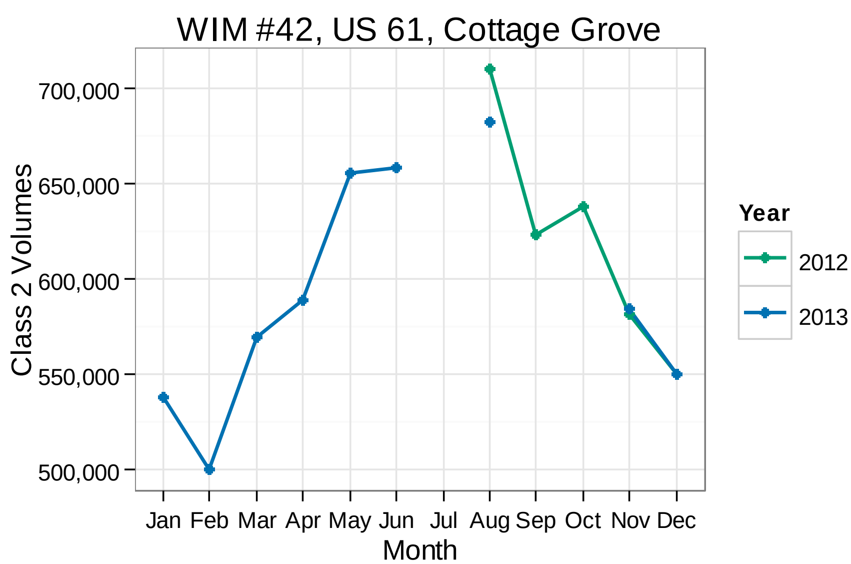


Figure 4.79b. Class 2 volume as a function of month and year.

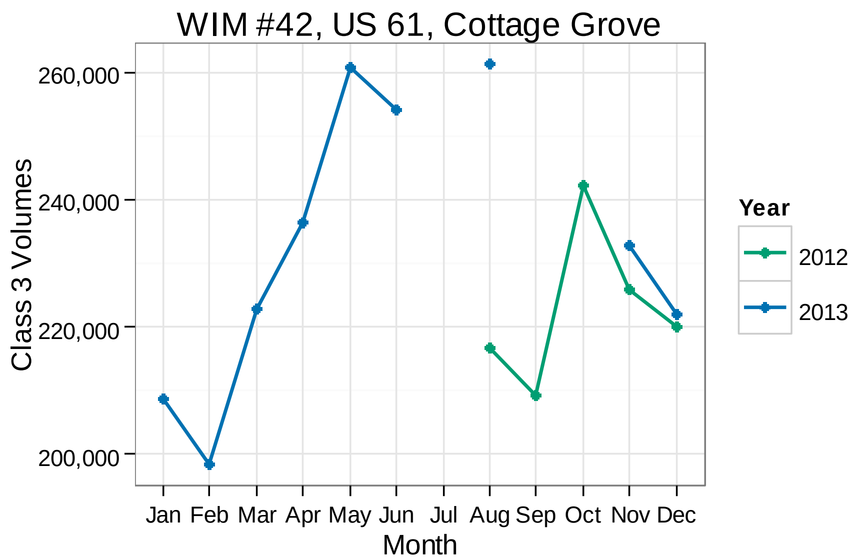


Figure 4.79c. Class 3 volume as a function of month and year.

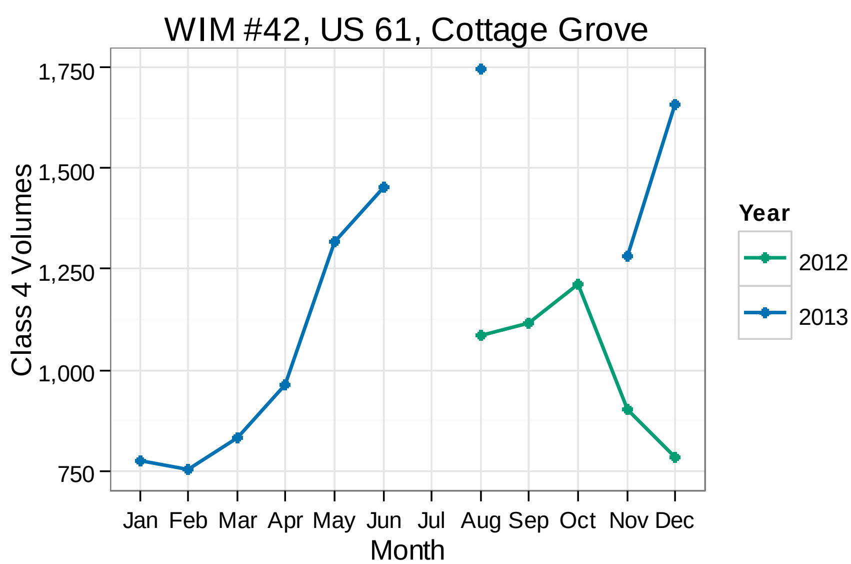


Figure 4.79d. Class 4 volume as a function of month and year.

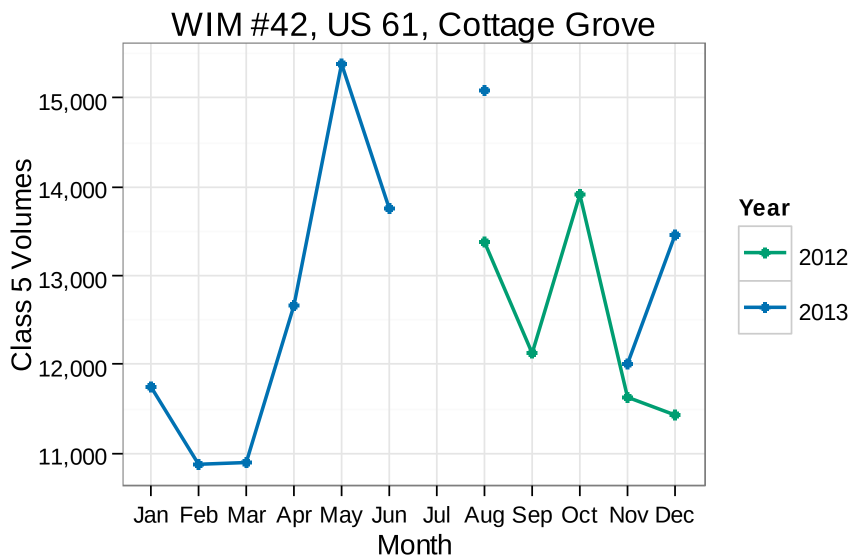


Figure 4.79e. Class 5 volume as a function of month and year.

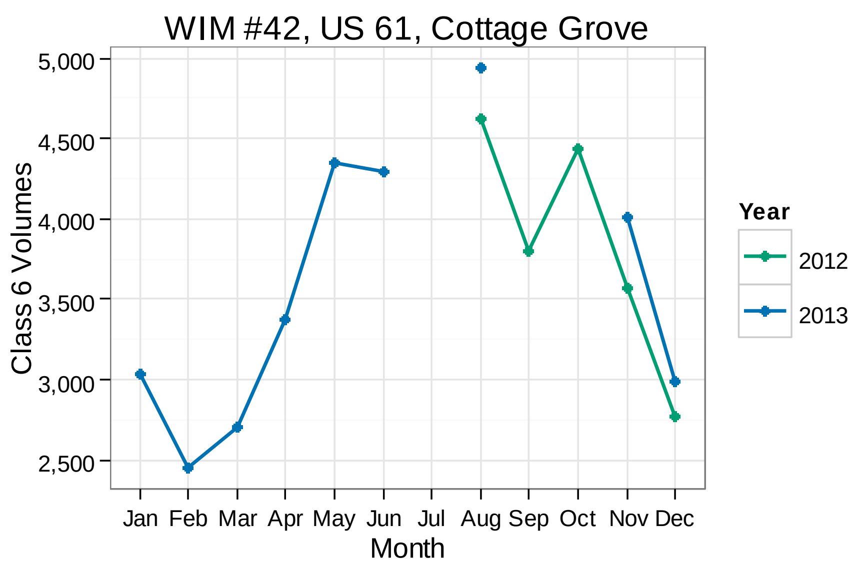


Figure 4.79f. Class 6 volume as a function of month and year.

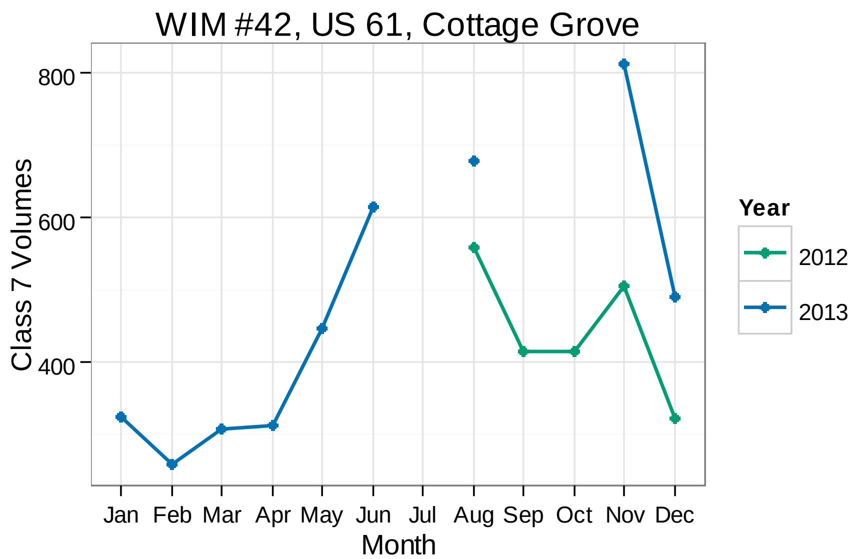


Figure 4.79g. Class 7 volume as a function of month and year.

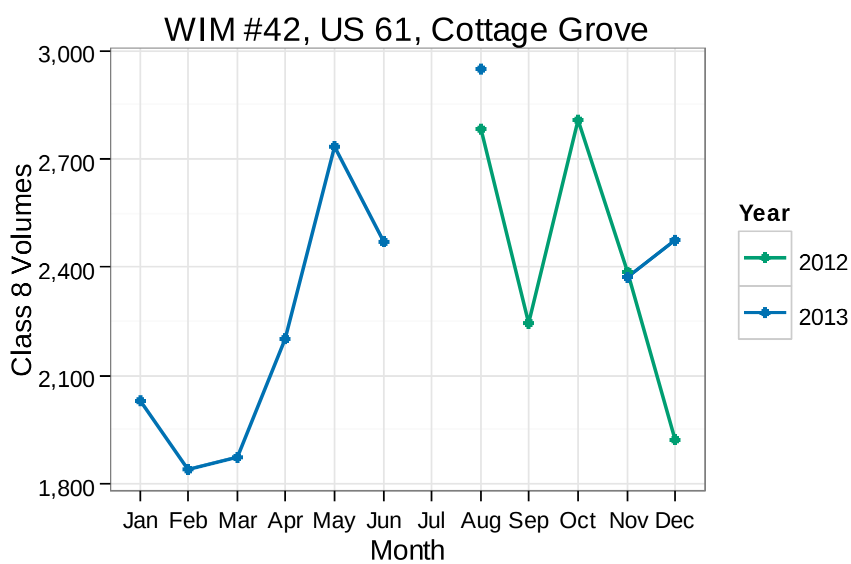


Figure 4.79h. Class 8 volume as a function of month and year.

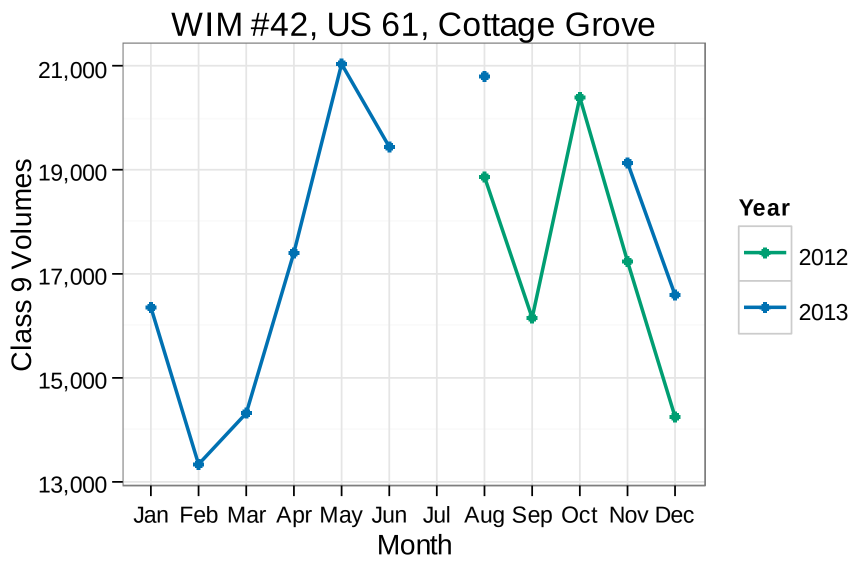


Figure 4.79i. Class 9 volume as a function of month and year.

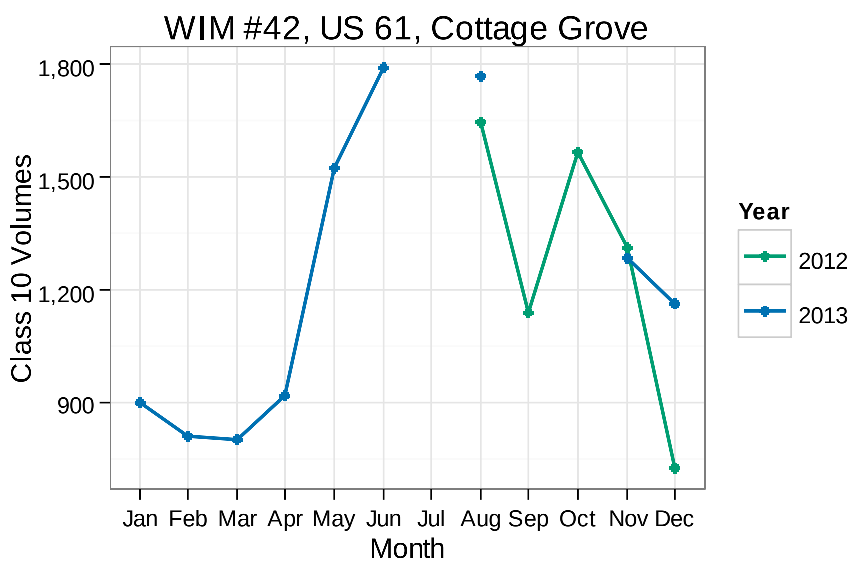


Figure 4.79j. Class 10 volume as a function of month and year.

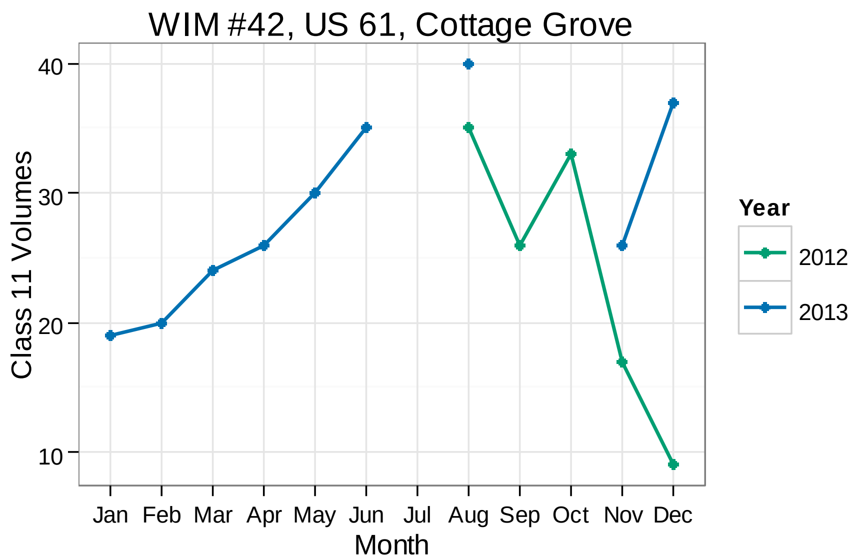


Figure 4.79k. Class 11 volume as a function of month and year.

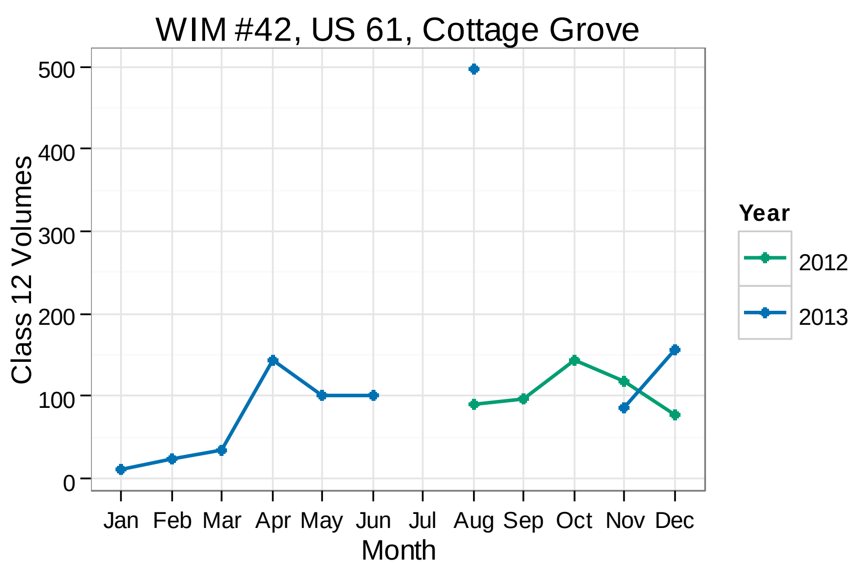


Figure 4.79l. Class 12 volume as a function of month and year.

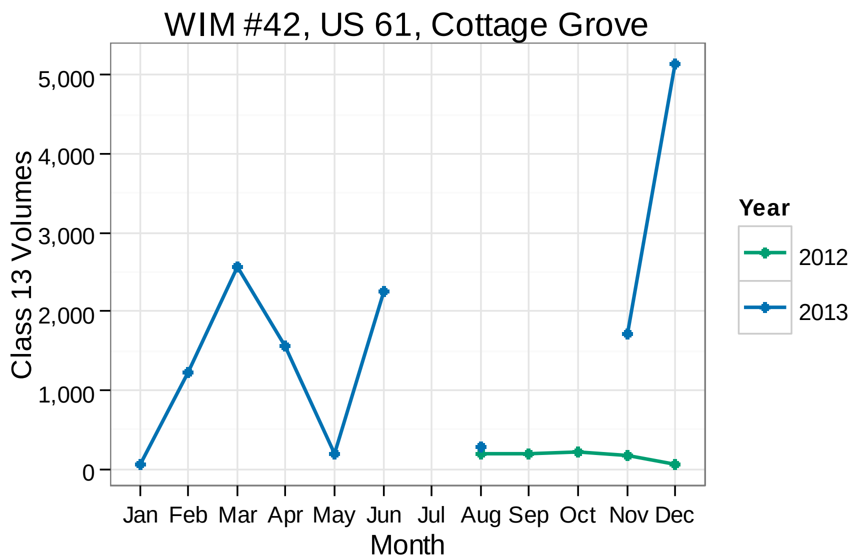


Figure 4.79m. Class 13 volume as a function of month and year.

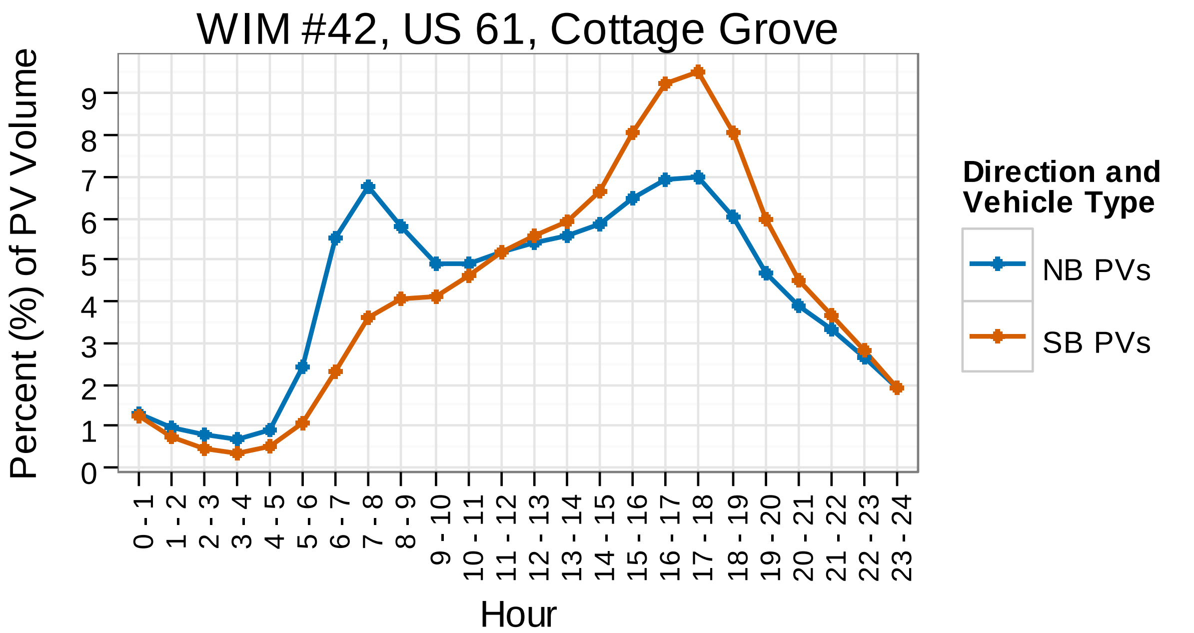


Figure 4.80a. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for passenger vehicles (PVs).

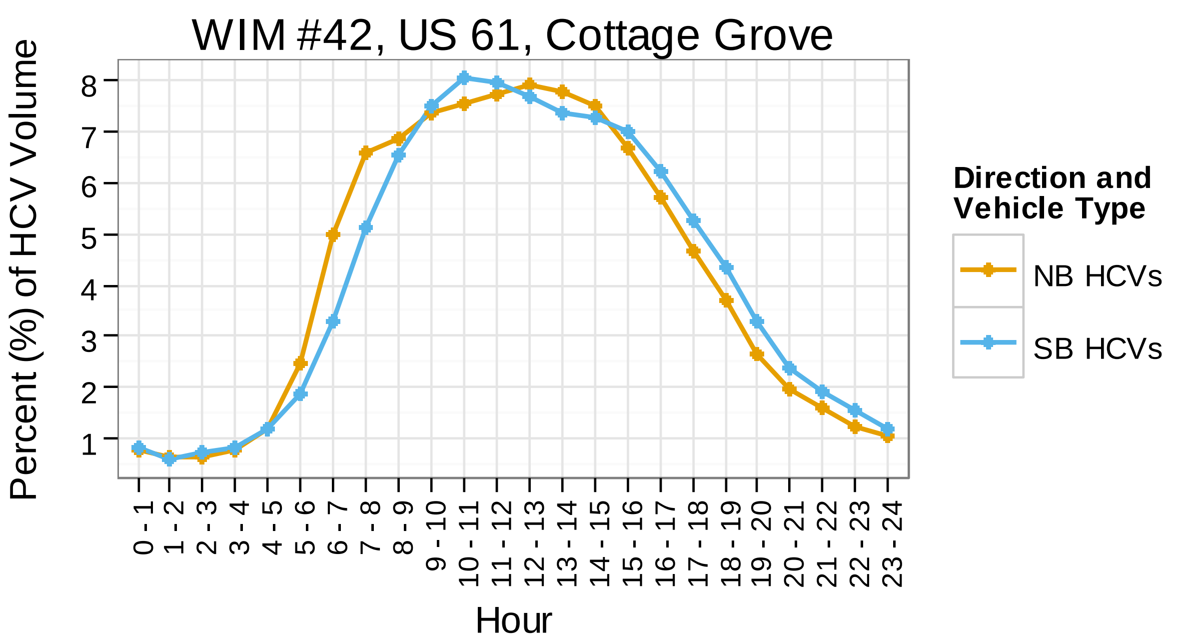


Figure 4.80b. Amount of traffic (% of volume) observed at an hourly basis for each direction (northbound; NB vs. southbound; SB) for heavy commercial vehicles (HCVs).

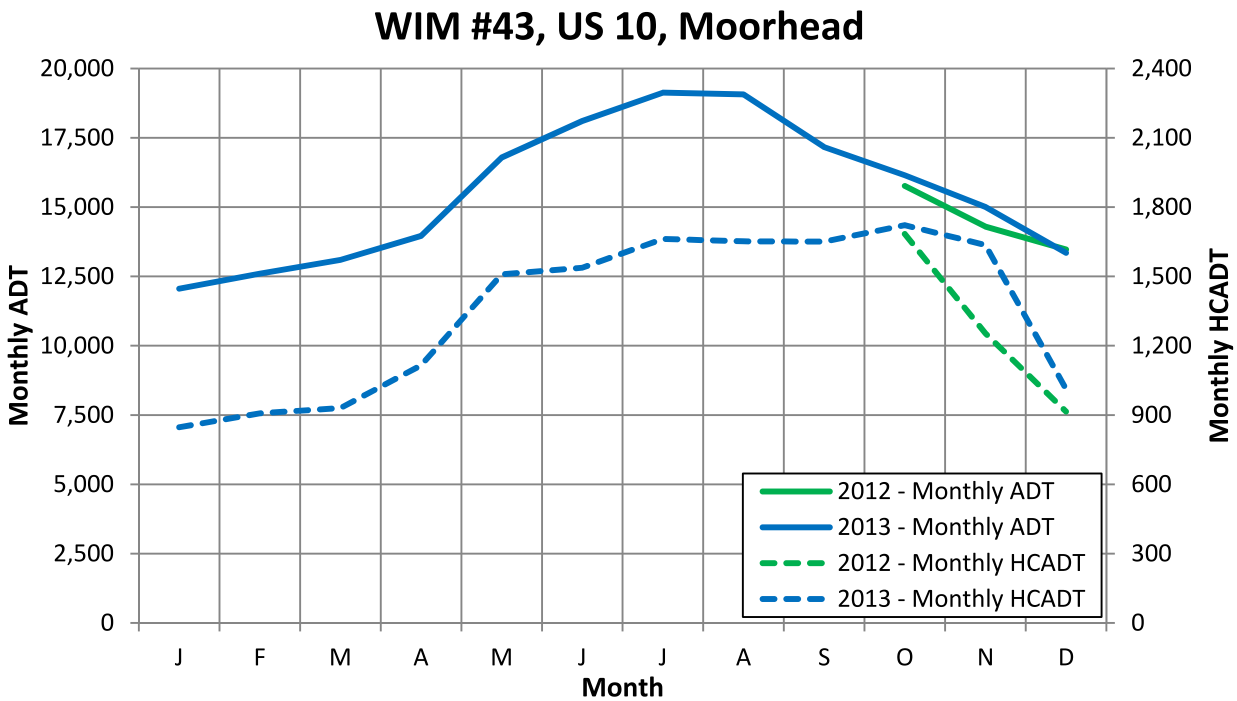


Figure 4.81. Monthly calculations of average daily traffic (ADT) and heavy commercial average daily traffic (HCADT).

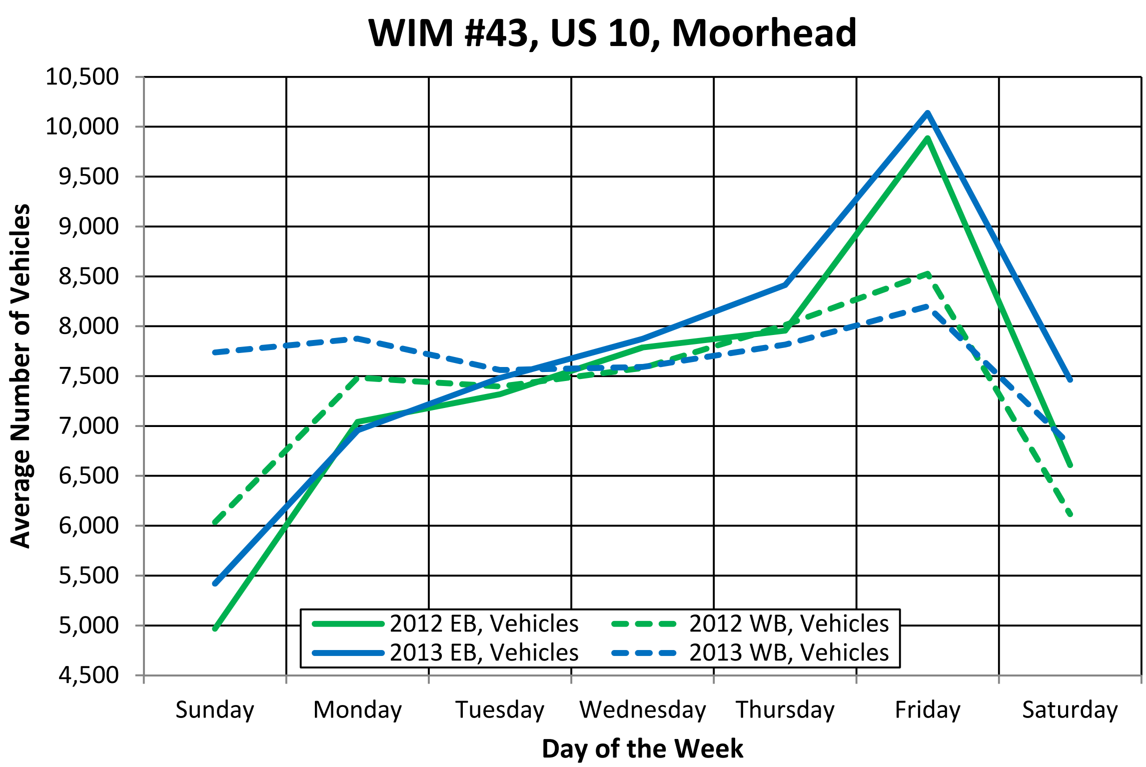


Figure 4.82. Mean number of vehicles by day of week, observed as a function of year and direction (eastbound vs. westbound; EB vs. WB).

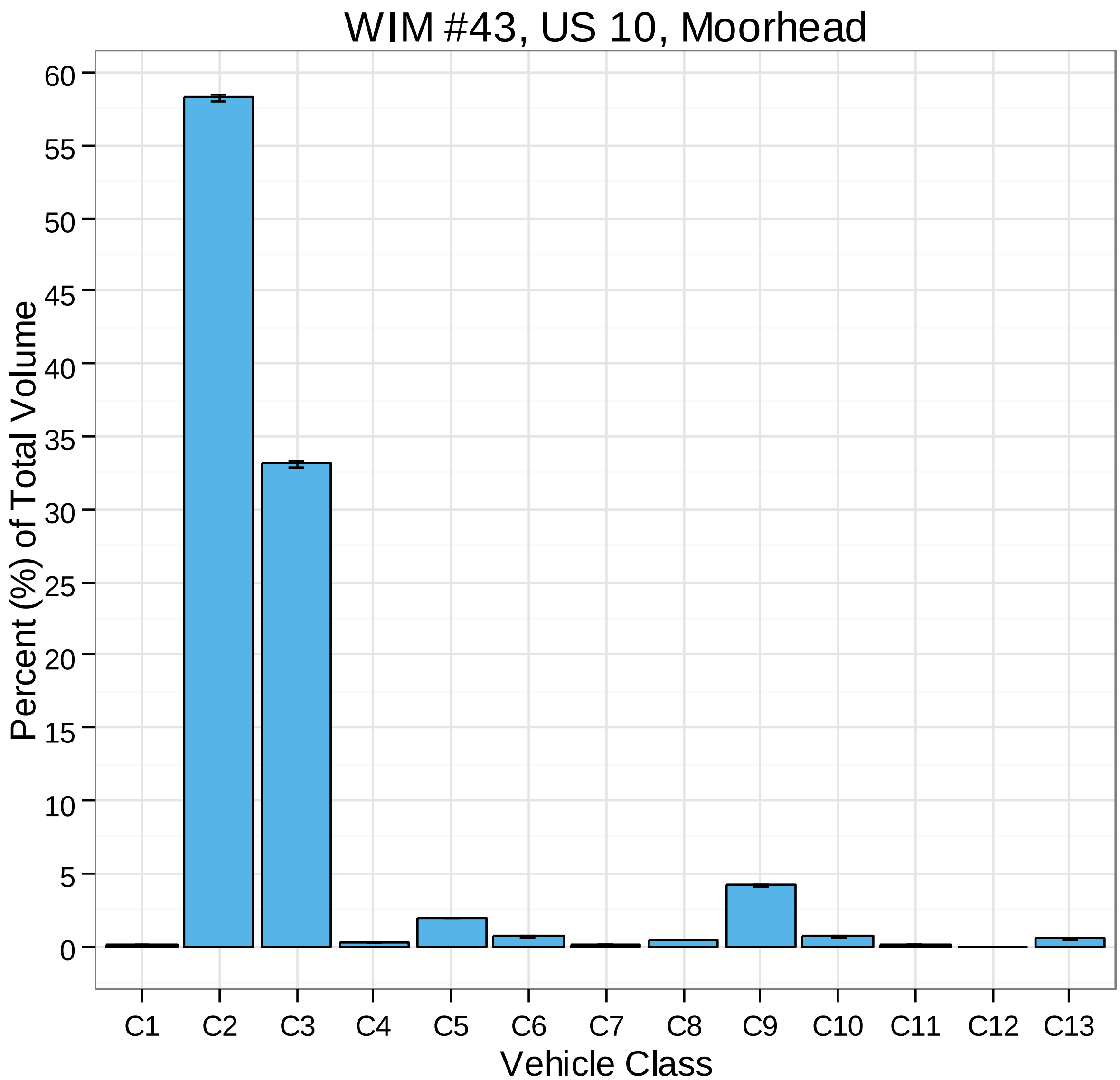


Figure 4.83. Average monthly vehicle class contributions (%) to total volume. Error bars represent standard error of the mean.

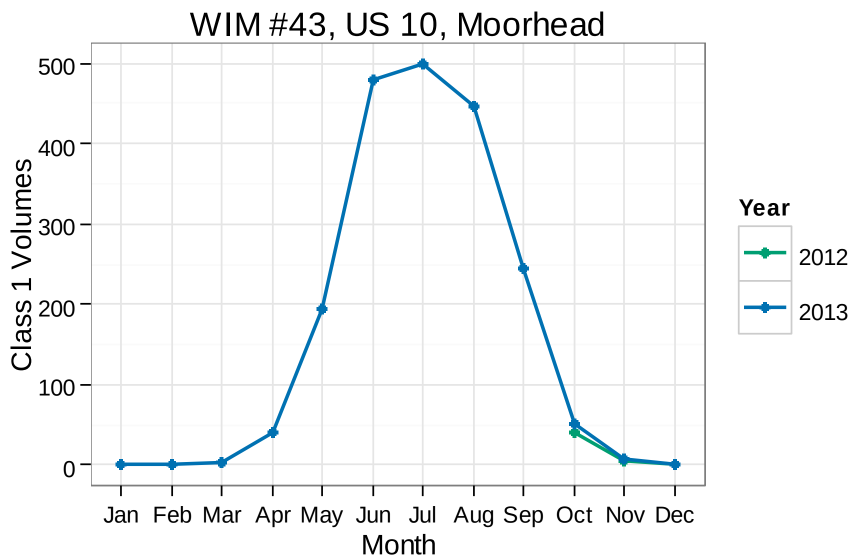


Figure 4.84a. Class 1 volume as a function of month and year.

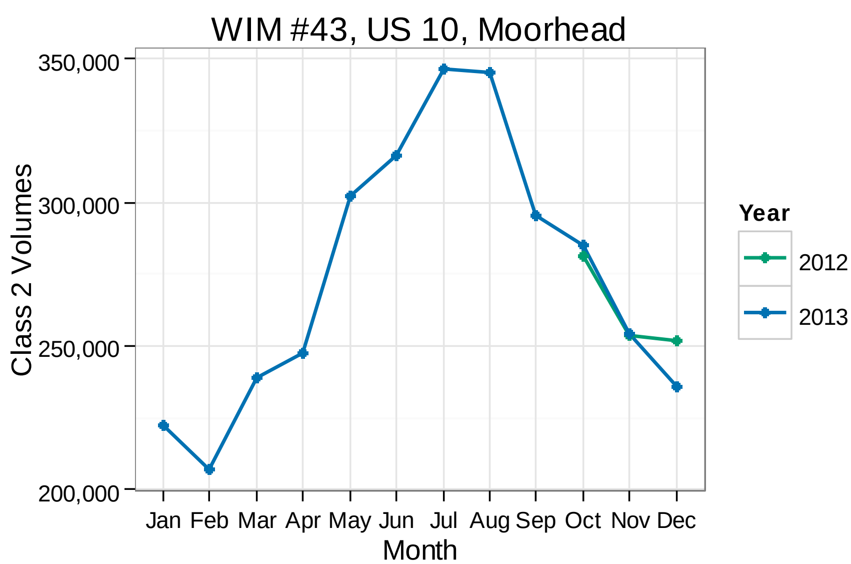


Figure 4.84b. Class 2 volume as a function of month and year.

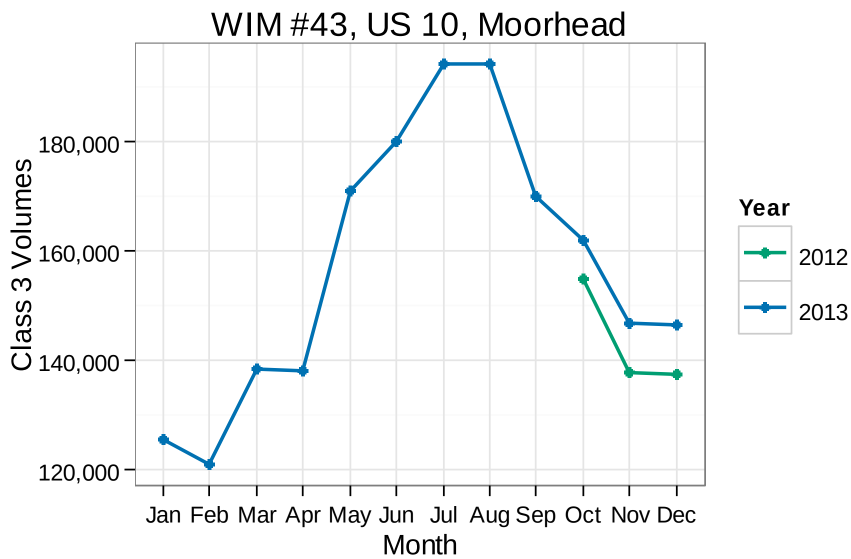


Figure 4.84c. Class 3 volume as a function of month and year.

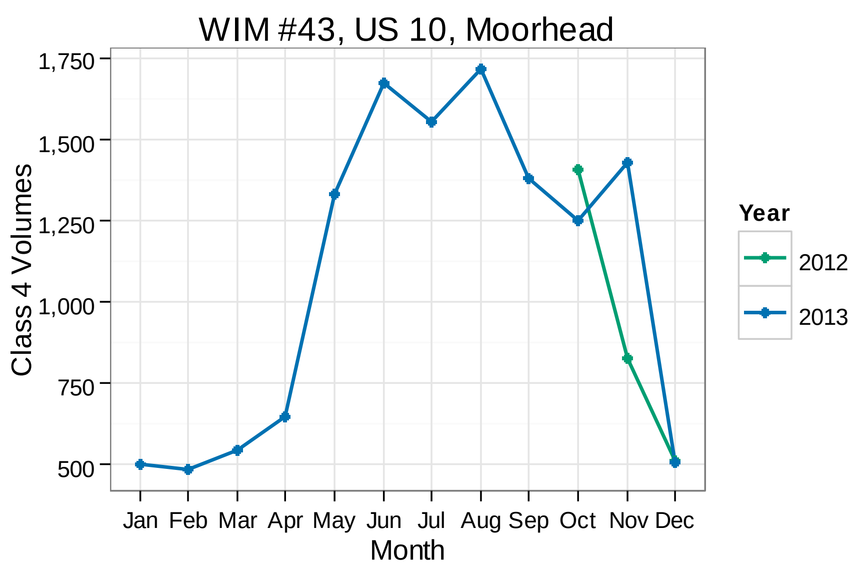


Figure 4.84d. Class 4 volume as a function of month and year.

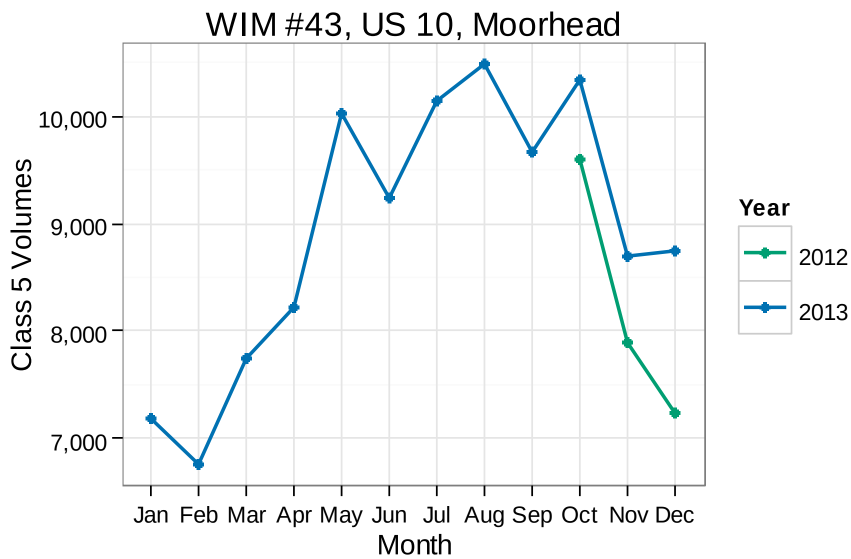


Figure 4.84e. Class 5 volume as a function of month and year.

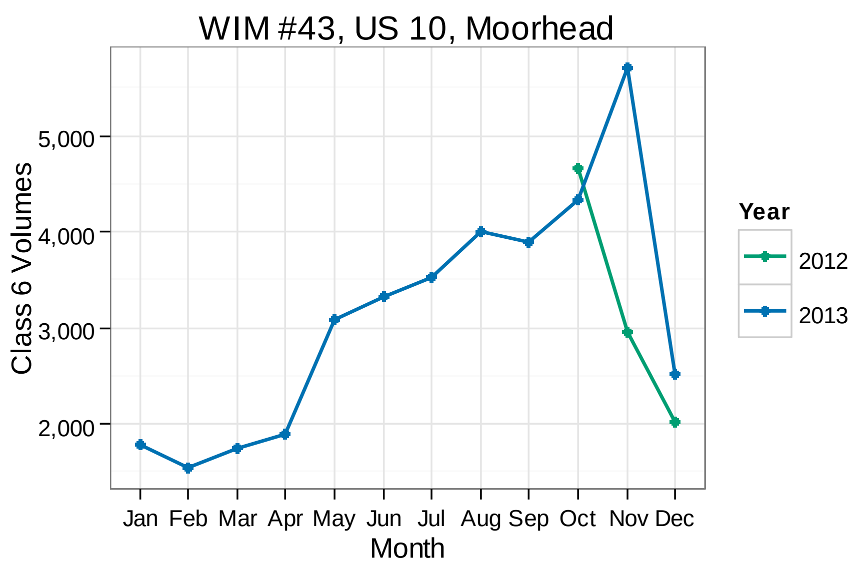


Figure 4.84f. Class 6 volume as a function of month and year.

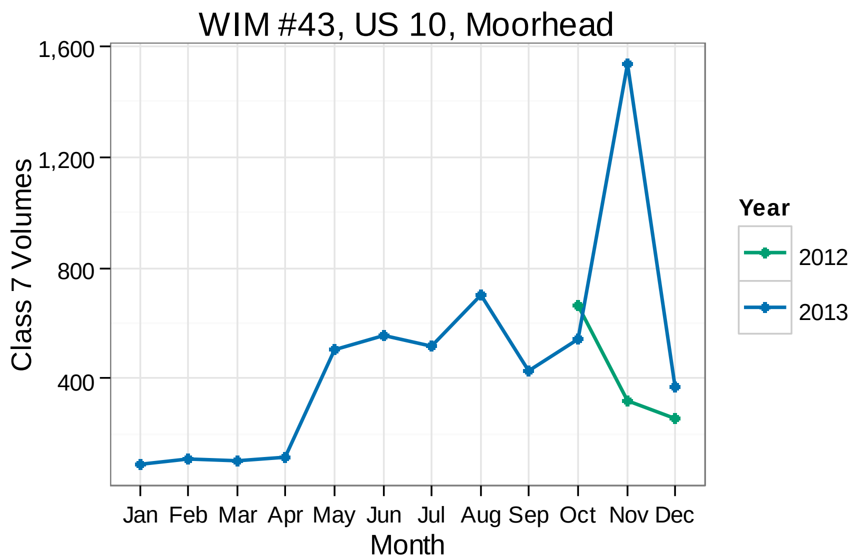


Figure 4.84g. Class 7 volume as a function of month and year.

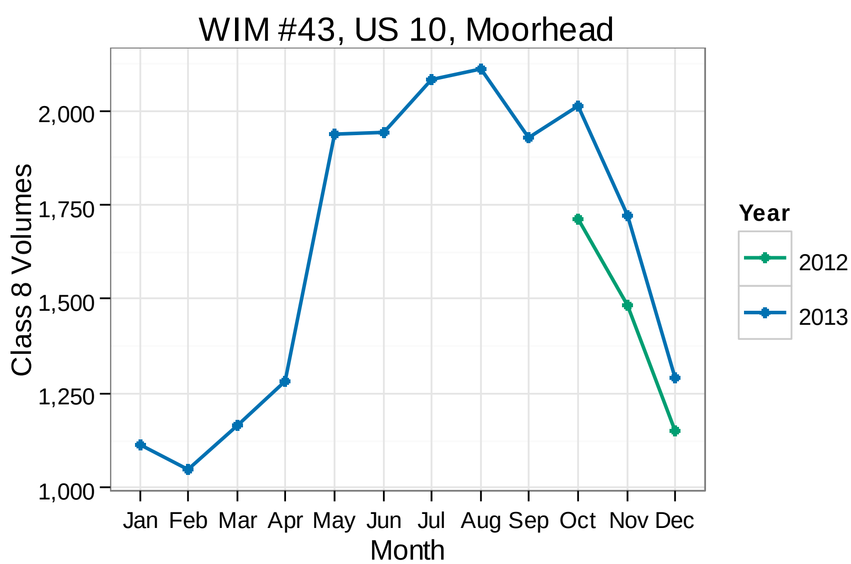


Figure 4.84h. Class 8 volume as a function of month and year.

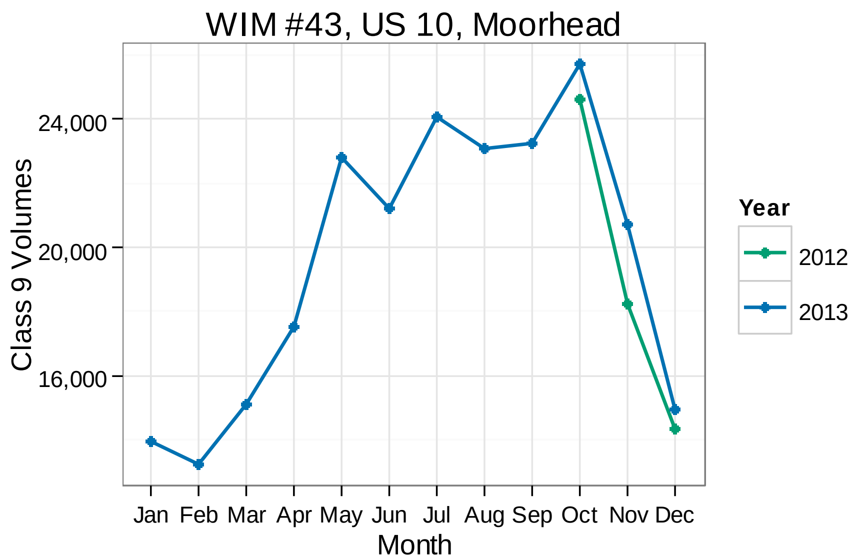


Figure 4.84i. Class 9 volume as a function of month and year.

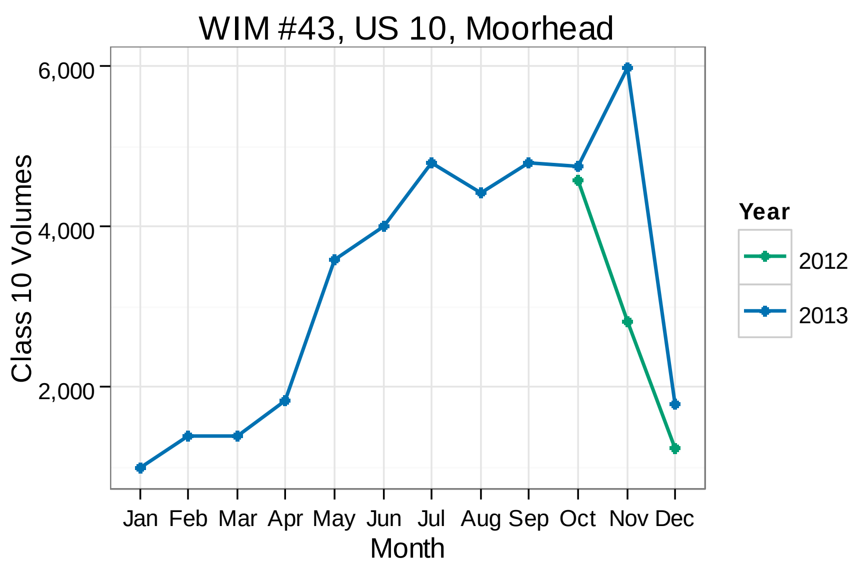


Figure 4.84j. Class 10 volume as a function of month and year.

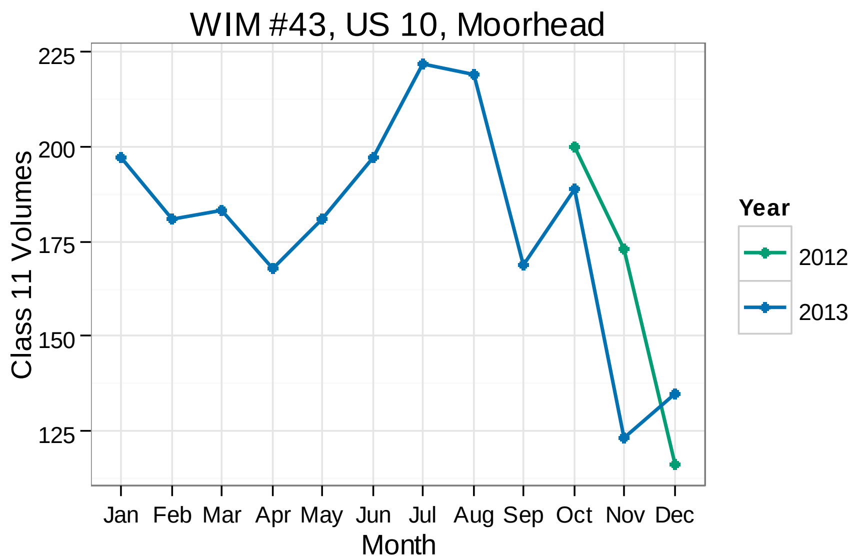


Figure 4.84k. Class 11 volume as a function of month and year.

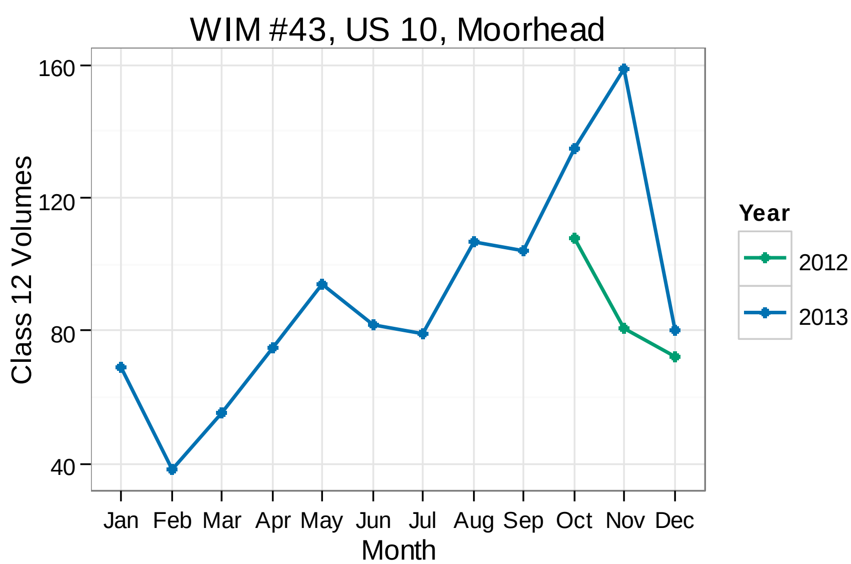


Figure 4.84l. Class 12 volume as a function of month and year.

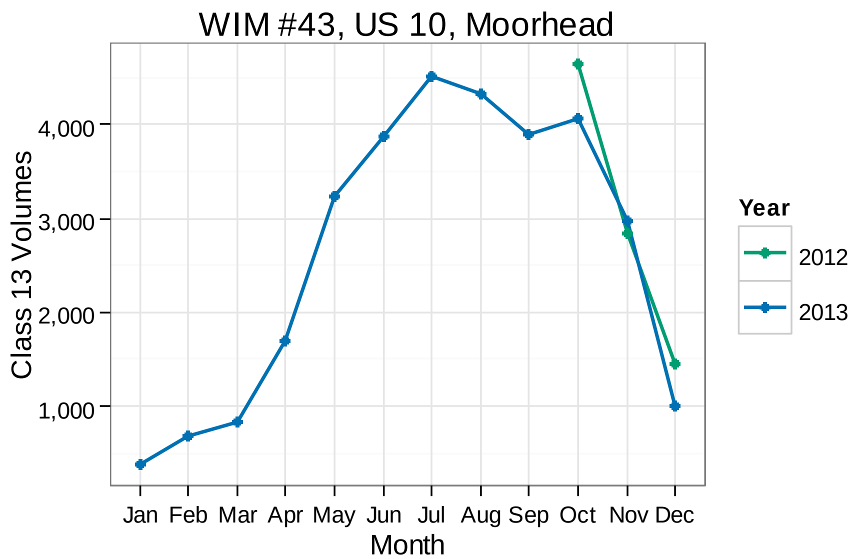


Figure 4.84m. Class 13 volume as a function of month and year.

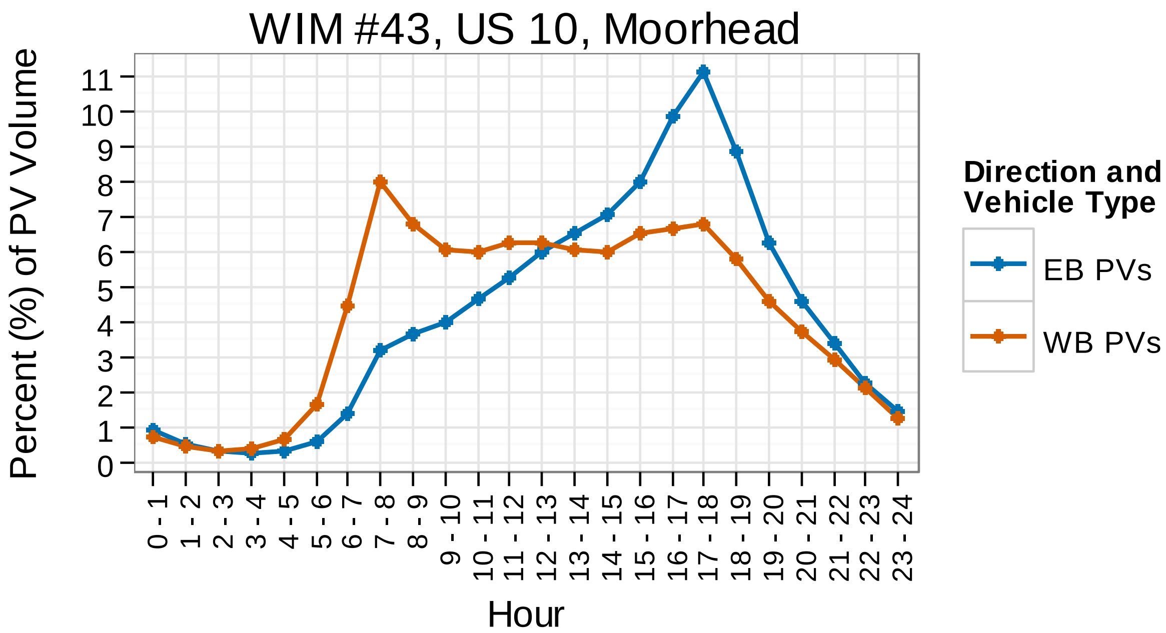


Figure 4.85a. Amount of traffic (% of volume) observed at an hourly basis for each direction (eastbound; EB vs. westbound; WB) for passenger vehicles (PVs).

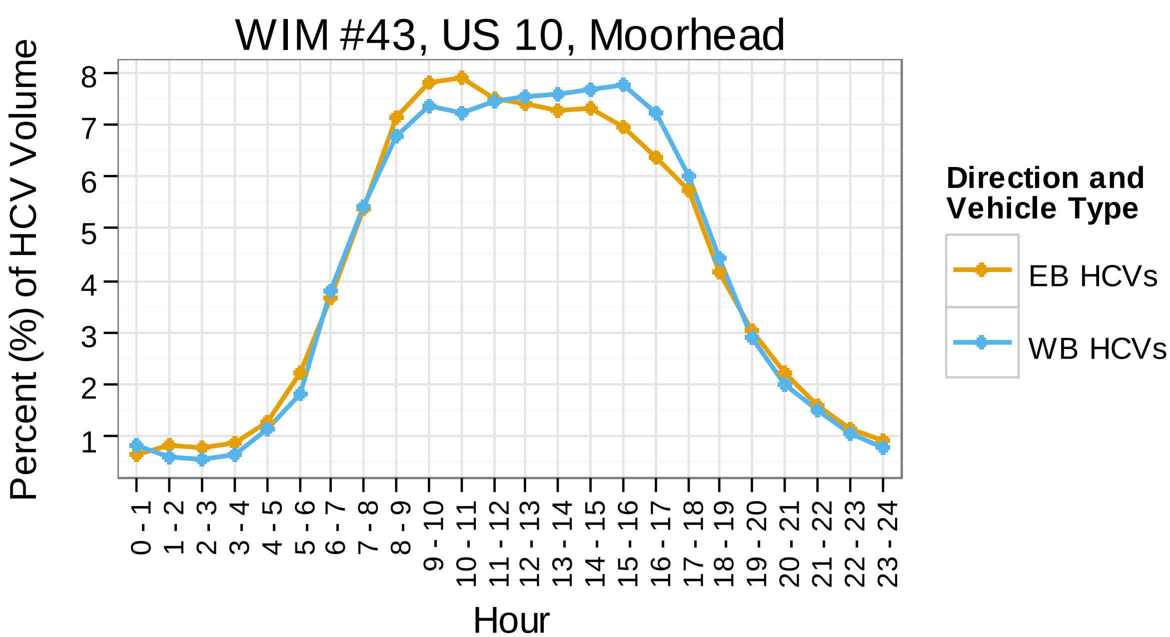


Figure 4.85b. Amount of traffic (% of volume) observed at an hourly basis for each direction (eastbound; EB vs. westbound; WB) for heavy commercial vehicles (HCVs).

