

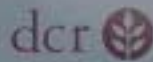
REDESIGN OF THE ARBORWAY

KELLEY CIRCLE TO MURRAY CIRCLE

BOSTON, MASSACHUSETTS

ARBORWAY

EMERALD NECKLACE



MASSACHUSETTS DEPARTMENT OF
CONSERVATION AND RECREATION

Prepared For:

Professor Peter Furth,
Northeastern University

Nicole Freedman,
Bicycle Planner, City of Boston

Prepared By:

HUB Engineering

Michelle Boccia
Andrew Caparco
Joseph Mayotte
Jocelyn Rothstein

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SECTION 1: INTRODUCTION

The Arborway, between Kelley and Murray Circle in Jamaica Plain, is a section of roadway that is currently dangerous for pedestrians and cyclists due to heavy traffic on the outer roadways and the lack of both safe crossings and a dedicated path for recreational users. It is also unsafe for motorists due to the high-speed merges necessary at the existing rotaries, which lack roadway geometry that dictates right of way. Improvements are necessary to ensure safety for motorists, cyclists and pedestrians as well as to provide a continuous path between Jamaica Pond and the Arnold Arboretum. Improvements will also include enhancement of the existing parkland and mature trees located along the Arborway.

The Department of Conservation and Recreation (DCR) would like to increase the recreational aspect of the area while maintaining the current capacity of the roadway for regional traffic. Increasing the recreational aspect includes making it safer for pedestrians to cross from one side of the Arborway to the other as well as traversing along the Arborway. A locus map and aerial photo are provided in the figures on the following pages.

In the following sections, we discuss the history of the Arborway, including both its original design and its current conditions. We review recent studies and explain any deficiencies



Figure 1.1: Multi-leg unprotected crossings place pedestrians and cyclists in danger when traveling along the Arborway.



Figure 1.2: Heavy vehicular flows around existing rotaries make merging and navigating dangerous for motorists.

in their designs. Based on our objectives and the results of these previous studies, we have developed a design, which is presented in Section 4. After the completion of various traffic studies, analysis of the design was completed using Synchro and VISSIM and the results are summarized in Section 6. Design of the paths and development of the greenspace was investigated and presented in Section 7 of this report. Lastly, a summary of the impacts to the area and conclusions of the proposed design are presented in Section 8.

Figure 1.3: Locus Map

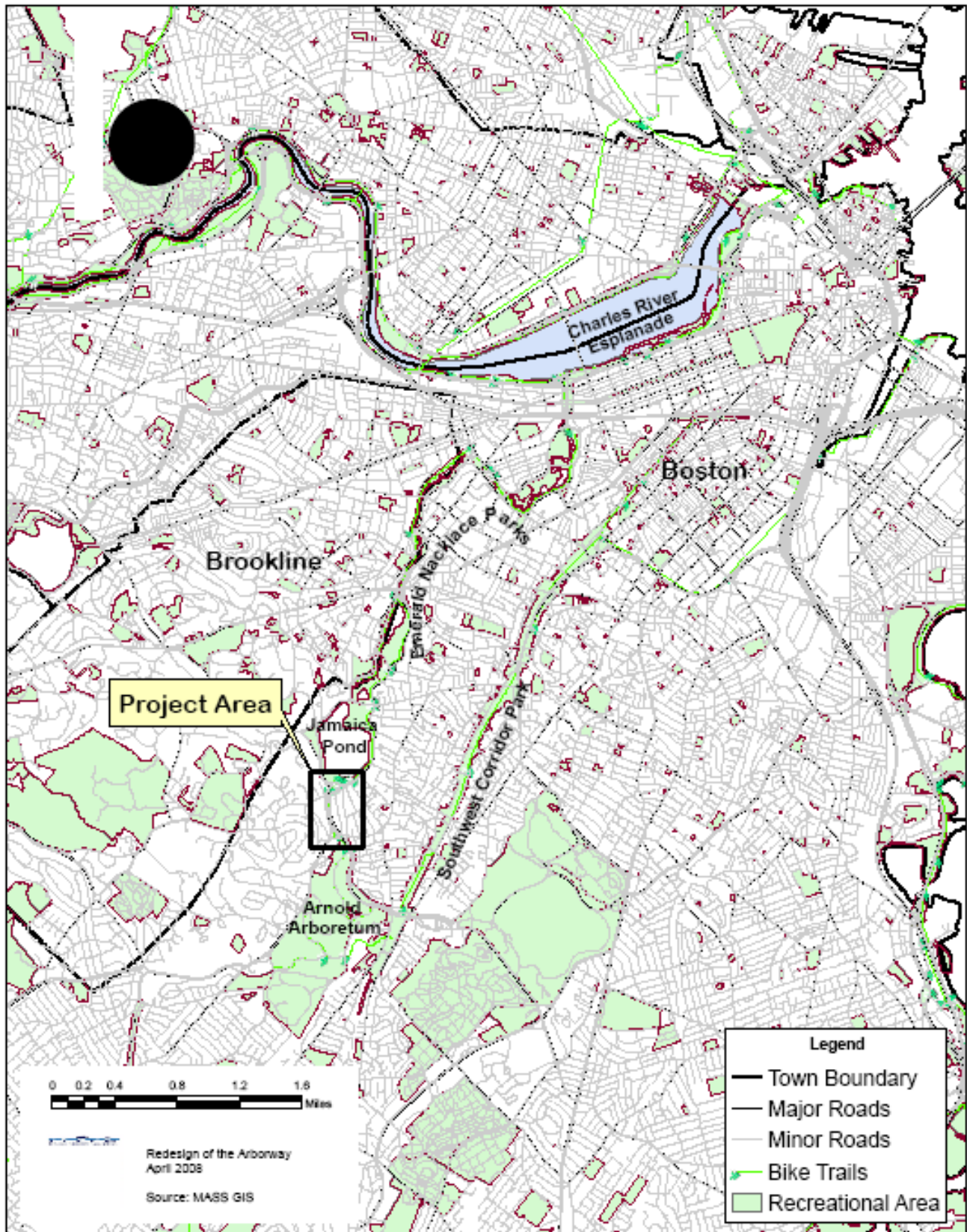


Figure 1.4: Aerial Map



SECTION 2: HISTORY OF THE ARBORWAY

The Arborway is the section of roadway that stretches from Jamaica Pond to Franklin Park. The name Arborway was designated to this section of roadway because the Arnold Arboretum lies between these two parks. The development of the Arborway as we know it today went through four main developmental periods which include:

- Early Park Period (1859-1877)
- Frederick Law Olmsted Period (1879-1897)
- Transition To Automobiles (1898-1949)
- Urban Roadway Period (1950-Present)

The following subsections will discuss relevant aspects from the four periods that affected the above mentioned section of the Arborway, as well as a description of the two most recent studies of the area.

2.1 OLMSTED'S ORIGINAL DESIGN

In 1869 the Mayor was pushed to petition the courts to pass an act allowing the City of Boston to either purchase land for one large park or purchase land for several small parks. Over the next few years, proposals were made for parks. The general trend of the proposals was to create a park system as opposed to just creating one large park. It took until May of 1875 for the Boston Park Act to be passed, which allowed public parks to exist within the city limits. Once this act was passed, the City of Boston consulted Frederick Law Olmsted to come up with a general plan.

By 1879, Olmsted had prepared a "Plan of the Parkway from Jamaica Park to Franklin Park" as well as a "Map of Proposed Arboretum Showing its Outlined and Local Connection, with a Study for Public Drive Passing Through It." The development of these plans was a result of the "Boston Parks Movement." He came up with a "triad of circulation" which involved routes for carriages, saddle horses, and pedestrians. At the time the roadways, better known as parkways, were designed to be used by carriages only.

In 1897, Olmsted, along with his brother, was chosen to be the landscape architect advisor for the new park system. At the time, the parks commission was more concerned with preserving scenery rather than getting people from one destination to another quickly. When the transition came about for automobile use in 1898 they wanted to keep the parkways looking like parks, since the system was initially focused on carriages, saddle horses, and pedestrian travel. Red Oak trees were planted along the Riverway as well as from Huntington Avenue, at the beginning of the Jamaica way, all the way down to Franklin Park.

During the course of development John A Pettigrew, the superintendent of the Boston Parks Commission, made changes to Olmsted's original park system design. Some of the changes included using shrubbery and other various plantings instead of just trees and grass. These plantings became a maintenance issue and were re-evaluated in 1911.

By the 1920's plantings weren't the commission's only concern. They were facing an increased pressure to modify the parkways to accommodate the increase in automobile traffic. The intersection of Prince Street and the Jamaicaway was deemed to be one of the most dangerous corners of the parkway system. To solve this problem they removed an existing stonewall and altered the pedestrian path to make it safer. By 1927 the commission was now focused on modernizing roadways and making them straighter in order to be more automobile friendly.

During the 1930's the city decided that it was necessary to construct a rotary on the Arborway at Centre Street. This was designed by B.H. French and executed in the mid 30's. This was the beginning of the lost of pedestrian linkages between Jamaica Pond and the Arnold Arboretum. In 1943 a similar conclusion was determined about the point of intersection of the Arborway with Prince Street, Pond Street, and the Jamaicaway. The result of this was the construction of Kelley Circle. Kelley Circle also resulted in the loss of pedestrian links. The trend at this point was that the automobile was more important and pedestrian paths suffered greatly.

2.2 EXISTING CONDITIONS

In the 1950's the Arborway started to undergo major modifications, which resulted in the current configuration of the Arborway. The most notable are the addition of the Casey overpass and the widening of the Arborway. In 1953 "Construction Plans Reconstructing and Widening Arborway to Dual Parkway from Centre Street Easterly about 2700 Feet" was developed. These plans called for the reconstruction of the Arborway to make it wider. Since the roadway was made larger, modifications also had to be made to the intersection at Centre Street.

In 1956 the City of Boston's Parks and Recreation Department gave the responsibility of the care, control, and maintenance of the Riverway, the Jamaicaway, and the Arborway to the Metropolitan District Commission (MDC.) The purpose if this decision was to attempt to get the MDC to link the existing parkways so they would become continuous. What ended up happening is that the MDC turned the parkways into urban commuter roads.

Currently, the Arborway between Kelley Circle and Murray Circle consists of a 4 lane inner roadway that carries two-way traffic and two outer roadways, both 2 lanes each that carry one-way traffic, one in each direction. Separating the three roadways are two islands that are lined with the Oak trees mentioned in Section 2.1. Figure 2.1 shows the current layout of the Arborway.



Figure 2.1: Current Arborway Cross Section

Since the installation of the rotaries in the 30's and the roadway expansion in the 50's very few changes have been made. The most notable changes or improvements to the rotaries are the implementation of a few signals to help control traffic. Signals were added at the intersections of Pond Street Eastbound with Kelley Circle as well as at Centre Street Northbound just before it hits Murray Circle.

Starting in 1989 efforts began to be made to recreate links for pedestrians and bicyclists with the "Emerald Necklace Master Plan" by Walmsley Pressely Joint Venture. This proposal focused on the portion of the Arborway between Kelley Circle and Murray Circle. Efforts to recreate these links have been continued to be analyzed ever since, with minor improvements made along the way.

2.3 RECENT STUDIES

In recent studies, both Rizzo Associates and Stantec, Inc. have developed alternatives to the current layout and traffic patterns along the Arborway. Below is a brief description of each of these alternatives. It was found that the alternatives with the most promise came from Stantec, Inc. This section includes figures showing Stantec's proposed changes as well as the advantages and disadvantages of these alternatives. They are presented in tables along with a description of each. It is our opinion that the Rizzo alternatives will not satisfy the needs of the DCR or the local residents for this project. Below are project descriptions, but since no further evaluation of these will be undertaken, no figures or tables for these alternatives are included.

Rizzo Alternative 1 – Roundabouts

Rizzo's Alternative 1 aims to improve safety by replacing the large rotaries at Kelley Circle and Murray Circle with smaller, modern roundabouts. Roundabouts have similar operations to existing rotaries, but new entrance geometries will force cars entering the rotary to slow significantly before merging with oncoming traffic. Also, the smaller radii of the new roundabouts will force lower vehicle speeds when in the rotary.

Rizzo's design attempts to remove some of the regional traffic using the Outer Arborway, so the outer northbound and southbound routes have been reduced from two lanes to one lane. This will be accomplished by doing the following:

- Removing access to Parkman Drive from the Outer Arborway Northbound at Kelley Circle. Parkman Drive is now accessible only from the Inner Arborway.
- Removing access to the Murray Circle roundabout from the Outer Arborway southbound. This street will connect to Centre Street west of Murray Circle.

By making these changes, the traffic demand on the Outer Arborway would have been reduced enough to accommodate the loss of a lane in each direction. The Outer Arborway would have served as less of a through route for regional traffic while providing better, safer local access for the residents.

The land regained from the lane removal was to be used for a separated, mixed use pedestrian/cyclist path which would be added along the western edge of the Outer Arborway southbound. Pedestrian and cyclist crossings are improved by the addition of a new signal at Elliot Street, providing a protected crossing between the Pondsides neighborhood and Jamaica Pond. Also, pedestrian crossings are improved using shorter crossings and lower vehicle design speed.

This design was not well received because the residents and the DCR did not like the idea of roundabouts. They felt that it did not improve safety enough for pedestrians. They also did not like the way access was going to be limited. The residents were mainly pushing for the implementation of intersections.

Rizzo Alternative 2 – Intersections

This design alternative aims to improve traffic safety like Alternative 1 by replacing the large unsafe rotaries at Kelley Circle and Murray Circle with signalized intersections. The intersections would be safer than the existing rotaries where motorists are able to enter the rotary at high speeds without slowing to yield to oncoming traffic. Also like Alternative 1, Alternative 2 seeks to separate local traffic from regional traffic by limiting access to the Outer Arborway's. The access that would be limited would be the same as Alternative 1.

By making changes to the accessibility of the Outer Arborway's, the traffic demand on the Outer Arborway will be reduced enough to allow the loss of a lane in each direction. The Outer Arborway would then serve as less of a through route for regional traffic while retaining local access for the residents.

The land regained from the lane cut would be used for a separated, mixed use pedestrian / cyclist path added along the western Arborway median, between the eastern edge of the Outer Arborway southbound and the Inner Arborway. This space is regained from reducing the Outer Arborways to one lane in each direction. Pedestrian and cyclist crossings are improved by the addition of a new signal at the Jamaica way and Elliot Street intersection, providing a protected crossing between the Pondsides neighborhood and Jamaica Pond. Also, pedestrian crossings are improved using shorter crossings.

The public and the DCR had similar concerns with this alternative as they did with Alternative 1. They did not like the way local access was going to be limited in efforts to calm traffic.

Rizzo Long Term Preferred Alternative

The Rizzo Long Term Preferred Alternative is a combination of Alternative 1 and Alternative 2 on a section-by-section basis. It retains the same rotaries used in Alternative 1. This would improve safety and traffic flow, as well as reduce traffic demand on the Outer Arborways. Also like Alternatives 1 and 2, both the Northbound and Southbound Outer

Arborway's are reduced to one travel lane. The only difference from Alternative 1 and the long term preferred alternative is the location of the shared-use cyclist / pedestrian path. In the Long Term Preferred Alternative, the shared-use path is added on the median between the Inner Arborway and the Outer Arborway northbound.

Results

Ultimately, it was determined that none of Rizzo's designs were sufficient. The community and the DCR were not satisfied with what was being proposed. The main concerns were that:

- The regional and local traffic was not being separated sufficiently.
 - Not fond of the fact that Prince Street was being made into a dead end.
 - Concerned that by limiting access from the Outer Arborways that it would send traffic into their neighborhoods.
- The pedestrian and bicycle crossings were not adequate or safe enough to get across the Arborway.
- The overall circulation of the proposed design was not seen as a desirable improvement from the existing conditions, based on local access and capacity.

Stantec Alternative A

Stantec's Alternative A attempts to separate regional traffic from local traffic through the use of conventional intersection configurations. The location and design of these intersections is different from what had previously been proposed by Rizzo Associates. All major traffic movements are directed to the Inner Arborway and the major intersecting streets including Centre Street and Parkman Drive.

A new four way signalized intersection is provided at Centre Street in the vicinity of Murray Circle. South of Centre Street, the Inner Arborway is realigned to direct traffic away from the Outer Arborway NB and onto the Inner Arborway, avoiding the heavy volumes on the local roadways. In addition, the existing signal at Prince Street and Centre Street is moved east to the intersection of Orchard Street and Centre Street. The Outer Arborways are designed to serve the local streets and provide access to the Inner Arborway without major disruption.

