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Traffic Safety Report

An Interactive Qualifying Project Report

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of the

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by

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Abstract

The Purpose of this project is to study traffic safety at Newton and Washington Square rotaries during peak travel times. The rotaries were chosen based on their use, location, and size. The two rotaries that our group chose for the project are contrasts of one another. Washington Square is a large rotary utilizing two lanes with four streets entering it, while the Newton Square rotary is a small rotary that has five streets entering it. The rotaries are also used by pedestrians very frequently with people walking through Washington Square to catch the commuter trains to Boston, and Newton Square is used mostly by students who are on their way to Doherty High School. A statistical and engineering approach is used to calculate the pedestrian and traffic safety of the rotaries. All traffic, pedestrian, turning counts from October and November of 2000 including the surveys of the surrounding residents at Newton Square and businesses at Washington Square were performed by the Interactive Qualifying Project group. All other statistical data were obtained from the City of Worcester Traffic Engineering Department. Suggestions on improvements are made based on the data obtained by the group and with the guidance of the City of Worcester Traffic Engineers.

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Acknowledgements:

Professor Hyunjoong Kim, Assistant Professor, Department of Mathematical Sciences Worcester Polytechnic Institute. Professor Kim introduced the group to the project and provided advice and guidance throughout the project. He also referred the group to the city of Worcester Traffic Engineering Department in order for the group to obtain assistance of the project. His knowledge of statistics provided the group with a basis to make recommendations.

Professor Balgobin Nandram, Associate Professor, Department of Mathematical Sciences Worcester Polytechnic Institute. Professor Nandram was a co-advisor to the project, and he provided a source of information, supervision, and suggestions on how to improve the project. He also referred the group to the city of Worcester Traffic Engineering Department in order for the group to obtain assistance of the project. His knowledge of statistic provided the group with a basis to make recommendations.

Mr. James Kempton, Junior Traffic Engineer, Department of Public Works, Traffic Engineering Division, City of Worcester MA. Mr. Kempton provided much information to the IQP group. He provided us with maps of the rotaries, accident data reports, recommendations, and knowledge of traffic engineering concepts. Mr. Kempton is a graduate of WPI. His understanding of an IQP helped us greatly. He gave us information of how to conduct traffic studies.

Mr. Ali Korasani, Traffic Engineer, Department of public works, Traffic Engineering Division, City of Worcester MA. Mr. Korasani gave us the idea to study Newton Square and Washington Square. He gave us information of how to conduct traffic studies.

Chapter 1

Introduction

1.1 Traffic Safety

Traffic safety could be a matter of life or death. It is a problem that all people have to face everyday of their lives. It is one of the leading causes of death each year in the United States. Whether they are the driver of a vehicle, a passenger of a vehicle or a pedestrian walking the streets, people die each day in traffic accidents. All these people, along with the roads and the automobiles, are factors in the safety of motor vehicle traffic.

People vary in all different aspects, especially when it comes to driving a motor vehicle. Some people have slower reflexes than others, some get more panicked in stressful situations, and some cannot concentrate as well as others. These characteristics of people factor into the safety of everyone that is out on the road. Drivers with slower reflexes may not be able to stop in time to avoid an accident. Drivers who get more panicked might not be able to think how to get out of an accident-causing situation. Drivers who do not have a high level of concentration might not be able to keep their minds on the road and can cause an accident. Also, the judgment of the driver must be taken into consideration. Drivers with bad judgment might speed, drive recklessly, or disobey regulatory signs. These are just a few of the characteristics of people that affect traffic safety.

The automobile also must be looked at when dealing with traffic safety. An unsafe car is not only illegal on the road, but is still a danger to society. Automobiles must be properly inspected to make sure that they are legal and safe to be driven on public roads. Not only should the automobile be inspected to preserve safety on the roads, but does the automobile have proper safety features that come standard with the car, such as airbags, mirrors, or seatbelts? Depending on how well-built the car is out of the factory and what safety features are in the car, the roads can be a safe or dangerous place for all people in the world.

The actual road that people drive or walk on is also a factor in traffic safety. The designs of the roads are extremely important to traffic safety. The roads must be designed with the correct number of lanes for the volume that travels on them, the proper streetlights and street signs, and the conditions of the roads. When designing roads, the designer must make sure the roads are not dangerous to drive on, such as a road with too sharp curves or a road with too steep. Also, he or she must factor in where traffic signals should be placed. This includes the timing of streetlights or the speed limits on certain streets. Determining the road conditions and characteristics of the pavement are also major factors in traffic safety. How the road will respond to the temperature or precipitation and whether this will create unsafe driving conditions should be factored in the construction of roads.

The main focus of this Interactive Qualifying Project (IQP) will be on the design of the roads (rotaries) and the proper strategy of traffic devices such as streetlights and signs in the Washington Square and Newton Square rotaries. As we have mentioned above, there are more factors in traffic safety, however, we will only focus on the ones that can help with our acquired engineering skills. The skills acquired will be presented in detail later in this report.

1.2 Traffic Congestion

Traffic congestion is a factor that must be considered when examining roadways. The flow of vehicles can be just as important as the safety on the roads. The roads must be designed and regulated well enough to keep the flow of traffic running smoothly and suitably. A combination of safety and traffic flow must be proportioned when examining roadways.

Traffic congestion is when the volume of cars exceeds the area of the roads, causing the traffic flow to slow down or come to a stop. There are many factors that must be considered when traffic congestion is examined. Some of these are the roads that people choose to travel on, the volume of people that are traveling on the roads, the sort of transportation that they choose, and back again to the design of the roads. These factors must all be examined when trying to prevent traffic congestion.

However, we cannot alter many of these factors. We cannot control the volume of cars on the streets or the roads that people choose to drive on. It is also hard to tell people to carpool or ride public transportation in order to cut down traffic congestion. The only factor that we can control enough to decrease traffic congestion is the design of the roads. All of the factors of designing roadways must be examined thoroughly, such as the number of lanes in the road, the timing of streetlights, and the speed limits of these roads. These will all be examined throughout the completion of the IQP.

1.3 Washington Square Problems

In the Washington Square rotary, the IQP group has found that the area of the rotary is greater than necessary. There is a large mass of land that is in the center of the rotary. Also, Washington Square is a highly commuted route for workers during the peak day shift times of 6 a.m. to 8 a.m. and 4 p.m. to 6 p.m. This is also a problem with pedestrian traffic, because the roads are wide where the crosswalks are and there are no stop signs in the rotary to give the pedestrians time to cross the roads. We also noticed a lack of yield signs for the streets that enter the rotary. This is a problem that we encountered while conducting the surveys for the project. Some automobile drivers are unaware of the laws of traffic flow in rotaries. Automobiles that are entering the rotaries are supposed to yield to automobiles that are already traveling in the rotary. We have seen automobiles "cutoff" traffic that is in the rotary and cause near accidents. These problems will all have suggestions for possible improvements later in the IQP.

1.4 Newton Square Problems

The main problem in Newton Square is traffic congestion. This is because of the small area of the rotary. This slows down the flow of traffic greatly, especially during the morning (6 a.m. to 8 a.m.) and afternoon (2 p.m. to 4 p.m.) commutes. Another problem is that there is a surplus of pedestrian traffic at the times mentioned earlier. This also slows down the traffic flow greatly and is also a danger to the pedestrians and the automobile drivers, because there are no signs regulating the flow of pedestrian traffic such as "pedestrian traffic" signs. These problems will all have suggestions for possible improvements later in the IQP.

1.5 Project Objectives

This project will evaluate problems dealing with traffic safety at two rotaries in Worcester, MA. The two rotaries are at Washington Square and Newton Square. This also includes the streets leading into the rotary.

To begin the project, the IQP group traveled around Worcester to get an understanding of traffic concerns and troublesome areas of random intersections. The group found two sites, which seemed to be of a problem at the time. The group then met with the City of Worcester Department of Traffic Engineering. The engineers, together with Professors Nandram and Kim, suggested several possibilities of areas that were of concern to them. The group decided to study the previously mentioned rotaries and the engineers agreed. The main concern of this project will be Washington Square, while Newton Square will allow a comparison of another rotary that is a problem.

The group has attained historical data through police reports, which will give them a basis to start their research. They will then go on to acquire traffic studies done by the Massachusetts Highway Department and compare them to studies done by the group. Interviews of surrounding businesses and residents will also be taken by the group to gain knowledge of people that are affected day to day by traffic through these rotaries. Surveys will also be distributed to the affected people for the same reason as above. This data will allow us to help identify problems and recommend a solution to them.

Chapter 2
Possible Studies

Certain traffic studies will help the IQP group gather data about how we can improve the two rotaries, Washington Square and Newton Square. This data will be collected in the field of study. With the help of the Worcester Traffic Department, the data will be calculated to show what changes will improve the rotaries. The following studies were ones that we learned about when we did our early research of traffic safety. We came to the conclusion that these studies could be used to improve the two rotaries.

2.1 Turning Movement Counts

A turning movement count (TMC) is a rather simple way to examine the traffic flow at any kind of intersection, including a rotary. The TMC counts the number of cars that travel through and intersection, giving a total volume of traffic flow, and more importantly, the direction that the car travels after it enters the rotary. This data that collection is tabulated and put onto charts and/or diagrams to get a better understanding of what could improve the traffic flow and safety of the rotary. TMC's are mainly used for intersections that are in question of reconstructing, whether it be turning the rotary into a four-way intersection or adding another lane or streetlight. These TMC's are most effective if they are done during the peak commuter hours (6-8am) and (4-6pm). This is because it will give you the worst possible situation for your intersection that you should ever encounter.

This project includes Turning Movement Counts on Washington Sqaure and Newton Square. The TMC's were completed at the morning and evening pak commuter hours. The traffic was most congested at this time and it gave us data for the worst possible driving situation. The possible solutions to the traffic flow in these two rotaries were proposed for the two time periods listed above.

2.2 Driver Observance Study

This study is an observance of how easily and readily drivers observe street signs and lights. This study is used to show how effective street signs and lights are in a certain intersection. Drivers volunteer to drive through intersections and observe the signs in the area and see how effective they are and if not, why they are not effective. This might show the traffic engineers that certain things should be changed, such as traffic sign locations. Certain observances that could cause traffic congestion are that the lights at the intersections are perhaps not long enough for one direction through an intersection or too long for the perpendicular direction. This usually always leads to traffic congestion and must be acknowledged by traffic engineers when studying the effectiveness of a certain intersection. Another observance by drivers might be a strong recommendation that another lane constructed at the intersection or a special turning signal in order to keep the traffic flow moving effectively.

2.3 Traffic Counting Study

Traffic Counting Studies will result in a close approximation of the traffic flow in a certain intersection. These studies not only tell traffic engineers what needs to be done to keep the intersection flowing effectively, but it also tells the city planners whether there should be certain parking lots in this area. This information is distributed not only to the traffic engineers, but also to transit authorities such as bus companies and taxi services. This information is also helpful to the police department of the town or city where the intersection resides. The study helps the police department by giving them more effective routes of travel and also the more necessary areas to patrol.

2.4 Crash Study

A Crash Study is the evaluation of actual crash records that are recorded and saved by the police department. These crash records provide traffic engineers with the ability to determine which intersections are in need of improvement based on the number of accident that occur per a unit of time. These crash records also aid traffic engineers in determining which traffic studies would be useful to solve the problems in certain intersections.

The Crash records are held and filed by the Department of Traffic Engineering, which are acquired from the police department. The police department keeps all of the original documentation. Well-kept traffic records are imperative for a good traffic study to be completed. These studies will result in spot map diagrams, driver crash and violation records, crash location records, and monthly analysis.

A Spot Map Diagram is a layout of an intersection in which a crash study is completed. Pins are placed where accidents have occurred based on the description of the crash reports. Spot map diagrams can have as many years of data on it, however, it is commonly found that there are one to three years of data researched on each spot map diagram. Spot map diagrams show the main problematic areas of an intersection, so that they can be reengineered. Spot map diagrams can also be more specific to time, kind of accident, and if there was a fatality.

When the most problematic areas have been found, research of what kind of accident happened should be completed. From this data, collision diagrams are prepared. These diagrams are a drawing of an intersection where problematic areas are found. Information such as the type of crash, time of the crash, the weather conditions, and if a fatality had occurred is represented on the diagram where the actual crash has occurred. This is done by creating a legend of the pertinent information that conveniently and effectively shows where the crash has occurred. This diagram also can be used to research varying time intervals, but the most common ones are a few months to a year.

Filing the crash records can be just as useful as a crash diagram. By filing these records into certain forms, engineers can see what problems exist in certain areas and how they can be fixed. An example of filing crash records appropriately to assist in the engineer's job is separating the time of crashes, whether they occur in the winter or summer, day or night, or weekday or weekend. The type of vehicle in the crash is also important. This will tell the engineer whether the crashes are caused by residential traffic or commuter traffic.

All of this information is useful in determining what can be done to solve the problems in the intersection in question.

2.5 Transit Traffic Study

A Transit Traffic Study is a study based on observations of transit vehicles in a specific area. The main purpose of this study is to acquire information about mass transportation in a specific area. Some of the necessary information that is needed to make a transit traffic study effective are the volumes of the transit, the speed of the transit, the time of loading and unloading, delays that may occur, and once again, crash data of transit vehicles. This information can easily be acquired with the proper studies: transit volume counts, speed and delay studies, transfer and loading points studies, and crash record analysis.

2.6 Parking Study

They show traffic engineers if parking lots or garages need to be constructed to condense traffic congestion and minimize accidents that occur because of traffic congestion. Parking studies are vital to traffic engineering. There are three main parking studies: Inventory Study, Usage Study, and Demand Study.

2.6.1 Inventory Study

Inventory studies research what types of parking are available in a specific area of a city. These could be parking lots, parking garages, or parking spaces on the sides of streets. This study is normally completed in commercial areas where many businesses are located, including their surrounding areas within a certain distance.

2.6.2 Usage Study

This study determines how the parking spaces, lots, or garages are being used. The study finds the number of automobiles parked in an area, the duration of the time that an automobile is parked in the area, and the type of automobile it is. This study is also done in the main commercial areas of a city.

2.6.3 Demand Study

This study is completed to see what areas are best needed to have parking facilities. Personal interviews are usually completed to find out where and why parking designations are needed. This study is also usually completed in commercial areas, but is also needed in residential areas, especially in large cities.

Chapter 3

Studies Performed by IQP Team

3.1 Studies Performed by Department of Traffic Engineering

The Worcester Department of Traffic Engineering was responsible for supplying our project group with a couple of vital studies that helped jump-start our project and data collection in the right direction. We received from the traffic department volume counts for Washington Square and police reports for both Washington and Newton Square.

3.1.1 Volume Counts

The volume counts that we received were for Washington Square on the date of 6/21/00. They also provided volume counts to us from the late 1980's, which we eventually discarded because they were out of date and we had in our custody the more recent data. The volume counts show us where and how many cars traveled through the Washington Square rotary for the peak times during the day. This was very helpful in showing us exactly which streets running into the rotary were being used more frequently. In this it showed us what the volume entering and exiting the rotary from every street, which helped us to realize where and how the rotary was being used i.e. (going to the train station or passing through the rotary going to work in downtown Worcester). We did not receive any previous volume counts for Newton Square because of the lack of interest of the city in that rotary.

3.1.2 Police Reports

The Worcester Traffic Engineering Department also provided us with the police reports from 1996 through the year of 1999. These reports are the crash records previously discussed in Chapter 2.4, and they reports provided us with a great deal of information about the two rotaries. The reports showed us exactly where, when, and what type of accidents occurred within the rotaries. These reports made it possible for us to compile many comparisons within the rotaries, such as spot diagrams, which show exactly where the accidents occur in the rotary for each year. We also made comparison in the rotary between what seasons accidents occur, different times during the day, and from which intersections in the rotary the accidents occurred. Overall the accident reports were of great importance to get a general feel of how well the rotaries are constructed.

3.2 Studies the IQP Group Performed

In order to gain a better understanding of the problems or lack thereof at Washington Square and Newton Square, traffic studies were done by the IQP group. Three studies were performed: a crash study, a turning movements count study, and a pedestrian count study. These studies were performed in order to gain a better understanding of the rotaries in question.

3.2.1 Crash Study

Crash data is important in order to gain information about when and where accidents are happening and whether they are random or at specific areas in the rotary. This will allow recommendations for traffic improvements if needed.

In the U.S. a police report must be written in the case of any type of motor vehicle accident. These reports are kept in the local police station, Traffic Engineering Department, or public library. The police reports provide a diagram of where accident took place, along with weather conditions, time of day, persons involved, persons injured, and type of accident (rear end, head on, or angle accidents).

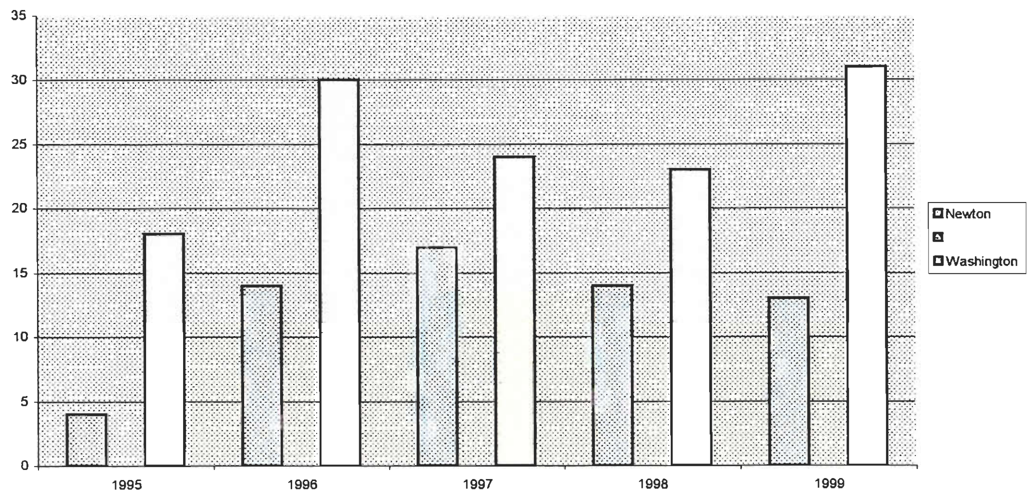
The information for this traffic study was obtained from the city of Worcester Department of Traffic Engineering. Accidents involving death or serious injury could not be collected for this report, because police hold this information to further investigate these accidents. Crash data was collected for the years of 1995 through 1999 for both Washington and Newton Squares. Five years of accident reports are sufficient for showing trends of accidents in the squares and allow for recommendations of improvements and which spots, if any, need to be looked at for further analysis.

3.2.1a Washington Square Traffic Accident Reports

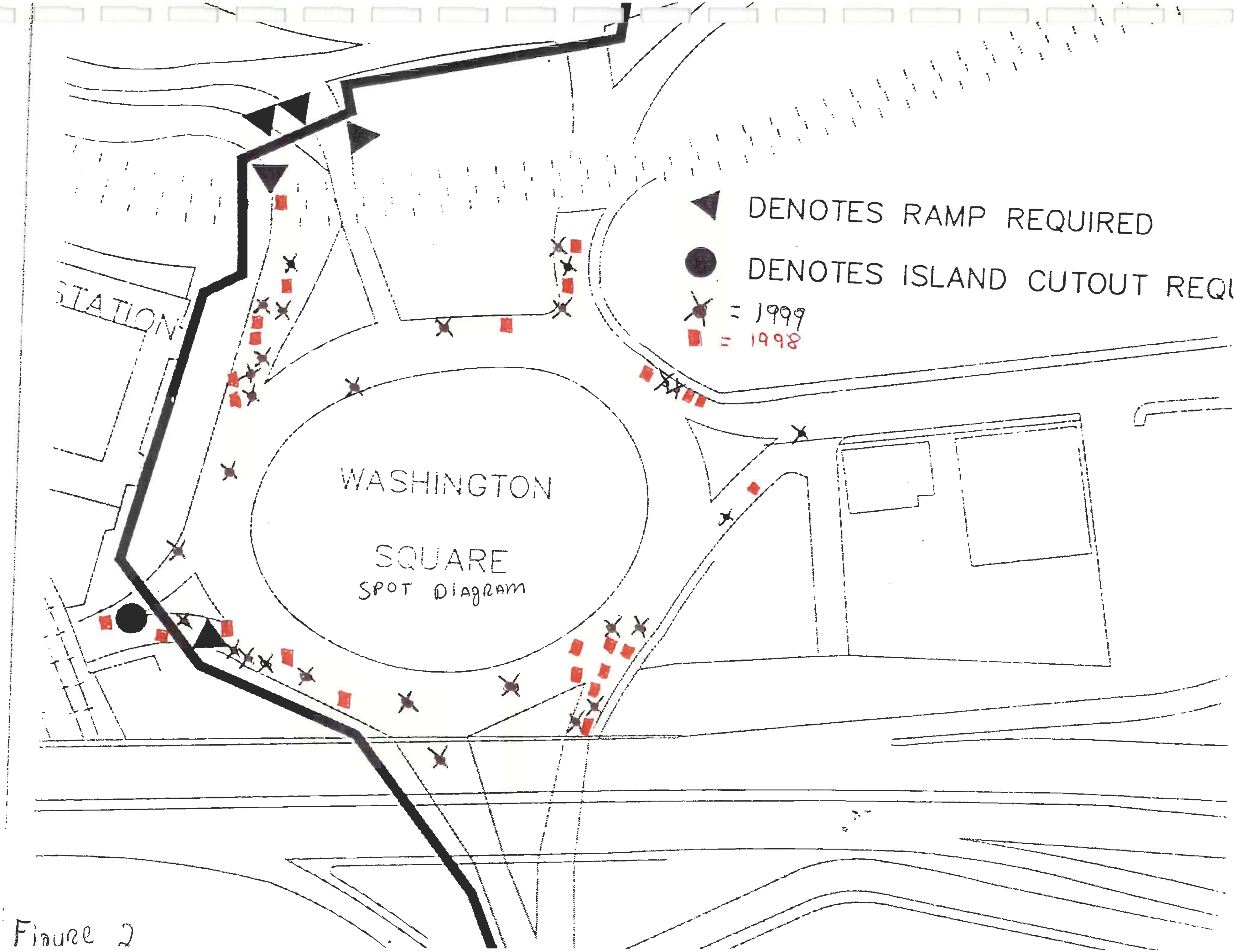
The Washington Square traffic accident reports were very valuable to understand the intensity of the problem that we were dealing with. The total number of accidents grew in Washington Square from 18 in 1995 to 31 in 1999.

1999 had the most accidents with just one more then in 1996. This information is presented in Figure 1. This data shows us that there is a problem with many accidents occurring within this rotary.

Fig. #1
Total Accidents



After completing this we wanted to see where the accidents were taking place in the rotary. The IQP group did this by making a spot diagram for the years of 1998 and 1999 from the accident reports. The spot diagram can be seen as Figure 2. We can see from this diagram that many of the accidents are occurring at the on ramps of the rotary. This can be contributed to people not understanding or following the laws of the posted signs as they enter the rotary. Incoming traffic might not yield to the traffic that is already in the rotary that has the right of way cutting them off, causing accidents or stopping suddenly and being rear-ended by other cars entering the rotary.

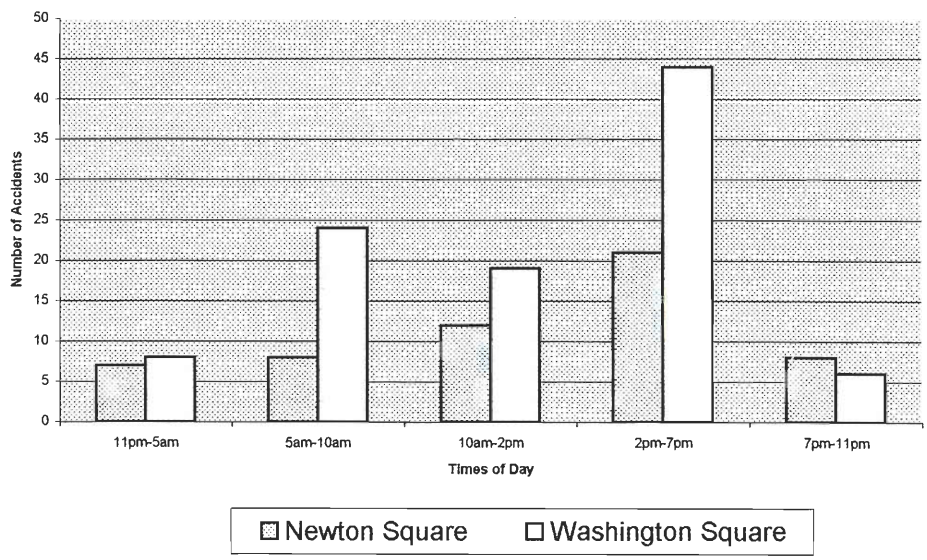


DENOTES RAMP REQUIRED
DENOTES ISLAND CUTOUT REQU
= 1999
= 1998
STATION
WASHINGTON
SQUARE
SPOT DIAGRAM

Figure 2

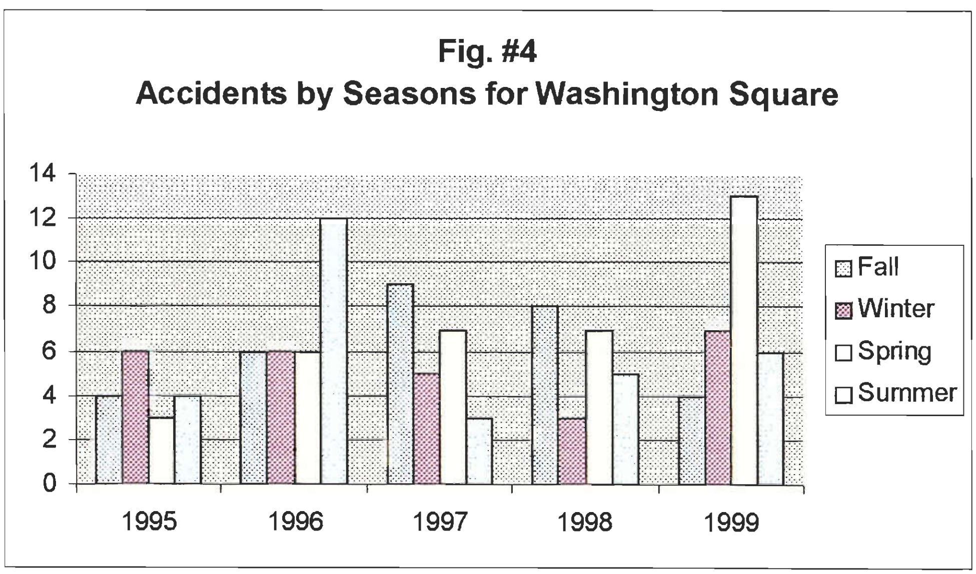
The next situation that we wanted to look at was if the time of day mattered for when accidents occurred. The IQP group did this by breaking the day into five time segments, which were 11 p.m. to 5 a.m., 5 a.m. to 10 a.m., 10 a.m. to 2 p.m., 2 p.m. to 7 p.m., and 7 a.m. to 11 p.m. The trend that we saw from this data in Washington Square was that the majority of the accidents happened during rush hour times. During the 5 a.m. to 10 a.m. morning rush hours was that there were 24 accidents and during the evening rush hours there were 44 accidents. During the other hours there were only 8 accidents from 11pm-5am, 19 accidents form 10am-2pm, and only 6 accidents from 7pm-11pm. These figures can be seen in Figure 3.

Fig. #3
Accident By What Time of Day For 1995-1999



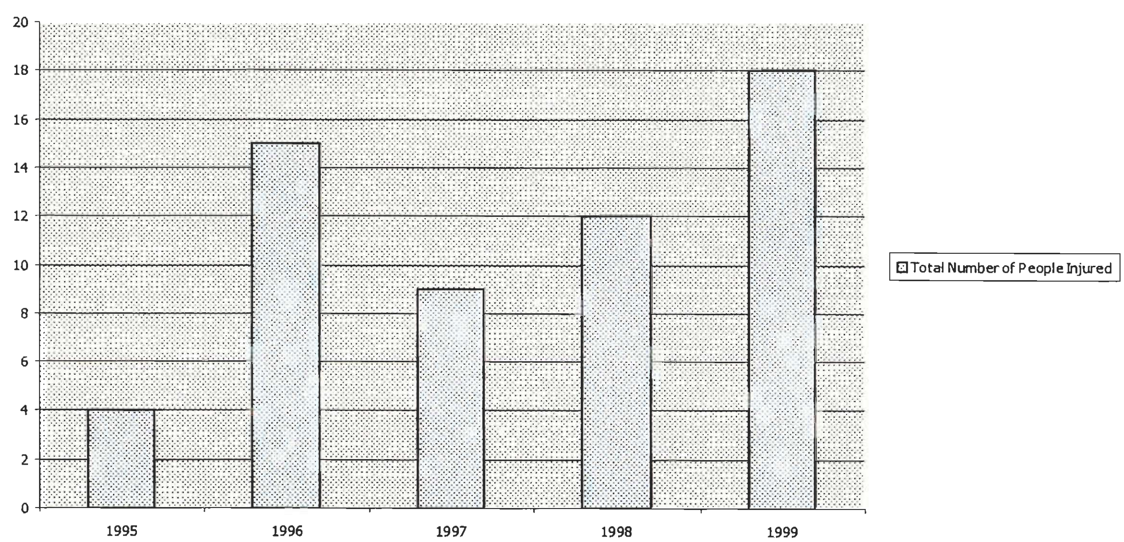
The relatively high number of accidents that occurred for 5am-10am can be attributed to the morning rush hour and that the traffic volume flowing through Washington Square is much larger then the other time. This is also true for the evening rush hour, because of the high volume of traffic that uses the rotary at this time. From 10 a.m. to 2 p.m. there are also a lot of accidents that occur, and this can be because of people using the rotary during their lunch breaks. But overall we see that the majority of the accidents occur during the peak travel time, which are both the morning and evening commute.

The next problem that we wanted to look at was if this happened more frequently during the different seasons. What we found for Washington Square was that the accidents by seasons did not really make much of a difference, but as we broke these seasons down by the years there was some important information that we found. In 1999 we saw that the most number of accidents occurred during the winter, which can be contributed to hazardous road conditions during the winter. Also during 1996 we found that 12 accidents occurred during the summer, which might have occurred from larger amount of people driving more frequently during the summer. This data can be seen in Figure 4.



We then next wanted to see if people were being injured in any of these accidents. This would be a large factor in seeing how dangerous Washington Square really is. The IQP group found that in five years many people had been hurt in Washington Square, with a total of 58 people becoming injured. We also found that the number of people injured per year was rising from that of only 4 in 1995 to 18 in 1999. There also were 15 people injured during the year of 1996. The number of injuries from these years and the other two can be seen in Figure 5. This is really alarming in that it has been rising. With further investigation we found that there was construction being done on the rotary during the 1999 year, which could have contributed to the rise in accidents. The number of accidents could have risen because of the larger number of traffic volume that is now flowing through the rotary than five years ago. A problem seems to exist, and the number of people being injured should be looked into and improvements should be made.

Fig. #5
Total Number of People Injured



3.2.1b Newton Square Traffic Accident Reports

The accident reports were also valuable to the IQP group in evaluating the problems of Newton Square. What we found for Newton Square was that the number of accidents that happened in the square was relatively similar for each year. The only year that was extremely different was 1995, which only had 4 accidents that happened in the rotary. This data is presented in Figure 1 previously. The total number of accidents was a lot smaller with 62 accidents in five years compared to Washington Square with 126 total accidents. This happened because the total volume of traffic flowing through Newton Square is considerably less than that of Washington Square. The concern with this rotary is that it is in a very residential area and very close to Doherty High School. This brings up the concern that many of the accidents will be involving children going to or leaving from the school. This is a major concern and will be analyzed further when the total number of injuries is reviewed.

Next again we wanted to see where the accidents were happening in the rotary. We did this by making a spot diagram for Newton Square. This showed us exactly where the accidents were taking place, and it again as with Washington Square many of its accidents occur where streets entered the rotary. Examining the spot diagram, the majority of the accidents occurred in between Pleasant Street (South) and Highland Street. This could be happening because most of the traffic entering the rotary is entering the rotary by Pleasant Street (South) and exiting the rotary onto Highland Street. This also adds to the notion that many of the accidents are occurring form people traveling to the high school, which is located on Highland Street. Another hot spot for accidents was by June Street and Pleasant Street (North). This can be seen in Figure 6.

The next situation that the IQP group wanted to assess was if the time of day mattered for the frequency of accidents that occurred within Newton Square. What we found was that the high number of accidents occurred during the 2pm-7pm range, which was 21 accidents. This could be happening because of the large number of people that use the rotary on their ride home from work, and the large number of students who are on their way home from school during this time. This data is presented in Figure 3 previously. The rest of the time periods were even with the number of accidents.

The next situation that the group looked at for Newton Square was if the different seasons effected when the accidents happened. What we found was the total number of accidents for the season did not affect the accident rate. Then when we broke the data into seasons by years we found that for 1996 and 1998 the majority of the accidents occurred during the fall. This could have happened from early winter conditions arriving, and people not being aware of the dangerous road conditions. These results can be seen in Figure 7. We also found that during 1997 the winter and summer had the most accidents occur. This could be due to the hazardous road conditions during the winter, and more people using the rotary during the summer.

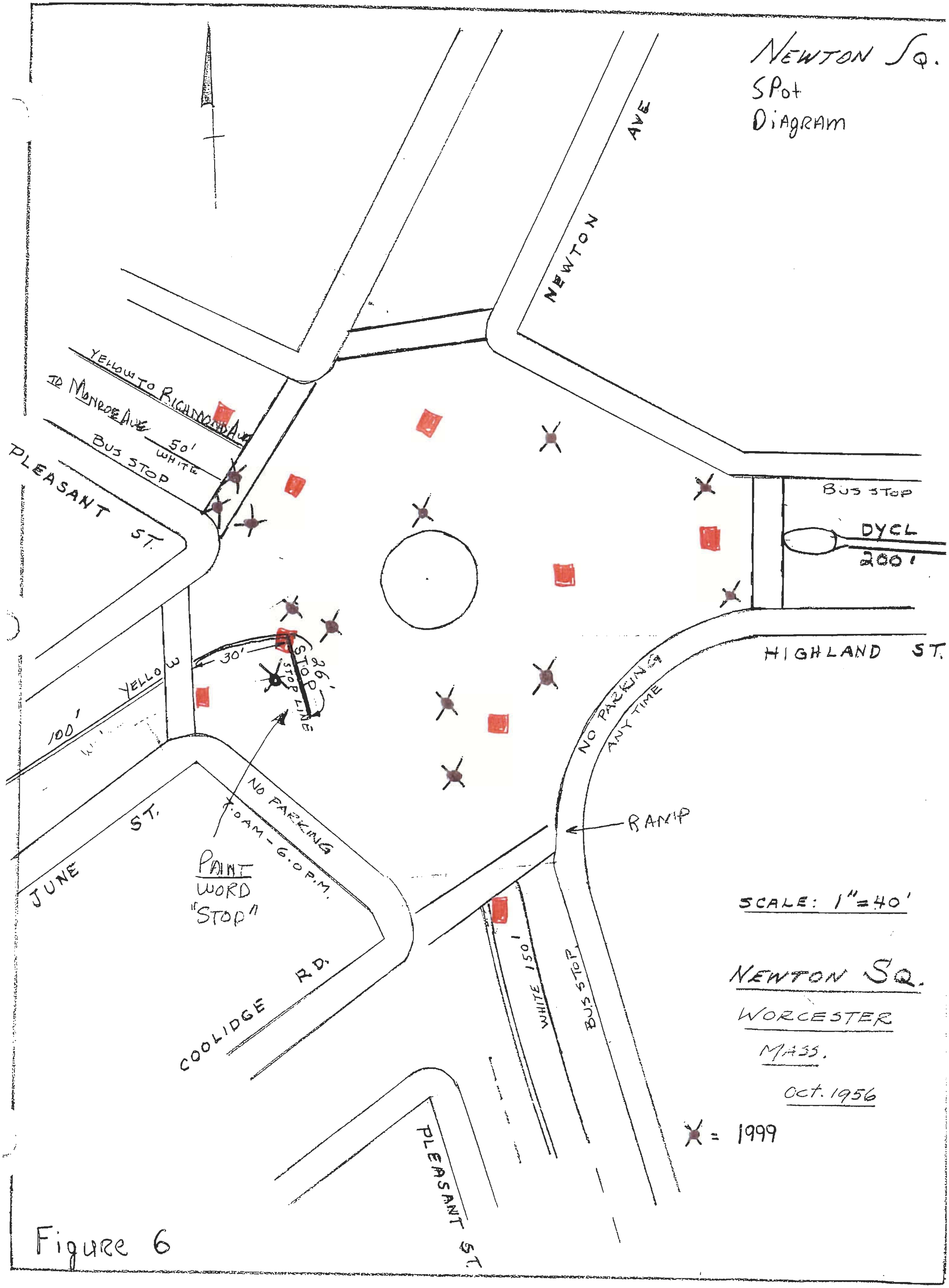
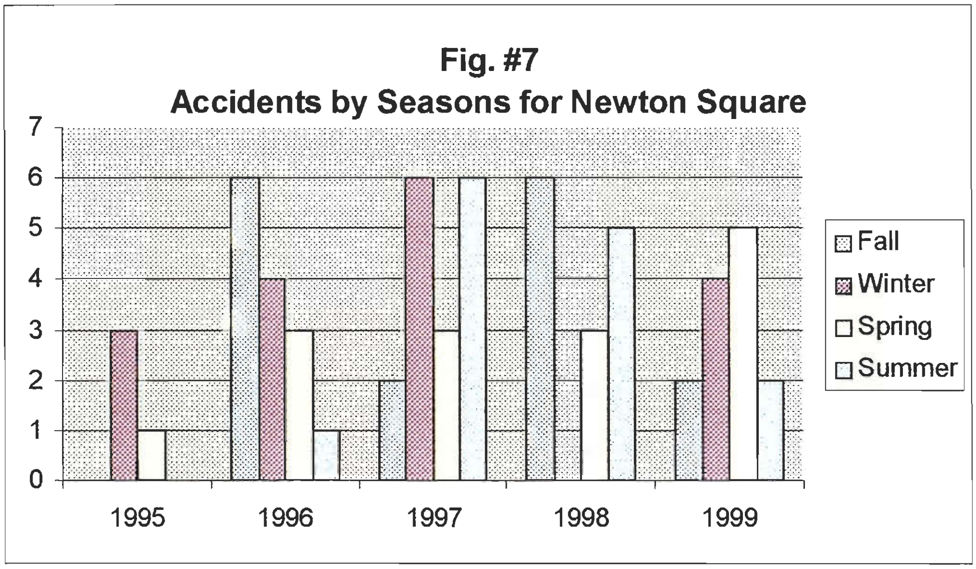
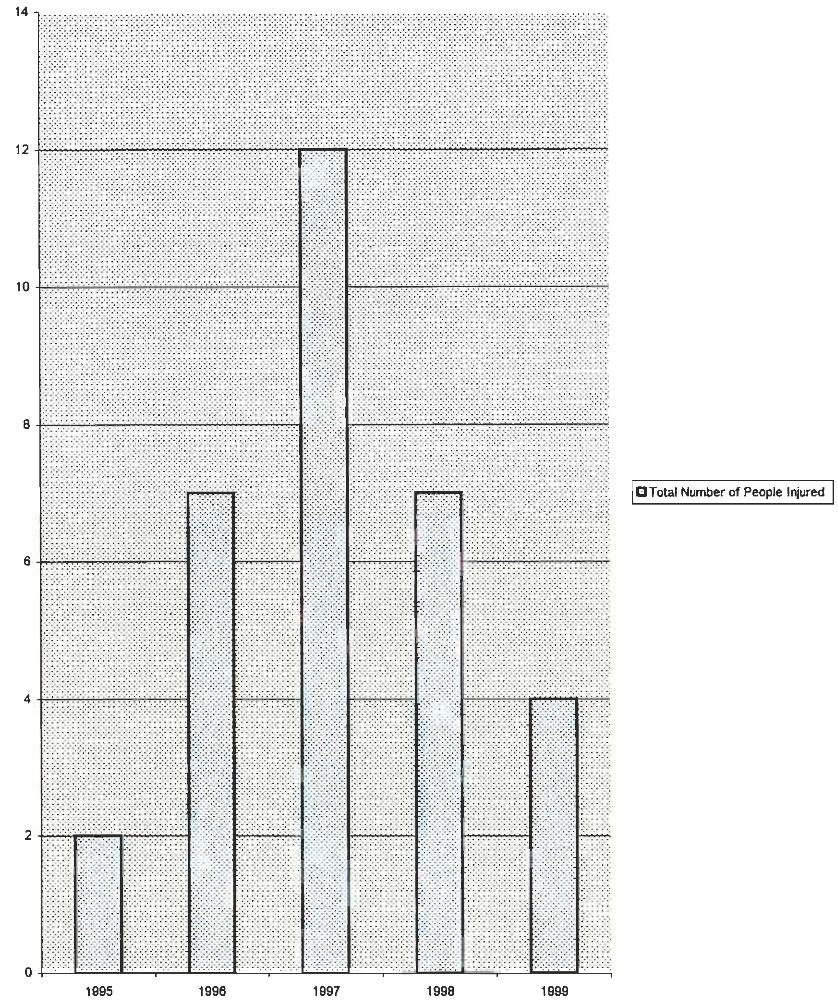

Newton Sq.
SPot
Diagram
NEWTON
AVE
YELLOW TO RICHMOND AVE
TO MONROE AVE
50'
WHITE
BUS STOP
PLEASANT
ST.
BUS STOP
DYCL
200'
HIGHLAND ST.
30'
26'
STOP
STOP LINE
YELLOW
100'
NO PARKING
ANY TIME
RAMP
JUNE
ST.
NO PARKING
7.0 AM - 6.0 P.M.
PAINT
WORD
"STOP"
COOLIDGE
RD.
WHITE 150'
BUS STOP
PLEASANT
ST.
SCALE: 1"=40'
NEWTON SQ.
WORCESTER
MASS.
Oct. 1956
= 1999

Figure 6



We next wanted to see if from these accidents that were occurring within Newton Square and if many people were being injured. We found that for 1995 and 1999 and number of people injured were relatively low, with 2 and 4 people injured. But it then grew to 7 people injured for the years of 1996 and 1998. These numbers are relatively low. But then in 1997 the total number of people injured jumped to 12, which calls for concern. The total number of people injured for Newton Square is less of that than Washington Square because the rotary is much smaller. This makes the traffic travel slower, hence, causing fewer injuries to occur when accidents happen. This data is show in Figure 8.

