APPENDIX A

Gorove/Slade Associates, Inc. Memorandum
National Cathedral Tour Bus and Automobile Parking Facilities

Board of Zoning Adjustment
District of Columbia
CASE NO. 17320
EXHIBIT NO. 25A2

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MEMORANDUM

DATE: April 7, 2004

TO: Kenneth Laden, District DOT

FROM: Louis J. Slade, P.E.

SUBJECT: National Cathedral Tour Bus and Automobile Parking Facilities
Parking Supply and Demand
Traffic Forecast and Analysis

Introduction

Project Description

This project, which consists of a below grade car garage and below grade bus garage, has been designed to alleviate a number of transportation related issues at the National Cathedral and the neighborhoods that surround it. Currently there is a deficit in regard to the number of parking spaces required by the Cathedral and the other institutions on the Cathedral grounds (called the "Close") versus the number of spaces available on Cathedral property. Consequently, many users of the Cathedral must park in the neighborhood, which causes traffic and congestion and does not serve the constituency of the Cathedral well. The car garage proposed will provide parking for 100% of the current "normal peak" demand, and will remove virtually all of the neighborhood congestion that results as motorists search for parking spaces on neighborhood streets.

In addition to the functional parking problem, there is an aesthetic one. Currently vehicles park within a few feet of the Cathedral to the north, on both sides of North Road, and to the east of Hearst Hall in a gravel lot. The Foundation's 1998 Master Plan calls for the establishment of a Sacred Precinct, which is a zone around the Cathedral where vehicles would be prohibited.

Another transportation related concern is the parking of tour buses along Wisconsin Avenue to the west of the Cathedral. At the present time, buses stack in the "dedicated bus lanes" and in the easternmost lane of Wisconsin Avenue, itself creating an unsightly condition, blocking views of the Cathedral from those driving by, and disrupting traffic. The solution proposed should eliminate all of these problems. The "dedicated bus lanes" were originally part of the Cathedral property but were deeded to the City in the 1970's. In the past, buses exited these lanes by turning east onto Woodley Road, but that is in the process of being changed pursuant to a new plan reached with DDOT that will keep all buses on Wisconsin Avenue. This plan will involve traffic signal modifications at the intersection of Woodley Road and Wisconsin Avenue.

Independent below-grade car and bus garages have been proposed to solve all of the above issues. When the garages are completed, the supply of parking spaces will actually exceed the daily parking demand.

The car garage is a four level 427-car garage below the lawn to the north of the Cathedral. The North Lawn will be replaced in a very similar condition as to what currently exists after the garage is constructed. Two ramps will access the car garage. One ramp is accessed from Wisconsin Avenue and the other from Woodley Road via North Road. The primary access and egress point will be on Wisconsin Avenue. The majority of the traffic using the parking garage will enter and exit using the Wisconsin Avenue driveway. Both entrance/exits are necessary to make the garage function efficiently and benefit the local community as a whole. In addition to other benefits, the Woodley Road entrance/exit will improve traffic flow and lessen congestion on Woodley Road by providing access for traffic to and from the east. Without this access, this traffic would add congestion onto Woodley Road and Wisconsin Avenue.

The bus garage will be created by depressing the current bus lanes that used to be Cathedral property and then excavating a parking area for the buses beneath the West Front plaza area, parallel to Wisconsin Avenue. Buses enter the bus lane from the south off of Wisconsin and immediately ramp down, turning right into an angled parking space. The buses park and allow visitors to take a stair or elevator up to grade in the plaza. When leaving the parking area, buses will continue north and ramp up to grade at the north end of the block, joining the recently designed fifth leg at the intersection of Woodley Road and Wisconsin Avenue described above. That new design includes a dedicated bus signal at the intersection of Wisconsin and Woodley that allows buses to travel either north or south on Wisconsin Avenue. The area above the bus lanes and ramps will be partially covered and planted; the area above the bus parking spaces themselves will be landscaped much as it is today.

This memorandum provides detailed technical information regarding the proposed parking facilities at the National Cathedral Close in Northwest Washington, DC. These matters were discussed with District DOT staff on Tuesday, March 16, 2004 and the concept for the garages and a summary of the technical points were presented.

It is important to note that these proposed facilities are totally consistent with the recent District of Columbia policies regarding managing and controlling tour bus operations in the District of Columbia, and neighborhood parking restriction policies. Furthermore, the Advisory Neighborhood Commission 3C passed a resolution in 2003 supporting the development of these facilities on the Cathedral Close.

This memorandum presents technical information covering the following topics:

- Transportation demand management
- Parking supply and demand.
- Traffic forecasts including traffic turning movements and intersection analysis.
- Description of bus lane egress plan.
- Analysis of signalization and impacts to Wisconsin Ave traffic flow.

Summary of Findings

- This proposed parking plan is consistent with District of Columbia policies regarding tour buses and neighborhood parking.
- With the exception of the proposed entrance from North Road on Woodley Road, this proposed parking plan is consistent with a resolution passed by the Advisory Neighborhood Commission on August 25, 2003.
- The automobile parking garage will, to a very great extent, eliminate the need for the usual Close parkers during an average peak weekday to use neighborhood streets and the concomitant excess traffic circulation and air pollutant emissions.
- Garage access patterns with two entrances and exits optimize the overall traffic flow and actually improve the flow on Woodley Road and Wisconsin Avenue. It significantly improves the functionality and flexibility of the garage.
- Close traffic will use arterial and collector streets that abut the Close. The majority of any traffic increases will occur on Wisconsin Avenue. The traffic change on the combination of Woodley Road, 34th Street, and Garfield Street will actually decrease by approximately 11 vehicles.
- The Wisconsin Avenue access to the garage and to Hearst Hall will be redesigned and a traffic signal must be provided so that the arterials can be kept as open as possible, and so that the garage can be cleared as quickly as possible, which limits the traffic that will exit onto Woodley Road.
- The new Wisconsin Avenue traffic signal will provide a safety improvement by helping to control speeds on this section of Wisconsin Avenue, by enabling Close motorists to leave and enter Wisconsin Avenue more safely, and by providing a safe pedestrian crossing on Wisconsin Avenue.
- All tour buses will be accommodated in the proposed below-grade facility out-of-sight, and they will continue to be required to park with their engines turned off.
- No tour buses will need to park on Wisconsin Avenue.
- ANC/PECF has requested through DDOT that all tour bus access will be from and to Wisconsin Avenue. Left turns will be permitted for buses only from southbound Wisconsin Avenue to eastbound Massachusetts Avenue so that tour buses will not have to use Garfield Street to make this turn. DDOT has not yet approved this request.
- Traffic operations on Wisconsin Avenue will be maintained at acceptable levels of service in terms of congestion and delays.

Transportation Demand Management

The Foundation will be exploring a transportation demand management program to encourage all persons who work or volunteer on the Close to use alternatives to driving alone. At the present time, 23 percent of Cathedral Foundation employees commute by means other than driving alone. The Foundation is exploring additional programs to further reduce automobile dependence and parking demand.

Parking Demand

Automobiles

The parking management consulting firm of Chance Management Advisors conducted extensive studies of the parking requirements of all of the entities located on the Cathedral Close. These entities include the Cathedral, St. Albans Parish Church, three private schools, and the College of Preachers. Chance determined that on an average peak day, which occurs during the school year with moderate visitation of tourists to the Cathedral, the number of automobiles parked at one time by individuals who have business on the Close is approximately 826. This exceeds the on-Close parking supply currently available of 532 spaces.

The parking demand generated at the Cathedral Close consists of several categories of persons as follows:

- Full time and part time employees of all of the entities on the Close, including faculty and staff of the schools
- Students of the schools
- Volunteers

In addition, the Close has a broad range of visitors that include visitors to the Cathedral, business and parental visitors to the other facilities on the Close, and other categories. Chance Management Advisors estimated that the number of automobiles that are parked on an average peak day by visitors is 145. This estimate is part of the 826 total accumulated parkers on an average peak day.

Tour Buses

The National Cathedral is a major tourist destination in Washington, D.C. attracting approximately 500,000 individuals who arrive by tour bus or automobile each year. Over the last few years, the National Cathedral has implemented a strong management scheduling procedure for all tour bus tourists, which requires that they register in advance and which limits the number of tour buses to 55 per day maximum. The Cathedral no longer permits any tours without a reservation, which has eliminated unscheduled tours that were once accommodated. Actually, the Cathedral hosts a typical peak day of only about 40 to 45 buses. This bus traffic is distributed through the tour hours from 10:00am to 4:30pm and the arrivals and departures are uniformly spread so that the maximum accumulation of parked buses at the Cathedral is no more than 18 when the total for the day is 55, and about 15 buses under current conditions.

Also, on average, a bus arrives or departs about once every 8 minutes under today's conditions and about once every 6 minutes under maximum conditions. The first bus arrives in the morning just before 10:00am, well after the morning commuter peak. The last bus departs just after 4:30pm, which is during the early portion of the afternoon peak.

Proposed Parking Supply

With the development of the automobile and the tour bus parking facilities, the total number of automobile parking spaces on the Close will increase from 532 spaces to approximately 854 spaces, an increase of 322 parking spaces. The capacity of the proposed parking garage is 427 parking spaces and the garage plan will displace and remove approximately 105 existing parking spaces. Thus, the arithmetic is: 532 existing spaces, minus 105 existing surface spaces that will be removed, plus 427 new spaces in the parking garage equals a future total of 854 parking spaces. There will be an additional 20 spaces on the North Road that will be used for special events and will not be available every day. Including these 20 spaces, the total supply is 874 spaces. However, since the 20 special event spaces are not available on a regular basis, they are not considered in the analysis.