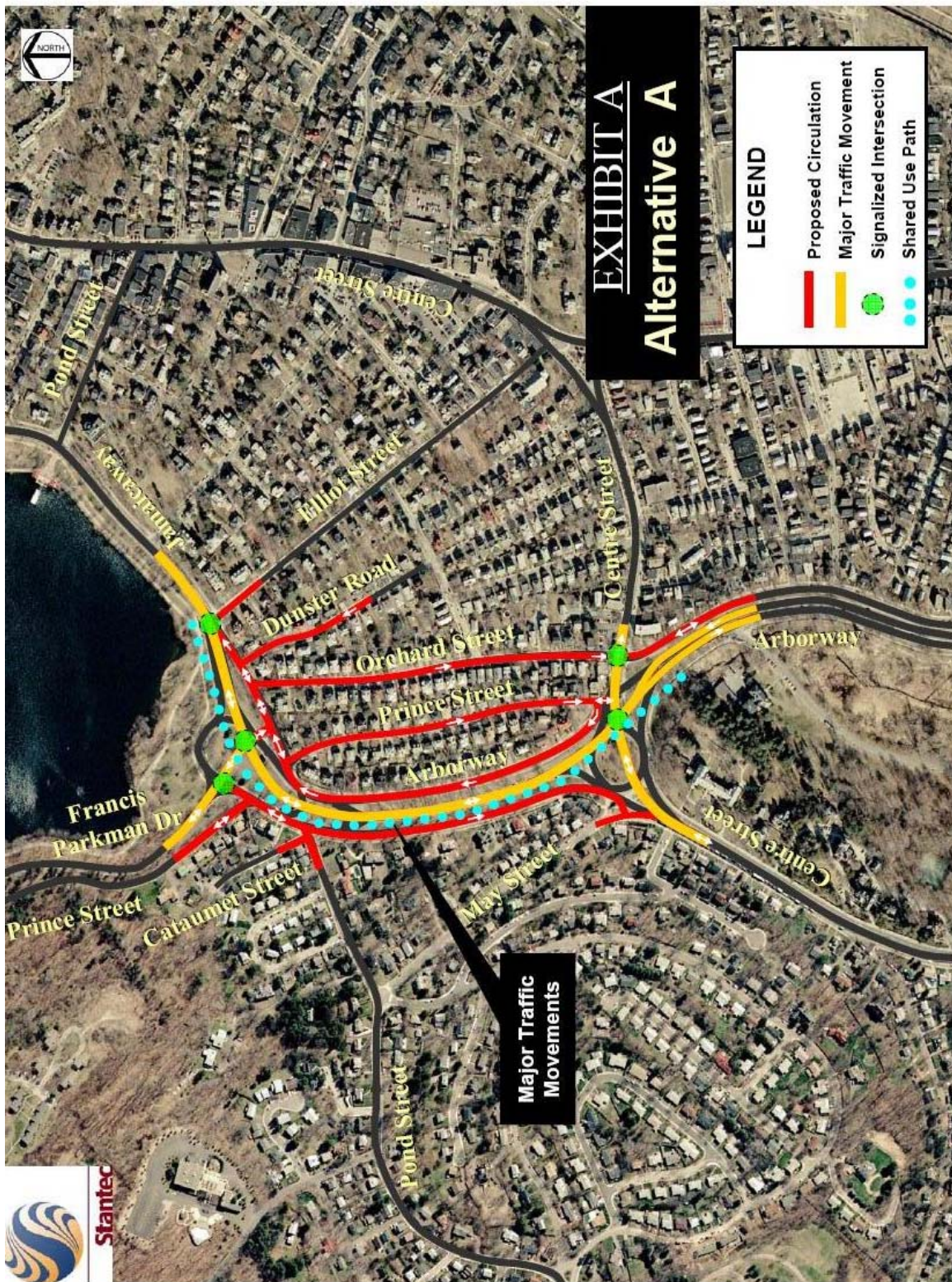
At Kelley circle, the rotary has been replaced with two intersections, Inner Arborway at Parkman Drive and the Western Outer Arborway at Parkman Drive. This configuration was designed to minimize the number of pedestrian crossings whether via sidewalks or a shared use path. This configuration does require the reconfiguration of some local streets. A segment of Pond Street will be converted to a two-way roadway between Prince Street and Dunster Avenue to provide access from Orchard Street to the Arborway thereby avoiding a circuitous route to the mainline. The existing u-turn provisions provided just south of Pond Street have been eliminated to improve safety. Pond Street will access the Arborway via a two-way Outer Arborway segment between Pond Street and Parkman Drive. The new configuration can be found on Figure 2.2:

Stantec Alternative A. A summary of the advantages and disadvantages of this alternative is located below in Table 2.1: Stantec Alternative A – Advantages and Disadvantages.

Table 2.1: Stantec Alternative A - Advantages and Disadvantages

Advantages	Disadvantages
<ul style="list-style-type: none">• Separates Regional/Local Traffic	<ul style="list-style-type: none">• A segment of Pond Street, between Prince St. and Dunster St., has two-way traffic. May encourage cut-through traffic.
<ul style="list-style-type: none">• Signalized intersections provide right of way for vehicular traffic.	<ul style="list-style-type: none">• A segment of Outer Arborway SB has two-way traffic. May encourage cut-through traffic.
<ul style="list-style-type: none">• Improved Local Access to Arborway	<ul style="list-style-type: none">• Indirect Connection of Pond St – Arborway SB
<ul style="list-style-type: none">• No directional changes for local streets other than small segments on Outer Arborway SB and Pond Street.	<ul style="list-style-type: none">• Kelley Circle intersection analysis does not include any time for path crossing
<ul style="list-style-type: none">• Fewer/Safer Pedestrian Crossings. Fewer crossings limit pedestrian-auto conflicts while still providing adequate pedestrian access.	

Figure 2.2: Stantec Alternative A

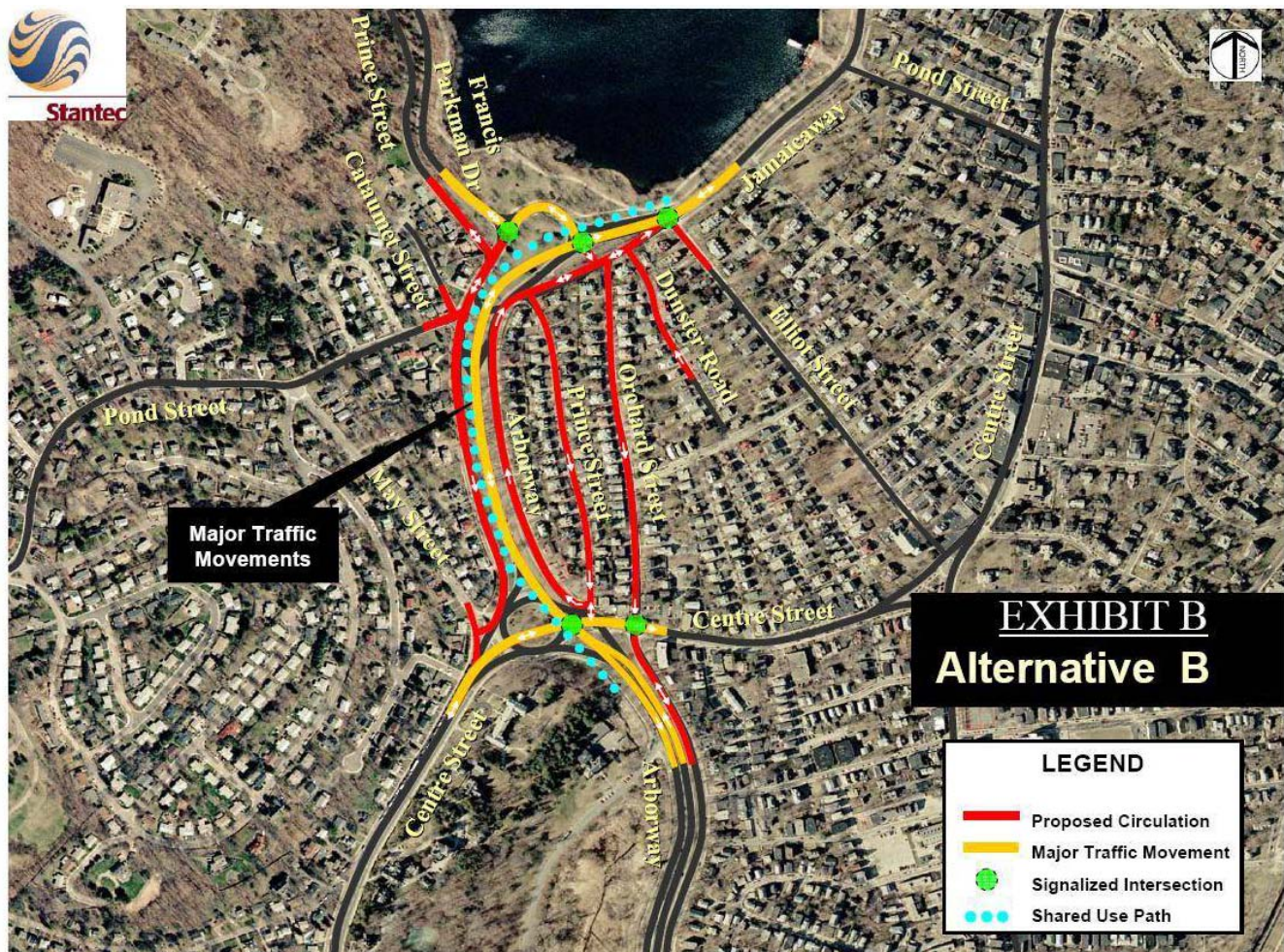


Stantec Alternative B

Stantec's Alternative B is identical to their Alternative A with the exception of one intersection at Kelley Circle. The loop configuration at Kelley Circle has been maintained and the signal moved to the east closer to Orchard Street. This is an attempt to use the existing roadways and increase the distance between the signal on the Arborway and the signal at Parkman Drive. This configuration can be found on Figure 2.3: Stantec Alternative B. Alternative B has the same advantages and disadvantages as Alternative A with the following additions:

- **Advantage:** Longer storage lane for signal between the Inner Arborway and Francis Parkman Drive
- **Disadvantage:** Roadway goes through the newly restored historic wall

Figure 2.3: Stantec Alternative B

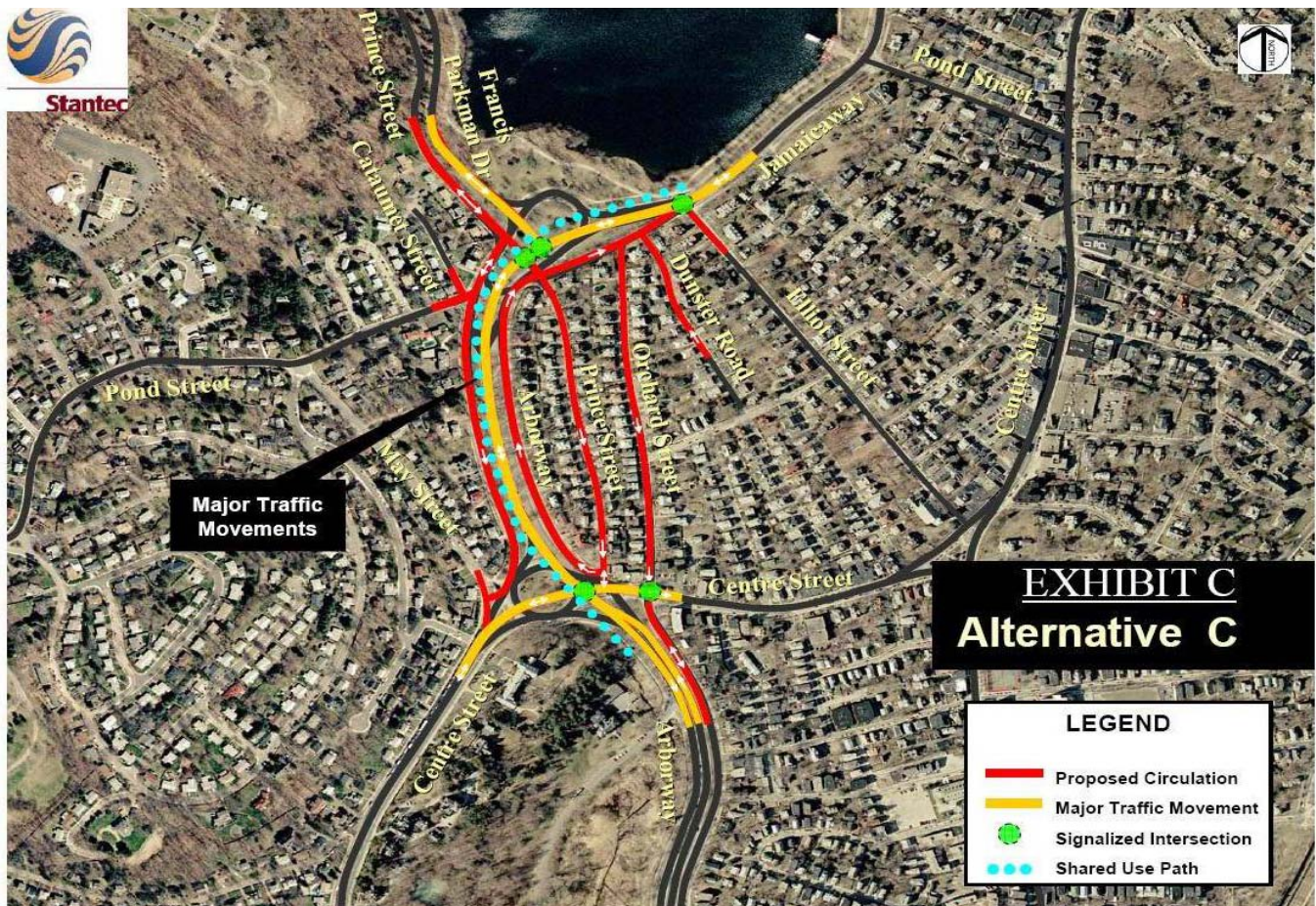


Stantec Alternative C

Stantec’s Alternative C is similar to both Alternatives A and B in the way it attempts to separate regional traffic from local traffic through the use of signalized intersections. What makes this alternative different is that the existing signal at Prince Street and Centre Street is moved east to the intersection of Orchard Street and Centre Street. Other improvements at Kelley Circle include the extension of Parkman Drive and Prince Street to the Inner Arborway. Both roadways will meet the Arborway at new signalized intersections. The concept is designed to provide more direct access from these streets to the Arborway whereby avoiding the use of local streets. This concept would reconnect Prince Street on either side of the Arborway. This configuration can be found on Figure 2.4: Stantec Alternative C. Alternative C has the same advantages and disadvantages as Alternative A with the following addition:

- **Advantage:** Reconnects Prince Street across the Arborway
- **Disadvantage:** May encourage through traffic on Prince St.
- **Disadvantage:** Break in median at Prince St. creates a discontinuity in the path.

Figure 2.4: Stantec Alternative C



Stantec Alternative D

The variation on Stantec's Alternative D is the treatment of Pond Street. At public meetings, particular portions of the community have expressed the need to reconnect Pond Street. This concept provides a new signalized intersection where Pond Street crosses the Inner Arborway. This would serve to reduce the volume on the Outer Arborway destined for the mainline. This alternative also reintroduces the loop configuration from Stantec's Alternative B. This is an attempt to use the existing roadways and increase the distance between the signal on the Arborway and the signal at Parkman Drive. This configuration can be found on Figure 2.5: Stantec Alternative D. Alternative D has the same advantages and disadvantages as Alternative A with the following additions:

- **Advantage:** Reconnects Pond Street across the Arborway
- **Disadvantage:** Difficult to coordinate signals that are too close together while maintaining capacity.
- **Disadvantage:** Break in median at Pond St. interrupts path.

Figure 2.4: Stantec Alternative D



Results

Overall Stantec's proposal was well received. The discussed advantages and disadvantages were determined by Stantec analyzing their own work as well as by HUB Engineering's analysis and research. Three out of four community groups, as well as the DCR, was satisfied with the design options. The group that was against the design feared that it would cause an increase in traffic on the local streets of their neighborhood. Others were not sure if enough local access was provided.

Stantec's design was not implemented mainly because it was not complete. Though the figures show a shared use path, the impact of pedestrians was not included in the signal timing analysis. While analyzing Stantec's proposal HUB engineering noticed some questionable turning movement counts. It was unclear how Stantec got from the collected data to the adjusted counts they used. Due to that fact, HUB Engineering deemed it necessary to do an origin-destination study in order to determine where the largest traffic volumes are coming from and going to. This was done in order to make our own adjustments to the turning movement counts and to ensure that the roadway design allowed efficient access between desired destinations.

SECTION 3: OBJECTIVES AND CONSTRAINTS

The study area, the Arborway, is unique in both location and in use. It is located in Boston's Jamaica Plain and is situated between Jamaica Pond and the Arnold Arboretum, both of which serve as areas of high recreational use. The Arborway currently serves multiple functions, one being a green space as part of America's first greenway, connecting two regional recreation destinations. It also serves as a local street, with homes directly fronting the Outer Arborway, as well as a regional motor vehicle route via the Inner and Outer Arborways. As vehicle traffic demand has increased over the past 80 years, the conflicting uses have presented a challenging problem.

3.1 DCR INTENTIONS

The Department of Conservation and Recreation (DCR) would like to make improvements within the study area that would maintain what remains of the area's original Olmsted design. The improvements will have to enhance the pedestrian and bicycle conditions and accommodate the current vehicle traffic demand. Safety is of the utmost importance to the DCR so any design must increase safety for both motorists and pedestrians. An off-road path is desired by the DCR in order to increase the safety for cyclists and pedestrians by providing a dedicated path for these users away from the flow of vehicle traffic.