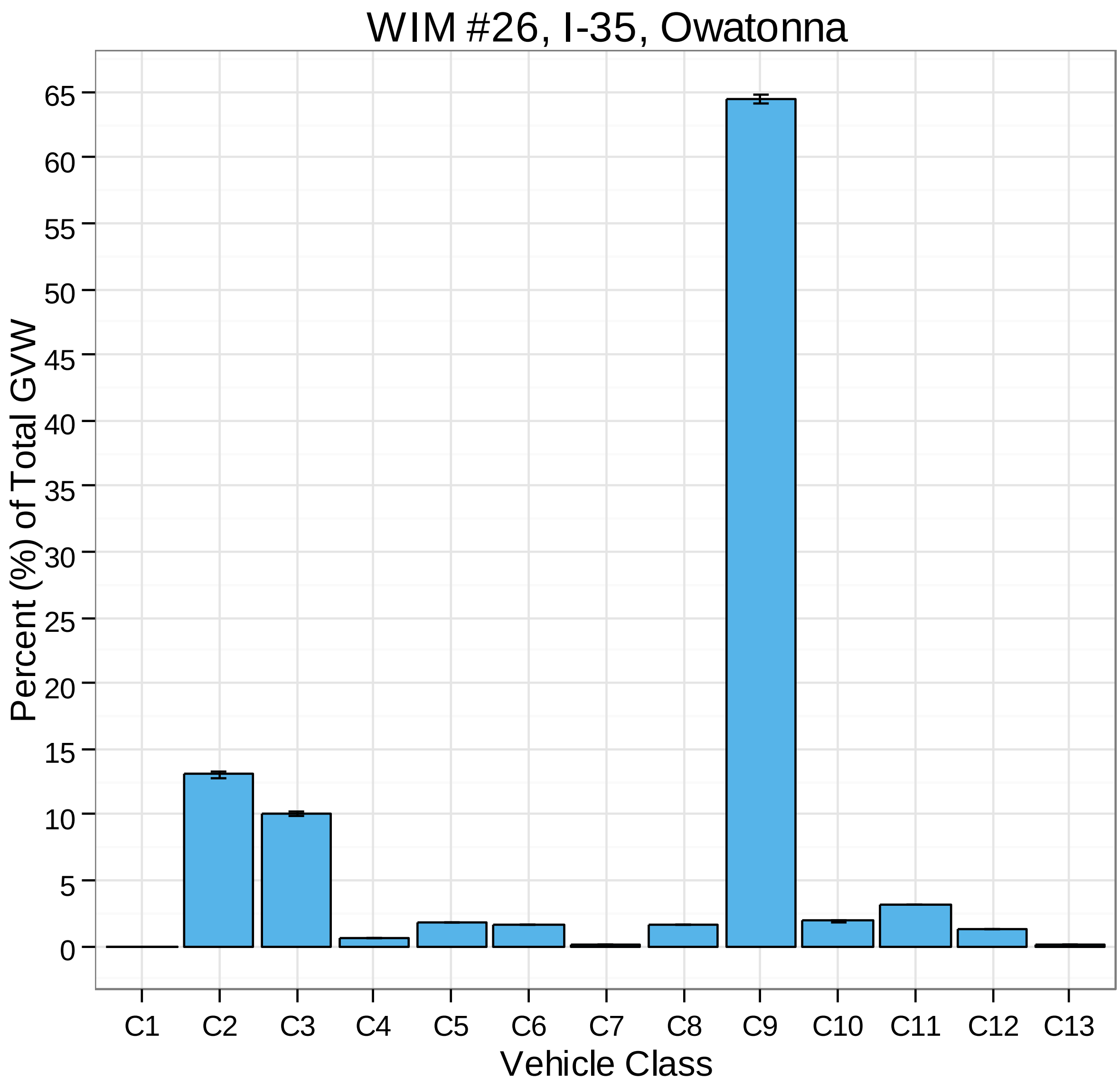


Figure 5.1. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

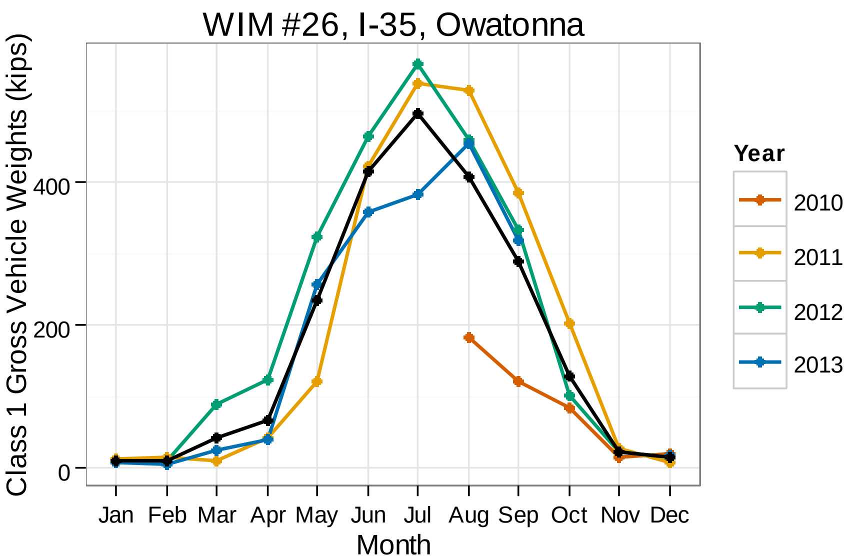


Figure 5.2a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

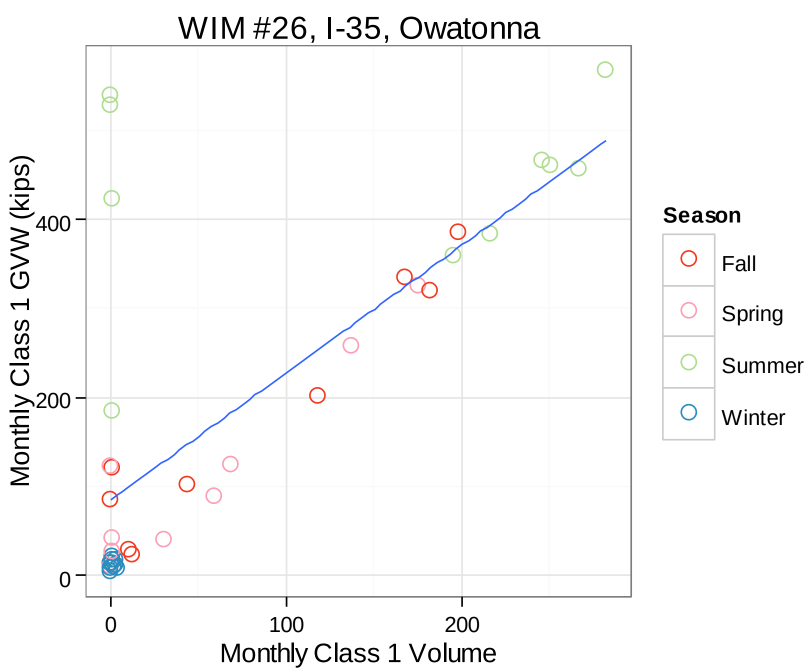


Figure 5.2b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

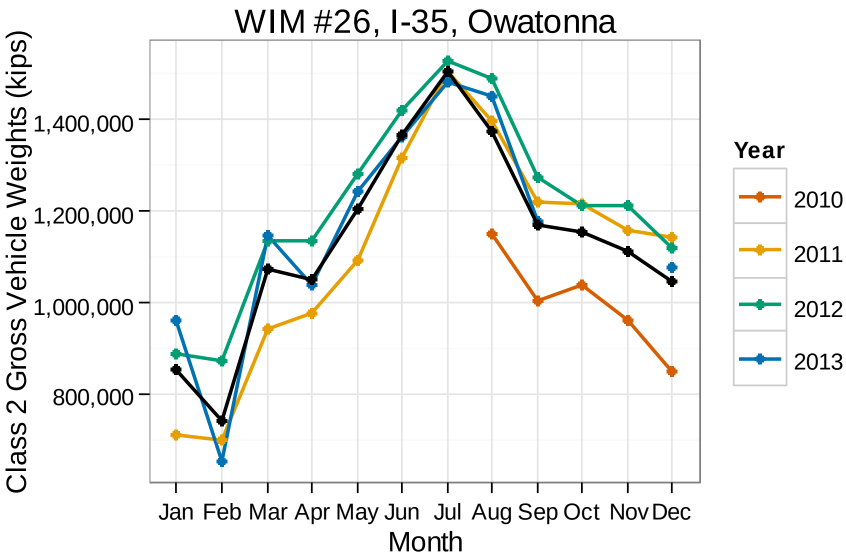


Figure 5.3a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

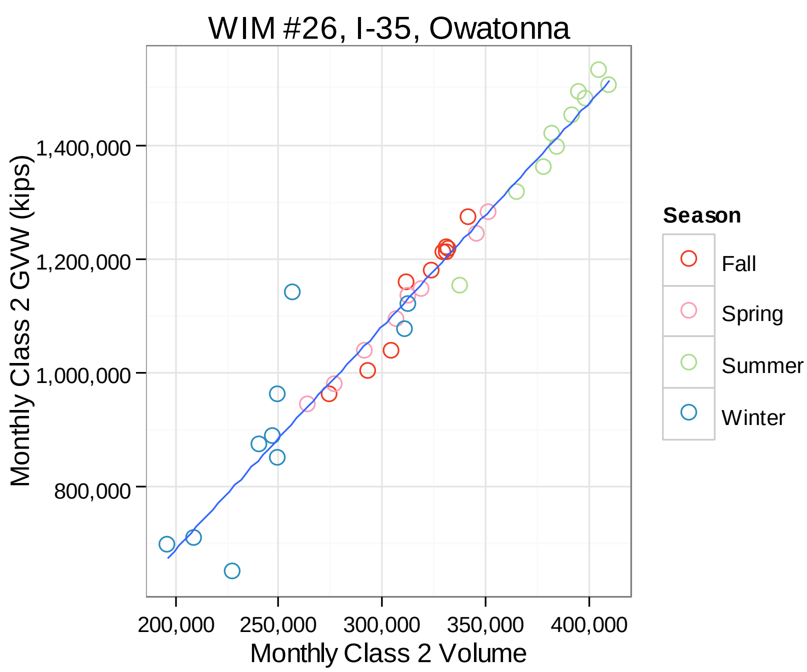


Figure 5.3b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

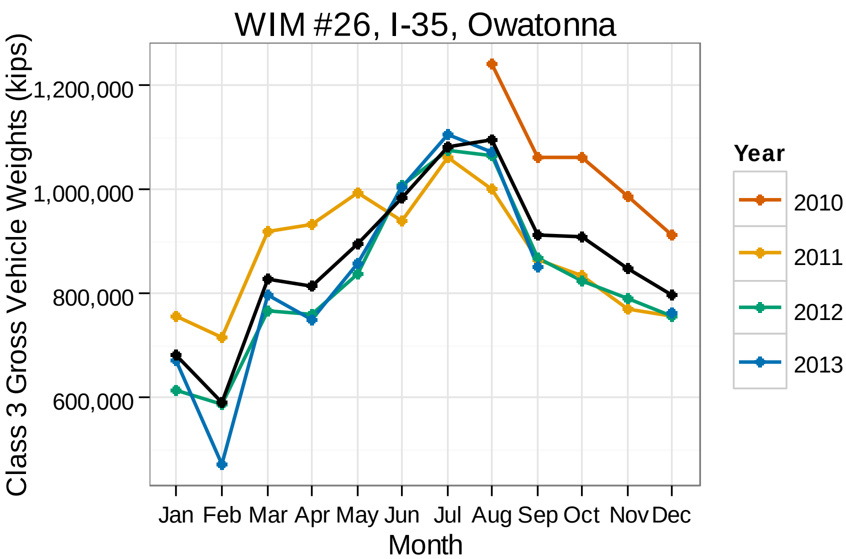


Figure 5.4a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

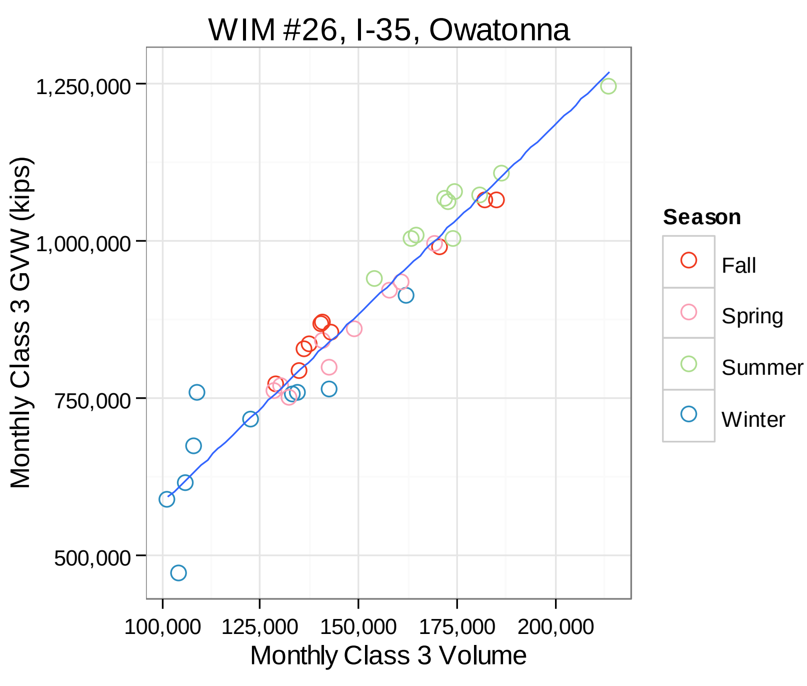


Figure 5.4b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

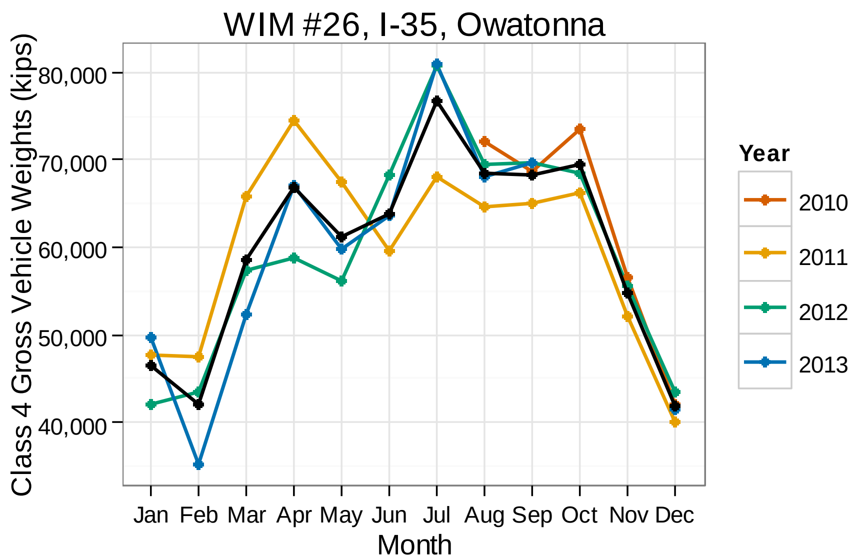


Figure 5.5a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

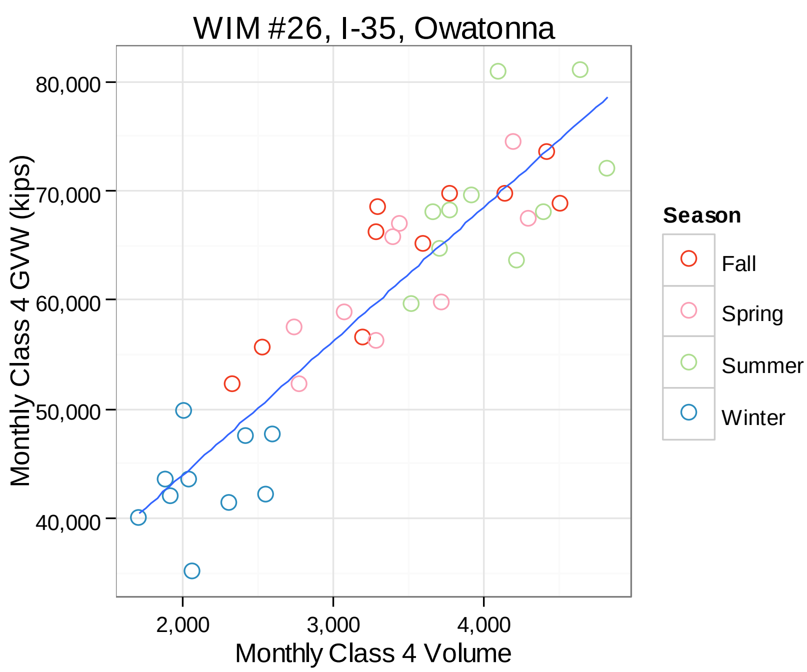


Figure 5.5b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

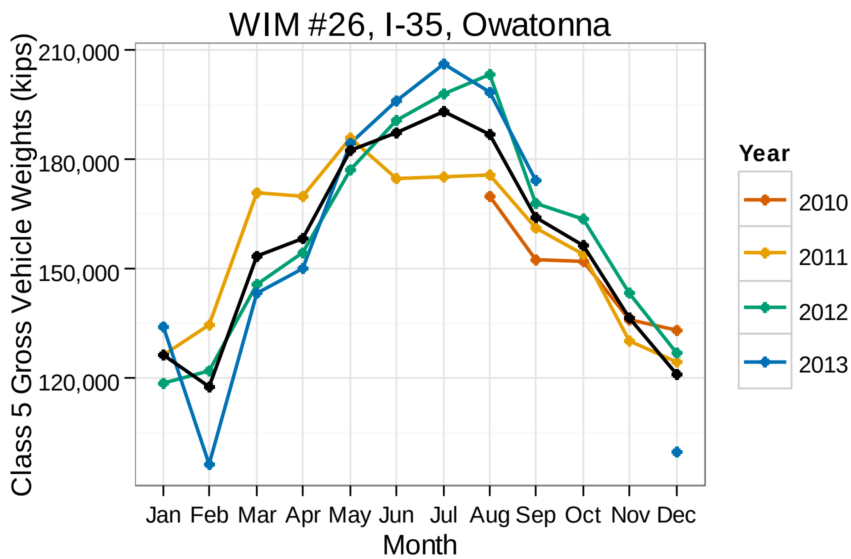


Figure 5.6a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

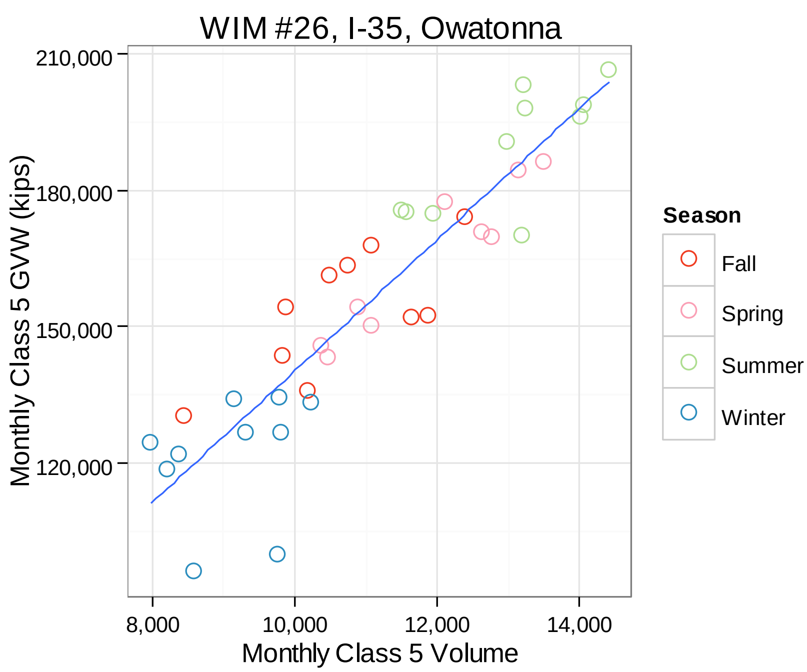


Figure 5.6b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

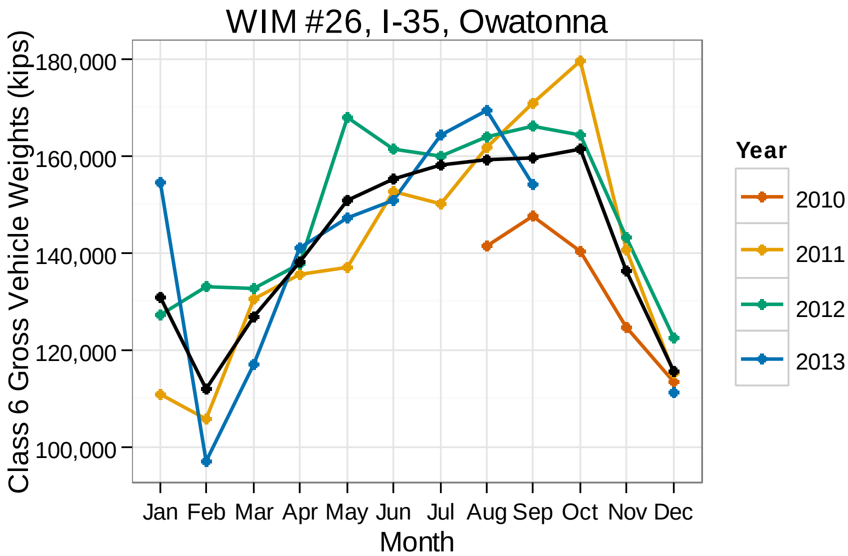


Figure 5.7a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

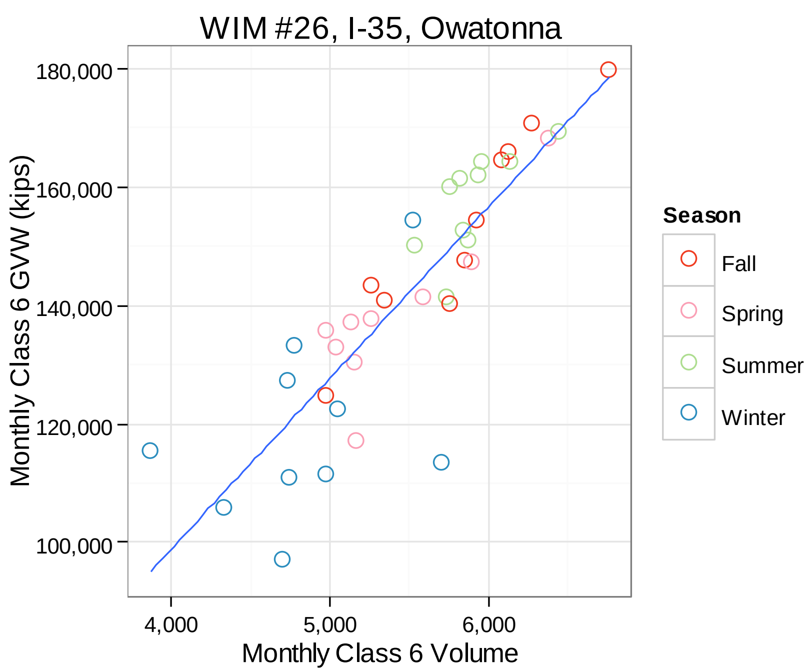


Figure 5.7b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

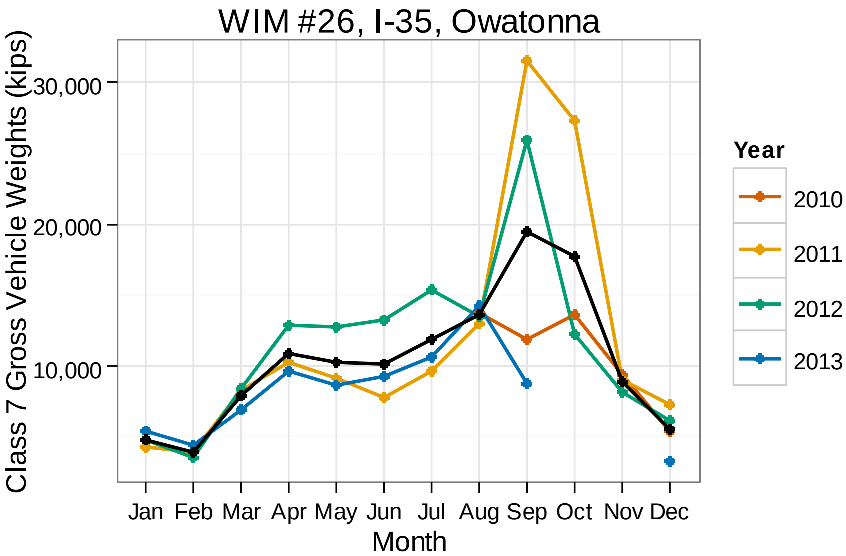


Figure 5.8a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

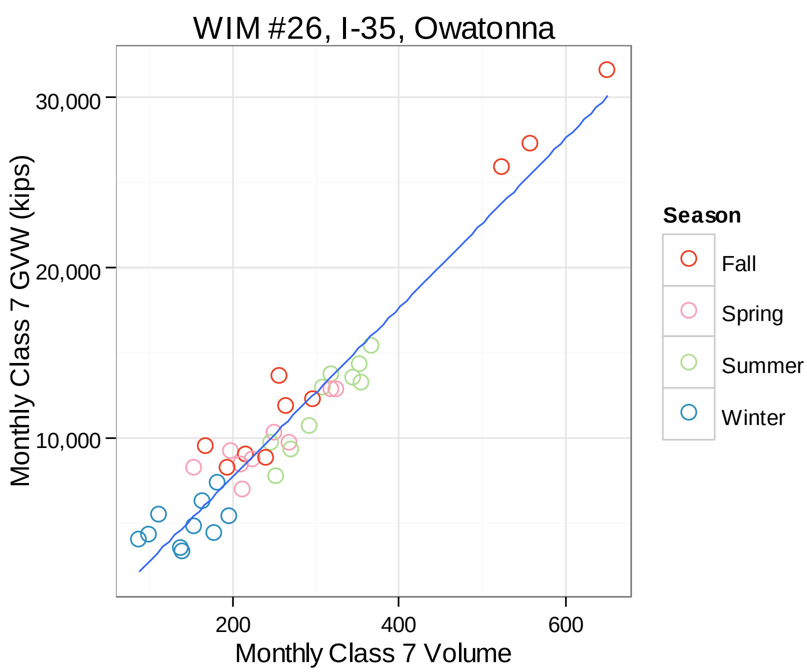


Figure 5.8b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

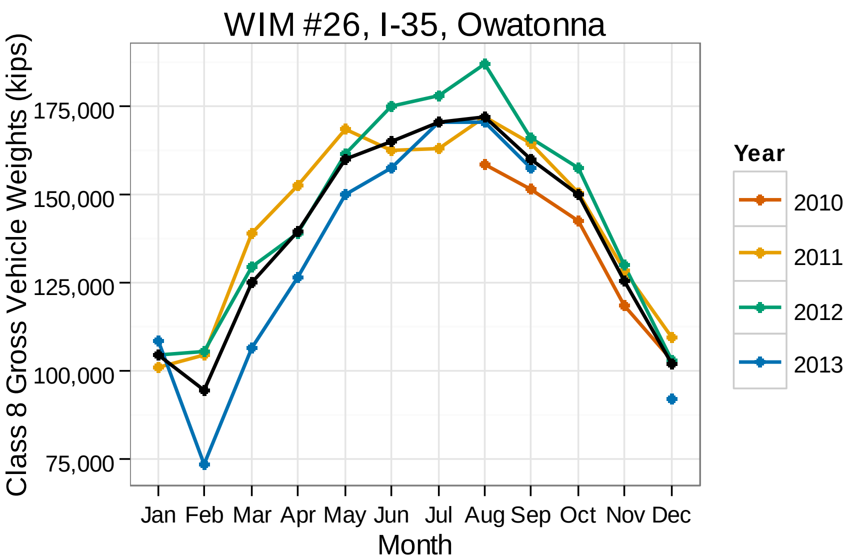


Figure 5.9a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

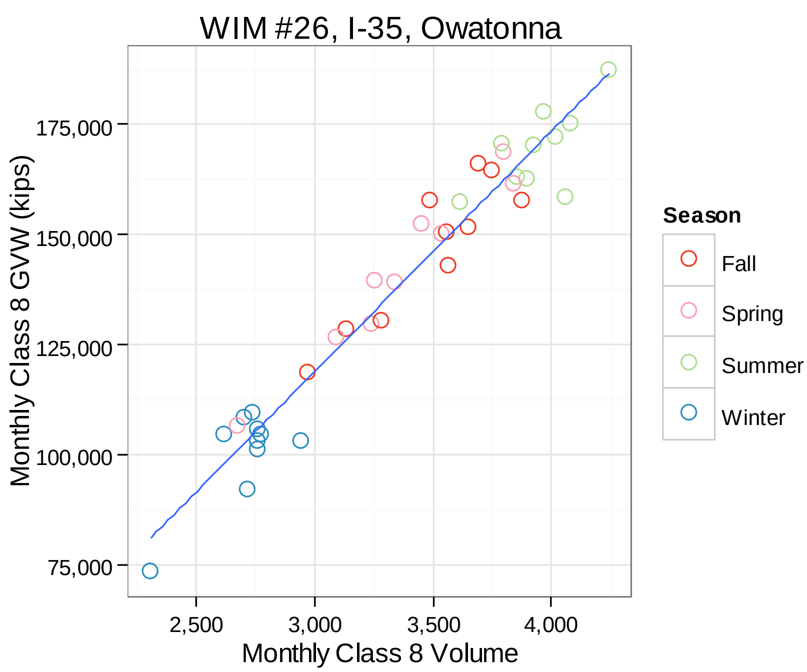


Figure 5.9b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

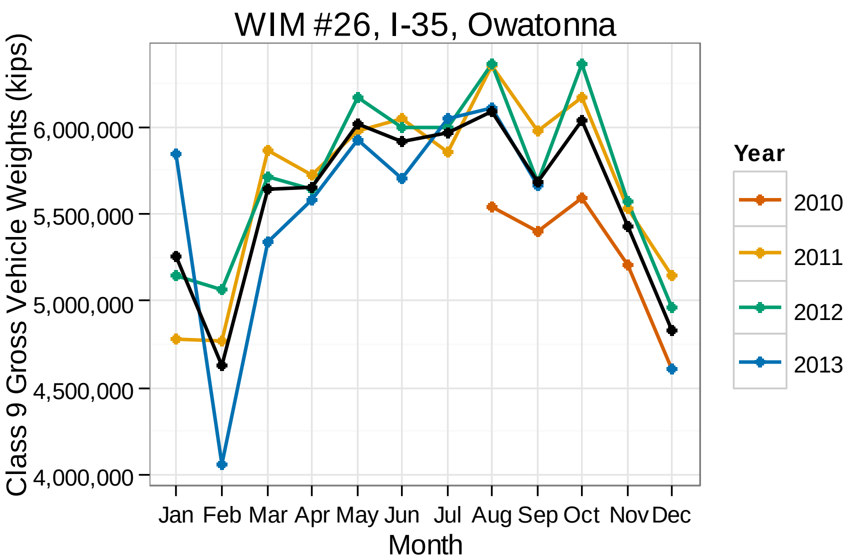


Figure 5.10a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

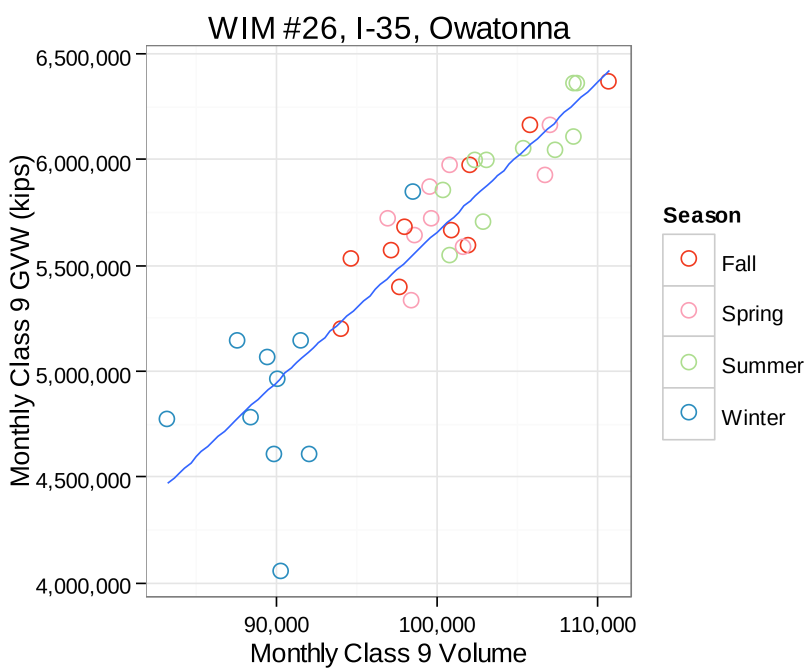


Figure 5.10b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

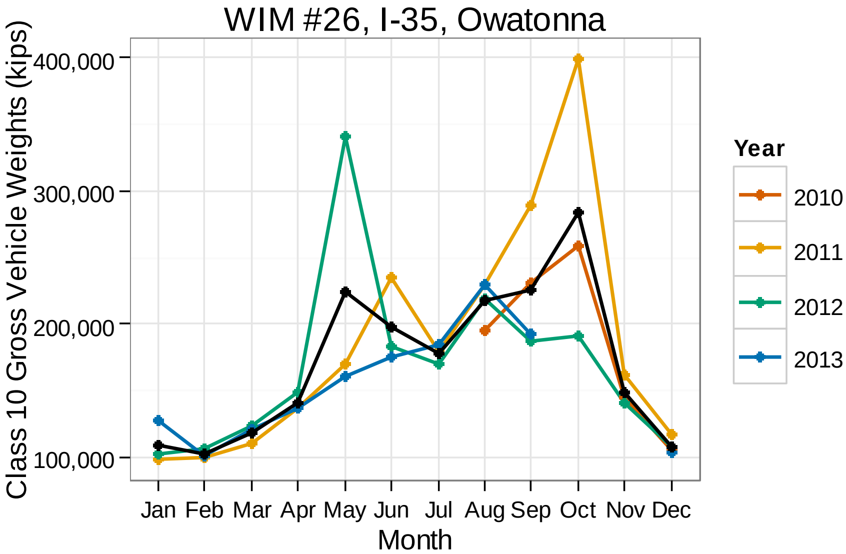


Figure 5.11a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

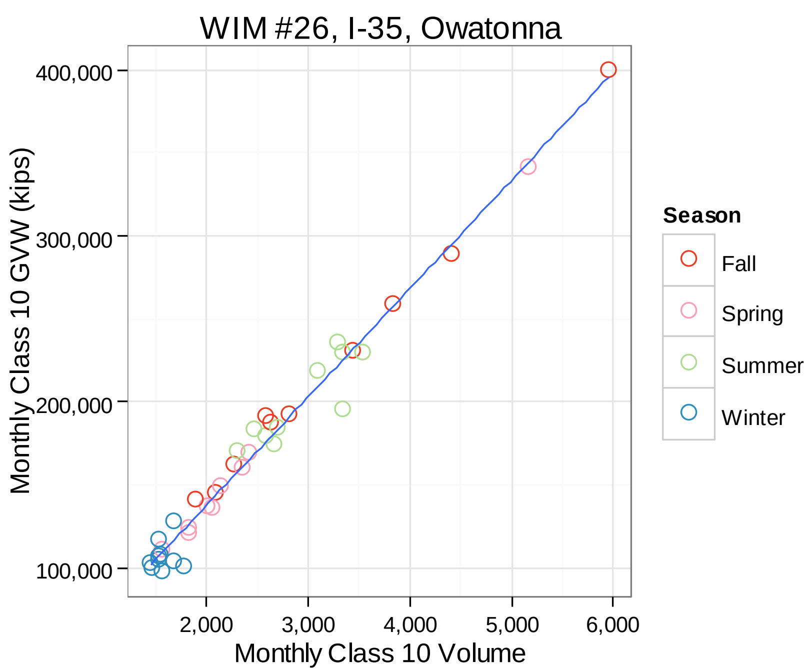


Figure 5.11b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

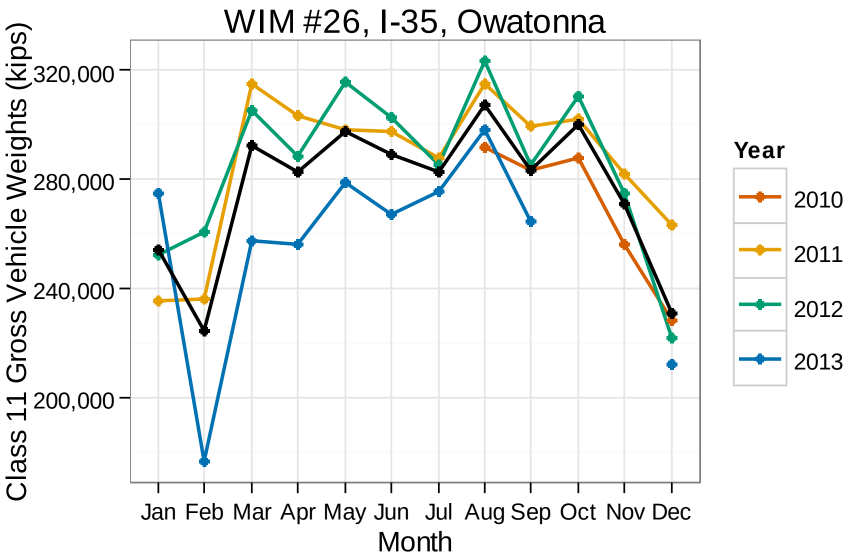


Figure 5.12a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

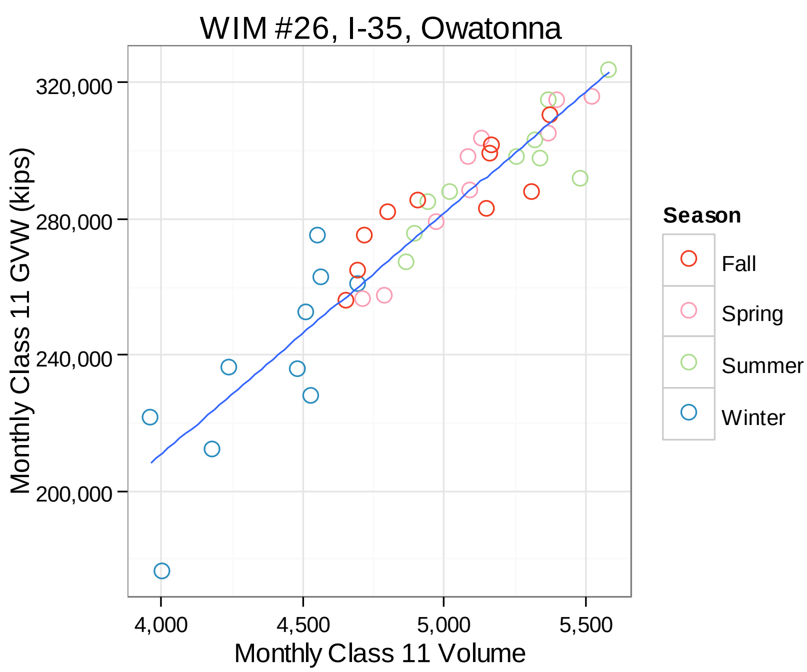


Figure 5.12b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

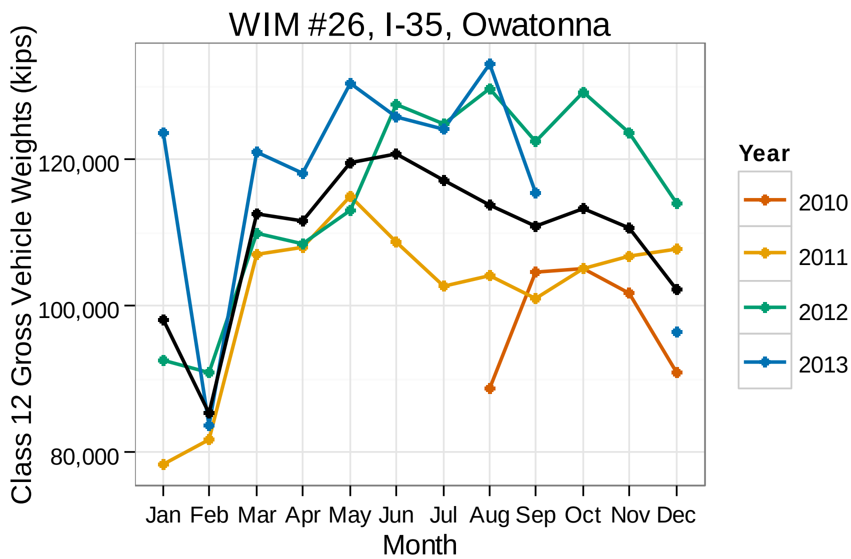


Figure 5.13a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

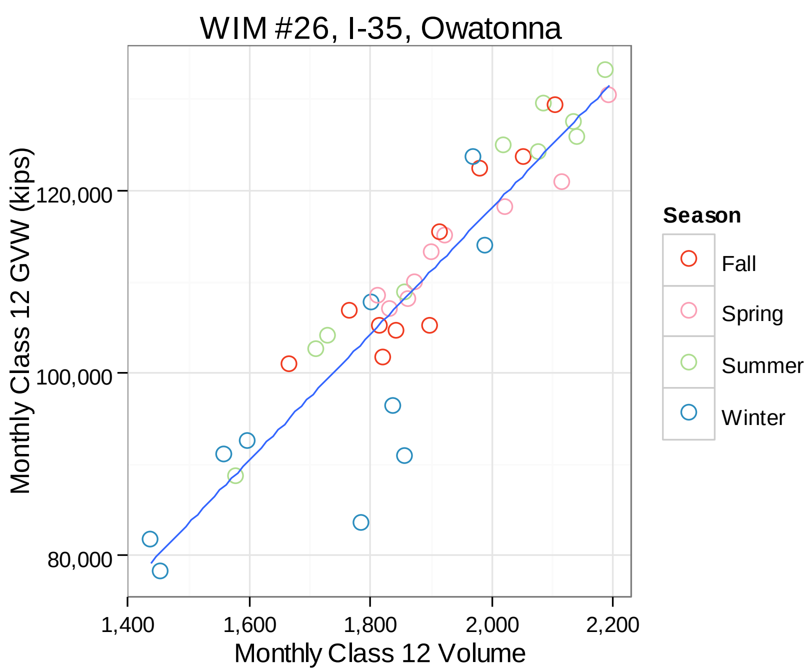


Figure 5.13b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

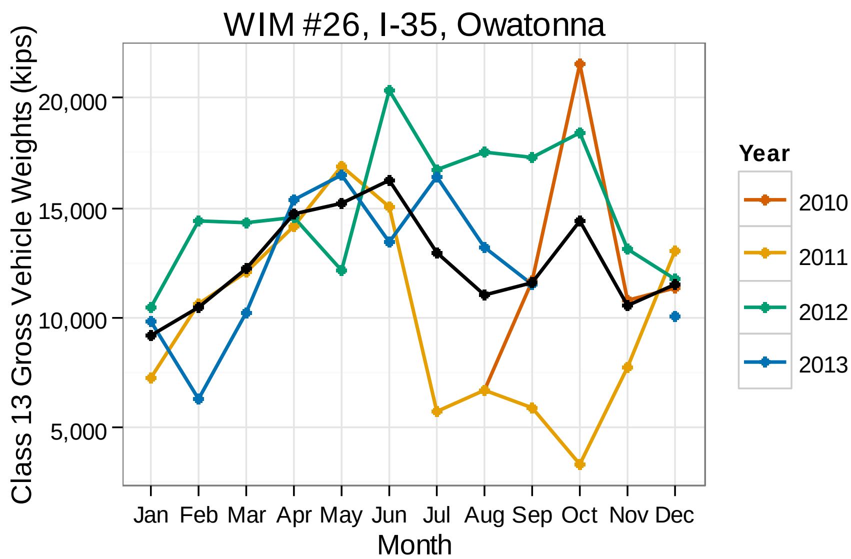


Figure 5.14a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

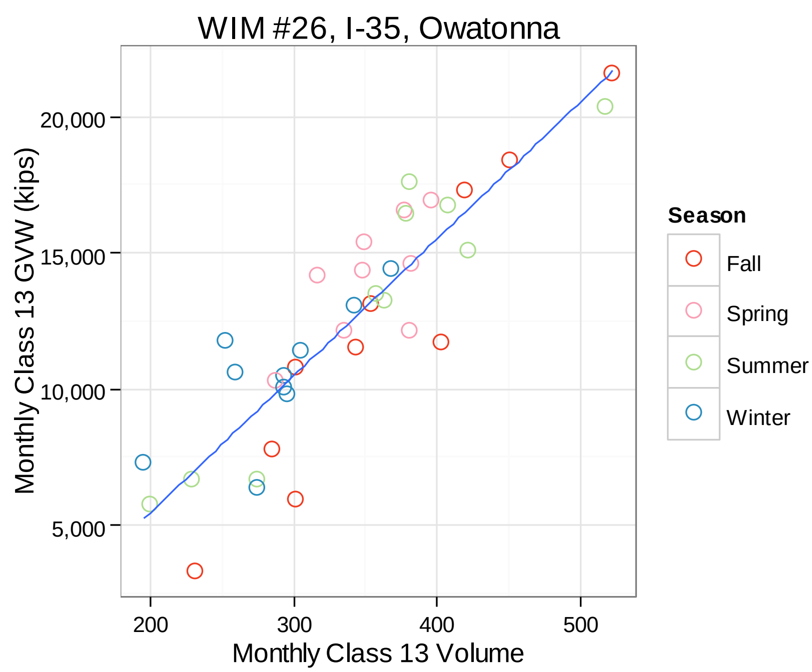


Figure 5.14b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

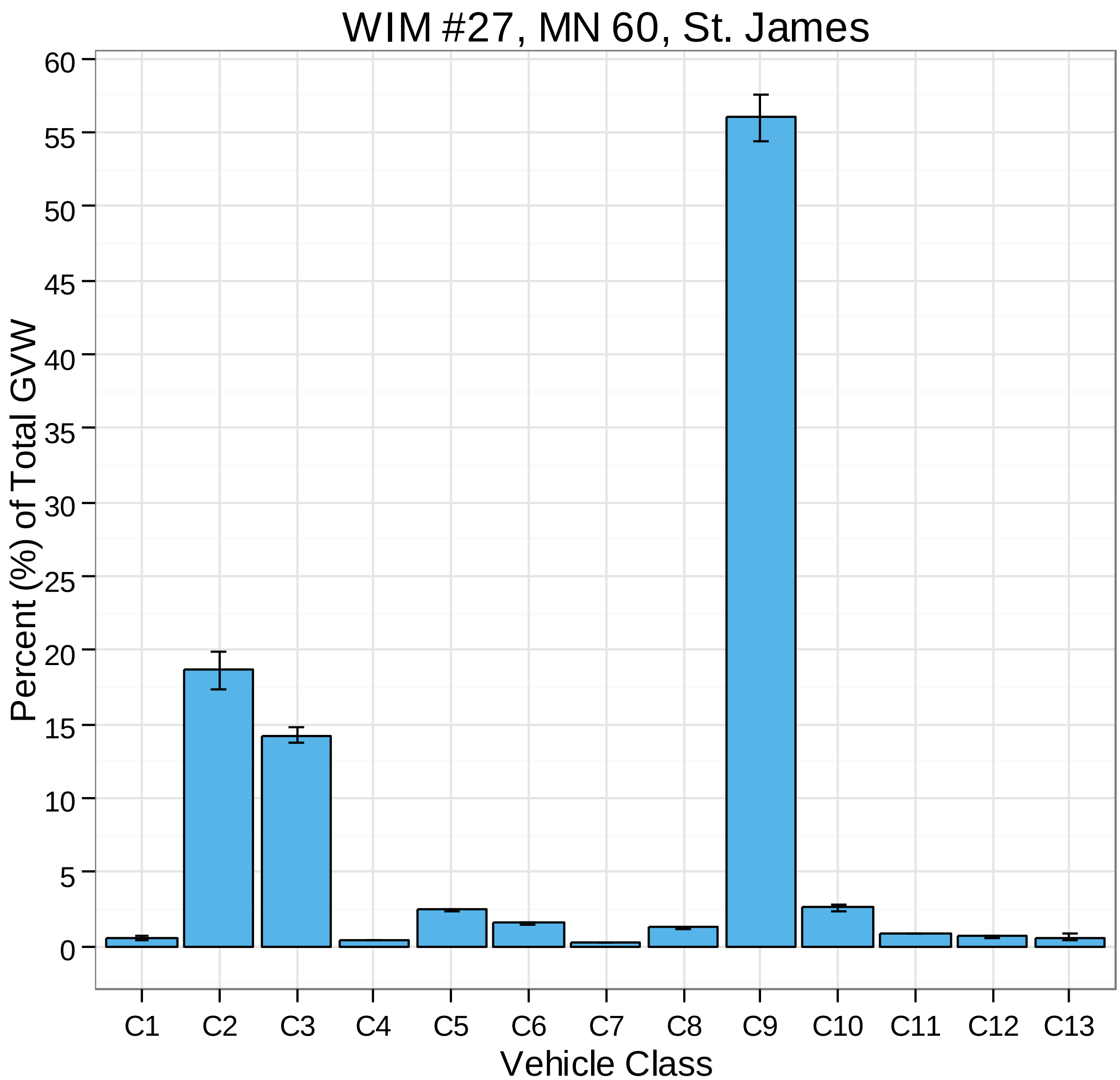


Figure 5.15. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

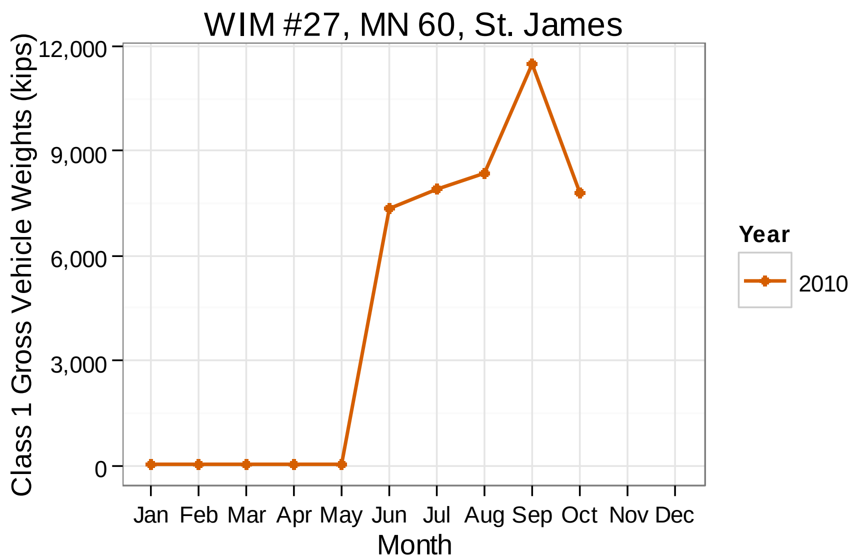


Figure 5.16a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

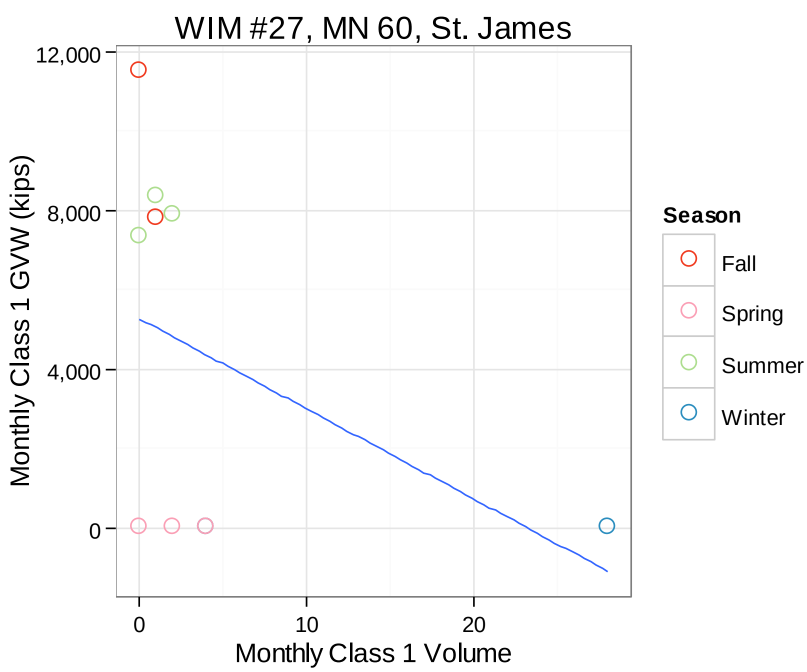


Figure 5.16b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

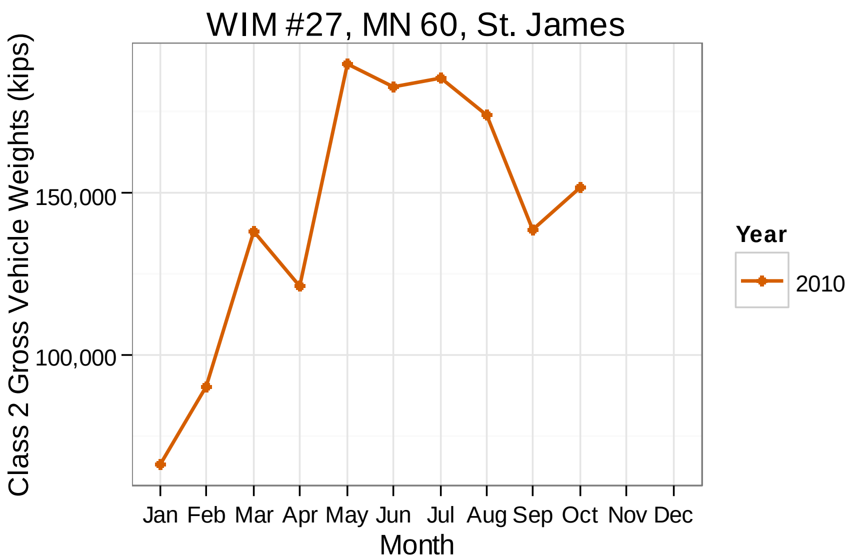


Figure 5.17a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

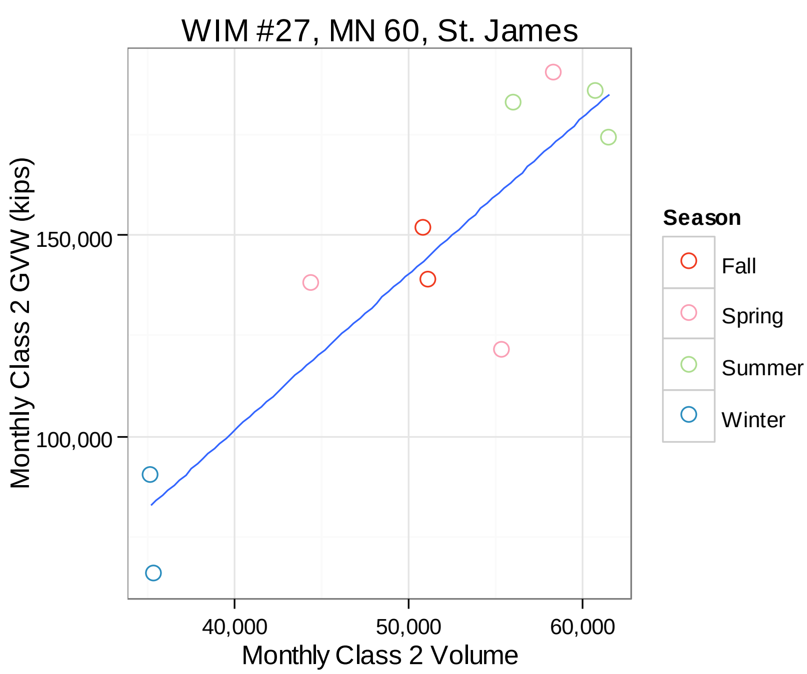


Figure 5.17b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

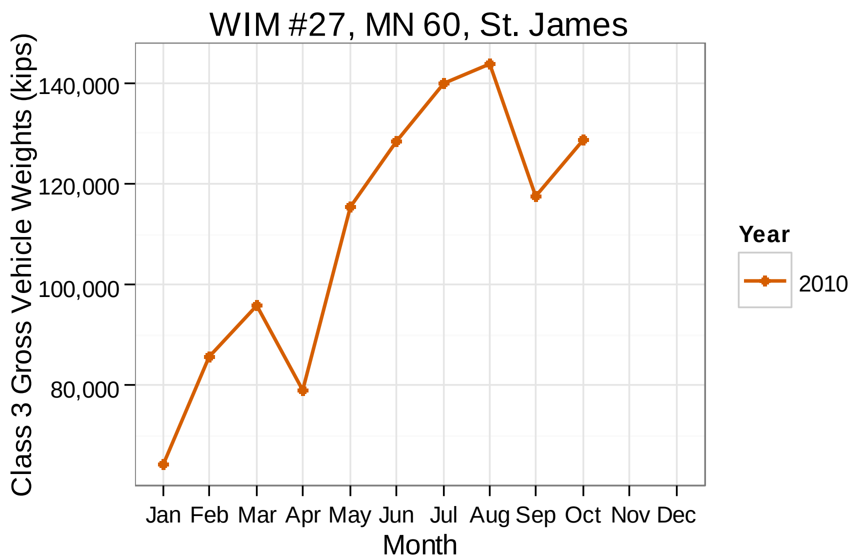


Figure 5.18a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

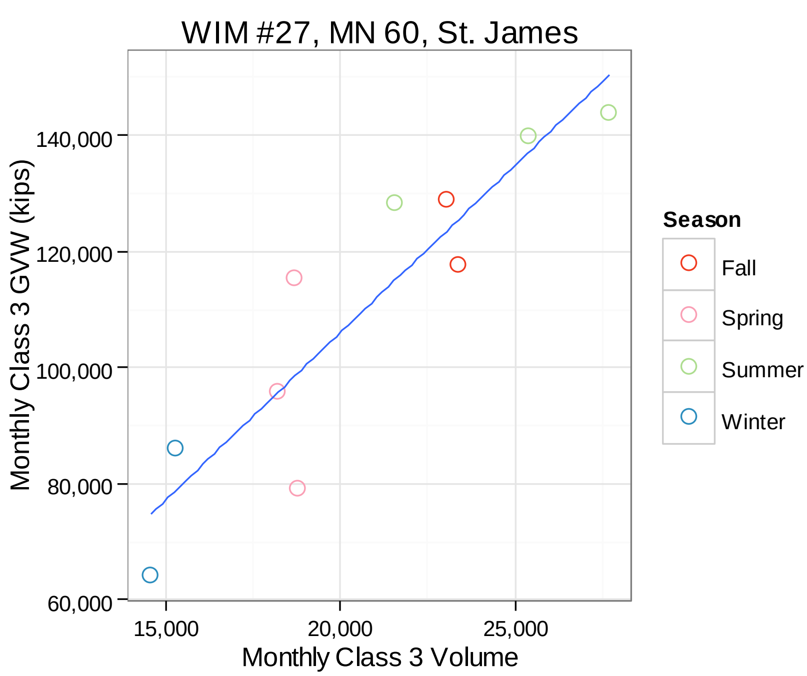


Figure 5.18b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

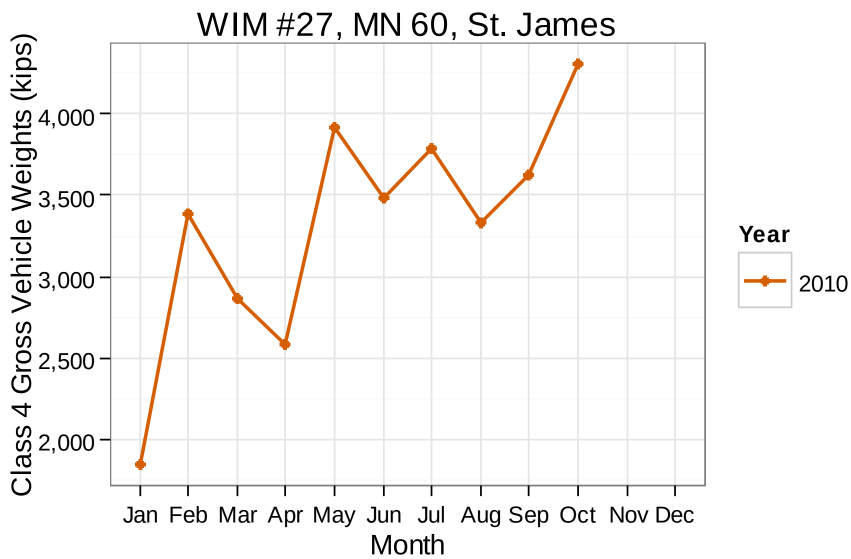


Figure 5.19a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

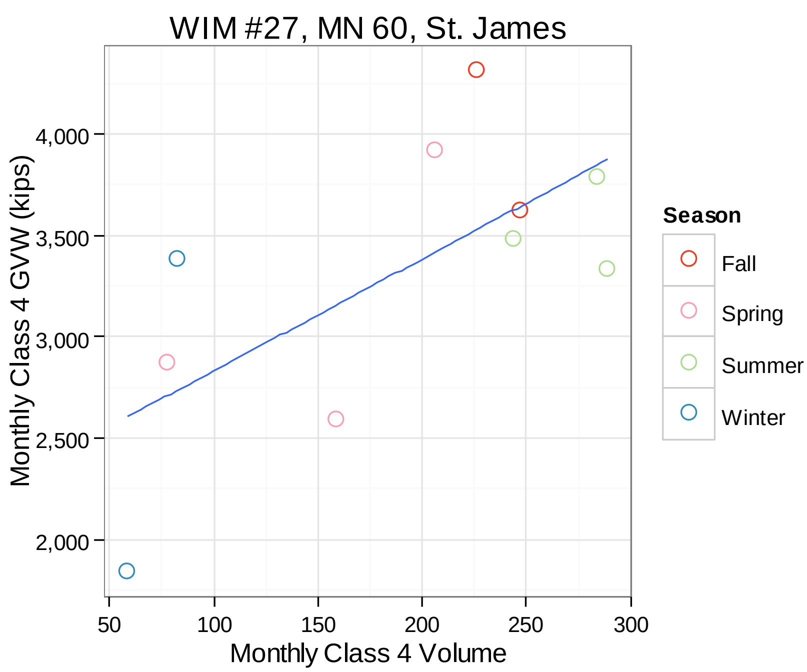


Figure 5.19b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

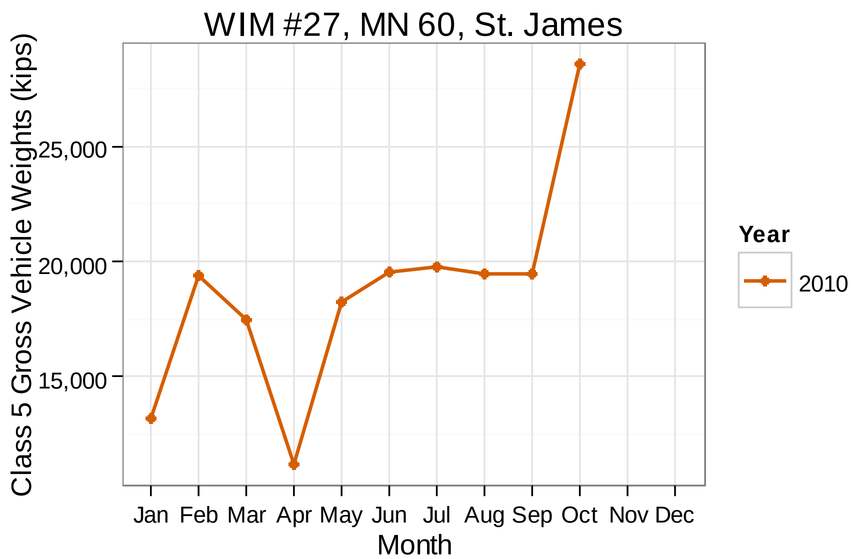


Figure 5.20a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

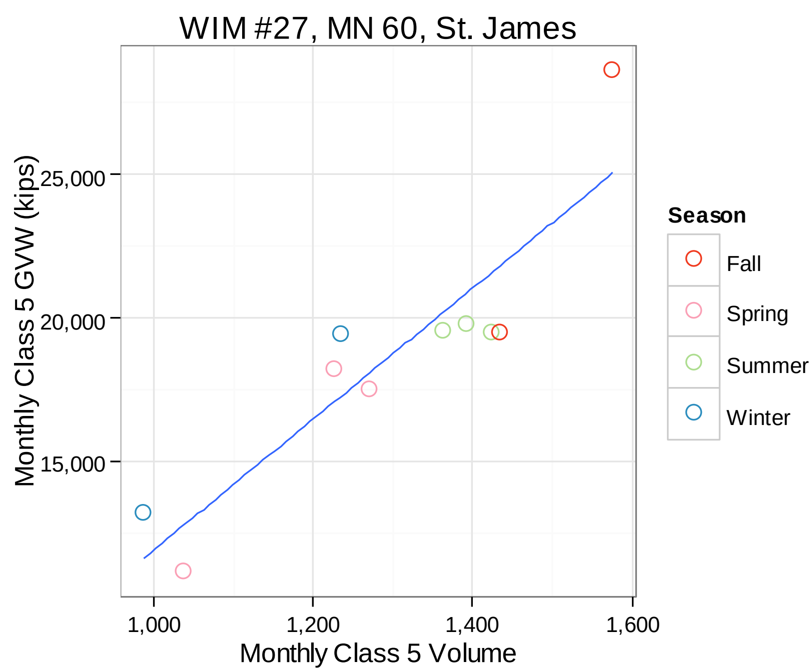


Figure 5.20b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

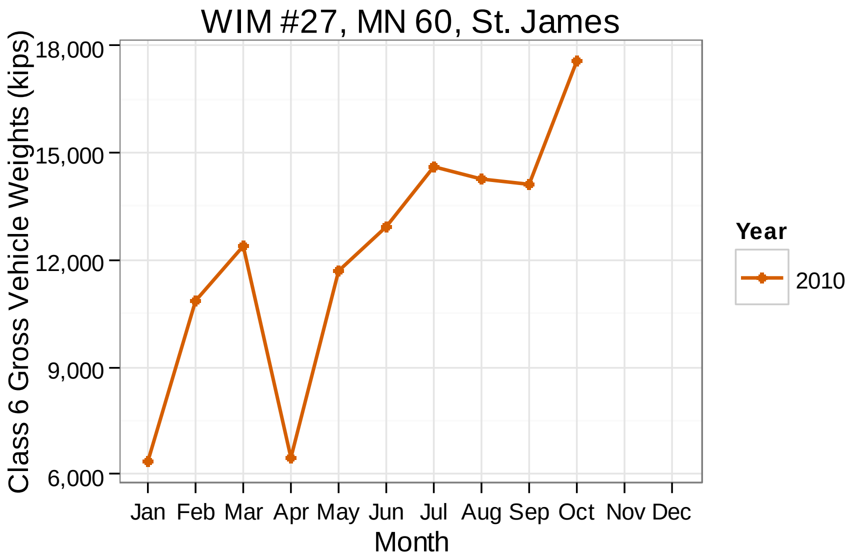


Figure 5.21a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

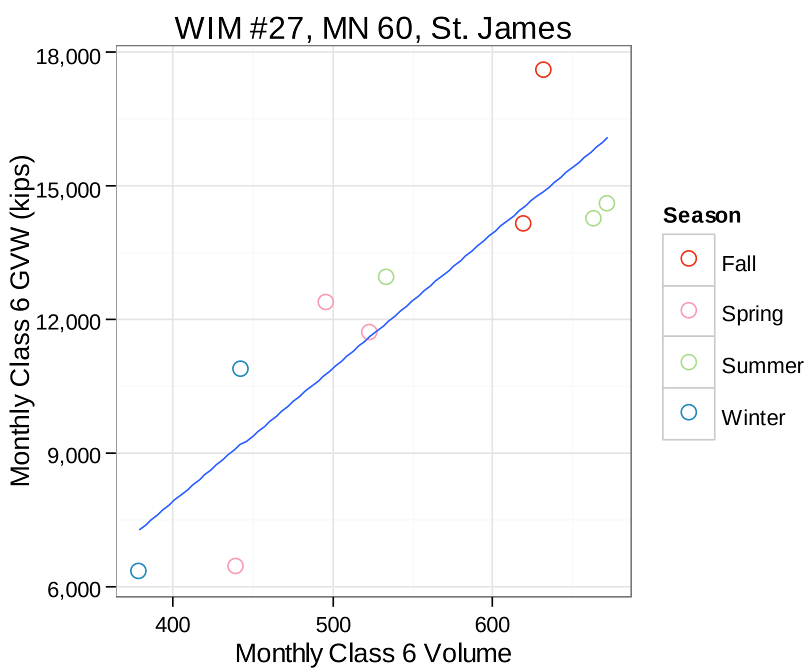


Figure 5.21b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

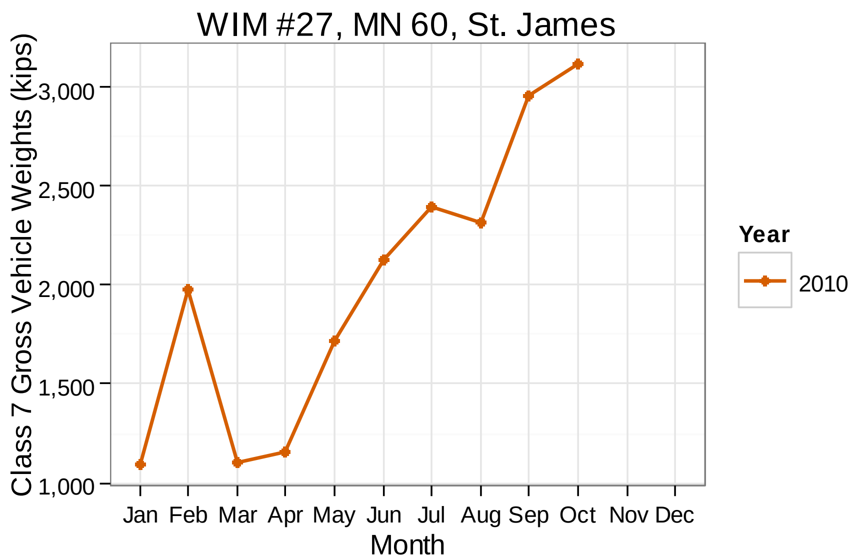


Figure 5.22a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

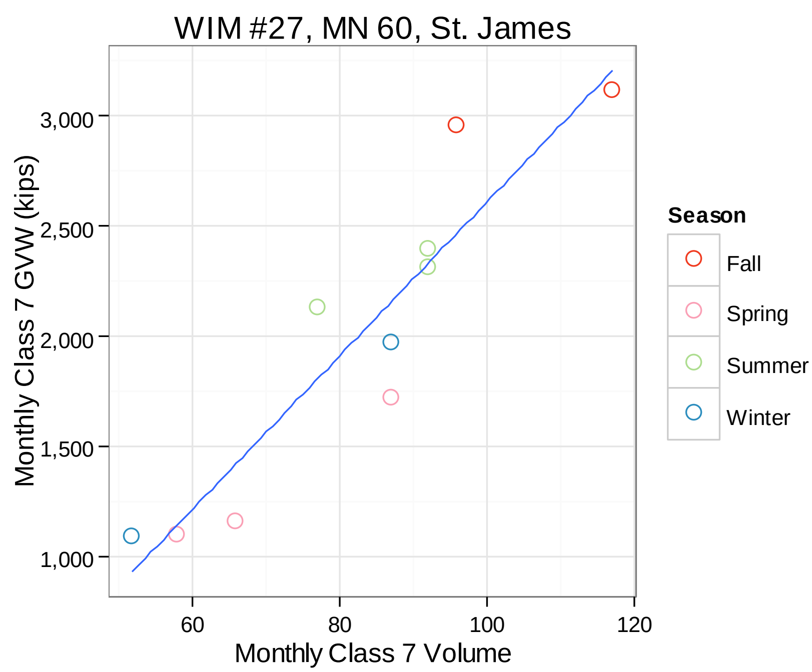


Figure 5.22b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

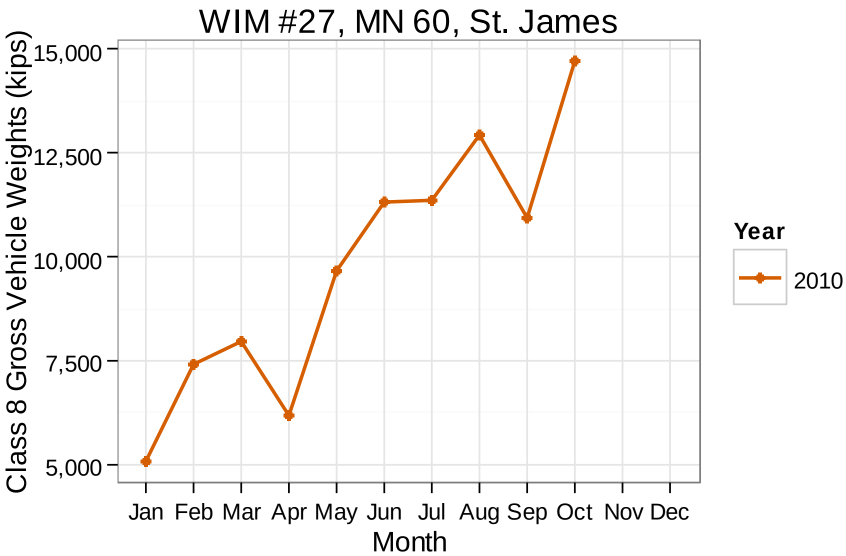


Figure 5.23a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

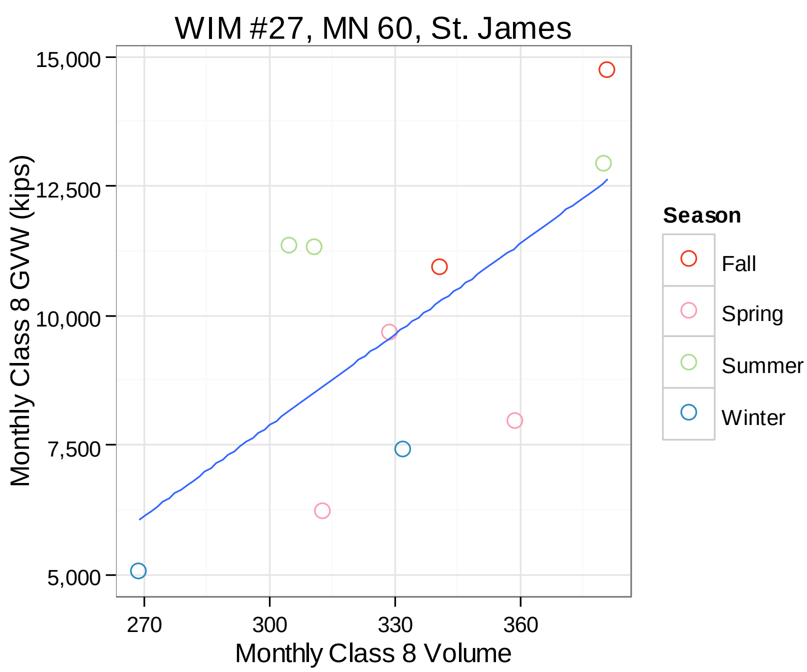


Figure 5.23b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

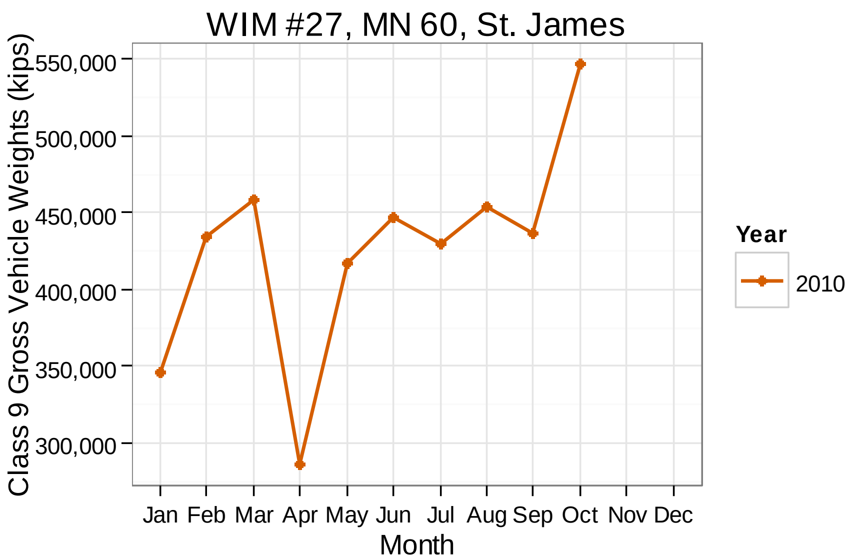


Figure 5.24a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

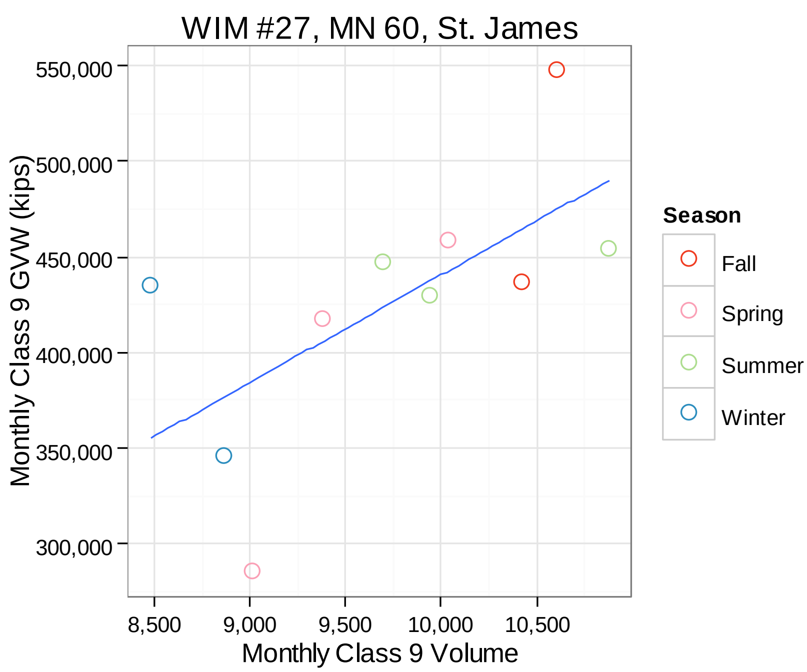


Figure 5.24b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

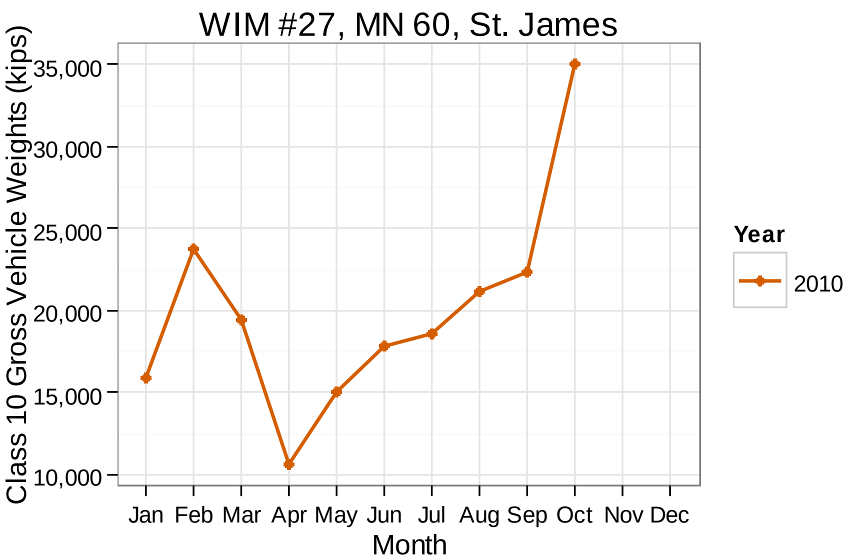


Figure 5.25a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

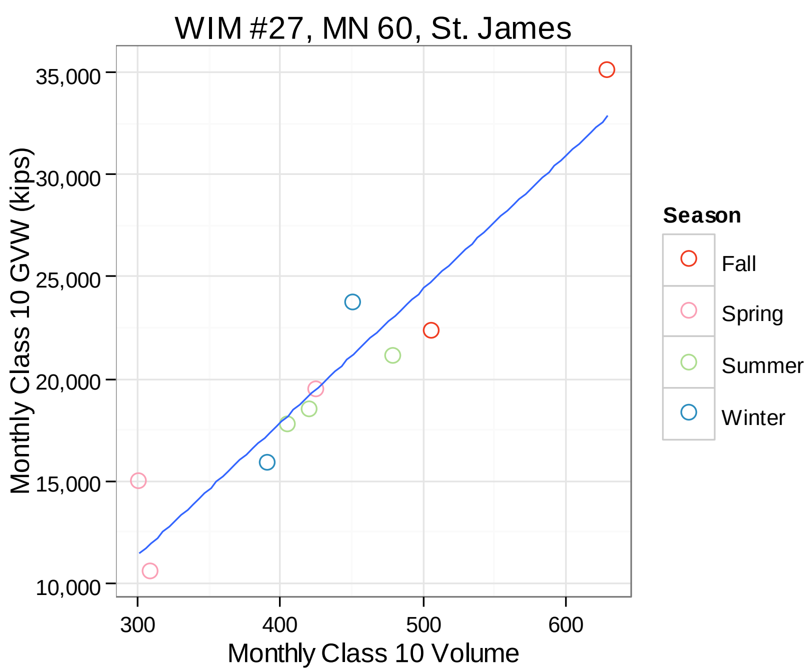


Figure 5.25b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

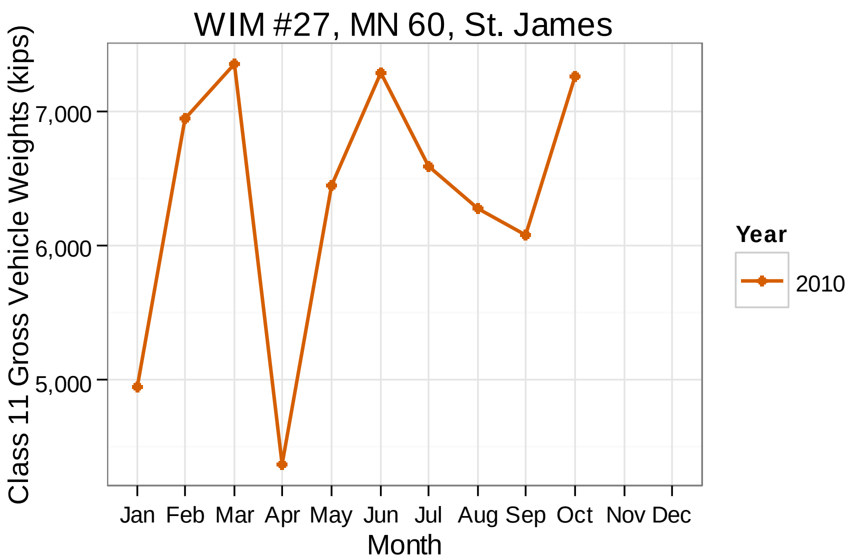


Figure 5.26a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

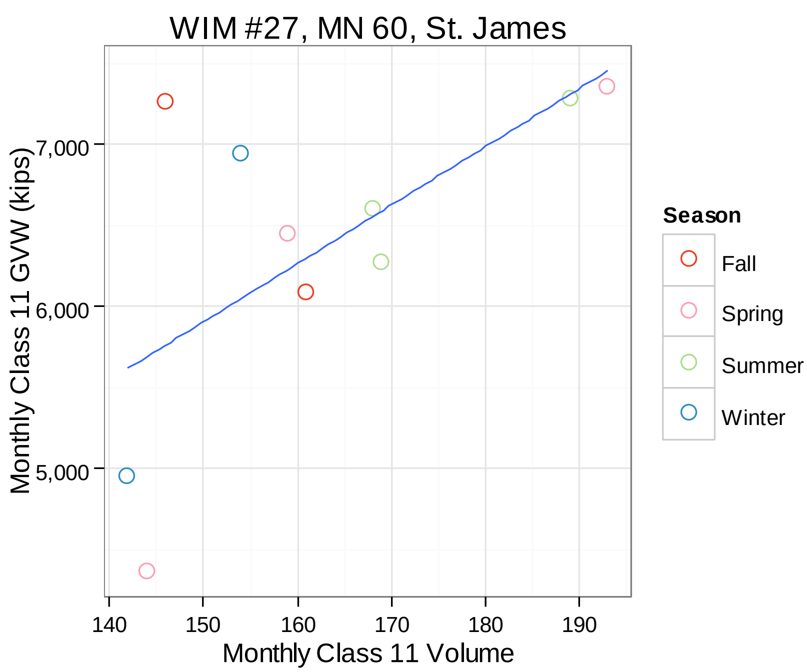


Figure 5.26b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

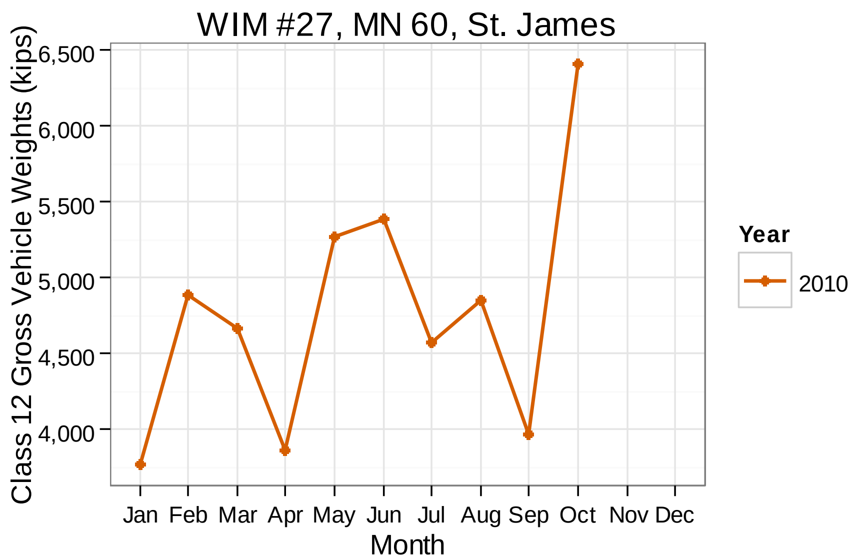


Figure 5.27a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

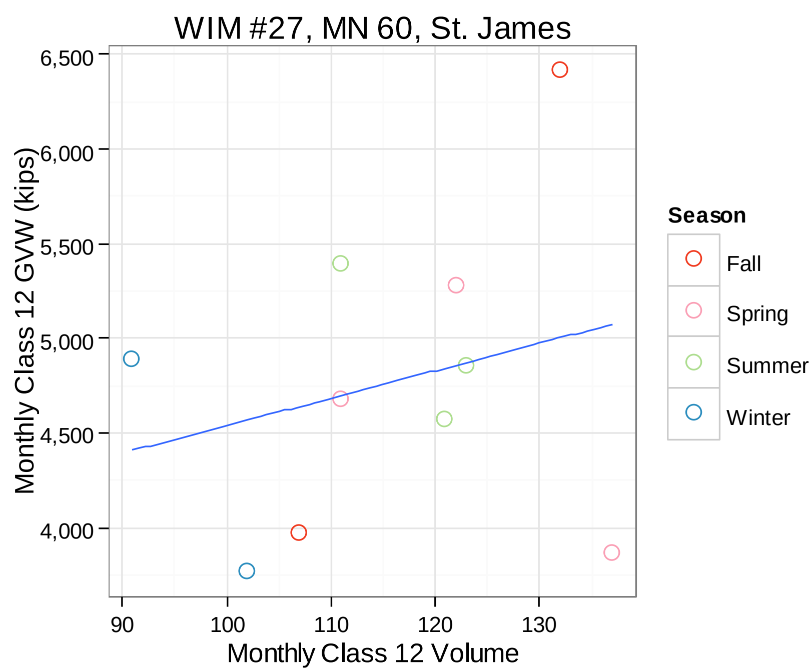


Figure 5.27b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

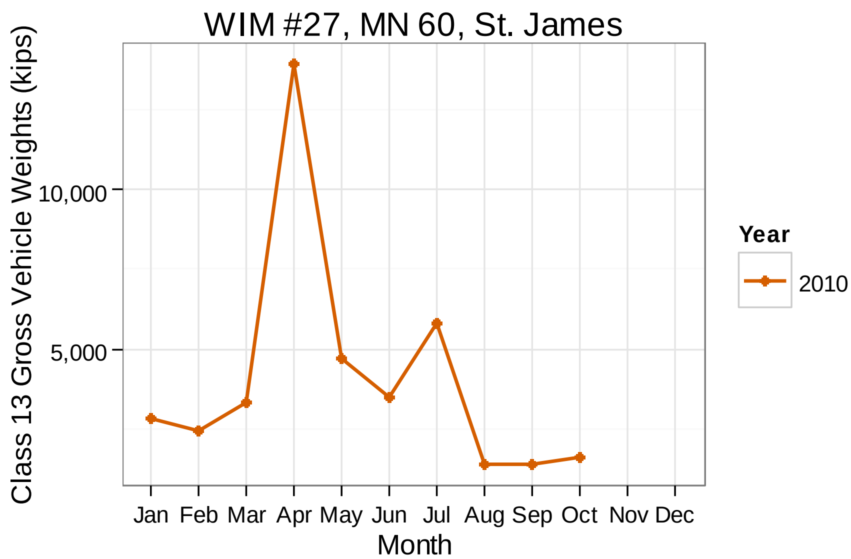


Figure 5.28a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

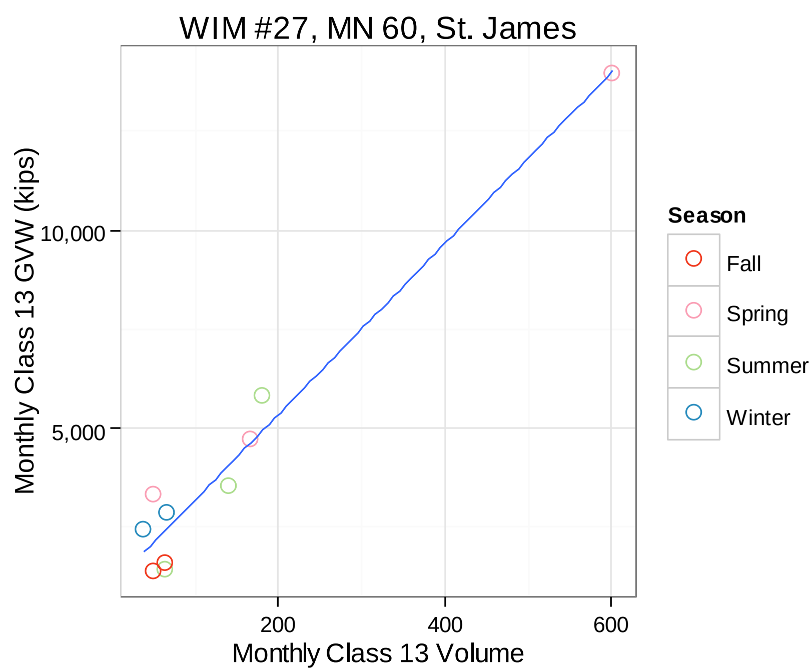


Figure 5.28b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

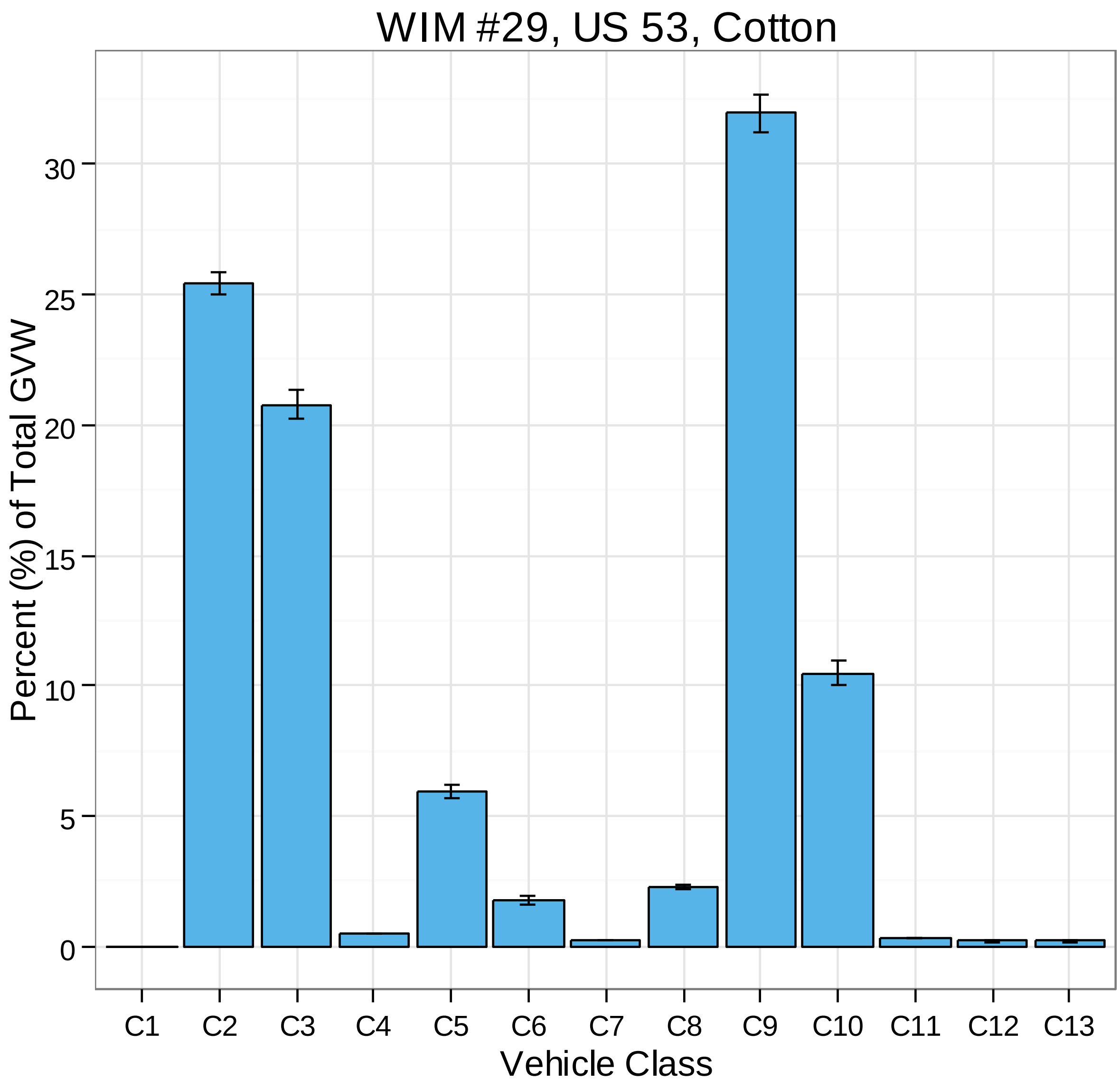


Figure 5.29. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

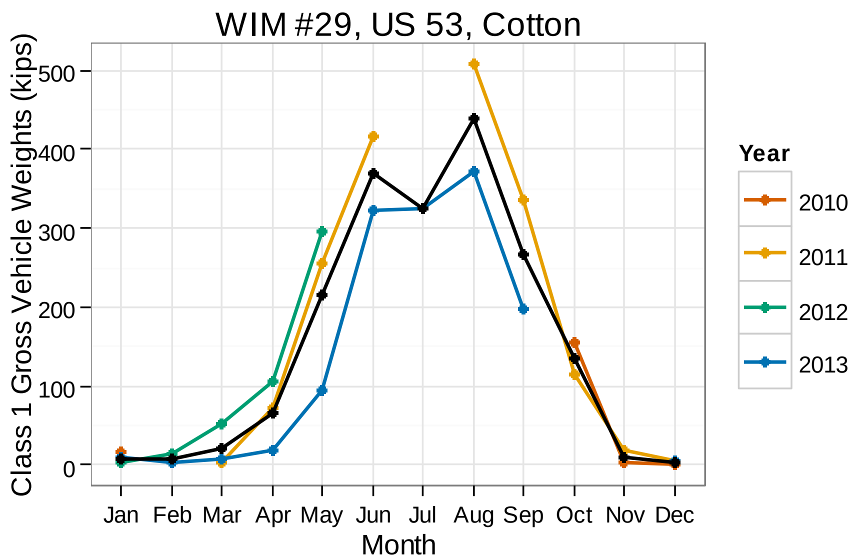


Figure 5.30a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

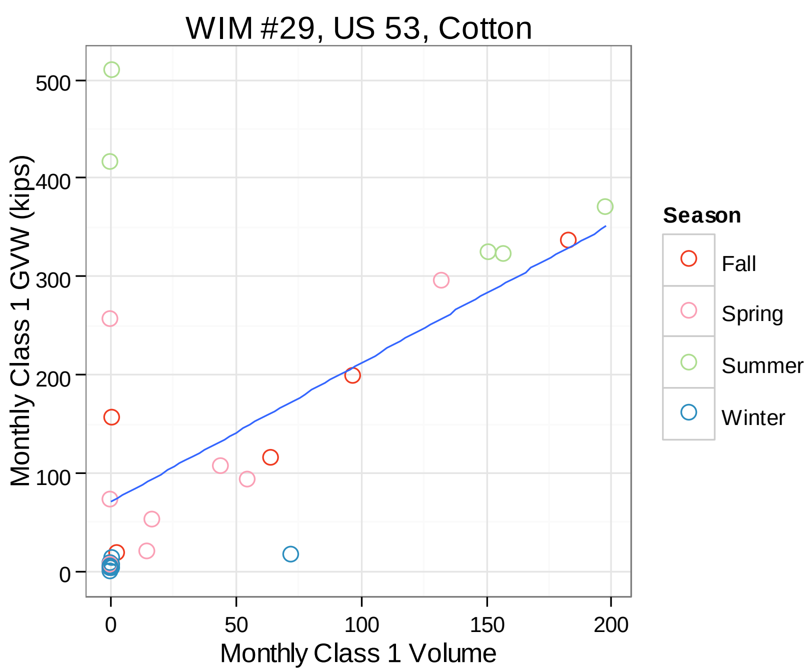


Figure 5.30b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

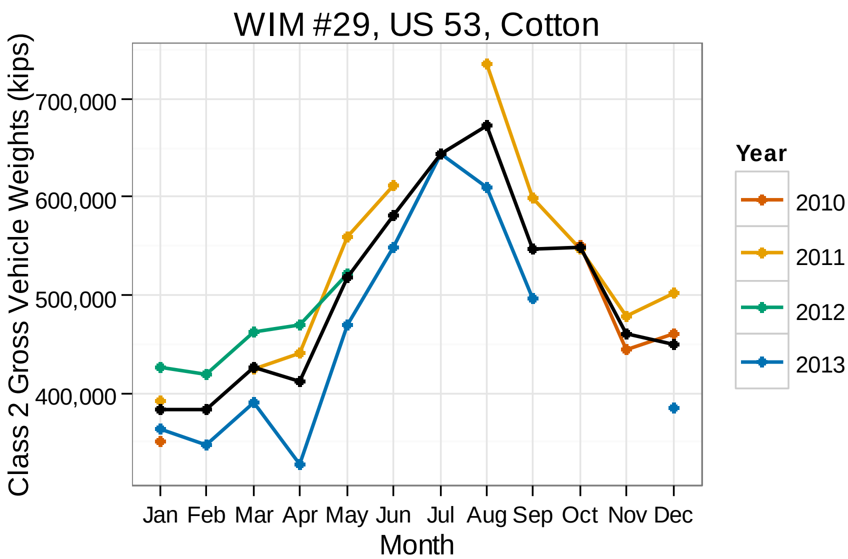


Figure 5.31a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

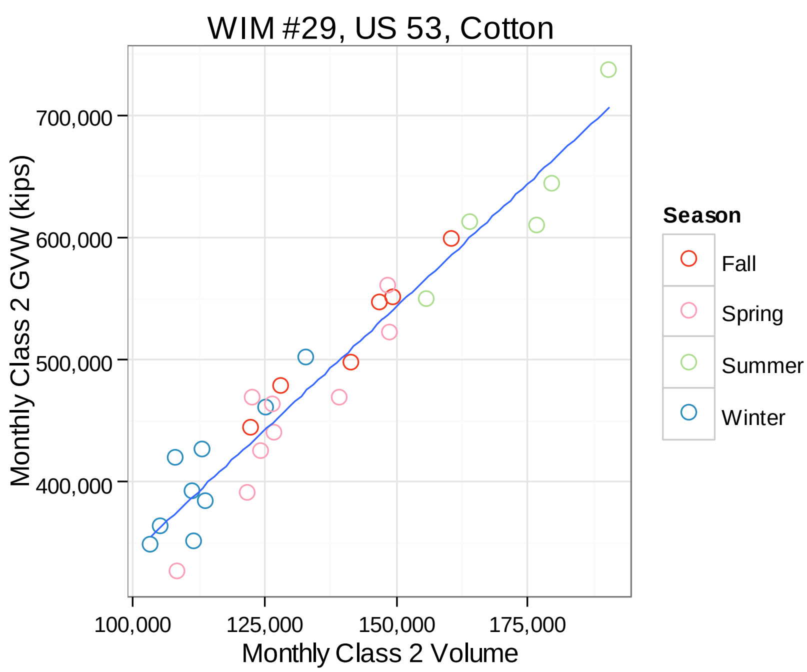


Figure 5.31b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

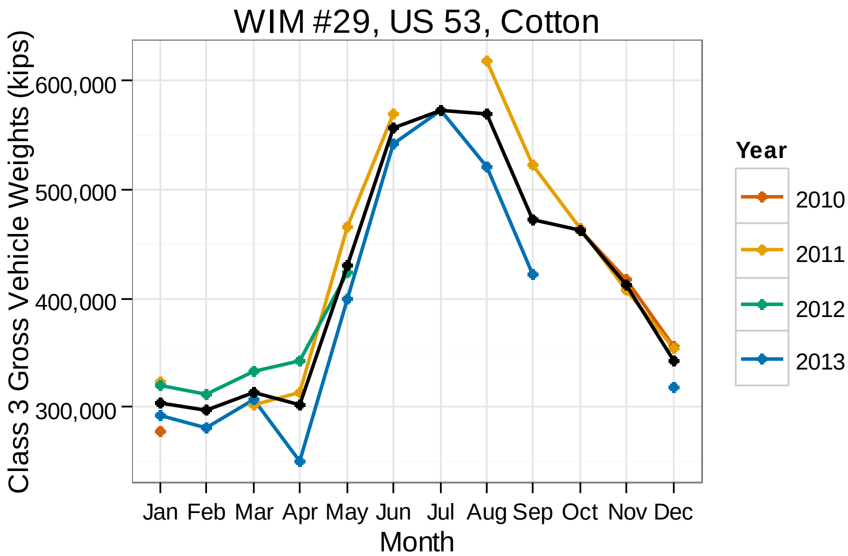


Figure 5.32a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

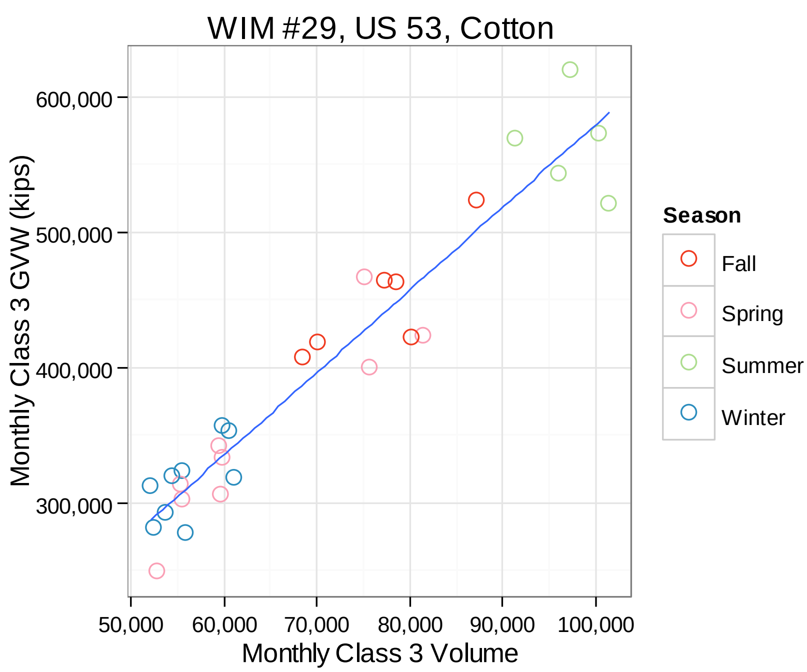


Figure 5.32b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

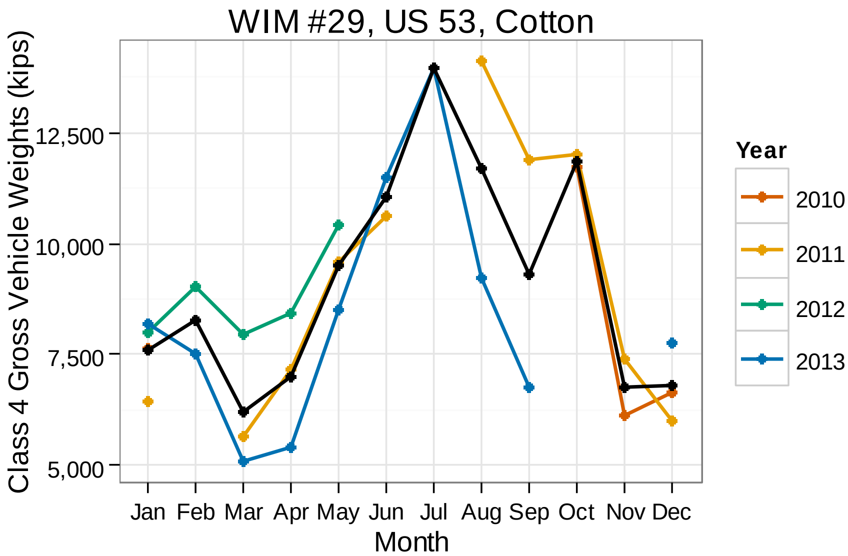


Figure 5.33a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

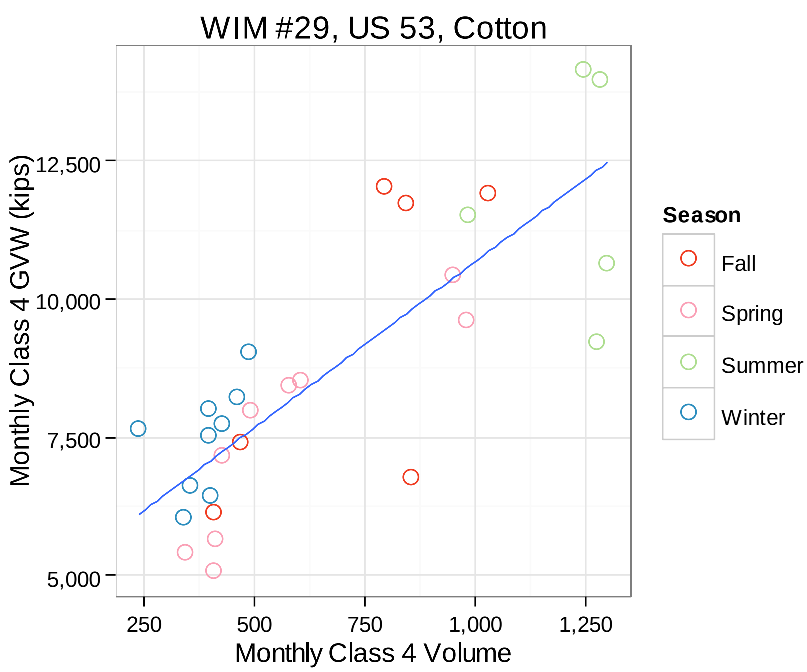


Figure 5.33b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

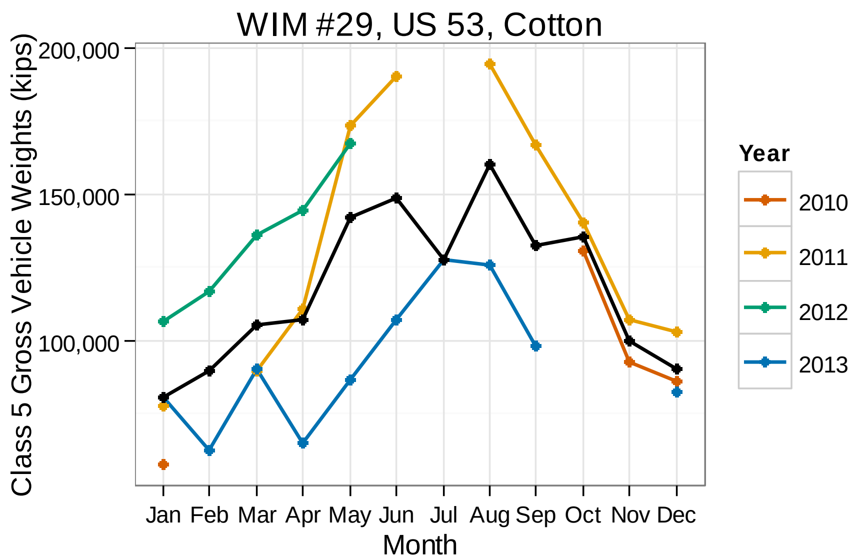


Figure 5.34a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

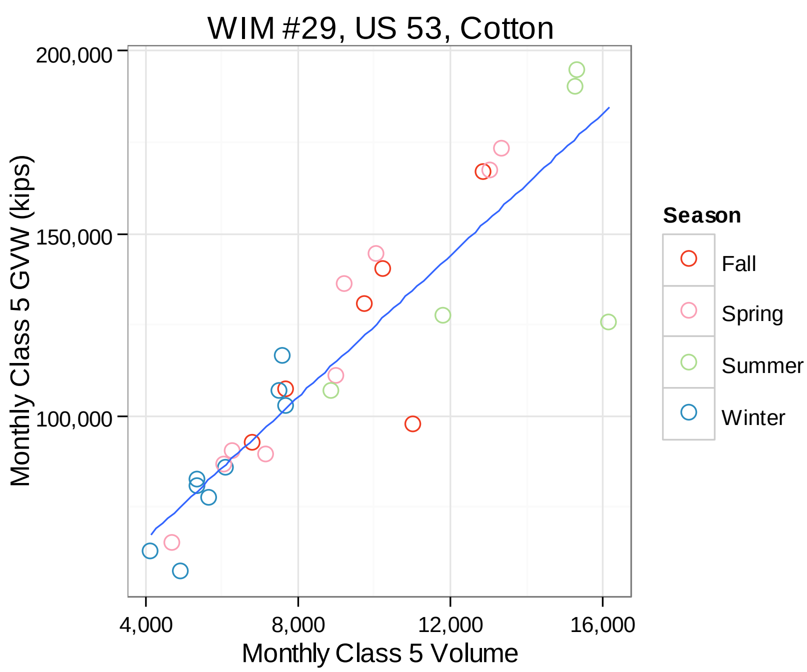


Figure 5.34b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

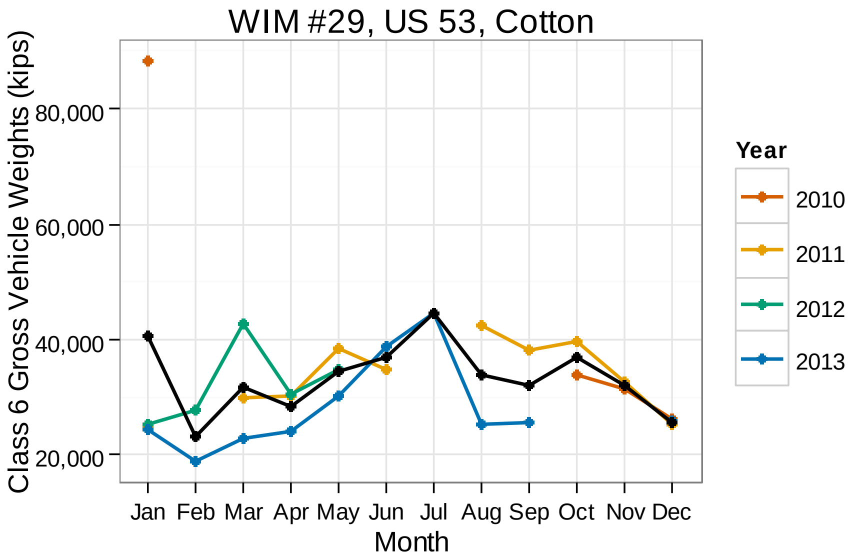


Figure 5.35a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

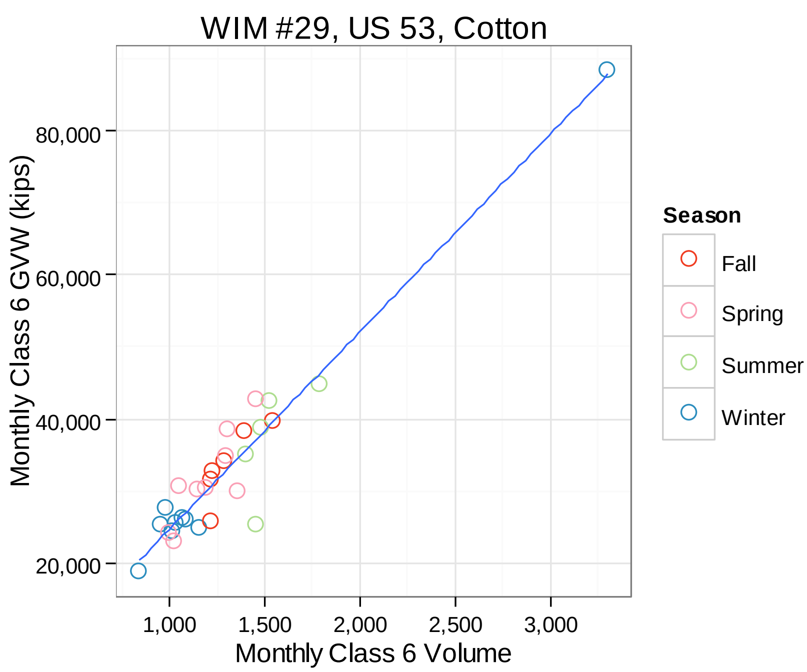


Figure 5.35b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

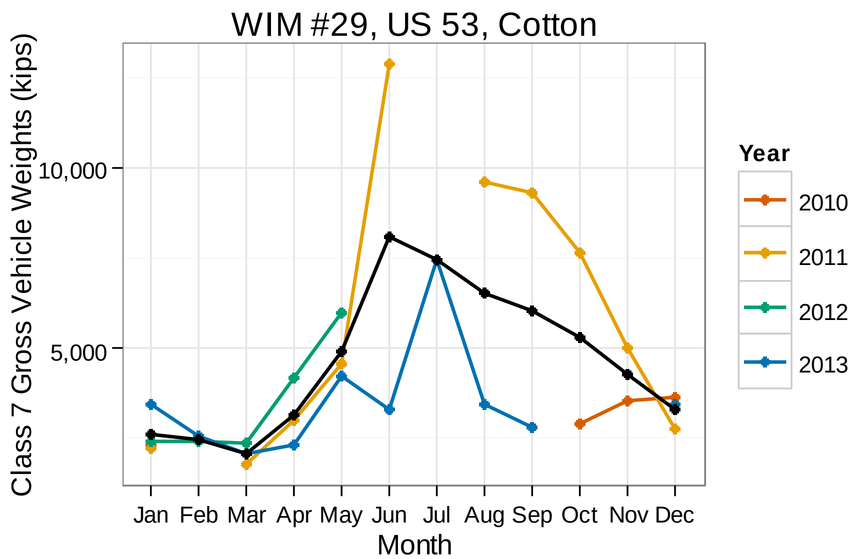


Figure 5.36a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

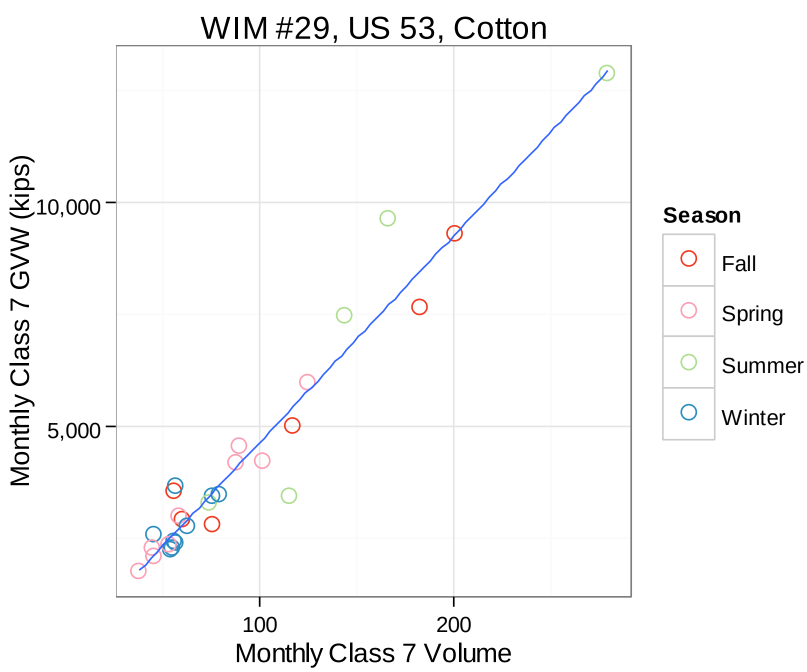


Figure 5.36b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

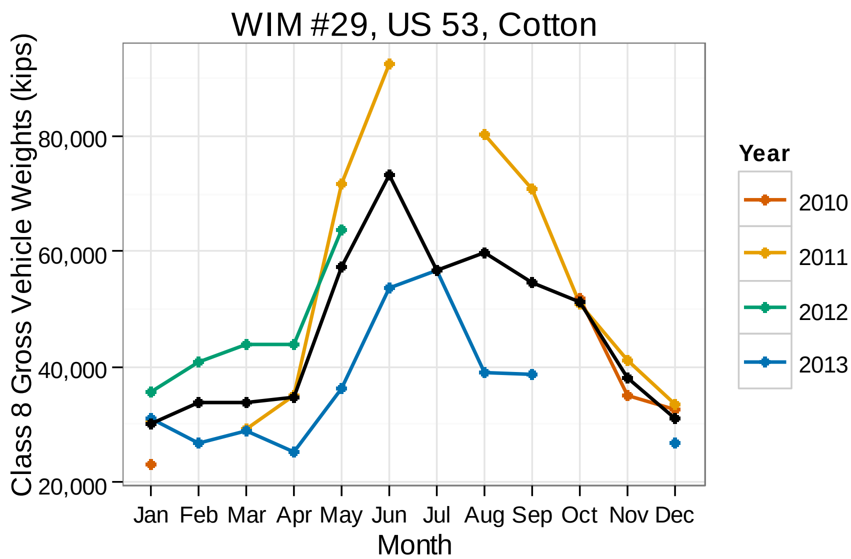


Figure 5.37a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

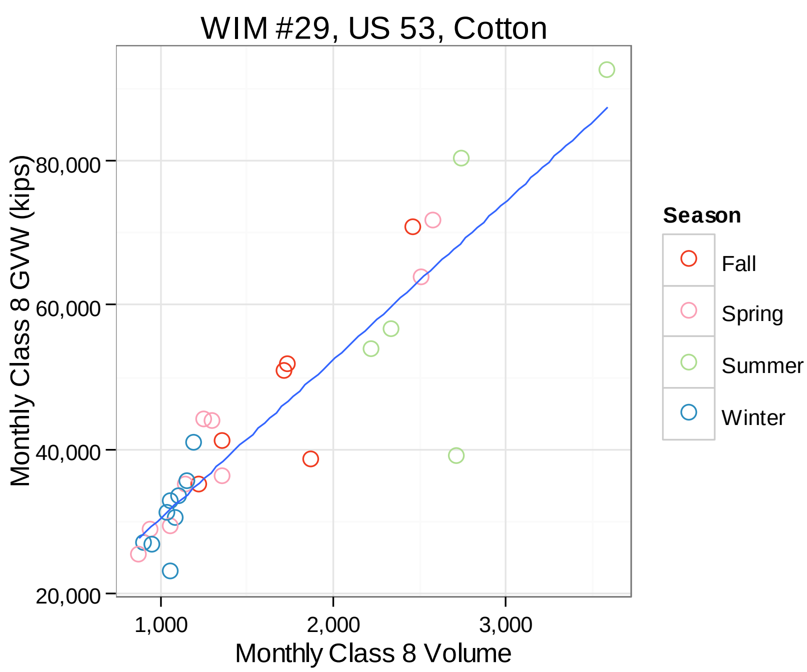


Figure 5.37b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

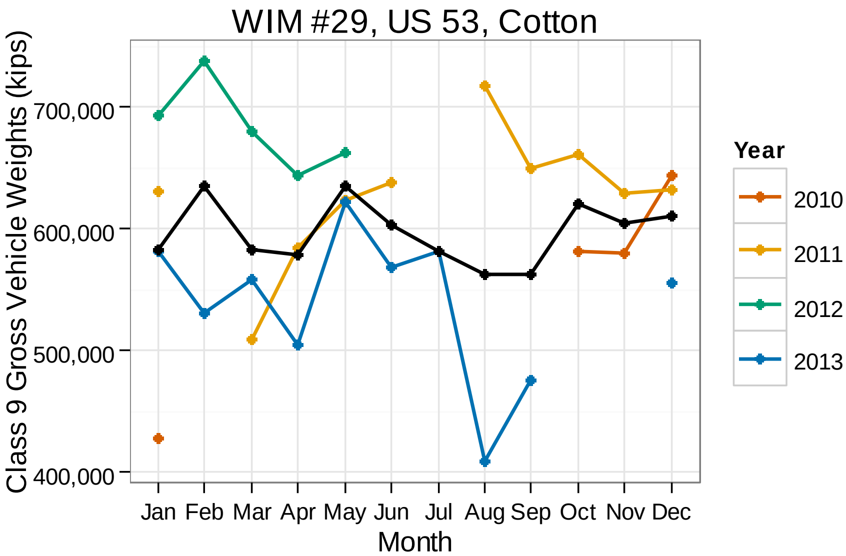


Figure 5.38a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

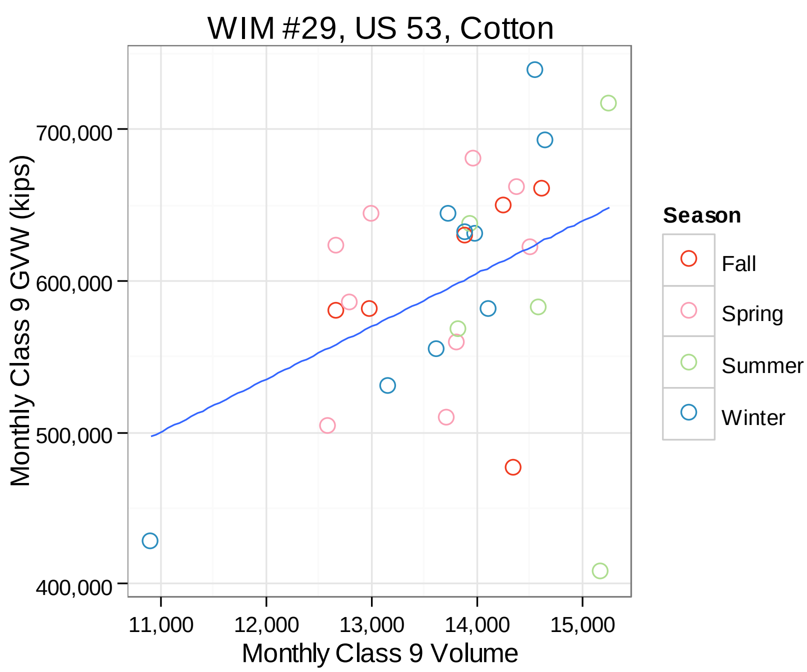


Figure 5.38b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

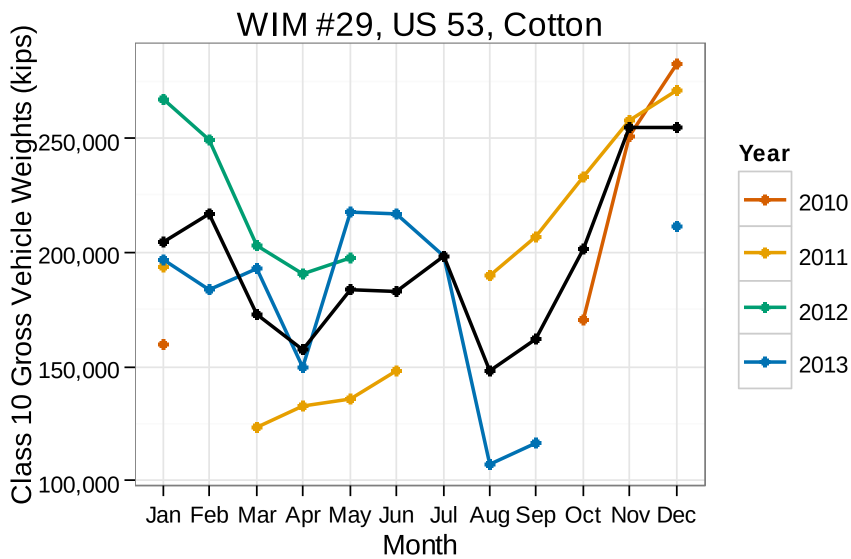


Figure 5.39a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

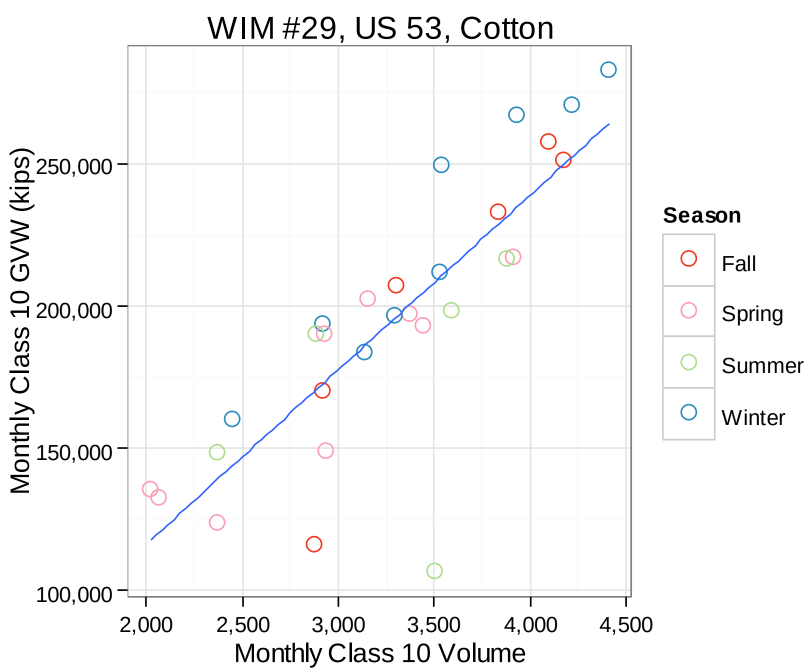


Figure 5.39b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

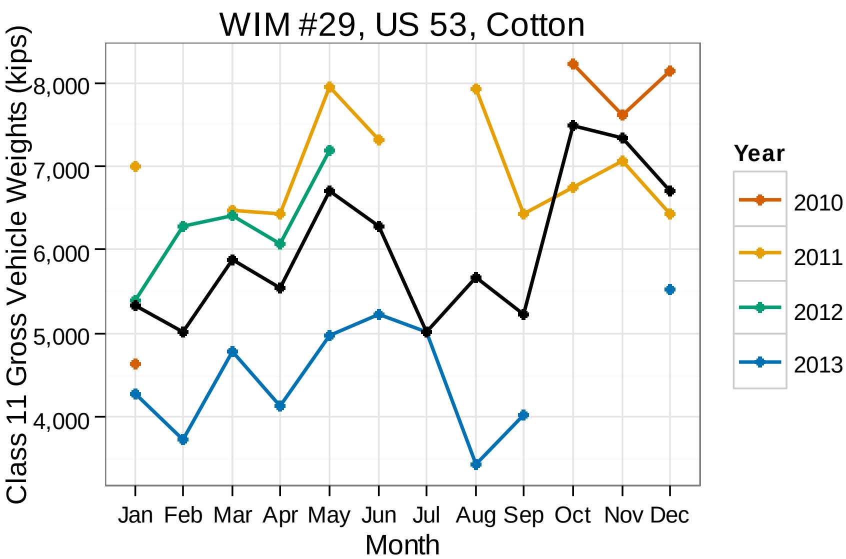


Figure 5.40a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

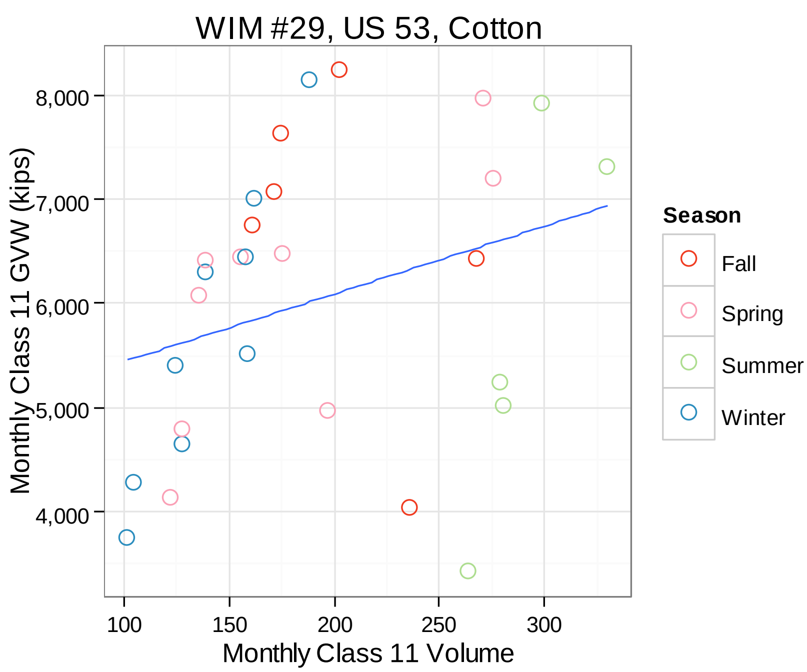


Figure 5.40b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

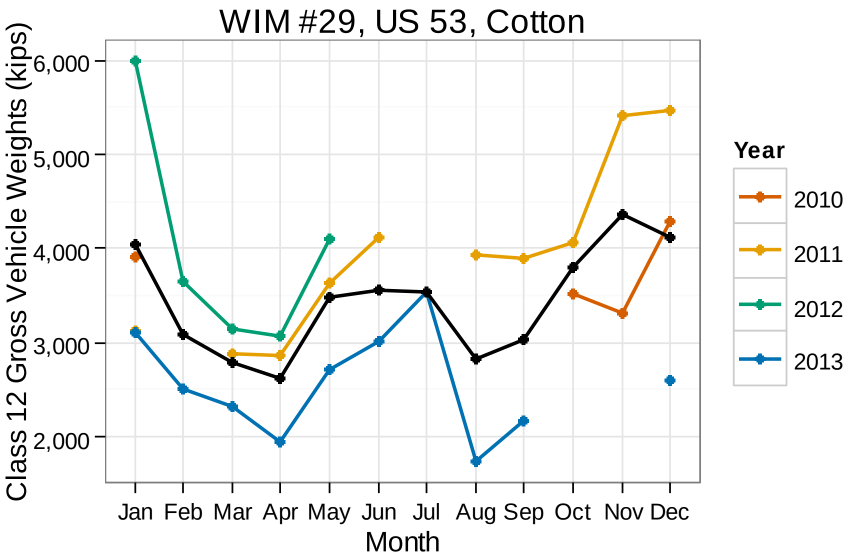


Figure 5.41a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

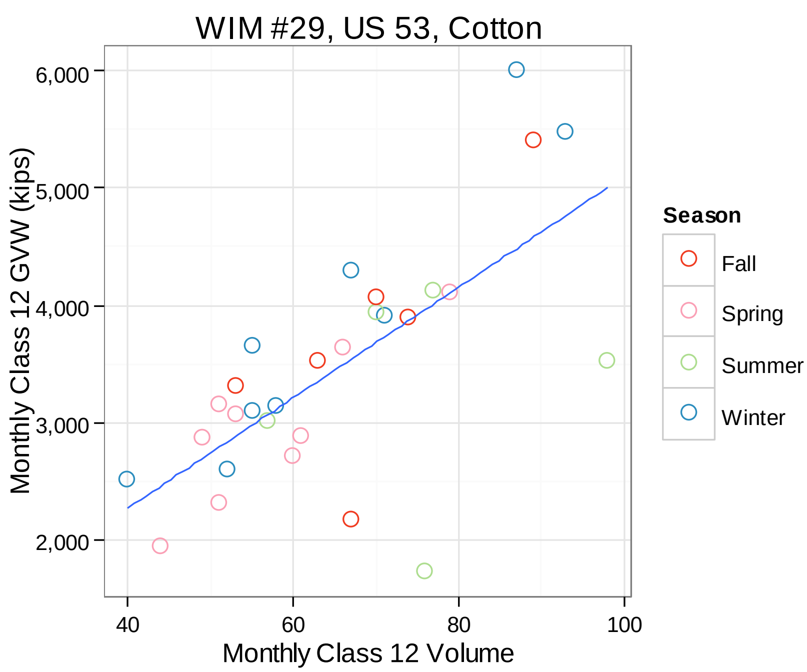


Figure 5.41b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

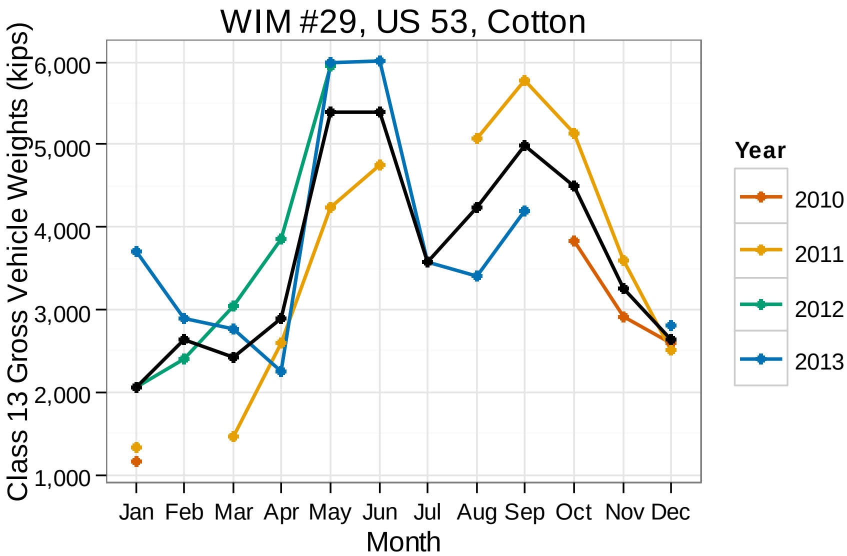


Figure 5.42a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

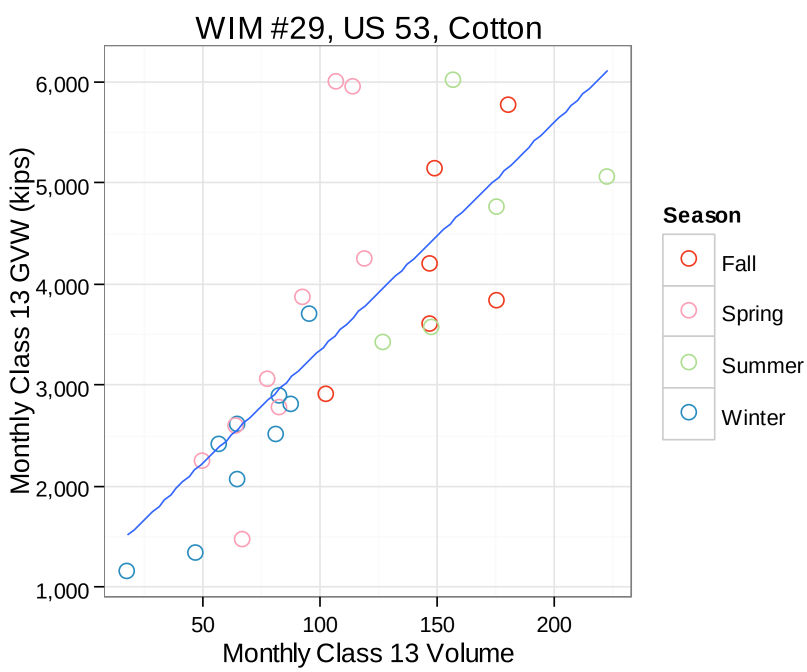


Figure 5.42b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

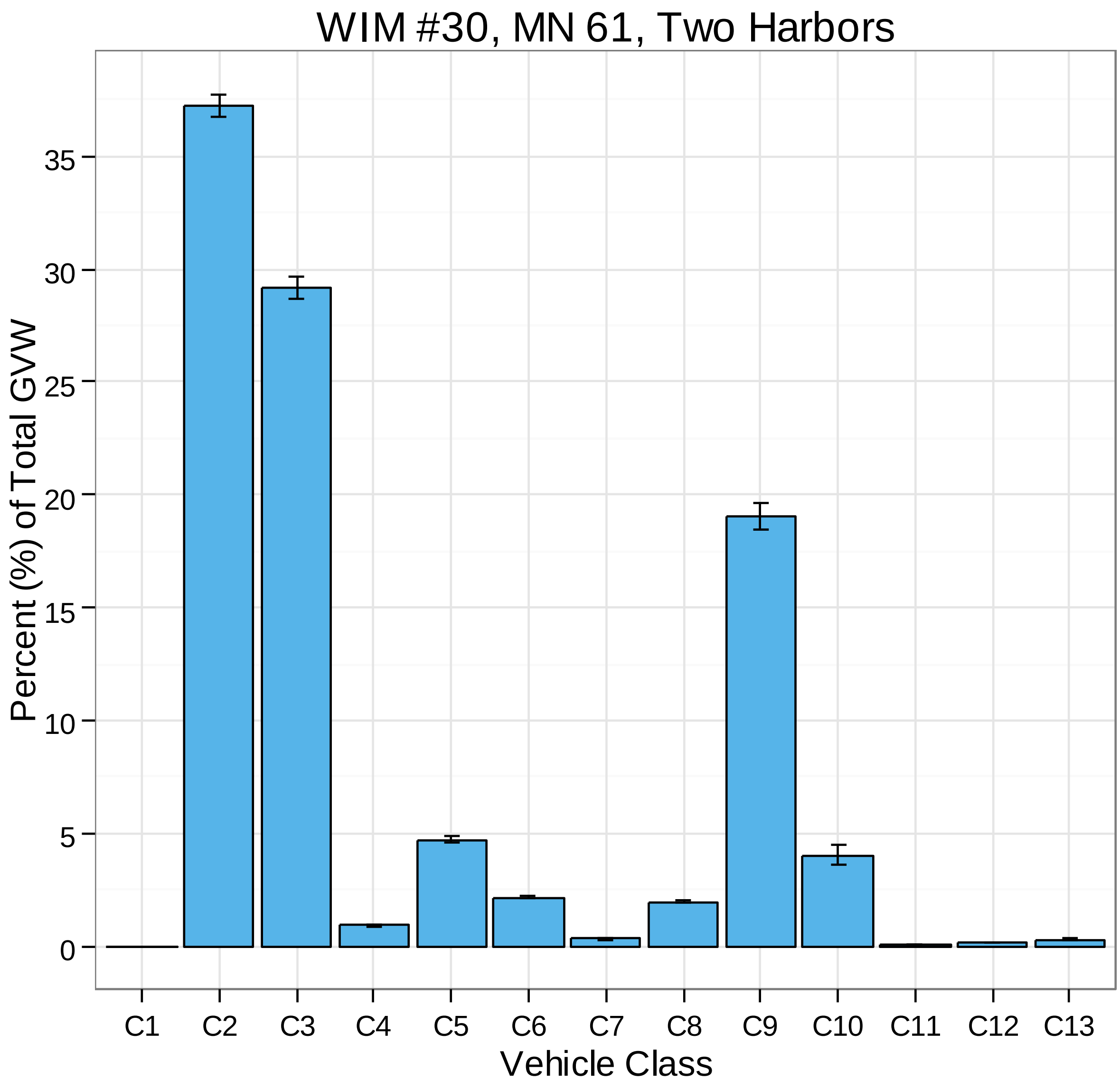


Figure 5.43. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

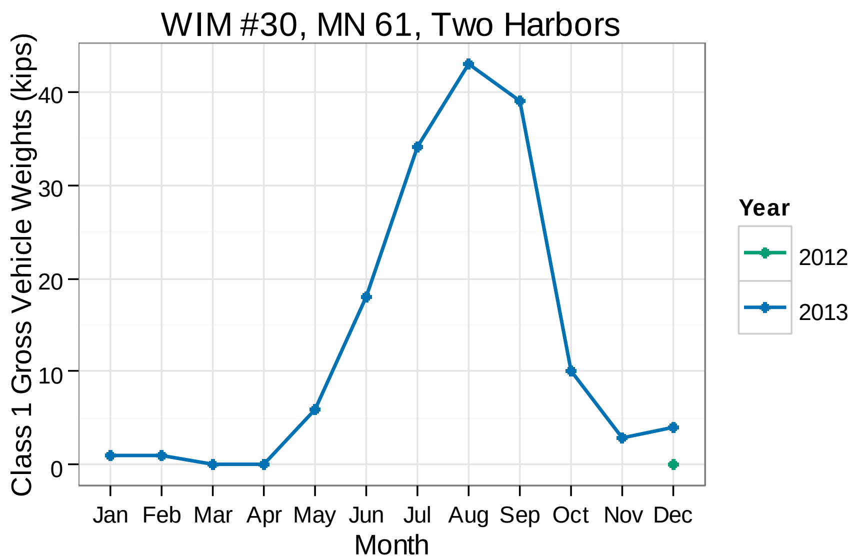


Figure 5.44a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

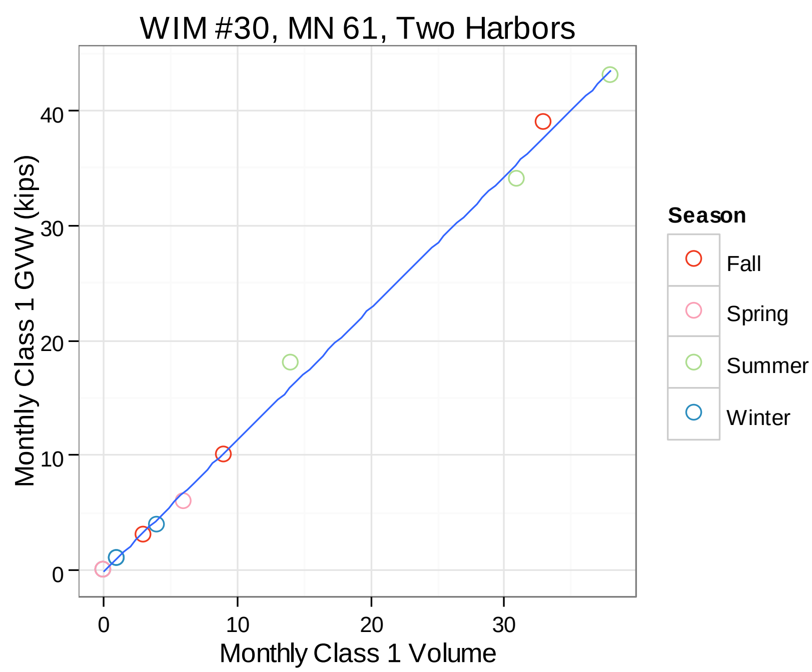


Figure 5.44b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

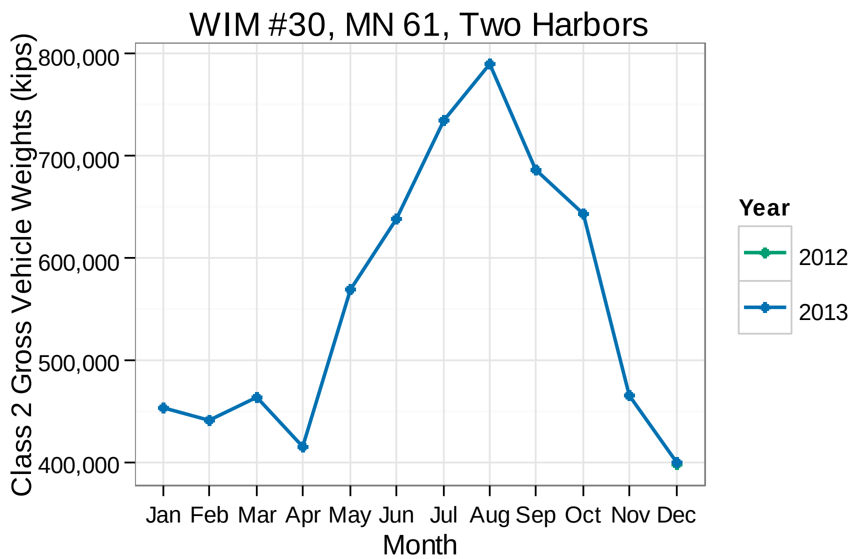


Figure 5.45a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

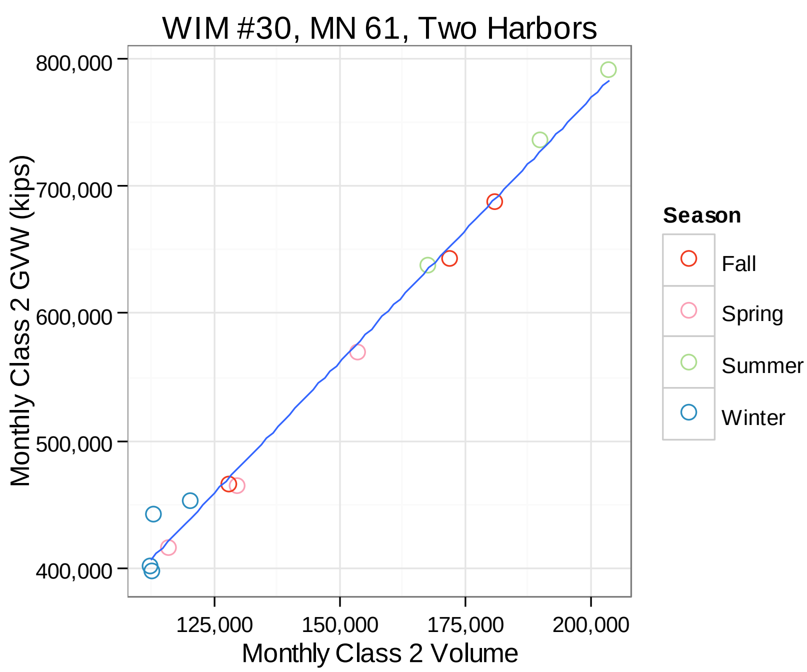


Figure 5.45b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

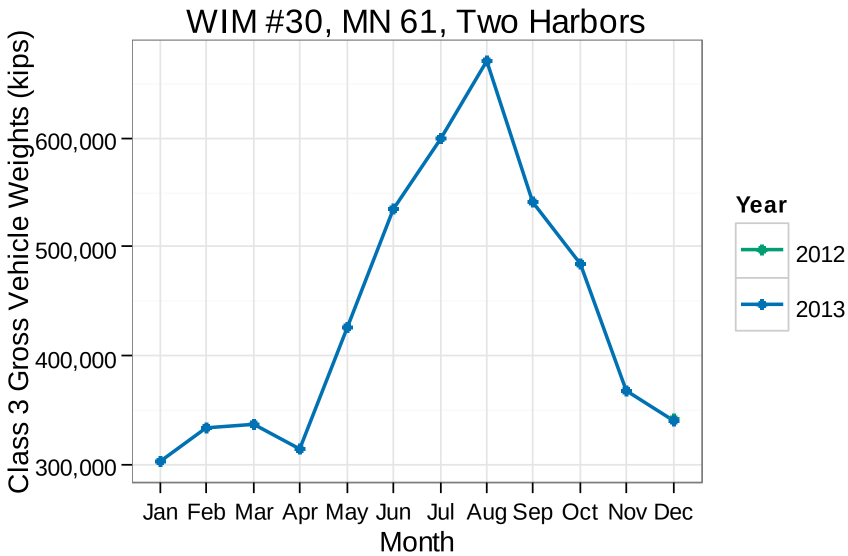


Figure 5.46a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

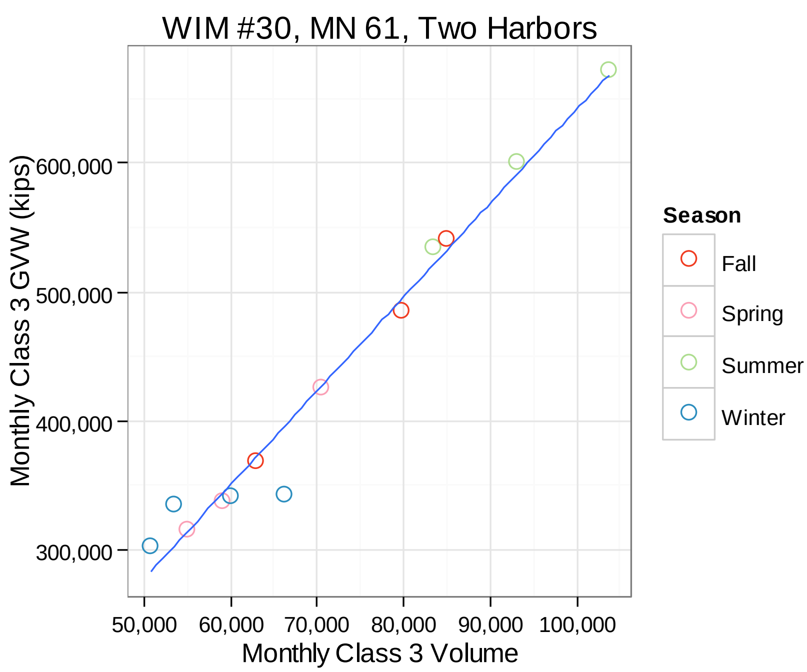


Figure 5.46b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

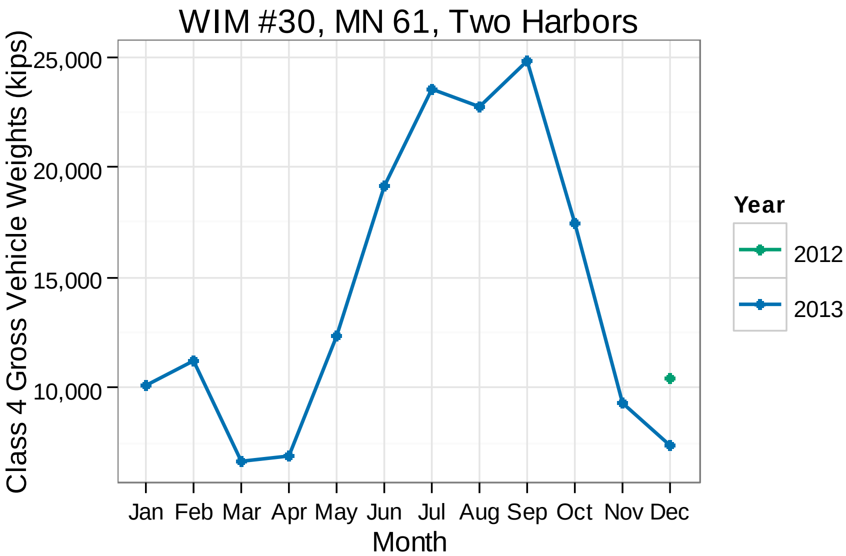


Figure 5.47a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

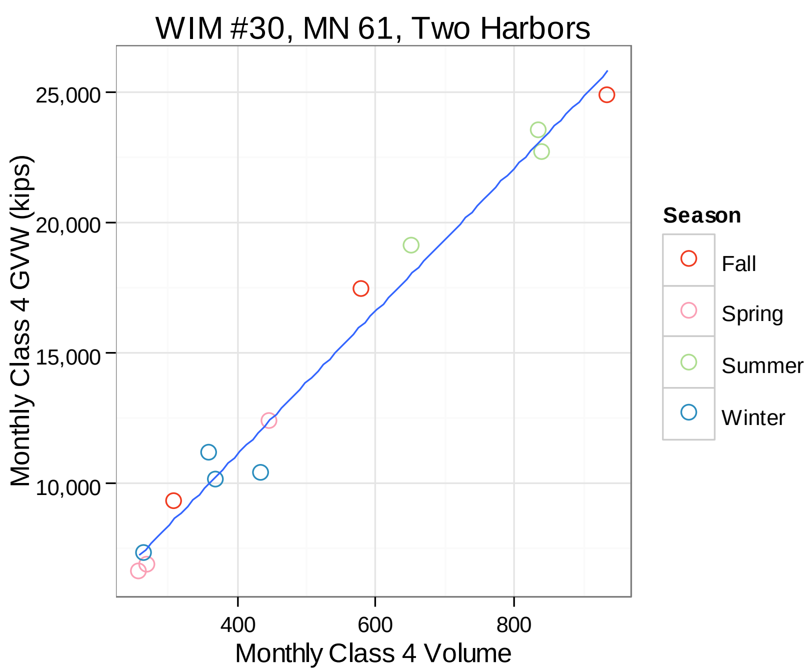


Figure 5.47b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

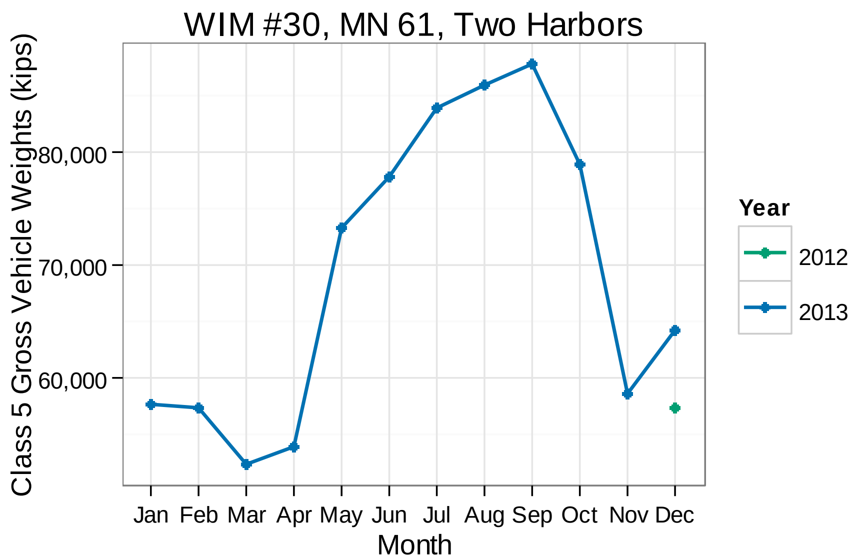


Figure 5.48a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

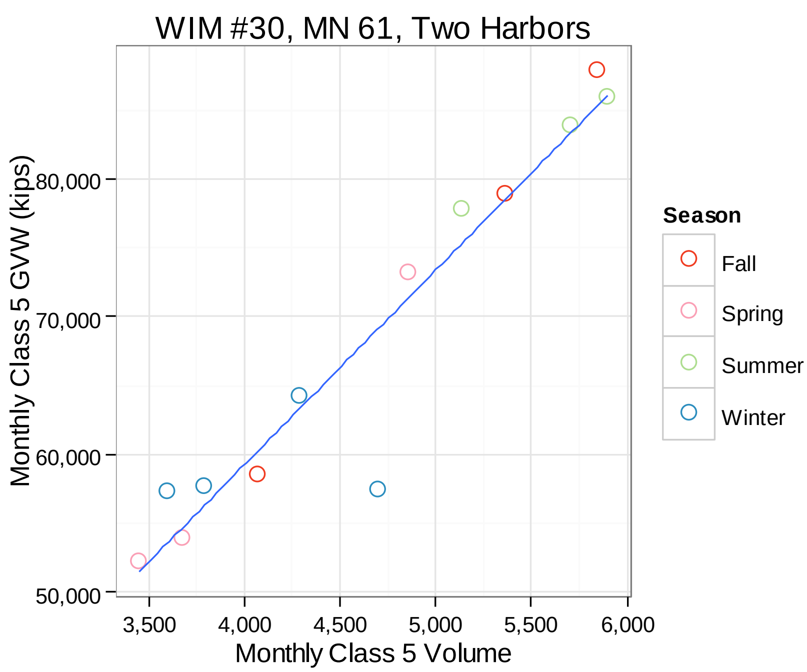


Figure 5.48b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

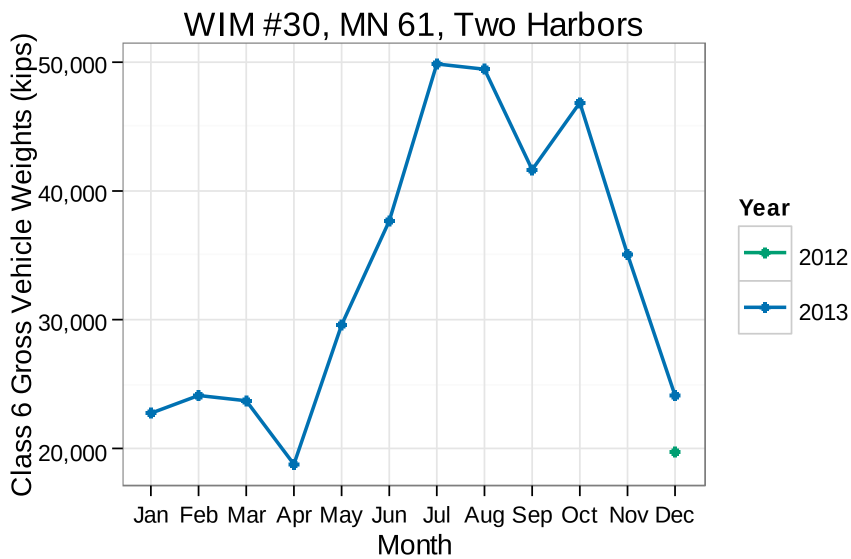


Figure 5.49a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

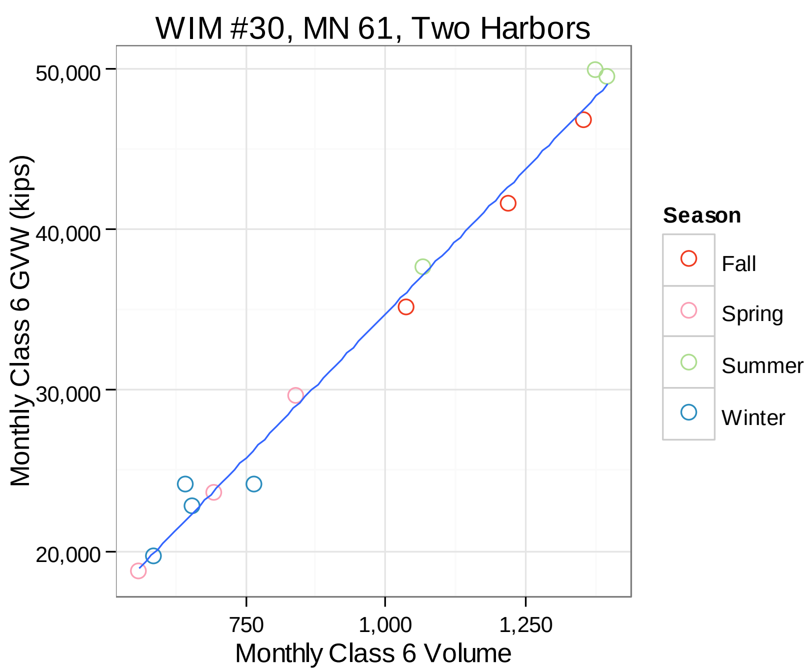


Figure 5.49b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

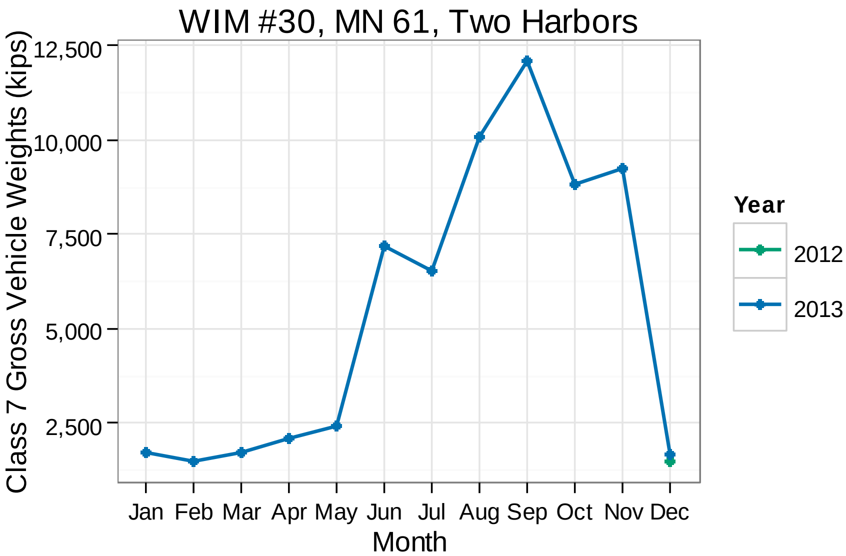


Figure 5.50a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

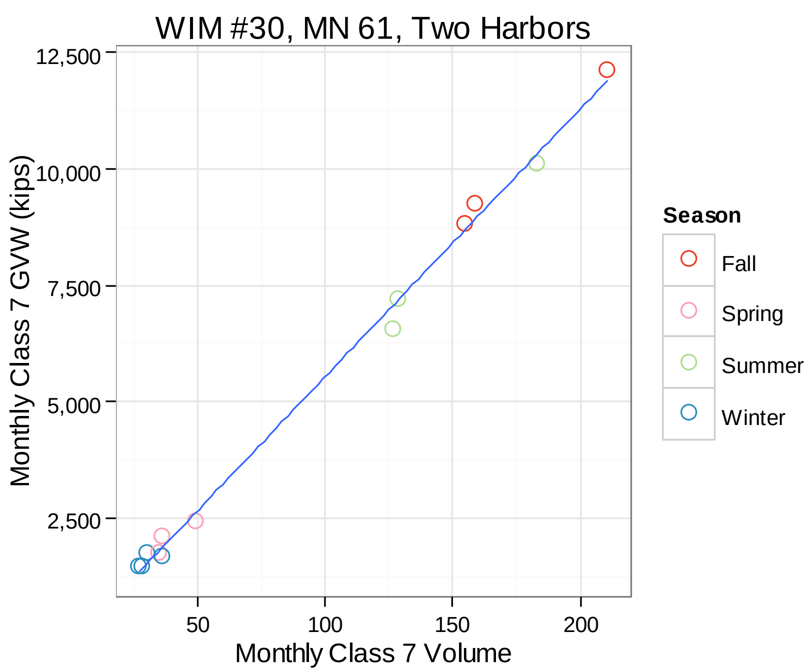


Figure 5.50b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

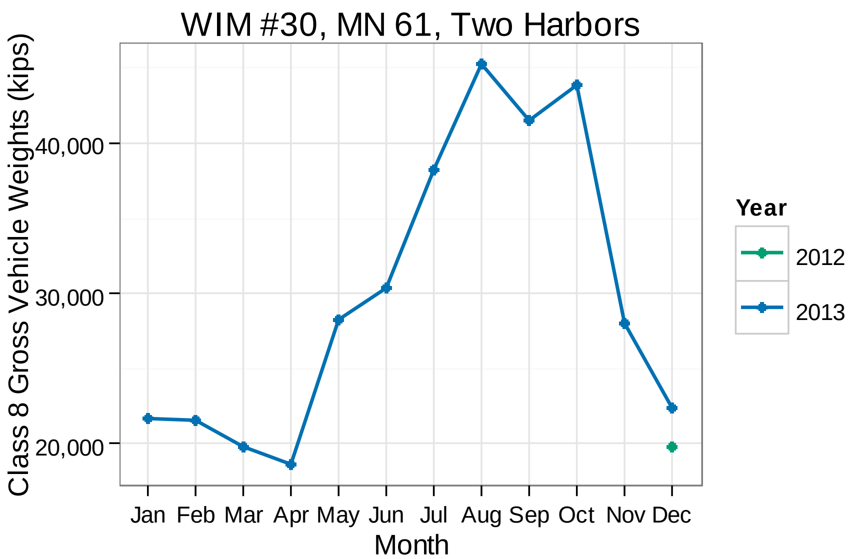


Figure 5.51a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

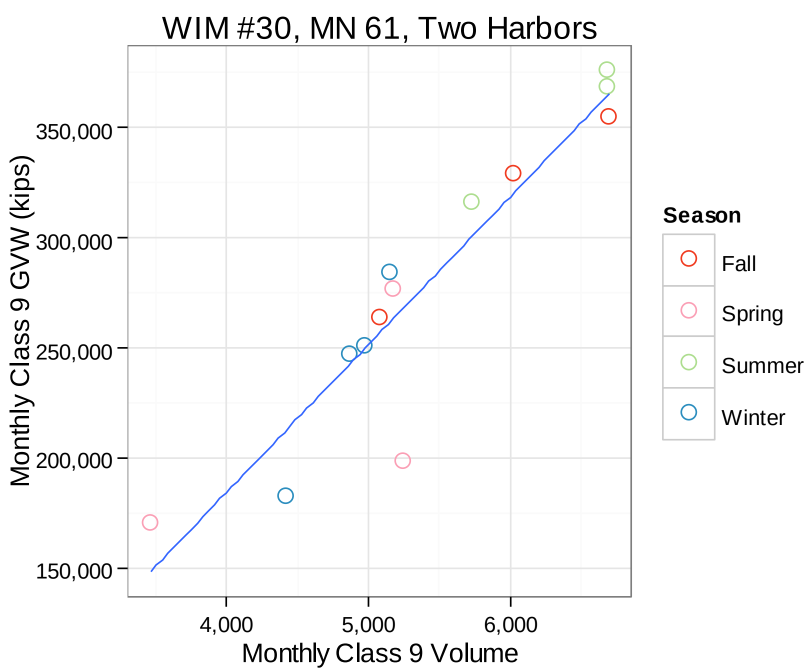


Figure 5.51b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

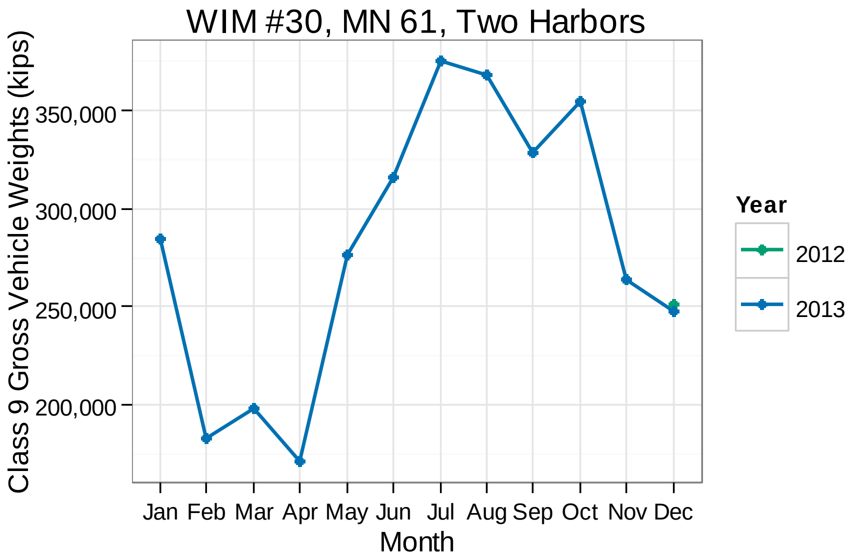


Figure 5.52a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

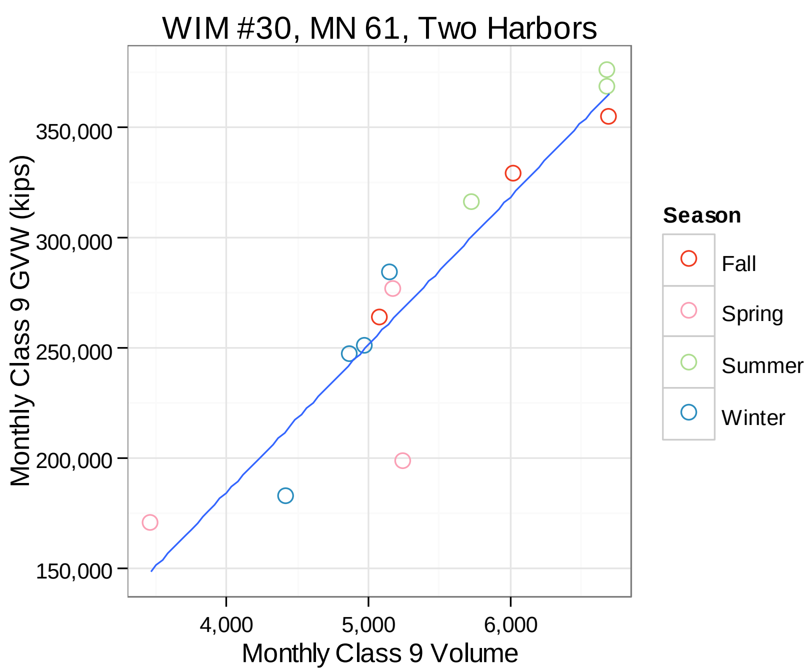


Figure 5.52b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

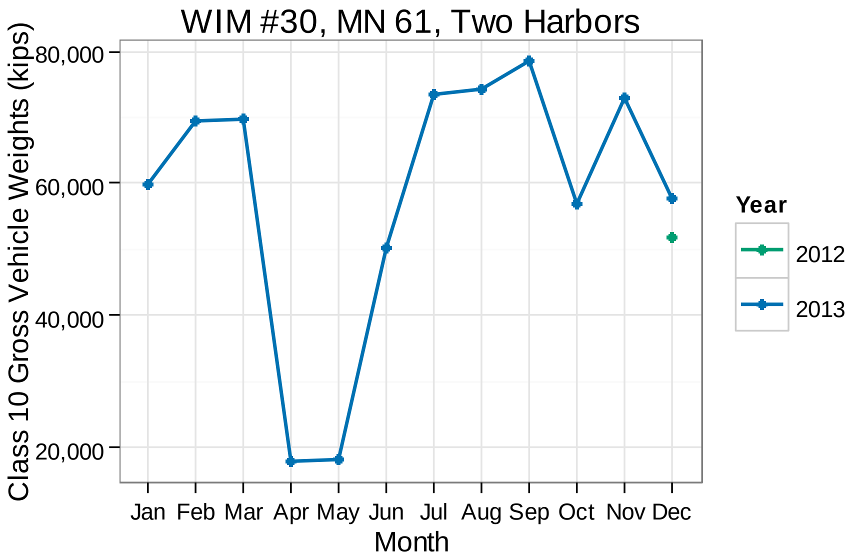


Figure 5.53a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

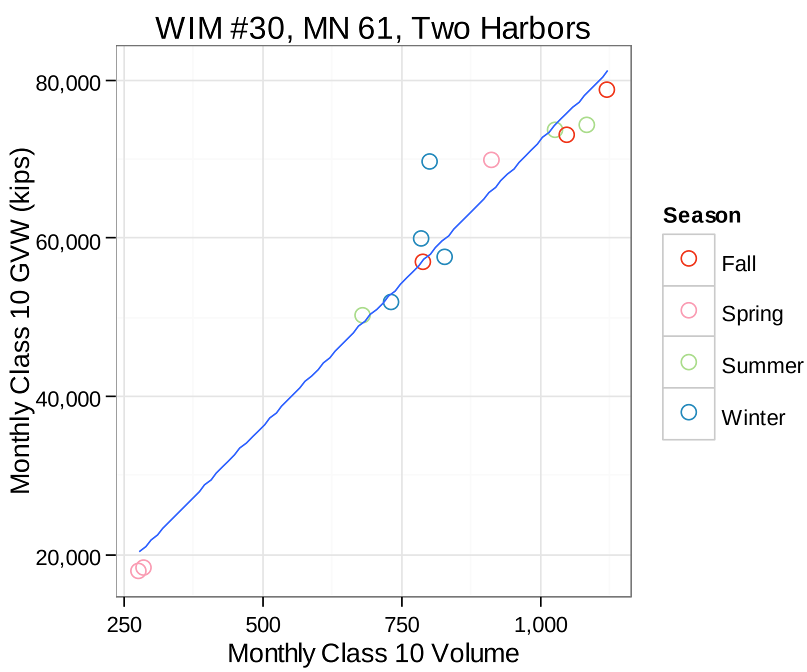


Figure 5.53b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

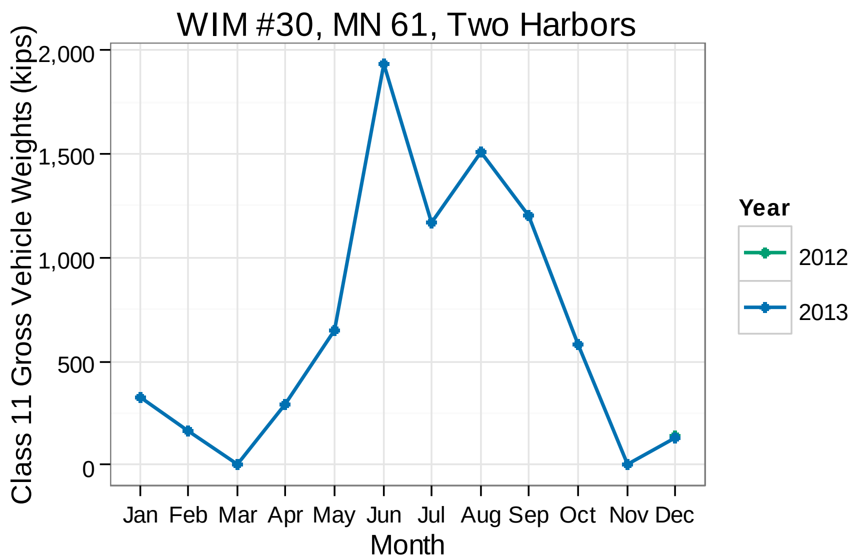


Figure 5.54a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

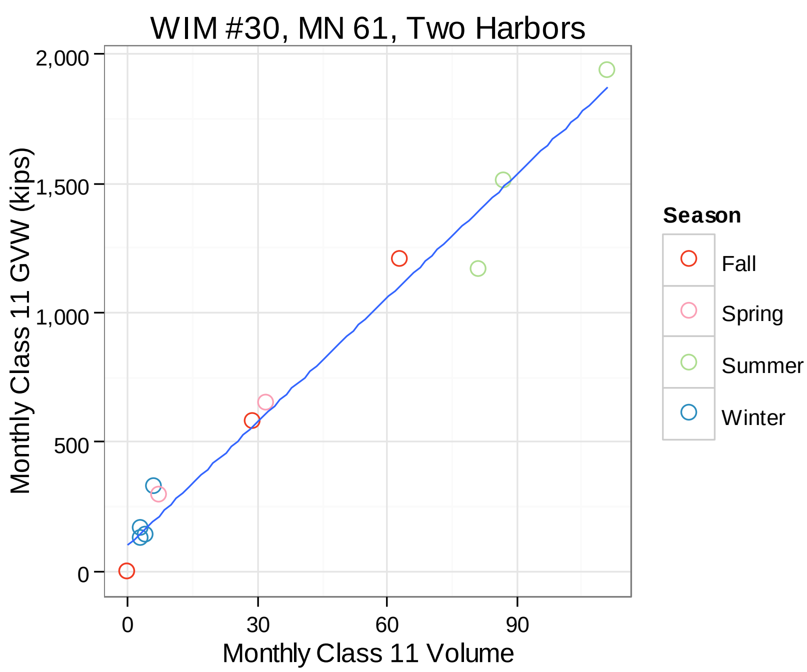


Figure 5.54b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

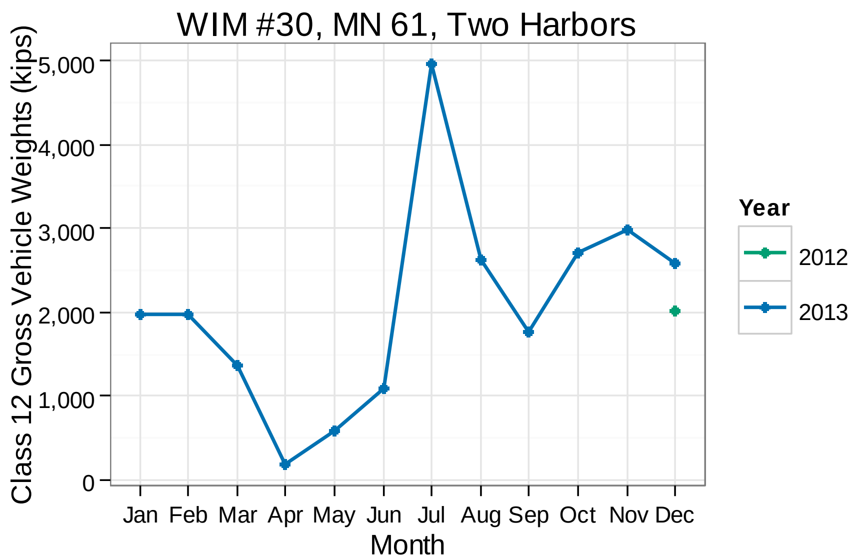


Figure 5.55a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

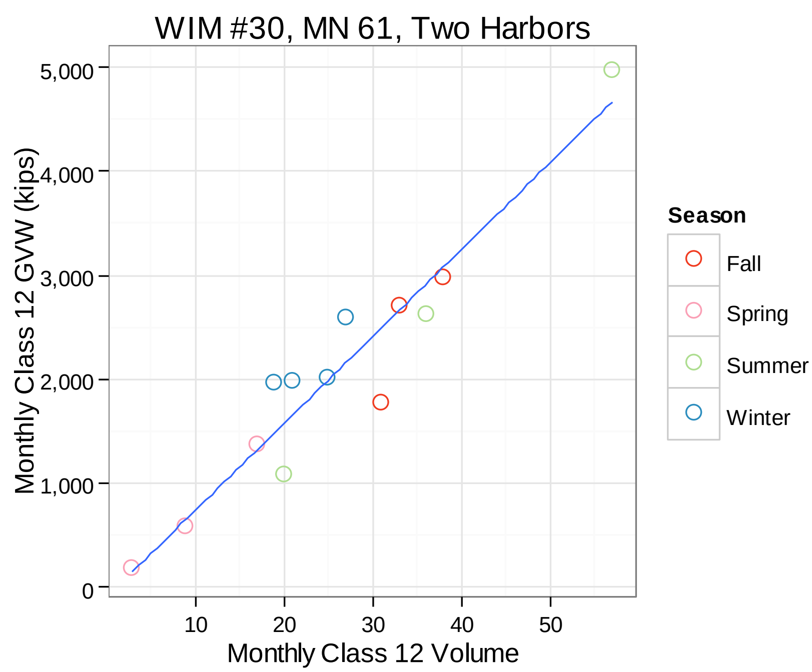


Figure 5.55b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

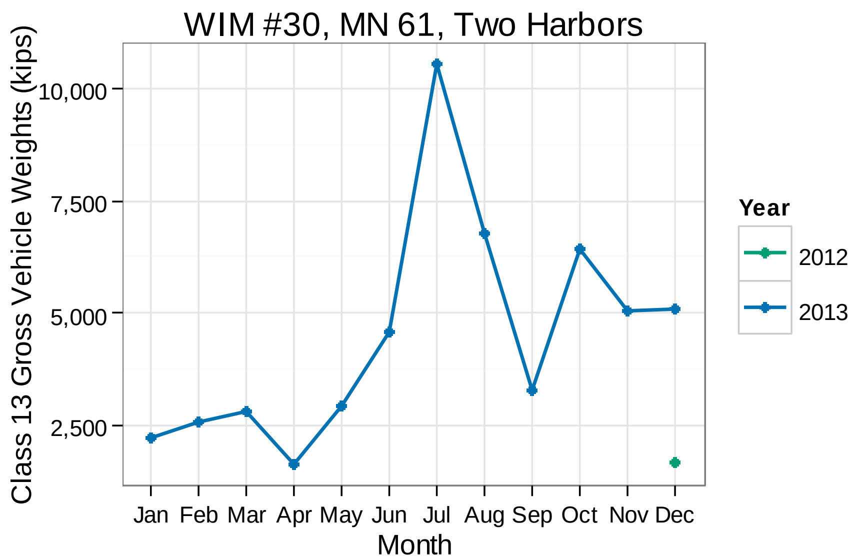


Figure 5.56a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

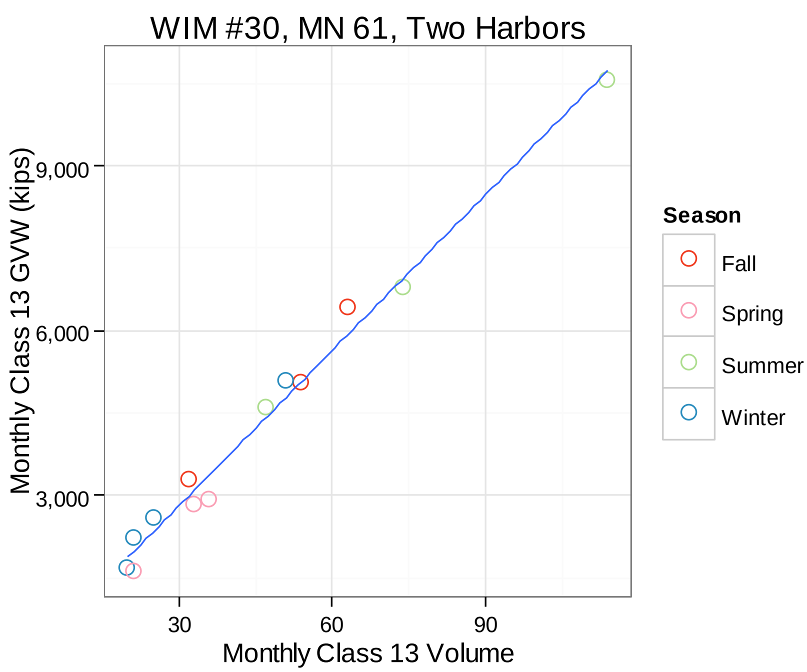


Figure 5.56b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

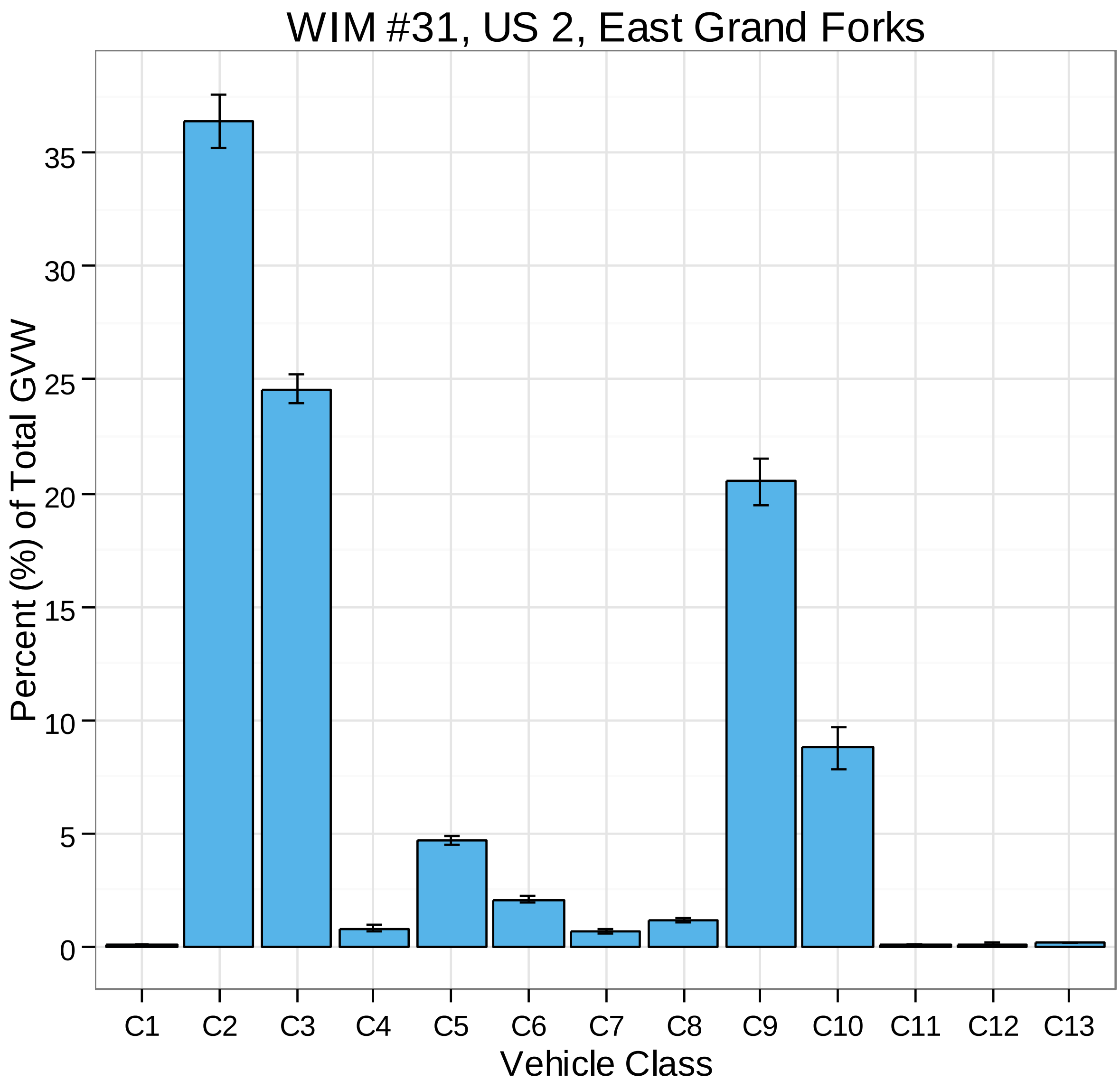


Figure 5.57. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