The future supply of 854 parking spaces will accommodate all employees, faculty, staff, students, volunteers and most visitors who drive to the Close daily. Absenteeism and school holidays will free more of these spaces that will be available for visitors.

Figures 1 & 2 show parking on neighborhood streets around the Close before and after the parking garage is constructed. These diagrams are based on surveys conducted in the spring and fall of 2003 during the school year. Figure 1 shows an approximation of the total number of vehicles parked on neighborhood streets during the mid-day peak period. That chart indicates an approximation of the number of those vehicles that are parked by individuals who have business on or are visiting the Cathedral Close. The second chart shows the removal of those Close related automobiles from the neighborhood street showing the drastic improvement of the current parking encroachment conditions in the neighborhood around the Close.

Figure 1

REPRESENTATIVE EXISTING PARKING DENSITIES



Figure 2

REPRESENTATIVE FUTURE PARKING DENSITIES



Existing Traffic Conditions

The Cathedral Close traffic demand patterns during the morning and evening commuter periods are presented in Figures 3 & 4. During the morning, the traffic arrives and departs from the Close during a concentrated period of about 90 minutes. This is because of the starting times of the private schools located on the Close and the competition for the limited number of parking spaces on the Close. As Figure 3 shows, a significant number of vehicles arrive and depart within that 1 ½ hour because these are parents who are dropping off children to the schools. The chart also shows the accumulation of cars parking on the Close and that accumulation reaches the capacity of 532 spaces at approximately 8:15am.

From 8:15am thru mid morning, automobiles continue to arrive to the Close or to the nearby neighborhood streets because parking availability becomes limited on the Close after 8:15 a.m. These vehicles must circulate on the neighborhood streets to find parking and then the motorists and their passengers walk to the Close.

The morning peak hour traffic analysis presented in this report assumes that in the future, traffic arriving to the Close will be in a less concentrated pattern. There will be less competition for parking spaces; motorists will not need to arrive to the Close as early as they do today to get a parking space on the Close. Additionally, the parking management plan will specifically assign parking spaces to each institution, which serves to diffuse traffic concentration.

Figure 4 shows the pattern of arrivals and departures throughout the afternoon. This is a completely different pattern than the morning pattern because schools begin letting out in the afternoon so the traffic demand is spread out over many more hours and the rate of arrival and departure is significantly lower than it is in the morning. For this reason, the traffic analysis presented in this memorandum focuses on peak hour traffic conditions between 7:15am and 8:15am. A less detailed afternoon analysis is also presented.

Figure 3

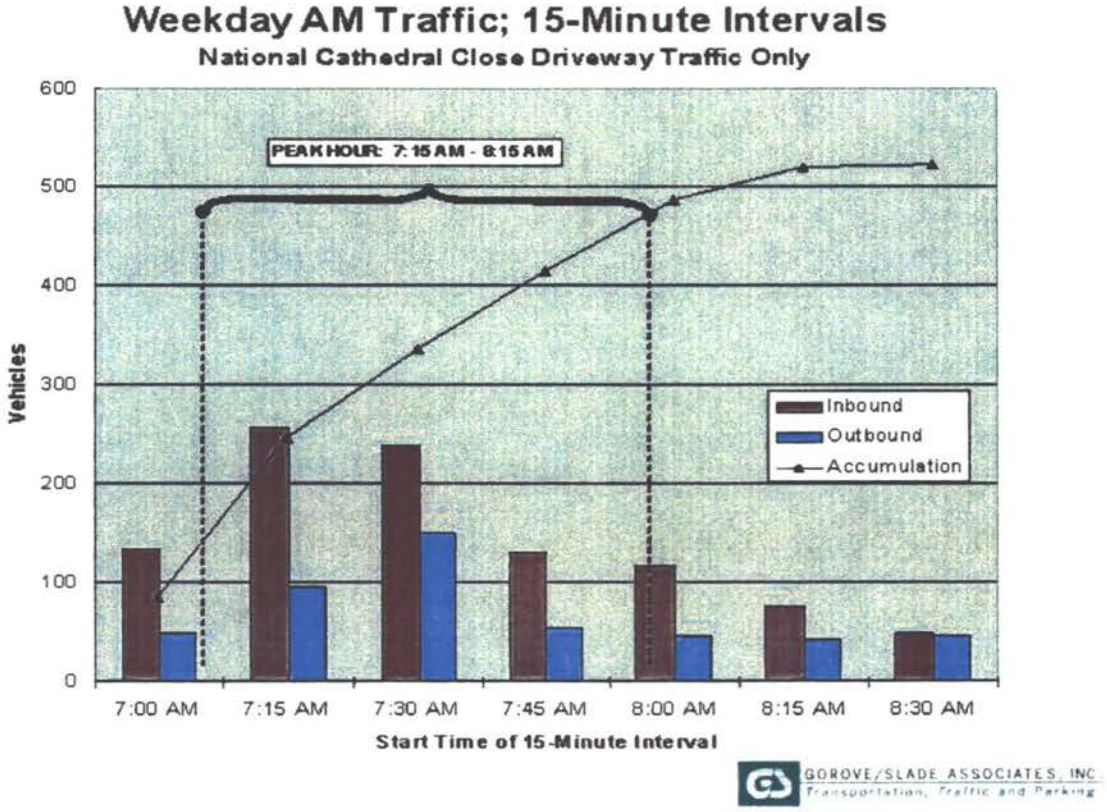

Weekday AM Traffic; 15-Minute Intervals
National Cathedral Close Driveway Traffic Only
PEAK HOUR: 7:15 AM - 8:15 AM
Inbound
Outbound
Accumulation
Vehicles
600
500
400
300
200
100
0
7:00 AM
7:15 AM
7:30 AM
7:45 AM
8:00 AM
8:15 AM
8:30 AM
Start Time of 15-Minute Interval
GOROVE/SLADE ASSOCIATES, INC
Transportation, Traffic and Parking

Figure 4

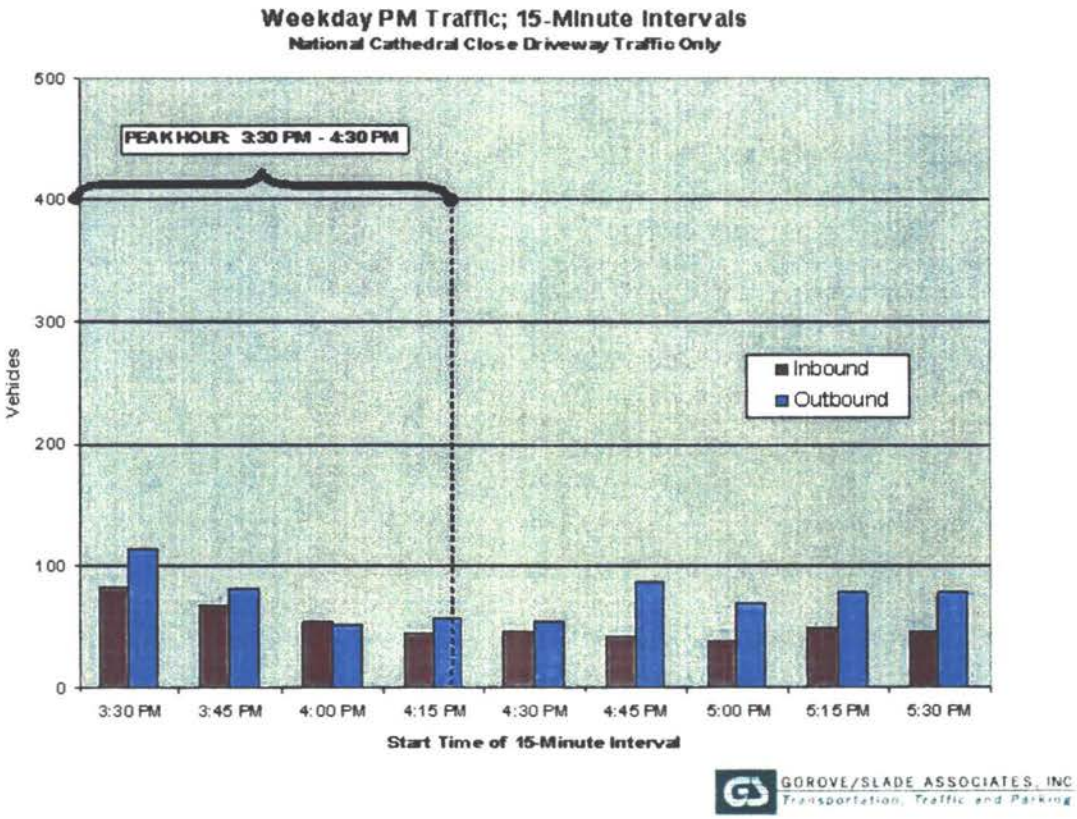
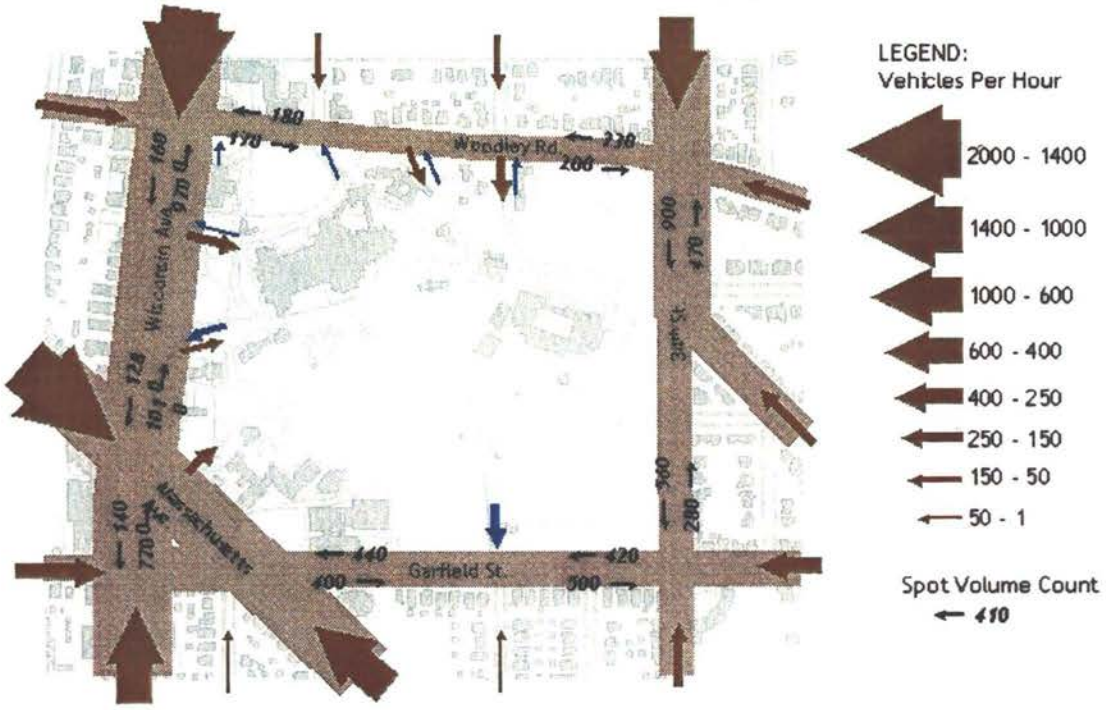