Along with increasing safety, the DCR also wishes to enhance the recreational aspect of the Arborway. This includes adding greenspace, protecting the parkland from areas of high vehicle flow, and making existing greenspace more accessible. The largest portions of inaccessible greenspace lie in the two large medians between the Inner Arborway and the two Outer Arborways. In order for these areas to be utilized for pedestrians and cyclists, the heavy regional traffic flows must be removed from the Outer Arborways. The current condition of heavy traffic volumes on either side of the medians makes crossing to the medians unsafe and makes being in the medians uncomfortable for pedestrians. These reasons make the medians unusable as recreational areas in their current state.

3.2 COMMUNITY CONCERNS

As discussed in the previous section, improvements for the Arborway have previously been presented by both Rizzo Associates in 2003 and Stantec in 2007. The Rizzo alternative, the Arborway Master Plan (which extended to the Forest Hills area), was not well received by members of the community due to modifications at existing rotary locations. It was determined that simply modifying the existing rotaries was not enough to increase overall safety or make the Arborway more suitable for recreational uses. The DCR then retained the services of Stantec to improve operations at Kelley and Murray Circle, whose alternatives of replacing the rotaries with signalized intersections gained further support from the community and actively involved local residents by conducting round table discussions. At these meetings, several general matters appeared. They are as follows:

- Traffic patterns should be simplified;
- Preservation of parkway character is important;
- Poor/ unsafe pedestrian and bicycle provisions/accommodations needs to be remedied;
- High volume and excessive speed on outer Arborway roadways;
- Regional traffic utilizes local streets;

- Historic stone wall along Pond Street at Orchard Street needs to be preserved;
- Elimination of Murray Circle creates local access problem for properties on Centre Street. Residents unable to go south on Centre Street.

Many of these concerns mirror the concerns of the DCR. After reviewing both the results of the public meeting as well as community comments provided by the DCR, it is apparent that the majority of residents would like to see the rotaries removed and replaced with more traditional intersections. Residents would also like to see the majority of traffic to utilize the inner Arborway. Finally, pedestrians would prefer to make fewer crossings and for those crossings to be protected by signals.

3.3 DESIGN OBJECTIVES

In response to the desires and concerns of the DCR as well as the concerns expressed by the residents of the surrounding neighborhoods, we have compiled a list of objectives we will strive to meet with our design and evaluation. They are as follows:

- Provide a high quality multi-use path connecting the existing paths at the Jamaica Pond and the Arnold Arboretum;
- Provide safe pedestrian crossings both along the path and across the Arborway;
- Separate regional and local traffic, reducing traffic on the Outer Arborways to the point that the medians can become accessible parklands;
- Maintain arterial capacity;
- Preserve/restore existing landscape and mature trees;
- Convert road space to green space;
- Convert inaccessible green space to accessible green space;
- Provide reasonable access to and from local streets while discouraging cut-thru traffic.

These objectives will guide our design and be used to evaluate the alternatives that are developed. Following the description and analysis of our proposed design, an evaluation is presented in which we discuss how the objectives were met and any further study that should be undertaken.

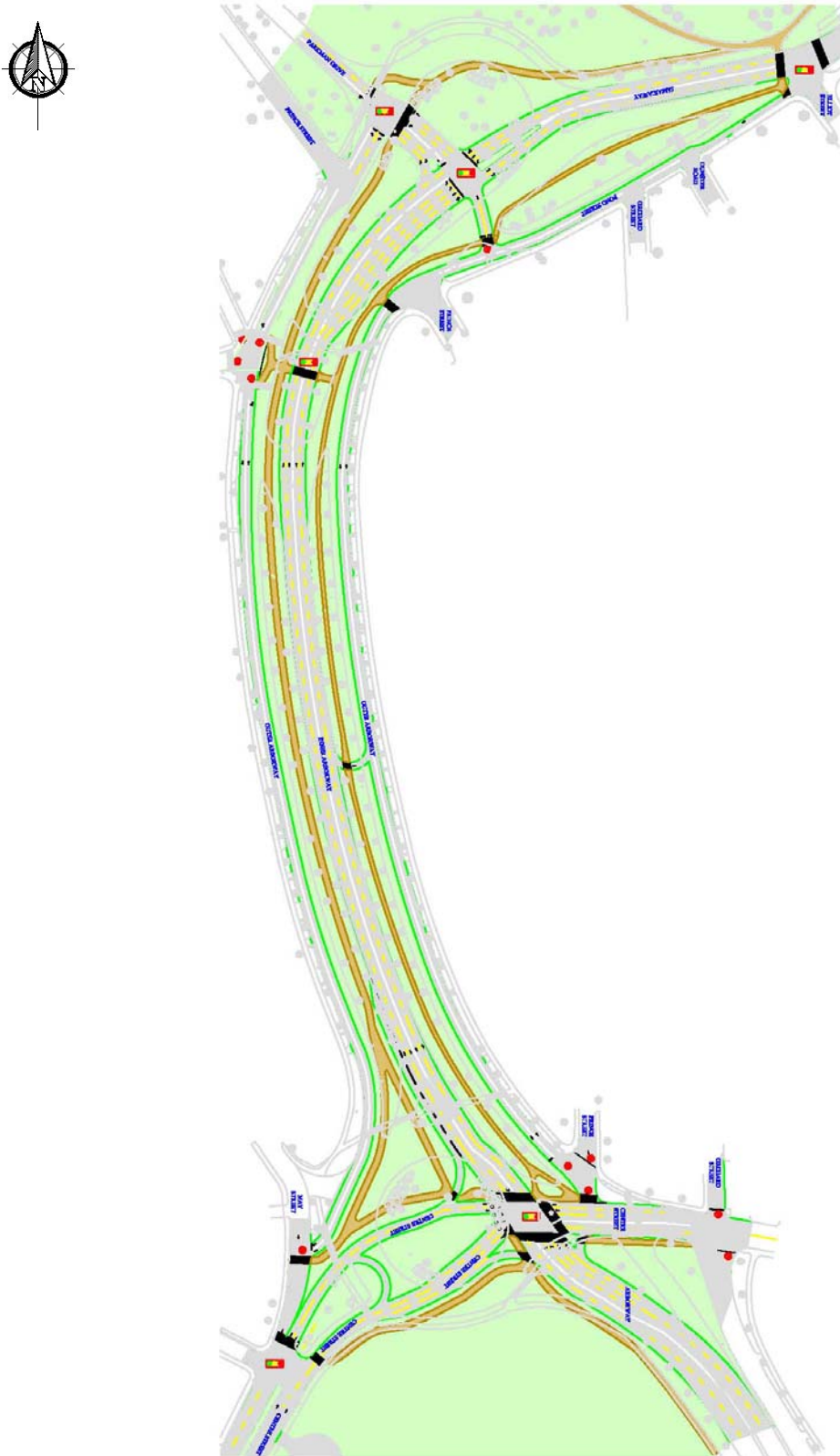
SECTION 4: DESCRIPTION OF NEW ALTERNATIVES

Northeastern's Alternatives are original designs with elements from previous attempts that will satisfy the needs and concerns of both the DCR and the local residents. Overall, the design improves traffic safety, reduces the traffic demand on the Outer Arborways, allows for adequate local access, and improves recreational cyclist and pedestrian access and safety along this route.

4.1 NORTHEASTERN'S ALTERNATIVE A

Like the Stantec Alternatives and Rizzo's Alternative 2, the Northeastern Alternative accomplishes these goals by using signalized intersections at Kelley Circle and Murray Circle to replace the large, unsafe, rotaries currently in use. Another major change in this design is making both sections of the Outer Arborway two-way streets, with one lane in each direction. Also, this design restricts access to the Outer Arborways, thus making them less useable as through routes by regional traffic. The design is shown in Figure 4.1.

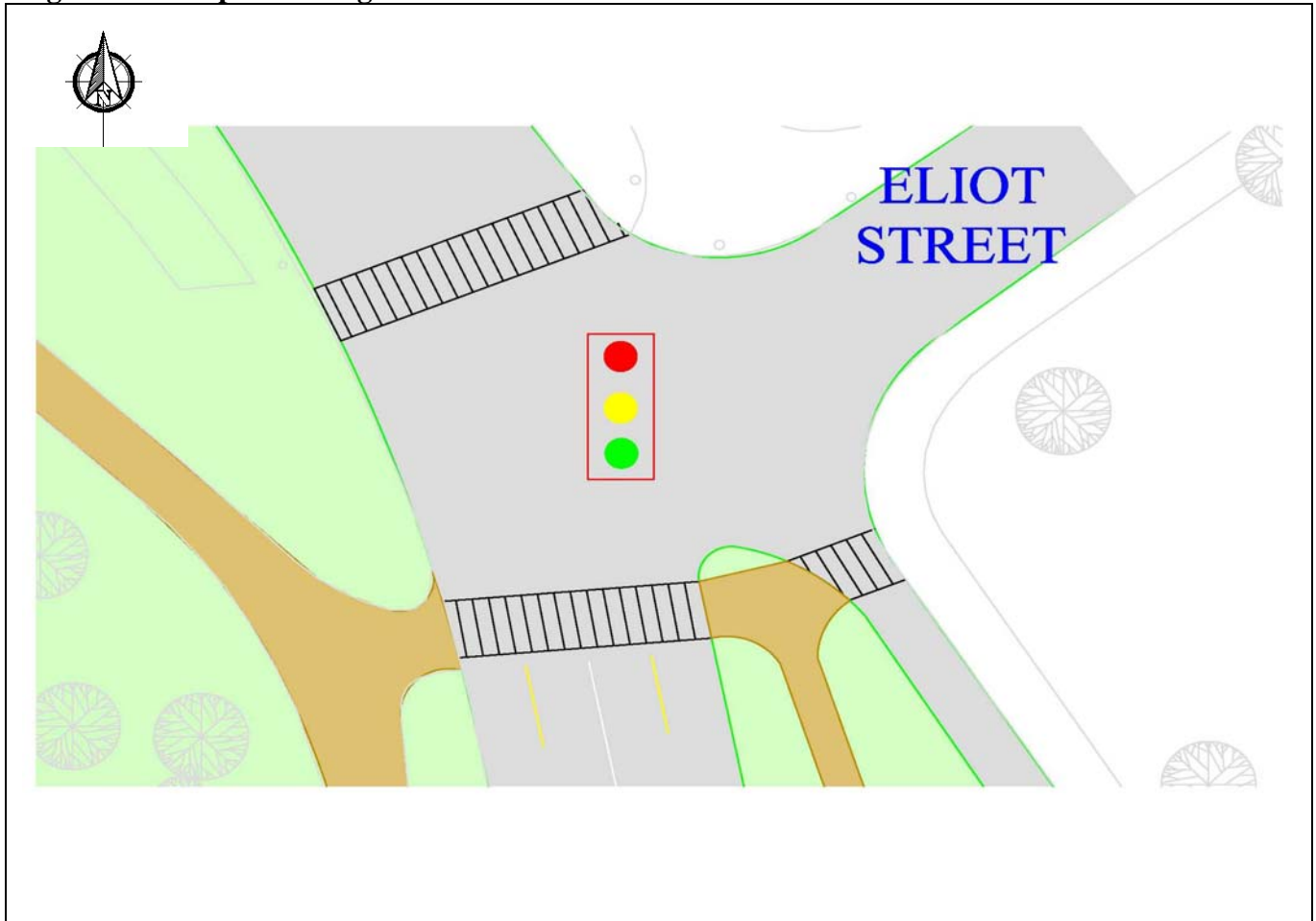
Figure 4.1: Alternative A



SIGNALIZED INTERSECTIONS

To start, one improvement that can be made as soon as possible is the installation of a traffic signal at the intersection of the Jamaicaaway and Eliot Street. It is a commonly used, but very unsafe crossing. The DCR has posted a sign saying that it is not a legal crossing. The reason that it is so commonly used is because it is near where the existing walking and bicycle path along Jamaica Pond reaches the Jamaicaaway. The proposed design of this intersection is shown below in Figure 4.2.

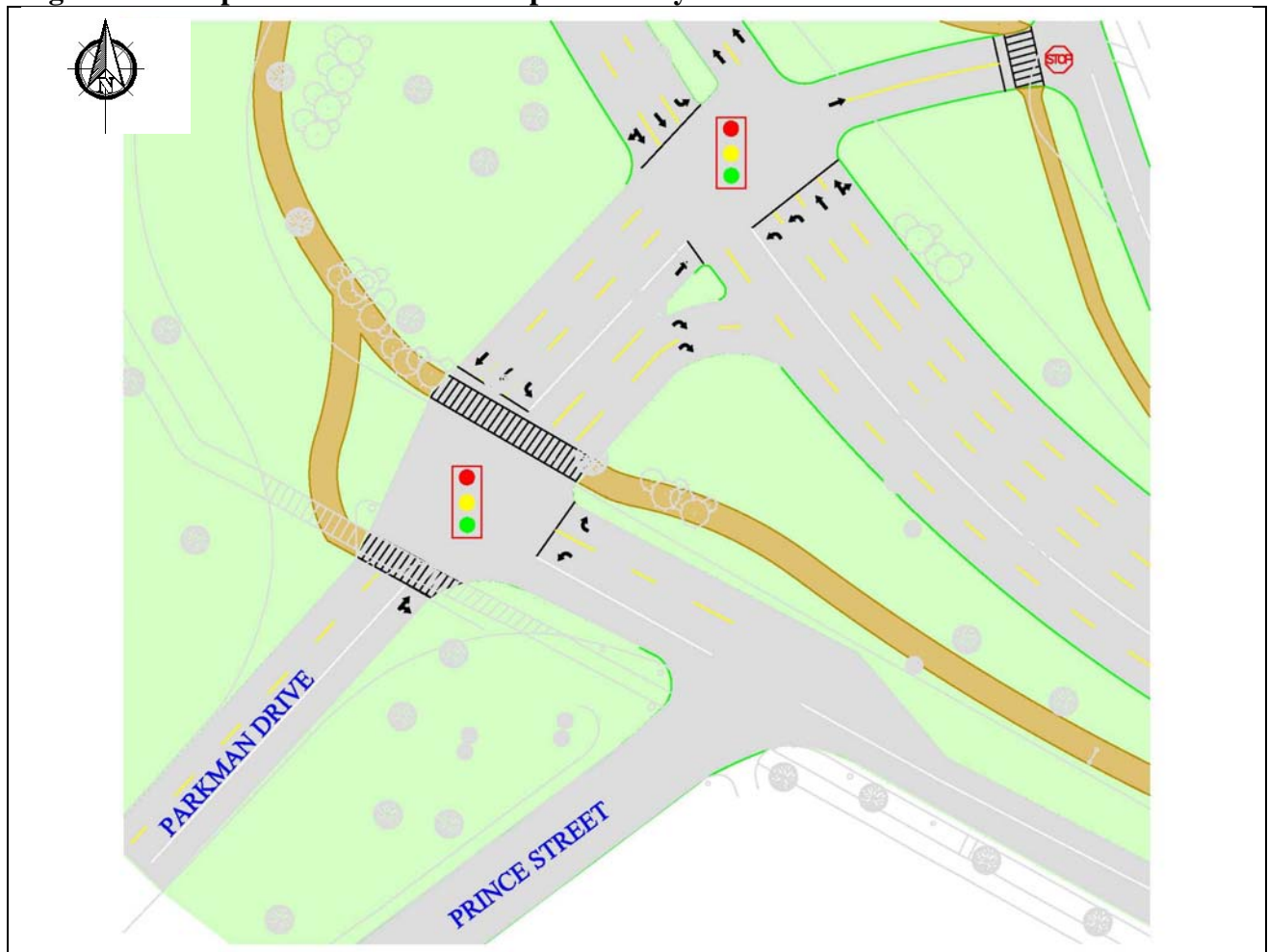
Figure 4.2: Proposed Design of Eliot Street Intersection



At Kelley Circle, the analyzed design is similar to Stantec's Alternative A with two signalized intersections. A 3-way signalized intersection will be placed where Parkman Drive meets Kelley Circle. The configuration of this intersection promotes the expected large volume of traffic coming from Parkman Drive looking to go south to head towards the Inner Arborway. This intersection will provide two safe crossings for cyclists and pedestrians. The design of this intersection is shown below in Figure 4.3.

East of the intersection discussed above is the main intersection at Kelley Circle. It is a large 4-way signalized intersection that will not permit pedestrians and cyclists to cross legally. This intersection is designed to promote the use of the Inner Arborway for regional movements. The lane configuration makes it easier for motorists to stay on or get on the Inner Arborway. Trying to get onto either Outer Arborway would be a much greater inconvenience than what currently exists. The design of this intersection is shown in Figure 4.3.