Fig. #8
Total Number of People Injured for Newton Square



3.2.2 Turning movement Counts

Turning Movement Counts were performed at peak travel times during the weekdays in clear weather for both squares. The peak travel times were determined to be the morning commutes (7:00 to 8:00am), afternoon traffic (12:00pm to 1:00pm), and the evening commute (5:00pm to 6:00pm). The purpose of performing turning movement counts is to determine the flow of traffic around the rotaries. This is crucial to determining whether traffic devices, such as stop signs, yield signs, or traffic lights, or if reconstruction is needed in order to obtain the safety needed in the rotaries. Appendix B shows all the turning movement counts that we preformed on both squares.

3.2.2a Washington Square Turning Movement Counts

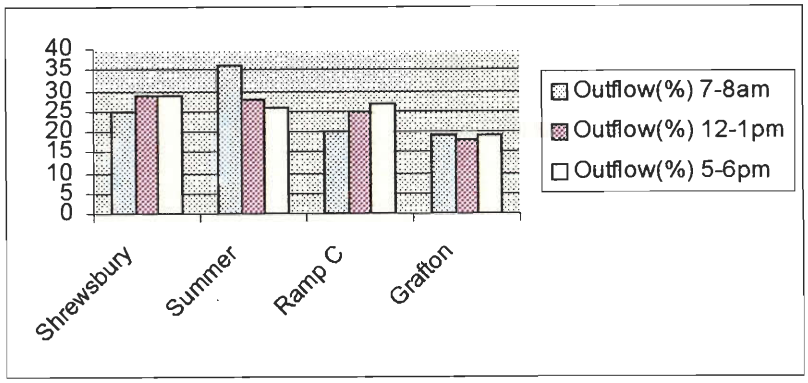
The Washington Square rotary turning movement counts will now be discussed for all times. While observing the Washington Square rotary during the morning commute hours (approximately 6:00 to 10:00am), we came to the conclusion that the peak volume hour stood between 7:00 and 8:00am. At this time we decided to take our turning movement counts for the morning commute. Four fifteen-minute interval traffic counts were recorded and through a series of equations the turning movement counts for this hour were calculated. From these values we determined the maximum traffic volumes and other traffic measurements. The turning movements count percentages for Washington Square for both outflow and inflow can be seen in Figure 9.

Figure 9

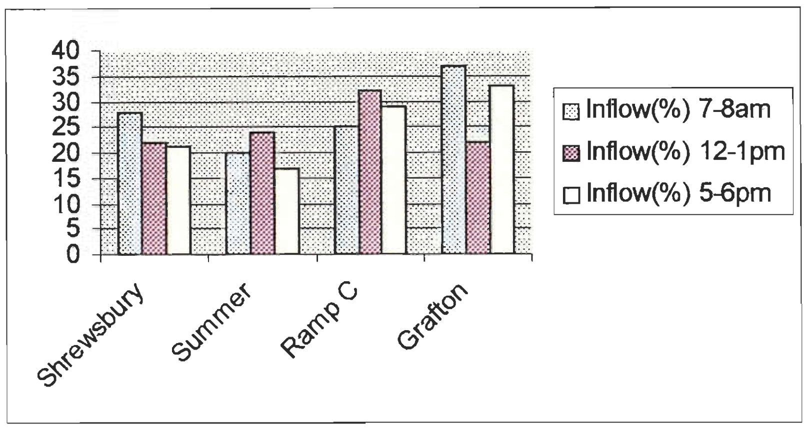
Flow Rate Comparison for Washington Square

	Outflow (%)		
	7-8am	12-1pm	5-6pm
Shrewsbury	25	29	29
Summer	36	28	26
Ramp C	20	25	27
Grafton	19	18	19

Figure 9 (cont.)



	Inflow (%) 7-8am	12-1pm	5-6pm
Shrewsbury	28	22	21
Summer	20	24	17
Ramp C	25	32	29
Grafton	37	22	33



From these measurements we could determine where congestion problems were evident and to what extent they affect traffic flow. We could also determine what percentage of traffic was entering and exiting the rotary and which streets were being used for exiting and entering. An explanation will also be made as to why the traffic could be using the relevant streets.

The majority of the traffic leaving the rotary exited via Summer Street (Appendix D14) and Shrewsbury Street (Appendix D11, D12). Over 60% of the traffic used these two streets. 36% exited the rotary through Summer Street. Summer Street leads to the north end of downtown Worcester, which is a popular business district in the area. 25% exited via Shrewsbury Street. The MBTA station is located on Shrewsbury Street where many of the morning commuters are dropped off or use the parking lot located at the MBTA station. There are also many businesses located on Shrewsbury Street and the adjacent streets.

While observing the Washington Square rotary during the evening commute hours (between 4:00 p.m. and 8:00 p.m.), we came to the conclusion that the peak volume hour stood somewhere between 5:00 p.m. and 6:00 p.m. This is when we decided to take our turning movement counts for the evening commute. Four fifteen-minute interval traffic counts were recorded and through a series of equations, turning movement counts for this hour were calculated. From these values we determined the maximum traffic volumes and other traffic measurements.

From these measurements, we could determine where congestion problems were evident and to what extent they affected the traffic flow. We could also compute where the majority of the traffic was entering and exiting the rotary and give possible explanations to why this is happening. The following paragraph will explain our conclusions.

The major part of the traffic entering the Washington Square rotary is from Grafton Street (Appendix D18) and Ramp C (Appendix D15). These two streets account for over 50% of the traffic entering the rotary. The highest percentage is from Grafton (33%) with the next coming from Ramp C (29%).

Less than ¼ of a mile down Grafton Street is a parking lot used for people riding on the commuter rail at the MBTA station. Many people return from work via the commuter rail at this time, which accounts for the highest percentage of people entering the rotary by Grafton Street. Ramp C is also used frequently for traffic entering the rotary. Ramp C connects Main Street to Washington Square. Main Street hence its name, is the main street used in Worcester. It is near the Worcester Common Outlets and the Worcester Centrum Centre. Many people coming from downtown use the rotary to either pick up people at the MBTA station or use it on their trek home.

While observing the Washington Square rotary during "afternoon traffic" hours (approximately 12:00pm to 1:00pm) we came to the conclusion that the peak volume hour stood somewhere between 11:00am and 2:00pm. At this time is when we decided to take our turning movement counts for "afternoon traffic". Four fifteen-minute interval traffic counts were recorded and through a series of equations turning movement counts for this hour were calculated. From these values we determined the maximum traffic volumes and other traffic measurements.

The biggest part of the traffic entering Washington Square rotary was by Ramp C. 32% entered the rotary via Ramp C. All other traffic entering the rotary by the other streets was about the same. Traffic from Ramp C is coming from downtown. We believe that many people are entering the rotary from downtown to get lunch at one of the establishments located near the rotary, particularly down Shrewsbury Street and Summer Street, where there are more restaurants.

The majority of the traffic leaving the Washington Square rotary is through Shrewsbury Street and Summer Street. Nearly 60% of the traffic is exiting the rotary via these two streets. 29% of the traffic in the rotary is leaving the rotary by Shrewsbury Street and 28% by Summer Street. The reason for this is that there are many food establishments on these two streets. Many people are taking their lunch break at this time while running some errands also.

Congestion in the rotary is not a problem. The rotary carries the flow of traffic very well. This is due to the large size of the rotary and the spacing of the streets connecting to Washington Square.

3.2.2b Newton Square Turning Movement Counts

In observing the rotary at Newton Square during the morning commuting hours one would come to the conclusion that the highest traffic volume and intensity would occur during the approximate hours of 7:00 and 8:00am. Newton Square is within ¼ mile of Doherty High School, within 1 mile of Worcester Polytechnic Institute, within 2 miles of Worcester State College, and within 2 and ½ miles of downtown Worcester. The location of this rotary could account for traffic problems due to the high volumes of traffic that use Newton Square as part of a particular travel route to a particular destination. The turning movements count percentages for Newton Square for both outflow and inflow can be seen in Figure 10.

Figure 10

Flow Rate Comparison for Newton Square

	Outflow (%) 7-8am	12-1pm	5-6pm
Pleasant (S)	31	25	23
Highland	24	19	18
Newton	6	11	12
Pleasant (N)	23	21	24
June	17	21	23

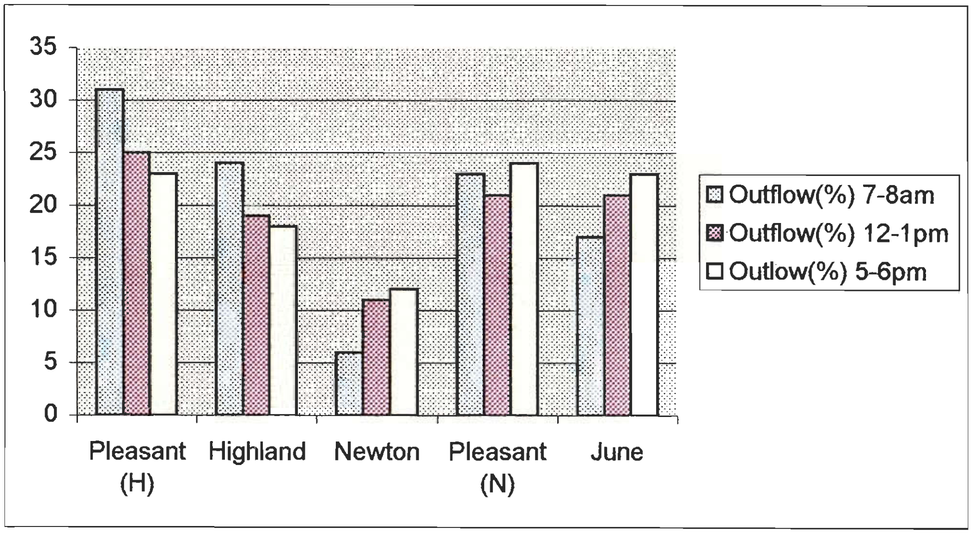
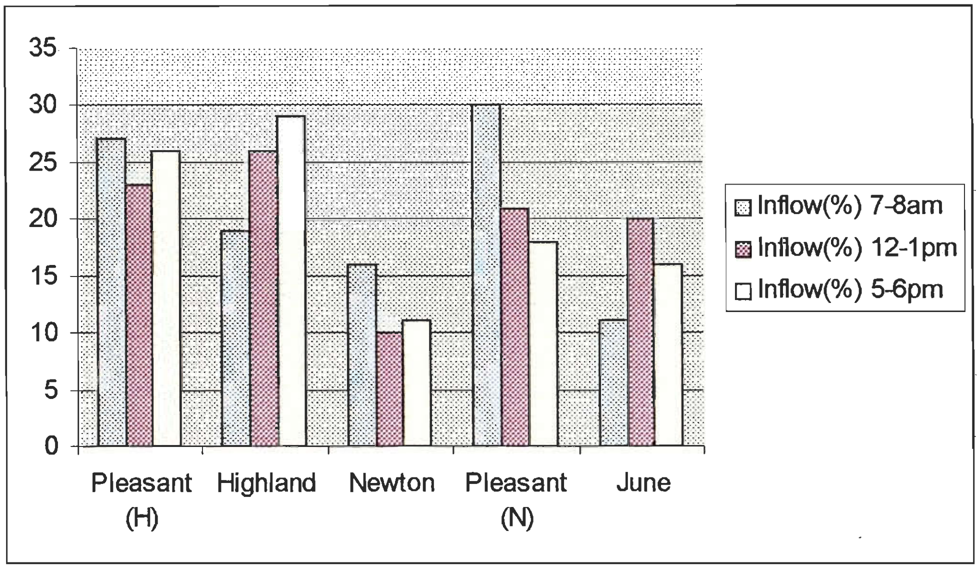


Figure 10 Continued

	Inflow (%) 7-8am	12-1pm	5-6pm
Pleasant (H)	27	23	26
Highland	19	26	29
Newton	16	10	11
Pleasant (N)	30	21	18
June	11	20	16



More specifically, our team studied the rotary by ways of traffic engineering methods. We took turning movement counts and determined other traffic measurements such as Traffic Flow Rates, Traffic Intensity Rates, Turning Movement Rates, and Traffic Volumes. These values one can be used to analyze a rotary, and to make judgments in explaining reasons in explaining reasons for problems such as congestion, or other accident related problems.

The major part of the morning traffic comes from Pleasant Street (North) (Appendix D5). Over 50% of the traffic enters the rotary via these two streets with 27% entering from Pleasant Street (South) and 30% from Pleasant Street

(North). There are many possible reasons for the high percentage of traffic entering the rotary through these two streets. Pleasant Street (North) and Pleasant Street (South) have the biggest percentage of homes in the residential area. The people using the traffic are commuting to work or dropping off their children at Doherty High School.

However, Pleasant Street (South) has the highest percentage of traffic leaving the rotary, with Pleasant Street (North) and Highland Street having nearly the same percentage leaving the rotary. Nearly all the traffic exits through these three streets. 31% exits from Pleasant Street (South) with 24% and 23% exiting from Highland Street and Pleasant Street (North), respectively. There are some possible reasons for the majority of the traffic exiting the rotary by these three streets. A reason for traffic exiting the rotary and entering Highland Street is due to the fact of Doherty High School is located within ¼ mile of Newton Square. School starts approximately at 8:00am. Many parents and even students enter Highland Street from the rotary to drop off their children or go to school. Another possible reason could be that that people are heading to downtown Worcester. Highland Street gives a direct route to downtown Worcester where many people might work or go shopping at the Worcester Outlet Center, which is also located in downtown Worcester. Pleasant Street (South) handles the most traffic exiting the rotary. There is a major industrial area located near the end of Pleasant Street (South). Many people are going to work at the locations in the industrial area. This accounts for the majority of the traffic entering that street. Some reasons for this could be that people are dropping off their children at school and then returning before they go to work.

Upon conducting turning movement counts and general observations of the rotary, we noticed that there was some congestion at all intersections in the rotary. This is due to the high volume being trafficked in the small rotary. The worst congestion took place at June Street. There is a stop sign at June Street. However, there are no stop signs at any of the other locations. All vehicles at June Street have to stop before entering the rotary, which makes it extremely hard for them to enter, because there was a high density of traffic in the rotary.

The hours of 4:00 p.m. to 6:00 p.m. constitute the "evening" commute or the commute of people leaving work. Newton Square is in the middle of a highly residential area that represents a high volume of traffic entering and exiting the rotary. The group performed turning movement counts of Newton Square from 5:00 p.m. to 6:00 p.m.

The major part of the evening traffic enters the rotary by Highland Street and Pleasant Street (South). Over 50% of the traffic enters the rotary through these two streets. 29% of the traffic enters the rotary from Highland and 26% from Pleasant Street (South). We believe the high percentage of traffic entering the rotary from Highland Street is due to the fact that people who work across town are coming home and also that people are coming back from downtown, which employs many people and where everyday business takes place. There are many banks, shops, and etc. near downtown Worcester Common Outlets. Another source for the traffic might be that of Doherty High School. Many sporting events that take place at the high school, such as athletic practices, generally end between the hours of 5:00 p.m. and 6:00 p.m. A large amount of students who attend Doherty High School live in the residential area surrounding Newton Square. Pleasant Street (South) extends to an industrial area starting about 1 mile down Pleasant Street (South) and continuing from there. Many people who live in the Newton Square residential could be employed by many of the companies located in the industrial area. For the morning commute, we noticed that many people were using Pleasant Street (Highland) to leave the rotary, possibly for work. The IQP team expected from this data that the people leaving the rotary are returning from work.

As far as exiting the rotary, most of the traffic left via Pleasant Street (North), June Street, and Pleasant Street (South). This accounted for 70% of the traffic leaving the rotary. Pleasant Street (North) contained 24% of the exiting traffic with June Street and Pleasant Street (South) containing 23% each of traffic exiting. There is a simple explanation for this. Both Pleasant Streets and June Street contain the highest density of homes in the residential area. There is also a street adjacent to Pleasant Street (South) that many people use to cut through the residential area on their way home, which accounts for much of the traffic flow to Pleasant Street (South).

The hours of 11:00 a.m. to 3:00 p.m. constitute the afternoon traffic commute. Turning movement counts were performed by the group from 12 p.m. to 1 p.m. and studied further to explain the reason for the traffic flow.

The traffic entering and exiting the rotary is nearly the same. The volume entering a particular street is approximately the same volume leaving that particular street. We believe that this is due to the fact that the people are coming home for lunch. This is due to the fact that Newton Square is located in the middle of a highly residential area.

3.2.3 Pedestrian Counts

Pedestrian counts were performed at both squares in order to see how many people cross the rotary and to observe how the pedestrians interact with the traffic. This will allow recommendations for pedestrian safety if any are needed.

3.2.3a Washington Square Pedestrian Counts

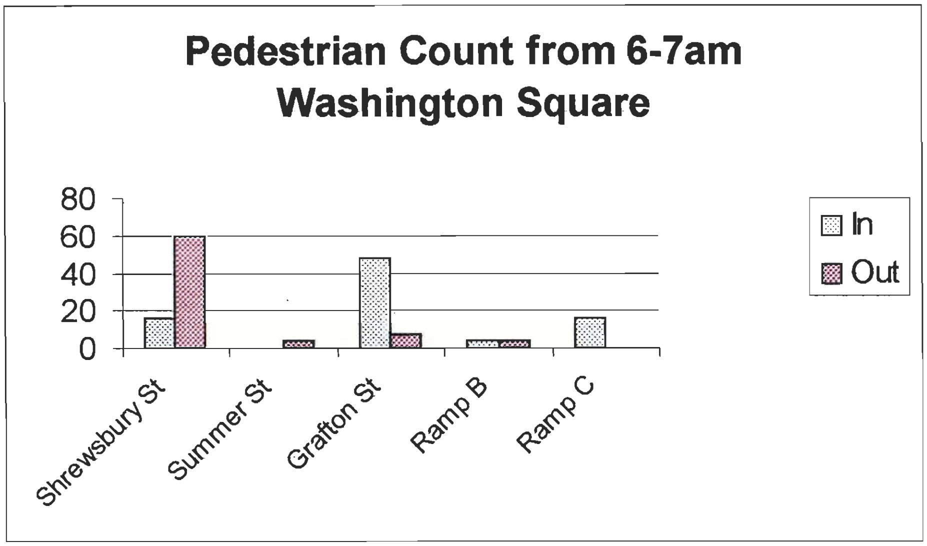
Washington Square Pedestrian Counts were performed from 6:00 a.m. to 7:00 a.m. This time was chosen based on the MBTA train station departure schedule. It was felt that the highest volume of pedestrian traffic would be at this time. There is a parking lot on Grafton Street where many of the pedestrians park their vehicles and walk to the train station, which accounts for much of the pedestrian traffic at this time. See Figure 11 for these pedestrian counts.

Figure 11

Washington Square
Pedestrian Count from 6-7am

Street Name	In To Rotary	Out of Rotary
Shrewsbury St	16	60
Summer St	0	4
Grafton St	48	8
Ramp B	4	4
Ramp C	16	0

Figure 11 Continued



There was also a pedestrian count done from 5:00 p.m. to 6:00 p.m. This time was chosen based on the MBTA train schedule, which returns riders from various locations to Worcester. See Figure 12 for pedestrian counts at this time.

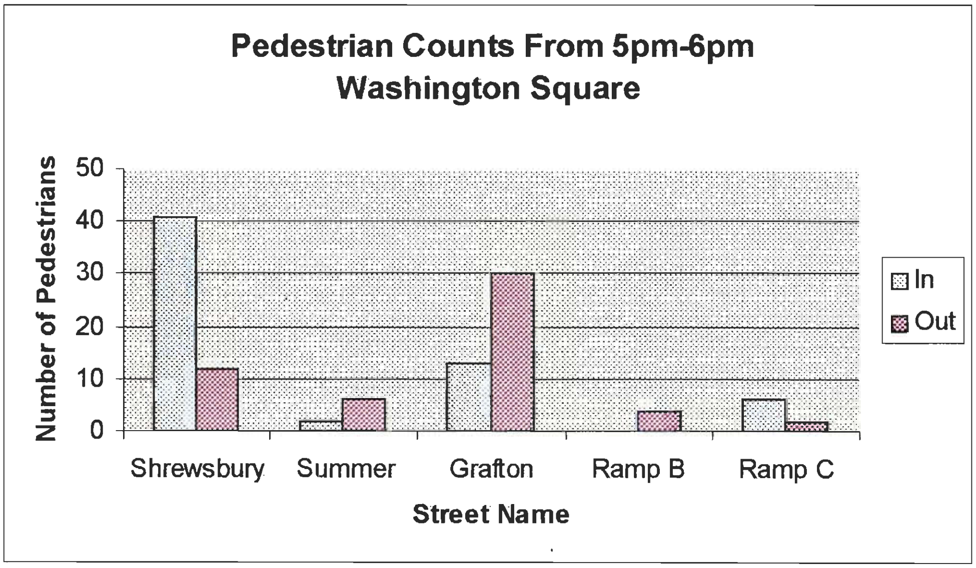
Figure 12

Washington Square

Pedestrian Count From 5pm to 6pm

Street	In to Rotary	Out of Rotary
Shrewsbury	41	12
Summer	2	6
Grafton	13	30
Ramp B	0	4
Ramp C	6	2

Figure 12 Continued



3.2.3b Newton Square Pedestrian Counts

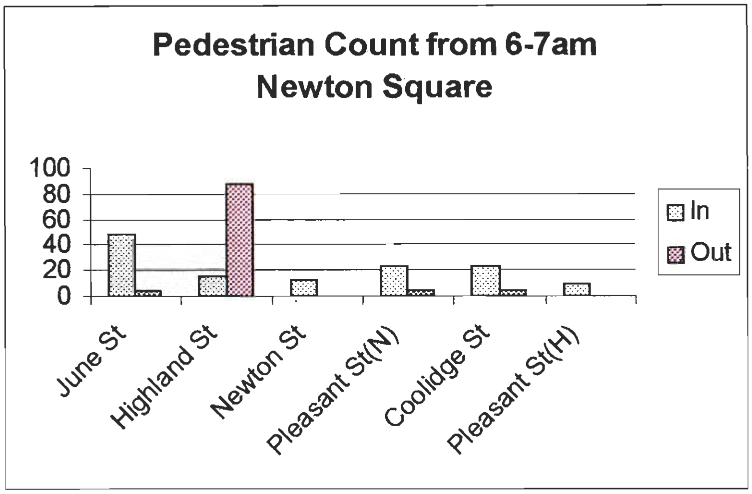
Newton Square counts were also done from 6:00 a.m. to 7:00 a.m. This time was determined based on the Doherty High School start time. The high school is less than ¼ mile from the rotary, which is in a highly populated residential area. It is felt that many students might walk to school from their home. See Figure 13 for pedestrian counts at this time.

Figure 13

Newton Square
Pedestrian Count from 6-7 am

Street Name	In To Rotary	Out of Rotary
June St	48	4
Highland St	16	88
Newton Ave	12	0
Pleasant St (N)	24	4
Coolidge St	24	4
Pleasant St (S)	10	0

Figure 13 Continued



Pedestrian counts were also done from 2:00 to 3:00pm based on when the students return home from school. See Figure 14 for pedestrian counts at this time. As you can see from the pedestrian counts, most pedestrians are crossing the rotary from the adjacent streets and heading down Highland Street where Doherty High School is located.

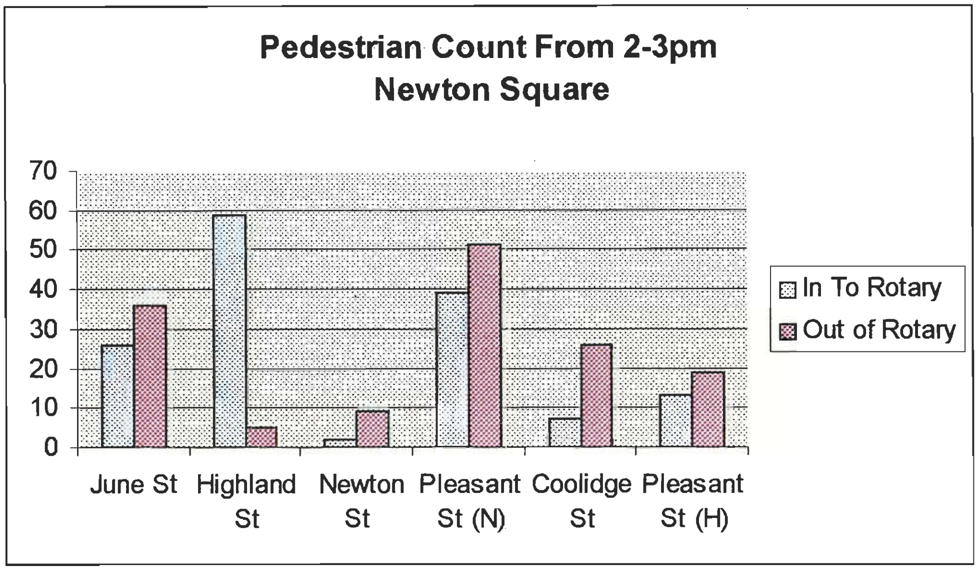
Figure 14

Newton Square

Pedestrian Count from 2-3 pm

Street Name	In To Rotary	Out Of Rotary
June St	26	36
Highland St	59	5
Newton Ave	2	9
Pleasant St (N)	39	51
Coolidge St	7	26
Pleasant St (S)	13	19

Figure14 Continued



3.2.4 Observance Study

Observance studies were performed on both Washington Square and Newton Square. These gave the IQP group a hands-on opinion of the traffic problems that the two rotaries in question. They saw the problems of both commuter traffic and pedestrian traffic.

3.2.4a Washington Square

We also observed Washington Square at peak travel times through out the day on various weekdays. The Washington Square rotary traffic volume flowed extremely well during peak hours. The rotary is large for the volume of traffic it sees throughout the day, which allows for the smooth flow during the peak travel times. Much of the traffic entering the rotary is via Grafton Street. Grafton Street is the source of a parking lot for the MBTA station. Much traffic is entering the rotary after work. Interstate-290 is also a source of much traffic entering the rotary. At the Grafton Street intersection, we observed, on occasion, vehicles not obeying the yield signs posted, many vehicles were being cut off and nearly causing accidents. There is no problem with traffic leaving the rotary at this intersection and traffic was rarely backed up for an extended period of time.

Shrewsbury Street is also the source of a lot of traffic inflow and outflow. The MBTA station is less than a 1/8 of a mile from the Shrewsbury Street intersection where many vehicles drop off and pick up riders on the MBTA train. Shrewsbury Street is also a highly populated commercial area. Again, the flow of traffic into the rotary was smooth with little back up at the intersection. Like Grafton Street, there were many potential accidents due to people not obeying the yield signs at the rotary intersection. There is also no problem with traffic leaving the rotary.

Many vehicle use Summer Street (Appendix D13) to enter the rotary and travel to work or the MBTA station. Summer Street is the main source of residential commuters. There is still no problem with the traffic entering or leaving the rotary other than the vehicles not obeying the yield signs.

At Ramp B there is no traffic entering the rotary. The flow out of the rotary at Ramp B is smooth.

Ramp C is also a source to traffic entering the rotary. It is the only way for downtown traffic to enter the rotary. The inflow from Ramp C did not appear to be as smooth as the inflow from the other streets. This is mainly due to the fact that not a great deal of traffic is entering the rotary from Ramp C. The rotary is fairly congested at all times and it is somewhat difficult for the traffic to enter the rotary from Ramp C for that reason. This caused many vehicles to cut off other vehicles in the rotary and nearly causing a few accidents.

The flow of the traffic in the rotary is smooth and controlled. The traffic entering the rotary is also smooth. There is no significant problem with the traffic in the rotary and leaving the rotary.

Pedestrian traffic, however, is a major problem. There is no way for pedestrian traffic to cross the rotary due to the high traffic volume in the rotary. The pedestrians must walk around the entire circumference of the rotary to go where they want. There are crosswalks at the intersections of each street. It is still difficult for the pedestrians to cross the intersection because of the high traffic volume entering and exiting the rotary.

3.2.4b Newton Square

We observed Newton Square on several weekdays at peak traffic times. During our observations, the traffic flowed fairly well through the rotary. At the Highland Street intersection, the majority of the traffic was traveling into the center of Worcester or to drop off children at Doherty High School less than ¼ mile from the intersection. Traffic flow out of the rotary was smooth with few problems. However, the traffic entering the rotary often backed up due to a high volume of traffic entering the rotary at the peak times. Many people did not obey the stop sign at Highland Street. Many vehicles did not stop completely and even disregarded the stop sign.

Pleasant Street (North) (Appendix D5) has the same general problems as Highland Street. Vehicles would disregard the stop sign. There was an added problem at Pleasant Street (North) also. Since the street is not used as much for incoming traffic to the rotary, many of the vehicles that obeyed the stop sign did not have the chance to enter the rotary as often as they should due to the high volume of traffic into the rotary. The vehicles were often stopped at the stop sign for an extended period of time.

Pleasant Street (South) (Appendix D10) is the second of the two major streets that have a high volume of traffic entering the rotary at the peak travel times. Pleasant Street (South) is the source of many commercial buildings. Highland Street and Pleasant Street comprise most of the traffic in the rotary and often prevent vehicles from entering via other streets.

Coolidge Street has the same problems as Pleasant Street (South). It is not used nearly as much as Highland Street and therefore vehicles are often forced to stay at the stop sign for an extended period of time.

June Street also has little traffic. It encounters the same problems as Coolidge Street and Pleasant Street (South). We also observed another factor that effects the flow of traffic into the rotary from June Street. June Street is designated as the bus stop for the residential area surrounding Newton Square. Every morning and afternoon the bus drops off and picks up the students who attend the public school system in Worcester. In the afternoon, when school gets out, this is not as much a problem. However, in the morning, the vehicles that are entering the rotary from June Street are held up because of the bus stop. This creates a problem for the entering vehicles, not only are they forced to stop behind the bus, it is also extremely hard for them to enter the rotary after the bus has left. This causes excessive delay and often results of vehicles trying to cut off the other vehicles already in the rotary.

Newton Avenue has the same problems as Coolidge Street and Pleasant Street (South).

While traffic was traveling in the rotary there were many near accidents. This is caused by vehicles trying to enter the rotary quickly because they do not want to wait a prolonged time, disobey traffic signs and bad driving techniques. Pedestrian traffic is also a concern of ours. We observed many pedestrians in the morning commute (i.e. students walking to school and people exercising.) We often saw pedestrians running across the rotary in order for them to not get hit by vehicles in the rotary. Many pedestrians also walked around the rotary so they would not have to cross the middle of the rotary during the peak morning commute. However, they would still have to cross the intersections, which sometimes caused a problem for traffic flow and for the pedestrians themselves. The pedestrian traffic is not nearly as bad when the students get out of school or during the commute home from work where there is a high traffic volume.

3.3 Current Improvement Proposals

3.3.1 Washington Square

Washington Square is currently being looked at for redesign. There are two possible designs that could be made to the rotary by the spring of 2001. The first proposal was to make Washington Square rotary into an intersection. This would allow for the flow of traffic to be regulated by either traffic signals or a four-way stop sign. This will prevent any entering vehicles having to wait an excessive time to enter the rotary/intersection, which is rarely a problem with the rotary now. This proposal will make the area of Washington Square smaller and allow for businesses to be placed around the intersection.

The next proposal is to make the rotary a smaller rotary. The traffic flow around the rotary now is excellent. If a smaller rotary were to be made the flow of traffic will still remain sufficient. This will also allow for more area around the square to be freed up and therefore allowing construction of the surrounding area. Figure 5-1 shows the proposal of the smaller rotary superimposed on the existing rotary.

3.3.2 Newton Square

No current proposals are being made to this rotary as of now.

Chapter 4

Interviews and Surveys

The IQP group conducted interviews with local companies in the Washington Square rotary. Interviews were not done in the Newton Square area, because of lack of commercial businesses. Instead, surveys were mailed to some of the local residents of the area. The interviews were done to get a broader range of opinions of Washington Square from people who use the rotary daily. We asked questions regarding how long they have been using the rotary and then moved on to how they thought the rotary was functioning and what improvements they believed would be best implemented to resolve current problems in the rotary.

4.1 Washington Square

Interviews were conducted with some of the businesses that are around the Washington Square rotary. These businesses include the following: Pat's Service Station, N-E-D Corporation, Worcester Medical Center, and a local construction company. The IQP group found the interviews to be helpful, because they gave us information about the rotary from people who use it often and for a long time. The answers seemed very informative and identified problems that we have found through our research during the year. The following are the details of each interview conducted.

4.1.1 N-E-D Corporation

Peter F Wyatt of the N-E-D Corporation, which is located on Grafton Street, was very insightful with showing us how well the rotary operates. His business have been located next to Washington Square for thirty-eight years, which gives him a good idea of what was going on in the rotary. Unlike Newton Square the feedback from Washington Square was quite positive. The time that Mr. Wyatt felt was the worst time to travel in the rotary was from 4:30 P.M. through 6:30 P.M. He said that the only reason for this is because of the high volume of traffic. But he felt that the rotary was very safe and effective overall. He stated this and told us that this was because he has never seen an accident in the thirty-eight years that he has traveled through the rotary. He did not believe that the rotary was safe for pedestrian traffic. This is because there are no traffic signals to let them cross and stop the vehicular traffic as they crossed. He believed that if there were traffic signals for pedestrians that it would make it safer. The next area of concern was if he felt that the rotary would be safer if it was to be turned into a four-way intersection and he did not. He felt that it the rotary would not be able to handle the amount of traffic entering the rotary during the morning and the evening from both Summer St and Grafton St coming from 290 East. Mr. Wyatt also brought to our attention that this would probably create more accidents because many people would try to beat the lights and create a more dangerous atmosphere for both the pedestrians and the vehicular traffic. Overall his attitude was quite positive toward the rotary, and he felt that it should stay as is.