Weekday PM Traffic; 15-Minute Intervals
National Cathedral Close Driveway Traffic Only
PEAK HOUR 3:30 PM - 4:30 PM
Inbound
Outbound
Vehicles
500
400
300
200
100
0
3:30 PM
3:45 PM
4:00 PM
4:15 PM
4:30 PM
4:45 PM
5:00 PM
5:15 PM
5:30 PM
Start Time of 15-Minute Interval
GOROVE/SLADE ASSOCIATES, INC
Transportation, Traffic and Parking

Figure 5 shows total traffic volumes and Cathedral traffic volumes on the principal roadways that are adjacent to the Cathedral Close. These traffic volumes are for the 7:15am to 8:15am peak hour and the chart is design to show the relative magnitude of traffic arriving and departing from the Close during this hour verses traffic on the adjacent streets. Close traffic constitutes approximately 16% of the total traffic on the streets during this peak hour, and this is the highest concentration of Close traffic that occurs on a typical weekday.

Figure 5

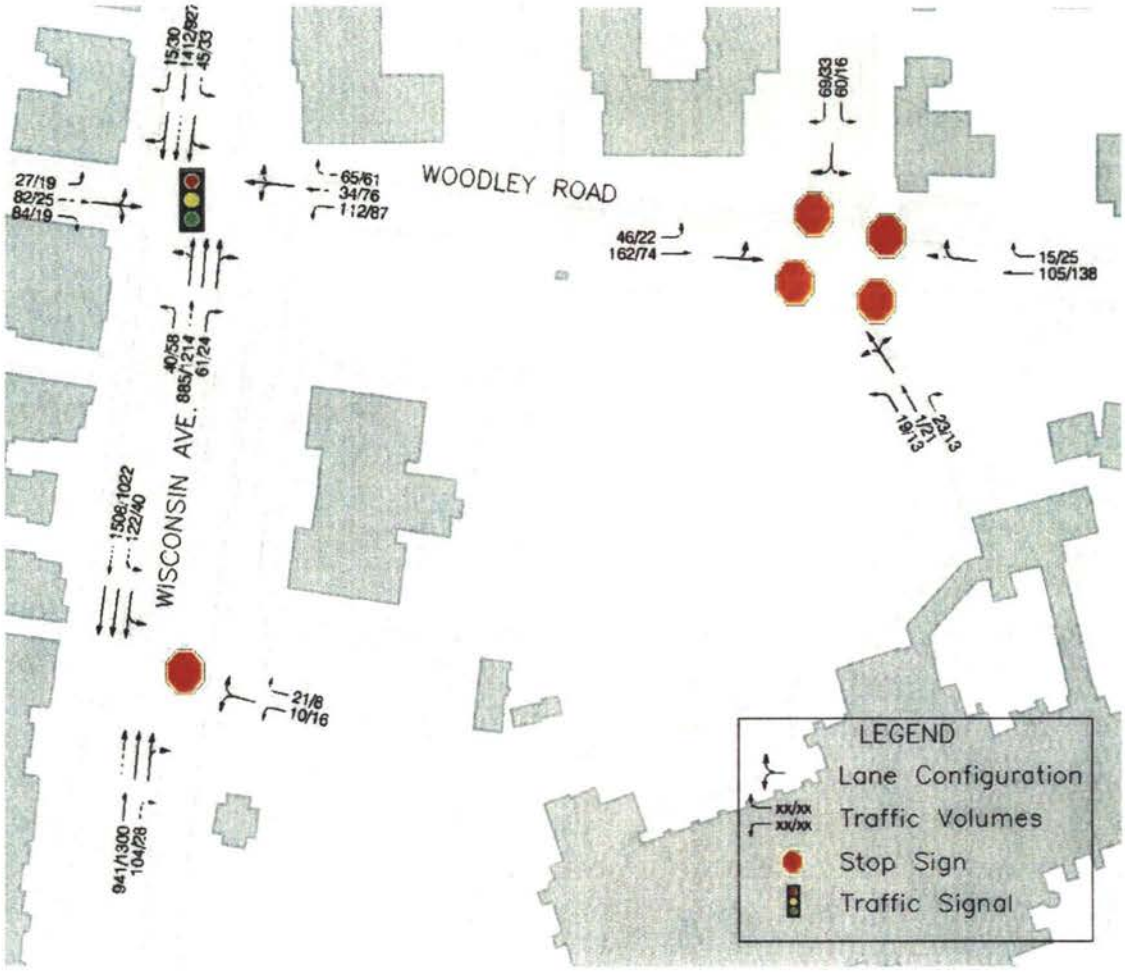
EXISTING TOTAL TRAFFIC VOLUMES
(WEEKDAY 7:15 AM - 8:15 AM HOUR)



The proposed parking facilities will be located in the Northwest corner of the Close and will have the most direct impact on Wisconsin Ave and Woodley Road in the vicinity of North Road which traverses the Northwest corner of the Close. Figure 6 shows the detailed existing traffic turning movements at all of the intersections in the vicinity of the proposed parking facilities. That figure also shows the configuration of traffic lanes at the intersections along these roadways.

Traffic analysis of existing conditions indicates acceptable levels of service at the three principal intersections of Wisconsin and Woodley Road, Woodley Road and North Road, and Wisconsin and North Road. However, congestion does occur along the segment of Woodley Road between North Road/36th Street and Wisconsin Ave due to the morning traffic flow to the west along Woodley Road.

Figure 6
Existing AM/PM Peak Hour Traffic Volumes



Future Traffic Conditions

The proposed parking facilities will serve traffic that is currently generated at the Close that must currently park on adjacent streets. No additional new traffic will be generated as a result of the development of these facilities. The development of these facilities will result in a redistribution of existing traffic.

Morning Peak Hour Traffic Projections

For automobile parking, the redistribution will result from three factors:

1. Factor 1. Individuals who park on neighborhood streets will now be able to park on the Close. This will remove traffic from the neighborhoods and concentrate it along the major roads that lead to parking garage entrances: Wisconsin Ave and Woodley Road. We estimated the change in a.m. peak hour traffic volume on the streets in the vicinity of the Close. Figures 7, 8, and 9 provide an example of the redistribution process for one of the sub areas around the Close. Similar redistributions were calculated for the other sub areas and these are shown in the appendix. The following paragraphs summarize our assumptions and methodology:

    - Parking accumulation during every half an hour for an average peak day was calculated and provided by Chance Management Advisors who studied the future parking demand related to specific users. The parking accumulation during the morning peak hour was calculated at 682, of which 30 are expected to be visitors and 652 are expected to be permit-holders.

    - The permit-holders are more likely to park on the surface spaces throughout the Close than in the garage because those spaces will likely be closer to their destination. Therefore, the 427 surface spaces on the Close will fill before the garage fills. Including the visitors, there will be 255 motorists entering the parking garage during the morning peak hour.

    - Currently 105 automobiles park on the North Road during the peak hour. We assigned an additional 150 vehicles to arrive during the peak hour for a total of 255 vehicles entering the garage access points from Wisconsin Avenue and Woodley Road. The number of vehicle that no longer park in the neighborhoods during the peak hour is 150 vehicles. Of course, the total traffic that will be removed from the neighborhoods is a greater number and is spread over a greater time period than just during the peak hour. In addition, the parking management plan within the Close will help to redistribute the traffic throughout a longer period of time because every user on the Close will have reserved parking.

    - We assigned the 150 peak hour vehicles to the adjacent neighborhood streets in proportion to the total automobiles parked on those streets during our mid-day parking surveys. This is an approximation of the current distribution of Close parked cars in the neighborhood.