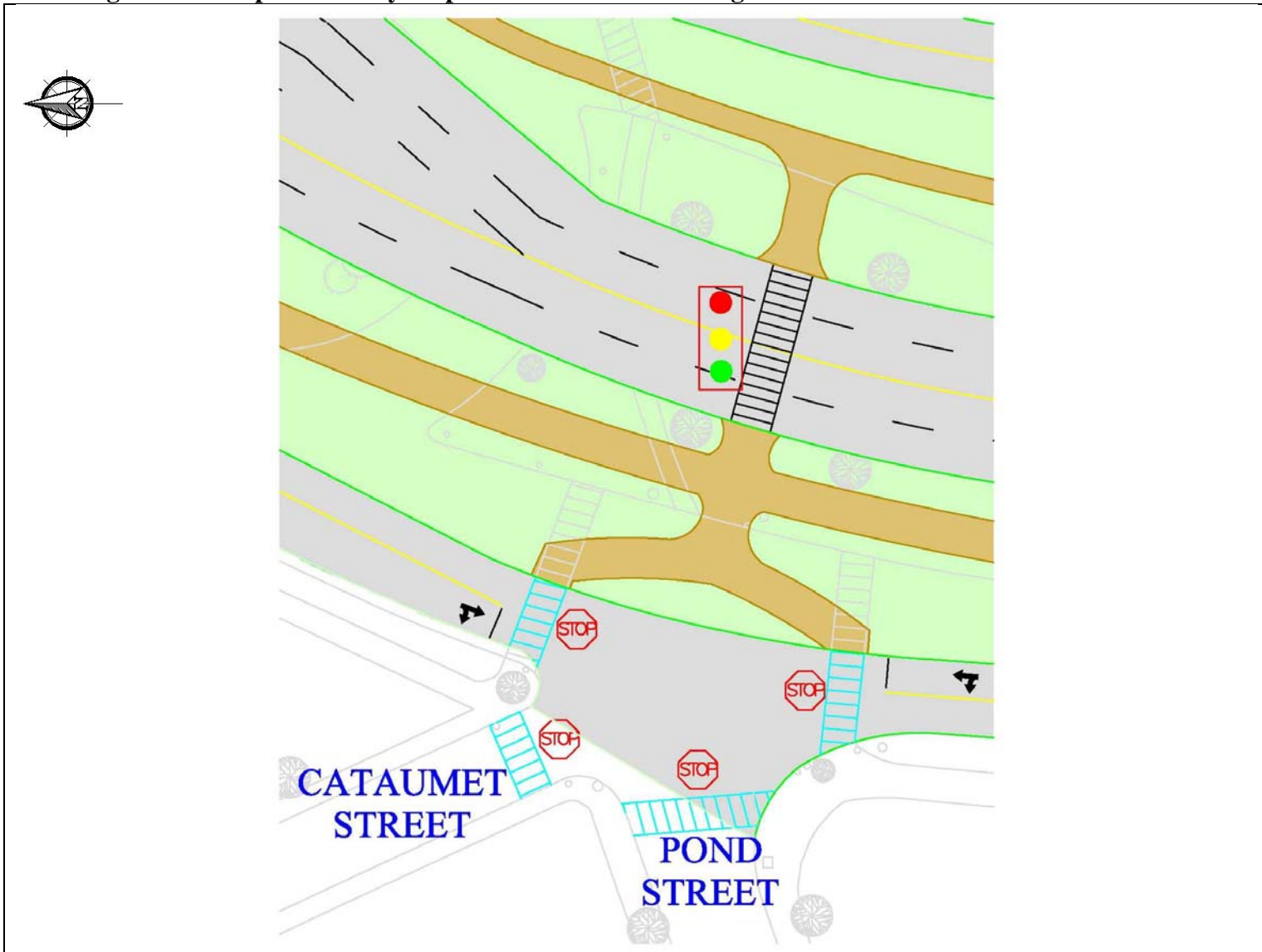
Figure 4.3: Proposed Intersection to replace Kelley Circle



Currently, at the southern edge of Kelley Circle there is a signalized intersection where Pond St. and Cataumet St. meet the Arborway. This signal will be removed but in order to maintain safety for motorists, pedestrians, and cyclists, a 4-way stop will be put in to control the

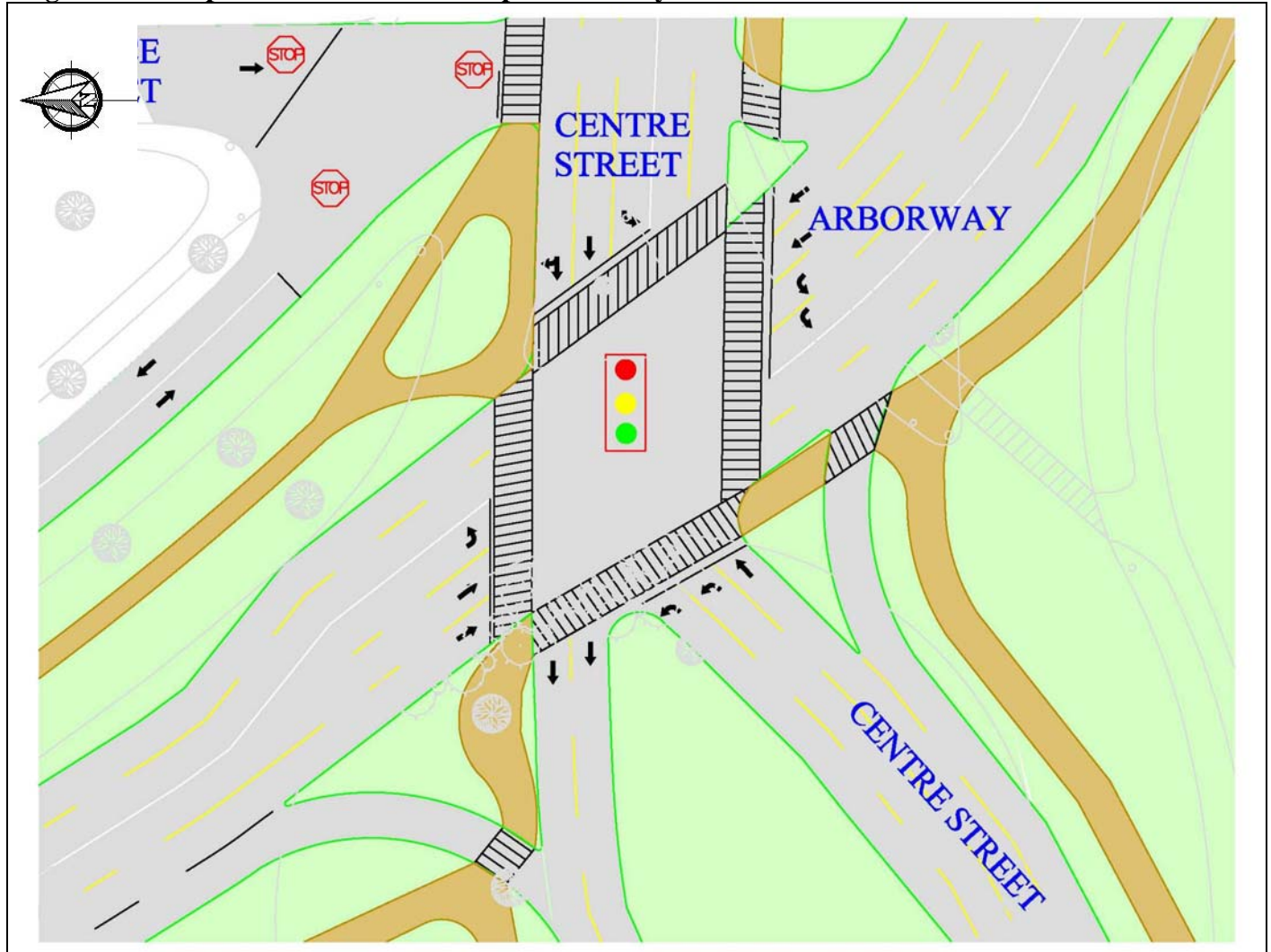
traffic coming from Pond St., Cataumet St. and the western Outer Arborway. At approximately the same location a pedestrian actuated signal will be added at the Inner Arborway to allow pedestrians to cross safely. This signal will be coordinated with the main intersection at Kelley Circle in order to minimize delay. This intersection is shown below in Figure 4.4.

Figure 4.4: Proposed 4-Way Stop and Pedestrian Crossing



The final new signalized intersection that this alternative proposes is at Murray Circle. It is a 4-way intersection for the meeting point of the Inner Arborway and Centre St. Like the main intersection at Kelley Circle, this intersection also makes it inconvenient to get onto the Outer Arborway for regional movements. The lane configuration at this intersection is designed to keep queue lengths to a minimum and keep turning movements flowing as freely as possible with the use of channelized rights. The design of the intersection at Murray Circle is shown below in Figure 4.5.

Figure 4.5: Proposed Intersection to Replace Murray Circle



ROADWAY FEATURES

All proposed lane widths, except for the Outer Arborways, are 10ft. and no proposed roadway, whether it's a link or a main road, is narrower than 18ft. This design turns the existing 30 foot, one-way, Outer Arborways into 18 foot, two-way, streets. The eastern Outer Arborway now connects directly to Pond St. on the north end and to Centre St. on the south end. What this does is it connects the two medians on the east side of the Arborway, with the exception of a small break just north of Prince St. This allows for better recreational use and pedestrian safety. As for the western Outer Arborway, it now ends at the proposed Parkman drive intersection and extends down to connect into May St.

Additionally, this design incorporates two turnarounds to make local movements a little easier. A turnaround midway down the Arborway was provided for the residents on the northern

portion of the east Outer Arborway to quickly and easily get onto the Inner Arborway northbound. This can be seen on the full layout in Figure 4.1.

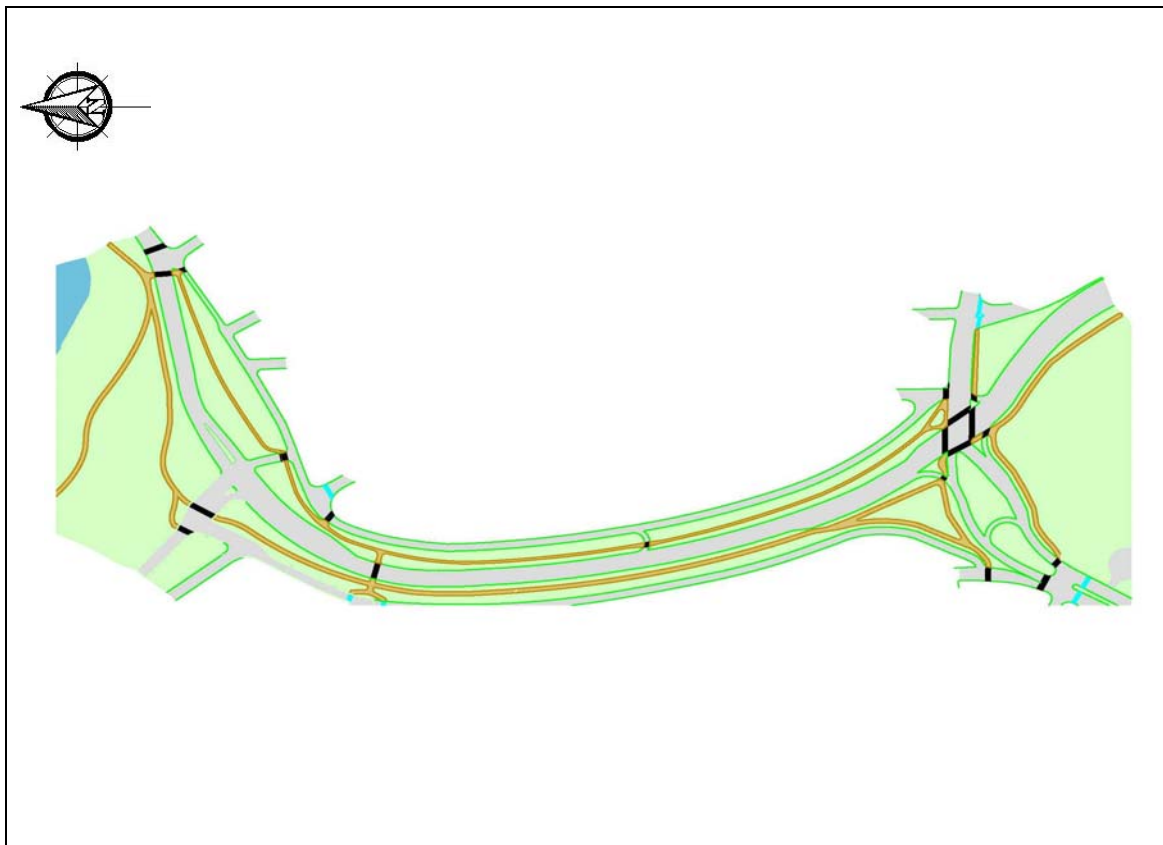
A second turnaround is located southwest of the proposed intersection at Murray Circle. This turnaround is being proposed because a u-turn is not allowed at the existing signal on Centre St. and it would be impractical to allow u-turns at the proposed intersection at Murray Circle. This turnaround allows residents on the east side of Centre St south of Murray Circle to be able to head southbound on Centre without having to travel all the way up to Kelley Circle to turn around. Figure 4.1 shows this proposed turnaround.

RECREATIONAL PATHS

To accommodate recreational bike and pedestrian users on the Arborway, two new paths have been added. A 10 foot shared-use path will run through the median separating the Inner Arborway and the western Outer Arborway and a 6 foot pedestrian path will run through the median between the Inner Arborway and the eastern Outer Arborway. The proposed paths can be seen below in Figure 4.6.

All designated pedestrian and cyclist crossings are marked out and accounted for in the signal timing plan in order to improve safety and connectivity. The paths and recreational space are explained in further detail in Section 7 of this report.

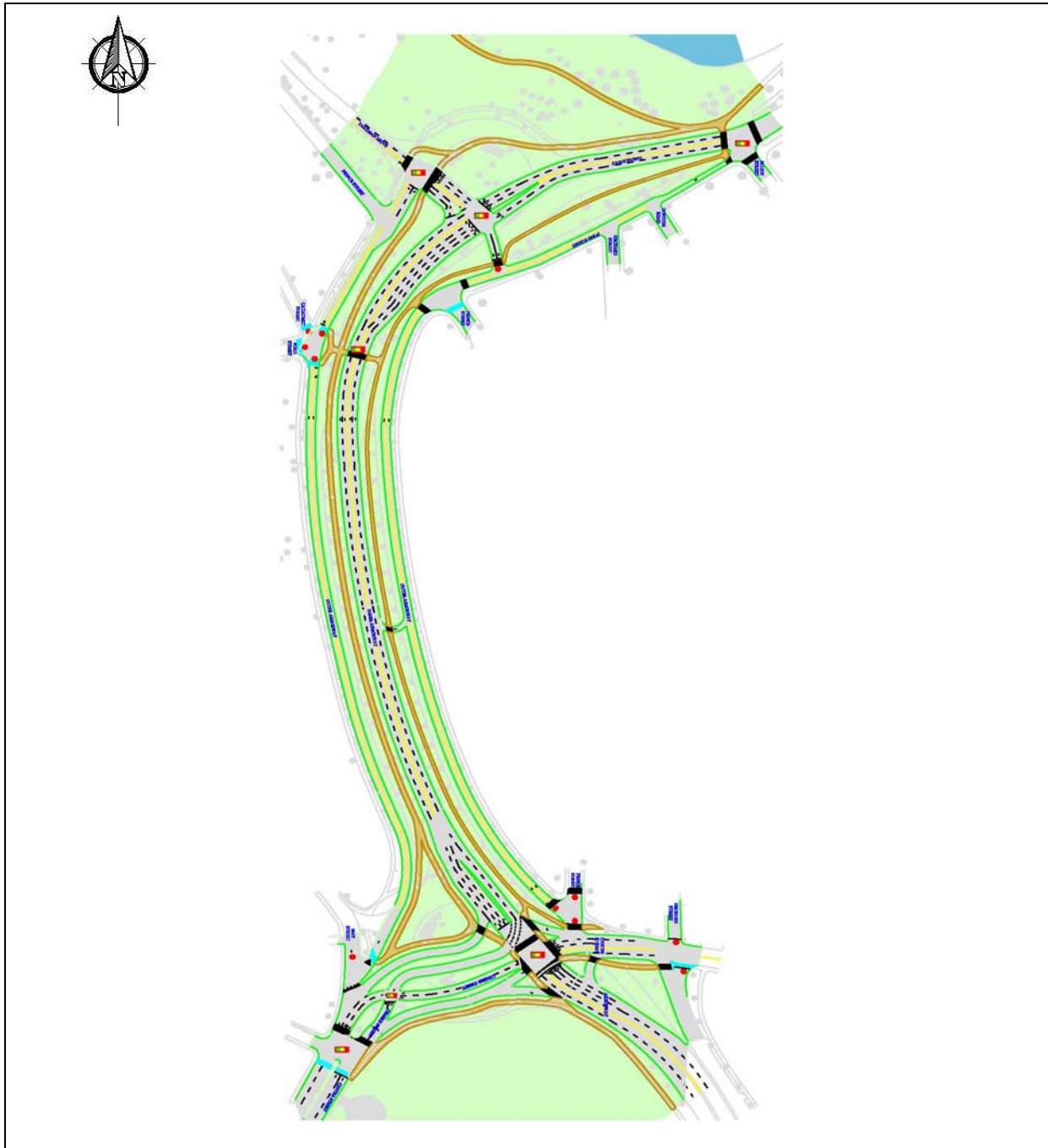
Figure 4.6: Proposed Recreational Path Locations



4.2 NORTHEASTERN'S ALTERNATIVE B

This design proposes a different layout for Murray Circle. Alternative A only involves one signal at Murray Circle while B proposes two signals. This alternative helps to separate traffic by intended direction of travel in order to aid in the ease of flow. This design results in a better LOS than Alternative A. The analysis for this intersection can be found in Section 6 of this report. The full layout of this alternative can be seen below in Figure 4.7.