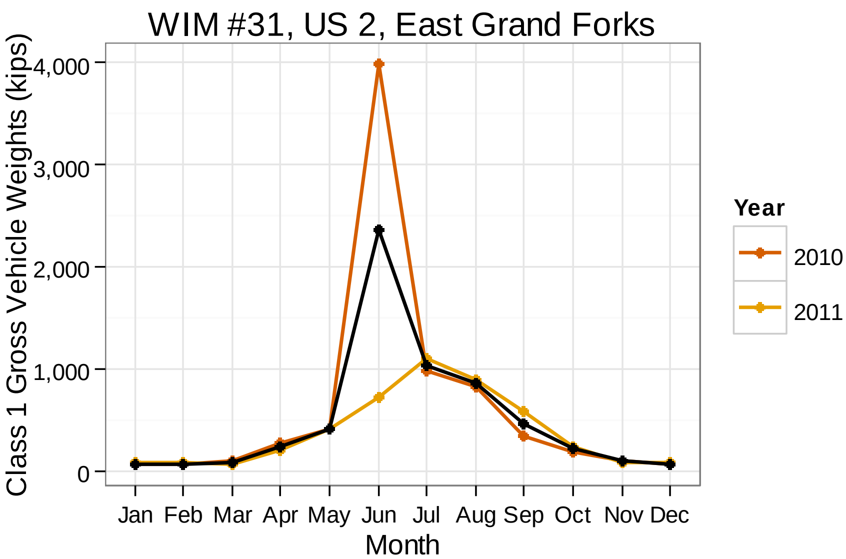


Figure 5.58a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

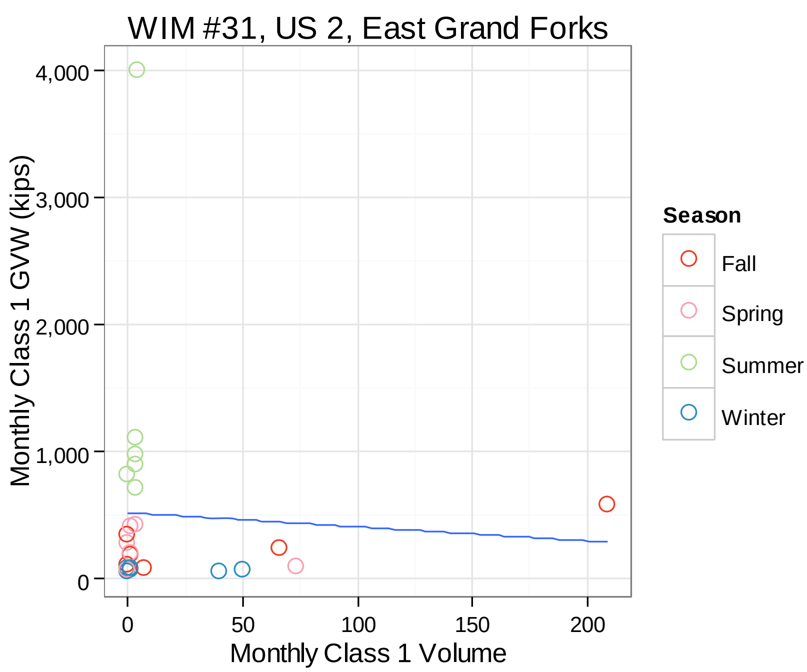


Figure 5.58b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

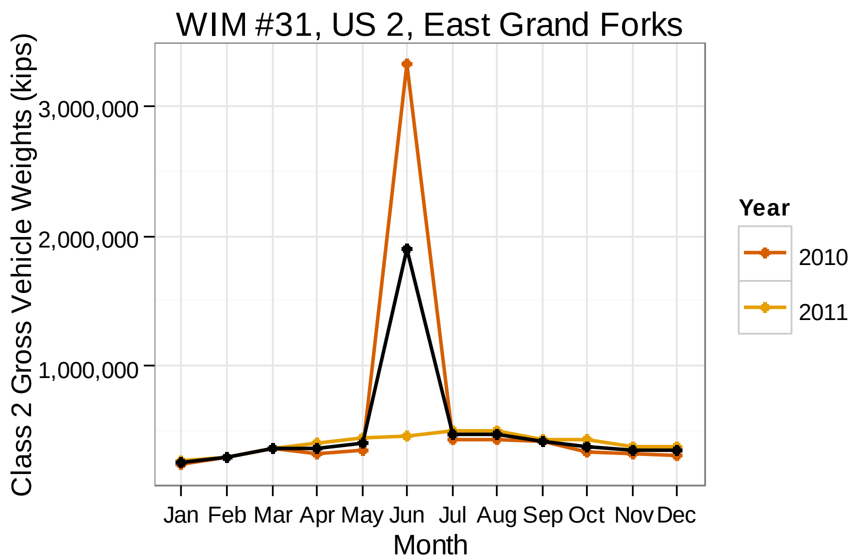


Figure 5.59a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

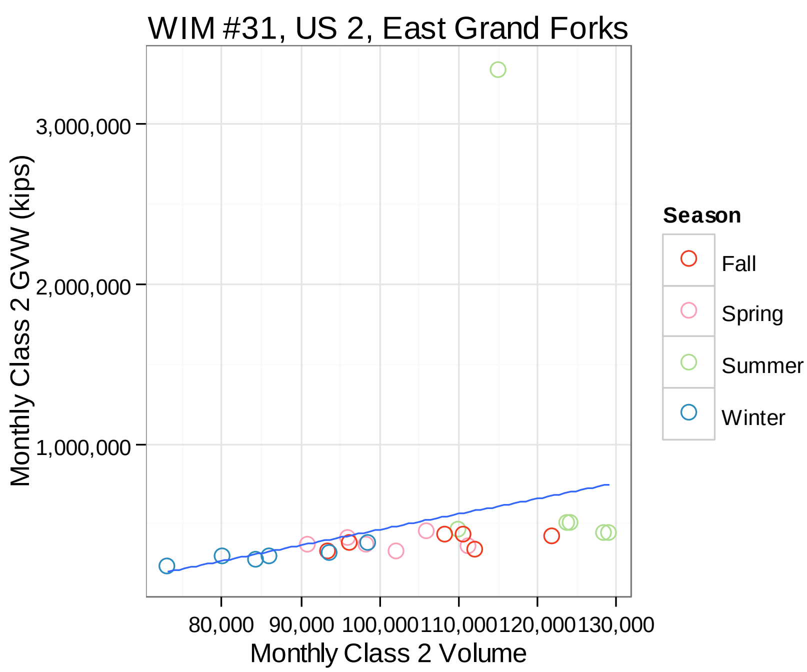


Figure 5.59b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

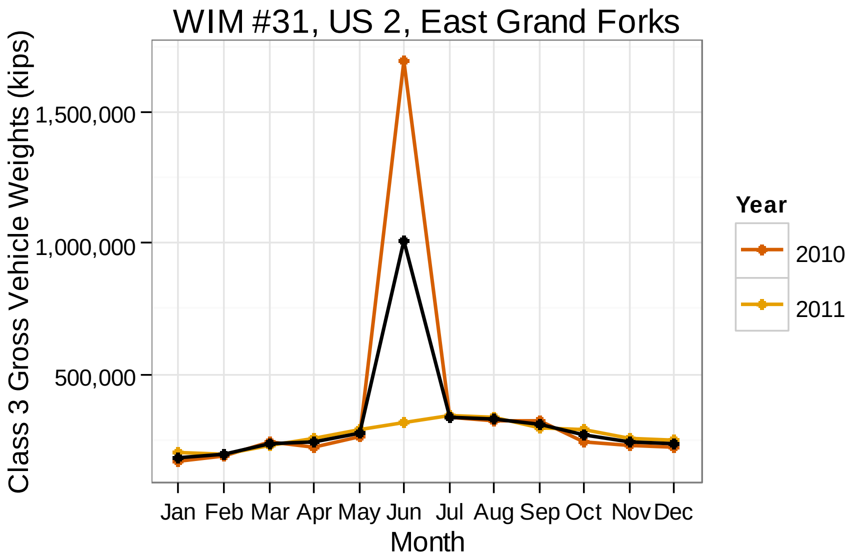


Figure 5.60a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

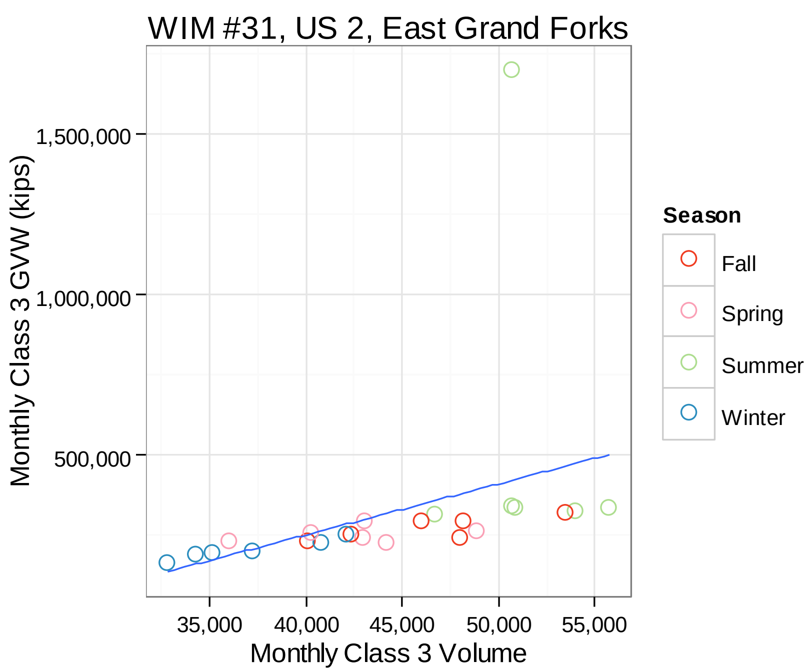


Figure 5.60b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

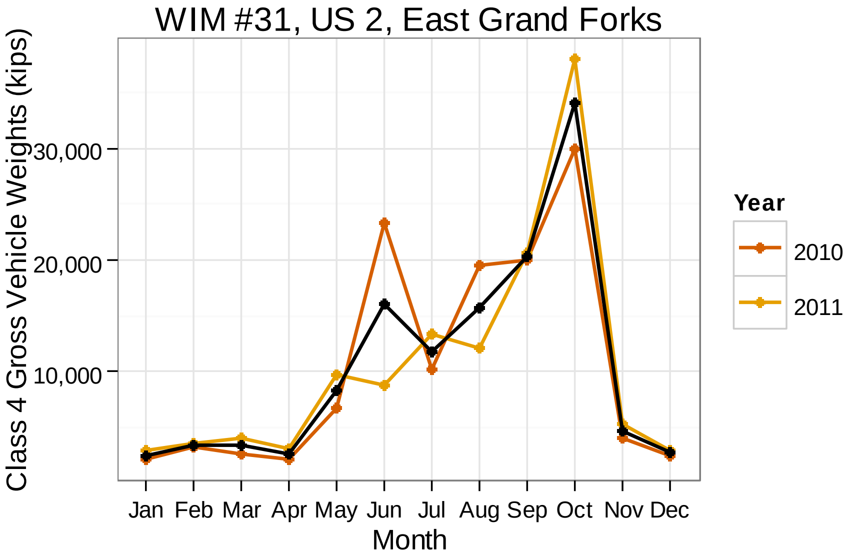


Figure 5.61a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

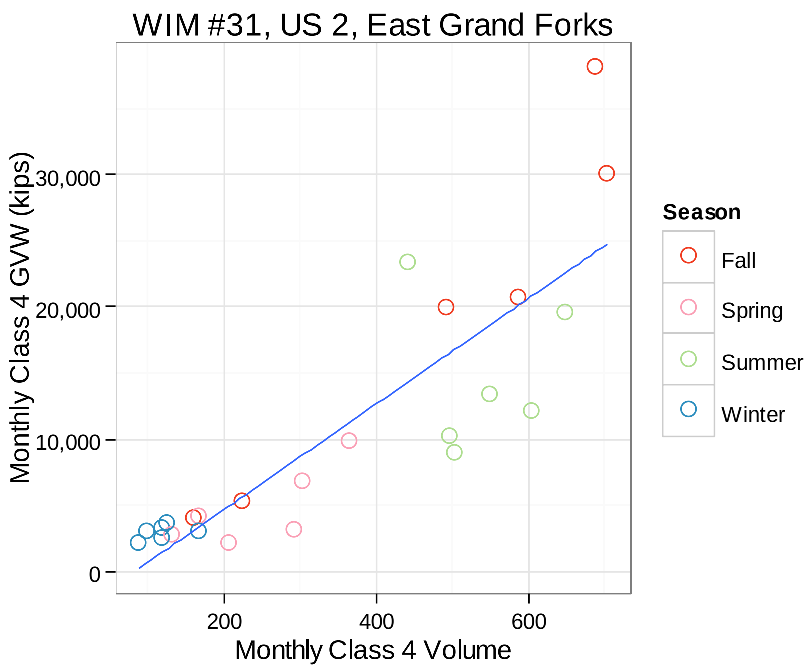


Figure 5.61b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

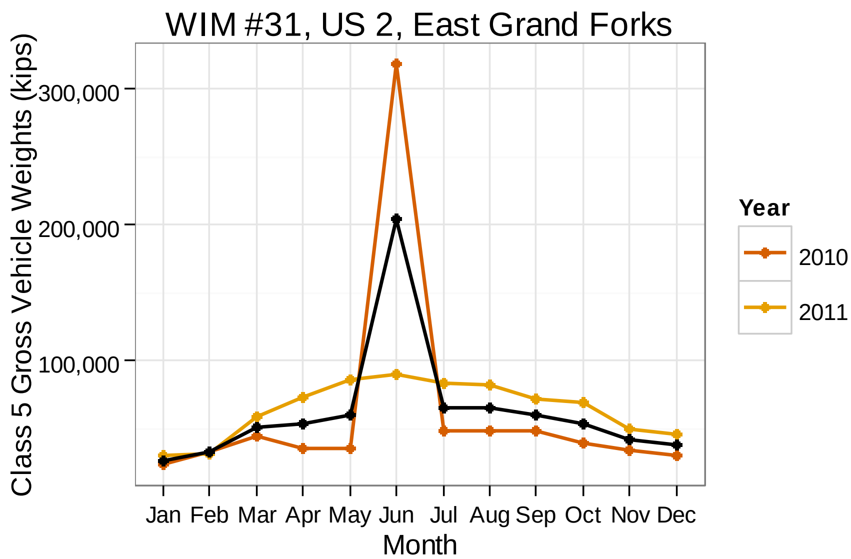


Figure 5.62a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

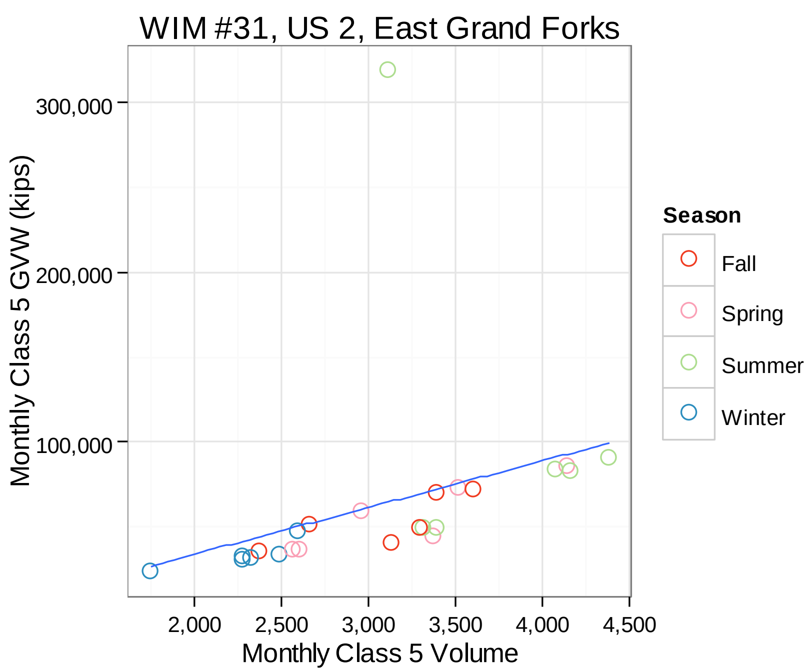


Figure 5.62b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

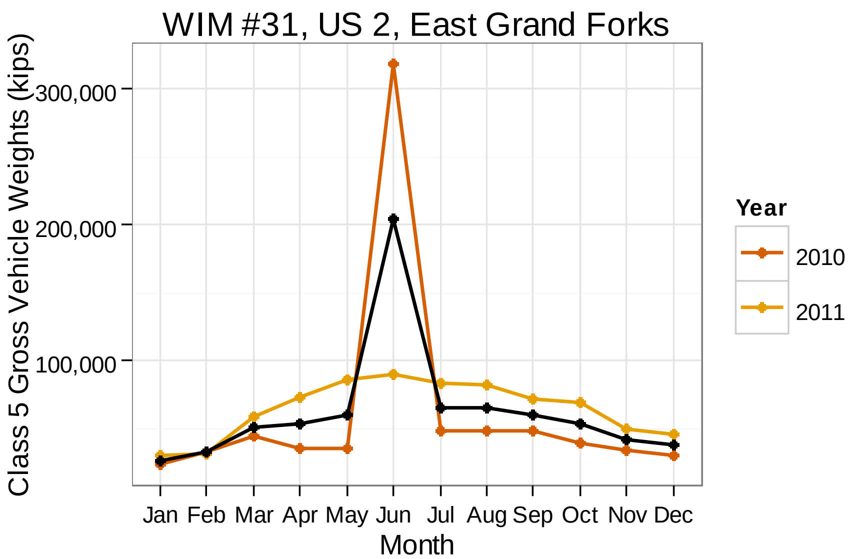


Figure 5.63a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

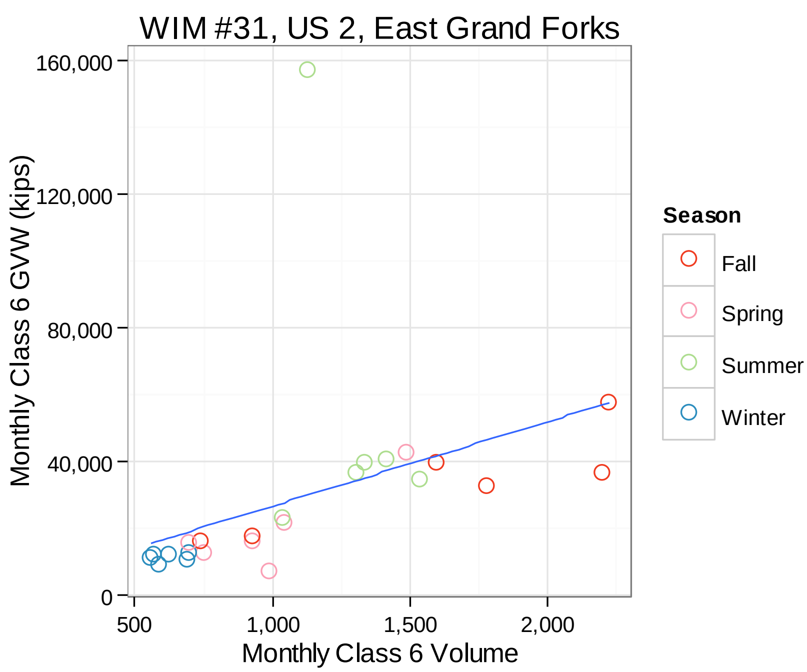


Figure 5.63b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

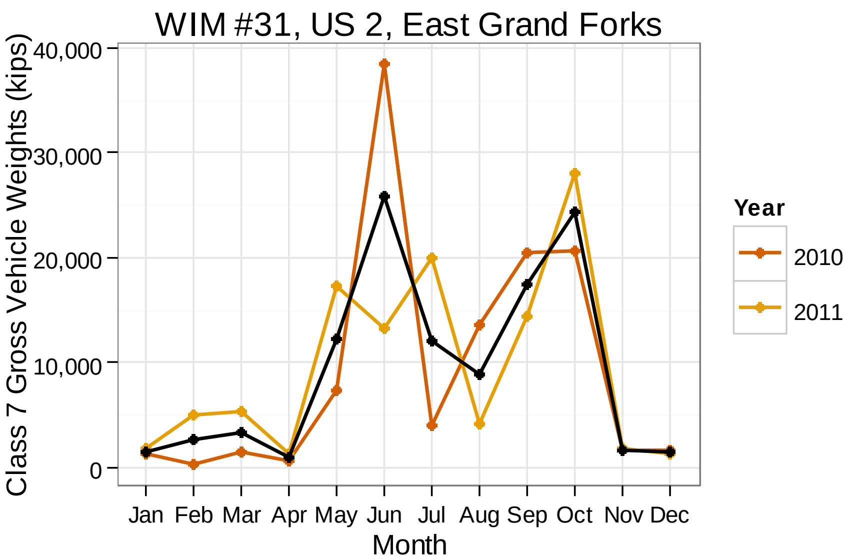


Figure 5.64a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

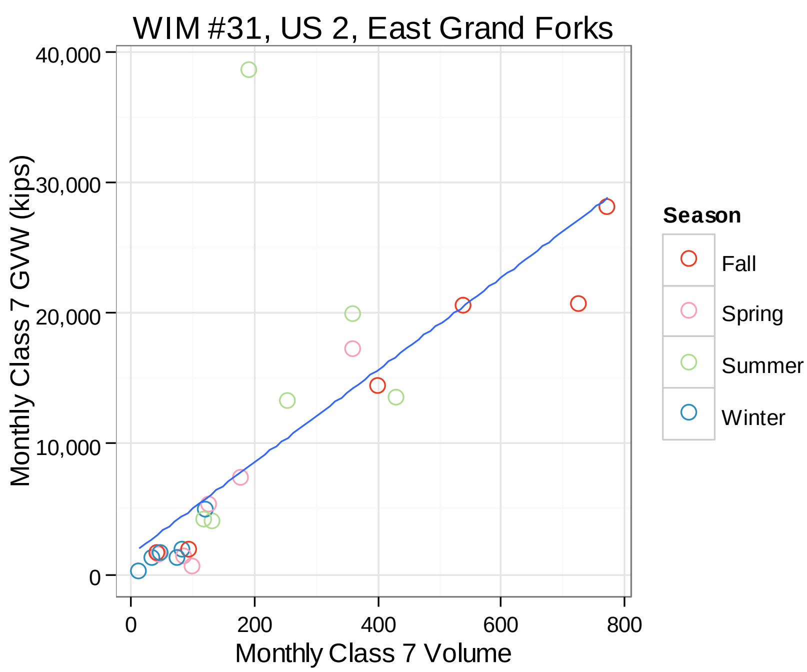


Figure 5.64b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

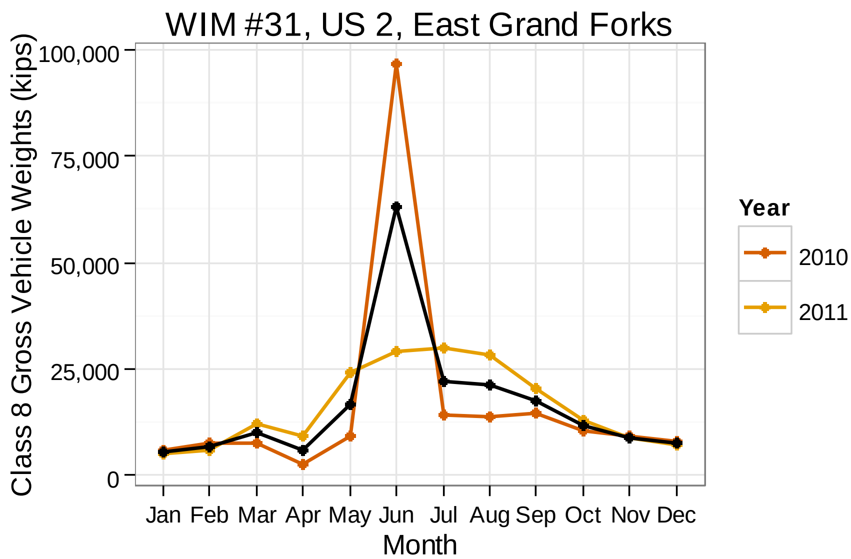


Figure 5.65a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

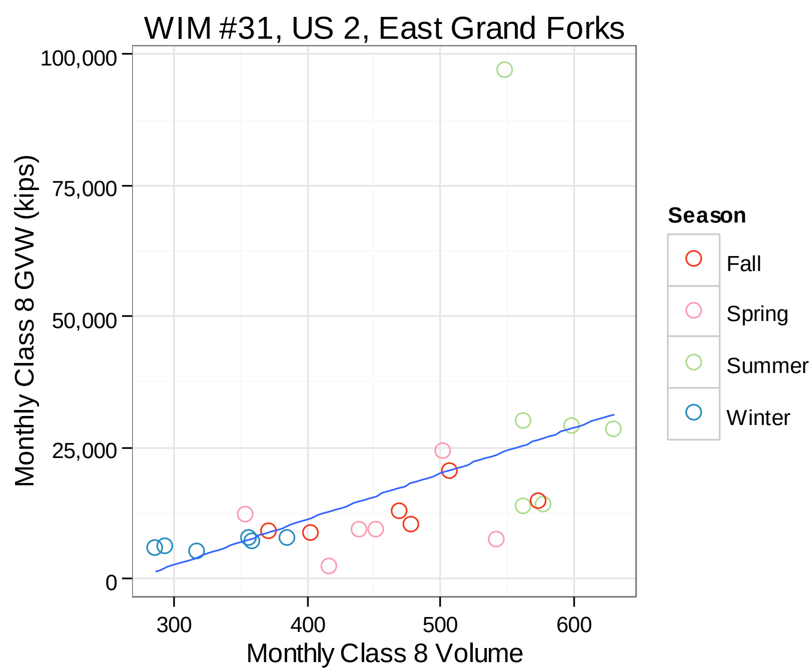


Figure 5.65b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

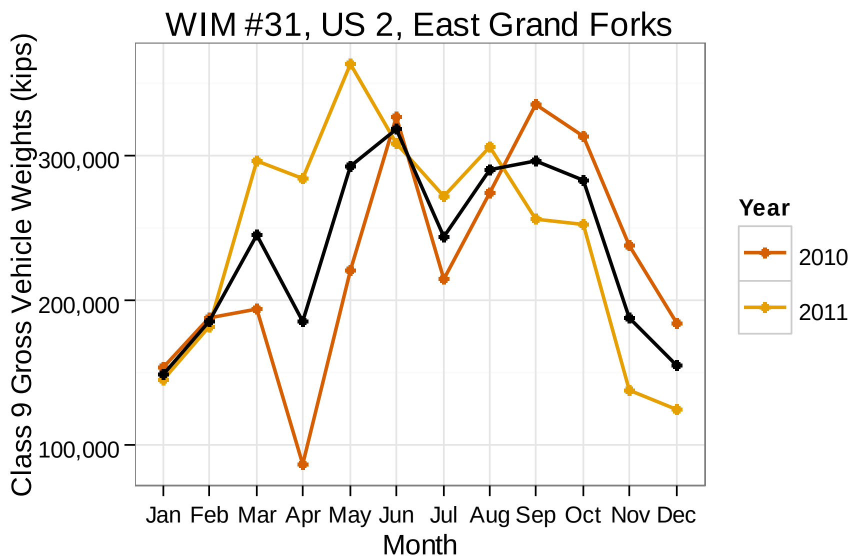


Figure 5.66a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

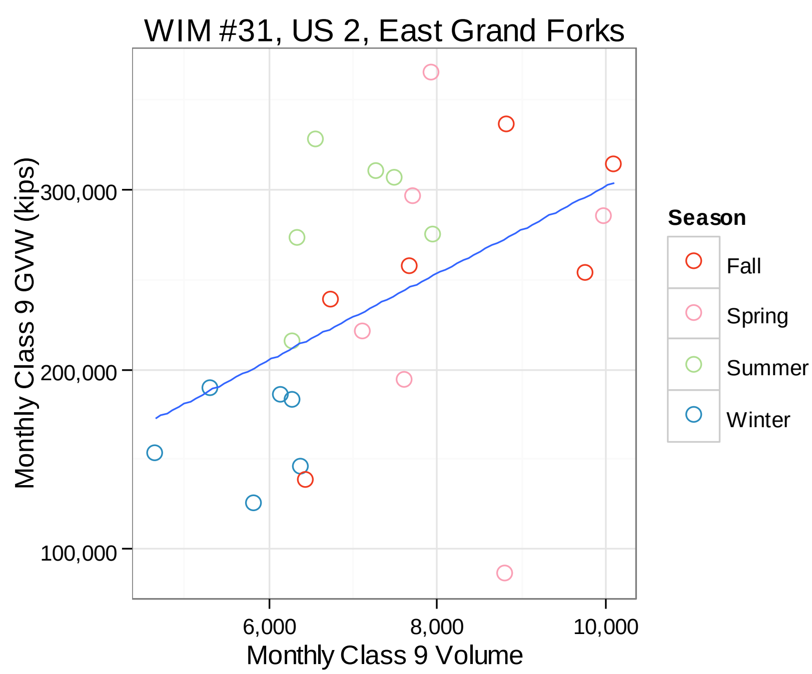


Figure 5.66b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

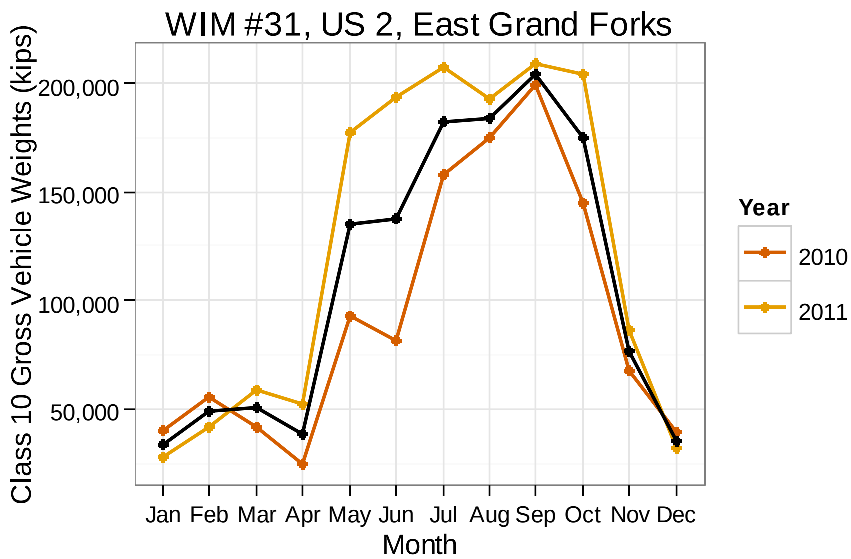


Figure 5.67a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

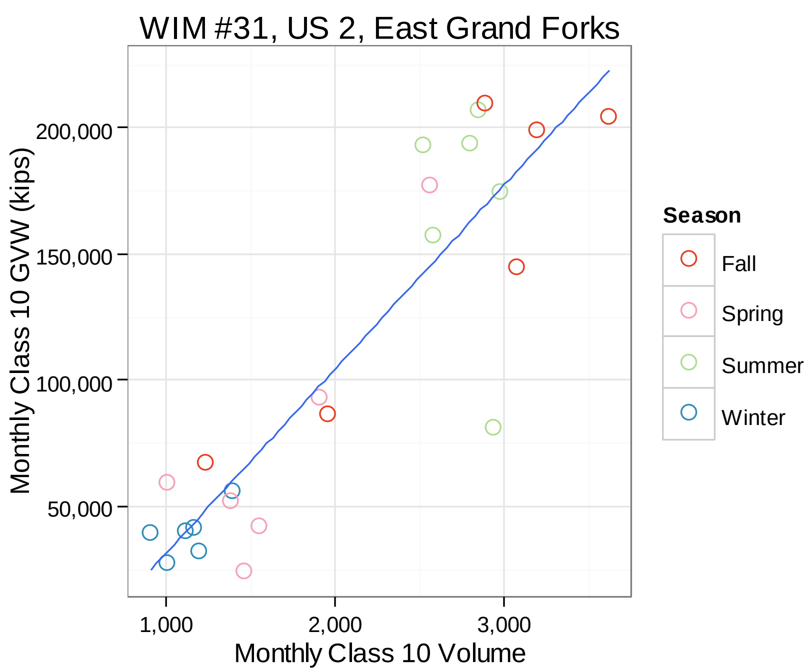


Figure 5.67b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

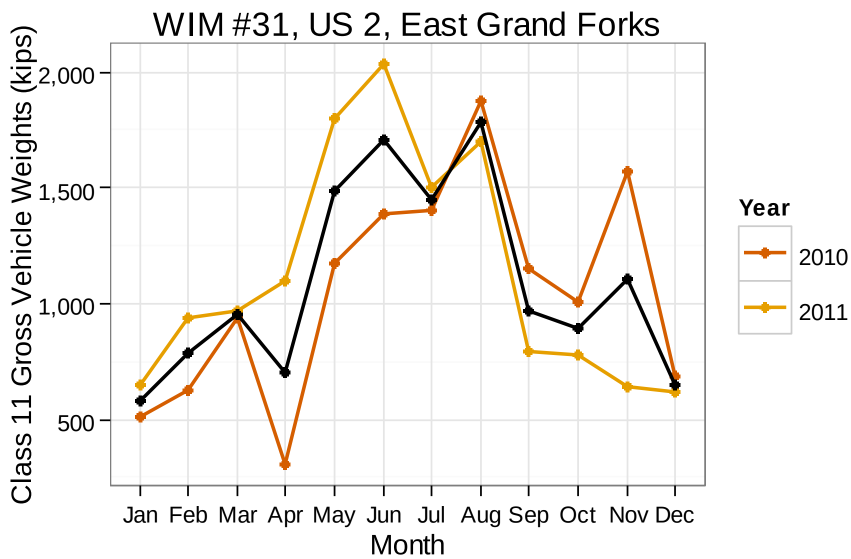


Figure 5.68a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

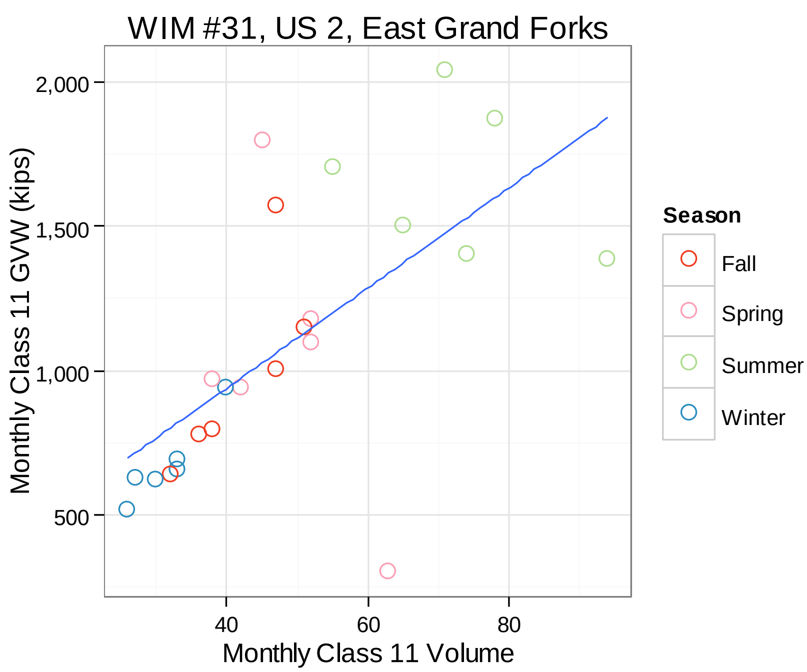


Figure 5.68b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

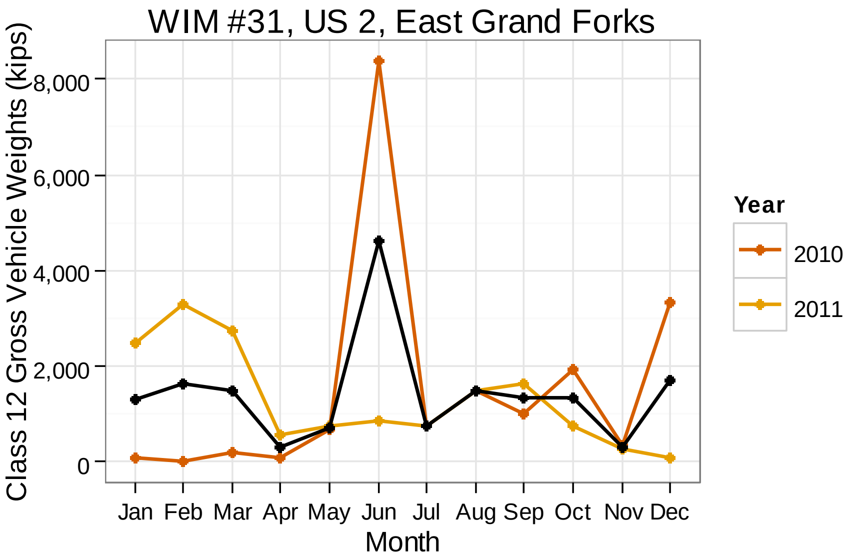


Figure 5.69a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

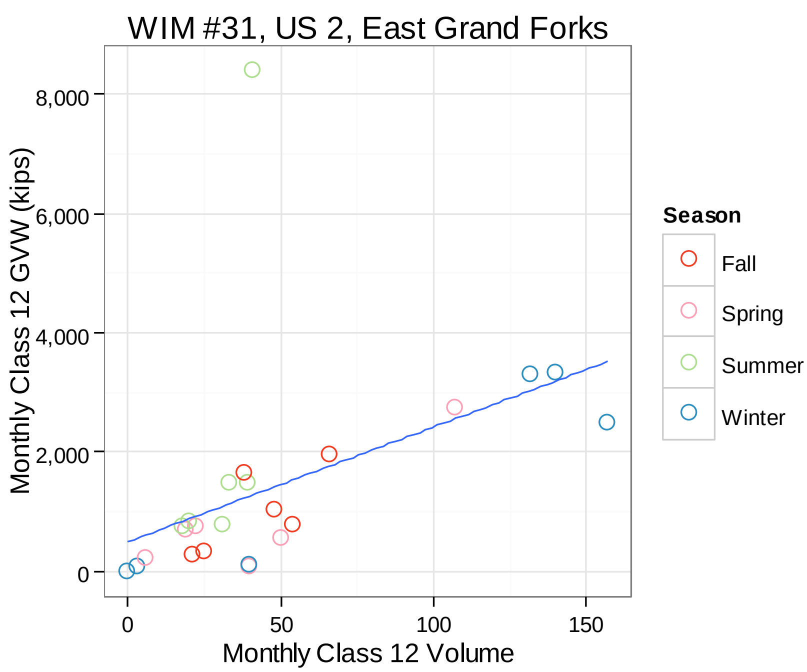


Figure 5.69b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

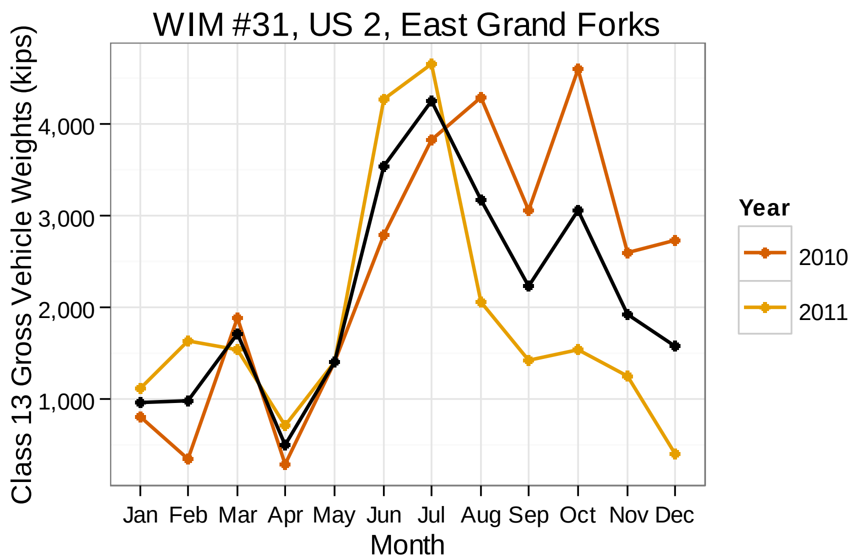


Figure 5.70a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

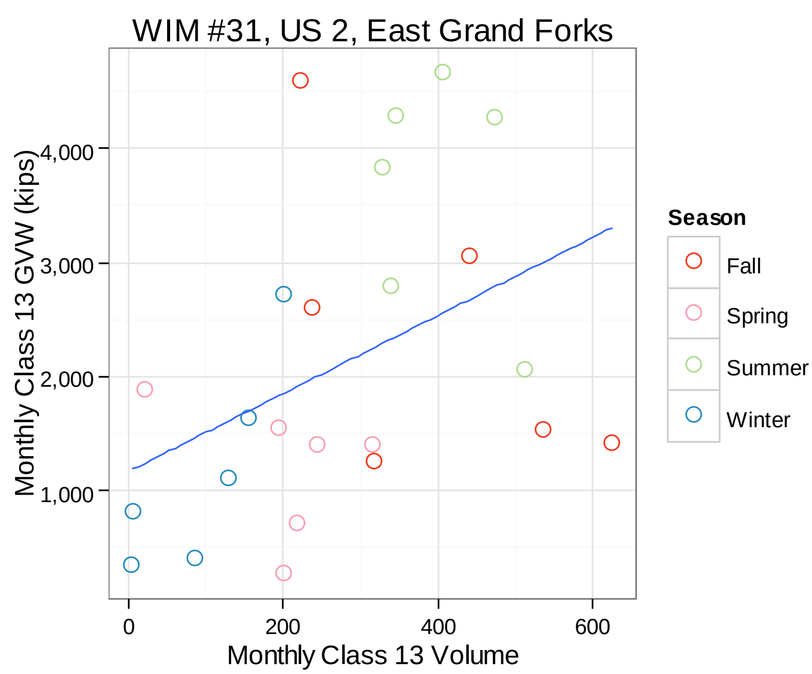


Figure 5.70b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

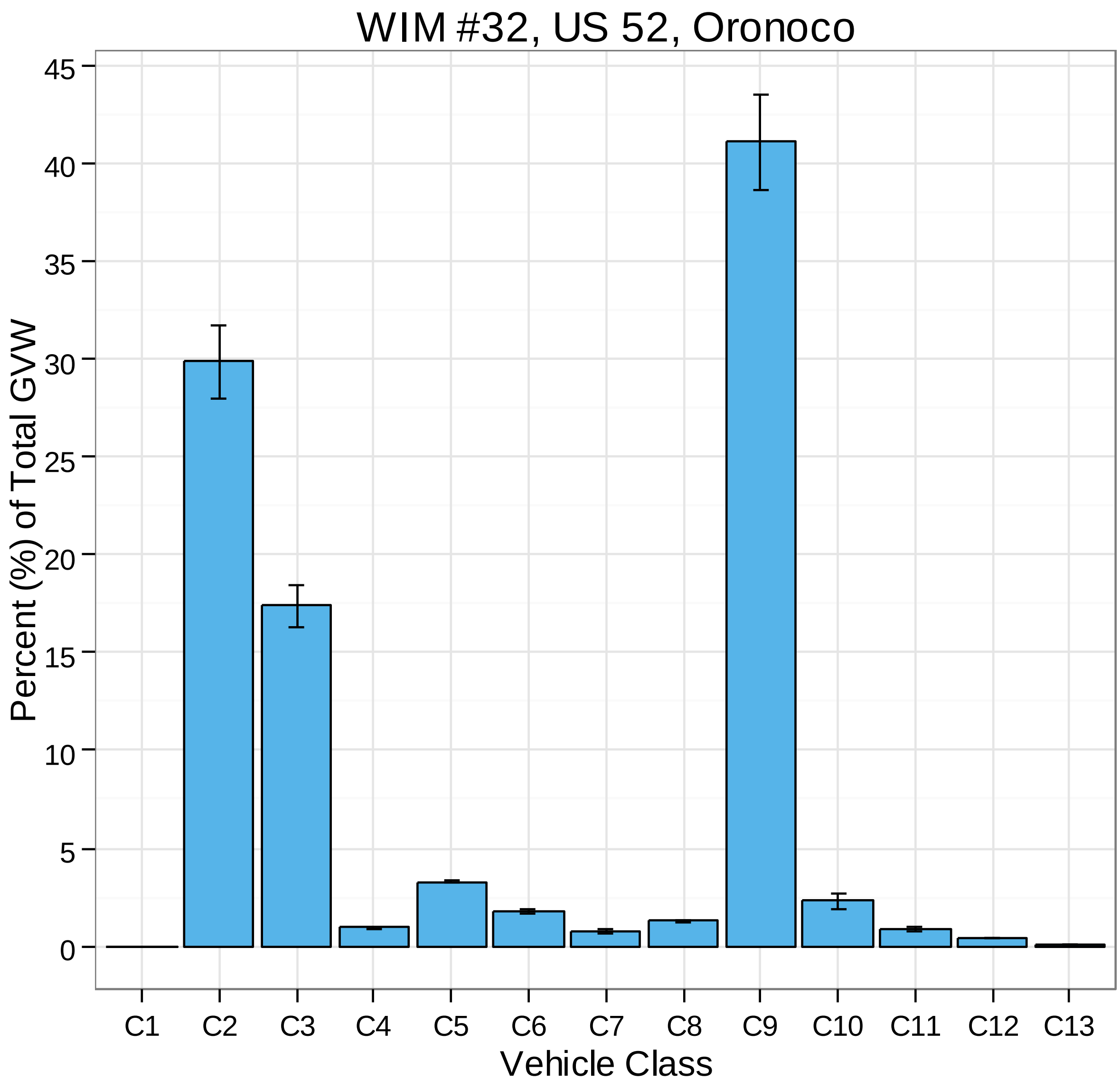


Figure 5.71. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

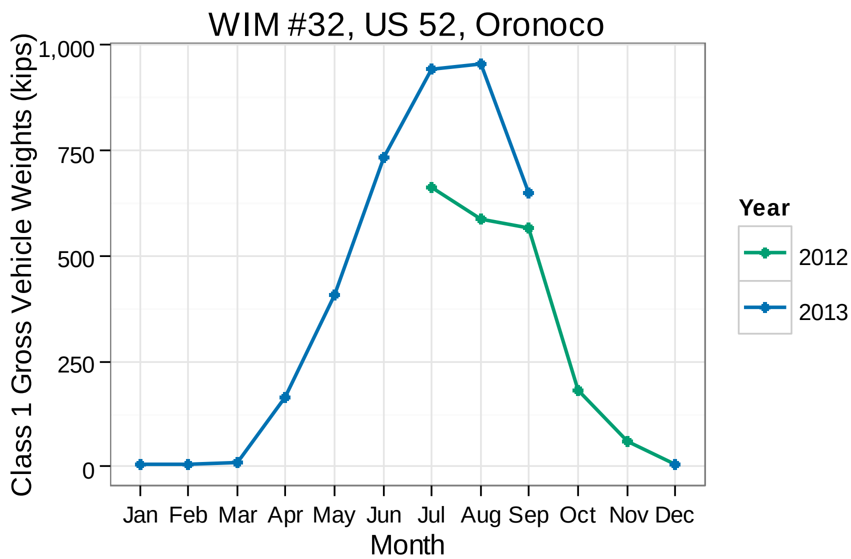


Figure 5.72a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

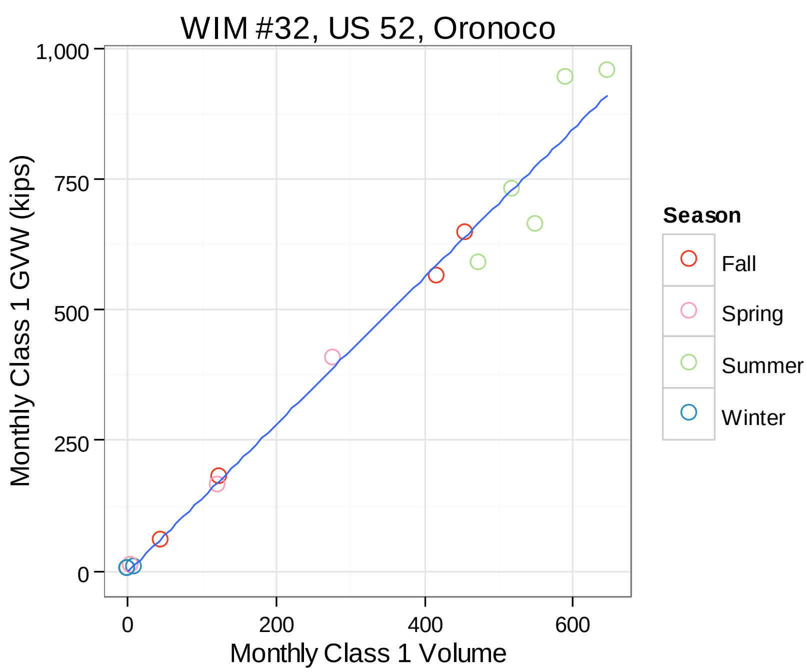


Figure 5.72b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

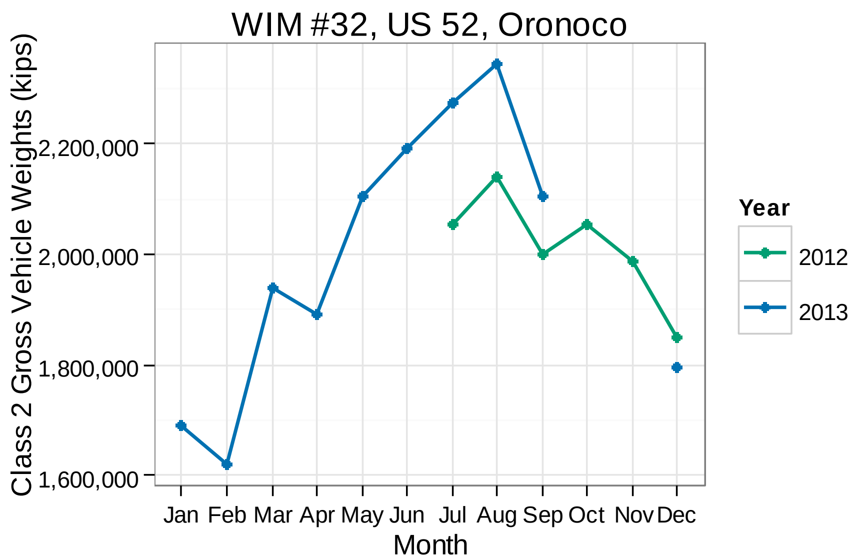


Figure 5.73a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

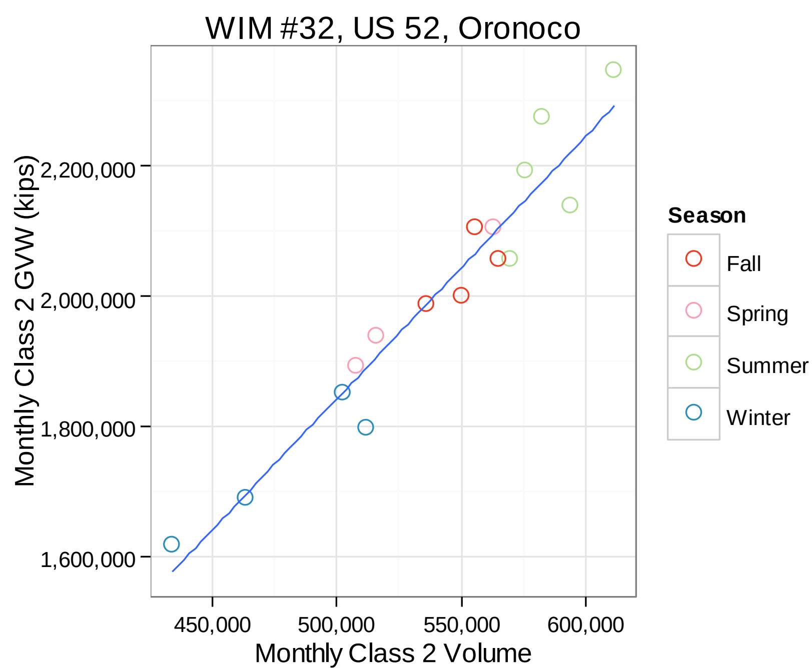


Figure 5.73b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

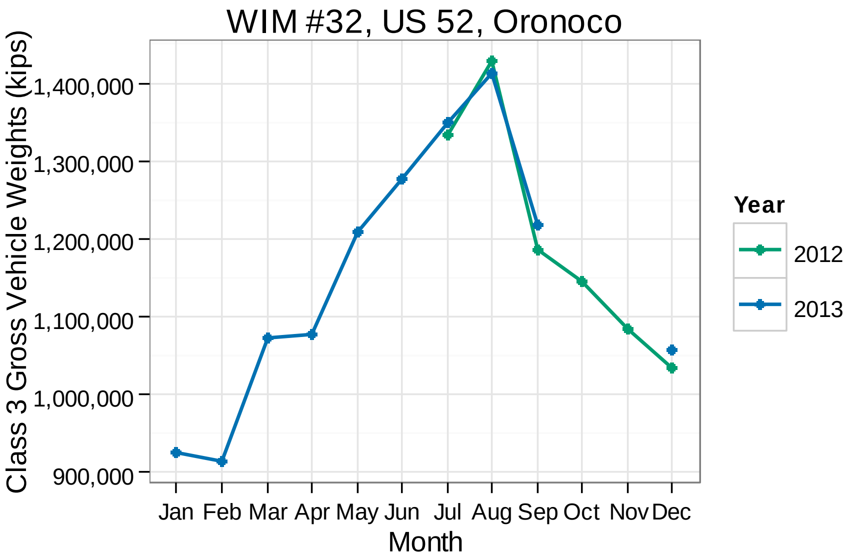


Figure 5.74a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

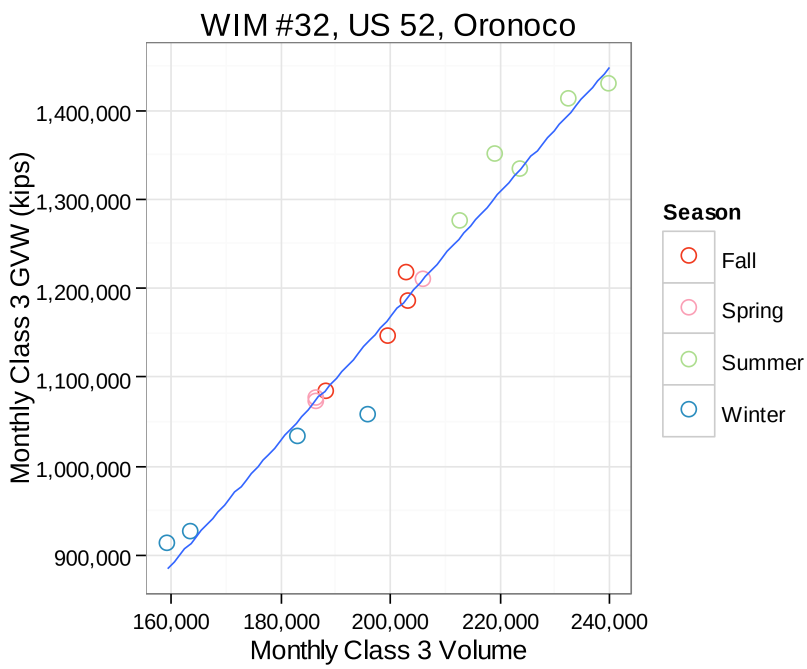


Figure 5.74b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

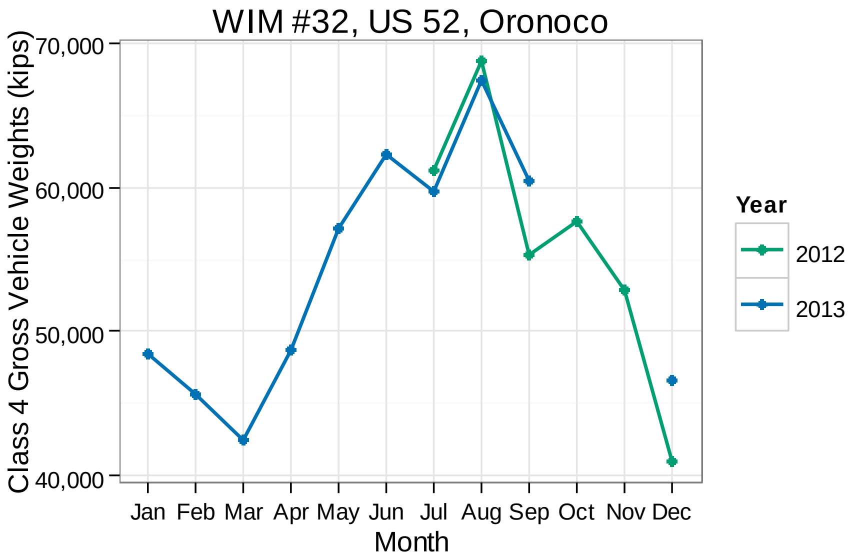


Figure 5.75a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

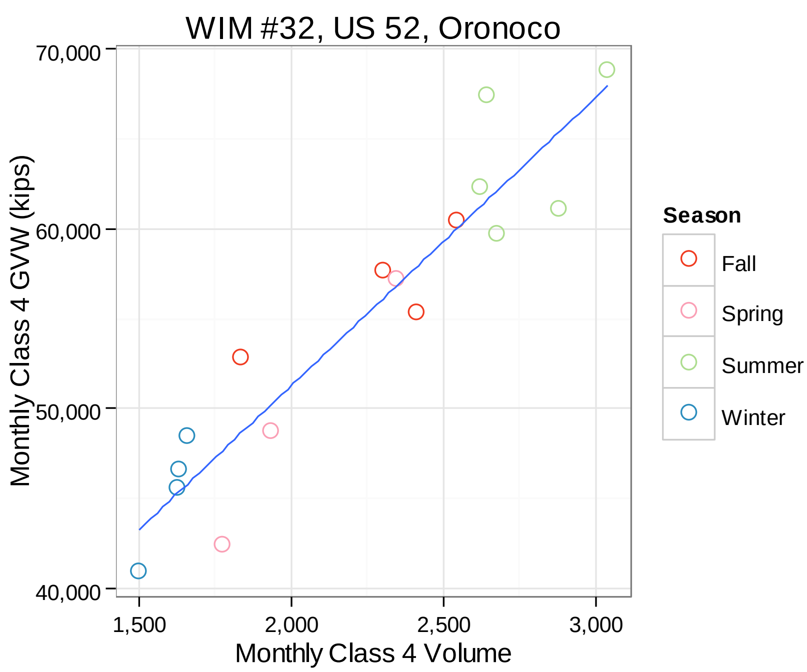


Figure 5.75b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

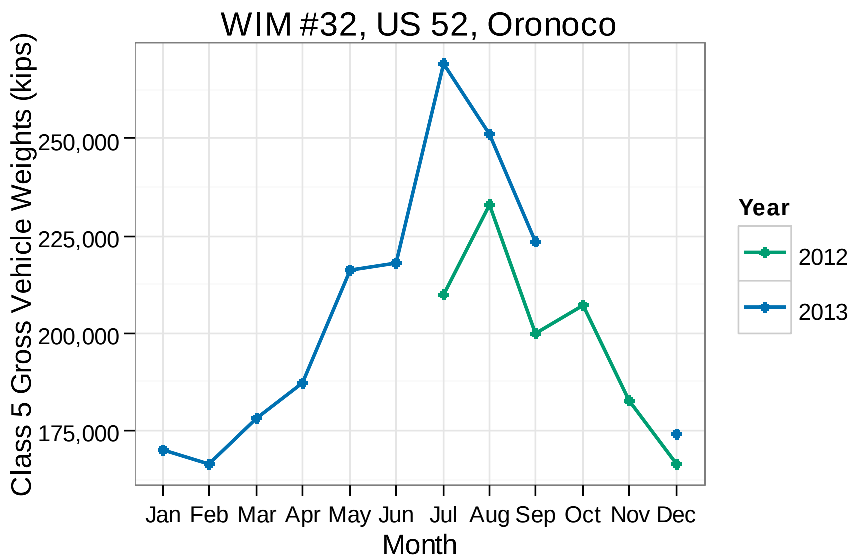


Figure 5.76a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

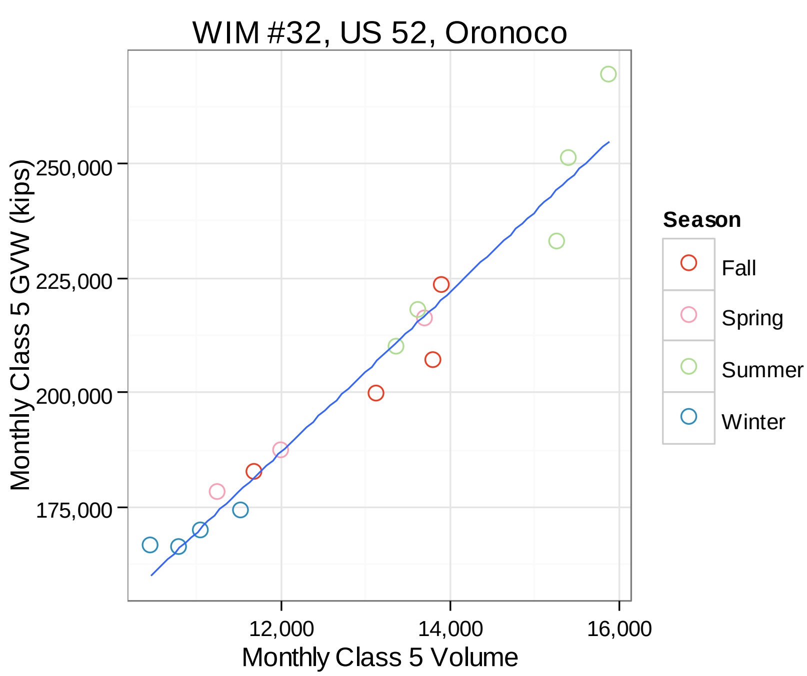


Figure 5.76b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

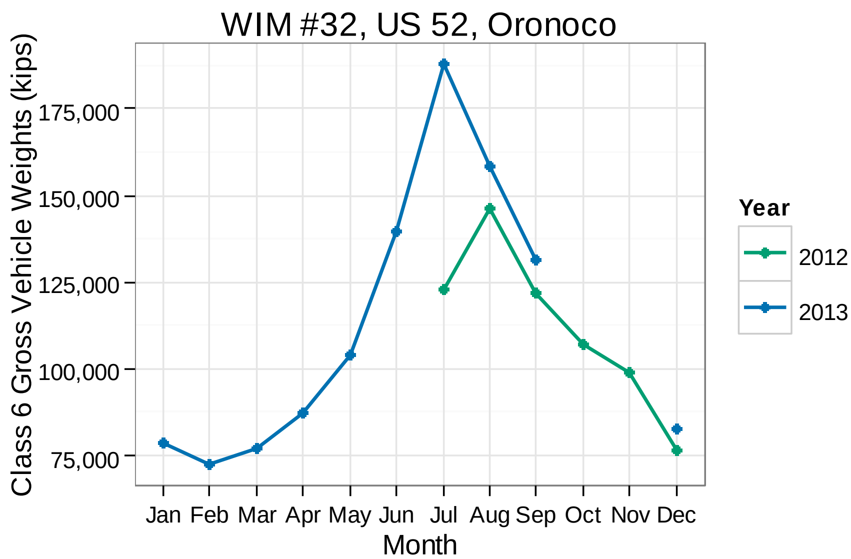


Figure 5.77a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

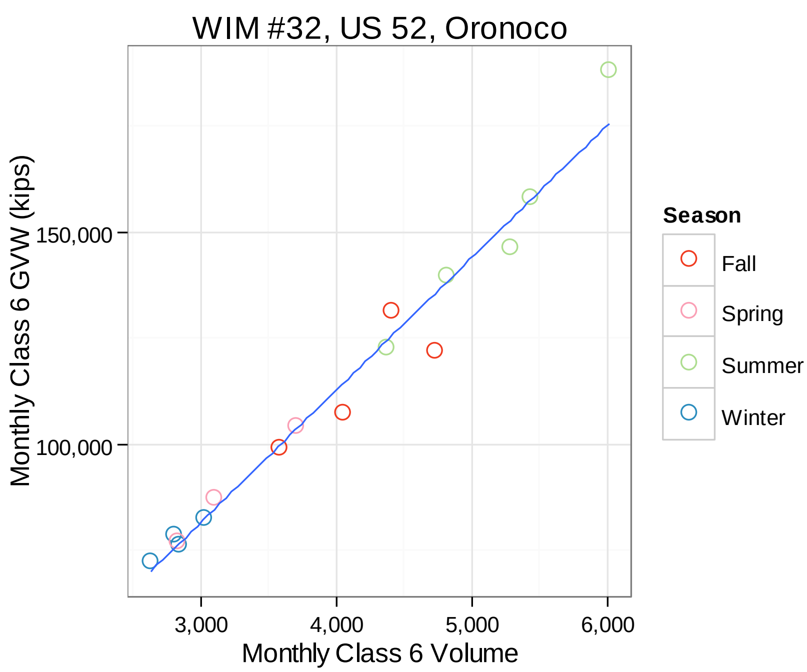


Figure 5.77b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

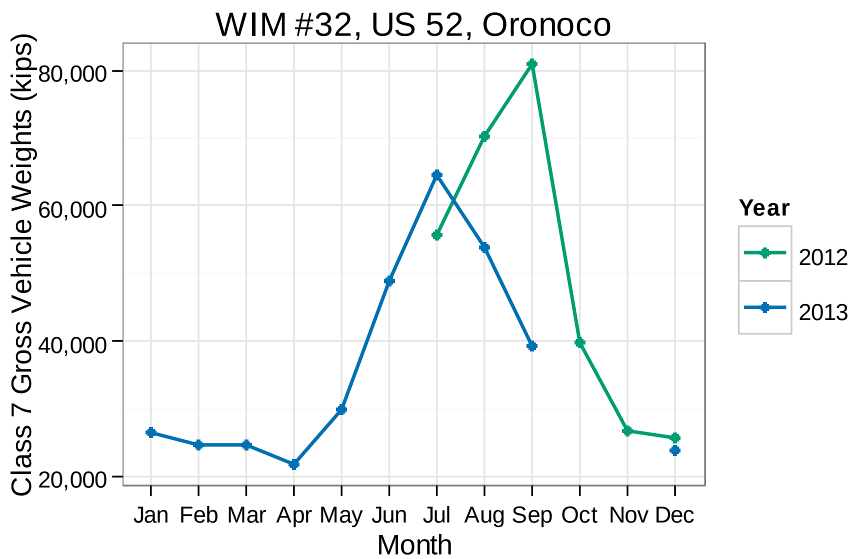


Figure 5.78a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

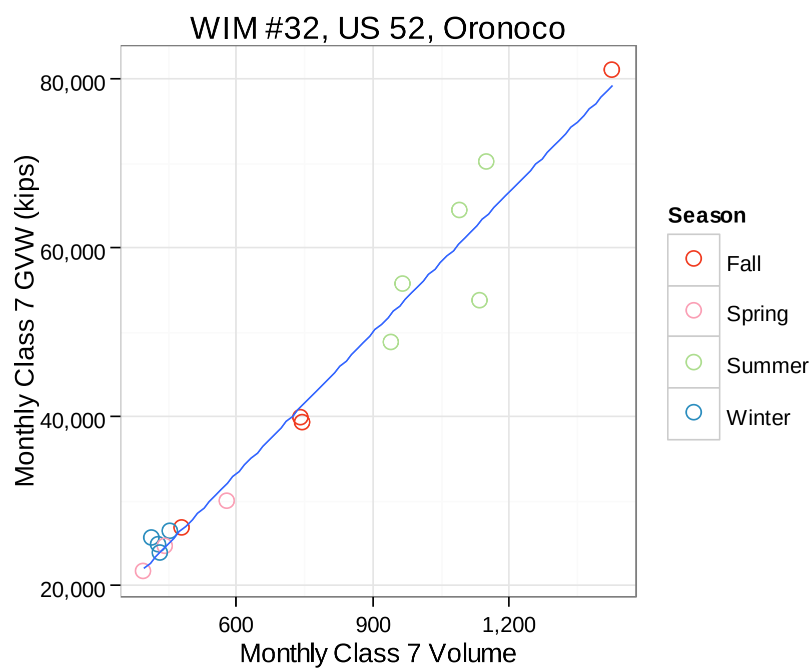


Figure 5.78b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

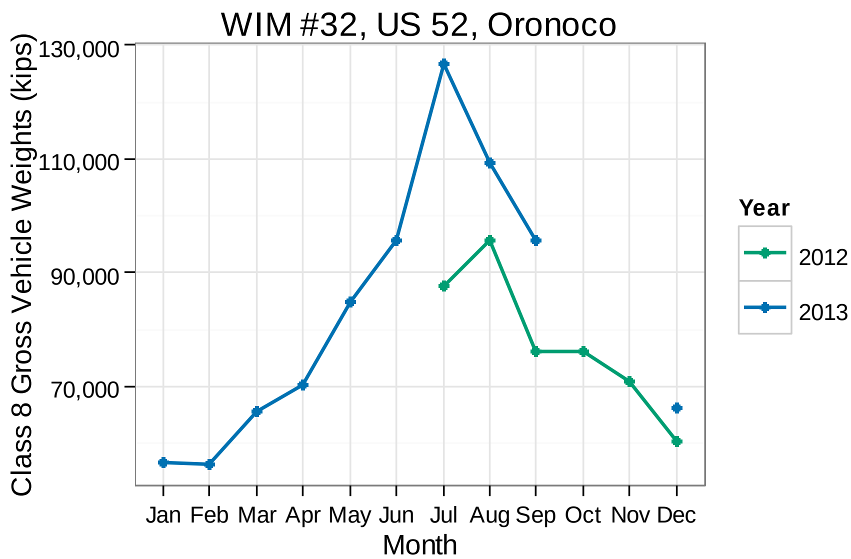


Figure 5.79a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

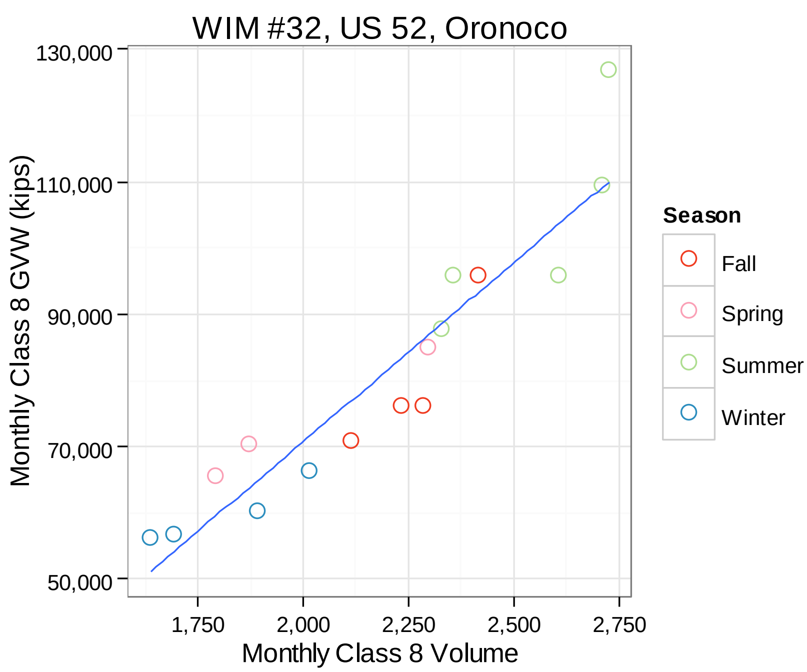


Figure 5.79b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

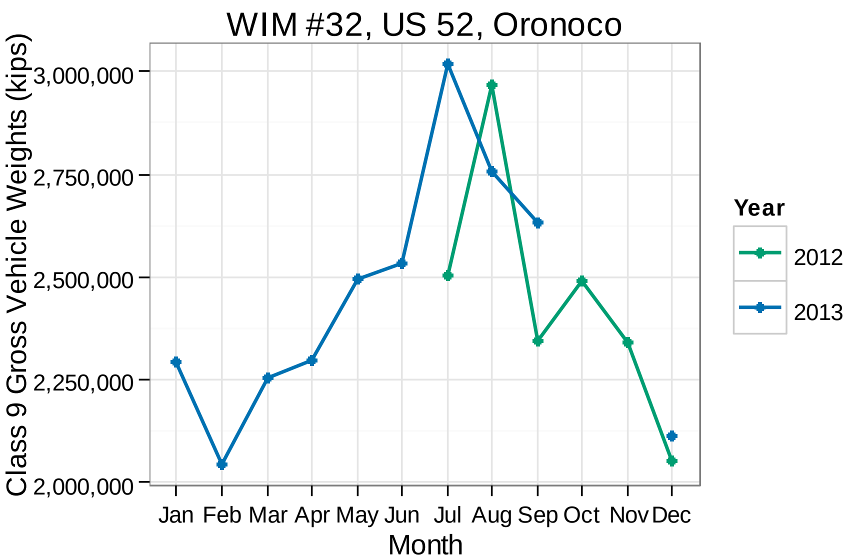


Figure 5.80a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

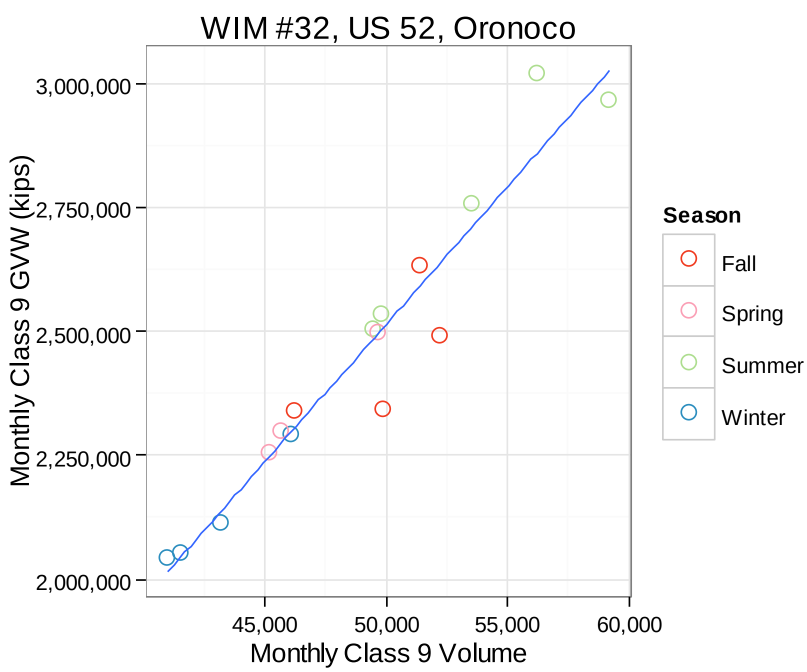


Figure 5.80b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

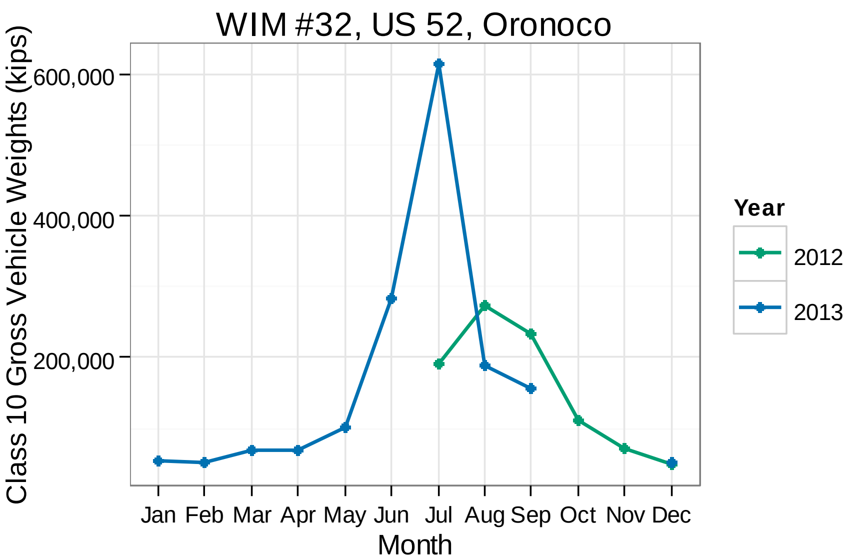


Figure 5.81a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

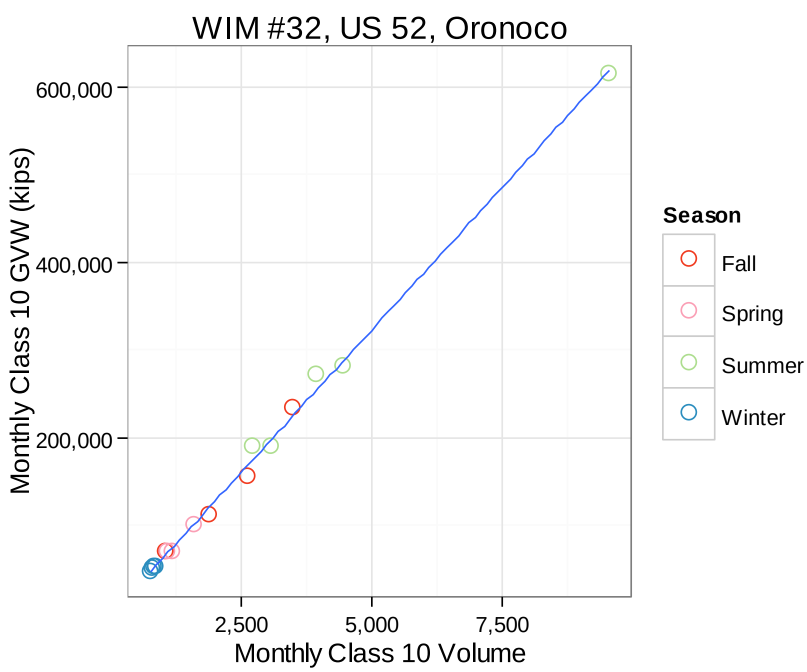


Figure 5.81b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

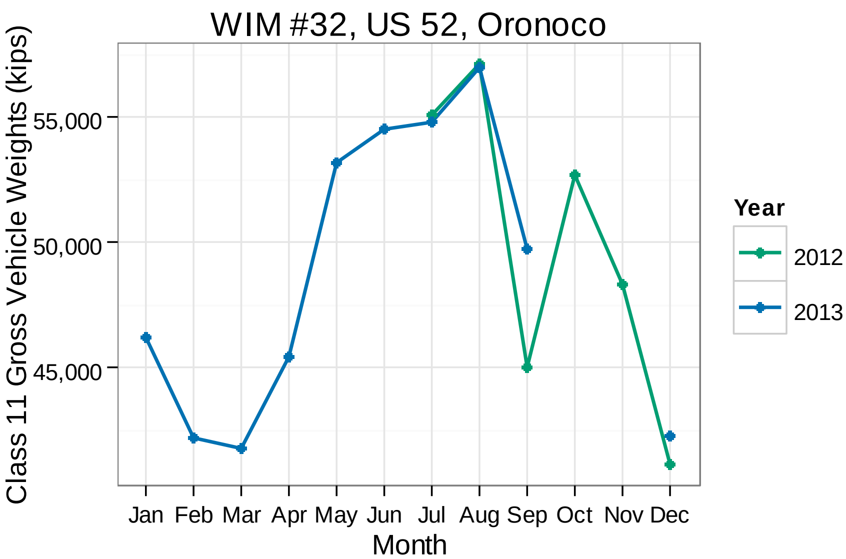


Figure 5.82a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

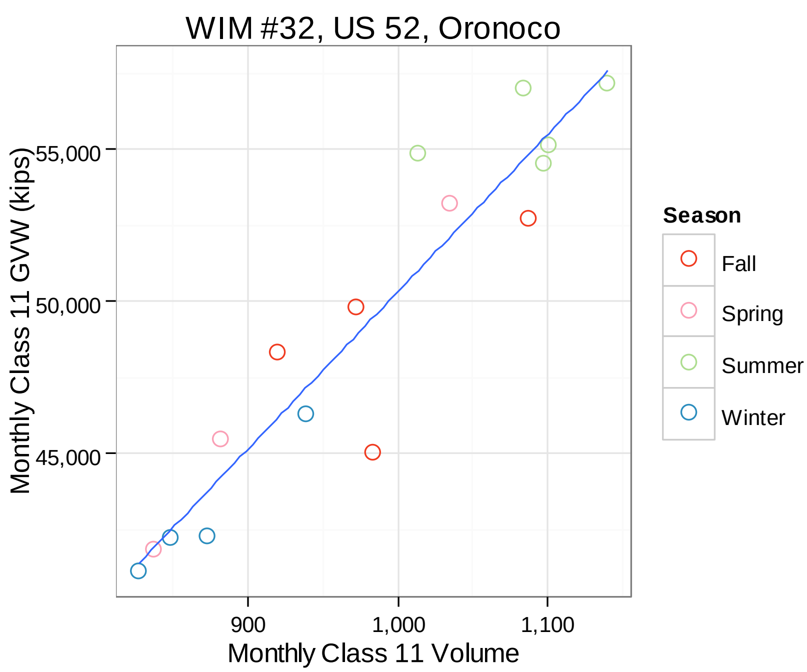


Figure 5.82b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

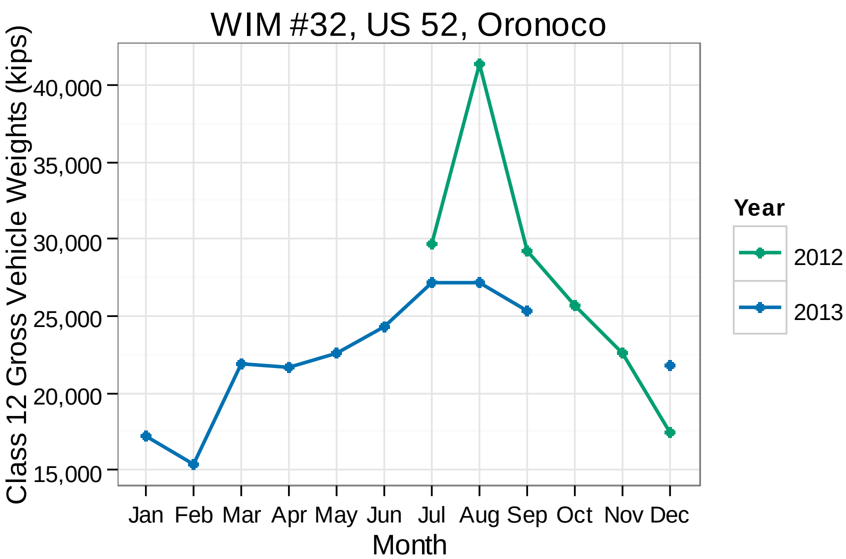


Figure 5.83a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

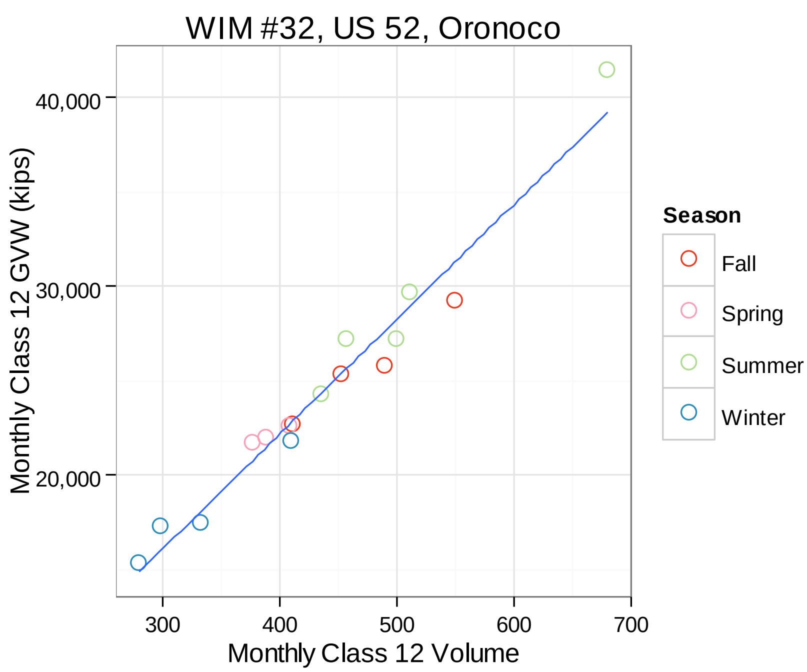


Figure 5.83b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

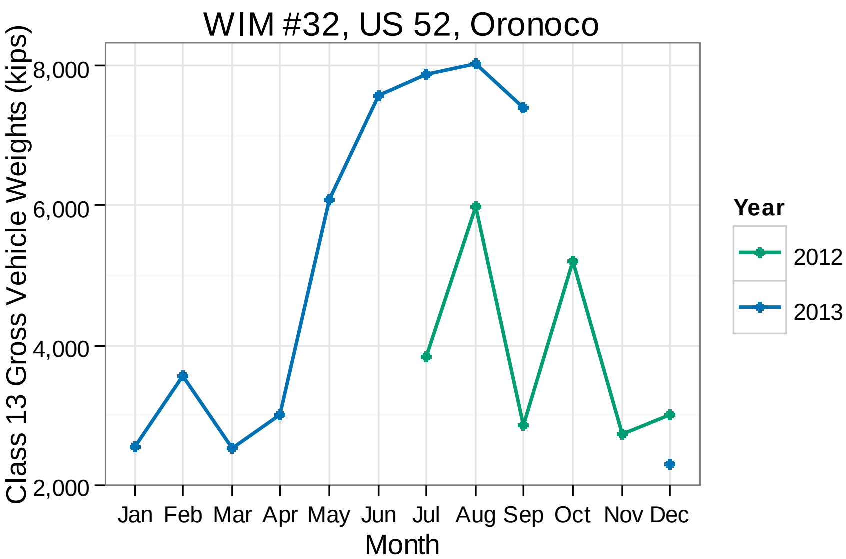


Figure 5.84a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

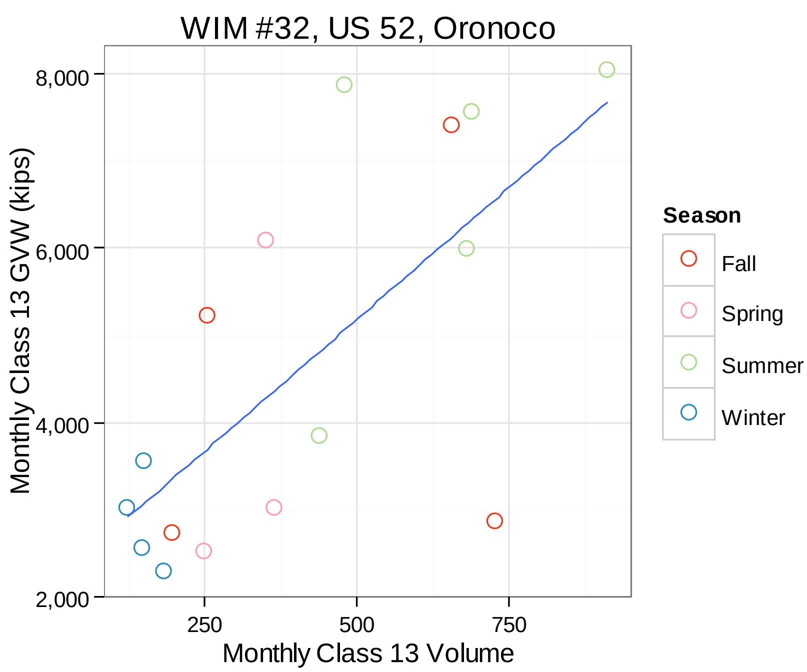


Figure 5.84b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

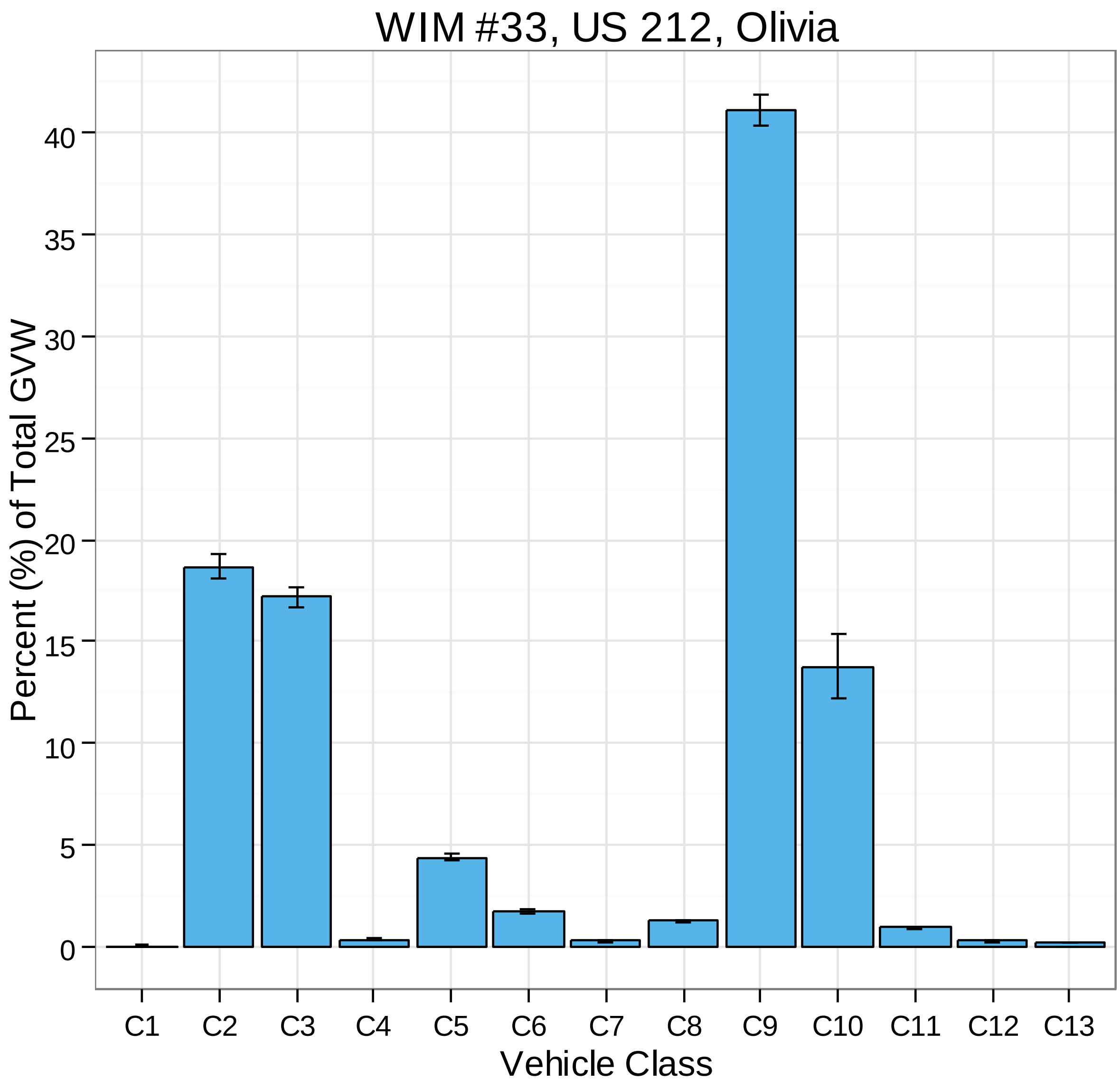


Figure 5.85. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

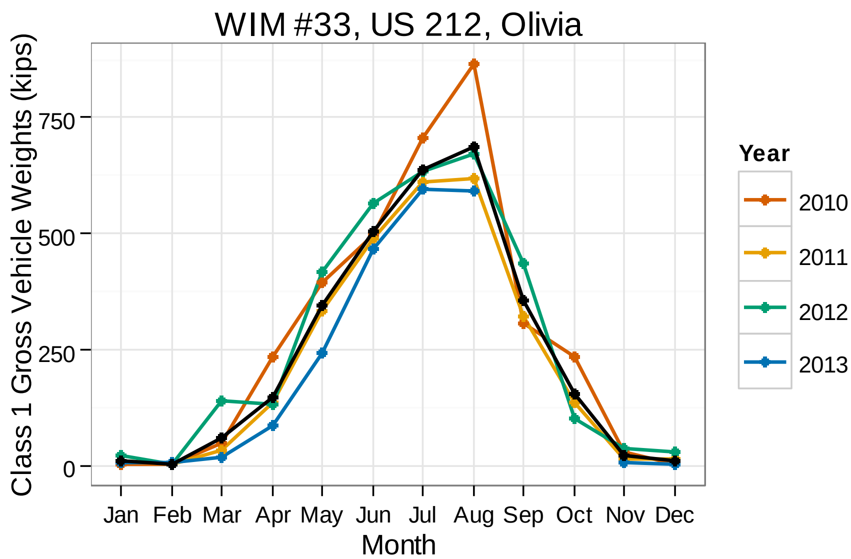


Figure 5.86a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

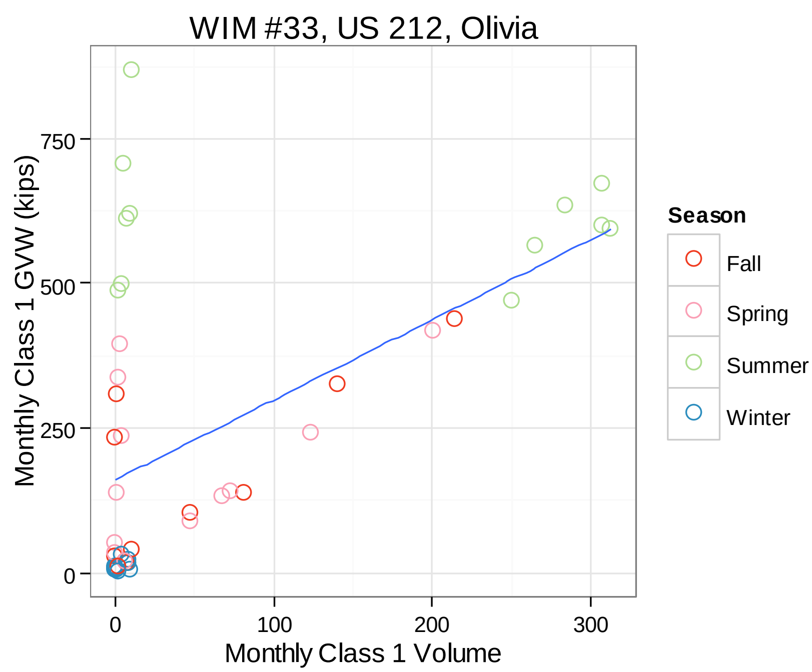


Figure 5.86b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

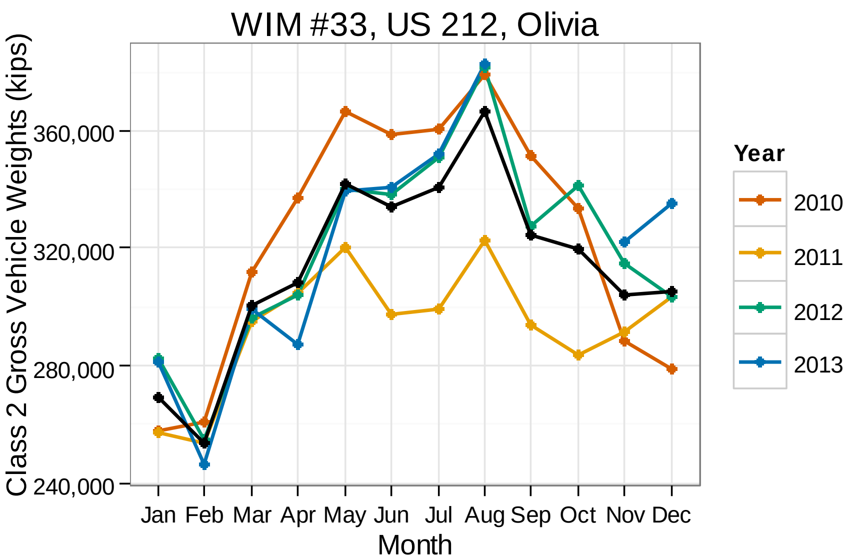


Figure 5.87a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

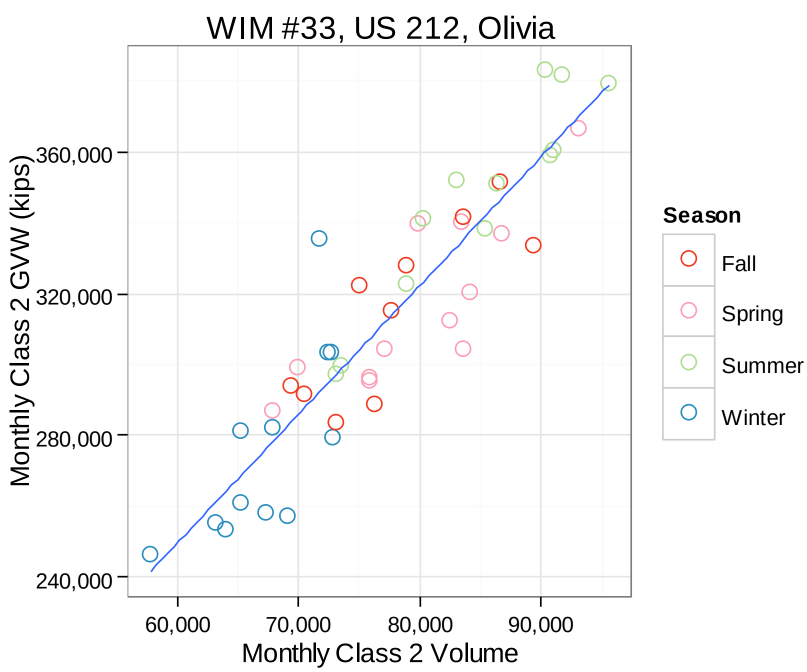


Figure 5.87b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

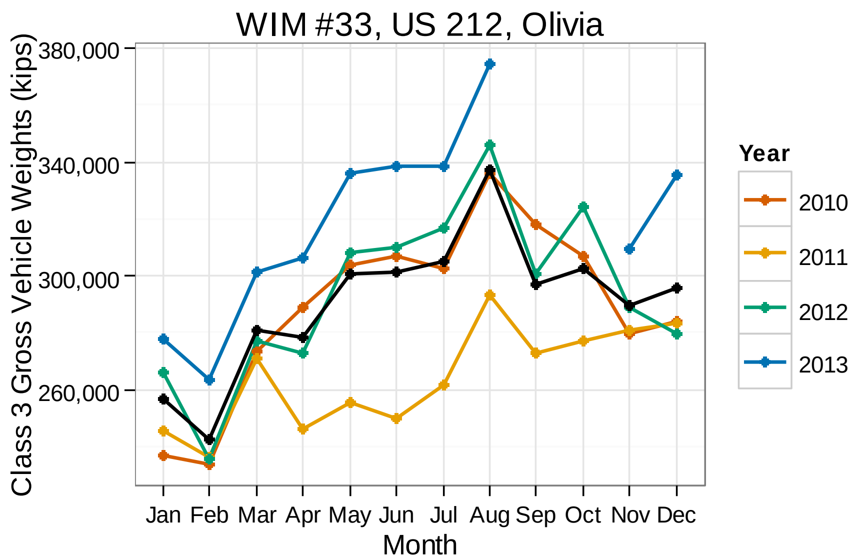


Figure 5.88a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

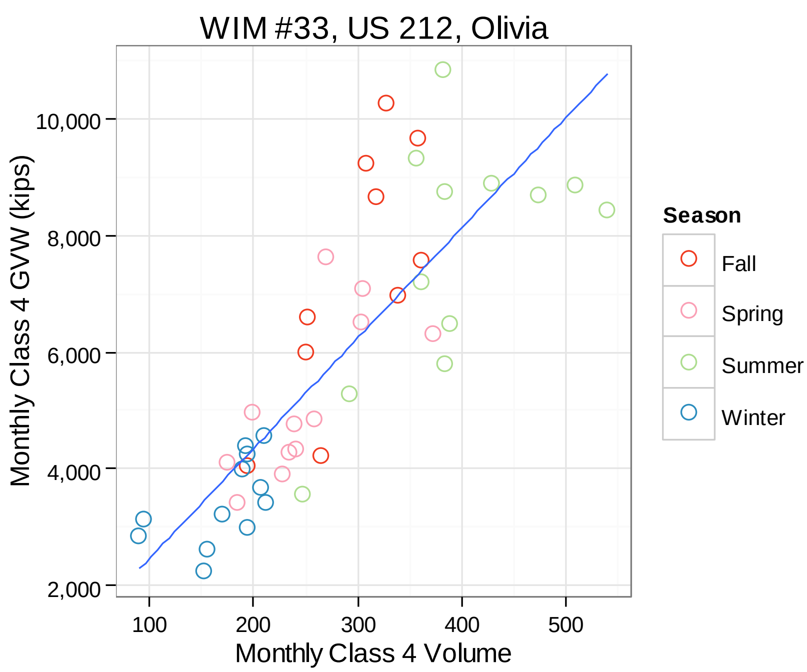


Figure 5.88b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

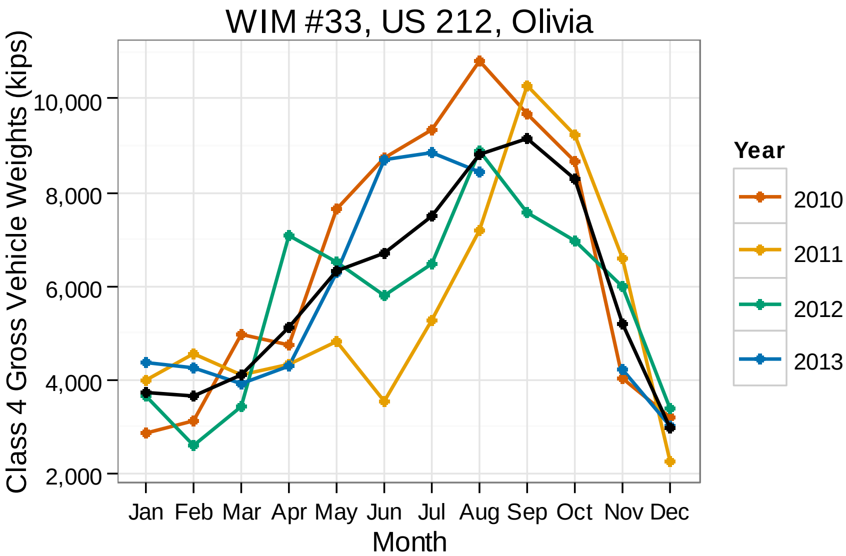


Figure 5.89a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

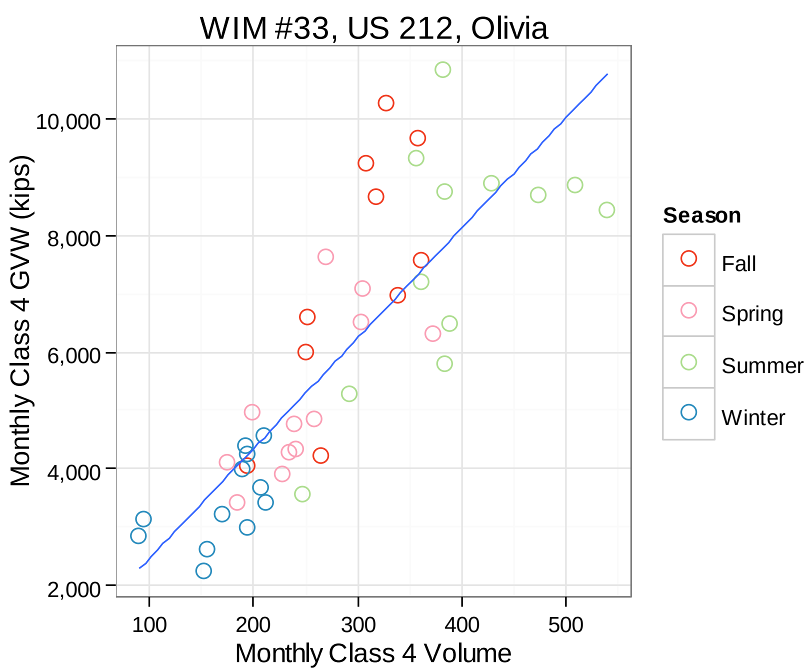


Figure 5.89b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

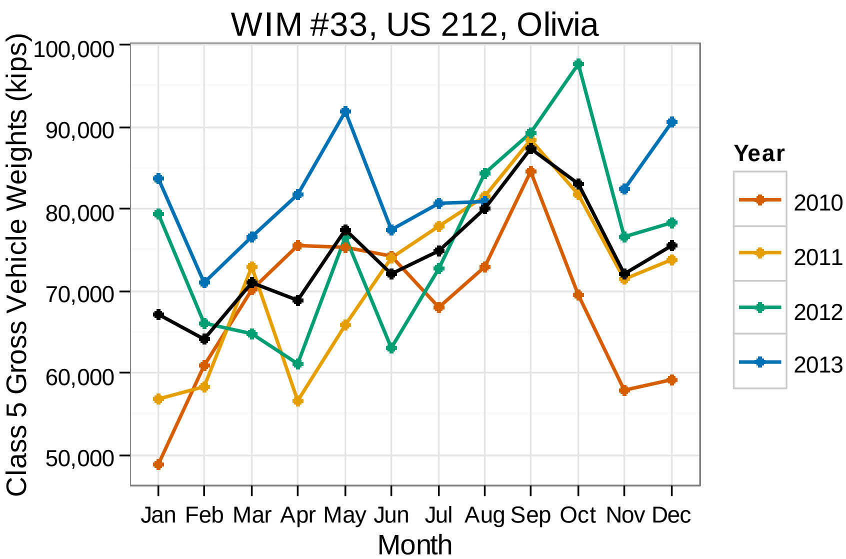


Figure 5.90a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

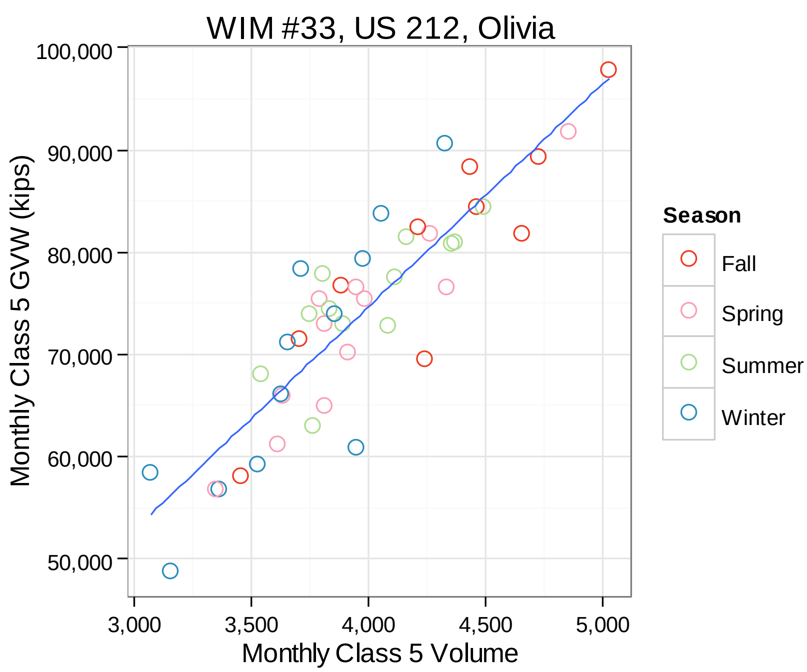


Figure 5.90b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

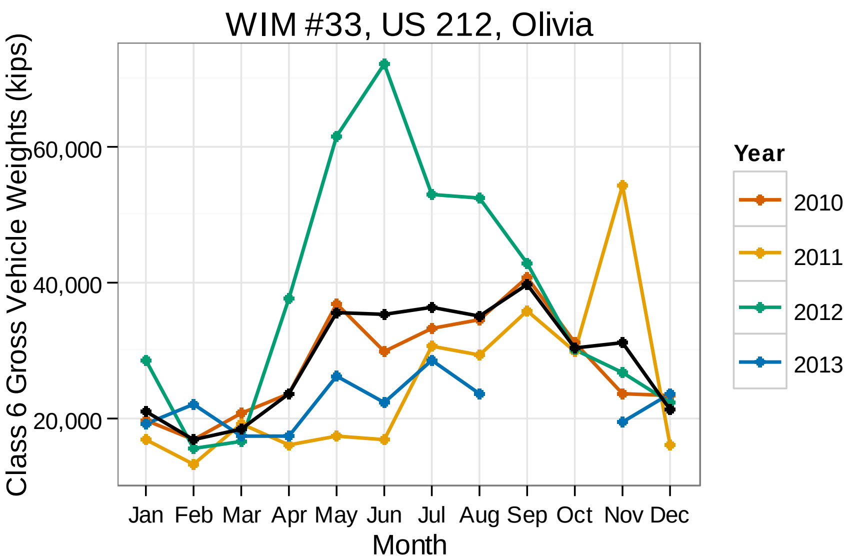


Figure 5.91a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

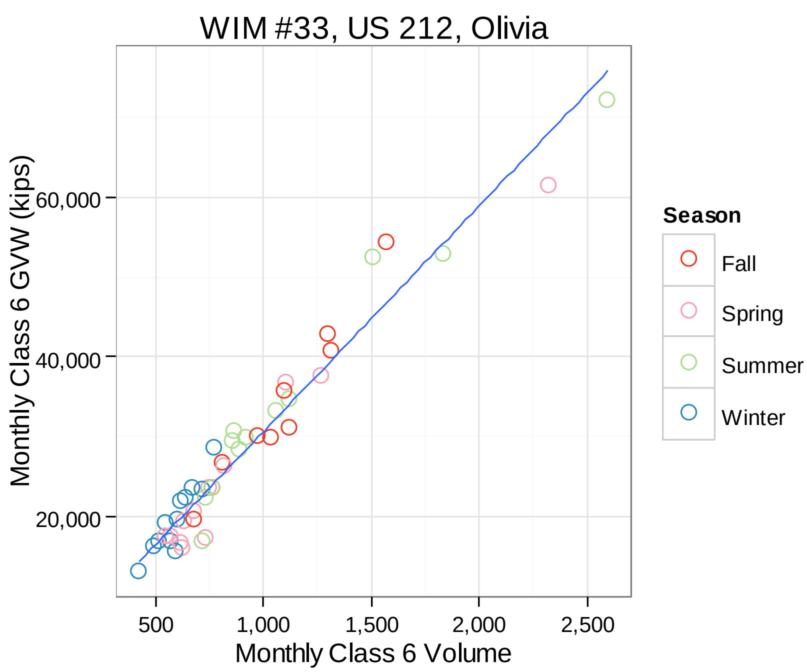


Figure 5.91b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

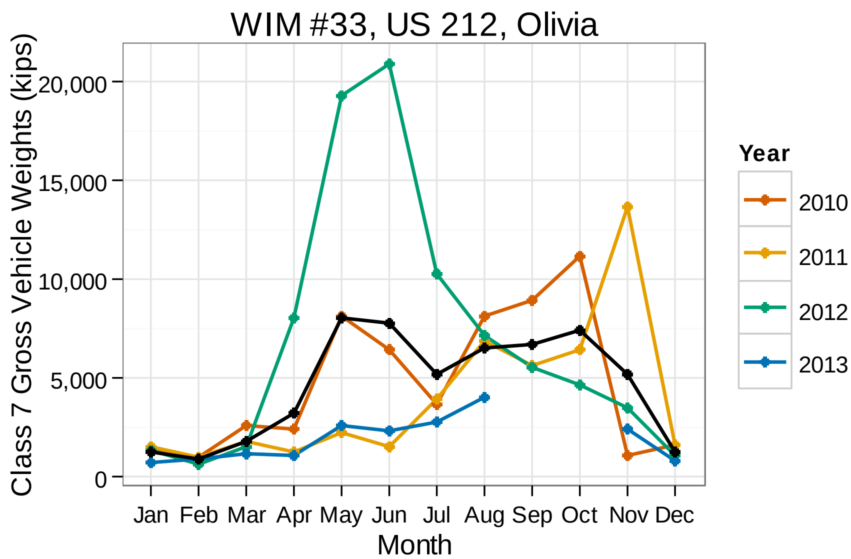


Figure 5.92a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

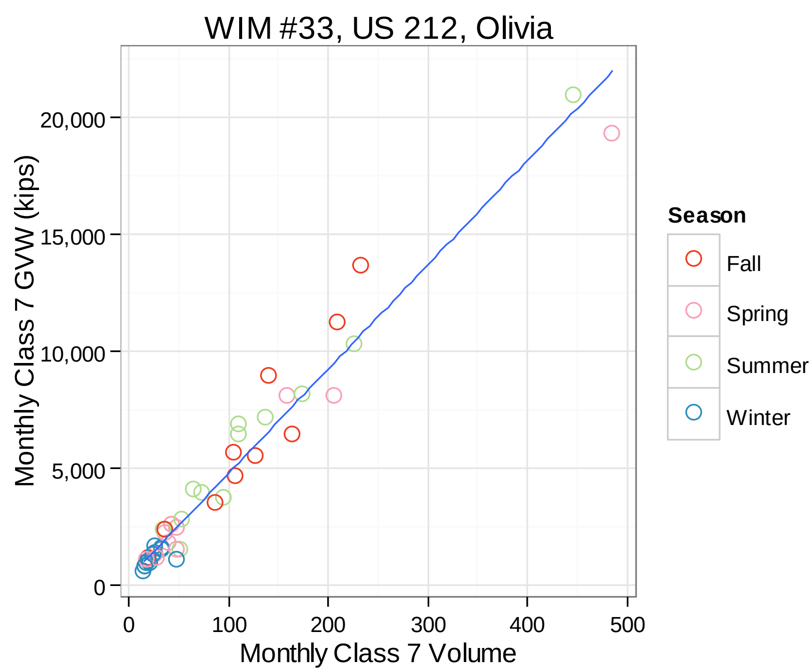


Figure 5.92b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

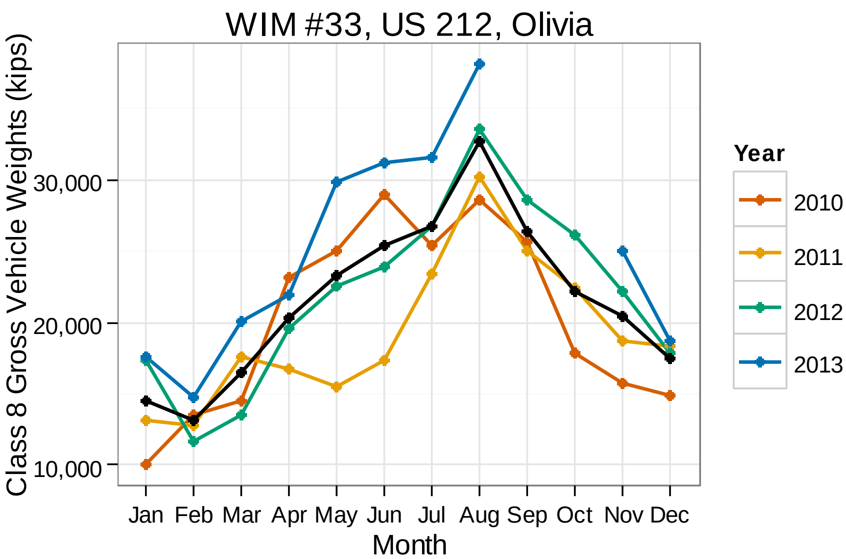


Figure 5.93a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

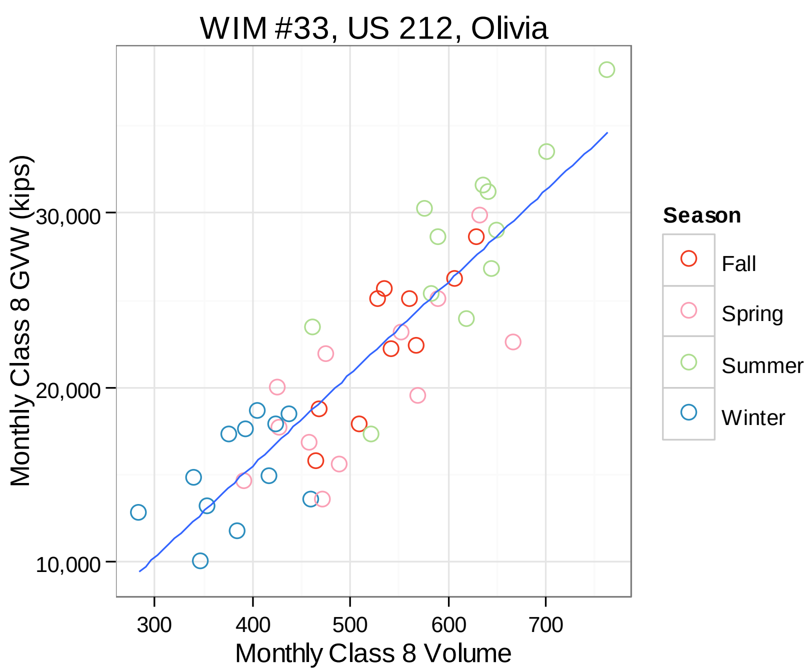


Figure 5.93b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

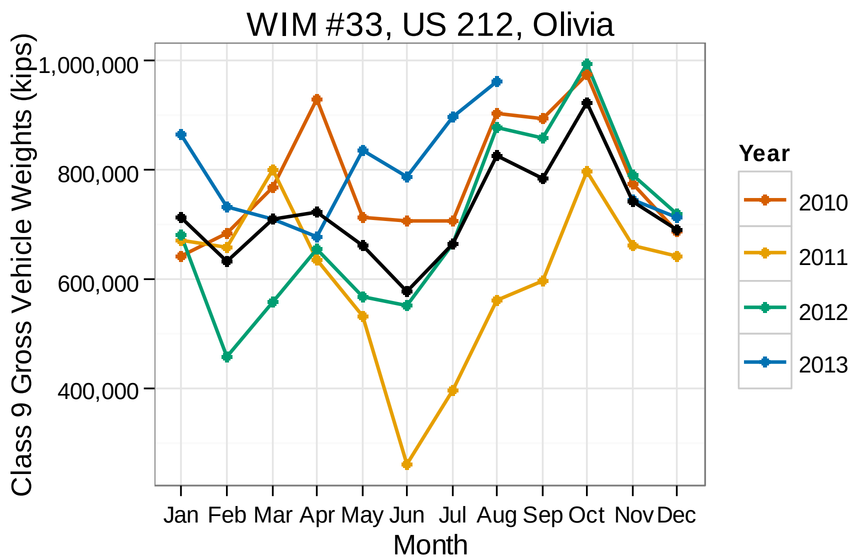


Figure 5.94a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

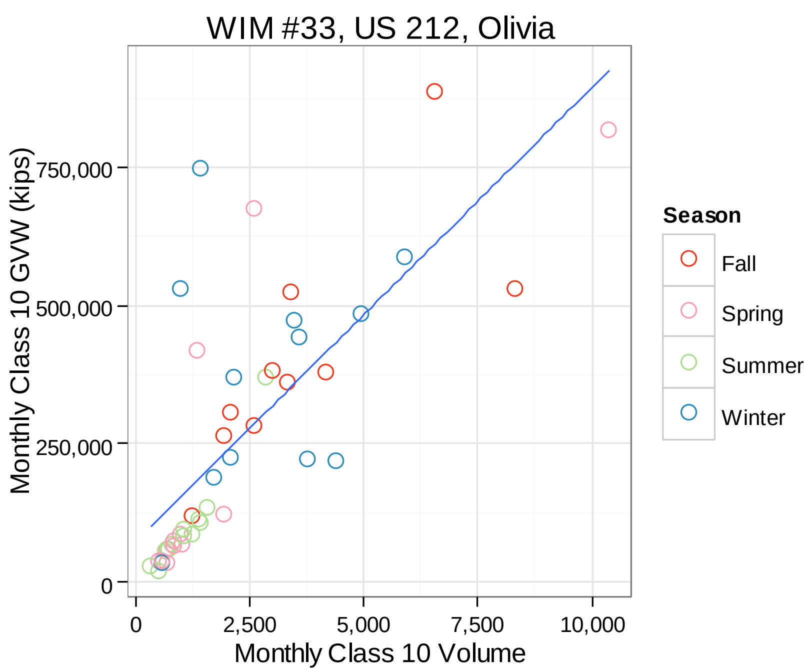


Figure 5.94b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

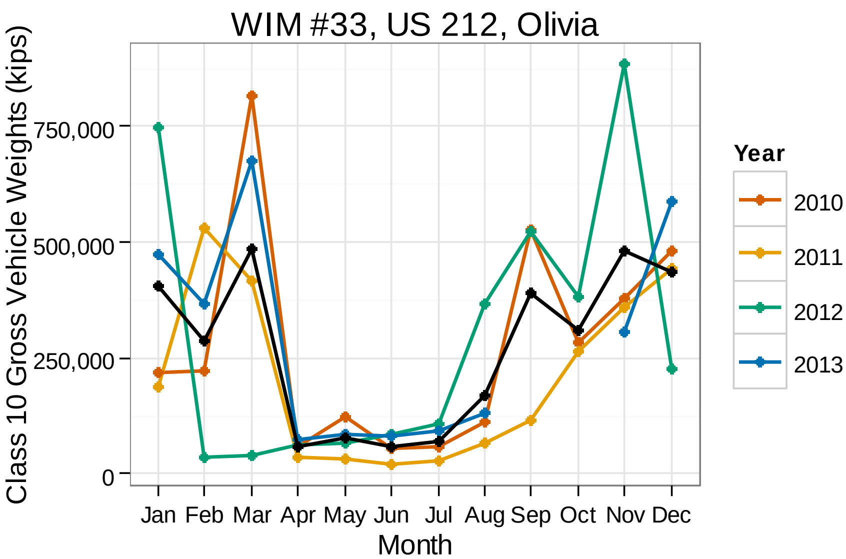


Figure 5.95a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

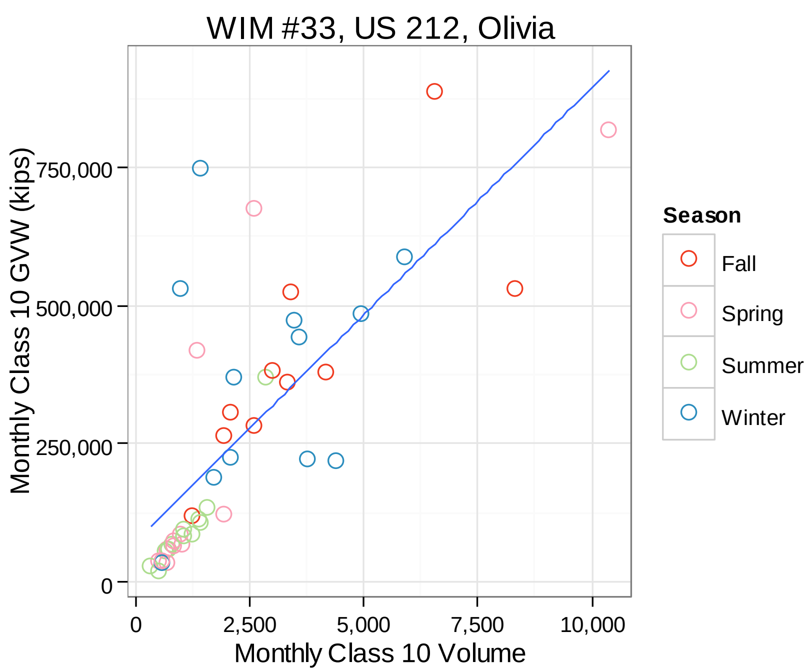


Figure 5.95b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

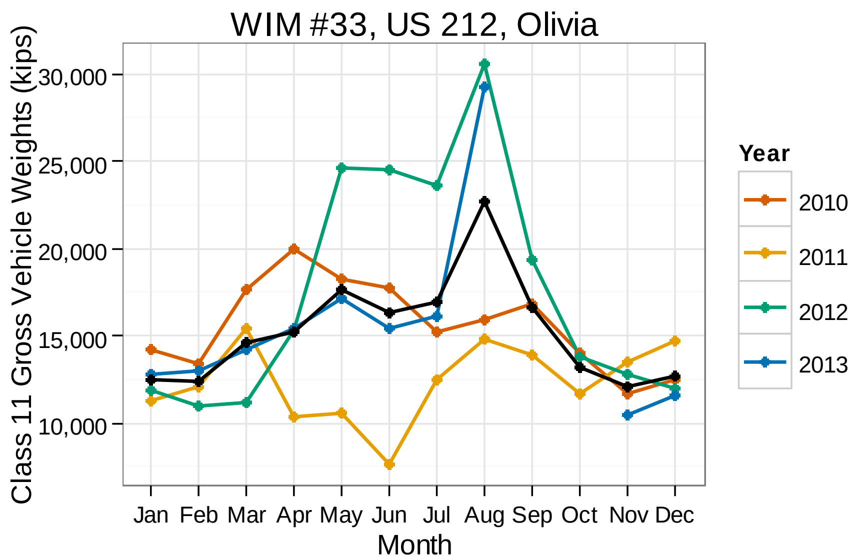


Figure 5.96a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

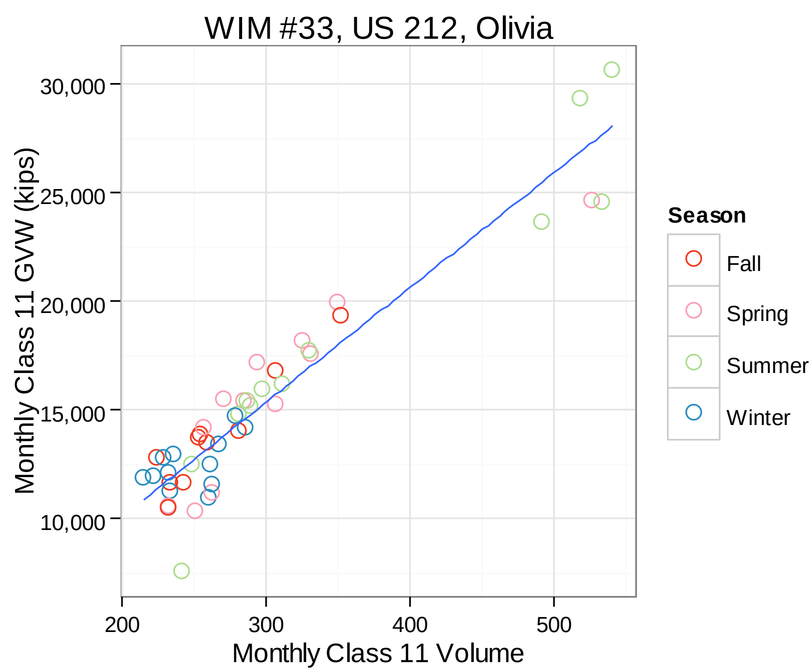


Figure 5.96b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

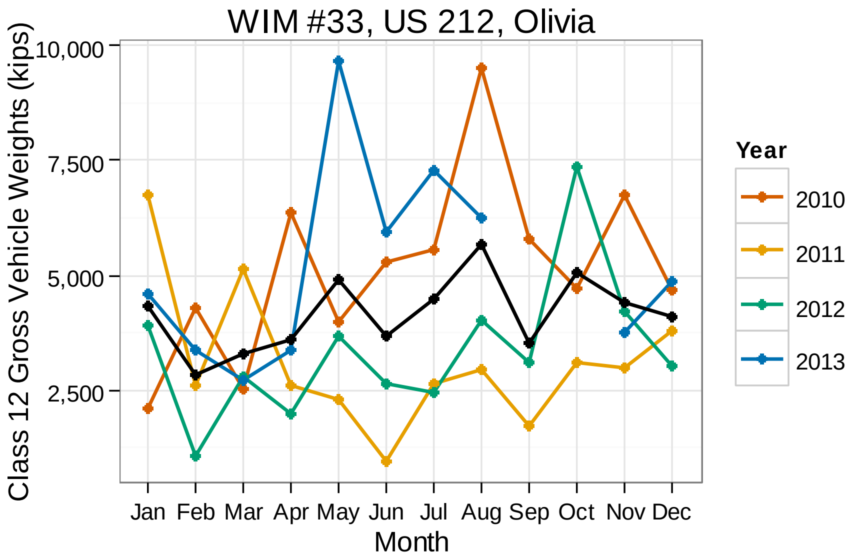


Figure 5.97a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

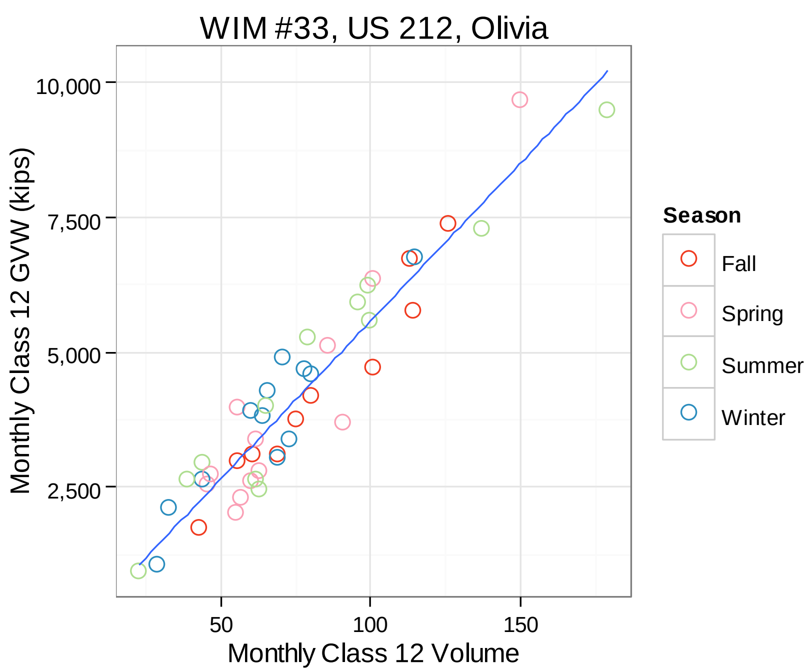


Figure 5.97b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

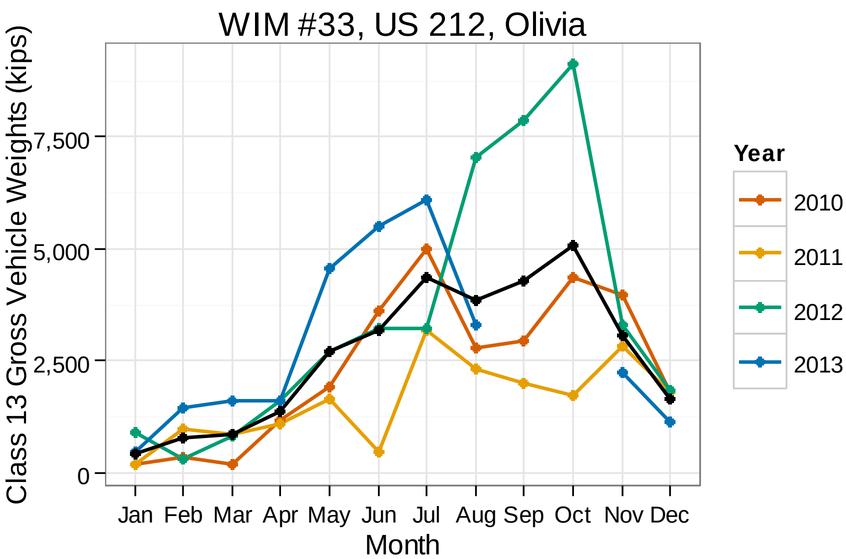


Figure 5.98a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

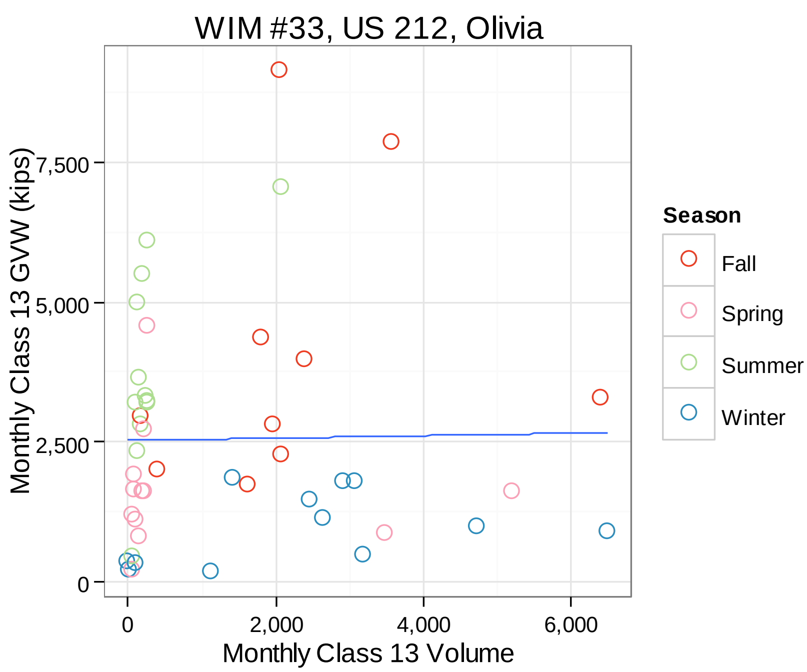


Figure 5.98b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

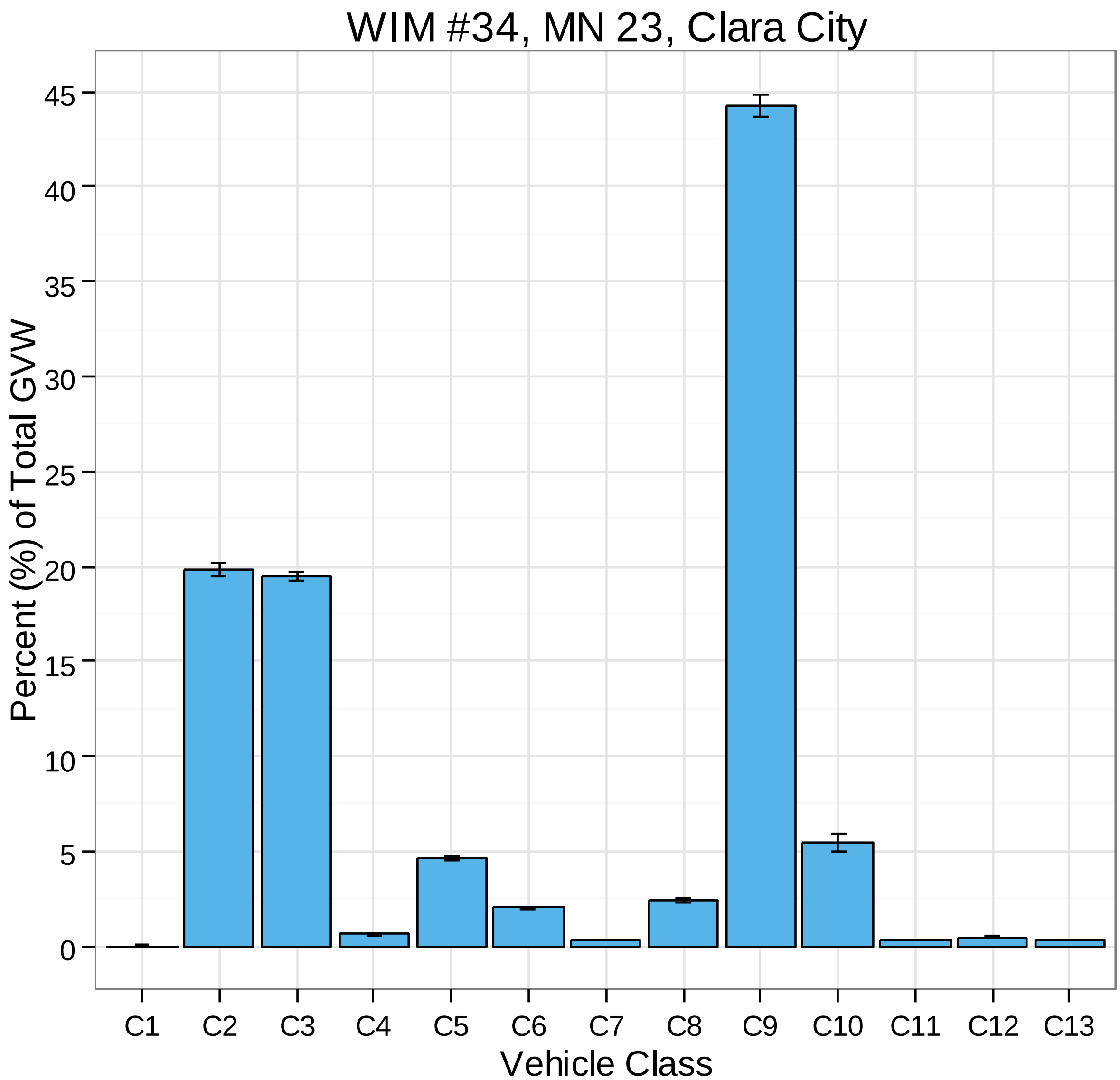


Figure 5.99. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

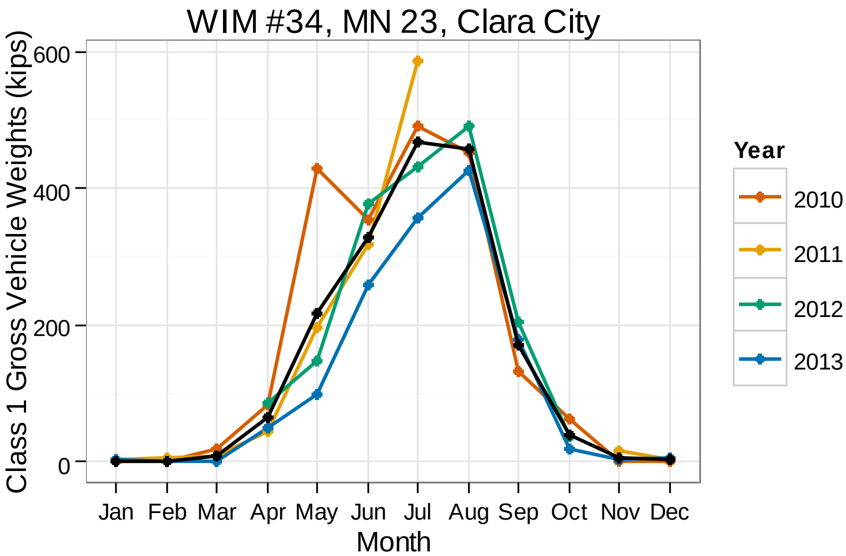


Figure 5.100a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

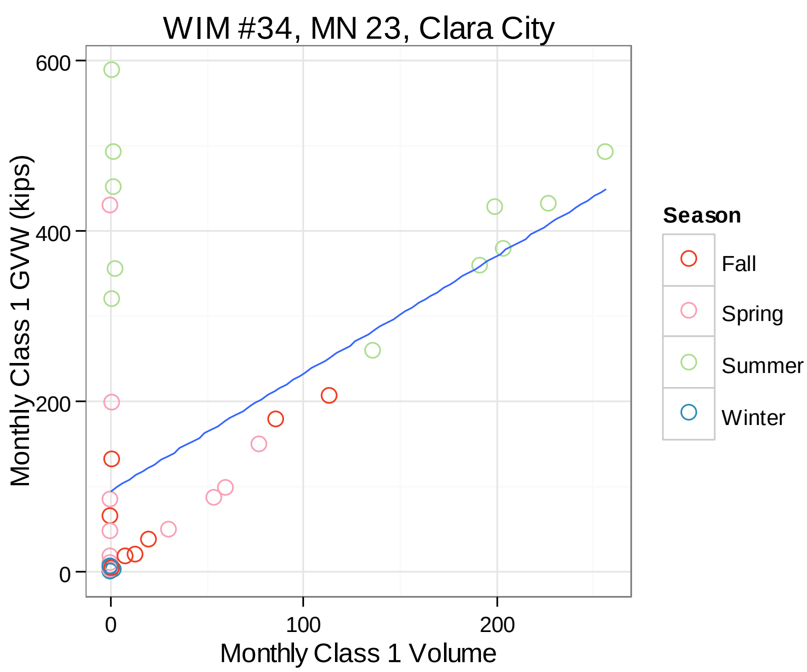


Figure 5.100b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

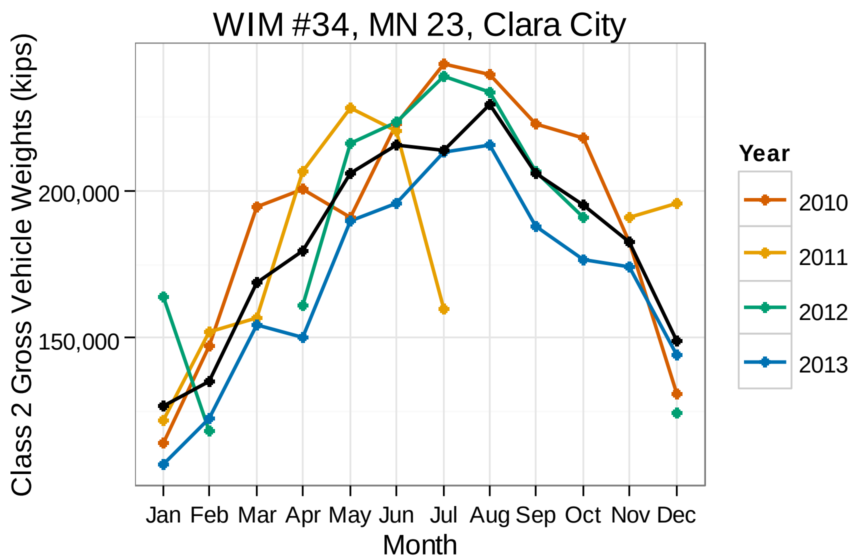


Figure 5.101a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

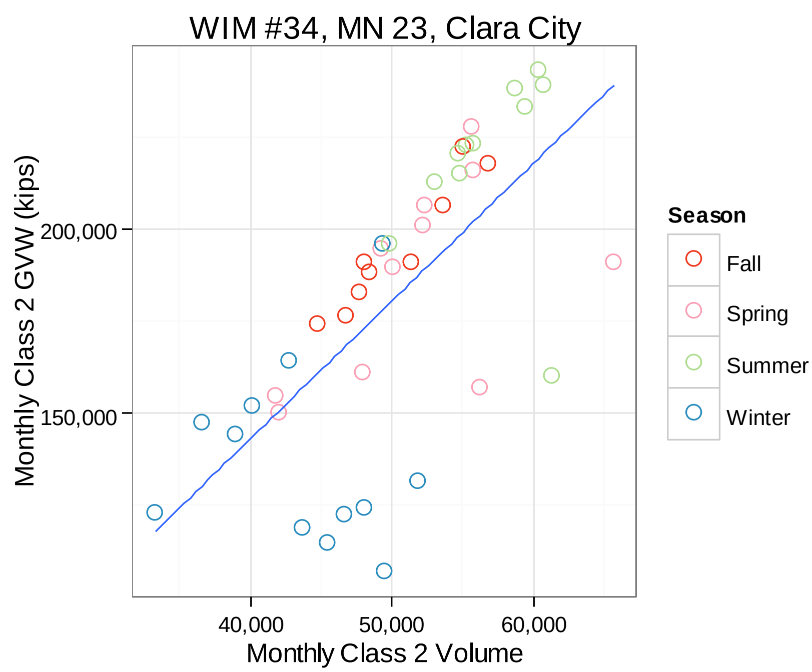


Figure 5.101b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

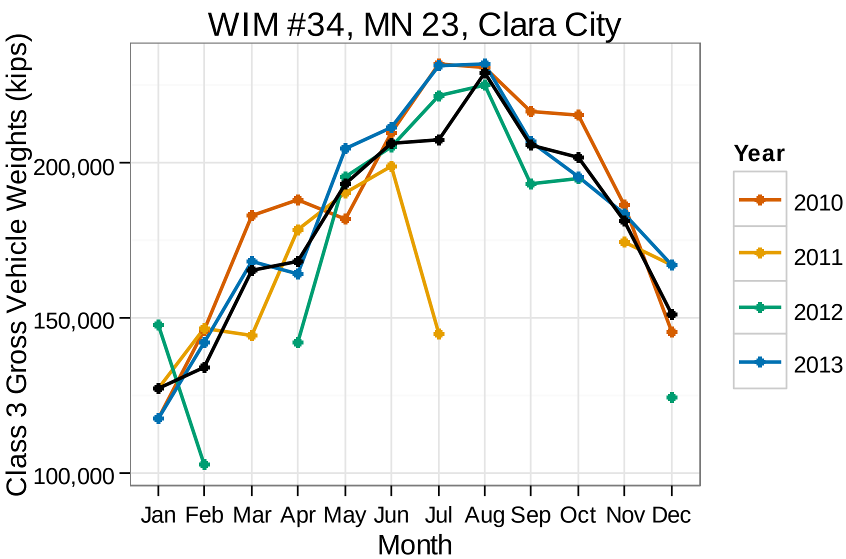


Figure 5.102a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

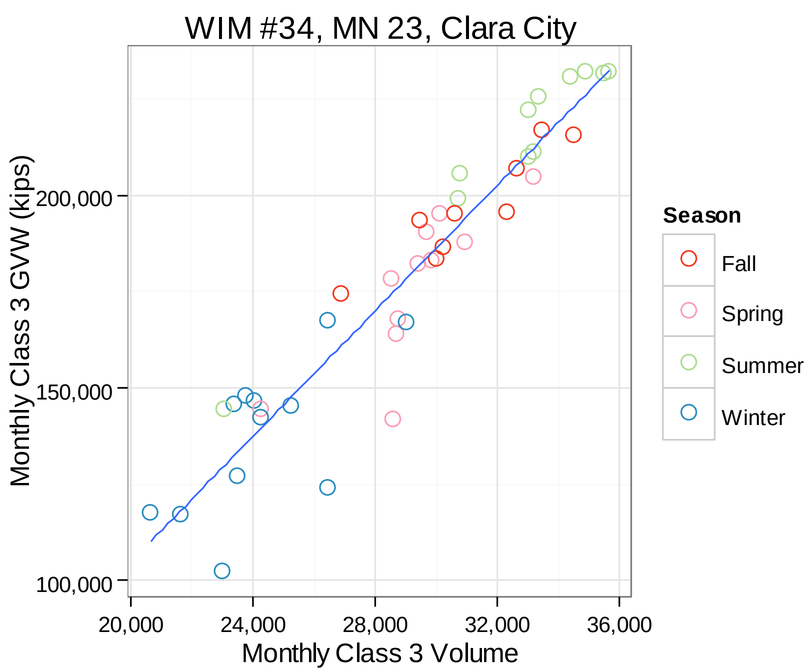


Figure 5.102b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

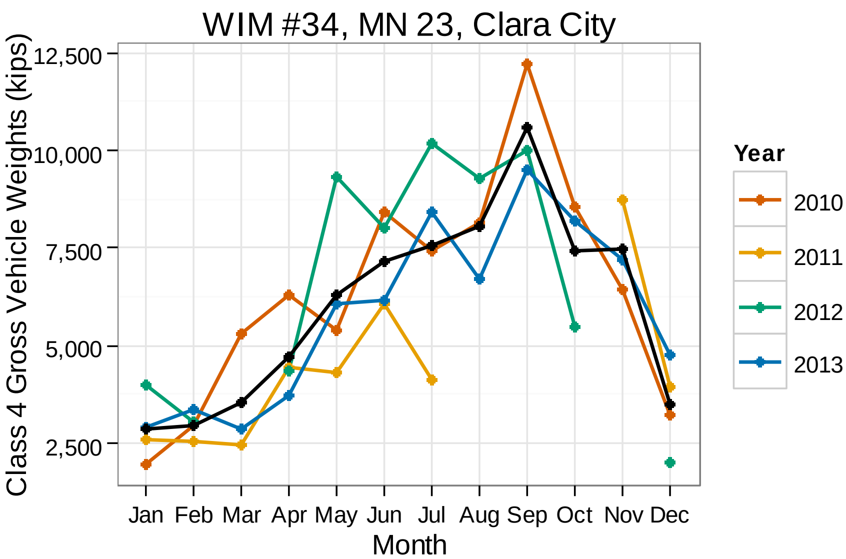


Figure 5.103a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

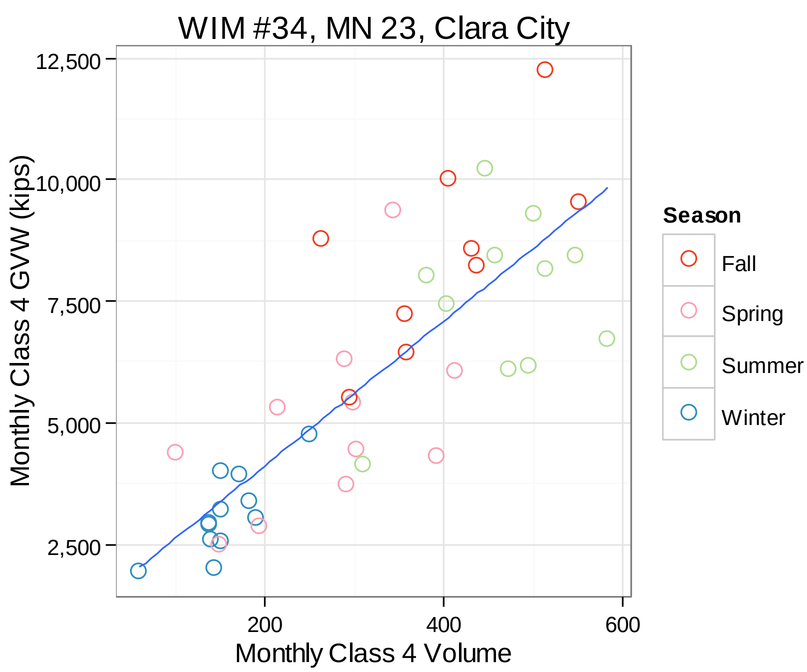


Figure 5.103b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

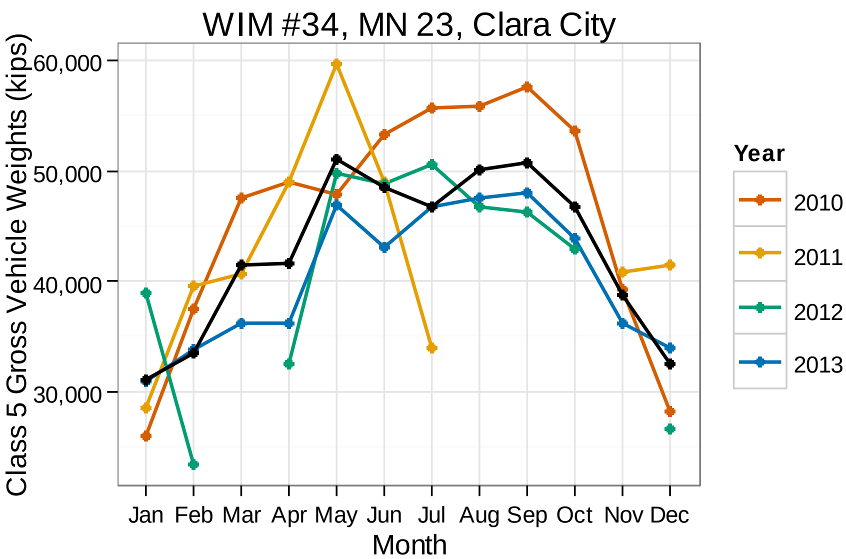


Figure 5.104a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

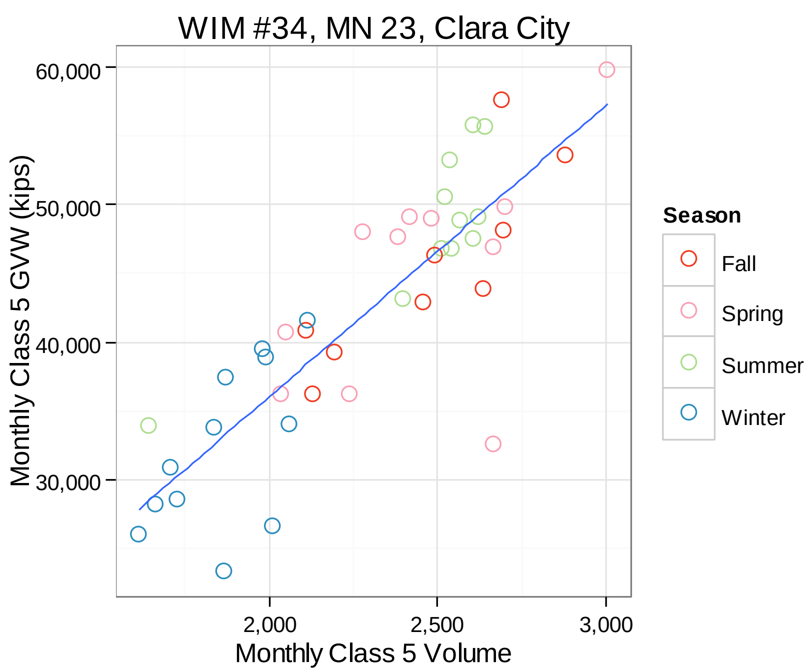


Figure 5.104b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

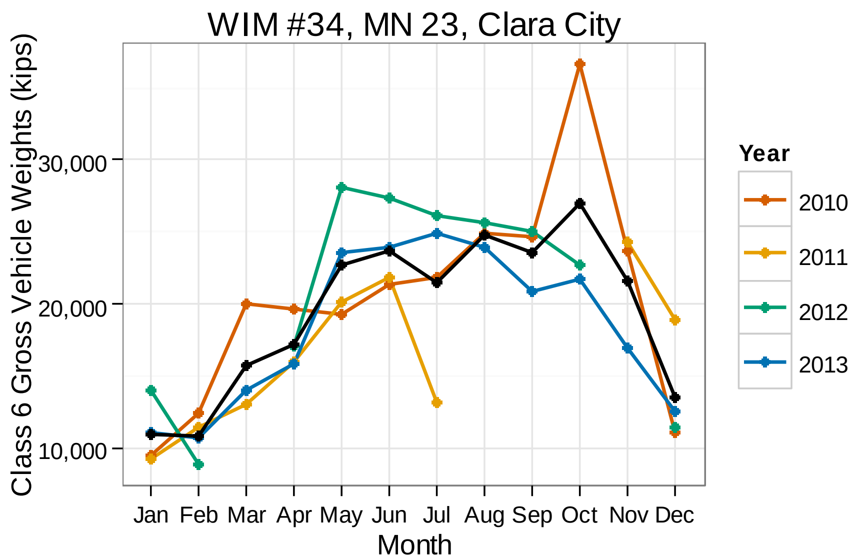


Figure 5.105a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

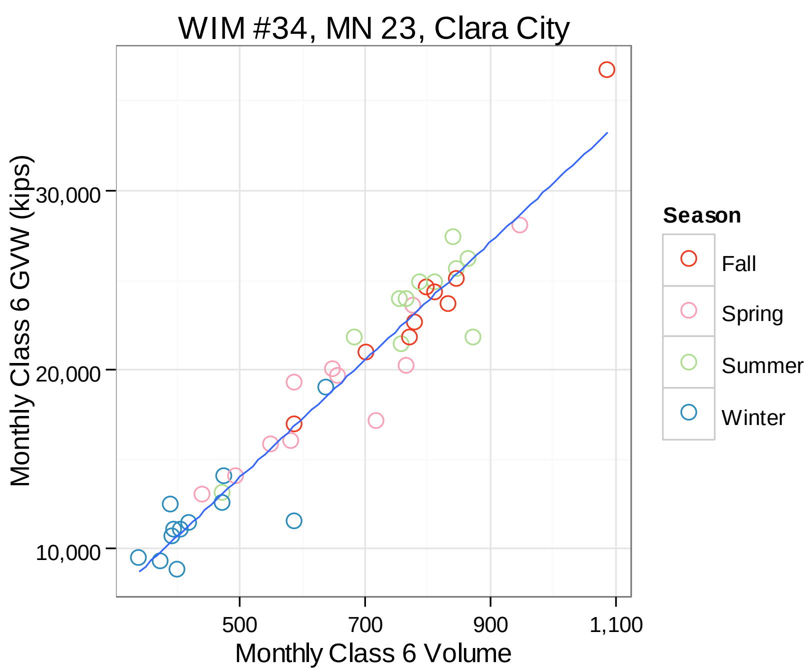


Figure 5.105b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

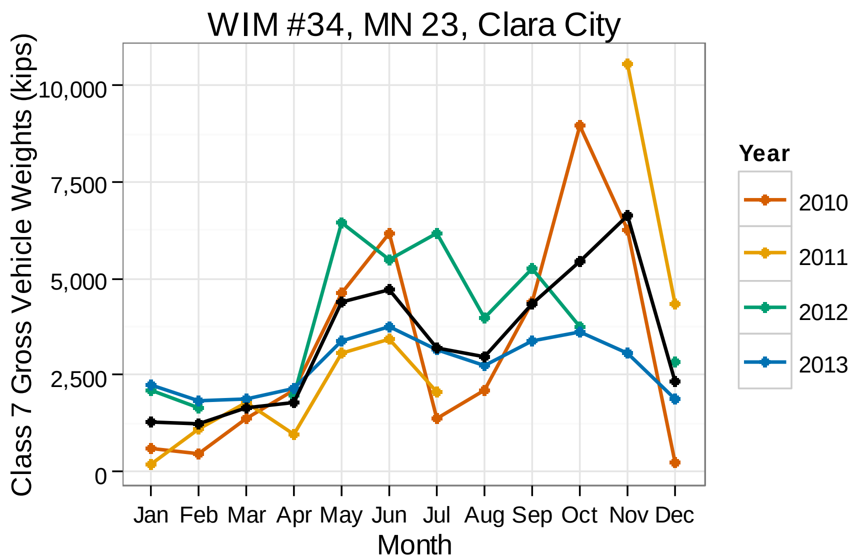


Figure 5.106a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

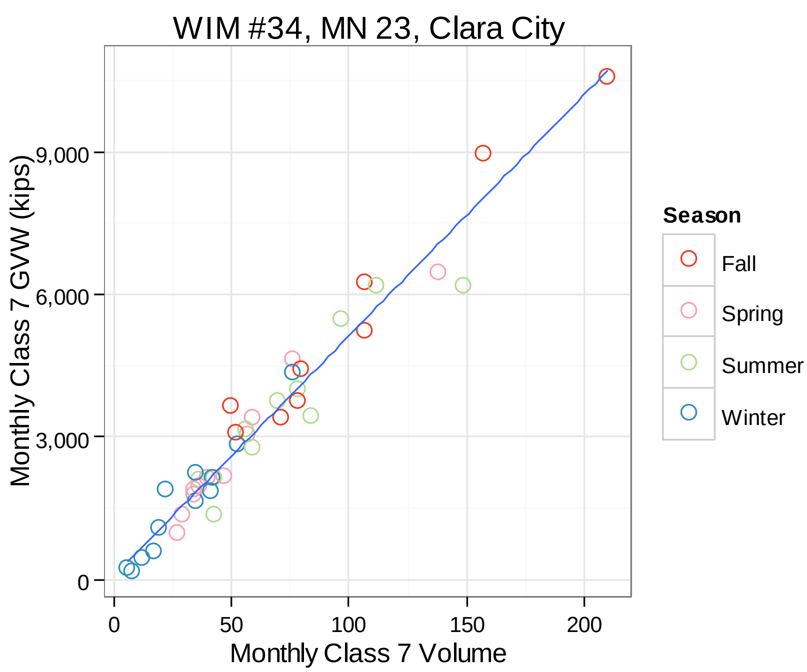


Figure 5.106b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

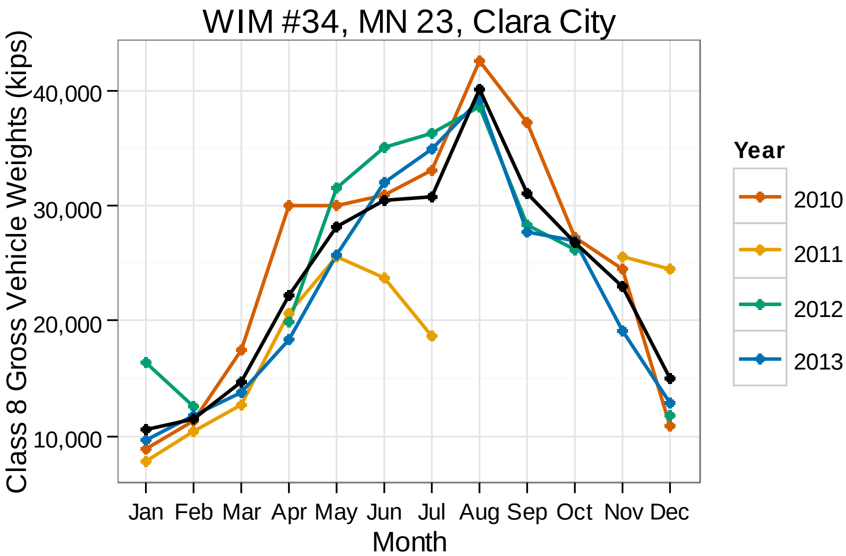


Figure 5.107a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

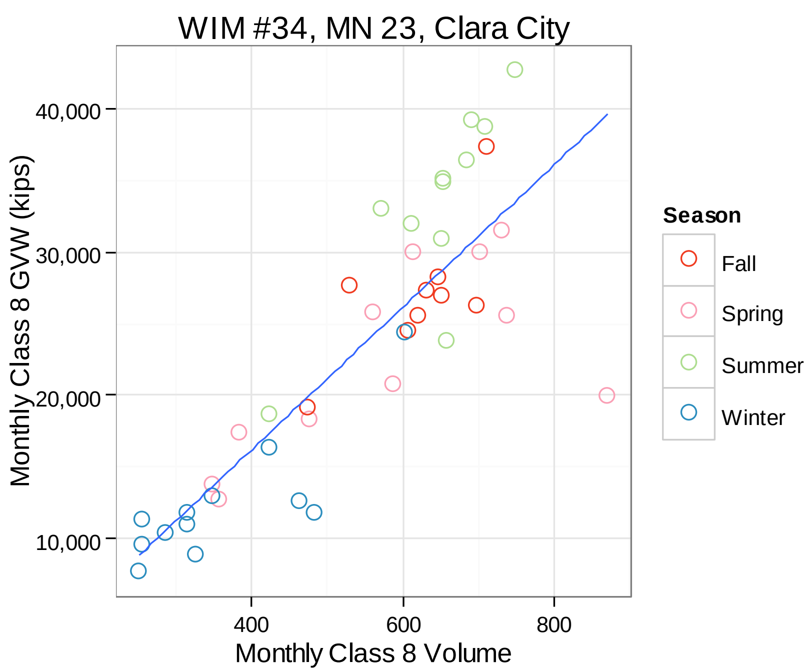


Figure 5.107b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

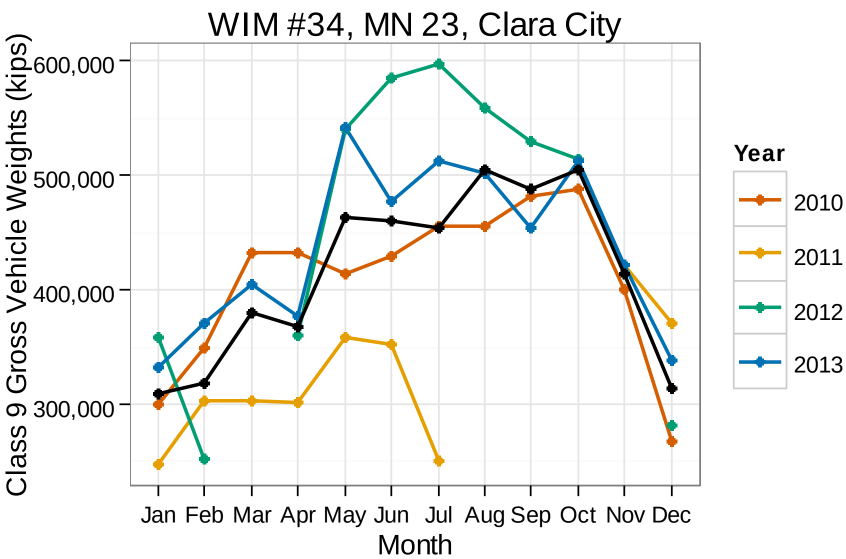


Figure 5.108a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

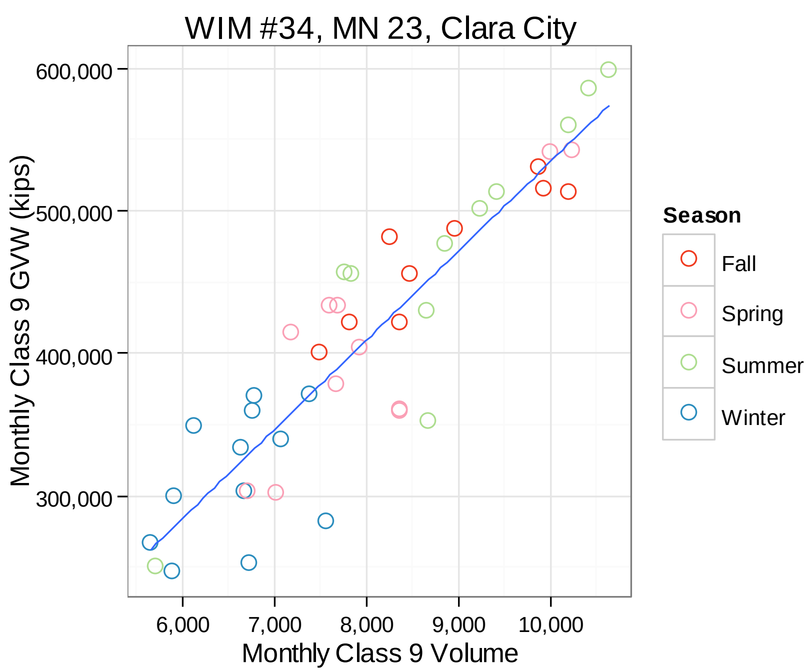


Figure 5.108b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

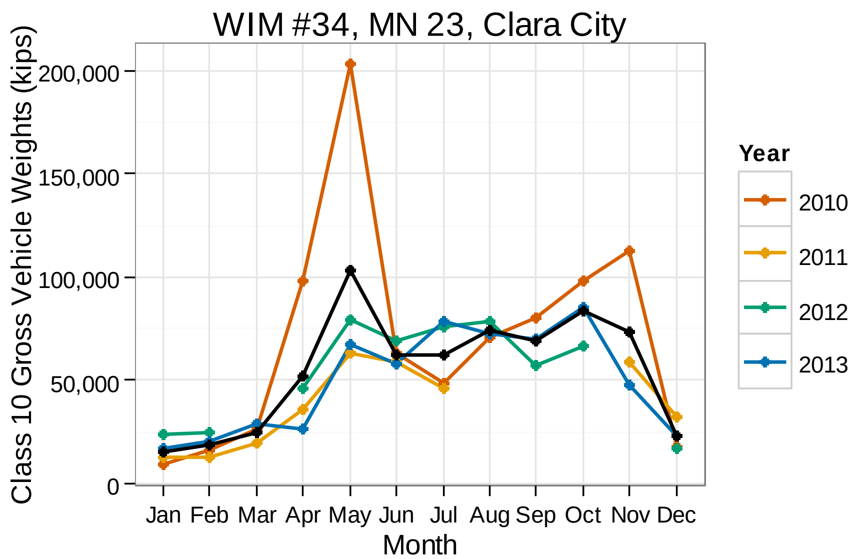


Figure 5.109a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

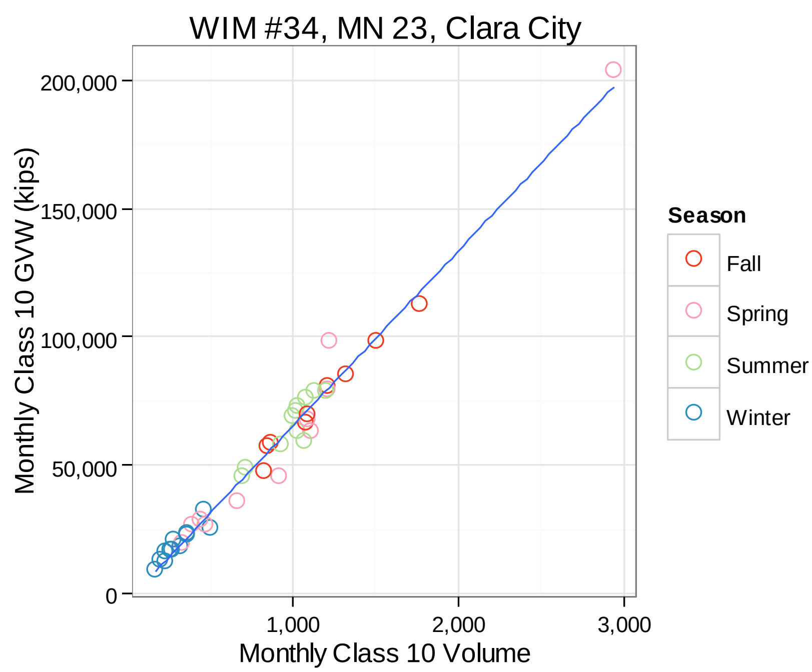


Figure 5.109b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

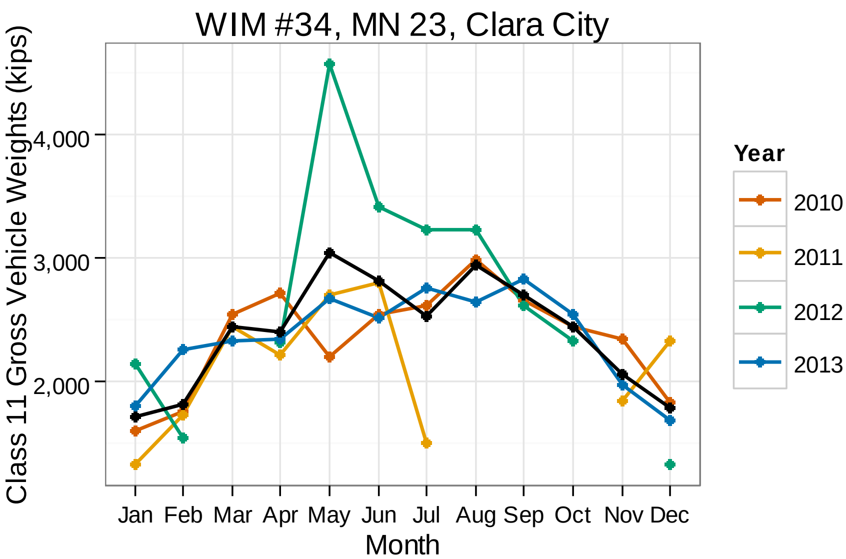


Figure 5.110a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

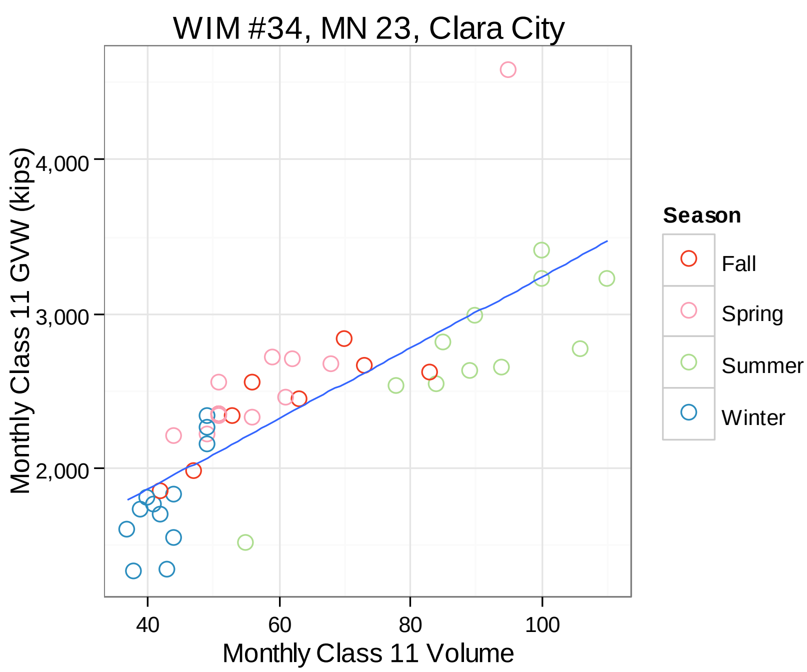


Figure 5.110b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

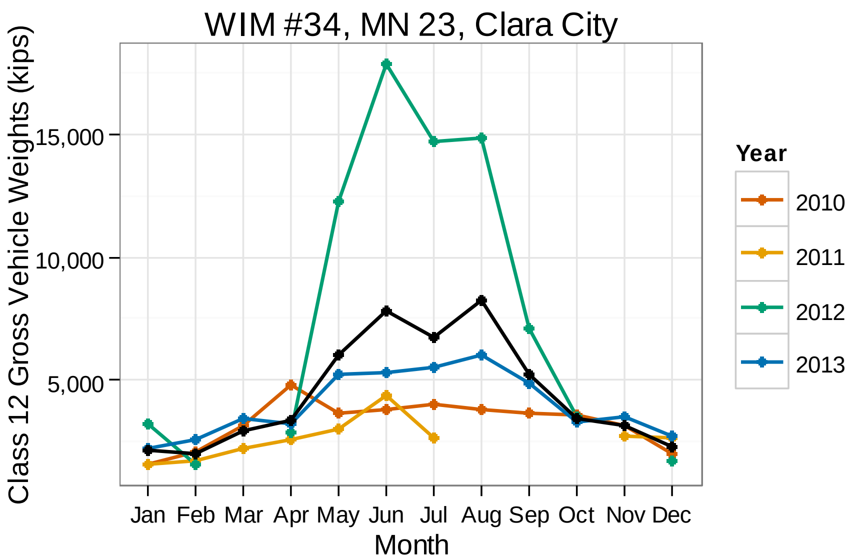


Figure 5.111a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

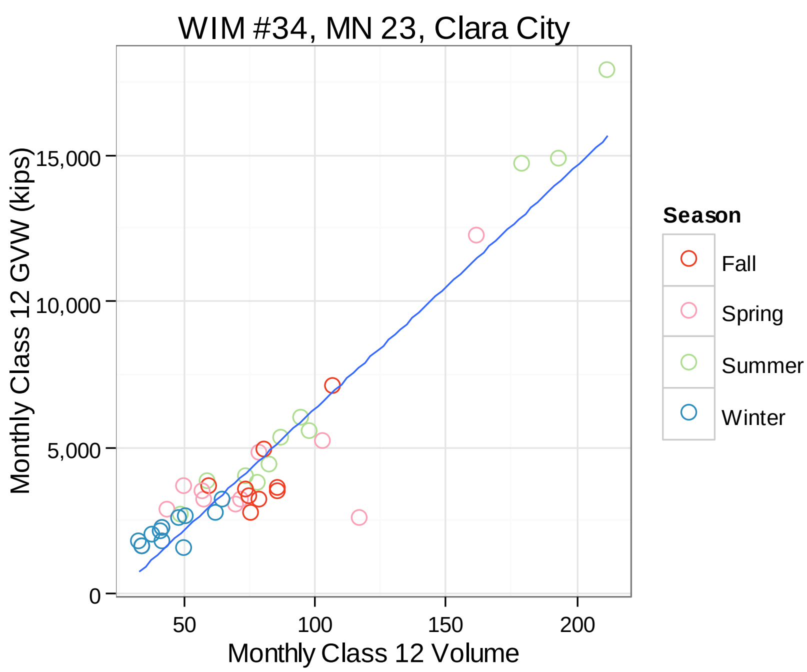


Figure 5.111b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

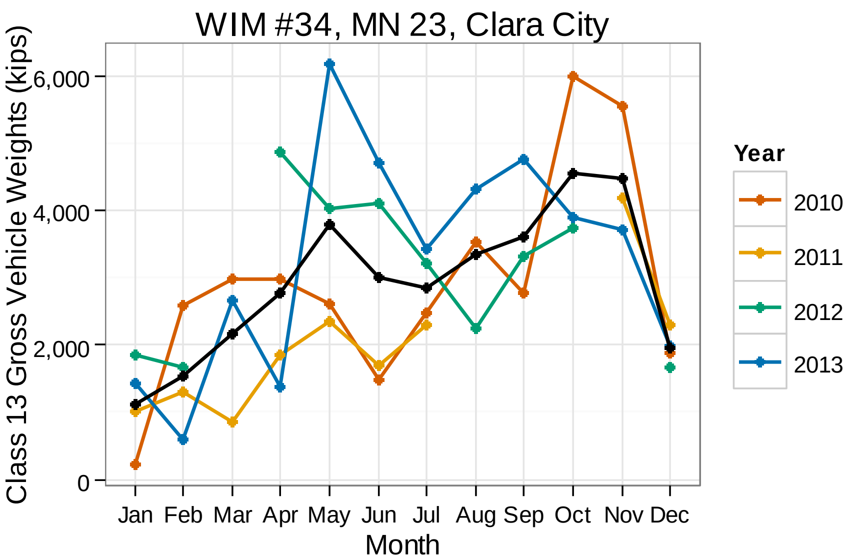


Figure 5.112a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

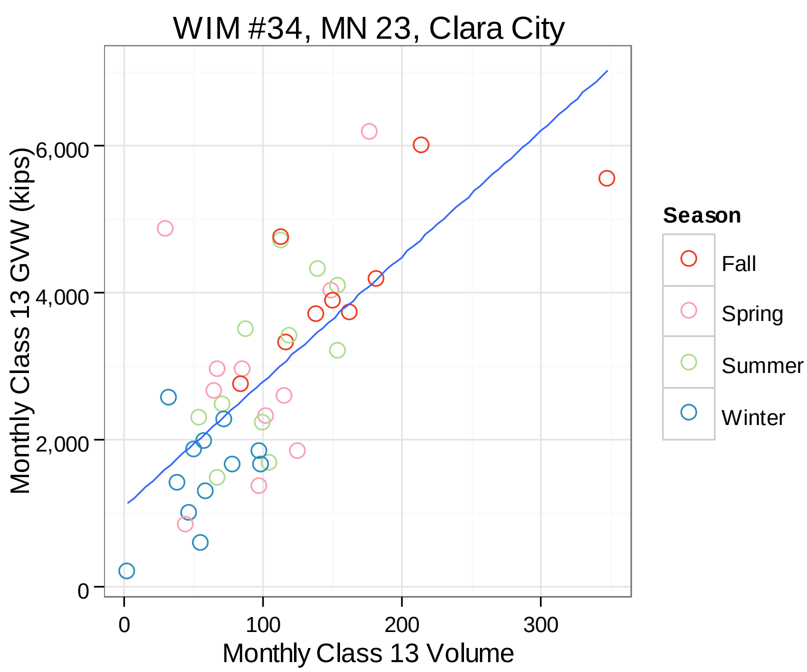


Figure 5.112b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

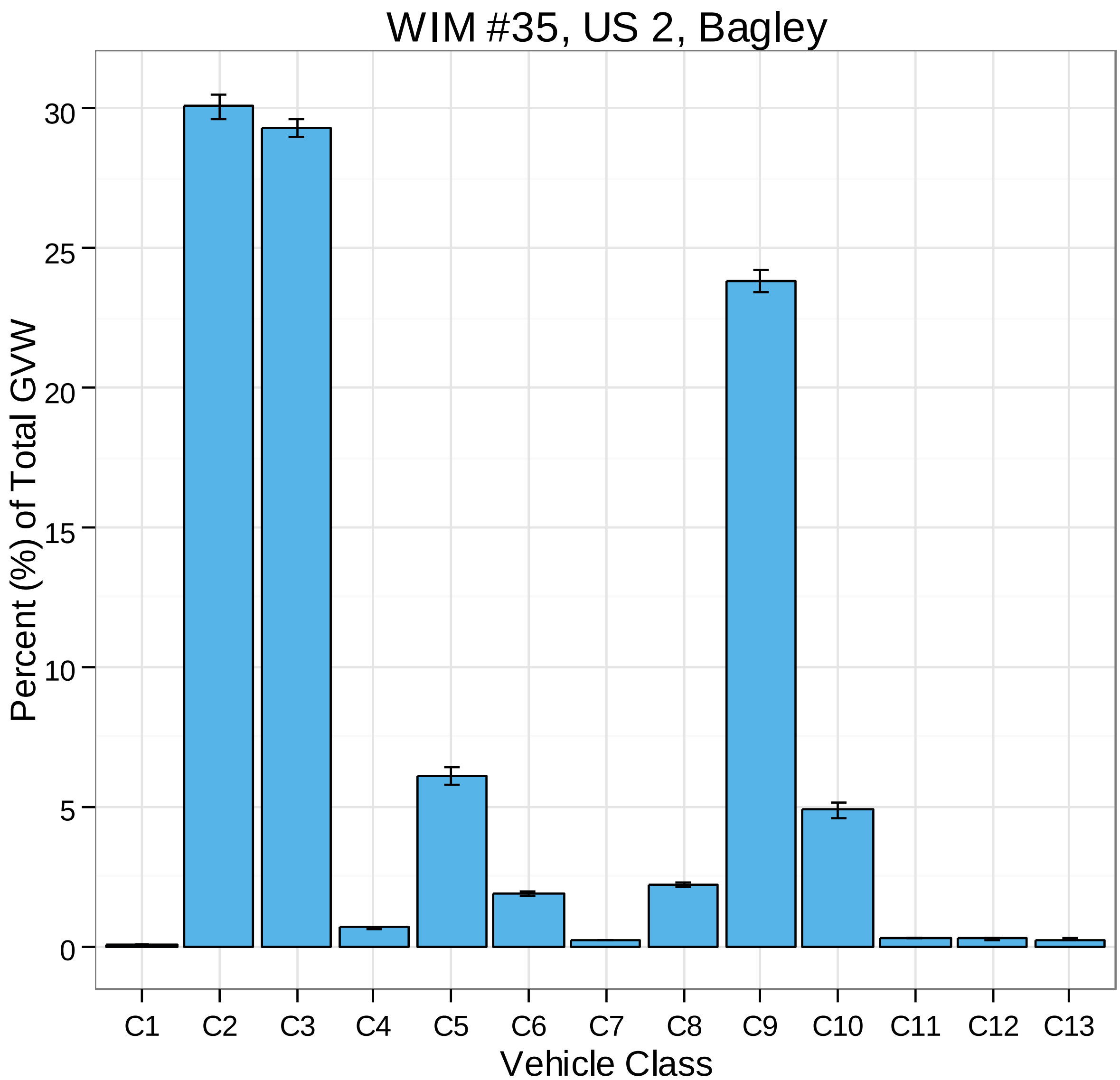


Figure 5.113. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

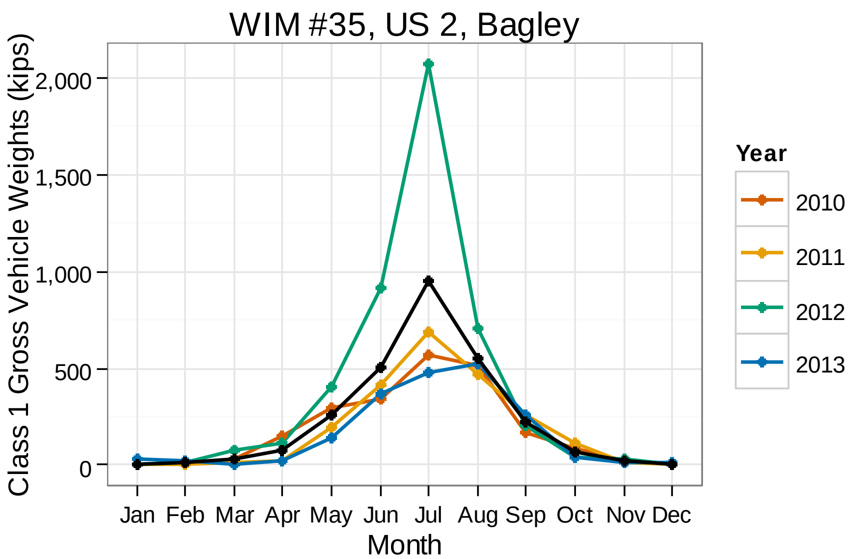


Figure 5.114a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