    - We assumed the routing of the 150 vehicles into the neighborhoods today using current traffic patterns in the area, the most direct routing into the neighborhoods, and our judgment. This provided an estimate of the a.m. peak hour traffic volume on all of the streets in the area that is associated with Close motorists who currently must park in the neighborhoods.

    - We reassigned these traffic patterns by the most direct route to the new Close automobile garage

Figure 7

Cathedral Vehicles Parking On-Street

(During AM Peak Hour 7:15 - 8:15 AM)

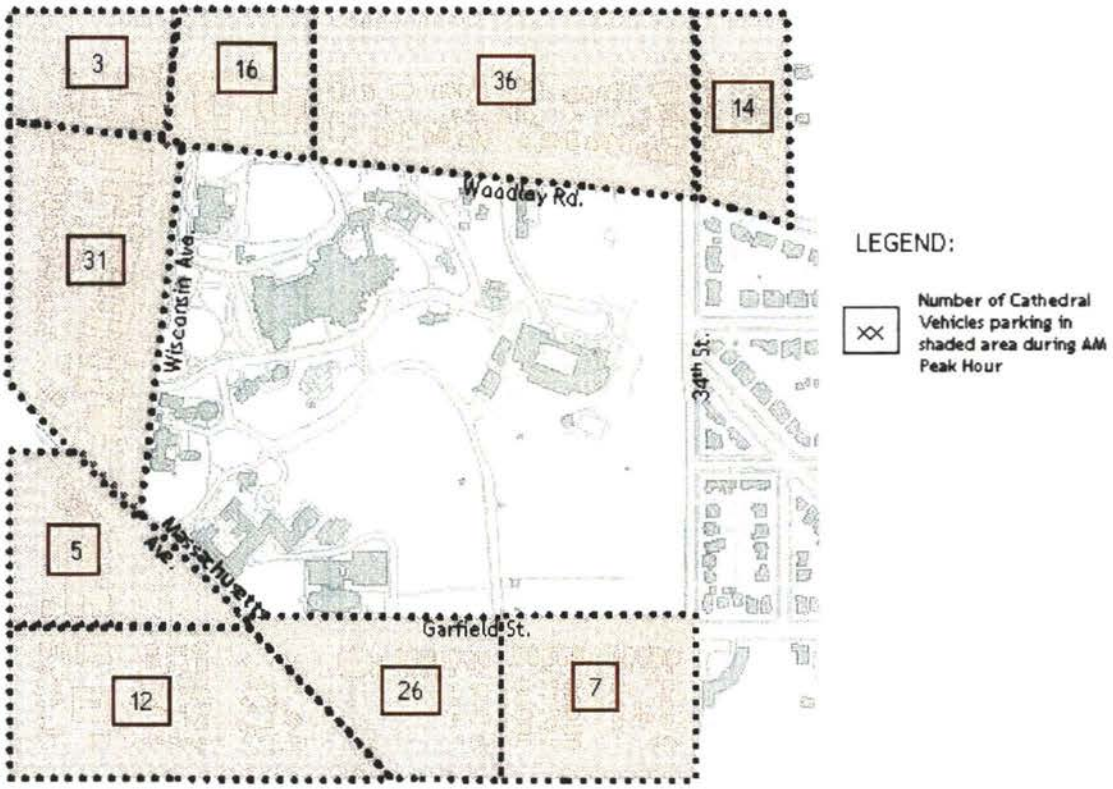
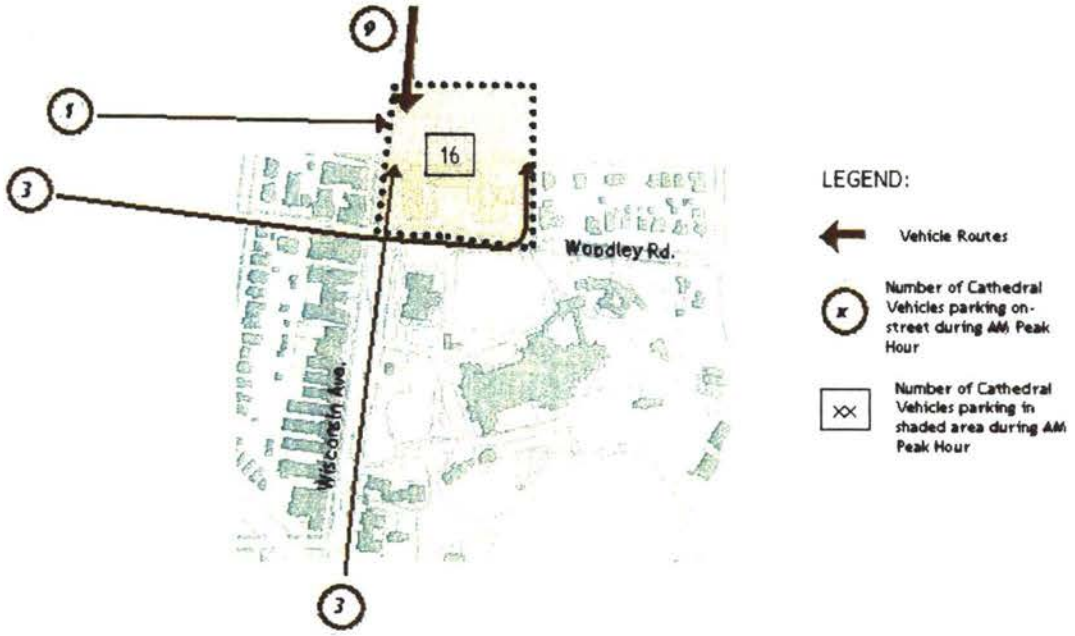


Figure 8

Example Distribution of Existing On-Street Parking Routes
(During AM Peak Hour: 7:15 - 8:15 AM)



Example Redistribution of Parking Routes with Parking Garage
(During AM Peak Hour: 7:15 - 8:15 AM)

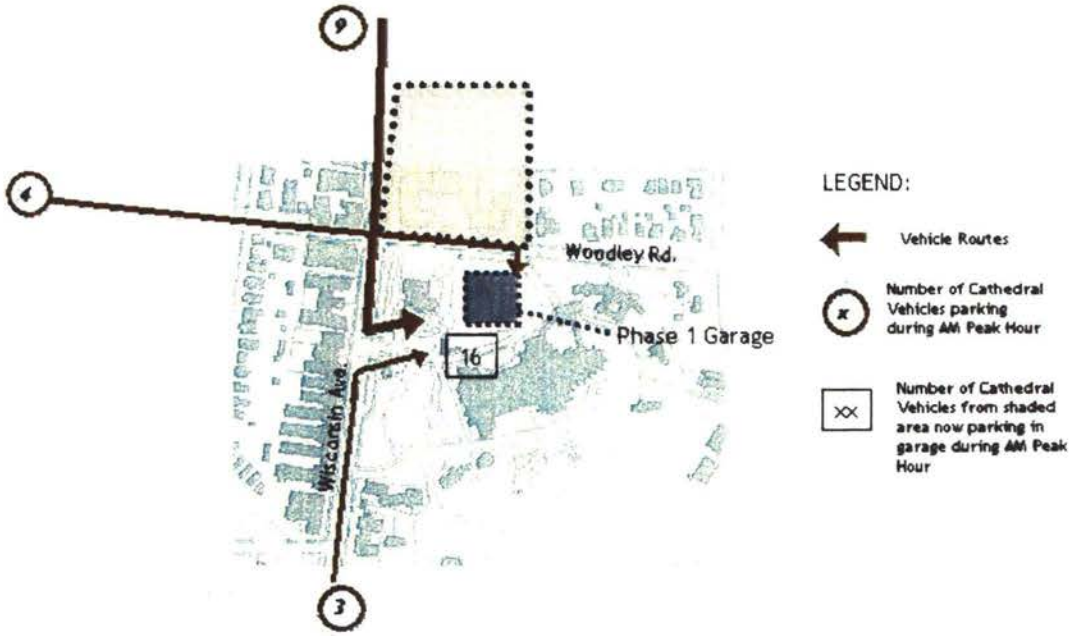
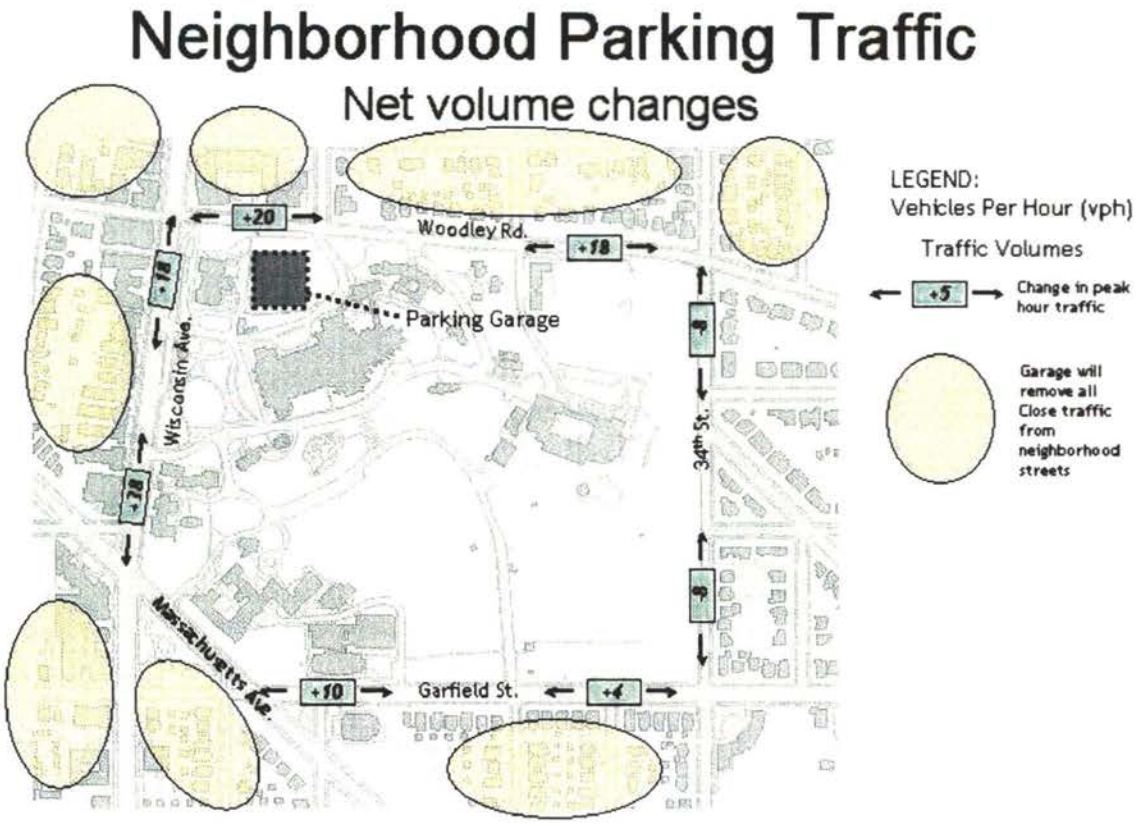