Figure 4.7: Alternative B



SIGNAL VARIATIONS FROM ALTERNATIVE A

This design adds a second intersection on Centre St. southwest of Murray Circle which allows the left turning traffic coming from Centre St. Falkner Hospital to cross over the thru traffic so that at the main intersection at Murray Circle the WBL and the EBT traffic will not be in conflict. By enabling them to run concurrently the main intersection at Murray Circle now only needs a 3-phase signal instead of a 4-phase signal as in Alternative A.

With the exception that the above mentioned left turning traffic has been moved, the rest of the intersection remains essentially the same, structurally, as Alternative A. The intersection will contain the same channelized rights but with a slightly different configuration. Vehicles heading southbound on the Inner Arborway and looking to go westbound on Centre St. get to bypass both intersections, instead of just one, and are given the same right of way to enter Centre St. as in Alternative A. An additional difference between the two Alternatives is that with the offset left hand turns the rest of the main intersection has a more rectangular shape. The layout for Murray Circle can be seen below in Figure 4.8.

Figure 4.8: Proposed Murray Circle Layout



The layout at Kelley Circle remains the same for this alternative and the two discussed intersections for Murray Circle will interact with the Kelley Circle layout the same as they do in Alternative A.

ROADWAY FEATURE VARIATIONS

The following points highlight the main differences between Alternative A and B excluding the previously discussed signals.

- The multi-use paths, and their crossings, have been shifted accordingly to match up with the roadway layout.
- The western Outer Arborway no longer ends at an intersection with May St. It now merges with 3 separate traffic flows. The design of this merge can be seen in Figure 4.7.
- A small section of the western Outer Arborway between the fire access and the merge at May St. will remain one-way southbound to allow for vehicles to merge safely.
- Pedestrian and cyclist crossings will not be allowed at the crossover intersection at Murray Circle.
- Main intersection at Murray Circle has shorter/safer pedestrian crossings.

4.3 PREFERENCE

Alternatives A and B were both analyzed and the results can be found in Section 6. Alternative B results in the best overall flow and is the preferred and recommended alternative by HUB engineering.

SECTION 5: TRAFFIC COUNTS AND DEMAND ESTIMATION

In order to produce the most accurate traffic analysis of the proposed design, several important values must be calculated. The parameters of saturation flow rate, capacity, and demand must be determined. The Highway Capacity Manual (HCM) defines these concepts.¹

- Saturation Flow Rate* - The equivalent hourly rate at which previously queued vehicles can pass through the intersection, assuming green signal is available at all times and the queue is infinite
- Demand* - The number of users desiring service on the highway system
- Capacity* - The maximum sustainable flow rate at which vehicles can travel through an intersection under given roadway, geometric traffic and control conditions

*Values are expressed in passenger vehicles per hour

Capacity for an approach is simply the product of its saturation flow rate, and fraction of time in the cycle that the approach gets a green. It is also used in the evaluation of an intersection. While capacity of an intersection is a value that is calculated and can be changed by altering design conditions, saturation flow rate and demand are two base parameters, which must be calculated by field counting or by estimation. For this project it was necessary for Hub Engineering to conduct field studies to determine both saturation flow rate and vehicle demand.

5.1 SATURATION FLOW DATA COLLECTION

Saturation flow may either be estimated using the HCM methodology, or determined using field counts. The HCM states that field-measured values of saturation flow rate will give more accurate results than values produced using the computational method². The HCM is the source of the measurement method used for this study. In order to get an accurate saturation flow rate for our project area, three (3) field studies were performed on two different dates. At all locations, lane widths were 10 ft. Figure 5.1: Saturation Flow Rate Measurement Locations shows the locations of each field measurement, along with the date and time of each. For each cycle, the following information was recorded:

- The start of green
- The time the 4th vehicle passed the stop line
- The time the 10th vehicle passed the stop line
- The time the last stopped vehicle before a non-stopper passed the stop line
- The number of this last stopped vehicle

A summary of this data is found below in Table 5.1: Saturation Flow Data. Complete data and calculations are located in Appendix B.

¹ Transportation and Research Board, *Highway Capacity Manual 2000*

² Transportation and Research Board, *Highway Capacity Manual 2000*

Figure 5.1: Saturation Flow Rate Measurement Locations Plan
Solid SQUARE – Indicates Location of saturation flow measurement

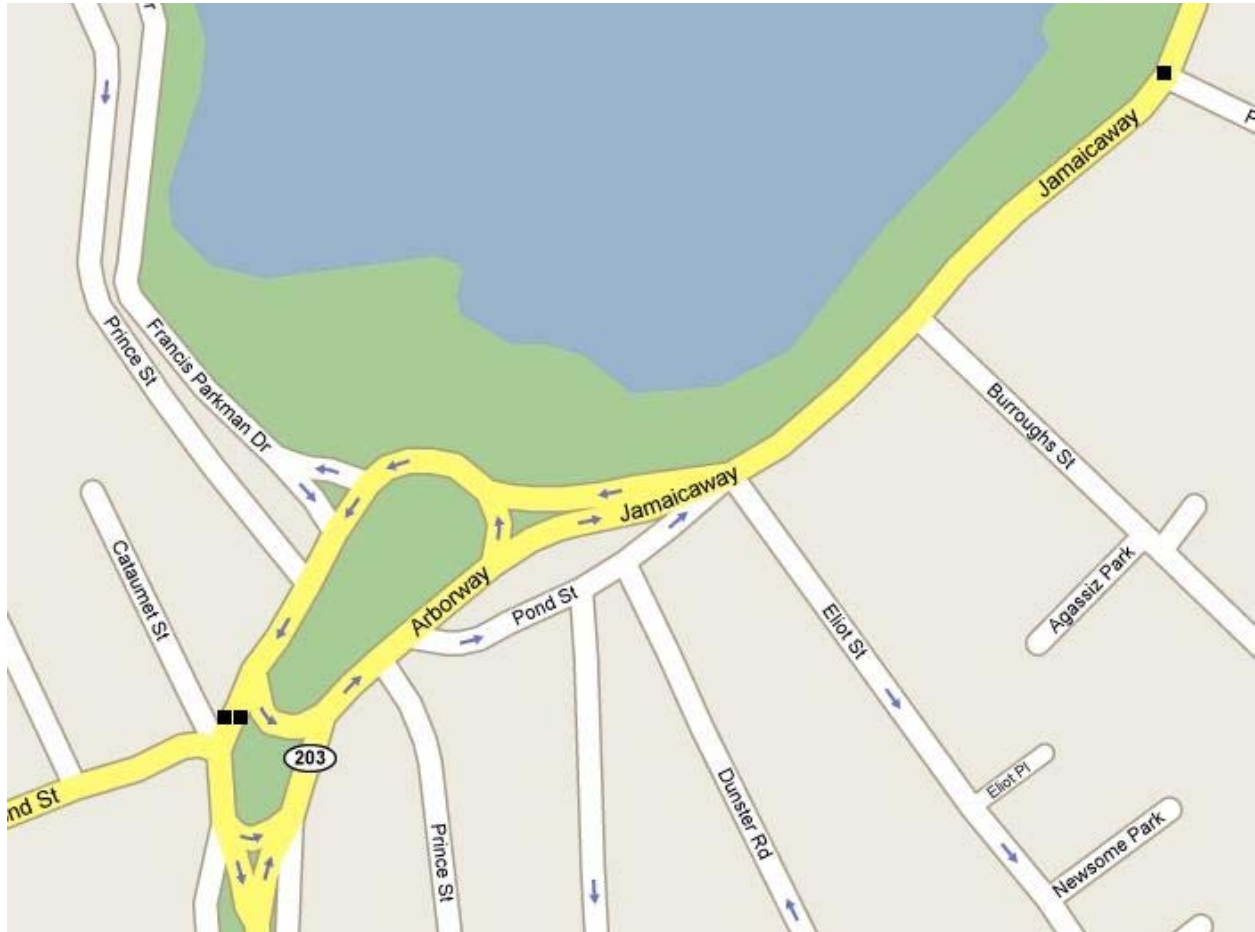


Table 5.1: Saturation Flow Data Summary

Average Values <i>*10 cycles observed</i>		*Study 1: Arborway at Pond Street - SB Center Lane	*Study 2: Jamaicaway at Pond Street - SB Right Lane	*Study 3: Arborway at Pond Street - SB Left Lane	Average
4th Vehicle Time	(sec)	8.8	8.4	6.8	8.0
10th Vehicle Time	(sec)	19.4	20.6	18.7	19.6
n th Vehicle Time	(sec)	28.6	54.6	33.6	38.9
n th Vehicle		15	29	18	21
n-4		11	25	14	17
Time for n-4	(sec)	20	46	27	31
Sat Headway	(sec)	1.79	1.89	1.90	1.86
Sat Rate	(veh/s)	0.57	0.53	0.53	0.54
Sat Rate	(veh/h)	2045	1925	1907	1959
Ideal Time for 4	(sec)	7.14	7.54	7.59	7.42
Start-up Loss	(sec)	1.64	0.87	-0.75	0.59

For the analysis of the current traffic conditions as well as our proposed design, we averaged the results of our three saturation flow studies. This result was compared with another project group currently evaluating the Riverway crossing over Route 9. This roadway contains the same traffic group and same roadway layout as the Arborway. The other group performed an independent saturation flow rate measurement study, using the same HCM methodology, and yielded a saturation flow rate of 2055 veh/hr.

Based on this analysis, a saturation flow rate of 1950 vehicles per hour will be used in the traffic analysis for protected through movements in 10-foot lanes.

5.2 INFLOW/OUTFLOW VERIFICATION AND ORIGIN-DESTINATION STUDY

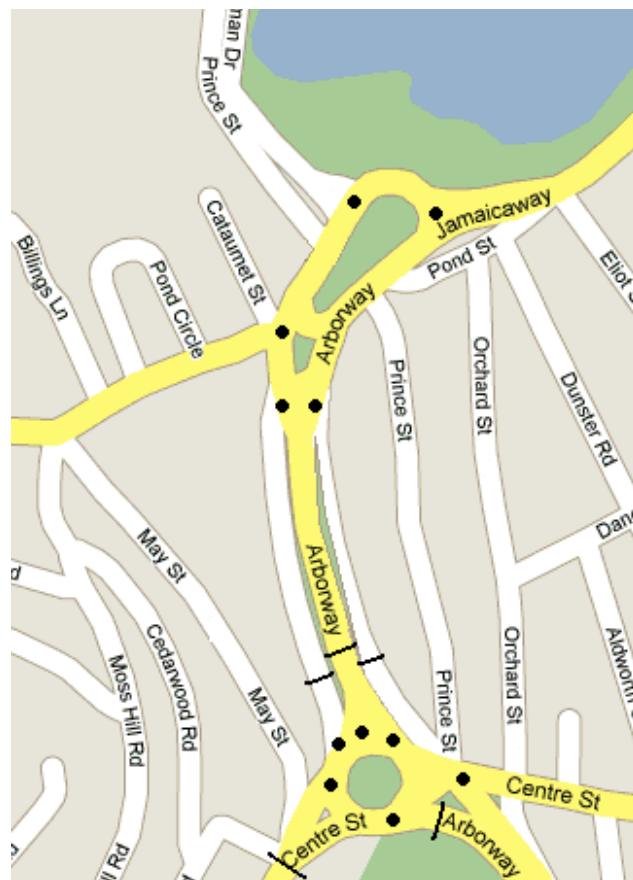
To calculate signal timings at the new intersections, demand volumes need to be established. The signal timings will be based on the vehicle demand of the different legs of said intersection. Demand volumes need to be accurate in order to establish signal timings, which will allow the intersection to operate at capacity and not cause vehicle delay.

When demand is measured, field counts of vehicles are used to establish volumes throughout the design area. Stantec contracted with Accurate Counts to perform a traffic study along the design area of the Arborway. Accurate Counts used automated traffic recorders (ATRs) and manual turning movement counts (TMCs) at different legs of the existing intersections to record average daily traffic volumes using the roadway in the target project area. The study was performed from 5/22/07 to 5/23/07. The locations of the ATRs and TMCs are shown in Figure 5.2: Accurate Counts Arborway Traffic Study Location Plan. The complete results of the traffic counting program are shown in Appendix B – Demand Analysis.

Figure 5.2: Accurate Counts Arborway Traffic Study Location Plan

Solid circle - indicates location of TMC

Solid line - indicates location of ATR



Due to the nature of the project area, raw counts obtained using these methods are not sufficient to determine origin-destination demand at the rotaries at Kelley Circle and Murray Circle. The ATRs and TMCs record volumes entering the rotary, and volumes exiting the rotary, but give no indication whatsoever of how the cars entering the rotary are distributed when exiting. In order to replace a rotary with a traffic signal, the origin-destination distribution of each leg needs to be known in order to produce optimal signal.

In the Stantec report, origin-destination was estimated using mapping software, which did not account for volumes at Parkman Drive, Pond Street, Cataumet Street, Prince Street, and Centre Street because they were considered minimal. Stantec's mapping software used the inflows from each leg to get their turning volumes. However it is noteworthy that while the inflow volumes are consistent with those found in the traffic study, the outflow volumes produced vary, substantially in many cases, from the outflow volumes in the traffic study. Table 5.2: Stantec In/Out Volume Comparison, on page 5-6 illustrates how the total in and out volumes used in the Stantec reports vary from the volumes obtained from Accurate Counts traffic study. The proposed design was analyzed using a balanced average of the inflow and outflow volumes at Kelley Circle and Murray Circle. The inflow volumes as well as the outflow volumes are consistent with the volumes found in the Accurate Counts traffic study. These volumes can be seen in Table 5.3: NU In/Out Volume Comparison, on page 5-7. It is noteworthy that none of the average inflow or outflow volumes used in the proposed design differs from the inflow or outflow volumes found in the Accurate Count traffic study by more than 2%.

Table 5.2: Stantec In/Out Volume Comparison

Compares Accurate Counts TMC volumes to Stantec's volumes at Kelley Circle and Murray Circle for peak AM and PM conditions.

Note: differences greater than 2% in GREY

Kelley Circle (volumes in vehicles / hour)											
AM	In From	Stantec	TMC	Difference	Percent Difference	Out To	Stantec	TMC	Difference	Percent Difference	
	Jamaicaway	1062	1062	0	0%		Jamaicaway	1685	1924	239	12%
	Parkman Drive	282	282	0	0%		Parkman Drive	1226	772	454	59%
	Pond Street	302	296	6	2%		Pond Street	493	431	62	14%
	Arborway (Central)	2856	2831	25	1%		Arborway (Central)	1098	1427	329	23%
	Total	4502	4471	31	--		Total	4502	4554	1084	--
PM	In	Stantec	TMC	Difference	ATR	Out	Stantec	TMC	Difference	ATR	
	Jamaicaway	1818	1832	14	1%	Jamaicaway	1177	1222	45	4%	
	Parkman Drive	558	558	0	0%	Parkman Drive	783	349	434	124%	
	Pond Street	403	401	2	0%	Pond Street	287	268	19	7%	
	Arborway (Central)	1588	1606	18	1%	Arborway (Central)	2120	2473	353	14%	
	Total	4367	4397	34	--	Total	4367	4312	851	--	
Murray Circle (volumes in vehicles / hour)											
AM	In From	Stantec	TMC	Difference	Percent Difference	Out To	Stantec	TMC	Difference	Percent Difference	
	Arborway (Central)	1383	1427	44	3%		Arborway (Central)	2289	2831	542	19%
	Centre Street	1936	1943	7	0%		Centre Street (Faulkner)	1497	1120	377	34%
	Arborway (Casey)	1647	1647	0	0%		Arborway (Casey)	1442	1331	111	8%
	Centre Street	622	622	0	0%		Centre Street (Monument)	360	377	17	5%
	Total	5588	5639	51	--		Total	5588	5659	1047	--
PM	In	Stantec	TMC	Difference	Percent Difference	Out	Stantec	TMC	Difference	Percent Difference	
	Arborway (Central)	2236	2473	237	10%	Arborway (Central)	1948	1606	342	21%	
	Centre Street	1275	1344	69	5%	Centre Street (Faulkner)	1261	1541	280	18%	
	Arborway (Casey)	1219	1219	0	0%	Arborway (Casey)	1670	1992	322	16%	
	Centre Street	431	419	12	3%	Centre Street (Monument)	282	371	89	24%	
	Total	5161	5455	318	--	Total	5161	5510	1033	--	

Table 5.3: NU In/Out Volume Comparison

Compares Accurate Counts TMC inflow/outflow volumes to NU's design inflow/outflow volumes at Kelley Circle and Murray Circle for peak AM and PM conditions.