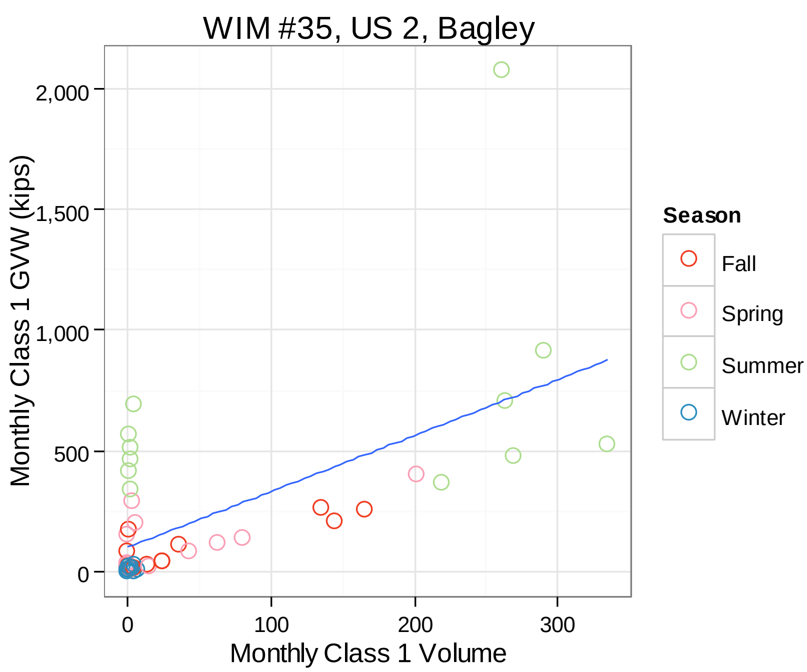


Figure 5.114b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

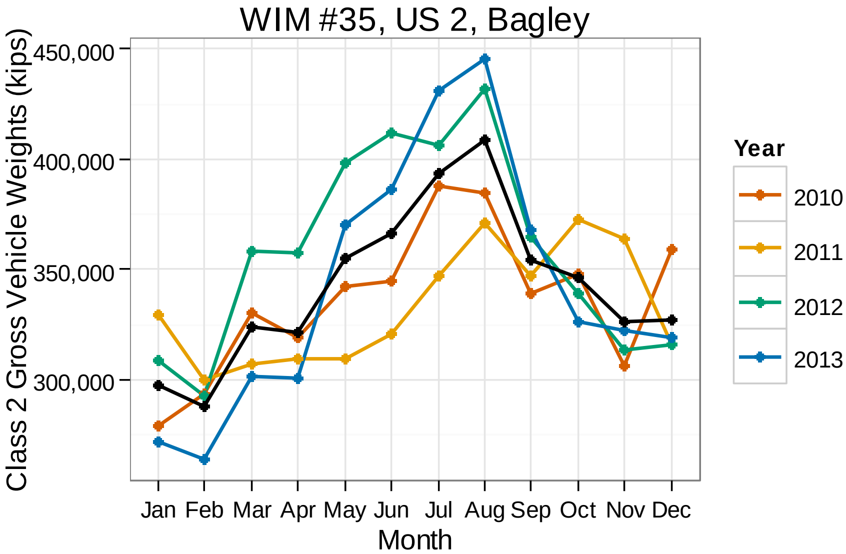


Figure 5.115a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

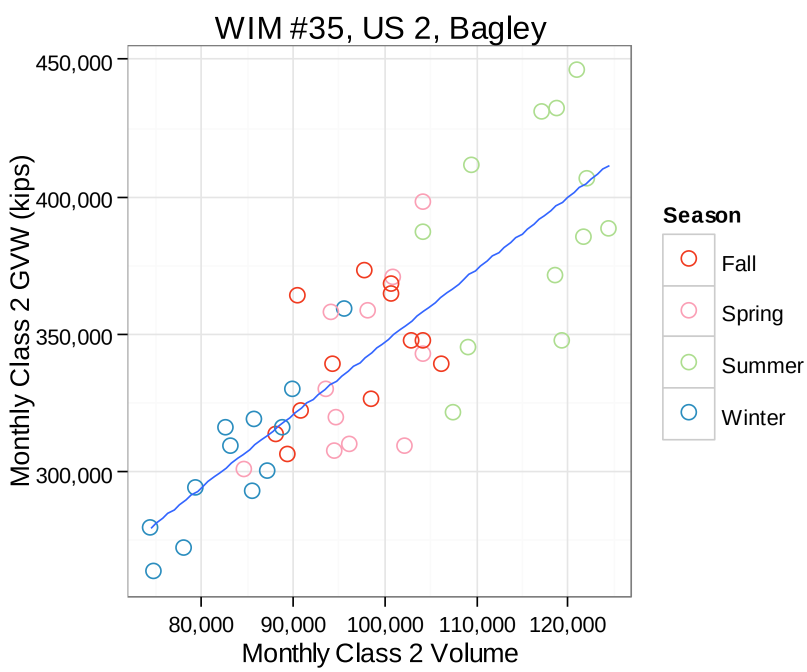


Figure 5.115b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

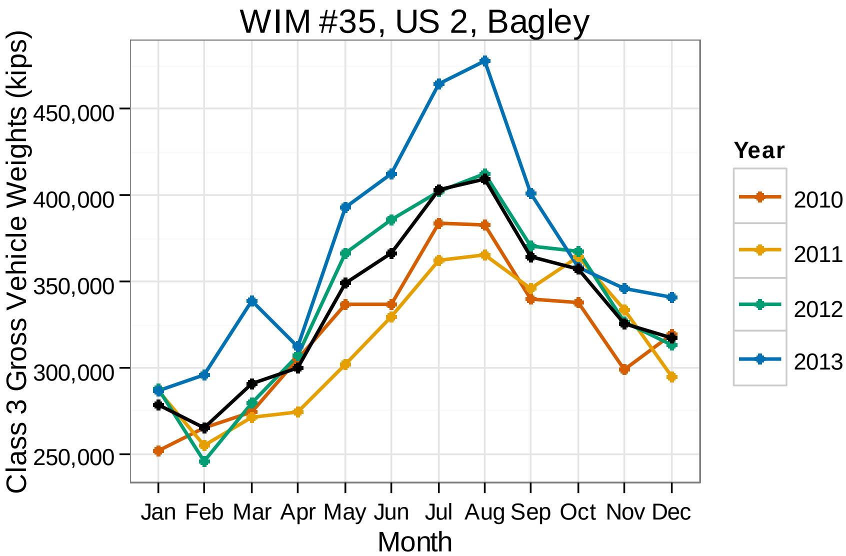


Figure 5.116a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

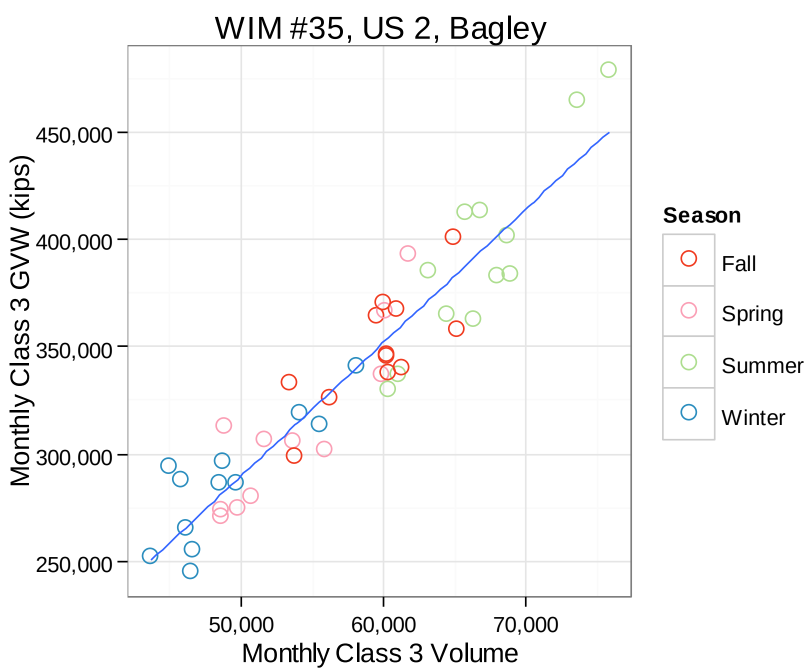


Figure 5.116b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

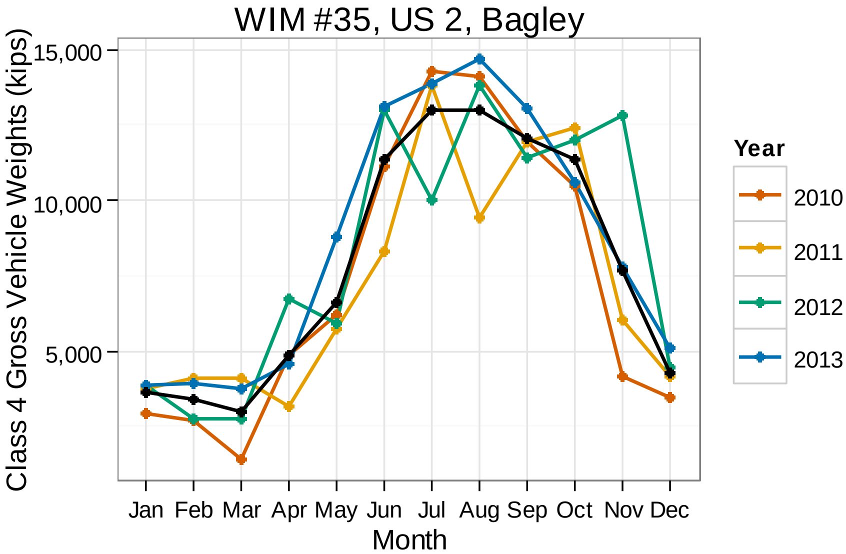


Figure 5.117a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

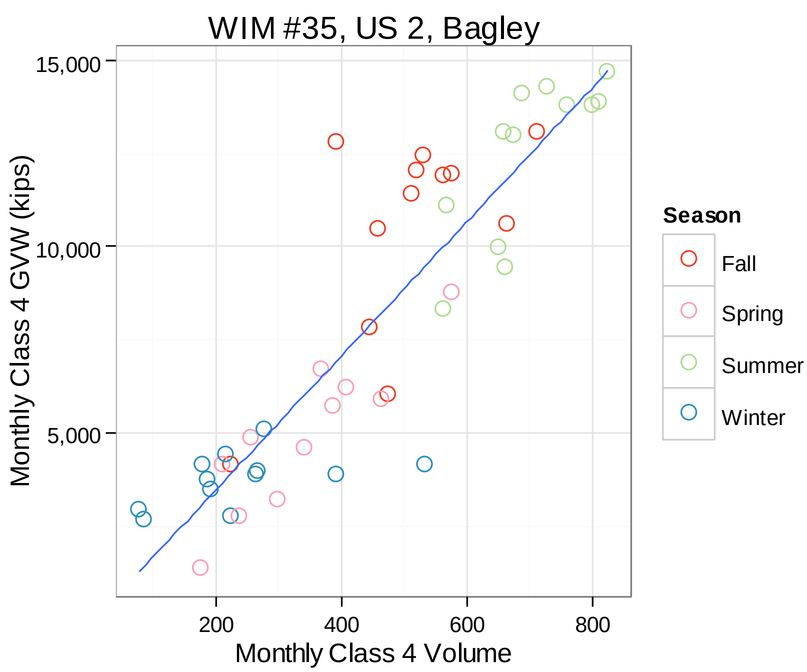


Figure 5.117b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

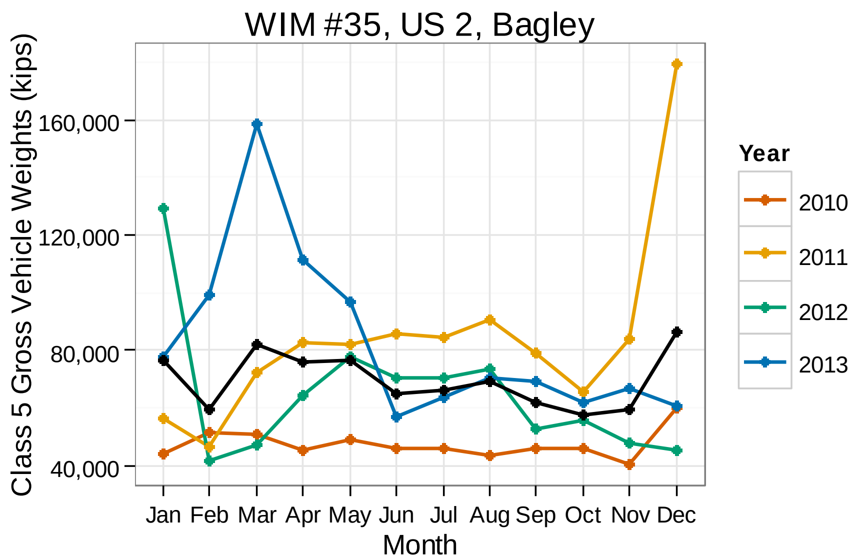


Figure 5.118a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

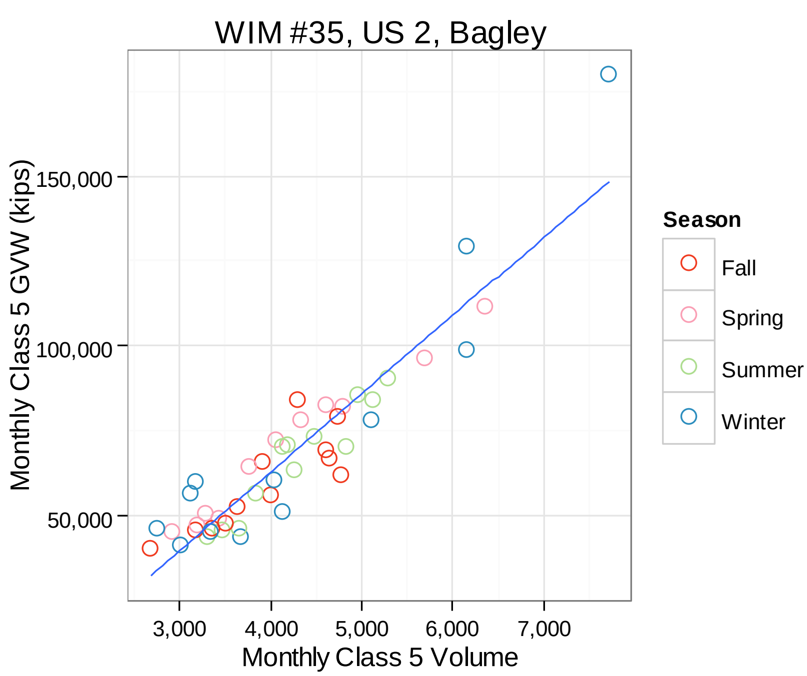


Figure 5.118b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

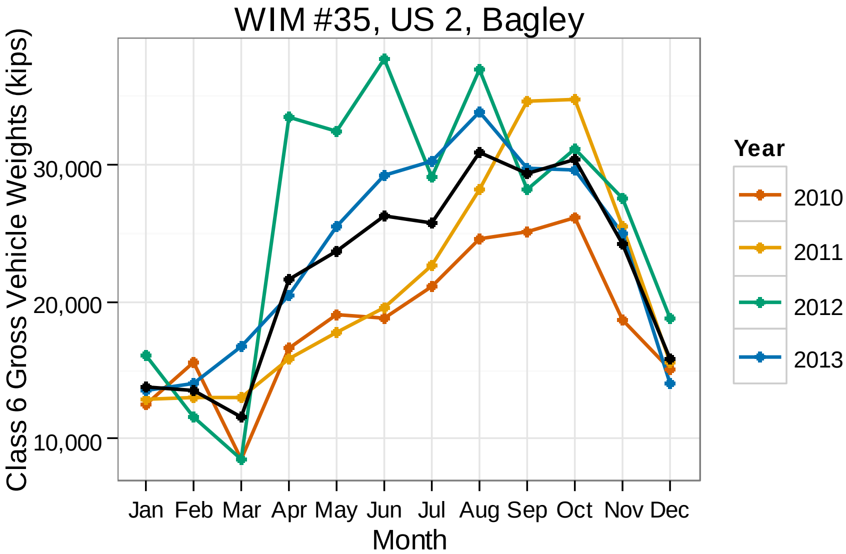


Figure 5.119a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

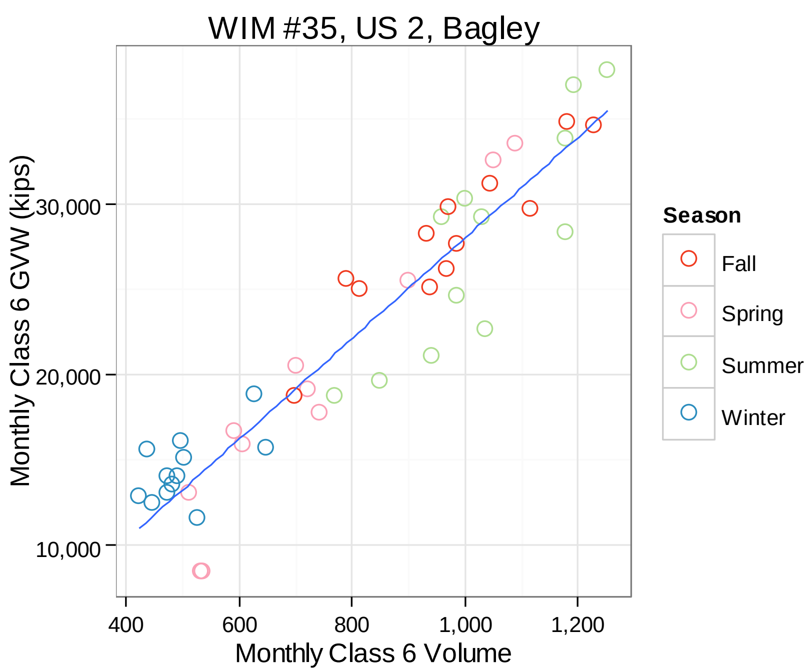


Figure 5.119b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

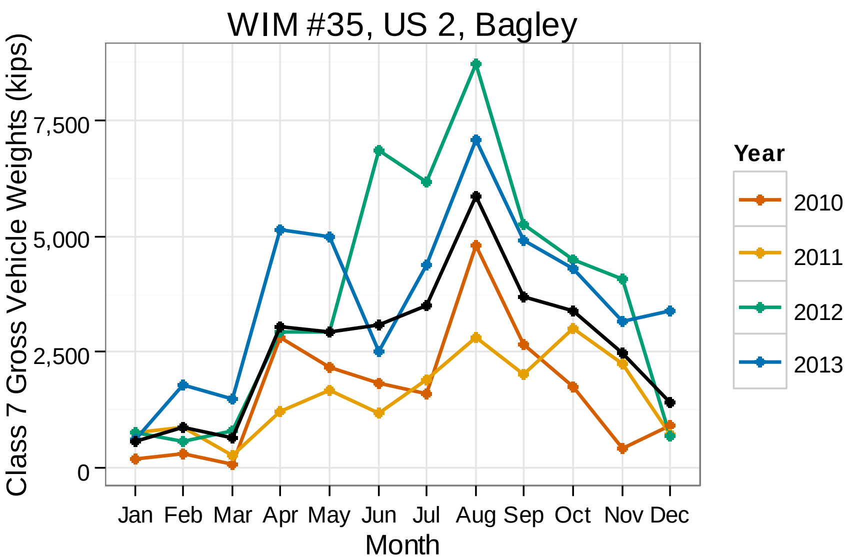


Figure 5.120a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

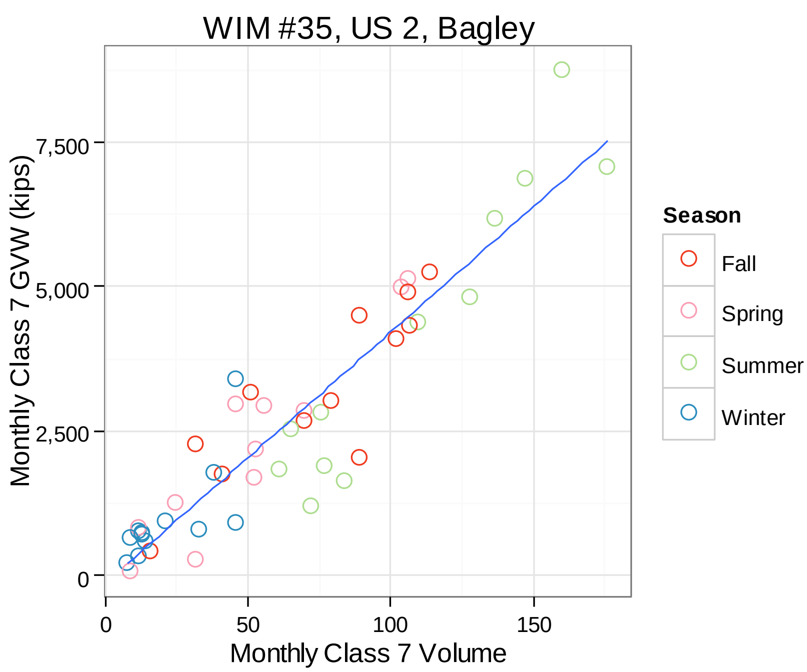


Figure 5.120b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

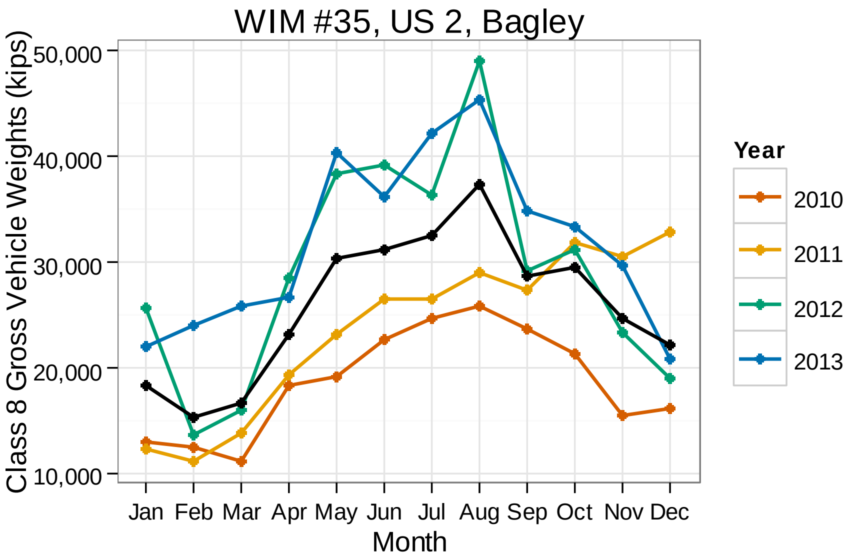


Figure 5.121a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

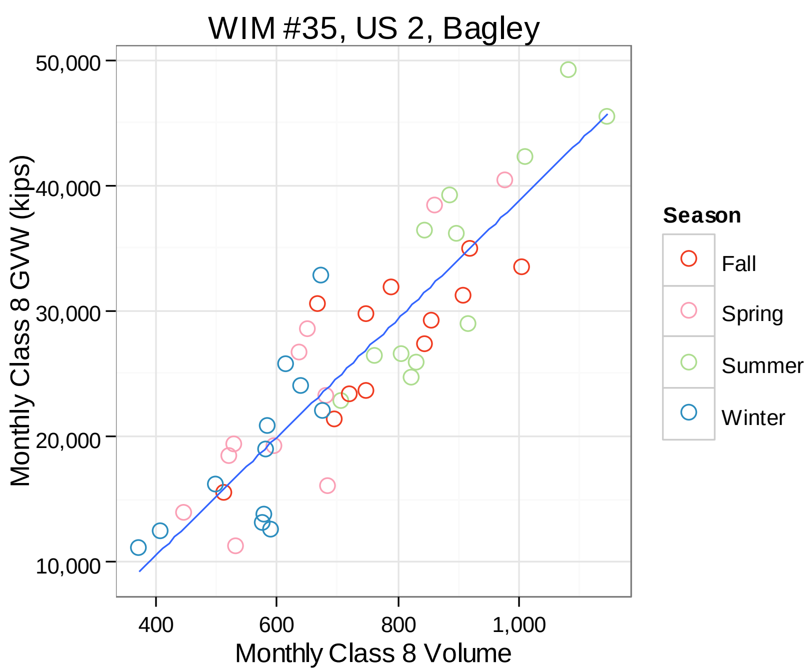


Figure 5.121b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

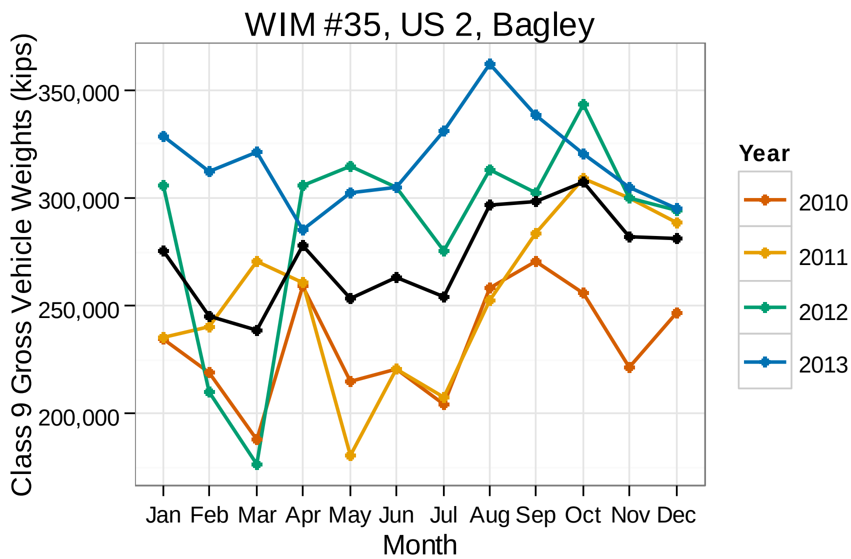


Figure 5.122a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

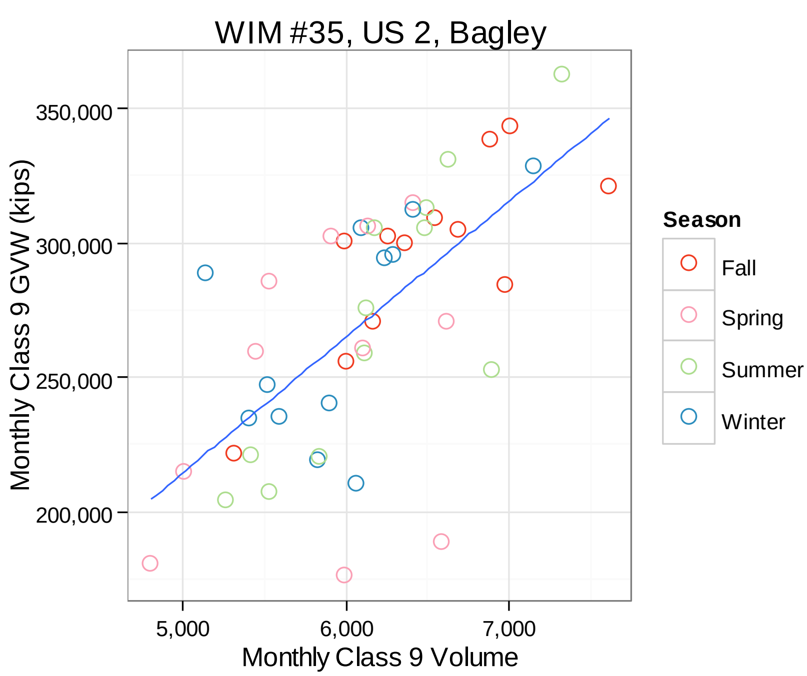


Figure 5.122b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

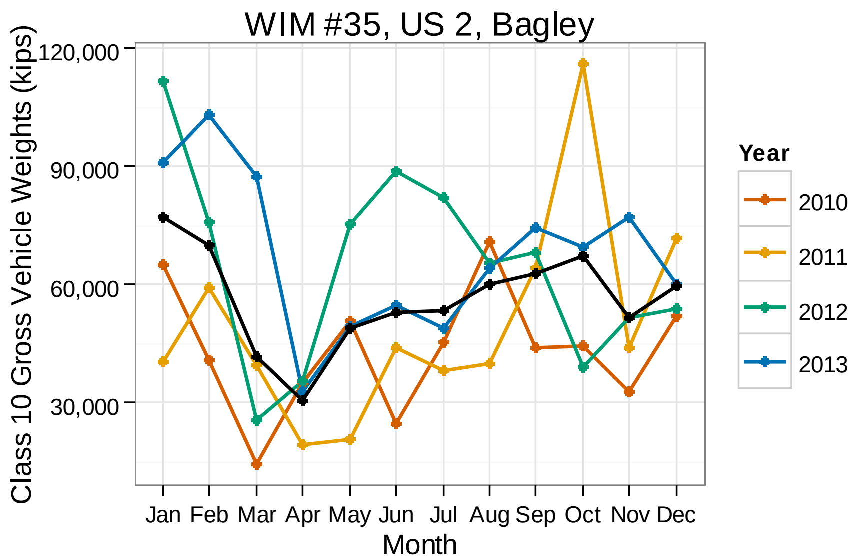


Figure 5.123a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

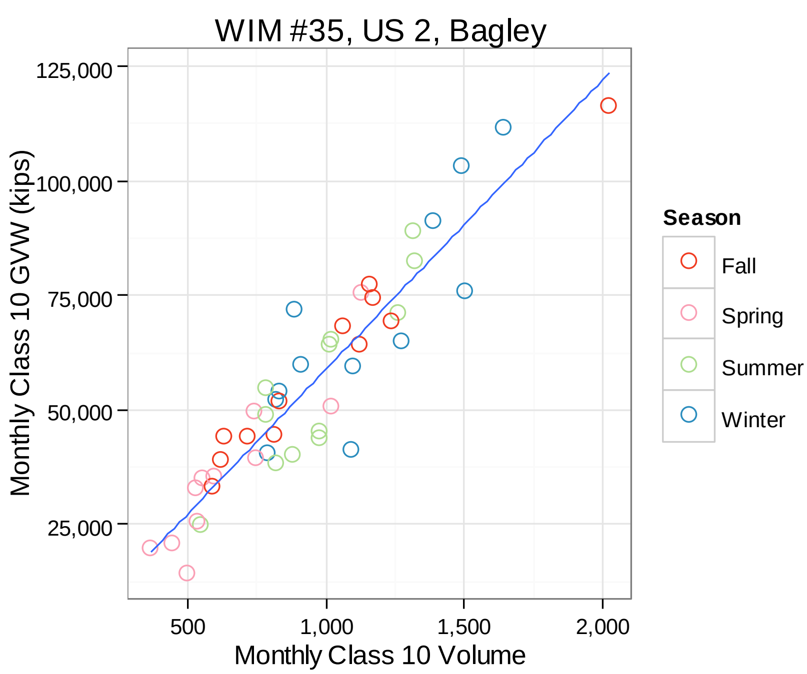


Figure 5.123b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

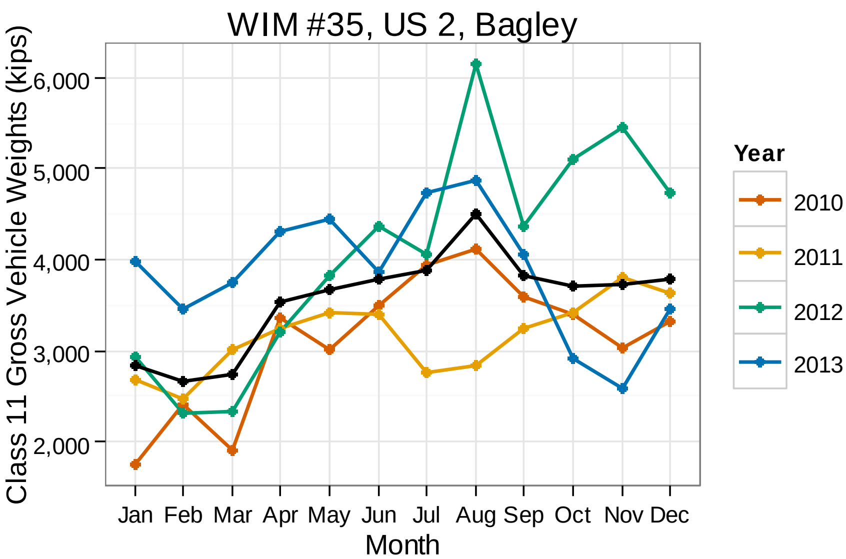


Figure 5.124a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

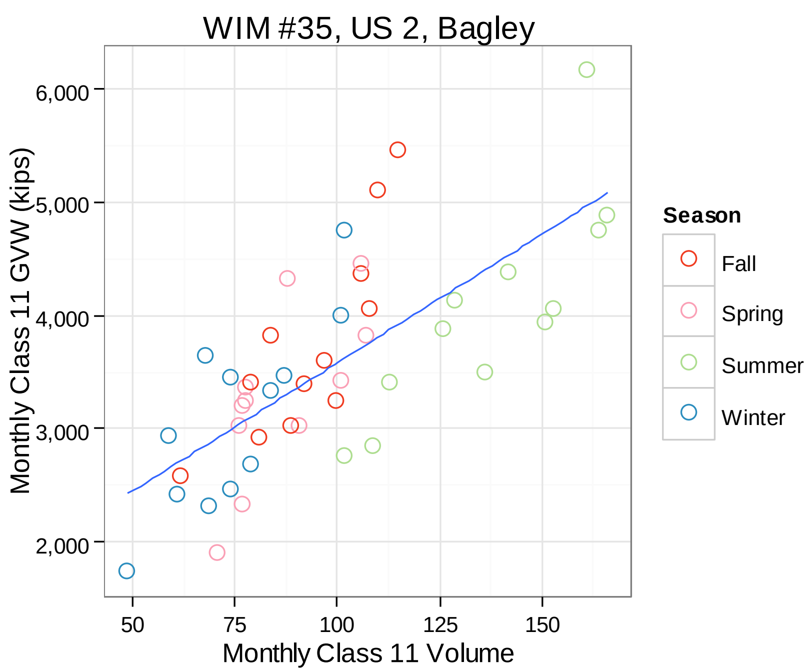


Figure 5.124b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

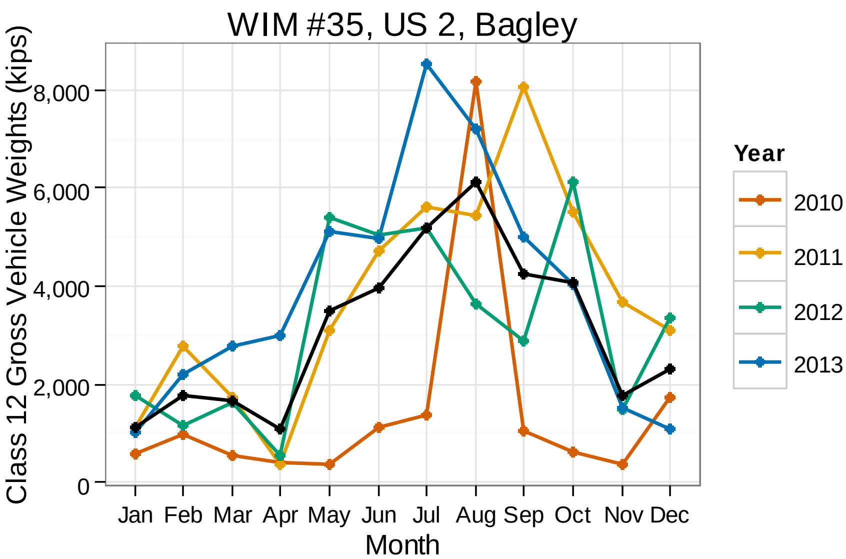


Figure 5.125a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

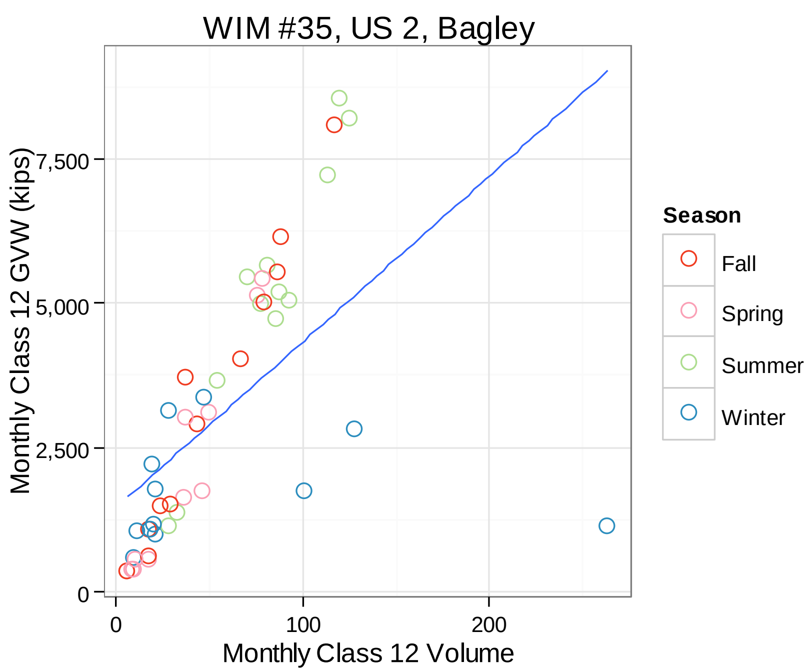


Figure 5.125b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

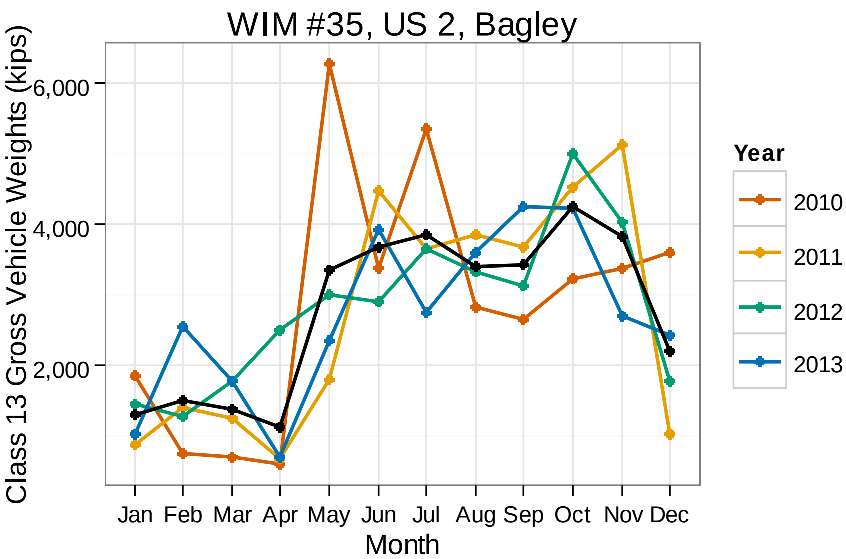


Figure 5.126a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

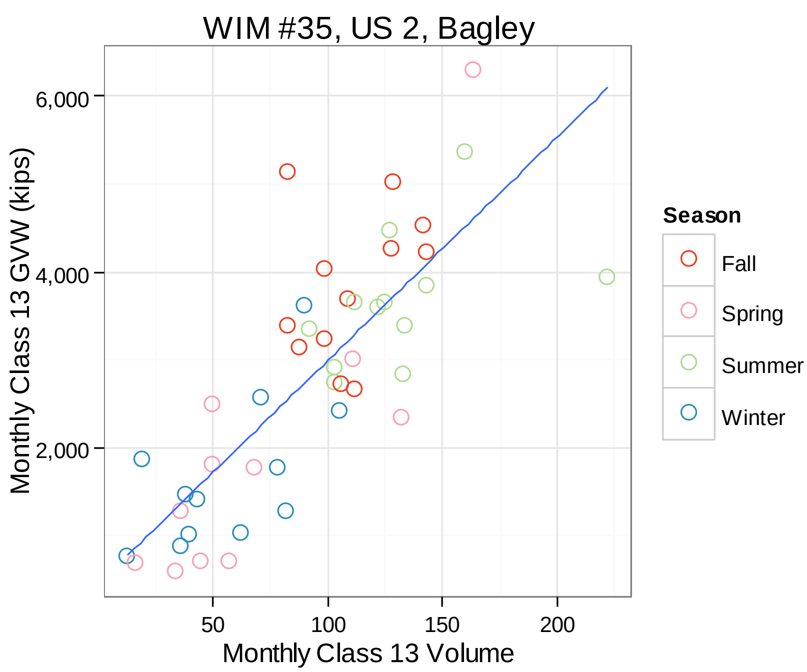


Figure 5.126b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

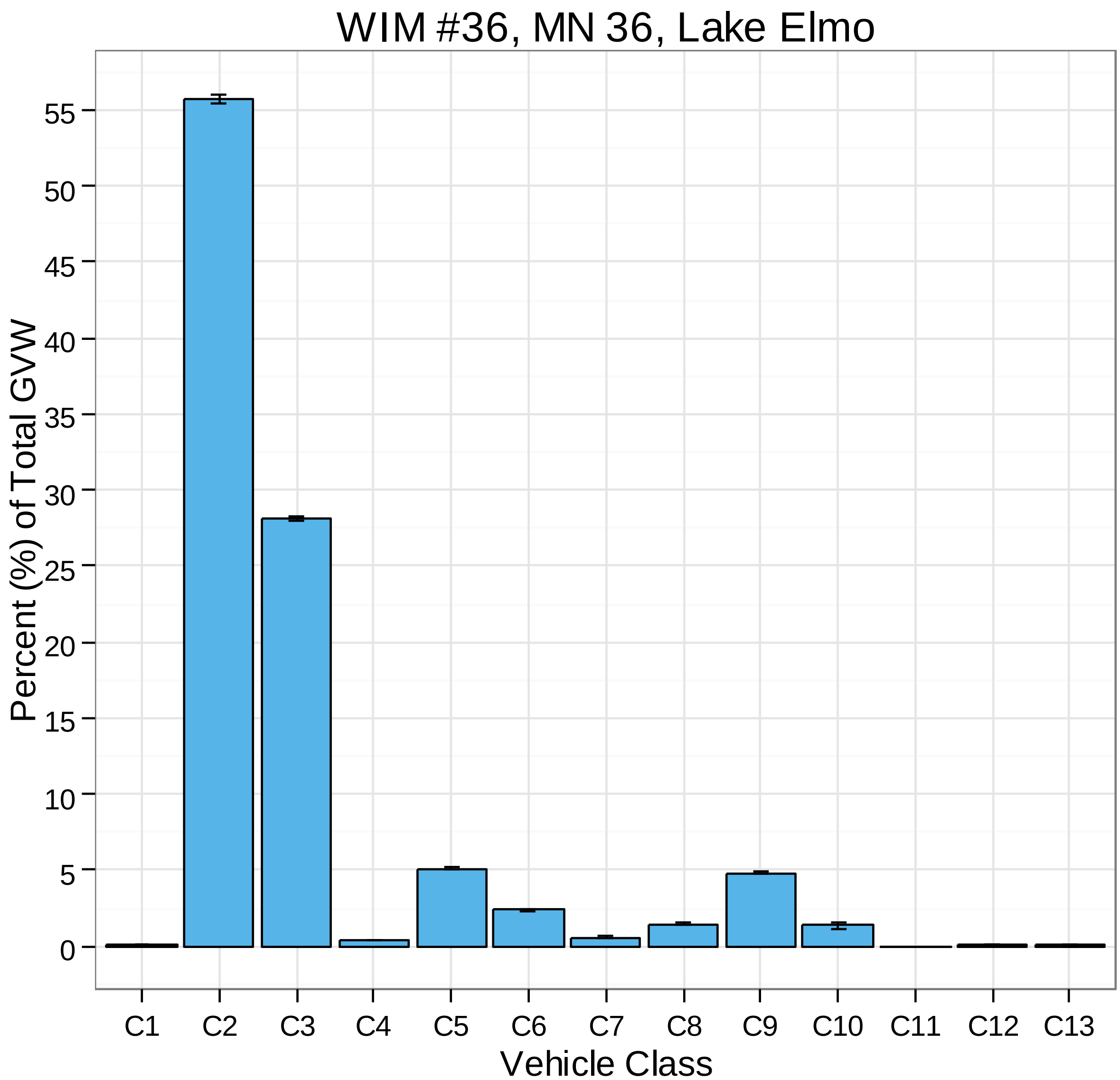


Figure 5.127. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

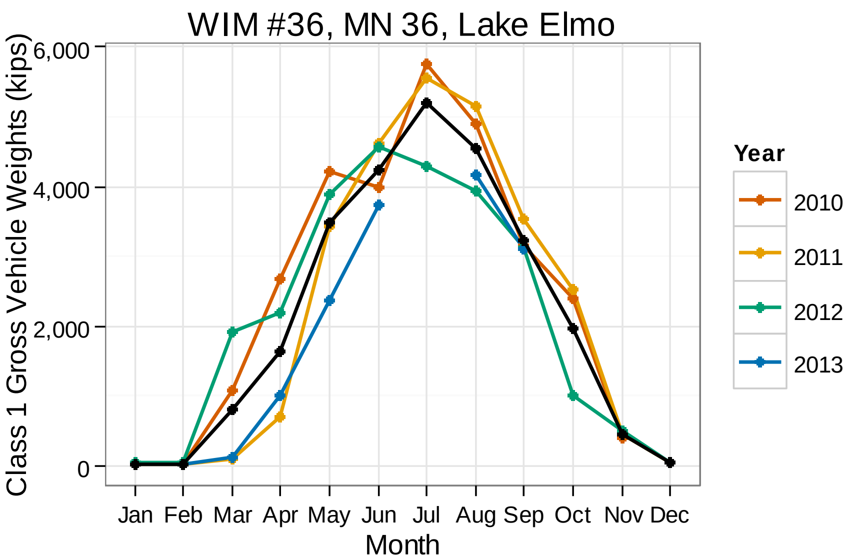


Figure 5.128a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

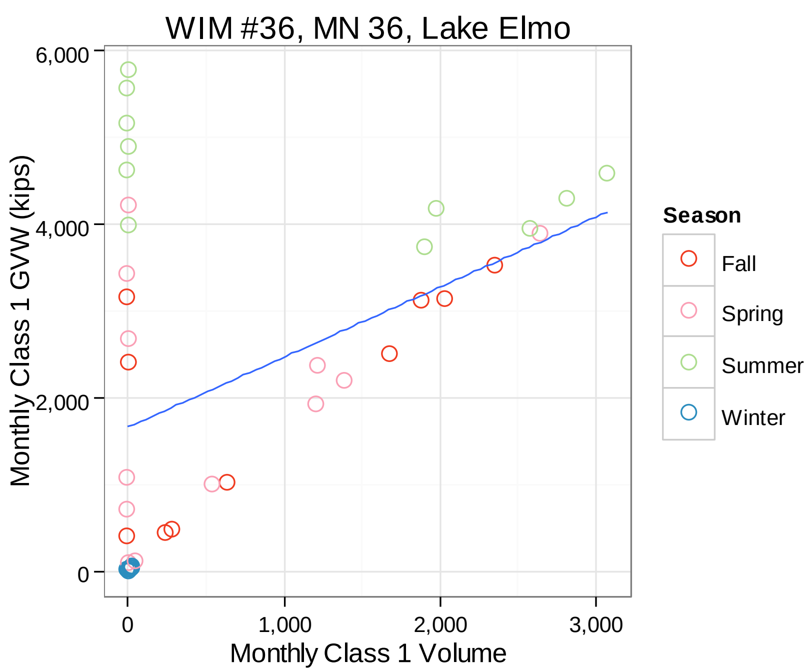


Figure 5.128b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

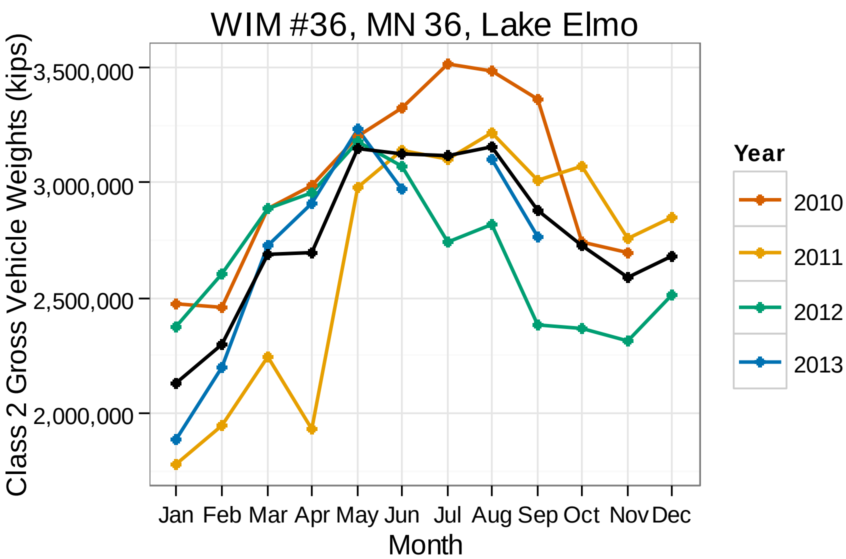


Figure 5.129a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

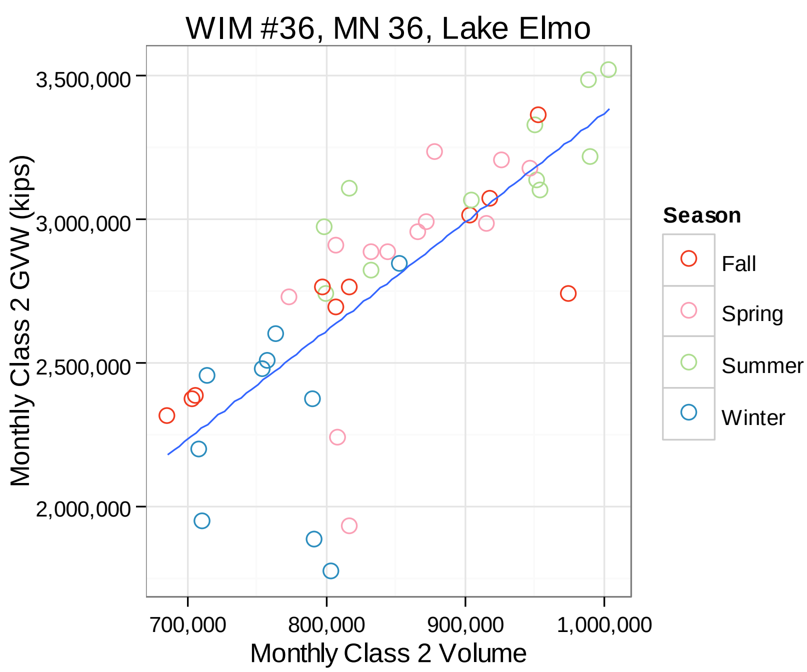


Figure 5.129b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

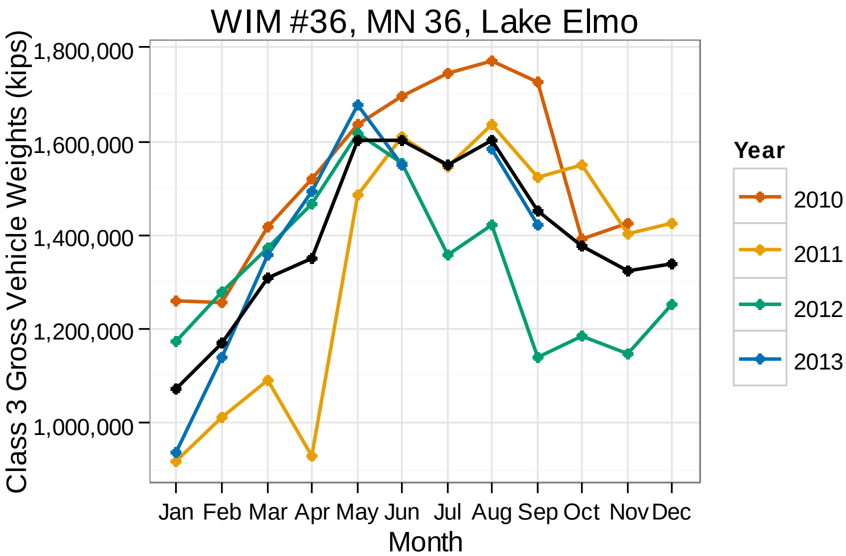


Figure 5.130a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

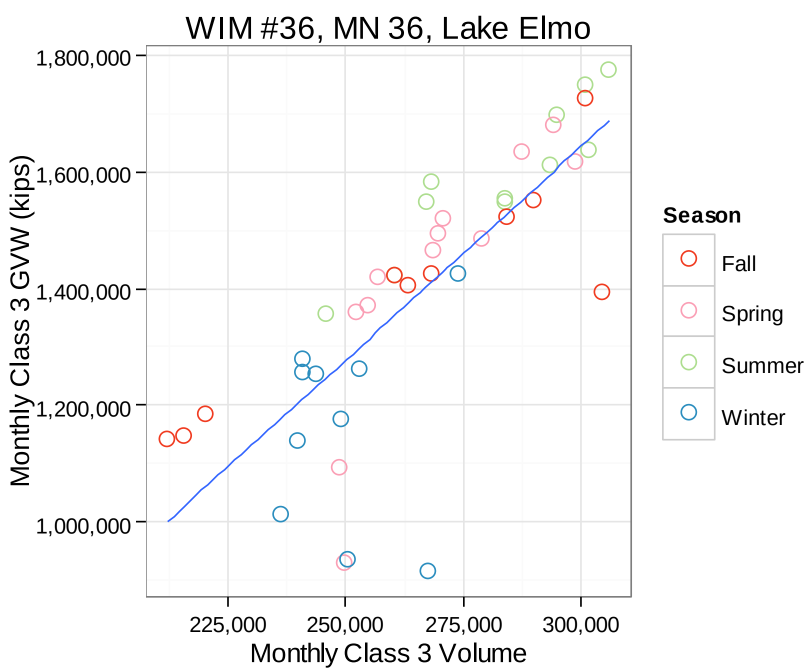


Figure 5.130b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

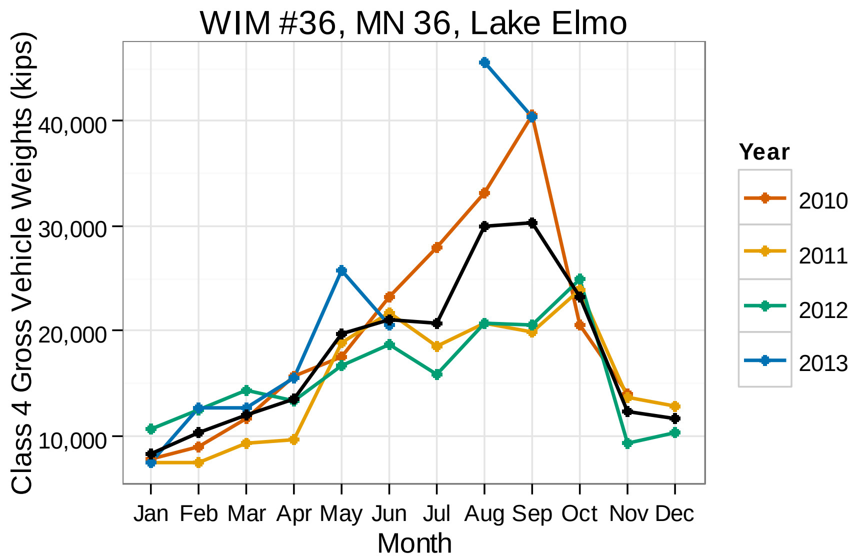


Figure 5.131a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

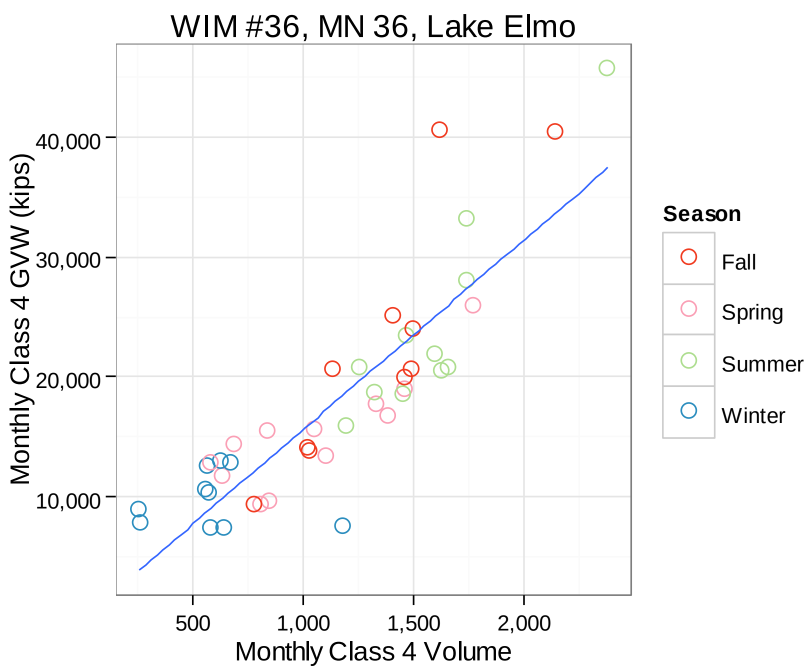


Figure 5.131b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

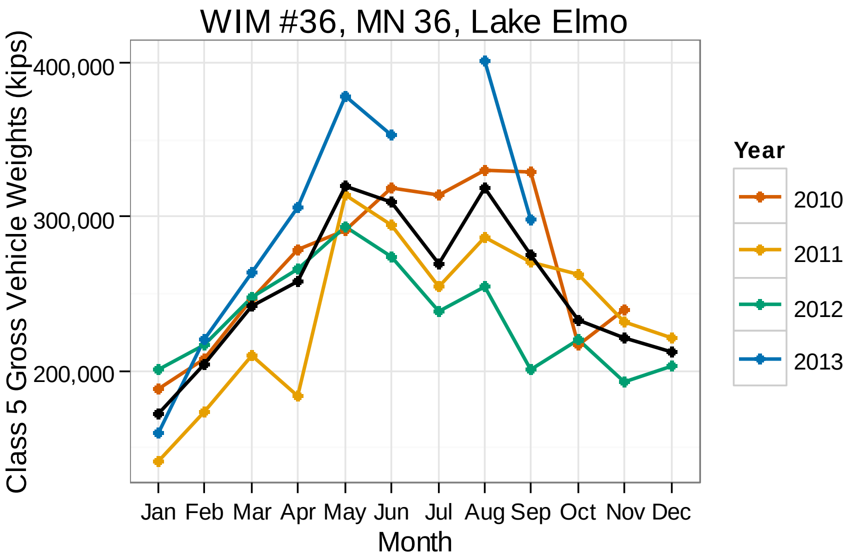


Figure 5.132a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

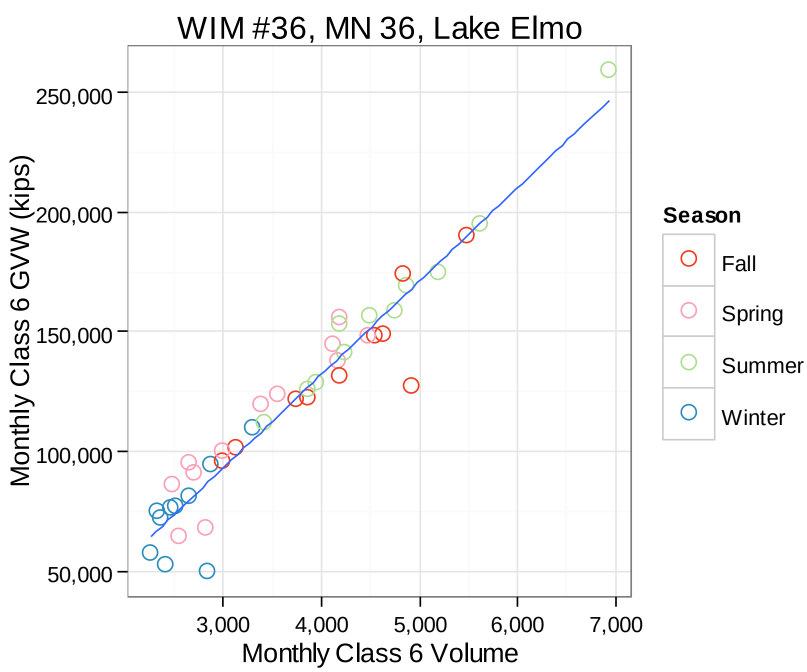


Figure 5.132b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

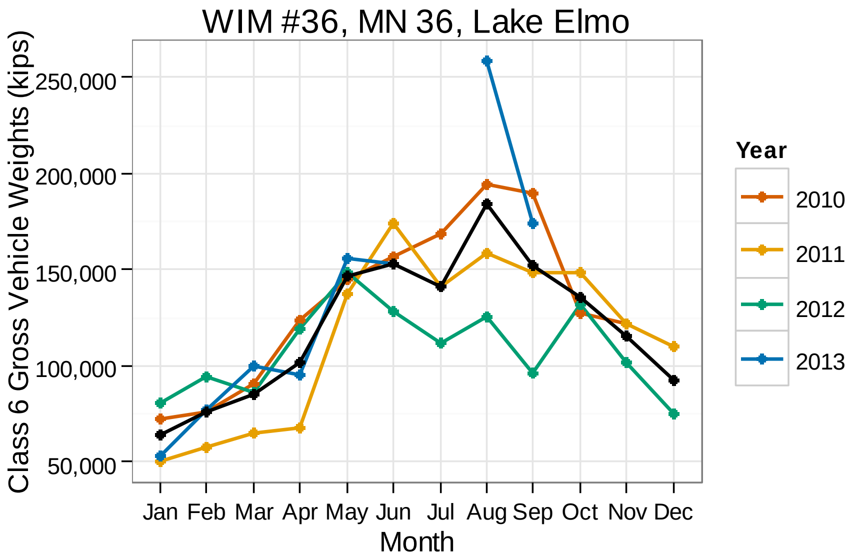


Figure 5.133a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

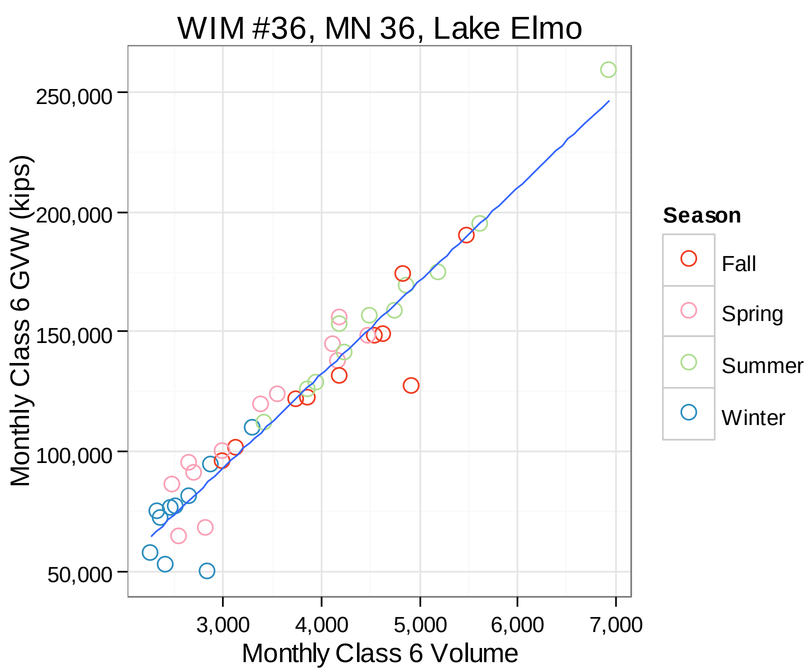


Figure 5.133b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

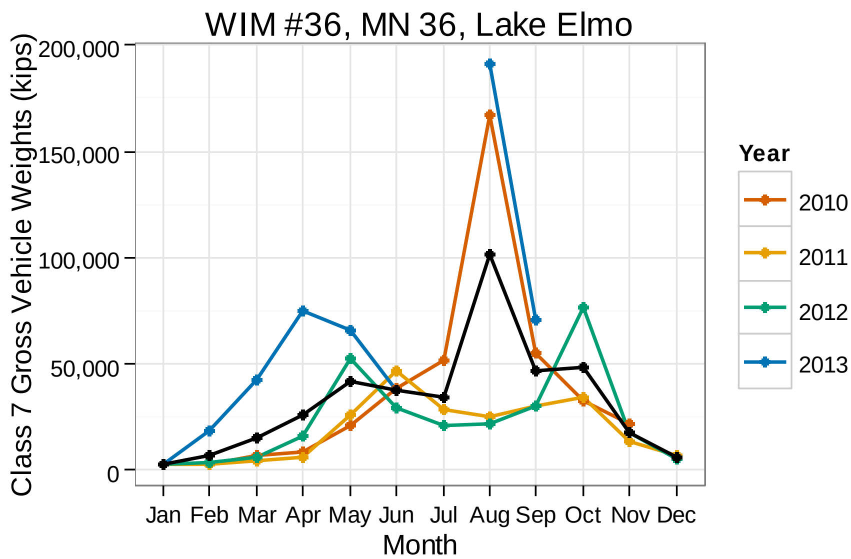


Figure 5.134a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

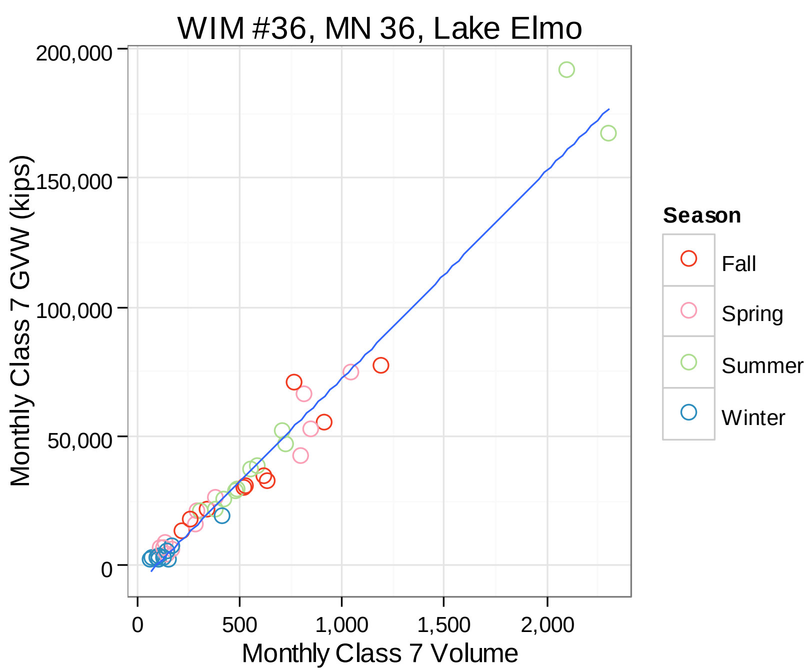


Figure 5.134b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

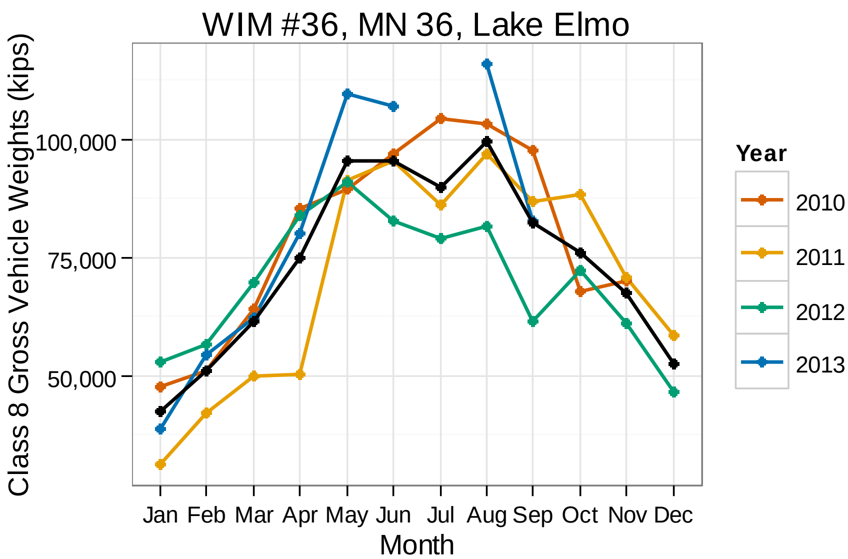


Figure 5.135a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

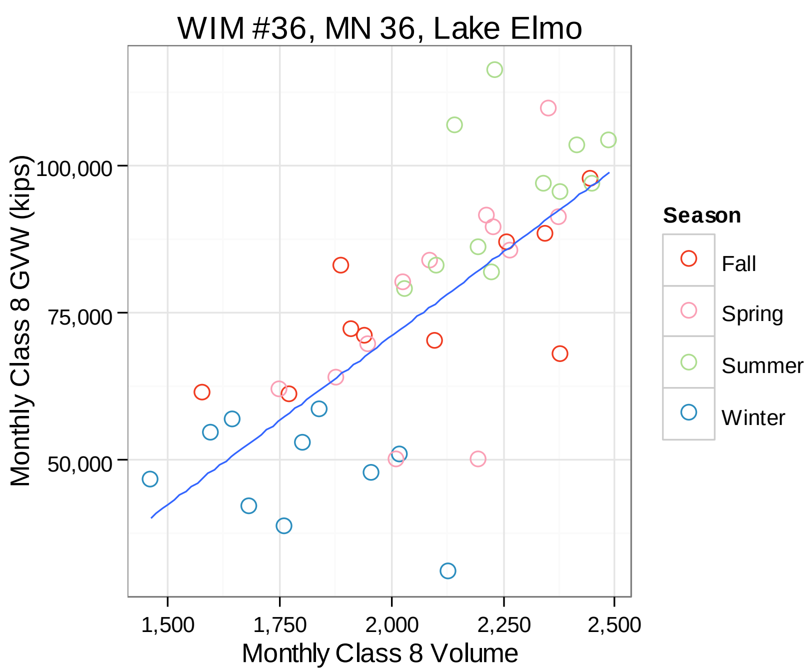


Figure 5.135b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

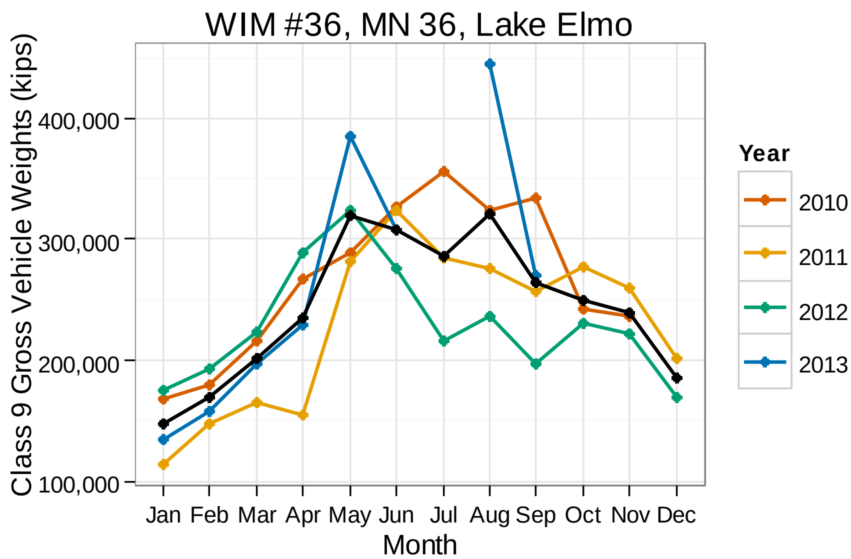


Figure 5.136a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

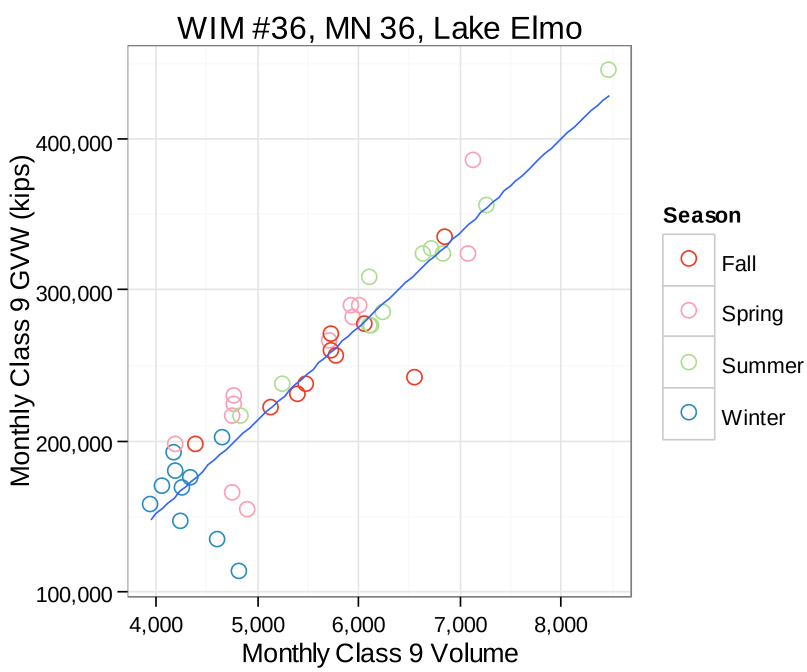


Figure 5.136b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

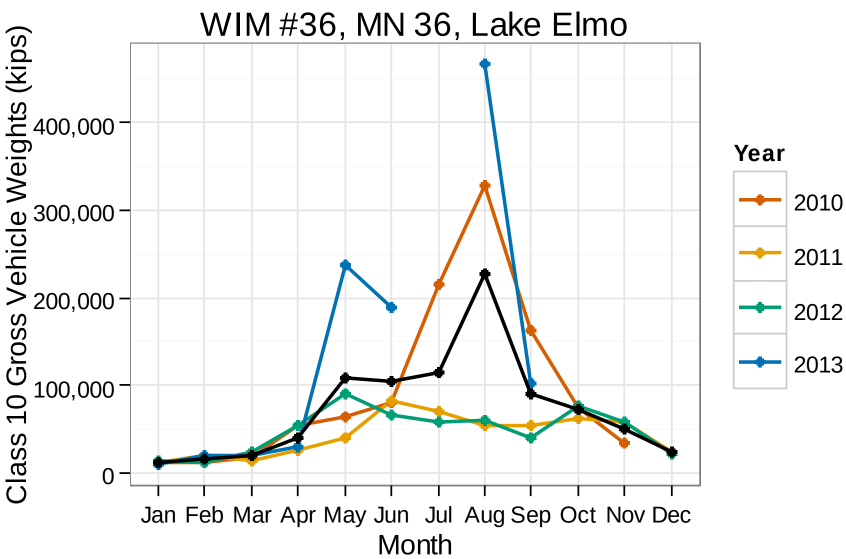


Figure 5.137a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

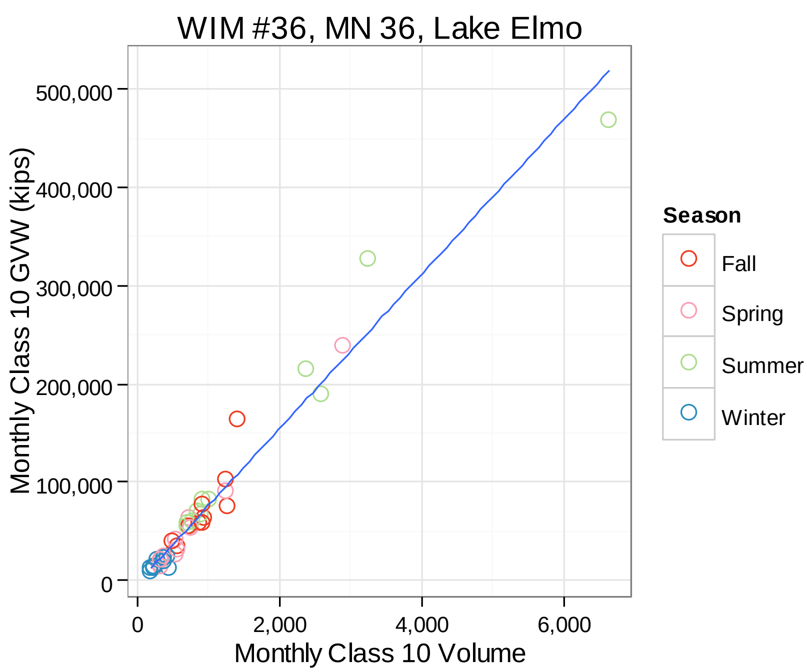


Figure 5.137b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

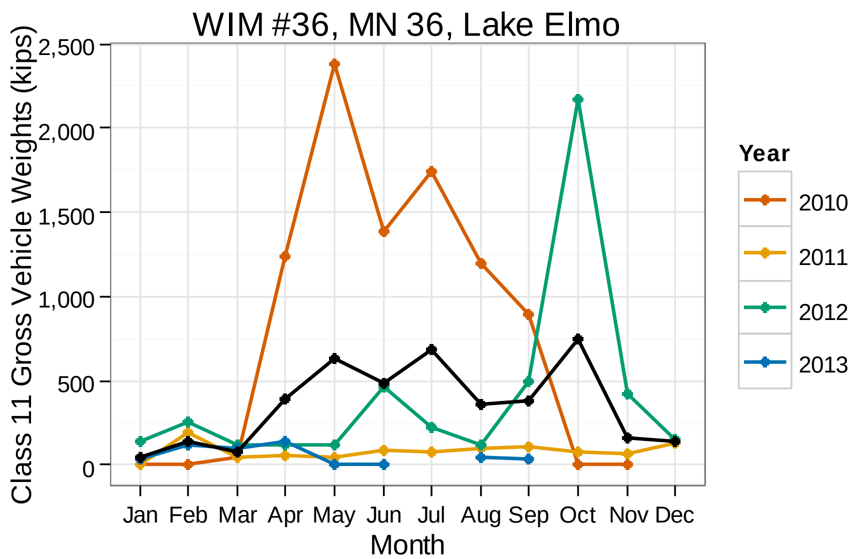


Figure 5.138a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

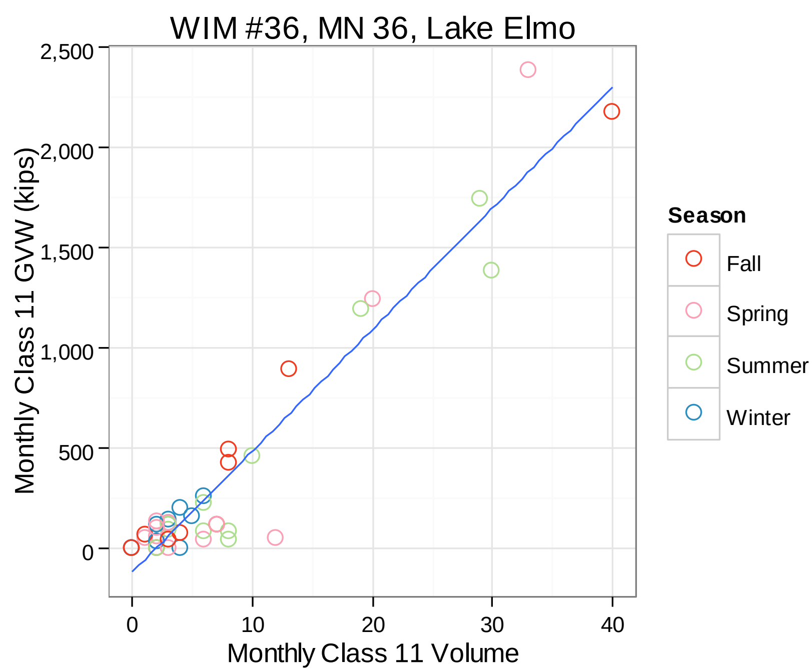


Figure 5.138b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

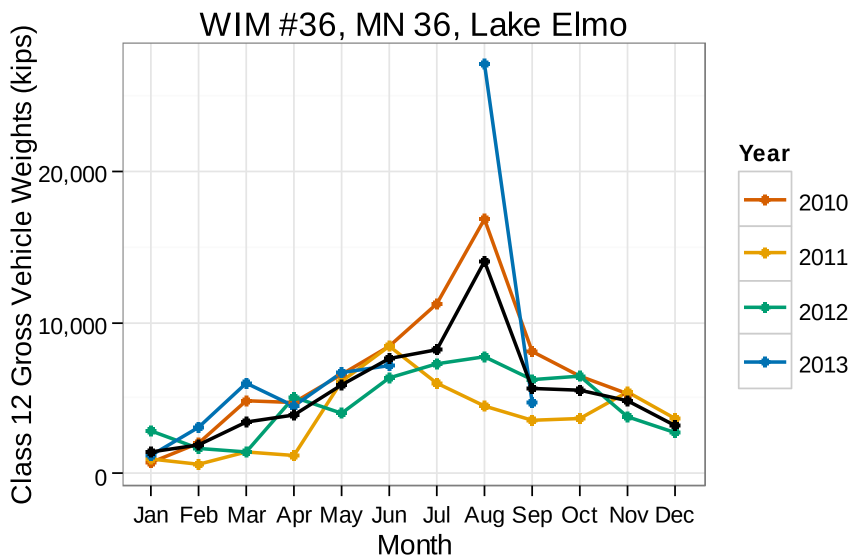


Figure 5.139a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

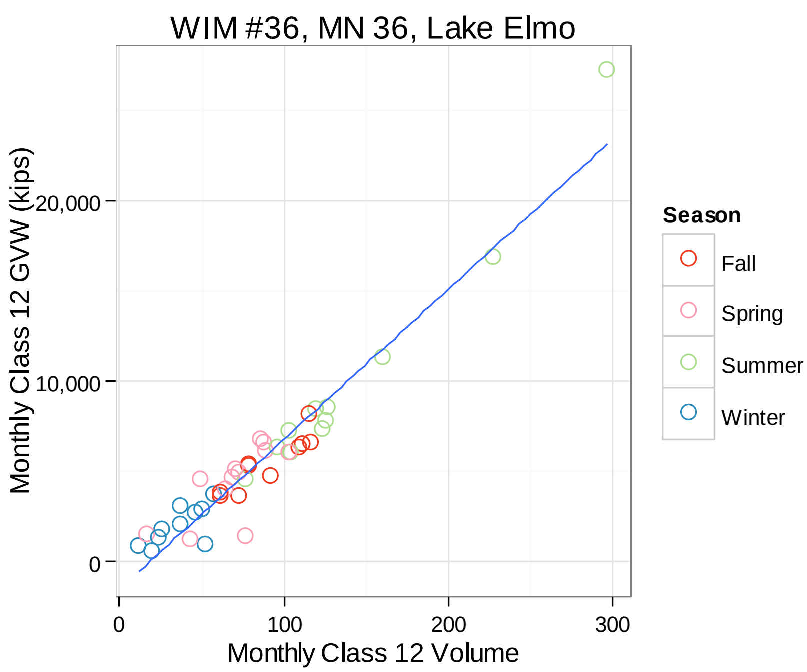


Figure 5.139b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

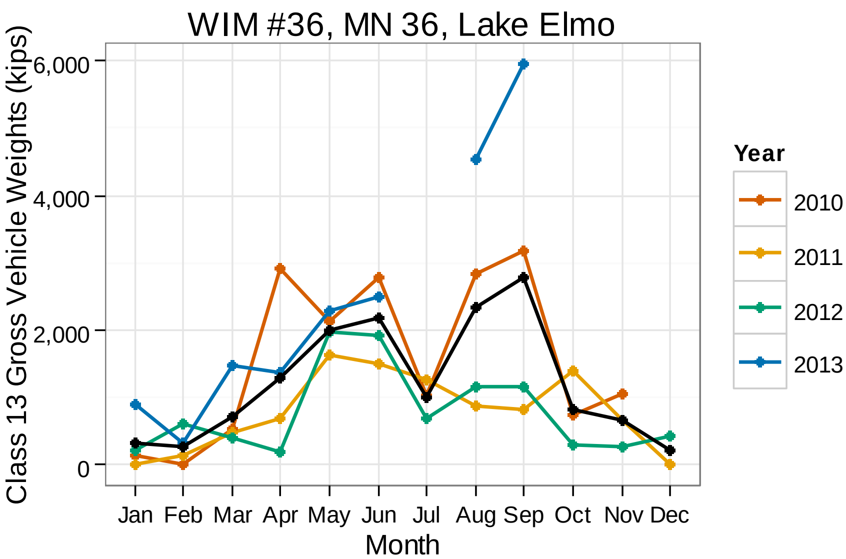


Figure 5.140a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

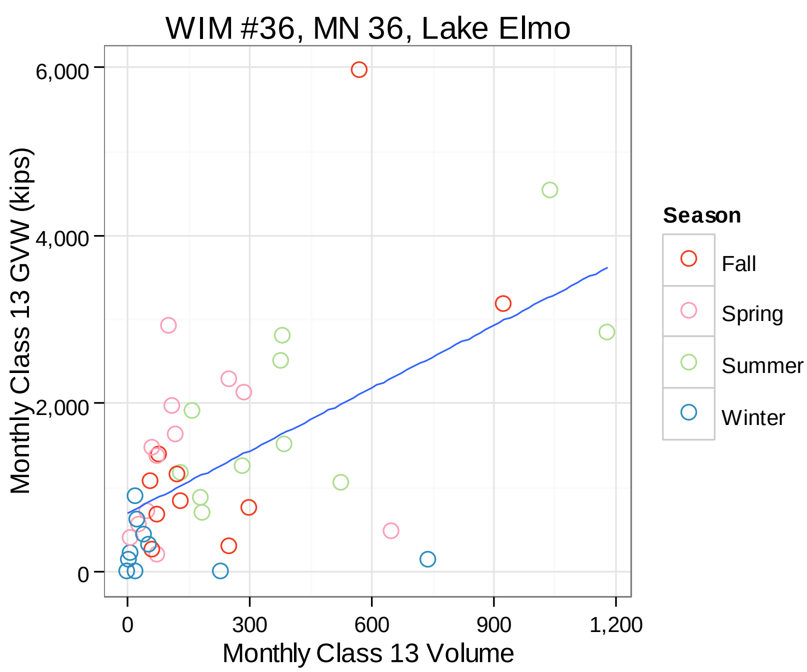


Figure 5.140b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

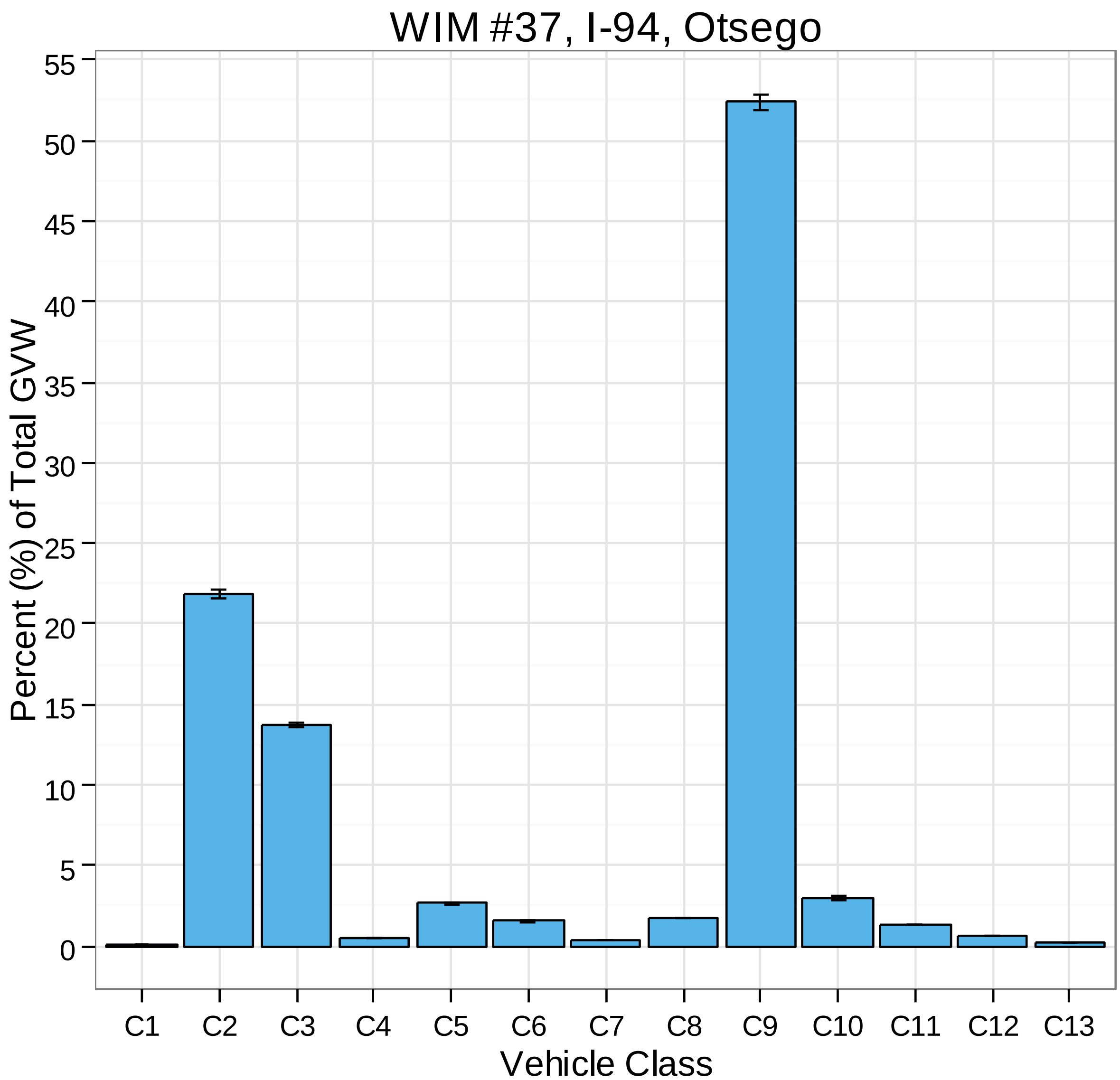


Figure 5.141. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

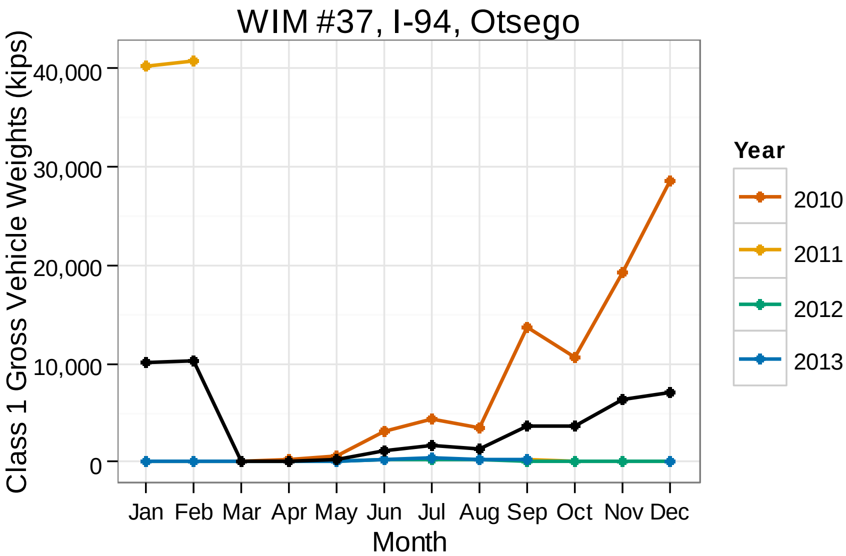


Figure 5.142a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

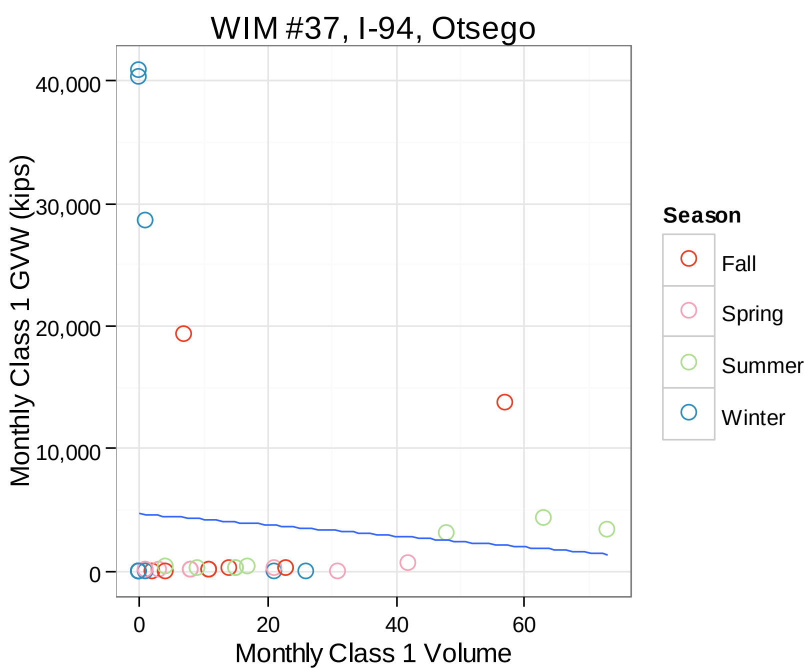


Figure 5.142b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

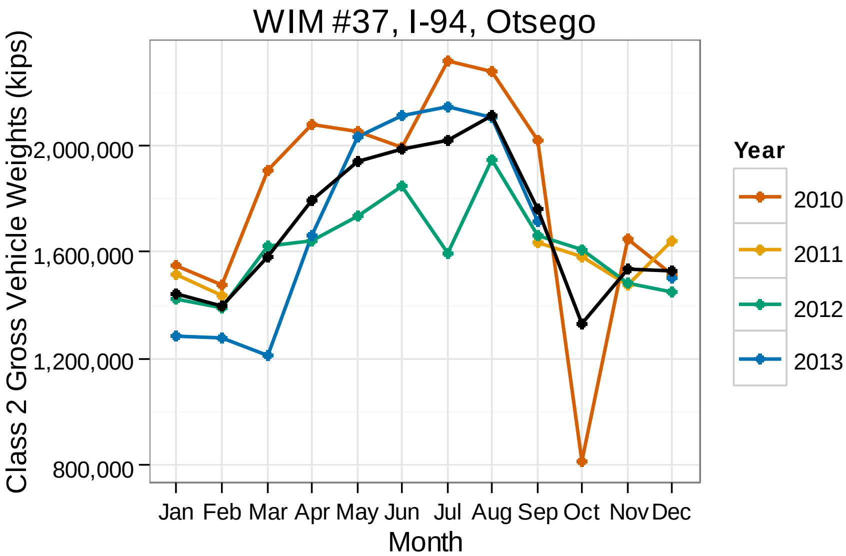


Figure 5.143a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

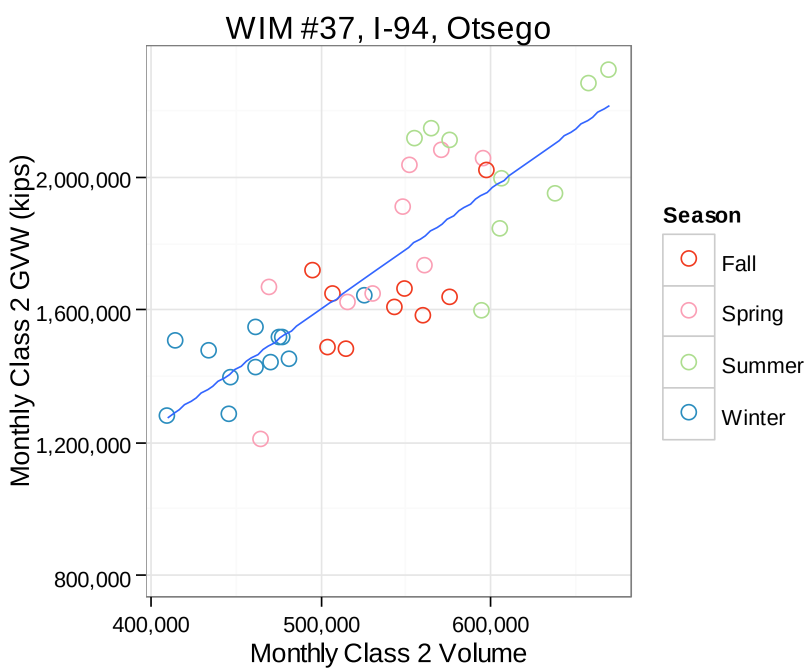


Figure 5.143b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

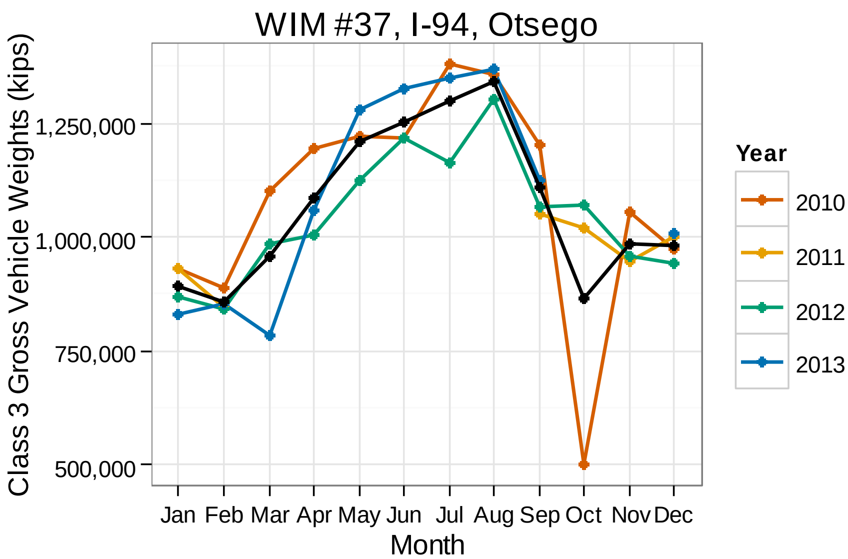


Figure 5.144a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

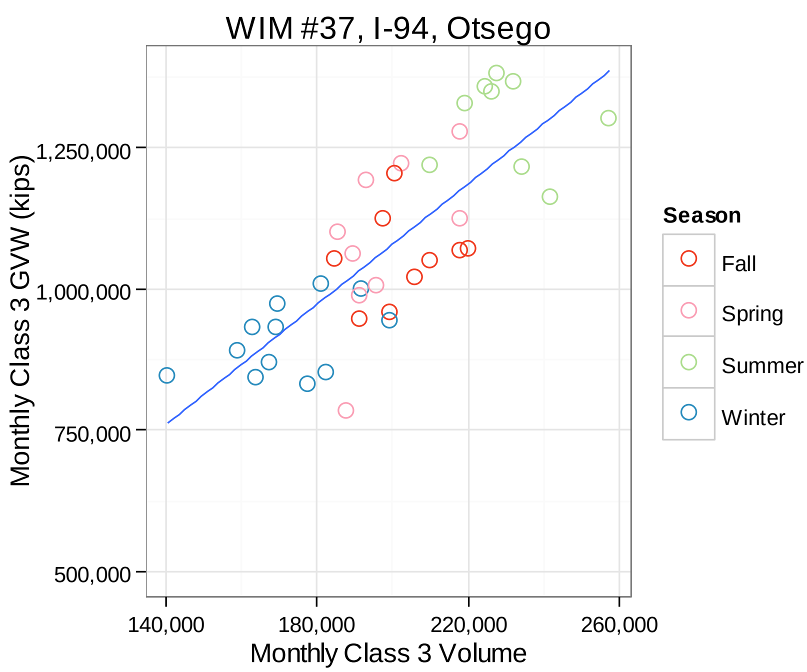


Figure 5.144b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

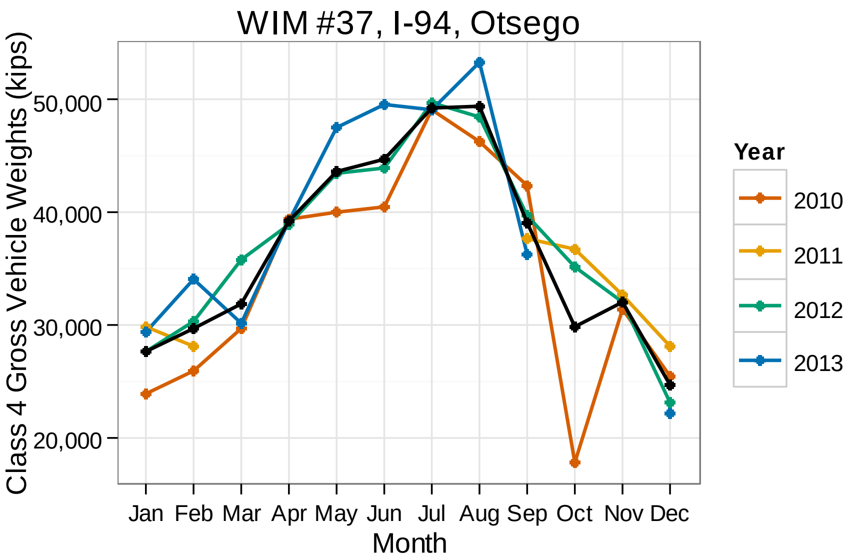


Figure 5.145a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

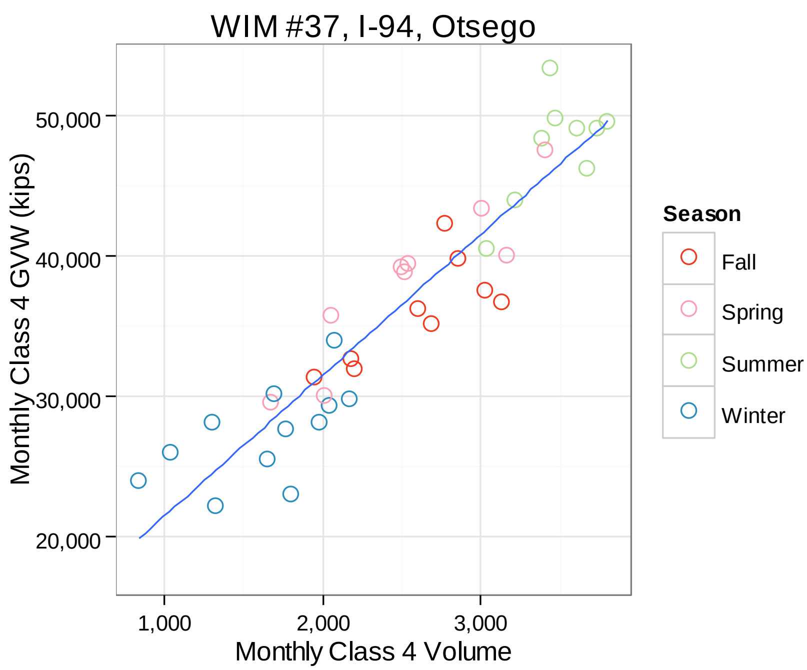


Figure 5.145b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

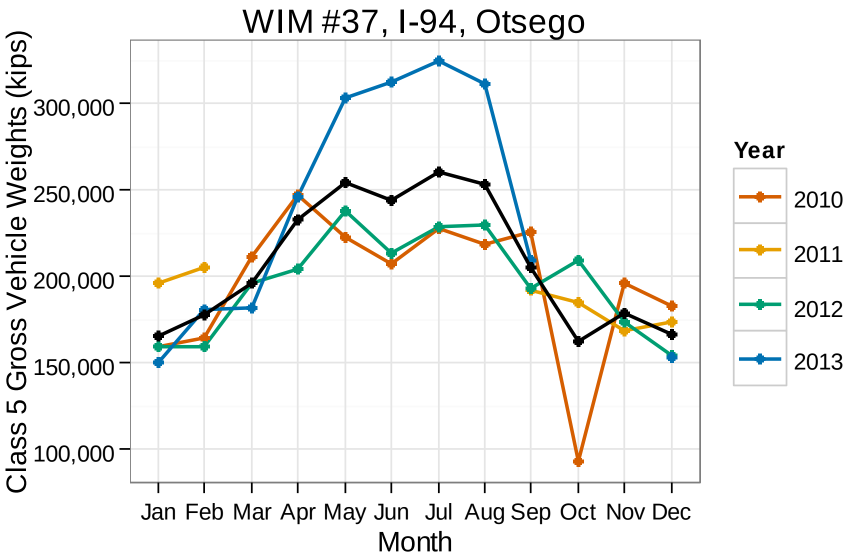


Figure 5.146a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

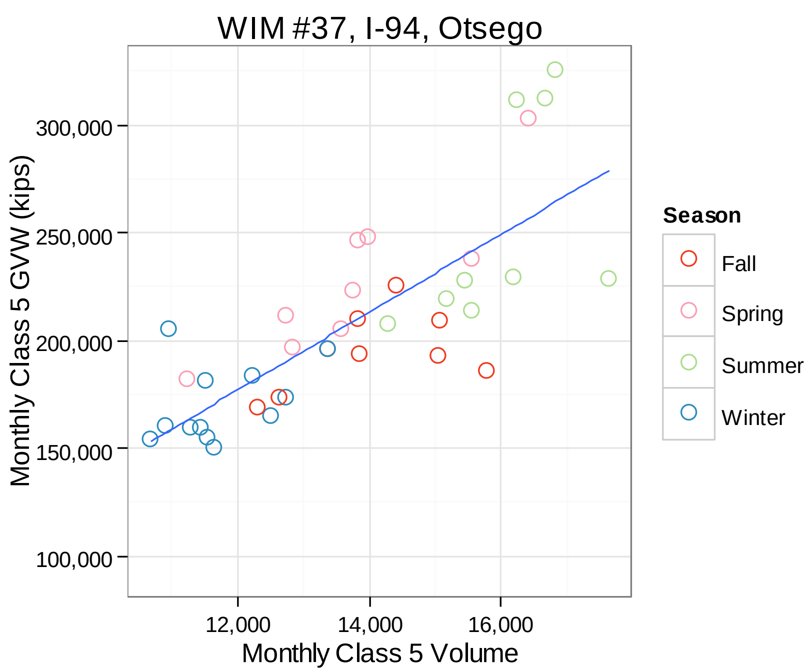


Figure 5.146b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

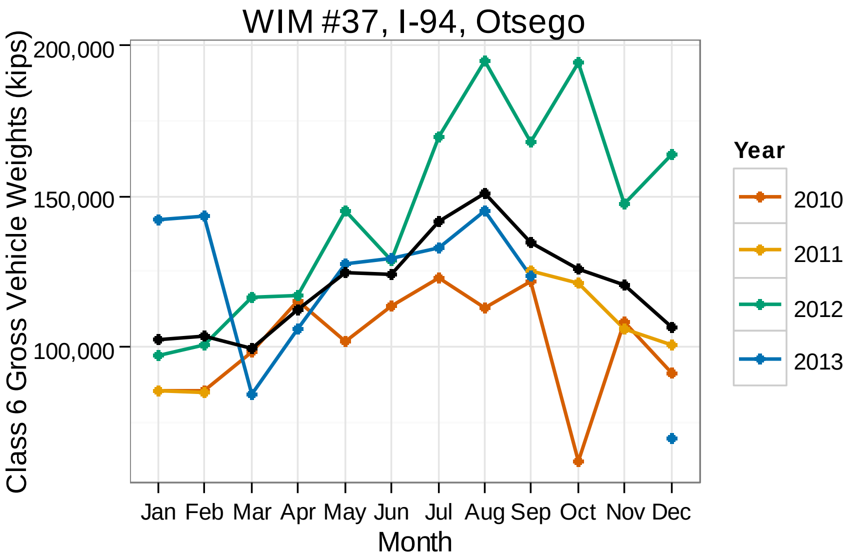


Figure 5.147a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

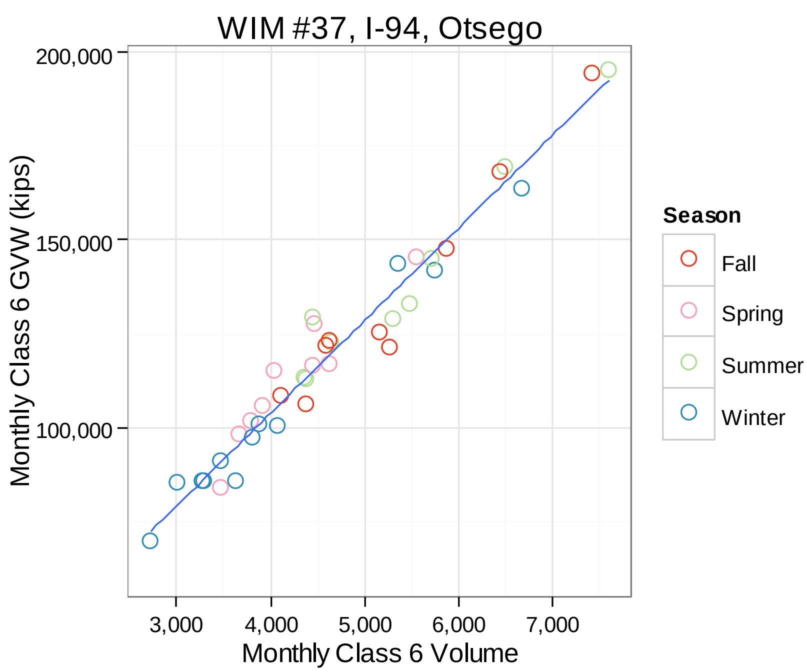


Figure 5.147b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

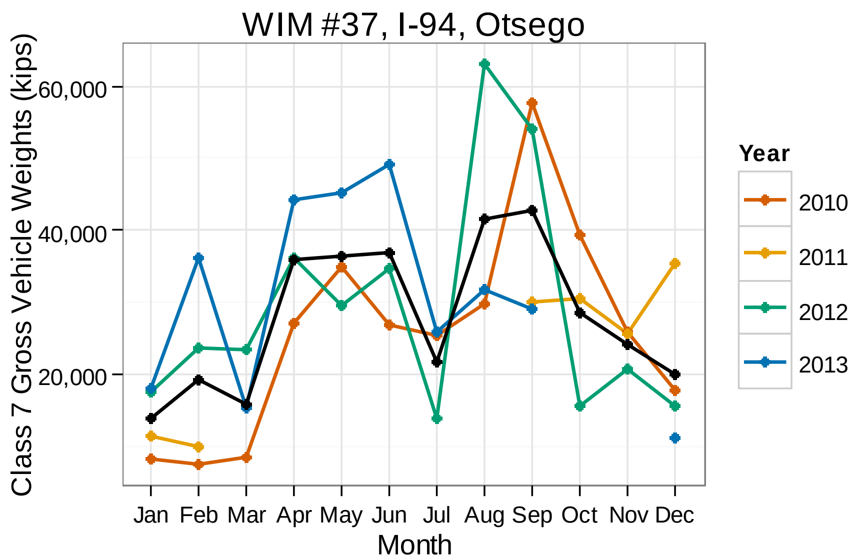


Figure 5.148a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

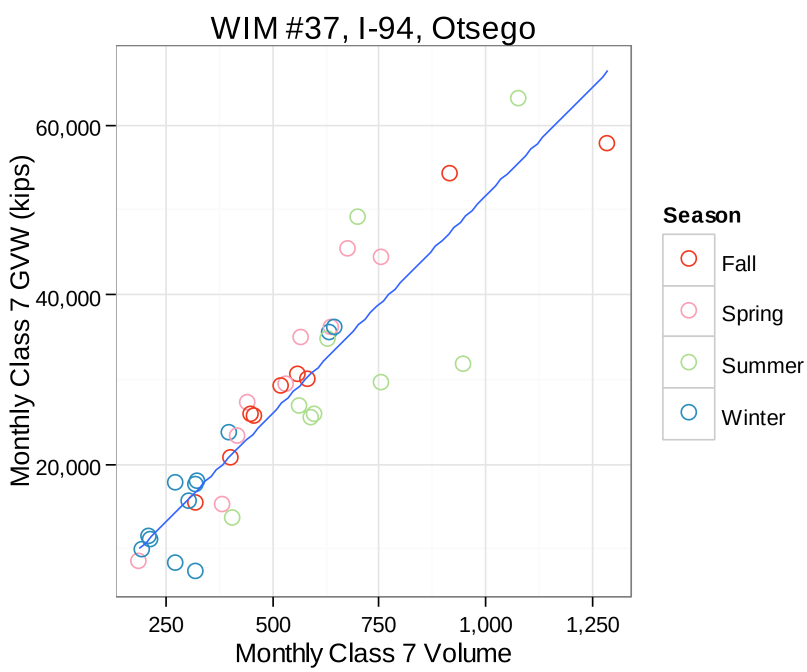


Figure 5.148b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

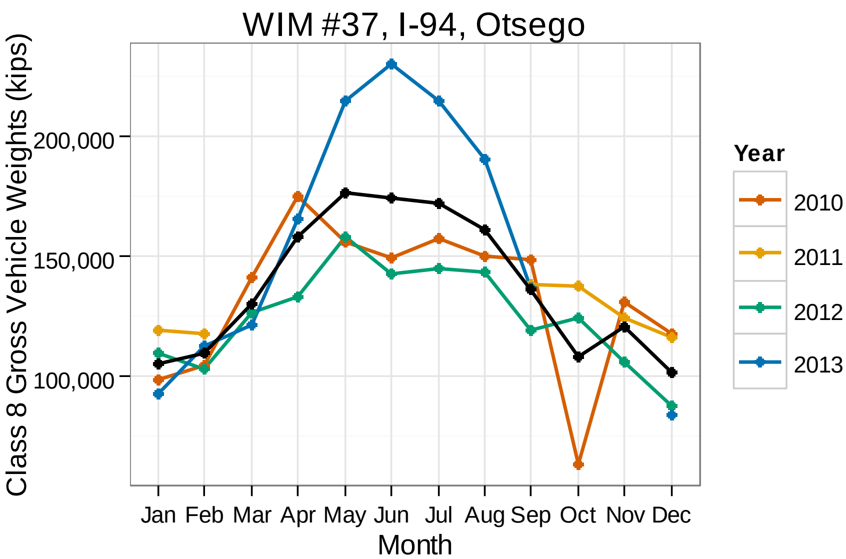


Figure 5.149a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

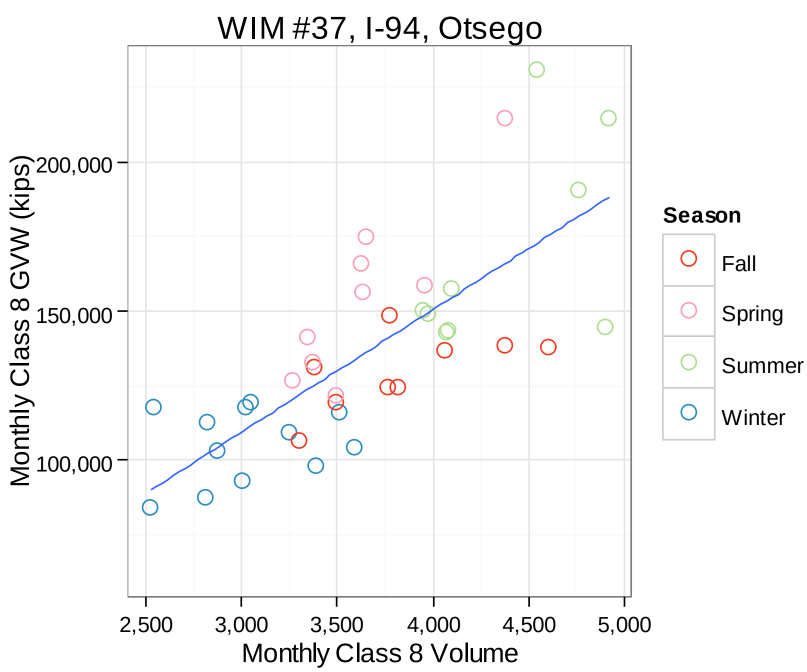


Figure 5.149b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

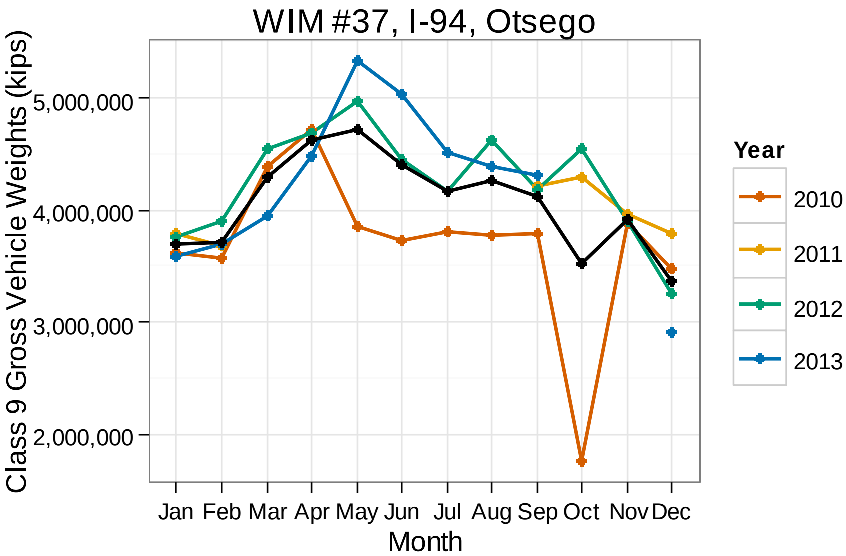


Figure 5.150a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

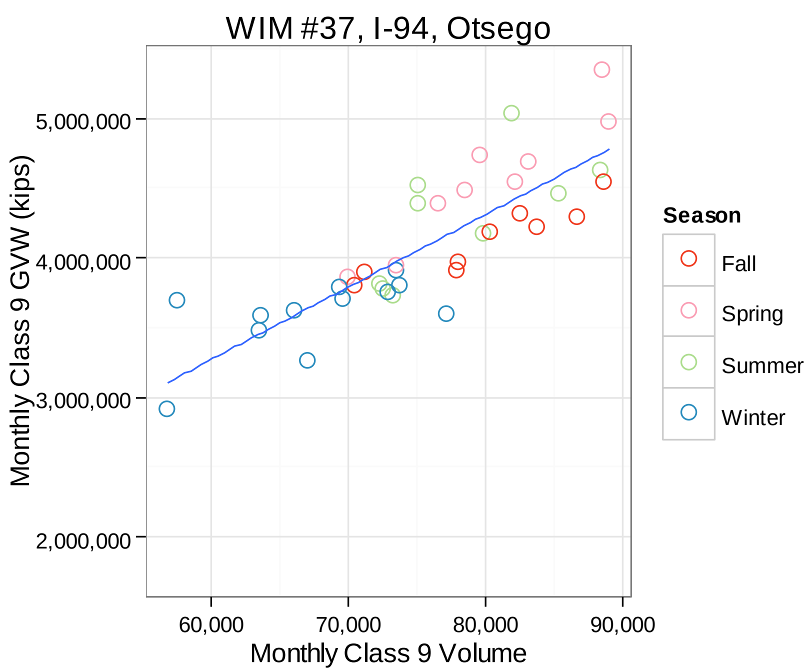


Figure 5.150b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

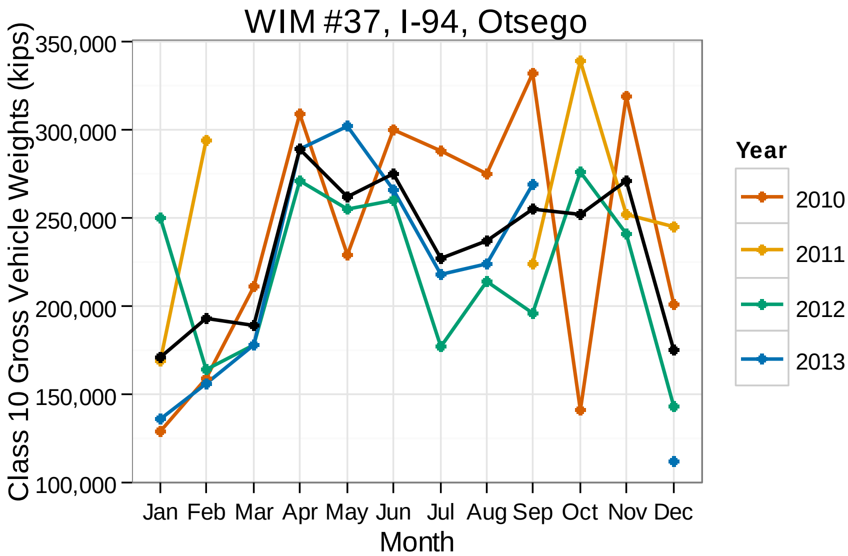


Figure 5.151a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

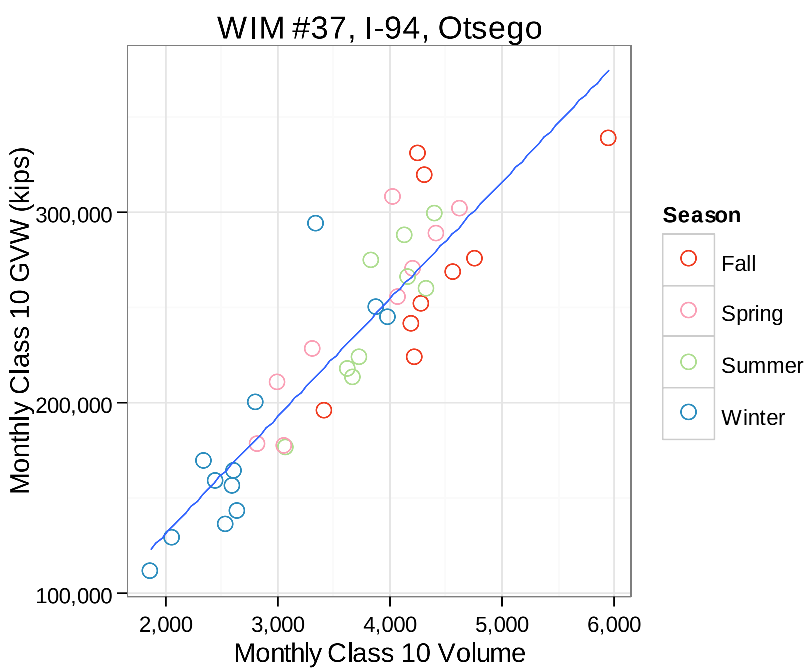


Figure 5.151b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

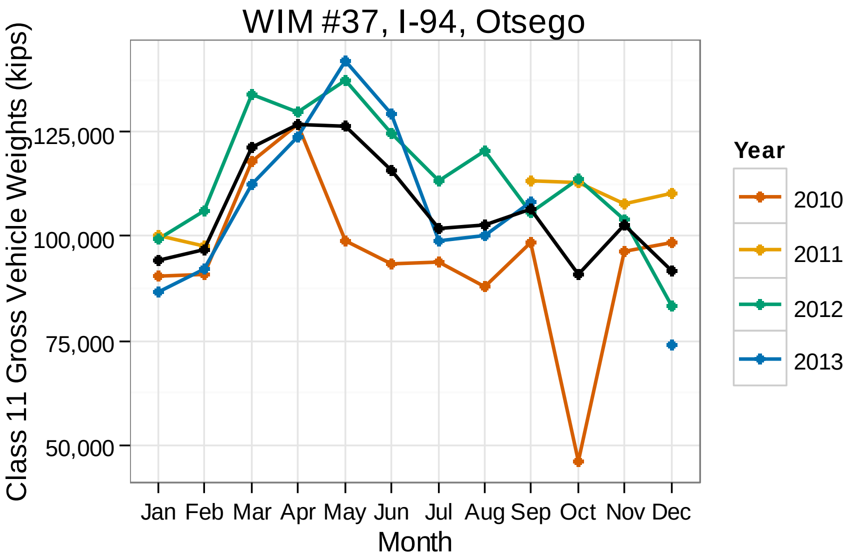


Figure 5.152a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

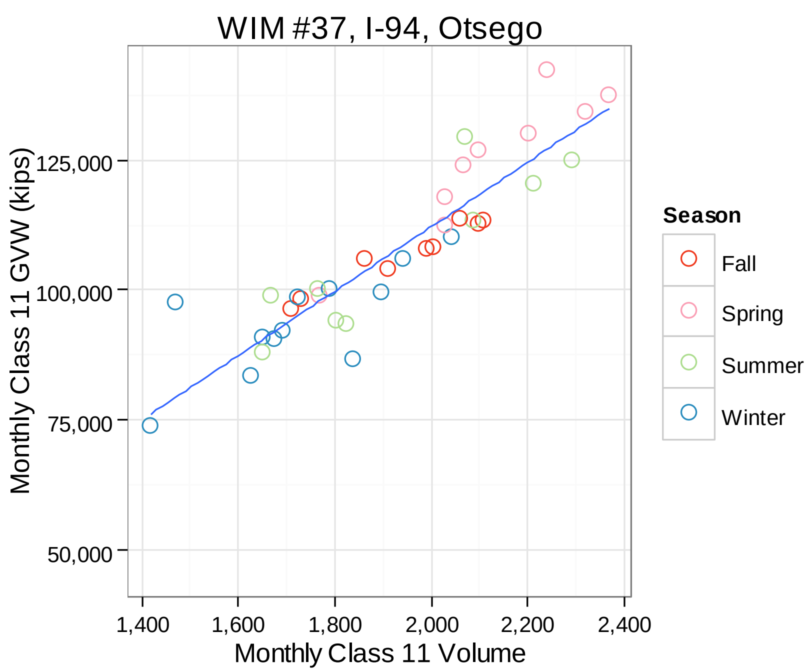


Figure 5.152b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

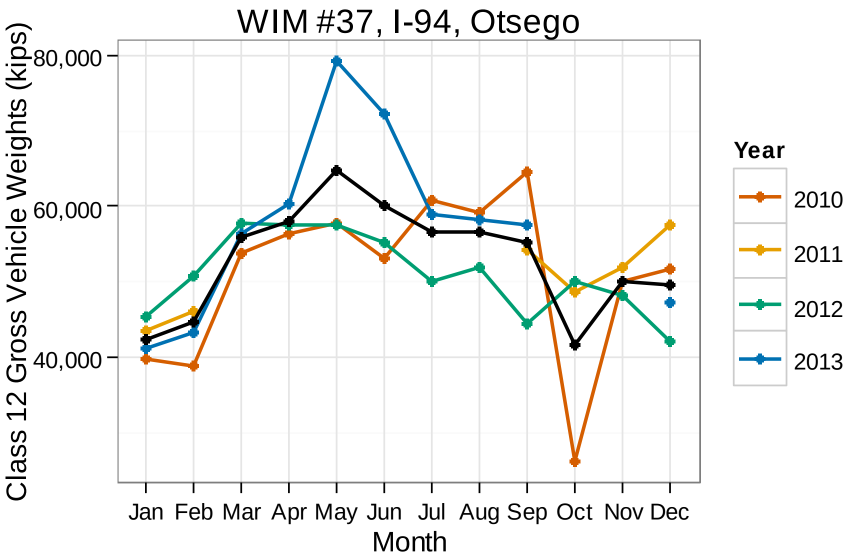


Figure 5.153a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

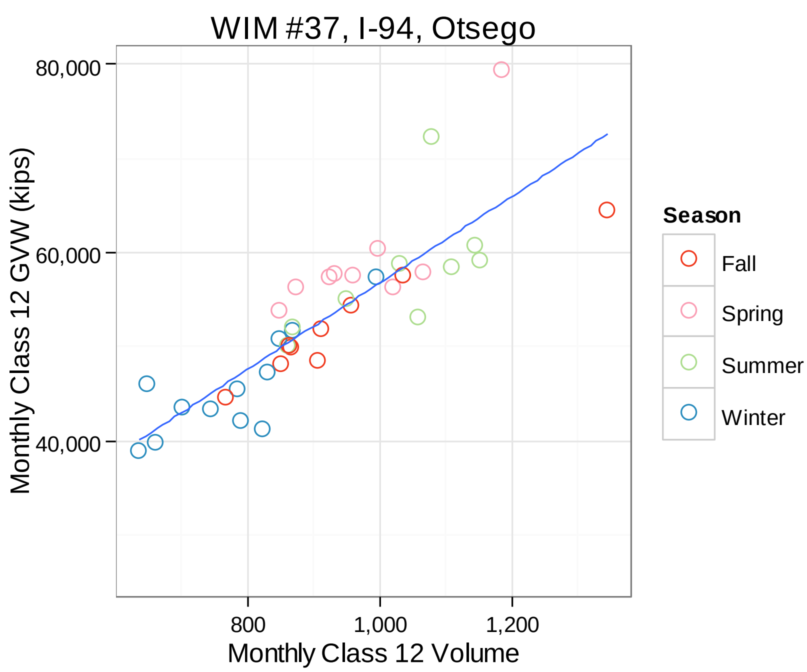


Figure 5.153b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

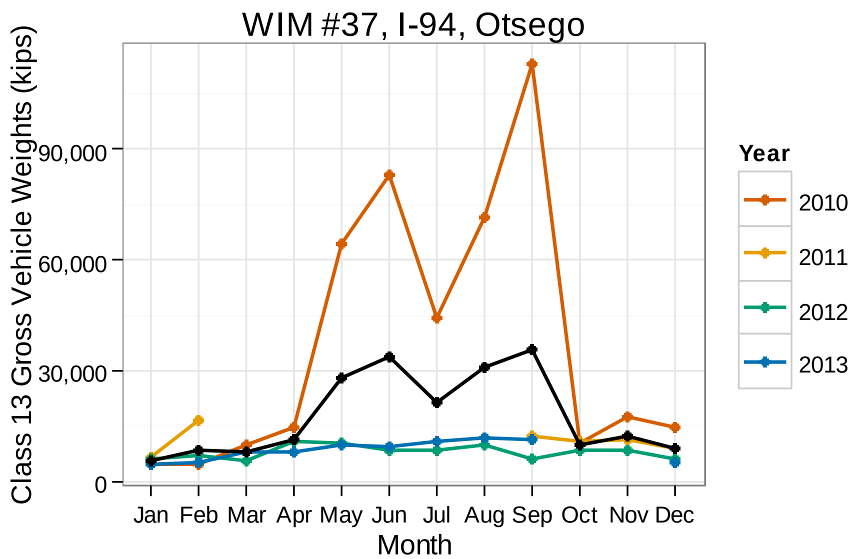


Figure 5.154a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

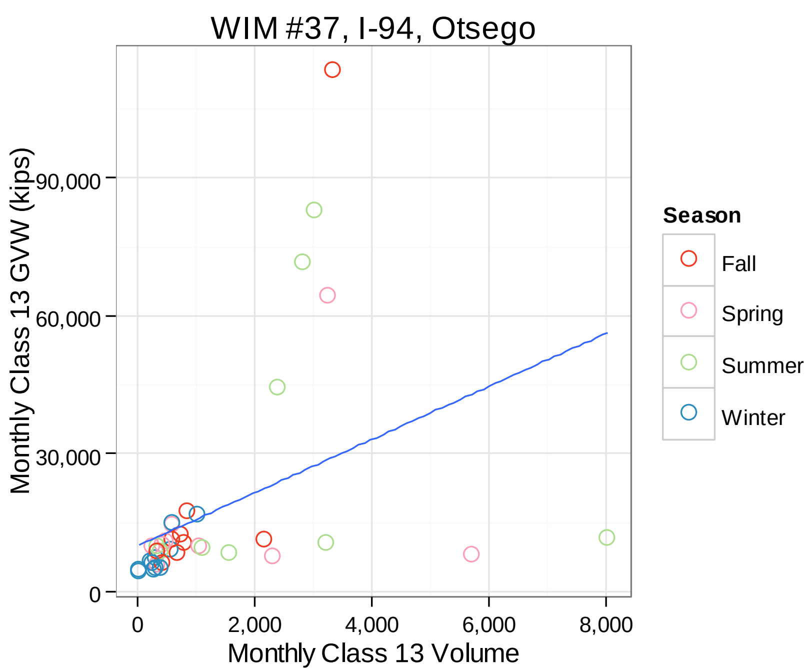


Figure 5.154b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

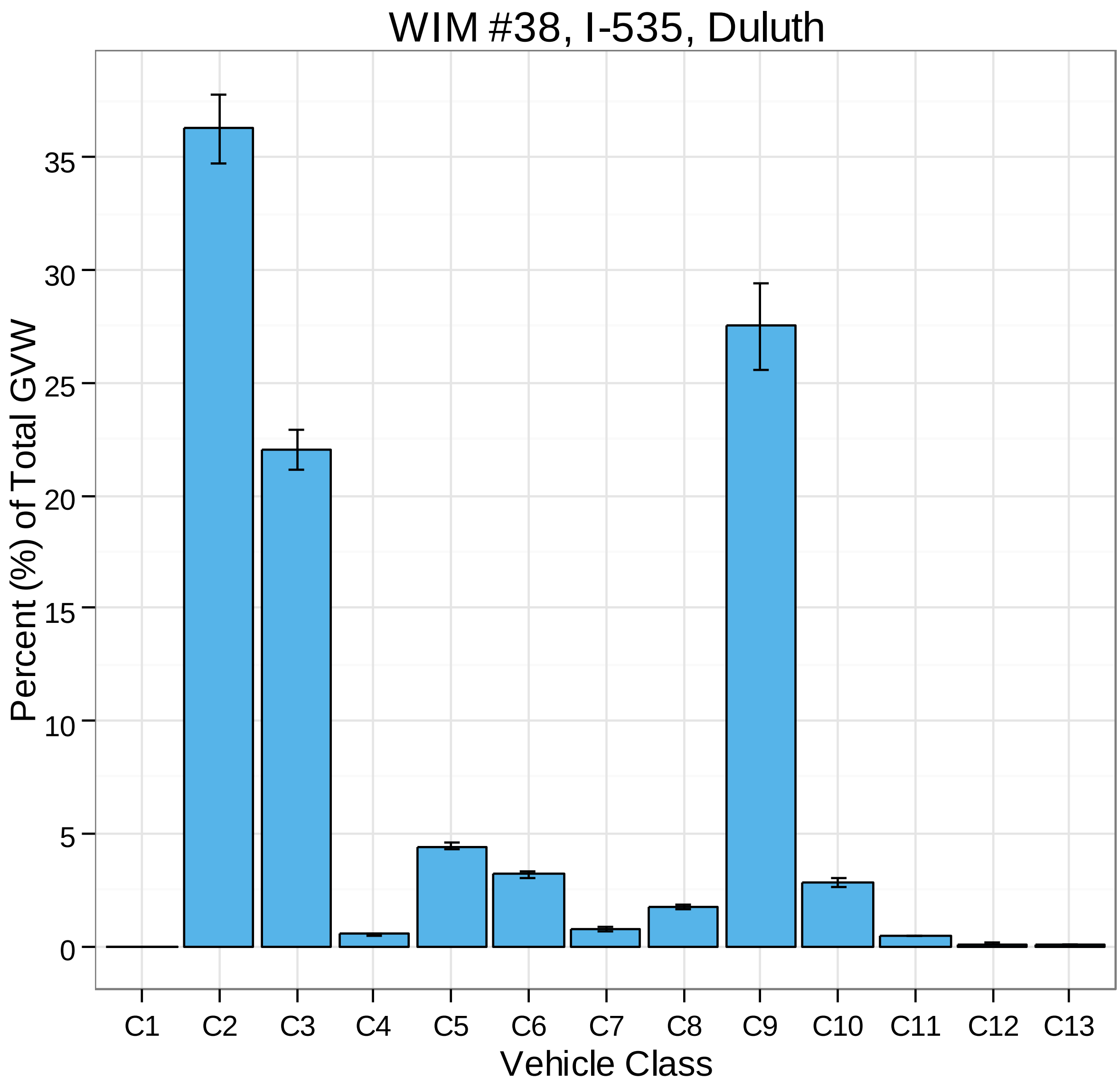


Figure 5.155. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

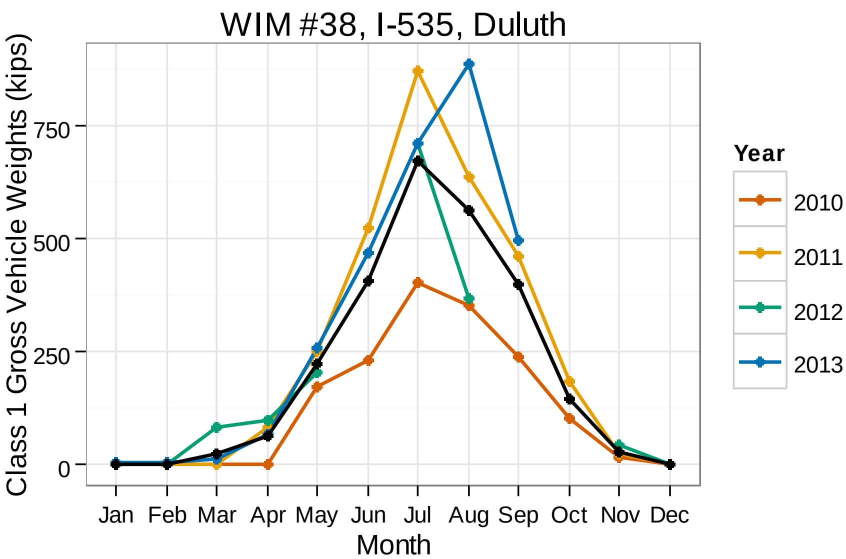


Figure 5.156a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

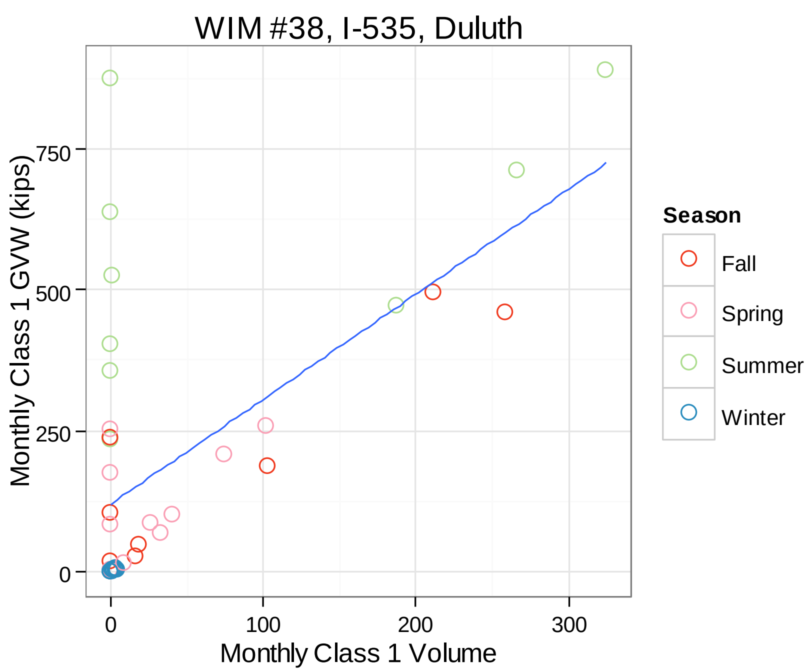


Figure 5.156b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

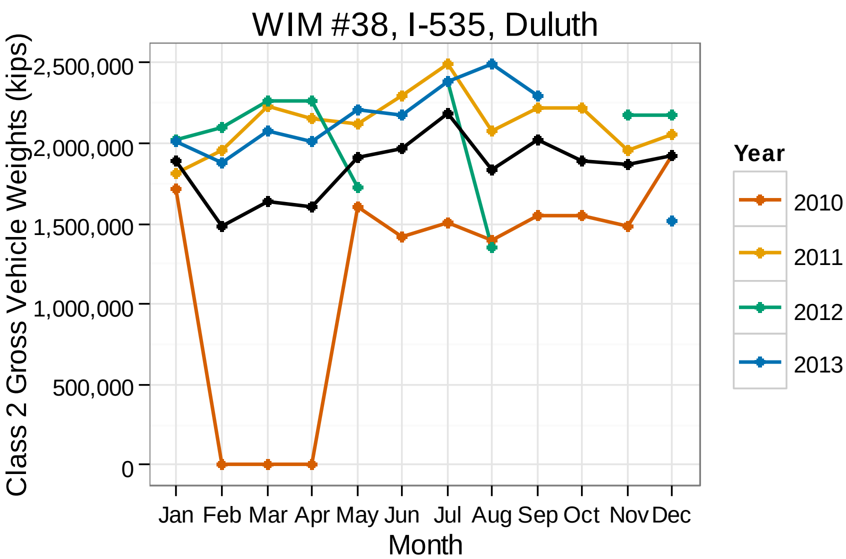


Figure 5.157a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

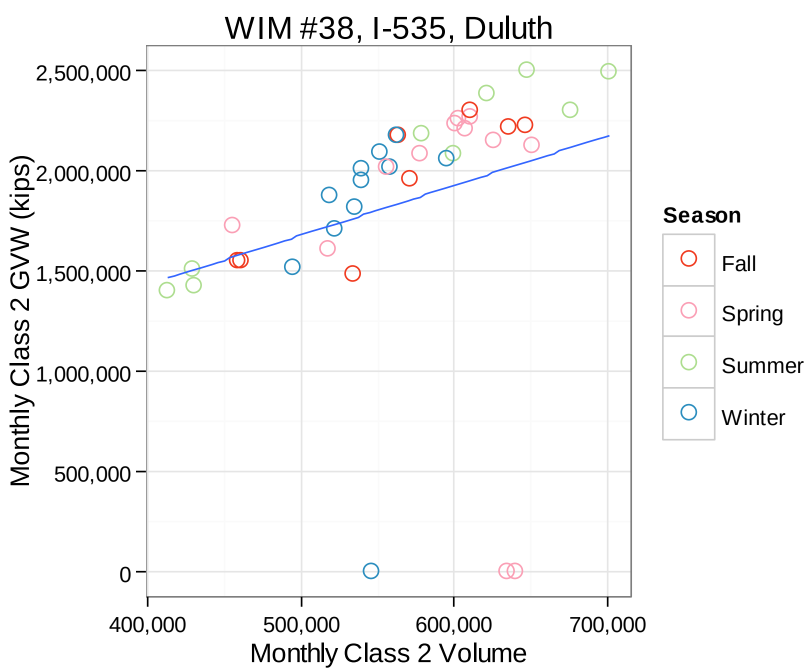


Figure 5.157b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

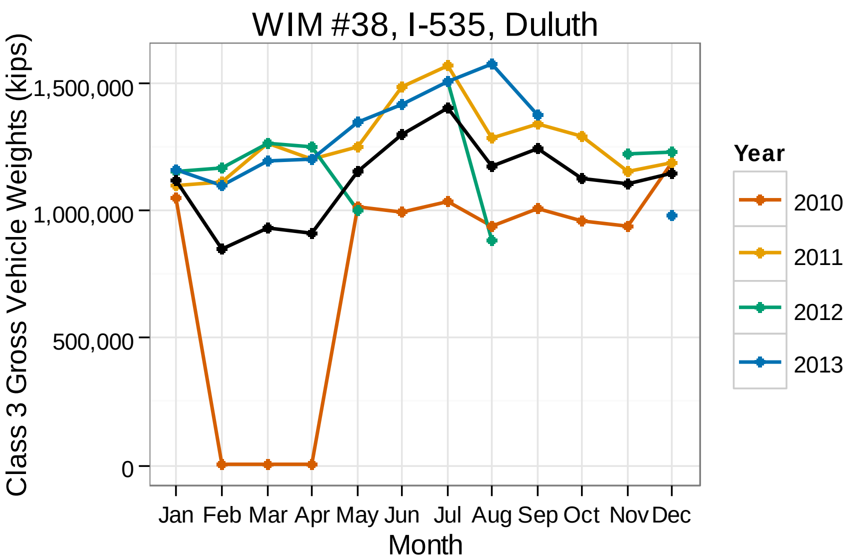


Figure 5.158a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

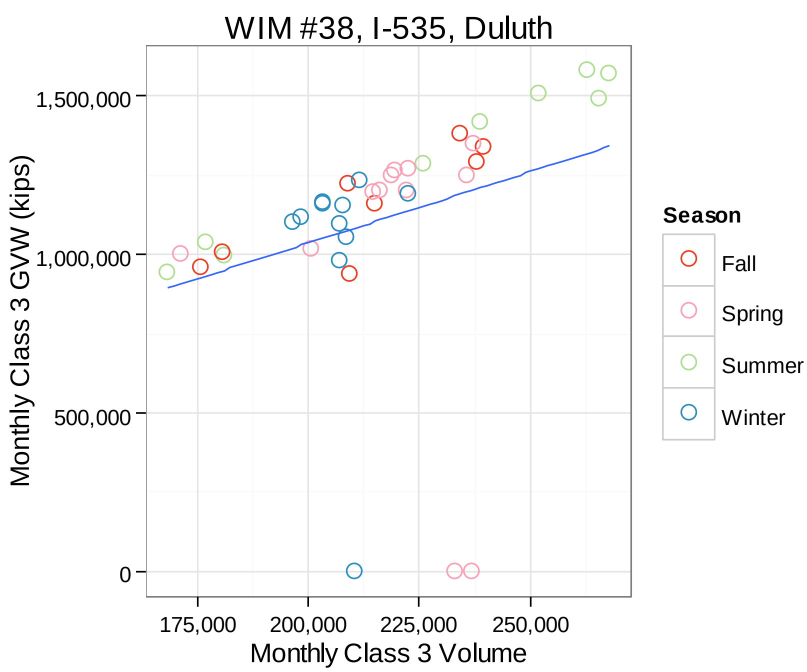


Figure 5.158b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

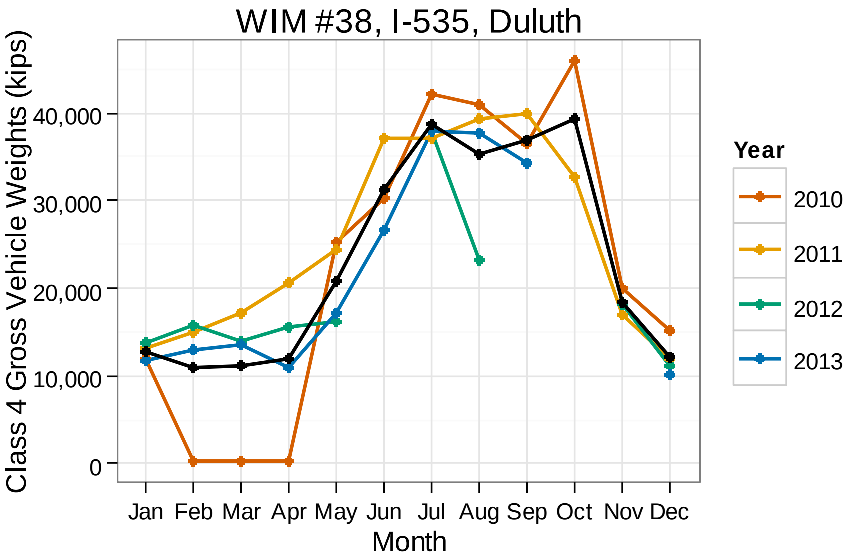


Figure 5.159a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

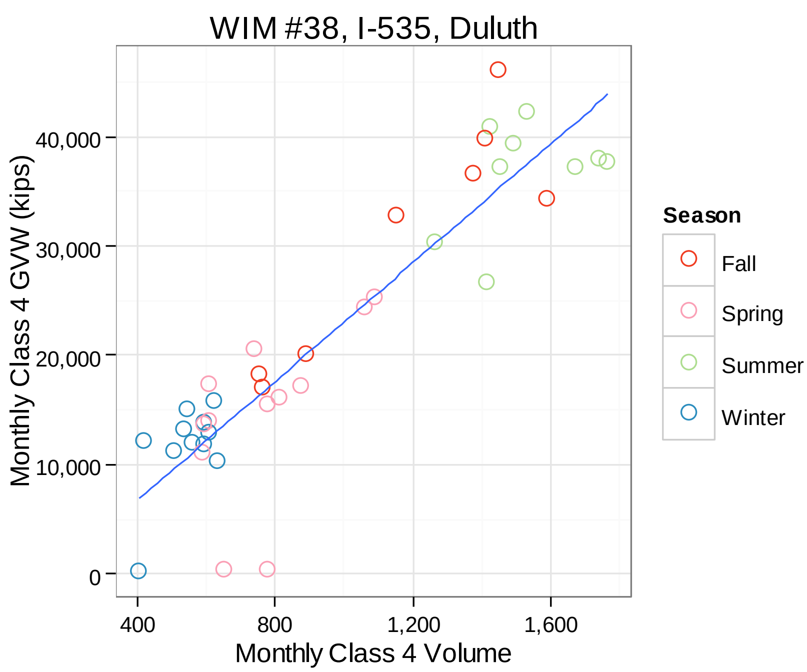


Figure 5.159b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

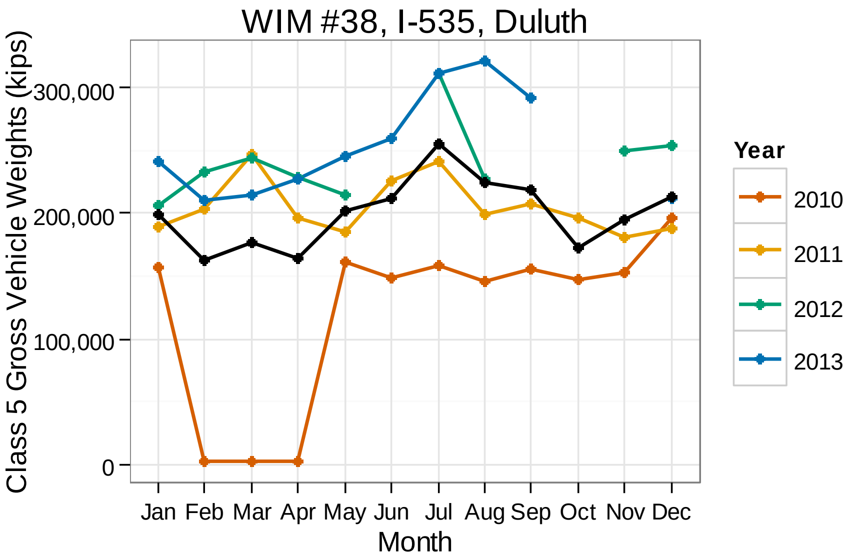


Figure 5.160a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

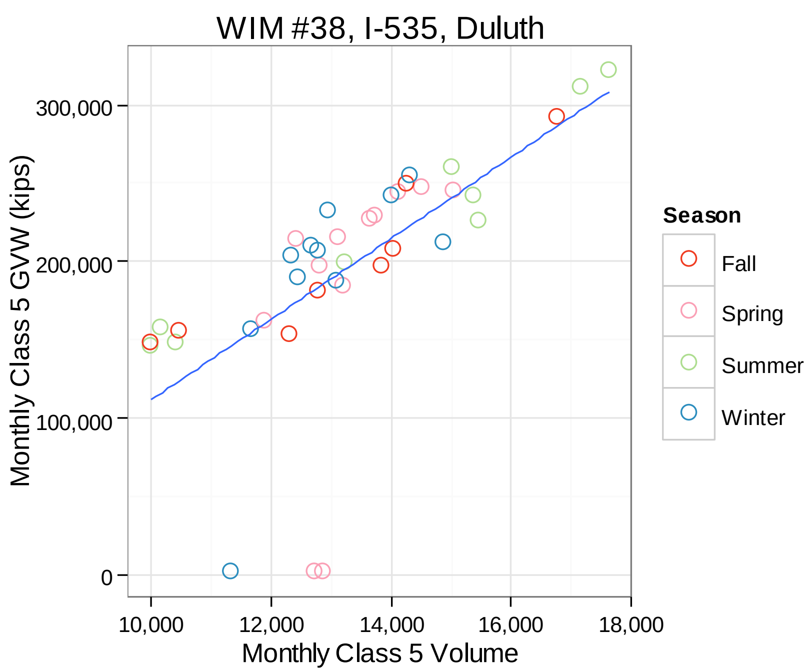


Figure 5.160b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

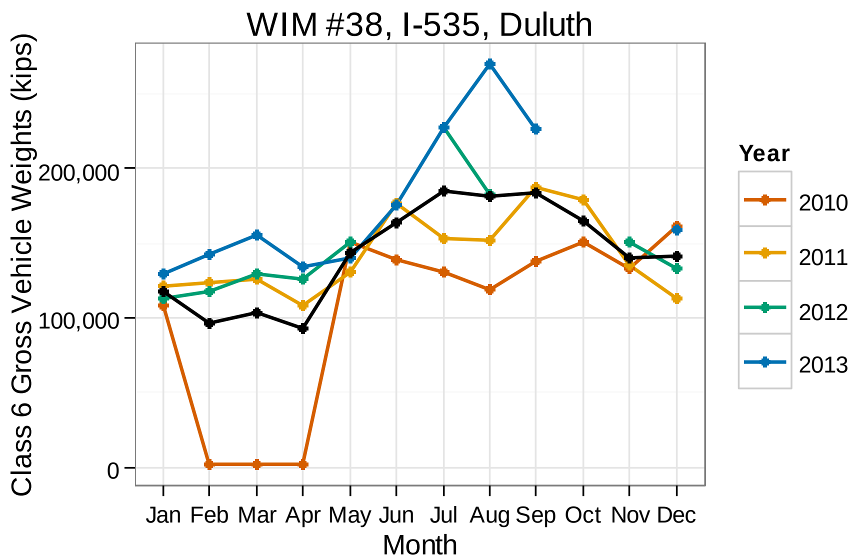


Figure 5.161a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

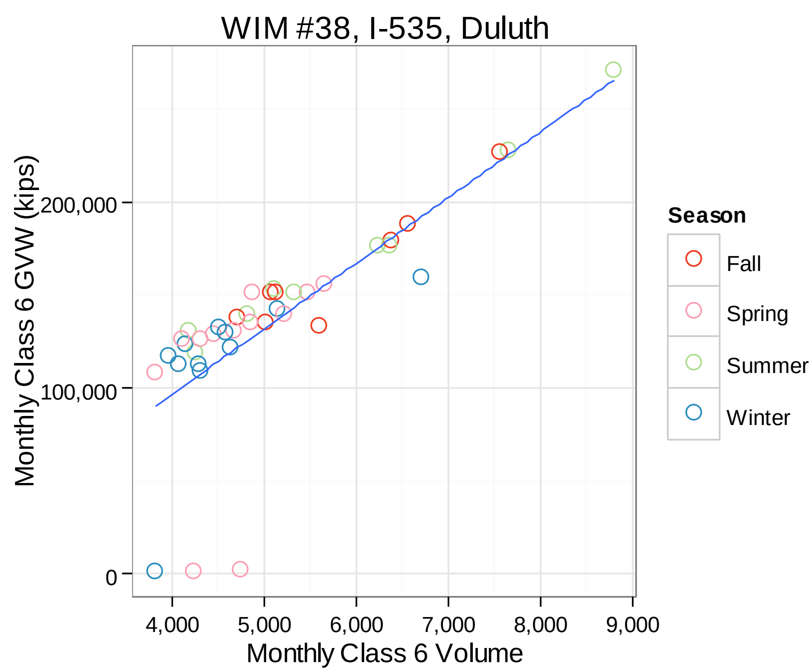


Figure 5.161b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

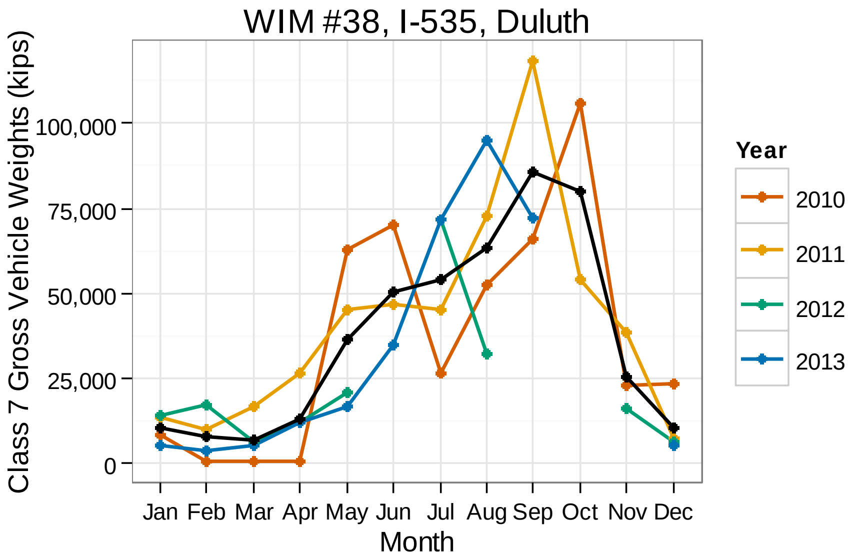


Figure 5.162a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

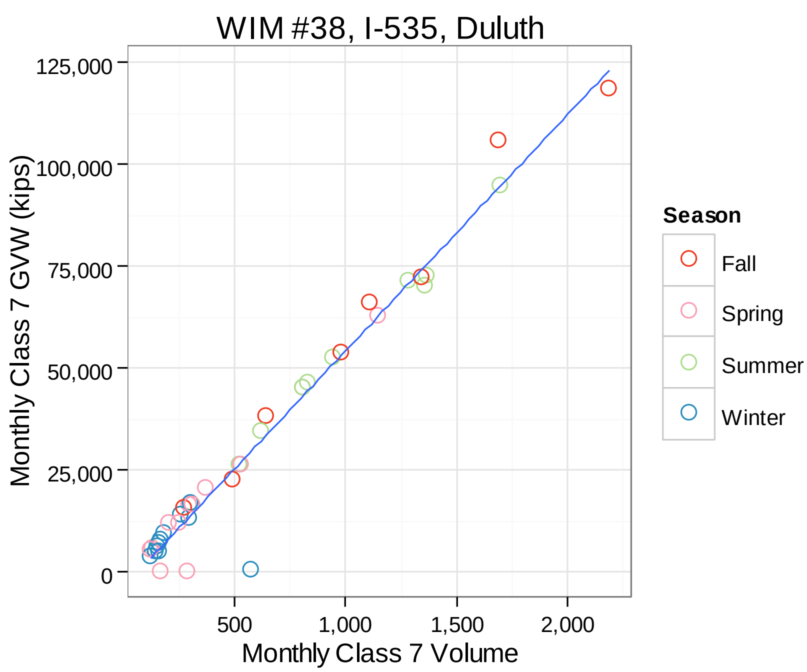


Figure 5.162b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

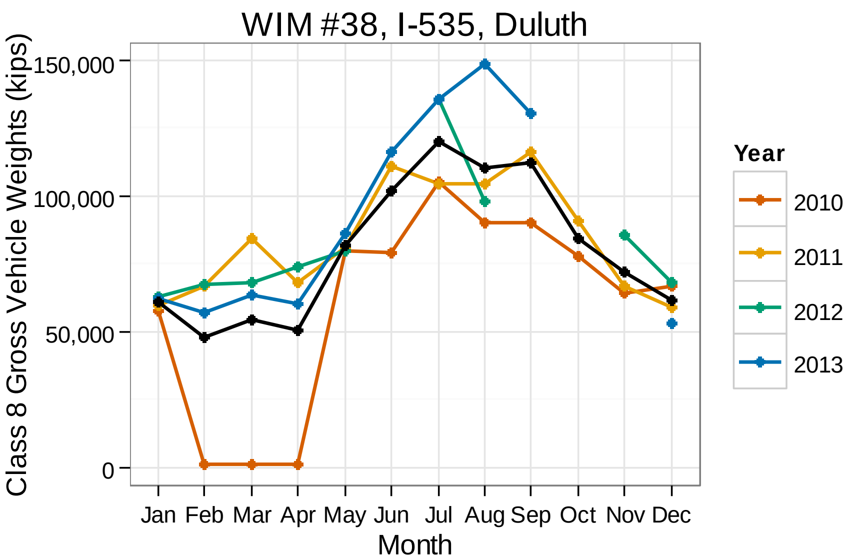


Figure 5.163a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

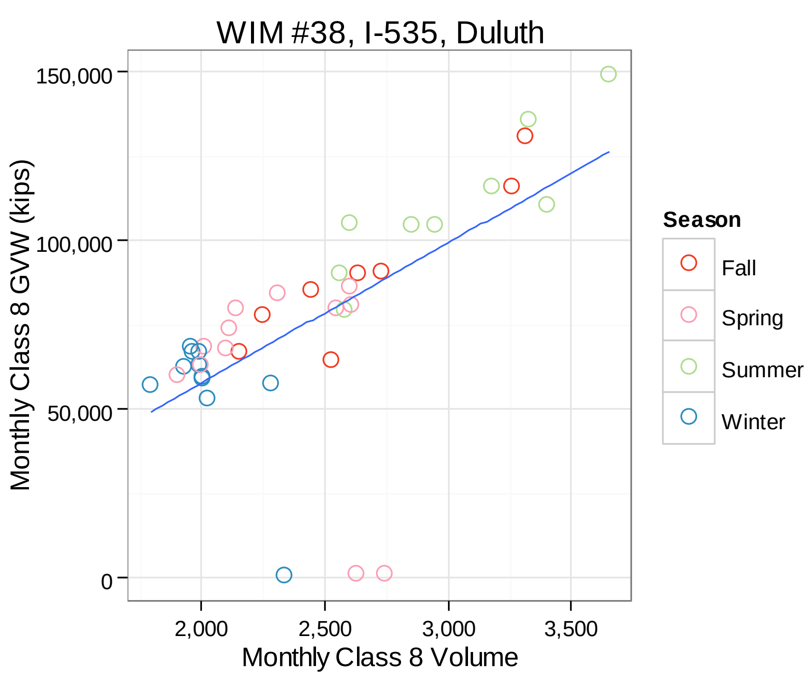


Figure 5.163b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

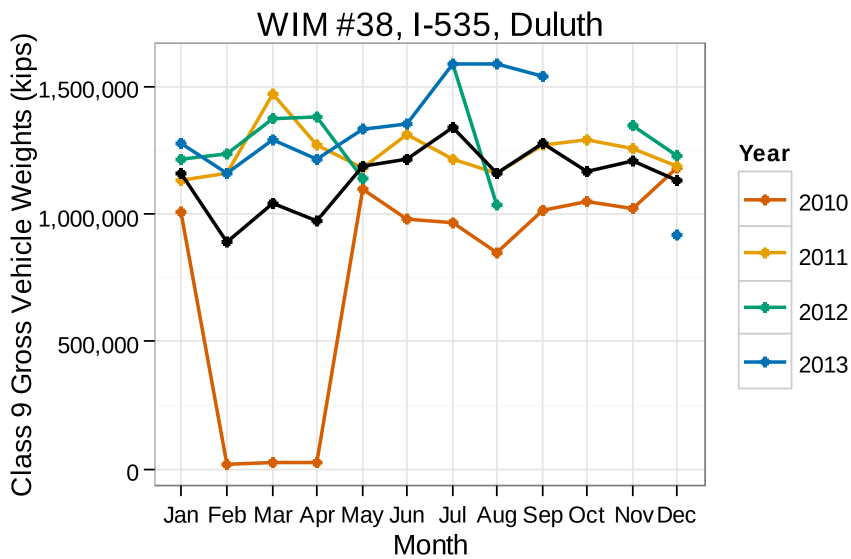


Figure 5.164a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

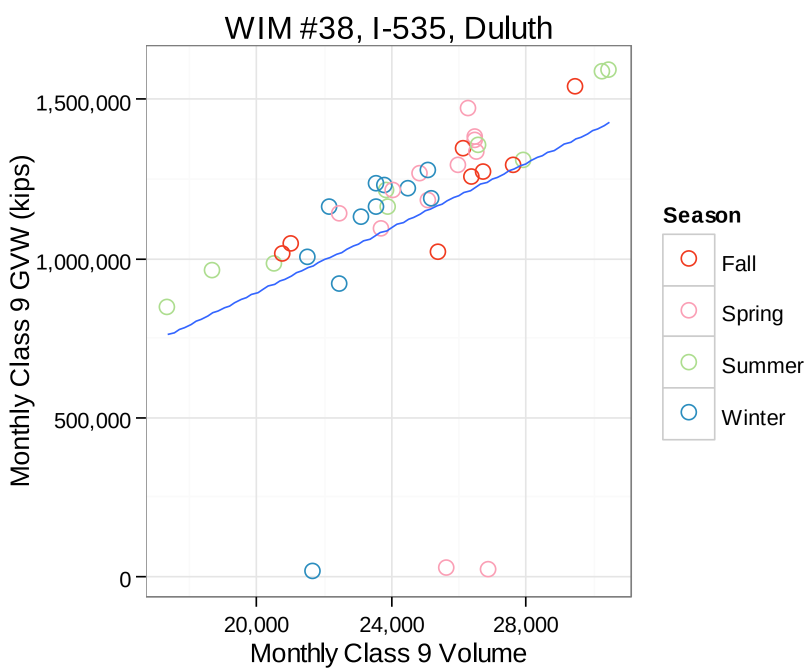


Figure 5.164b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

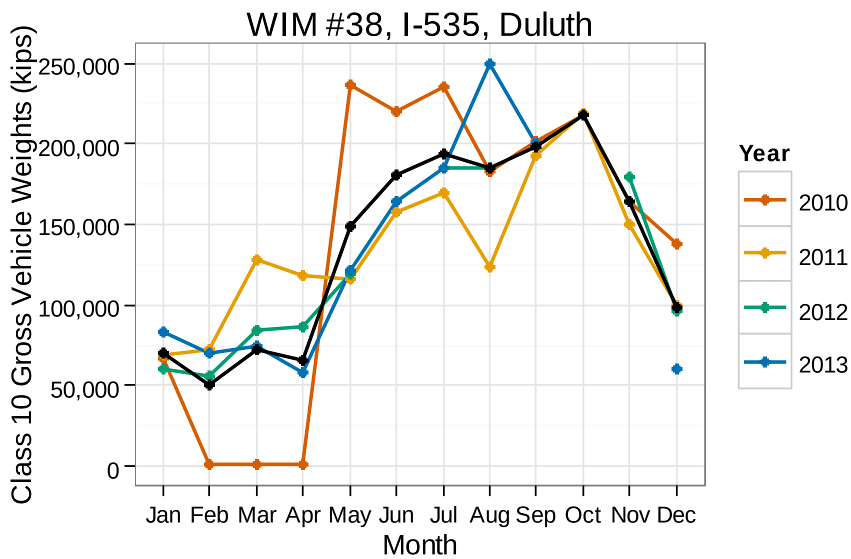


Figure 5.165a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

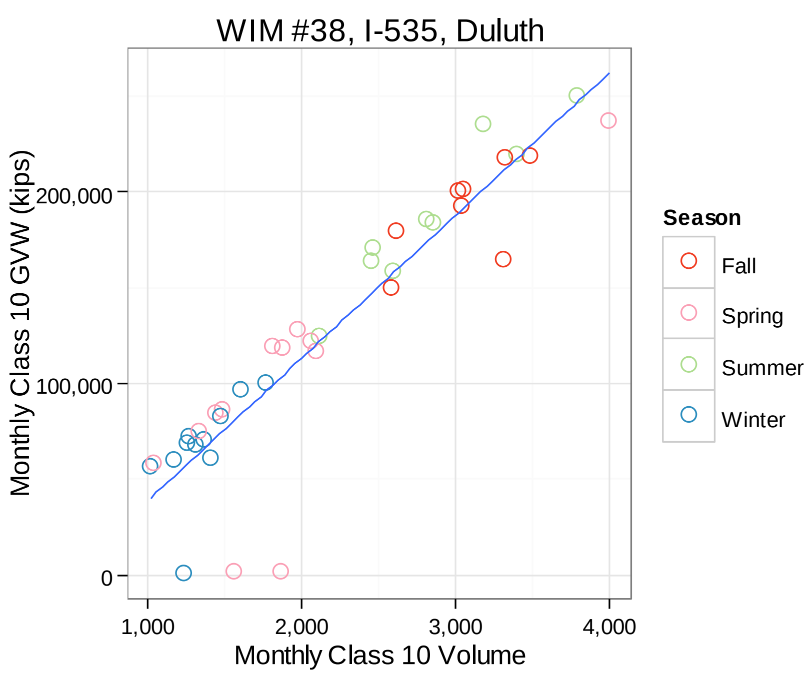


Figure 5.165b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

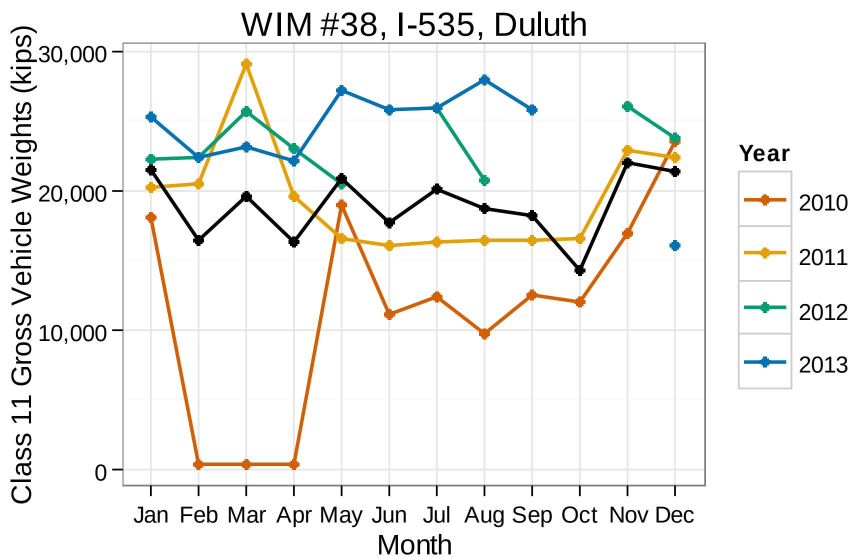


Figure 5.166a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

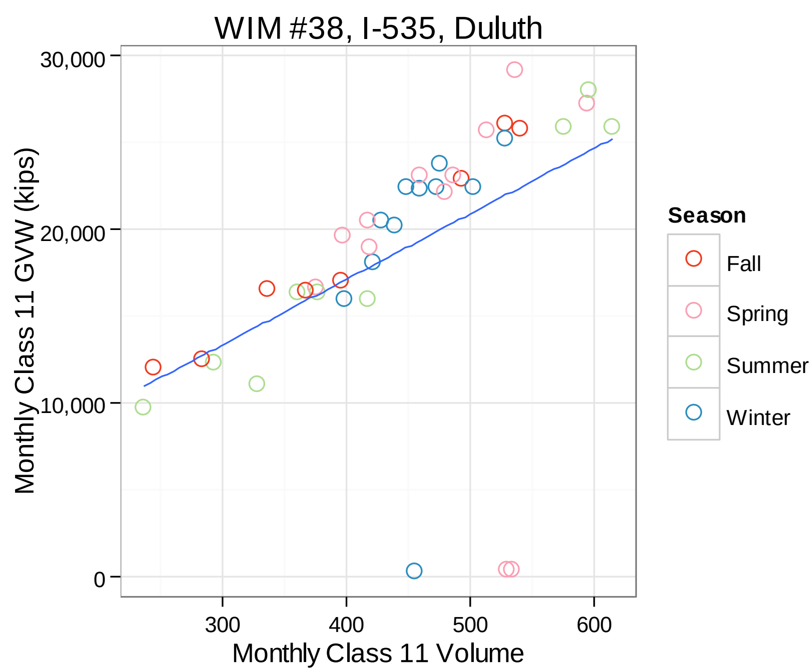


Figure 5.166b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

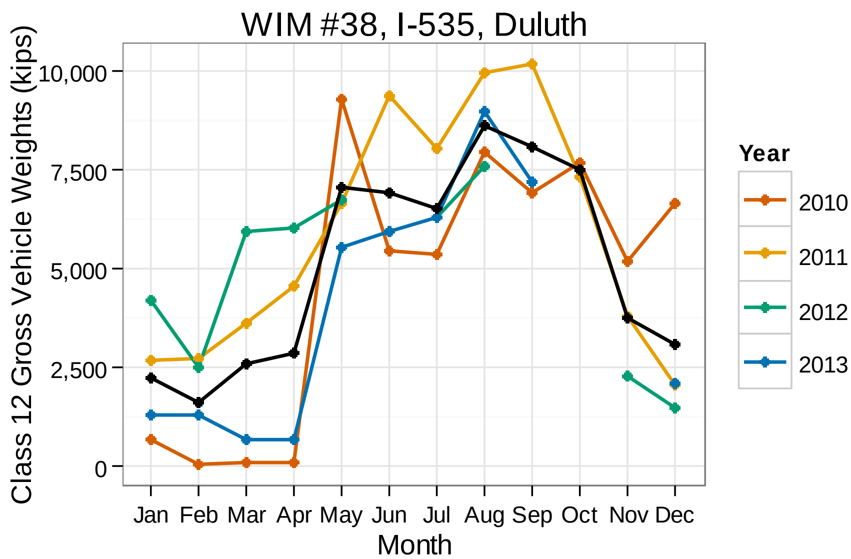


Figure 5.167a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

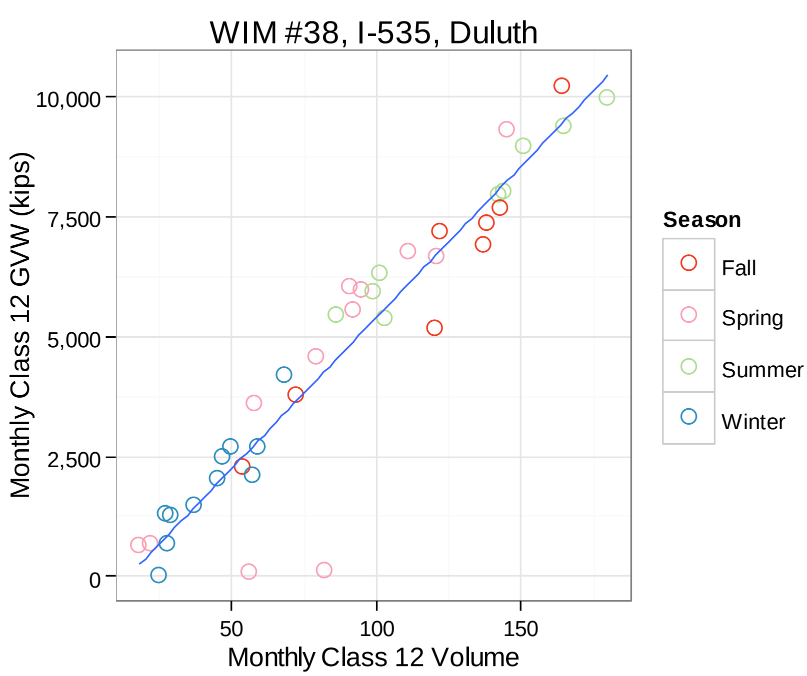


Figure 5.167b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

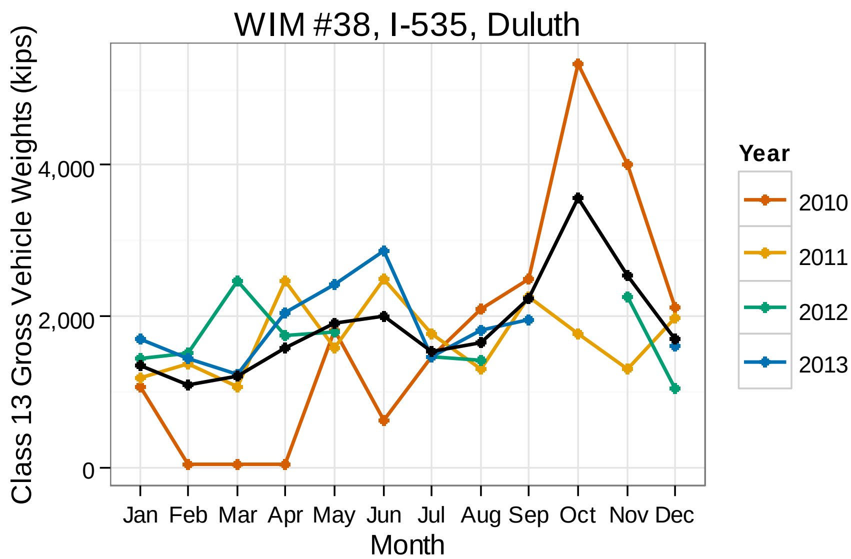


Figure 5.168a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

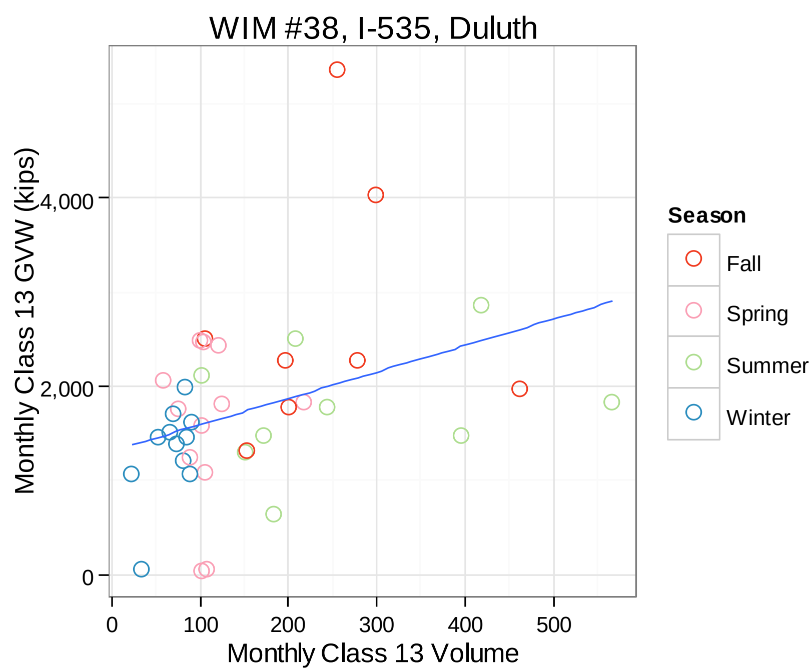


Figure 5.168b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

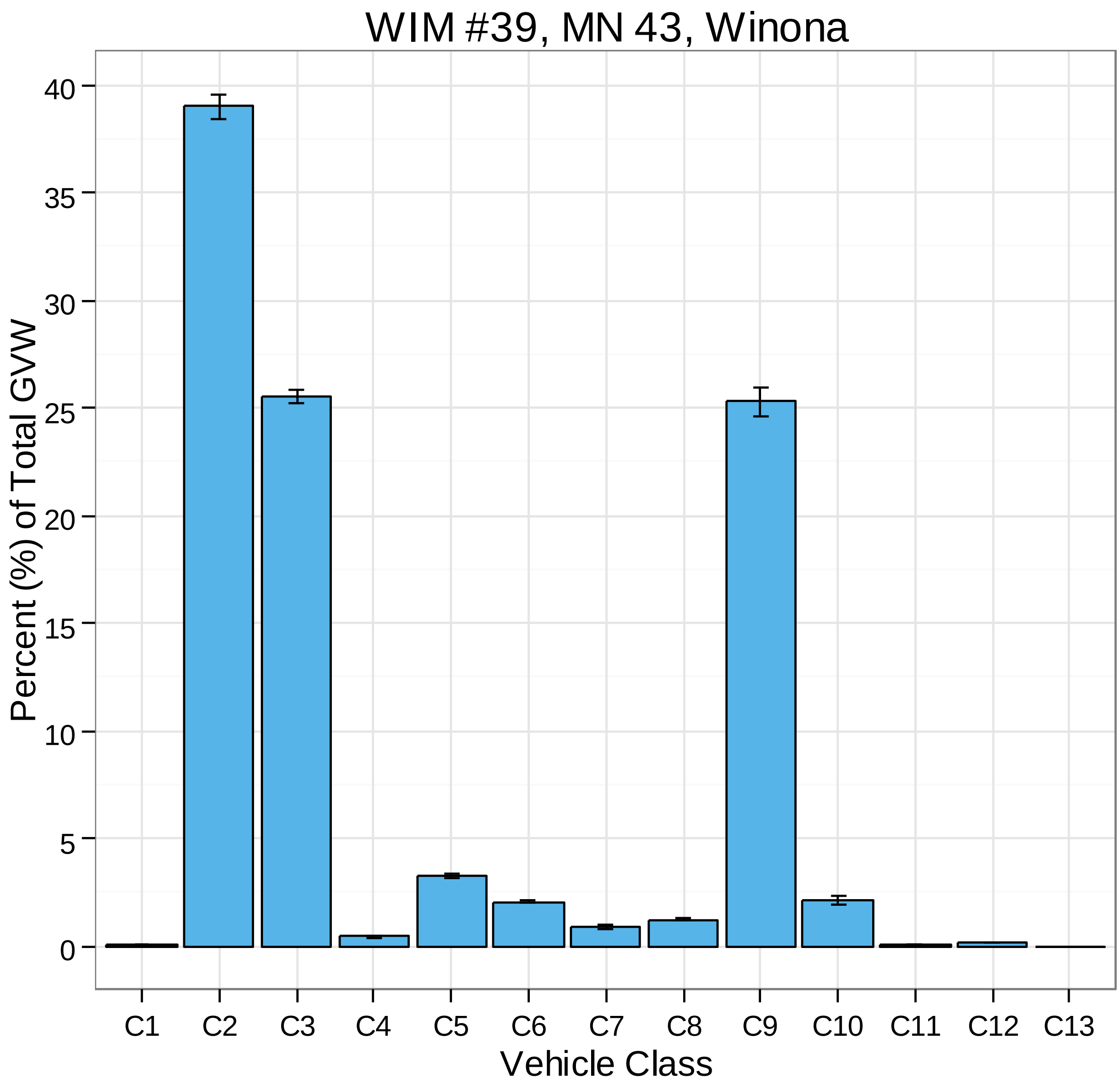


Figure 5.169. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

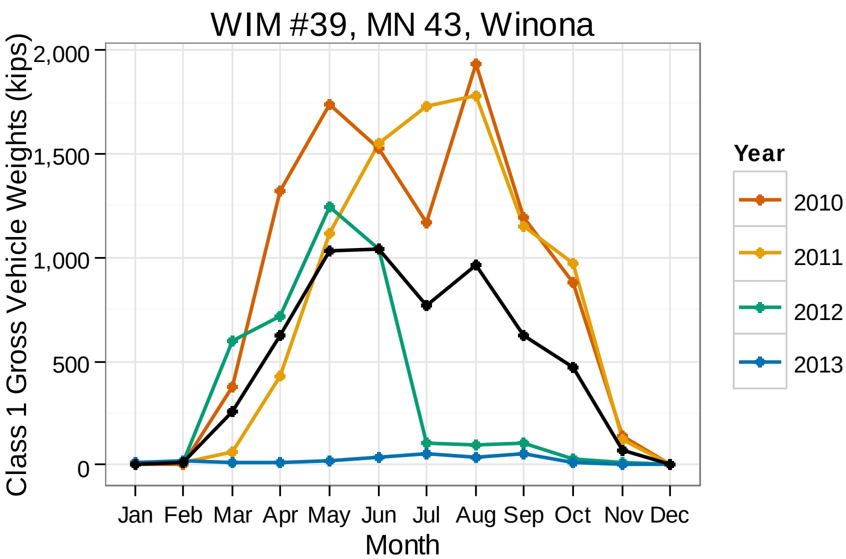


Figure 5.170a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