Figure 9



While Figure 9 shows that redistributing the motorists who are currently parking in the neighborhood increases the traffic volume on Woodley Road, the analyses of the other two factors actually offsets the increase. The end result, as will be described in the next sections, is that the combined net effect is a decrease of 11 vehicles during the AM peak hour on Woodley Road, 34th Street, and Garfield Street.

2. Factor 2. Individuals who park on North Road on the Close today must enter North Road from Wisconsin Avenue. In the future, these individuals will park on the Close and will be able to enter the garage at either the Wisconsin Avenue entrance or Woodley Road entrance, or they may be assigned to park elsewhere on the Close and use other entrances. This will slightly change the distribution of that traffic which currently parks on North Road. This is shown graphically on Figures 10 and 11.

Figure 10

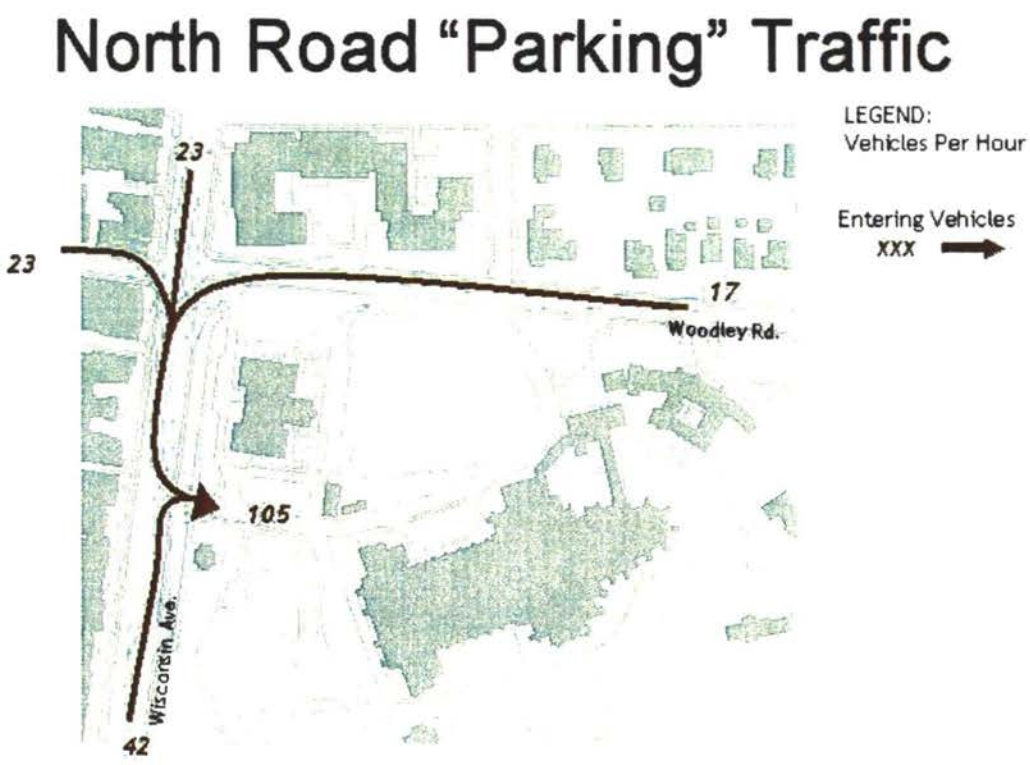
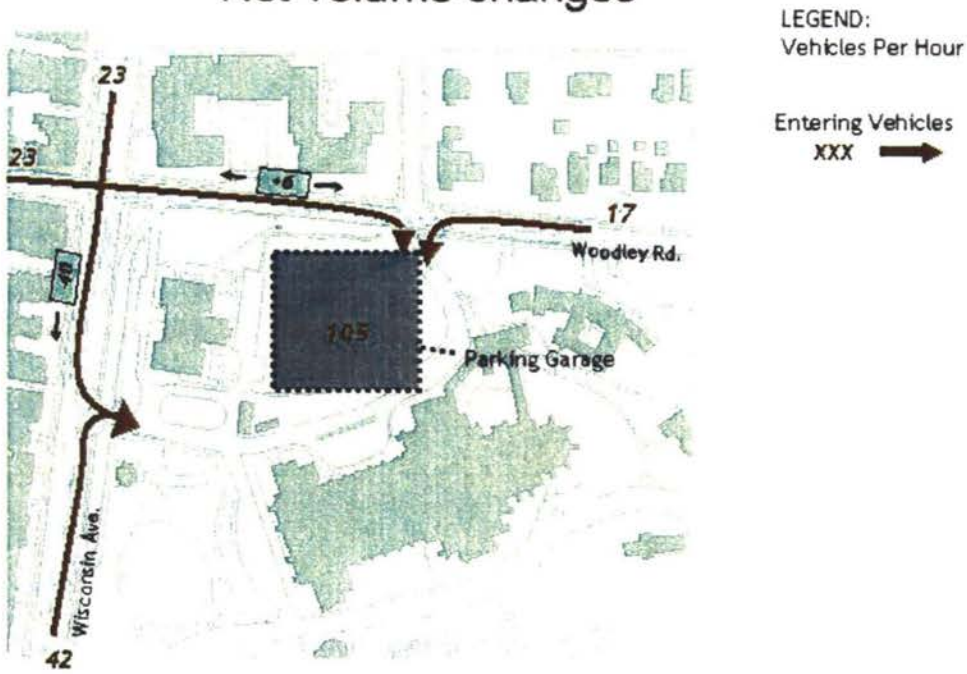


Figure 11

North Road "Parking" Traffic

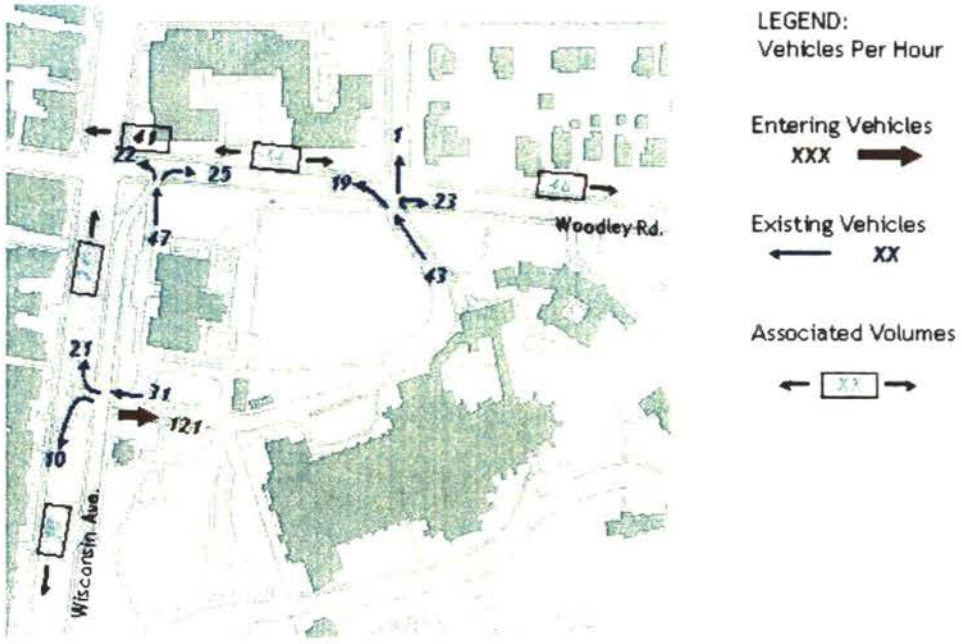
Net volume changes



3. Factor 3. A significant amount of traffic currently enters North Road from Wisconsin Avenue and passes through the Close to exit onto Woodley Road. Most of this through traffic is parents who are dropping off students at NCS. With the construction of the parking garage, North Road will no longer pass through the Close. Also, the NCS passenger loading area on the south side of Hearst Hall will be enlarged and improved and a traffic signal will be installed; this will provide a much better parent car pool drop off that is less congested, safer and easier to use. Thus, this through traffic movement along North Road will be eliminated and all of the through traffic will simply loop around the new passenger loading facility and back onto Wisconsin Avenue. This change is presented graphically on Figure 12.