Note: Variation between NU volumes and TMC volumes does not exceed 2%

Kelley Circle (volumes in vehicles / hour)											
	In From	Stantec	TMC	Difference	Percent Difference		Out To	Stantec	TMC	Difference	Percent Difference
	AM	Jamaicaway	1062	1062	0		0%	Jamaicaway	1889	1924	35
Parkman Drive		282	282	0	0%	Parkman Drive	758	772	14	2%	
Pond Street		296	296	0	0%	Pond Street	423	431	8	2%	
Arborway (Central)		2831	2831	0	0%	Arborway (Central)	1401	1427	26	2%	
Total		4471	4471	0	--	Total	4471	4554	82	--	
PM		In	Stantec	TMC	Difference	ATR	Out	Stantec	TMC	Difference	ATR
	Jamaicaway	1832	1832	0	0%	Jamaicaway	1246	1222	24	2%	
	Parkman Drive	558	558	0	0%	Parkman Drive	356	349	7	2%	
	Pond Street	401	401	0	0%	Pond Street	273	268	5	2%	
	Arborway (Central)	1606	1606	0	0%	Arborway (Central)	2522	2473	49	2%	
	Total	4397	4397	0	--	Total	4397	4312	86	--	
Murray Circle (volumes in vehicles / hour)											
	In From	Stantec	TMC	Difference	Percent Difference		Out To	Stantec	TMC	Difference	Percent Difference
	AM	Arborway (Central)	1401	1427	26		2%	Arborway (Central)	2831	2831	0
Centre Street		1943	1943	0	0%	Centre Street (Faulkner)	1102	1120	18	2%	
Arborway (Casey)		1647	1647	0	0%	Arborway (Casey)	1309	1331	22	2%	
Centre Street		622	622	0	0%	Centre Street (Monument)	371	377	6	2%	
Total		5613	5639	26	--	Total	5613	5659	46	--	
PM		In	Stantec	TMC	Difference	Percent Difference	Out	Stantec	TMC	Difference	Percent Difference
	Arborway (Central)	2522	2473	49	2%	Arborway (Central)	1606	1606	0	0%	
	Centre Street	1344	1344	0	0%	Centre Street (Faulkner)	1538	1541	3	0%	
	Arborway (Casey)	1219	1219	0	0%	Arborway (Casey)	1989	1992	3	0%	
	Centre Street	419	419	0	0%	Centre Street (Monument)	370	371	1	0%	
	Total	5504	5455	49	--	Total	5504	5510	6	--	

Due to the inconsistencies between the Stantec report in/out volumes and the volumes recorded in the traffic study, Hub Engineering conducted its own origin-destination studies at Kelley Circle and Murray Circle, in order to develop new volumes, independent of those used in the Stantec report. The study was consisted of vehicle tracking at all major entering locations at Kelley and Murray Circle. Tracking every entering vehicle requires a large manpower effort. With limited resources, Hub Engineering did a sample population vehicle tracking program, following only red colored vehicles entering and exiting the rotaries. It was determined that following vehicles based solely on color was an unbiased criterion, and that this would produce a representative sample of the entire traffic population.

Three (3) studies were conducted. The locations of each study are shown in Figure 5.3: NU Origin – Destination Study Locations. The results from this study are shown in Table 5.4: NU Origin - Destination Study Results.

Figure 5.3: NU Origin – Destination Study Locations

Solid circle - indicates location of TMC

Solid line - indicates location of ATR

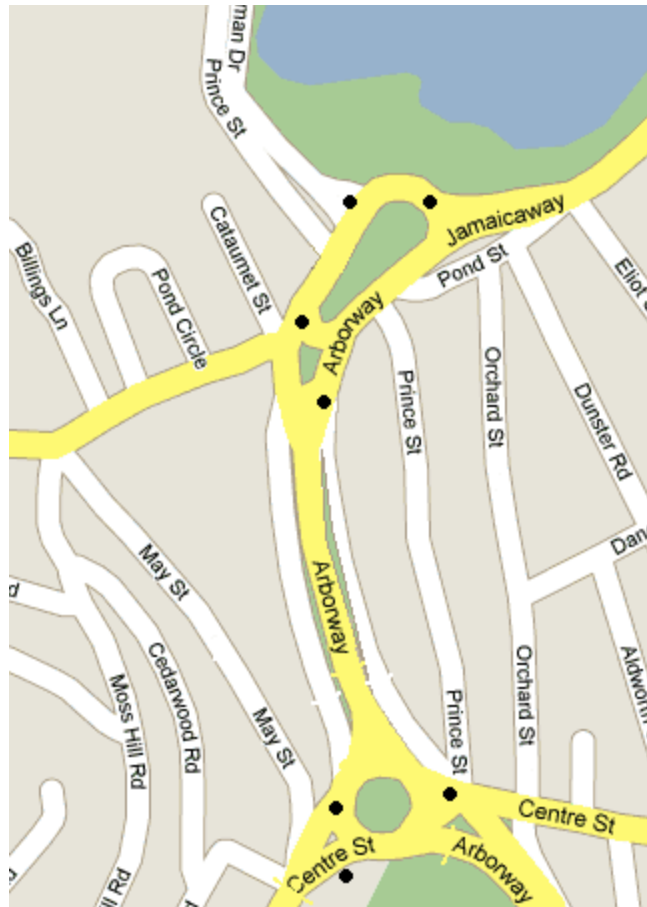


Table 5.4: NU Origin-Destination Study Results
Results showing inflows and destinations of tracked cars at Kelley Circle and Murray Circle

KELLEY CIRCLE						MURRAY CIRCLE					
AM	Jamaicaway	Parkman Drive	Pond Street	Arbway (Central)	Total ins	AM	Arbway (Central)	Centre Street (Faulkner)	Arbway (Casey)	Centre Street (Monument)	Total ins
Jamaicaway	0	13	2	37	52	Arbway (Central)	0	16	29	2	47
Parkman Drive	2	0	0	13	15	Centre Street (Faulkner)	38	0	17	6	61
Pond Street	6	0	0	41	47	Arbway (Casey)	68	18	0	3	89
Arbway (Central)	70	35	1	0	106	Centre Street (Monument)	9	13	1	0	23
Total outs	78	48	3	91	220	Total outs	115	47	47	11	220
PM	Jamaicaway	Parkman Drive	Pond Street	Arbway (Central)	Total ins	PM	Arbway (Central)	Centre Street (Faulkner)	Arbway (Casey)	Centre Street (Monument)	Total ins
Jamaicaway	0	19	4	89	112	Arbway (Central)	0	46	44	6	96
Parkman Drive	8	0	12	80	100	Centre Street (Faulkner)	23	0	13	16	52
Pond Street	21	3	0	79	103	Arbway (Casey)	39	17	0	1	57
Arbway (Central)	74	17	9	0	100	Centre Street (Monument)	10	14	2	0	26
Total outs	103	39	25	248	415	Total outs	72	77	59	23	231

5.3 APPLICATION OF ORIGIN-DESTINATION STUDY – DEMAND CREATION

It was determined that the origin-destination data presented in the Stantec report was inaccurate. The volumes collected by Accurate Counts in their traffic study are still valid data, particularly the total volumes entering and exiting Kelley Circle and Murray Circle. By using the spreadsheet program TMOVES Lite³, a version of TMOVES, turning volumes of the proposed intersections can be calculated. TMOVES estimates turning movements at intersections to match user-supplied approach inflows and outflows based on a “seed matrix” of turning flows⁴. The inflow/outflow matrix uses the entering/exiting volumes while the seed matrix is the results of the origin destination study. TMOVES utilizes the biproportional method of matrix balancing to estimate turning propensities. The program produced the new turning movement volumes shown below in:

Figure 5.4: Turning Movement Volumes - NU Alternative A

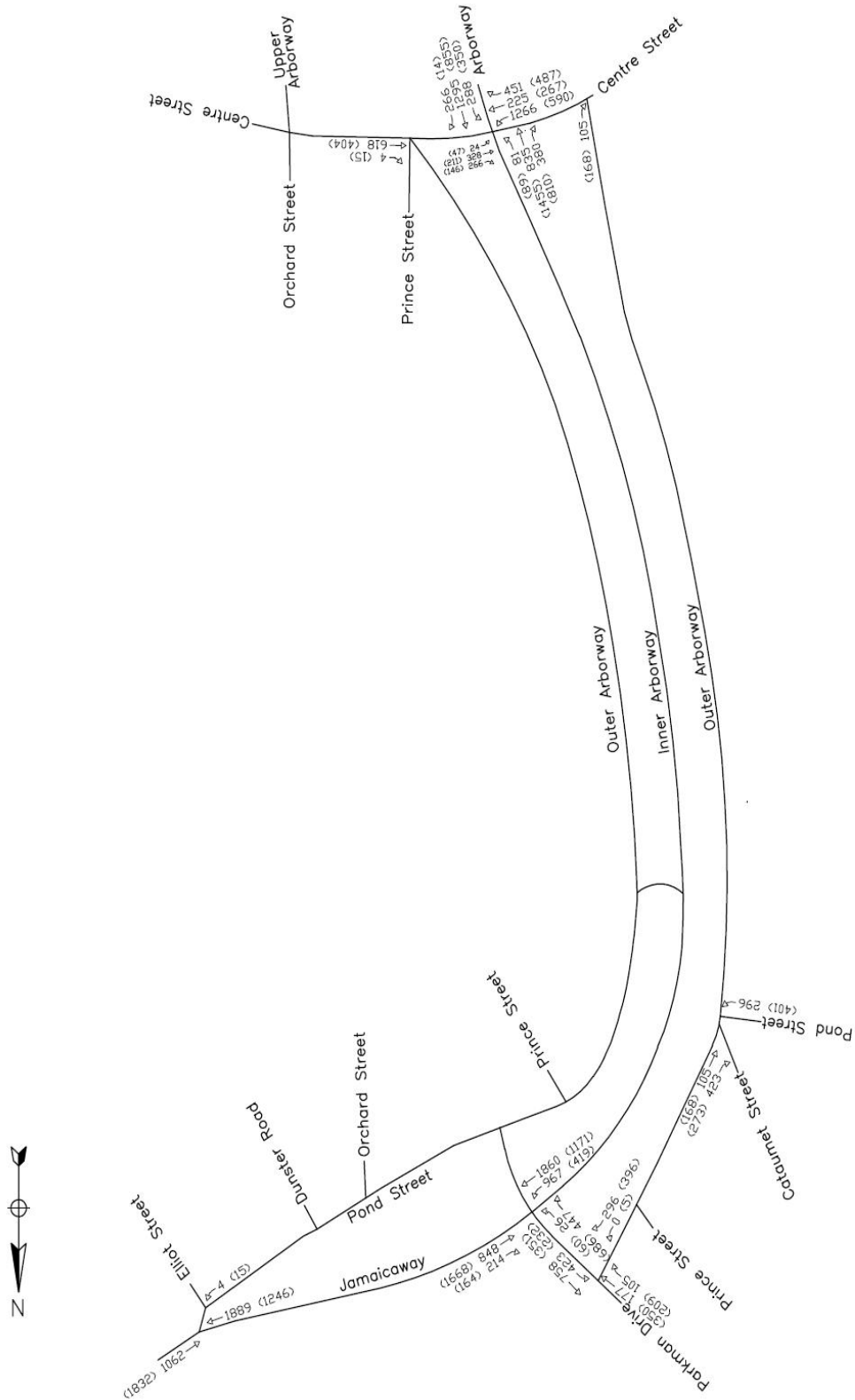
Figure 5.5: Turning Movement Volumes - NU Alternative B

These volumes are used for the major movements for the traffic analysis of the proposed Kelley Circle and Murray Circle intersection designs NU Alternative A, and NU Alternative B.

³ Furth, P.G. 2006, *TMOVES Lite*, Unpublished

⁴ Furth, P.G. 2006, *TMOVES*, University of Florida McTrans Center, 1994

Figure 5.4: Turning Movement Volumes - NU Alternative A
Turning volumes were produced by TMOVES Lite using total inflow/outflow volumes and seed matrices determined by the Northeastern University study. Shown are NU Alternative A proposed conditions.



SECTION 6: CAPACITY ANALYSIS AND SIGNAL TIMING PLAN DESIGN

Capacity depends on the green time allocation for each approach of an intersection, therefore signal timing plans that provide proper green time is essential. For intersections that are close to one another, timing plans include coordination to prevent long queues from interfering with nearby intersections. Once an optimal timing plan is found, the following analyses can be performed:

- Signalized Intersection Capacity and LOS Analyses
- Unsignalized Intersection Capacity and LOS Analyses
- Pedestrian Delay and LOS Analyses

The evaluation criteria used to analyze the study area intersections and pedestrian level-of-service are based on the methodologies from the 2000 Highway Capacity Manual (HCM).

CAPACITY ANALYSIS CRITERIA

The capacity of the study area is the maximum hourly rate at which vehicles can be expected to travel through a point at a given period of time under prevailing roadway, traffic, and control conditions¹. Capacity is reported as a volume-to-capacity (v/c) ratio; therefore a value of one indicates the point of interest has reached the maximum capacity. Detailed analyses of existing and alternative conditions are reported in Tables 6.1-6.3, which indicate that capacity is maintained for all signalized and unsignalized intersections.

INTERSECTION LEVEL-OF-SERVICE (LOS) AND DELAY CRITERIA

The term LOS is used to denote the different operating conditions that occur on a given roadway segment under various traffic volume loads. It is a measurement that considers a number of quantitative factors including roadway geometry, speed, travel delay, and freedom to maneuver.

- Level of service provides an index to the operational qualities of an intersection. Level-of-service designations range from A to F, representing the least and most amount of delay, respectively.
- Delay is based on the amount of time, in seconds, that a vehicle is delayed and is calculated based on a number of variables such as quality of signal progression, cycle length, allocation of green time, and volume-to-capacity (v/c) ratio.

SIGNALIZED INTERSECTIONS

Signalized Intersections report the volume-to-capacity ratio, delay, and LOS for each movement entering the intersection, as well as the overall parameters. In the alternative analyses, coordination amongst signals will ensure adequate progression and limited delay within the study area. Coordination will exist at the signalized intersections in Kelley Circle; Jamaicaway at Eliot Street, Inner Arborway at Parkman Drive, Outer Arborway at Parkman Drive, and Inner

Arborway at Pond Street Crossing. In addition to the coordination at Kelley Circle, the mitigation plan for B coordinates Inner Arborway at Centre Street with Centre Street at Centre Street- Left. Tables 6.1 & 6.2 present a summary of the signalized intersections within the study area, as well as Figure 6.1, which displays the v/c ratio and LOS at each intersection.

UNSIGNALIZED INTERSECTIONS

When presenting the results for unsignalized intersections only the critical movement is reported, which in most cases is the approach entering the main flow of traffic, such as a side street. Methodologies used to analyze unsignalized intersections consider highly conservative parameters, such as an extended gap time. In most cases motorists do not require such time; therefore the results recorded can be considered conservative. Table 6.3 presents a summary of unsignalized intersection within the study area.

PEDESTRIAN DELAY AND LEVEL-OF-SERVICE (LOS)

Pedestrian delay and level-of service (LOS) are a critical element to the analyses of the study area. The DCR requests that pedestrians be accommodated and served throughout the study area; therefore, pedestrian crossings are provided at intersections that meet the paths. The level of delay experienced by a pedestrian is based on the effective green time for pedestrians versus the total cycle length. When pedestrian delays begins to exceed thirty seconds, which means that some pedestrians will be delayed sixty seconds while others zero seconds, they become impatient and engage in risk-taking behavior¹. A pedestrian LOS of A indicates the least amount of pedestrian delay, while a LOS of F represents the most. The likelihood of noncompliance is relatively low at intersections that experience a minimal amount of pedestrian delay, and contrarily high at intersections with a sizeable pedestrian delay. Pedestrian delays at signalized intersections in the study area are presented in Table 6.4.

SIGNAL TIMING PLAN DESIGN

In order to ensure proper green time allocation, a signal timing plan is necessary. Coordination between signalized intersections at Kelley Circle prevents vehicle queues from blocking nearby intersections, and allows adequate progression to limit the amount of delay a vehicle experiences. Coordination between the nearby intersections at Murray Circle is critical due to the limited store length between Inner Arborway at Centre Street & Centre Street at Centre Street-Left. The progression between the intersections at Murray Circle also limits the amount of delay a vehicle experiences. A coordination timing plan (Figure 6.2) provides details for the design.

¹ Transportation Research Board, Highway Capacity Manual, Washington, D.C., 2000

FIGURE 6.1- NU ALTERNATIVE B CAPACITY AND LOS ANALYSES

Figure 6.1 represents the volume-to-capacity ratio and LOS for the signalized intersections.



TABLE 6.1- SIGNALIZED INTERSECTION CAPACITY AND LOS ANALYSES FOR KELLEY CIRCLE
Table 6.1 represents the signalized intersection capacity and LOS analyses for the mitigation at Kelley Circle. As reported, after the mitigation capacity remains comparable to present day conditions.