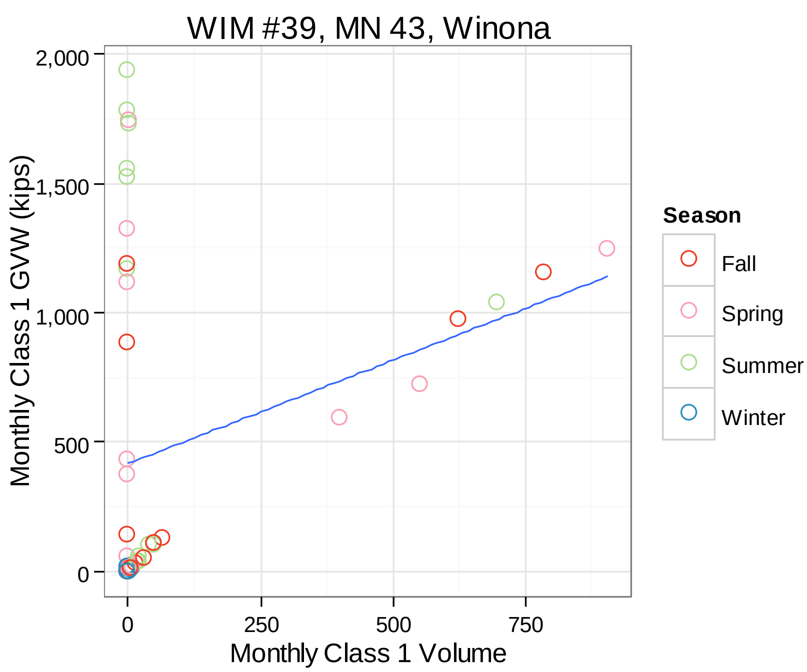


Figure 5.170b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

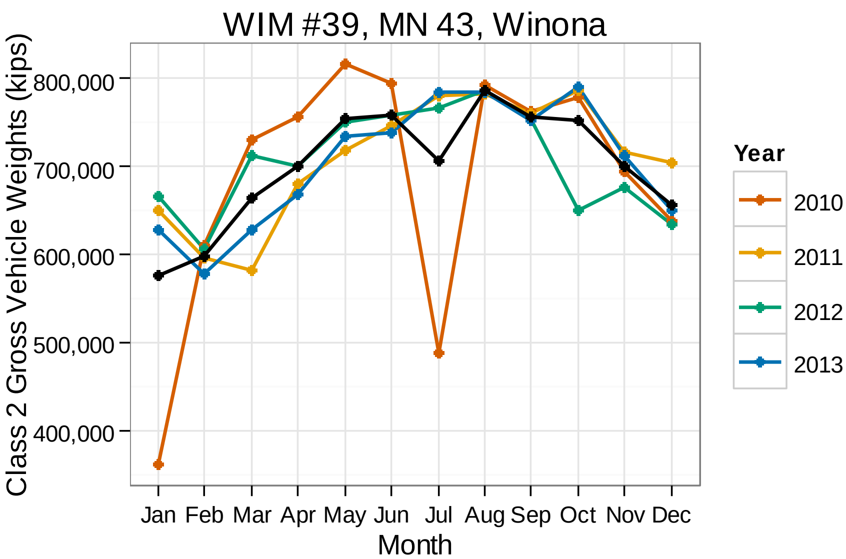


Figure 5.171a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

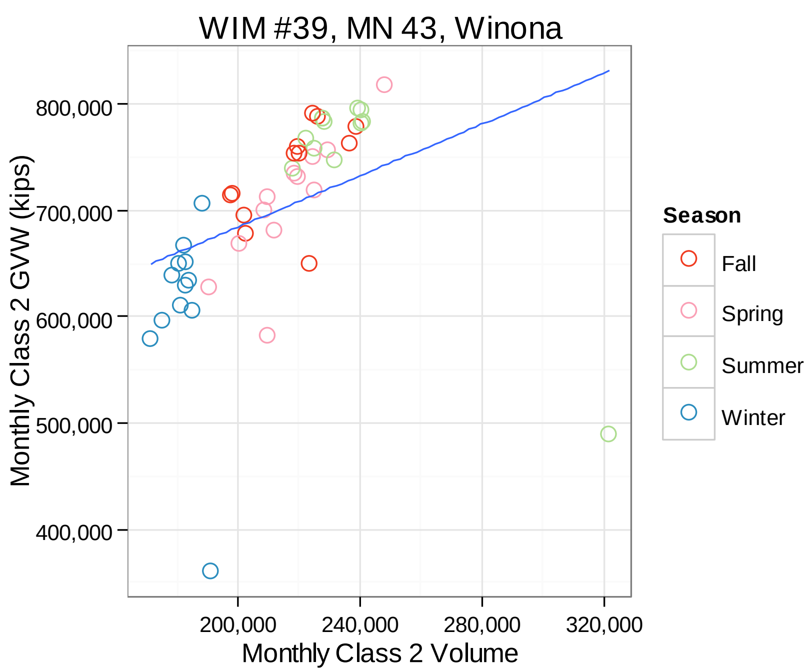


Figure 5.171b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

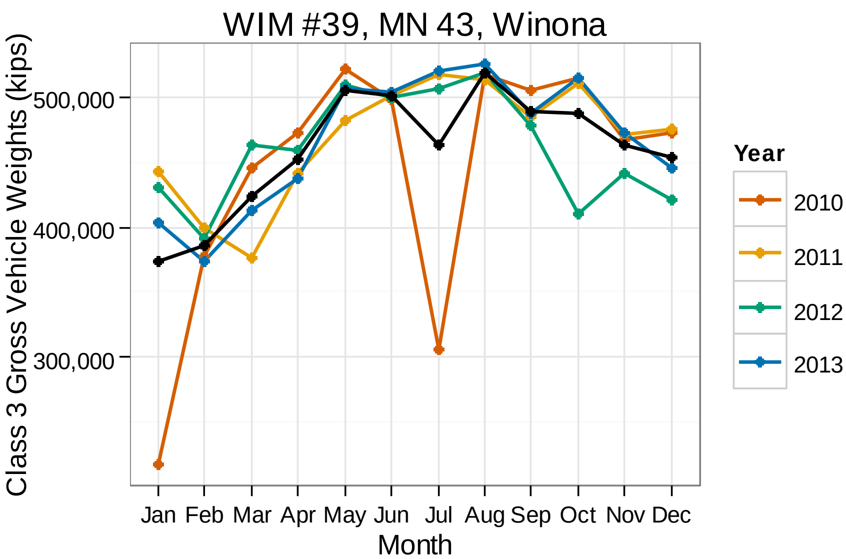


Figure 5.172a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

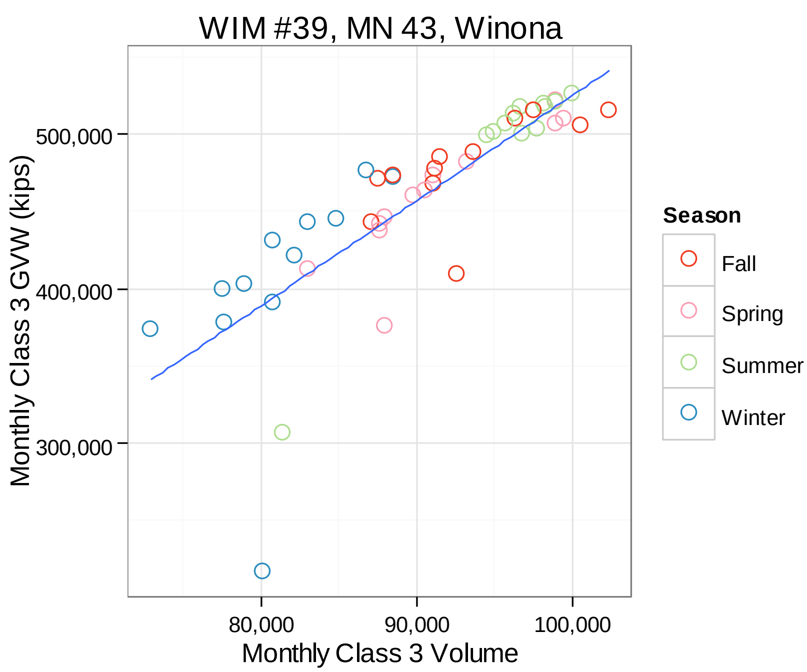


Figure 5.172b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

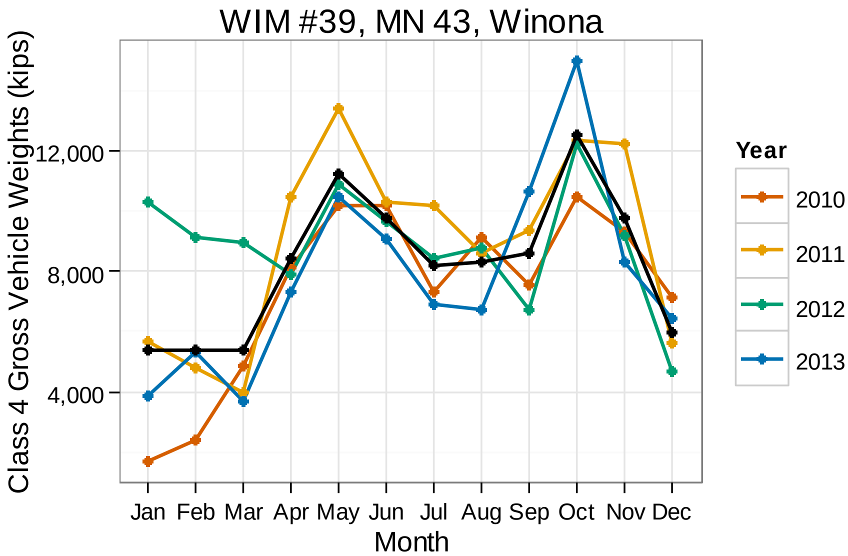


Figure 5.173a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

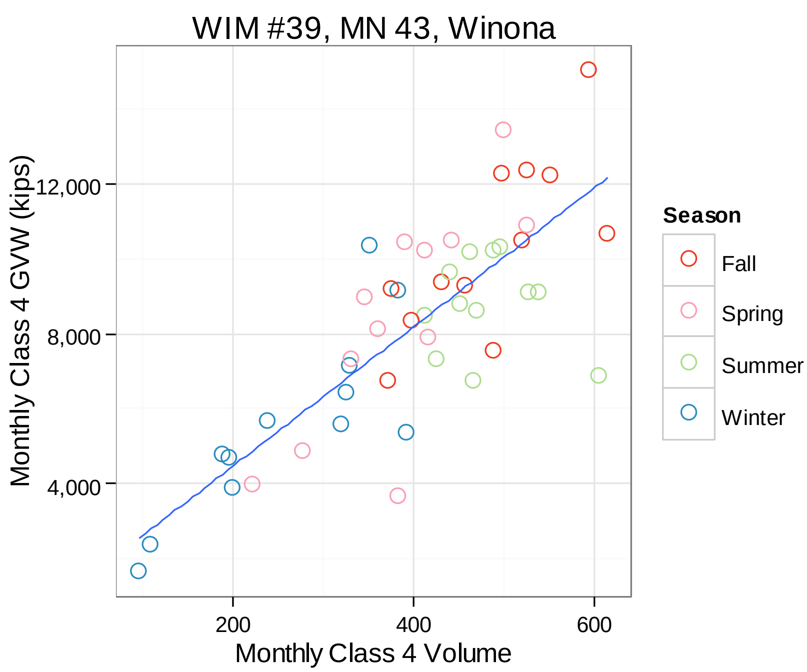


Figure 5.173b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

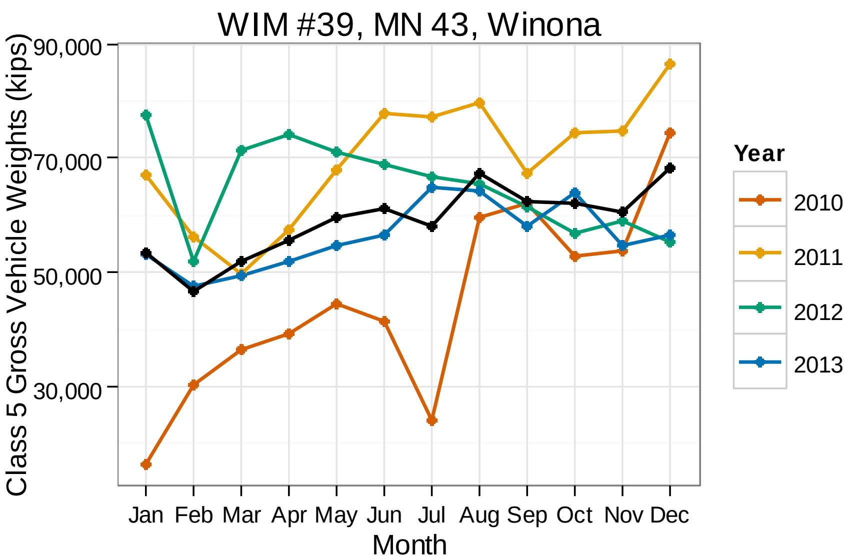


Figure 5.174a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

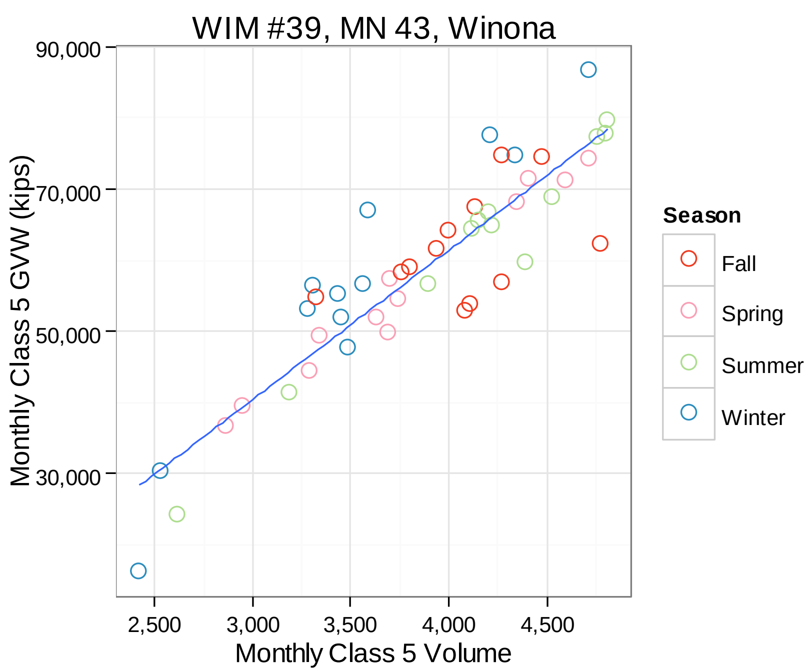


Figure 5.174b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

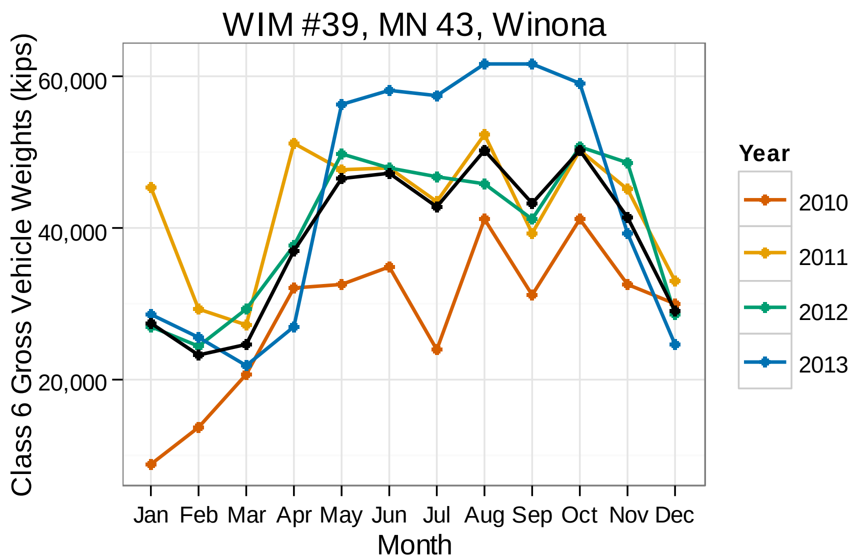


Figure 5.175a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

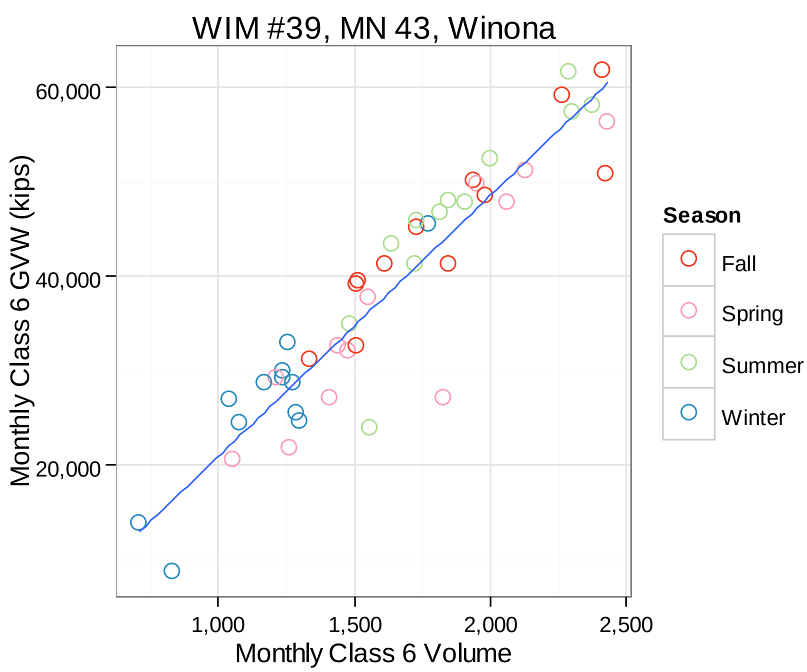


Figure 5.175b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

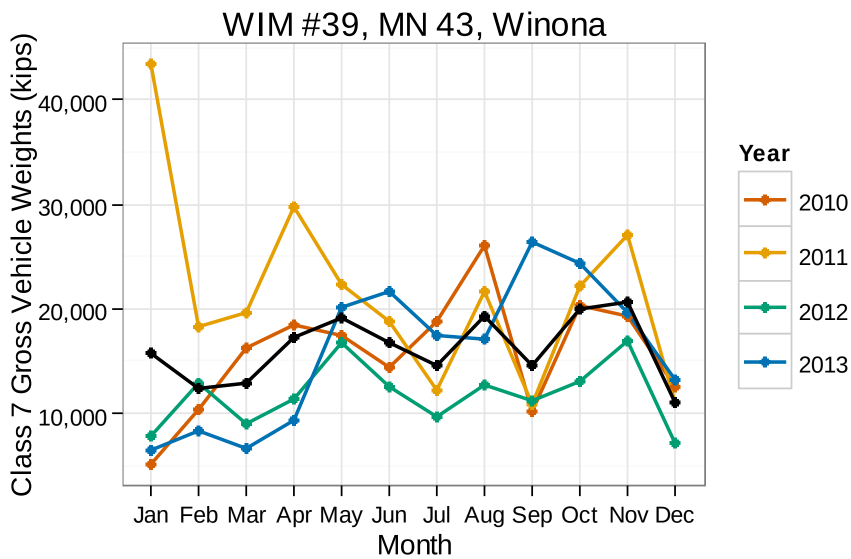


Figure 5.176a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

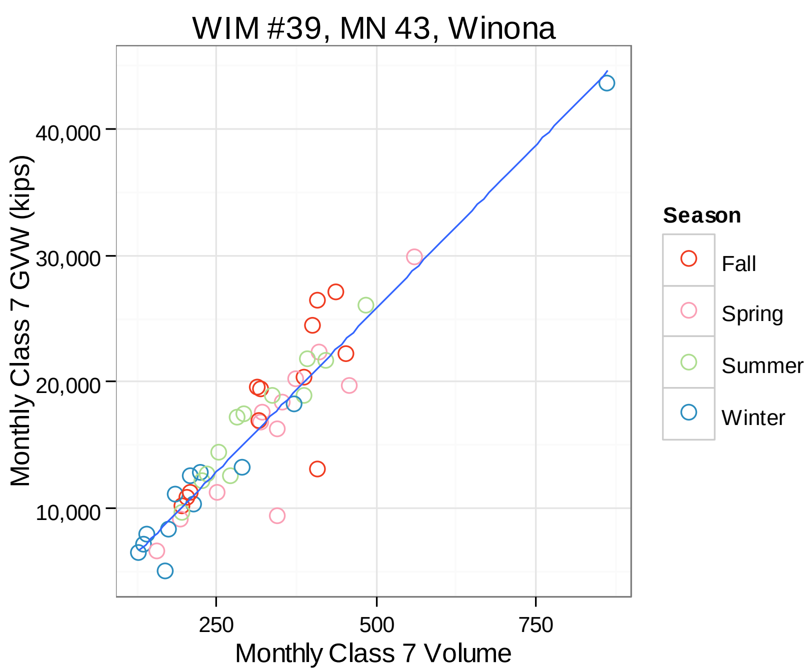


Figure 5.176b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

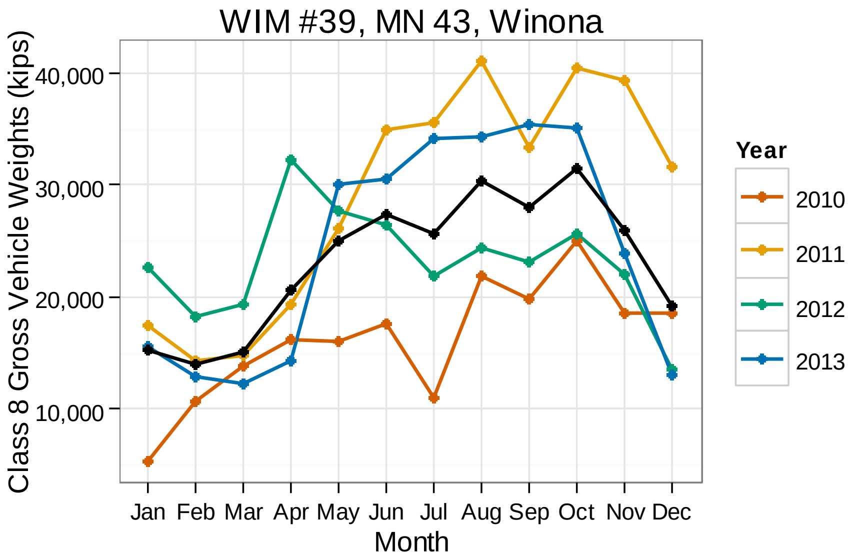


Figure 5.177a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

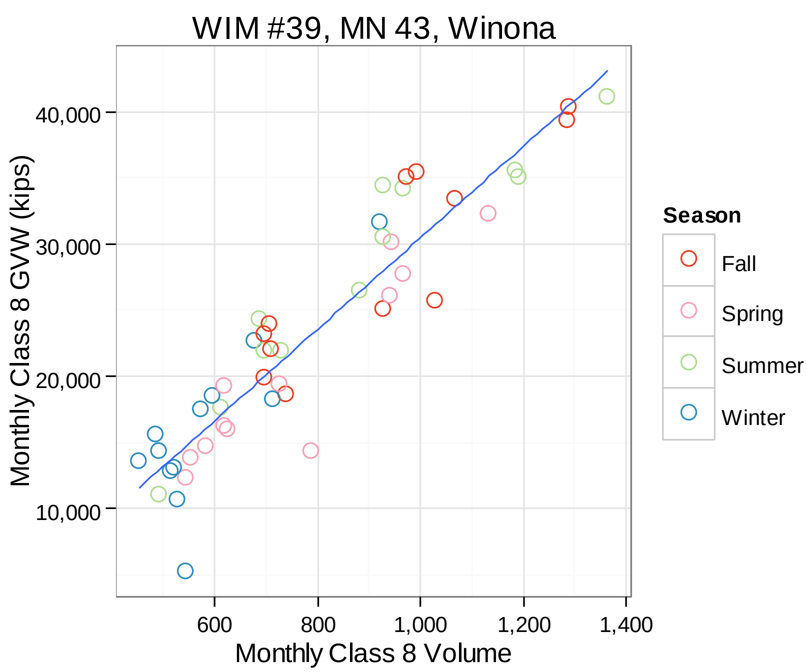


Figure 5.177b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

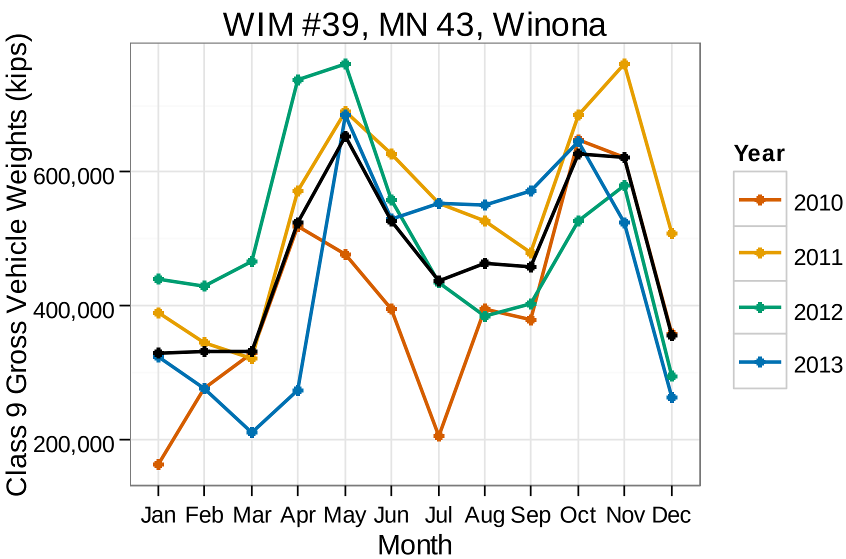


Figure 5.178a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

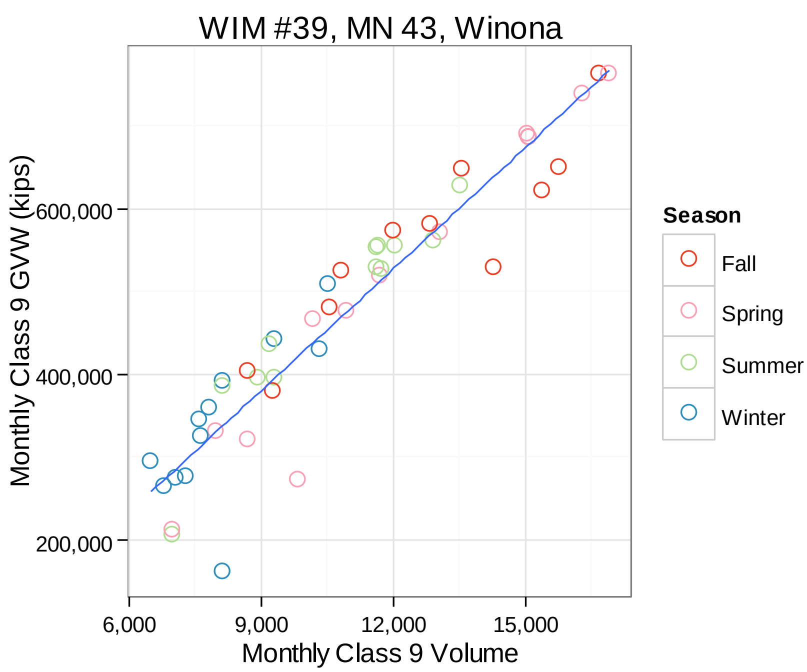


Figure 5.178b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

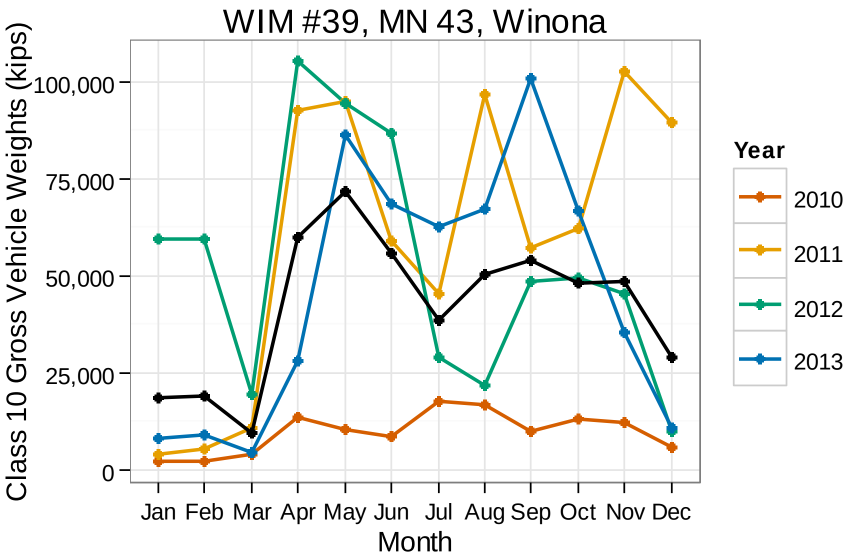


Figure 5.179a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

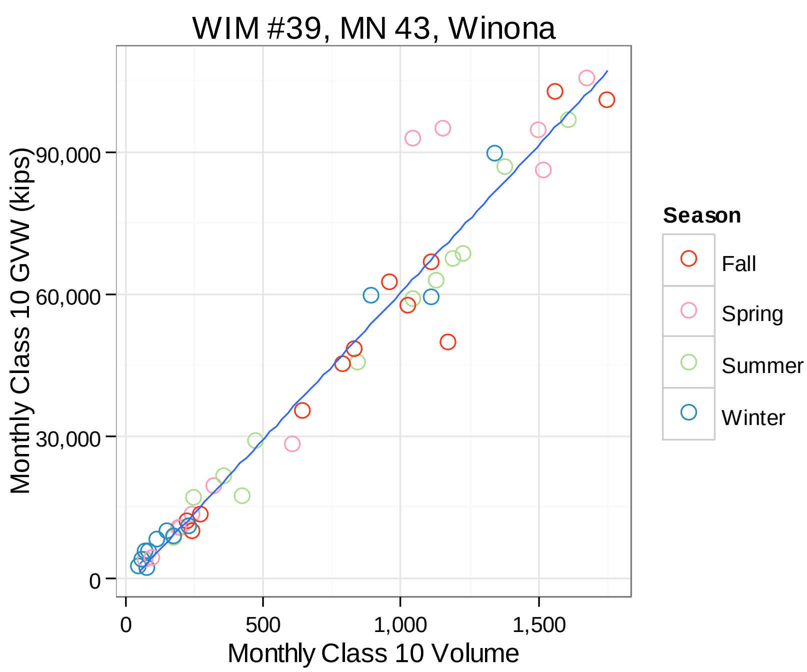


Figure 5.179b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

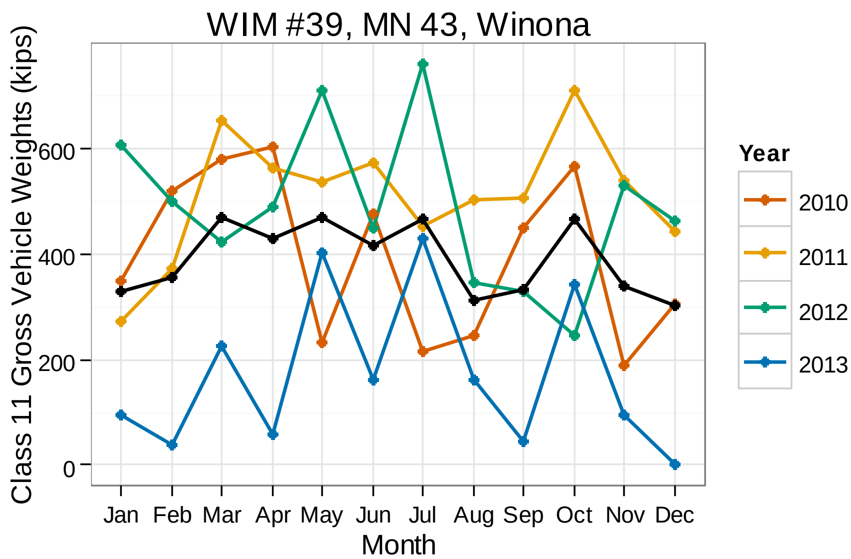


Figure 5.180a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

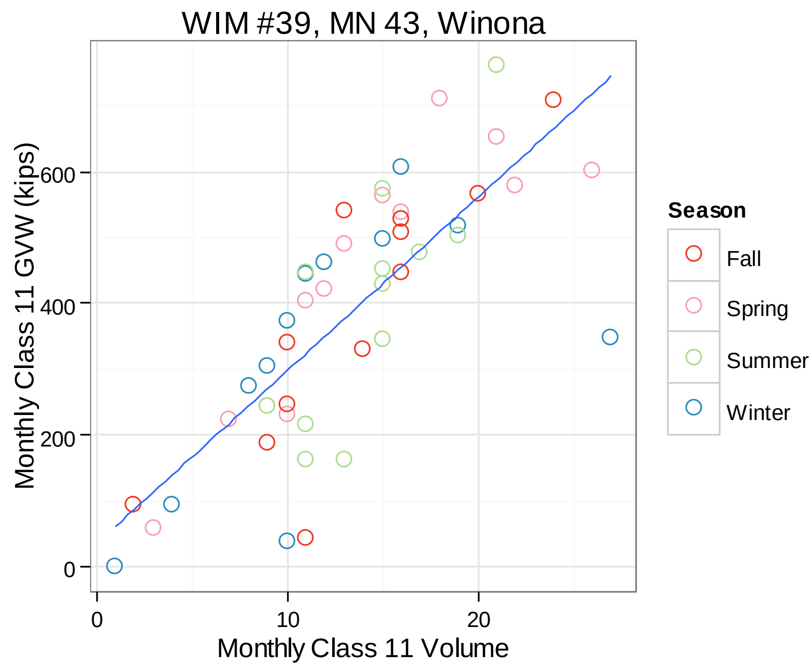


Figure 5.180b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

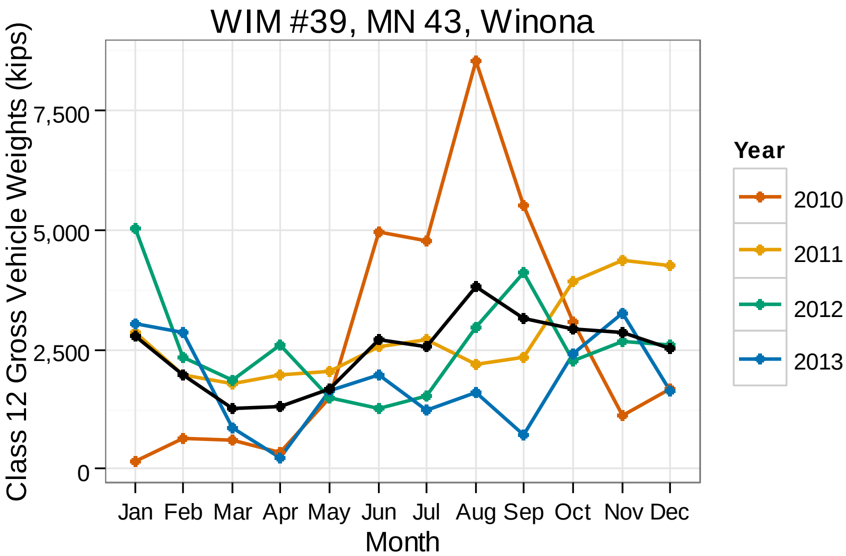


Figure 5.181a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

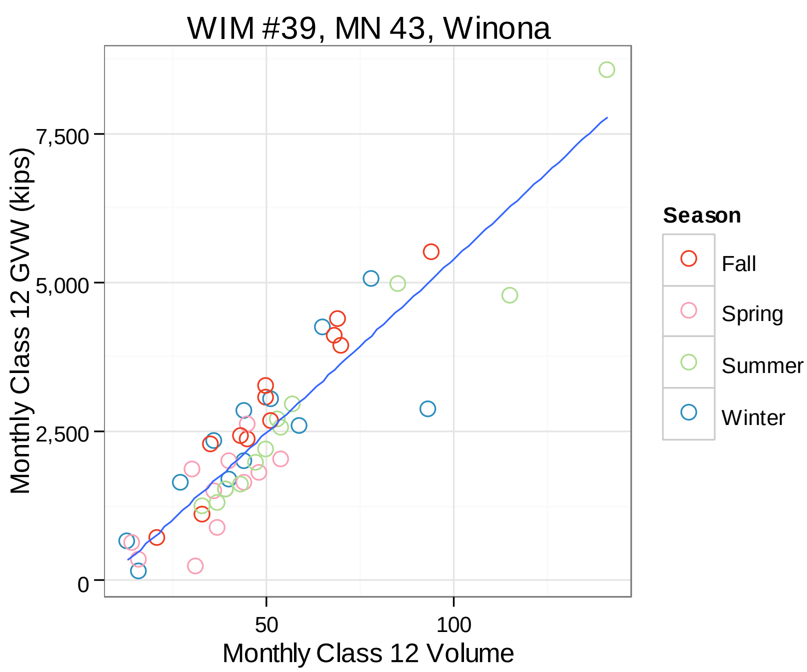


Figure 5.181b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

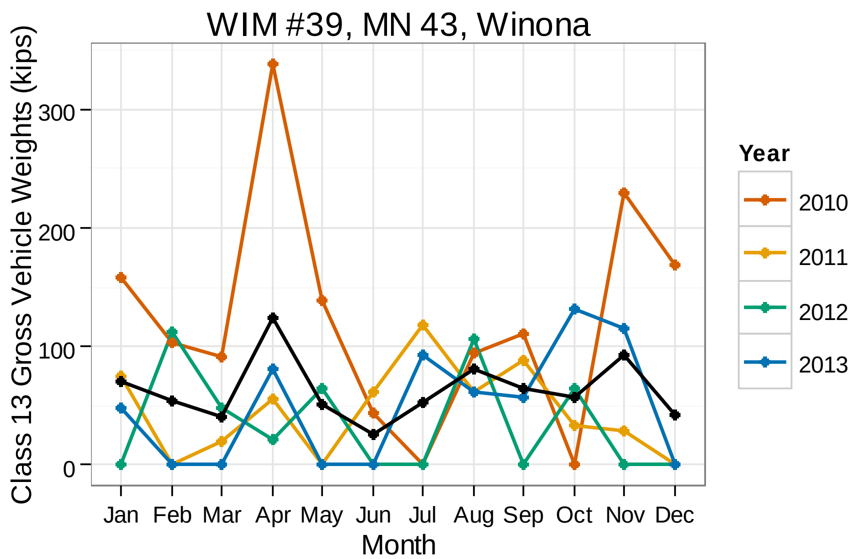


Figure 5.182a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

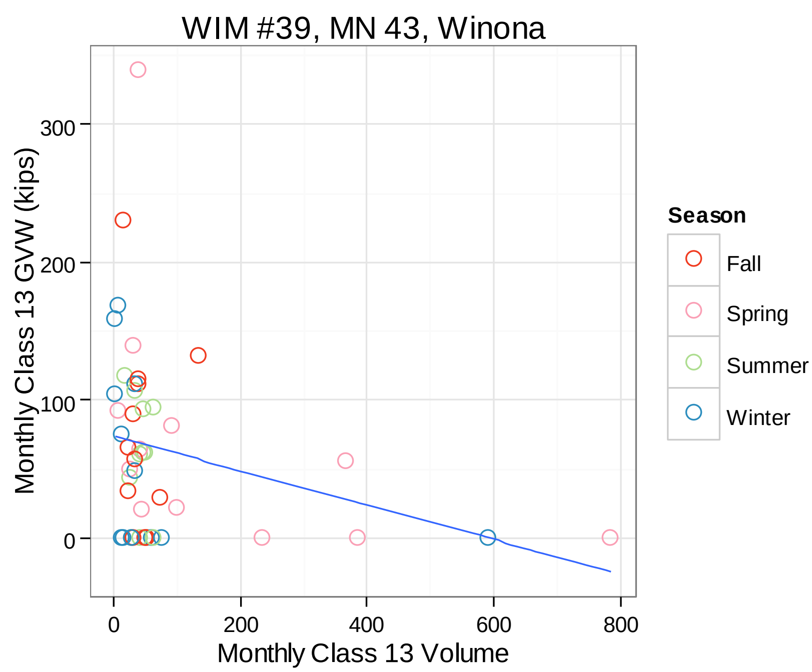


Figure 5.182b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

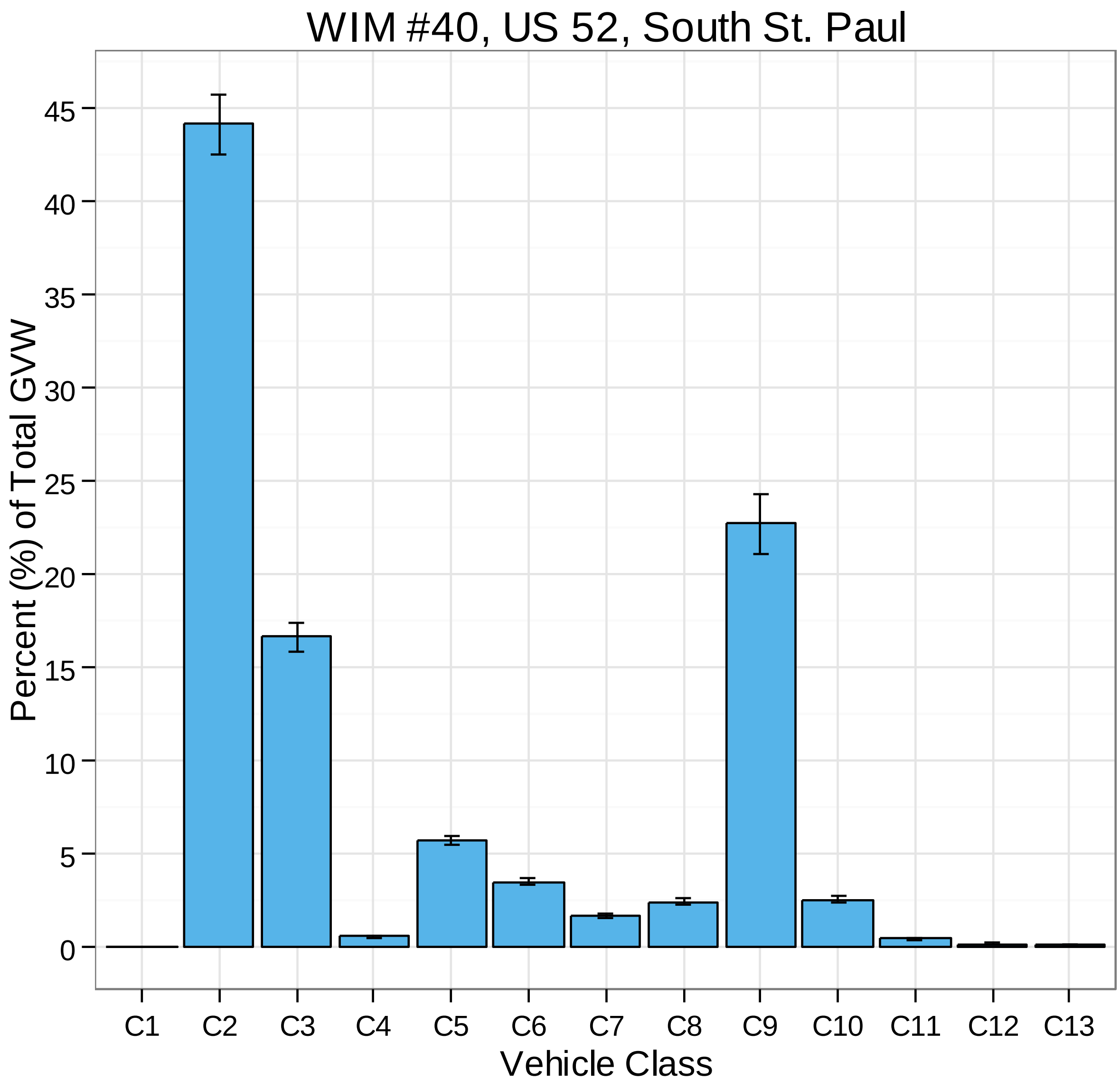


Figure 5.183. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

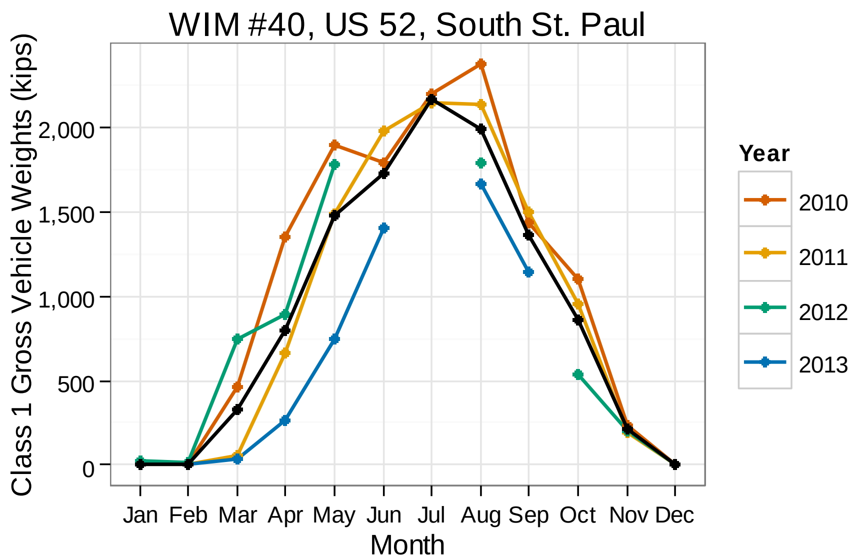


Figure 5.184a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

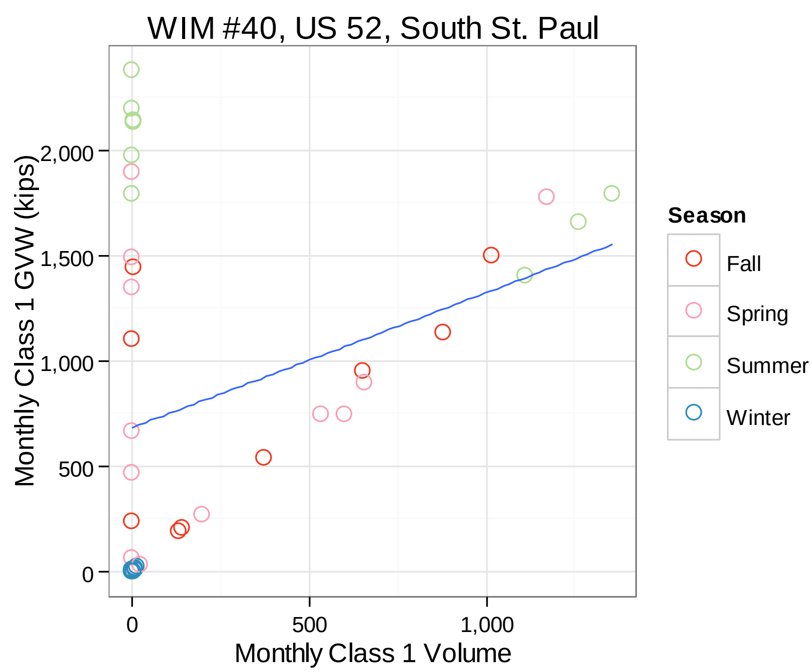


Figure 5.184b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

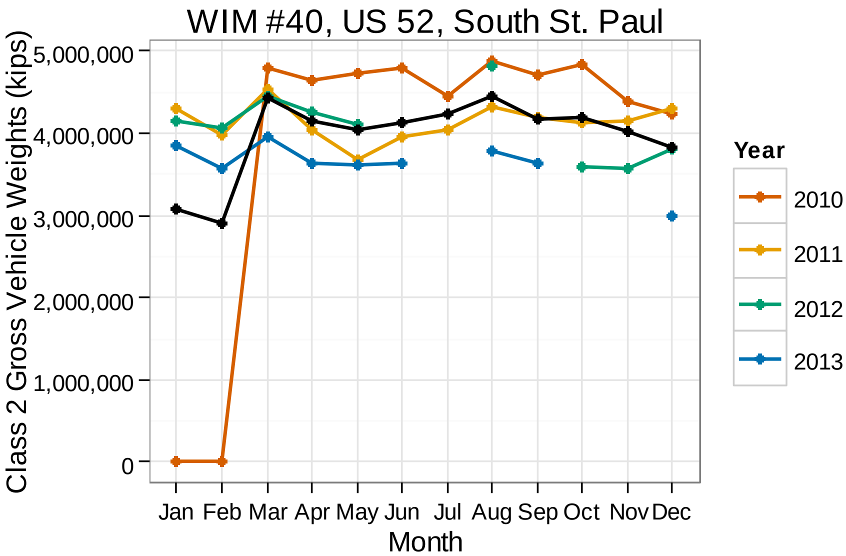


Figure 5.185a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

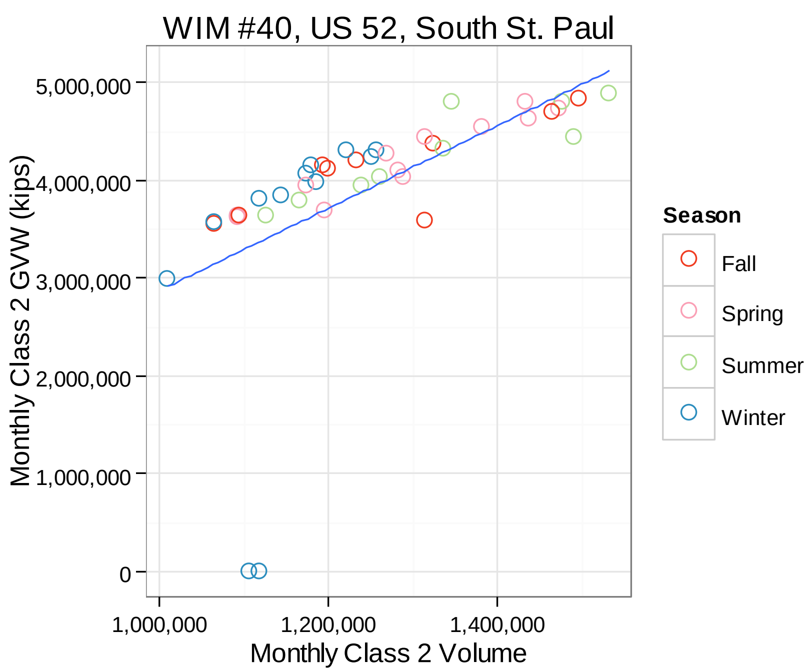


Figure 5.185b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

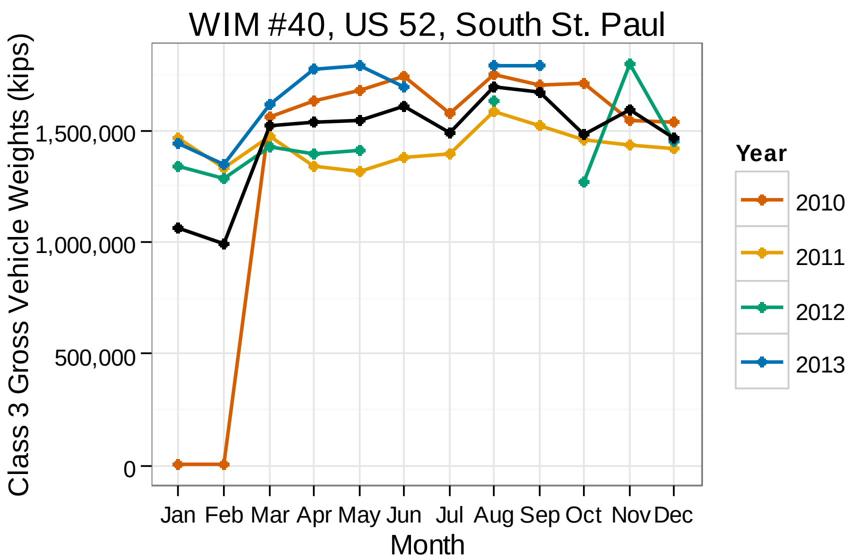


Figure 5.186a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

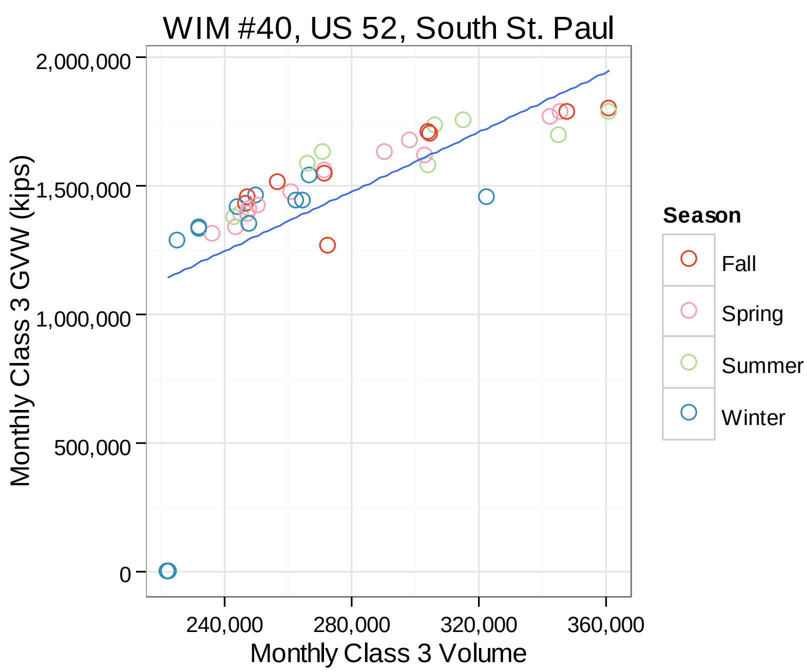


Figure 5.186b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

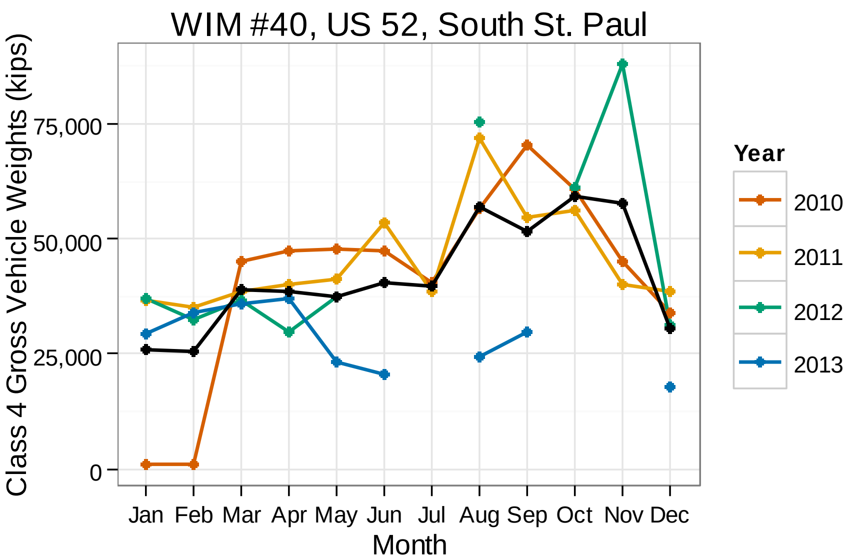


Figure 5.187a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

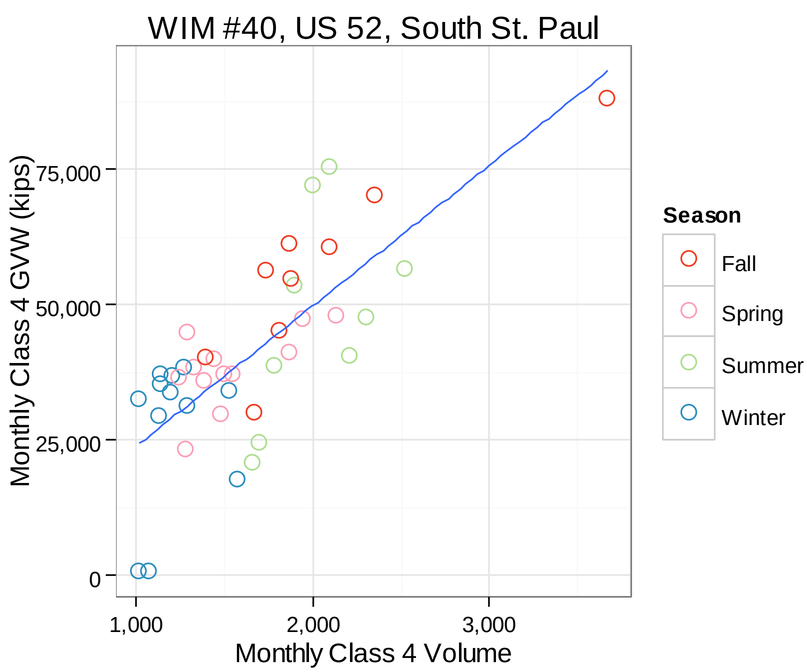


Figure 5.187b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

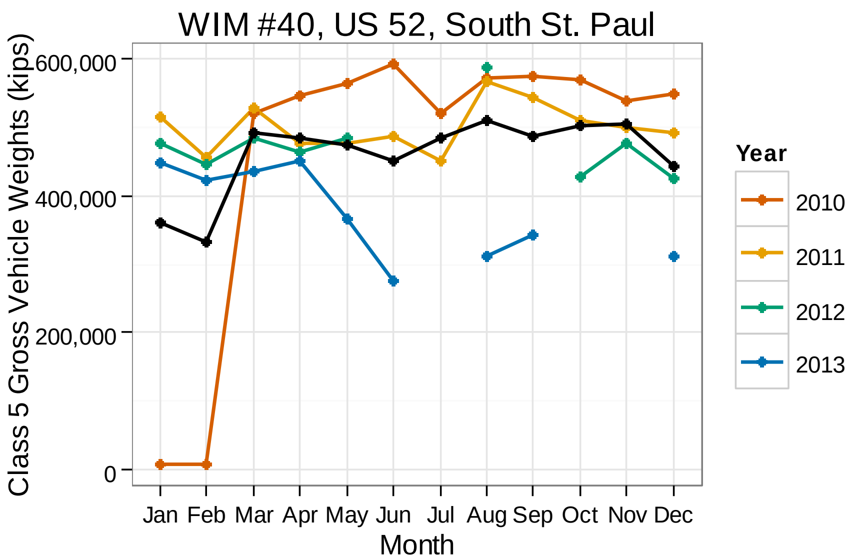


Figure 5.188a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

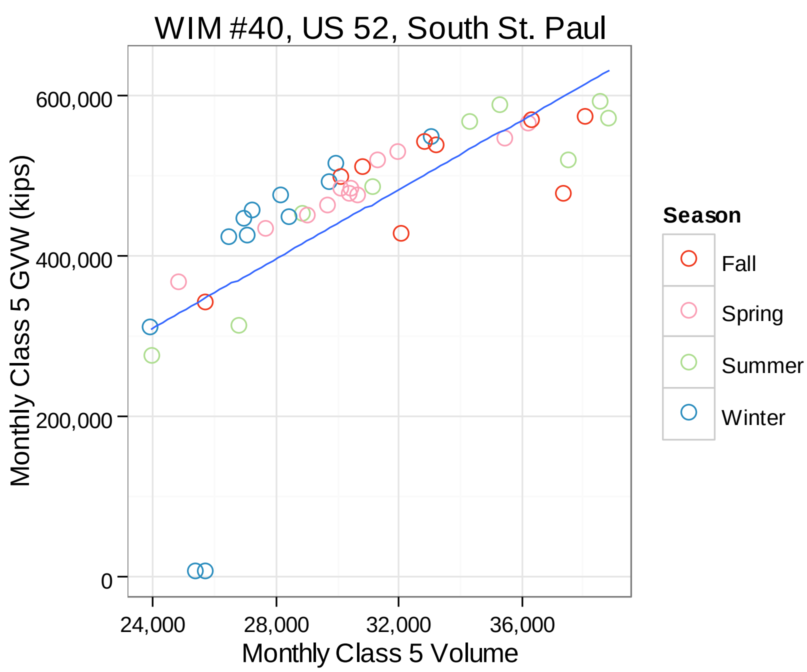


Figure 5.188b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

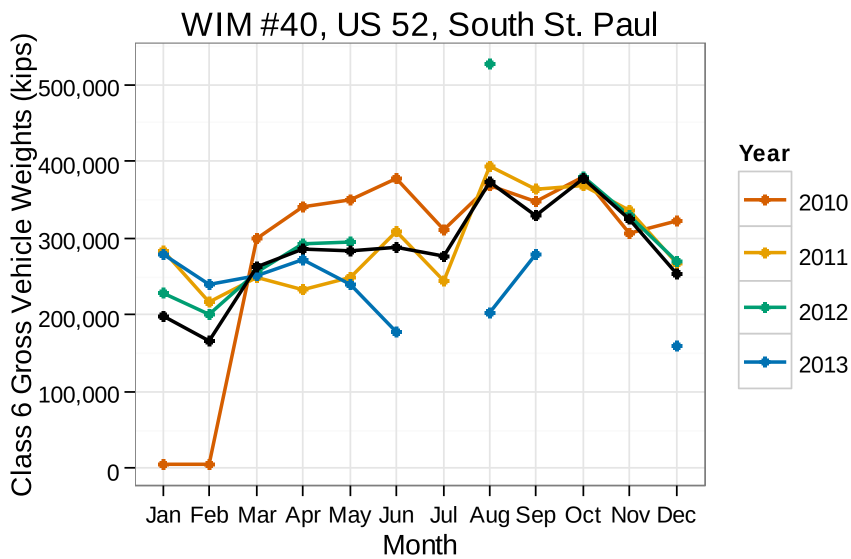


Figure 5.189a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

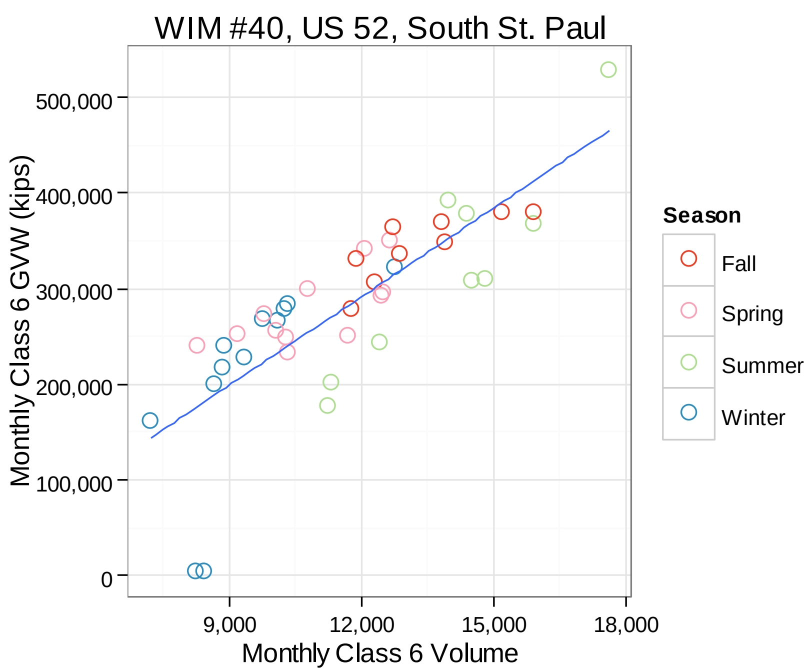


Figure 5.189b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

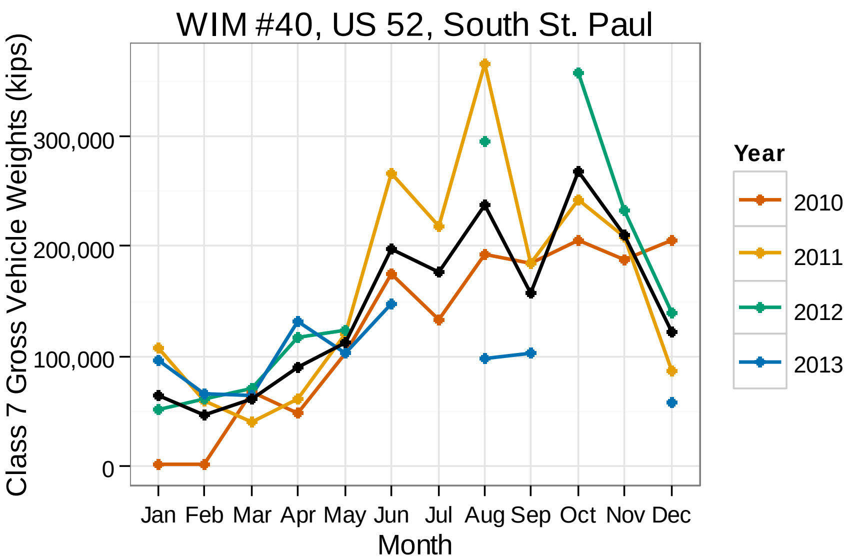


Figure 5.190a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

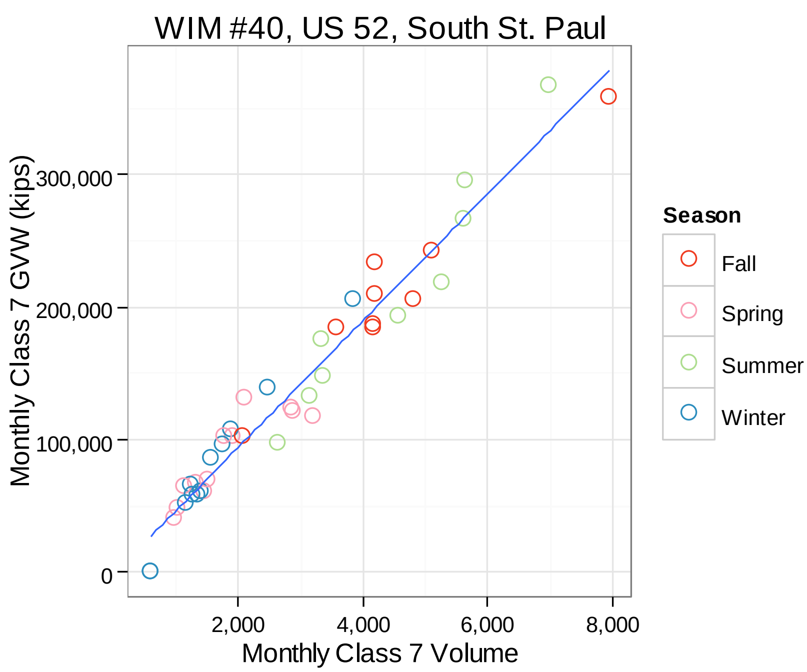


Figure 5.190b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

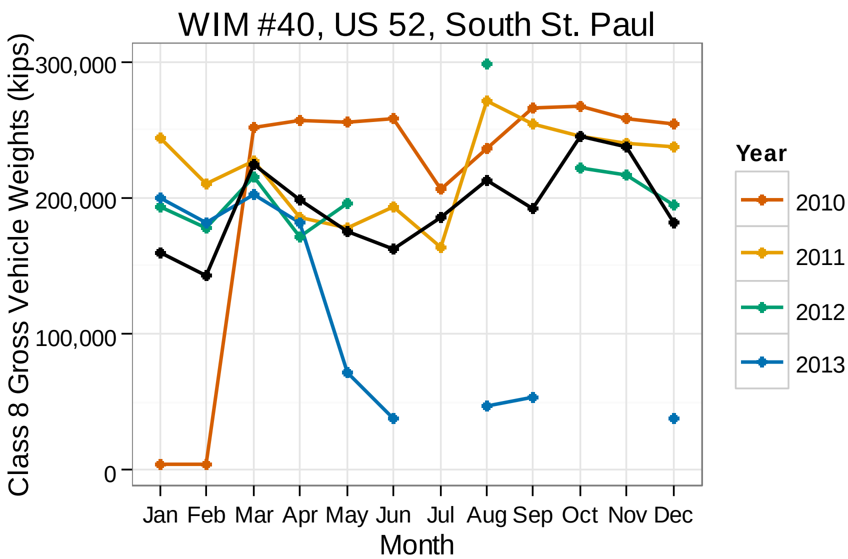


Figure 5.191a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

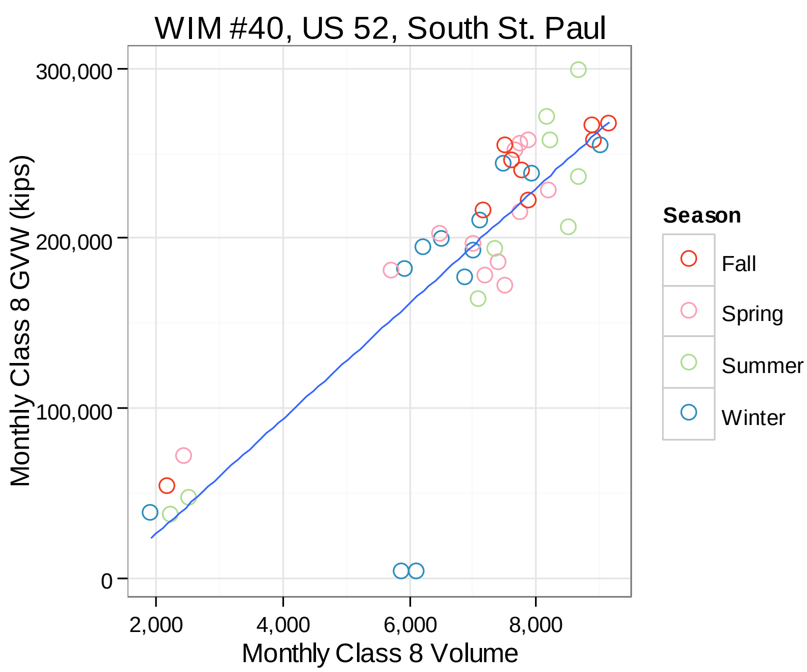


Figure 5.191b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

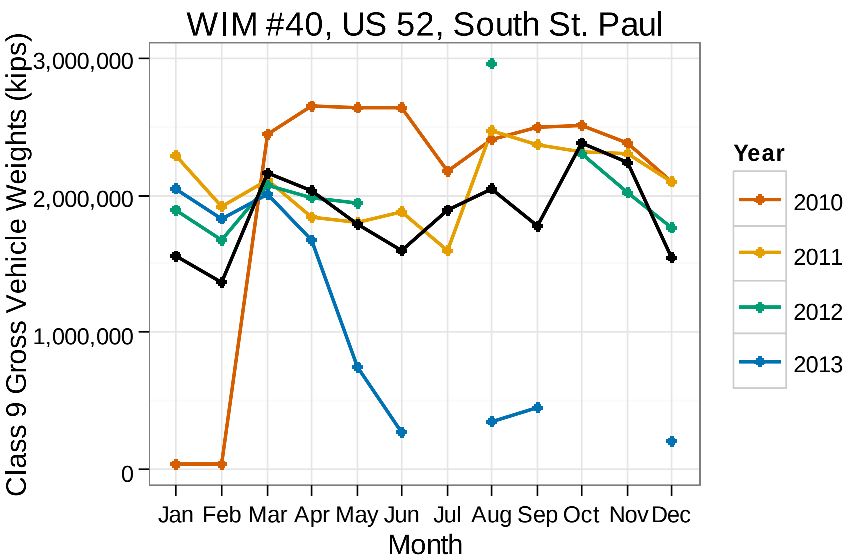


Figure 5.192a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

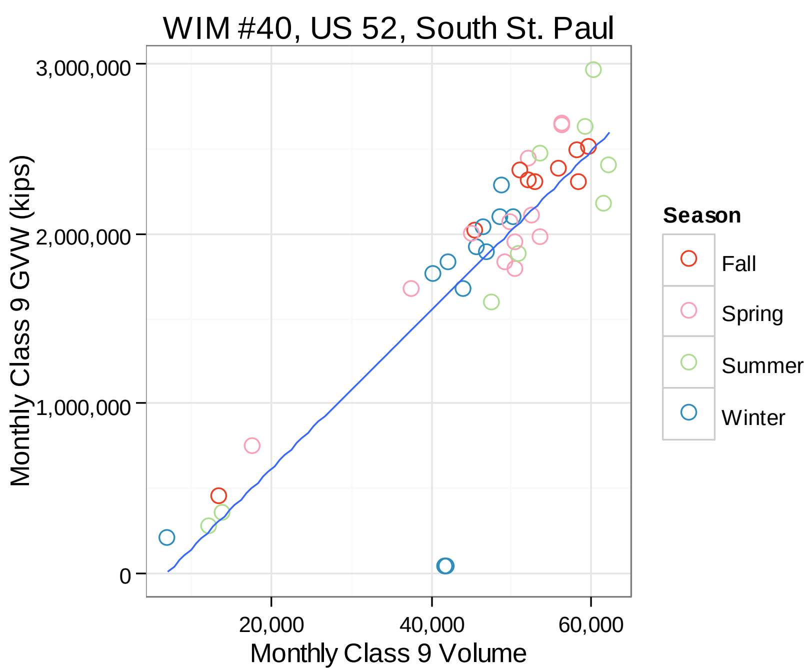


Figure 5.192b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

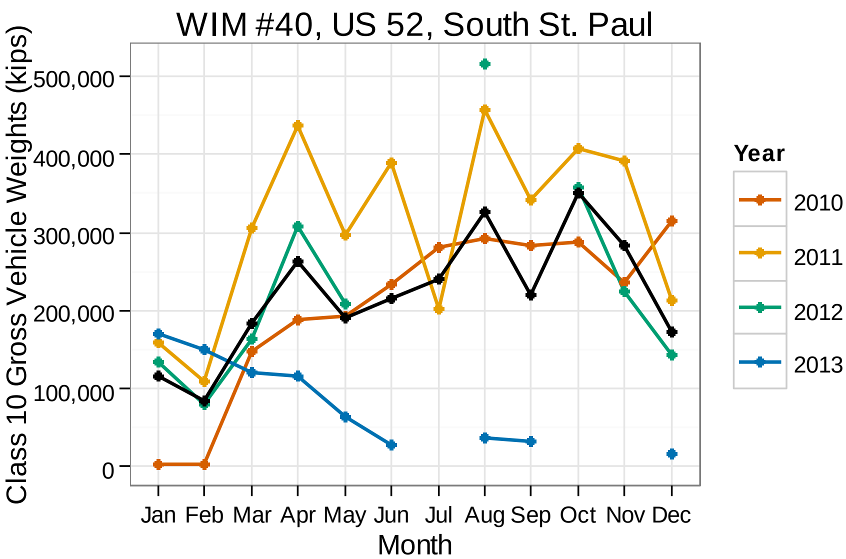


Figure 5.193a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

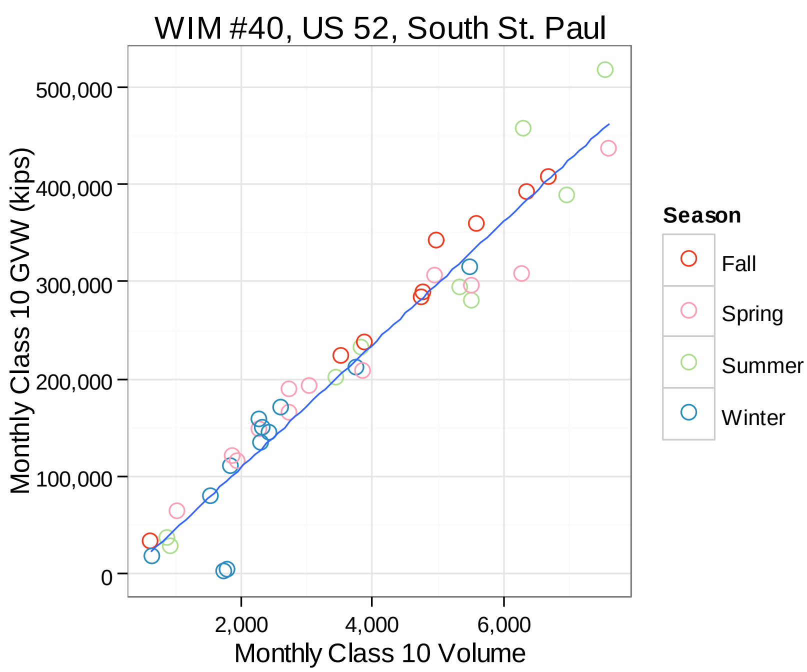


Figure 5.193b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

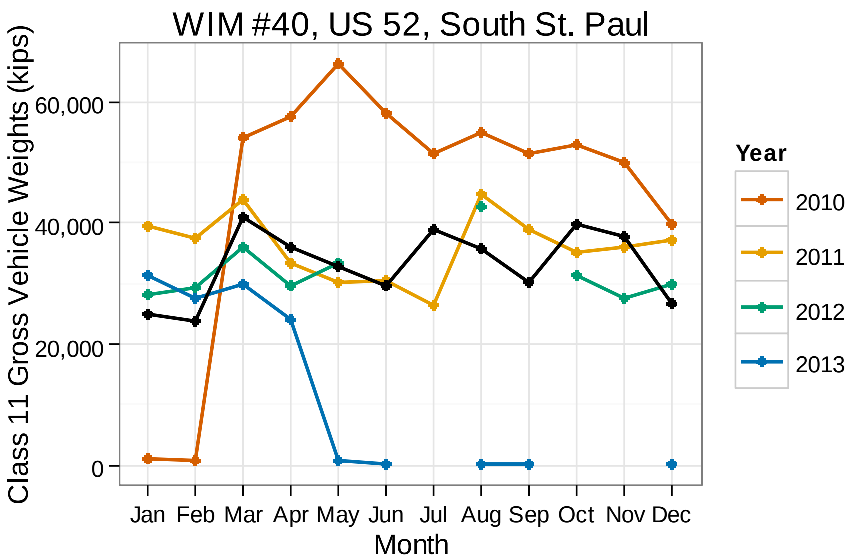


Figure 5.194a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

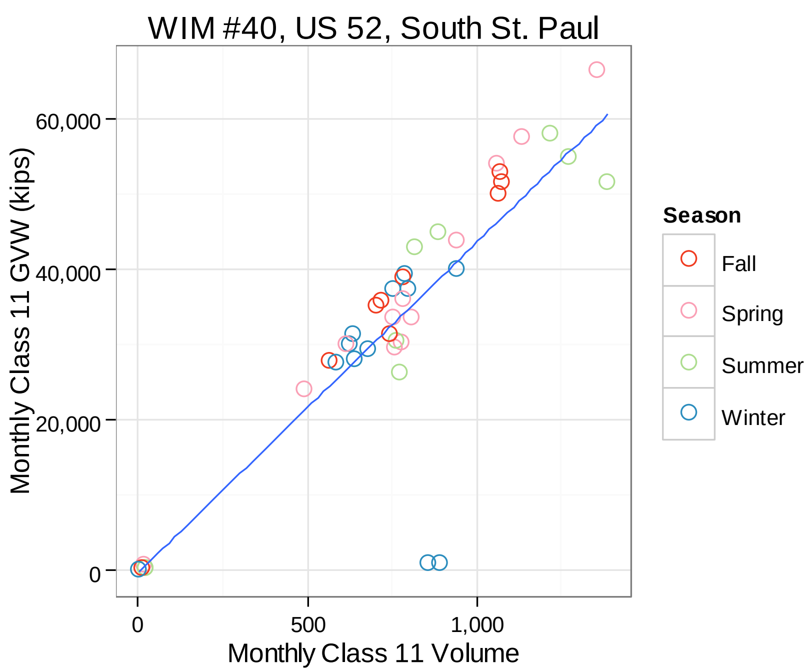


Figure 5.194b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

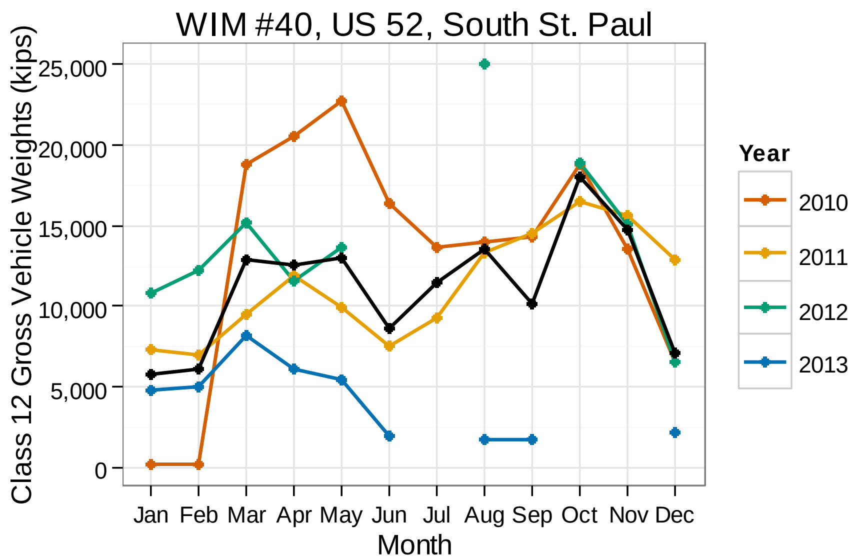


Figure 5.195a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

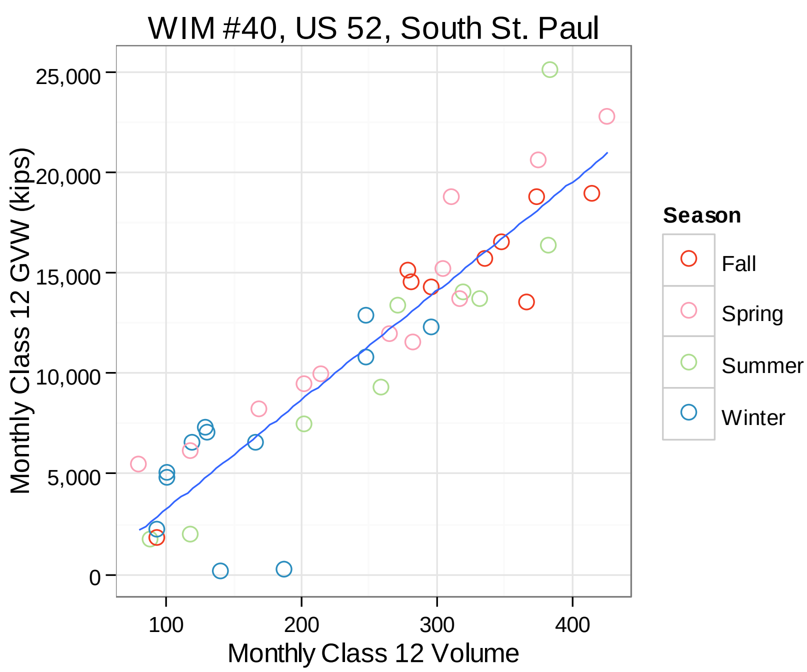


Figure 5.195b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

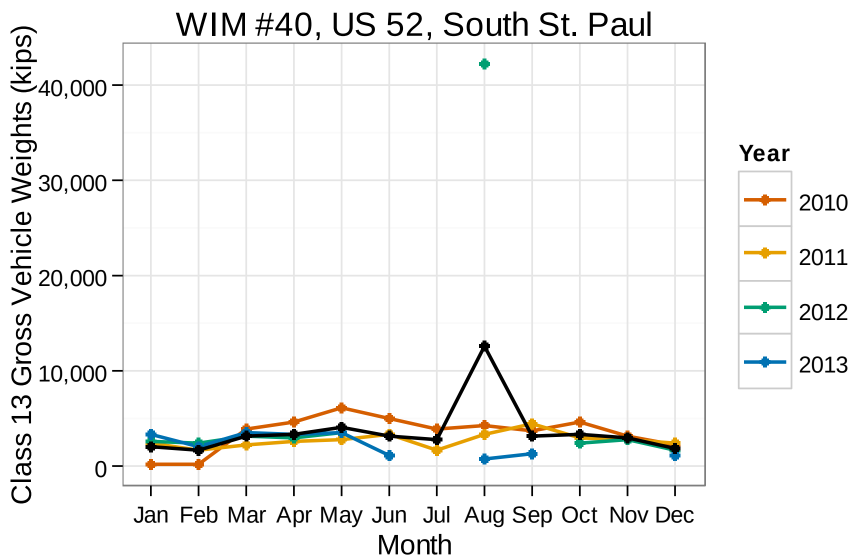


Figure 5.196a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

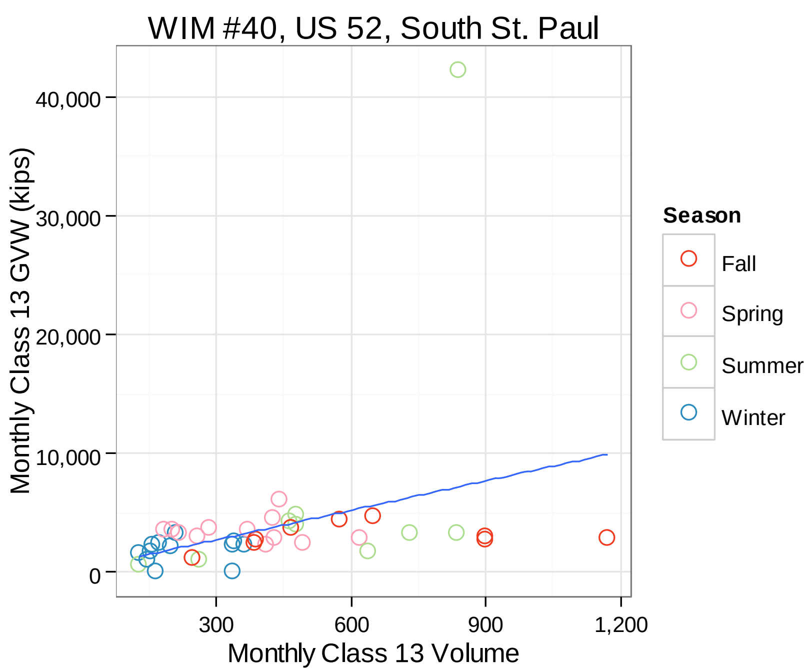


Figure 5.196b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

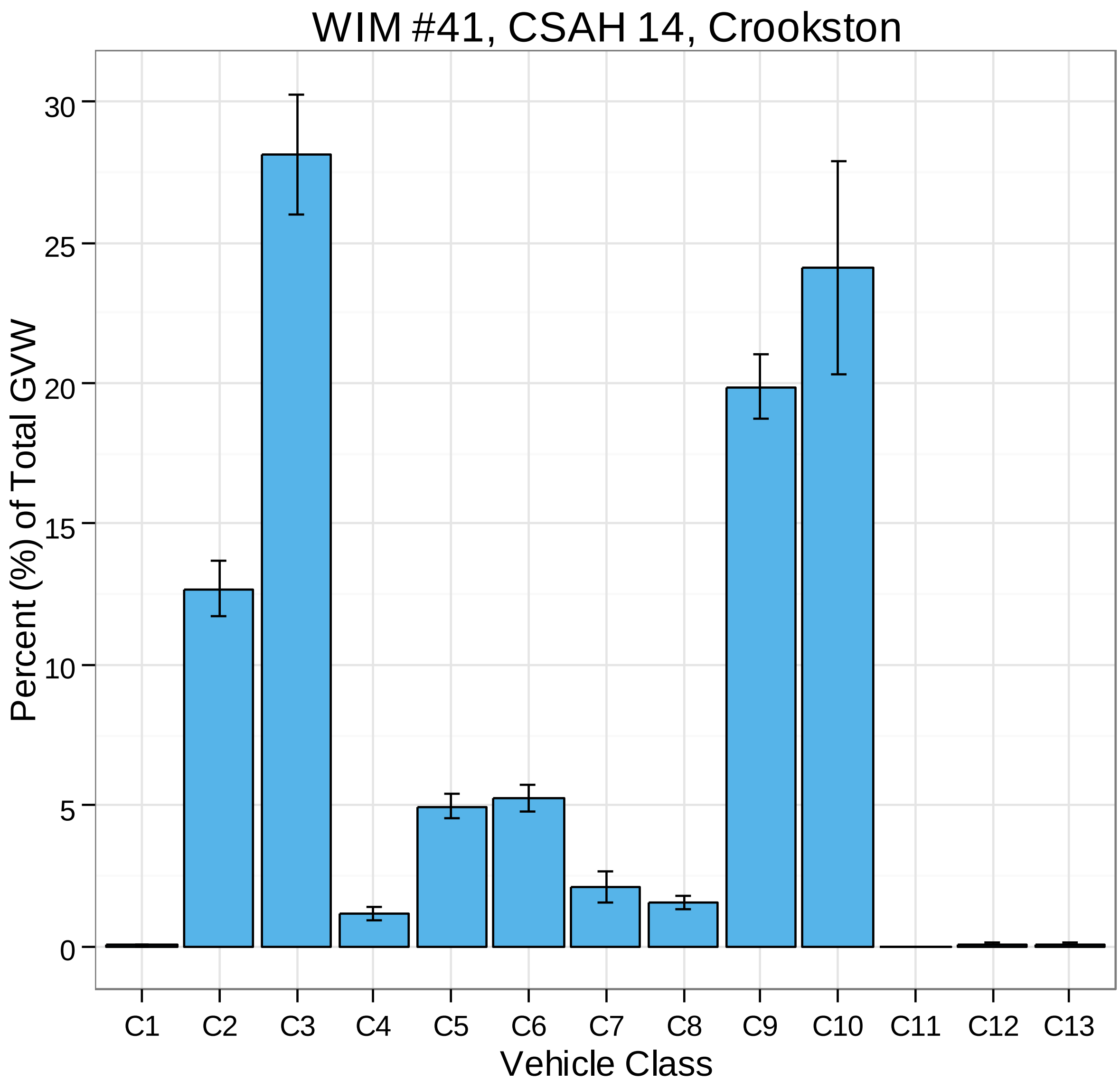


Figure 5.197. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

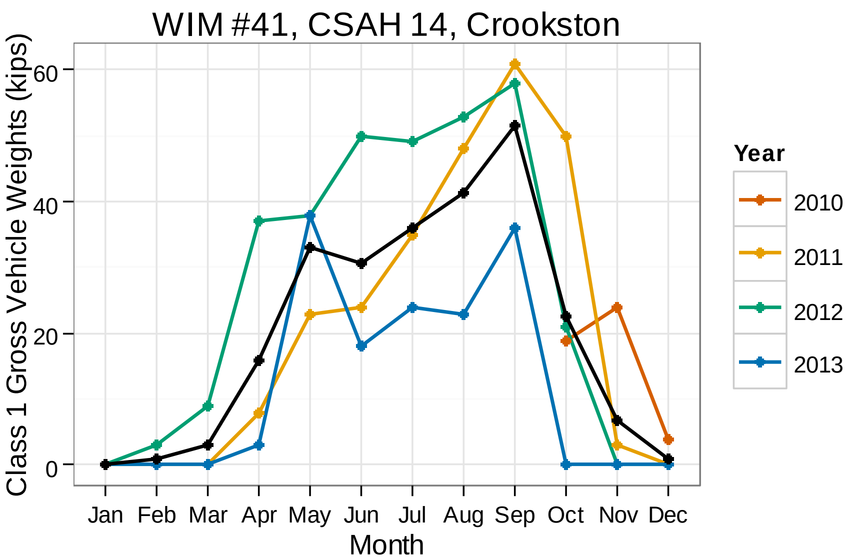


Figure 5.198a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

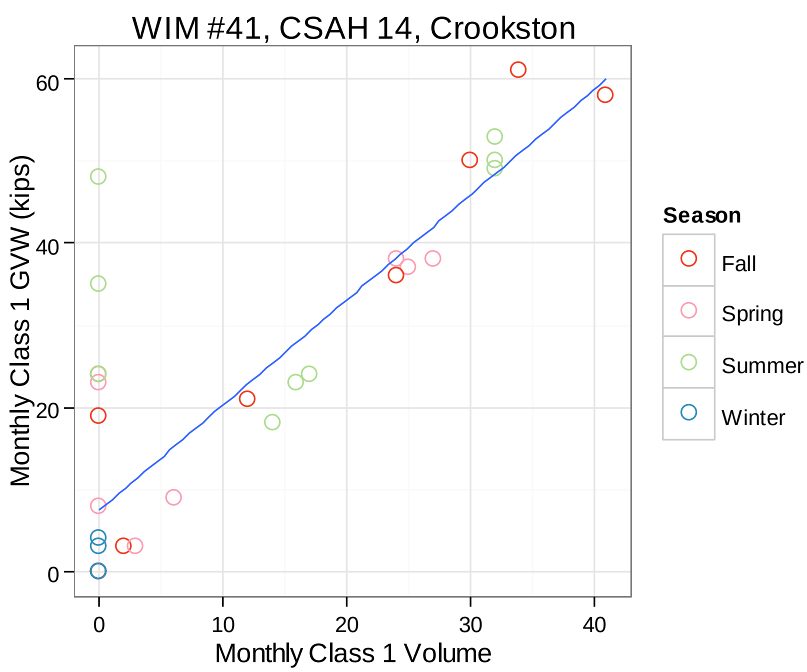


Figure 5.198b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

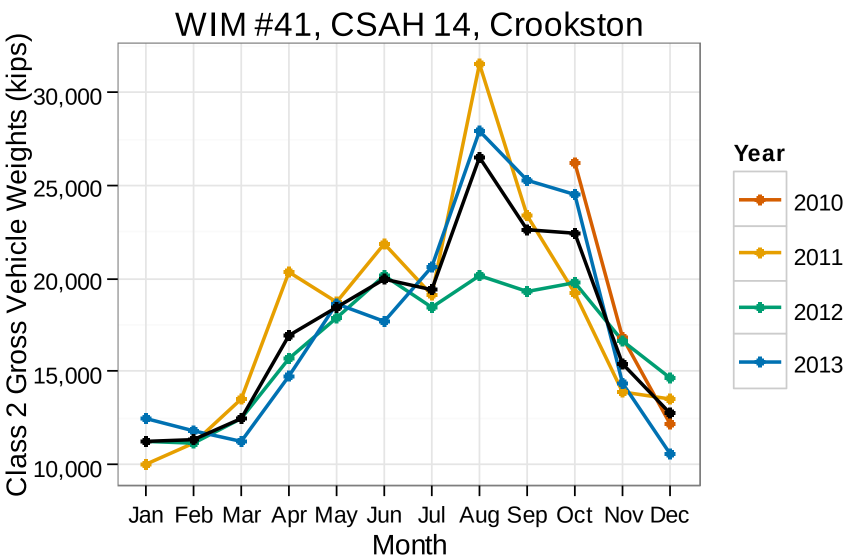


Figure 5.199a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

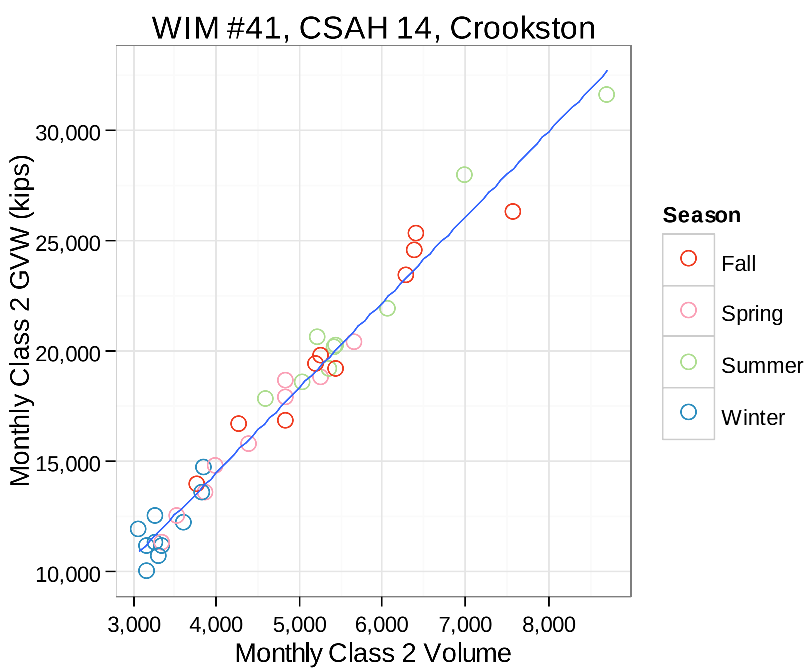


Figure 5.199b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

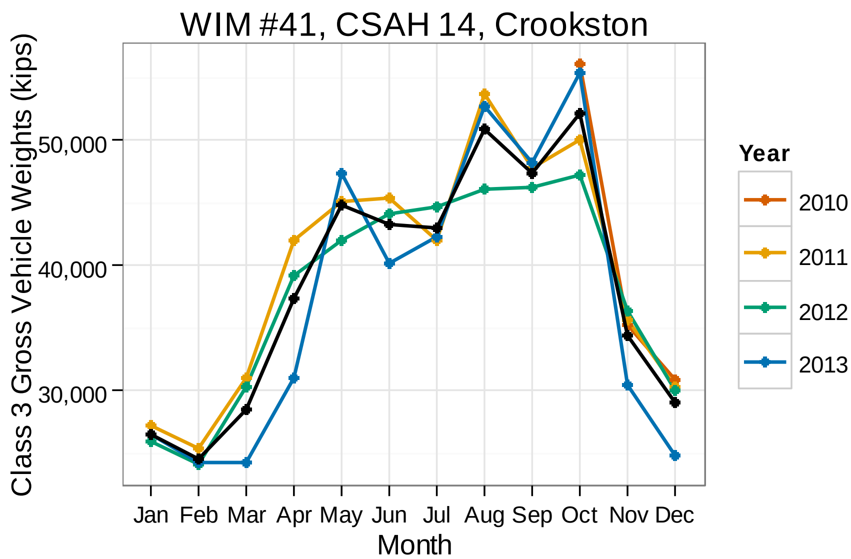


Figure 5.200a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

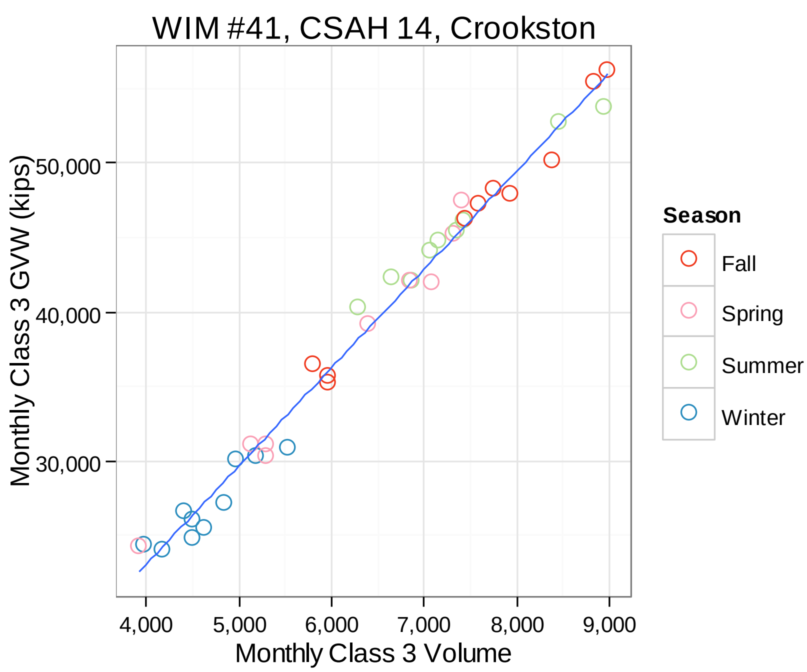


Figure 5.200b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

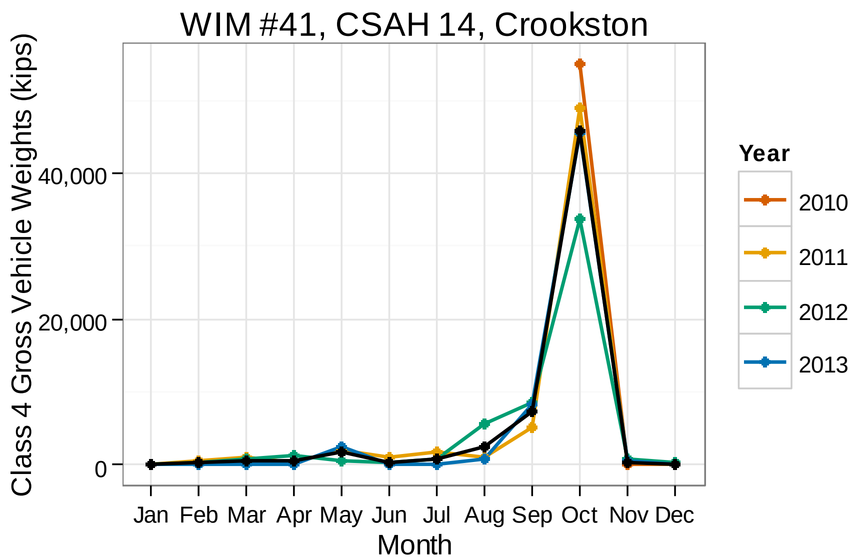


Figure 5.201a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

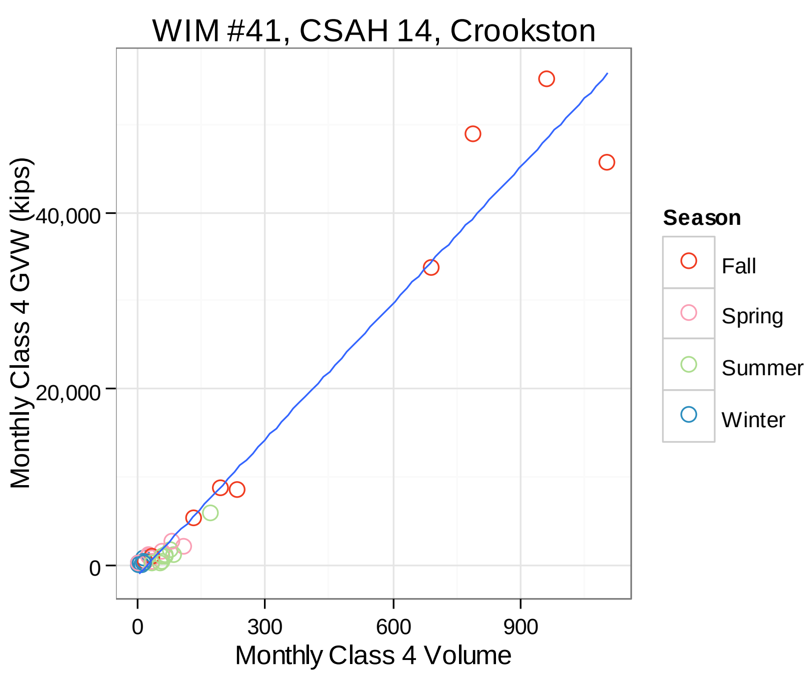


Figure 5.201b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

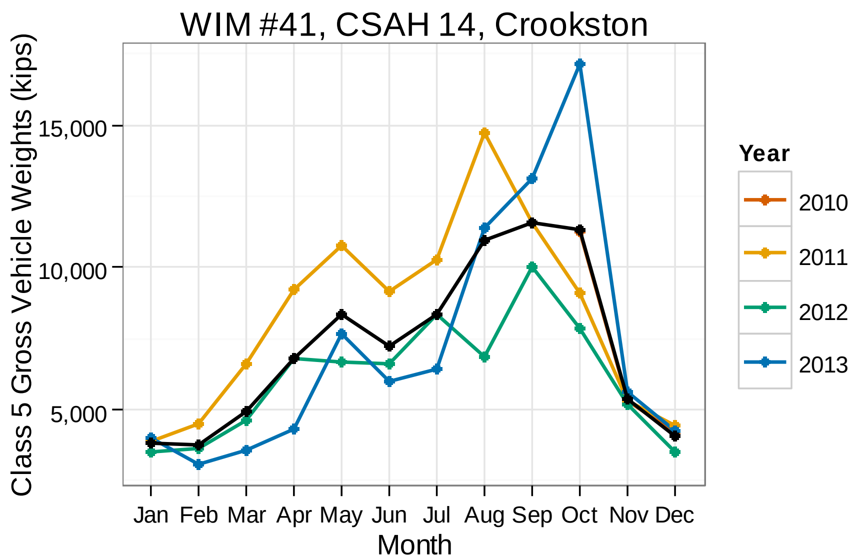


Figure 5.202a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

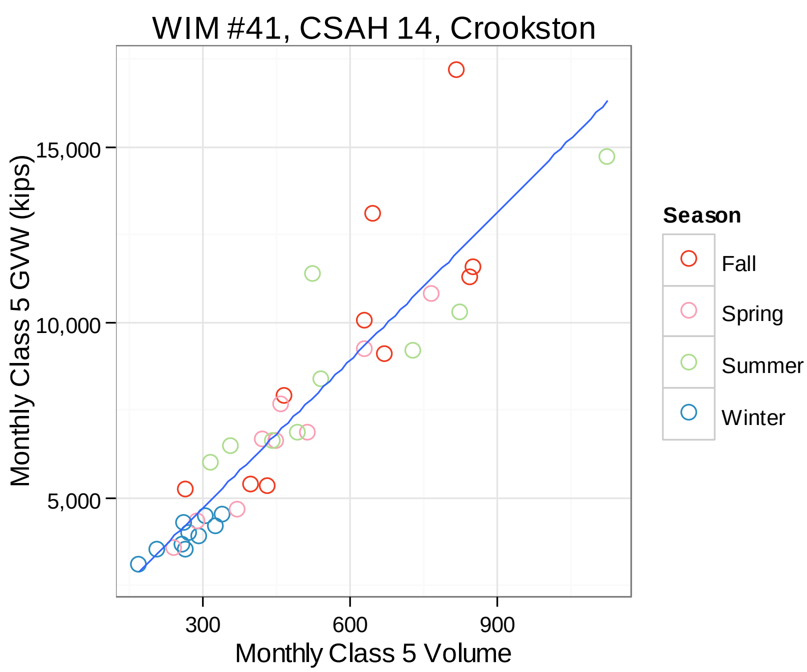


Figure 5.202b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

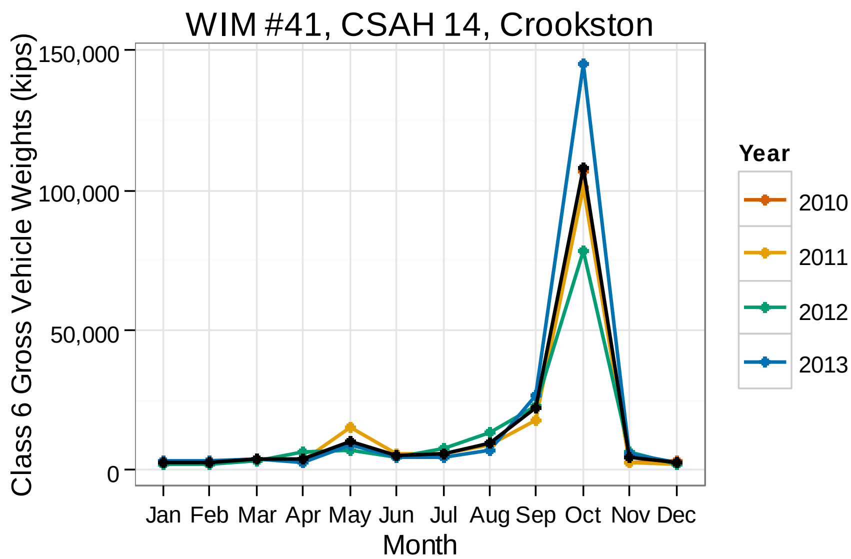


Figure 5.203a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

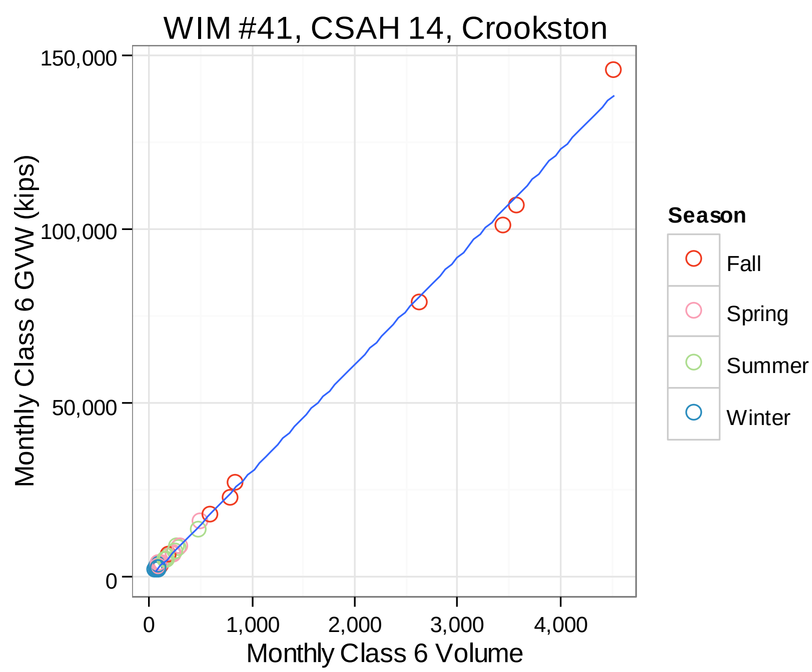


Figure 5.203b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

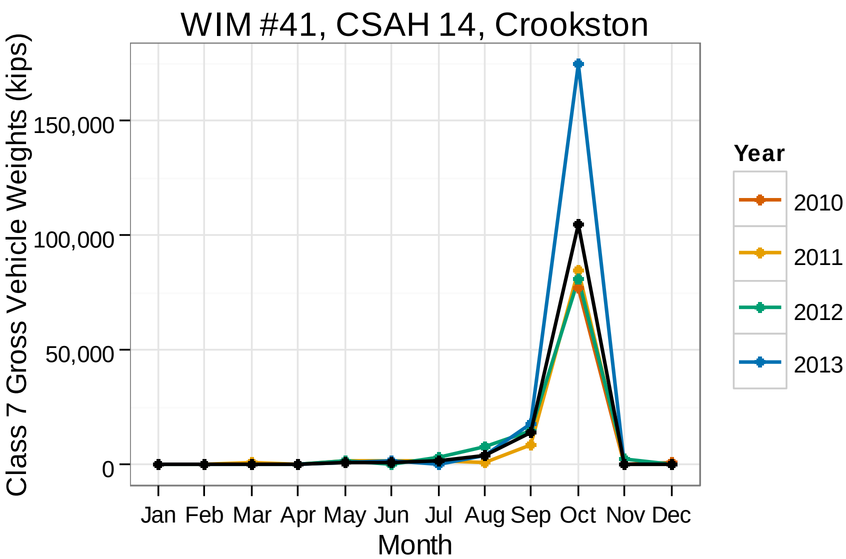


Figure 5.204a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

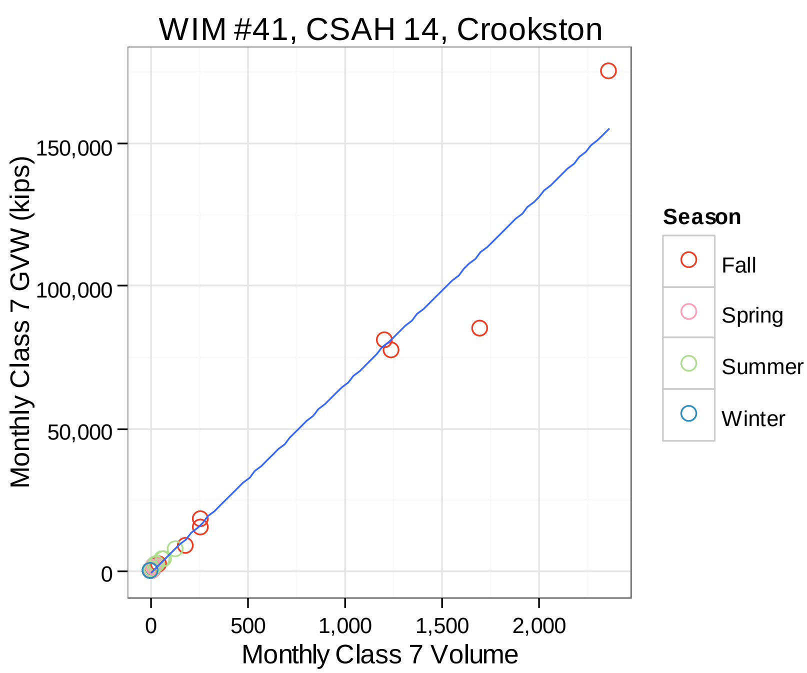


Figure 5.204b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

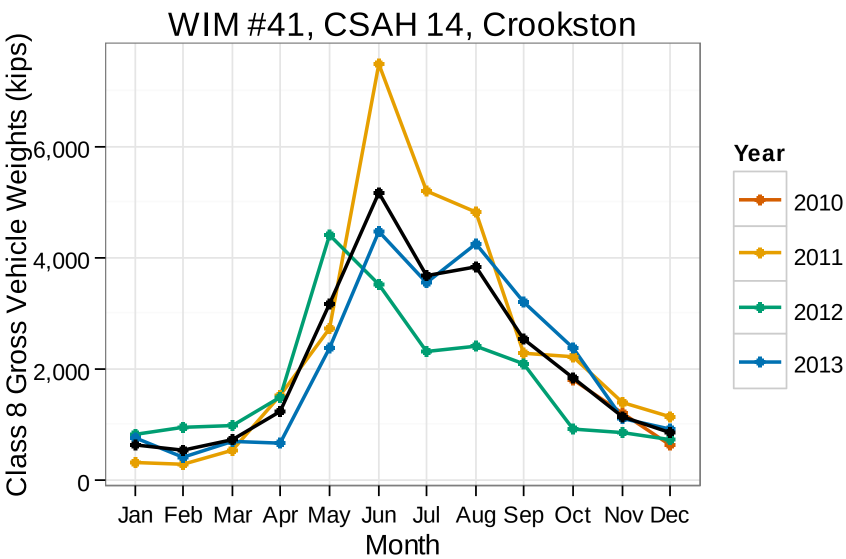


Figure 5.205a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

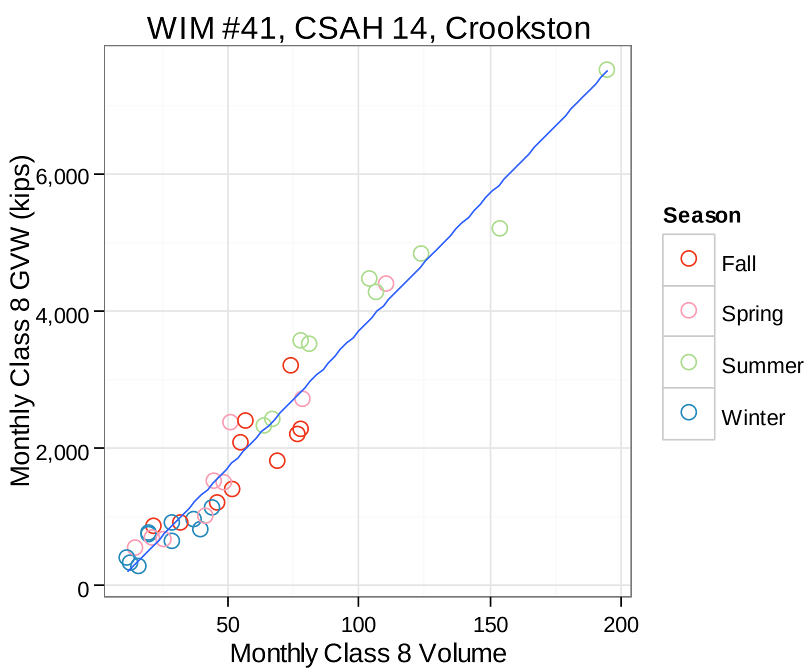


Figure 5.205b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

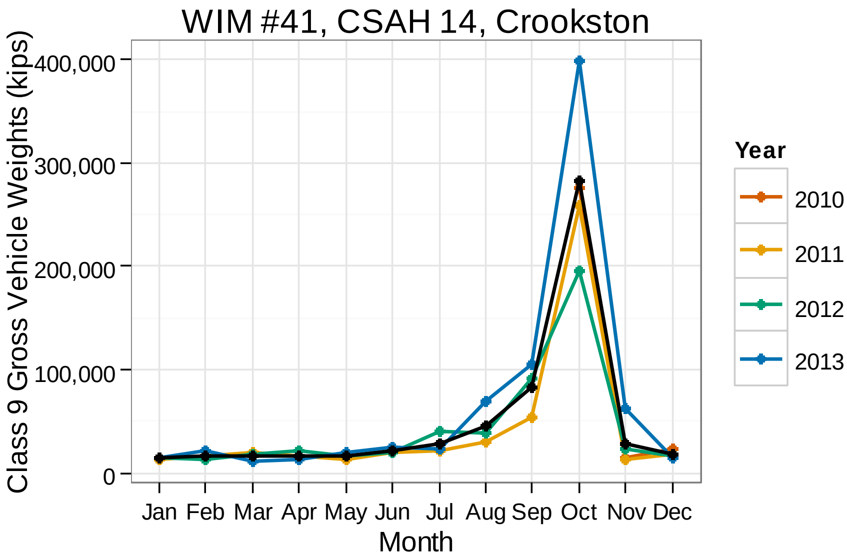


Figure 5.206a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

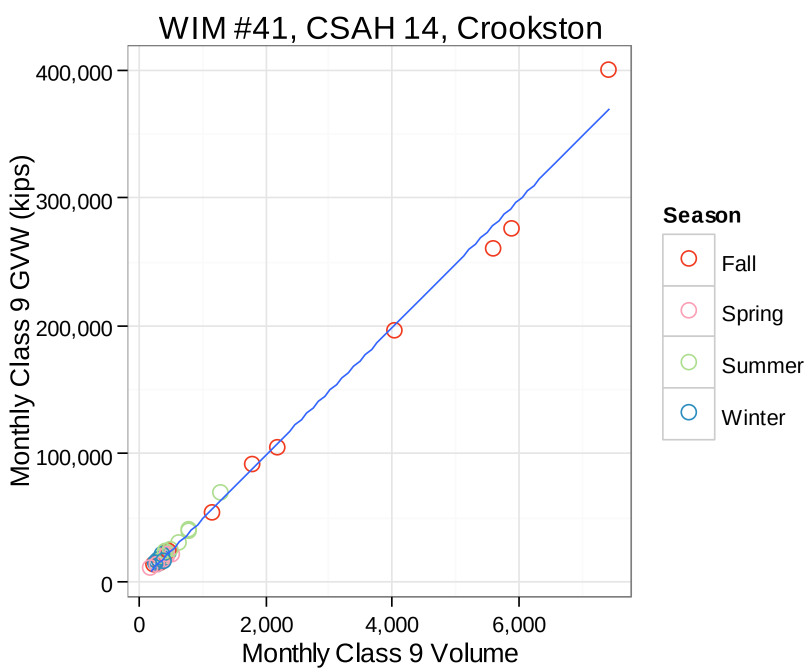


Figure 5.206b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

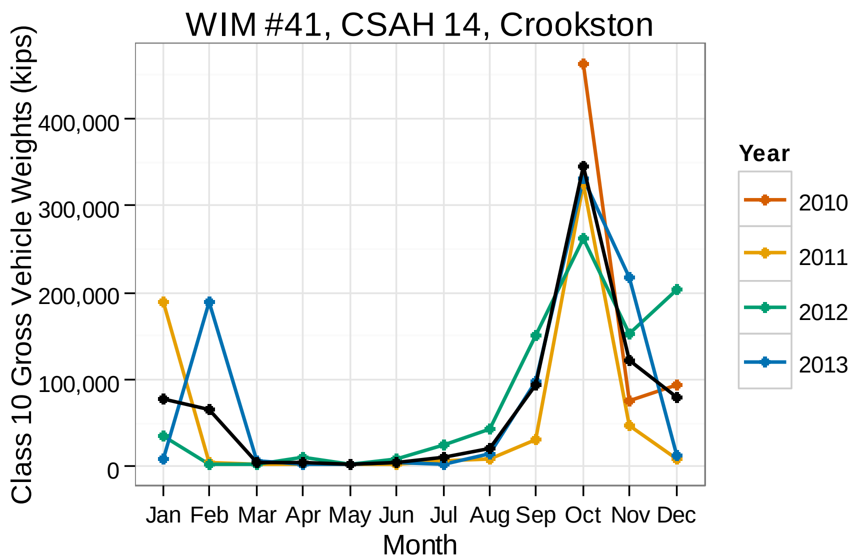


Figure 5.207a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

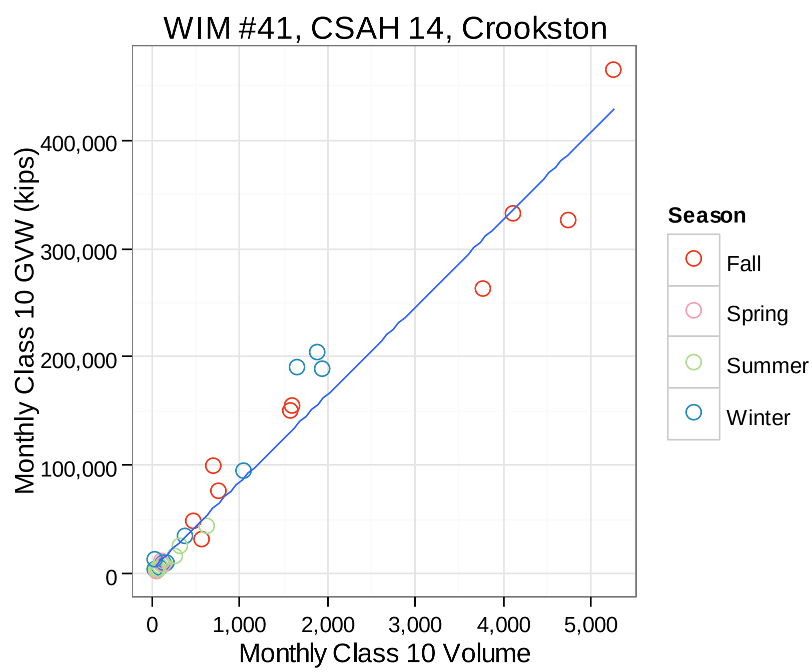


Figure 5.207b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

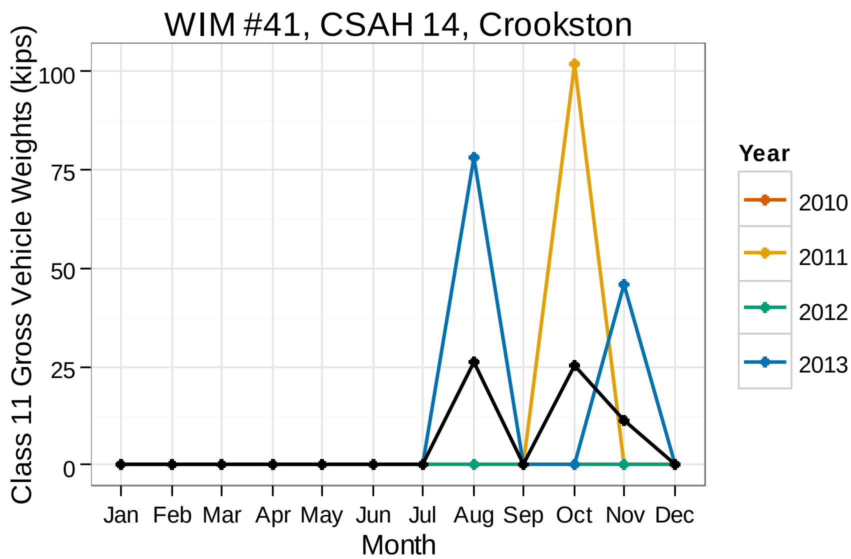


Figure 5.208a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

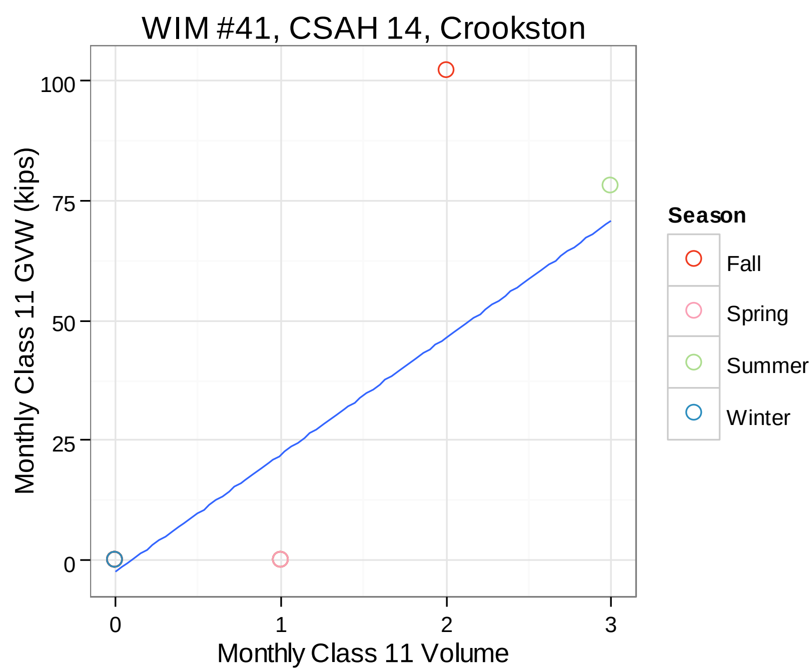


Figure 5.208b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

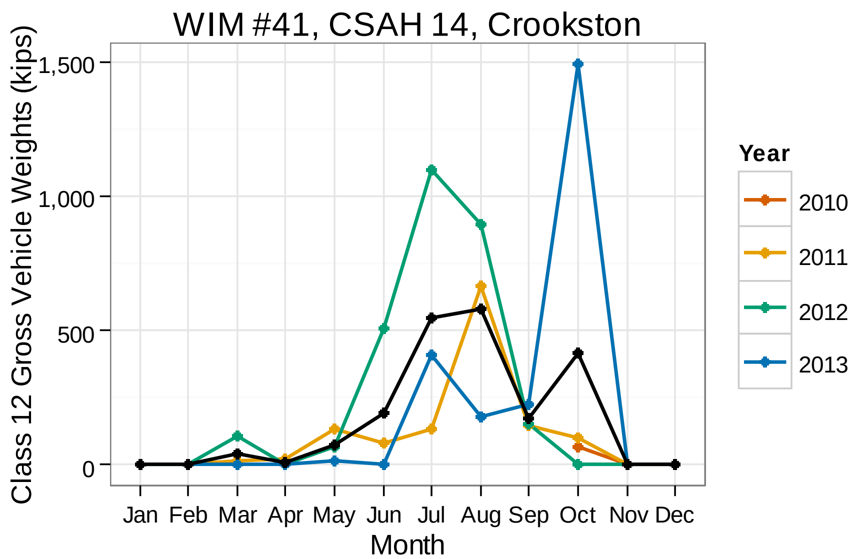


Figure 5.209a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

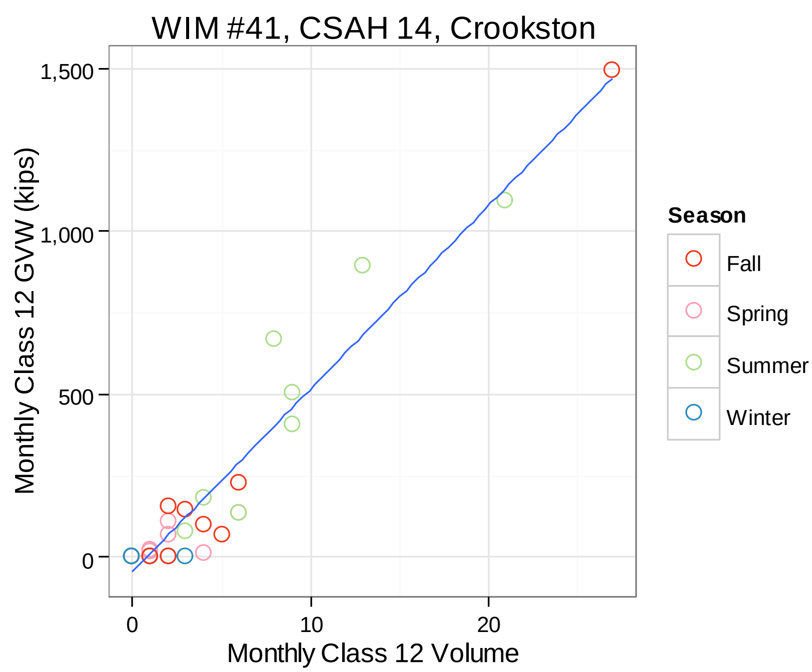


Figure 5.209b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

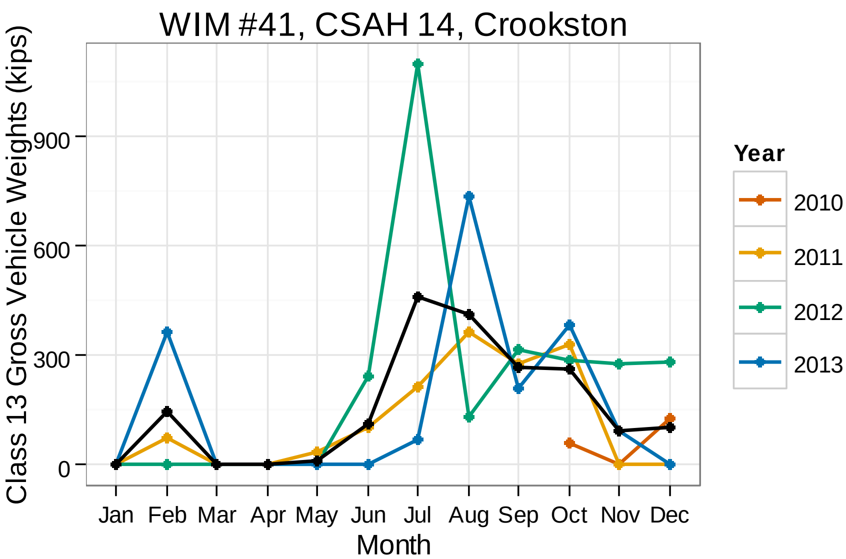


Figure 5.210a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

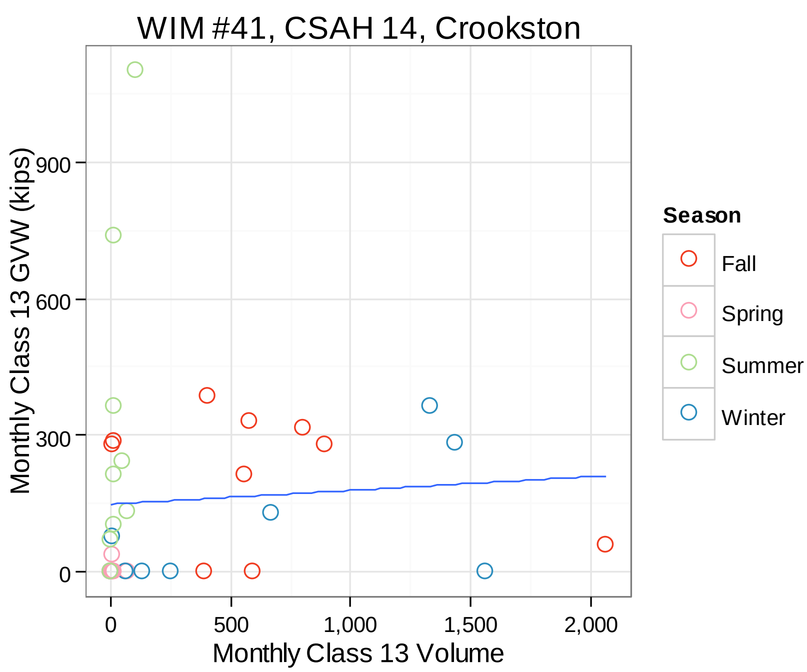


Figure 5.210b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

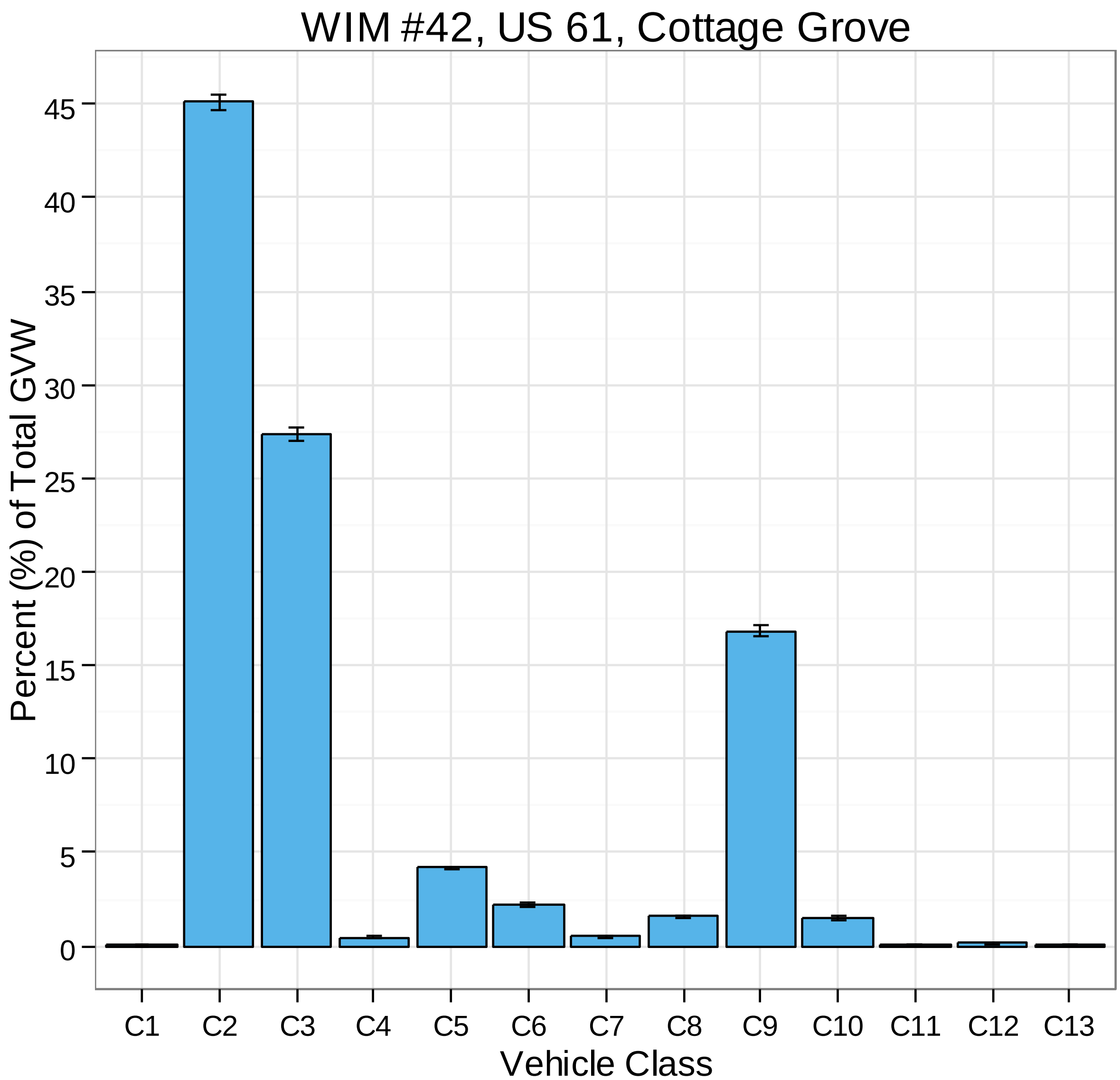


Figure 5.211. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

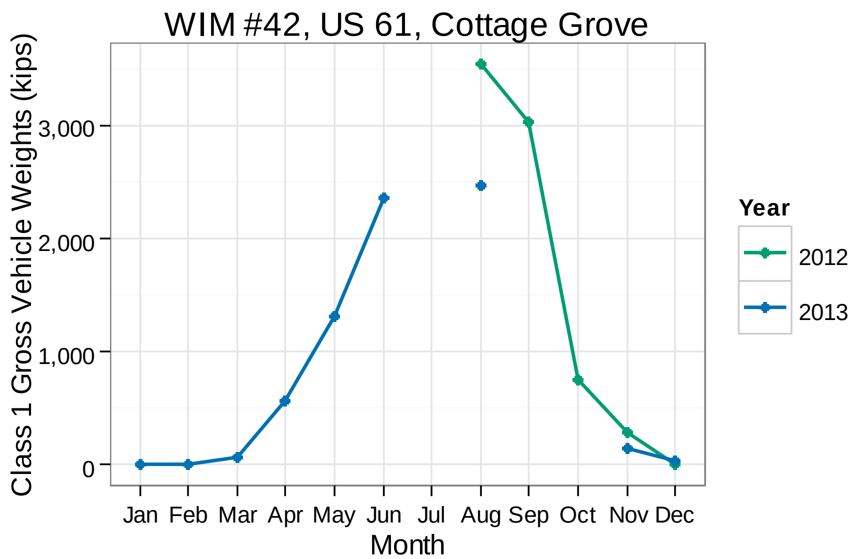


Figure 5.212a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

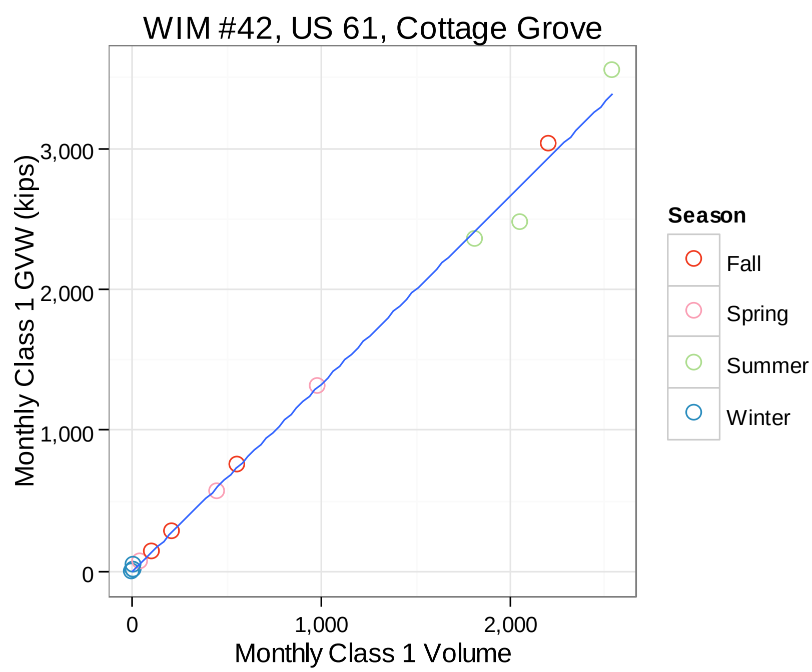


Figure 5.212b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

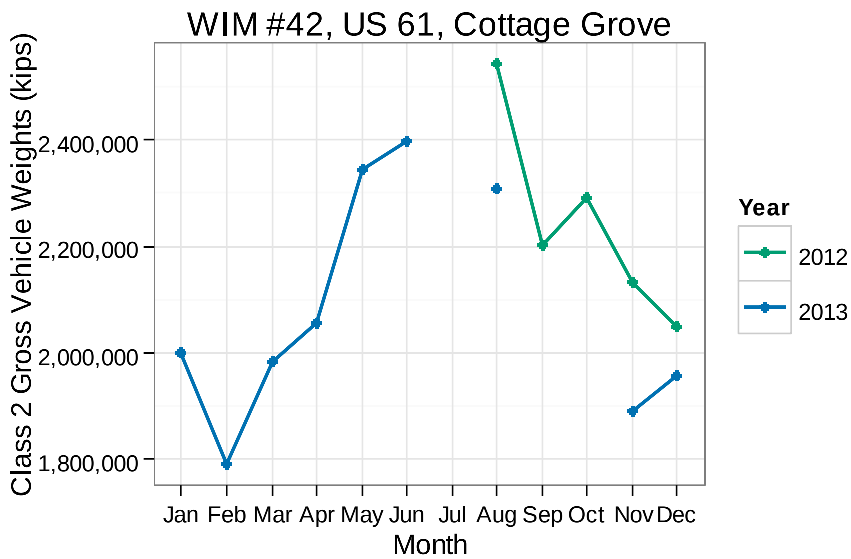


Figure 5.213a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

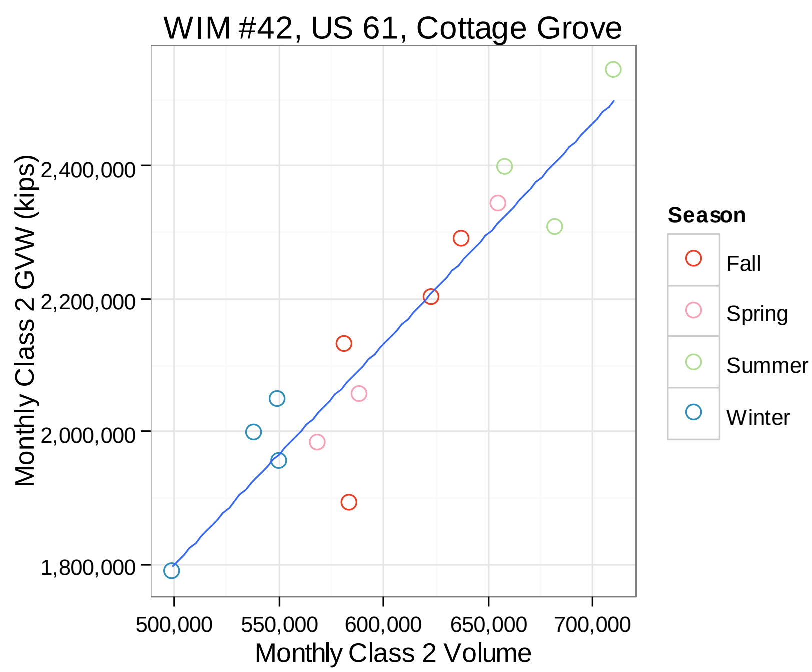


Figure 5.213b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

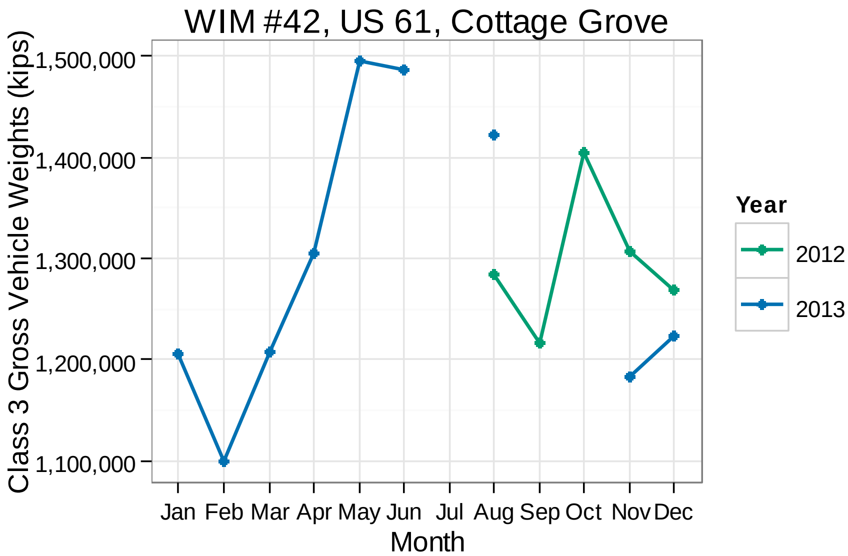


Figure 5.214a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

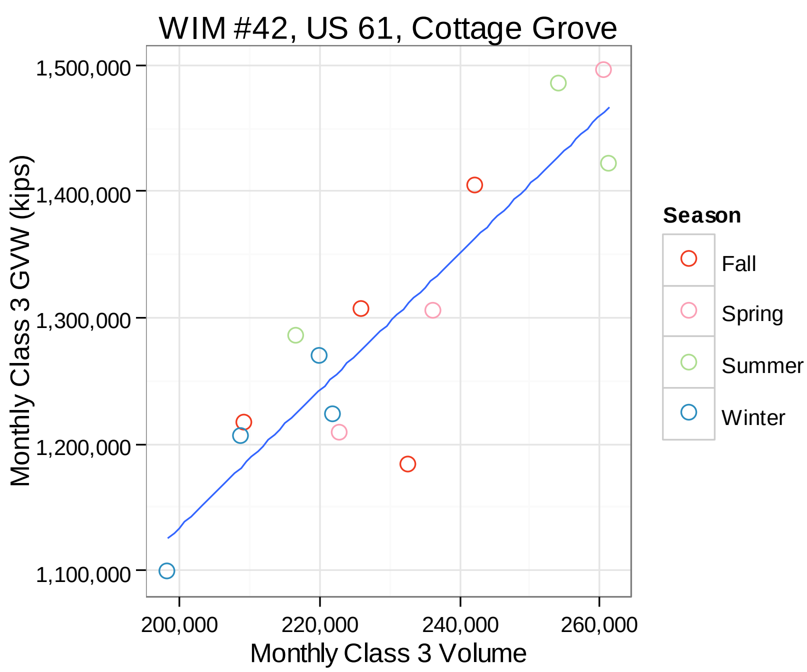


Figure 5.214b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

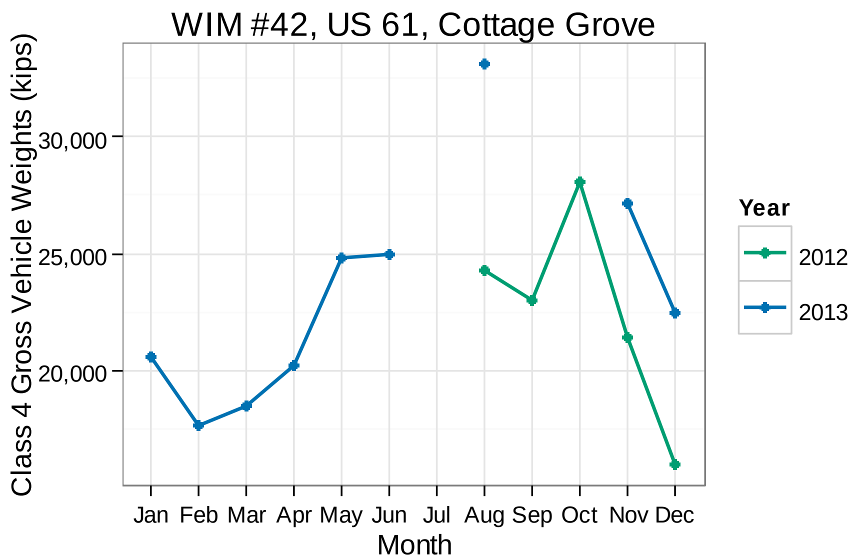


Figure 5.215a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

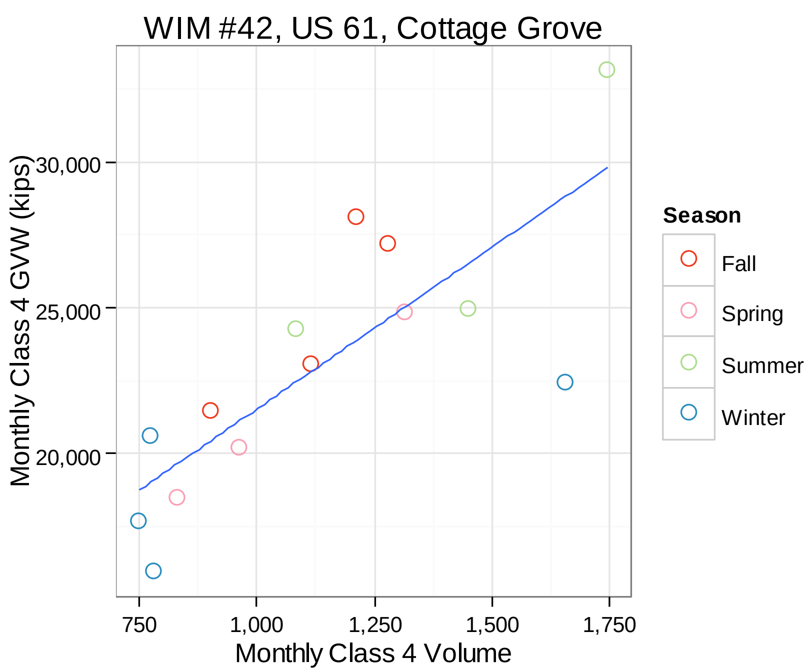


Figure 5.215b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

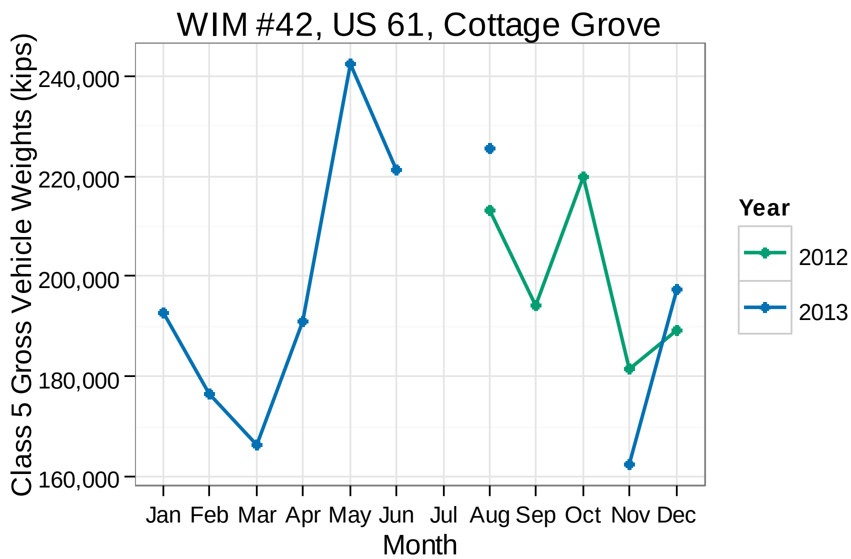


Figure 5.216a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

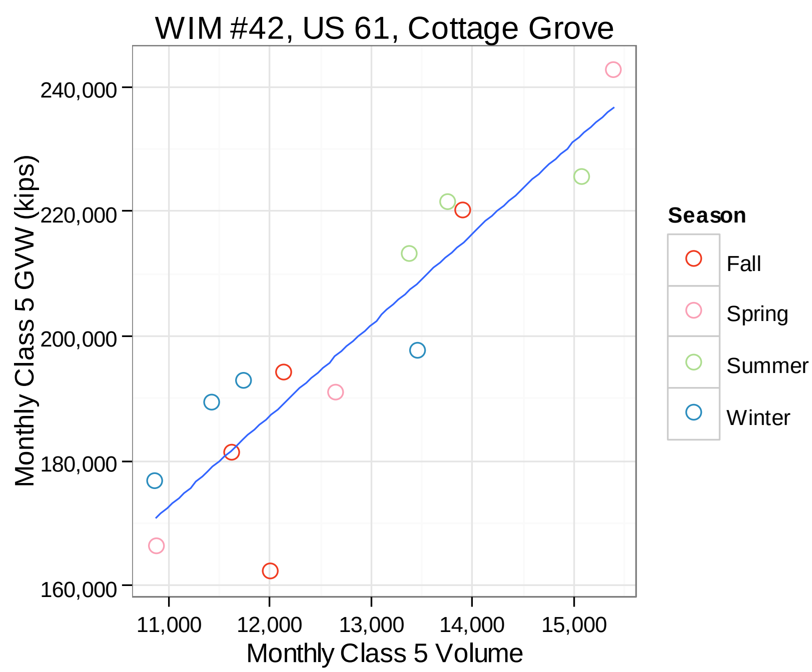


Figure 5.216b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

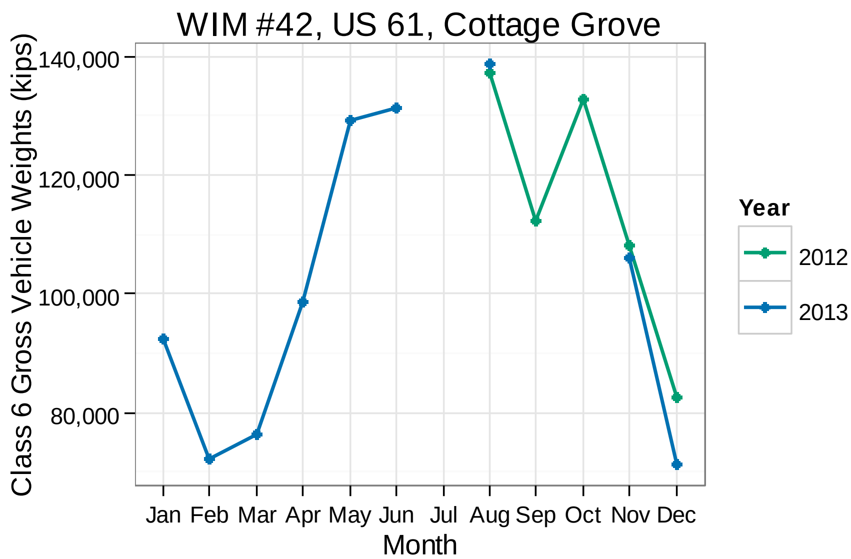


Figure 5.217a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

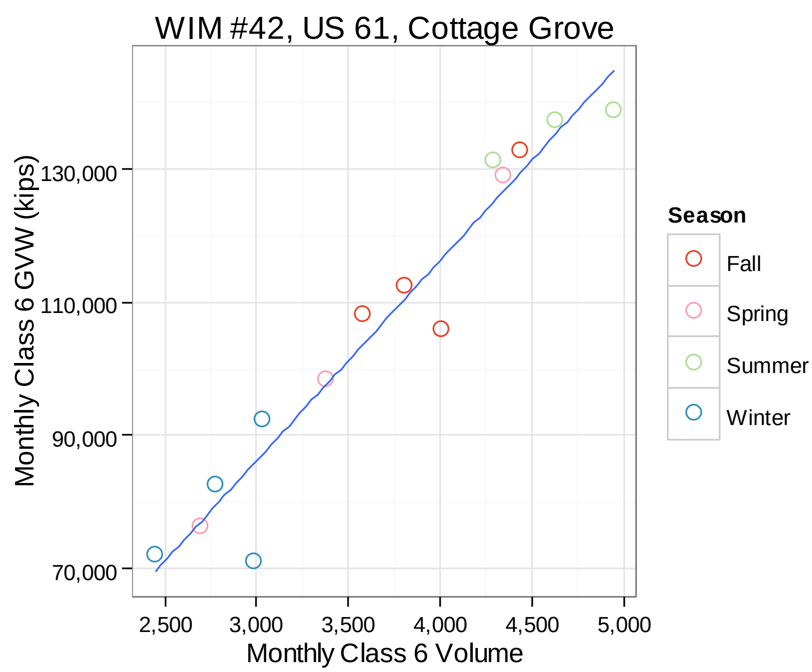


Figure 5.217b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

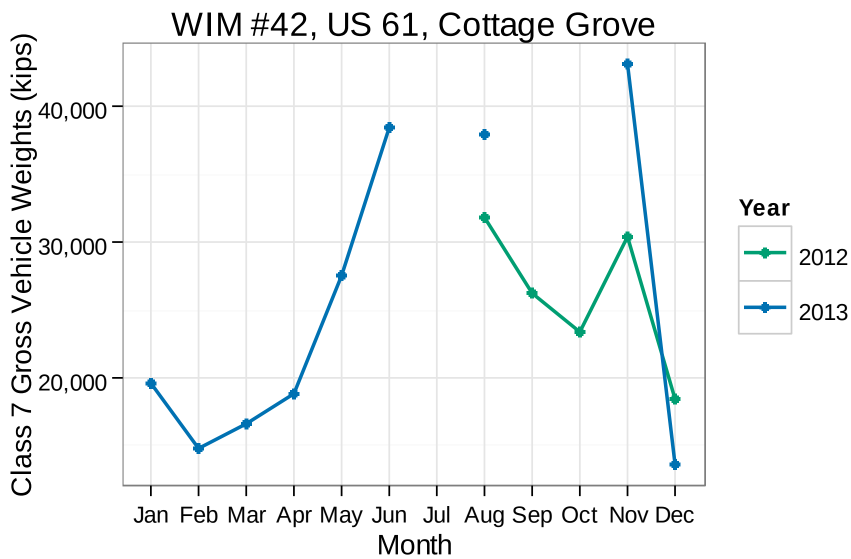


Figure 5.218a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

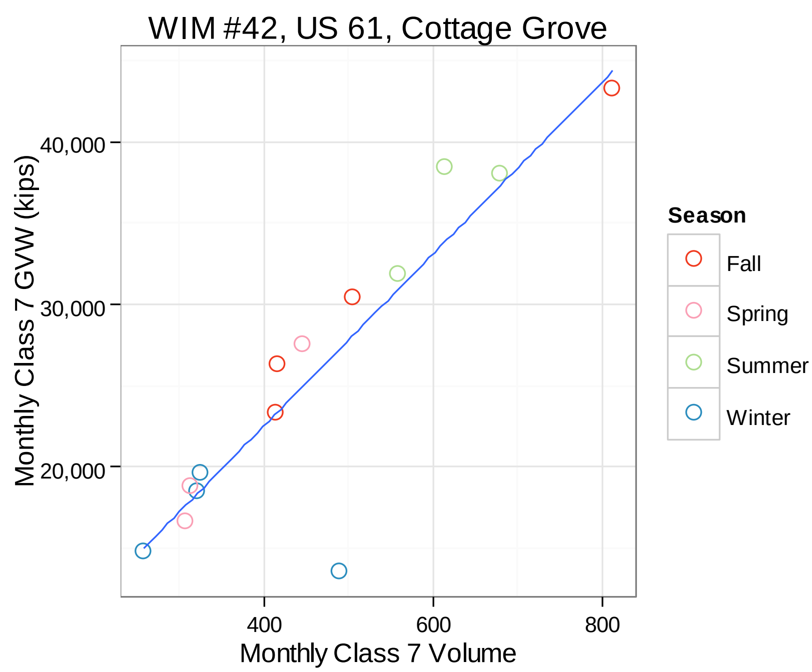


Figure 5.218b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

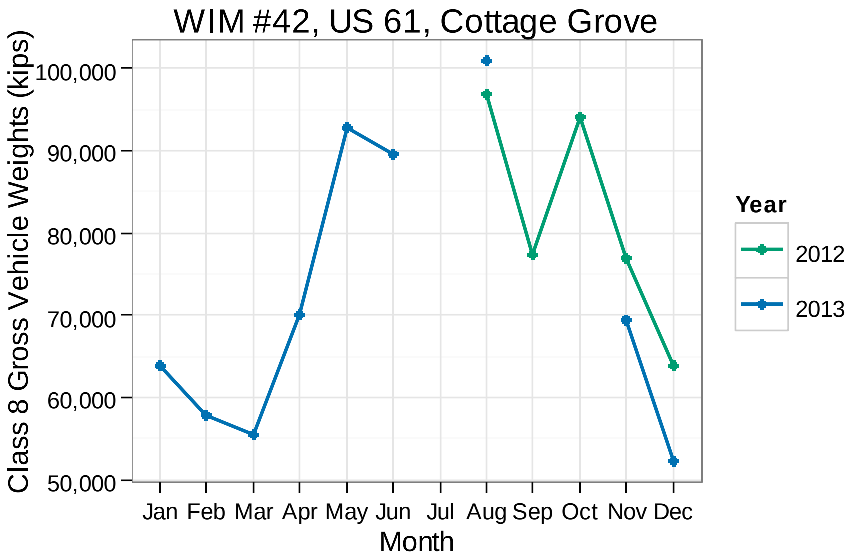


Figure 5.219a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

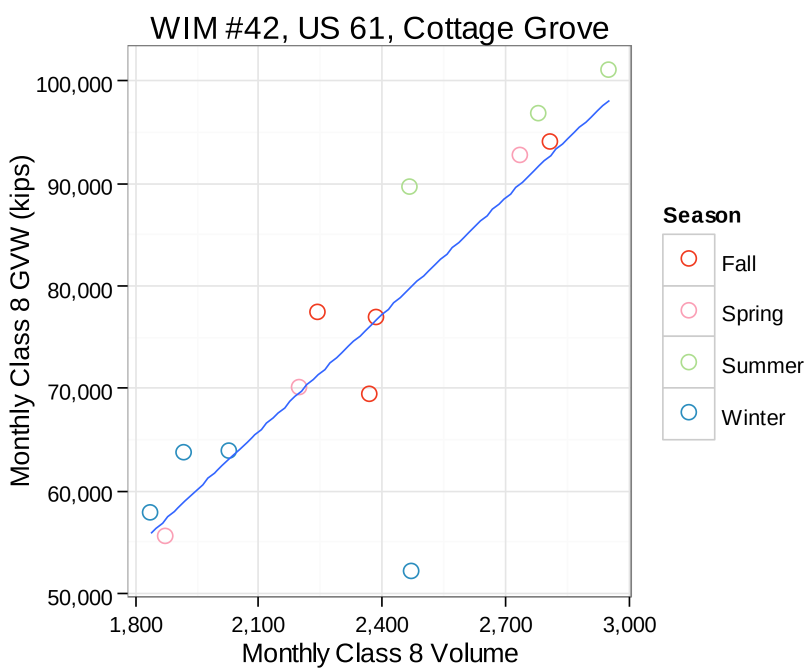


Figure 5.219b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

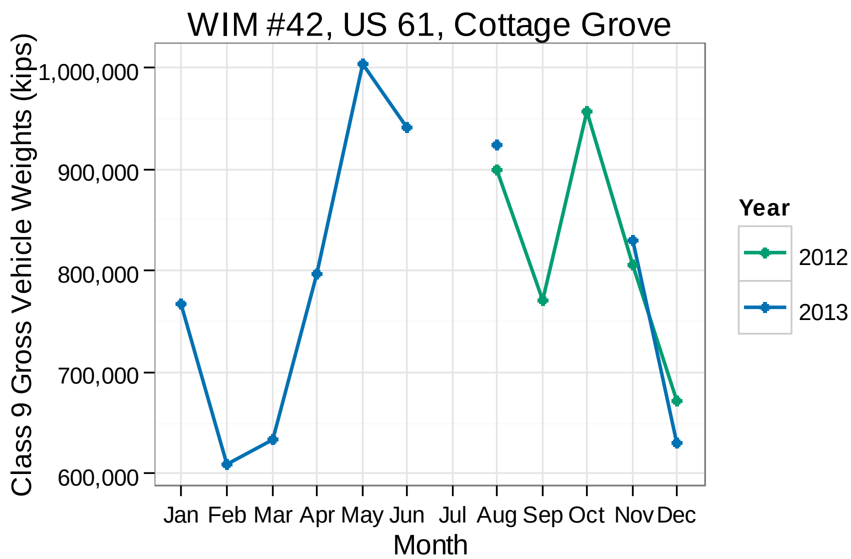


Figure 5.220a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

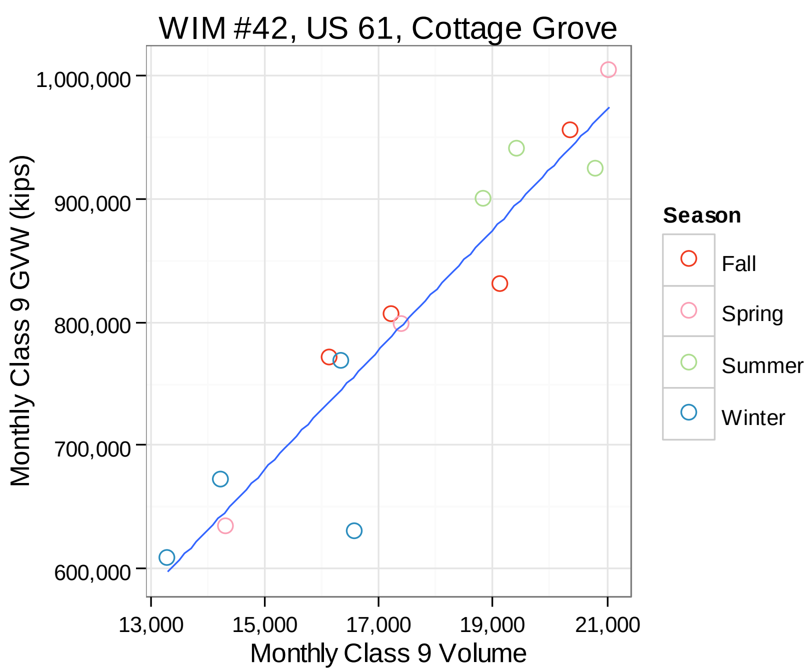


Figure 5.220b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

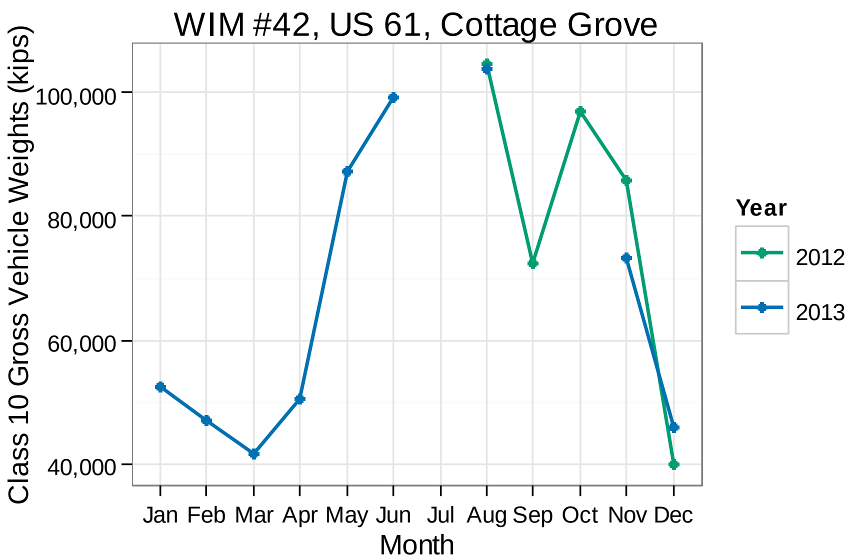


Figure 5.221a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

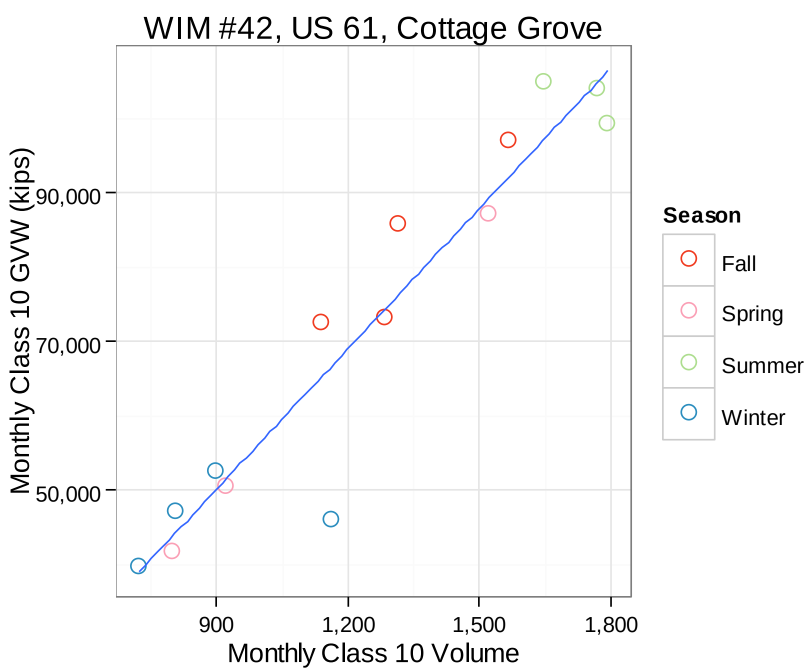


Figure 5.221b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

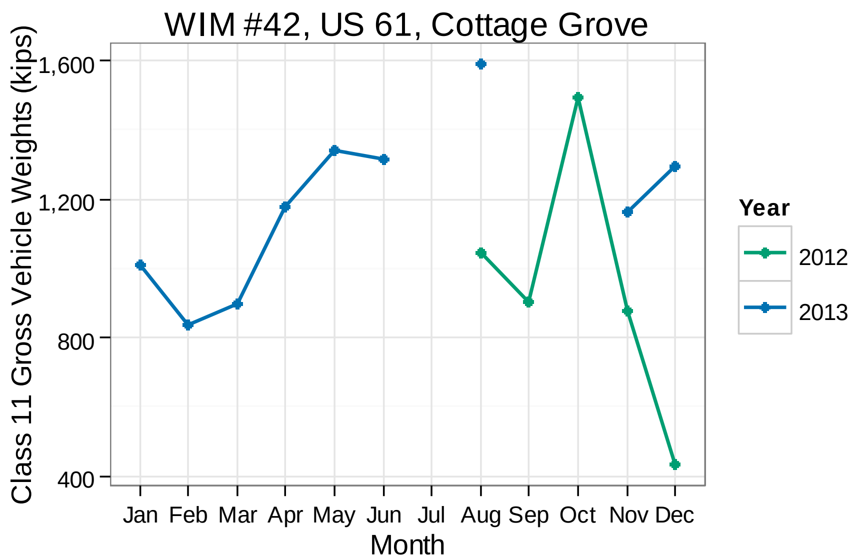


Figure 5.222a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

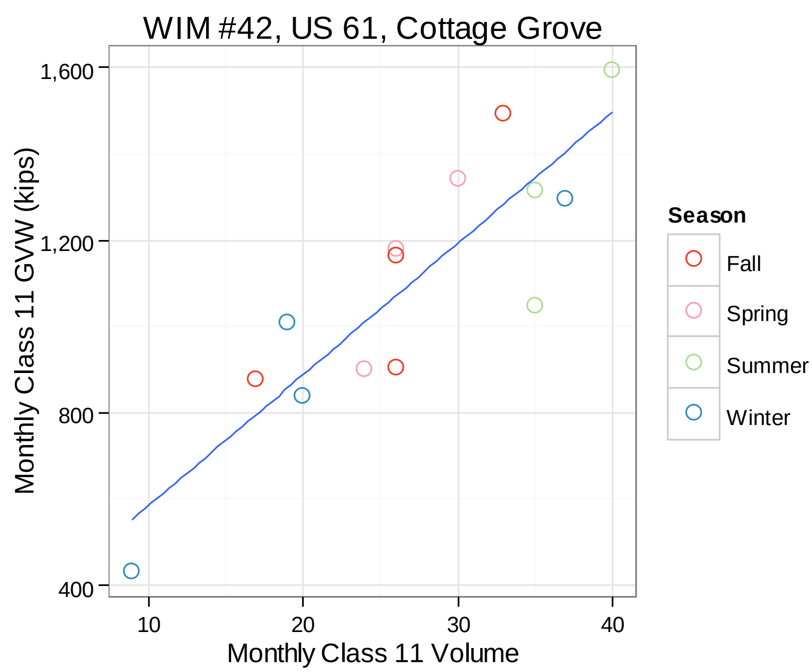


Figure 5.222b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

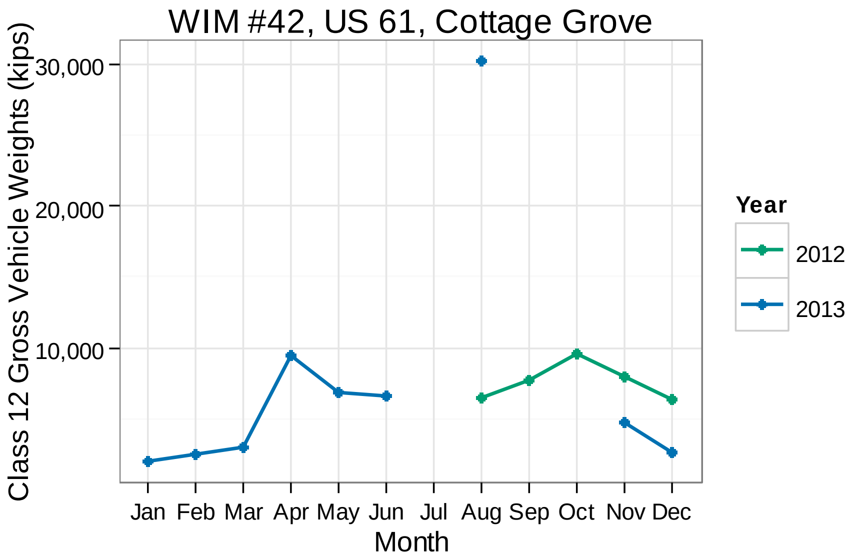


Figure 5.223a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

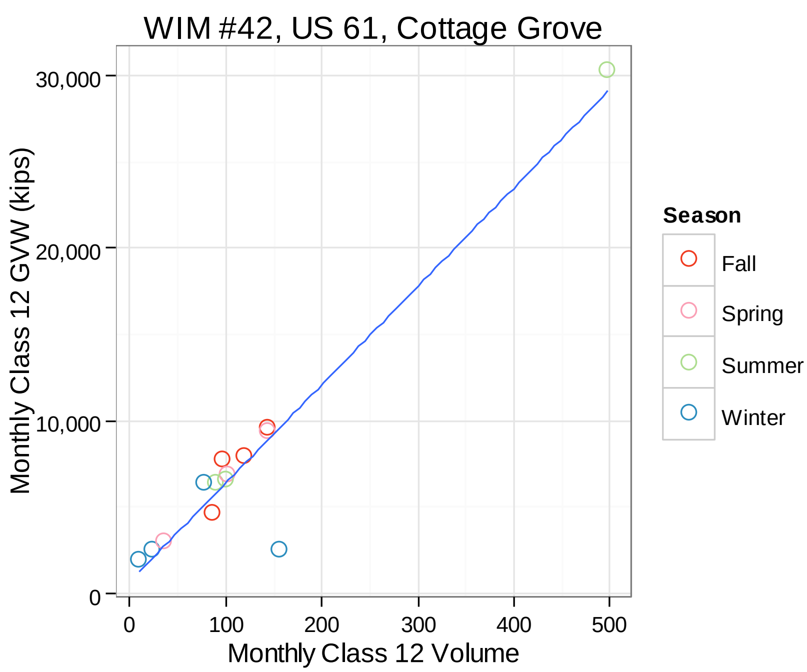


Figure 5.223b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

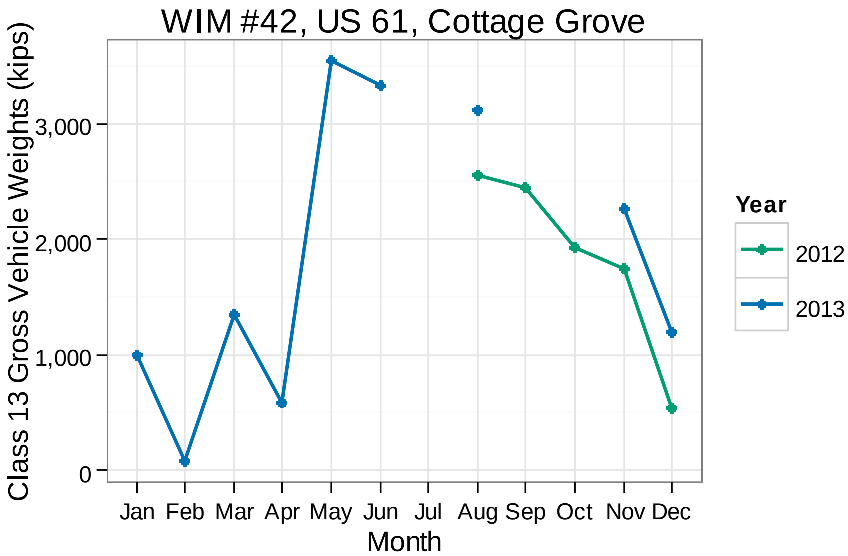


Figure 5.224a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

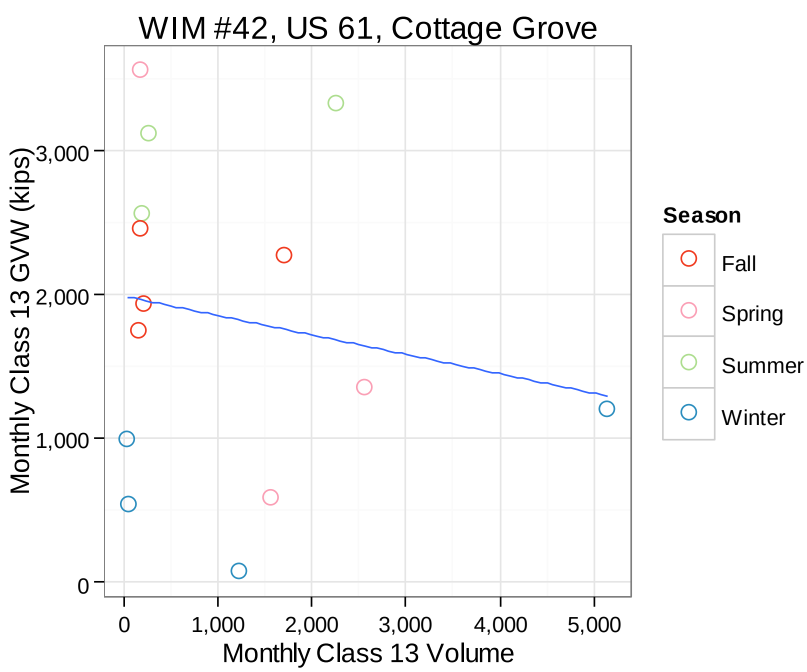


Figure 5.224b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

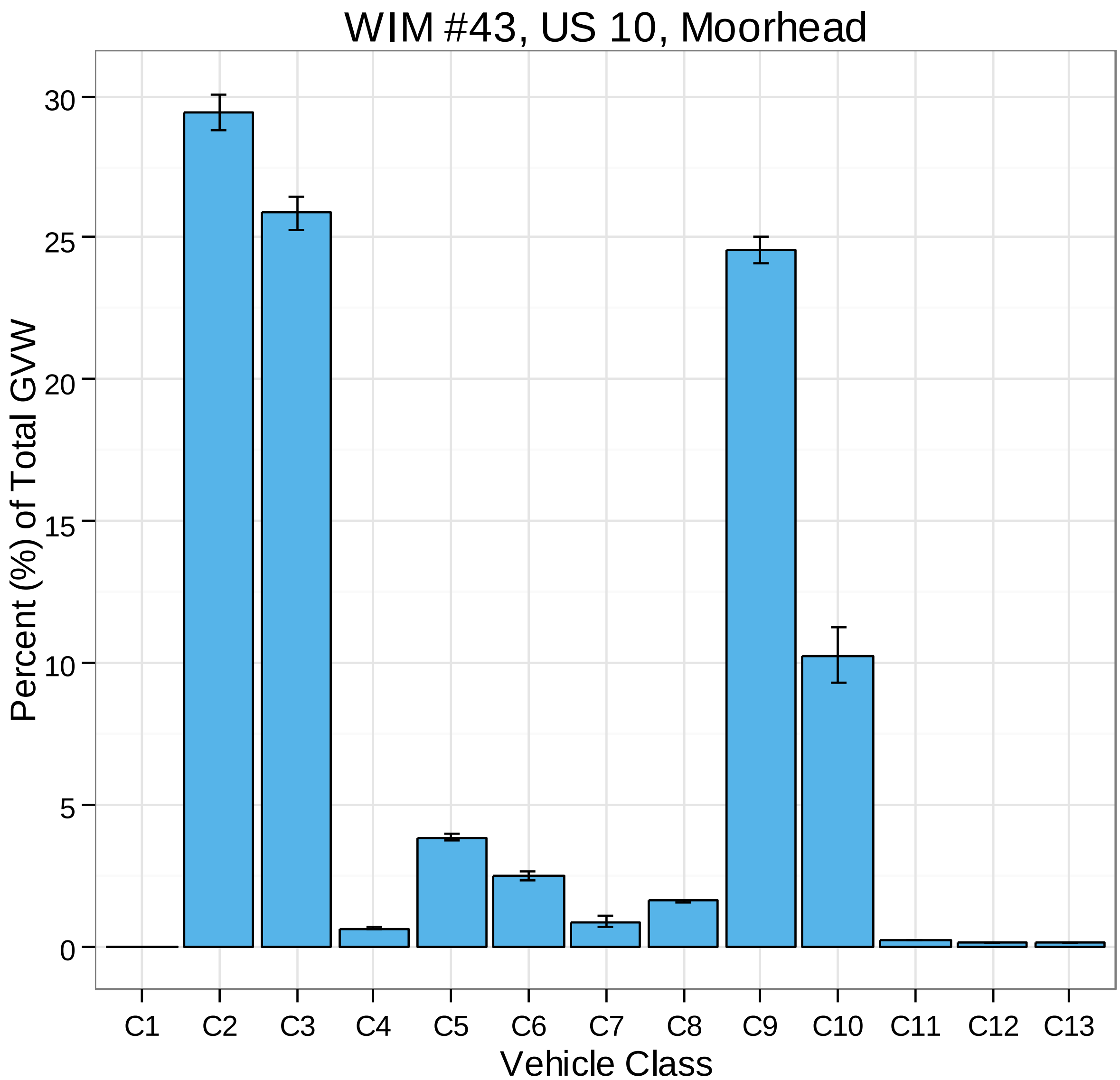


Figure 5.225. Average monthly vehicle class contributions (%) to total gross vehicle weight. Error bars represent standard error of the mean.