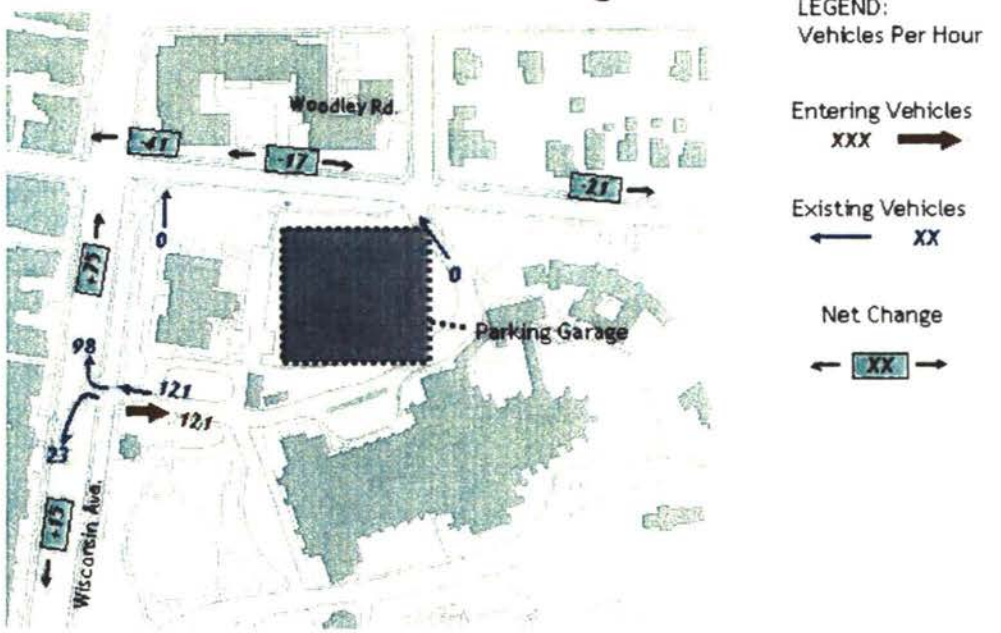
Figure 12

North Road "Through" Traffic



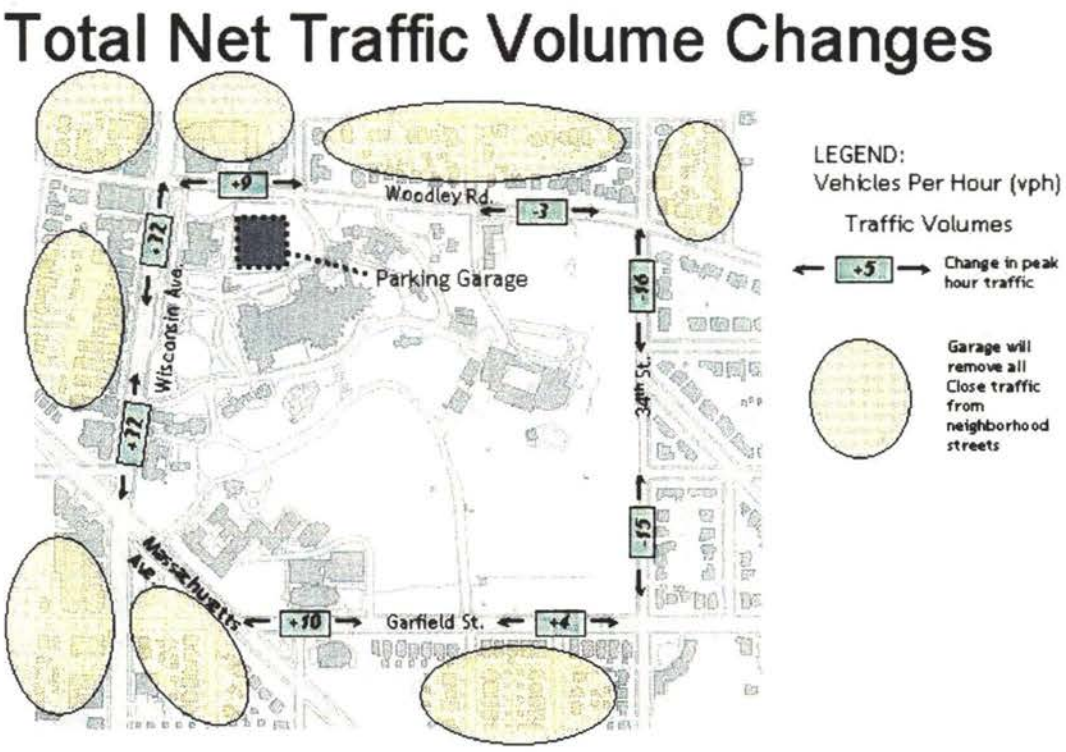
North Road "Through" Traffic

Net volume changes



The total adjustments of the traffic volumes on the neighboring streets are shown on Figure 13. This shows that the impact of the garage on traffic patterns will eliminate Close traffic from local neighborhood streets. The greatest increase in traffic will impact Wisconsin Avenue. There will be small changes in traffic volumes on Woodley Road, 34th Street, and Garfield Street, but these will either be negligible or actually result in reducing the traffic volumes.

Figure 13



The results of the analysis are as follows:

- The vehicles that are currently in the neighborhoods and on North Drive will instead use the main roadways surrounding the Close.
- The majority of the redistributed traffic will relocate to Wisconsin Avenue.
- Combining the volume changes on Woodley Road, 34th Street and Garfield Street, there is expected to be a net decrease of traffic by 11 vehicles during the morning peak hour.

Description of Tour Bus Egress Lane Design and Operations

At the present time, tour bus parking is accommodated in a bus lane which is separated from Wisconsin Avenue by a 4-foot wide median and on Wisconsin Avenue in parking spaces that are reserved for buses during the tourist season, and are used as metered automobile parking spaces for the balance of the year. Buses enter the parking lane from the south on Wisconsin Avenue at an entry point located between North and South Drive along the Cathedral Wisconsin Avenue frontage. The bus lane is one-way northbound; buses park along the east curb and depart at the bus lane exit point onto Woodley Road. This bus lane was originally designed for buses to turn east on Woodley Road, travel clockwise around the Cathedral and continue back downtown on Massachusetts Avenue

In 2003, the Cathedral Foundation, the Advisory Neighborhood Commission, and District DOT agreed to a modification to the north end of the bus lane that would permit buses to turn west from the bus lane and go directly out to Wisconsin Ave where they could turn north or south. To accommodate this turning movement through the Wisconsin Ave, Woodley Road intersection, the traffic signal will be modified to provide a special bus phase where all other approaches to the intersection are given the red signal stop designation and buses are permitted to turn out into the intersection. A loop detector will be placed in the pavement at the north end of bus lane to trigger this special bus phase. Typically, only one bus will trigger the phase on the average of once every six minutes at most between the hours of 11:00am and 4:30pm. Occasionally, two buses may be prepared to depart at the same time. Thus, the interruption to the traffic signal will only occur on average of about once every 6 to 8 minutes and will only take approximately nine seconds away from the other phases of the signal. Also, this level of activity will occur during the spring and summer peak tourist periods when commuter and school traffic are at lower than peak levels. The roadway and signal modifications have been designed, are being reviewed by DDOT, and should be constructed and fully implemented in the summer of 2004.

Detailed Traffic Forecast and Analysis

Figure 14 presents estimates of turning movements in the sections of Wisconsin Avenue and Woodley Road that will be impacted by the construction of the tour bus and automobile parking facility. These are based on the previously presented calculations and the assumptions that:

1. There will be some growth in background traffic on the adjacent public roads: 1% per year for the approval, design and construction period of the garages.
2. The Cathedral will place signs in the parking garage at the North Road exit indicating that exiting traffic is restricted to turn right or left onto Woodley Road, and not to continue north on 36th Street.
3. The Cathedral will discourage parents from using the Hearst Hall service drive as an exit from the Hearst Hall passenger loading area.