4.1.2 Saint Vincent Hospital

The IQP group interviewed Gerry Boucher about the safety of the Washington Square rotary. Mrs. Boucher is an employee of Saint Vincent Hospital, which is located on Summer Street. She has been using the rotary for about one year and has had plenty of experiences involving automobile and pedestrian traffic in Washington Square.

What the IQP group found when interviewing Mrs. Boucher was that she thought the worst time for commuter traffic is from 4:00pm to 5:30pm. She said that the traffic convenes from all sides of the rotary and that this causes back ups in the commuter traffic. The group then went on to ask Mrs. Boucher about how she felt about the commuter traffic at all times of the day. She told us that she believed that it was fairly safe, due to the visibility of the rotary for a driver. She said this was because the rotary is so large and that there is more room to work with when traveling through it. She also said that because of the large size of the rotary, the turns when entering and exiting the rotary are easy to make.

When the IQP group asked her about the safety of the rotary when encountering pedestrian traffic, she said that it was not safe at all for pedestrians. She said this was mostly on part of the fact that most vehicles travel at speeds greater than that of the speed limit. This does not give the pedestrians time to cross the streets in a safe manner. When the group asked Mrs. Boucher what she believed would help in the case of pedestrian traffic, she came up with a unique idea. She suggested that a pedestrian bridge put across the rotary at a certain spot could be the most useful and safest means of pedestrian traffic in Washington Square. She also suggested the idea of putting a traffic light up at certain parts of the rotary and has a pedestrian crossing button to stop traffic and allow adequate time for pedestrians to cross the streets. The group found these ideas to be intelligent and useful to some of the problem solving of the Washington Square rotary.

When the IQP group asked Mrs. Boucher what she thought of the idea of turning Washington Square into a four-way intersection, she thought that it would take away from the historic rotary of Washington Square. She thought that it would help in the problem of pedestrian traffic. The lights would give the pedestrians more time to travel across the roads, but that it would decrease the safety of commuter traffic. Turning Washington Square into a four-way intersection would increase the occasion for head-on collisions or "T-bone" accidents. She believed that it would tempt motorists that are traveling east to go much faster where they enter Shrewsbury Street. This is also where the Interstate-290 ramp merges with Shrewsbury Street.

For the most part, Mrs. Boucher believed that the rotary with concern to commuter traffic should remain unchanged. However, she believed that adding traffic lights or a pedestrian bridge should help the pedestrian traffic in the rotary somehow. The Mrs. Boucher interview was very helpful and informative to the IQP group's research.

4.1.3 Pat's Service Station

Pat's Service Station (Appendix D12) is located on Shrewsbury Street less than 100 feet from the rotary. Pat's Service Station employs 5 tow-truck drivers that use the rotary many times throughout the day. The drivers felt that there is no problem with the rotary, as far as commuting is concerned, rarely ever having trouble entering or exiting the rotary. On occasion they have experienced a problem but they felt it was due to incompetence of the drivers. They believe that the flow of traffic in the rotary is smooth at all times, even during the peak travel hours. They believe that if it was not for the incompetence of the drivers that there would be no accidents in the rotary.

When asked how they felt about pedestrian traffic in the rotary, they stated that it is not a good place for pedestrians to walk. The speed of the vehicles in the rotary is high which makes it unsafe for pedestrians to cross the rotary safely or without running. They feel the only way to increase pedestrian safety is to lower the speed of the vehicles in the rotary. They believe a smaller rotary will be just as efficient as the current rotary and be safer for pedestrians as long as the speed is reduced.

4.2 Newton Square

Interview methods for Newton Square were performed differently than that of Washington Square. In order to obtain a sufficient and meaningful public response towards the rotary at Newton Square the IQP group used a residential questionnaire method for residents in and around Newton Square. The reason for choosing a questionnaire instead of an interview is because of the basic set up of Newton Square. The area is mainly a residential district, which begins the west side of the city of Worcester. Twenty-five questionnaires were hand delivered by the members of the group to homes in and around the rotary. These questionnaires included a self addressed stamped envelope for retrieval and interviewee convenience purposes. Nine questionnaires were returned to the group (located in Appendix C). The public response for Newton Square proved to be the most important factor of study to the group for the Recommendations for Improvement section labeled Chapter 5. The overall response towards the effectiveness and safety of Newton Square was rather negative. The following are details of the questionnaires returned to the IQP group.

4.2.1 Questionnaire #1

This particular resident has been using the rotary at Newton Square for 31 years. He/she believed that the rotary was 'fairly safe' for both pedestrians and commuters. The only recommendations for improvement were was for there to be a police officer present during the rush hour segmented times.

4.2.2 Questionnaire #2

This particular interviewee was unhappy with the safety of the rotary. The main concern written was student safety as pedestrians in traffic. He/she felt that they needed to use the crosswalks more often and that the 'Jay-walking' law needed to be enforced. On the issue of commuter safety he/she wrote that during election periods the rotary is used for campaigning and the distraction of campaigners and campaign signs was a major problem.

4.2.3 Questionnaire #3

Improvement recommendations cited by this survey were very provoking. This interviewee was a woman with strong feeling for the safety of her children crossing the streets in the rotary. She cited that she and her children had come close to being hit several times. Her recommendations were that pedestrian safety reminders be posted in the streets around the rotaries as well as better law enforcement of traffic violations in and around the rotary.

4.2.4 Questionnaire #4

This interviewee put a little humor into the answers of the survey questions. His/her recommendations for a safe pedestrian use of Newton Square was 'to run, very fast!' But he/she did believe that the rotary had a potential for being a safe rotary if the traffic laws were better obeyed for rotary use.

4.2.5 Questionnaire #5

This survey presented only opinions on the rotary, and that it was fairly safe for commuters, but unsafe for pedestrians. He/she wrote that with the converging of the particular streets it would be hard to actually have a safe rotary.

4.2.6 Questionnaire #6

This interviewee said that nothing can be done to the rotary to improve it. He/she wrote that, 'as a life long resident of Newton Square, I think I can safely say that unless a large sum of money can be spent, this rotary will never be anything more than a traffic headache to all motorists and pedestrians using it.

4.2.7 Questionnaire #7

This survey recommended the change to a traffic light intersection to regulate speeds better for the safety of all. He/she also wrote that, ' a simple traffic light to allow crossing (not eliminating the rotary)' would help improve pedestrian safety.

4.2.8 Questionnaire #8

This survey simply showed that the interviewee felt the rotary was unsafe and should be converted to an intersection with lights.

4.2.9 Questionnaire #9

The group believed that questionnaire #9 was the most important one received. This interviewee felt that the pedestrian crossing locations should be located further down the streets away from the rotary. He/she felt that Newton Square was unsafe for pedestrian and commuter traffic. He/she also added that she witnessed a pedestrian accident in the rotary at 7:30AM on 2/7/01 involving a Penske truck.

4.2.10 Questionnaire #10

This particular person who responded to the survey has been living near the rotary for over 20 years. He/she noticed the commuter and pedestrian traffic has increased over the years. He/she felt that the rotary at one time was probably sufficient enough to control the flow of traffic but the volume has increased due to the Newton Square residential population increasing over the past years. He/she feels that police officers should regulate speed in the rotary during school start and stop times.

4.2.11 Questionnaire #11

The last survey received was of a concerned mother of a Doherty high school student. She feels that the students who use the rotary to go to school are not safe at all. She believes the cars that travel in the rotary use excess speed at all times but feels it is worse in the morning because traffic and pedestrian volumes are high. She feels that pedestrian crossing signs should be placed in the rotary to help reduce the speed and notify traffic of the pedestrian crosswalks.

Chapter 5

Recommendations For Improvements

5.1 Recommendations

This final chapter will conclude the IQP report. It will go into detail about what the IQP group recommends could be done to improve Washington Square and Newton Square rotaries. The project could be studied in more depth, such as doing more elaborate studies on the rotaries, but with the tools and the finances that the IQP group had, the best recommendations from our work are considered in this chapter.

5.1.1 Newton Square

There were a few main problems found with the rotary at Newton Square. There were also some minor problems that the IQP group has found through the studies and surveys. The following problems will be identified, each followed by a recommendation on how to solve it.

- **June Street stop sign is poorly located.** The June Street stop sign (Appendix D1, D2, and D7) entering the rotary is too far from the intersection. Motorists ignore where the stop line on the road is and come too far into the rotary in order for them to see the traffic flow in the rotary. This can be solved by either relocating the stop line to a more appropriate distance from the rotary in order for motorists to be able to see the traffic flow. The second solution would be to put more of an enforcing stop sign or cautionary sign in the area to give the motorist more of an earlier warning of this stop sign. This was a major problem that should be solved by either of the two methods mentioned above.

- **Pedestrian traffic is a problem at Newton Square.** The cross walks at Newton Square are not as bright and labeled as they should be. This would be an easy problem to solve. Better, more informative signs to designate where pedestrian traffic is allowed to cross the rotary could be a large factor in solving this problem. An orange pedestrian crossing barrel in the middle of the road could also aid pedestrian traffic. Through surveys and observation, jaywalking was found to be a problem also. A possible recommendation to would be to have a cross guard at the rotary at peak pedestrian traffic periods (7 a.m. to 8 a.m. and 2 p.m. to 3 p.m.)

- **Lack of Police Patrolling the Area.** The Newton Square rotary lacks police patrolling and enforcing the automotive laws in the rotary. This makes the motorists feel like they can operate their vehicles in dangerous behaviors. A solution to this problem would be to have a patrol car parked by the rotary that is highly visible. This would give the motorists a warning to slow down and to obey the laws of driving through the rotary. The best time for the patrol car to be in the area would be through the peak commuter traveling hours. This is from 6 a.m. to 8 a.m. and from 4 p.m. to 6 p.m. This is when the traffic congestion builds up greatly in the rotary, because of all of the motorists commuting to work in the morning and back to home in the evening.

- **Lack of Clear Designation of Right of Way.** Another problem that has been identified is a lack of regulatory signs before entering the rotary on all of the streets. There are not enough, if any, signs on the streets before entering the rotary that tell the motorists the laws of driving in the rotary. The biggest concern was that the cars entering the rotary do not know that the traffic flowing in the rotary has the right of way. This causes near accidents or indeed, automobile accidents. A recommendation would be to put signs up that state that the traffic flowing in the rotary has the right of way. These signs must be put up in a highly visible area, that motorists are sure to see. They must also be eye catching, so as to attract the attention of the motorists to the law when entering the rotary.

- **Careless and Reckless Driving in the rotary.** As mentioned in an earlier problem, careless and reckless driving, which includes speeding and failure to obey traffic rotary laws, should be regulated greatly. A rotary is hard enough to drive in even if everyone is driving at or below the speed limit and obeying the laws. An idea that the IQP group gathered through surveys was that even something as simple as a sign saying "drive carefully" or "rotary dangerous" could make the motorists slow down and pay more attention to the traffic laws. These could be put up on the streets before entering the rotary or in the rotary. Even a sign that says "Highly Patrolled Area" could do the trick for preventing a possible dangerous situation in the rotary.

- **Picketing in the rotary during Election Time.** Through a couple of surveys that the IQP group gathered, we discovered that politicians and their supporters picket in the Newton Square rotary. This adds to the problem of pedestrian traffic and also to commuter traffic. When it is election time, we have found out that the pedestrian traffic increases greatly. This is a problem that, although it only occurs at most once a year, should be looked into. Also, the signs that are held up by the picketers are a distraction to motorists who are driving through the rotary. The signs block traffic regulatory signs and the partial visibility of automobiles traveling through the rotary. A recommendation to solve this problem would be to ban picketers in the center circle of the rotary or in an unsafe area that is involved with the rotary. This could be a hard thing to do, but it was a problem that a few of the surveys said is a major problem in the rotary and we believed that it should be looked into further.

To change the design of the Newton Square rotary would be extremely expensive and not worth the time and money to see only limited improvements. Appendix B shows that from 7 a.m. through 8 a.m. that the total volume of vehicles to use the rotary was 1668. Then the total volume increases to 1918, but as we can see most of the traffic is using either Highland Street, Pleasant Street, and in the evening June Street. The total number of vehicles traveling through the square is so drastic that an intersection with signals would be unfeasible. The first problem is that there are five separate streets that are entering the rotary, which will make the creation of an intersection very untypical. The lights would help to improve the safety for pedestrians that use the rotary as many of the Doherty High School students do on their way to and from school. But in the long run this intersection would probably lead to more time delays and create more problems than it solves because of its total lack of symmetry and multiple roads that would be entering it from different directions.

The next situation that could be tried was the implementation of lights in the rotary that exists now. These lights would not be used to control traffic flow because they would interfere with the natural flow of the rotary. What they could be used for was for pedestrian safety, and stop traffic only to let pedestrians cross when needed. This might be a very useful idea, because in many of the surveys that we received back from the residence of Newton Square they complained that vehicles never stopped to let them cross the rotary. In general because of the five streets that are entering the intersection and the limited space around the rotary to do any serious remodeling would not be worth the money put into it. The majority of the money spent on this rotary should be used to help create a safer atmosphere for pedestrians by placing police officers there on duty during the morning rush hours and when Doherty High School is released. Placing the cross walks further up the streets and not right in the rotary would also help, because it would eliminate the pedestrians from the rotary itself. This is because drivers while entering and exiting the rotary are concentrating more about timing there moves with other cars in the rotary and not looking and staying aware the pedestrians are. Overall the functionality of Newton Square works rather well considering the number of streets that intersect at this location that is relatively small amount of real estate.

5.1.2 Washington Square

In and around the Washington Square there remain problems involving pedestrian traffic along the entrances and exits of the rotary itself. Complimentary with pedestrian traffic problems there is also a slight commuter traffic problem mainly with safety issues involving speed and proper usage of rotary rules and regulations. There were also some other minor problems that the IQP group has found through studies and interviews. The following problems will be identified followed by a recommendation on how to solve them.

- **High Pedestrian Volumes.** Washington Square (Appendix D23) is the site of two major train stations in the Worcester area. Furthermore, in addition to the obvious commuter and pedestrian traffic, one could also present the problem of congestion towards the location and major usage of the Amtrak Railroad Line and the MBTA Commuter Rail Line. The high volume of pedestrians is a direct result of the usage of the two train stations. In observing the general area, one would find parking garages at the corner of Franklin Street and Grafton Street (Appendix D21, D22), which happens to lie about 100 yards away from the rotary entrance, a parking garage in the rotary between the entrance and exit of Ramps B and C, and a parking lot directly after the rotary on Shrewsbury Street (Appendix D19). The problem with the parking on Shrewsbury Street and Grafton Street is that the crossing of Grafton Street (Appendix D11) seems to be the only way to get to one of the two train stations, which are located on both sides of Grafton Street. What many pedestrians don't realize is that the light at the intersection of Franklin and Grafton has an actuated crossing light system for pedestrians to safely cross (Appendix D20). Instead of crossing down the street where they parked they choose to walk up the same side they are on and cross at the crosswalk in the rotary, which is far more dangerous. Another alternative to crossing at Grafton Street rotary entrance is to use the bridge that goes over Grafton Street, which has a sidewalk designed for a pedestrian bridge (Appendix D16.) The recommendation for the Grafton Street leg is to post these pedestrian routes along the street to make walkers aware of the safe-route. However Grafton Street is only one leg of the four-leg rotary, which includes eight crosswalks, one at each entrance or exit. Unfortunately, there is not much room for improvement in terms of an altered pedestrian route at the other three streets so general safety recommendations for pedestrian safety similar to the ones at Newton Square can only be rendered for the existing design of the rotary.

- **Speed Control.** As discussed in Chapter 4 'Current Improvement Proposals' the rotary at Washington Square is currently under redesign. In addition the aspects, reasons, and tendencies stated in Chapter 4, one of the main improvements of this new rotary design is the speed control it will provide. The existing rotary is a large size rotary in comparison to a standard roundabout. The advantage with large rotaries is the ability to minimize volume problems that have to do with congestion versus area. With a low volume per area rate comes higher rates of speed in the roundabout. In a situation without a high pedestrian traffic volume a model of a large rotary is an excellent effectiveness rating. However in this particular case where speed control needs to be a major issue because of pedestrian safety, not to mention commuter safety, the issue of lowering the average speed approaching the rotary and the average speed in the rotary needs to be addressed. The design of a smaller rotary (Appendix D23) will bring a correspondingly lower speed limit and hopefully an actual lower speed rate. The effectiveness rating calculated from the SIDRA program (located in Appendix C) of the existing rotary due to motorist traffic is slightly higher than the effectiveness of the proposed design of Washington Square. However, it is the opinion of this Interactive Qualifying Project Group that the slight change in commuter convenience will certainly pay off from the appreciation of safety from a pedestrian standpoint.

Similar to recommendations for the Newton Square rotary, it is evident that an improvement in traffic law enforcement in and around the rotary could make conditions safer for both the motorist and the pedestrian. In observing the rotary numerous times one notice immediately the high level of speed in the rotary itself, not to mention all four approaches. Lowering speeds for a driver would increase the time between noticing a conflict and reacting to it. Reaction time is inevitably the most important factor in accident prevention. If improving reaction time levels throughout this rotary is increased, then accidents will decrease and the goal for obtaining a safe rotary at Washington Square will be one step closer.

Design and Analysis Comparison In order to make improvements for the rotary at Washington Square a simulation to analyze proposed intersection designs was needed as well as professional assistance. Traffic Engineers at the Department of Traffic Engineering in the Worcester Department of Public Works provided methods of comparing and contrasting levels of effectiveness for the existing conditions at the intersection, two separate design proposals for the rotaries at the intersection, and a signaled four-way intersection. Data collected in Appendix B, as well as geometric properties given and recommended by the Traffic Engineers were used in processing an evaluation of the different intersection conditions. In order to do this, evaluation methods of traffic analysis as well as traffic simulation software were needed. Method were obtained by instruction of the assisting engineers as well as conceptual learning from the text cited.

Programs used were CIDRA, Synchro Plus SimTraffic, and SIDRA, which were all generously donated by the Traffic Engineering Department of Worcester. These programs are designed to input the data of an intersection and then output and evaluation, which is standard rate level of effectiveness. To evaluate an intersection, volumetric properties, traffic speeds and tendencies, and pedestrian data are figured into a series of analytical equations. Calculated properties, such as flow, flow rate, delay times, and for a signalized intersection signal timing and phasing are determined by these programs. From these calculated properties a certain 'level of effectiveness' is determined. This 'level of effectiveness' is an evaluation grading based on the letters A through F, with designated as the most effective and F designated as the least effective.

For a four-way intersection a series of conditions were evaluated until the best-case scenario design involving lane usage and timing patterns were obtained. The proposed signalized four-way intersection scored extremely poor as a practical intersection. Delay time were high and 'level of effectiveness' scored was extremely low. The ideal signaled intersection at Washington Square based in CINCH format also scored an 'F.' This tells us that to change the existing rotary into an intersection would drastically increase traffic problems at this intersection and furthermore would not be recommended by this group.

For the existing rotary, the simulation ran was performed by the Worcester City Traffic Engineers. The simulation program used was SIDRA, which has a roundabout program as well as other intersection conditions. SIDRA is considered the most recent and predominant over the other two traffic software programs. This run determined that the existing rotary at Washington Square is rated as an 'A' intersection with low delay times. However, the concern, as stated earlier is that average speeds in and around the rotary are too high for the level of service of pedestrian use. As noted in Chapter 4, a smaller size rotary may pose as a solution to the problem. Discussed, studied, and tested by the Traffic Engineers were sample proposals for a smaller rotary design. Simulation results showed that although the 'level of effectiveness' rating jumped from an 'A' intersection to ratings of 'B' and 'C' with the proposed conditions the average speed in the simulation model was far lower than that of the existing rotary.

Based on every aspect observed, calculated, tested, etc., it is the recommendation of the group to the best of their ability and knowledge in analyzing Washington Square that the existing rotary be redesigned to a smaller, more compact roundabout so that under a simulation run a 'level of effectiveness' rating be no less than a 'B' and speeds upon the approach and in the rotary be at a safe level so that pedestrian conflicts remain at a minimum. Under these circumstances it is forecasted by the group to the best of their ability that the conditions stated above will reflect a safer intersection for both the commuter and the pedestrian.

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Appendix A

Traffic Study Definitions

A1. Traffic Counting Study:

A Traffic Counting Study, which is being performed for a central desired location, is done at every major street leading to the region. The intersection line, which encompasses the studied region, is known as a Cordon Ring, and each intersection of the line and a major road is a Counting Station. A Counting Unit, usually consisting of two people, is placed at each one of these counting stations from 7:00 a.m. to 7:00 p.m. for two back to back days. The days selected should be days which the traffic flow is anticipated to be normal business traffic, excluding weekends and holidays. Each Counting Unit performs a count of all vehicles and pedestrians entering and leaving the encompassed district, and separates the collected data into half-hour intervals. Generally, in the two day study format, vehicles (excluding buses and streetcars) are monitored one day, and pedestrian are studied the next. Vehicles are separated into three categories so as to provide a better description of the various types of traffic flow in the region which are (1) automobiles and taxi cabs, (2) motor trucks of all kinds, (3) motorcycles, bicycles and other miscellaneous vehicles.

The pedestrian study is separated into two sections. One member of the Counting Unit keeps record of the number of pedestrians entering and leaving the area. The second member of the unit conducts a count on vehicle occupancy at the Counting Station, so as to determine the amount of people traveling the Cordon Area by way of automobile, truck, or miscellaneous vehicle. These results together will provide an accurate estimation of the total number of people entering and leaving the region, and more importantly, when and where they do. The pedestrian studies will also be conducted in the same half-hour increments, as was the vehicle study.

A2. Speed Spot Study:

To perform the study, an observer, stop watch, a 50 or 100-foot tape (or an 88-foot rope), field sheets, summary sheets, pencils, erasers, and an endoscope are needed. (An endoscope is an L shaped box, open at both ends, which has a mirror placed at 45-degree angle in the corner. This instrument is used so that the observer's line of sight will be perpendicular to the end point being checked.) Three tests should be done, during normal weather conditions, each for the duration of one hour, from each of the following time categories: 9:00 a.m. to 12:00 p.m., 3:00 p.m. to 6:00 p.m., and 8:00 p.m. to 10:00 p.m.

A test length must first be chosen. The length must be long enough so that the shortest time being recorded is not less than 1.5 seconds and the speed times are on average between 2.0 and 2.5 seconds. (88 feet is a convenient length because it makes conversion into miles per hour simpler.) The measuring tape should be laid 5 to 10 feet from the curb. The observer should place himself at one end of the rope, and the endoscope at the other. It is best if the driver can stand perpendicular to a tree or post on the opposite side of the street, so that when a car passes the line of sight to the tree will be broken. At that instant the stopwatch should be started. When the car drives past the end of the designated course, the observer will see a flash in the endoscope and the time should be stopped. If an endoscope cannot be used, a second observer can stand at the end of the marked course and signal to the observer when the car passes the end of the course. The time for each car should be recorded. However, if this is not possible, because there is too much traffic, every second or every third car can be recorded.

After the observer has left the field, the results can be tabulated to find the average speed of any vehicle through the tested area.

Note: It is important during this study that the driver is not aware that a study is being performed, because often if people know that they are being tested then they will drive slower, thus affecting the results.

A3. Time Travel Study:

The staff at CMRPC strongly suggested that a study should be done during one hour of each of the following times: 7:00 a.m. to 9:00 a.m. (at morning peak flow), 10:00 a.m. to 2:00 p.m. (at midday off-peak flow), 4:00 p.m. to 6:00 p.m. (at afternoon peak flow), and 8:00 p.m. to 10:00 p.m. (at evening off-peak flow). Checks should be done during normal traffic conditions, (unless the survey is specifically to check abnormal conditions). The license plate method or the test vehicle method may be employed.

A3.1 License Plate Method

A section to be studied should be selected, preferably in a location with no major intersections. The observation team should simultaneously start their stopwatches. Then members of the team should place themselves so that there are people on both sides of the street at both ends of the tested area. As a car drives by a recorder must record both the license plate number and the time that the car traveled past. (If the high volume of traffic on the road being studied makes it impossible to record all cars, observers may agree to only record license plates that end in either zero or one, thus giving a representative 20 percent count of the total amount of automobiles that have passed.) An audio recorder may be used to give more accurate results, but it is not necessary. After the test is complete, the observers at either end of the road will compile their results to find the average speed of a vehicle that traveled the length of the road.

A3.2 Test Vehicle Method:

For this test, a test vehicle, a driver, a recorder, and a stopwatch are required. The driver should drive along the selected route attempting to stay an equal distance from the car in front of him to the car behind him. (An alternate method called "floating" may be used, in which the driver passes as many cars as the test vehicle does. This method is however is not recommended by the CMRPC.) This method will allow the driver to find the average speed it takes to drive the selected roadway, as well as observe problem spots. Several test-drives should be completed for accurate results.

A4. Observance Study:

These studies should be made at high accident frequency locations with traffic signals or locations with considerable congestion. Another area should also be looked at in comparison. This, in a way, is used to determine whether it is poor location of signals that are resulting in faulty driver observance or whether it is the type of drivers in the area. This study should cover at least one hour per location and at least 50 vehicles should be checked at each approach to the intersection. The length of the entire study at one location is three hours, one morning, one afternoon, and one evening. If this study is used at an intersection of high accident frequency it should be performed during the hours when most accidents occur. An inconspicuous person not in any type of uniform so as not to inhibit the driver's decision at the signal being studied should perform the study.

A.5 Transit Traffic Study:

Transit volume counts are generally made through two types of counts, spot counts and riding checks. These counts are usually made during weekdays and are separated by morning rush hour, evening rush hour, and part or all of the day. Spot counts involve an observer to be placed on a curb at points that are critical in determining the spacing of vehicles and number of passengers at the point. The Transit Company routinely makes spot counts on important lines. Local regulatory bodies usually require the study to be made a few times every year. The riding check involves an observer on the transit vehicle for a certain length of the line. The observer will record passengers getting on and off the bus. The information gathered could be presented with graphs in a diagram that would show the amount of passengers getting on and off at each stop and the total amount of passengers being carried by the transit carrier through the line. This information is useful for fitting the service to the demand, locating possible re-routing and/or coupling with other lines.

Speed and Delay studies are performed to determine the relationship between the speed of the transit vehicle and how it can effect other types of delays. An observer traveling on the transit vehicle or following it in another vehicle can record this study. For this reason, you should record slow downs as well as vehicle stops. Slow downs are anytime when the operator applies the brakes to check the speed of the vehicle to intentionally adhere to a schedule. The physical characteristics of the vehicle and that of the street will also effect the delays.

Origin and Destination studies are to be performed as well. The procedures for this study are similar to ones for automobiles. This study can be given through questionnaires or postcards. A questionnaire would involve a passenger filling out a survey when he or she boards the vehicle and then returning it before they exit. Postcards would allow the passenger to fill out the card and mail it on their own. Data gathered must be separated by time of day and/or trip. This study can provide data for further studies of proposed new routings or other major changes to the transit system.

Transfer and Loading Points will indicate the location, movements, and the direction of transfer points during certain times of the day. Our contacts at the CMRPC, Adam Gordon and Richard Rydant, hinted that this method can be useful for determining the movement of passengers between lines. Observers are placed at various locations and record for each transit vehicle, the time of arrival, number of transfer passengers, and direction of their movement.

Accident Analysis can be conducted to determine whether certain operating methods, types of transit vehicles, or transit operators are the cause for accidents. This study is done the same way for autos as is for transit vehicles. A list of accidents in the given area is collected and interpreted and changes would be made concerning what type of results are gathered.

A6 Parking Study: Inventory Method

The study is simply made by placing information on a master map of the area with a scale of no more than 200 feet to an inch. All parking spaces (including curbside parking), parking lots, and parking facilities should be marked on the map. Information to be recorded onto the map includes prohibited parking spaces, time-limited parking, angle parking, bus stops, taxi stands, and commercial and passenger loading zones. The capacity and type of vehicles allowed in off street lots should also be included. These studies are done in order to provide data for parking usage studies and in order to analyze the supply and demand of parking.

A6.1 Usage Study:

To perform the studies, field observers must record the duration of each vehicle in each parking space. The tests should be done for 10-hour periods between 8:00 a.m. and 6:00 p.m., during normal days. (Days near holidays, special shopper days and days when stores are not operating on their normal hours are not normal days.) One observer generally covers four blocks at a time. He or she would walk around the same four blocks (taking 15 minutes per cycle), for the duration of their shift. Their duty would be to record the license plate, location, and duration of stay for each vehicle. (Commercial trucks should be marked as such.) On the first trip around the course, the observer must record the license plates of each vehicle encountered. On the second time around, if cars have left, they are recorded as having been parked for 15 minutes. If a car stays for 2 loops, they are recorded, as having stayed 30 minutes, 3 loops is 45 minutes, etc. The results of this study can be used to determine if the current parking regulations can be enhanced (i.e. lengthening time restrictions, or shortening them in order to increase turnover). They can also be helpful in determining improvements should be made to increase parking capacity.

A6.2. Demand Study:

The interviewer must begin by recording the time that a vehicle parks. Once the driver has returned, an interviewer must ask the driver their origin, their destination, the purpose of their trip, and their home address. The number of feet they had to walk to their stop must also be recorded. Another method of data collection is to place questionnaires on the windshields of each car. This method is not at accurate however, since not everyone will return the questionnaire, and most people will take the interview. This study can reveal a deficiency or surplus in parking spaces, which can aid in renovations and future planning. Appropriate parking restrictions can be determined. Transit service integration can also be studied.

A7. Land Mileage and Travel Delay Study:

The Land/Mileage study involves measuring the distances, speed limits, and amount of lanes in the certain stretch of road under review. Two people will drive through the location with the passenger acting as the recorder. He or she will record the distance to each intersection as well as the amount of lanes traveling on and they will also mark down the speed limit in the area. This will be done for both directions. The attached sheet Lane/Mileage Inventory is an example of what is used to record the data.

The Travel Time and Delay study involves the recording of time of travel in the area. Two individuals will drive through the area and record data relevant to the study. They will record how long it takes to get from one intersection to the next. When they are delayed, they mark down the time of the delay and the reason for the elapsed time. This will also be done in both directions. There is an attached sheet Travel Time and

Appendix B

Volume Data


NEWTON
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16%
PLEASANT (N)
23%
30%
19%
HIGHLAND
24%
Volume = 1668
17%
11%
FLOW RATES
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JUNE
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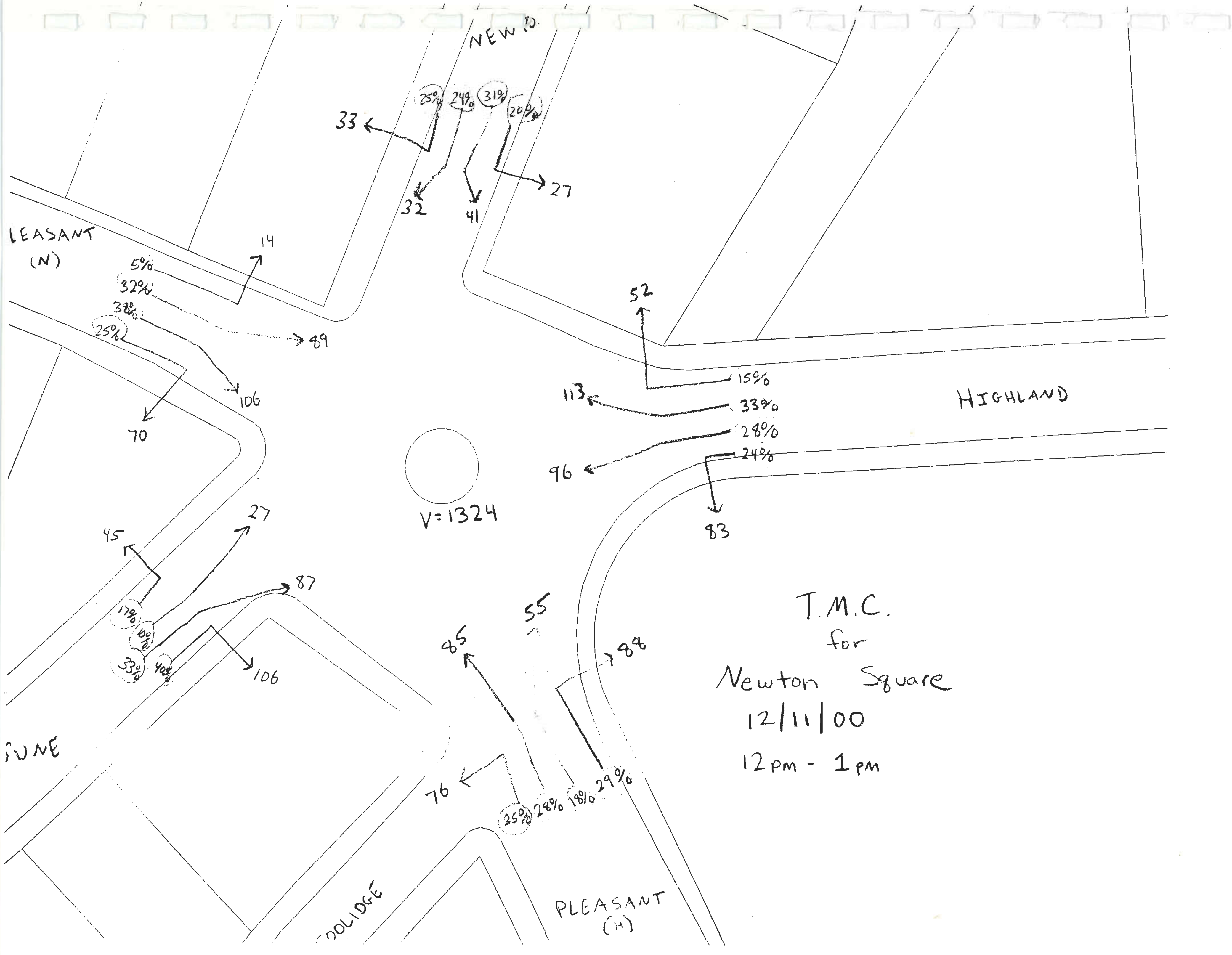
27%
PLEASANT (H)
COOLIDGE



T.M.C.
for
Newton Square
12/11/00
12pm - 1pm
V=1324
NEW
LEASANT
(N)
HIGHLAND
UNE
OOLIDGE
PLEASANT
25%
24%
31%
20%
33
32
41
27
14
5%
32%
38%
25%
89
106
70
52
15%
33%
28%
24%
113
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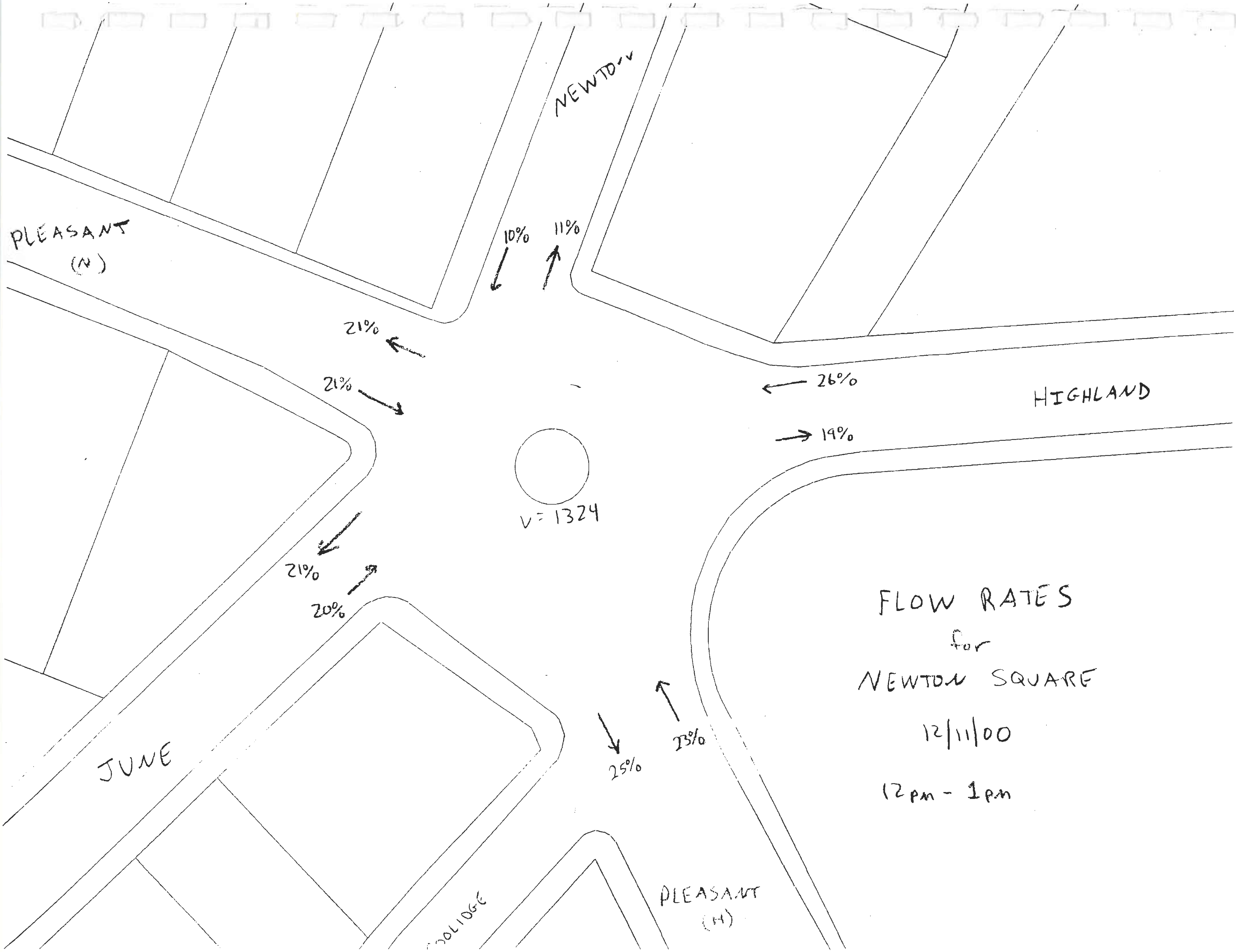