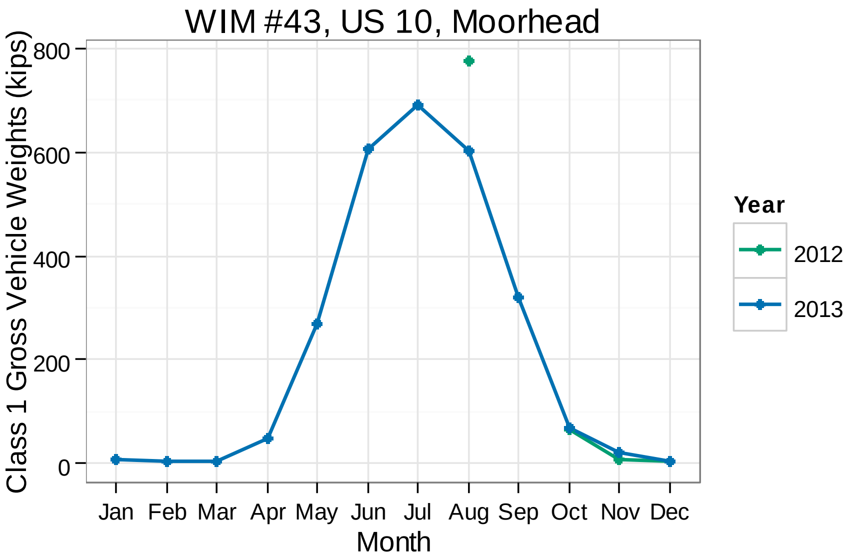


Figure 5.226a. Class 1 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

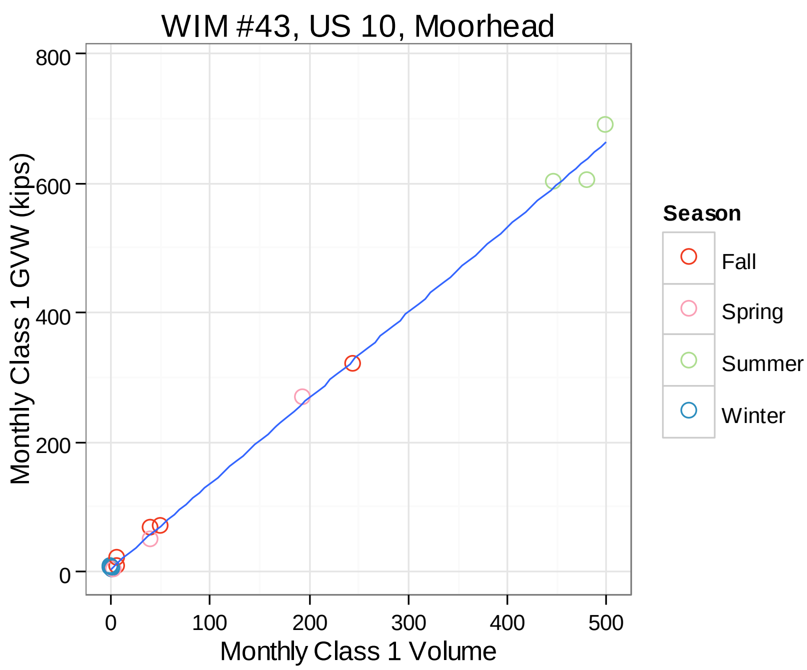


Figure 5.226b. Class 1 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

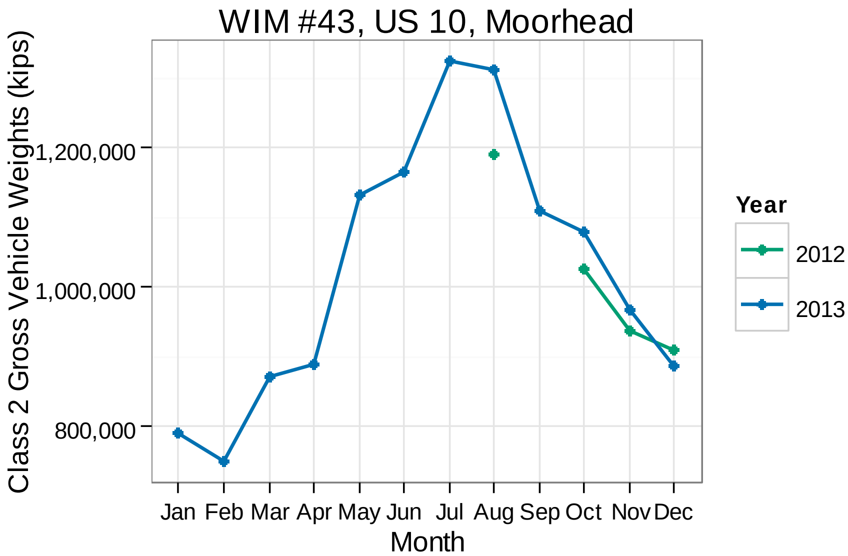


Figure 5.227a. Class 2 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

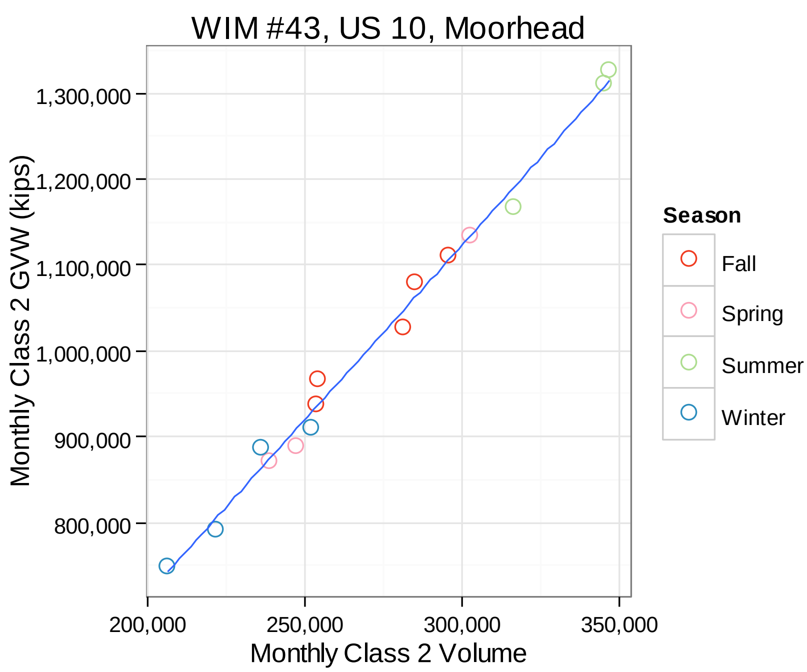


Figure 5.227b. Class 2 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

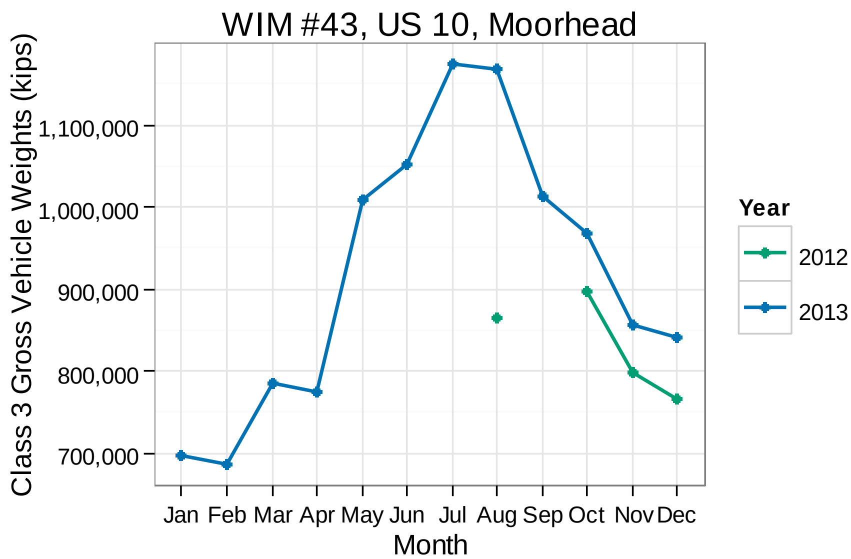


Figure 5.228a. Class 3 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

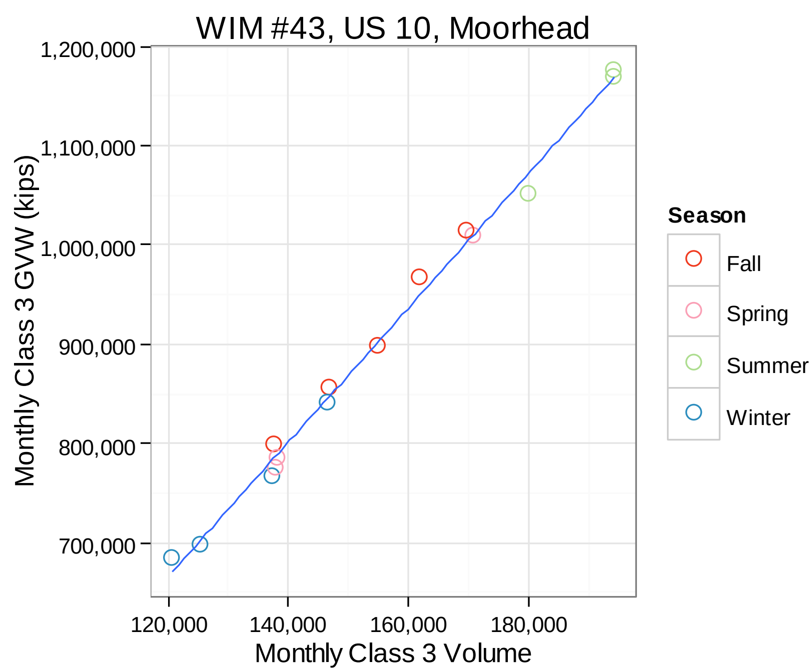


Figure 5.228b. Class 3 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

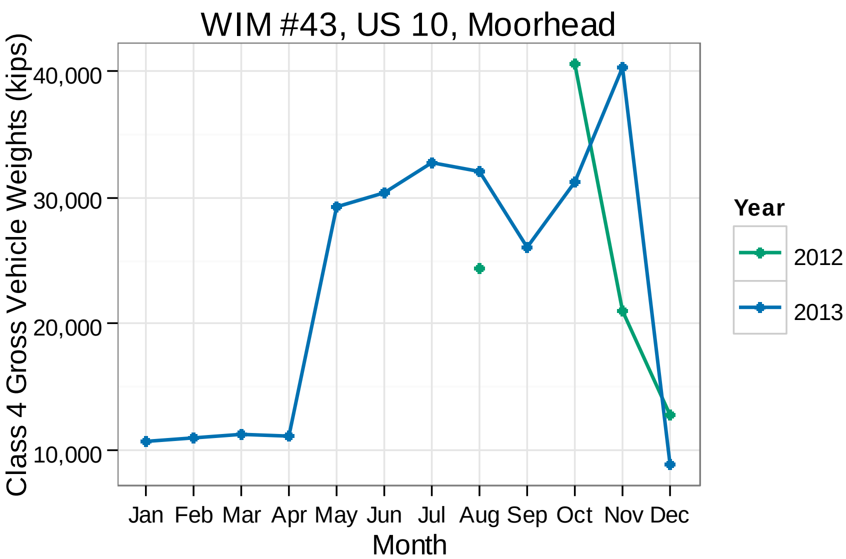


Figure 5.229a. Class 4 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

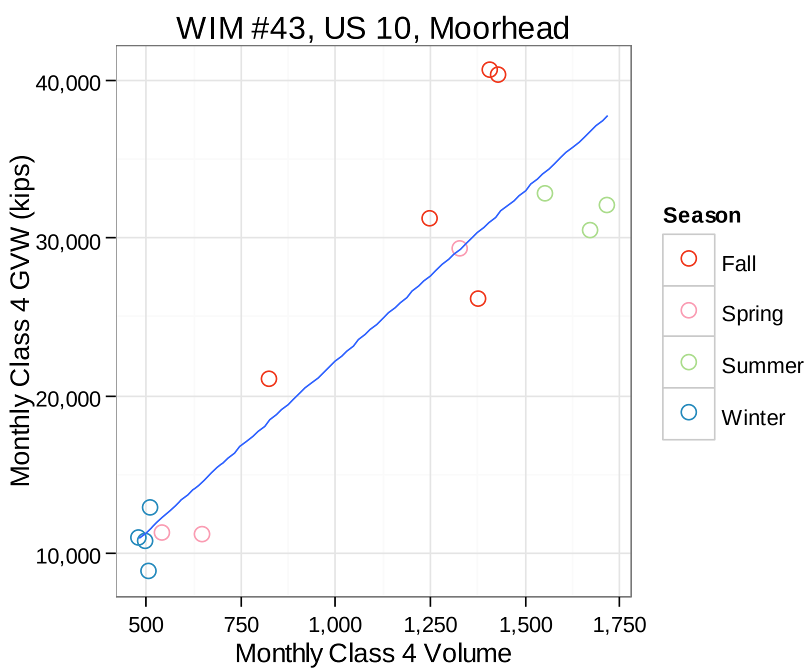


Figure 5.229b. Class 4 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

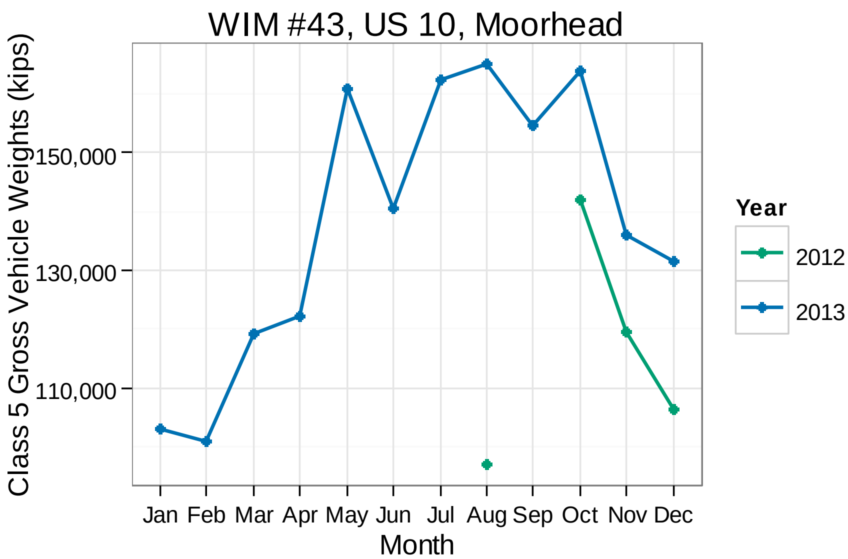


Figure 5.230a. Class 5 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

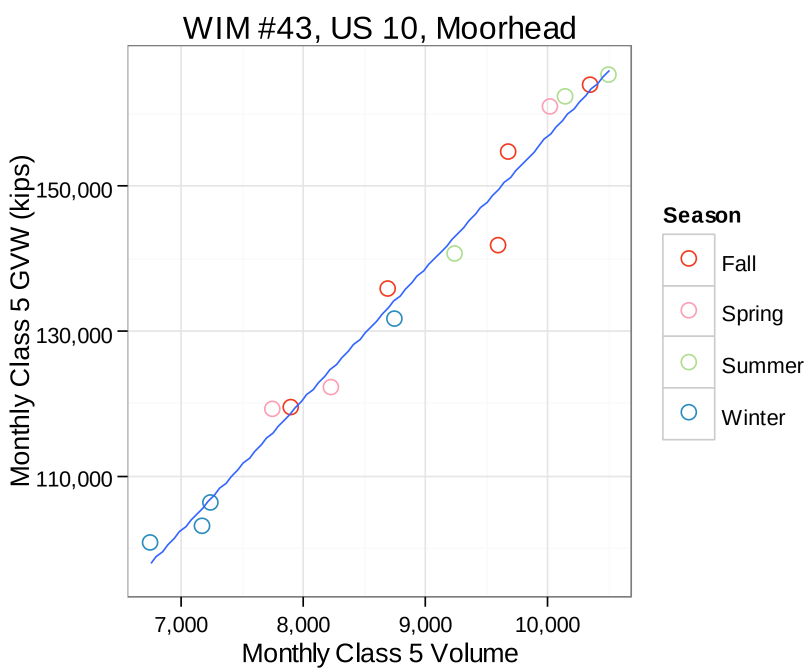


Figure 5.230b. Class 5 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

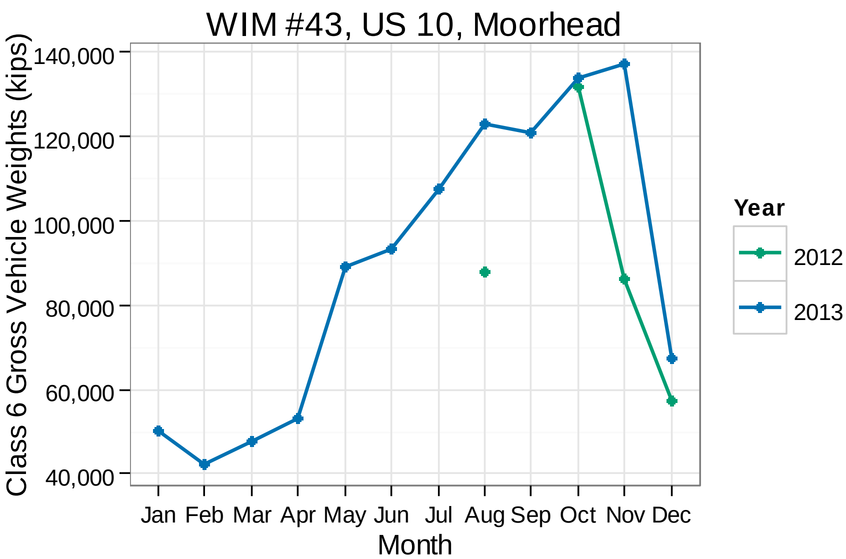


Figure 5.231a. Class 6 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

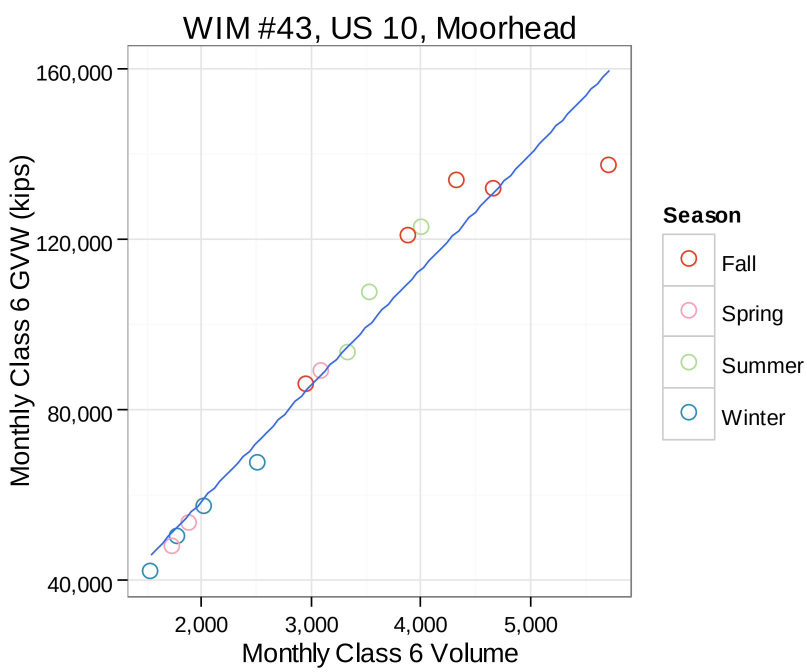


Figure 5.231b. Class 6 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

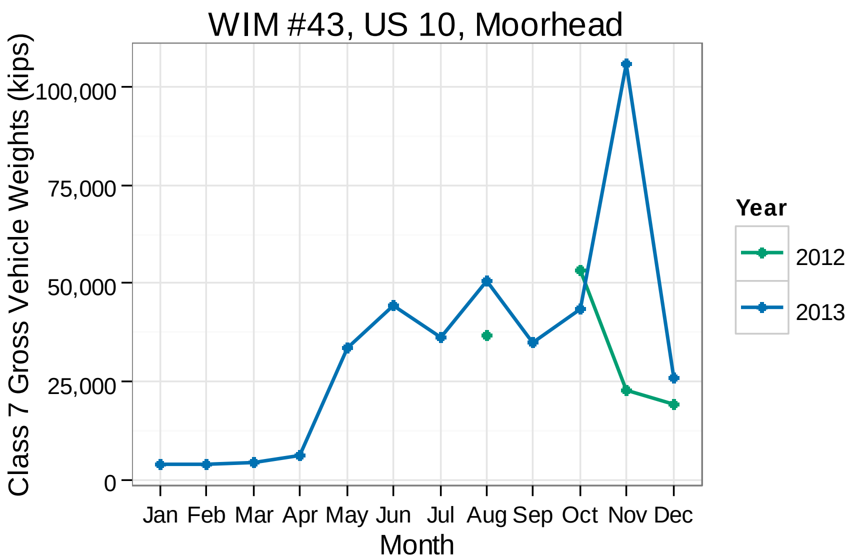


Figure 5.232a. Class 7 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

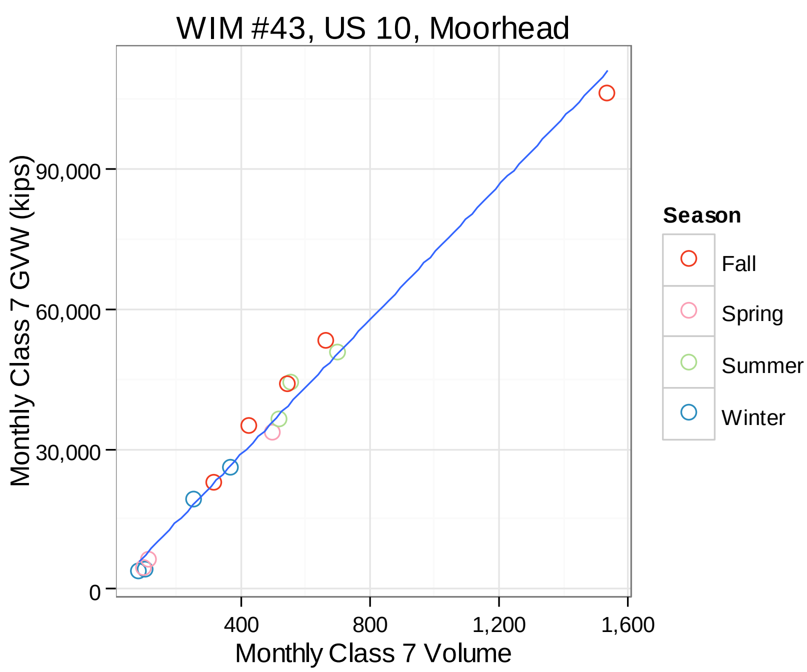


Figure 5.232b. Class 7 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

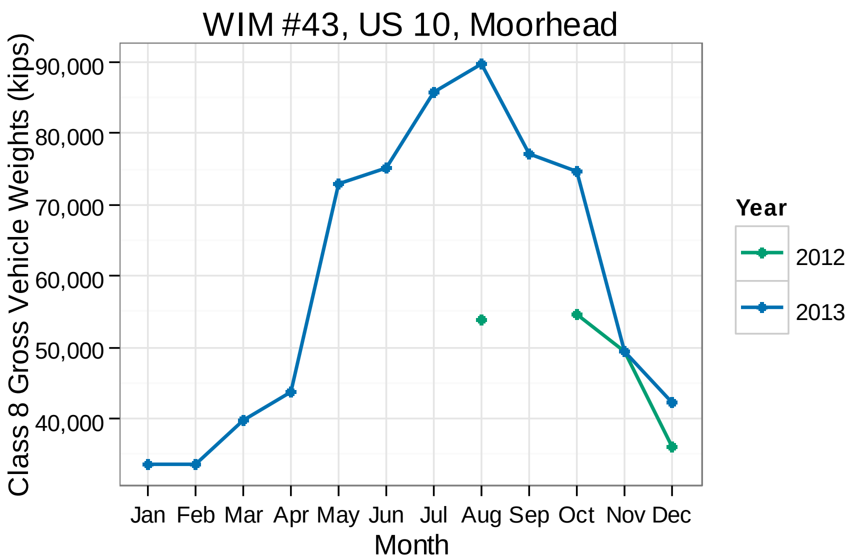


Figure 5.233a. Class 8 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

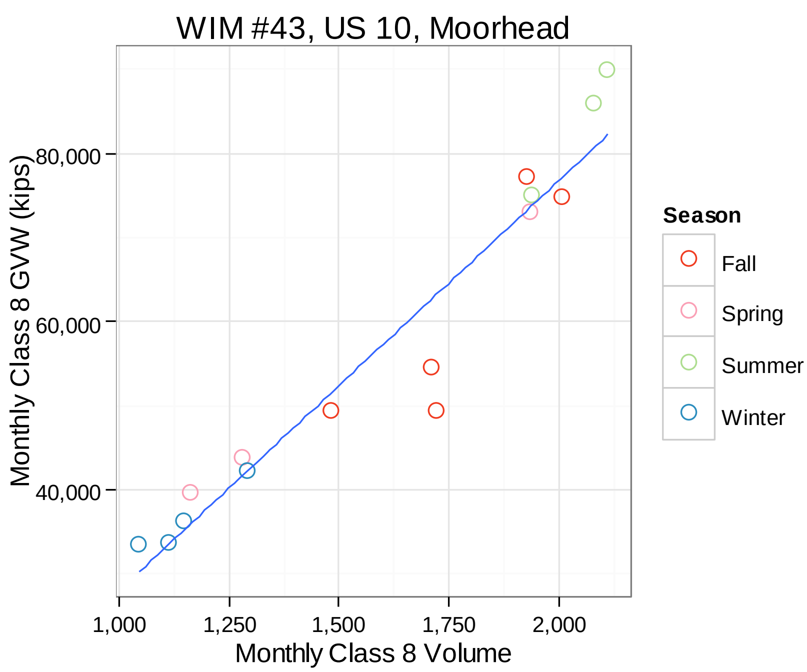


Figure 5.233b. Class 8 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

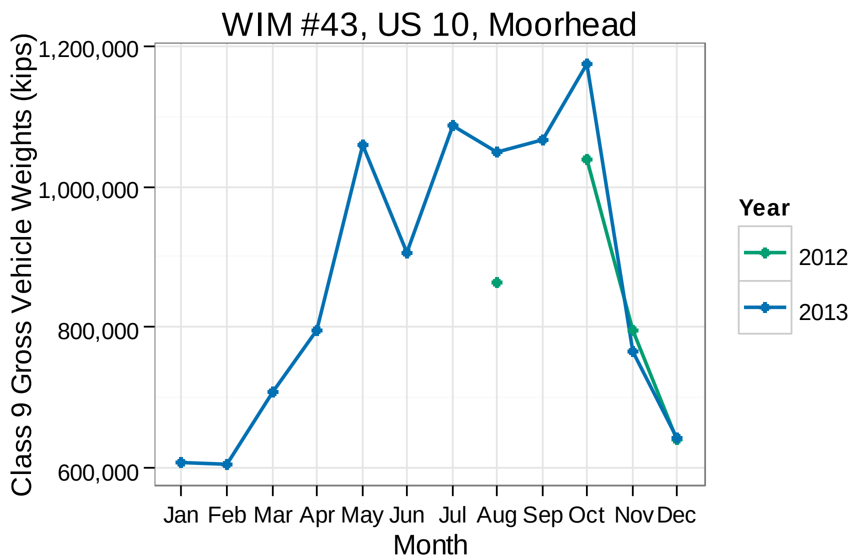


Figure 5.234a. Class 9 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

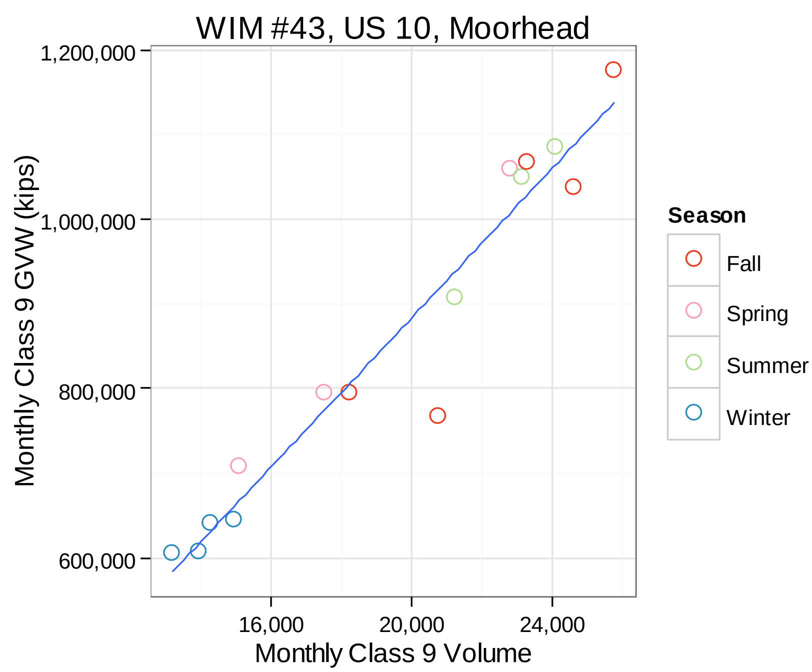


Figure 5.234b. Class 9 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

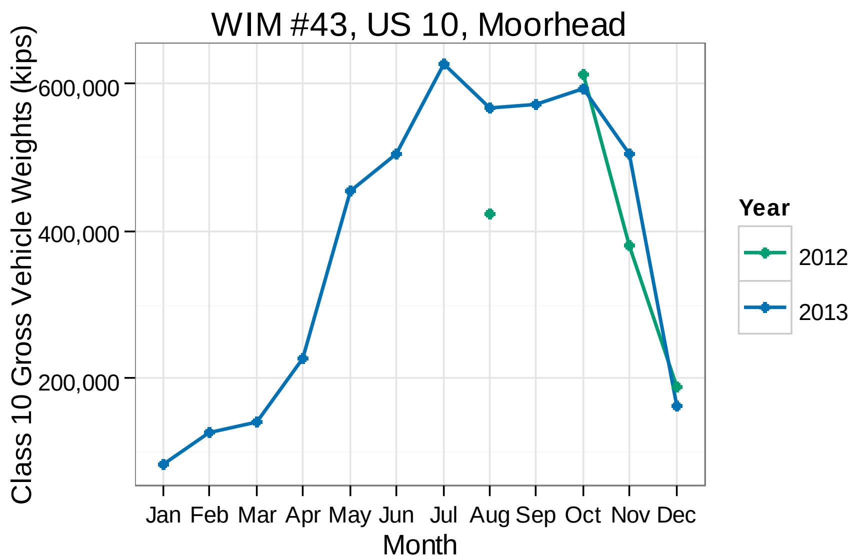


Figure 5.235a. Class 10 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

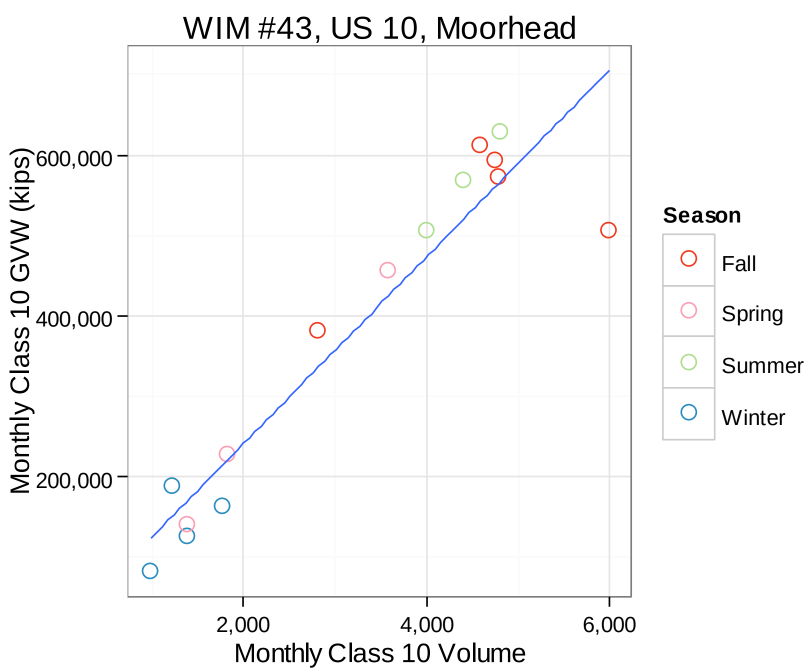


Figure 5.235b. Class 10 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

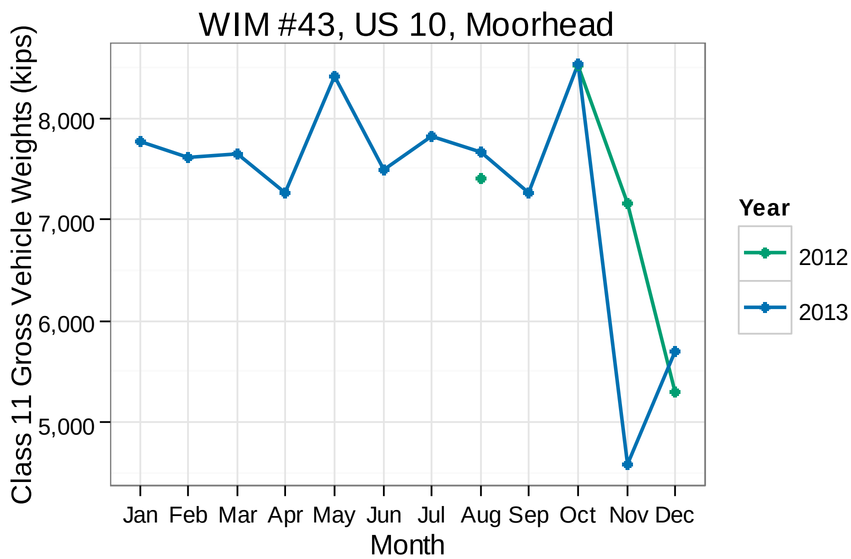


Figure 5.236a. Class 11 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

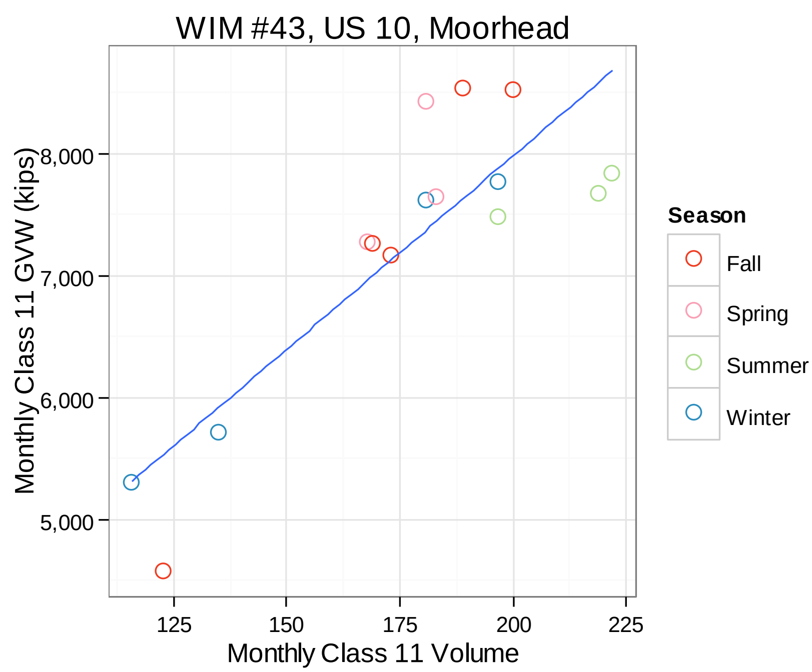


Figure 5.236b. Class 11 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

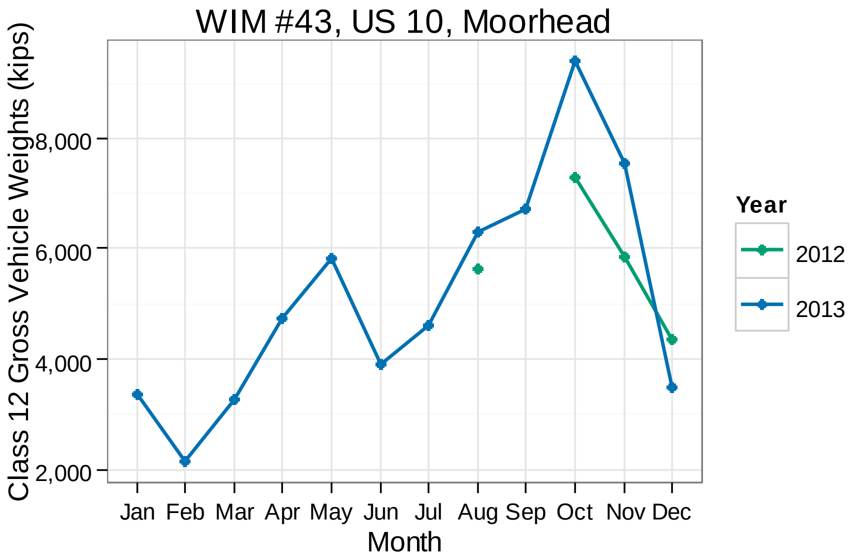


Figure 5.237a. Class 12 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

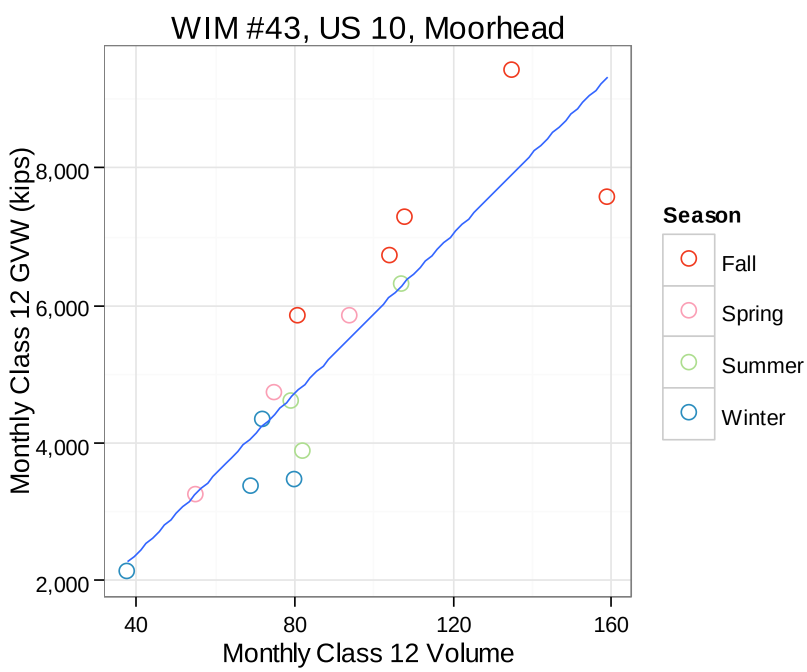


Figure 5.237b. Class 12 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

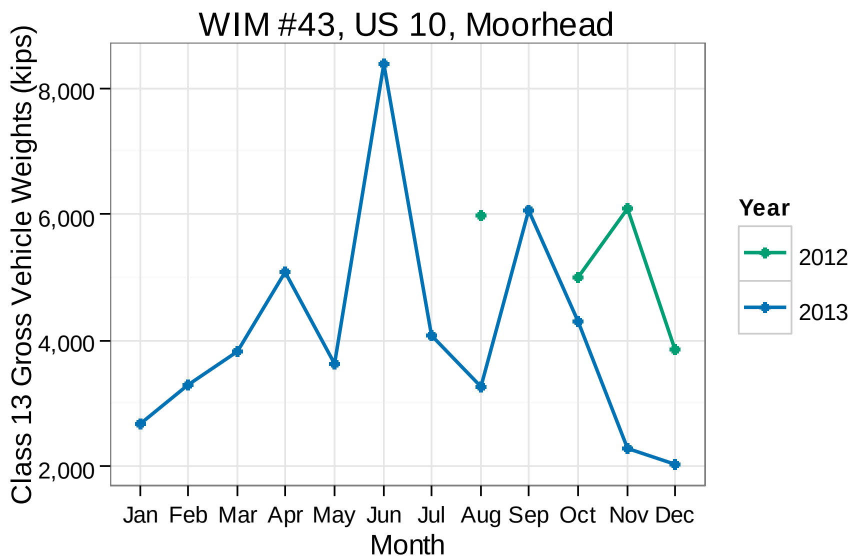


Figure 5.238a. Class 13 gross vehicle weights (kips) as a function of month and year. Black line represents the average volume within each month across all years.

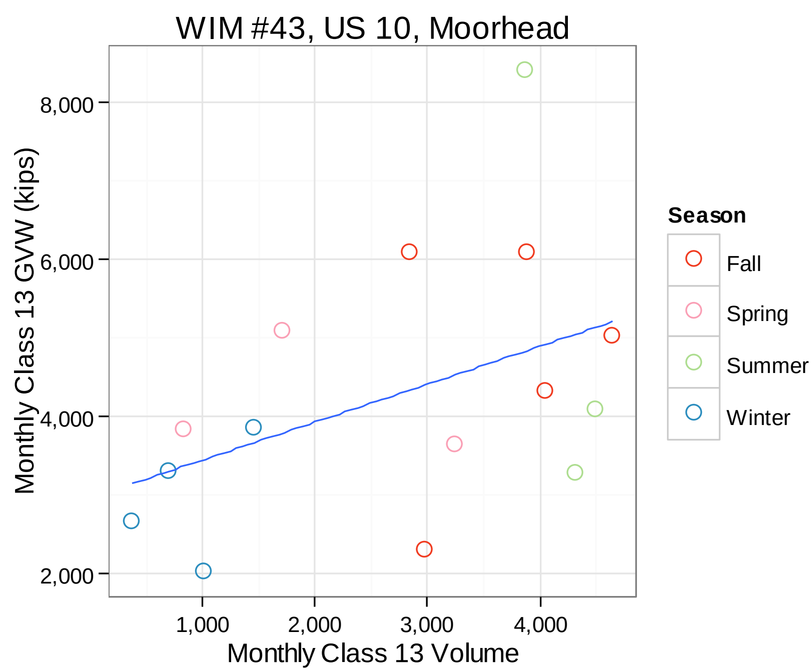


Figure 5.238b. Class 13 scatterplot between monthly volumes and monthly gross vehicle weights (GVWs; measured in kips). Blue line is the trend line that best represents the relationship between variables.

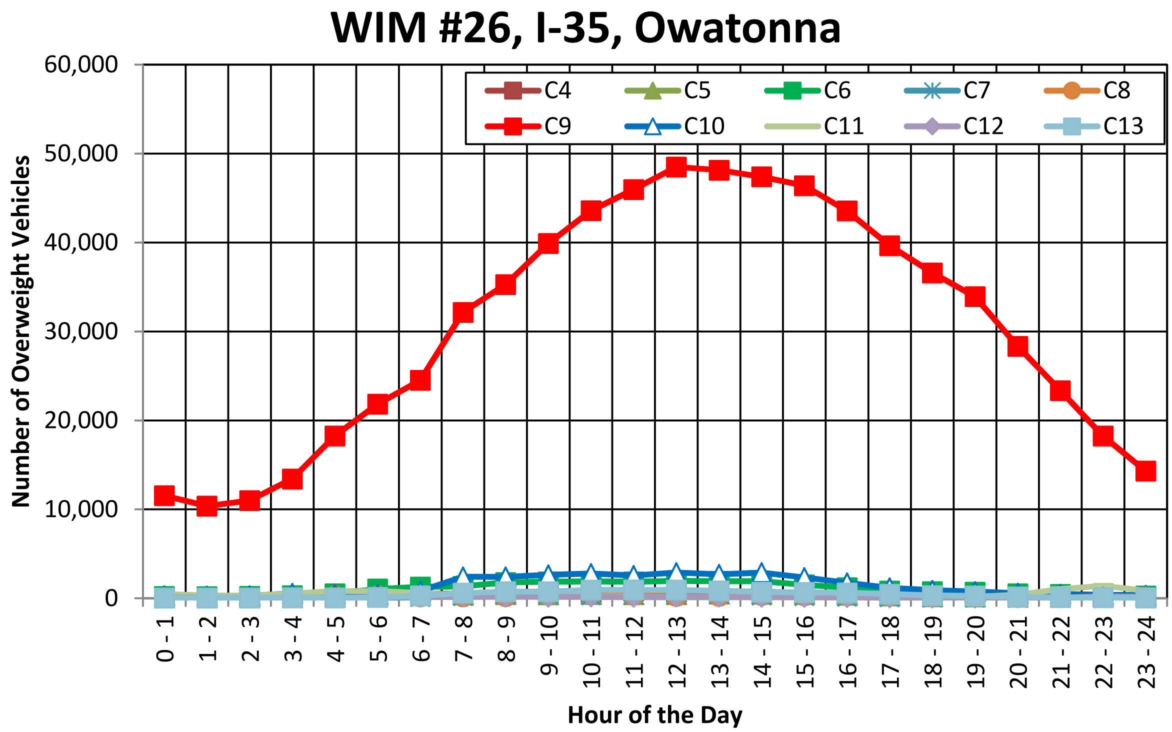


Figure 6.1. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from January 2010 to December 2013.

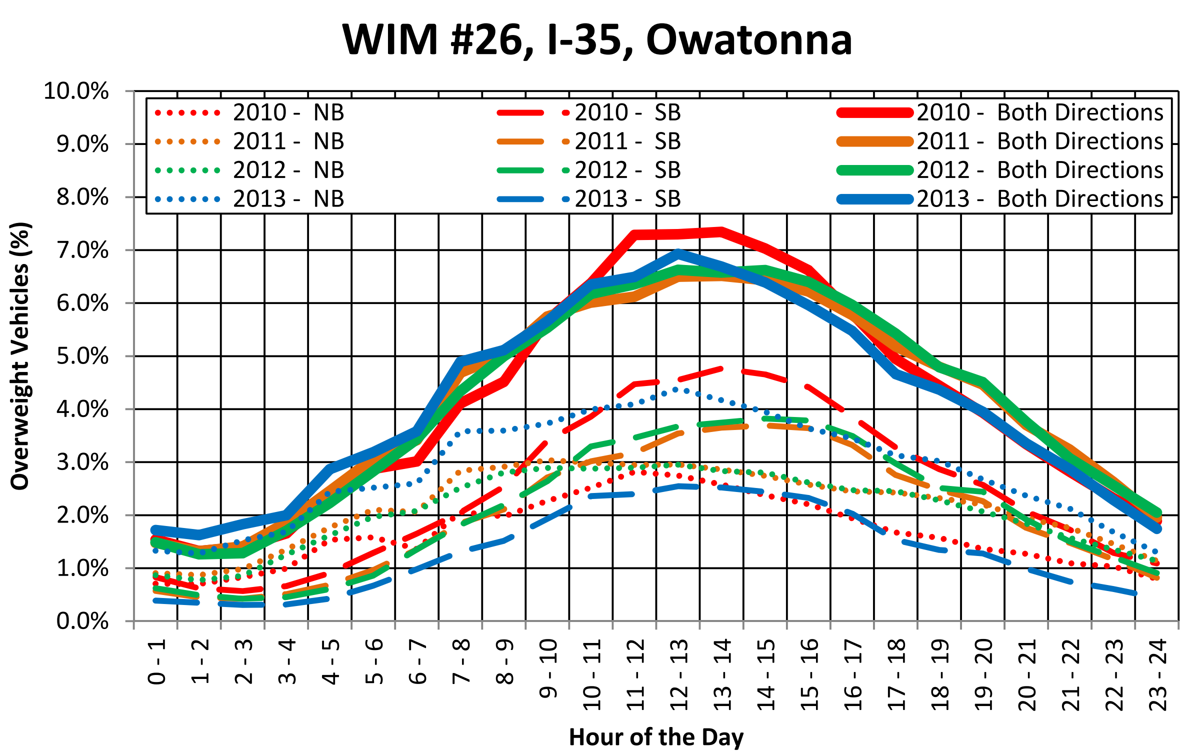


Figure 6.2. Volume distributions for overweight HCVs over a typical 24-hour day. Data from January 2010 to December 2013.

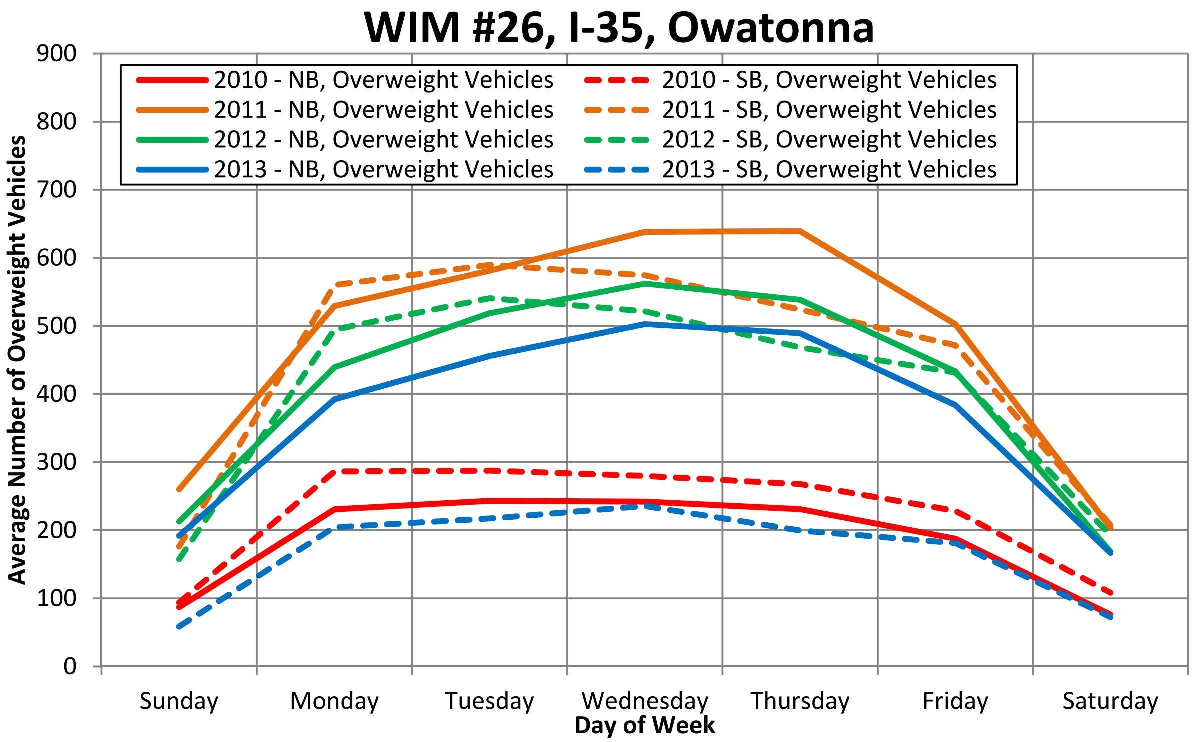


Figure 6.3. Average overweight HCV volume distributions over a typical 7-day week. Data from January 2010 to December 2013.

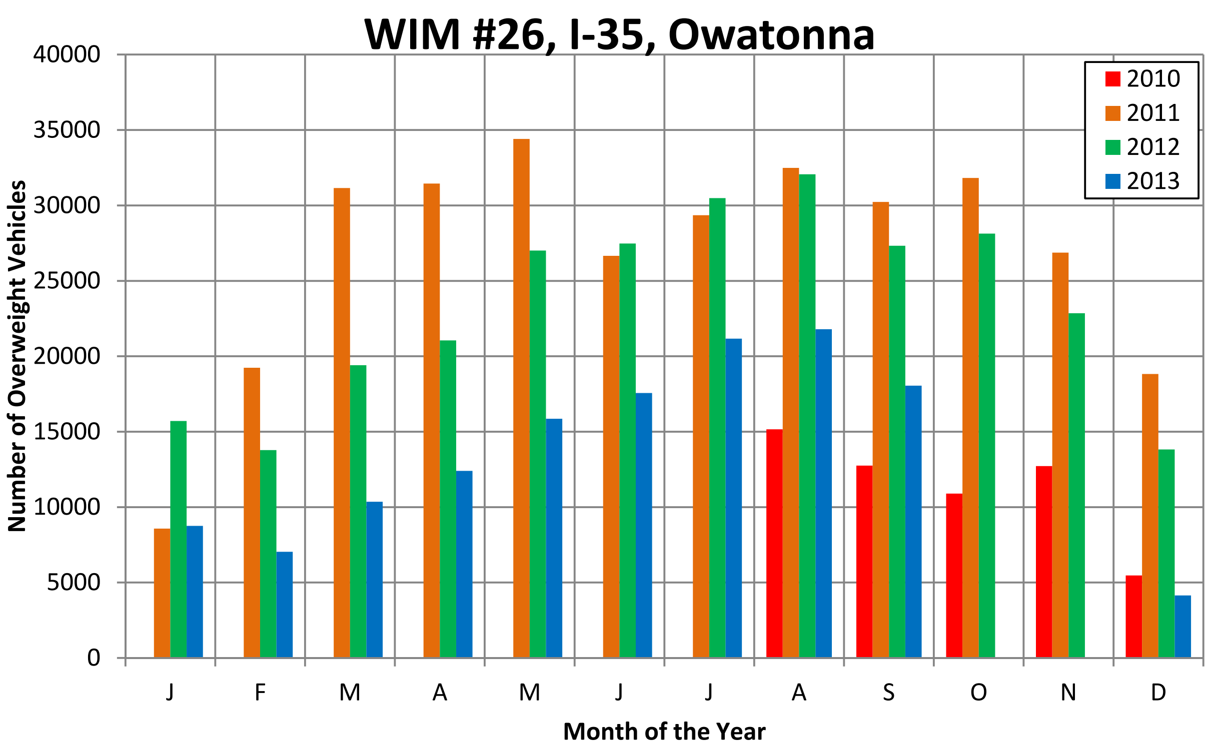


Figure 6.4. Monthly volumes of overweight HCVs by year. Data from January 2010 to December 2013.

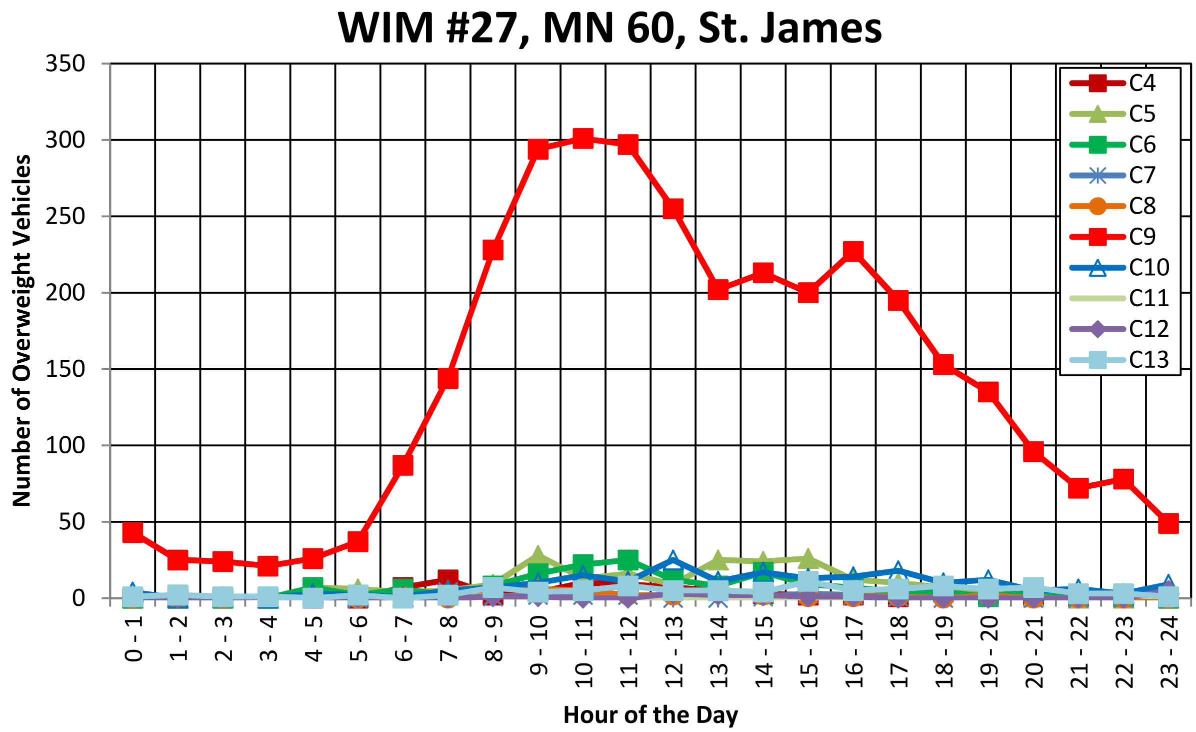


Figure 6.5. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from January 2010 to September 2010.

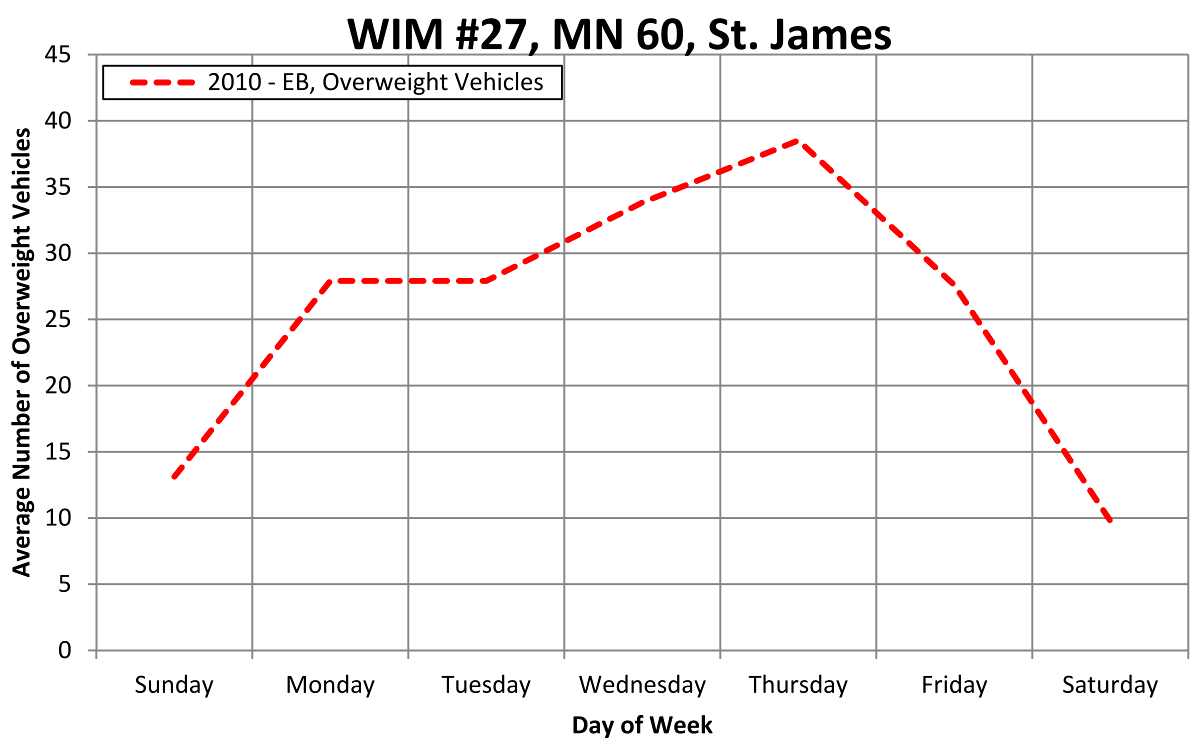


Figure 6.6. Average overweight HCV volume distributions in the eastbound direction over a typical 7-day week. Data from January 2010 to September 2010.

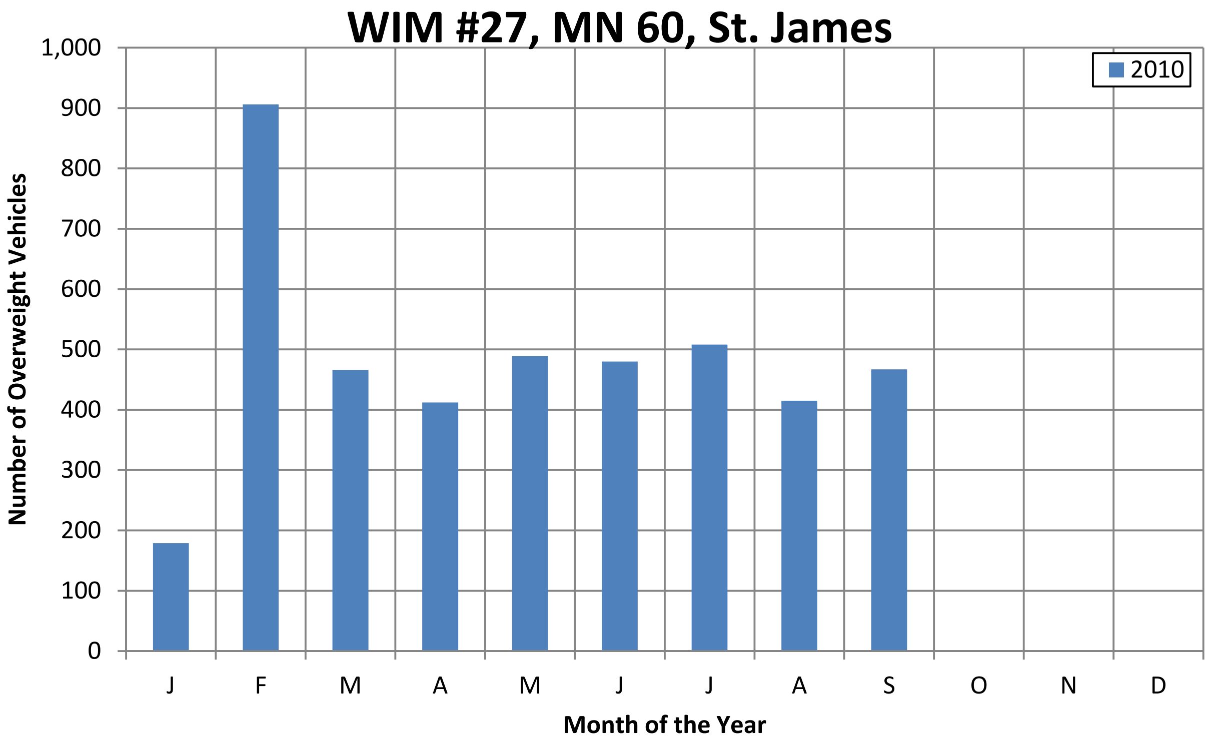


Figure 6.7. Monthly volumes of overweight HCVs by year. Data from January 2010 to September 2010.

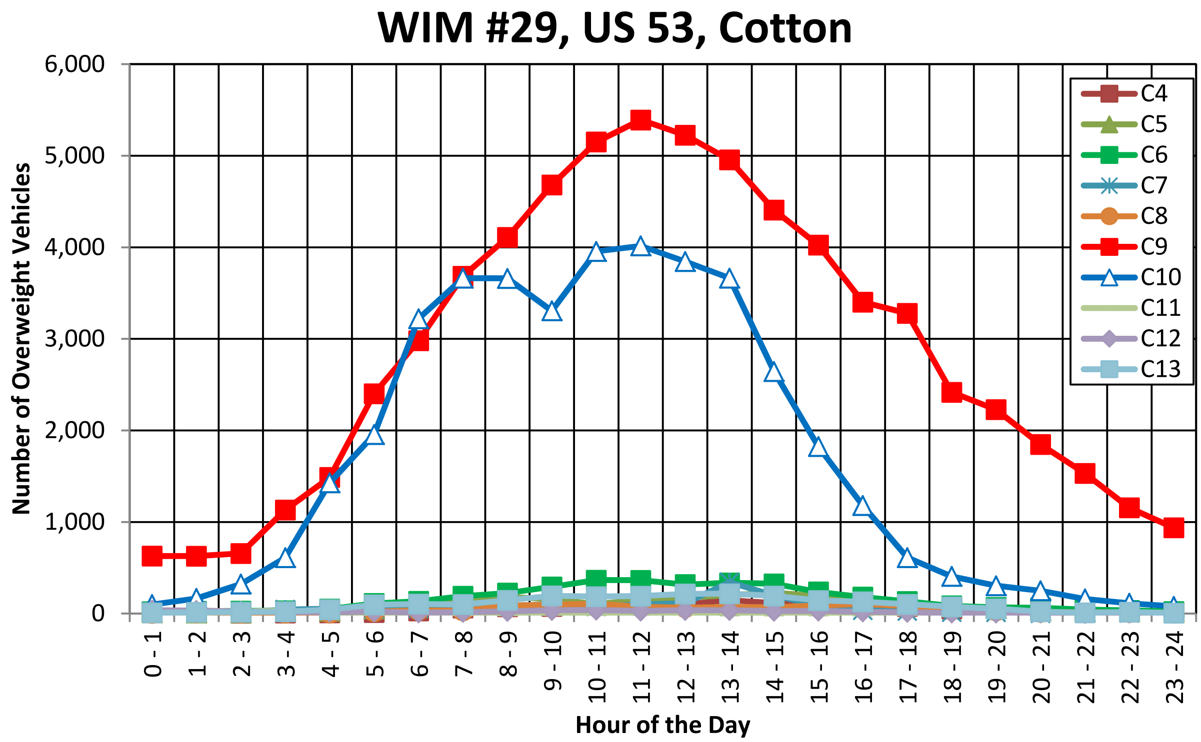


Figure 6.8. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from January 2010 to December 2013.

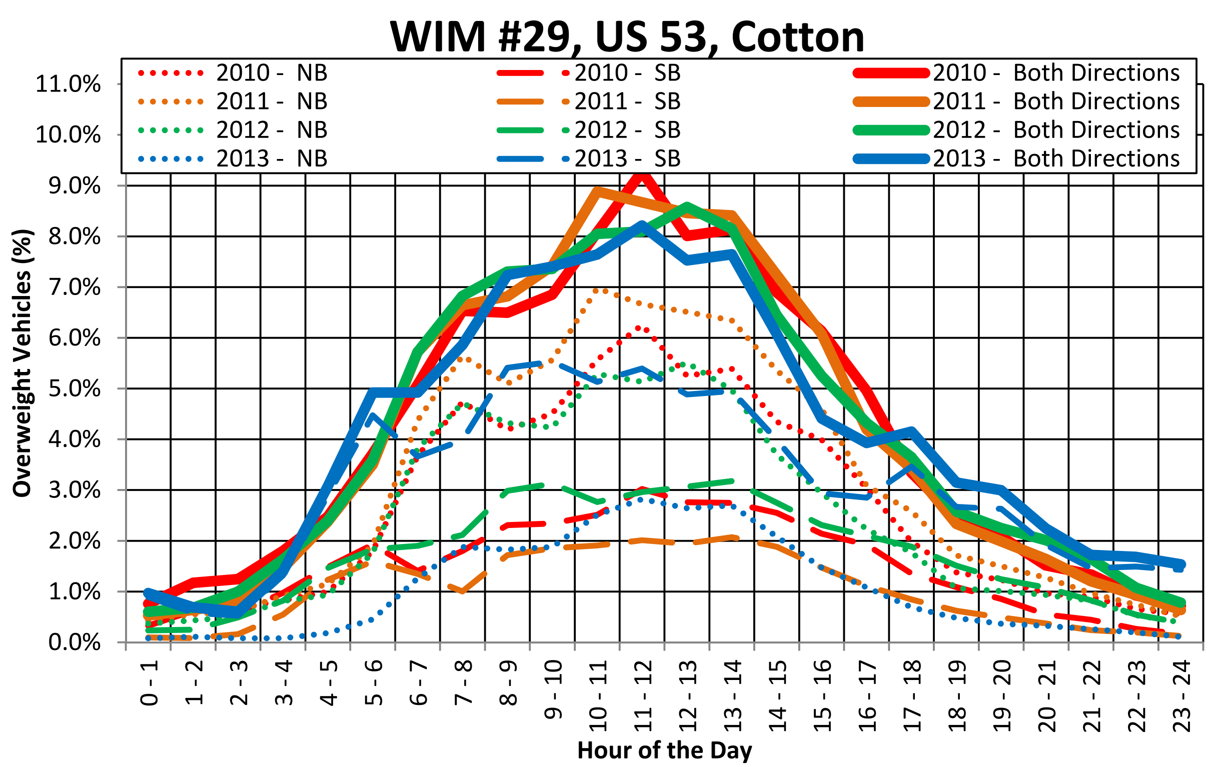


Figure 6.9. Volume distributions for overweight HCVs over a typical 24-hour day. Data from January 2010 to December 2013.

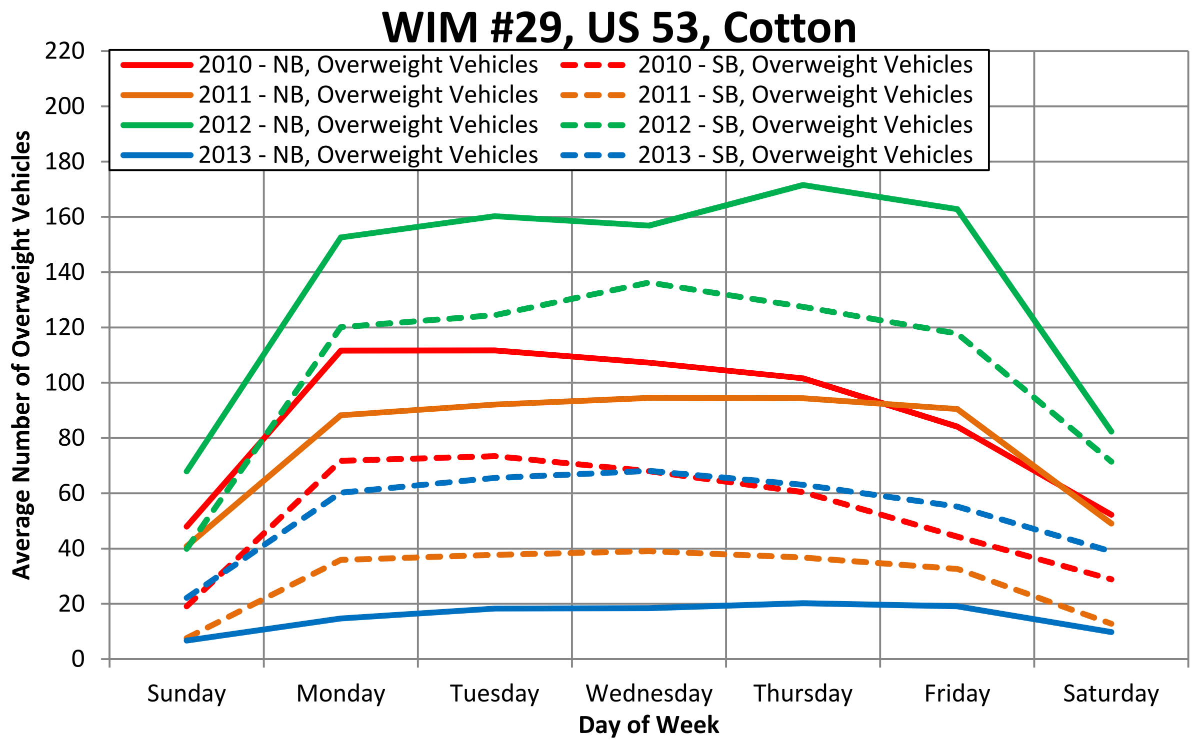


Figure 6.10. Average overweight HCV volume distributions over a typical 7-day week. Data from January 2010 to December 2013.

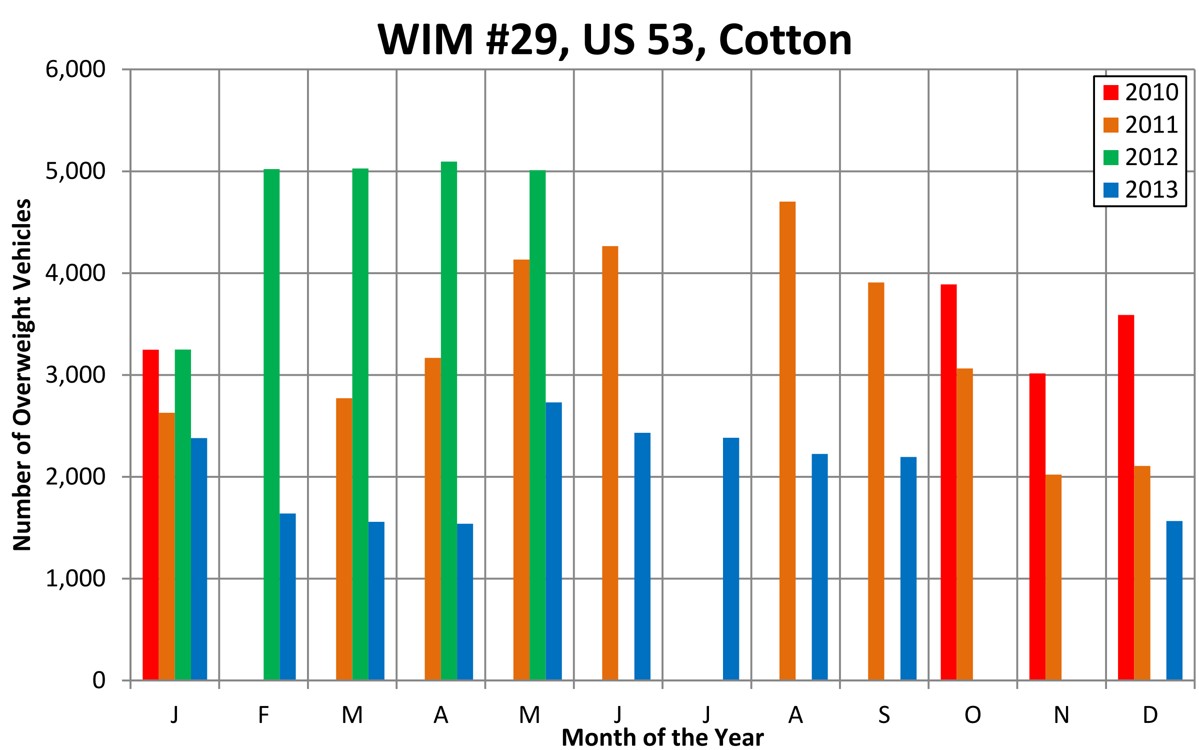


Figure 6.11. Monthly volumes of overweight HCVs by year. Data from January 2010 to December 2013.

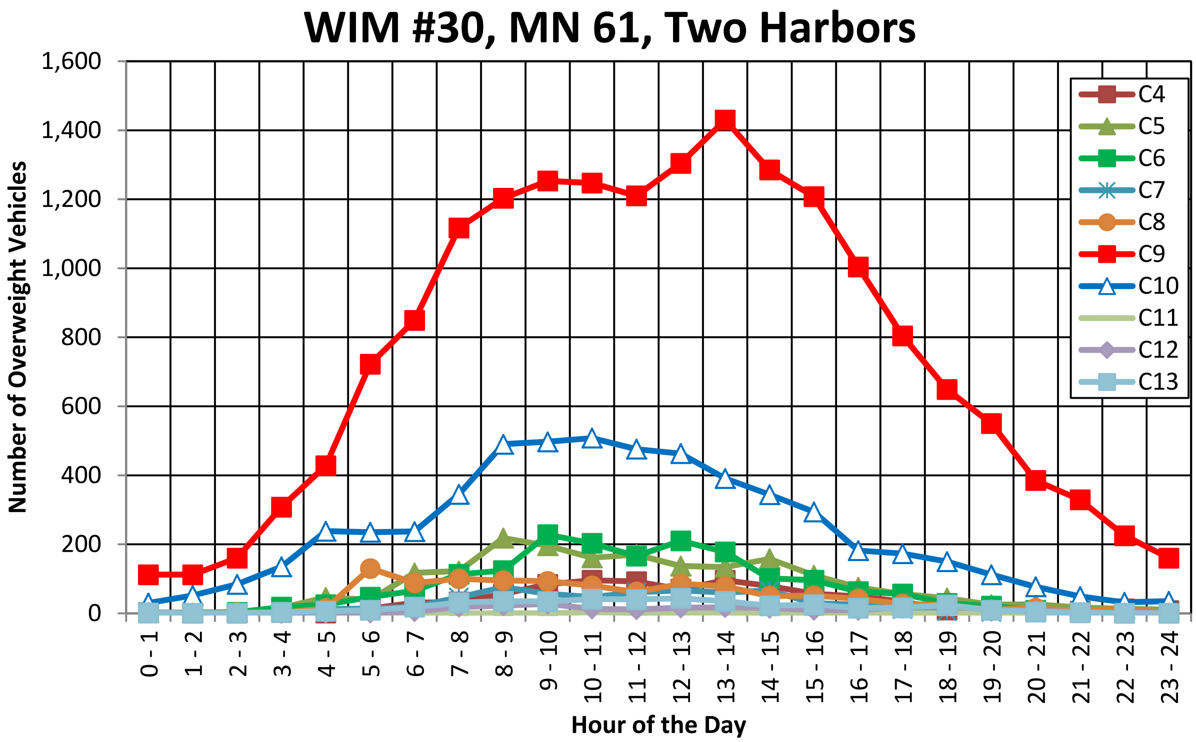


Figure 6.12. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from December 2012 to December 2013.

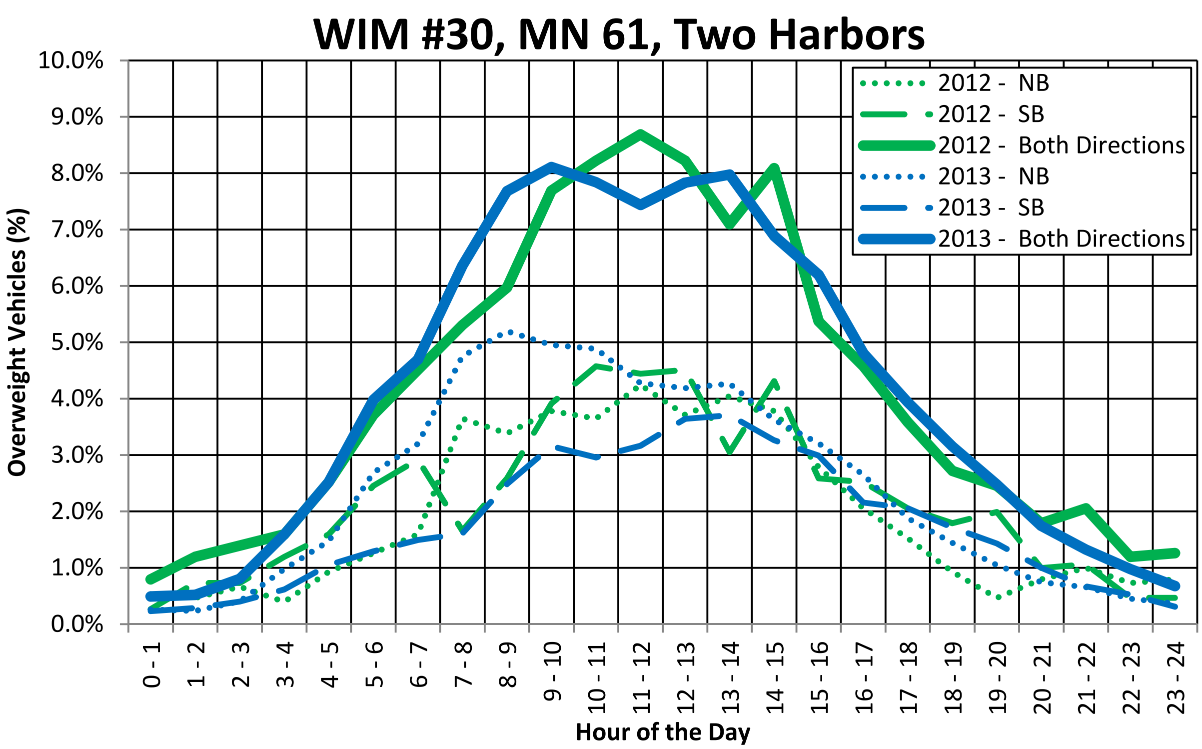


Figure 6.13. Volume distributions for overweight HCVs over a typical 24-hour day. Data from December 2012 to December 2013.

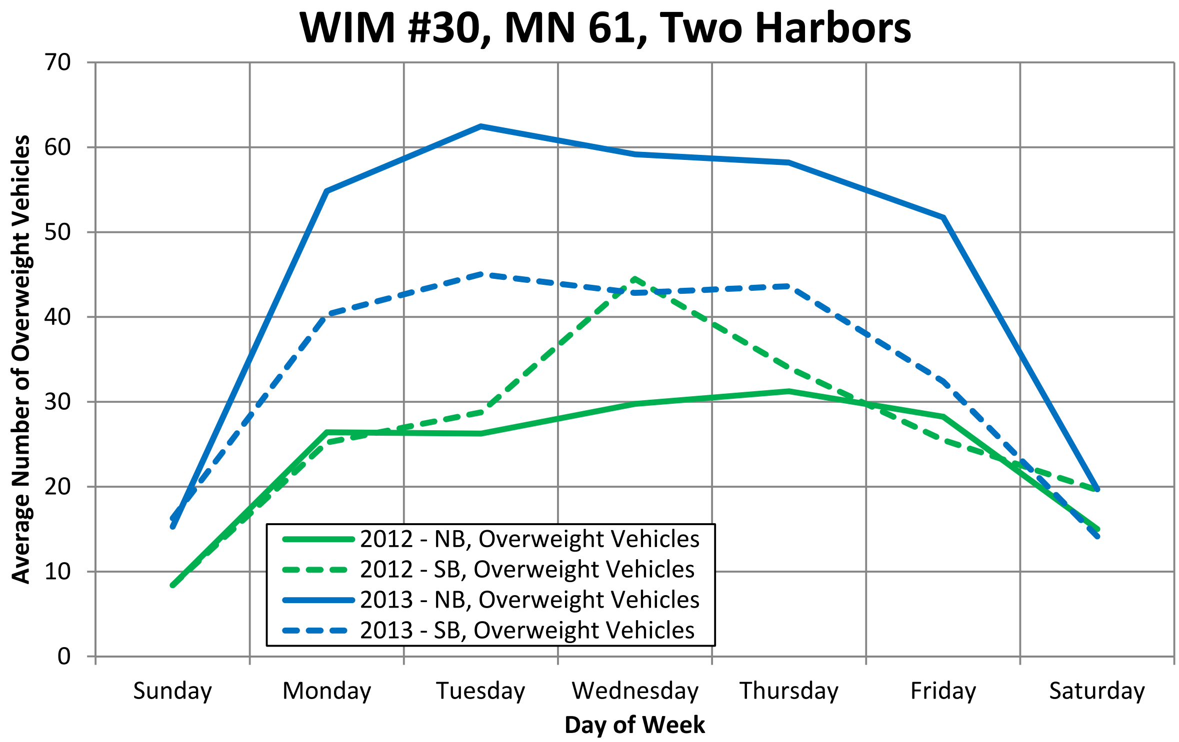


Figure 6.14. Average overweight HCV volume distributions over a typical 7-day week. Data from December 2012 to December 2013.

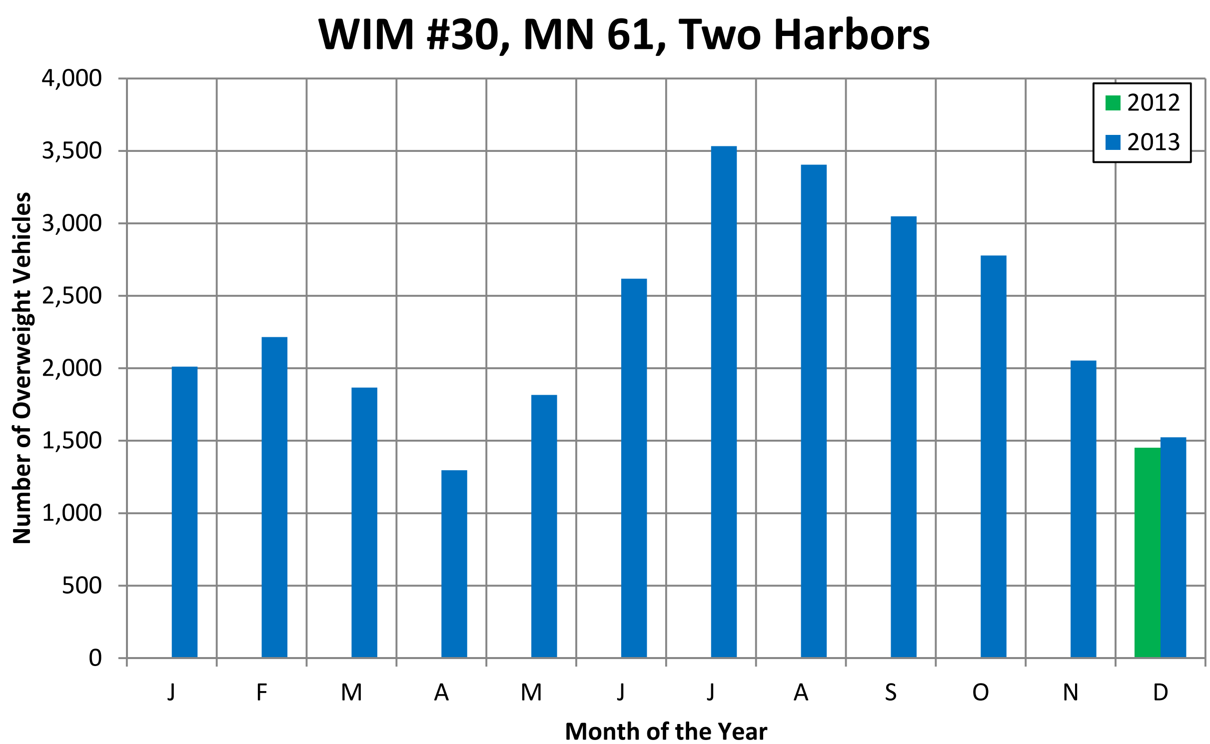


Figure 6.15. Monthly volumes of overweight HCVs by year. Data from December 2012 to December 2013.

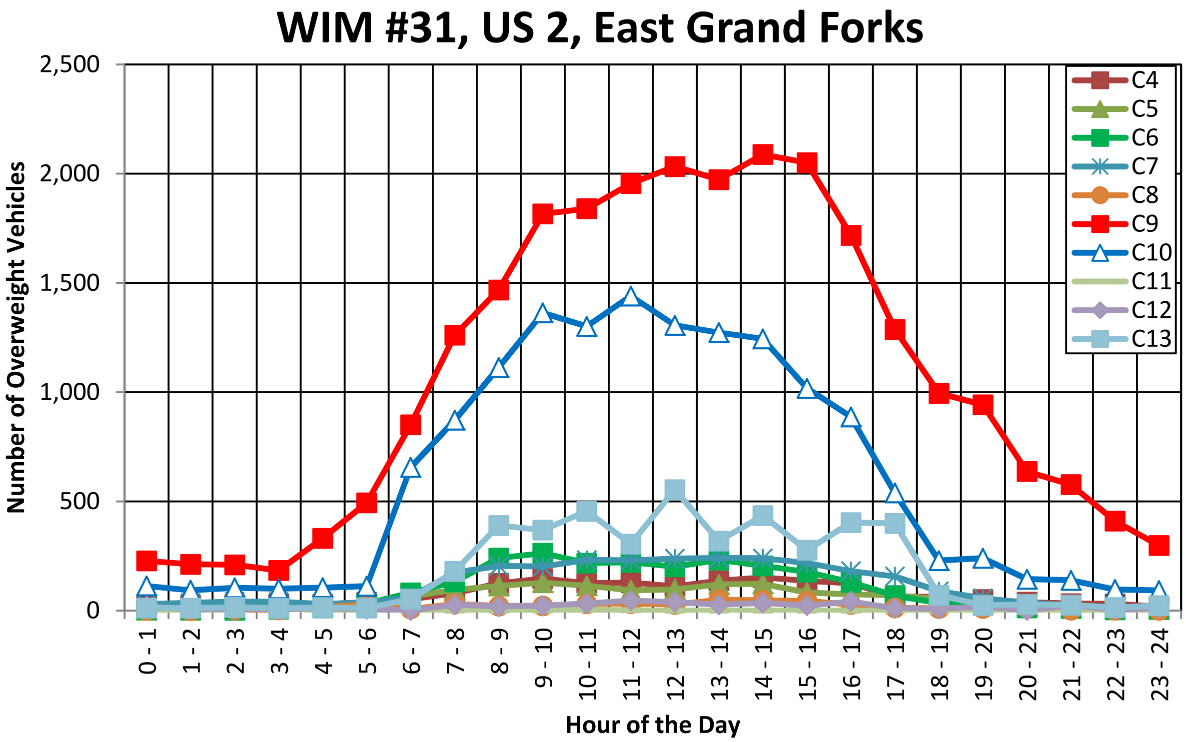


Figure 6.16. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from January 2010 to January 2012.

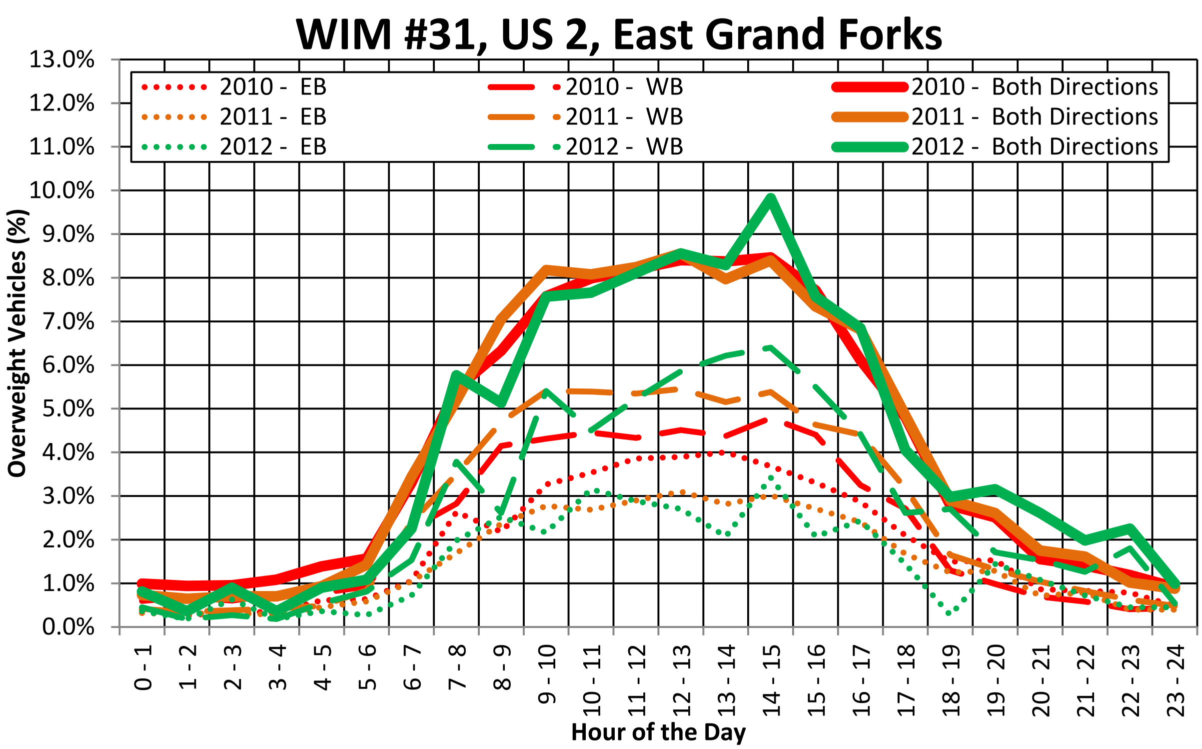


Figure 6.17. Volume distributions for overweight HCVs over a typical 24-hour day. Data from January 2010 to January 2012.

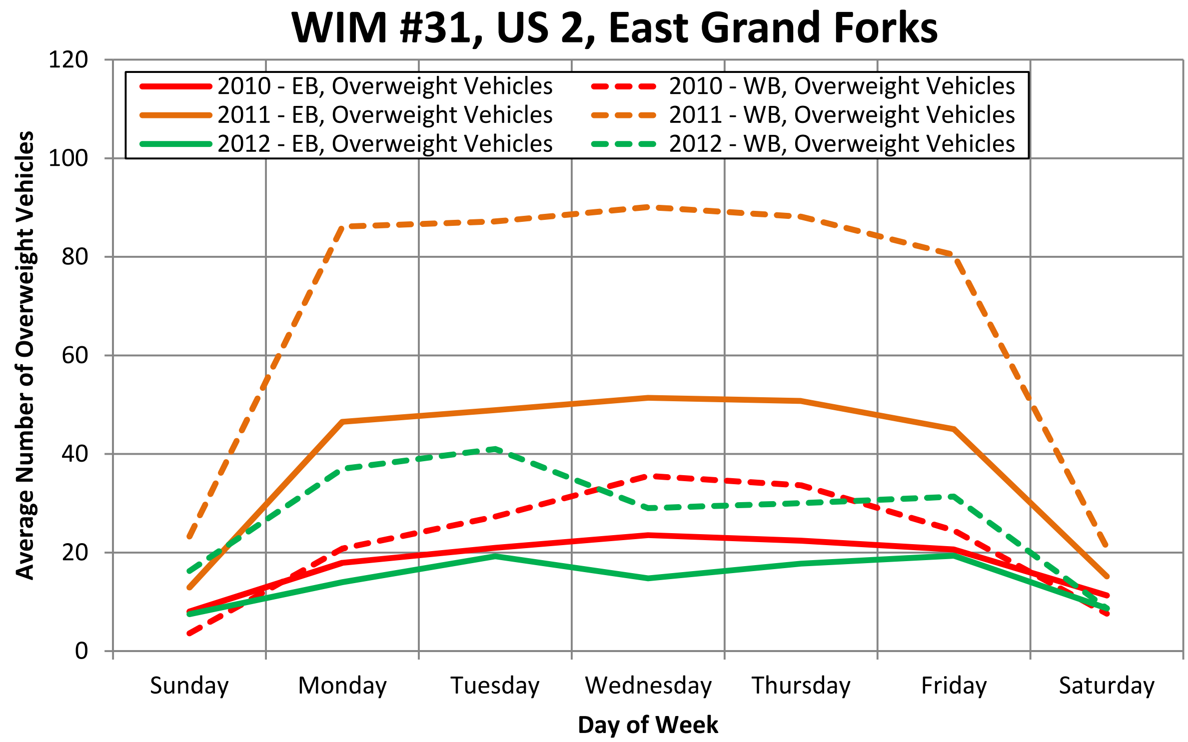


Figure 6.18. Average overweight HCV volume distributions over a typical 7-day week. Data from January 2010 to January 2012.

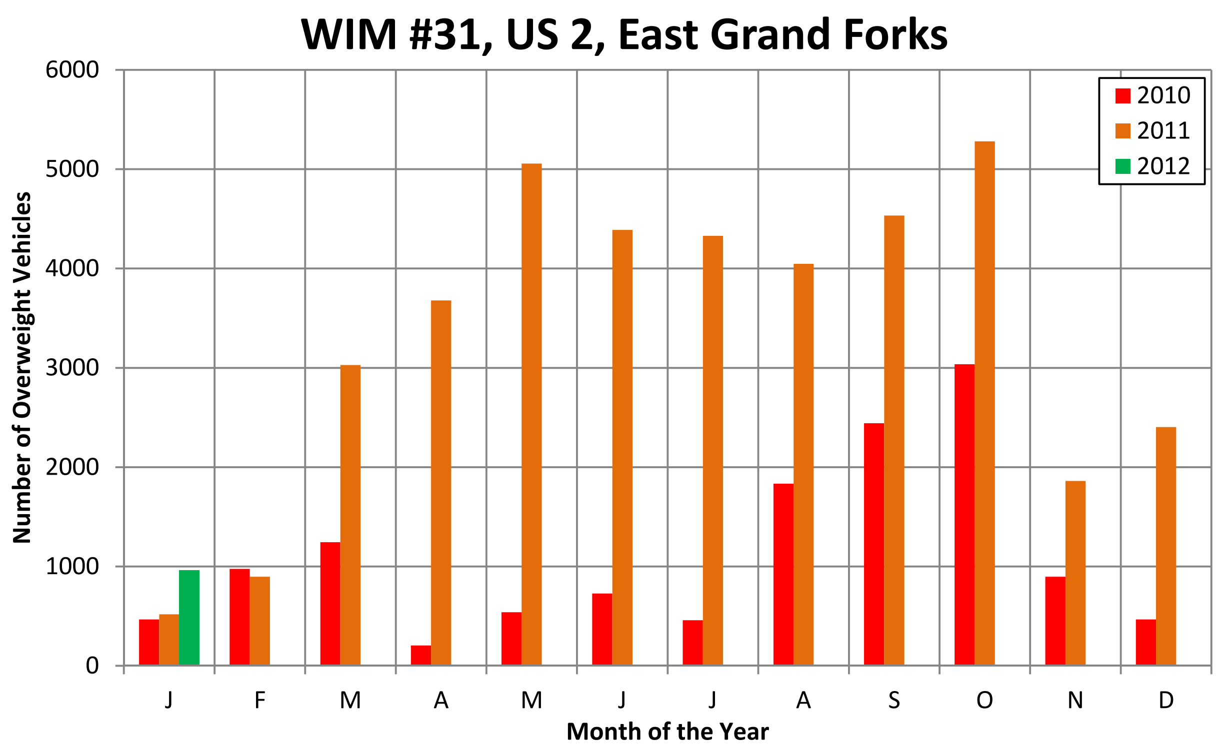


Figure 6.19. Monthly volumes of overweight HCVs by year. Data from January 2010 to January 2012.

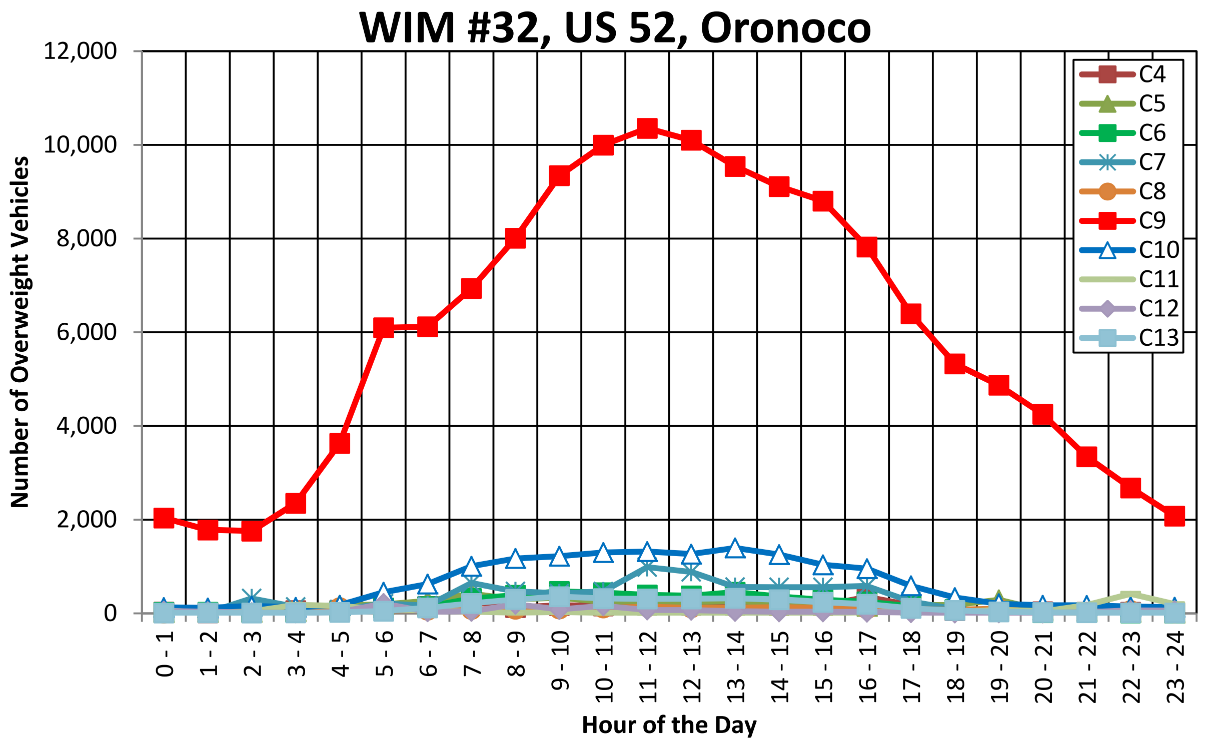


Figure 6.20. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from July 2012 to December 2013.

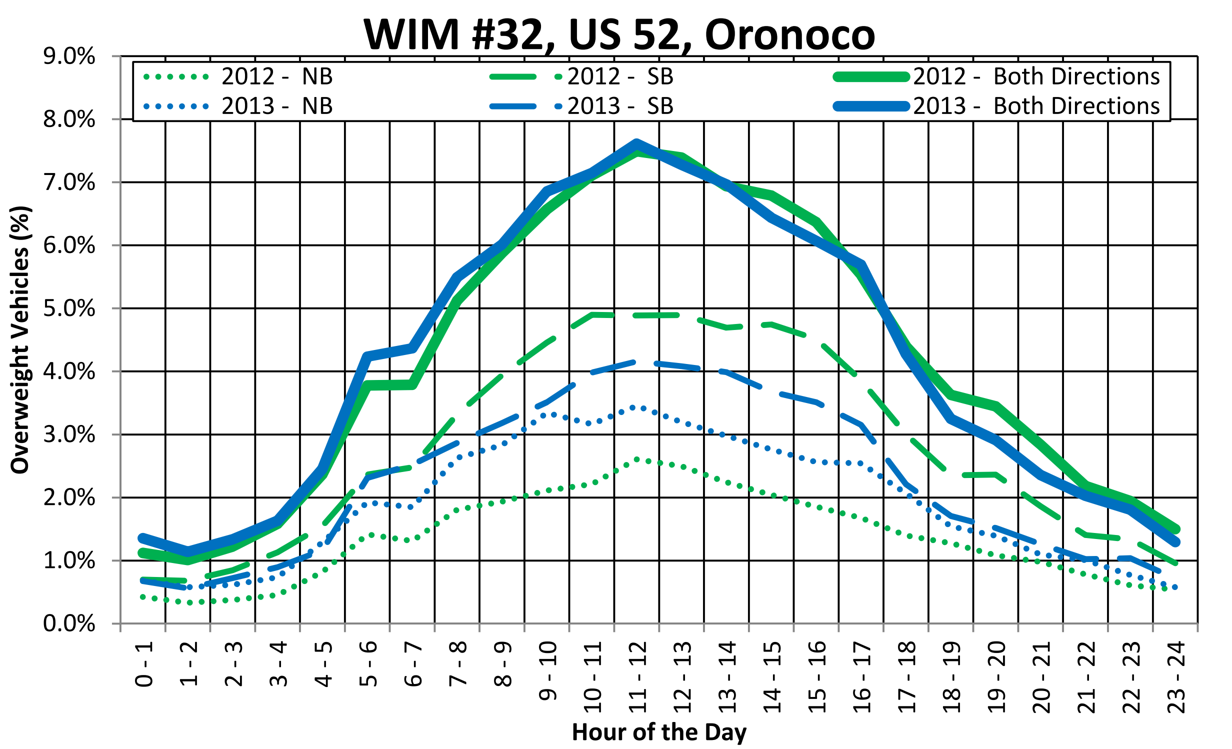


Figure 6.21. Volume distributions for overweight HCVs over a typical 24-hour day. Data from July 2012 to December 2013.

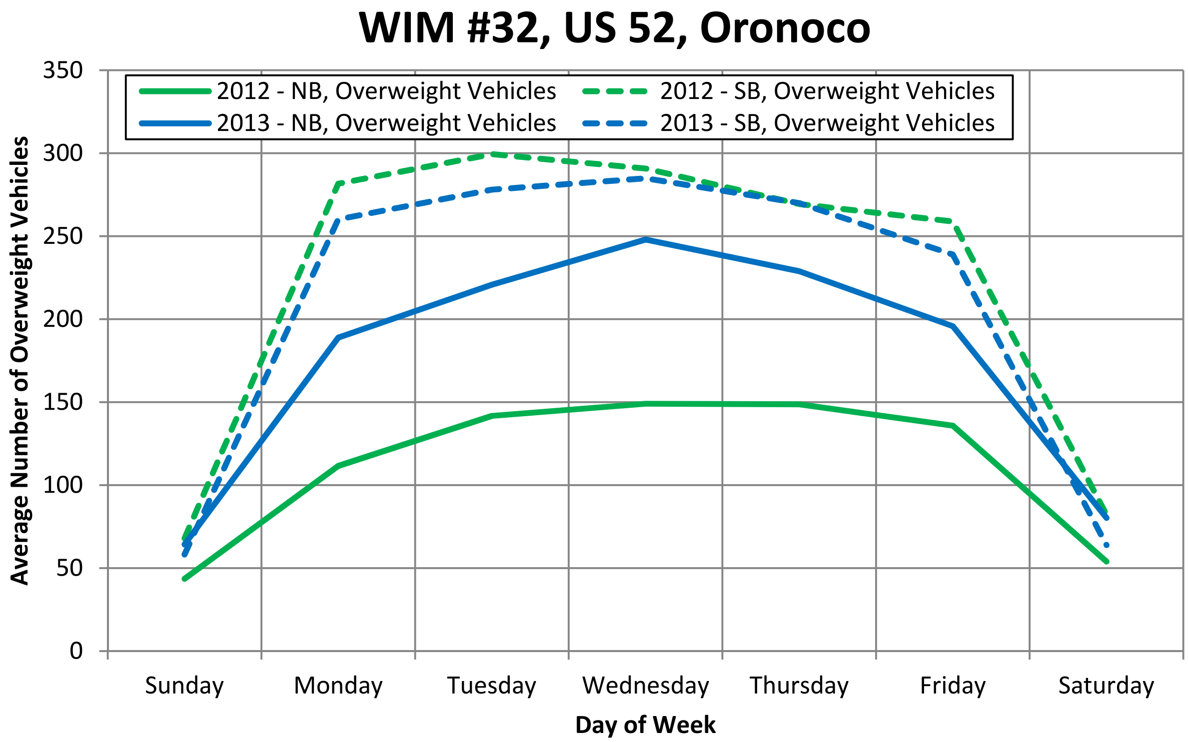


Figure 6.22. Average overweight HCV volume distributions over a typical 7-day week. Data from July 2012 to December 2013.

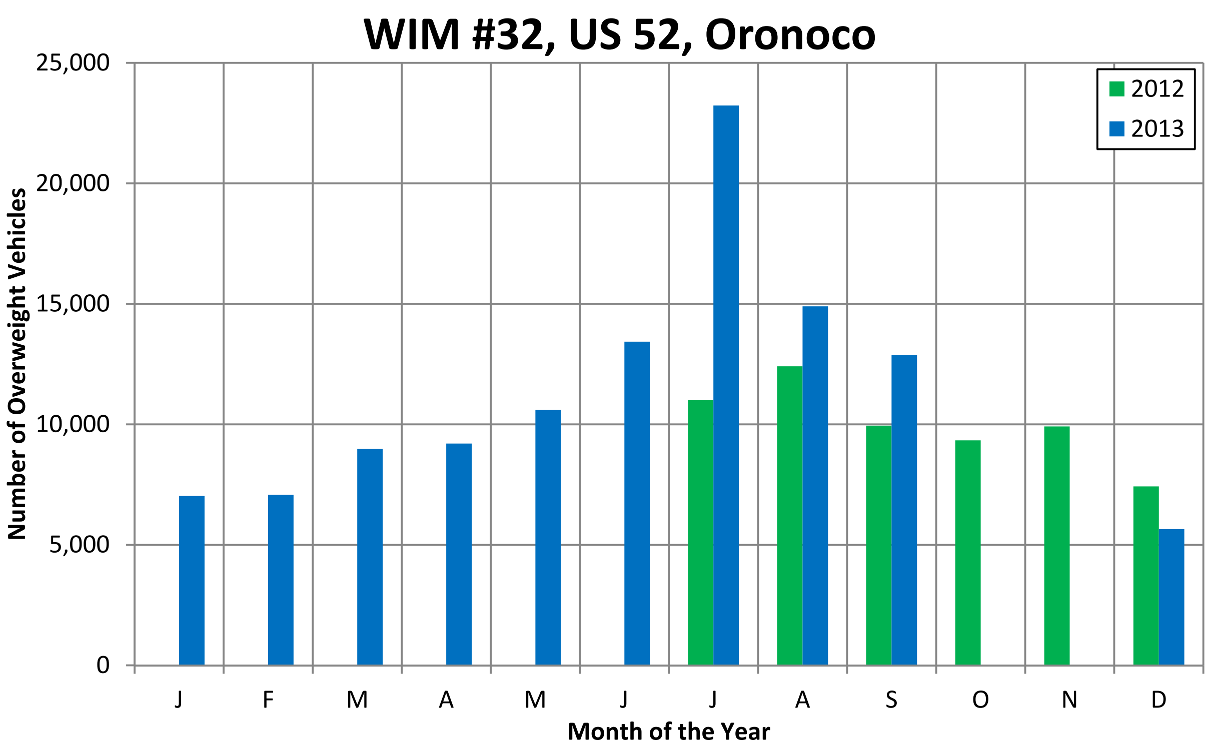


Figure 6.23. Monthly volumes of overweight HCVs by year. Data from July 2012 to December 2013.

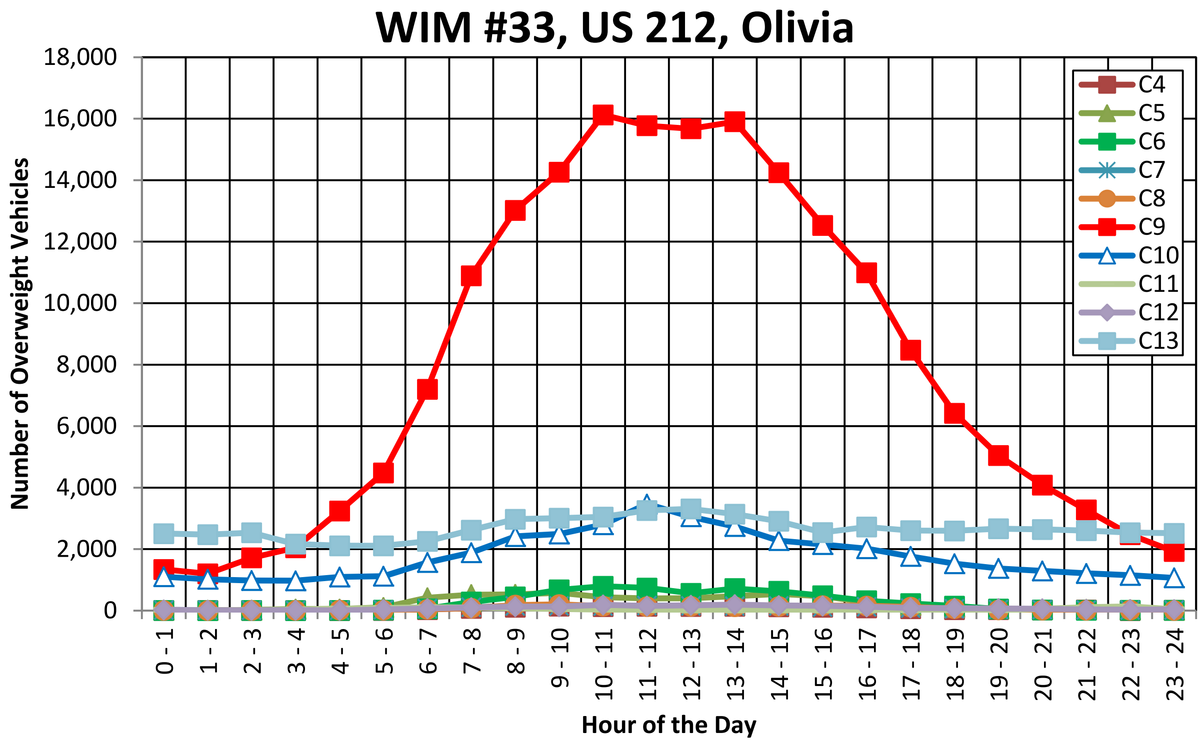


Figure 6.24. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from January 2010 to December 2013.

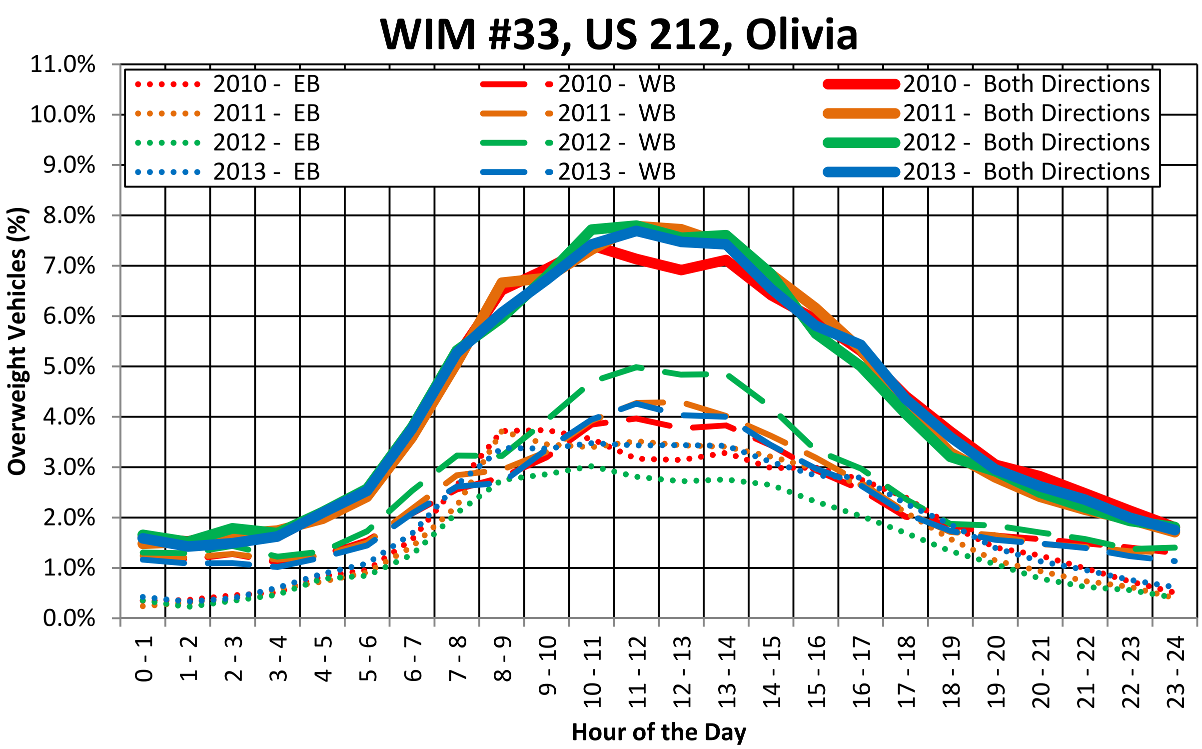


Figure 6.25. Volume distributions for overweight HCVs over a typical 24-hour day. Data from January 2010 to December 2013.

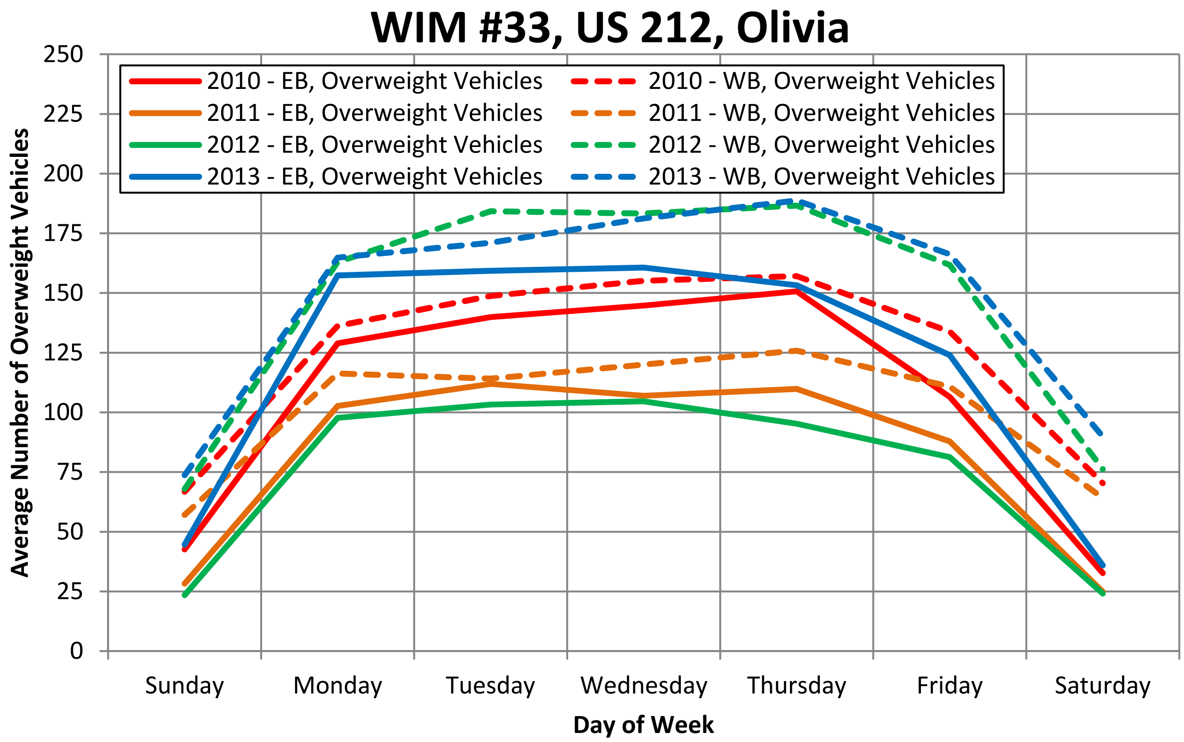


Figure 6.26. Average overweight HCV volume distributions over a typical 7-day week. Data from January 2010 to December 2013.

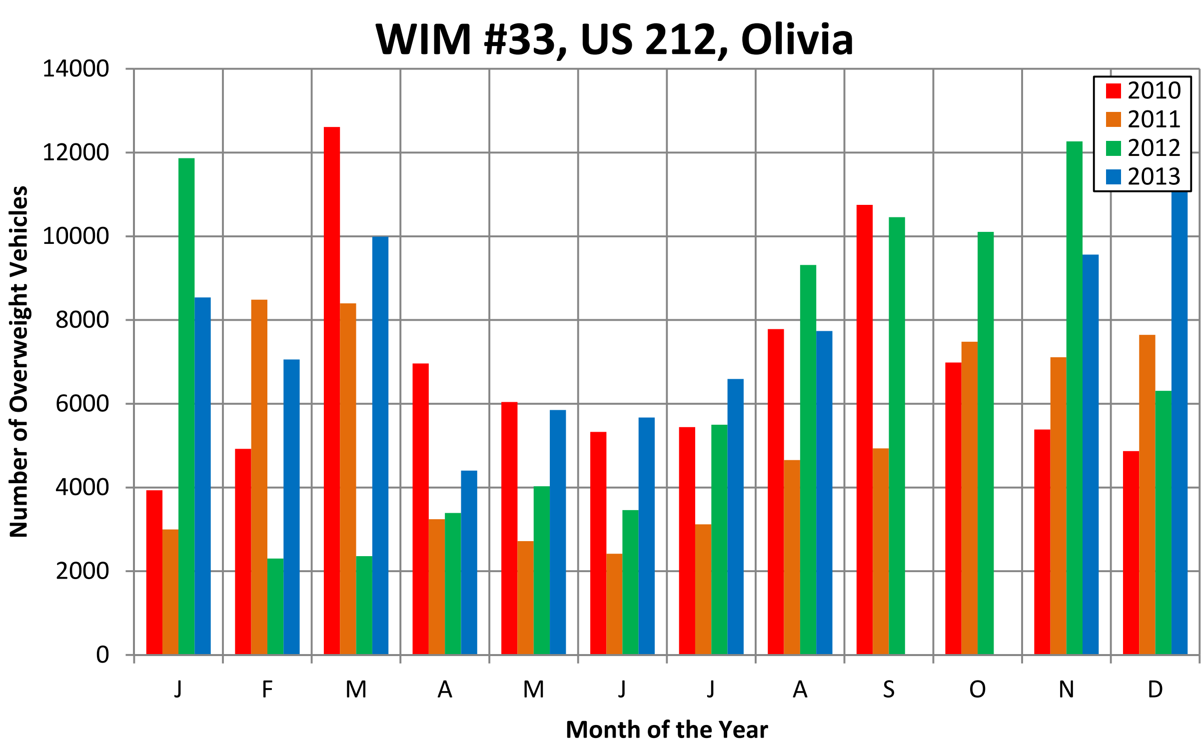


Figure 6.27. Monthly volumes of overweight HCVs by year. Data from January 2010 to December 2013.

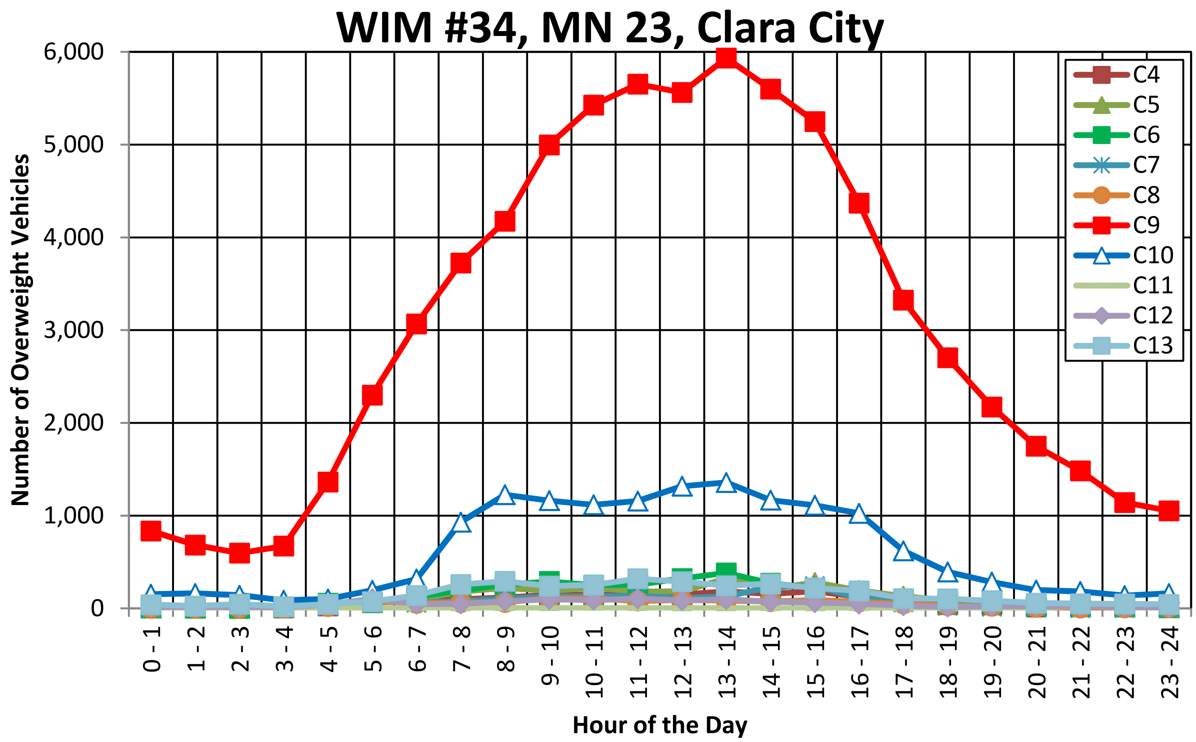


Figure 6.28. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from January 2010 to December 2013.

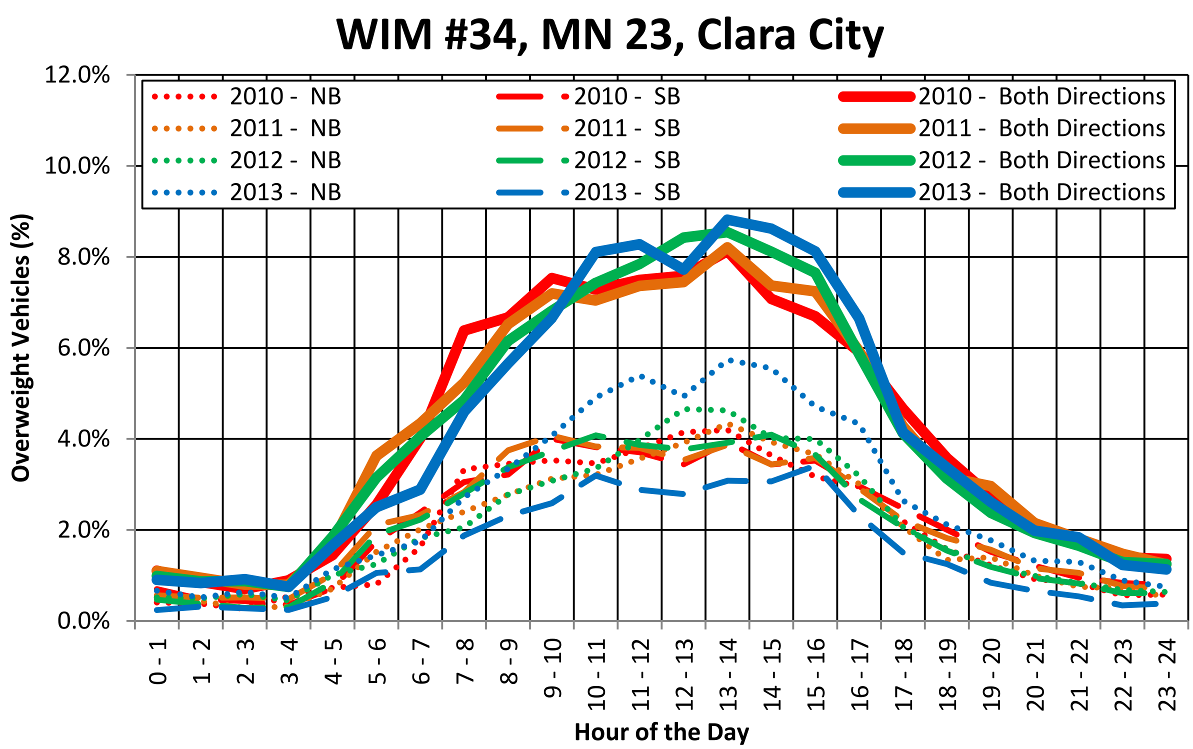


Figure 6.29. Volume distributions for overweight HCVs over a typical 24-hour day. Data from January 2010 to December 2013.

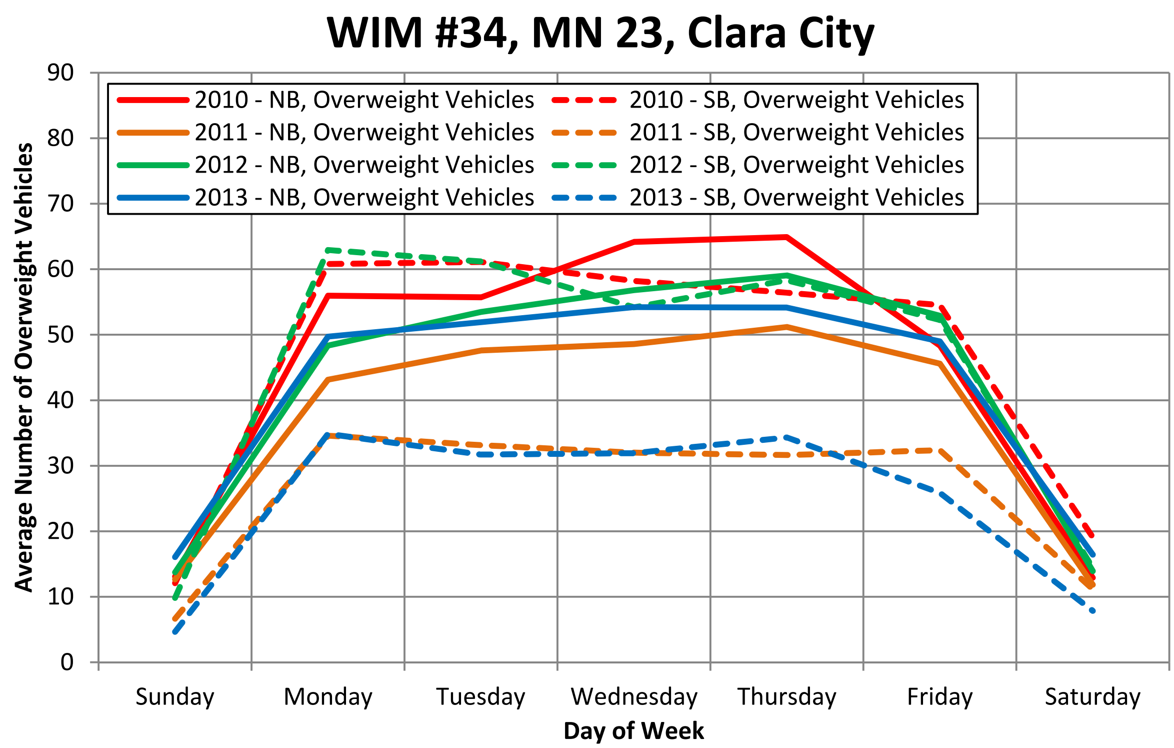


Figure 6.30. Average overweight HCV volume distributions over a typical 7-day week. Data from January 2010 to December 2013.

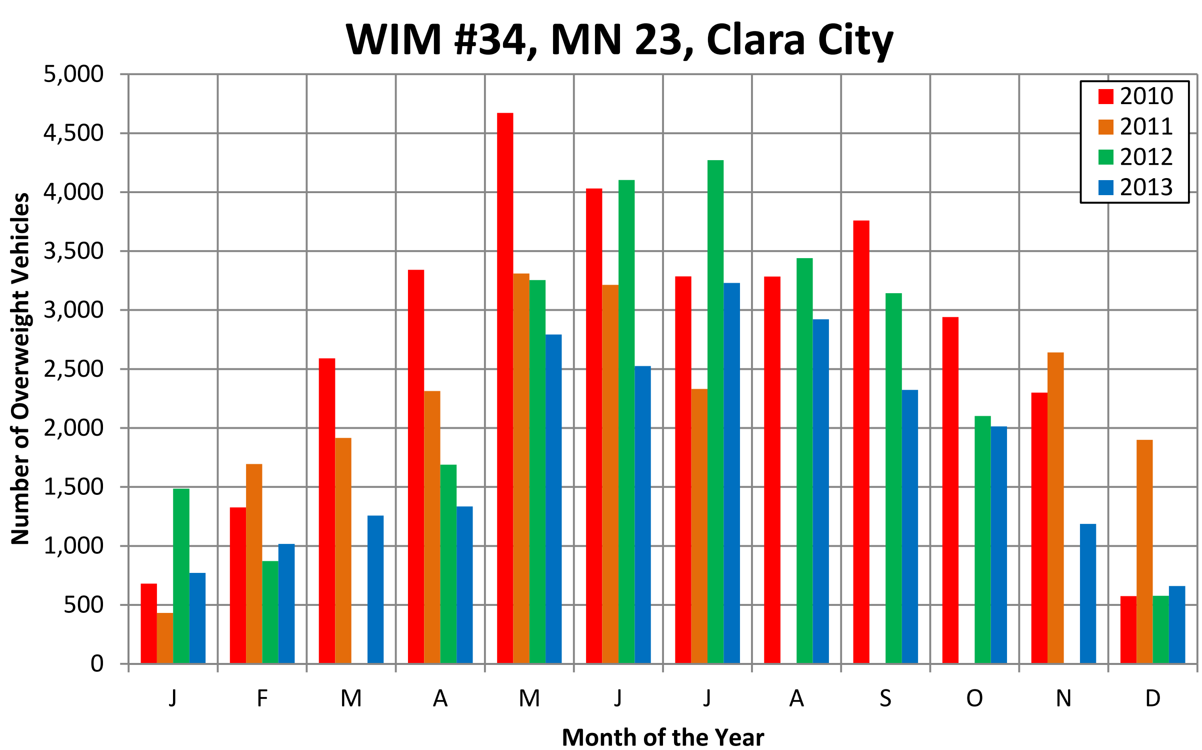


Figure 6.31. Monthly volumes of overweight HCVs by year. Data from January 2010 to December 2013.

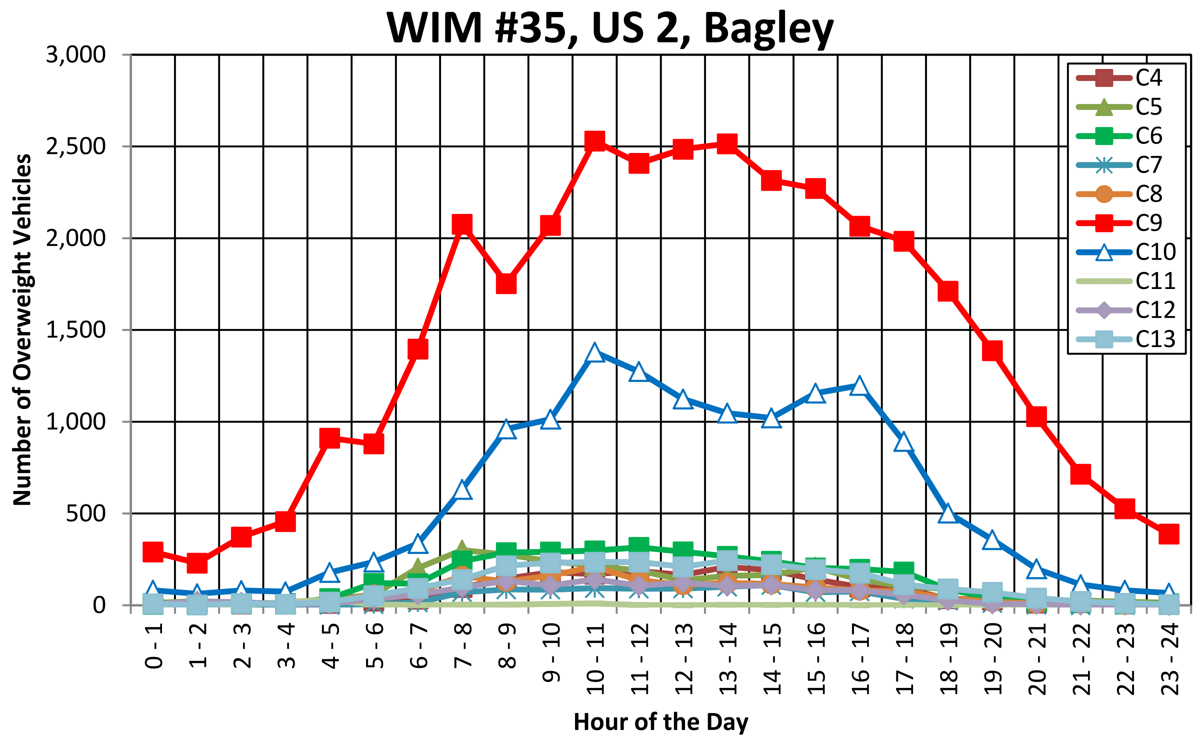


Figure 6.32. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from January 2010 to December 2013.