Figure 14

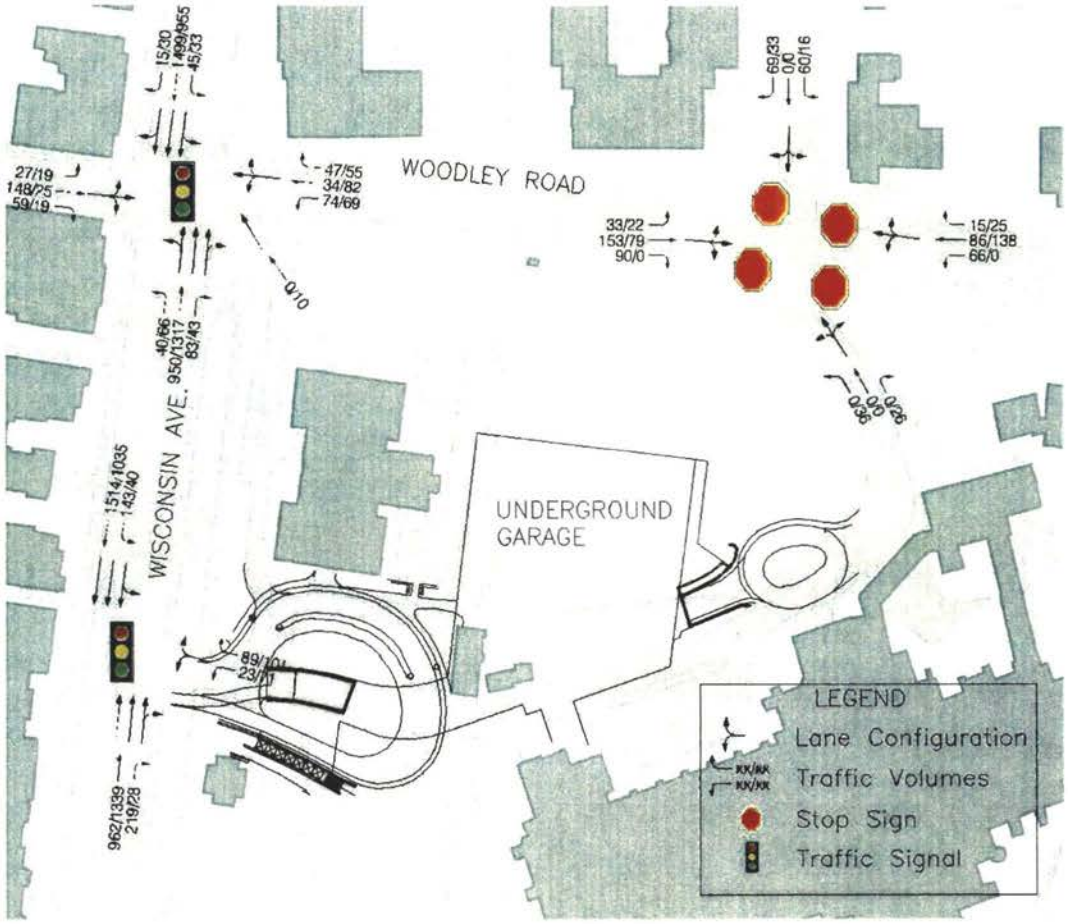


Table 1 summarizes the level of service at these three intersections within this impacted area including queue lengths, delay and levels of service.

The Requirement for Woodley Road Access

It is critical that the proposed parking garage have access to both Woodley Road and Wisconsin Avenue. The Wisconsin Avenue access will be more heavily used, but the Woodley Road access will serve those motorists arriving from and departing to the east. Without this access, that approaching traffic from the east would have to continue to Wisconsin Avenue and, in doing so, would congest the segment of Woodley Road west of 36th Street and would mix with the NCS traffic. During the morning peak period, the traffic back-up at the Wisconsin/Woodley intersection would extend almost to the NCS crosswalk. That could in turn cause greater back ups from the crosswalk back to 36th Street.

We prepared an analysis of this morning peak hour condition assuming there was no Woodley Road access. The results are shown on Table 1.

The garage would function at an unacceptable level of efficiency with only the Wisconsin Avenue access. Peak inbound traffic would backup onto Wisconsin Avenue, and peak exiting traffic after large events would be significantly delayed in the garage. The entrance and exit on Woodley reduces the traffic congestion on Woodley Road because motorists are pulled out of the traffic stream earlier than they would be if they had to enter/exit on Wisconsin Avenue. The Woodley Road access is also essential for circumstances when the Wisconsin Avenue access may be closed to traffic due to an accident, mechanical breakdown, or street or utilities maintenance. In addition, two entrances and exits provide the greatest flexibility for separating functions of the garage. If needed, there can be separate policies for different user groups.

The entrance and exit at Woodley Road does not result in an increase in traffic volume on Woodley Road. The traffic that is already on Woodley Road will simply be routed to and from the garage instead of onto the neighborhood streets or to the intersection of Wisconsin and Woodley Road.

Summary

The primary results of the traffic forecast and analysis as described within this document are the following:

- There are no new trips generated as a result of the construction of the bus or car garages. The trips are simply redistributed on the roadway network; being eliminated from the neighborhood streets. There is actually a traffic volume decrease expected on the combined Woodley Road, 34th Street, and Garfield Street segments surrounding the Close.

- The proposed traffic signal at the intersection of Wisconsin Avenue and North Road improves operations at that location and along Woodley Road for the following reasons: 1) provides a safe pedestrian crossing across Wisconsin Avenue; 2) coordinates NCS pick-up an drop-off traffic with the parking garage traffic; 3) Provides easy access and egress for the garage, encouraging its use and eliminating traffic from the neighborhood streets; and 4) operates with minimal delay and thereby eliminates the need for motorists to use the Woodley access and egress unless they originate from or are destined to Woodley Road.

- Two entrances and exits are needed at the garage for the following reasons: 1) traffic flow is improved on Woodley Road and operations at the intersection of Woodley Road and Wisconsin by minimizing the potential westbound queues; 2) flexibility is maintained with respect to the potential for implementing policies for different user groups; 3) internal congestion is minimized after large events; and 4) outbound traffic flow is preserved in the case of an incident or maintenance operations at the Wisconsin Avenue exit.

- The proposed bus garage will eliminate bus traffic on Woodley Road but will, instead, force buses to use Wisconsin Avenue.

- The bottom line of the analysis is that there will be a combined net decrease of traffic on Woodley Road, 34th Street, and Garfield Street.

Table 1 Intersection	Approach	Level of Service							
		AM				PM			
		Avg. Delay (sec.)	Level of Service	Queues (vehicles)		Avg. Delay (sec.)	Level of Service	Queues (vehicles)	
				Average	Maximum			Average	Maximum
Existing Conditions									
Wisconsin Ave. & North Road Unsignalized (two-way stop)									
	Westbound Approach	46.8	E	n/a	n/a	77.2	F	n/a	n/a
	Southbound Left Turn	6.3	A	n/a	n/a	0.8	A	n/a	n/a
	Overall	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Wisconsin Ave. & Woodley Road Signalized									
	Eastbound Approach	31.0	C	5	7	26.0	C	2	3
	Westbound Approach	123.5	F	7	12	54.9	D	6	11
	Northbound Approach	4.6	A	2	3	10.3	B	7	8
	Southbound Approach	13.7	B	11	14	9.5	A	6	7
	Overall	**19.8**	**B**	**n/a**	**n/a**	**14.3**	**B**	**n/a**	**n/a**
Woodley Road & North Road Unsignalized (all-way stop)									
	Eastbound Approach	8.0	A	n/a	n/a	7.6	A	n/a	n/a
	Westbound Approach	7.8	A	n/a	n/a	7.8	A	n/a	n/a
	Northbound Approach	7.8	A	n/a	n/a	7.6	A	n/a	n/a
	Southbound Approach	7.8	A	n/a	n/a	7.4	A	n/a	n/a
	Overall	**7.9**	**A**	**n/a**	**n/a**	**7.7**	**A**	**n/a**	**n/a**
Future Conditions with One Garage Entrance									
Wisconsin Ave. & North Road Signalized									
	Westbound Approach	26.4	C	n/a	n/a	11.3	B	n/a	n/a
	Westbound left	*26.3*	*C*	*1*	*2*	*29.9*	*C*	*3*	*5*
	Westbound right	*26.5*	*C*	*0*	*2*	*0.5*	*A*	*0*	*3*
	Northbound Approach	10.7	B	5	14	16.7	B	9	11
	Southbound Approach	14.4	B	n/a	n/a	9.2	A	n/a	n/a
	Southbound left	*15.7*	*B*	*2*	*3*	*6.6*	*A*	*1*	*1*
	Southbound thru	*14.2*	*B*	*24*	*32*	*9.3*	*A*	*9*	*11*
	Overall	**13.5**	**B**	**n/a**	**n/a**	**13.2**	**B**	**n/a**	**n/a**
Wisconsin Ave. & Woodley Road Signalized									
	Eastbound Approach	30.4	C	5	8	29.8	C	2	3
	Westbound Approach	53.0	D	5	8	40.2	D	4	7
	Northbound Approach	3.8	A	1	2	21.4	C	10	18
	Southbound Approach	14.0	B	12	17	6.3	A	4	10
	Bus Exit Lane Approach	0.0	A	--	--	42.2	D	1	1
	Overall	**14.1**	**B**	**n/a**	**n/a**	**17.4**	**B**	**n/a**	**n/a**
Woodley Road and North Road Unsignalized (all-way stop)									
	Eastbound Approach	7.9	A	n/a	n/a	7.5	A	n/a	n/a
	Westbound Approach	7.8	A	n/a	n/a	7.7	A	n/a	n/a
	Northbound Approach	0.0	A	n/a	n/a	0.0	A	n/a	n/a
	Southbound Approach	7.8	A	n/a	n/a	7.4	A	n/a	n/a
	Overall	**7.9**	**A**	**n/a**	**n/a**	**7.6**	**A**	**n/a**	**n/a**
Future Conditions with Two Garage Entrances									
Wisconsin Ave. & North Road Signalized									
	Westbound Approach	26.4	C	n/a	n/a	14.2	B	--	--
	Westbound left	*26.3*	*C*	*1*	*2*	*29.8*	*C*	*3*	*9*
	Westbound right	*26.5*	*C*	*0*	*2*	*0.3*	*A*	*0*	*2*
	Northbound Approach	10.7	B	5	10	16.7	B	7	9
	Southbound Approach	14.3	B	n/a	n/a	9.2	A	--	--
	Southbound left	*8.8*	*A*	*1*	*1*	*6.6*	*A*	*1*	*1*
	Southbound thru	*14.7*	*B*	*23*	*32*	*9.3*	*A*	*9*	*12*
	Overall	**13.4**	**B**	**n/a**	**n/a**	**13.5**	**B**	**n/a**	**n/a**
Wisconsin Ave. & Woodley Road Signalized									
	Eastbound Approach	35.1	D	5	8	29.8	C	2	3
	Westbound Approach	49.2	D	4	6	48.6	D	6	10
	Northbound Approach	3.3	A	1	2	19.1	B	9	17
	Southbound Approach	10.6	B	9	17	7.1	A	4	10
	Bus Exit Lane Approach	0.0	A	--	--	42.2	D	1	1
	Overall	**11.7**	**B**	**n/a**	**n/a**	**17.4**	**B**	**n/a**	**n/a**
Woodley Road and North Road Unsignalized (all-way stop)									
	Eastbound Approach	7.9	A	n/a	n/a	7.7	A	n/a	n/a
	Westbound Approach	7.9	A	n/a	n/a	7.9	A	n/a	n/a
	Northbound Approach	0.0	A	n/a	n/a	7.7	A	n/a	n/a
	Southbound Approach	7.9	A	n/a	n/a	7.4	A	n/a	n/a
	Overall	**7.9**	**A**	**n/a**	**n/a**	**7.8**	**A**	**n/a**	**n/a**