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21%
26%
HIGHLAND
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FLOW RATES for NEWTON SQUARE
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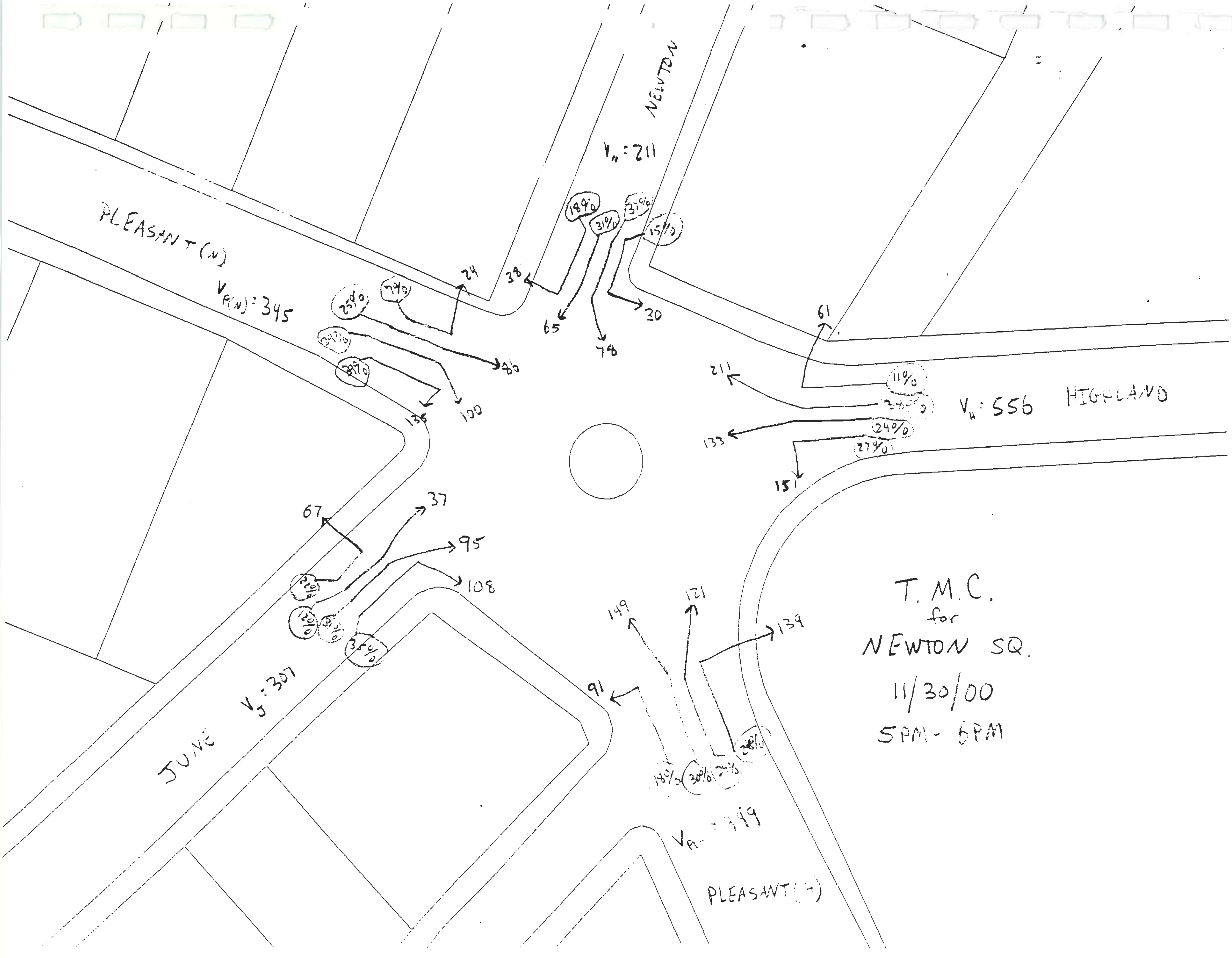
JUNE
PLEASANT (H)



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31%
15%
11%
24%
27%
35%
30%
24
38
65
78
30
61
211
133
151
86
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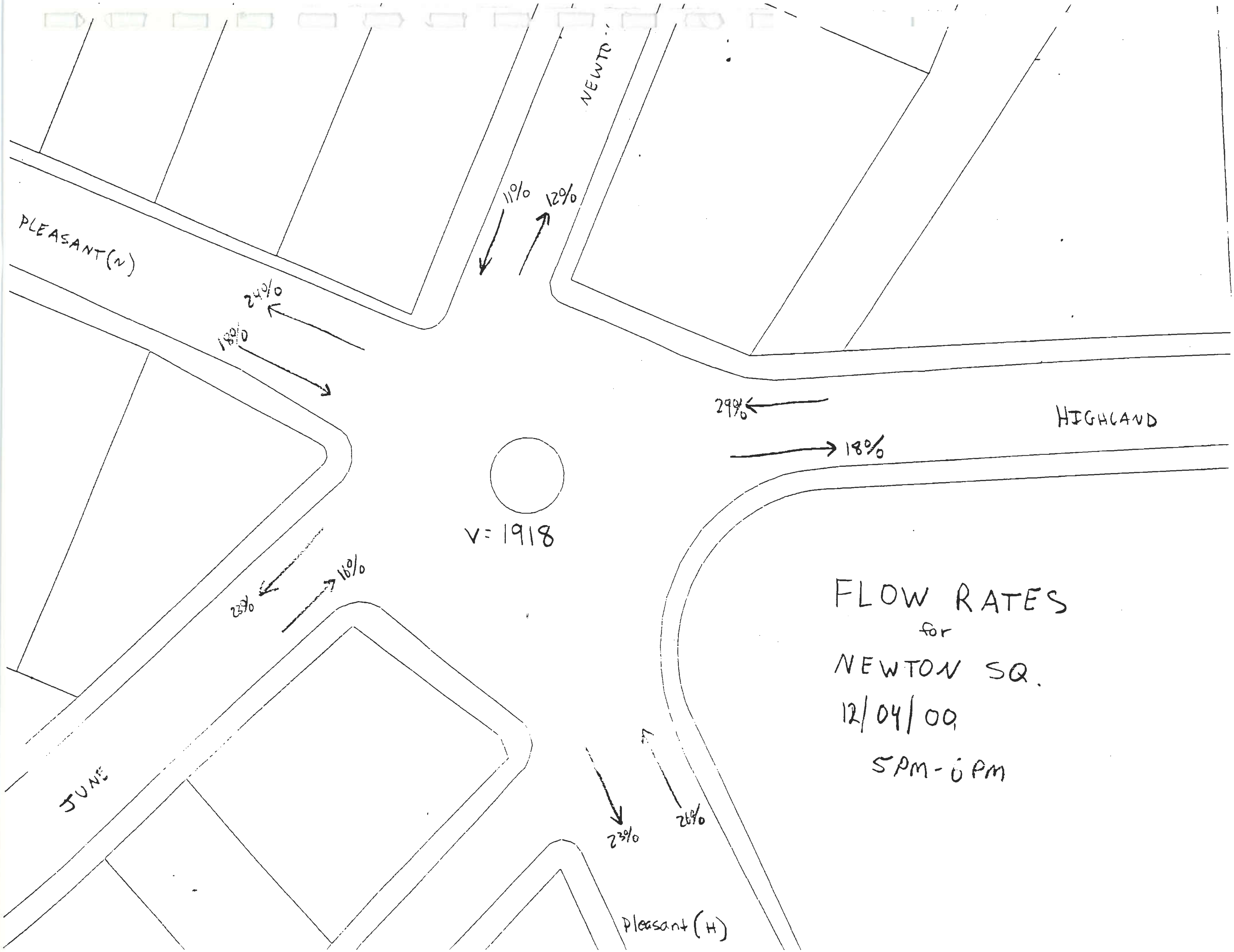
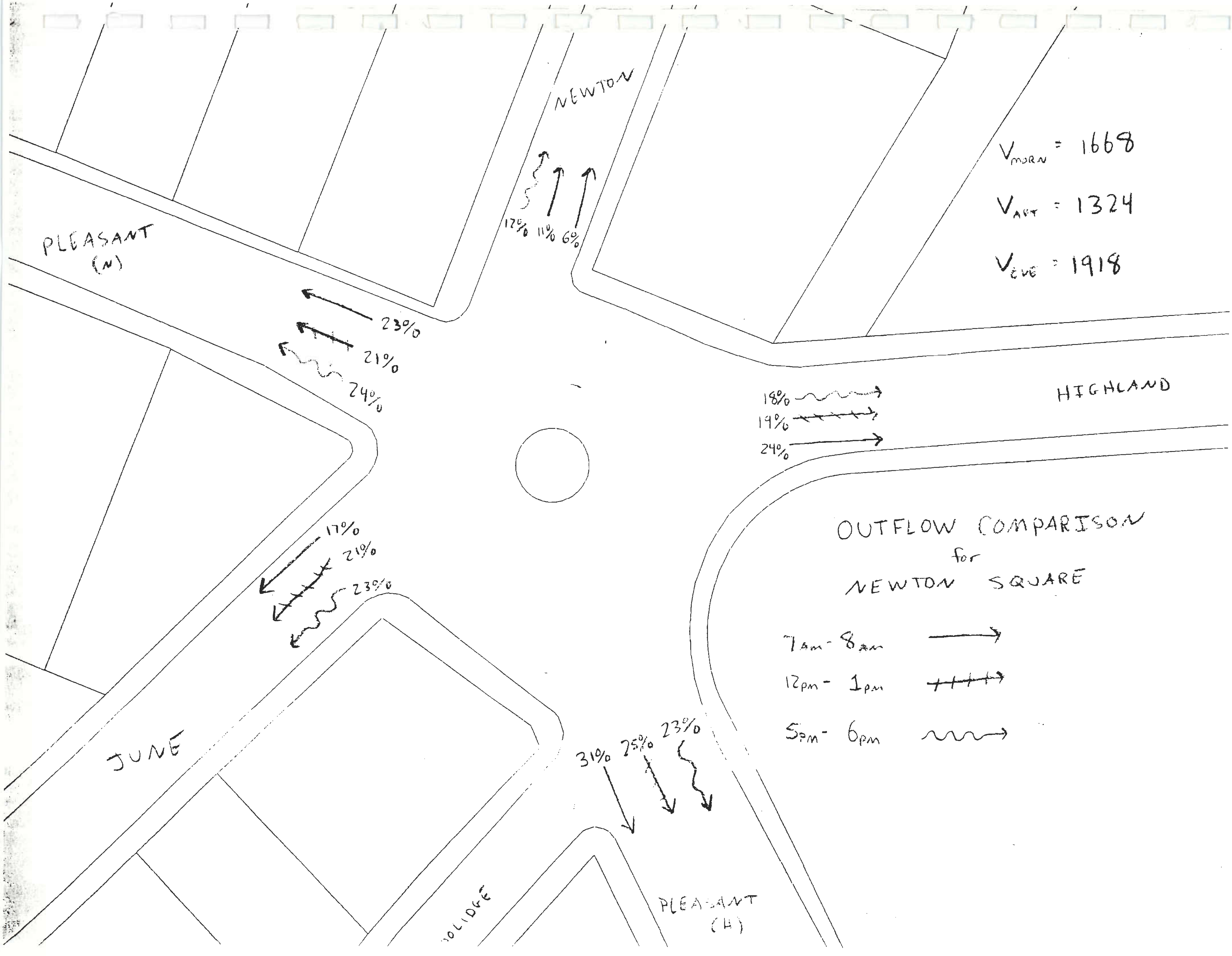
T. M. C.
for
NEWTON SQ.
11/30/00
5PM - 6PM

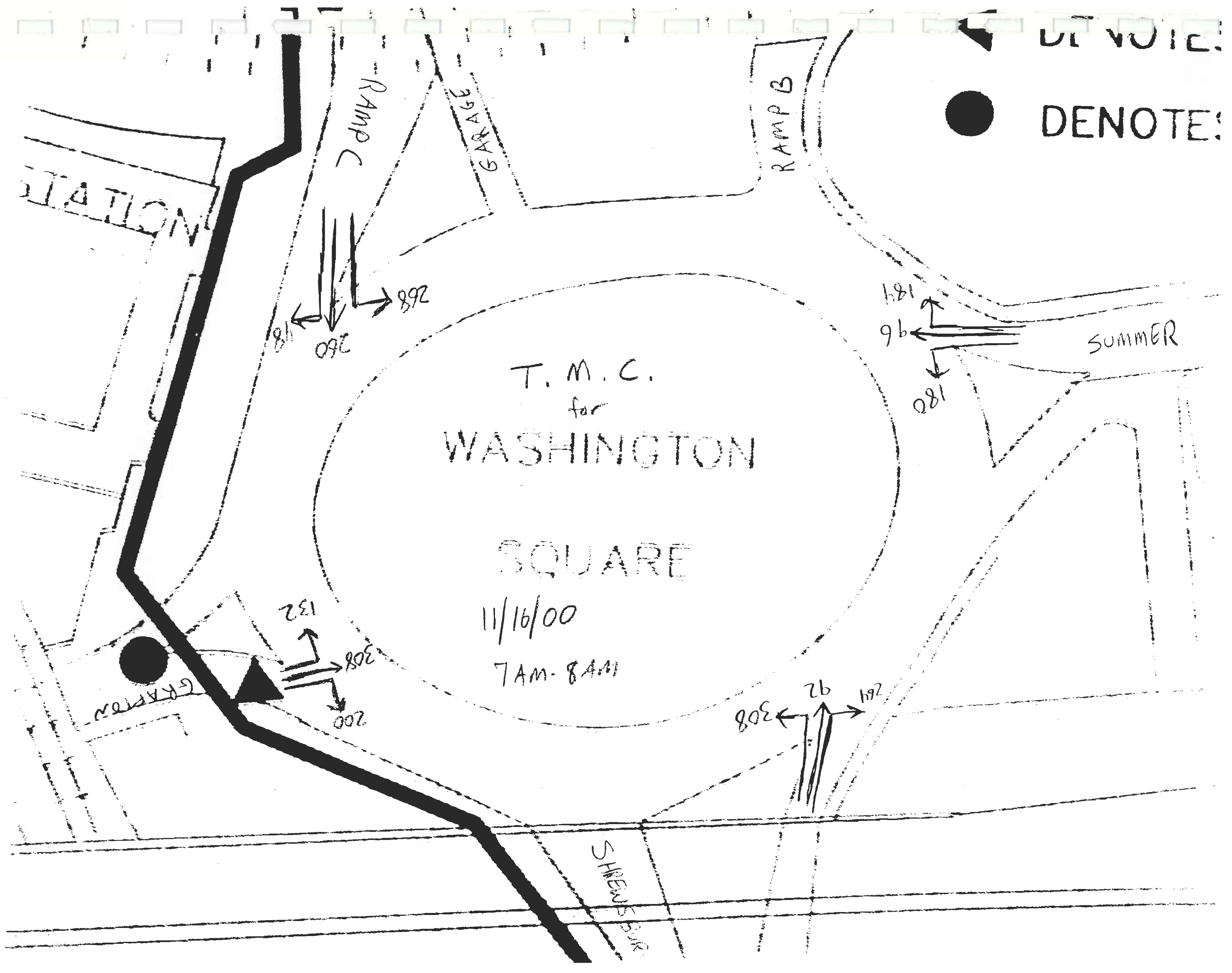


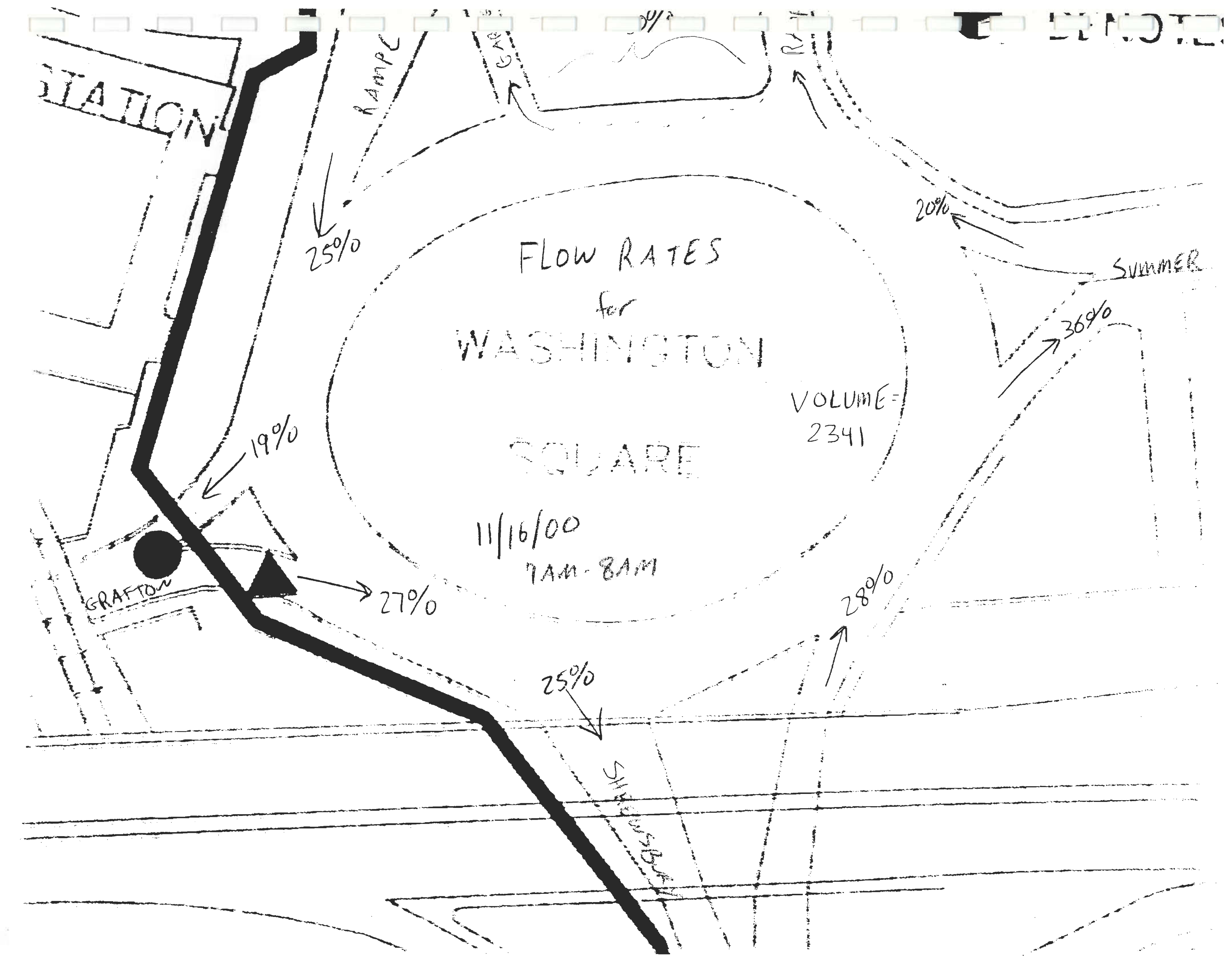
NEWTO
11%
12%
PLEASANT (N)
24%
18%
29%
HIGHLAND
18%
V = 1918
23%
16%
FLOW RATES
for
NEWTON SQ.
12/04/00
5PM-6PM
JUNE
23%
26%
Pleasant (H)

V_{MORN} = 1,668
V_{AFT} = 1,324
V_{EVE} = 1,918
NEWTON
16%
10%
11%
PLEASANT (N)
18%
21%
30%
19%
26%
29%
HIGHLAND
INFLOW COMPARISON for NEWTON SQUARE
7Am - 8Am
12pm - 1pm
5pm - 6pm
16%
20%
11%
JUNE
26%
23%
27%
PLEASANT (H)

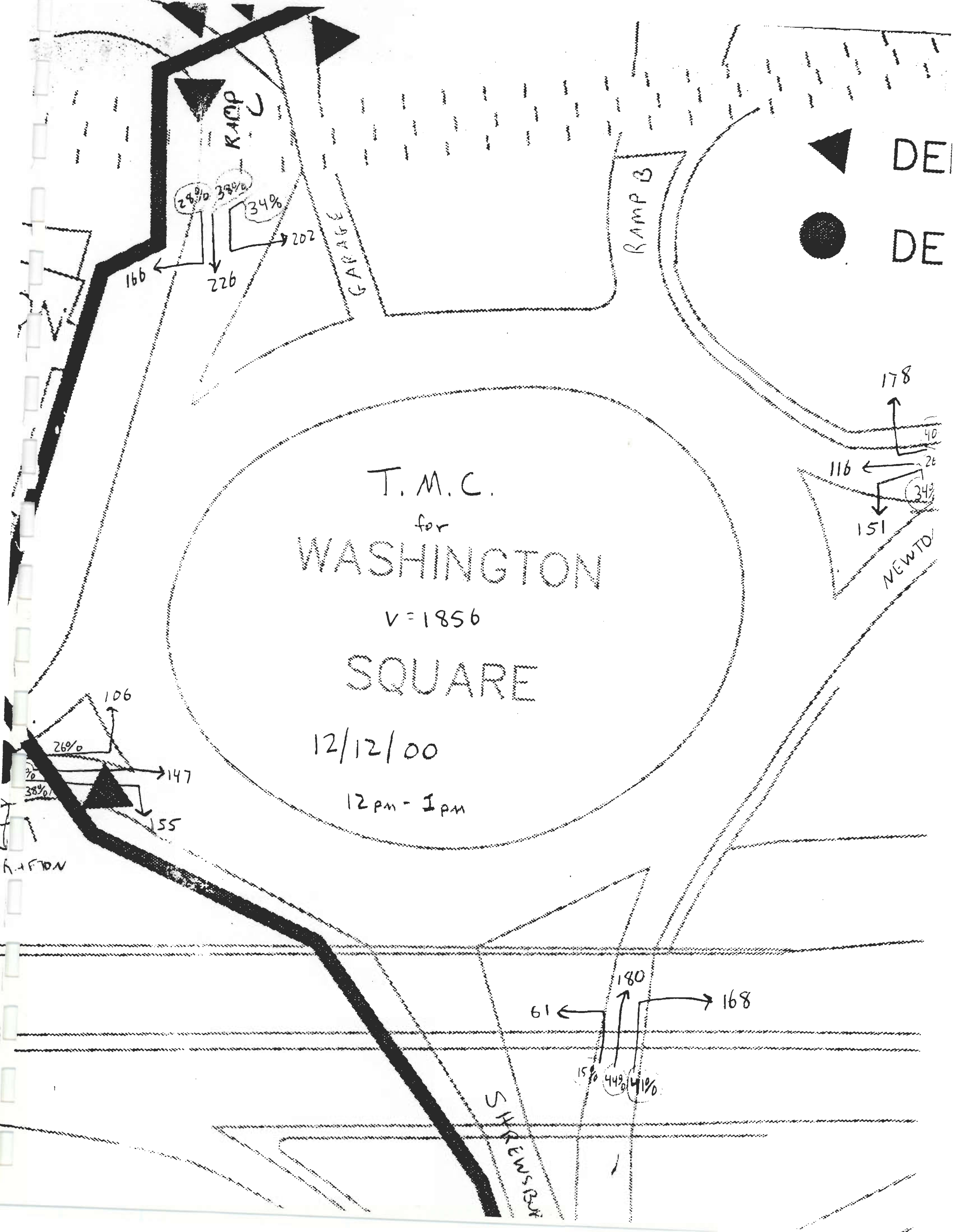


NEWTON
17% 11% 6%
V_MORN = 1668
V_AFT = 1324
V_EVE = 1918
PLEASANT (N)
23%
21%
24%
HIGHLAND
18%
19%
24%
OUTFLOW COMPARISON for NEWTON SQUARE
7am - 8am
12pm - 1pm
5pm - 6pm
17%
21%
23%
JUNE
31% 25% 23%
PLEASANT (H)

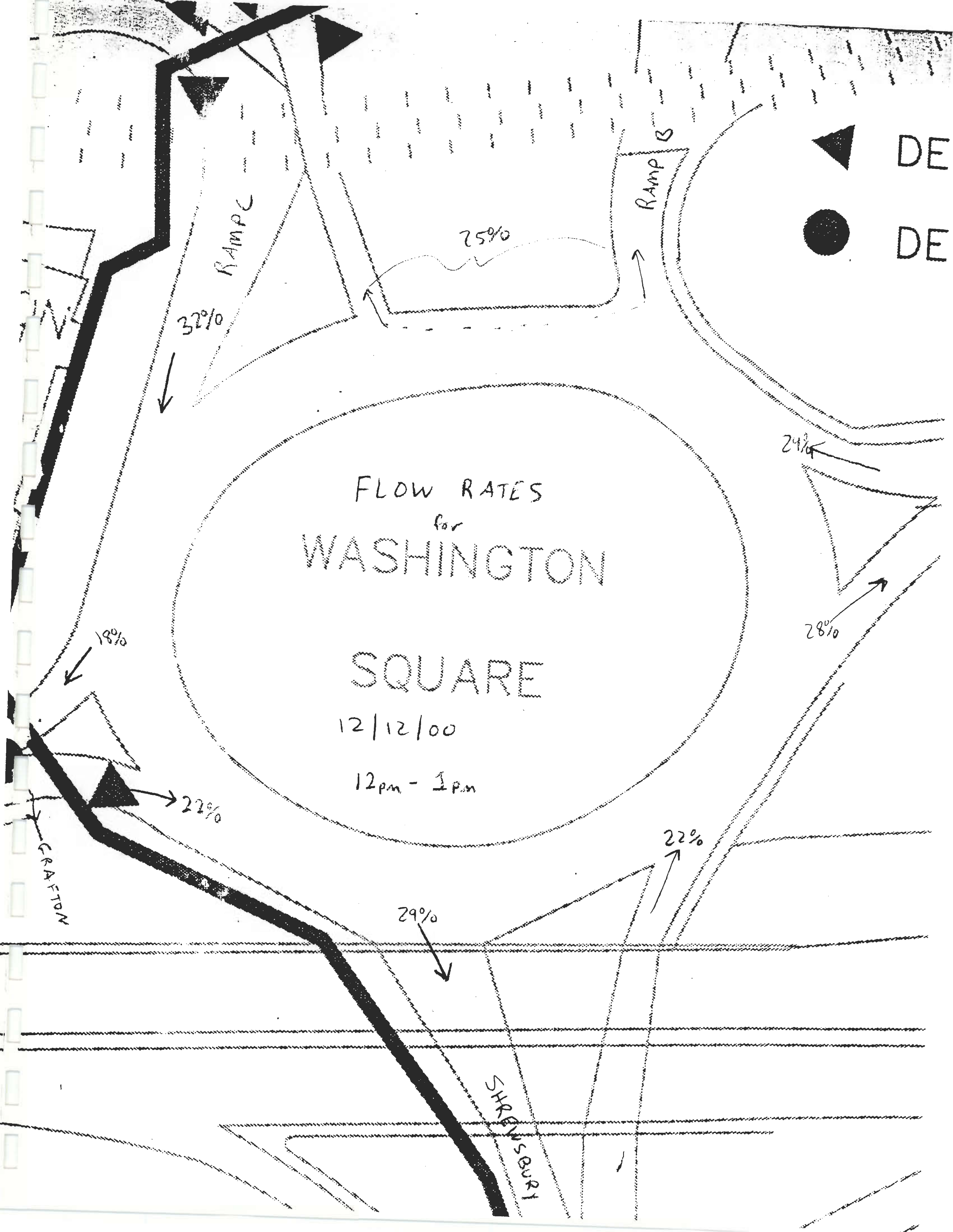

DENOTES
STATION
RAMP C
GARAGE
RAMP B
SUMMER
T.M.C.
for
WASHINGTON
SQUARE
11/16/00
7AM-8AM
GRAFTON
268
280
181
96
180
132
308
200
308
92
194

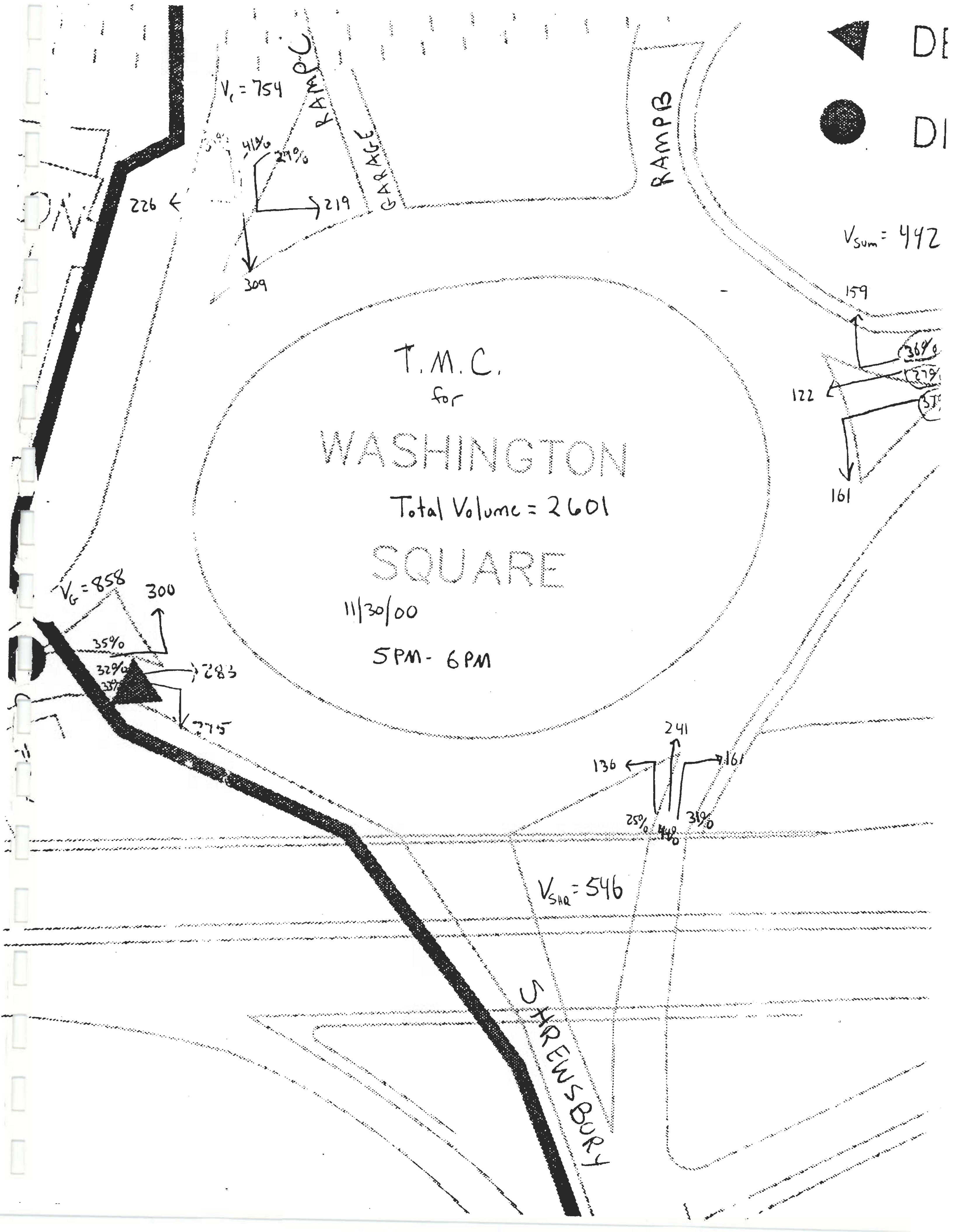


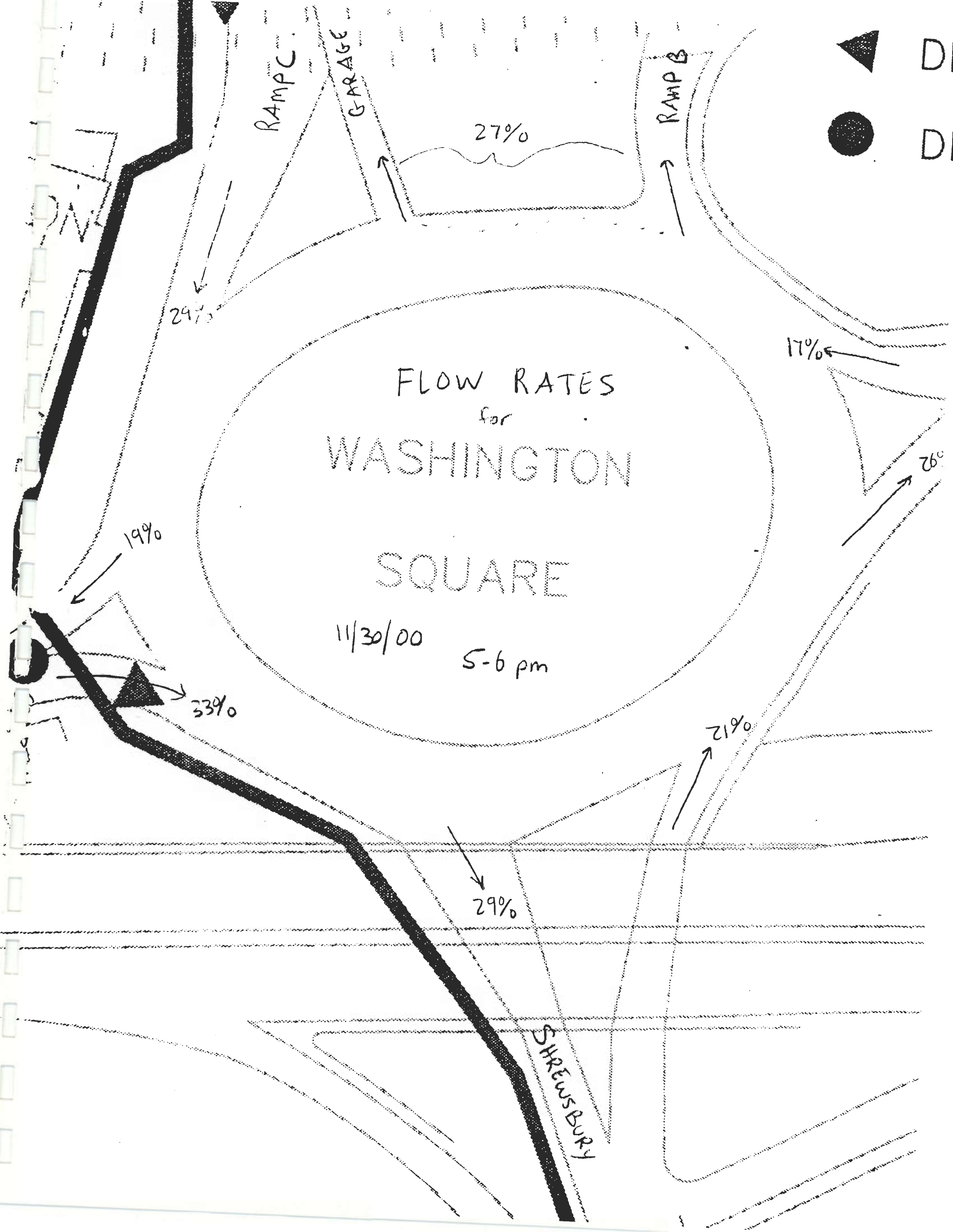
FLOW RATES for WASHINGTON SQUARE
VOLUME= 2341
11/16/00
7AM-8AM
STATION
RAMP
GRAFTON
SUMMER
25%
19%
27%
25%
28%
36%
20%



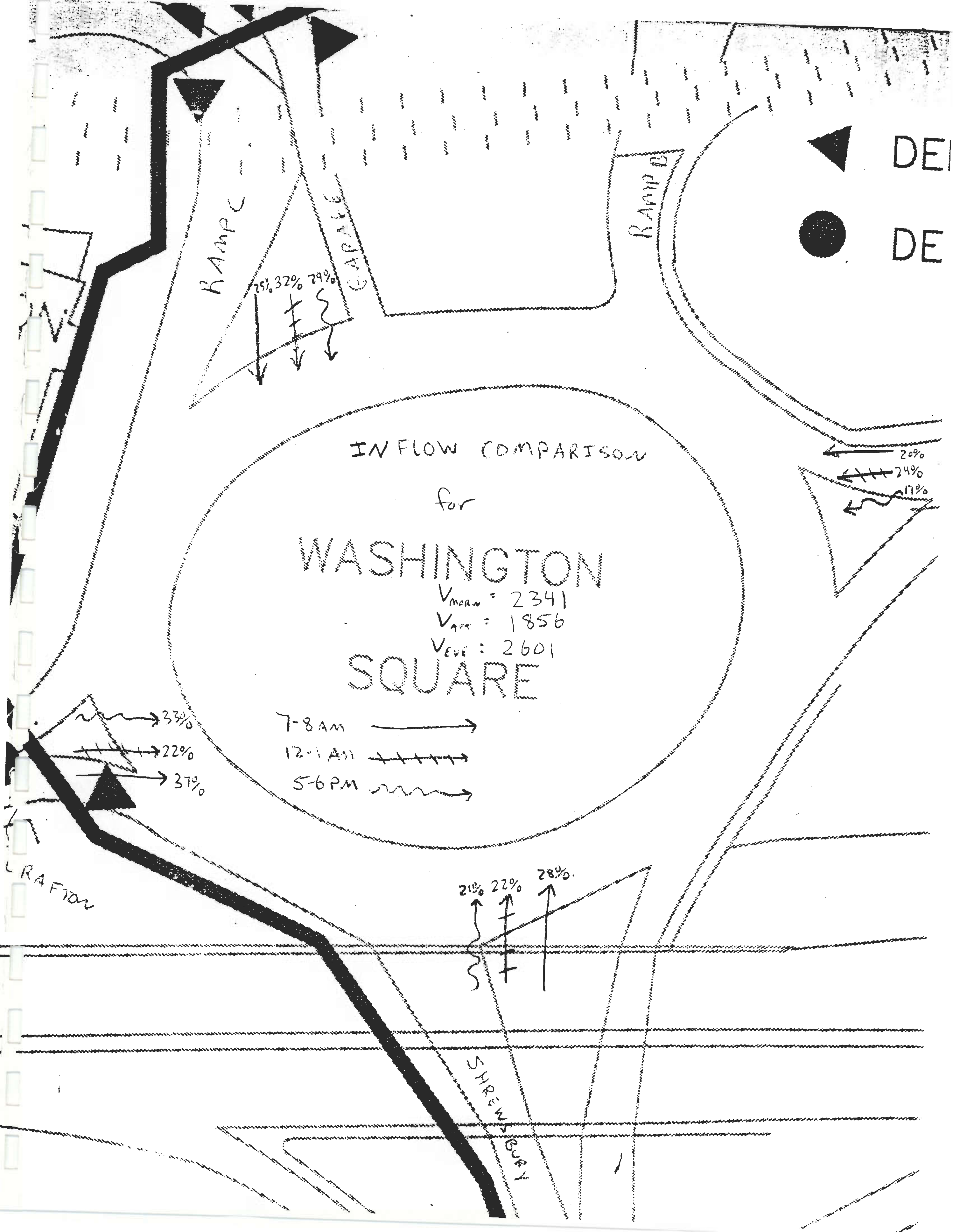
T.M.C.
for
WASHINGTON
V=1856
SQUARE
12/12/00
12pm - 1pm
RAMP C
GARAGE
RAMP B
28%
38%
34%
166
226
202
178
40
116
26
34%
151
NEWTO
106
26%
147
38%
155
61
180
168
15%
44%
41%
SHREWSBU