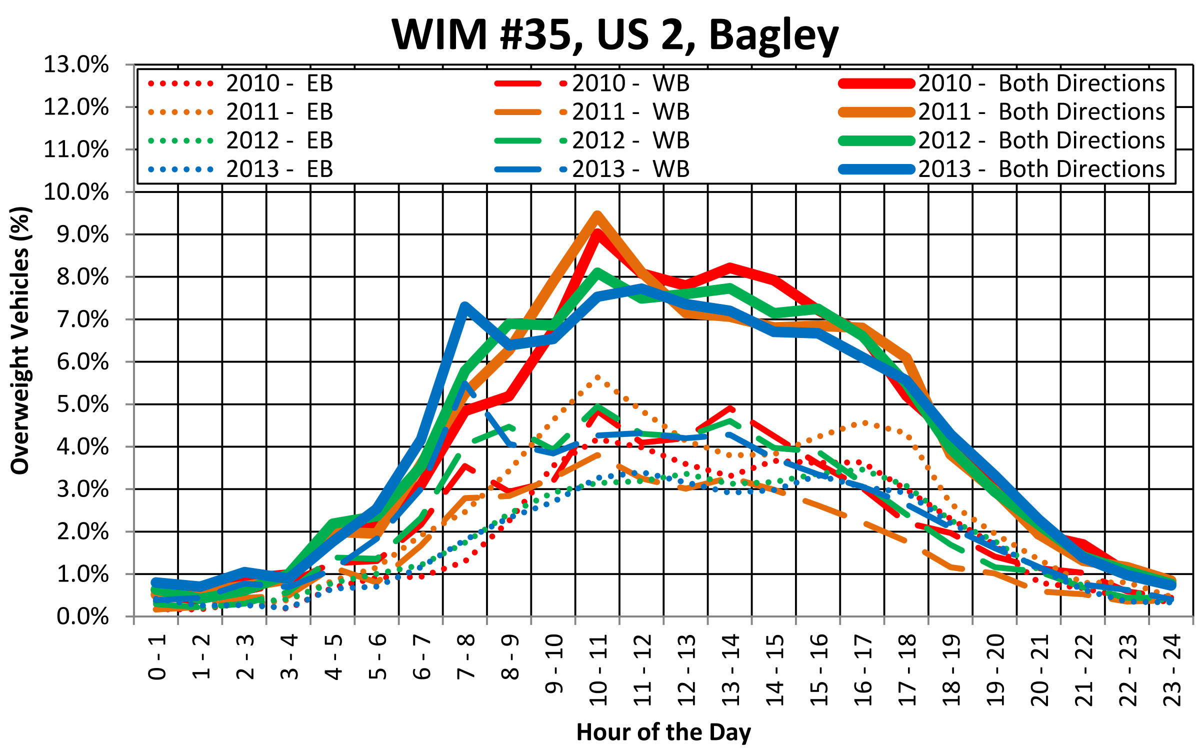


Figure 6.33. Volume distributions for overweight HCVs over a typical 24-hour day. Data from January 2010 to December 2013.

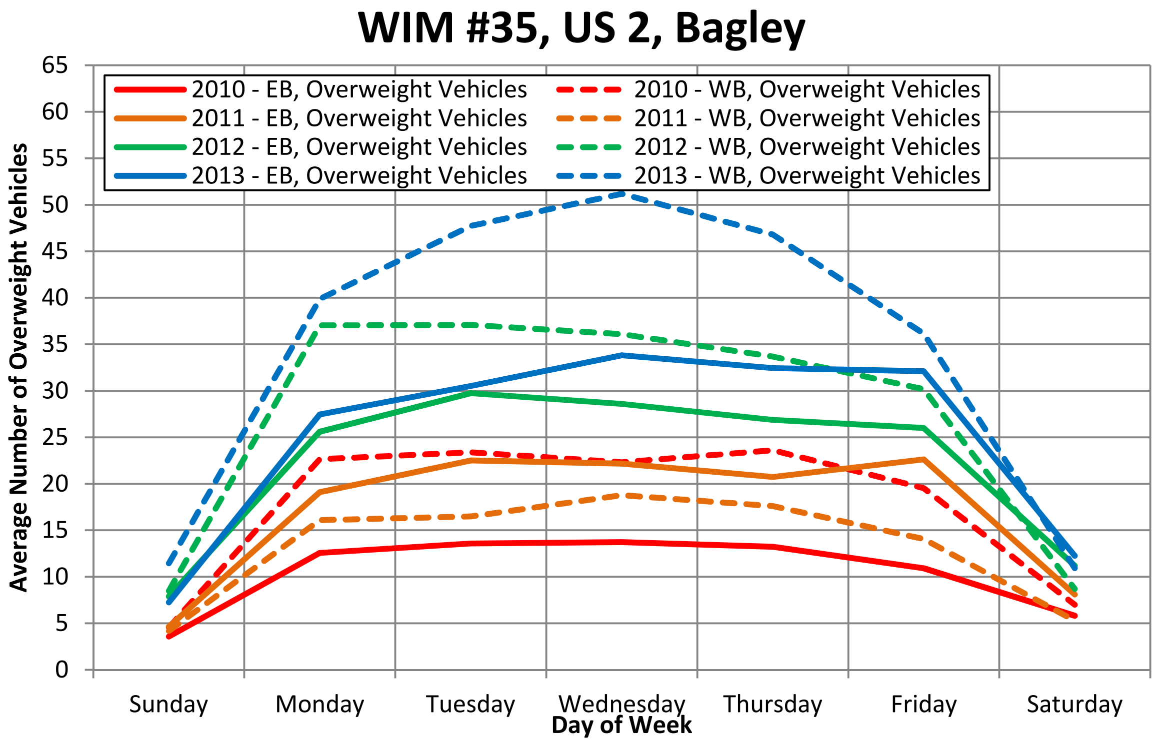


Figure 6.34. Average overweight HCV volume distributions over a typical 7-day week. Data from January 2010 to December 2013.

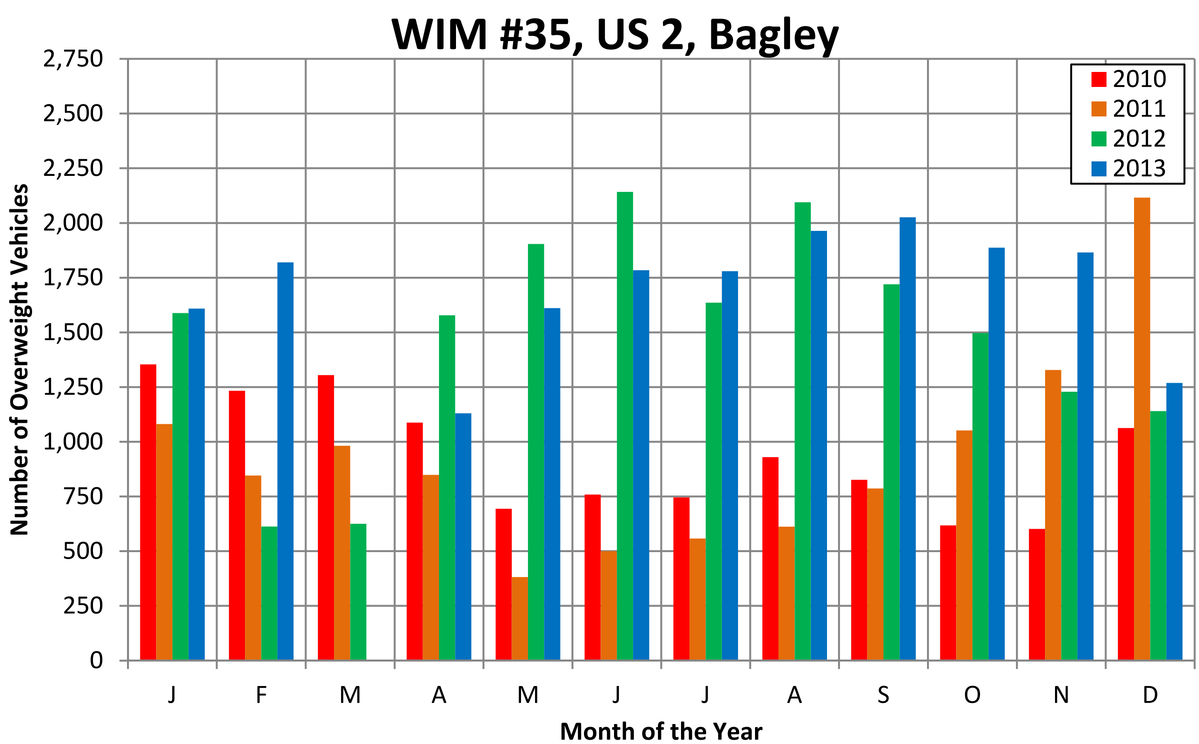


Figure 6.35. Monthly volumes of overweight HCVs by year. Data from January 2010 to December 2013.

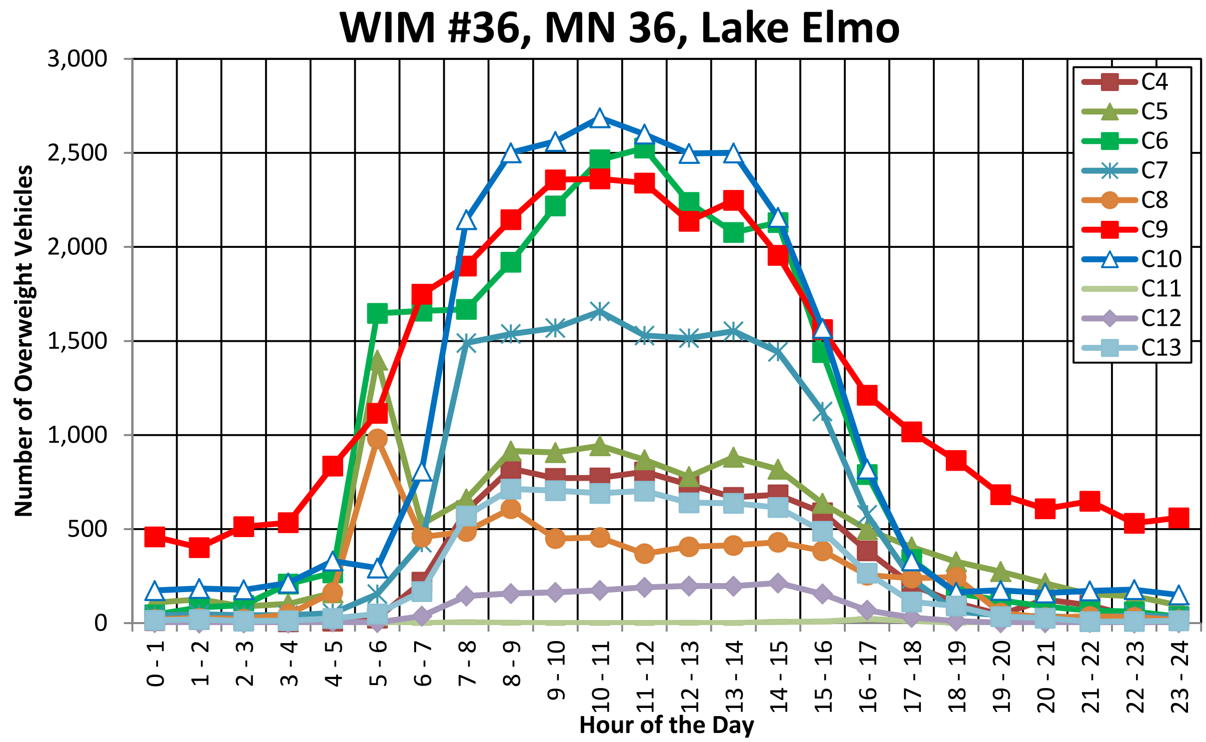


Figure 6.36. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from January 2010 to December 2013.

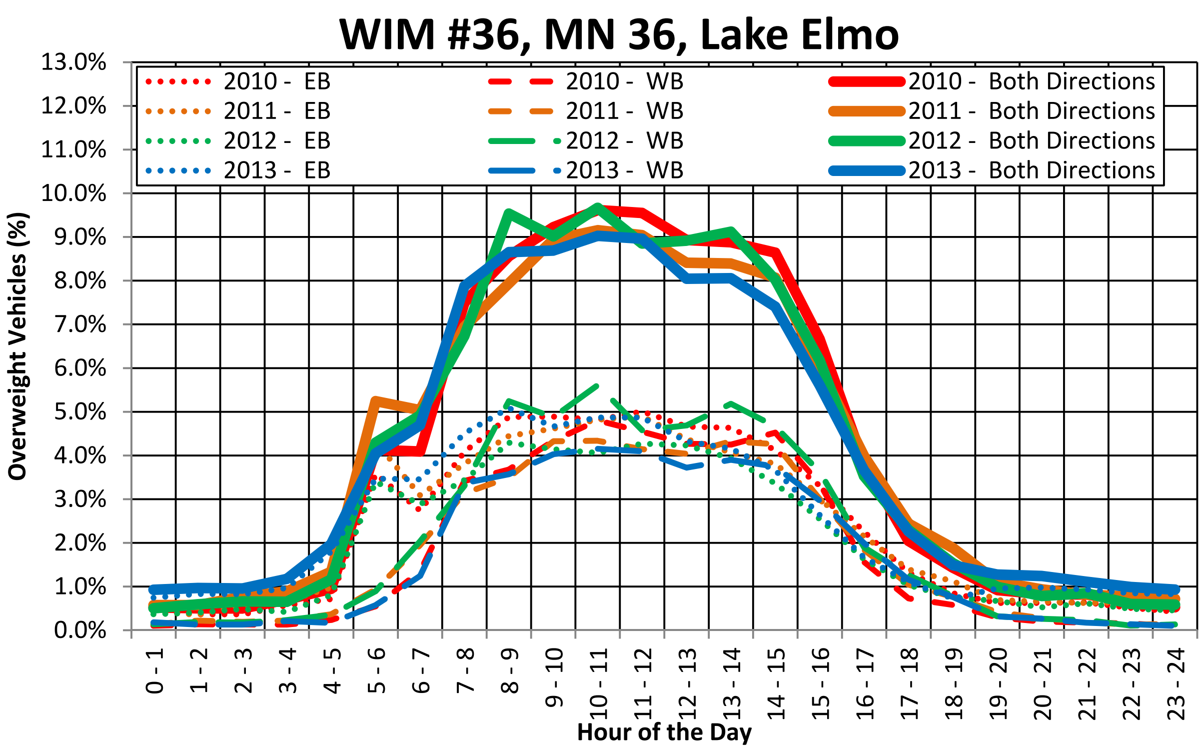


Figure 6.37. Volume distributions for overweight HCVs over a typical 24-hour day. Data from January 2010 to December 2013.

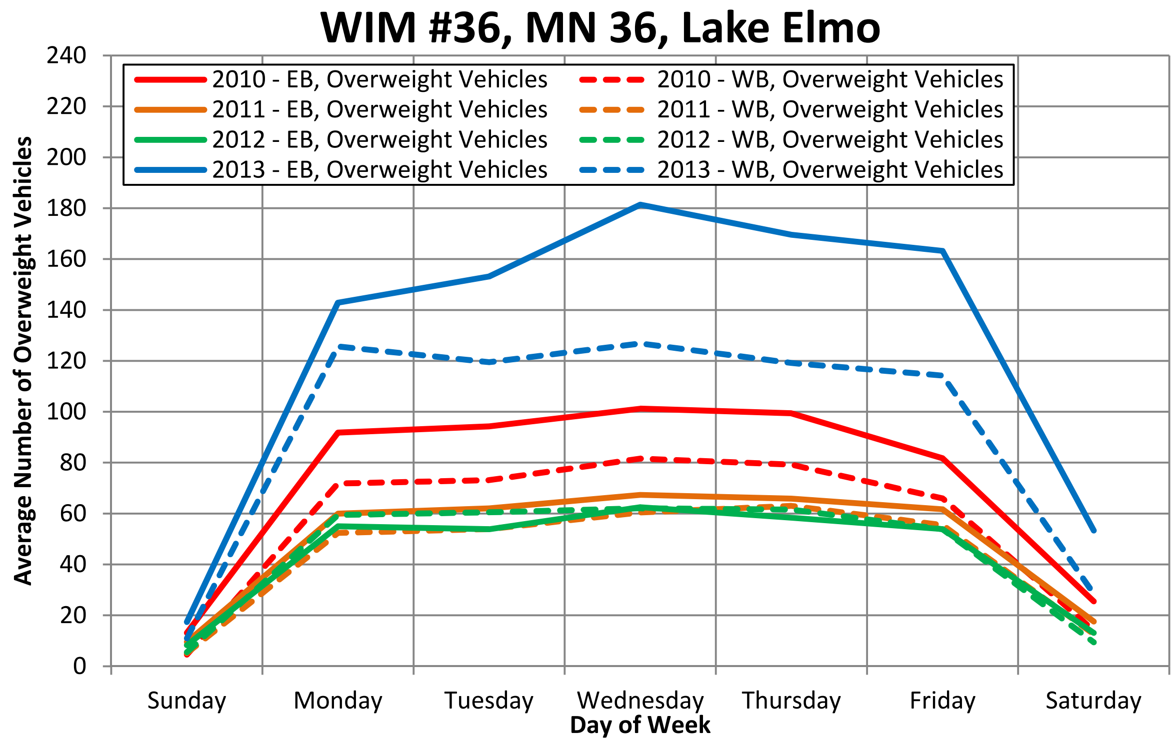


Figure 6.38. Average overweight HCV volume distributions over a typical 7-day week. Data from January 2010 to December 2013.

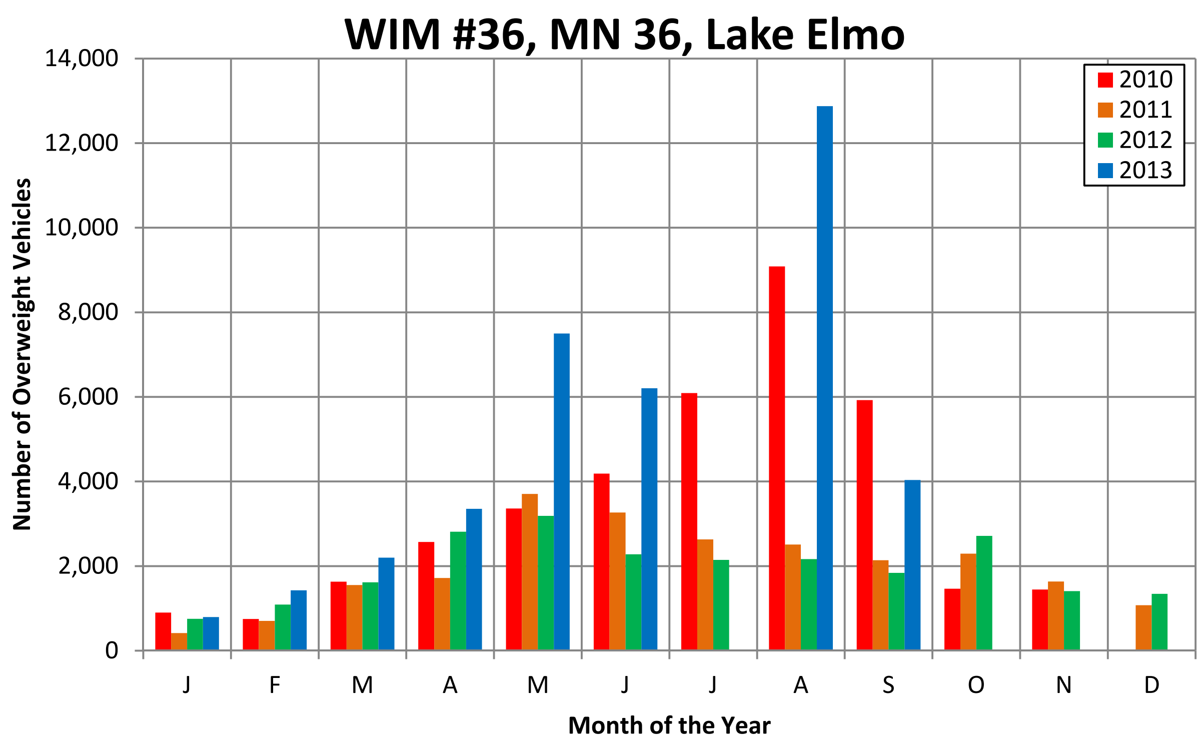


Figure 6.39. Monthly volumes of overweight HCVs by year. Data from January 2010 to December 2013.

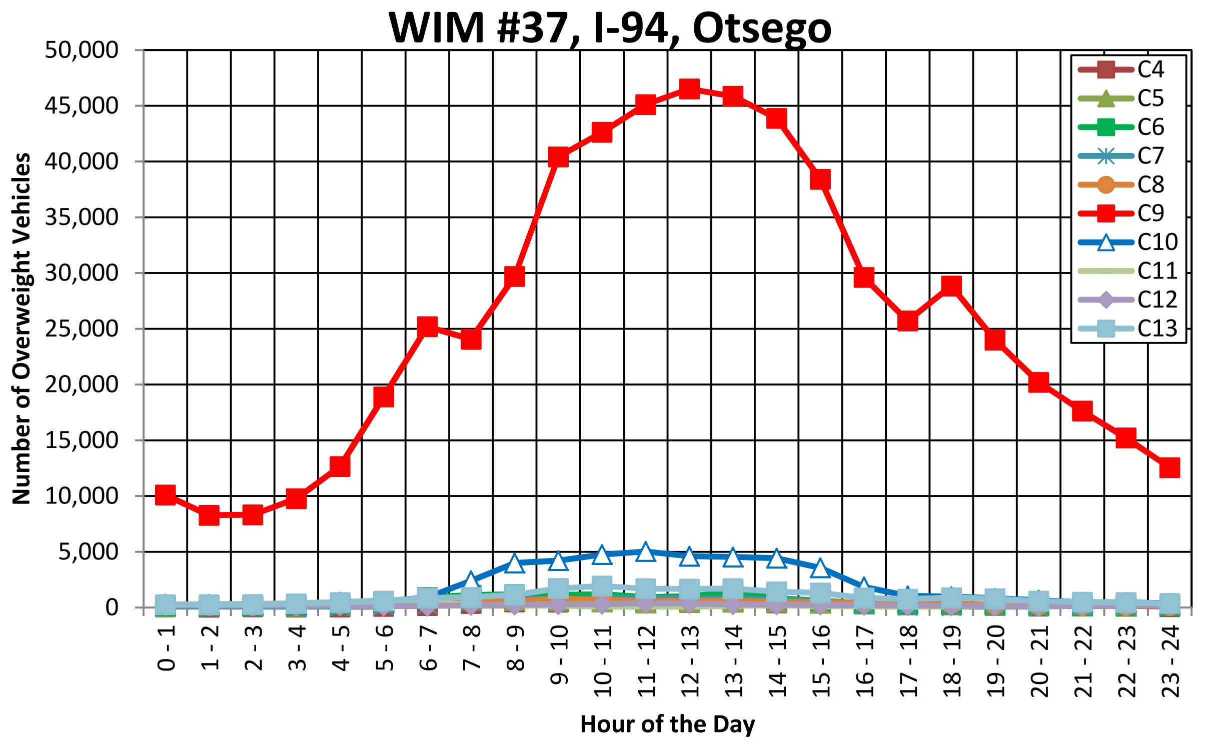


Figure 6.40. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from January 2010 to December 2013.

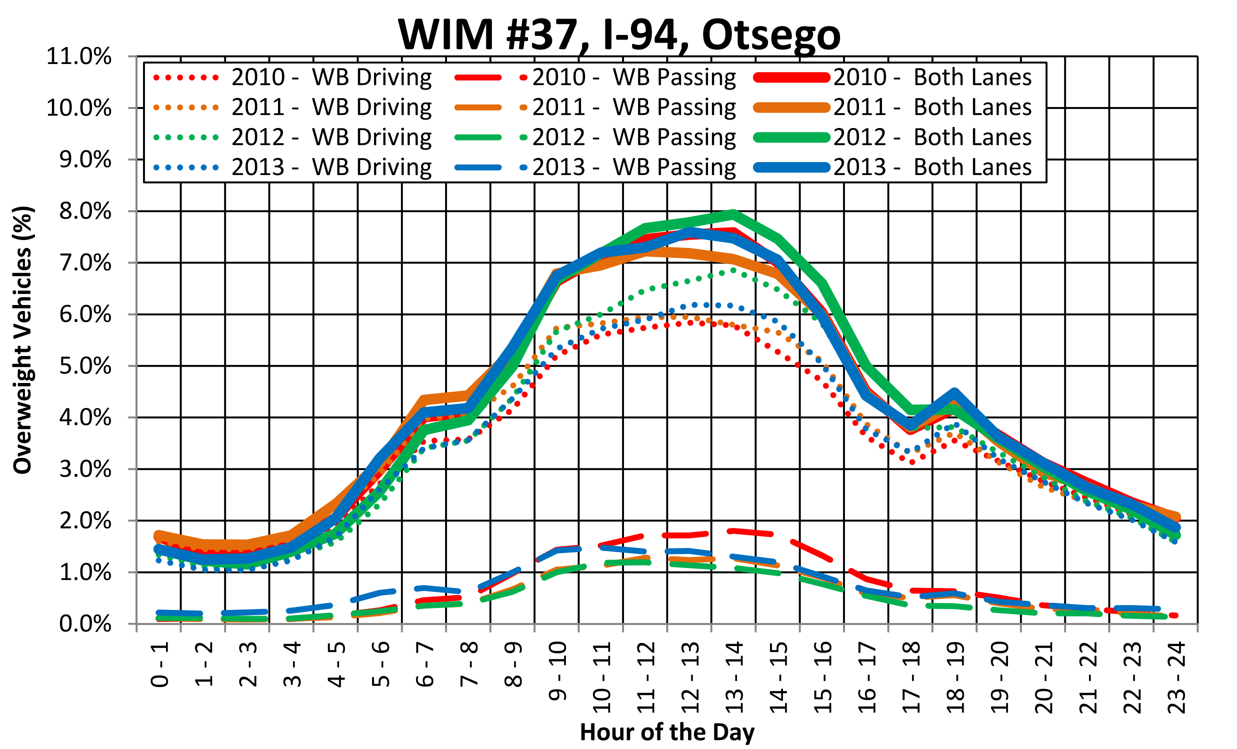


Figure 6.41. Westbound volume distributions for overweight HCVs over a typical 24-hour day. Data from January 2010 to December 2013.

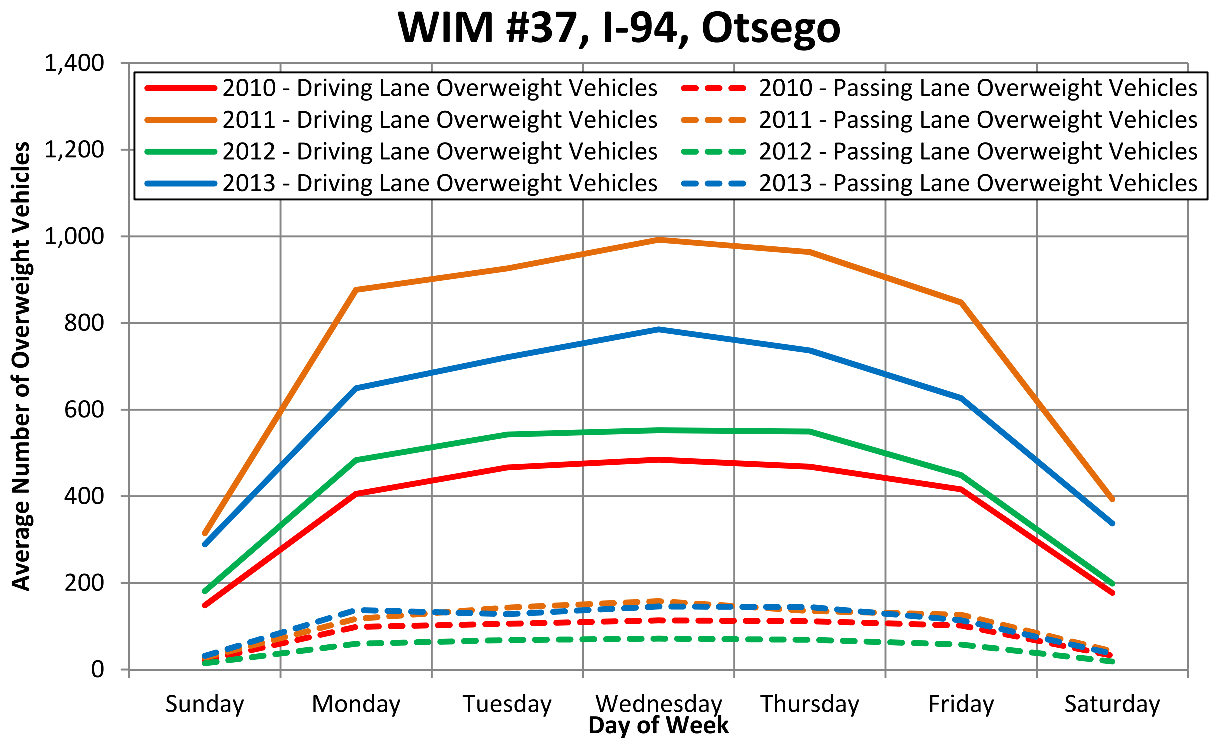


Figure 6.42. Average overweight HCV volume distributions in the westbound direction over a typical 7-day week. Data from January 2010 to December 2013.

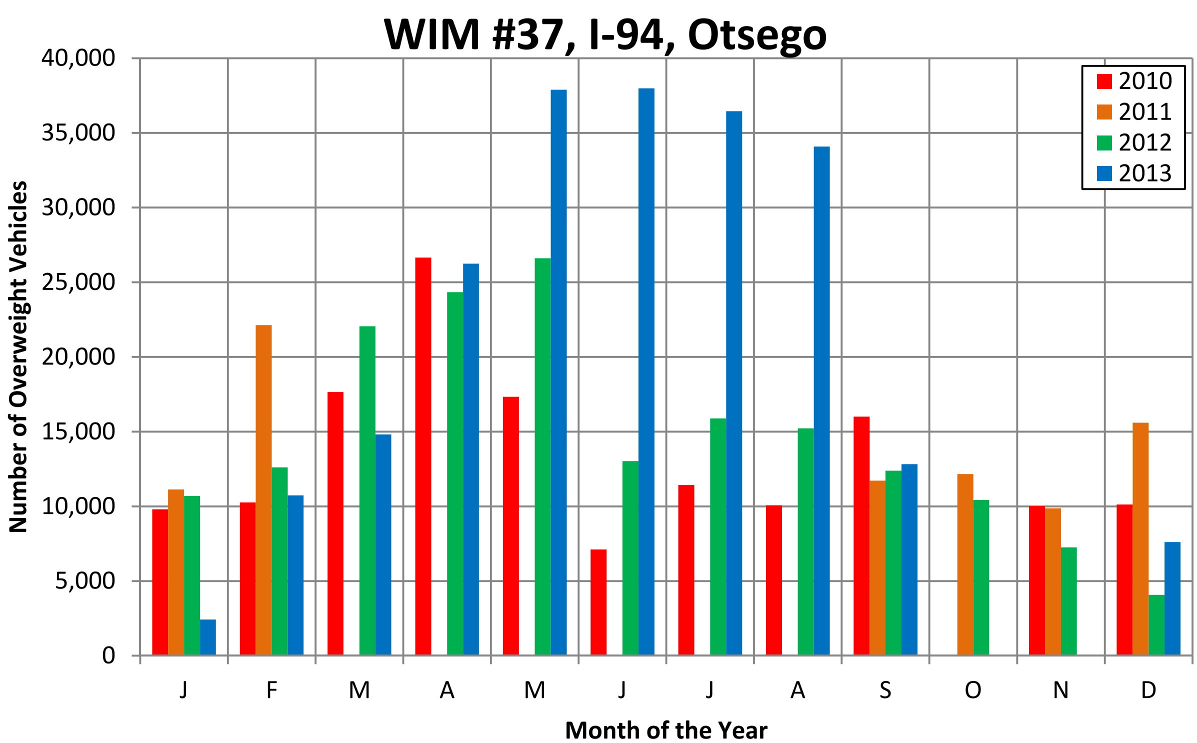


Figure 6.43. Monthly volumes of overweight HCVs by year. Data from January 2010 to December 2013.

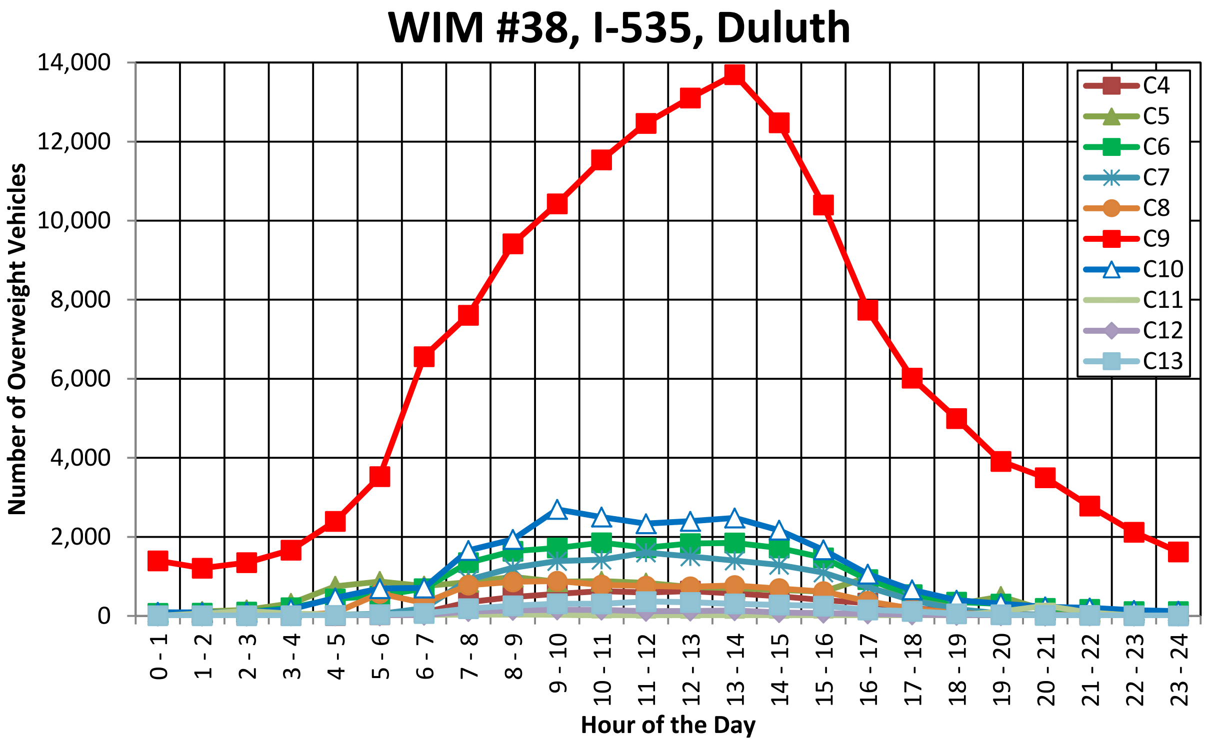


Figure 6.44. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from January 2010 to December 2013.

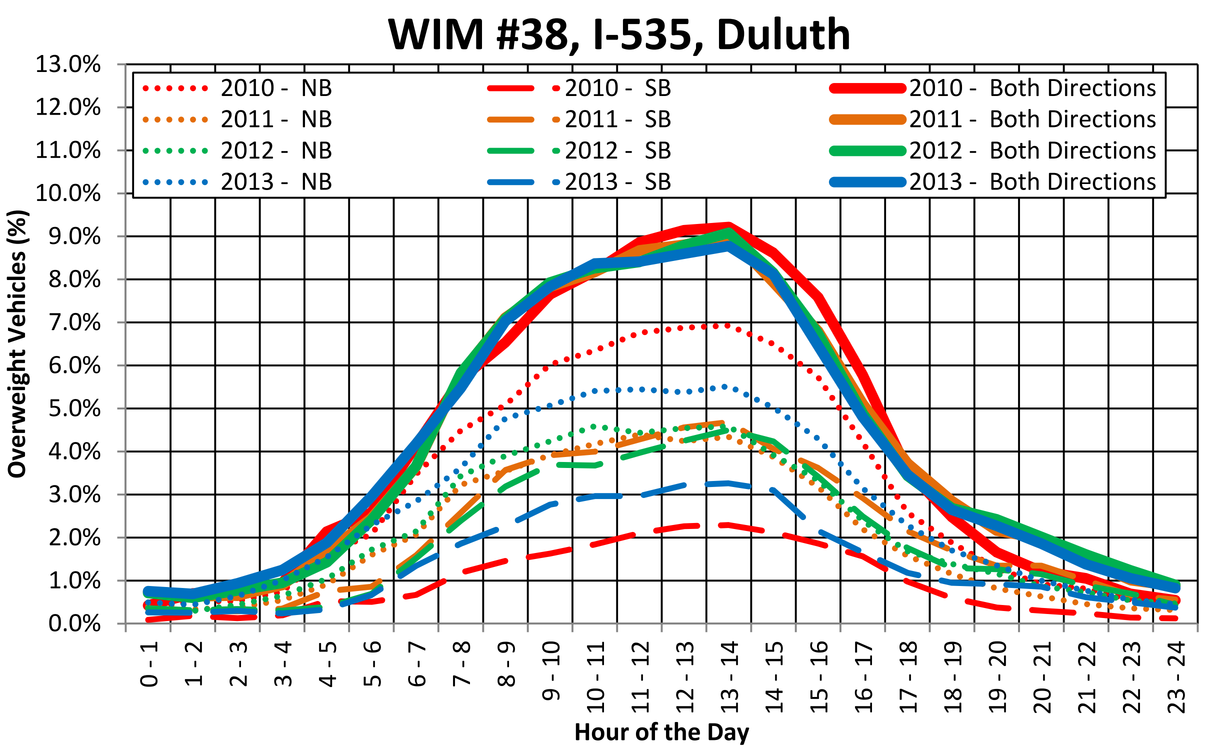


Figure 6.45. Volume distributions for overweight HCVs over a typical 24-hour day. Data from January 2010 to December 2013.

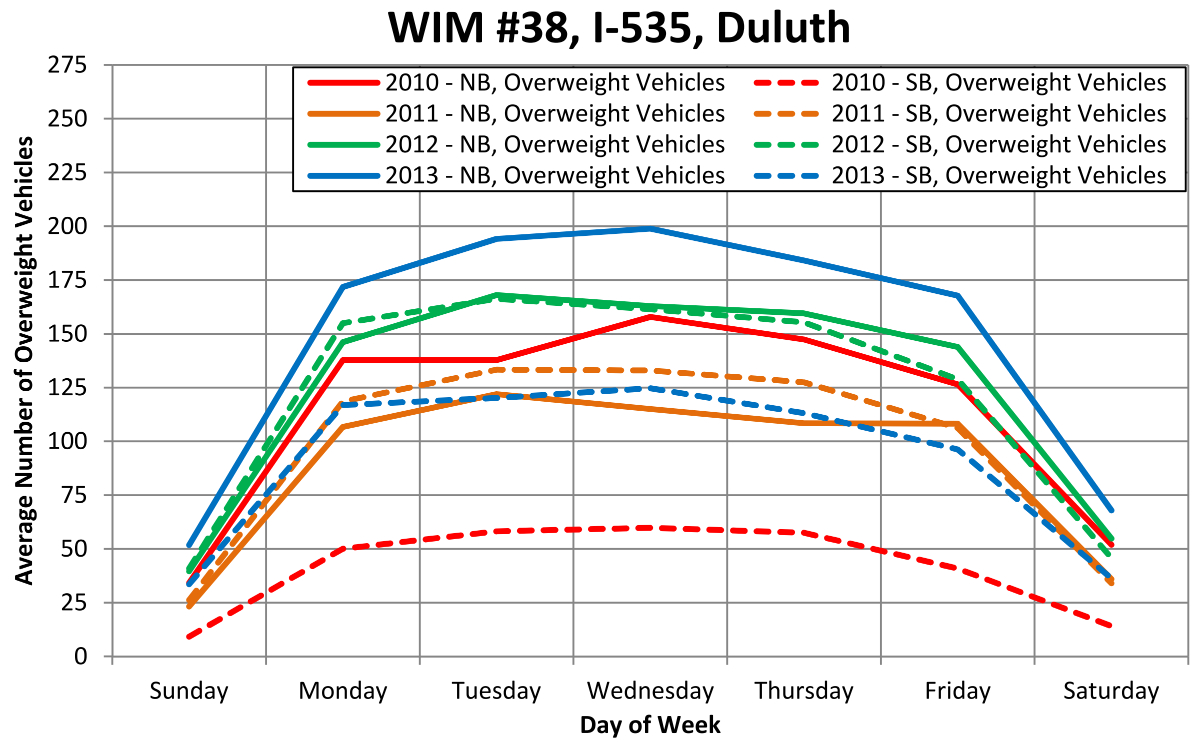


Figure 6.46. Average overweight HCV volume distributions over a typical 7-day week. Data from January 2010 to December 2013.

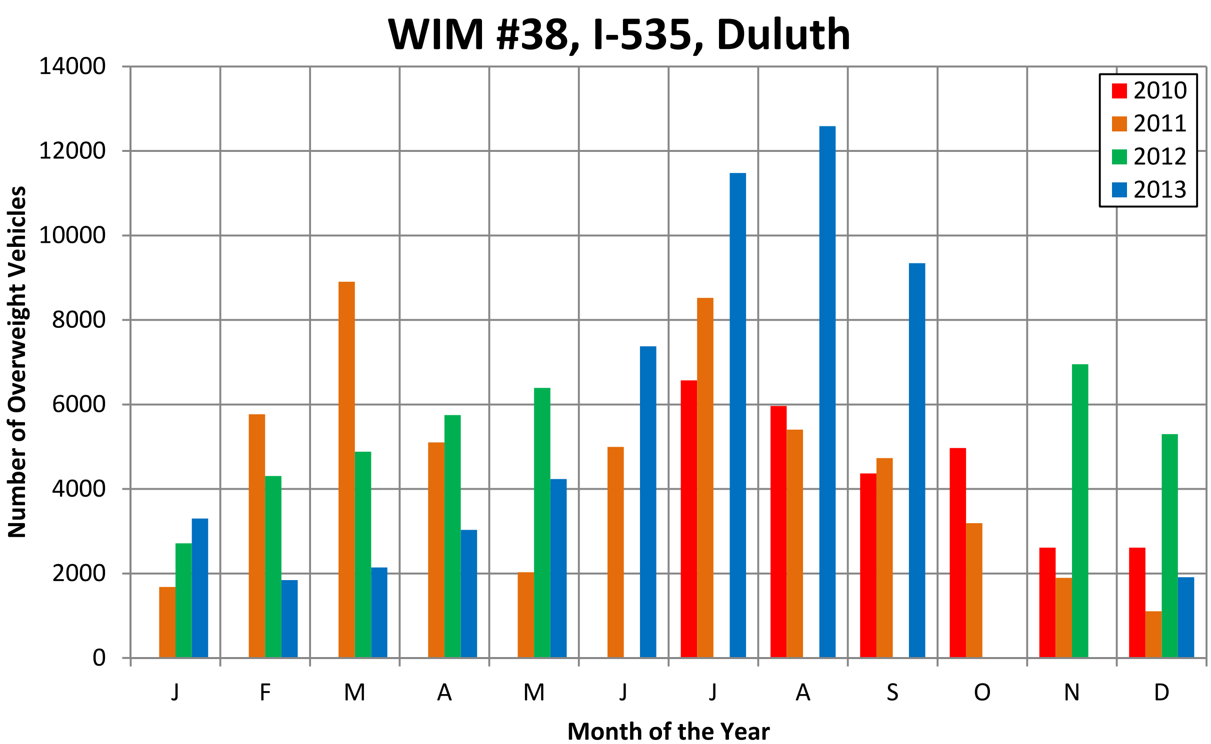


Figure 6.47. Monthly volumes of overweight HCVs by year. Data from January 2010 to December 2013.

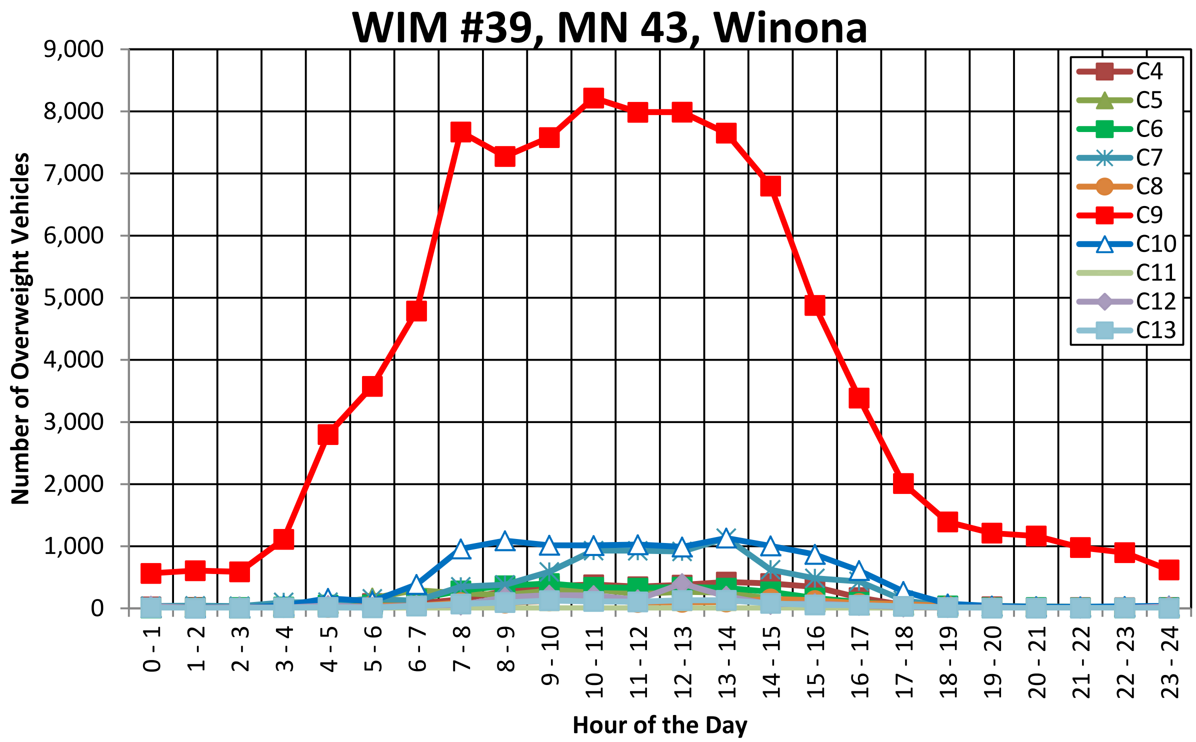


Figure 6.48. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from January 2010 to December 2013.

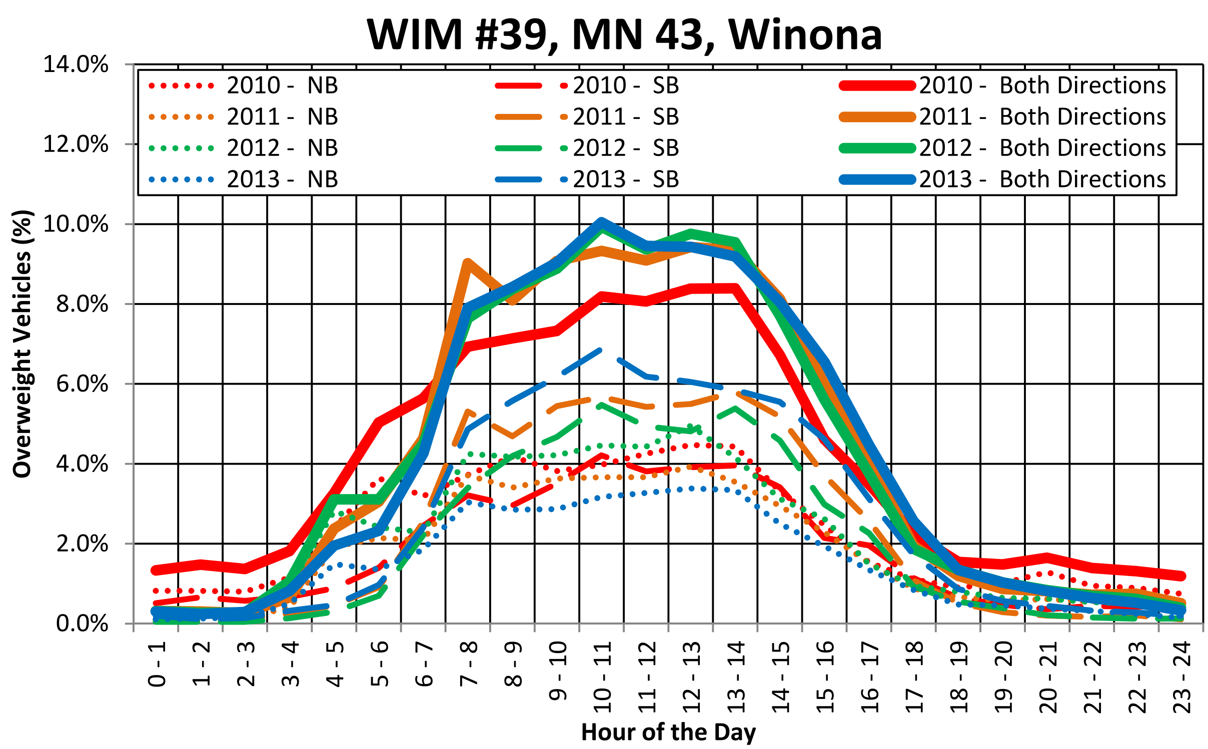


Figure 6.49. Volume distributions for overweight HCVs over a typical 24-hour day. Data from January 2010 to December 2013.

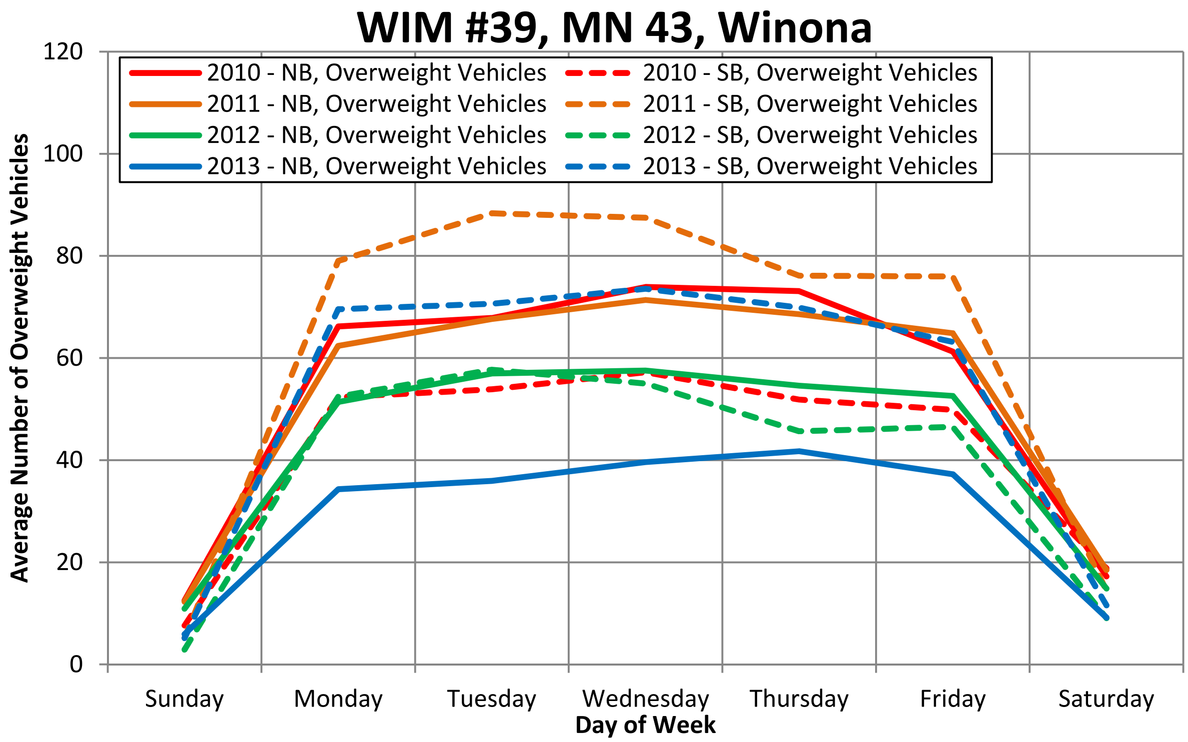


Figure 6.50. Average overweight HCV volume distributions over a typical 7-day week. Data from January 2010 to December 2013.

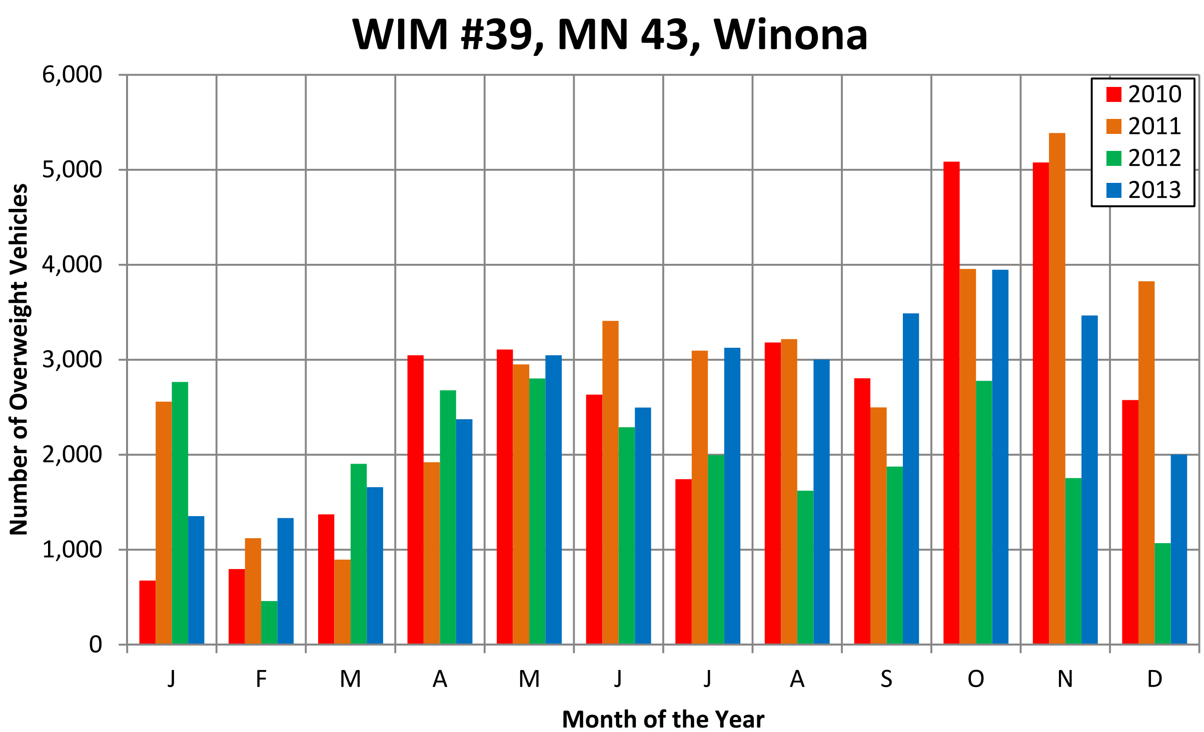


Figure 6.51. Monthly volumes of overweight HCVs by year. Data from January 2010 to December 2013.

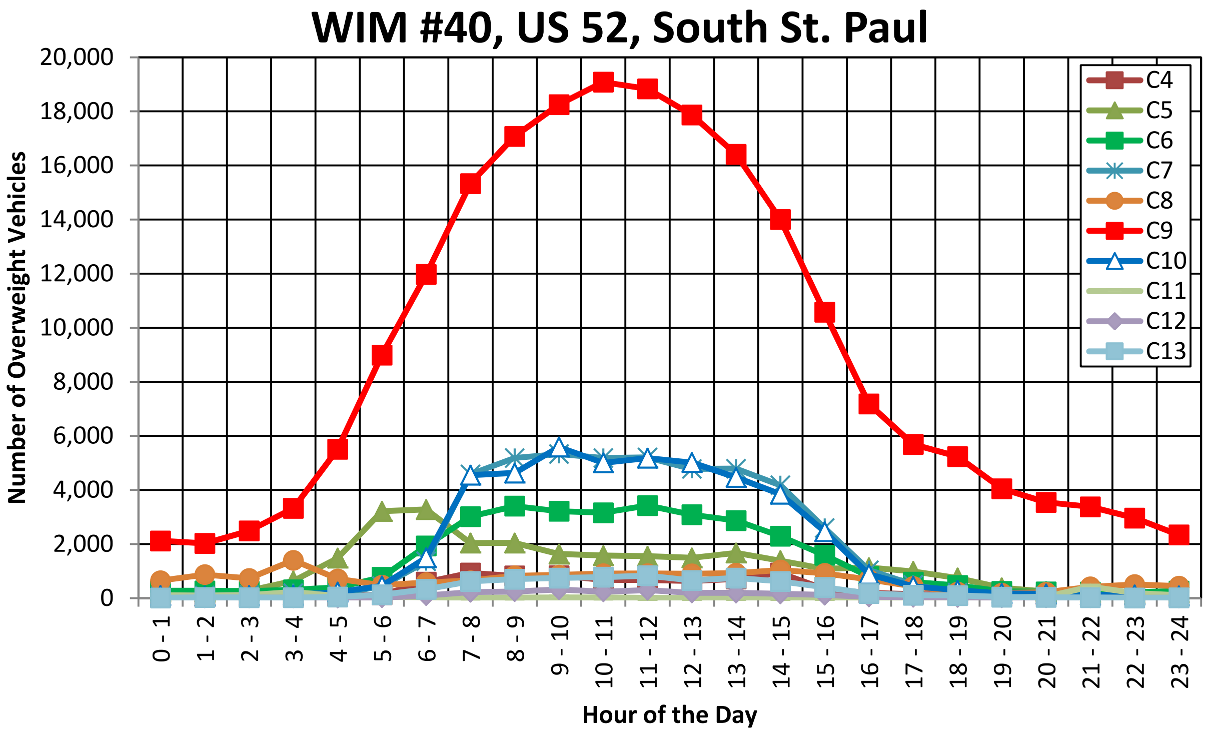


Figure 6.52. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from January 2010 to December 2013.

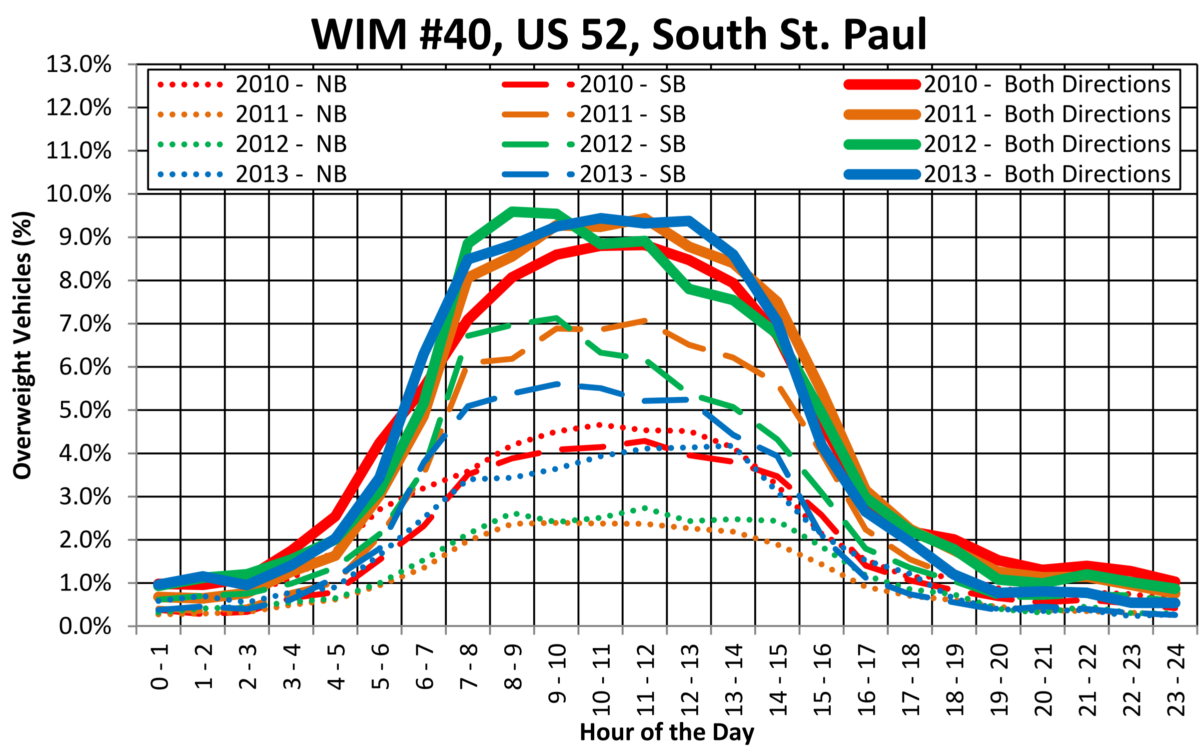


Figure 6.53. Volume distributions for overweight HCVs over a typical 24-hour day. Data from January 2010 to December 2013.

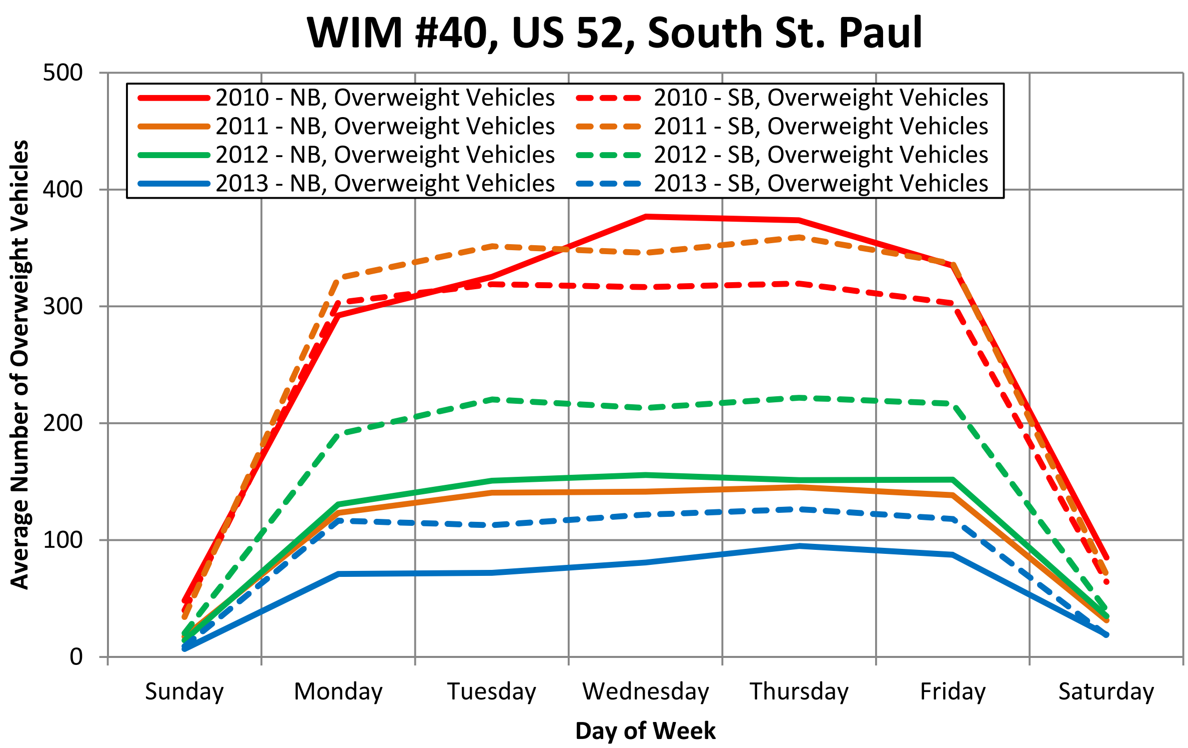


Figure 6.54. Average overweight HCV volume distributions over a typical 7-day week. Data from January 2010 to December 2013.

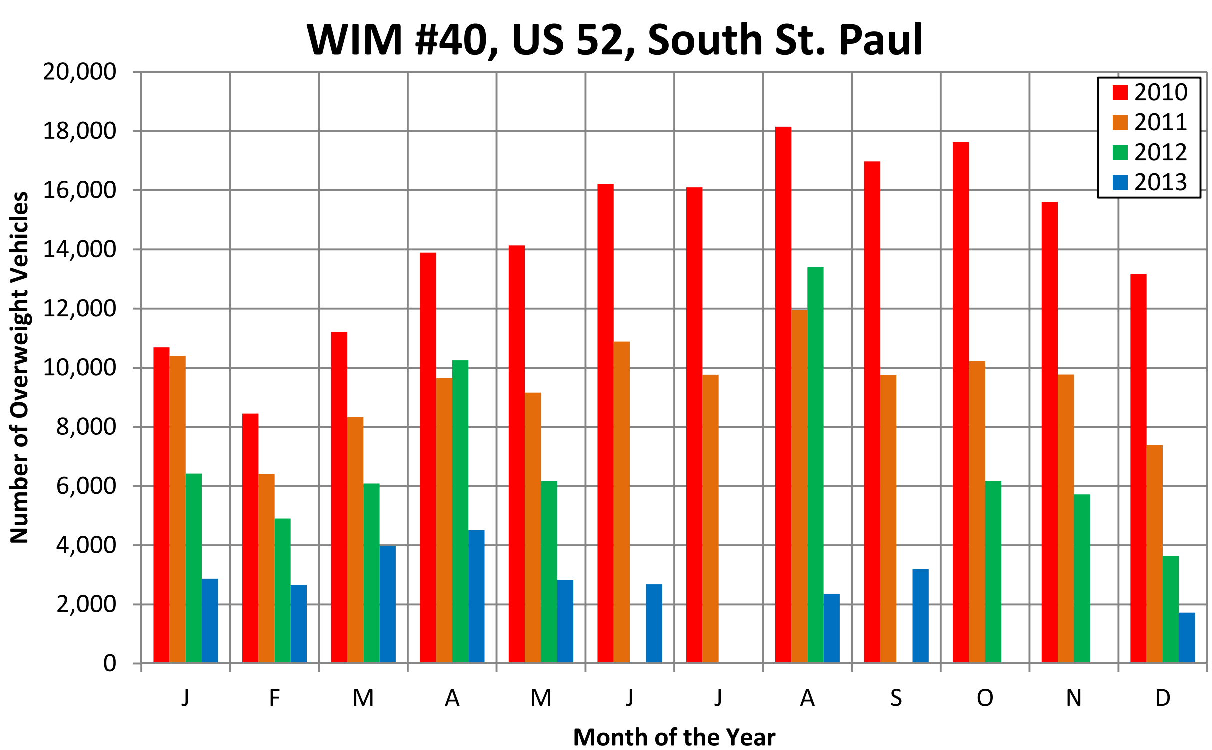


Figure 6.55. Monthly volumes of overweight HCVs by year. Data from January 2010 to December 2013.

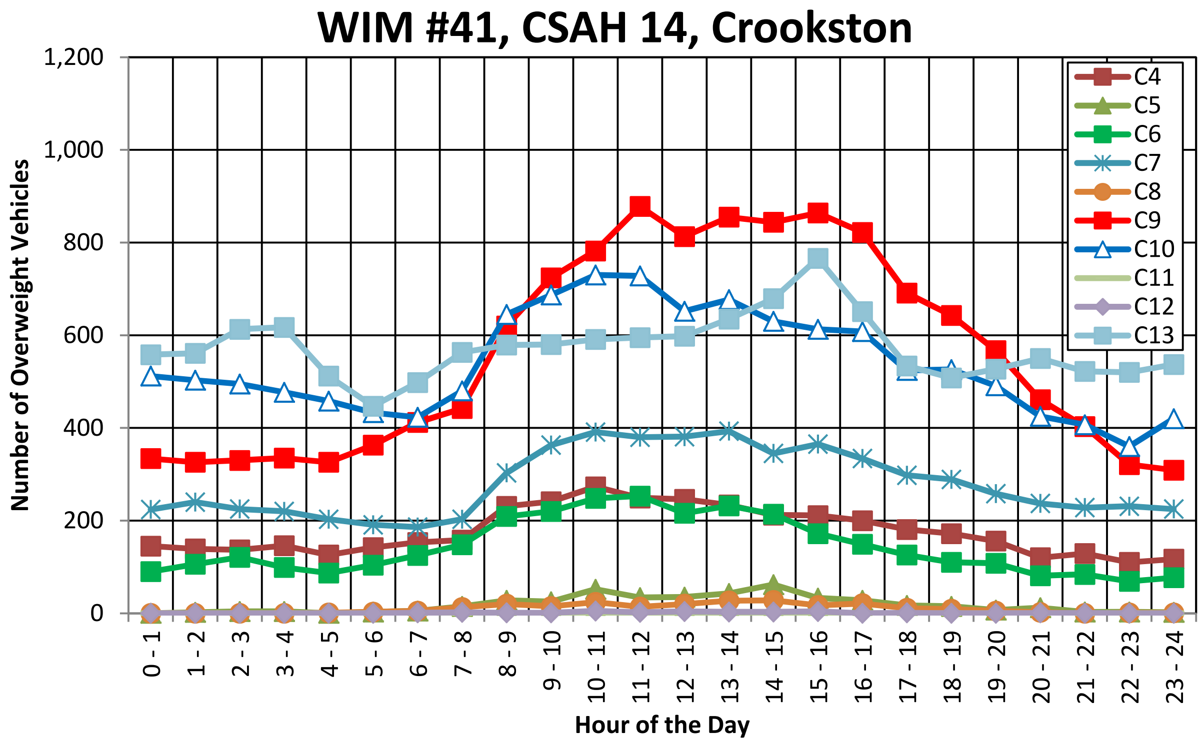


Figure 6.56. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from October 2010 to December 2013.

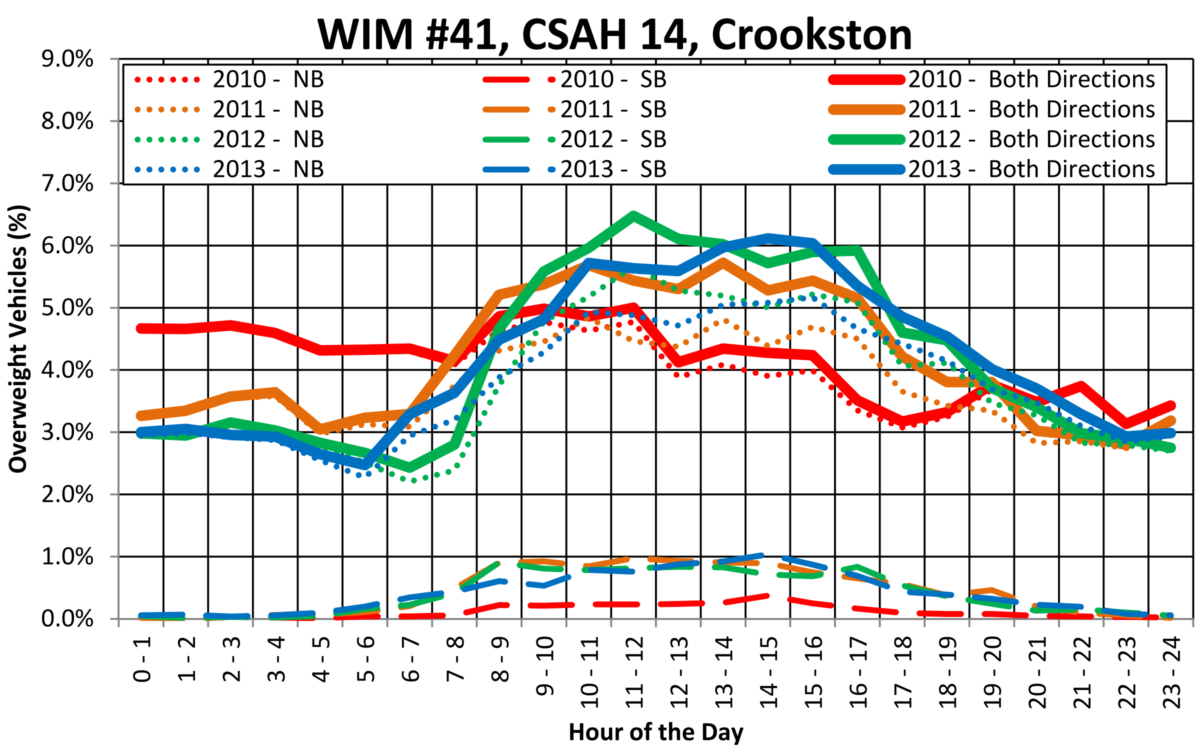


Figure 6.57. Volume distributions for overweight HCVs over a typical 24-hour day. Data from October 2010 to December 2013.

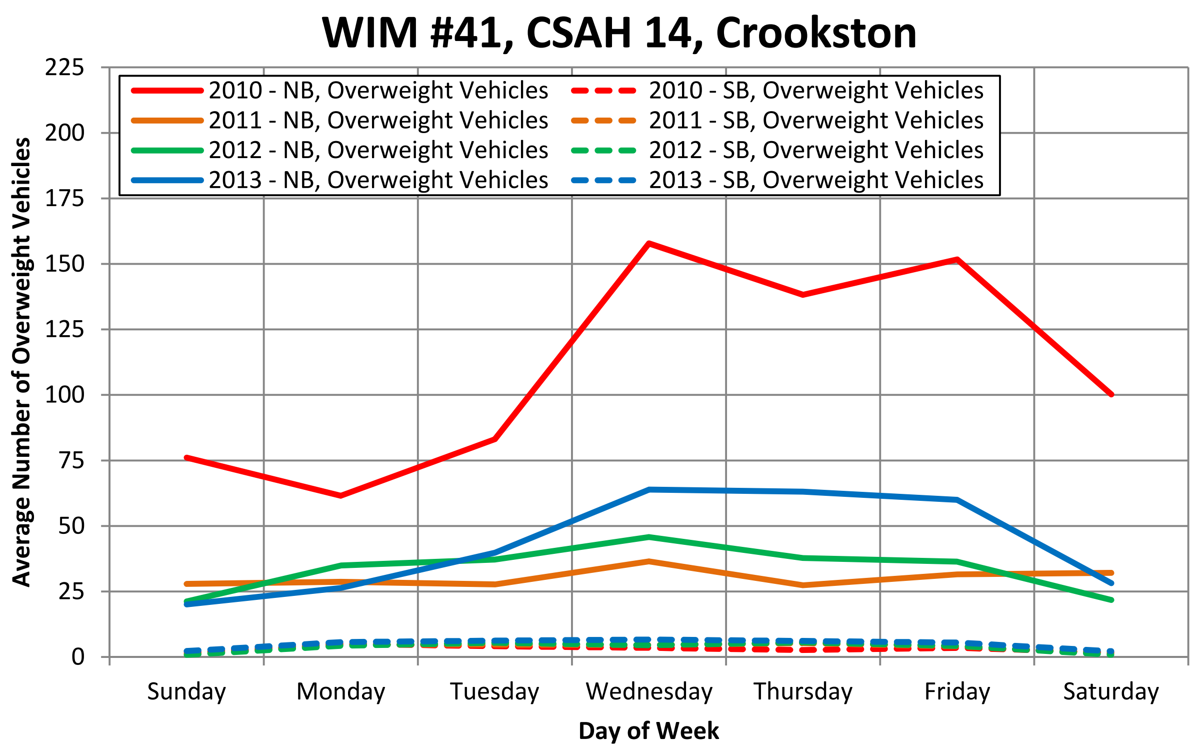


Figure 6.58. Average overweight HCV volume distributions over a typical 7-day week. Data from October 2010 to December 2013.

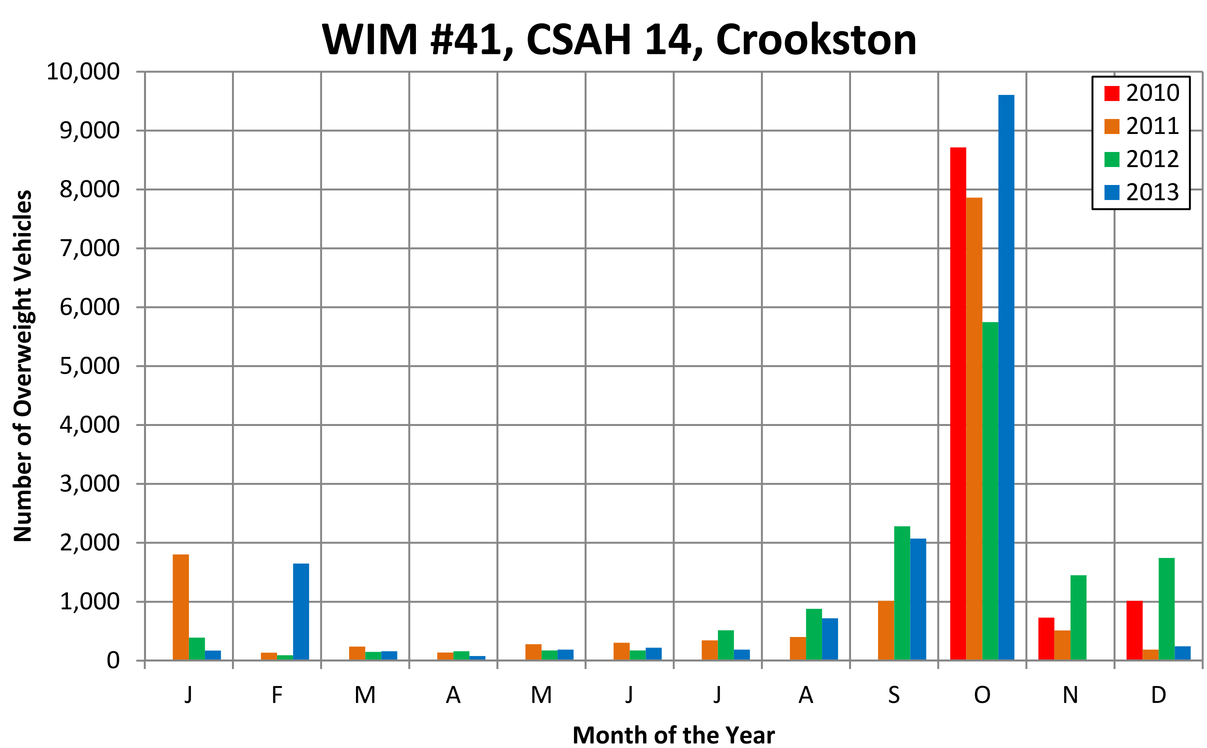


Figure 6.59. Monthly volumes of overweight HCVs by year. Data from October 2010 to December 2013.

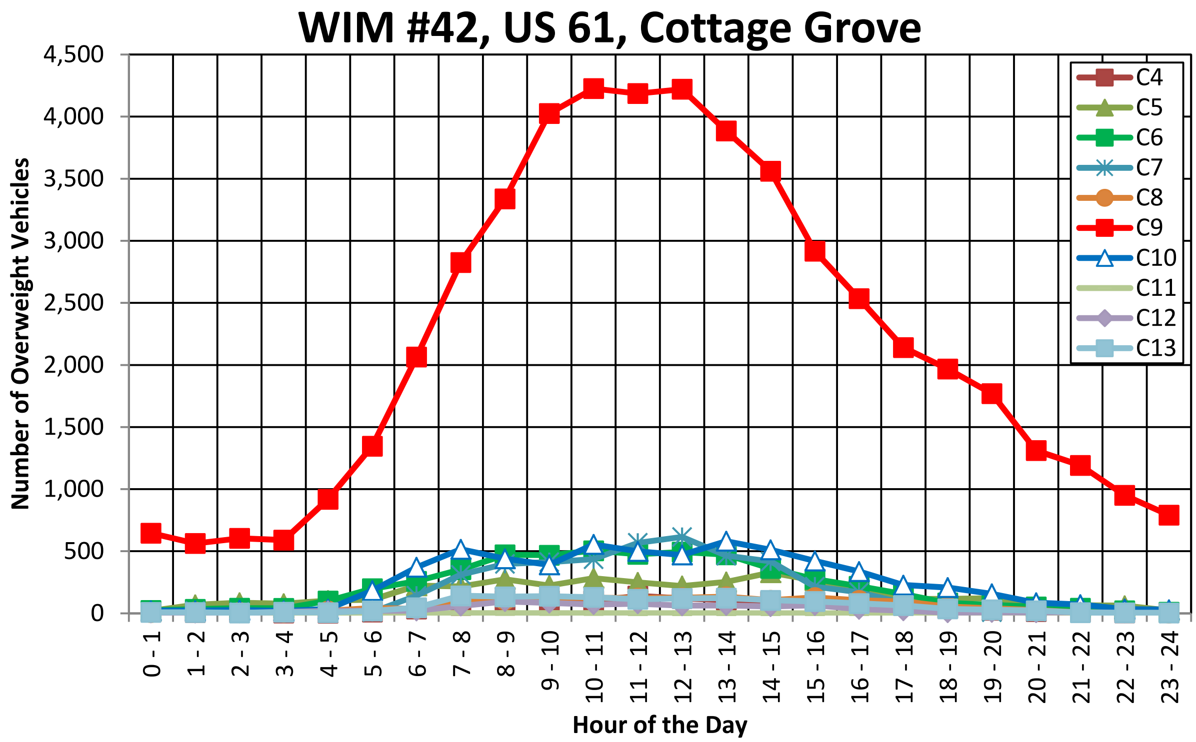


Figure 6.60. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from August 2012 to December 2013.

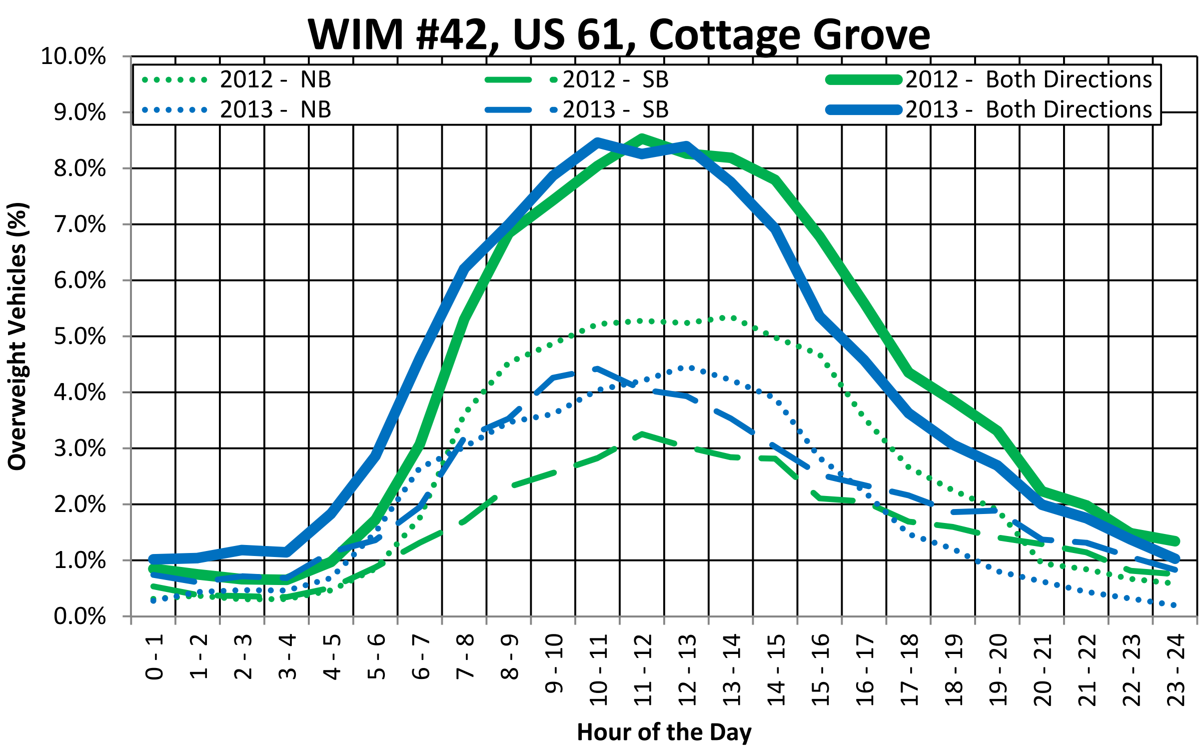


Figure 6.61. Volume distributions for overweight HCVs over a typical 24-hour day. Data from August 2012 to December 2013.

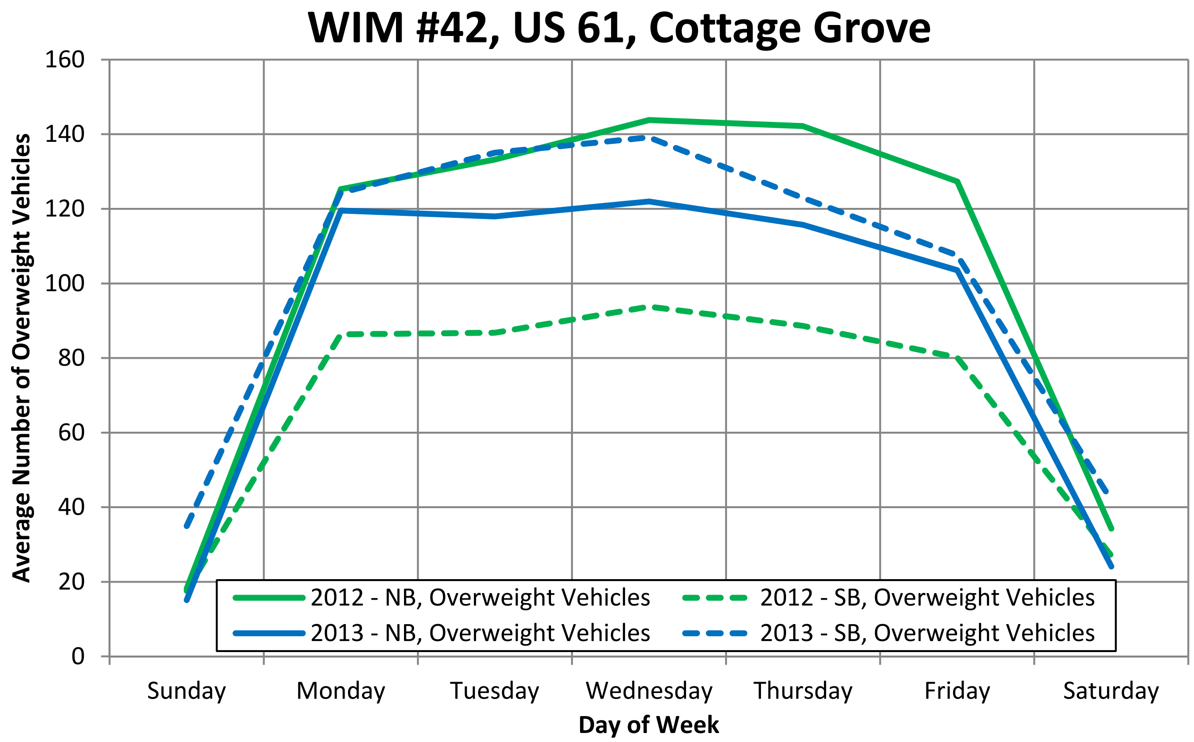


Figure 6.62. Average overweight HCV volume distributions over a typical 7-day week. Data from August 2012 to December 2013.

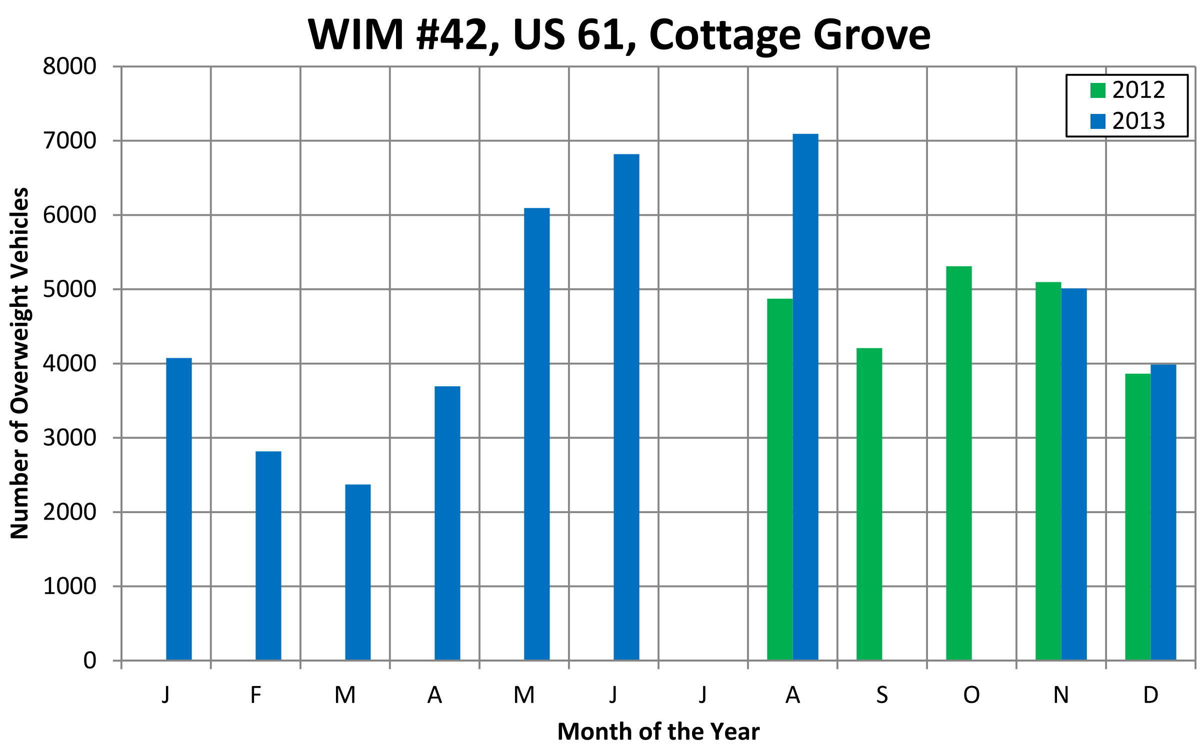


Figure 6.63. Monthly volumes of overweight HCVs by year. Data from August 2012 to December 2013.

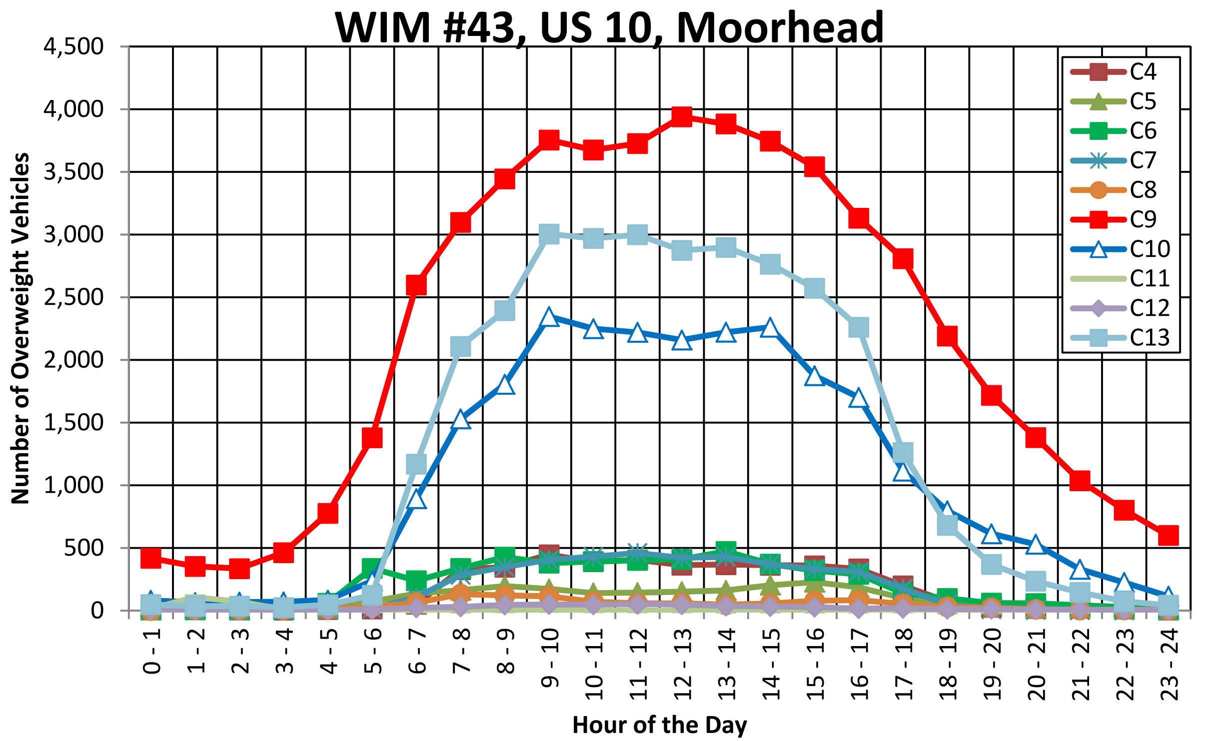


Figure 6.64. Volume distributions for overweight heavy commercial vehicle (HCV) classes over a typical 24-hour period. Data from October 2012 to December 2013.

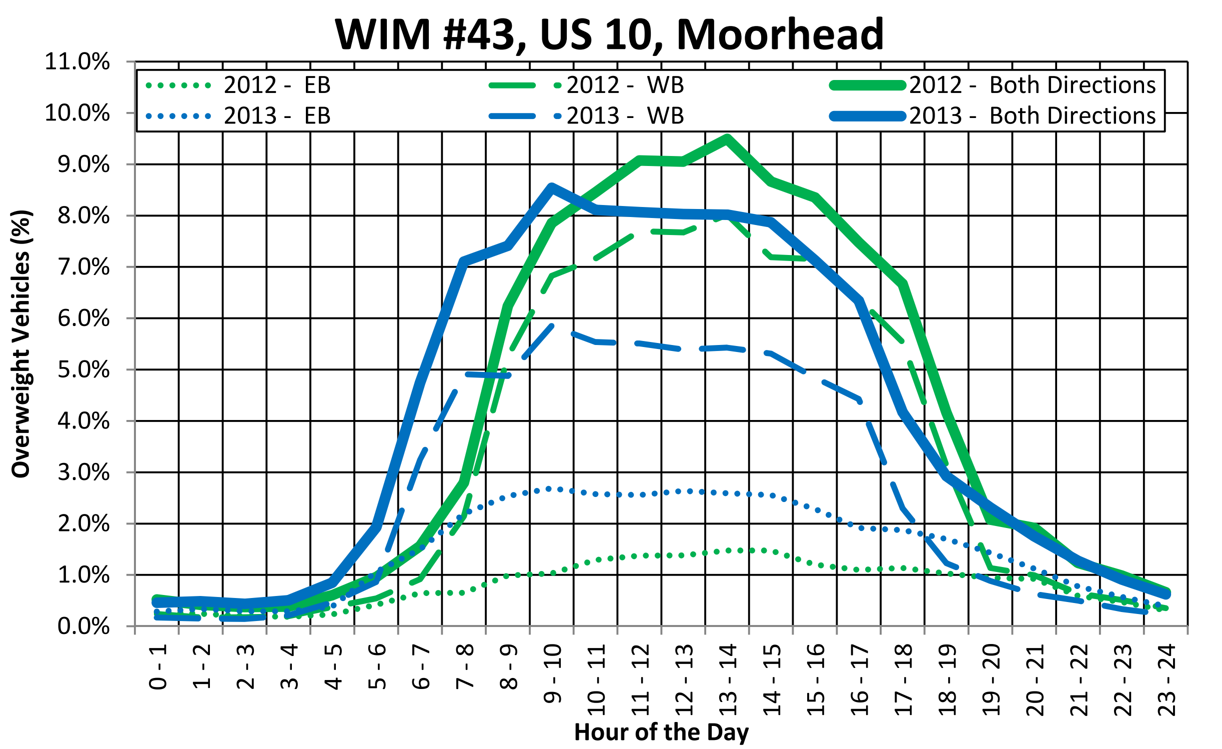


Figure 6.65. Volume distributions for overweight HCVs over a typical 24-hour day. Data from October 2012 to December 2013.

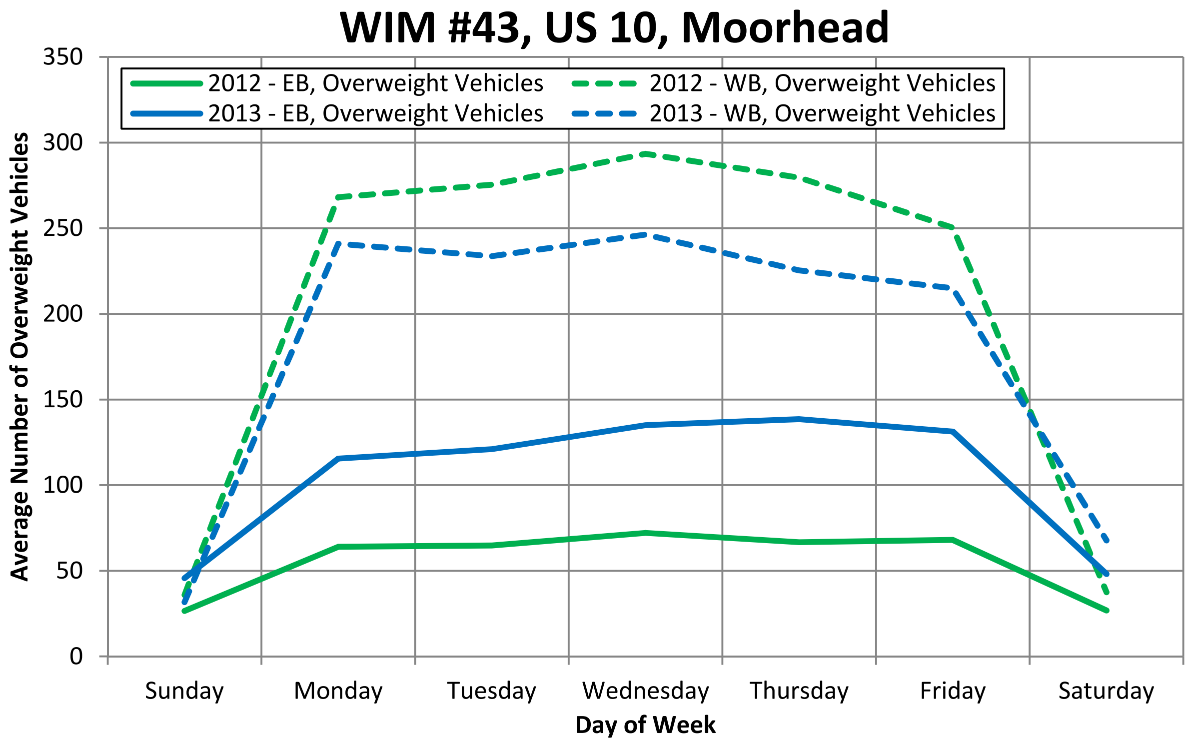


Figure 6.66. Average overweight HCV volume distributions over a typical 7-day week. Data from October 2012 to December 2013.

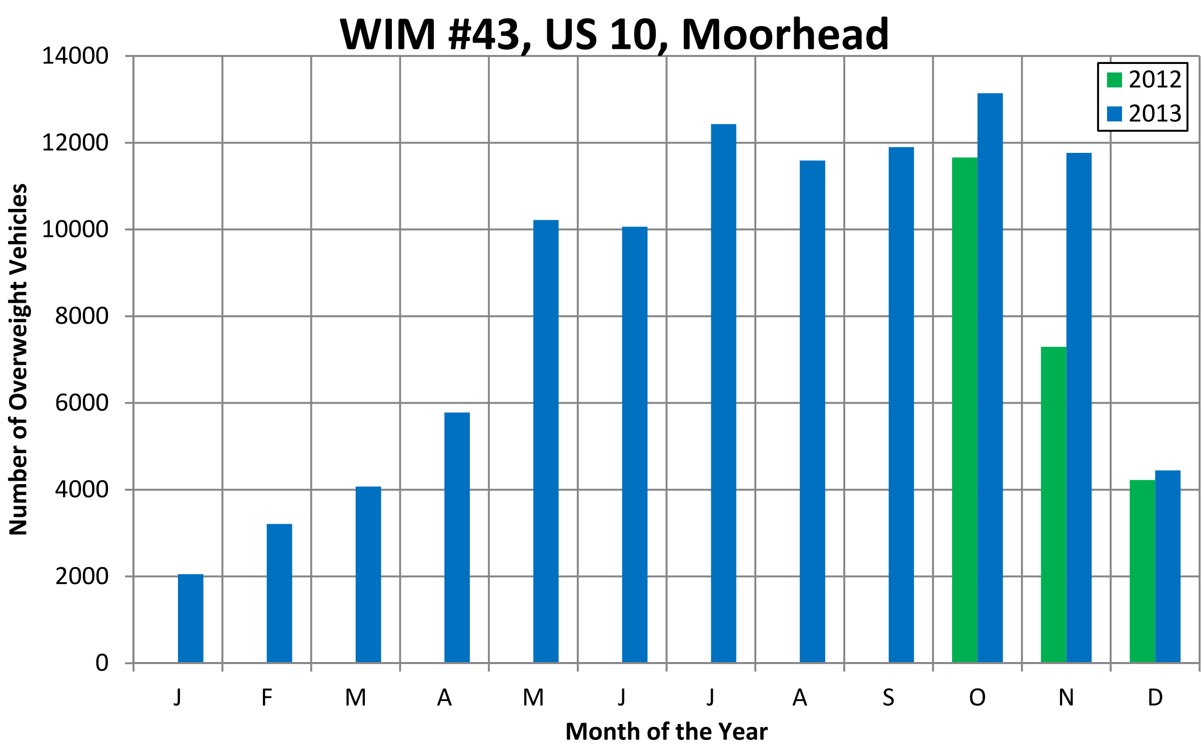


Figure 6.67. Monthly volumes of overweight HCVs by year. Data from October 2012 to December 2013.

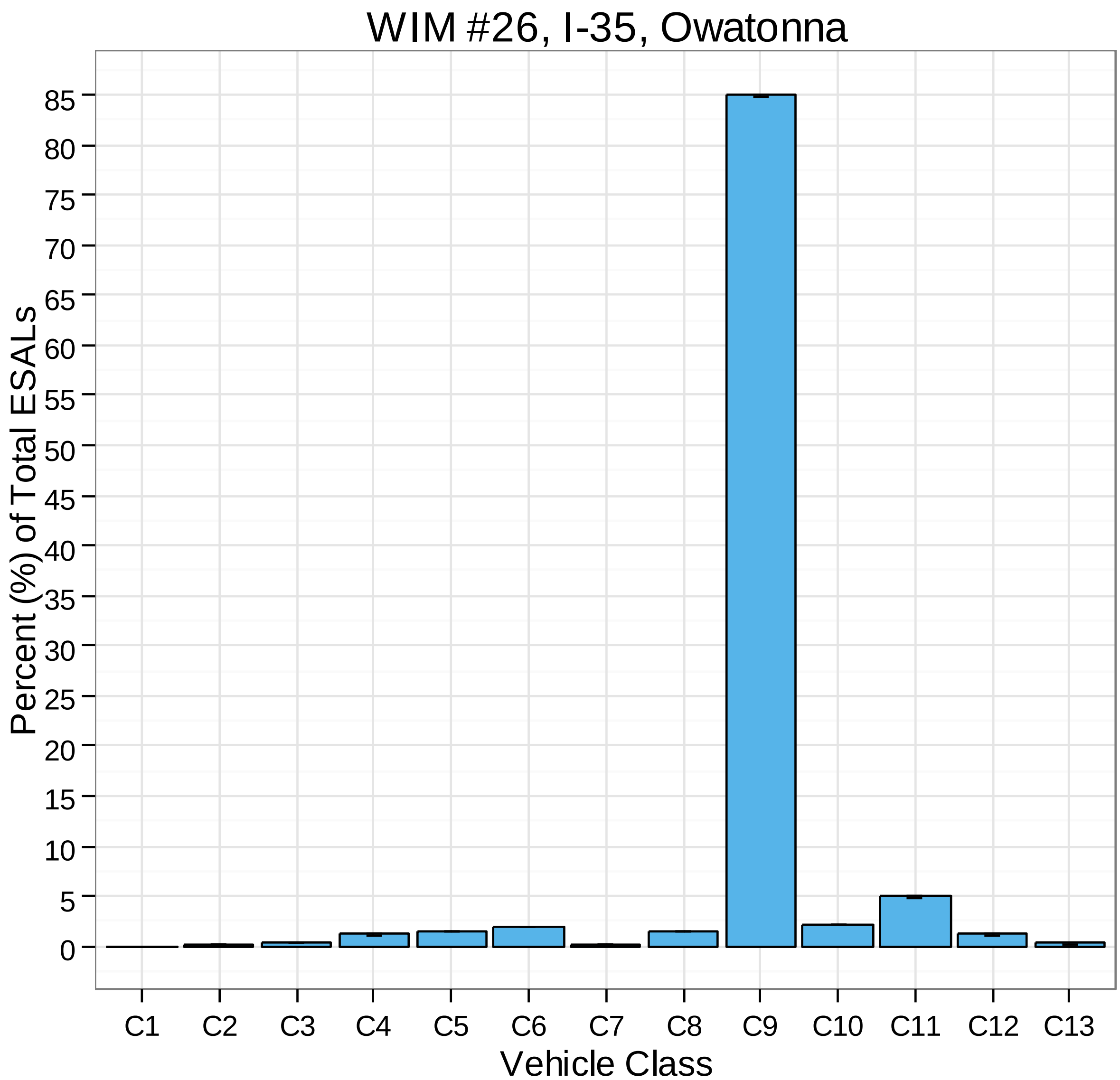


Figure 7.1. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

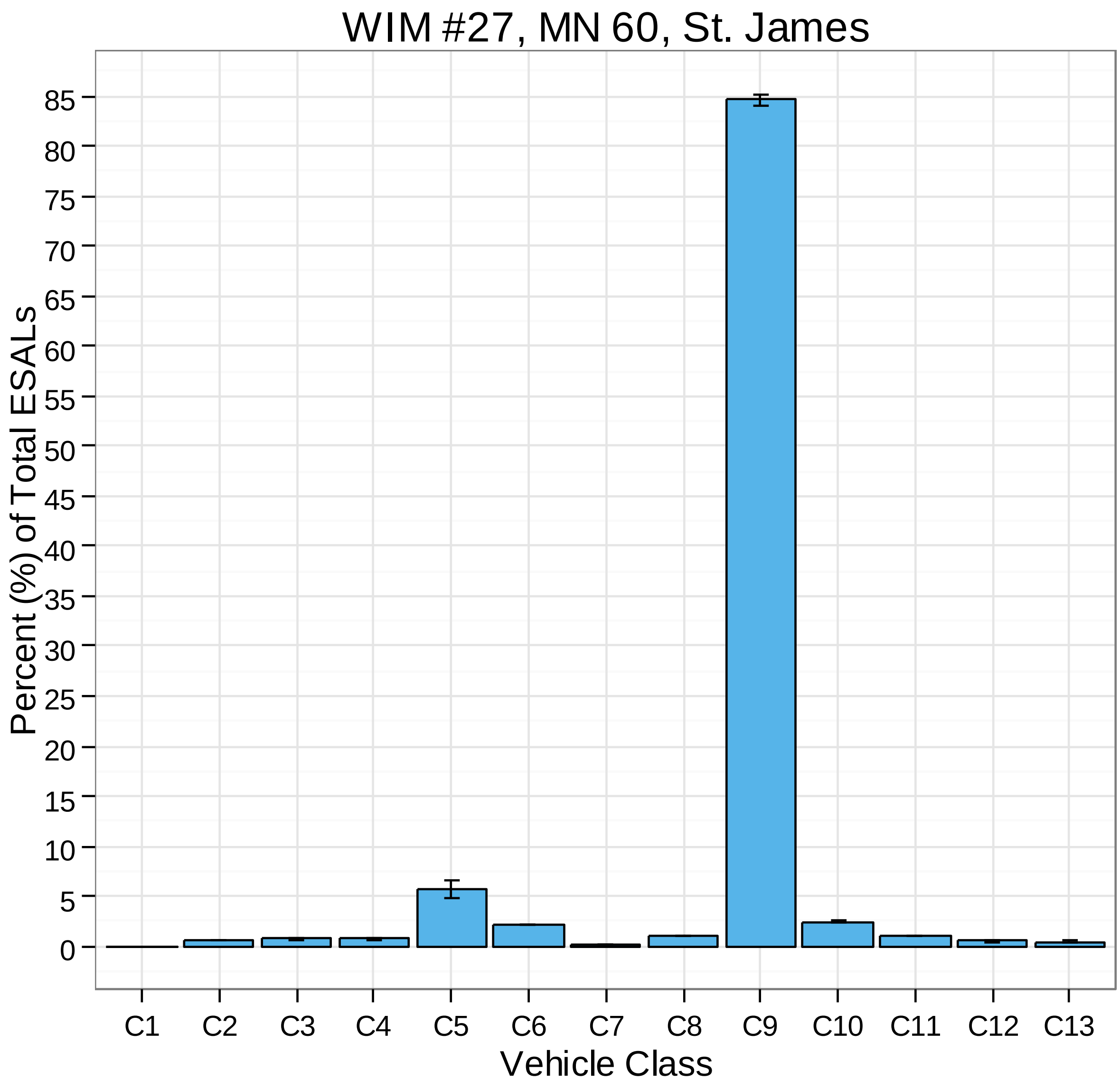


Figure 7.2. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

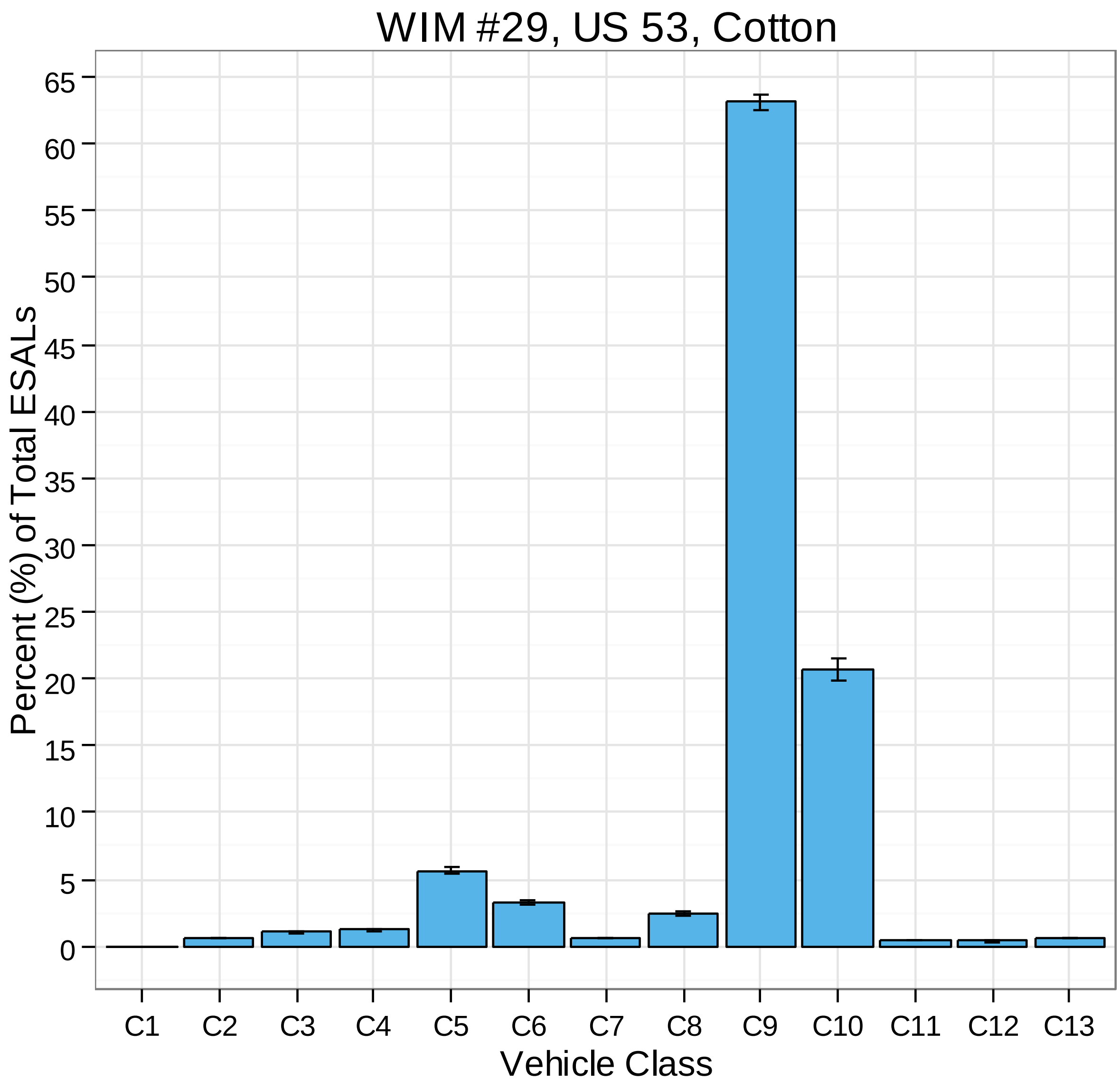


Figure 7.3. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

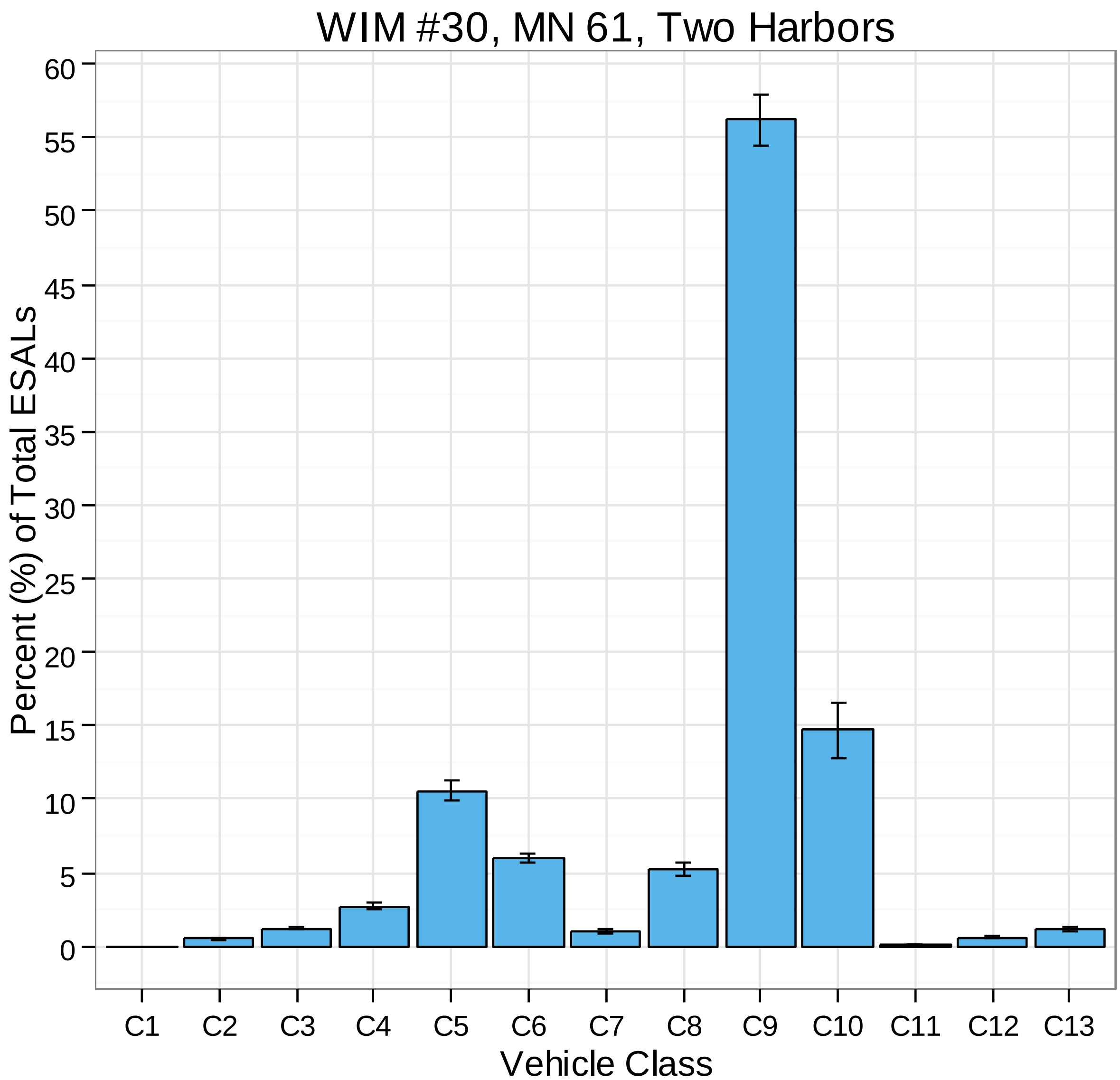


Figure 7.4. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

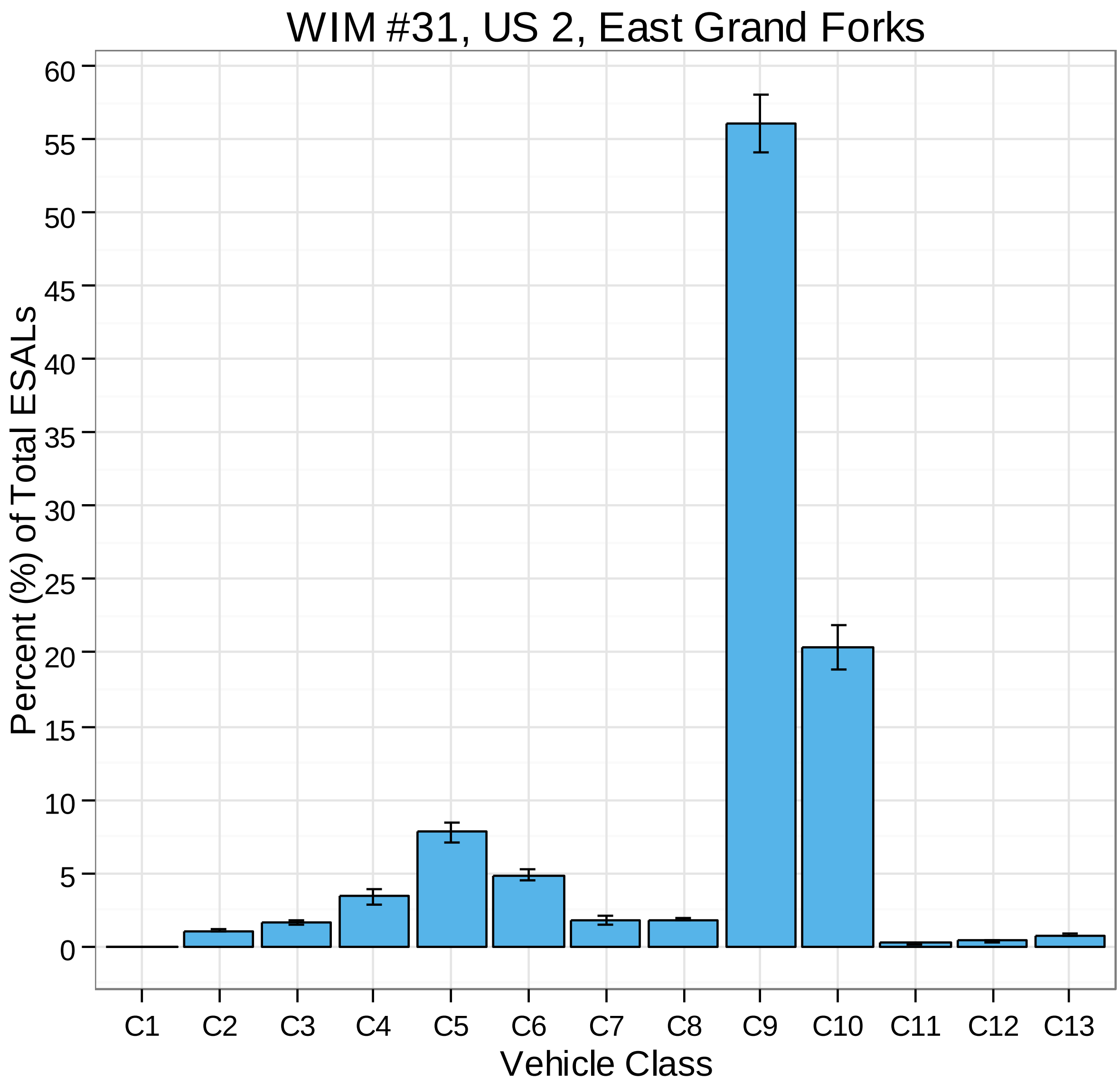


Figure 7.5. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

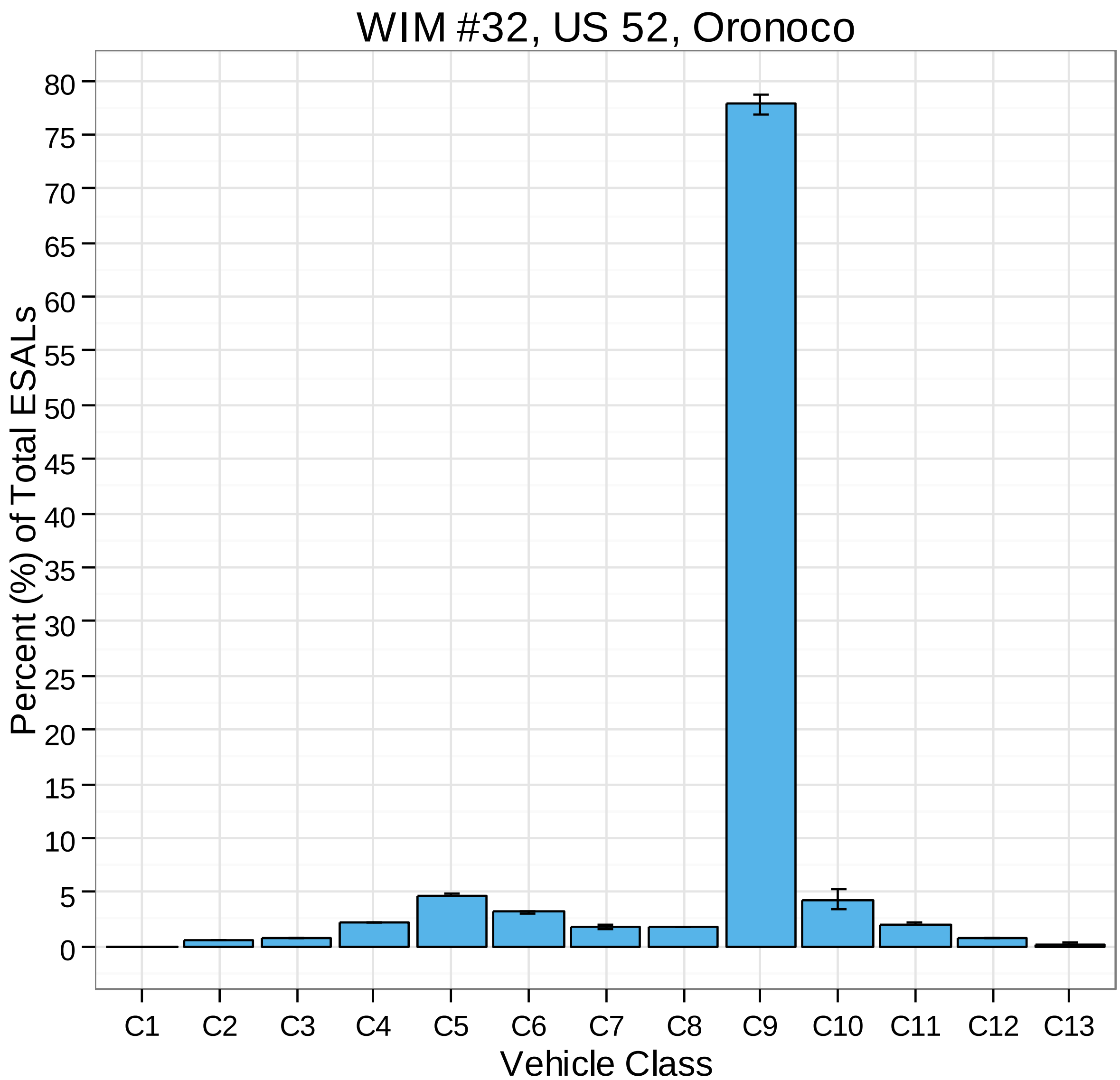


Figure 7.6. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

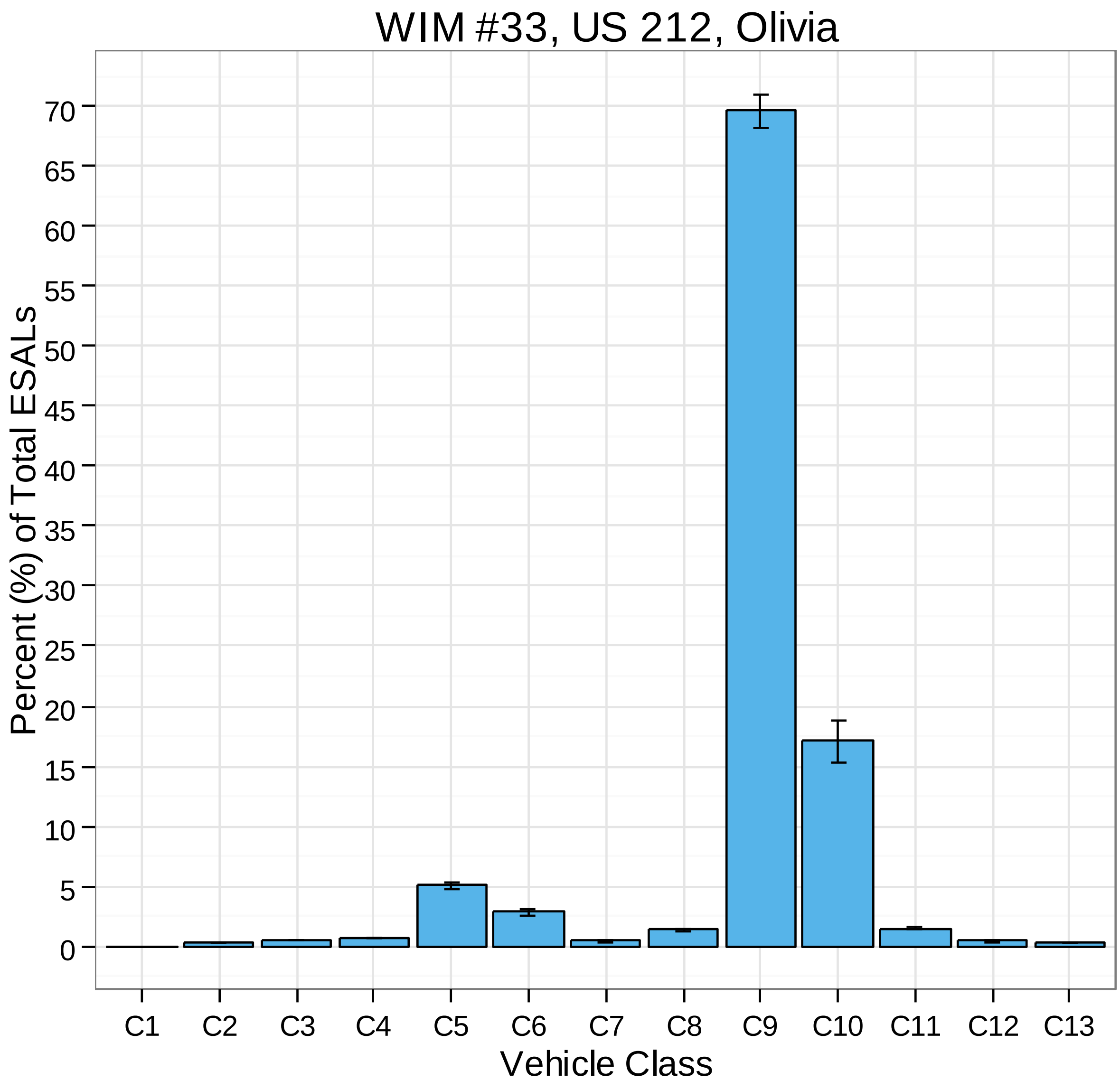


Figure 7.7. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

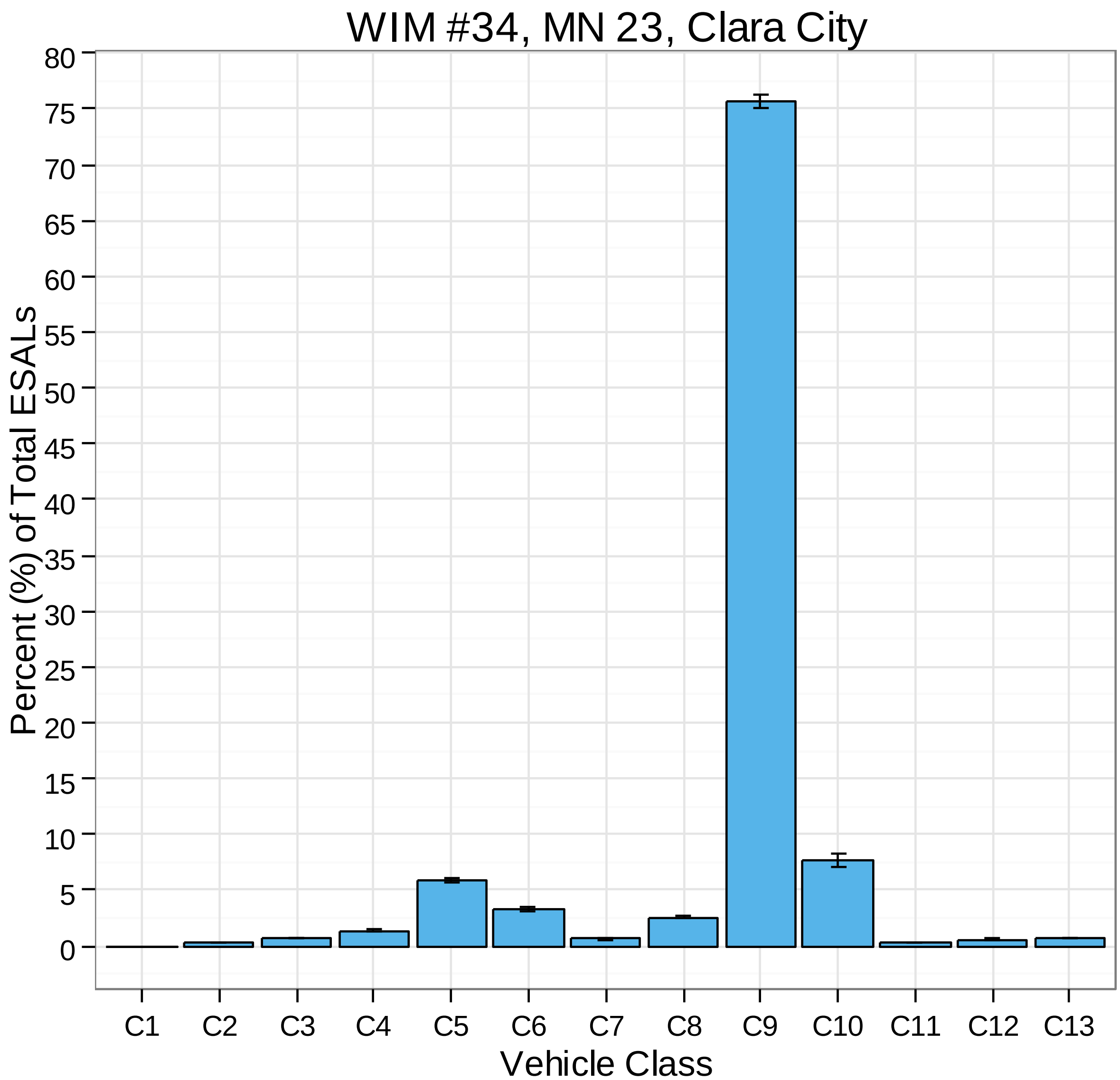


Figure 7.8. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

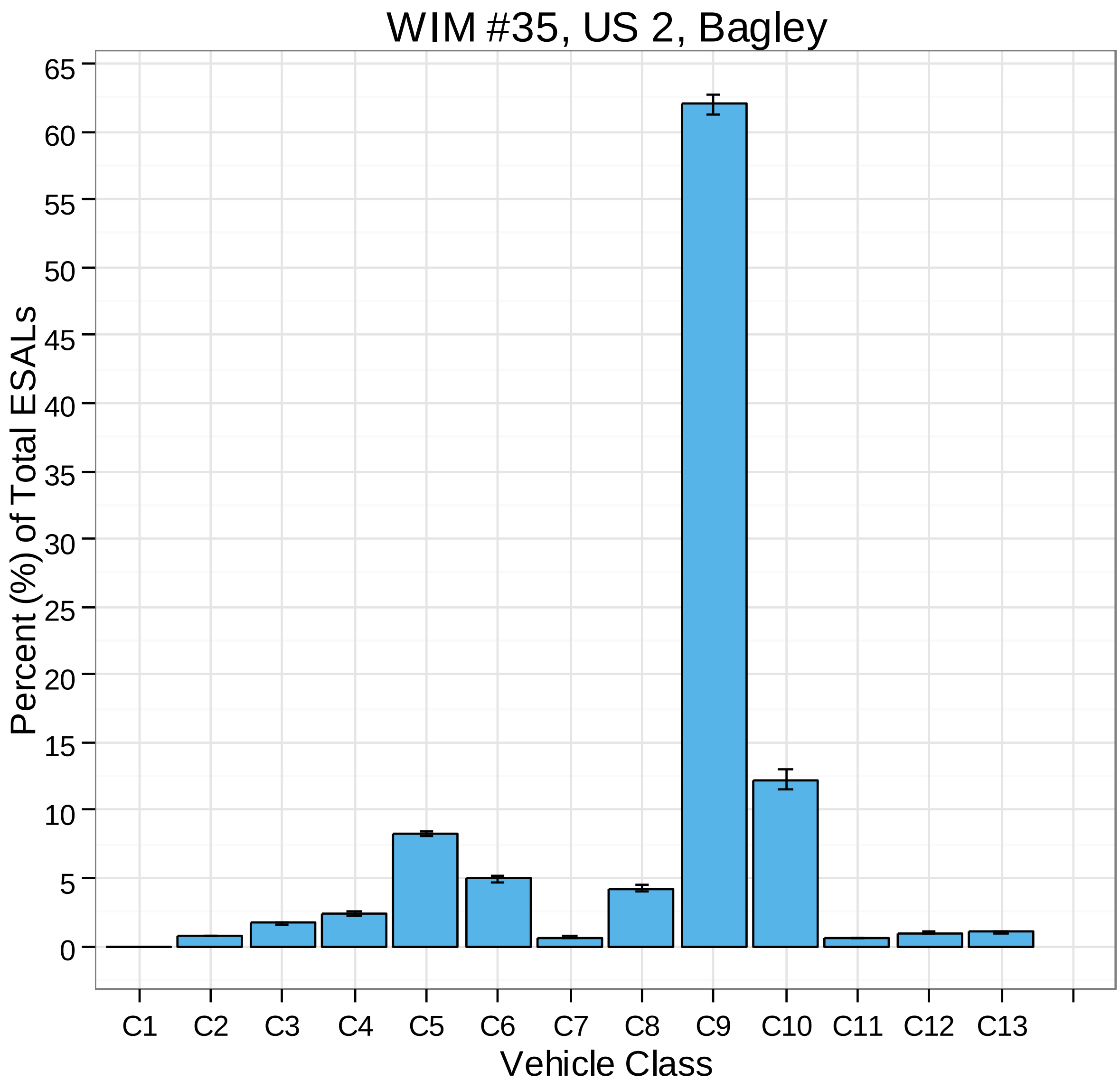


Figure 7.9. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

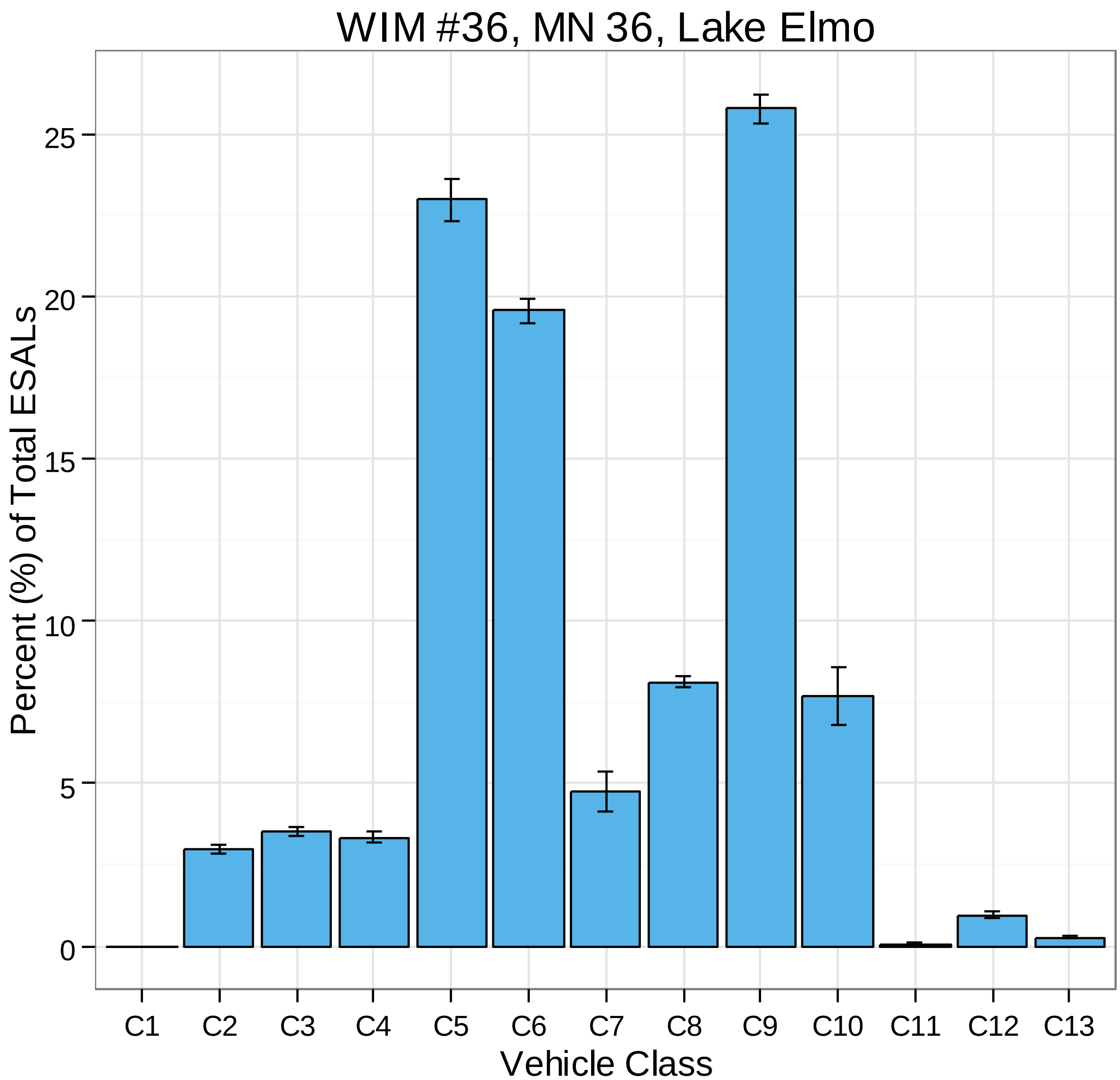


Figure 7.10. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

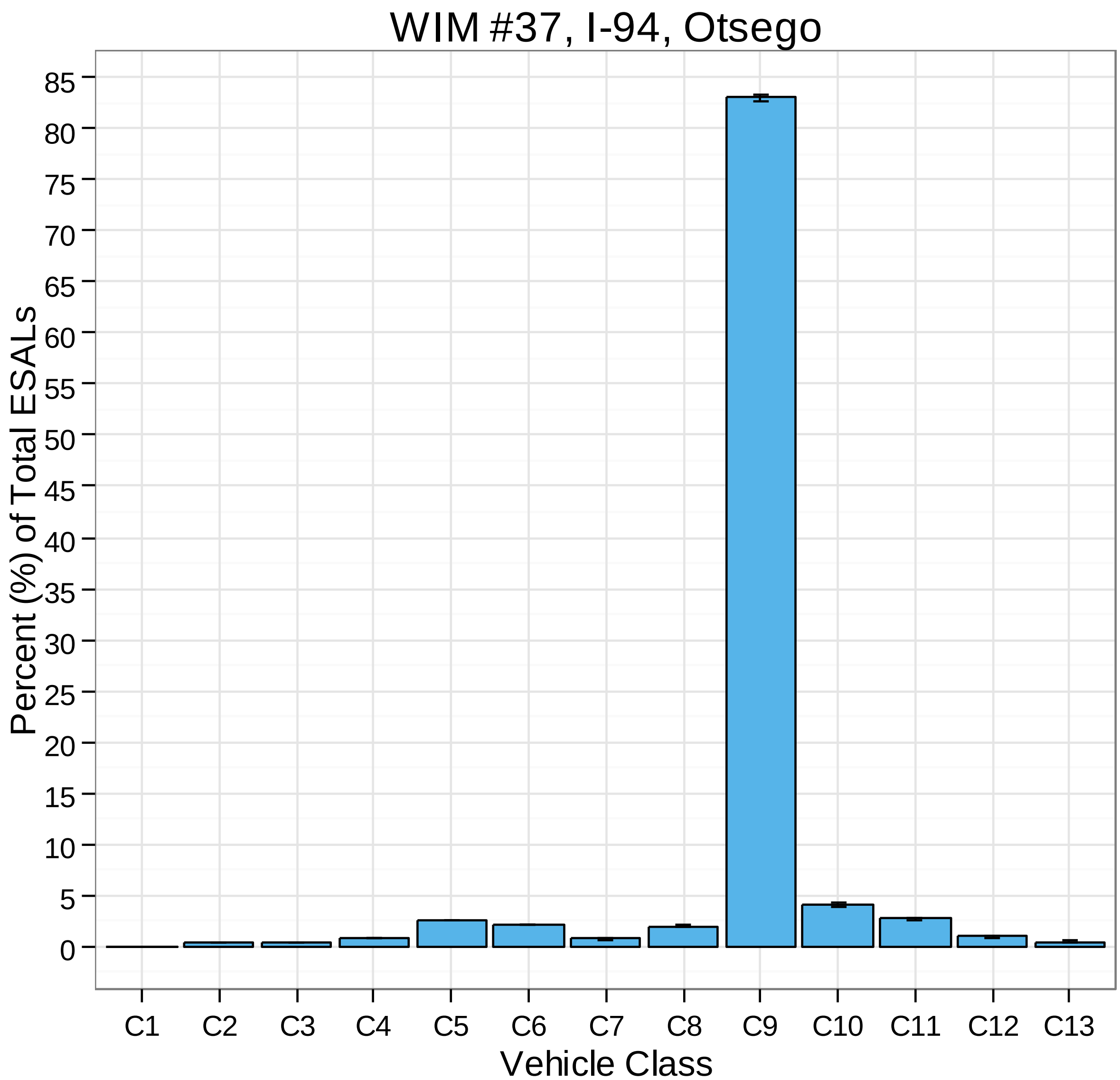


Figure 7.11. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

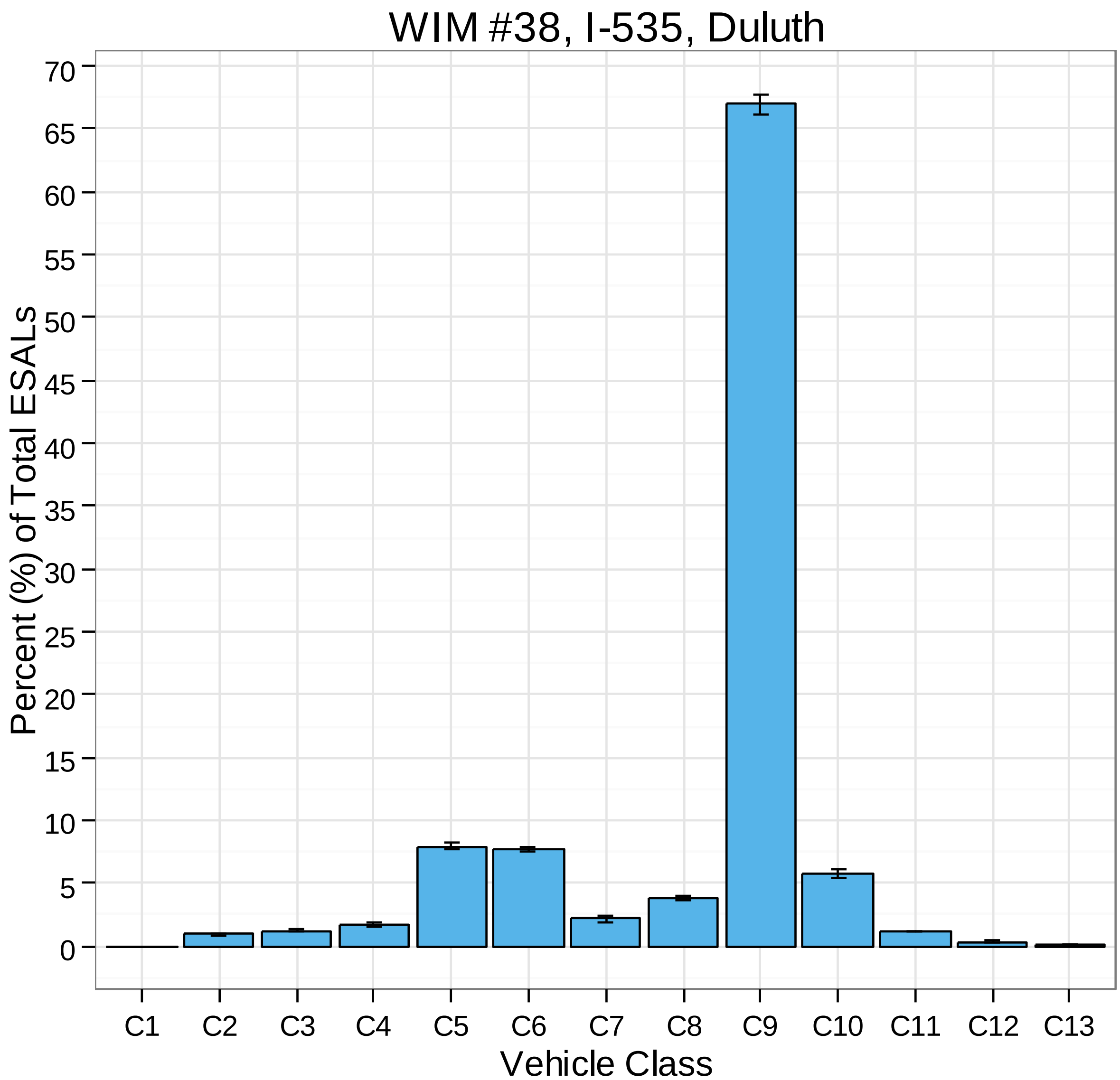


Figure 7.12. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

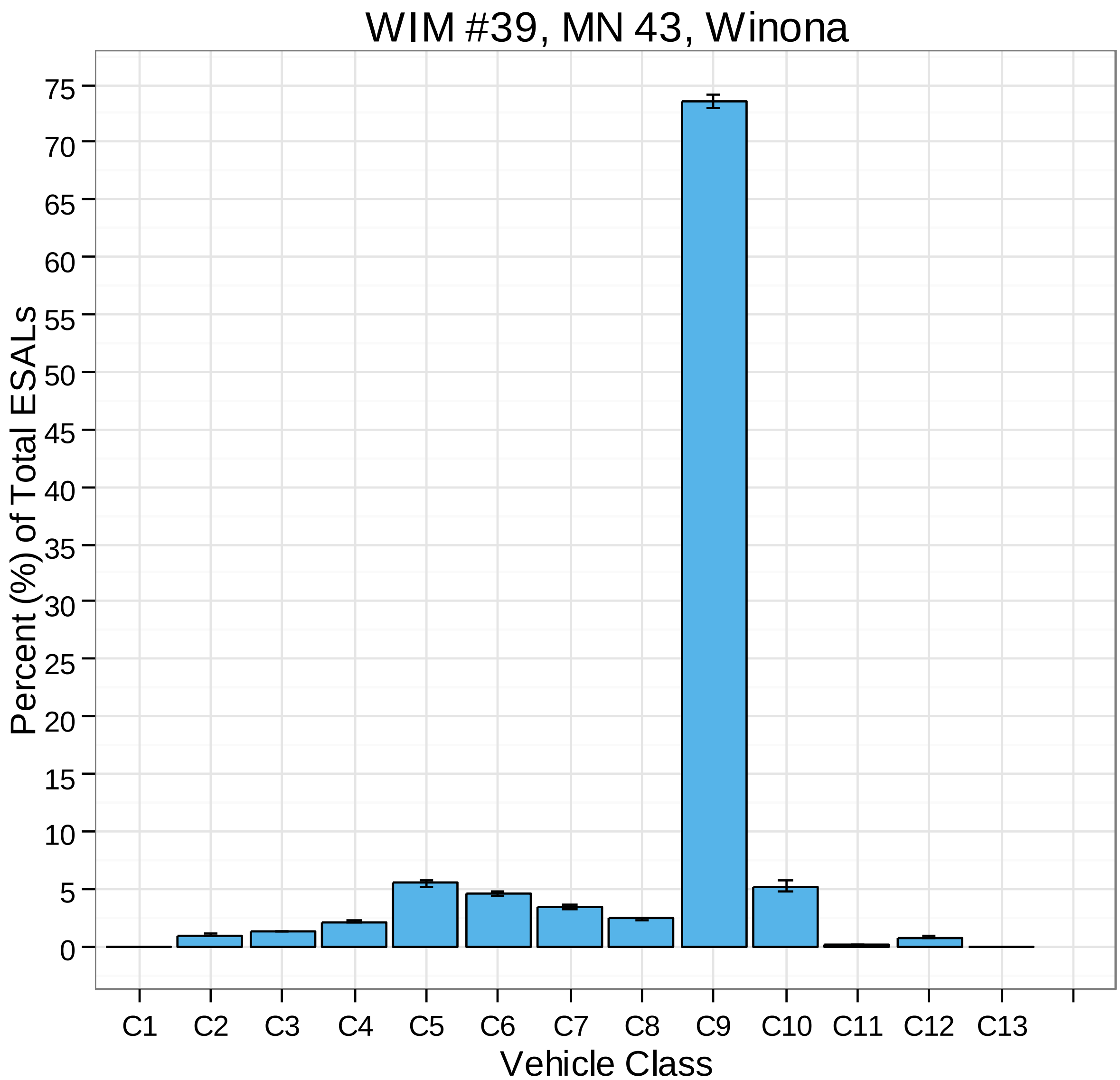


Figure 7.13. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

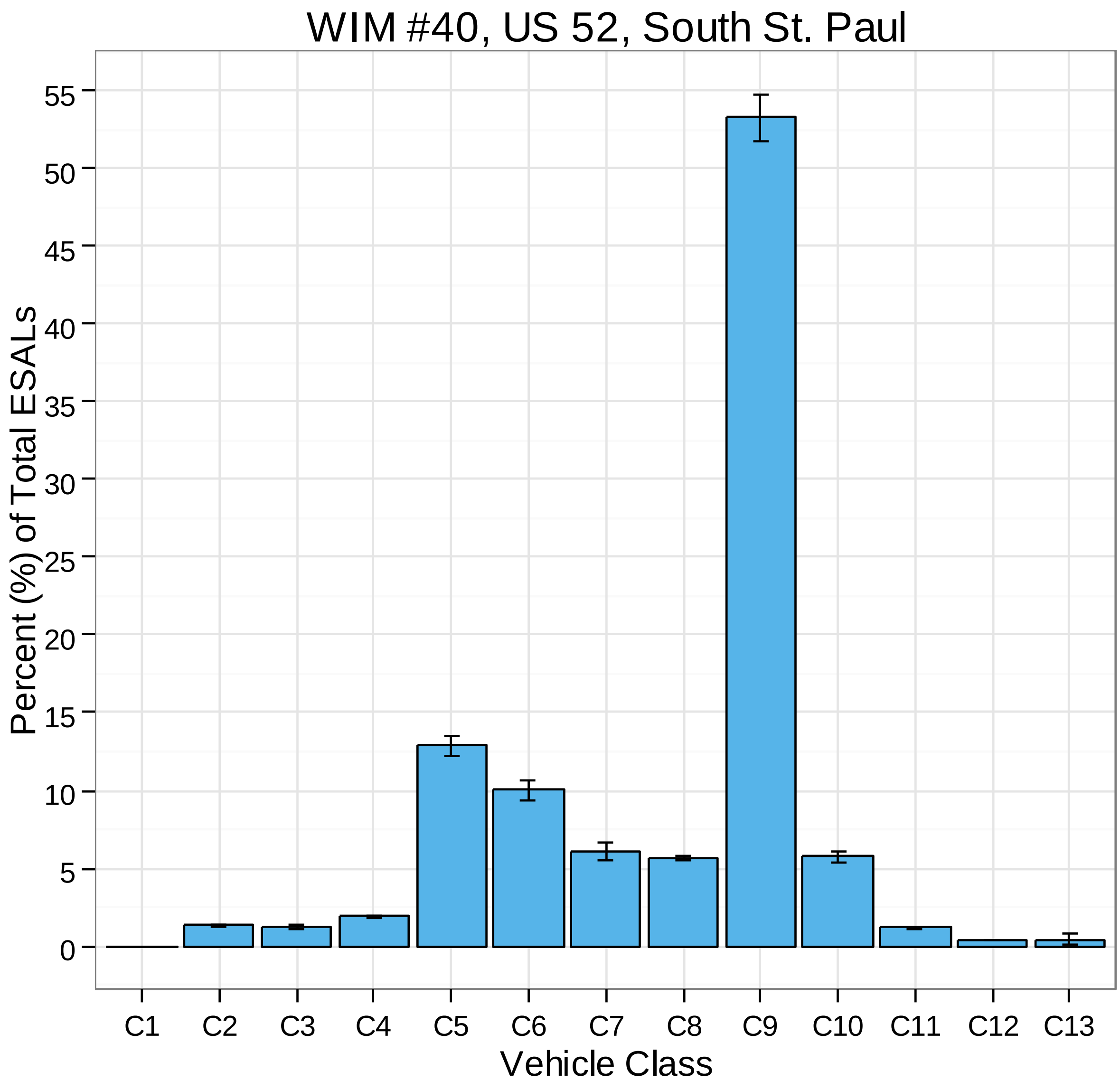


Figure 7.14. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

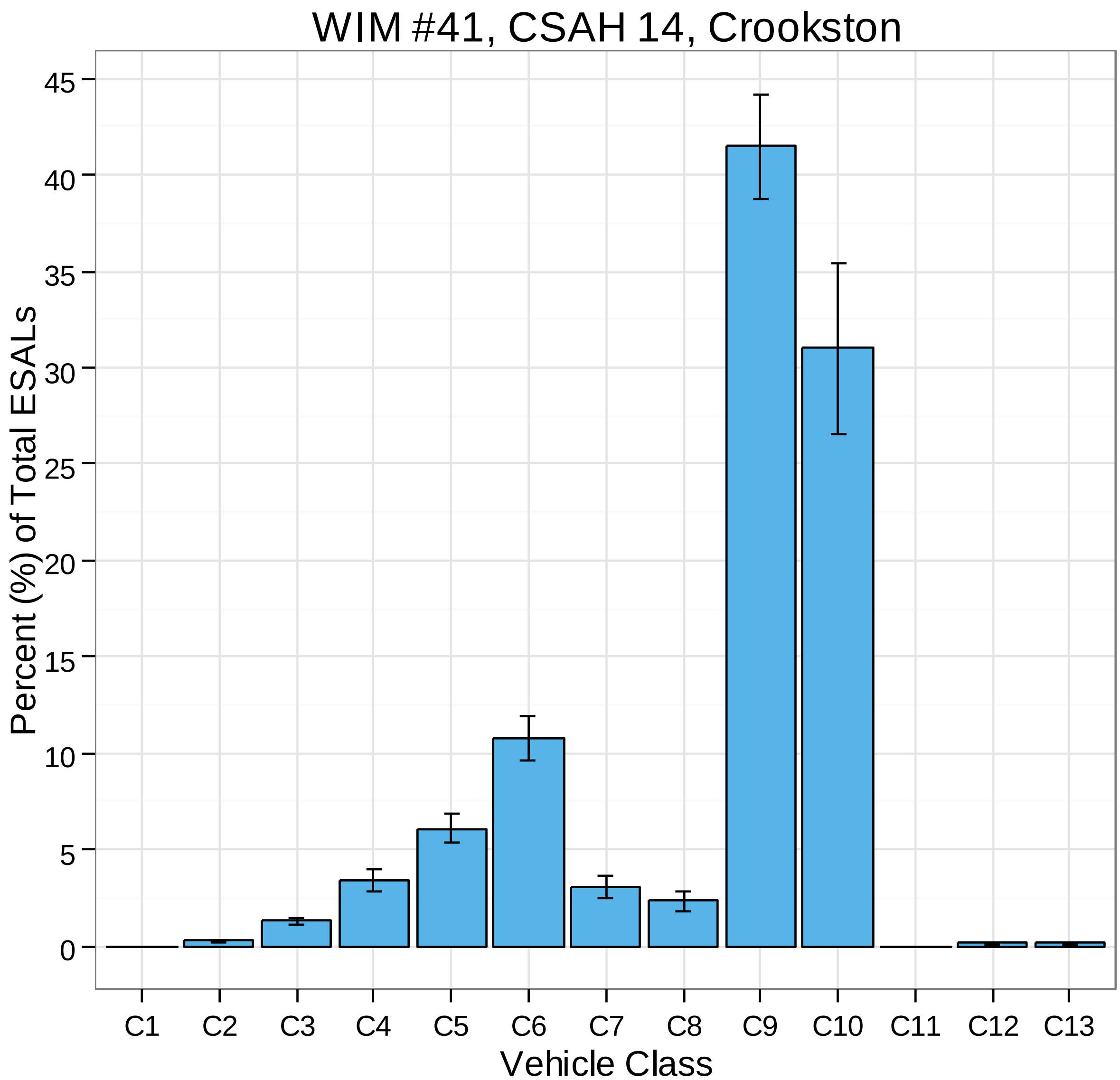


Figure 7.15. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

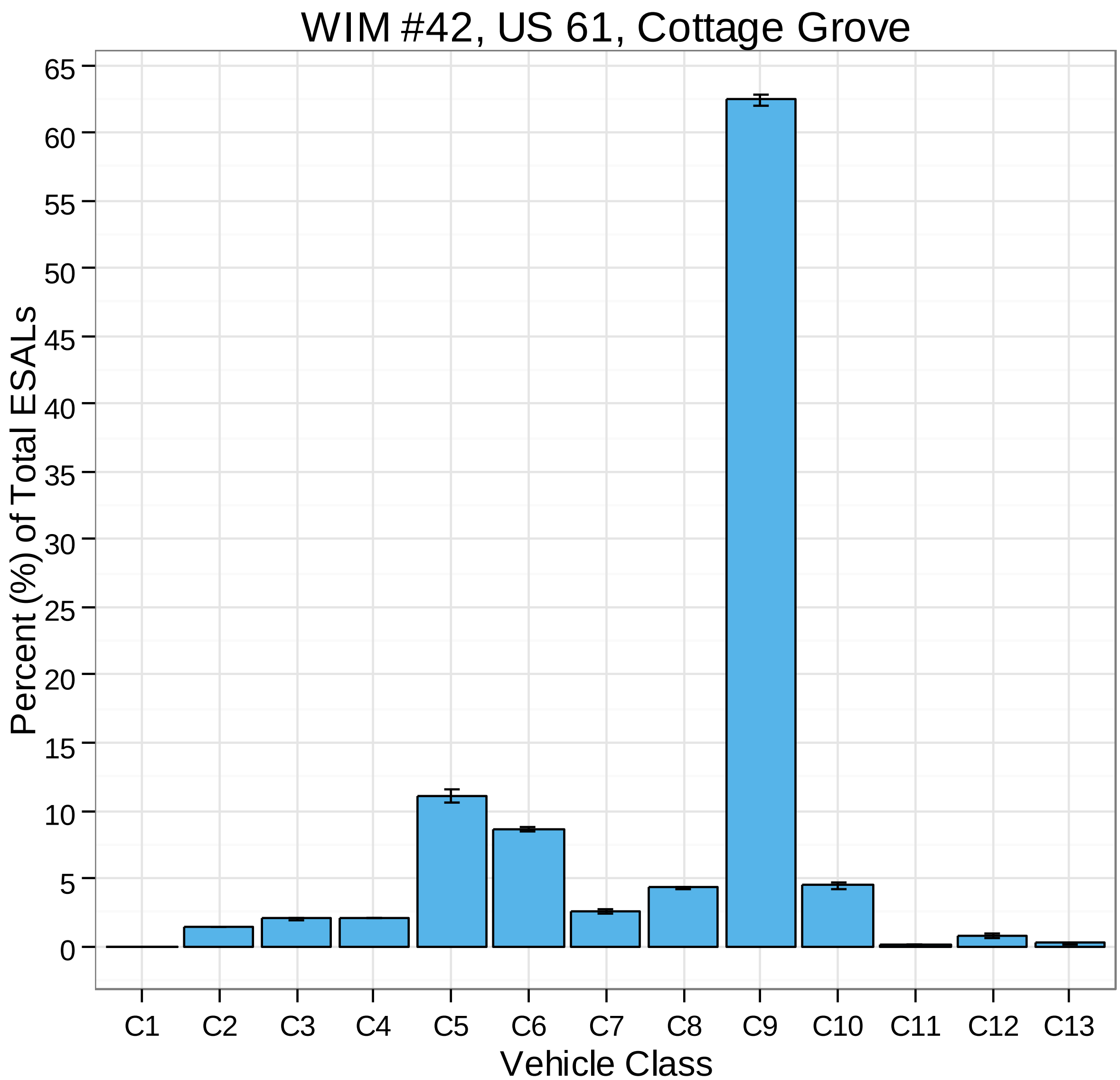


Figure 7.16. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

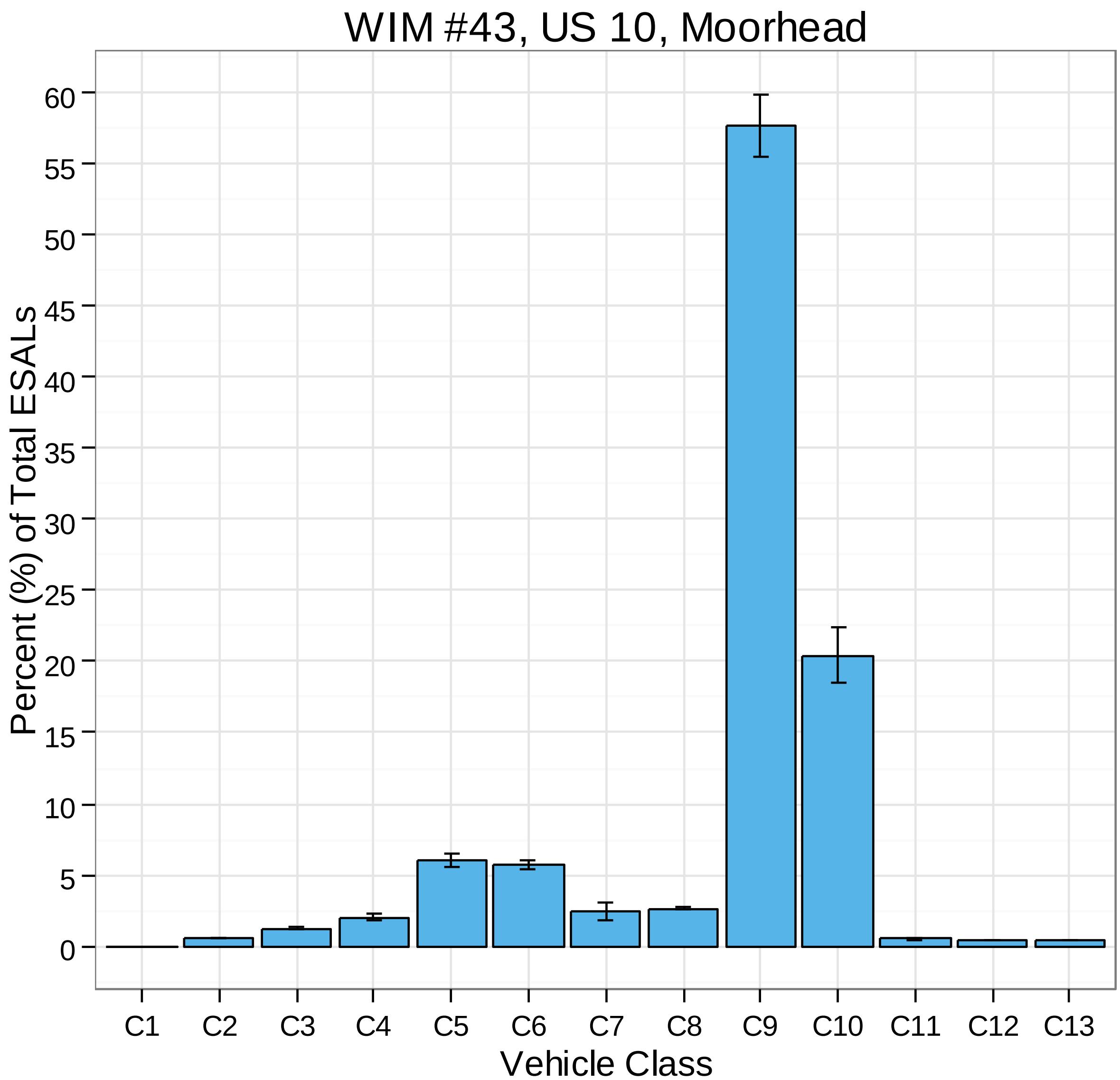


Figure 7.17. Average monthly vehicle class contributions (%) to total equivalent single-axle loads (ESALs). Error bars represent standard error of the mean.