Intersection	Period	Movement	2008 NU Alternative Conditions				
			v/c	Delay	LOS		
Inner Arborway at: Parkman Drive	Weekday Morning	NB L	0.70	24	C		
		NB TR	0.73	5	A		
		SB L	0.05	31	C		
		SB TR	0.77	21	C		
		SE LT	0.30	41	D		
		SE R	0.25	9	A		
		Overall	0.67	14	B		
		Weekday Evening	Weekday Evening	NB L	0.68	38	D
NB TR	0.47			4	A		
SB L	0.05			29	C		
SB TR	0.87			14	B		
SE LT	0.55			41	D		
SE R	0.64			20	B		
Overall	0.80			15	B		
Parkman Drive at: Outer Arborway	Weekday Morning			EB TR	0.44	18	B
		WB L	0.65	37	D		
		WB T	0.26	1	A		
		NB L	0.01	30	C		
		NB R	0.33	11	B		
		Overall	0.53	14	B		
		Weekday Evening	Weekday Evening	EB TR	0.85	32	C
				WB L	0.65	16	B
WB T	0.16			2	A		
NB L	0.01			20	B		
NB R	0.56			15	B		
Overall	0.64			18	B		
Eliot Street at: Jamaicaway	Weekday Morning			EB L	0.63	1	A
				NE TR	0.35	2	A
		SW R	0.01	1	A		
		Overall	0.57	1	A		
Weekday Morning	Weekday Morning	EB L	0.43	1	A		
		NE TR	0.63	4	A		
		SW R	0.01	2	A		
		Overall	0.63	3	A		
Pond Street Crossing at: Inner Arborway	Weekday Morning	NB T	0.97	16	B		
		SB T	0.44	2	A		
		Overall	0.97	12	B		
Weekday Evening	Weekday Evening	NB T	0.54	3	A		
		SB T	0.80	4	A		
		Overall	0.80	4	A		

TABLE 6.2- SIGNALIZED INTERSECTION CAPACITY AND LOS ANALYSES FOR MURRAY CIRCLE
Table 6.2 represents the mitigated conditions for the signalized intersections at Murray Circle. Comparison between the Alternatives for Murray Circle proves that Northeastern Alternative B would operate more efficiently in the peak hour.

Intersection	Period	Movement	2008 NU Alternative A Conditions			2008 NU Alternative B Conditions		
			v/c	Delay	LOS	v/c	Delay	LOS
Pedestrian Crossing at: Arborway SB Right	Weekday Morning	SB T	0.21	1	A	0.21	1	A
		Overall	0.21	1	A	0.21	1	A
	Weekday Evening	SB T	0.45	1	A	0.45	1	A
		Overall	0.45	1	A	0.45	1	A
Pedestrian Crossing at: Centre Street- Right	Weekday Morning	EB T	0.25	1	A	0.26	1	A
		Overall	0.25	1	A	0.26	1	A
	Weekday Evening	EB T	0.27	1	A	0.30	1	A
		Overall	0.27	1	A	0.30	1	A
Centre Street at: Inner Arborway	Weekday Morning	EB L	1.01	67	E	N/A		
		EB T	0.29	23	C	0.34	22	C
		WB L	0.17	48	D	N/A		
		WB T	0.87	72	E	0.33	21	C
		NB L	0.81	66	E	0.60	42	D
		NB TR	0.97	53	D	0.81	25	C
		SB L	0.71	77	E	0.59	11	B
		Overall	0.72	39	D	0.63	2	A
	Weekday Evening	EB L	0.84	43	D	N/A		
		EB T	0.63	34	C	0.70	38	D
		WB L	0.4	45	D	N/A		
		WB T	0.87	68	E	0.56	36	D
		NB L	0.87	56	E	0.72	46	D
		NB TR	0.46	14	B	0.39	10	A
		SB L	0.31	13	B	0.28	1	A
		Overall	0.89	29	C	0.77	2	A
Centre Street Left at: Inner Arborway	Weekday Morning	EB L	N/A			0.95	26	C
		NB T	N/A			0.93	13	B
		SB T	N/A			0.69	27	C
		Overall	N/A			0.90	21	C
	Weekday Evening	EB L	N/A			0.77	38	D
		NB T	N/A			0.45	3	A
		SB T	N/A			0.81	22	C
		Overall	N/A			0.76	19	B
Centre Street Left at: Centre Street WB	Weekday Morning	EB L	N/A			0.67	17	B
		EB T	N/A			0.37	1	A
		WB T	N/A			0.43	24	C
		Overall	N/A			0.57	14	B
	Weekday Evening	EB L	N/A			0.44	17	B
		EB T	N/A			0.15	1	A
		WB T	N/A			0.30	10	B
		Overall	N/A			0.36	11	B

TABLE 6.3- UNSIGNALIZED INTERSECTION CAPACITY AND LOS ANALYSES

Table 6.3 represents the unsignalized intersection capacity and LOS analyses for the study area. As previously mentioned, analyses for unsignalized intersections prove to be conservative due to a conventional gap time versus aggressive gap time estimated in the field. At the intersection of Jamaicaway southbound at Arborway northbound, the entering Jamaicaway volume is yield controlled and reports a high v/c ratio and delay, but field observations proves the Jamaicaway volume tends to have the right-of-way, making this estimation of operations inaccurate.

Intersection	Period	Movement	2007 Existing Conditions			2008 Alternative NU Conditions		
			v/c	Delay	LOS	v/c	Delay	LOS
Jamaicaway SB at: Kelley Circle	Weekday Morning	WB R	1.26	159	F	N/A		
	Weekday Evening	WB R	1.43	221	F			
Inner U-Turn at: Arborway NB	Weekday Morning	EB L	0.15	24	C	N/A		
	Weekday Evening	EB L	0.12	14	B			
Parkman Drive at: Kelley Circle	Weekday Morning	SE R	0.61	37	E	Signalized under 2008 Conditions		
	Weekday Evening	SE R	1.08	117	F			
Prince Street at: Kelley Circle	Weekday Morning	SE R	0.12	13	B	0.19	18	C
	Weekday Evening	SE R	0.24	16	C	0.30	20	C
Pond Street at: Kelley Circle	Weekday Morning	SB LR	0.01	11	B	0.01	13	B
	Weekday Evening	SB LR	0.01	10	A	0.01	13	B
Orchard Street at: Centre Street	Weekday Morning	NB LTR	0.81	58	F	0.78	53	F
	Weekday Evening	NB LTR	0.36	23	C	0.34	21	C
Inner U-Turn at: Kelley Circle	Weekday Morning	SB TL	0.02	<5	A	N/A		
	Weekday Evening	SB TL	0.03	<5	A			
Outer U-Turn at: Inner Arborway NB	Weekday Morning	EB L	0.29	21	C	N/A		
	Weekday Evening	EB L	0.16	12	B			
Pond Street at: Outer Arborway	Weekday Morning	EB LR	Signalized under Existing Conditions			0.40	12	B
	Weekday Evening	EB LR				0.52	14	B
Outer Arborway E at: Inner Arborway U-Turn	Weekday Morning	WB R	N/A			0.05	40	E
	Weekday Evening	WB R				0.02	17	C
Outer Arborway at: Parkman Drive East	Weekday Morning	SEB L	N/A			0.01	9	A
	Weekday Evening	SEB L				0.01	9	A
Outer Arborway at: Dunster Road	Weekday Morning	NB L	N/A			0.01	9	A
	Weekday Evening	NB L				0.01	9	A
Arborway SB- Right at: Centre Street (Faulkner)	Weekday Morning	SB R	N/A			0.61	18	C
	Weekday Evening	SB R				1.24	142	F
Centre Street (Faulkner)- Right at: Arborway NB (Casey)	Weekday Morning	EB R	N/A			0.88	42	E
	Weekday Evening	EB R				1.59	310	F

TABLE 6.4- PEDESTRIAN DELAY AND LOS ANALYSES

Table 6.4 represents the pedestrian delay and LOS for the signalized intersections in the study area. As shown below, pedestrians waiting to cross will experience an average delay of twenty-five seconds, which yields a LOS of C. The corresponding likelihood of noncompliance indicates the degree for which pedestrians will engage in risk-taking behavior, which means crossing at unsafe times in the cycle.

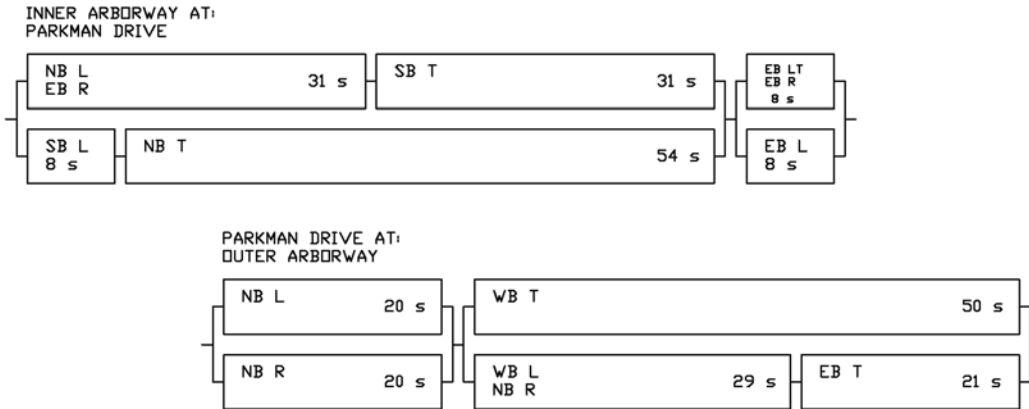
<u>Intersection</u>	<u>Crosswalk</u>	<u>2008 NU Alternative Conditions</u>		
		<u>Delay</u>	<u>LOS</u>	<u>Likelihood of Noncompliance</u>
Parkman Drive at: Outer Arborway	West	28	C	Moderate
	East	28	C	Moderate
Jamaicaway at: Eliot Street	East	27	C	Moderate
	West	27	C	Moderate
	Pond	19	B	Low
	Eliot	22	C	Moderate
Inner Arborway at: Pond Street Crossing	North	26	C	Moderate
Inner Arborway at: Centre Street	West*	34	D	Moderate
	East	20	B	Low
	North	27	C	Moderate
	South	27	C	Moderate
	Arborway SB- Right	19	B	Low
	Centre St EB- Right	12	B	Low

* Indicates the delay from Centre St-left across Centre St West

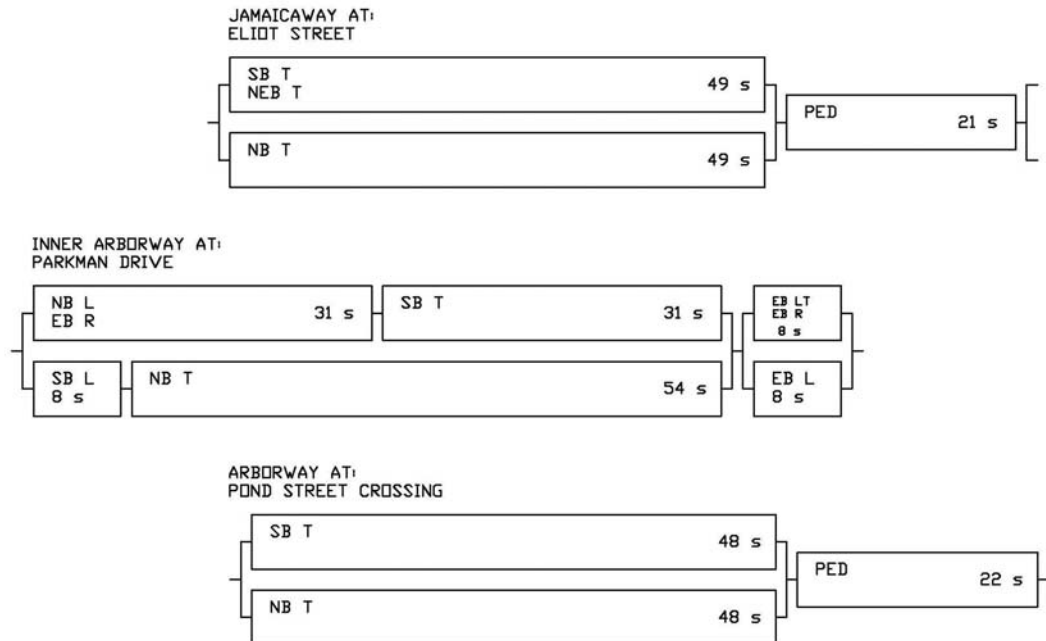
FIGURE 6.2 SIGNAL TIMING PLAN DESIGN

Figure 6.2 represents the signal timing plan for the coordination at Kelley Circle and Murray Circle. At Kelley Circle, Inner Arborway at Parkman Drive is the master intersection, and is coordinated with Eliot Street and Pond Street Crossing, as well as Outer Arborway at Parkman Drive. At Murray Circle, Inner Arborway at Centre Street is the master intersection and is coordinated with Centre Street at Centre Street-Left.

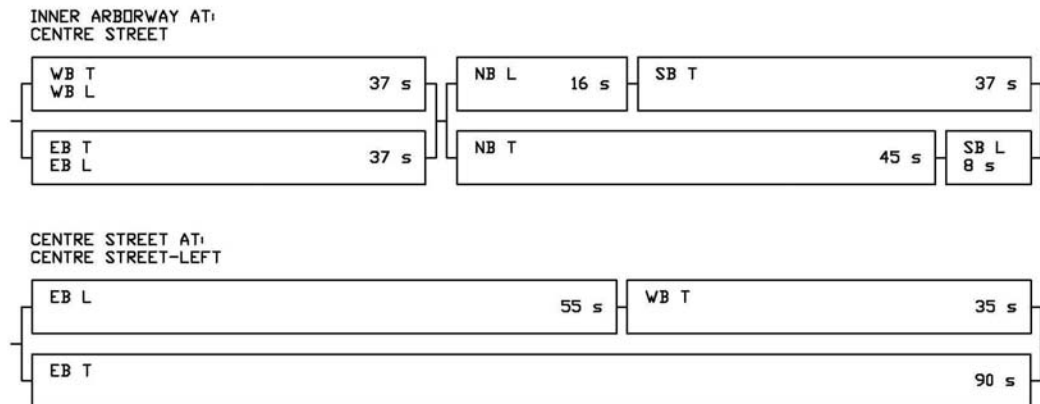
COORDINATION PLAN: INNER ARBORWAY AT PARKMAN DRIVE & OUTER ARBORWAY AT PARKMAN DRIVE



COORDINATION PLAN: INNER ARBORWAY AT PARKMAN DRIVE, JAMAICAWAY AT ELIOT STREET, & INNER ARBORWAY AT POND STREET CROSSING



COORDINATION PLAN: INNER ARBORWAY AT CENTRE STREET & CENTRE STREET AT CENTRE STREET- LEFT



CONCLUSION

The current conditions for the Arborway, between Kelley and Murray Circle, present a number of problems for both vehicles and pedestrians. The existing rotaries have insufficient capacity at several points. Jamaica way southbound, entering Kelley circle, is supposed to yield upon entry. This law is not observed, which is currently what alleviates the delay they would have experienced and replaces the delay with serious safety concerns. At Murray Circle, long queues are observed for vehicles entering the rotary from Centre Street traveling eastbound. Arborway northbound at Murray Circle also presents a long queuing issue, which sometimes extends to the Casey Overpass. Aside from having inefficient capacity at three separate points, there are a number of unsafe pedestrian crossings. For example, just north of Murray Circle there are four unprotected crosswalks, separated by grass medians, and vehicles traveling at high speeds entering the rotary.

The alternative conditions provide an average volume-to capacity ratio of 0.70, with an average delay of 17 seconds, which proves the capacity and delay will be improved over the existing conditions. While maintaining capacity and delay, protected crosswalks were added along with designated paths. The average delay for pedestrians is approximately twenty-five seconds, with a LOS of C. The alternative conditions prove to accommodate all users safely and adequately.

SECTION 7: PATHS AND RECREATIONAL USES

Many of the objectives of this design involve the recreational uses and parkland of the Arborway. This includes the addition of two new paths as well as both adding new greenspace and making previously inaccessible greenspace accessible. These two paths will serve to connect the existing pedestrian paths along the Jamaica Pond and the Arnold Arboretum, creating a safe, continuous connection along this desired route. Adding and enhancing the greenspace will preserve the character of the historic area.