FLOW RATES
for
WASHINGTON
SQUARE
12/12/00
12pm - 1pm
RAMP C
RAMP B
25%
32%
24%
28%
18%
22%
22%
29%
GRAFTON
SHREWSBURY
DE
DE

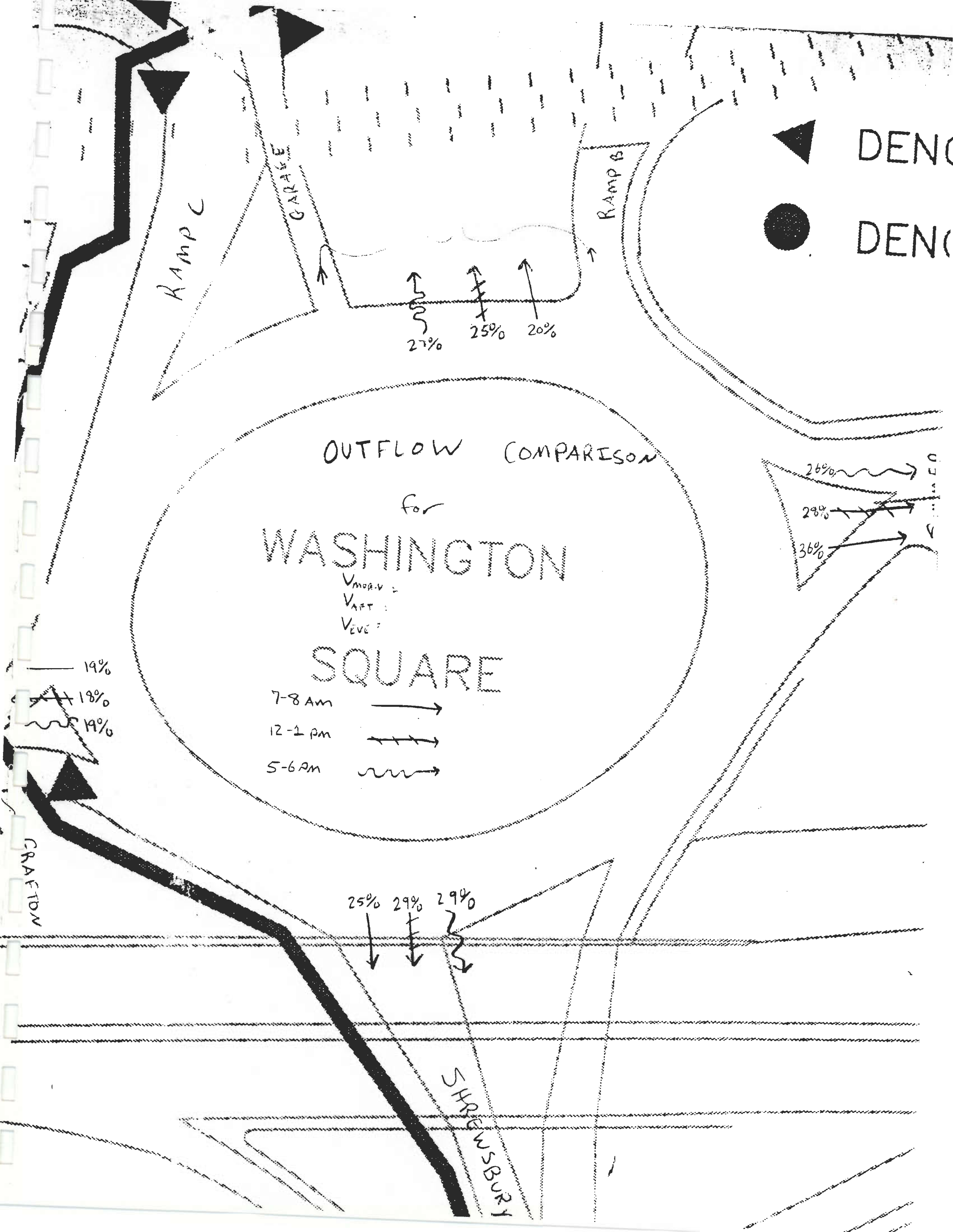

T.M.C.
for
WASHINGTON
Total Volume = 2601
SQUARE
11/30/00
5PM - 6PM
V_c = 754
RAMP C
GARAGE
RAMP B
V_sum = 442
226
219
309
41%
27%
159
36%
27%
122
161
V_G = 858
300
35%
32%
283
275
241
136
161
25%
44%
31%
V_SHR = 546
SHREWSBURY



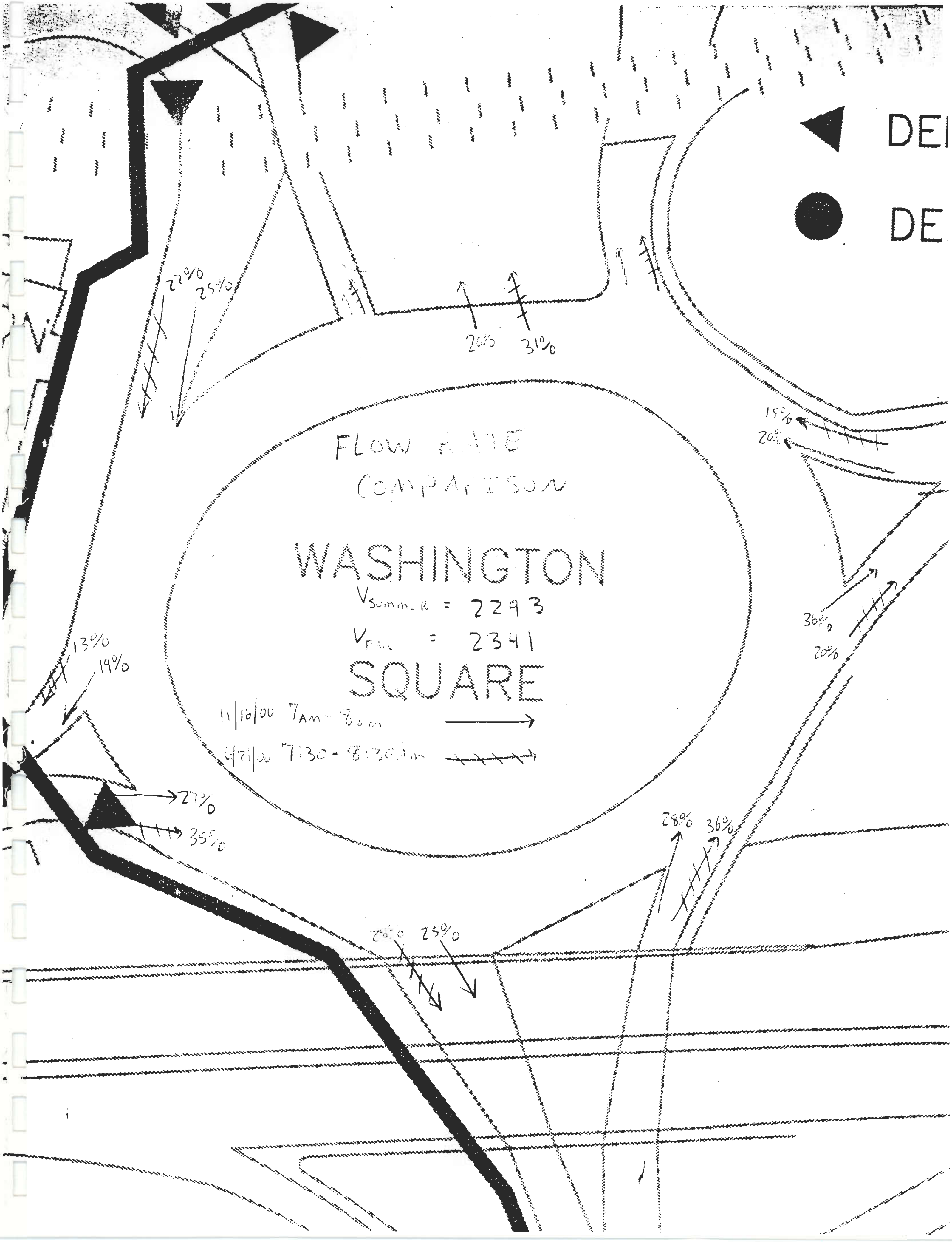
FLOW RATES
for
WASHINGTON
SQUARE
11/30/00
5-6 pm
RAMP C
GARAGE
RAMP B
27%
29%
17%
19%
33%
21%
29%
SHREWSBURY



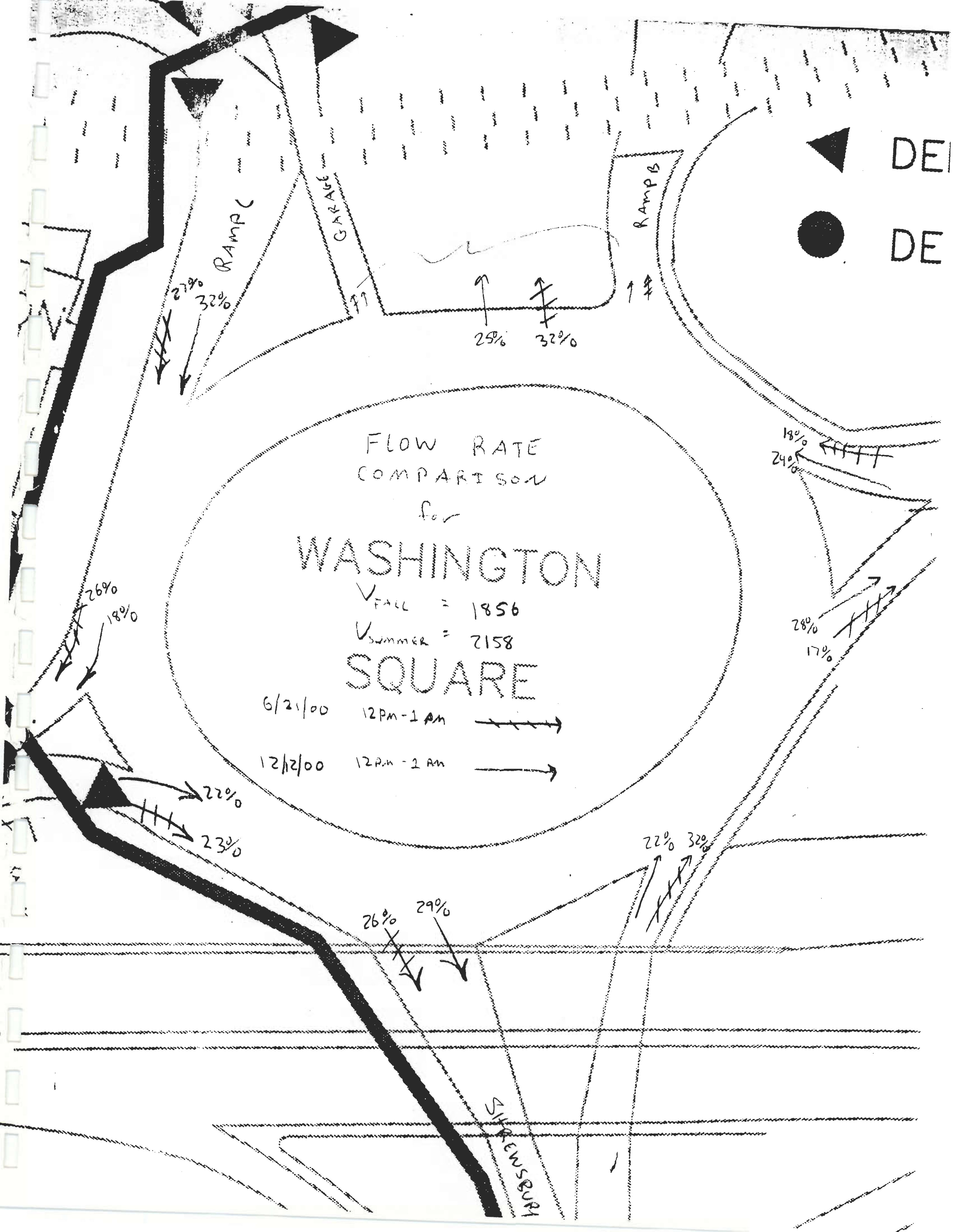
INFLOW COMPARISON
for
WASHINGTON
SQUARE
V_{MORN} : 2341
V_{AFT} : 1856
V_{EVE} : 2601
7-8 AM
12-1 AM
5-6 PM
RAMP C
GARAGE
RAMP B
25% 32% 29%
20%
24%
17%
33%
22%
37%
21% 22% 28%
GRAFTON
SHREWSBURY
DE
DE



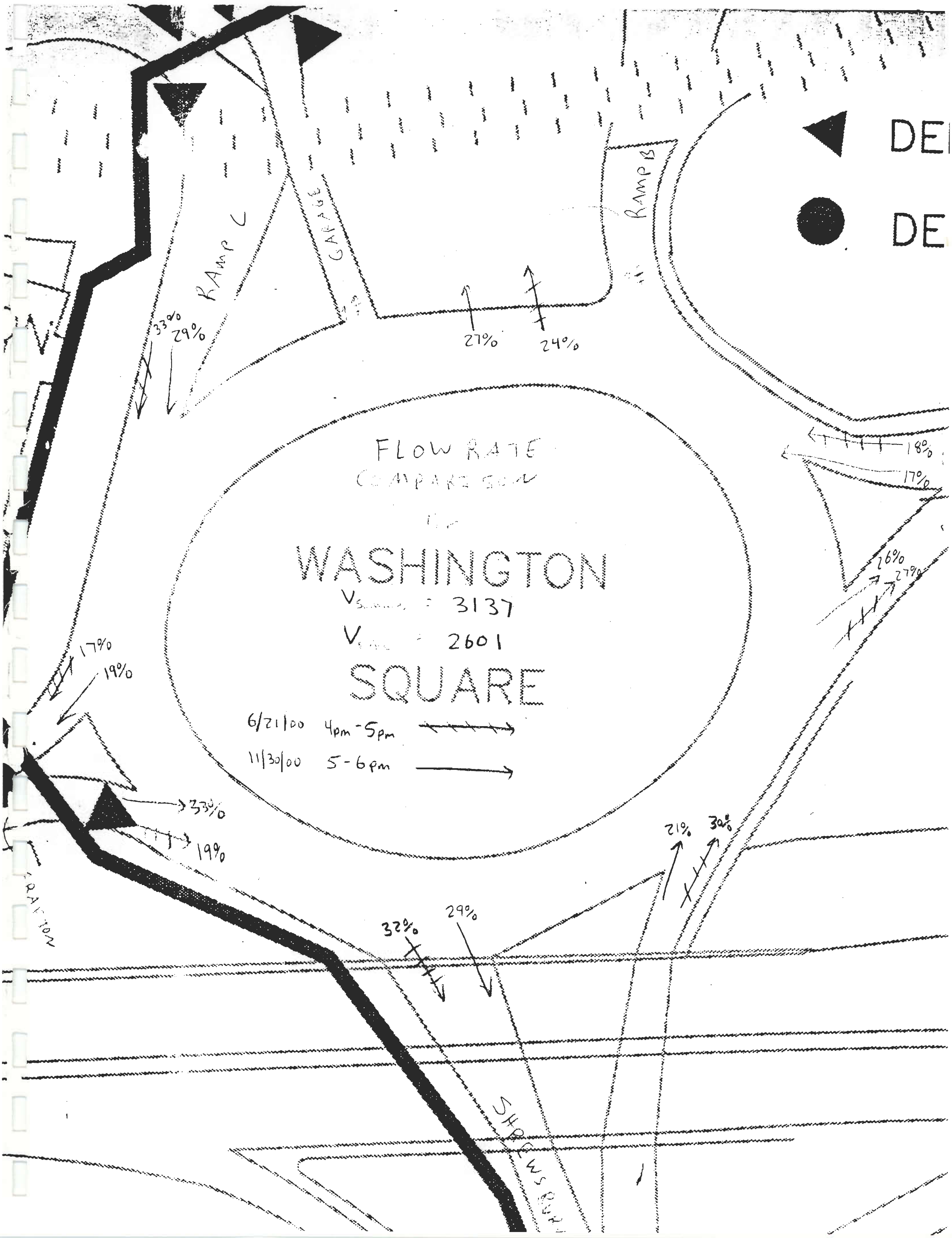
OUTFLOW COMPARISON
for
WASHINGTON
SQUARE
7-8 Am
12-1 pm
5-6 Pm
RAMP C
GARAGE
RAMP B
DENO
DENO
27%
25%
20%
26%
28%
36%
19%
18%
19%
25%
29%
29%
GRAFTON
SHREWSBURY

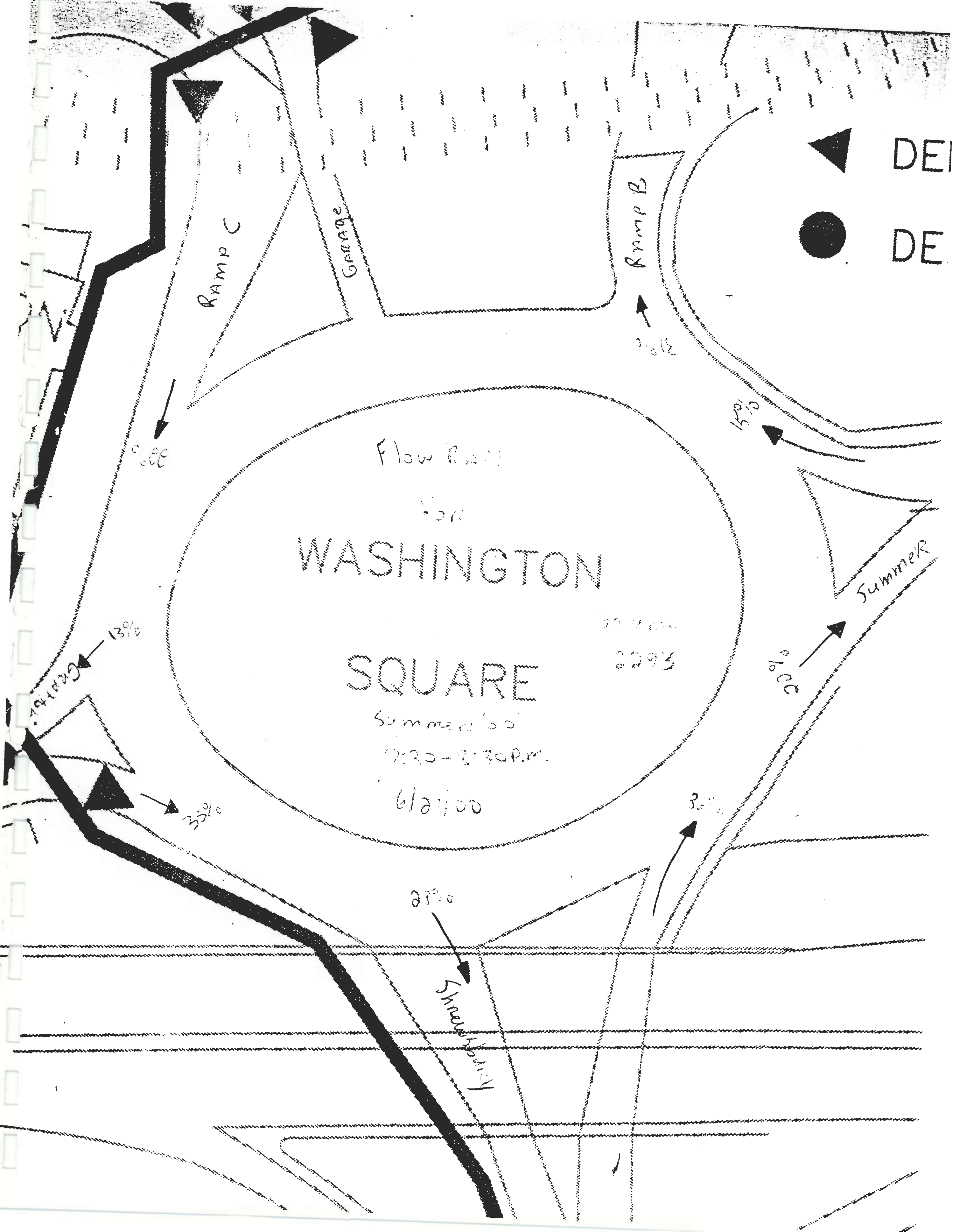


DE
DE
FLOW RATE COMPARISON
WASHINGTON
Vsummer = 2293
Vfall = 2341
SQUARE
11/16/00 7am - 8am
9/7/00 7:30 - 8:30 am
22%
25%
20%
31%
15%
20%
36%
20%
28%
36%
26%
25%
13%
19%
27%
35%

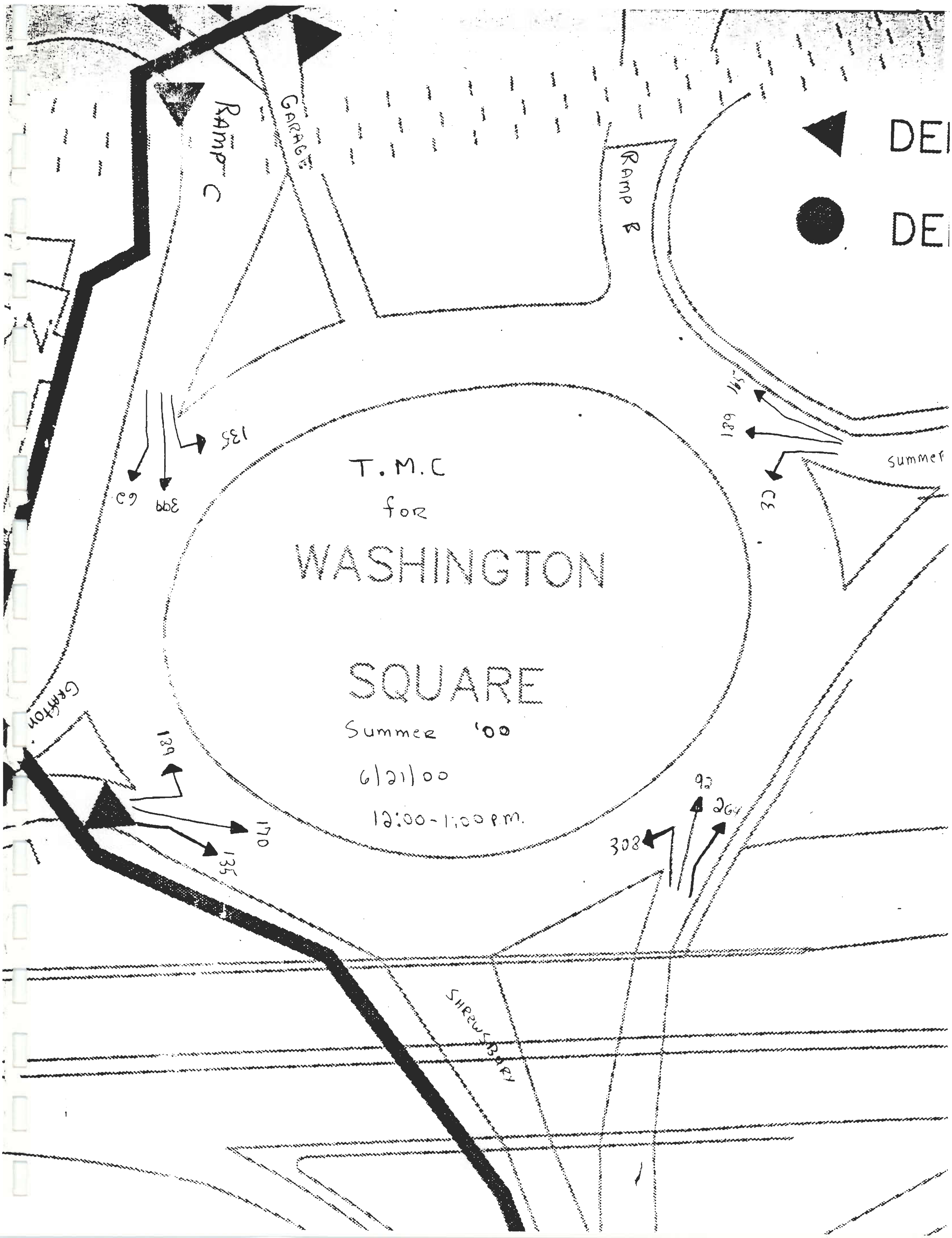


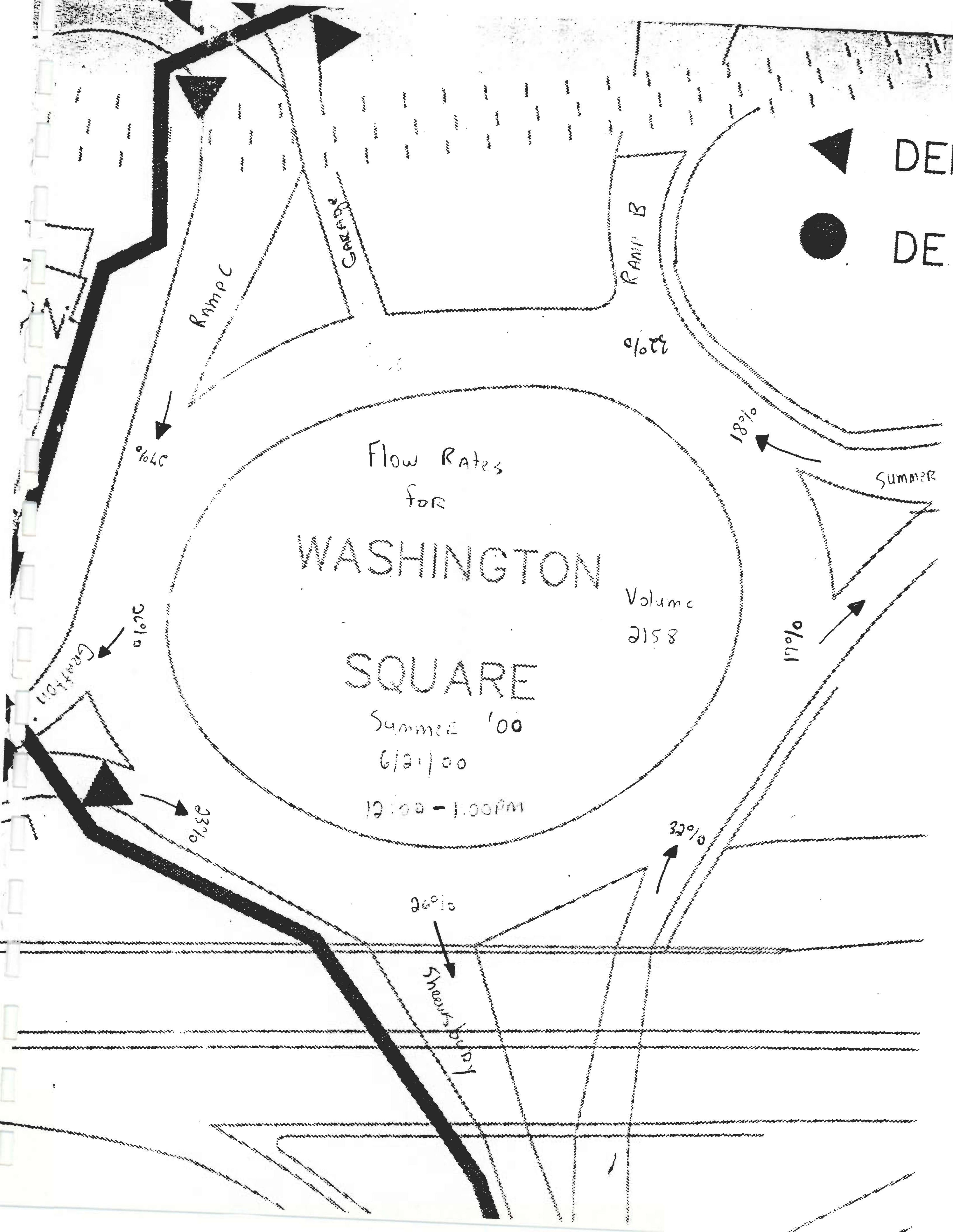
DE
DE
RAMP C
GARAGE
RAMP B
27%
32%
25%
32%
18%
24%
FLOW RATE
COMPARISON
for
WASHINGTON
V FALL = 1856
V SUMMER = 2158
SQUARE
6/21/00 12PM-1AM
12/12/00 12PM-1AM
26%
18%
28%
17%
22%
23%
22%
32%
26%
29%
SHREWSBURY


FLOW RATE
WASHINGTON
V = 3137
V = 2601
SQUARE
6/21/00 4pm-5pm
11/30/00 5-6pm
RAMP C
GARAGE
RAMP B
33%
29%
27%
24%
18%
17%
26%
27%
17%
19%
33%
19%
32%
29%
21%
30%

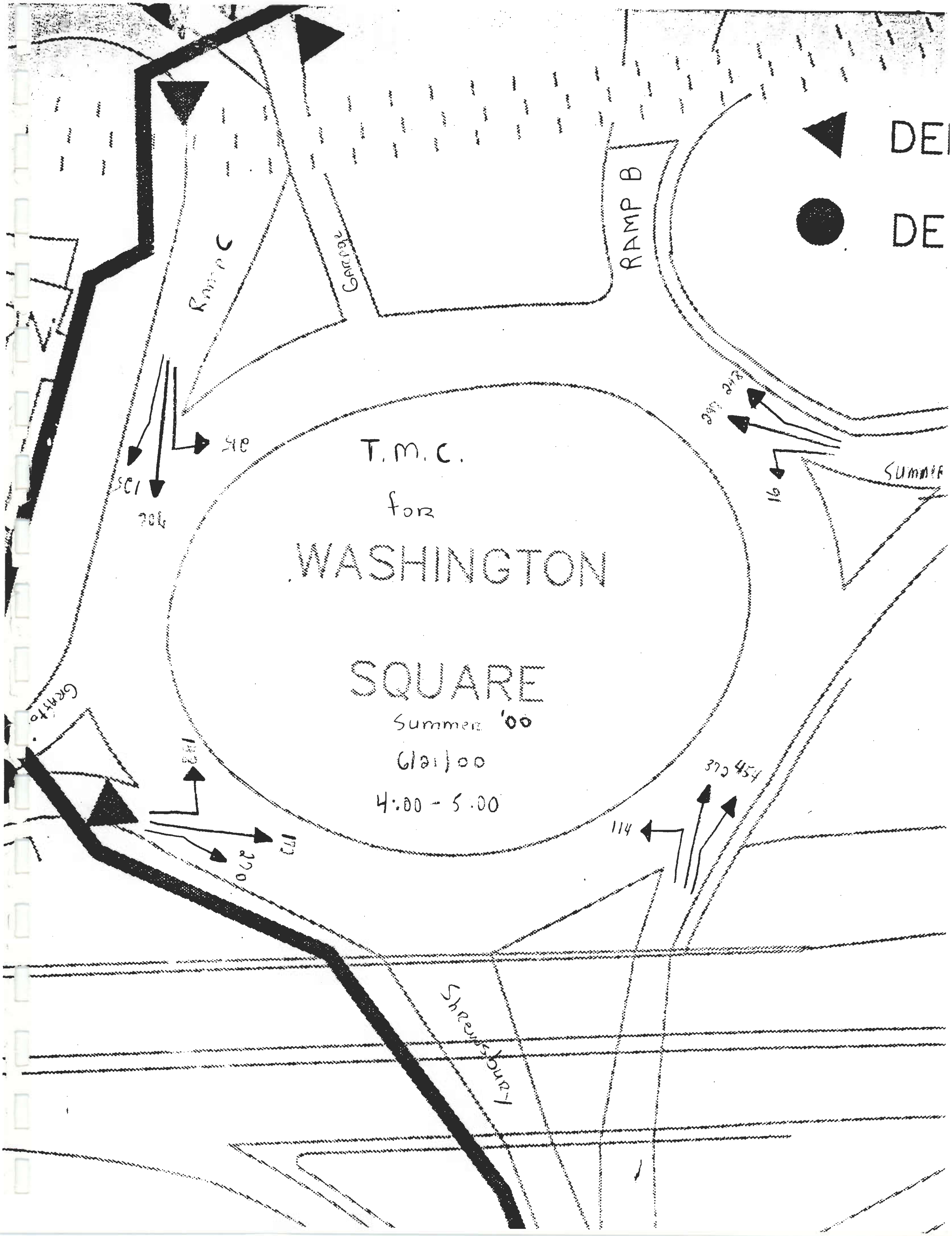


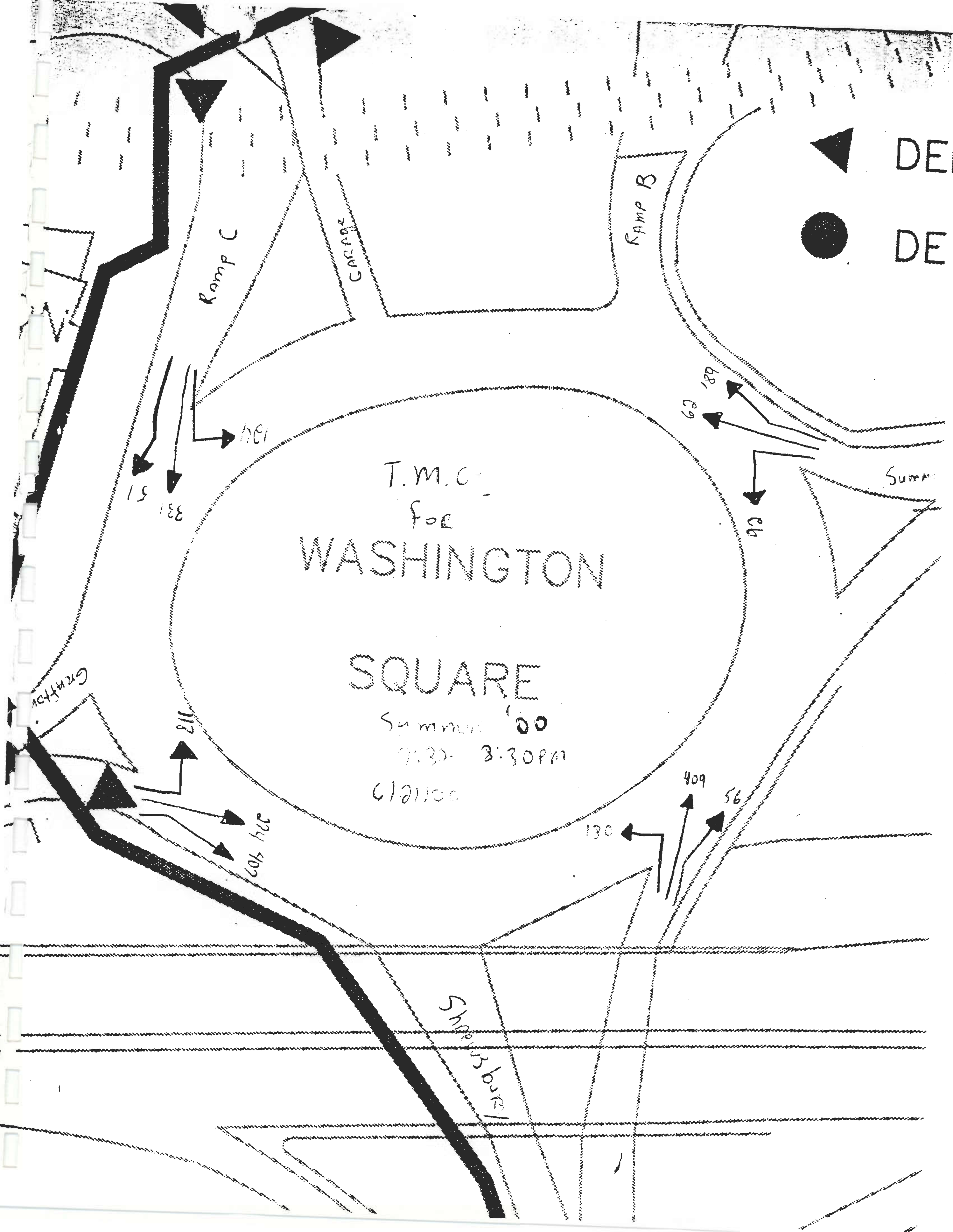
Ramp C
Garage
Ramp B
33%
31%
15%
Flow Rate
for
WASHINGTON
2293
SQUARE
Summer '00
7:30-8:30 P.M.
6/29/00
Summer
20%
13%
35%
30%
27%
Shrewsbury


DE
DE
RAMP C
GARAGE
RAMP B
135
63
399
T.M.C
for
WASHINGTON
SQUARE
Summer '00
6/21/00
12:00-1:00 pm.
165
189
32
Summer
Grafton
189
170
135
92
264
308
SHREWSBURY