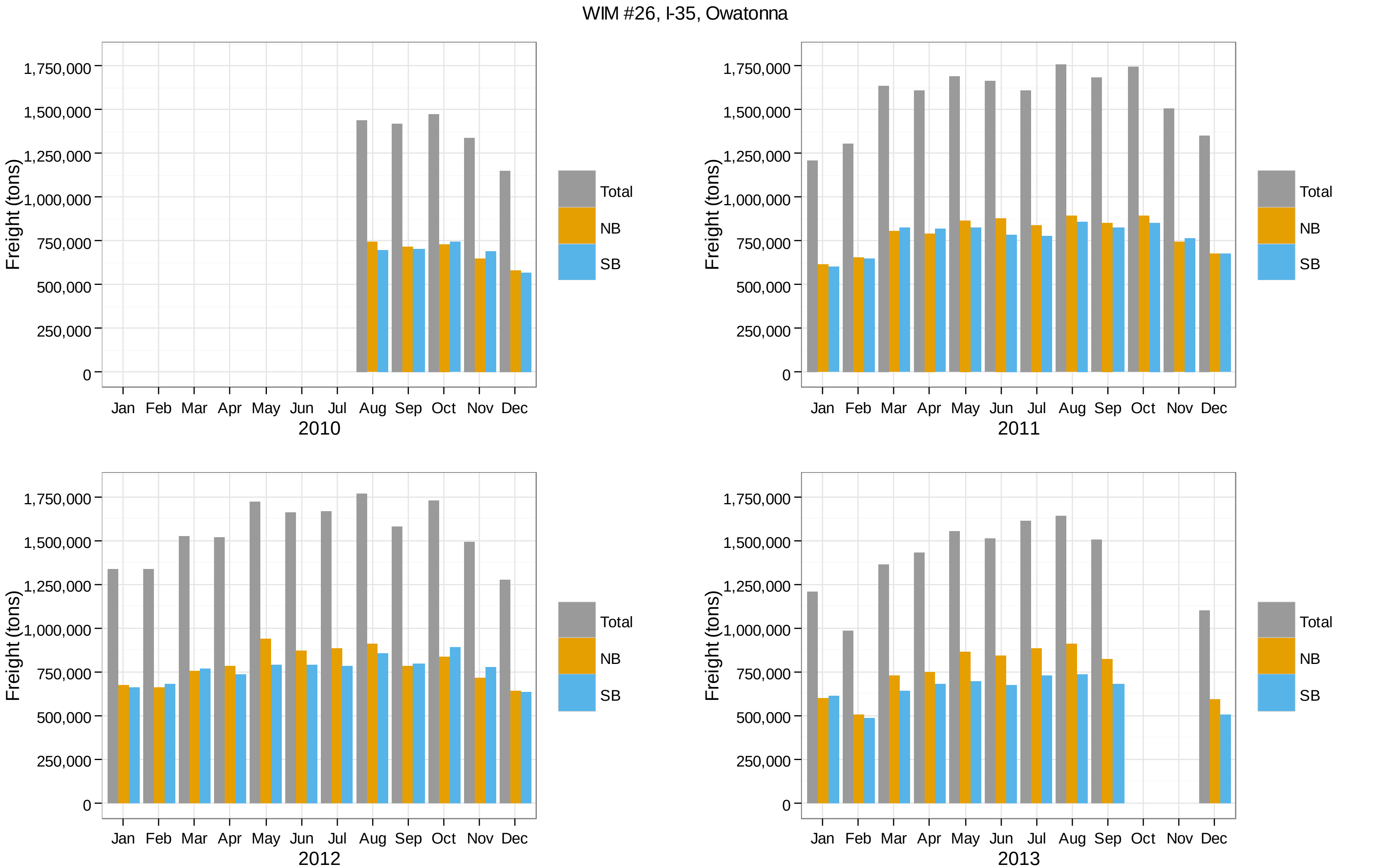


Figure 8.1. Monthly freight (tons) observed from 2010-2013, with freight movement also depicted by direction (northbound vs. southbound; NB vs. SB).

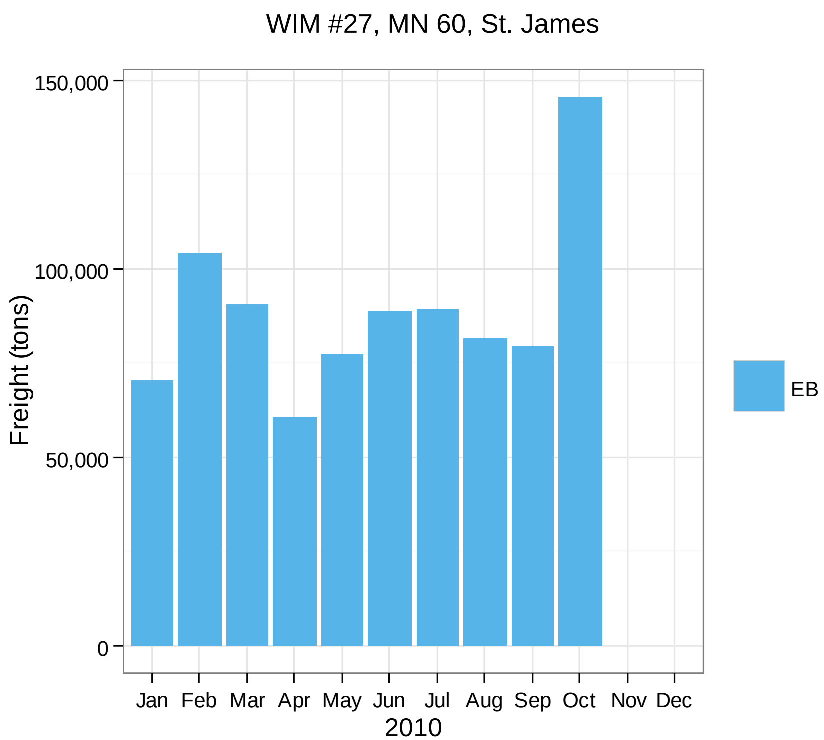


Figure 8.2. Monthly freight (tons) observed from 2010 in the eastbound (EB) lane. [In-pavement WIM scale only exists in the EB lane at this site]

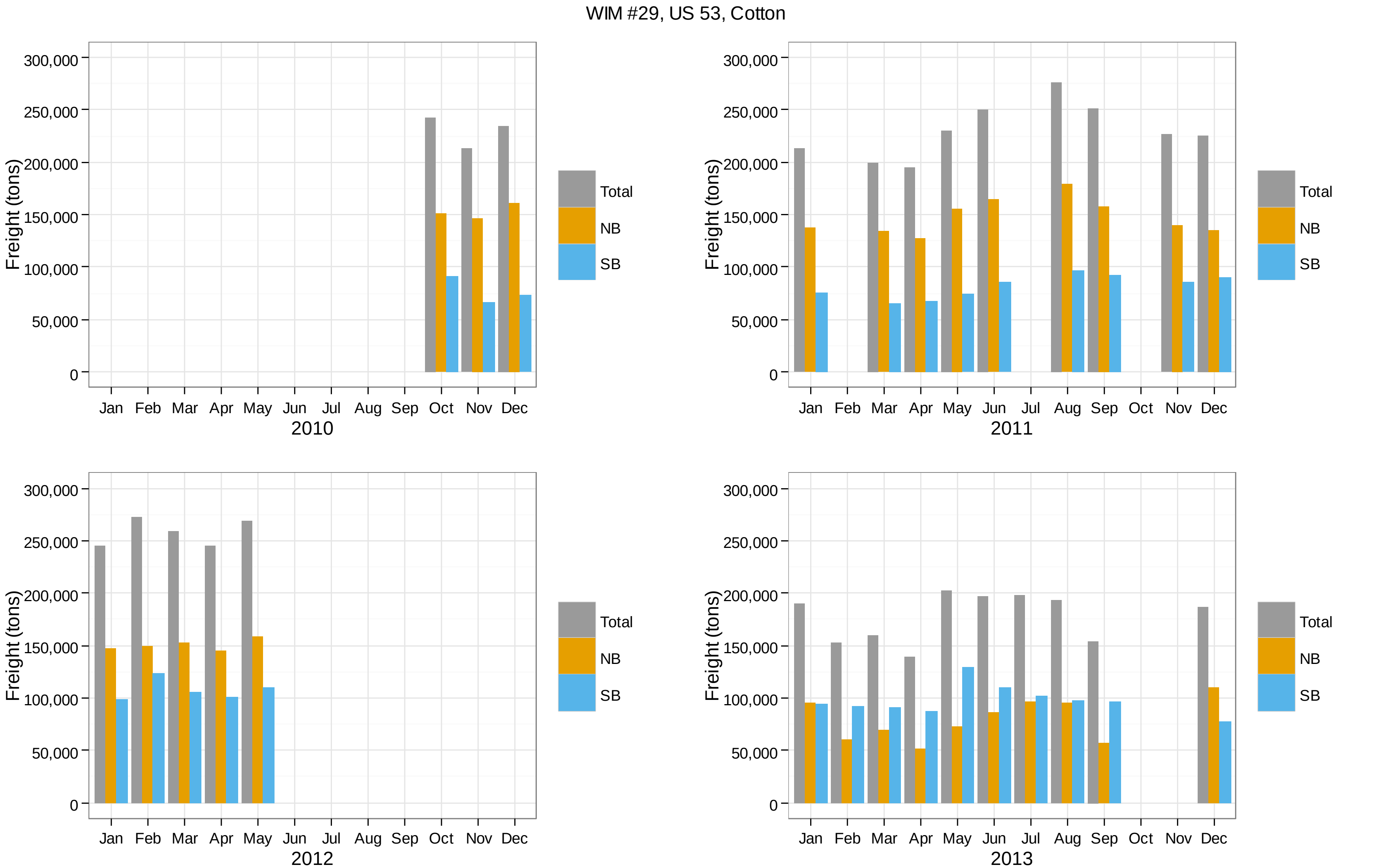


Figure 8.3. Monthly freight (tons) observed from 2010-2013, with freight movement also depicted by direction (northbound vs. southbound; NB vs. SB).

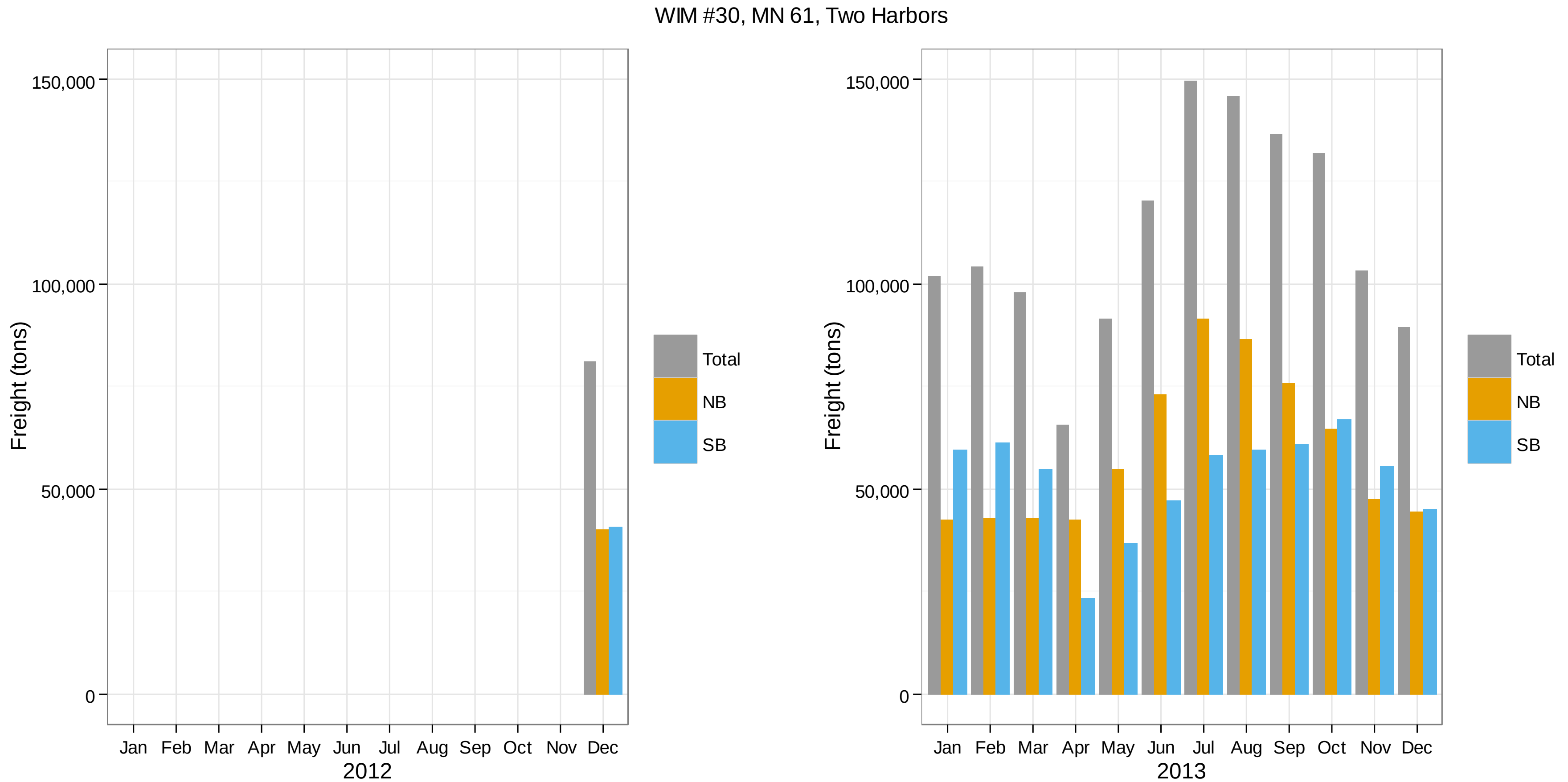


Figure 8.4. Monthly freight (tons) observed from 2012-2013, with freight movement also depicted by direction (northbound vs. southbound; NB vs. SB).

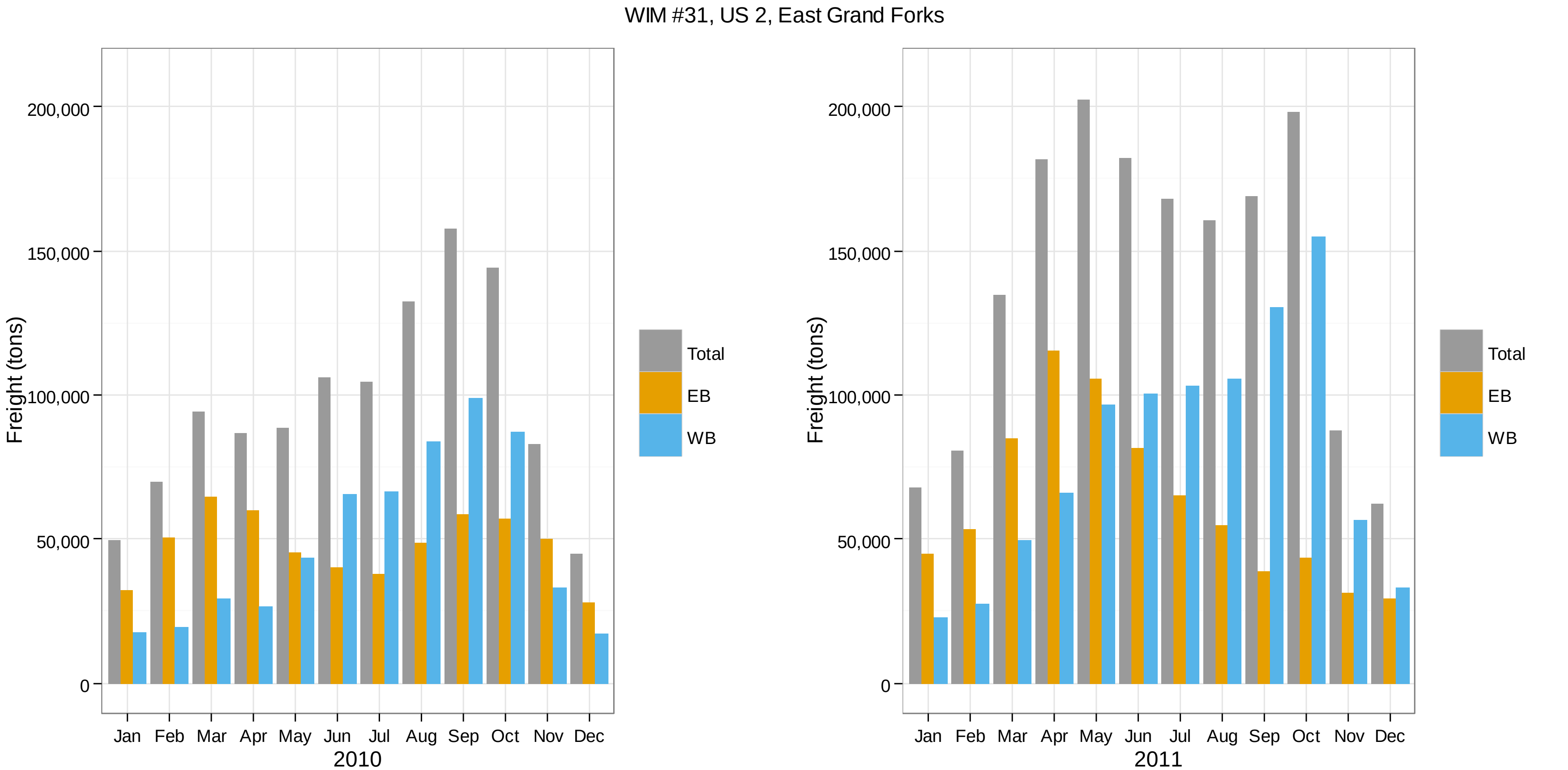


Figure 8.5. Monthly freight (tons) observed from 2010-2011, with freight movement also depicted by direction (eastbound vs. westbound; EB vs. WB).

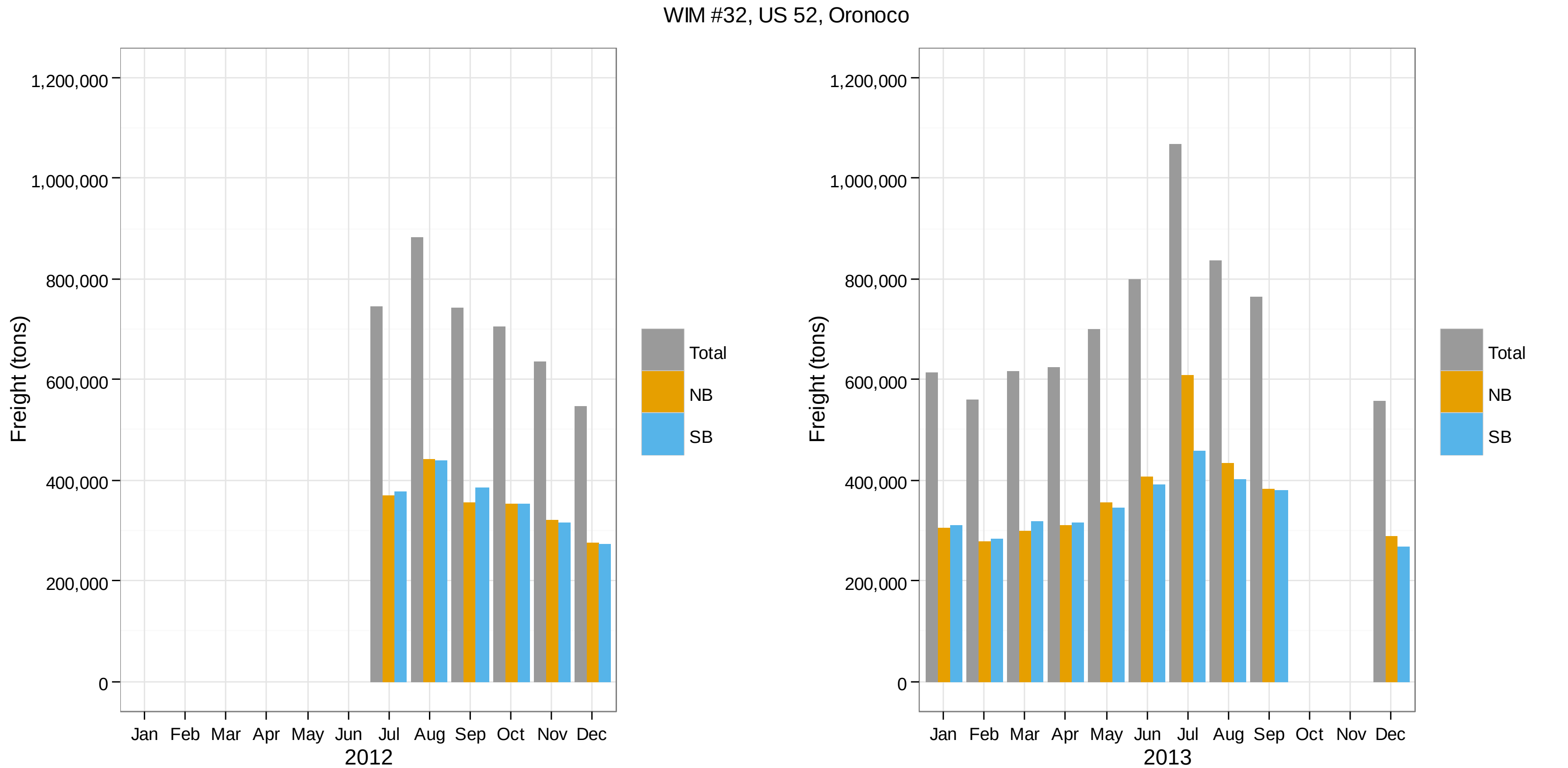


Figure 8.6. Monthly freight (tons) observed from 2012-2013, with freight movement also depicted by direction (northbound vs. southbound; NB vs. SB).

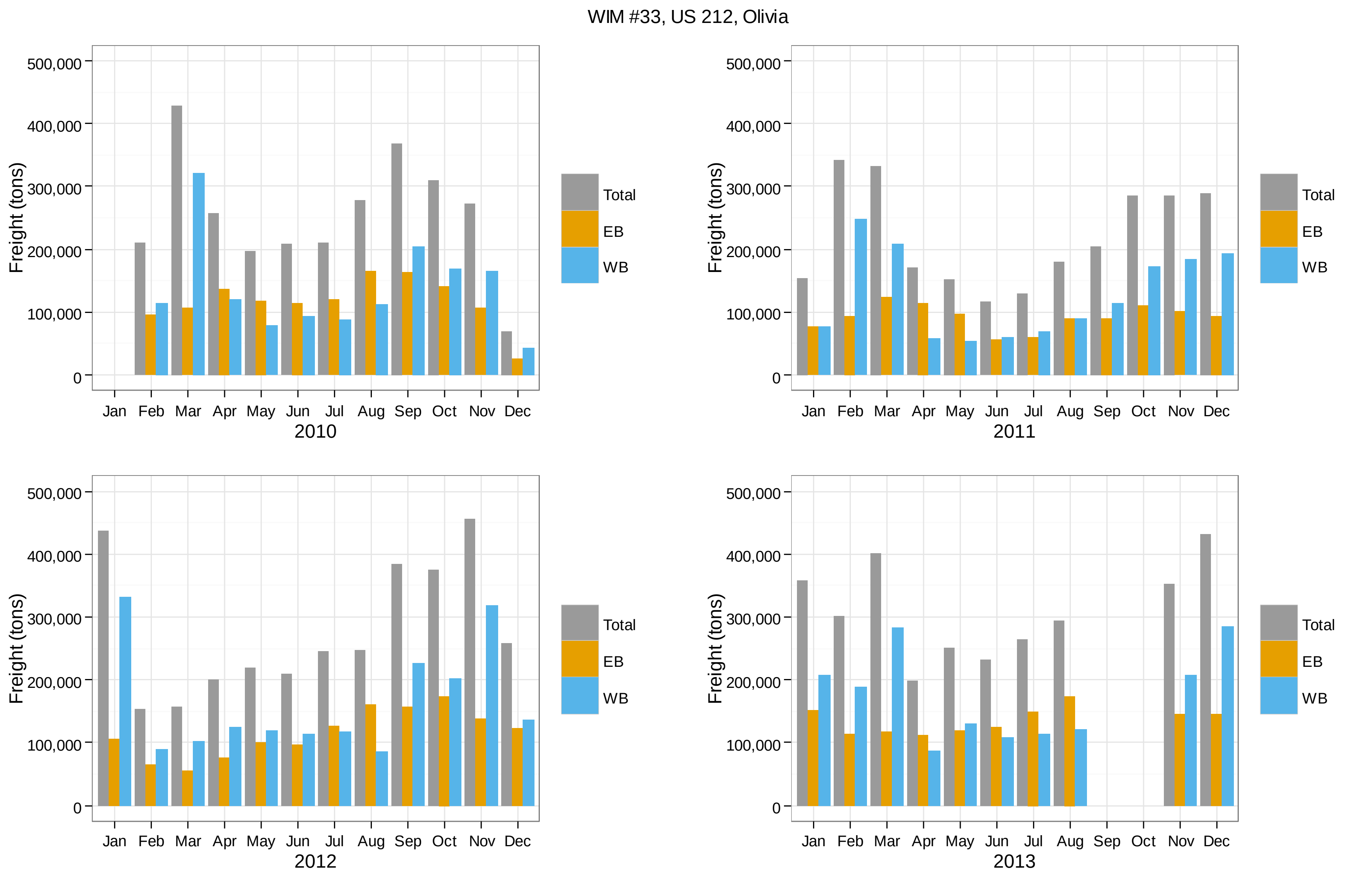


Figure 8.7. Monthly freight (tons) observed from 2010-2013, with freight movement also depicted by direction (eastbound vs. westbound; EB vs. WB).

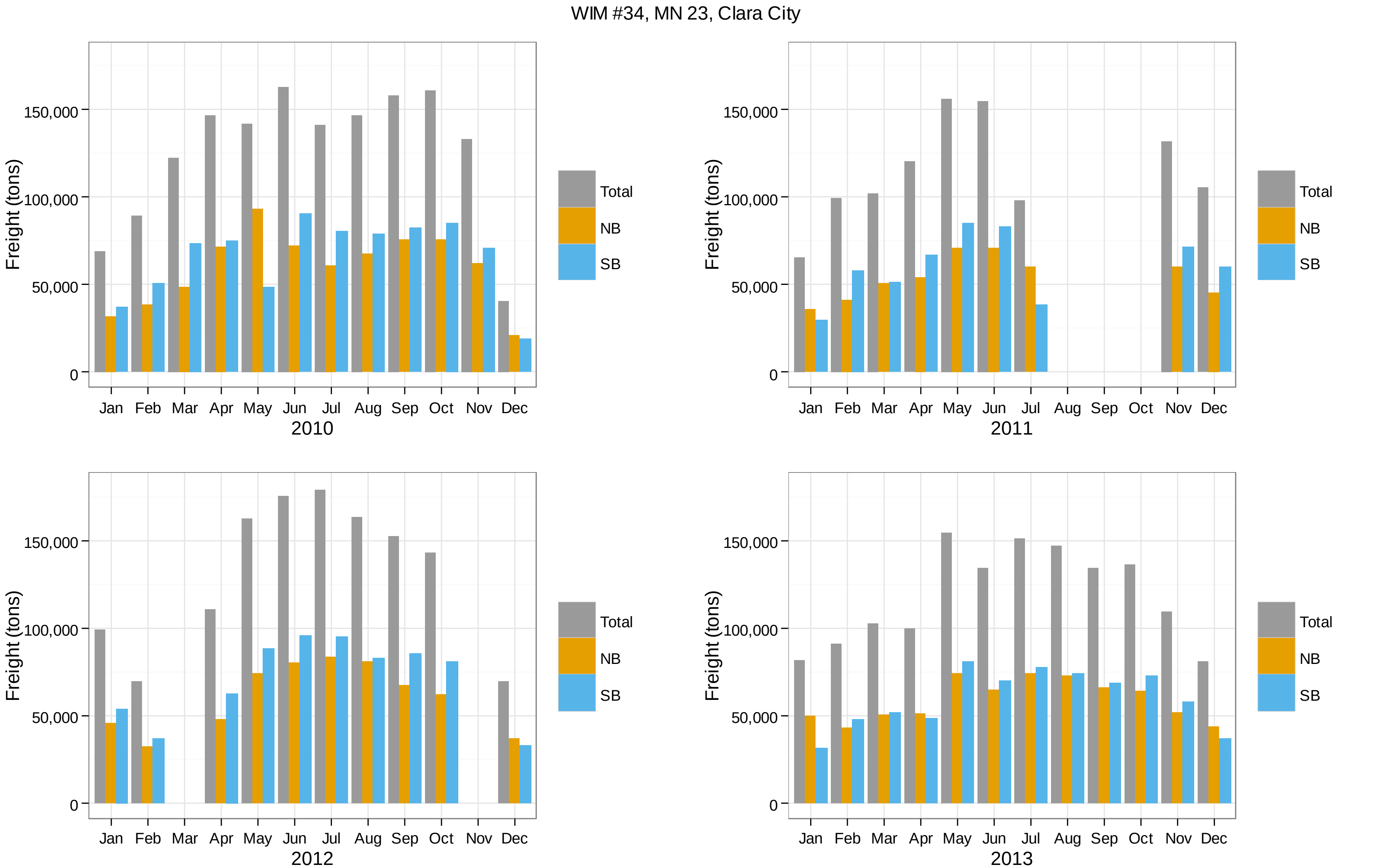


Figure 8.8. Monthly freight (tons) observed from 2010-2013, with freight movement also depicted by direction (northbound vs. southbound; NB vs. SB).

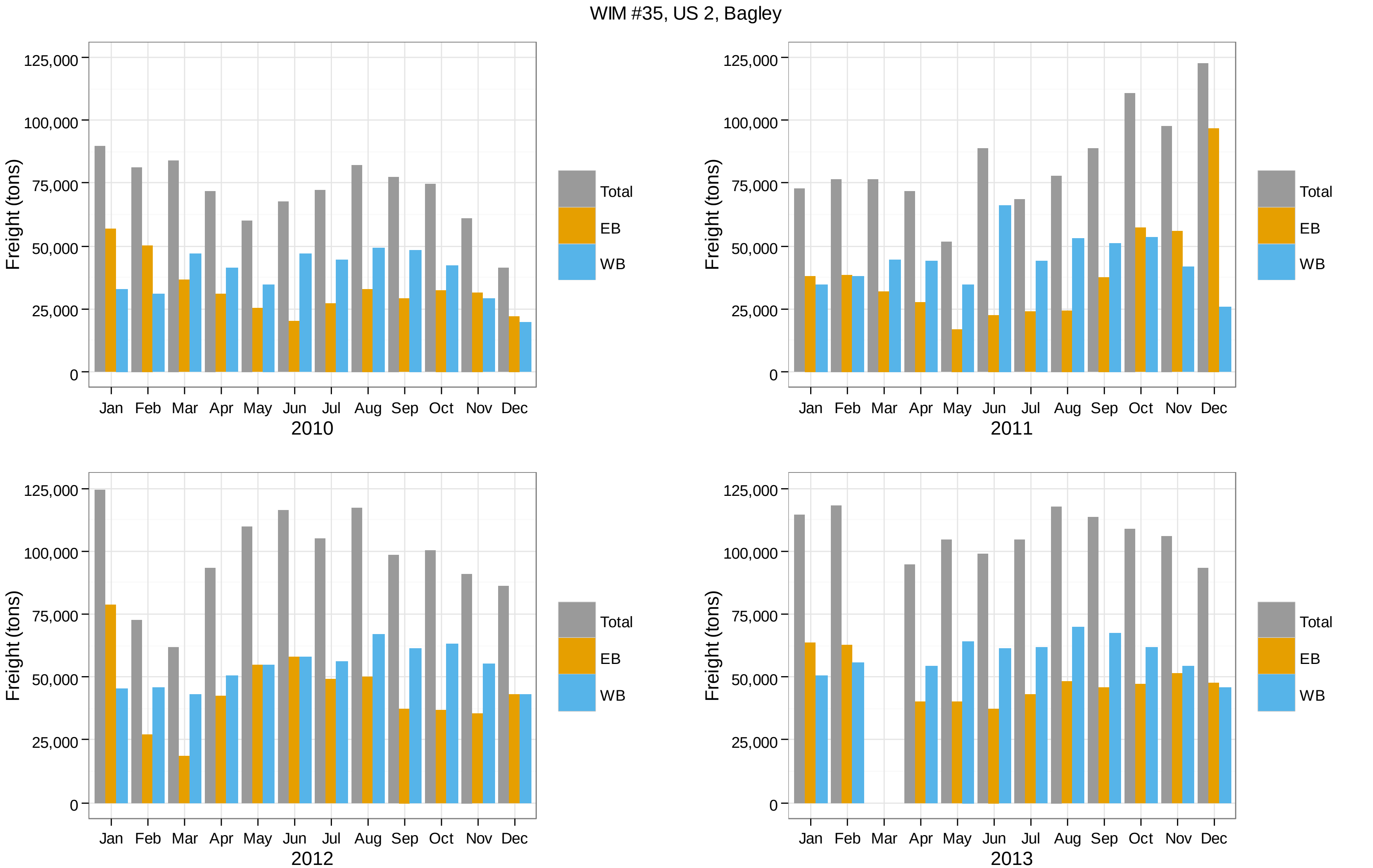


Figure 8.9. Monthly freight (tons) observed from 2010-2013, with freight movement also depicted by direction (eastbound vs. westbound; EB vs. WB).

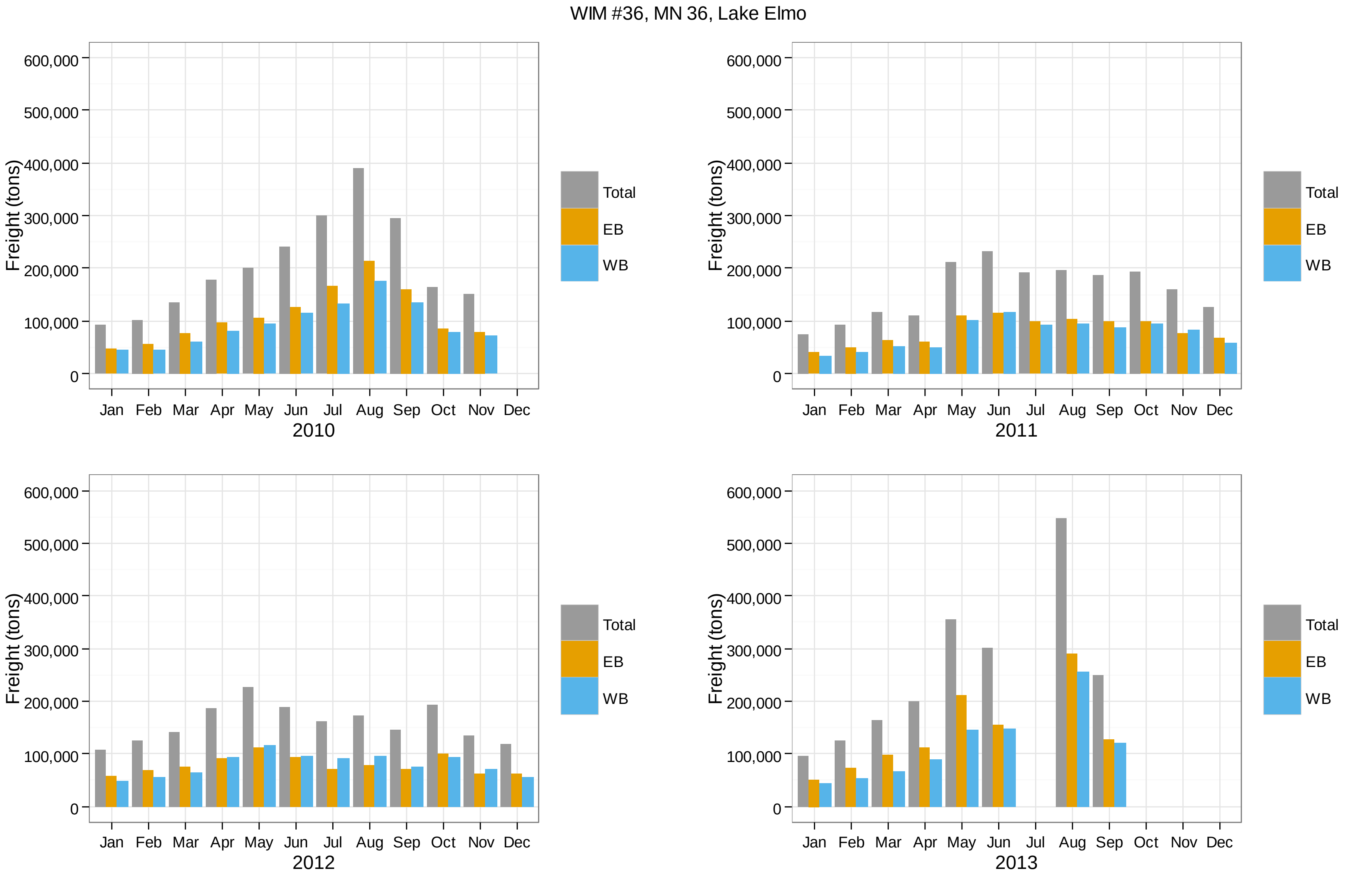


Figure 8.10. Monthly freight (tons) observed from 2010-2013, with freight movement also depicted by direction (eastbound vs. westbound; EB vs. WB).

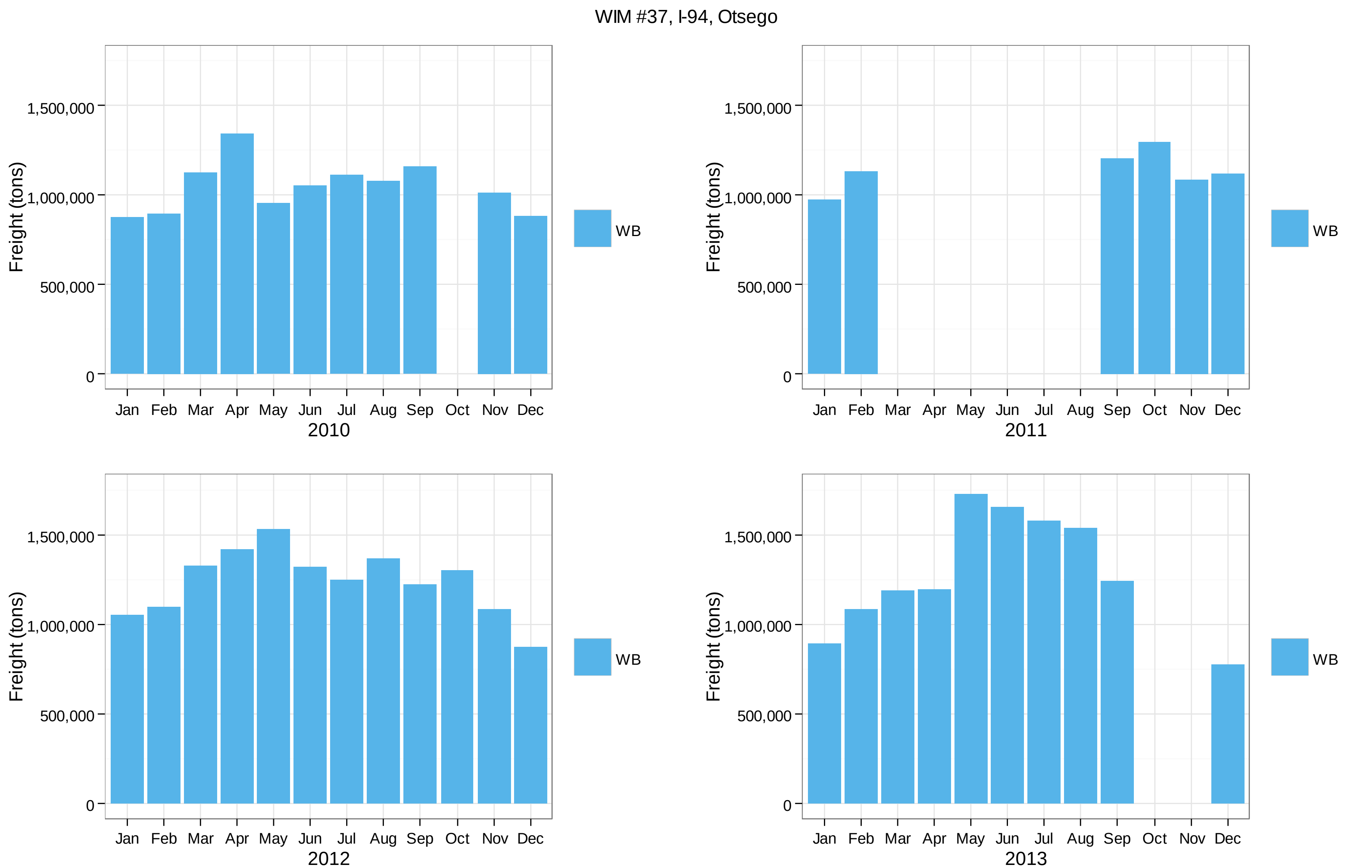


Figure 8.11. Monthly freight (tons) observed from 2010-2013 in the westbound (WB) lane. [In-pavement WIM scale only exists in the WB lane at this site]

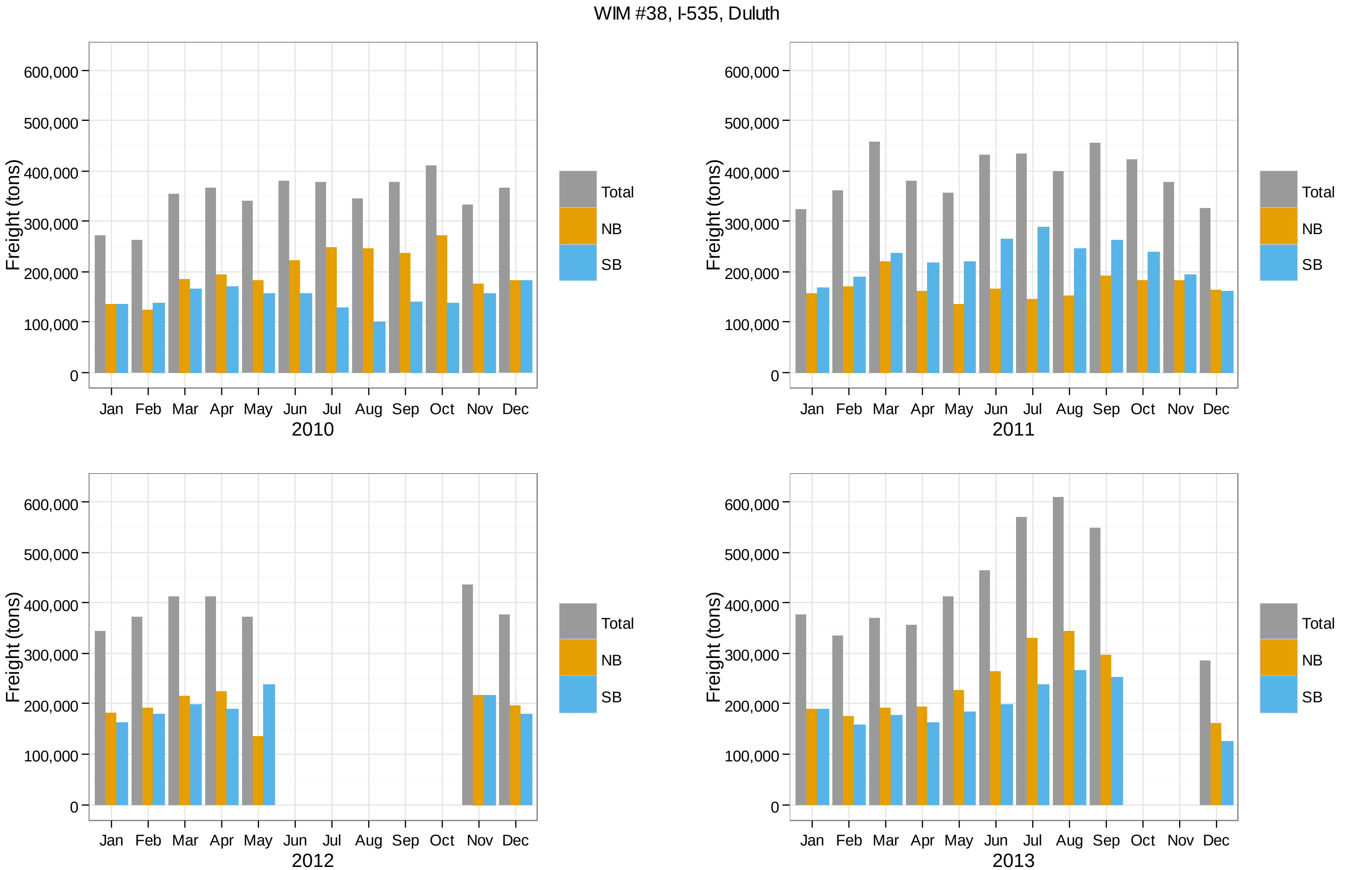


Figure 8.12. Monthly freight (tons) observed from 2010-2013, with freight movement also depicted by direction (northbound vs. southbound; NB vs. SB).

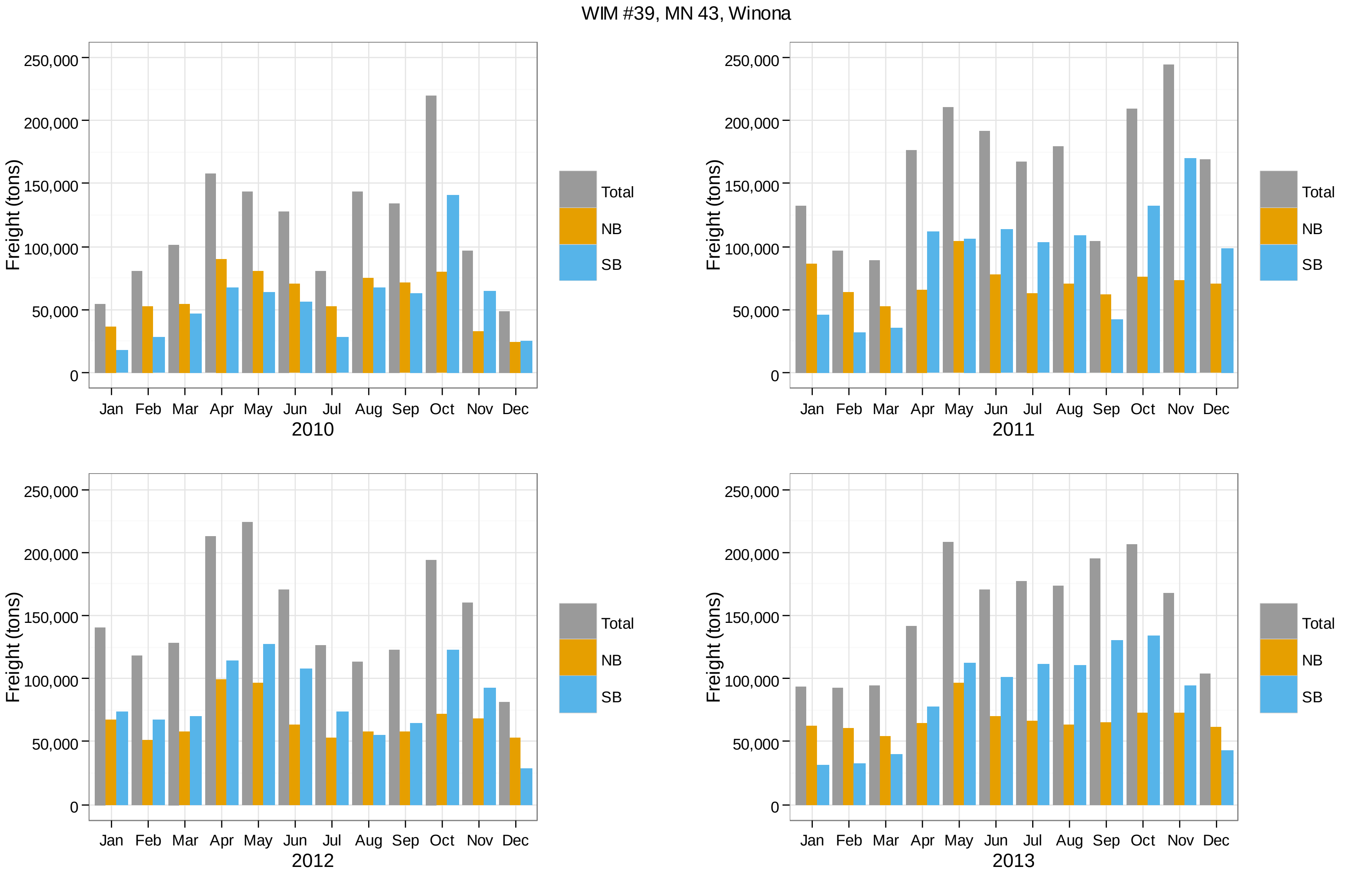


Figure 8.13. Monthly freight (tons) observed from 2010-2013, with freight movement also depicted by direction (northbound vs. southbound; NB vs. SB).

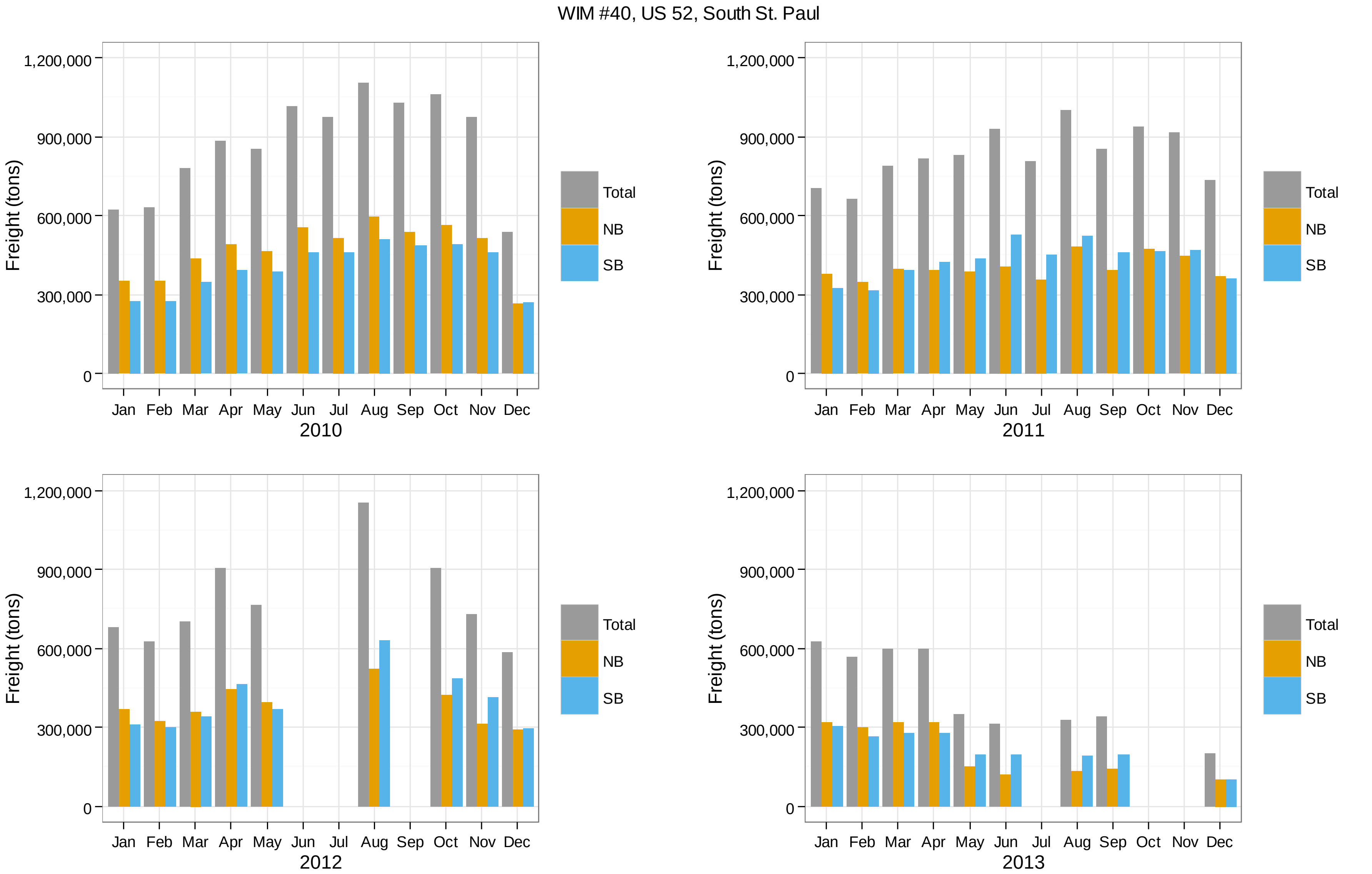


Figure 8.14. Monthly freight (tons) observed from 2010-2013, with freight movement also depicted by direction (northbound vs. southbound; NB vs. SB).

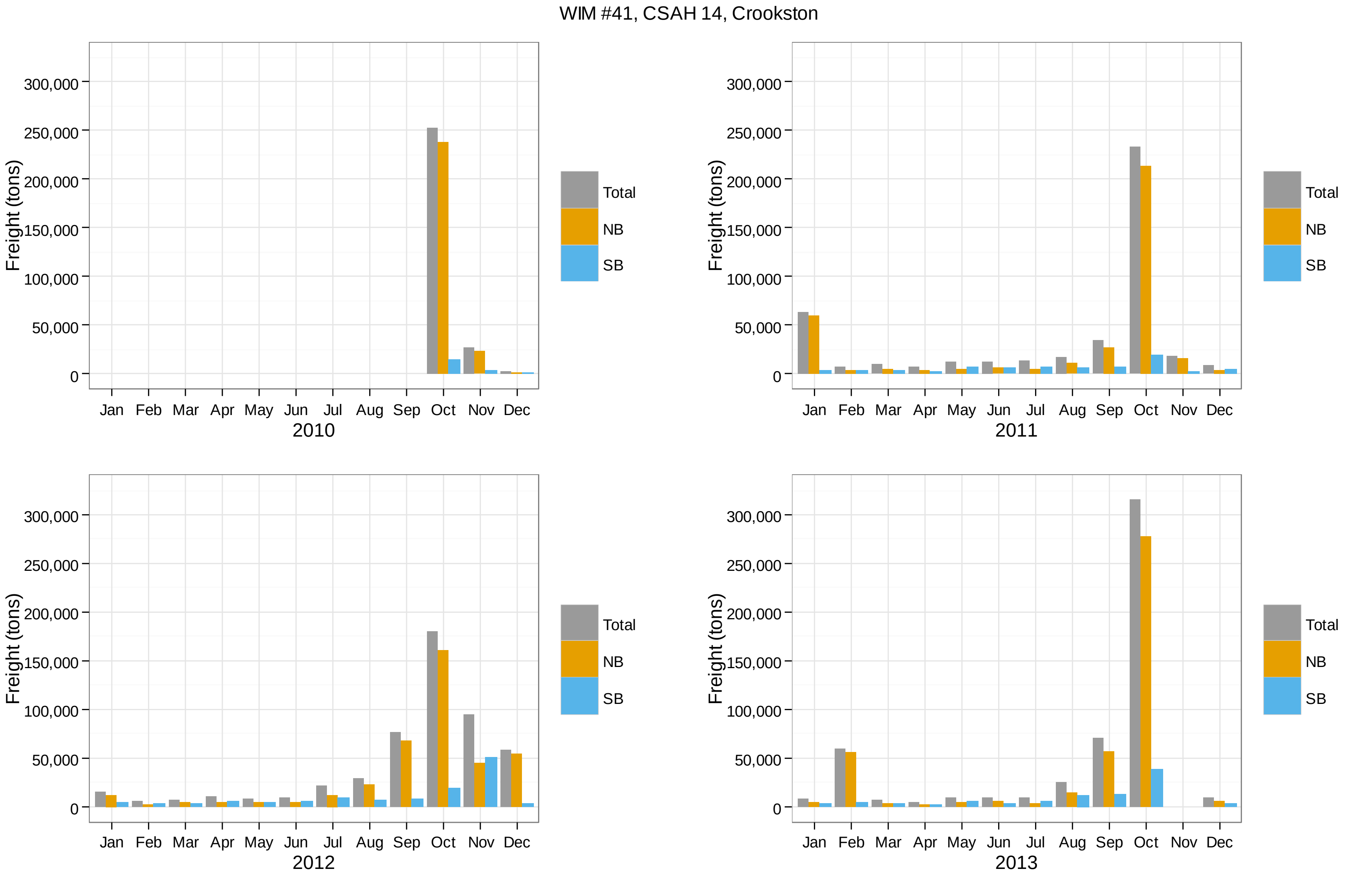


Figure 8.15. Monthly freight (tons) observed from 2010-2013, with freight movement also depicted by direction (northbound vs. southbound; NB vs. SB).

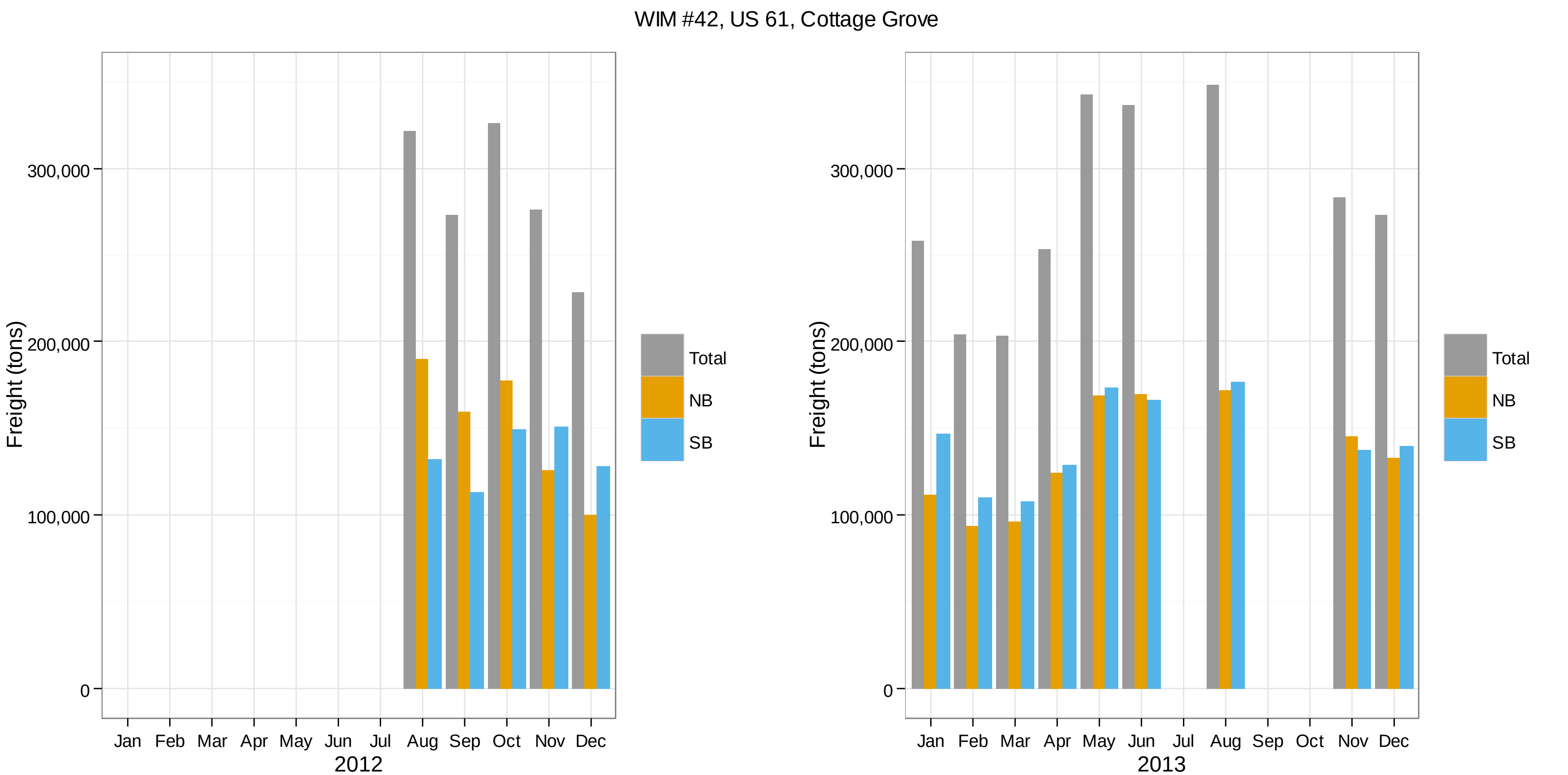


Figure 8.16. Monthly freight (tons) observed from 2012-2013, with freight movement also depicted by direction (northbound vs. southbound; NB vs. SB).

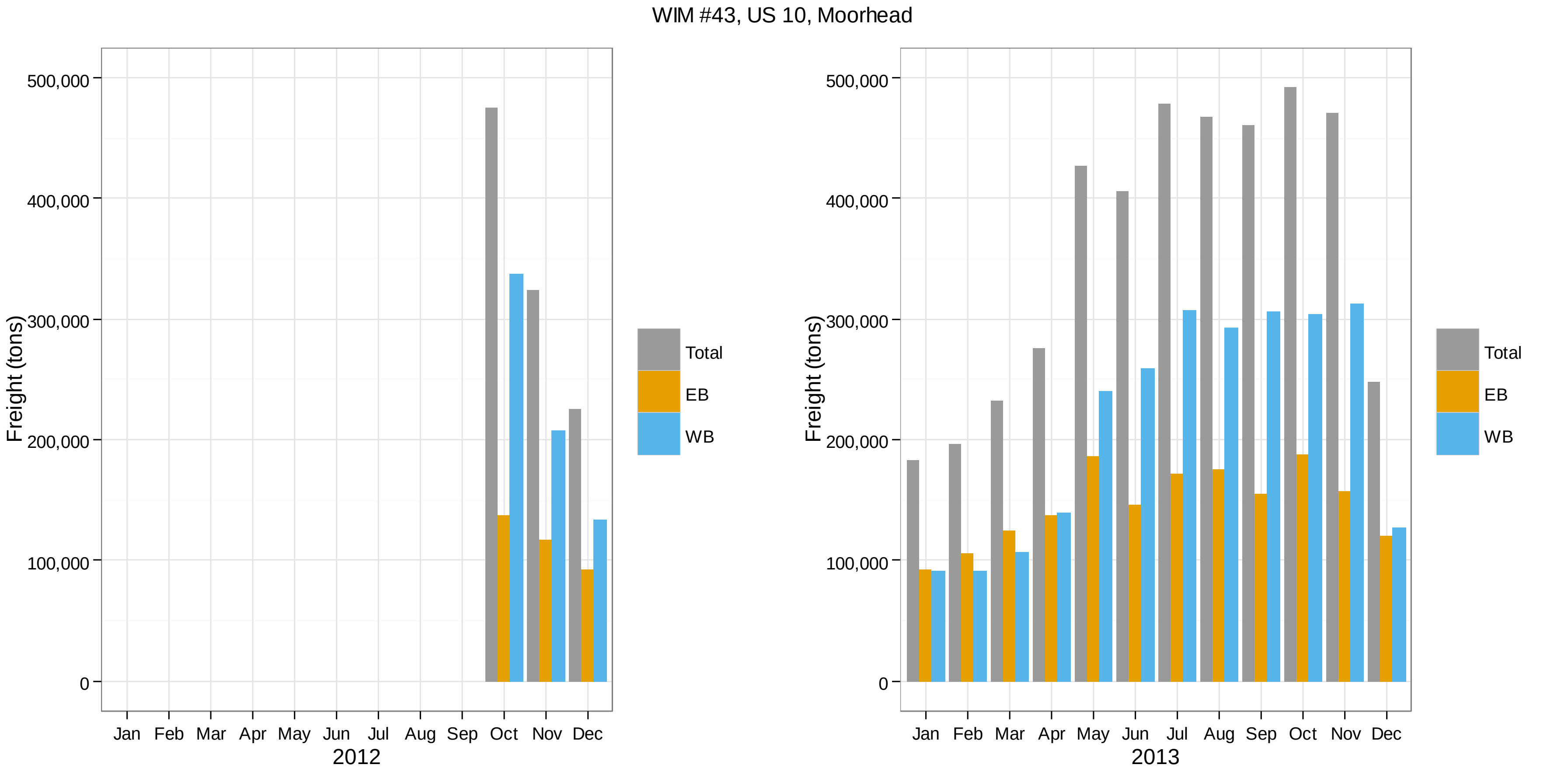


Figure 8.17. Monthly freight (tons) observed from 2012-2013, with freight movement also depicted by direction (eastbound vs. westbound; EB vs. WB).

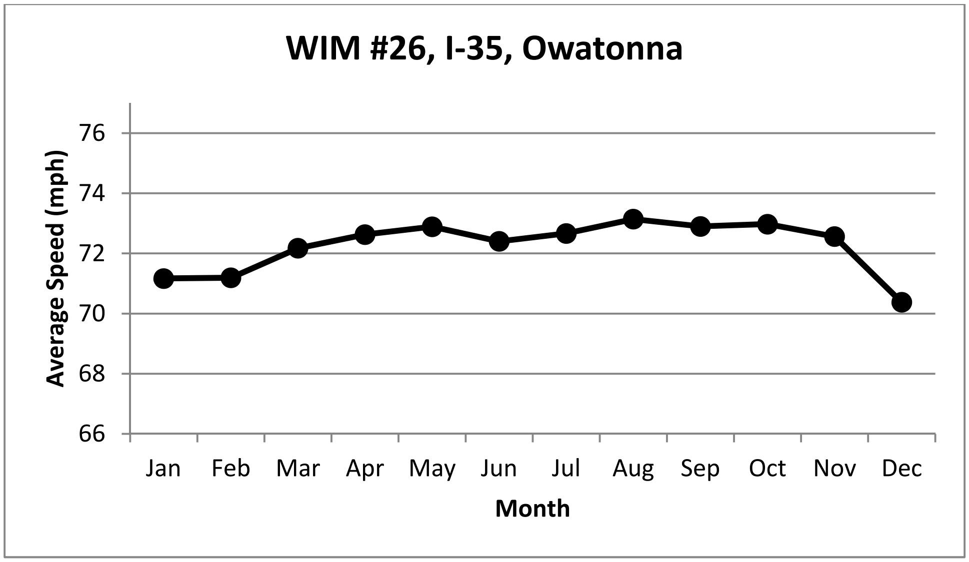


Figure 9.1. Average speed (mph) as a function of month. Data from August 2010-December 2013.

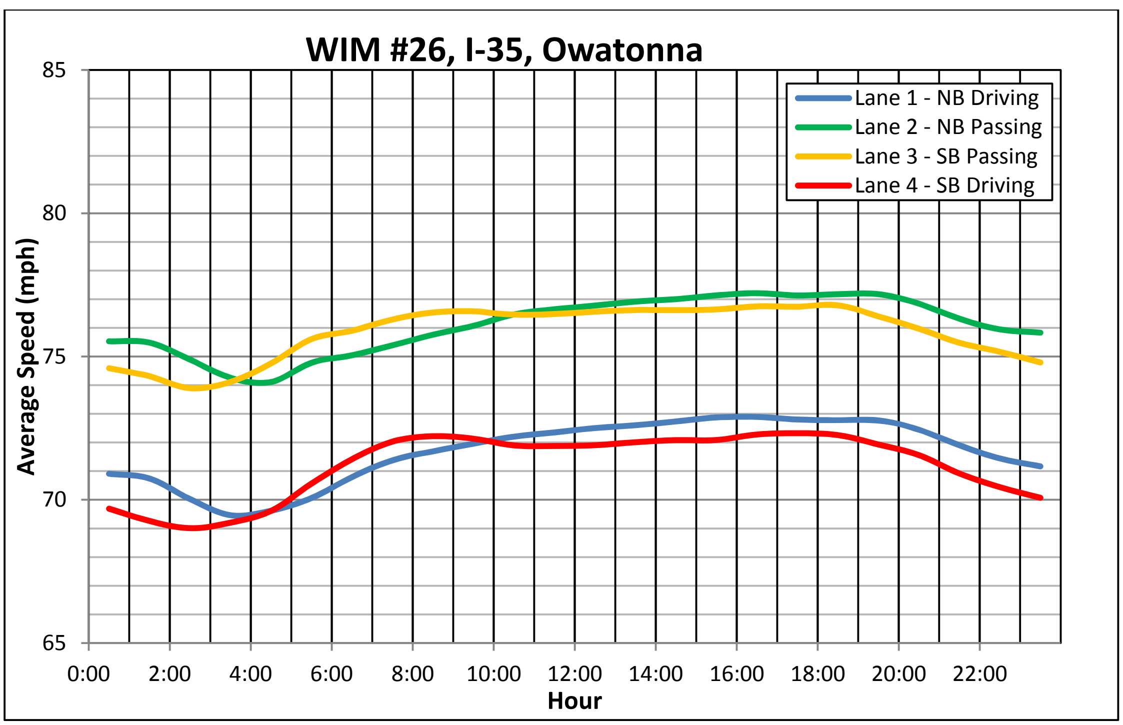


Figure 9.2. Average speed (mph) observed in the driving and passing lanes for each direction (northbound; NB vs. southbound; SB) on an hourly basis. Speed limit: 70 mph.

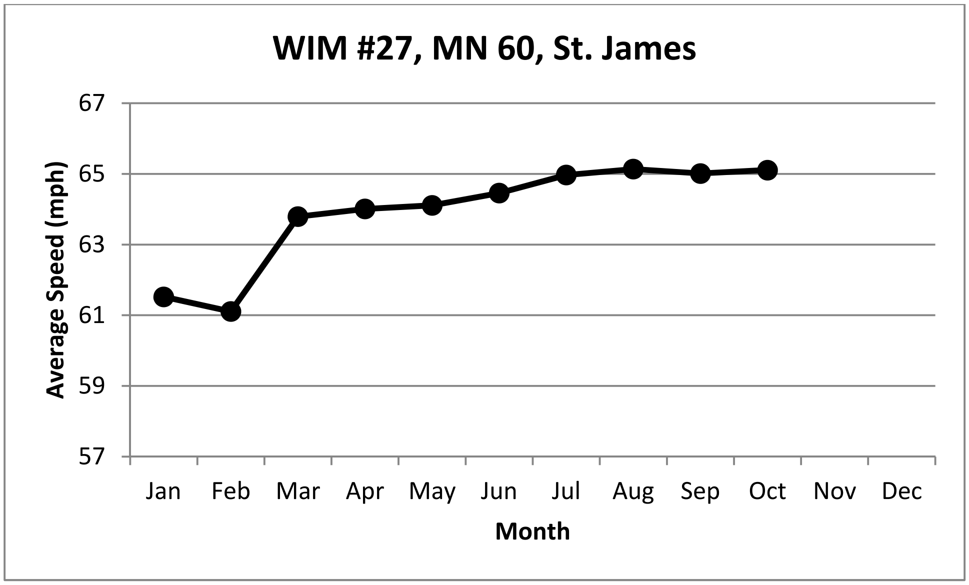


Figure 9.3. Average speed (mph) as a function of month. Data from January 2010-October 2010.

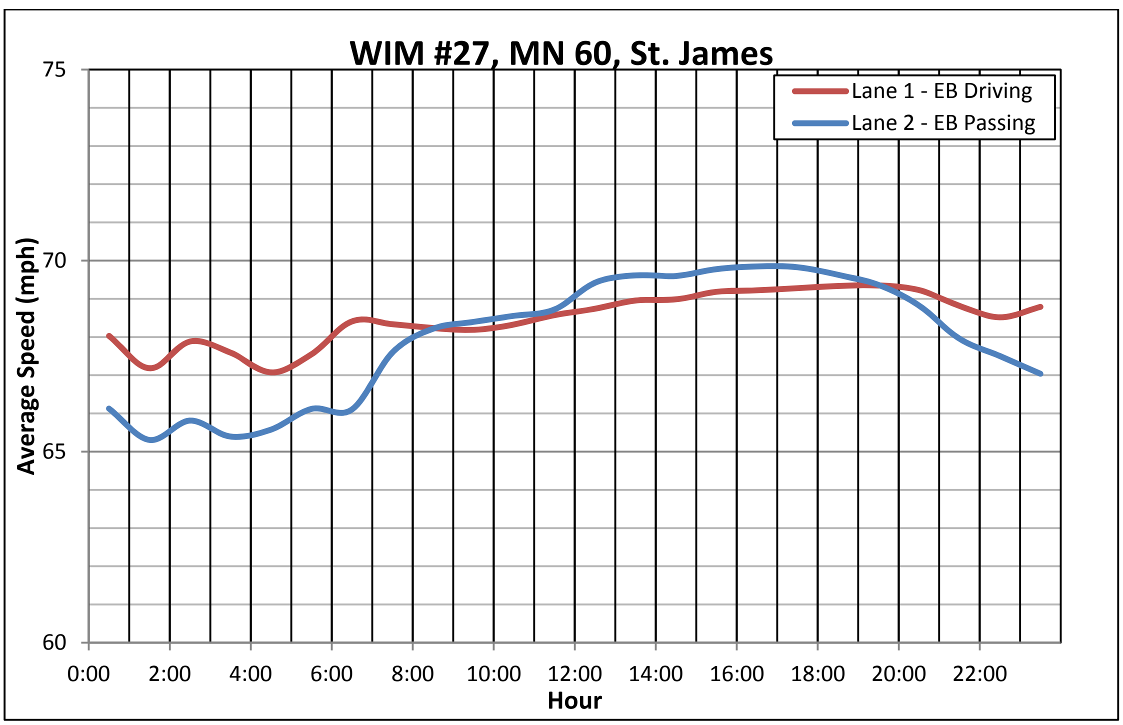


Figure 9.4. Average speed (mph) observed in the driving and passing lanes for eastbound direction (EB) on an hourly basis. Speed limit: 65 mph.

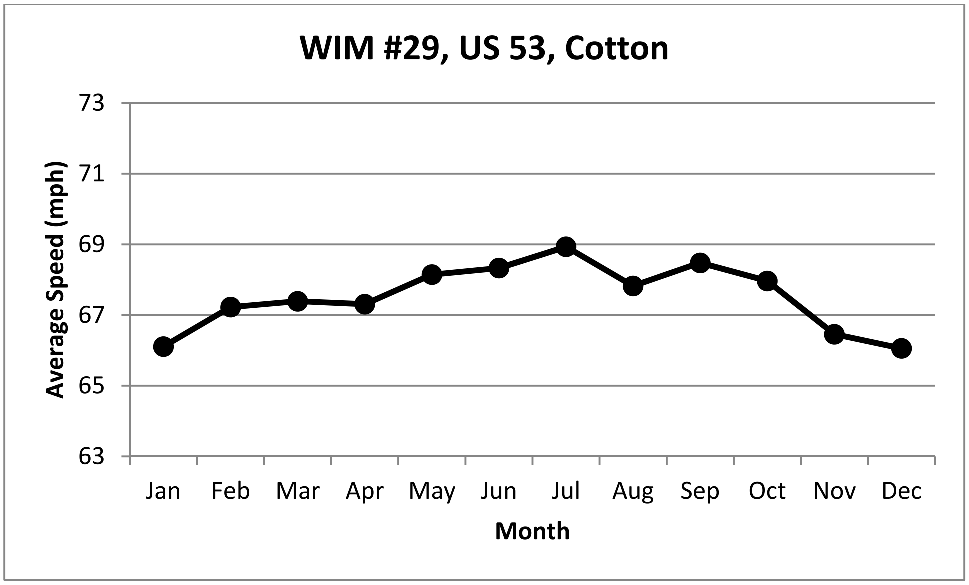


Figure 9.5. Average speed (mph) as a function of month. Data from September 2010-December 2013.

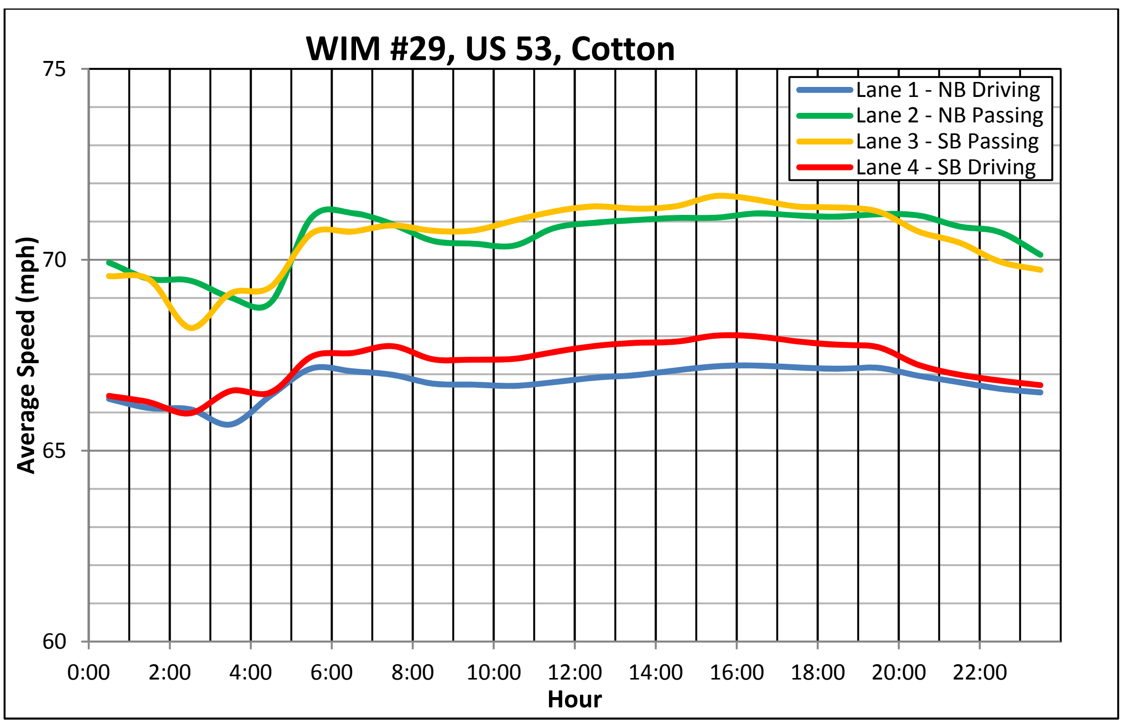


Figure 9.6. Average speed (mph) observed in the driving and passing lanes for each direction (northbound; NB vs. southbound; SB) on an hourly basis. Speed limit: 65 mph.

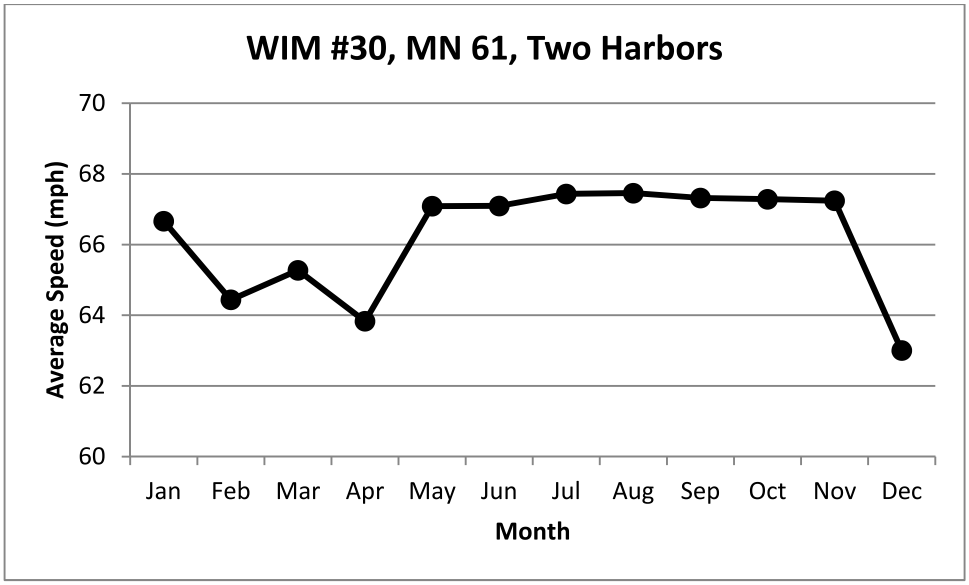


Figure 9.7. Average speed (mph) as a function of month. Speed limit: 65 mph.

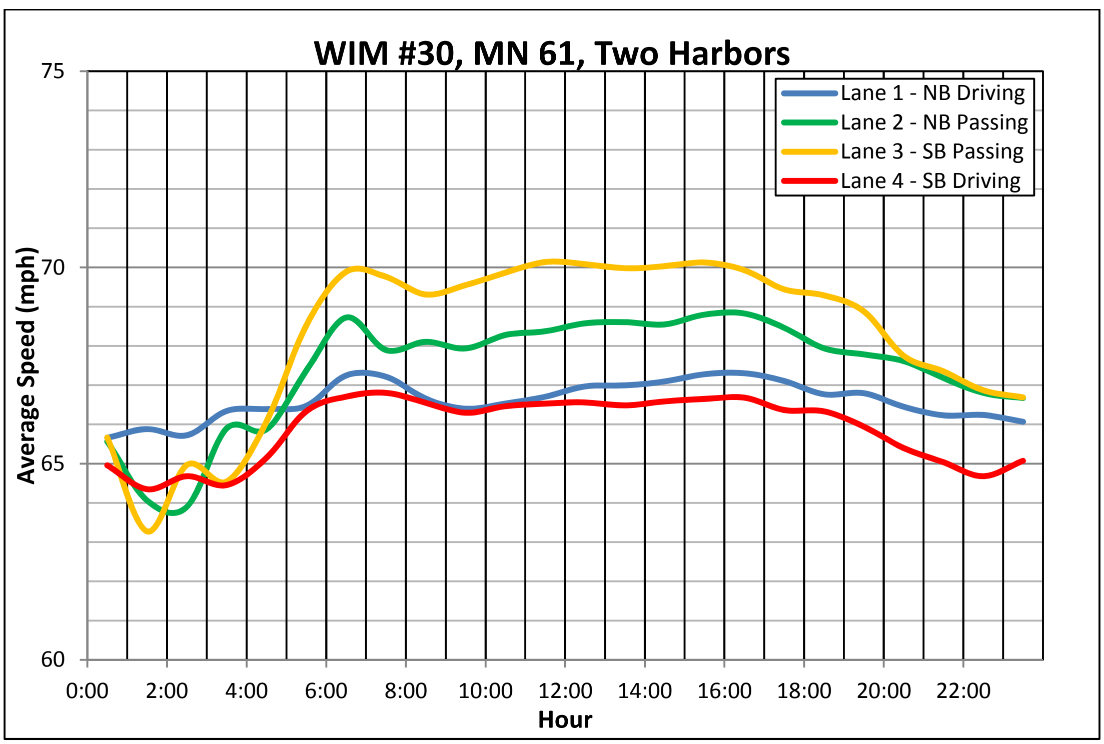


Figure 9.8. Average speed (mph) observed in the driving and passing lanes for each direction (northbound; NB vs. southbound; SB) on an hourly basis. Speed limit: 65 mph.

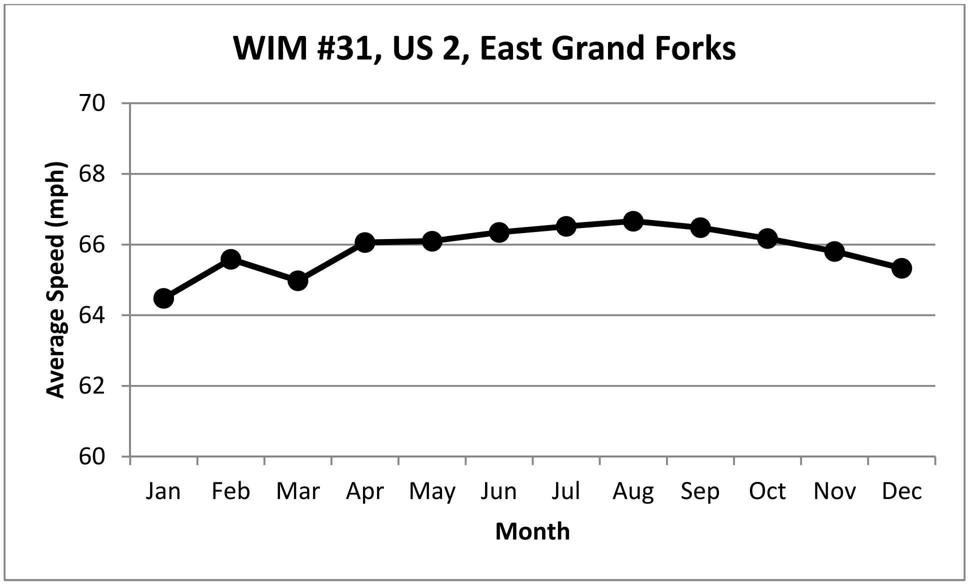


Figure 9.9. Average speed (mph) as a function of month.

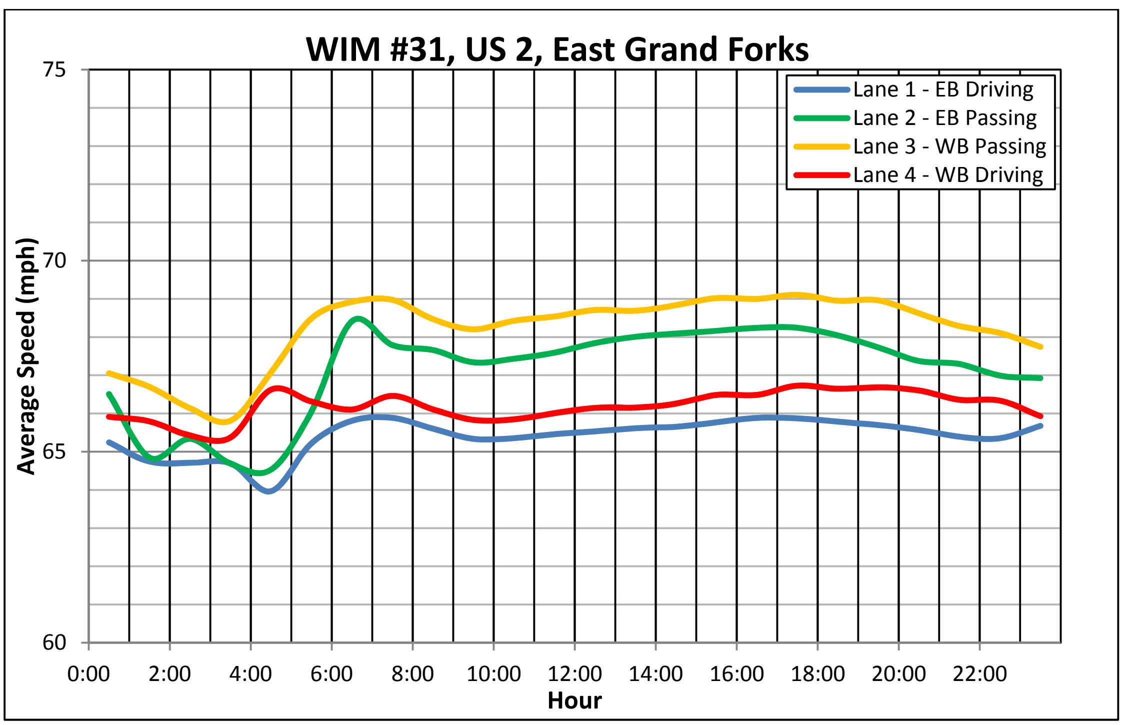


Figure 9.10. Average speed (mph) observed in the driving and passing lanes for each direction (eastbound; EB vs. westbound; WB) on an hourly basis. Speed limit: 65 mph.

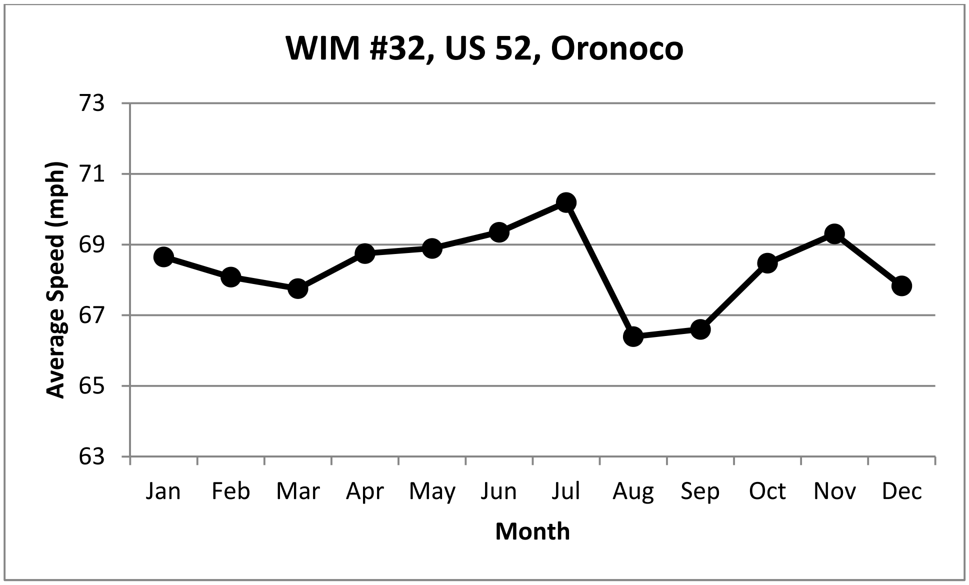


Figure 9.11. Average speed (mph) as a function of month.

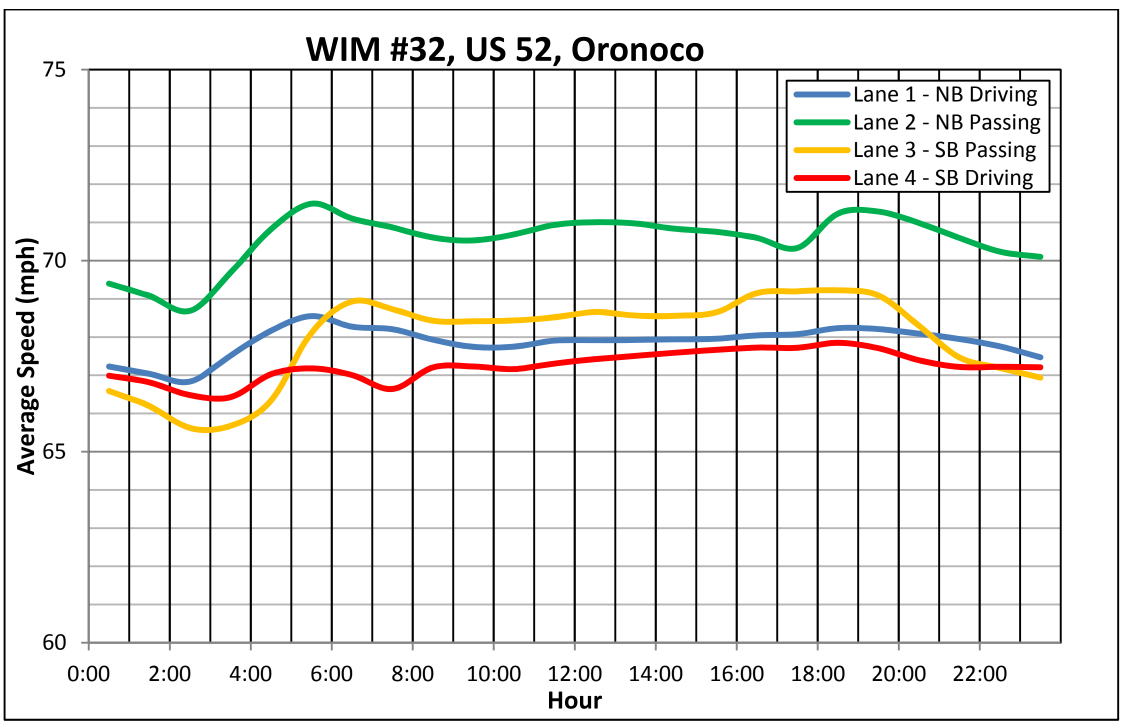


Figure 9.12. Average speed (mph) observed in the driving and passing lanes for each direction (northbound; NB vs. southbound; SB) on an hourly basis. Speed limit: 65 mph.

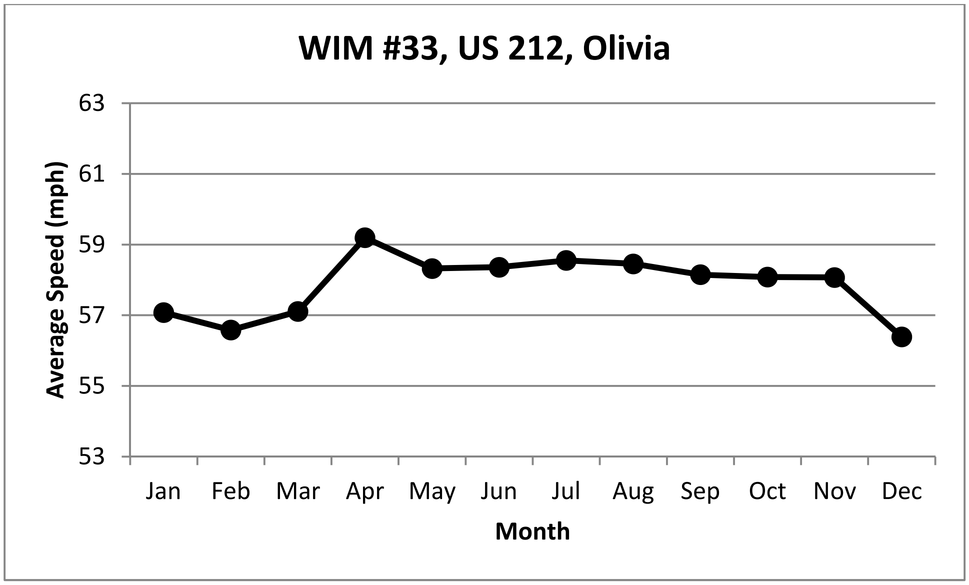


Figure 9.13. Average speed (mph) as a function of month.

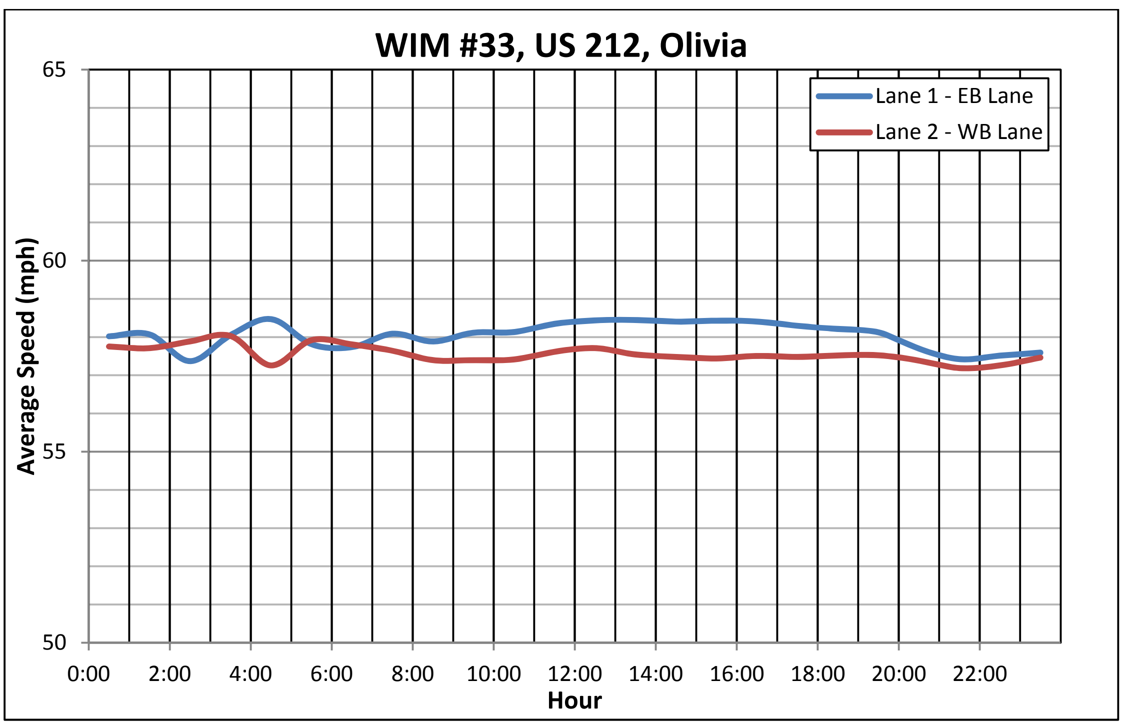


Figure 9.14. Average speed (mph) observed for each direction (eastbound; EB vs. westbound; WB) on an hourly basis. Speed limit: 55 mph.

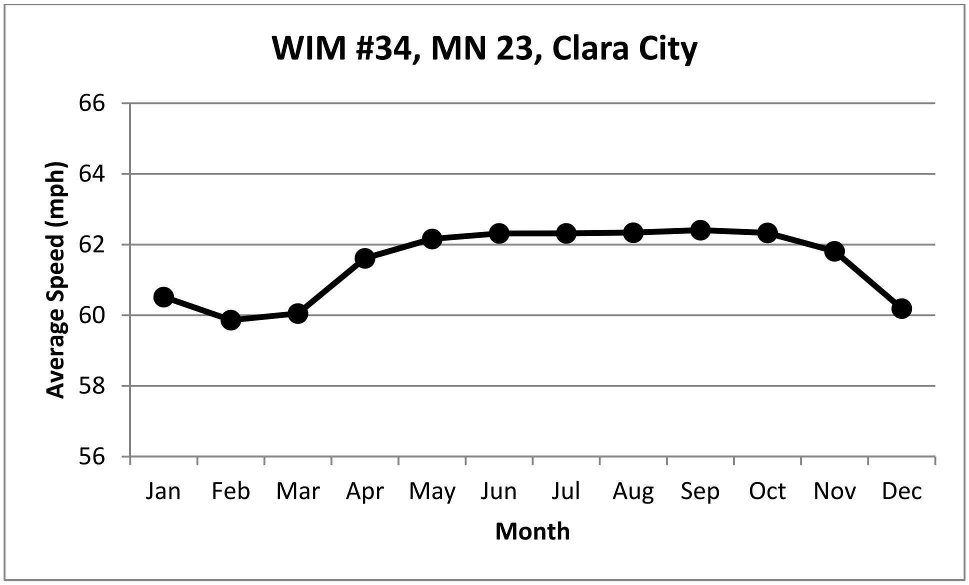


Figure 9.15. Average speed (mph) as a function of month.

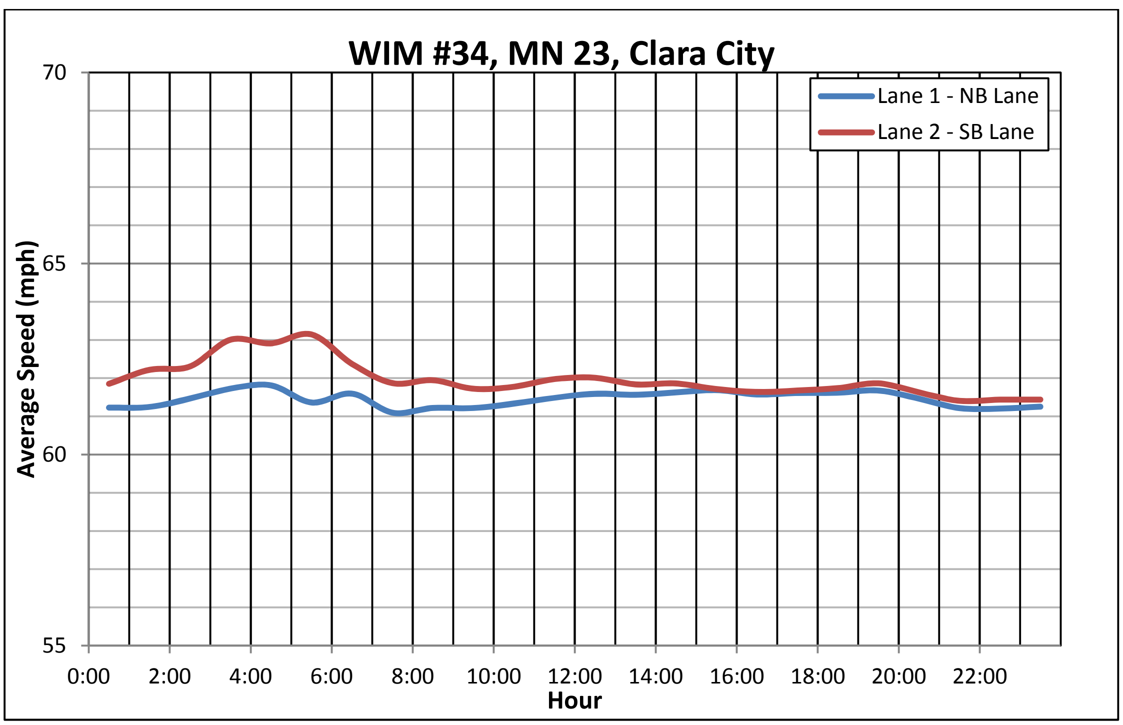


Figure 9.16. Average speed (mph) observed for each direction (northbound; NB vs. southbound; SB) on an hourly basis. Speed limit: 60 mph.

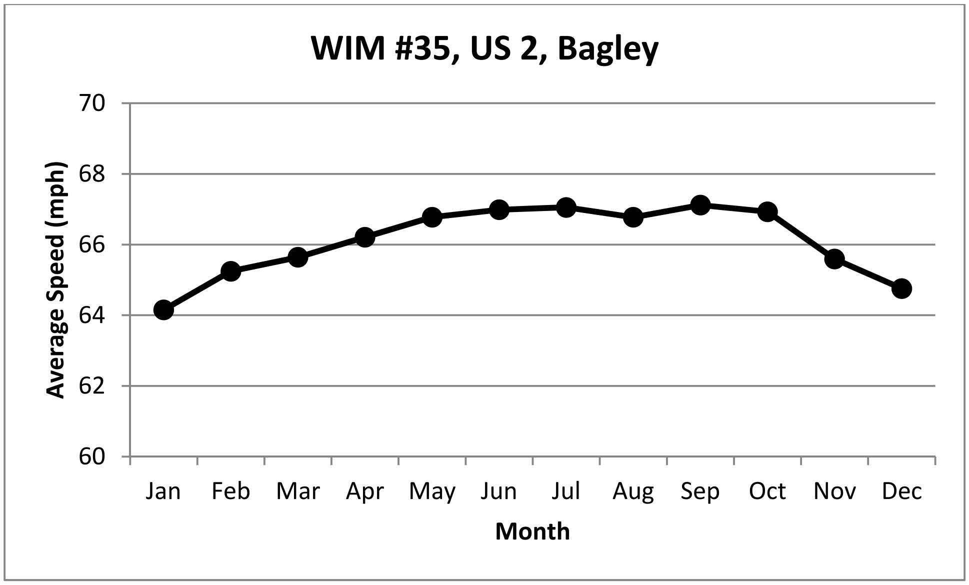


Figure 9.17. Average speed (mph) as a function of month.

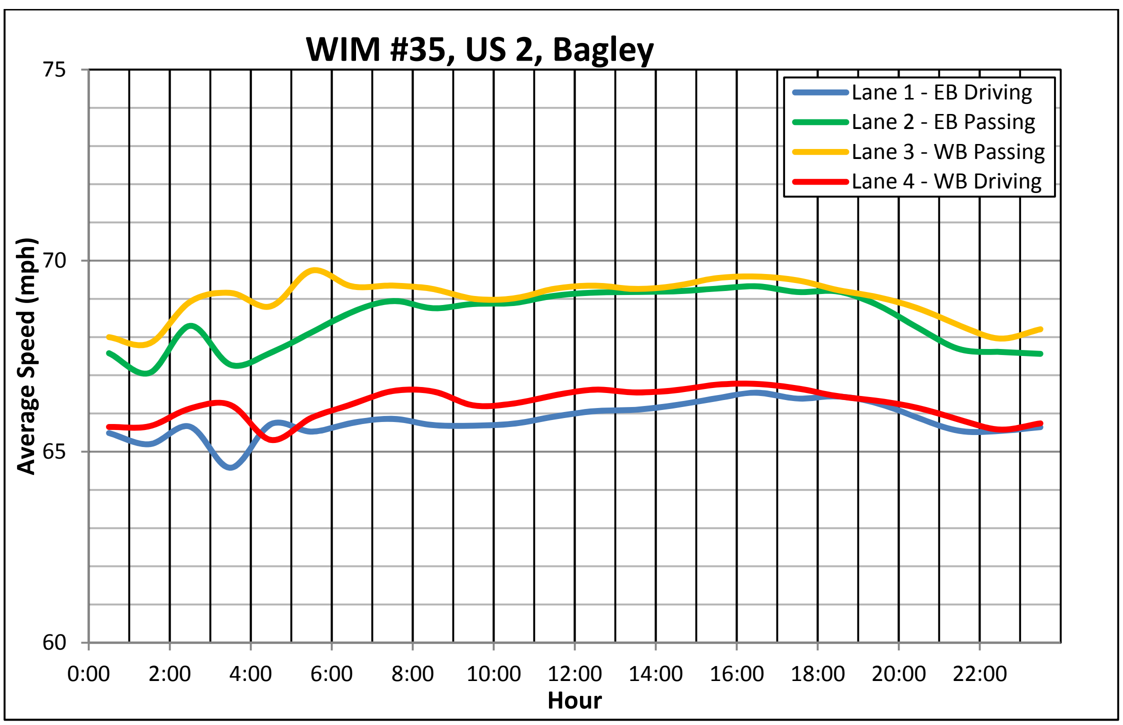


Figure 9.18. Average speed (mph) observed in the driving and passing lanes for each direction (eastbound; EB vs. westbound; WB) on an hourly basis. Speed limit: 65 mph.

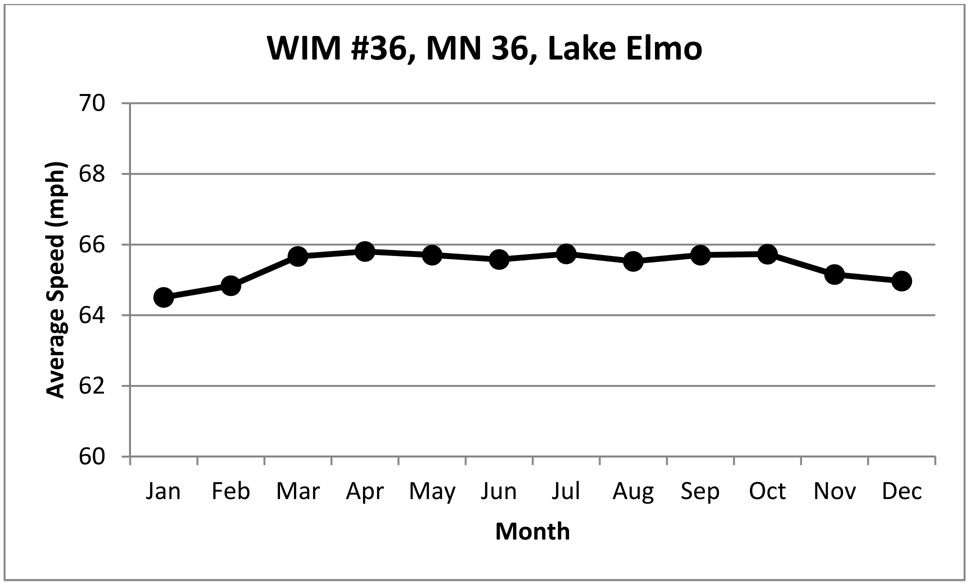


Figure 9.19. Average speed (mph) as a function of month.

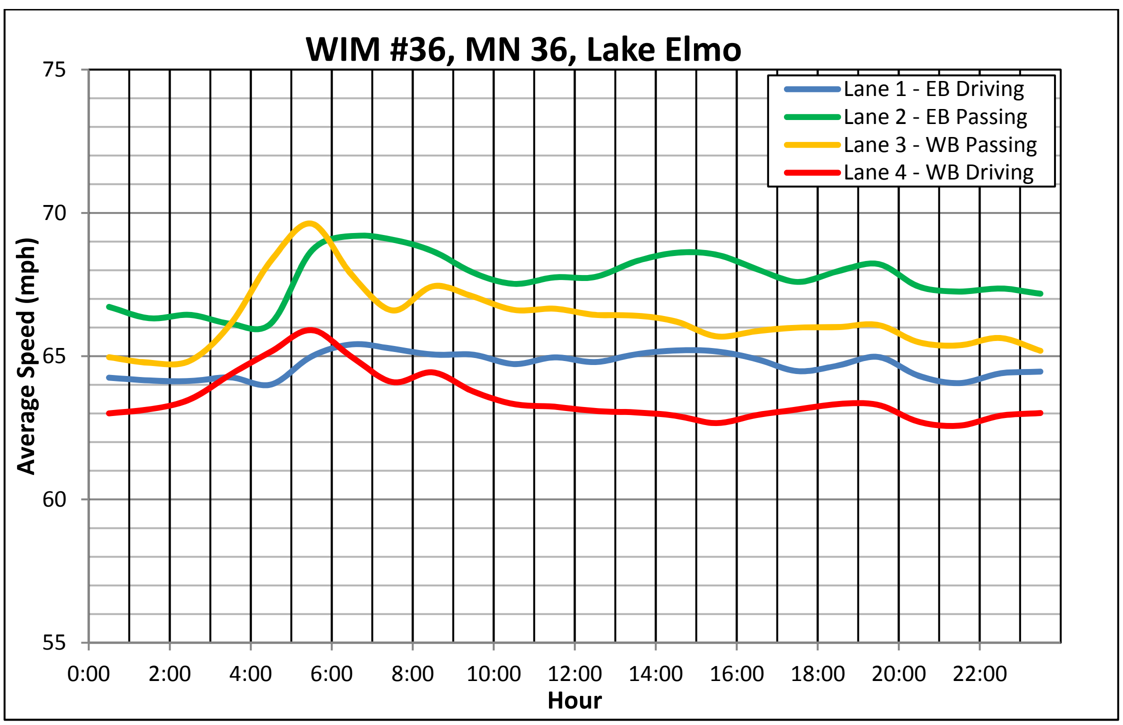


Figure 9.20. Average speed (mph) observed in the driving and passing lanes for each direction (eastbound; EB vs. westbound; WB) on an hourly basis. Speed limit: 65 mph.

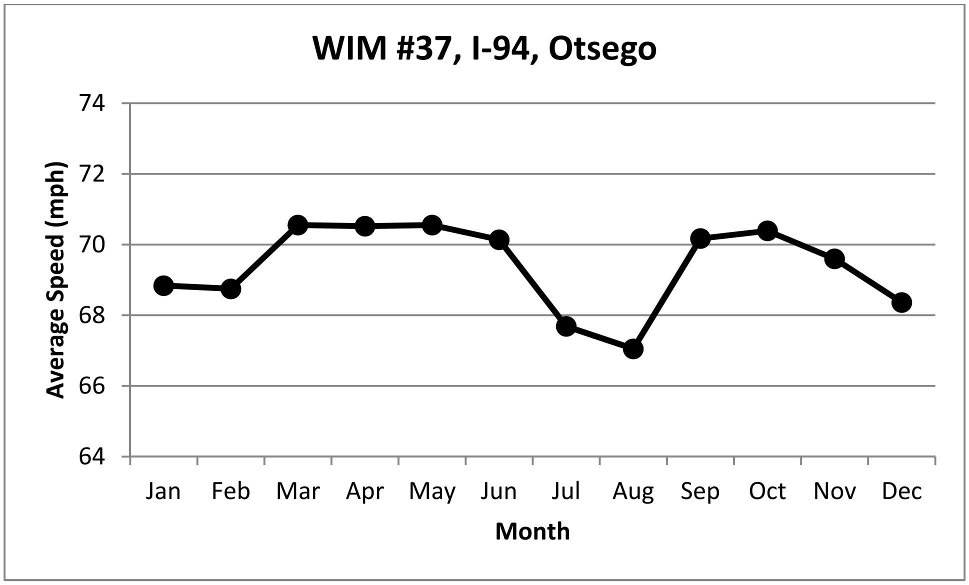


Figure 9.21. Average speed (mph) as a function of month.

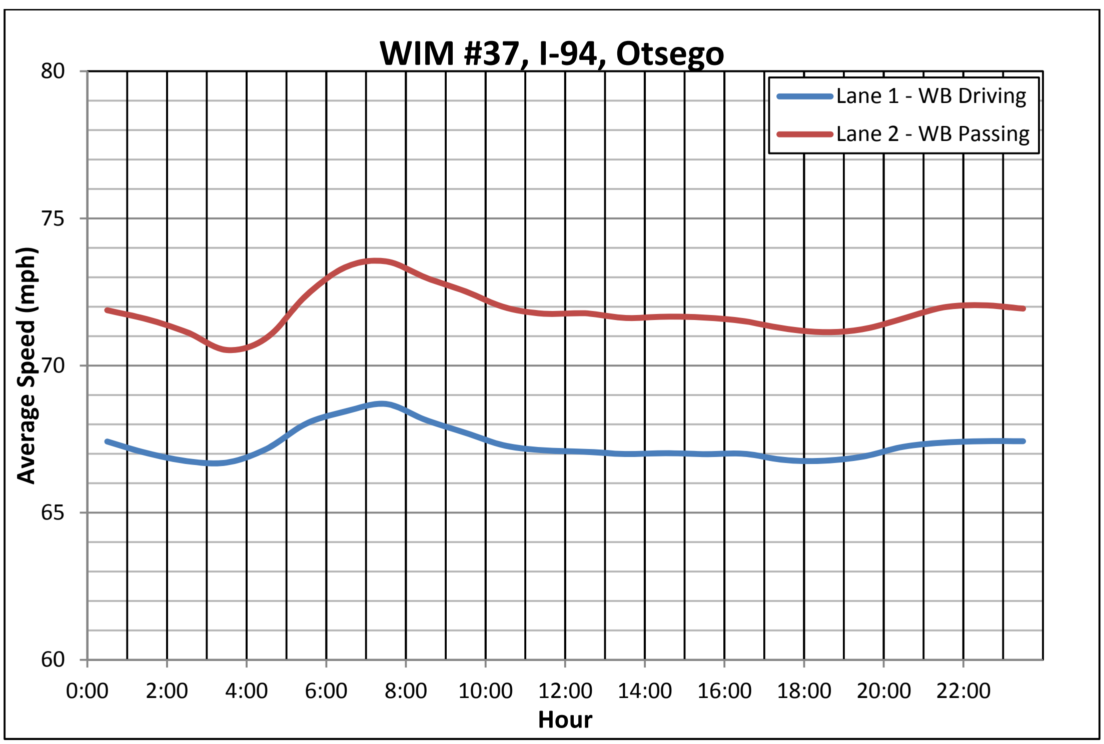


Figure 9.22. Average speed (mph) observed in the driving and passing lanes for westbound direction (WB) on an hourly basis. Speed limit: 70 mph.

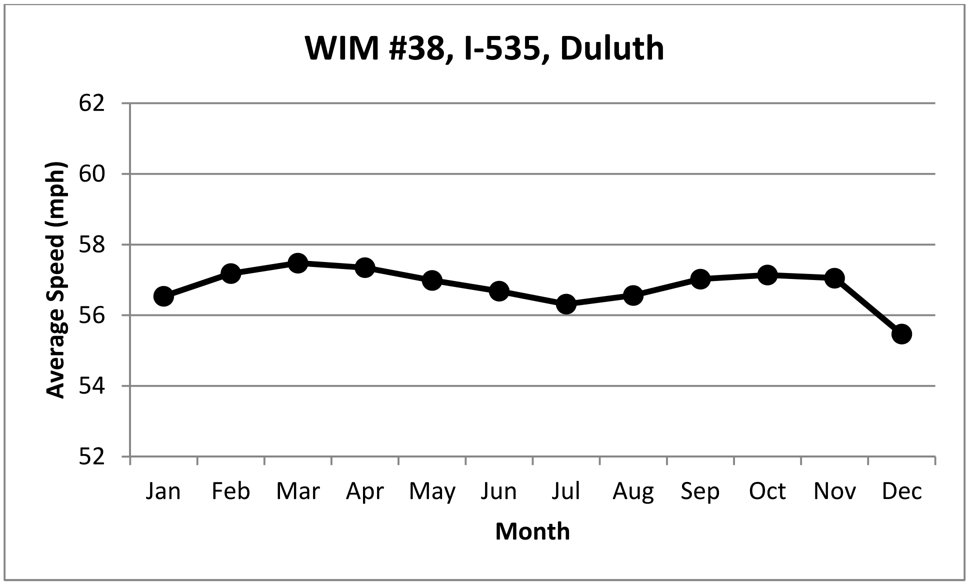


Figure 9.23. Average speed (mph) as a function of month.

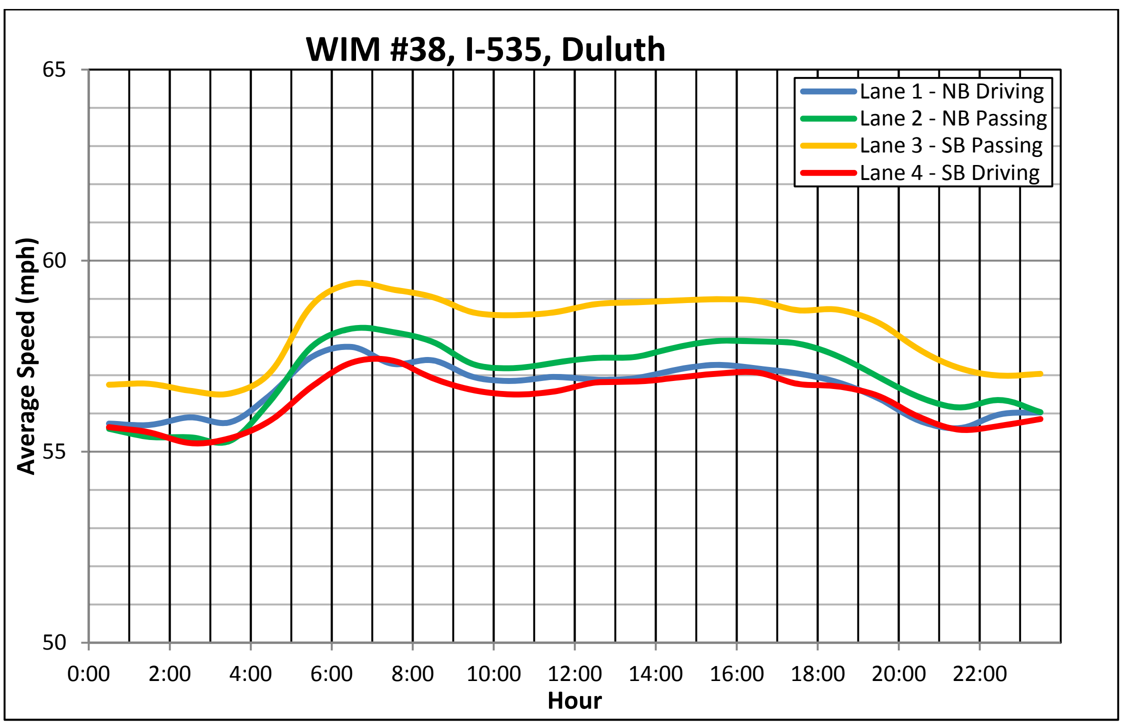


Figure 9.24. Average speed (mph) observed in the driving and passing lanes for each direction (northbound; NB vs. southbound; SB) on an hourly basis. Speed limit: 55 mph.

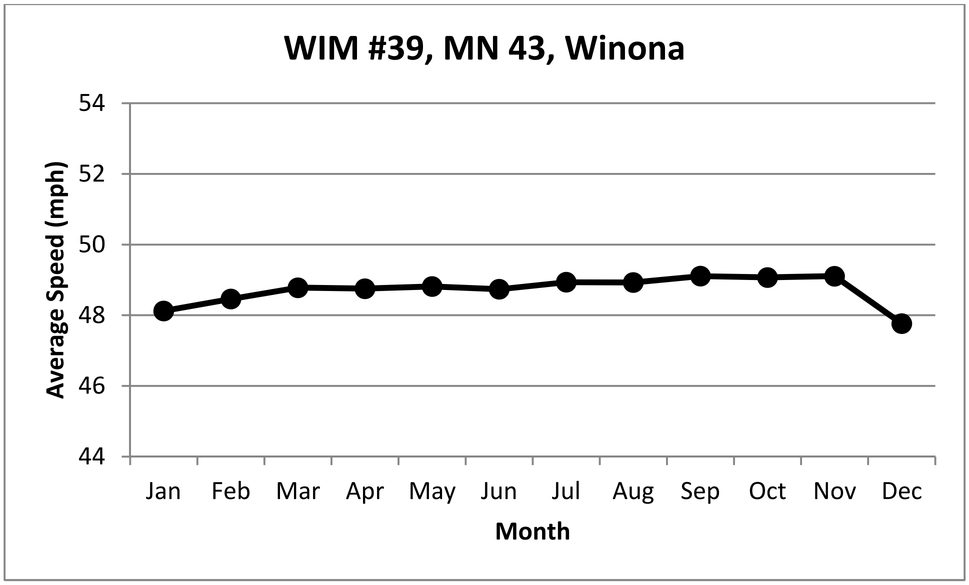


Figure 9.25. Average speed (mph) as a function of month.

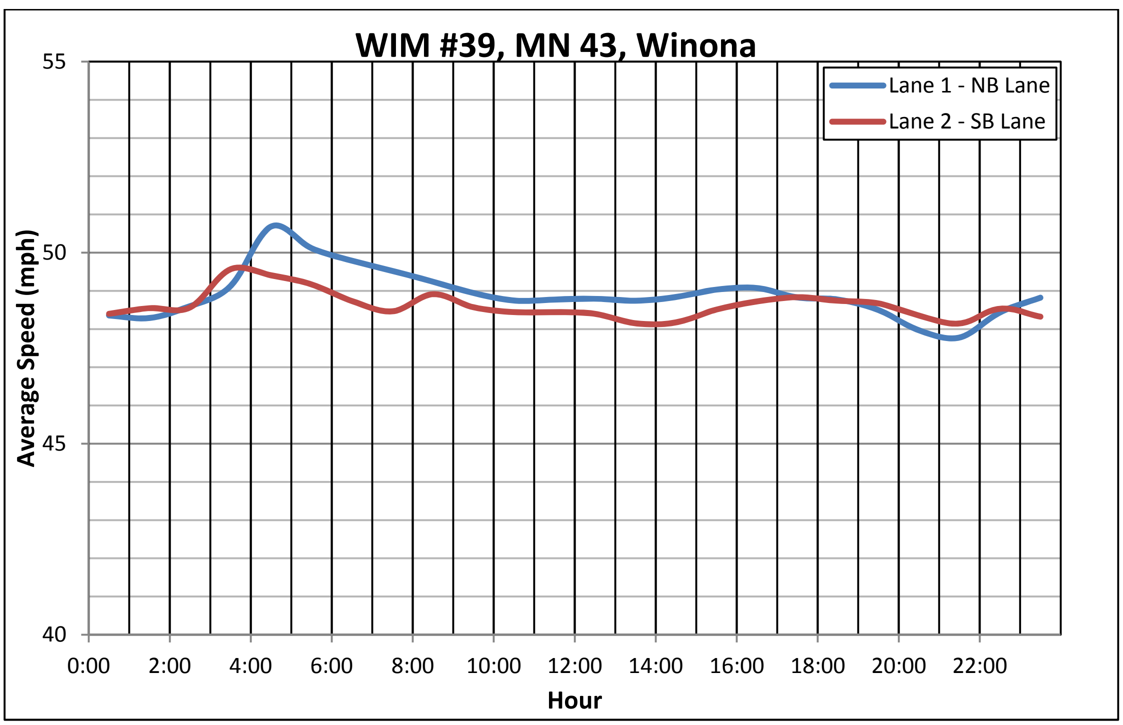


Figure 9.26. Average speed (mph) observed for each direction (northbound; NB vs. southbound; SB) on an hourly basis. Speed limit: 50 mph.

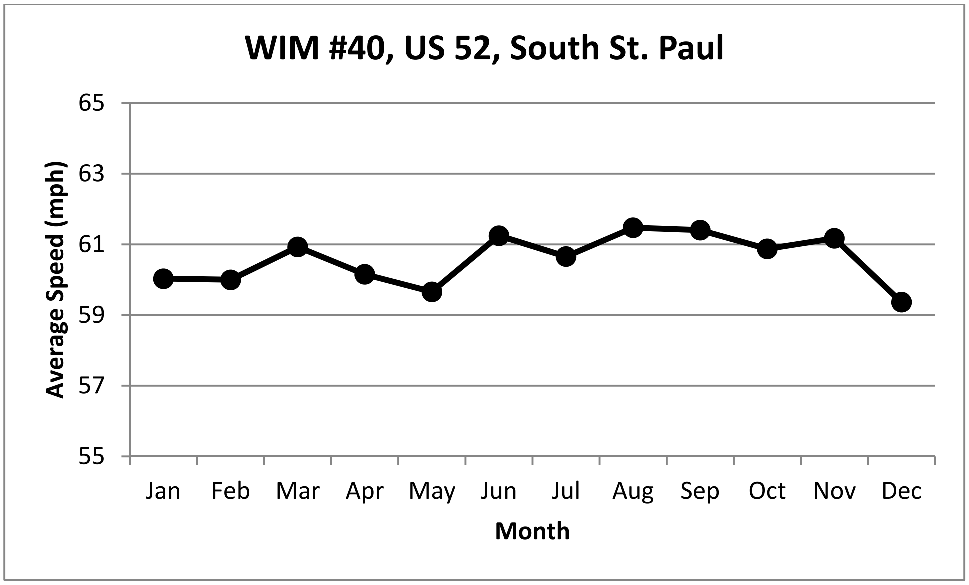


Figure 9.27. Average speed (mph) as a function of month.

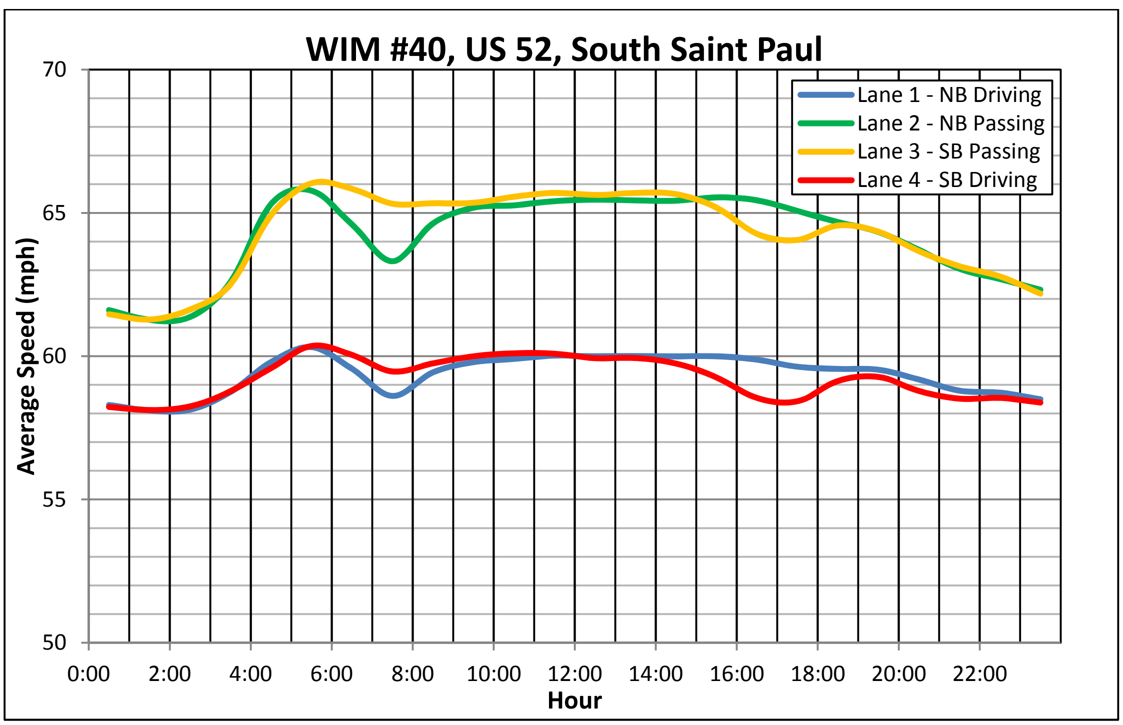


Figure 9.28. Average speed (mph) observed in the driving and passing lanes for each direction (northbound; NB vs. southbound; SB) on an hourly basis. Speed limit: 55 mph.

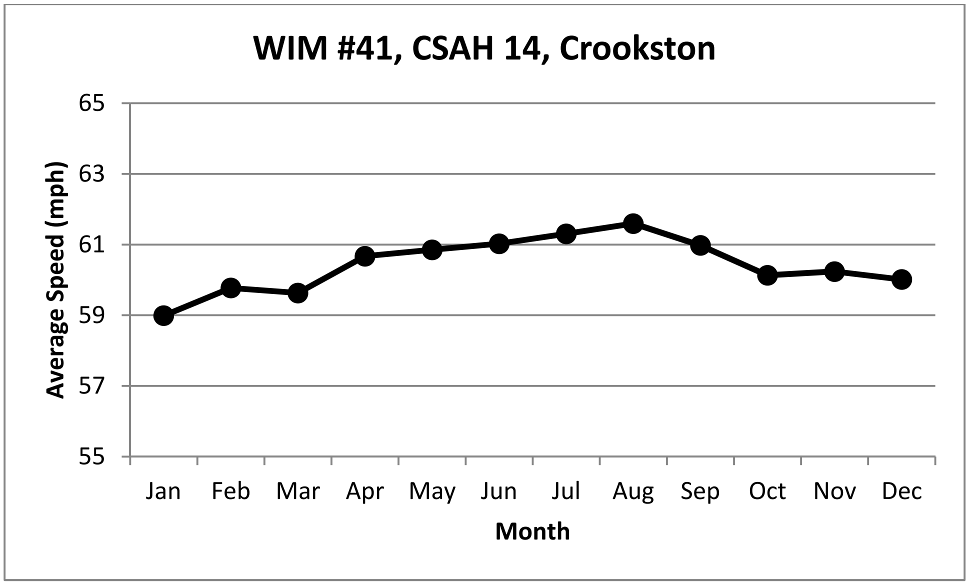


Figure 9.29. Average speed (mph) as a function of month.

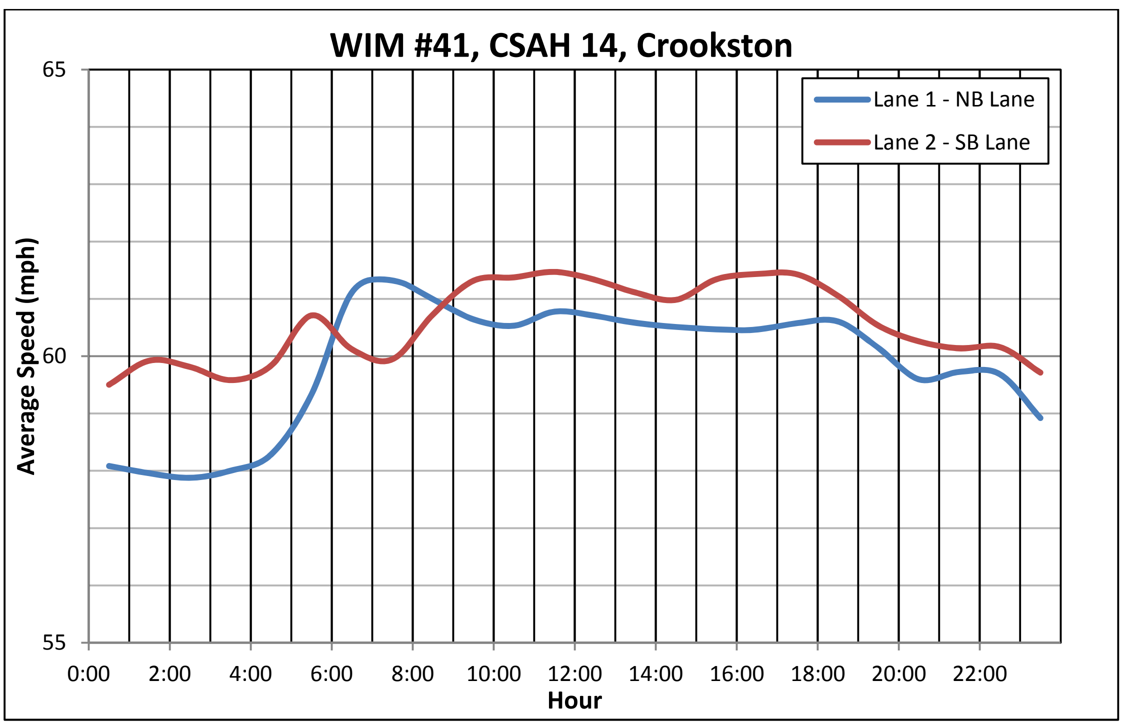


Figure 9.30. Average speed (mph) observed for each direction (northbound; NB vs. southbound; SB) on an hourly basis. Speed limit: 55 mph.

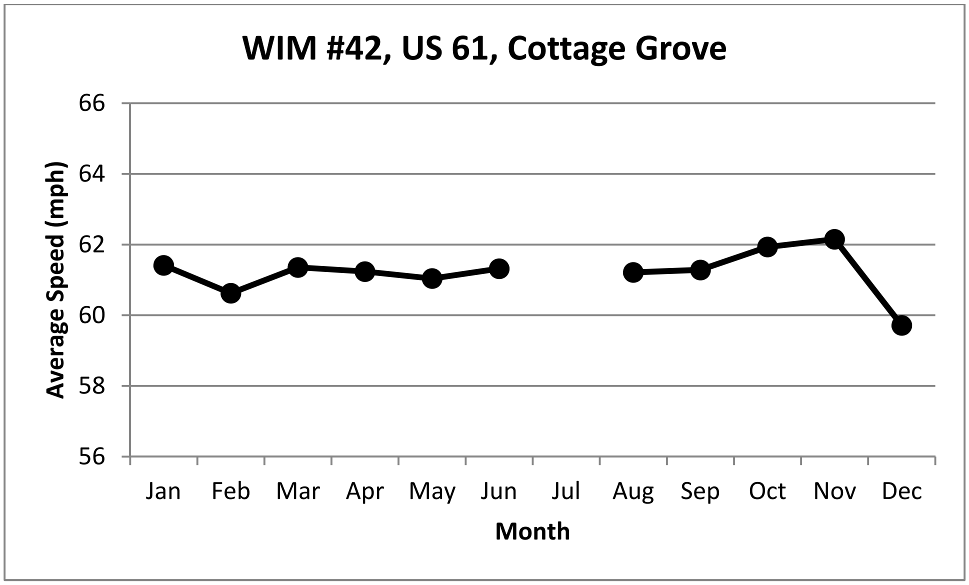


Figure 9.31. Average speed (mph) as a function of month. Data from August 2012-December 2013.

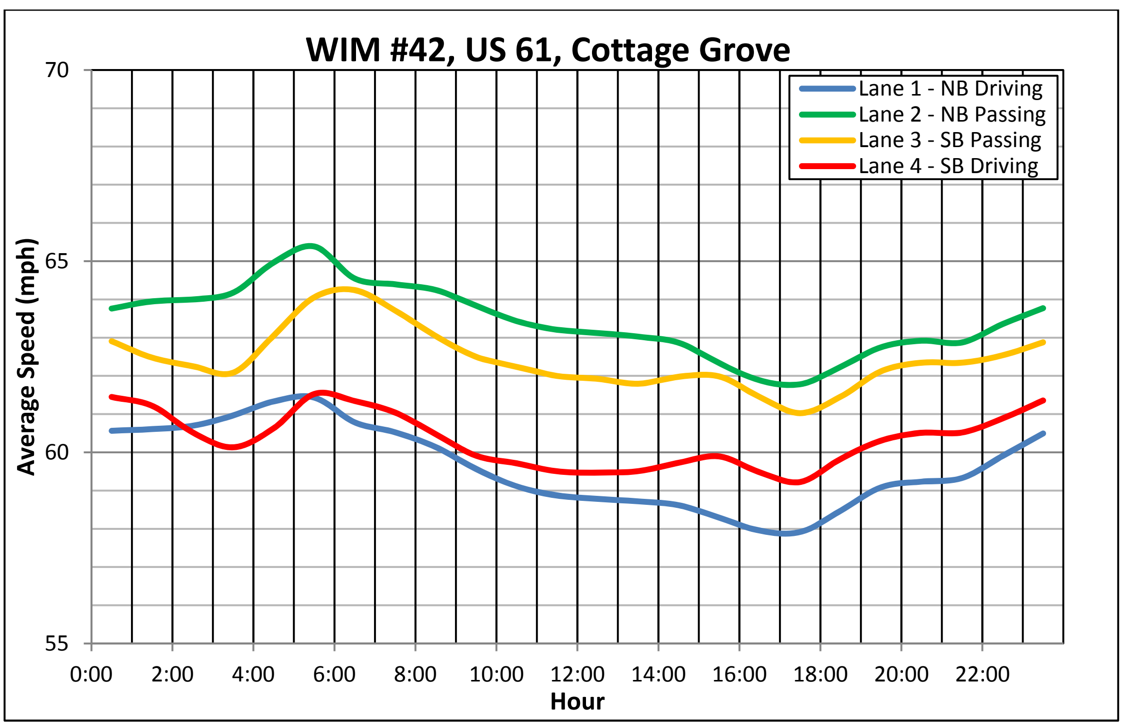


Figure 9.32. Average speed (mph) observed in the driving and passing lanes for each direction (northbound; NB vs. southbound; SB) on an hourly basis. Speed limit: 60 mph.

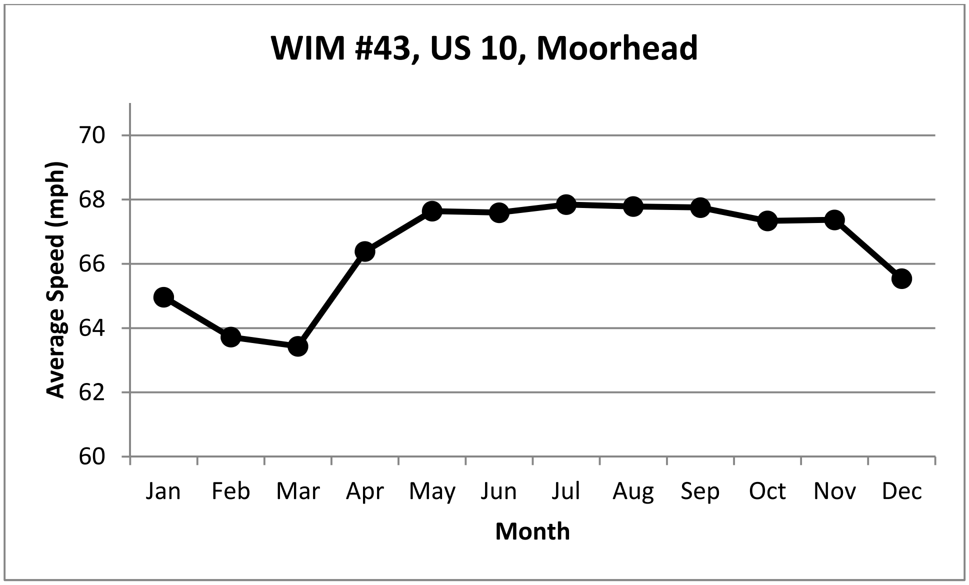


Figure 9.33. Average speed (mph) as a function of month.

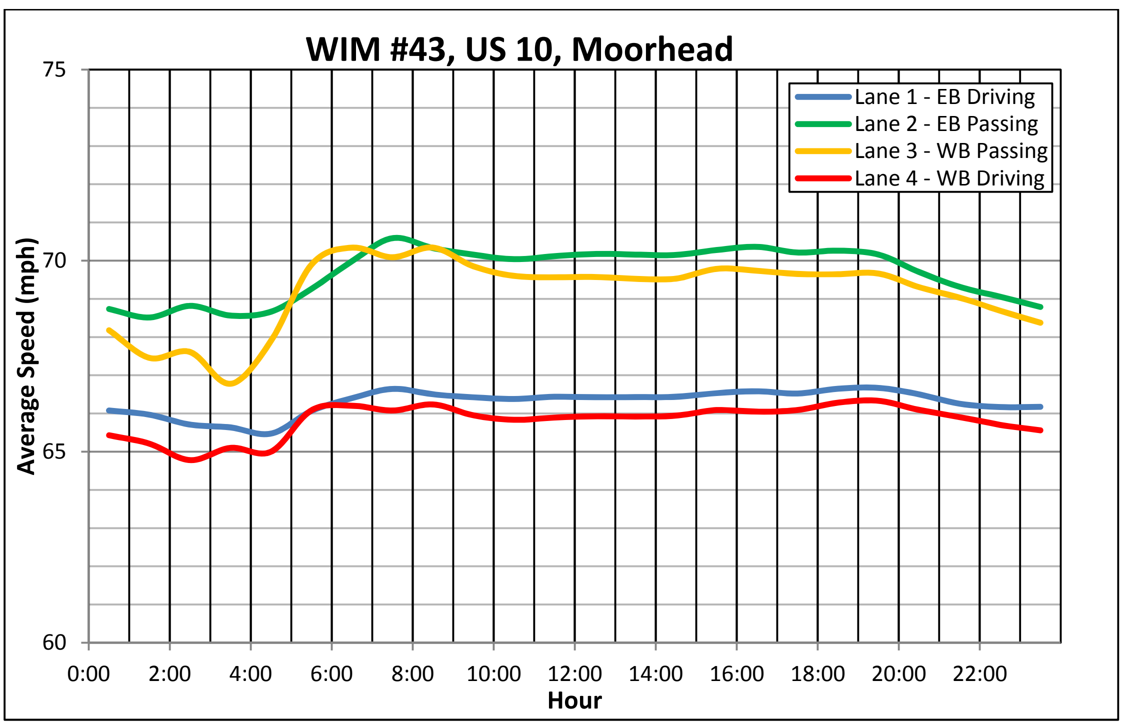


Figure 9.34. Average speed (mph) observed in the driving and passing lanes for each direction (eastbound; EB vs. westbound; WB) on an hourly basis. Speed limit: 65 mph.