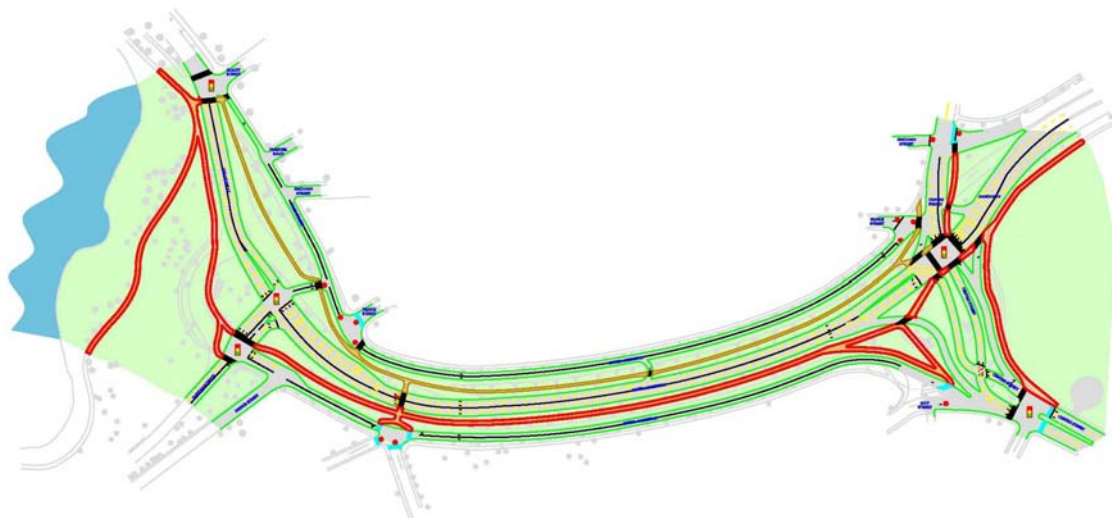
7.1 SHARED-USE PATH

The first of the two new paths is a paved shared use path that will run inside the west median. Figure 7.1 shows its route from its northern connection at Jamaica Pond to the south where it connects to existing paths at the Arnold Arboretum. It will serve both cyclists and pedestrians and will have a dashed white centerline to increase safety and circulation. AASHTO recommends a width of ten feet for a two-way, shared use path on a separate right of way. Other critical measurements include:

- 2 feet of graded area to be maintained adjacent to both sides of the path.
- 3 feet of clear distance to be maintained between the edge of the trail and trees, poles, walls, fences, guardrails or other lateral obstructions.
- 8 feet of vertical clearance to obstructions should be maintained.¹

A typical cross-section of this path as it lies inside the median is shown in Figure 7.2.

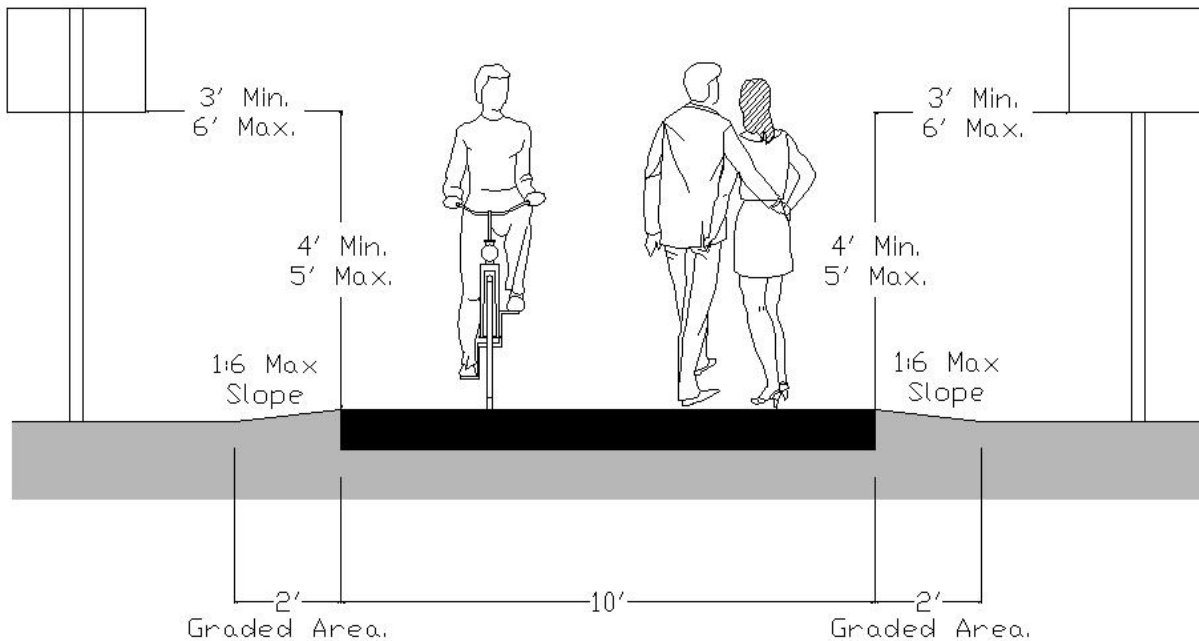
Figure 7.1: Location of Shared-Use Path



¹ American Association of State Highway and Transportation Officials. *Guide for the Development of Bicycle Facilities*, 1999.

The path will be paved with a quality, all-weather pavement surface such as asphalt or Portland cement concrete. It is important that a smooth riding surface be constructed and maintained on the shared use path.

Figure 7.2: Typical Cross Section of Shared-Use Path



Source: AASHTO *Guide for the Development of Bicycle Facilities*, 1999

7.2 WALKING PATH

The second of the two new paths is a stone-dust paved walking path that will run inside the east median. Figure 7.3 shows its route from its northern connection at Jamaica Pond to the south where it connects to existing paths at the Arnold Arboretum. This path will serve pedestrians who wish to have the comfort of being on a path separate from cyclists. This path will be six feet wide and contain no markings on the path surface. Other critical measurements include:

- 2 feet of graded area to be maintained adjacent to both sides of the path.
- 3 feet of clear distance to be maintained between the edge of the trail and trees, poles, walls, fences, guardrails or other lateral obstructions.
- 8 feet of vertical clearance to obstructions should be maintained.²

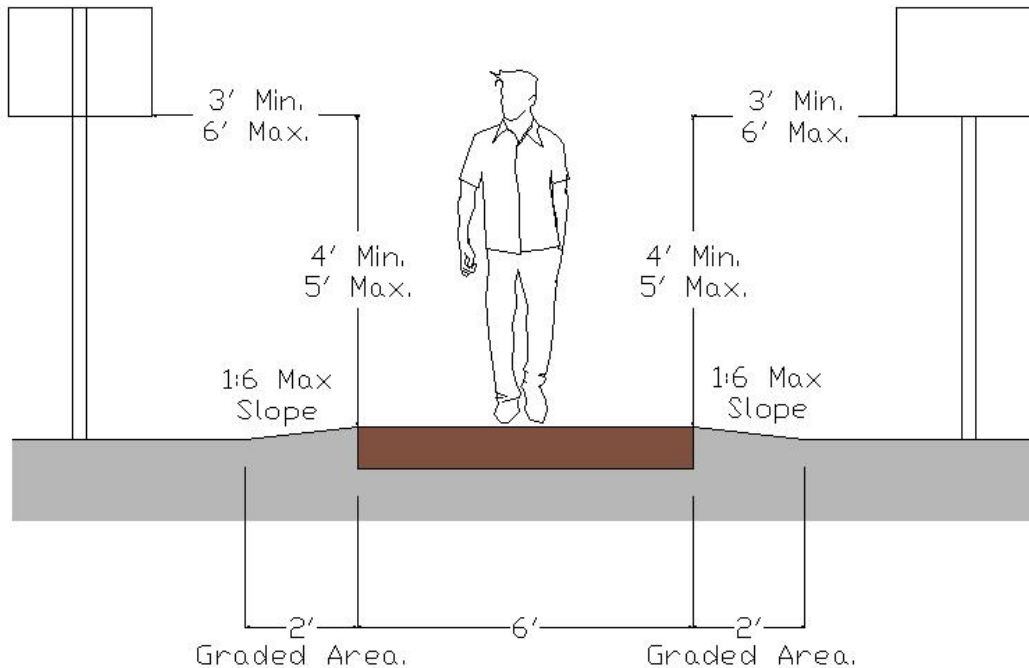
² American Association of State Highway and Transportation Officials. *Guide for the Development of Bicycle Facilities*, 1999.

The path will be surfaced with stone dust rather than traditional pavement in order to have a more natural path, with less environmental impact. This path will not add any impervious surfaces to the project area. A typical cross-section of this path as it lies inside the median is shown in Figure 7.4.

Figure 7.3: Location of Walking Path

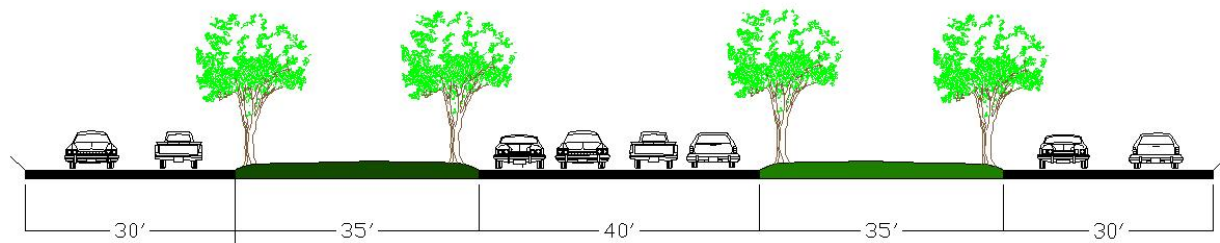


Figure 7.4: Typical Cross Section of Walking Path

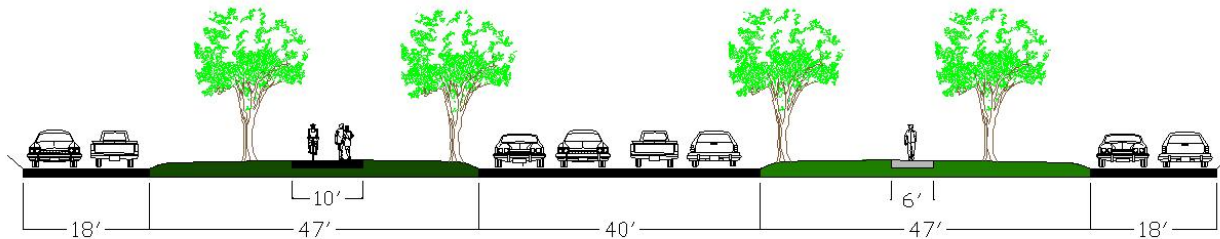


Source: AASHTO *Guide for the Development of Bicycle Facilities*, 1999

Figure 7.5: Typical Cross Section of Arborway



Existing Cross Section



Proposed Cross Section

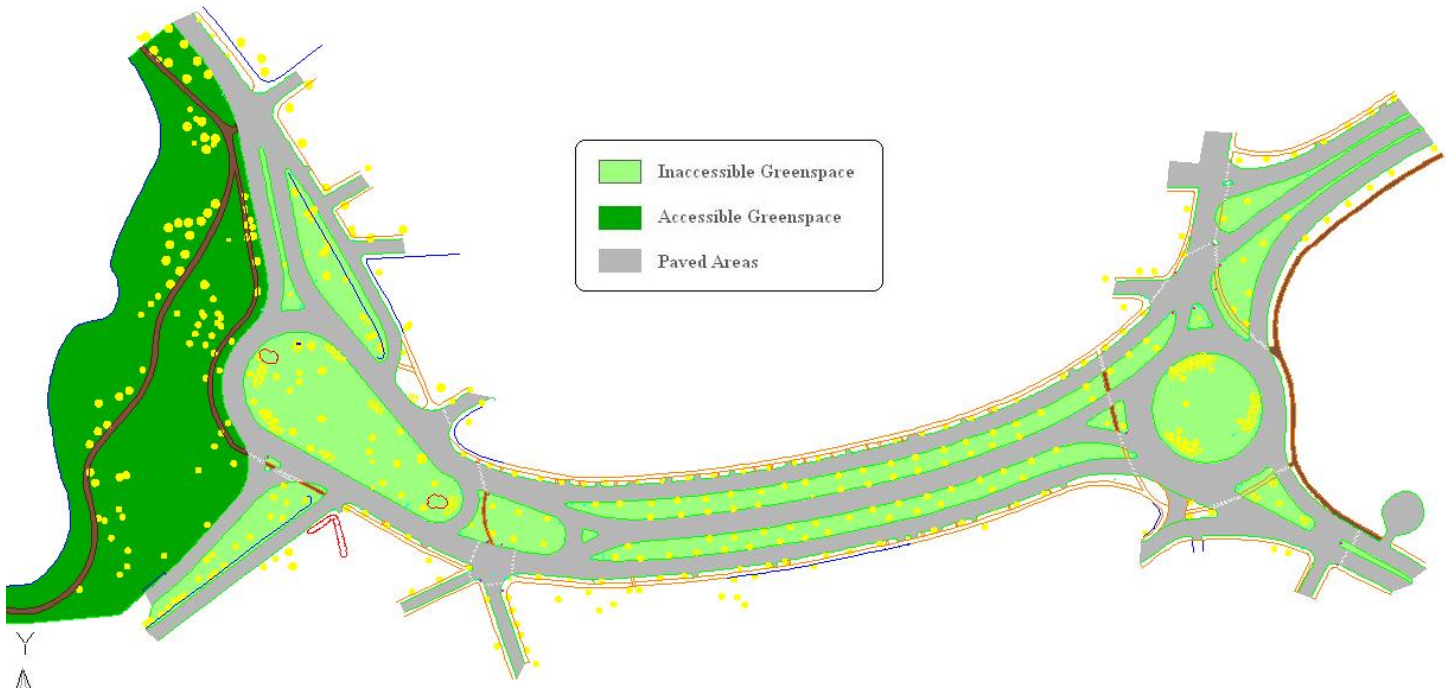
7.3 RECREATIONAL GREENSPACE

With the removal of the two rotaries and the installation of signalized intersections, greenspace has been added to the Arborway. The shrinking of the Outer Arborways from 30 feet to 18 feet has also provided more parkland for recreational use. Overall, 4.45 acres of new greenspace has been added. In addition to this new greenspace, much of the previously inaccessible greenspace has been opened up to pedestrians and cyclists. Of the existing 6.80 acres of greenspace, over 91% of it is currently inaccessible. In the new design, over 94% of the 11.25 acres of greenspace is accessible for recreational use. This equates to over 10 acres of newly accessible greenspace. The existing and proposed greenspace areas are summarized in Table 7.1. Figure 7.5 illustrates the existing and proposed greenspace.

Table 7.1: Existing and Proposed Greenspace

	Existing Conditions	Proposed Design	Net Area
	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>
Greenspace	6.80	11.25	4.45
Accessible	0.61	10.66	10.05
Inaccessible	6.19	0.59	-5.60
Paved Surface	11.93	7.48	-4.45

Figure 7.5: Existing and Proposed Greenspace



SECTION 8: EVALUATION

The Arborway serves a large regional traffic flow, but also has the potential to be a high use route for pedestrians and cyclists. The Arborway can serve as a connection for recreational users between two major recreation destinations, Jamaica Pond and the Arnold Arboretum. While the potential for high recreation use exists, the Arborway is not often used in this manner, mostly due to inadequate and often unsafe pedestrian and cyclist access along the route. While providing safe and adequate accommodations for recreational users would be ideal, it also poses unique challenges to those wishing to address the issue.

The proposed design provides a separated high quality paved multi use path for pedestrians and cyclists as well as an additional separated walking path for recreational use. The paths effectively connect Jamaica Pond and the Arnold Arboretum for recreational users wishing to travel this route. In addition to providing separated safety from heavy traffic flows, the paths serve as scenic parkland themselves, adding to the aesthetic value of the roadway.

The DCR wishes to better accommodate recreational users but not at the expense of lowering the capacity of the route for the large volume of traffic the road serves on a daily basis. This design utilizes signalized intersections to replace the existing rotaries at Kelley Circle and Murray Circle in order to provide protected crossings at critical points along the route. The proposed intersections in the design effectively maintain capacity at all points of the study area.

The signalized intersections, in addition to maintaining existing capacity, also separate the regional traffic and the area's local traffic so that the medians along the Arborway can be used as parklands. By altering intersection geometry at Murray Circle, and by providing green waves at critical points, particularly at the Arborway and Parkman Drive, regional through traffic is directed to use the Inner Arborway, minimizing cut through traffic onto the Outer Arborways or other local streets. However, the design still provides local traffic access to and from the Outer Arborways.

While the design will significantly change the existing layout of Kelley Circle and Murray Circle, the alterations will have minimal impacts to the historic portions of the area. The design follows and preserves what's left of the original Olmsted layout of the area as well as preserving the recently restored historic wall along Pond Street east of Kelley Circle. The design, to the extent possible, preserves the majority of the long-standing mature majestic oak trees lining the inner and outer Arborway. However, the design does require the removal a total of nine (9) of the mature oak trees in order to create the new signalized intersections at Kelley Circle and Murray Circle. Although these trees will be removed, the trade-off will be gaining access to the currently inaccessible green space in the medians between the Inner Arborway and the Outer Arborways. Additionally, the removal of the rotaries and their replacement with signalized intersections yields a net increase of usable green space area at the Kelley Circle and Murray Circle Locations.

Overall, this design gives a solution to the problems of safety and access for cyclists and pedestrians along the project area. The design does this while satisfying traffic problems associated with making this study area more recreational-user friendly. It separates local and regional traffic while giving access to local destinations, and maintains existing traffic capacity throughout the project area. Lastly, this design requires minimal historical and environmental impact, provides a net gain in usable parkland, and enhances the recreational and aesthetic value of the existing parkland.