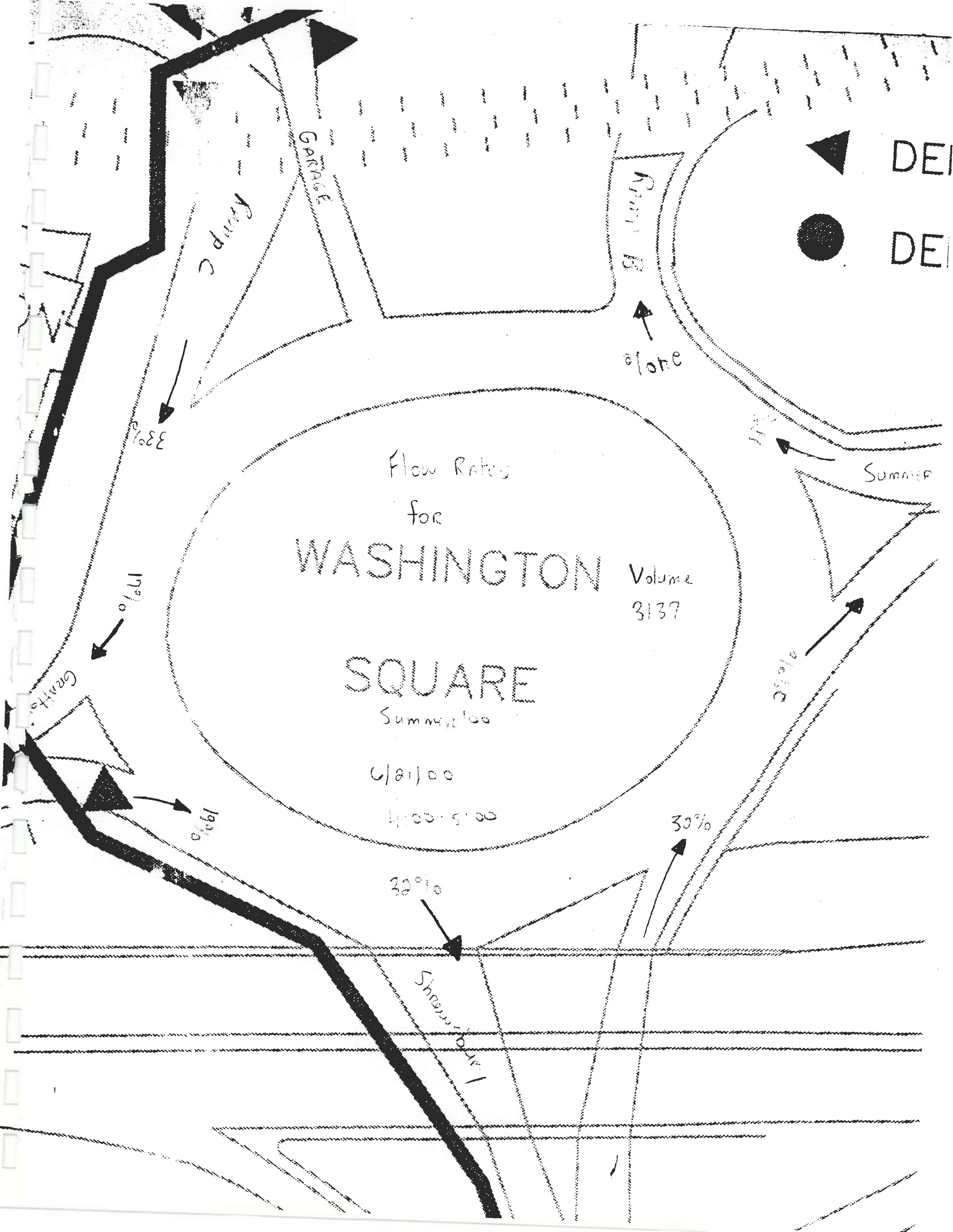


Flow Rates for
WASHINGTON SQUARE
Summer '00
6/21/00
12:00 - 1:00PM
Volume 2158
Ramp C
Garage
Ramp B
Summer
18%
17%
32%
26%

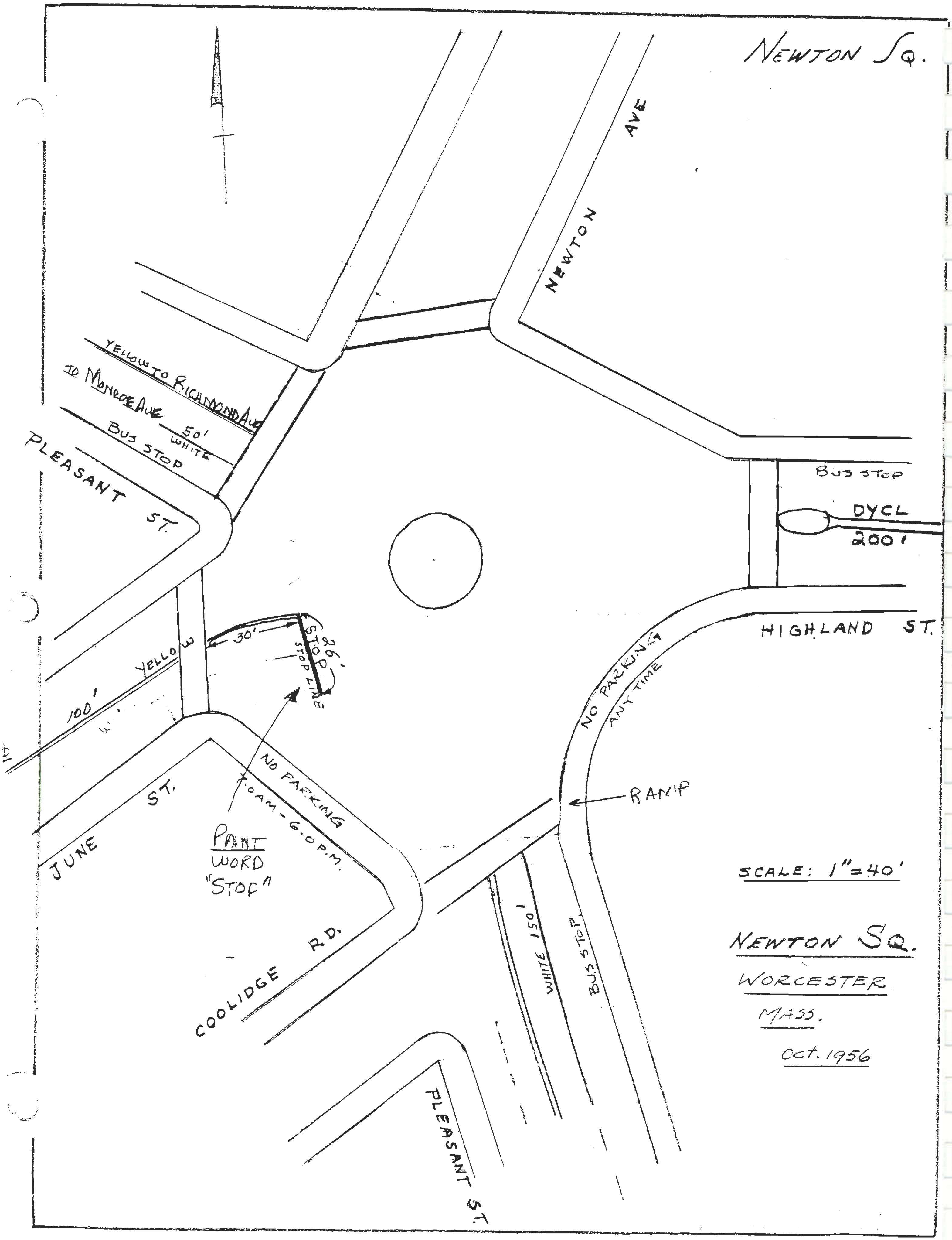

T.M.C.
for
WASHINGTON
SQUARE
Summer '00
6/21/00
4:00 - 5:00
RAMP B
Ramp C
Garage
454
114
16



Ramp B
Ramp C
GARAGE
T.M.C.
for
WASHINGTON
SQUARE
Summer '00
3:30PM
6/21/00
134
51
331
189
62
96
117
324
409
130
409
56
Grafton
Shrewsbury

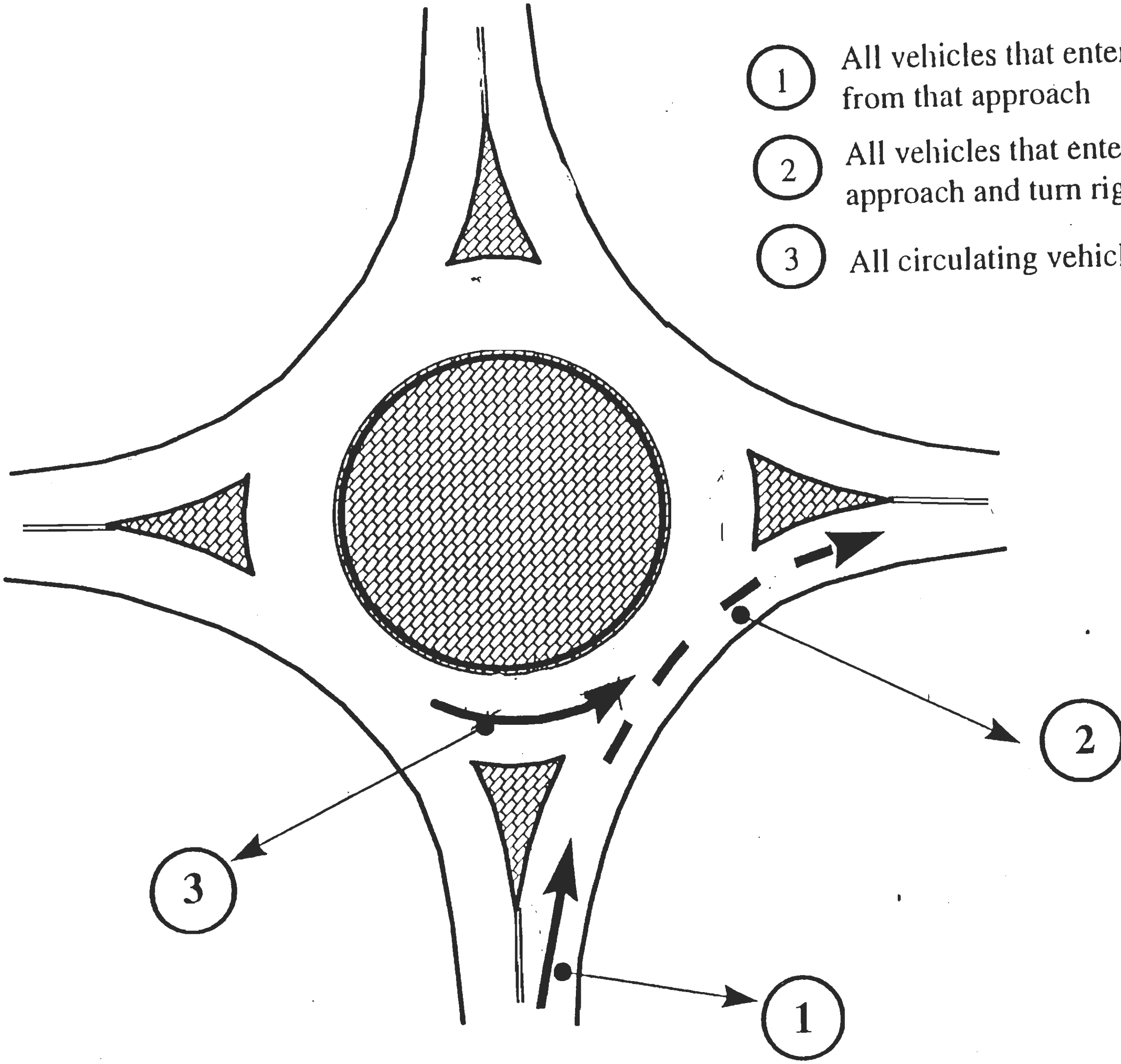


Flow Rates
for
WASHINGTON
SQUARE
Summer '00
6/21/00
Volume
3137
GARAGE
Summer
33%
19%
19%
32%
30%



NEWTON SQ.
NEWTON AVE
YELLOW TO RICHMOND AVE
TO MONROE AVE
50' WHITE
BUS STOP
PLEASANT ST.
BUS STOP
DYCL
200'
HIGHLAND ST.
NO PARKING ANY TIME
30'
26'
STOP
STOP LINE
YELLOW
100'
NO PARKING 7.0AM-6.0P.M.
PAINT WORD "STOP"
RAMP
JUNE ST.
COOLIDGE RD.
WHITE 150'
BUS STOP
PLEASANT ST.
SCALE: 1"=40'
NEWTON SQ.
WORCESTER
MASS.
Oct. 1956

Turning Movement Counts at a Roundabout

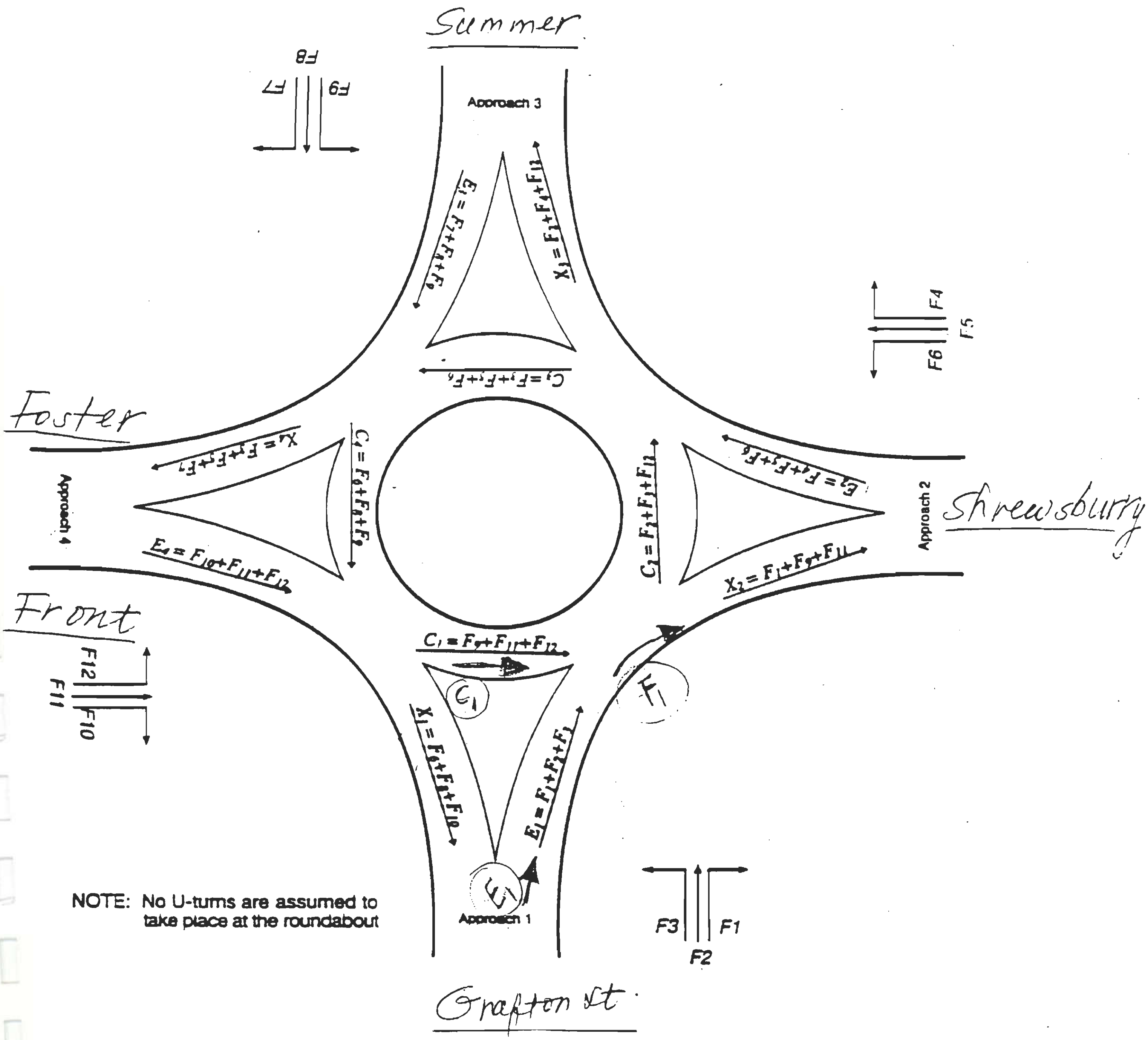


1 — All vehicles that enter the roundabout from that approach

2 — All vehicles that enter the roundabout from that approach and turn right (exiting at the next approach)

3 — All circulating vehicles at that approach

FIGURE A2.
Composition of Traffic Movements in a Four-Leg Roundabout



NOTE: No U-turns are assumed to take place at the roundabout

TRAFFIC VOLUMES

LOCATION NEWTON SQ. NO. OF ACCIDENTS ____

DATA OBTAINED FROM POLICE FILES DATE 2-86

FROM 1-1-84 TO 12-31-85 BY KB

DEPT. OF TRAFFIC ENGINEERING WORCESTER, MASS.

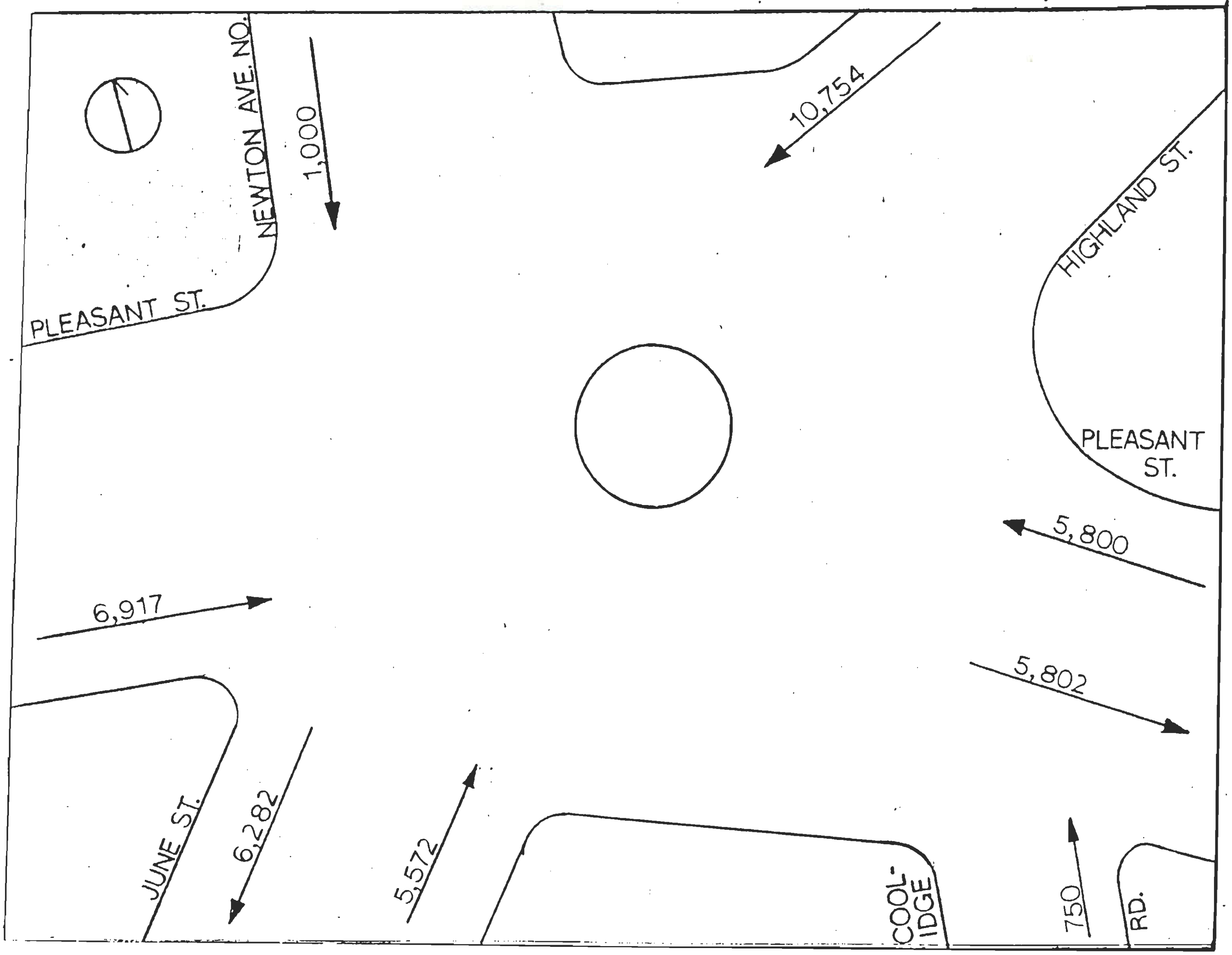


Table 6

Washington Square

June 21, 2000, 16:00-18:00 PM, All Vehicles, Adjusted Counts

Summer St/Front Street/Foster St/Grafton St/Shrewsbury St

15-Minute Counts

		To							
Approach	Position	16:15	16:30	16:45	17:00	17:15	17:30	17:45	18:00
Front #4	7L	20	12	17	13	9	11	7	14
	7R	77	74	82	102	99	94	87	79
	8L	165	**201**	**200**	**192**	**245**	254	218	176
	8R	25	**23**	25	23	**35**	37	24	21
	4C	*97*	*86*	*99*	*115*	*108*	*105*	*94*	*93*
	4R	25	29	25	24	39	37	24	21
	4E	*190*	*224*	*225*	*215*	*280*	*291*	*242*	*197*
Grafton #1	1L	94	92	113	125	108	96	104	92
	1R	27	33	49	33	34	32	41	39
	2L	67	67	73	**65**	73	89	71	40
	2R	**103**	134	**132**	**165**	175	165	**154**	**140**
	1C	*170*	*201*	*205*	*230*	*248*	*254*	*225*	*180*
	1R	27	33	49	33	34	32	41	39
	1E	*121*	*125*	*162*	*158*	*142*	*128*	*145*	*131*
Shrewsbu #2	3L	138	121	131	119	118	118	123	101
	3R	103	102	102	121	123	108	92	74
	4L	46	38	**40**	43	34	40	41	36
	4R	121	112	**120**	145	125	110	101	96
	2C	167	150	160	188	159	150	142	132
	2R	103	102	102	121	123	108	92	74
	2E	241	223	233	240	241	226	215	175
Summer #3	6L	**57**	63	86	80	71	76	63	57
	6R	53	48	53	61	65	69	46	41
	5L	57	54	46	47	44	41	35	49
	5R	133	108	151	144	141	142	135	109
	3C	*190*	*162*	*197*	*191*	*185*	*183*	*170*	*158*
	3R	53	48	53	61	65	69	46	41
	3E	*110*	*111*	*139*	*141*	*136*	*145*	*109*	*98*

Adjusted traffic counts are indicated in **bold face**. Values in *italics* were calculated from raw counts

Table 5

Washington Square

June 21, 2000, 12:00-14:00 PM, All Vehicles, Adjusted Counts

Summer St/Front Street/Foster St/Grafton St/Shrewsbury St

15-Minute Counts

		To							
Approach	**Position**	**12:15**	**12:30**	**12:45**	**13:00**	**13:15**	**13:30**	**13:45**	**14:00**
Front	7L	16	17	**15**	8	18	12	12	15
#4	7R	67	59	**70**	84	68	56	68	55
	8L	130	133	**135**	136	**136**	156	149	136
	8R	18	12	20	12	19	23	16	16
	4C	*83*	*76*	*85*	*92*	*86*	*68*	*80*	*70*
	4R	18	12	20	12	19	23	16	16
	4E	*148*	*145*	*155*	*148*	*155*	*179*	*165*	*152*
Grafton	1L	76	89	97	**97**	92	83	91	91
#1	1R	32	35	35	33	25	30	29	32
	2L	**37**	**40**	**45**	39	**40**	49	41	51
	2R	**98**	**100**	**100**	107	**110**	115	**118**	101
	1C	*135*	*140*	*145*	*146*	*150*	*164*	*159*	*152*
	1R	32	35	35	33	25	30	29	32
	1E	*108*	*124*	*132*	*130*	*117*	*113*	*120*	*123*
Shrewsbu	3L	103	111	110	104	95	86	101	**91**
#2	3R	46	75	73	66	55	58	44	49
	4L	31	41	42	41	42	39	51	60
	4R	65	83	106	85	74	85	80	92
	2C	*96*	*124*	*148*	*126*	*116*	*124*	*131*	*152*
	2R	46	75	73	66	55	58	44	49
	2E	*149*	*186*	*183*	*170*	*150*	*144*	*145*	*140*
Summer	6L	53	50	**61**	57	43	48	37	36
#3	6R	44	49	39	33	33	34	35	27
	5L	40	37	43	48	40	35	42	39
	5R	117	113	100	119	106	92	111	**106**
	3C	*157*	*150*	*143*	*167*	*146*	*127*	*153*	*145*
	3R	44	49	39	33	33	34	35	27
	3E	*97*	*99*	*100*	*90*	*76*	*82*	*72*	*63*

Adlusted traffic counts are indicated in **bold face**. Values in *italics* were calculated from raw counts.

Table 4
Washington Square
June 21, 2000, 7:00-9:00 AM, All Vehicles, Adjusted Counts
Summer St/Front Street/Foster St/Grafton St/Shrewsbury St

15-Minute Counts

		To							
Approacl	**Position**	**7:15**	**7:30**	**7:45**	**8:00**	**8:15**	**8:30**	**8:45**	**9:00**
Front #4	7L	14	12	12	**15**	10	5	12	18
	7R	**32**	46	**48**	**45**	36	39	43	39
	8L	74	**110**	**124**	**116**	**120**	**105**	82	106
	8R	13	**14**	**16**	12	10	13	14	8
	4C	*46*	*58*	*60*	*60*	*46*	*44*	*55*	*57*
	4R	13	14	16	12	10	13	14	8
	4E	*87*	*124*	*140*	*128*	*130*	*118*	*96*	*114*
Grafton #1	1L	88	133	148	196	179	158	122	119
	1R	28	37	36	32	33	17	21	29
	2L	34	**35**	46	**30**	**28**	**24**	**24**	34
	2R	56	**94**	**89**	**110**	**117**	**103**	**101**	97
	1C	*90*	*129*	*135*	*140*	*145*	*127*	*125*	*131*
	1R	28	37	36	32	33	17	21	29
	1E	*116*	*170*	*184*	*228*	*212*	*175*	*143*	*148*
Shrewsbu #2	3L	57	88	122	131	101	111	115	100
	3R	43	47	45	48	44	43	45	36
	4L	69	67	87	96	102	97	74	58
	4R	38	88	110	114	115	84	72	72
	2C	*107*	*155*	*197*	*210*	*217*	*181*	*146*	*130*
	2R	43	47	45	48	44	43	45	36
	2E	*100*	*135*	*167*	*179*	*145*	*154*	*160*	*136*
Summer #3	6L	**42**	40	**45**	42	**45**	34	47	42
	6R	**45**	33	**40**	44	**52**	53	55	46
	5L	30	39	53	36	27	24	24	25
	5R	93	131	155	187	197	193	154	146
	3C	*123*	*170*	*208*	*223*	*224*	*217*	*178*	*171*
	3R	45	33	40	44	52	53	55	46
	3E	*87*	*73*	*85*	*86*	*97*	*87*	*102*	*88*

Adjusted traffic counts are indicated in **bold face**. Values in *italics* were calculated from raw counts.

Table 2
Washington Square

Summer St/Front St/Foster St/Grafton St/Shrewsbury St
June 21, 2000, 12:00 noon to 14:00 PM

Approach	Movement	12:00-12:15	12:15-12:30	12:30-12:45	12:45-13:00	13:00-13:15	13:15-13:30	13:30-13:45	13:45-14:00	Peak Hour 12:00-13:00
Grafton	F_1	32	35	35	33	25	30	29	32	135
(Approach 1)	F_2	22	50	64	34	41	42	39	37	170
	F_3	54	39	33	63	51	41	52	54	189
Shrewsbury	F_4	46	75	73	66	55	58	44	49	260
(Approach 2)	F_5	73	85	86	69	52	66	58	57	313
	F_6	30	26	24	35	43	20	43	34	115
Summer	F_7	44	49	39	33	33	34	35	27	165
(Approach 3)	F_8	48	43	51	47	29	40	27	20	189
	F_9	5	7	10	10	14	8	10	16	32
Foster/Front	F_{10}	18	12	20	12	19	23	16	16	62
(Approach 4)	F_{11}	110	98	84	107	112	115	109	75	399
	F_{12}	20	35	51	29	24	41	40	61	135

Table 3
Washington Square

Summer St/Front St/Foster St/Grafton St/Shrewsbury St
June 21, 2000, 16:00 to 18:00 PM

Approach	Movement	16:00-16:15	16:15-16:30	16:30-16:45	16:45-17:00	17:00-17:15	17:15-17:30	17:30-17:45	17:45-18:00	Peak Hour 16:15-17:15
Grafton	F_1	27	33	49	33	34	32	41	39	148
(Approach 1)	F_2	42	84	47	53	41	31	57	35	172
	F_3	52	8	66	72	67	65	47	57	270
Shrewsbury	F_4	103	102	102	121	123	108	92	74	454
(Approach 2)	F_5	98	98	118	84	81	89	92	65	372
	F_6	40	23	13	35	37	29	31	36	114
Summer	F_7	53	48	53	61	65	69	46	41	248
(Approach 3)	F_8	52	57	81	76	64	76	56	53	297
	F_9	5	6	5	4	7	0	7	4	16
Foster/Front	F_{10}	25	29	25	24	39	37	24	21	125
(Approach 4)	F_{11}	92	137	153	163	190	200	180	136	706
	F_{12}	73	58	47	63	51	54	38	40	215

Table 1
Washington Square

Summer St/Front St/Foster St/Grafton St/Shrewsbury St
June 21, 2000, 7:00 to 9:00 AM

Approach	Movement	7:00-7:15	7:15-7:30	7:30-7:45	7:45-8:00	8:00-8:15	8:15-8:30	8:30-8:45	8:45-9:00	Peak Hour 7:30-8:30
Grafton	F_1	28	37	36	32	33	17	21	29	118
(Approach 1)	F_2	22	51	62	104	56	52	59	48	274
	F_3	66	82	86	92	123	106	63	71	407
Shrewsbury	F_4	43	47	45	48	44	43	45	36	180
(Approach 2)	F_5	49	70	107	113	88	101	107	85	409
	F_6	8	18	15	18	13	10	8	15	56
Summer	F_7	45	33	40	44	52	53	55	46	189
(Approach 3)	F_8	22	22	24	18	8	12	22	17	62
	F_9	16	18	21	24	25	22	25	25	92
Foster/Front	F_{10}	13	14	16	12	10	13	14	8	51
(Approach 4)	F_{11}	55	89	65	102	82	82	76	95	331
	F_{12}	19	22	49	14	38	23	24	11	124

2-27-86 KB

Traffic Volumes

Street	Direction	Volume	Count Location	Date
Coolidge Rd.	NB	750	Estimated	
Highland St.	NB	10,754	200' E of Newton Sq.	4-29-85
June St	NB	5,572	W of Pleasant St.	10-29-84
	SB	6,282		
Newton Ave.	SB	1,000	Estimated	
Pleasant St. (W)	EB (2-way)	6,917 (13,568)	BTW Richmond & Newton Sq.	1-1-82
Pleasant St. (E)	EB	5,802	BTW Newton Sq. & Park Ave.	6-19-81
	WB	5,800	Estimated	

Total into square 30,793

East and West meaning East & West of Newton Sq.

APPENDIX C

Traffic Software Simulation Data

ARRB Transport Research Ltd - SIDRA 5.02a

Traffic Safety Report
WPI Intermediary Qualifying Project
Chris Decker
Chris Newton
Jeremiah Johnson
Michael Wojcik
Date of Analysis 02/22/01

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:

SIDRA US Highway Capacity Manual (1994) Version
Roundabout

RUN INFORMATION

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* Basic Parameters:
Intersection Type: Roundabout
Driving on the right-hand side of the road
SIDRA US Highway Capacity Manual (1994) Version
Input data specified in US units
Default Values File No. 11
Peak flow period (for performance): 15 minutes
Unit time (for volumes): 60 minutes (Total Flow Period)
Delay definition: Overall delay,
Geometric delay included
Delay formula: Highway Capacity Manual
Level of Service based on: Delay (HCM)
Queue definition: Back of queue, 95th_Percentile

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:

PARAMETERS

Default values for some of the important general parameters:
(Default Values File: DEF11.SDF)

1. Basic saturation flow: 1900 tcu/h

This value applies to signalised intersections and priority and continuous movements at roundabouts and unsignalised intersections. Saturation flows (capacities) for all opposed movements at roundabouts and sign-controlled intersections are estimated from a gap-acceptance based model.

2. Through car equivalents for signalised intersections

	LEFT LV	LEFT HV	THROUGH LV	THROUGH HV	RIGHT LV	RIGHT HV
Normal	1.053	2.000	1.000	2.000	1.176	2.000
Restricted	1.303	2.500			1.426	2.500

3. Opposed turn parameters (Roundabout)

	Crit. Gap	Fol.up Hdway	Min. Deps	% Exit Flow Opposing
Left turns :	V	V	1.0	0
Through :	V	V	1.0	0
Right turns:	V	V	1.0	0

4. Cruise speed= 40 mi/h, Approach Distance= 1500 ft

5. Queue space per vehicle in feet
   Light vehicles: 25.0 Heavy vehicles: 45.0

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table S.0 - TRAFFIC FLOW DATA (Flows in veh/hour as used by the program)

Mov No.	Left LV	Left HV	Through LV	Through HV	Right LV	Right HV	Flow Scale	Peak Flow Factor
West: WCB Ramp								
12	232	7	0	0	0	0	1.00	0.90
11	0	0	761	24	0	0	1.00	0.90
13	0	0	0	0	135	4	1.00	0.90
South: Grafton Street								
32	156	8	0	0	0	0	1.00	0.90
31	0	0	182	10	0	0	1.00	0.90
33	0	0	0	0	285	15	1.00	0.90
East: Shrewsbury Street								
22	122	5	0	0	0	0	1.00	0.90
21	0	0	397	17	0	0	1.00	0.90
23	0	0	0	0	484	20	1.00	0.90
North: Summer Street								
42	17	1	0	0	0	0	1.00	0.90
41	0	0	320	10	0	0	1.00	0.90
43	0	0	0	0	267	8	1.00	0.90

Based on unit time = 60 minutes.
Flow Scale and Peak Hour Factor effects included in flow values.

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table R.0 - ROUNDABOUT BASIC PARAMETERS

Cent Island Diam (ft)	Circ Width (ft)	Insc Diam. (ft)	No.of Circ. Lanes	No.of Entry Lanes	Av.Ent Lane Width (ft)	Circulating/Exiting Stream Flow (veh/h)	%HV	Adjust. Flow (pcu/h)	%Exit Incl. Flow Effect	Cap. Constr.
West: WCB Ramp										
380	40	460	2	2	12.00	474	3.3	474	0	N
South: Grafton Street										
150	30	210	2	2	12.00	1041	3.0	1041	0	N
East: Shrewsbury Street										
150	30	210	2	2	12.00	594	4.2	594	0	N
North: Summer Street										
150	30	210	2	2	12.00	704	4.2	704	0	N

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table R.1 - ROUNDABOUT GAP ACCEPTANCE PARAMETERS

Turn	Lane No.	Lane Type	Circ/ Exit Flow (pcu/h)	Intra- Bunch Headway (s)	Prop. Bunched Vehicles	Critical Gap (s)	Follow Up Headway (s)
West: WCB Ramp							
Left	1	Dominant	474	1.41	0.572#	3.30	1.98
Thru	1	Dominant	474	1.41	0.572#	3.30	1.98
	2	Subdominant	474	1.41	0.572#	3.89	2.33
Right	2	Subdominant	474	1.41	0.572#	3.89	2.33
South: Grafton Street							
Left	1	Subdominant	1041	1.21	0.784#	3.46	2.32
Thru	1	Subdominant	1041	1.21	0.784#	3.46	2.32
	2	Dominant	1041	1.21	0.784#	2.95	1.98
Right	2	Dominant	1041	1.21	0.784#	2.95	1.98
East: Shrewsbury Street							
Left	1	Subdominant	594	1.52	0.666#	3.90	2.39
Thru	1	Subdominant	594	1.52	0.666#	3.90	2.39
	2	Dominant	594	1.52	0.666#	3.41	2.09
Right	2	Dominant	594	1.52	0.666#	3.41	2.09
North: Summer Street							
Left	1	Subdominant	704	1.39	0.692#	3.81	2.39

Thru	1	Subdominant	704	1.39	0.692#	3.81	2.39
	2	Dominant	704	1.39	0.692#	3.34	2.09
Right	2	Dominant	704	1.39	0.692#	3.34	2.09

\# "Extra" bunching (i.e. a percentage increase or decrease in the amount of bunching in the circulating flow) was specified by the user.

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table S.2 - MOVEMENT CAPACITY PARAMETERS

Mov No.	Arv Flow (veh /h)	Total Opng Flow (veh/h)	%HV	Adjust. Opng Flow (pcu/h)	Total Cap. (veh /h)	Prac. Deg. Satn xp	Prac. Spare Cap. (%)	Lane Util (%)	Deg. Satn x
West: WCB Ramp									
12 L	239	474	3.3	474	495	0.85	76	100	0.483
11 T	785	474	3.3	474	1625	0.85	76	100	0.483
13 R	139	474	3.3	474	288	0.85	76	100	0.483
South: Grafton Street									
32 L	164	1041	3.0	1041	420	0.85	118	100	0.390
31 T	192	1041	3.0	1041	491	0.85	117	100	0.391
33 R	300	1041	3.0	1041	768	0.85	118	100	0.391
East: Shrewsbury Street									
22 L	127	594	4.2	594	257	0.85	72	100	0.494*
21 T	414	594	4.2	594	838	0.85	72	100	0.494*
23 R	504	594	4.2	594	1020	0.85	72	100	0.494*
North: Summer Street									
42 L	18	704	4.2	704	57	0.85	169	100	0.316
41 T	330	704	4.2	704	1037	0.85	167	100	0.318
43 R	275	704	4.2	704	864	0.85	167	100	0.318

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table S.3 - INTERSECTION PARAMETERS

Degree of Saturation (Highest) = 0.494
Practical Spare Capacity (Lowest) = 72 %
Total Vehicle Flow = 3487
Total Vehicle Capacity (all lanes) = 8159

Washington Square * WASH_SQ *

Existing Conditions
Intersection No.:
Roundabout

Table S.5 - MOVEMENT PERFORMANCE

Mov No.	Total Delay (veh-h/h)	Aver. Delay (sec)	Prop. Queued	Eff. Stop Rate	Longest Queue 95% Back (vehs)	Longest Queue 95% Back (ft)	Perf. Index	Aver. Speed (mph)
West: WCB Ramp								
12 L	0.35	5.2	0.55	0.37	4.3	109	3.42	24.7
11 T	1.35	6.2	0.56	0.52	4.3	109	10.21	21.7
13 R	0.28	7.2	0.57	0.67	4.0	103	1.79	19.0
South: Grafton Street								
32 L	0.62	13.6	0.71	0.76	3.0	78	2.89	18.5
31 T	0.69	12.9	0.71	0.73	3.3	85	3.13	18.7
33 R	0.95	11.4	0.71	0.71	3.3	85	4.42	18.0
East: Shrewsbury Street								
22 L	0.41	11.6	0.66	0.71	4.5	116	2.59	21.9
21 T	1.31	11.4	0.66	0.69	4.8	123	7.99	22.4
23 R	1.42	10.2	0.65	0.67	4.8	123	8.97	22.5
North: Summer Street								
42 L	0.04	7.7	0.61	0.70	2.4	63	0.28	19.7
41 T	0.74	8.0	0.61	0.60	2.6	66	4.92	22.0
43 R	0.71	9.3	0.60	0.66	2.6	66	3.87	19.7

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table S.6 - INTERSECTION PERFORMANCE

Total Flow (veh/h)	Total Delay (veh-h/h)	Aver. Delay (sec)	Prop. Queued	Eff. Stop Rate	Perf. Index	Aver. Speed (mph)
West: WCB Ramp						
1163	1.98	6.1	0.562	0.51	15.42	22.1
South: Grafton Street						
656	2.25	12.4	0.713	0.73	10.44	18.4
East: Shrewsbury Street						
1045	3.14	10.8	0.660	0.68	19.55	22.3
North: Summer Street						
623	1.48	8.6	0.610	0.63	9.07	21.0

INTERSECTION:
3487 8.85 9.1 0.628 0.62 54.48 21.4

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table S.7 - LANE PERFORMANCE

Lane No.	Mov No.	Arv Flow (veh /h)	Cap (veh /h)	Deg. Satn x	Aver. Delay (sec)	Eff. Stop Rate	Queue 95% Back (vehs)	Queue 95% Back (ft)	Short Lane (ft)
West: WCB Ramp									
1 LT	12, 11	638	1320	0.483	5.2	0.50	4.3	109	
2 TR	11, 13	525	1087	0.483	7.2	0.67	4.0	103	
South: Grafton Street									
1 LT	32, 31	296	758	0.391	13.6	0.74	3.0	78	
2 TR	31, 33	360	921	0.391	11.4	0.71	3.3	85	
East: Shrewsbury Street									
1 LT	22, 21	481	974	0.494	11.6	0.69	4.5	116	
2 TR	21, 23	564	1141	0.494	10.2	0.67	4.8	123	
North: Summer Street									
1 LT	42, 41	287	901	0.318	7.7	0.60	2.4	63	
2 TR	41, 43	336	1057	0.318	9.3	0.66	2.6	66	

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table S.8 - LANE FLOW AND CAPACITY INFORMATION

West: WCB Ramp

Effective Lane Use	Mov No.	Arv Flow (veh/h) Lef	Thru	Rig	Tot	Saturation Flow Basic (tcu)	Aver(veh) 1st	2nd	Min Cap (veh /h)	Tot Cap (veh /h)	Deg. Satn x	Lane Util %
*												

```
   ***
    * *
****** ****    12, 239 399   0 638  -   -   -  60 1320 0.483  100
       *     11
       *
****** ****    11,   0 386 139 525  -   -   -  60 1087 0.483  100
    * *      13
   ***
    *
---------------------------------------------------------------------------
South: Grafton Street
                              Saturation Flow  Min  Tot
Effective           Arv Flow (veh/h) --------------- Cap  Cap  Deg.  Lane
Lane Use      Mov   ----------------- Basic Aver(veh) (veh (veh  Satn  Util
              No.  Lef Thru  Rig  Tot (tcu) 1st   2nd  /h)  /h)   x     %
    *
   ***
    * *
****** ****    32, 164 132   0 296  -   -   -  60  758 0.391  100
       *     31
       *
****** ****    31,   0  60 300 360  -   -   -  60  921 0.391  100
    * *      33
   ***
    *
---------------------------------------------------------------------------
East: Shrewsbury Street
                              Saturation Flow  Min  Tot
Effective           Arv Flow (veh/h) --------------- Cap  Cap  Deg.  Lane
Lane Use      Mov   ----------------- Basic Aver(veh) (veh (veh  Satn  Util
              No.  Lef Thru  Rig  Tot (tcu) 1st   2nd  /h)  /h)   x     %
    *
   ***
    * *
****** ****    22, 127 354   0 481  -   -   -  60  974 0.494  100
       *     21
       *
****** ****    21,   0  60 504 564  -   -   -  60 1141 0.494  100
    * *      23
   ***
    *
---------------------------------------------------------------------------
North: Summer Street
                              Saturation Flow  Min  Tot
Effective           Arv Flow (veh/h) --------------- Cap  Cap  Deg.  Lane
Lane Use      Mov   ----------------- Basic Aver(veh) (veh (veh  Satn  Util
              No.  Lef Thru  Rig  Tot (tcu) 1st   2nd  /h)  /h)   x     %
    *
   ***
    * *
****** ****    42,  18 269   0 287  -   -   -  60  901 0.318  100
       *     41
       *
****** ****    41,   0  61 275 336  -   -   -  60 1057 0.318  100
    * *      43
   ***
```

*

Washington Square   * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table S.12A - FUEL CONSUMPTION, EMISSIONS AND COST - TOTAL

Mov No.	Fuel Total ga/h	Cost Total $/h	HC Total kg/h	CO Total kg/h	NOX Total kg/h	CO2 Total kg/h	Lead Total kg/h
West: WCB Ramp							
12 L	2.8	35.00	0.034	1.44	0.047	26.2	0.00000
11 T	7.3	90.54	0.091	4.42	0.138	68.5	0.00000
13 R	1.3	15.61	0.017	0.92	0.029	12.4	0.00000
	11.3	141.15	0.141	6.78	0.214	107.1	0.00000
South: Grafton Street							
32 L	1.9	24.98	0.024	1.21	0.038	18.2	0.00000
31 T	2.0	24.92	0.025	1.34	0.042	19.0	0.00000
33 R	3.0	35.32	0.038	2.11	0.066	27.9	0.00000
	6.9	85.22	0.088	4.67	0.146	65.2	0.00000
East: Shrewsbury Street							
22 L	2.1	26.94	0.024	1.09	0.038	19.7	0.00000
21 T	6.0	77.31	0.073	3.20	0.105	56.2	0.00000
23 R	6.9	87.47	0.086	3.93	0.127	65.1	0.00000
	14.9	191.72	0.183	8.22	0.270	141.0	0.00000
North: Summer Street							
42 L	0.2	2.81	0.003	0.12	0.004	2.0	0.00000
41 T	3.6	42.78	0.042	2.12	0.071	33.5	0.00000
43 R	2.7	33.24	0.035	1.81	0.056	25.4	0.00000
	6.5	78.83	0.079	4.06	0.131	60.9	0.00000
INTERSECTION:	39.7	496.93	0.492	23.73	0.762	373.3	0.00000

Washington Square   * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table S.12B - FUEL CONSUMPTION, EMISSIONS AND COST - RATE

Mov No.	Fuel Eff.	Cost Rate	HC Rate	CO Rate	NOX Rate	CO2 Rate	Lead Rate

	mpg	c/mi	g/km	g/km	g/km	g/km	g/km
West: WCB Ramp							
12 L	22.4	35.11	0.339	14.49	0.467	262.4	0.00000
11 T	19.7	39.39	0.395	19.21	0.602	298.0	0.00000
13 R	14.9	49.67	0.525	29.28	0.931	394.0	0.00000
	19.8	39.10	0.391	18.78	0.593	296.5	0.00000
South: Grafton Street							
32 L	16.4	48.98	0.478	23.78	0.747	357.8	0.00000
31 T	15.8	48.49	0.495	26.15	0.823	370.5	0.00000
33 R	14.2	52.07	0.560	31.18	0.970	411.3	0.00000
	15.3	50.07	0.516	27.44	0.859	382.9	0.00000
East: Shrewsbury Street							
22 L	18.7	42.96	0.389	17.42	0.601	313.3	0.00000
21 T	19.5	41.44	0.391	17.17	0.563	301.3	0.00000
23 R	18.6	42.44	0.416	19.07	0.618	316.0	0.00000
	18.9	42.10	0.402	18.06	0.593	309.6	0.00000
North: Summer Street							
42 L	18.1	45.66	0.436	20.17	0.628	323.3	0.00000
41 T	18.7	40.10	0.391	19.86	0.670	314.4	0.00000
43 R	16.3	47.11	0.496	25.70	0.790	360.1	0.00000
	17.7	42.98	0.433	22.12	0.714	332.3	0.00000
INTERSECTION:	18.3	42.47	0.420	20.28	0.651	319.0	0.00000

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table S.15 - CAPACITY AND LEVEL OF SERVICE (HCM STYLE)

Mov No.	Mov Typ	Total Flow (veh /h)	Total Cap. (veh /h)	Deg. of Satn (v/c)	Aver. Delay (sec)	LOS
West: WCB Ramp						
12	L	239	495	0.483	5.2	A
11	T	785	1625	0.483	6.2	A
13	R	139	288	0.483	7.2	A
		1163	2408	0.483	6.1	A
South: Grafton Street						
32	L	164	420	0.390	13.6	A
31	T	192	491	0.391	12.9	A

33 R	300	768	0.391	11.4	A
	656	1679	0.391	12.4	A
East: Shrewsbury Street					
22 L	127	257	0.494*	11.6	A
21 T	414	838	0.494*	11.4	A
23 R	504	1020	0.494*	10.2	A
	1045	2115	0.494	10.8	A
North: Summer Street					
42 L	18	57	0.316	7.7	A
41 T	330	1037	0.318	8.0	A
43 R	275	864	0.318	9.3	A
	623	1958	0.318	8.6	A
ALL VEHICLES:	3487	8159	0.494	9.1	A
INTERSECTION:	3487	8159	0.494	9.1	A

Level of Service calculations are based on delay (HCM criteria).
* Maximum v/c ratio, or critical green periods

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table D.0 - GEOMETRIC DELAY DATA

From Approach	To Approach	Negn Radius (ft)	Negn Speed (mph)	Negn Distance (ft)
West: WCB Ramp				
	South	49	14	77
	East	150	24	412
	North	210	28	907
South: Grafton Street				
	West	90	18	389
	East	49	14	77
	North	90	18	247
East: Shrewsbury Street				
	West	90	18	247
	South	90	18	389
	North	49	14	77
North: Summer Street				
	West	49	14	77
	South	150	24	412

East 90 18 389

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table D.1 - LANE DELAYS

		Deg.	Delay (seconds/veh) Analytical Model			Acc.	Queu	Ratio	Stopd		
Lane	Mov	Satn	1st	2nd	Total	Dec.	-ing	dm/	(Idle)	Geom	Overall
No.	No.	x	dm1	dm2	dm	dn	dq	di	di	dg	d
West: WCB Ramp											
1 LT	12,	0.483	2.1	0.0	2.1	4.5	0.0	0.00	0.0	1.9	5.2
	11						3.9				
2 TR	11,	0.483	2.5	0.0	2.5	4.2	0.0	0.00	0.0	3.9	7.2
	13						6.8				
South: Grafton Street											
1 LT	32,	0.391	5.1	0.0	5.1	4.6	0.5	10.93	0.5	9.4	13.6
	31						7.3				
2 TR	31,	0.391	4.5	0.0	4.5	4.0	0.5	8.52	0.5	7.3	11.4
	33						6.9				
East: Shrewsbury Street											
1 LT	22,	0.494	3.7	0.0	3.7	4.3	0.0	0.00	0.0	9.4	11.6
	21						7.3				
2 TR	21,	0.494	3.3	0.0	3.3	3.6	0.0	0.00	0.0	7.3	10.2
	23						6.8				
North: Summer Street											
1 LT	42,	0.318	3.4	0.0	3.4	4.8	0.0	0.00	0.0	9.4	7.7
	41						3.9				
2 TR	41,	0.318	3.0	0.0	3.0	3.5	0.0	0.00	0.0	3.9	9.3
	43						6.8				

dn is average stop-start delay for all vehicles queued and unqueued

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table D.2 - LANE STOPS

		Deg.	-- Effective Stop Rate --				Queue Prop.	Move-up
Lane	Mov	Satn			Geom.	Overall	Queued	Rate
No.	No.	x	he1	he2	hg	h	pq	hqm

West: WCB Ramp							
1 LT	12, 11	0.483	0.33	0.00	0.12	0.45	0.552	0.00
2 TR	11, 13	0.483	0.41	0.00	0.17	0.57	0.575	0.00
South: Grafton Street							
1 LT	32, 31	0.391	0.59	0.00	0.16	0.75	0.713	0.00
2 TR	31, 33	0.391	0.55	0.00	0.16	0.71	0.713	0.00
East: Shrewsbury Street							
1 LT	22, 21	0.494	0.51	0.00	0.18	0.69	0.666	0.00
2 TR	21, 23	0.494	0.48	0.00	0.19	0.67	0.654	0.00
North: Summer Street							
1 LT	42, 41	0.318	0.47	0.00	0.13	0.61	0.614	0.00
2 TR	41, 43	0.318	0.45	0.00	0.20	0.65	0.607	0.00

hqm is average queue move-up rate for all vehicles queued and unqueued

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table D.3 - LANE QUEUES

Lane No.	Mov No.	Deg. Satn x	Ovrfl. Queue No	Average Queue Nb1	Nb2	Nb	Percentile Queue 90%	95%	98%	Stor. Ratio
West: WCB Ramp										
1 LT	12, 11	0.483	0.0	1.4	0.0	1.4	3.4	4.3	5.0	0.27
2 TR	11, 13	0.483	0.0	1.3	0.0	1.3	3.3	4.0	4.7	0.26
South: Grafton Street										
1 LT	32, 31	0.391	0.0	1.0	0.0	1.0	2.4	3.0	3.5	0.19
2 TR	31, 33	0.391	0.0	1.1	0.0	1.1	2.6	3.3	3.8	0.21
East: Shrewsbury Street										
1 LT	22, 21	0.494	0.0	1.5	0.0	1.5	3.6	4.5	5.2	0.12
2 TR	21, 23	0.494	0.0	1.6	0.0	1.6	3.8	4.8	5.6	0.12

North: Summer Street									
1 LT	42, 41	0.318	0.0	0.8	0.0	0.8	2.0	2.4	2.8	0.13
2 TR	41, 43	0.318	0.0	0.8	0.0	0.8	2.1	2.6	3.0	0.13

Values printed in this table are back of queue.

Washington Square * WASH_SQ *
Existing Conditions
Intersection No.:
Roundabout

Table D.4 - MOVEMENT SPEEDS (mph)

Mov No.	App. Speeds Cruise	App. Speeds Negn	Exit Speeds Negn	Exit Speeds Cruise	Queue Move-up 1st Grn	Queue Move-up 2nd Grn	Av. Section Spd Running	Av. Section Spd Overall
West: WCB Ramp								
12	30.0	28.0	28.0	30.0			24.7	24.7
11	30.0	24.0	24.0	30.0			21.7	21.7
13	30.0	14.0	14.0	30.0			19.0	19.0
South: Grafton Street								
32	30.0	18.0	18.0	30.0			18.7	18.5
31	30.0	18.0	18.0	30.0			18.9	18.7
33	30.0	14.0	14.0	30.0			18.5	18.0
East: Shrewsbury Street								
22	30.0	18.0	18.0	30.0			21.9	21.9
21	30.0	18.0	18.0	30.0			22.4	22.4
23	30.0	14.0	14.0	30.0			22.5	22.5
North: Summer Street								
42	30.0	18.0	18.0	30.0			19.7	19.7
41	30.0	24.0	24.0	30.0			22.0	22.0
43	30.0	14.0	14.0	30.0			19.7	19.7

--- End of SIDRA Output ---

ARRB Transport Research Ltd - SIDRA 5.02a

Traffic Safety Report
WPI Intermediary Qualifying Project
Chris Decker
Chris Newton
Jeremiah Johnson
Michael Wojcik
Date of Analysis 02/20/01

Time and Date of Analysis 14:56:04 02/20/01

Washington Square with 140 Diameter and 30 foot pavement
* WASHSQ2 *
Future Conditions AM Peak Period
Intersection No.:

SIDRA US Highway Capacity Manual (1994) Version
Roundabout
Flow Scale = 114%

RUN INFORMATION

----

* Basic Parameters:
  Intersection Type: Roundabout
  Driving on the right-hand side of the road
  SIDRA US Highway Capacity Manual (1994) Version
  Input data specified in US units
  Default Values File No. 11
  Peak flow period (for performance): 15 minutes
  Unit time (for volumes): 60 minutes (Total Flow Period)
  Delay definition: Overall delay,
  Geometric delay included
  Delay formula: Highway Capacity Manual
  Level of Service based on: Delay (HCM)
  Queue definition: Back of queue, 95th_Percentile

Washington Square with 140 Diameter and 30 foot pavement
* WASHSQ2 *
Future Conditions AM Peak Period
Intersection No.:

PARAMETERS

Default values for some of the important general parameters:
(Default Values File: DEF11.SDF)

1. Basic saturation flow: 1900 tcu/h

This value applies to signalised intersections and priority and continuous movements at roundabouts and unsignalised intersections.
Saturation flows (capacities) for all opposed movements at roundabouts

and sign-controlled intersections are estimated from a gap-acceptance based model.

2. Through car equivalents for signalised intersections

	LEFT LV	LEFT HV	THROUGH LV	THROUGH HV	RIGHT LV	RIGHT HV
Normal	1.053	2.000	1.000	2.000	1.176	2.000
Restricted	1.303	2.500			1.426	2.500

3. Opposed turn parameters (Roundabout)

	Crit. Gap	Fol.up Hdway	Min. Deps	% Exit Flow Opposing
Left turns :	V	V	1.0	0
Through :	V	V	1.0	0
Right turns:	V	V	1.0	0

4. Cruise speed= 40 mi/h, Approach Distance= 1500 ft

5. Queue space per vehicle in feet
Light vehicles: 25.0 Heavy vehicles: 45.0

Washington Square with 140 Diameter and 30 foot pavement
* WASHSQ2 *
Future Conditions AM Peak Period
Intersection No.:
Roundabout
Flow Scale = 114%

Table S.0 - TRAFFIC FLOW DATA (Flows in veh/hour as used by the program)

Mov No.	Left LV	Left HV	Through LV	Through HV	Right LV	Right HV	Flow Scale	Peak Flow Factor
West: Front Street								
12	217	9	0	0	0	0	1.14	0.90
11	0	0	537	18	0	0	1.14	0.90
13	0	0	0	0	72	9	1.14	0.90
South: Grafton Streeth								
32	578	25	0	0	0	0	1.14	0.90
31	0	0	440	19	0	0	1.14	0.90
33	0	0	0	0	153	19	1.14	0.90
East: Shrewsbury Street								
22	100	4	0	0	0	0	1.14	0.90

21	0	0	585	25	0	0	1.14	0.90
23	0	0	0	0	255	32	1.14	0.90
North: Summer Street								
42	189	6	0	0	0	0	1.14	0.90
41	0	0	143	6	0	0	1.14	0.90
43	0	0	0	0	334	0	1.14	0.90

Based on unit time = 60 minutes.
Flow Scale and Peak Hour Factor effects included in flow values.

Washington Square with 140 Diameter and 30 foot pavement
* WASHSQ2 *
Future Conditions AM Peak Period
Intersection No.:
Roundabout
Flow Scale = 114%

Table R.0 - ROUNDABOUT BASIC PARAMETERS

Cent Island Diam (ft)	Circ Width (ft)	Insc Diam. (ft)	No.of Circ. Lanes	No.of Entry Lanes	Av.Ent Lane Width (ft)	Circulating/Exiting Stream Flow (veh/h)	%HV	Adjust. Flow (pcu/h)	%Exit Incl.	Cap. Constr. Effect
West: Front Street										
140	30	200	2	2	12.00	448	3.7	448	0	N
South: Grafton Streeth										
140	30	200	2	2	12.00	975	3.4	975	0	N
East: Shrewsbury Street										
140	30	200	2	2	12.00	1287	4.1	1287	0	N
North: Summer Street										
140	30	200	2	2	12.00	1317	4.1	1317	0	N

Washington Square with 140 Diameter and 30 foot pavement
* WASHSQ2 *
Future Conditions AM Peak Period
Intersection No.:
Roundabout
Flow Scale = 114%

Table R.1 - ROUNDABOUT GAP ACCEPTANCE PARAMETERS

Turn	Lane No.	Lane Type	Circ/ Exit Flow (pcu/h)	Intra-Bunch Headway (s)	Prop. Bunched Vehicles	Critical Gap (s)	Follow-Up Headway (s)
West: Front Street							
Left	1	Dominant	448	1.39	0.450#	3.58	2.13
Thru	1	Dominant	448	1.39	0.450#	3.58	2.13
	2	Subdominant	448	1.39	0.450#	4.06	2.42
Right	2	Subdominant	448	1.39	0.450#	4.06	2.42
South: Grafton Streeth							
Left	1	Dominant	975	1.36	0.702#	3.08	2.03
Thru	1	Dominant	975	1.36	0.702#	3.08	2.03
	2	Subdominant	975	1.36	0.702#	3.57	2.36
Right	2	Subdominant	975	1.36	0.702#	3.57	2.36
East: Shrewsbury Street							
Left	1	Subdominant	1287	1.34	0.798#	3.29	2.28
Thru	1	Subdominant	1287	1.34	0.798#	3.29	2.28
	2	Dominant	1287	1.34	0.798#	2.76	1.91
Right	2	Dominant	1287	1.34	0.798#	2.76	1.91
North: Summer Street							
Left	1	Subdominant	1317	1.57	0.861#	3.28	2.28
Thru	1	Subdominant	1317	1.57	0.861#	3.28	2.28
	2	Dominant	1317	1.57	0.861#	2.74	1.90
Right	2	Dominant	1317	1.57	0.861#	2.74	1.90

"Extra" bunching (i.e. a percentage increase or decrease in the amount of bunching in the circulating flow) was specified by the user.

Washington Square with 140 Diameter and 30 foot pavement
* WASHSQ2 *
Future Conditions AM Peak Period
Intersection No.:
Roundabout
Flow Scale = 114%

Table S.3 - INTERSECTION PARAMETERS

Degree of Saturation (Highest) = 0.854

Practical Spare Capacity (Lowest) = 0 %
Total Vehicle Flow = 3775
Total Vehicle Capacity (all lanes) = 6047

Washington Square with 140 Diameter and 30 foot pavement
* WASHSQ2 *
Future Conditions AM Peak Period
Intersection No.:
Roundabout
Flow Scale = 114%

Table S.6 - INTERSECTION PERFORMANCE

Total Flow (veh/h)	Total Delay (veh-h/h)	Aver. Delay (sec)	Prop. Queued	Eff. Stop Rate	Perf. Index	Aver. Speed (mph)
3775	21.63	20.6	0.793	1.16	99.06	16.1

Washington Square with 140 Diameter and 30 foot pavement
* WASHSQ2 *
Future Conditions AM Peak Period
Intersection No.:
Roundabout
Flow Scale = 114%

Table S.10 - MOVEMENT CAPACITY AND PERFORMANCE SUMMARY

Mov No.	Mov Typ	Arv Flow (veh /h)	Total Cap. (veh /h)	Lane Util (%)	Deg. Satn x	Aver. Delay (sec)	Eff. Stop Rate	95% Back of Queue (veh)	Perf. Index
West: Front Street									
12	L	226	565	100	0.400	9.8	0.67	2.7	3.15
11	T	555	1386	100	0.400	9.4	0.65	2.7	7.23
13	R	81	202	100	0.401	9.2	0.68	2.6	1.01
South: Grafton Streeth									
32	L	603	793	100	0.760	19.0	1.16	12.2	14.95
31	T	459	604	100	0.760	18.7	1.19	12.2	11.29
33	R	172	226	100	0.761	18.6	1.21	11.1	4.13
East: Shrewsbury Street									
22	L	104	122	100	0.852	30.5	1.59	15.7	4.12
21	T	610	715	100	0.853	29.4	1.59	17.6	23.24
23	R	287	336	100	0.854*	28.0	1.60	17.6	10.47
North: Summer Street									
42	L	195	316	100	0.617	27.7	1.19	8.9	6.08
41	T	149	241	100	0.618	26.5	1.17	9.8	4.41
43	R	334	541	100	0.617	23.7	1.13	9.8	8.99

* Maximum degree of saturation

Washington Square with 140 Diameter and 30 foot pavement
* WASHSQ2 *
Future Conditions AM Peak Period

Intersection No.:
Roundabout
Flow Scale = 114%

Table S.15 - CAPACITY AND LEVEL OF SERVICE (HCM STYLE)

Mov No.	Mov Typ	Total Flow (veh /h)	Total Cap. (veh /h)	Deg. of Satn (v/c)	Aver. Delay	LOS (sec)
West: Front Street						
12	L	226	565	0.400	9.8	A
11	T	555	1386	0.400	9.4	A
13	R	81	202	0.401	9.2	A
		862	2153	0.401	9.5	A
South: Grafton Streeth						
32	L	603	793	0.760	19.0	B
31	T	459	604	0.760	18.7	B
33	R	172	226	0.761	18.6	B
		1234	1623	0.761	18.8	B
East: Shrewsbury Street						
22	L	104	122	0.852	30.5	C
21	T	610	715	0.853	29.4	C
23	R	287	336	0.854*	28.0	C
		1001	1173	0.854	29.1	C
North: Summer Street						
42	L	195	316	0.617	27.7	B
41	T	149	241	0.618	26.5	B
43	R	334	541	0.617	23.7	B
		678	1098	0.618	25.5	B
ALL VEHICLES:		3775	6047	0.854	20.6	B
INTERSECTION:		3775	6047	0.854	20.6	B

Level of Service calculations are based on delay (HCM criteria).
* Maximum v/c ratio, or critical green periods

Washington Square with 140 Diameter and 30 foot pavement
* WASHSQ2 *
Future Conditions AM Peak Period
Intersection No.:
Flow Scale - Variable Flow Scale applies to all movements

Table S.22 - VARIABLE FLOW SCALE RESULTS

Design Life Analysis:
Zero Practical Spare Capacity (for x=xp) was
between Flow Scales of 110 % and 120 %

Try a range of Flow Scales around 114 % with 1% Flow Scale increment

----

Washington Square with 140 Diameter and 30 foot pavement
* WASHSQ2 *
Future Conditions AM Peak Period
Intersection No.:
Flow Scale = Variable Flow Scale applies to all movements

Table V.22 - INTERSECTION SUMMARY FOR VARIABLE FLOW SCALE

Flow Scale (%)	Total Veh. Cap.	Intersn Deg. of Satn	Prac. Spare Cap.	Aver. Delay (sec)	Stop Rate	Longest Queue (veh)	Perf. Index	FUEL Tot. (ga/h)
100	6677	0.641	33	14.0	0.88	7.1	64.3	40.3
110	6224	0.789	8	17.8	1.06	13.1	85.4	47.6
120	5781	0.968	-12	28.6	1.42	28.6	132.1	60.9

--- End of SIDRA Output ---

ARRB Transport Research Ltd - SIDRA 5.02a

Traffic Safety Report
WPI Intermediary Qualifying Project
Chris Decker
Chris Newton
Jeremiah Johnson
Michael Wojcik
Date of Analysis 01/19/01

Time and Date of Analysis 14:57:34 01/19/01

Washington Square *
WASH_SQ1
Proposed Conditions 2
Intersection No.:

SIDRA US Highway Capacity Manual (1994) Version
Roundabout

RUN INFORMATION

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* Basic Parameters:
Intersection Type: Roundabout
Driving on the right-hand side of the road
SIDRA US Highway Capacity Manual (1994) Version
Input data specified in US units
Default Values File No. 11
Peak flow period (for performance): 15 minutes
Unit time (for volumes): 60 minutes (Total Flow Period)
Delay definition: Overall delay,
Geometric delay included
Delay formula: Highway Capacity Manual
Level of Service based on: Delay (HCM)
Queue definition: Back of queue, 95th_Percentile

Washington Square *
WASH_SQ1
Proposed Conditions
Intersection No.:

PARAMETERS

Default values for some of the important general parameters:
(Default Values File: DEF11.SDF)

1. Basic saturation flow: 1900 tcu/h

This value applies to signalised intersections and priority and continuous movements at roundabouts and unsignalised intersections. Saturation flows (capacities) for all opposed movements at roundabouts and sign-controlled intersections are estimated from a gap-acceptance based model.

2. Through car equivalents for signalised intersections

	LEFT LV	LEFT HV	THROUGH LV	THROUGH HV	RIGHT LV	RIGHT HV
Normal	1.053	2.000	1.000	2.000	1.176	2.000
Restricted	1.303	2.500			1.426	2.500

3. Opposed turn parameters (Roundabout)

	Crit. Gap	Fol.up Hdway	Min. Deps	% Exit Flow Opposing
Left turns :	V	V	1.0	0
Through :	V	V	1.0	0
Right turns:	V	V	1.0	0

4. Cruise speed= 40 mi/h, Approach Distance= 1500 ft

5. Queue space per vehicle in feet
Light vehicles: 25.0 Heavy vehicles: 45.0

Washington Square *
WASH_SQ1
Proposed Conditions
Intersection No.:
Roundabout

Table S.0 - TRAFFIC FLOW DATA (Flows in veh/hour as used by the program)

Mov No.	Left LV	Left HV	Through LV	Through HV	Right LV	Right HV	Flow Scale	Peak Flow Factor
West: WCB Ramp								
12	232	7	0	0	0	0	1.00	0.90
11	0	0	761	24	0	0	1.00	0.90
13	0	0	0	0	135	4	1.00	0.90
South: Grafton Street								
32	156	8	0	0	0	0	1.00	0.90
31	0	0	182	10	0	0	1.00	0.90
33	0	0	0	0	285	15	1.00	0.90
East: Shrewsbury Street								
22	122	5	0	0	0	0	1.00	0.90
21	0	0	397	17	0	0	1.00	0.90
23	0	0	0	0	484	20	1.00	0.90
North: Summer Street								
42	17	1	0	0	0	0	1.00	0.90
41	0	0	320	10	0	0	1.00	0.90
43	0	0	0	0	267	8	1.00	0.90

Based on unit time = 60 minutes.
Flow Scale and Peak Hour Factor effects included in flow values.

Washington Square *
WASH_SQ1
Proposed Conditions
Intersection No.:
Roundabout

Table R.0 - ROUNDABOUT BASIC PARAMETERS

Cent Island Diam (ft)	Circ Width (ft)	Insc Diam. (ft)	No.of Circ. Lanes	No.of Entry Lanes	Av.Ent Lane Width (ft)	Circulating/Exiting Stream Flow (veh/h)	%HV	Adjust. Flow (pcu/h)	%Exit Incl.	Cap. Constr. Effect
West: WCB Ramp										
380	40	460	2	2	12.00	474	3.3	474	0	N
South: Grafton Street										
380	30	440	2	2	12.00	1041	3.0	1041	0	N
East: Shrewsbury Street										
380	30	440	2	2	12.00	594	4.2	594	0	N
North: Summer Street										
380	30	440	2	2	12.00	704	4.2	704	0	N

Washington Square *
WASH_SQ1
Proposed Conditions
Intersection No.:
Roundabout

Table R.1 - ROUNDABOUT GAP ACCEPTANCE PARAMETERS

Turn	Lane No.	Lane Type	Circ/ Exit Flow (pcu/h)	Intra-Bunch Headway (s)	Prop. Bunched Vehicles	Critical Gap (s)	Follow Up Headway (s)
West: WCB Ramp							
Left	1	Dominant	474	1.41	0.572#	3.30	1.98
Thru	1	Dominant	474	1.41	0.572#	3.30	1.98
	2	Subdominant	474	1.41	0.572#	3.89	2.33
Right	2	Subdominant	474	1.41	0.572#	3.89	2.33
South: Grafton Street							
Left	1	Subdominant	1041	1.21	0.784#	3.35	2.25
Thru	1	Subdominant	1041	1.21	0.784#	3.35	2.25
	2	Dominant	1041	1.21	0.784#	2.76	1.85
Right	2	Dominant	1041	1.21	0.784#	2.76	1.85
East: Shrewsbury Street							
Left	1	Subdominant	594	1.52	0.666#	3.80	2.33
Thru	1	Subdominant	594	1.52	0.666#	3.80	2.33

	2	Dominant	594	1.52	0.666#	3.23	1.98
Right	2	Dominant	594	1.52	0.666#	3.23	1.98
North: Summer Street							
Left	1	Subdominant	704	1.39	0.692#	3.70	2.32
Thru	1	Subdominant	704	1.39	0.692#	3.70	2.32
	2	Dominant	704	1.39	0.692#	3.14	1.97
Right	2	Dominant	704	1.39	0.692#	3.14	1.97

"Extra" bunching (i.e. a percentage increase or decrease in the amount of bunching in the circulating flow) was specified by the user.

Washington Square *
WASH_SQ1
Proposed Conditions
Intersection No.:
Roundabout

Table S.2 - MOVEMENT CAPACITY PARAMETERS

Mov No.	Arv Flow (veh /h)	Total Opng Flow (veh/h)	%HV	Adjust. Opng Flow (pcu/h)	Total Cap. (veh /h)	Prac. Deg. Satn xp	Prac. Spare Cap. (%)	Lane Util (%)	Deg. Satn x
West: WCB Ramp									
12 L	239	474	3.3	474	495	0.85	76	100	0.483*
11 T	785	474	3.3	474	1626	0.85	76	100	0.483*
13 R	139	474	3.3	474	288	0.85	76	100	0.483*
South: Grafton Street									
32 L	164	1041	3.0	1041	447	0.85	132	100	0.367
31 T	192	1041	3.0	1041	523	0.85	132	100	0.367
33 R	300	1041	3.0	1041	817	0.85	131	100	0.367
East: Shrewsbury Street									
22 L	127	594	4.2	594	271	0.85	81	100	0.469
21 T	414	594	4.2	594	882	0.85	81	100	0.469
23 R	504	594	4.2	594	1074	0.85	81	100	0.469
North: Summer Street									
42 L	18	704	4.2	704	60	0.85	183	100	0.300
41 T	330	704	4.2	704	1098	0.85	183	100	0.301
43 R	275	704	4.2	704	915	0.85	183	100	0.301

Washington Square *
WASH_SQ1
Proposed Conditions
Intersection No.:
Roundabout

Table S.3 - INTERSECTION PARAMETERS

Degree of Saturation (Highest) = 0.483
Practical Spare Capacity (Lowest) = 76 %
Total Vehicle Flow = 3487
Total Vehicle Capacity (all lanes) = 8496

Washington Square *
WASH_SQ1
Proposed Conditions
Intersection No.:
Roundabout

Table S.5 - MOVEMENT PERFORMANCE

Mov No.	Total Delay (veh-h/h)	Aver. Delay (sec)	Prop. Queued	Eff. Stop Rate	Longest Queue 95% Back (vehs)	Longest Queue 95% Back (ft)	Perf. Index	Aver. Speed (mph)
West: WCB Ramp								
12 L	0.24	3.6	0.55	0.37	4.3	109	3.31	24.7
11 T	0.97	4.4	0.56	0.36	4.3	109	9.47	23.7
13 R	0.20	5.3	0.57	0.67	4.0	103	1.71	19.0
South: Grafton Street								
32 L	0.30	6.5	0.70	0.62	2.8	74	2.77	23.8
31 T	0.41	7.7	0.70	0.59	3.2	82	2.86	22.7
33 R	0.84	10.0	0.70	0.70	3.2	82	4.23	18.2
East: Shrewsbury Street								
22 L	0.18	5.0	0.65	0.51	4.3	110	2.47	25.6
21 T	0.66	5.7	0.65	0.47	4.6	118	7.18	25.2
23 R	1.29	9.2	0.63	0.66	4.6	118	8.71	22.5
North: Summer Street								
42 L	0.02	4.7	0.60	0.48	2.3	60	0.28	24.6
41 T	0.50	5.5	0.60	0.45	2.5	64	4.53	23.9
43 R	0.65	8.5	0.59	0.65	2.5	64	3.75	19.8

Washington Square *
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Table S.6 - INTERSECTION PERFORMANCE

Total Flow (veh/h)	Total Delay (veh-h/h)	Aver. Delay (sec)	Prop. Queued	Eff. Stop Rate	Perf. Index	Aver. Speed (mph)
West: WCB Ramp						
1163	1.41	4.4	0.562	0.40	14.49	23.4
South: Grafton Street						
656	1.54	8.5	0.707	0.65	9.86	21.2
East: Shrewsbury Street						
1045	2.12	7.3	0.645	0.57	18.36	24.1
North: Summer Street						
623	1.18	6.8	0.603	0.54	8.57	22.2

INTERSECTION:

3487 6.25 6.5 0.621 0.52 51.28 23.1

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Table S.7 - LANE PERFORMANCE

Lane No.	Mov No.	Arv Flow (veh /h)	Cap (veh /h)	Deg. Satn x	Aver. Delay (sec)	Eff. Stop Rate	Queue 95% Back (vehs)	Queue 95% Back (ft)	Short Lane (ft)
West: WCB Ramp									
1 LT	12, 11	638	1321	0.483	3.6	0.34	4.3	109	
2 TR	11, 13	525	1088	0.483	5.3	0.67	4.0	103	
South: Grafton Street									
1 LT	32, 31	290	789	0.367	6.5	0.61	2.8	74	
2 TR	31, 33	366	997	0.367	10.0	0.70	3.2	82	
East: Shrewsbury Street									
1 LT	22, 21	472	1007	0.469	5.0	0.48	4.3	110	
2 TR	21, 23	573	1220	0.469	9.2	0.66	4.6	118	
North: Summer Street									
1 LT	42, 41	281	935	0.300	4.7	0.46	2.3	60	
2 TR	41, 43	342	1138	0.300	8.5	0.65	2.5	64	

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Table S.8 - LANE FLOW AND CAPACITY INFORMATION

West: WCB Ramp

Lane Use	Mov No.	Arv Flow (veh/h) Lef	Thru	Rig	Tot	Saturation Flow Basic (tcu)	Aver(veh) 1st	2nd	Min Cap (veh /h)	Tot Cap (veh /h)	Deg. Satn x	Effective Lane Util %

*
***
* *

```
 ****** ****       12,  239  399    0  638   -    -     -    60 1321 0.483
100
           *       11
           *
 ****** ****       11,    0  386  139  525   -    -     -    60 1088 0.483
100
        *  *       13
       ***
        *
 ---------------------------------------------------------------------------
-----
  South: Grafton Street
                                            Saturation Flow  Min  Tot
  Effective                Arv Flow (veh/h) ---------------  Cap  Cap  Deg.
Lane
  Lane Use         Mov    ------------------ Basic Aver(veh) (veh (veh  Satn
Util
                   No.    Lef Thru  Rig  Tot (tcu) 1st   2nd   /h)  /h)   x
%
        *
       ***
        *  *
 ****** ****       32,  164  126    0  290   -    -     -    60  789 0.367
100
           *       31
           *
 ****** ****       31,    0   66  300  366   -    -     -    60  997 0.367
100
        *  *       33
       ***
        *
 ---------------------------------------------------------------------------
-----
  East: Shrewsbury Street
                                            Saturation Flow  Min  Tot
  Effective                Arv Flow (veh/h) ---------------  Cap  Cap  Deg.
Lane
  Lane Use         Mov    ------------------ Basic Aver(veh) (veh (veh  Satn
Util
                   No.    Lef Thru  Rig  Tot (tcu) 1st   2nd   /h)  /h)   x
%
        *
       ***
        *  *
 ****** ****       22,  127  345    0  472   -    -     -    60 1007 0.469
100
           *       21
           *
 ****** ****       21,    0   69  504  573   -    -     -    60 1220 0.469
100
        *  *       23
       ***
        *
 ---------------------------------------------------------------------------
-----
  North: Summer Street
                                            Saturation Flow  Min  Tot
  Effective                Arv Flow (veh/h) ---------------  Cap  Cap  Deg.
Lane
  Lane Use         Mov    ------------------ Basic Aver(veh) (veh (veh  Satn
Util
                   No.    Lef Thru  Rig  Tot (tcu) 1st   2nd   /h)  /h)   x
%
```

```
          *
        ***
          *   *
 ****** ****        42,    18  263    0  281    -     -      -     60   935 0.300
100
              *     41
              *
 ****** ****        41,     0   67  275  342    -     -      -     60  1138 0.300
100
          *   *     43
        ***
          *
 ------------------------------------------------------------------------------
-----
```

Washington Square *
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Table S.12A - FUEL CONSUMPTION, EMISSIONS AND COST - TOTAL

Mov No.	Fuel Total ga/h	Cost Total $/h	HC Total kg/h	CO Total kg/h	NOX Total kg/h	CO2 Total kg/h	Lead Total kg/h
West: WCB Ramp							
12 L	2.8	35.00	0.034	1.44	0.047	26.2	0.00000
11 T	7.2	87.05	0.090	4.27	0.133	67.8	0.00000
13 R	1.3	15.61	0.017	0.92	0.029	12.4	0.00000
	11.3	137.66	0.140	6.63	0.209	106.4	0.00000
South: Grafton Street							
32 L	2.1	24.88	0.025	1.20	0.038	19.5	0.00000
31 T	2.0	22.49	0.024	1.28	0.040	18.5	0.00000
33 R	2.9	35.02	0.038	2.11	0.066	27.8	0.00000
	7.0	82.38	0.087	4.59	0.144	65.7	0.00000
East: Shrewsbury Street							
22 L	2.2	27.23	0.025	1.09	0.039	21.0	0.00000
21 T	5.8	72.36	0.070	2.99	0.098	54.7	0.00000
23 R	6.9	87.35	0.086	3.92	0.127	65.0	0.00000
	14.9	186.94	0.181	7.99	0.264	140.7	0.00000
North: Summer Street							
42 L	0.2	2.81	0.003	0.12	0.004	2.1	0.00000
41 T	3.6	41.48	0.041	2.09	0.070	33.6	0.00000
43 R	2.7	33.20	0.035	1.81	0.056	25.4	0.00000
	6.5	77.50	0.079	4.01	0.130	61.1	0.00000
INTERSECTION:	39.6	484.48	0.488	23.23	0.747	373.0	0.00000

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Table S.12B - FUEL CONSUMPTION, EMISSIONS AND COST - RATE

Mov No.	Fuel Eff. mpg	Cost Rate c/mi	HC Rate g/km	CO Rate g/km	NOX Rate g/km	CO2 Rate g/km	Lead Rate g/km
West: WCB Ramp							
12 L	22.4	35.11	0.339	14.49	0.467	262.4	0.00000
11 T	21.4	35.20	0.364	17.26	0.538	274.3	0.00000
13 R	14.9	49.67	0.525	29.28	0.931	394.0	0.00000
	20.9	36.37	0.371	17.53	0.552	281.1	0.00000
South: Grafton Street							
32 L	20.3	36.93	0.375	17.82	0.569	288.9	0.00000
31 T	19.0	37.47	0.407	21.36	0.665	307.4	0.00000
33 R	14.3	51.63	0.557	31.12	0.969	409.7	0.00000
	17.4	42.20	0.448	23.53	0.737	336.5	0.00000
East: Shrewsbury Street							
22 L	21.1	36.12	0.331	14.43	0.521	278.4	0.00000
21 T	22.0	35.27	0.343	14.56	0.478	266.8	0.00000
23 R	18.6	42.38	0.415	19.01	0.617	315.5	0.00000
	20.3	38.41	0.372	16.43	0.543	289.2	0.00000
North: Summer Street							
42 L	22.1	35.42	0.344	14.77	0.475	265.2	0.00000
41 T	19.9	36.38	0.364	18.29	0.618	294.5	0.00000
43 R	16.3	47.06	0.495	25.65	0.788	359.7	0.00000
	18.5	40.25	0.411	20.84	0.675	317.2	0.00000
INTERSECTION:	19.6	38.67	0.389	18.54	0.596	297.7	0.00000

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Table S.15 - CAPACITY AND LEVEL OF SERVICE (HCM STYLE)

Mov No.	Mov Typ	Total Flow (veh /h)	Total Cap. (veh /h)	Deg. of Satn (v/c)	Aver. Delay (sec)	LOS
West: WCB Ramp						
12 L		239	495	0.483*	3.6	A
11 T		785	1626	0.483*	4.4	A
13 R		139	288	0.483*	5.3	A
		1163	2409	0.483	4.4	A
South: Grafton Street						
32 L		164	447	0.367	6.5	A

31 T	192	523	0.367	7.7	A
33 R	300	817	0.367	10.0	A
	656	1787	0.367	8.5	A
East: Shrewsbury Street					
22 L	127	271	0.469	5.0	A
21 T	414	882	0.469	5.7	A
23 R	504	1074	0.469	9.2	A
	1045	2227	0.469	7.3	A
North: Summer Street					
42 L	18	60	0.300	4.7	A
41 T	330	1098	0.301	5.5	A
43 R	275	915	0.301	8.5	A
	623	2073	0.301	6.8	A
ALL VEHICLES:	3487	8496	0.483	6.5	A
INTERSECTION:	3487	8496	0.483	6.5	A

Level of Service calculations are based on delay (HCM criteria).
* Maximum v/c ratio, or critical green periods

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Table D.0 - GEOMETRIC DELAY DATA

From Approach	To Approach	Negn Radius (ft)	Negn Speed (mph)	Negn Distance (ft)
West: WCB Ramp				
	South	49	14	77
	East	208	28	572
	North	210	28	907
South: Grafton Street				
	West	205	28	886
	East	49	14	77
	North	205	28	564
East: Shrewsbury Street				
	West	205	28	564
	South	205	28	886
	North	49	14	77
North: Summer Street				
	West	49	14	77
	South	208	28	572
	East	205	28	886

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WASH_SQ1

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Table D.1 - LANE DELAYS

Lane No.	Mov No.	Deg. Satn x	Analytical 1st dm1	Analytical 2nd dm2	Model Total dm	Acc. Dec. dn	Queu -ing dq	Ratio dm/ di	Stopd (Idle) di	Geom dg	Overall d
West: WCB Ramp											
1 LT	12, 11	0.483	2.1	0.0	2.1	4.8	0.0	0.00	0.0	1.9 1.3	3.6
2 TR	11, 13	0.483	2.5	0.0	2.5	4.5	0.0	0.00	0.0	1.3 6.8	5.3
South: Grafton Street											
1 LT	32, 31	0.367	4.9	0.0	4.9	6.2	0.0	0.00	0.0	1.9 1.3	6.5
2 TR	31, 33	0.367	4.2	0.0	4.2	4.2	0.3	13.77	0.3	1.3 6.9	10.0
East: Shrewsbury Street											
1 LT	22, 21	0.469	3.5	0.0	3.5	5.7	0.0	0.00	0.0	1.9 1.3	5.0
2 TR	21, 23	0.469	3.0	0.0	3.0	3.7	0.0	0.00	0.0	1.3 6.8	9.2
North: Summer Street											
1 LT	42, 41	0.300	3.3	0.0	3.3	5.3	0.0	0.00	0.0	1.9 1.3	4.7
2 TR	41, 43	0.300	2.8	0.0	2.8	3.6	0.0	0.00	0.0	1.3 6.8	8.5

Delay (seconds/veh)

dn is average stop-start delay for all vehicles queued and unqueued

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Table D.2 - LANE STOPS

Lane No.	Mov No.	Deg. Satn x	Effective Stop Rate he1	he2	Geom. hg	Overall h	Prop. Queued pq	Queue Move-up Rate hqm
West: WCB Ramp								
1 LT	12,	0.483	0.28	0.00	0.07	0.35	0.552	0.00

	11							
2 TR	11, 13	0.483	0.35	0.00	0.10	0.46	0.575	0.00
South: Grafton Street								
1 LT	32, 31	0.367	0.57	0.00	0.04	0.62	0.706	0.00
2 TR	31, 33	0.367	0.53	0.00	0.14	0.67	0.707	0.00
East: Shrewsbury Street								
1 LT	22, 21	0.469	0.44	0.00	0.05	0.49	0.652	0.00
2 TR	21, 23	0.469	0.45	0.00	0.18	0.63	0.639	0.00
North: Summer Street								
1 LT	42, 41	0.300	0.41	0.00	0.05	0.46	0.607	0.00
2 TR	41, 43	0.300	0.41	0.00	0.19	0.60	0.599	0.00

hqm is average queue move-up rate for all vehicles queued and unqueued

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Table D.3 - LANE QUEUES

Lane No.	Mov No.	Deg. Satn x	Ovrfl. Queue No	Average Nb1	Nb2	Nb	Percentile 90%	95%	98%	Queue Stor. Ratio
West: WCB Ramp										
1 LT	12, 11	0.483	0.0	1.4	0.0	1.4	3.4	4.3	5.0	0.27
2 TR	11, 13	0.483	0.0	1.3	0.0	1.3	3.3	4.0	4.7	0.26
South: Grafton Street										
1 LT	32, 31	0.367	0.0	0.9	0.0	0.9	2.3	2.8	3.3	0.18
2 TR	31, 33	0.367	0.0	1.0	0.0	1.0	2.6	3.2	3.7	0.21
East: Shrewsbury Street										
1 LT	22, 21	0.469	0.0	1.4	0.0	1.4	3.4	4.3	5.0	0.11
2 TR	21, 23	0.469	0.0	1.5	0.0	1.5	3.7	4.6	5.3	0.12
North: Summer Street										
1 LT	42, 41	0.300	0.0	0.7	0.0	0.7	1.9	2.3	2.7	0.12
2 TR	41, 43	0.300	0.0	0.8	0.0	0.8	2.0	2.5	2.9	0.13

Values printed in this table are back of queue.

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Table D.4 - MOVEMENT SPEEDS (mph)

Mov No.	App. Speeds Cruise	App. Speeds Negn	Exit Speeds Negn	Exit Speeds Cruise	Queue Move-up 1st Grn	Queue Move-up 2nd Grn	Av. Section Spd Running	Av. Section Spd Overall
West: WCB Ramp								
12	30.0	28.0	28.0	30.0			24.7	24.7
11	30.0	28.0	28.0	30.0			23.7	23.7
13	30.0	14.0	14.0	30.0			19.0	19.0
South: Grafton Street								
32	30.0	28.0	28.0	30.0			23.8	23.8
31	30.0	28.0	28.0	30.0			22.7	22.7
33	30.0	14.0	14.0	30.0			18.5	18.2
East: Shrewsbury Street								
22	30.0	28.0	28.0	30.0			25.6	25.6
21	30.0	28.0	28.0	30.0			25.2	25.2
23	30.0	14.0	14.0	30.0			22.5	22.5
North: Summer Street								
42	30.0	28.0	28.0	30.0			24.6	24.6
41	30.0	28.0	28.0	30.0			23.9	23.9
43	30.0	14.0	14.0	30.0			19.8	19.8

--- End of SIDRA Output ---

CINCH PROGRAM VERSION DATE 4-29-1988
985 HCM - CHAPTER 9: SIGNALIZED - OPERATIONAL ANALYSIS
'PI IQP C01
WASH SQ. INTERSECTION
late:02-27-2001 time:15:57:20
AST DATA SET NAMES LOADED OR SAVED
'OLUME= GEOMETRICS= SIGNAL=WASHSIG1
LOCATED IN CBD:Y
'OLUME & GEOMETRICS

	VOLUMES			# OF LANES			LANE WIDTH			CROSS
DIR	LT	TH	RT	LT	TH	RT	LT	TH	RT	WALK
:B	219	309	226	1	2	0	12.0	12.0	0.0	60
/B	136	241	161	1	2	0	12.0	12.0	0.0	60
.IB	300	283	275	1	2	1	12.0	12.0	12.0	72
'B	161	122	159	1	2	1	12.0	12.0	12.0	72

'RAFFIC & ROADWAY CONDITIONS

			ADJ	PARK			PEDESTRIANS			ARR
)IR	GRADE	%HV	Y/N	MOVES	BUSES	PHF	CROSS	BUT	MIN TIME	TYPE
:B	1.0%	5.0%	N	0	0	.870	12	Y	22.0	1
WB	2.0%	5.0%	N	0	0	.870	54	Y	22.0	1
IB	1.0%	5.0%	N	0	0	.870	43	Y	20.0	1
;B	1.0%	5.0%	N	0	0	.870	9	Y	20.0	1

'HASINGS

	EASTBOUND				WESTBOUND				NORTHBOUND				SOUTHBOUND				GREEN	Y+R	PRE/ACT
	l	t	r	p	l	t	r	p	l	t	r	p	l	t	r	p			
1	*				*												19.5	5	P
2		*	*			*	*					*				*	25.6	5	P
3									*				*				26.7	5	P
4								*		*	*			*	*		28.2	5	P

:YCLE= 120.0

'OLUME ADJUSTMENT WORKSHEET
'ART 1 (MOVEMENT ADJUSTMENTS)

)IR	LTV	THV	RTV	PHF	LTFR	THFR	RTFR
EB	219	309	226	.870	252	355	260
/B	136	241	161	.870	156	277	185
.IB	300	283	275	.870	345	325	316
SB	161	122	159	.870	185	140	183

'ART 2 (LANE GROUP ADJUSTMENTS)

)IR	LN GROUP	FLOW	N	LU	v	Plt	Prt
EB	LT	252	1	1.00	252	1.00	0.00
:B	TH-RT	615	2	1.05	646	0.00	0.42
WB	LT	156	1	1.00	156	1.00	0.00
WB	TH-RT	462	2	1.05	485	0.00	0.40
IB	LT	345	1	1.00	345	1.00	0.00
IB	TH	325	2	1.05	342	0.00	0.00
NB	RT	316	1	1.00	316	0.00	1.00
SB	LT	185	1	1.00	185	1.00	0.00
;B	TH	140	2	1.05	147	0.00	0.00
SB	RT	183	1	1.00	183	0.00	1.00

'ART 3 (OPPOSING VOLUME ADJUSTMENTS)

LEFT TURN	OPPOSING APPROACH									
BEING OPPOSED	VOLUMES			% OPPOSING LEFT TURN			# LANES			OPPOSING
	LT	TH	RT	LT	TH	RT	LT	TH	RT	VOLUME
:ASTBOUND	156	277	185	100	0	0	1	2	0	0

PHF = .87

PHV = 5%

Phase 1 N - S Left Exclusive

Phase

P1 → 18.5

24.3

25.4

26.8

Amber Time

$$Y = t + \frac{1}{2} \cdot \frac{v}{a} + \frac{(w + l)}{v}$$

Y = 3.5

Y = Amber Time
t = reaction time = 1 sec
v = approach speed = 35 mph
a = deceleration of clearing vehicle = 15
w = intersection width = 60' & 70'
l = length of vehicle = 20'

All Red Time = 2 sec

y' = amber effectively used as though it were green
V = approach speed, MPH

$y' = 1.32 + 0.050V$ = 3.07 sec

"Go" interval (green) [Based on Pedestrian crossing during "Go"]

Go" = Ped. Start Time (7 sec) + Ped. cross time (4(width)) - Amber = 19 sec

— or —

Go" = 2.1n + 3.7 n = # vehicles in one lane

use "Go" = 21 sec.

Flow

PHF ⇒ Shrews = .83
Graff = .79
Front = .94
Sum = .91

PHF_{Avg} = .87

$Flow_{(15 min)} = PHF \left(\frac{N}{4}\right)$ N = PK Hour Flow

$Flow_{Sh}$ = 114
$Flow_{Su}$ = 100
$Flow_{Gr}$ = 170
$Flow_{F}$ = 177

Headway = from pg. 352 use 2.5 sec.

Passenger Car Equivalent (pce)

PCE_{car} = 1.0
$PCE_{Bus/truck}$ = 1.5
$PCE_{left\ turn}$ = 1.6
$PCE_{right\ turn}$ = 1.3

3.5 ft/s ped. walk

30 mph all approach => 44.1 ft/s

10 parking

5% truck

27% left turn FS

33% left turn GS

$f_{e\,truck} = 1.5$

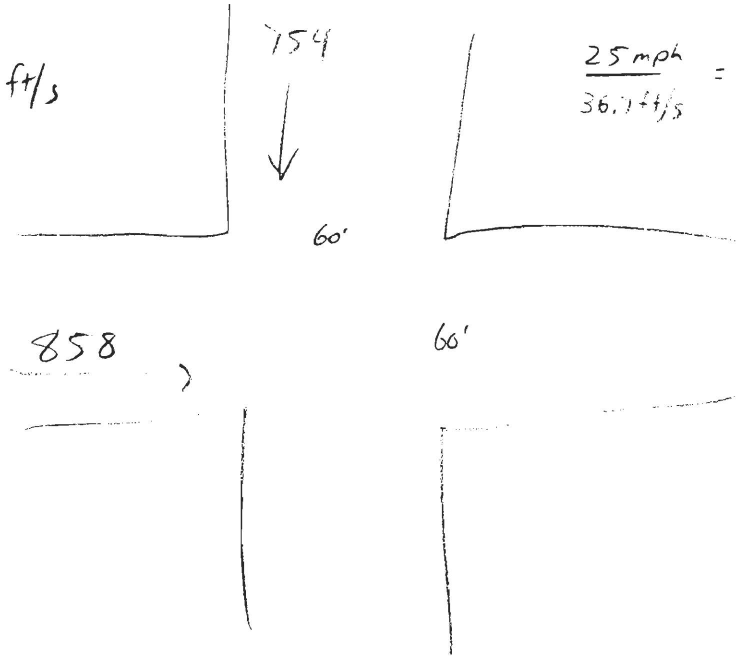
$f_{e\,left} = 1.6$

$f_{e\,right} = 1.2$

PHF = .87

30% right turn FS

33% right turn GS



$$\frac{25\text{ mph}}{36.7\text{ ft/s}} = \frac{30\text{ mph}}{x\ \frac{ft}{s}}$$

Equivalent Volume:

$$Vol_{FS} = 754(.05)(1.5) + 754(.27)(1.6) + 754(.3)(1.2) + 754(.35) = 918 \text{ cars}$$

$$Vol_{GS} = 858(.05)(1.5) + 858(1.6)(.33) + 858(.33)(1.2) + 858(.29) = 1106 \text{ cars}$$

$$N_1 = \frac{vol}{3} = 306$$

$$N_2 = \frac{vol}{3} = 369$$

$$Y = (t=1) + \frac{1}{2}\frac{(v=44.1)}{(a=15)} + \frac{(60' + 20')}{44.1} = 4.3$$

$$R = 5 + \frac{60}{3.5} = 22.2 \text{ sec}$$

$$G = 22.2 - 4.3 = 17.9 \text{ sec}$$

$$G_{FS} = 17.9$$

$$G_{GS} = 19.7$$

$$C_{min_1} = \frac{2(4.3)}{1 - (306(2.5) + 369(2.5))/3600(.87))} = 19 \text{ sec}$$

$$C_{min_2} = 17.9 + 19.7 + (4.3)2 = 46.2 \text{ sec}$$

NCH

Arr. Type = 1

Ped. Button - yes

N_1 = crit. lane volume (major street) $N_{GS} = 225$

C = cycle length (sec) $N_{FS} = 250$

$S_{1,2}$ = headway = 2.5 sec

$Y_{1,2}$ = Amber = 3.07 sec

K = # signal cycles in 15 min.

PHF = .87

- The total time required to pass all vehicles through the intersection during the 15 min peak:

$$T = \frac{2N_1 S_1}{4(PHF)}$$

- Total time for Amber

$$K(Y_1 + Y_2)$$

$$T + K(Y_1 + Y_2) \leq 900 \text{ sec} \qquad K = \frac{900}{C}$$

$$C_{min} = \frac{Y_1 + Y_2}{1 - \left(N_1 S_1 + N_2 S_2 / 3600(PHF)\right)} = 10 \text{ sec.}$$

APPENDIX D

Visual Figures

Newton Square

Figure 1.

June St. Entrance

Figure 2.

June St. Entrance

Newton Square
Figure 3.
June St. Entrance

Figure 4.
Newton Ave. Entrance

Newton Square
Figure 5.
Pleasant St. (N) Entrance

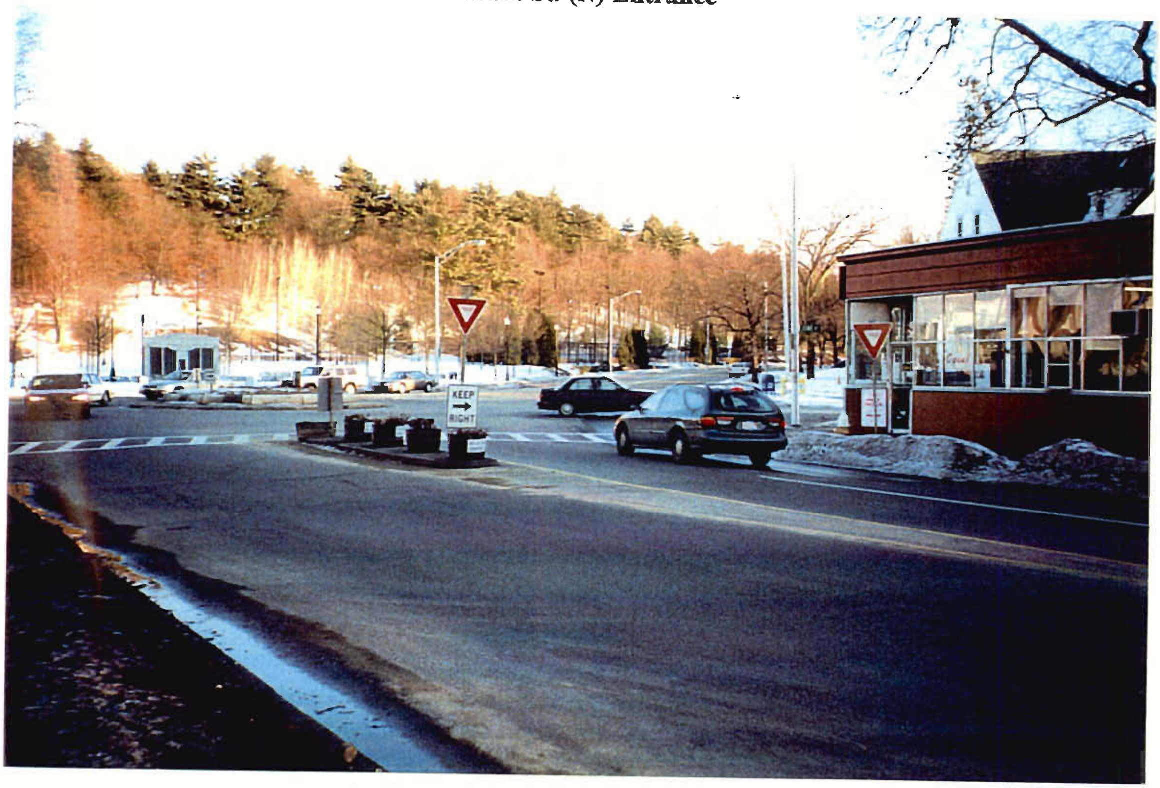


Figure 6.
Duffy Field

Newton Square

Figure 7.

June St.

Figure 8.

Doherty High School

Newton Square
Figure 9.
Doherty High School

Figure 10.
Pleasant St. (S) Entrance

Washington Square
Figure 11.
Shrewsbury St. Entrance

Figure 12.
Shrewsbury St. Entrance(Pat's Auto in backround)

Washington Square

Figure 13.

Summer St. Entrance

Figure 14.

Summer St. Exit

Washington Square
Figure 15.
Ramp C Entrance

Figure 16.
Railroad and Pedestrian bridge over Grafton St.

Washington Square
Figure 17.
Grafton St. Entrance and Exit

Figure 18.
Grafton St. Entrance

Washington Square

Figure 19.
Parking Lot Adjacent to Shrewsbury St.

Figure 20.
Pedestrian Crossing Zone at Grafton St./Franklin St. Intersection

Washington Square

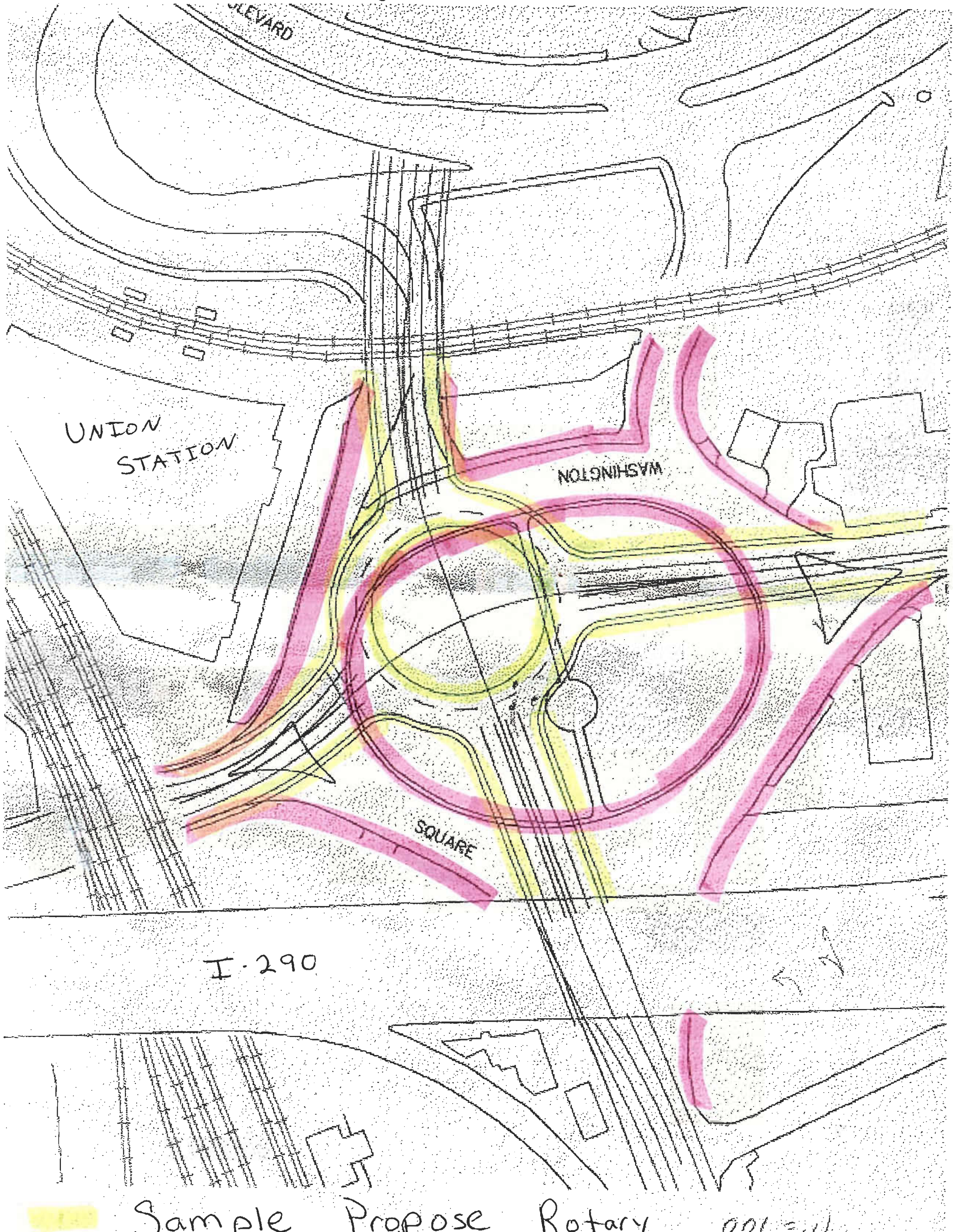
Figure 21.

Parking Lot Adjacent to Grafton St.

Figure 22.

Parking Lot Adjacent to Grafton St.

Figure 23



Sample Propose Rotary

Existing Rotary

Washington Square A View.

Appendix E

Newton Square Surveys

(T)

Survey for Newton Square

1. When do you believe is the worst time to travel in the Newton Square rotary? Why? Mornings around 7:20 is the worst time to travel the rotary going down Highlad St b/c of Doherty H.S. Afternoons 5:30 is the worst time to travel around the rotary going up Pleasant b/c everyone is going home in that direction.

2. Do you believe that Newton Square is a safe rotary for commuter traffic? Why or why not? Yes, I believe it is safe because I have lived here my whole life (31 years) and for the most part, people yield and/or stop where and when they are supposed to. And I have seen very few accidents.

3. Do you believe that Newton Square is a safe rotary for pedestrian traffic? Why or why not? Yes, I believe it is safe for pedestrians for the reasons listed above,

4. What do you believe can be done, if anything, to make the rotary safer for commuter traffic? Police presence at rush hour.

5. What do you believe can be done, if anything, to make the rotary safer for pedestrian traffic? Same as above.

6. If you have any other comments or suggestions it would be greatly appreciated.

9

Survey for Newton Square

1. When do you believe is the worst time to travel in the Newton Square rotary? Why? 7:30-8:15 am, 2 pm (Roberts gets out at 2) 4:30-530 pm normal rush hour

2. Do you believe that Newton Square is a safe rotary for commuter traffic? Why or why not? no - People coming into the rotary ~~on~~ from June St. pull way out to stop "line" & don't stop - go right into traffic. also, see comment under #4 re: elections

3. Do you believe that Newton Square is a safe rotary for pedestrian traffic? Why or why not? no - Students cross all over - don't use crosswalks

4. What do you believe can be done, if anything, to make the rotary safer for commuter traffic? 1) Do not allow politicians to disrupt the traffic with signs, supporters waving at drivers, etc. 2) Do something about people coming from June St who don't stop

5. What do you believe can be done, if anything, to make the rotary safer for pedestrian traffic? Enforce the Jay-walking

6. If you have any other comments or suggestions it would be greatly appreciated.

Do something about not allowing people to clog the rotary at election time. It is a nightmare & an accident waiting to happen

3

Survey for Newton Square

1. When do you believe is the worst time to travel in the Newton Square rotary? Why? Morning commute and when School gets out. ~~Everyone knows not~~ Everyone is in such a rush they don't give anyone a chance.

2. Do you believe that Newton Square is a safe rotary for commuter traffic? Why or why not? It's not very safe. Everyone has a different opinion of who has the right of way. Alot of people also ignore the stop sign on June St.

3. Do you believe that Newton Square is a safe rotary for pedestrian traffic? Why or why not? NO I always try to cross with my 3 children and no one stops for you. They come so fast around the rotary they don't see you in the middle of the street and they either can't stop or they slam on their brakes. (Even when there is a crossing guard)

4. What do you believe can be done, if anything, to make the rotary safer for commuter traffic? Put better signs that explain the Law and have a police there for a while giving out citations.

5. What do you believe can be done, if anything, to make the rotary safer for pedestrian traffic? A walk light. Better crosswalks (brighter and bolder) and one of those cones in the middle of the street that says "It's the law stop for Pedestrian

6. If you have any other comments or suggestions it would be greatly appreciated.

My children and I have almost been hit many times and also been stuck in the middle of the street because no one will stop. It's about time someone looks into the problem. Many thanks to you!

4

Survey for Newton Square

1. When do you believe is the worst time to travel in the Newton Square rotary? Why? 700-800 am when everyone is going to work and to Doherty H.S.
   200 pm when Doherty H.S. is released.
   500-600 pm when everyone is coming home from work

2. Do you believe that Newton Square is a safe rotary for commuter traffic? Why or why not? It could be if people would follow the signs. People coming from either side of Pleasant St. rarely stop or yield. People from Coolidge Rd. stop at the sign but then, I don't think they know what they're supposed to do. People coming from Highland St are dangerous. Newton Ave is the only stop sign that people actually stop.

3. Do you believe that Newton Square is a safe rotary for pedestrian traffic? Why or why not? Yes, if you run! (very fast)

4. What do you believe can be done, if anything, to make the rotary safer for commuter traffic? I'm not sure, it might help if rotaries were discussed more in driving schools, also if police were more visible, people might adhere to the signs more.

5. What do you believe can be done, if anything, to make the rotary safer for pedestrian traffic?
   Just running! (very fast)

6. If you have any other comments or suggestions it would be greatly appreciated.
   I think its wonderful you chose our rotary for your project, and if you can find a way to make it work smoothly you all deserve an "A"!

3

Survey for Newton Square

1. When do you believe is the worst time to travel in the Newton Square rotary? Why?

   ~~3~~ 2 to 5:30pm. Congestion. It's worst when picketers are at the rotary.

2. Do you believe that Newton Square is a safe rotary for commuter traffic? Why or why not?

   Yes, however it's a very tough rotary. I've seen some accidents and near misses.

3. Do you believe that Newton Square is a safe rotary for pedestrian traffic? Why or why not?

   No! People can be so rude, Even when there's a cross guard.

4. What do you believe can be done, if anything, to make the rotary safer for commuter traffic?

   No clue!

5. What do you believe can be done, if anything, to make the rotary safer for pedestrian traffic?

   No clue!

6. If you have any other comments or suggestions it would be greatly appreciated.

   When you have almost 6 street converging into one area, what else can be done besides a rotary? Good Luck!

(6)

Survey for Newton Square

1. When do you believe is the worst time to travel in the Newton Square rotary? Why?

   7:30 – 8:30 AM
   4:30 – 5:30 PM

2. Do you believe that Newton Square is a safe rotary for commuter traffic? Why or why not?

   No. Drivers do not yield the right of way to motorists in the rotary.

3. Do you believe that Newton Square is a safe rotary for pedestrian traffic? Why or why not?

   Yes. It's as safe as any other major intersection in the city with clearly marked crosswalks.

4. What do you believe can be done, if anything, to make the rotary safer for commuter traffic?

   It can't be improved, only eliminated, or changed to an intersection. This solution is of course very expensive.

5. What do you believe can be done, if anything, to make the rotary safer for pedestrian traffic?

   Probably nothing.

6. If you have any other comments or suggestions it would be greatly appreciated.

   As a life long resident of Newton square, I think I can safely say that unless a large sum of money can be spent, this rotary will never be anything more than a traffic headache to all motorists and pedestrians using it.

7)

Survey for Newton Square

1. When do you believe is the worst time to travel in the Newton Square rotary? Why? Between 7:30AM - 8:30AM Business people and School buses

2. Do you believe that Newton Square is a safe rotary for commuter traffic? Why or why not?
No. Most people just fly through with no regard for traffic signs

3. Do you believe that Newton Square is a safe rotary for pedestrian traffic? Why or why not?
No. same reason as above

4. What do you believe can be done, if anything, to make the rotary safer for commuter traffic?
Maybe traffic lights "instead" of a rotary would work better.

5. What do you believe can be done, if anything, to make the rotary safer for pedestrian traffic?
A simple traffic light to allow crossing (not eliminating the rotary)

6. If you have any other comments or suggestions it would be greatly appreciated.

(5)

Survey for Newton Square

1. When do you believe is the worst time to travel in the Newton Square rotary? Why? Noon-time to 2:00--School release 5:00-6:30- Commute times

2. Do you believe that Newton Square is a safe rotary for commuter traffic? Why or why not? NO- everyone today thinks they all have the right away -they should do away with Rotary and put traffic lights

3. Do you believe that Newton Square is a safe rotary for pedestrian traffic? Why or why not?
NO-

4. What do you believe can be done, if anything, to make the rotary safer for commuter traffic?
Put in traffic lights

5. What do you believe can be done, if anything, to make the rotary safer for pedestrian traffic?
Same as above

6. If you have any other comments or suggestions it would be greatly appreciated.

eliminate Rotary - AND put in traffic lights

9

Survey for Newton Square

1. When do you believe is the worst time to travel in the Newton Square rotary? Why?
Commuter traffic times – morning & evening and probably when Doherty gets out

2. Do you believe that Newton Square is a safe rotary for commuter traffic? Why or why not?
Everyone for themselves – kinda like Kelley Square now. It's not safe. But ~~stop~~ lights would jam up the streets in the morning traffic

3. Do you believe that Newton Square is a safe rotary for pedestrian traffic? Why or why not?
No! People go very fast through the rotary often times not stopping just sort of "sliding" in with traffic especially the Highland St entrance to rotary

4. What do you believe can be done, if anything, to make the rotary safer for commuter traffic?
People need to come to a full stop upon entering the rotary – They're not doing that now.

5. What do you believe can be done, if anything, to make the rotary safer for pedestrian traffic?
Pedestrians should cross further down any of the streets and avoid the rotary its dangerous.

6. If you have any other comments or suggestions it would be greatly appreciated.

9

P.S. Chris -

Check into incident involving pedestrian and Penske truck yesterday 2/7/01 in the morning around 7:30. You may be able to obtain police reports