APPENDIX B

2004-2005 Trapier Theatre Schedule of Events

St. Albans School
Traffic and Parking Analysis

1. Trapier Theatre Events 2004-2005

- Winter Play (Upper School) — 11/12, 11/13 – 8 p.m.
  (3 hr performance) — 11/14 – 2 p.m.
  310 audience members/34 cast & crew members

- Battle of the Bands — 11/19 - 7:30 p.m.
  (3 ½ hr event)
  Over the 325 theatre capacity, with people standing in the aisles

- Winter Play (Lower School) — 12/10 – 6 p.m.
  (3 hr performance) — 12/11 – 7 p.m.

- Workshop — 1/29
  150 attendees — All Day

- Winter Musical (Upper School) — 2/25, 2/26 – 8 p.m.
  (3 hr performance) — 2/27 – 2 p.m.
  300 audience members/24 cast & crew members

- Variety Show — 3/11, 3/12 – 8 p.m.
  (2-3 hr event) — 3/13 – 2 p.m.
  300 audience members/65 cast & crew members

- Spring Musical (Lower School) — 4/15 – 6 p.m.
  (3 hr performance) — 4/16 – 7 p.m.
  — 4/17 – 2 p.m.
  300 audience members/55 cast & crew members

- Spring Musical (Upper School) — 4/29, 4/30 – 8 p.m.
  (3 hr performance) — 5/1 – 2 p.m.
  — 5/6, 5/7 – 8 p.m.
  300 audience members/90 cast & crew members

- Lower School Music Concert — 4/29 – 1:30 p.m.
  (1 hr performance)
  300 audience members/30 boys in ensemble

- Concert — 5/13 – 8 p.m.
  (2 hr performance)
  250 audience members/30 performers

APPENDIX C

St. Albans School Performance Arrival Rates

2. **Arrival Patterns**

   (Ex. 8 p.m. show)
   - Cast arrives at 6 p.m. (2 hours prior to show)
     Audience begins to arrive at 7 p.m.
     Arrival surge at 7:45 p.m.

3. Arrival Pattern (in 15 minute increments)

   - (before curtain goes up)
     6:00 p.m. – 80 people
     6:15 p.m. – 10 people
     6:30 p.m. – 5 people
     6:45 p.m. – 0 people
     7:00 p.m. – 25 people
     7:15 p.m. – 25 people
     7:30 p.m. – 50 people
     7:45 p.m. – 50 people
     8:00 p.m. – 50 people

   - (after curtain goes down)
     275 people leave within 15 minutes
     The rest leave within 30 minutes

4. Average Number per Vehicle

   - Cast – 3 per car
   - Audience – 3 per car

F

ADVISORY NEIGHBORHOOD COMMISSION 3C
GOVERNMENT OF THE DISTRICT OF COLUMBIA
CATHEDRAL HEIGHTS • CLEVELAND PARK • MASSACHUSETTS AVE. HEIGHTS
MCLEAN GARDENS • WOODLEY PARK

Single Member District Commissioners
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RESOLUTION 2005-033

Regarding St. Albans School HPRB Application (05-213)

WHEREAS the Protestant Episcopal Cathedral Foundation (PECF) has applied to the District of Columbia Historic Preservation Board (HPRB) for conceptual approval of a master plan development for St. Albans School on the grounds of the Cathedral Close, a local and federal landmark property; and

WHEREAS the HPRB will evaluate whether this application retains and enhances the historic landmark, encourages adaptation for current use, and ensures that changes to the landmark are compatible with its historic character; and

WHEREAS the Cathedral Close landmark is notable for the cathedral structure and the grounds, which were planned and designed by Frederick Law Olmsted, Jr.; and

WHEREAS the proposed project includes a new 3-story structure that would connect existing St. Albans buildings and a new partially underground 600-seat performing arts center; and

WHEREAS the plans for this building complex are incomplete since a proposed tower structure is being redesigned, but the new building plans that have been submitted are architecturally compatible with existing structures at St. Albans and do not appear to interfere in any way with the views of the Cathedral; and

WHEREAS the building complex plans include the removal of 73 trees, 8 of which are covered by the District Tree Protection Act; and

WHEREAS the proposed project includes an enlargement and reconfiguration of athletic fields for St. Albans School in the southeast quadrant of the Cathedral Close; and

WHEREAS Frederick Law Olmsted, Jr. wrote on March 16, 1920 that the southeast quadrant (at the time extending only as far as 34th Place and Garfield St.) was the only appropriate location for the "Boys' School" athletic field:

Replying to your letter of March 14th we beg to say that an athletic field approaching anywhere near 400 feet square and placed immediately eastward of the Boys' School would block the important entrance to the cathedral grounds from Massachusetts Avenue and Garfield Street. On the whole, the only practicable place anywhere on the Cathedral property for a considerable athletic field is in the southeast corner. Anywhere it is put it will involve a very large amount of grading and the full dimensions of 400 feet square cannot be secured anywhere without cutting very badly into the wooded hill close to the approach drive. We are making up two studies: one for an athletic field nearly 400 feet square and one for a smaller field of more irregular shape providing space enough for one full sized gridiron and for a full sized baseball field, the latter overlapping the gridiron.[1]

WHEREAS the proposed athletic complex would cut into the hillside separating Beauvoir School from the existing athletic fields, remove portions of the Beauvoir playground, relocate the Beauvoir outdoor swimming pool, and remove 177 trees, at least 30 of which are trees with a trunk circumference of more than 55" and thus, are covered by the District Tree Protection Act; and

WHEREAS the approach to the Cathedral from Pilgrim Road was designed by Frederick Law Olmsted, Jr. to gradually reveal the structure through the trees and winding road; and

WHEREAS Mr. Olmsted in commenting on a planting plan wrote:
This idea of purple flowers in connection with the cathedral landscape work is an interesting one, and it could be made a recurring note, as it were, about the grounds, always, watching carefully the color combinations and especially the maintenance of the dominant, permanent foliage effects, especially as typified by those evergreens like box and yew and rhododendrons which attain great age and in combination with long lived large trees are among the most essential elements in creating that venerable permanency of aspect which should be the fundamental landscape quality both of the Bishop's Garden and of other parts of the Close[2].; and

WHEREAS the proposed plans call for 6-to-10-foot chain link fencing along the 34th Street and Garfield Street edge of the Cathedral Close, as well as part of Pilgrim Road, and this would continue the use of chain link fencing to enclose the eastern and southern portions of the Cathedral Close; and

WHEREAS the athletic field plans include substantial re-grading of this part of the Cathedral Close, which will interfere with some views of the Cathedral:

- raising the ground level of the baseball field on the Garfield Road side by approximately 5' at the right field edge to approximately 9' at the center field edge, which will obscure some ground level views of the Cathedral;
- lowering the ground level for the tennis courts at Garfield Road and 34th Street to the level of 34th Street, which will place them about 11 feet below the adjoining baseball field, and which should not obscure views of Cathedral
- lowering the ground level for the second group of tennis courts on 34th Street by approximately 12', which places them 1 foot higher than the

[1] March 16, 1920 letter from Frederick Law Olmsted, Jr. to Rev. George Bratenahl, Dean of the Cathedral
[2] January 5, 1926 letter from Frederick Law Olmsted, Jr. to Rev. James E. Freeman, Washington Cathedral

sidewalk and 6.5 feet higher than the courts fronting on Garfield Street and 6 feet lower than the baseball field

- lowering and leveling the ground level for the proposed practice field on 34th Street by approximately 1 to 6 feet, which places the field 7 feet higher than the tennis courts below it
- raising the ground level for the proposed football/track stadium on the 34th Street side by approximately 2 to 11 feet by sloping the ground level up, (northern edge calls for lowering the ground level approximately 2 feet before the slope up begins), which could impact views of Cathedral
- installing a retaining wall in public space on 34th Street side of football/track stadium to accommodate grade changes
- raising the ground level of the proposed football/track area (where there is an existing field) by approximately 9 feet and lowering the ground level at the northern end of the proposed field (where there is a treed ridge) by approximately 35 feet to accommodate a new football field/track located farther to the north, which will impact views of Cathedral
- building a 20 foot high arcaded retaining wall between the baseball field level and the football/track field level
- creating 20.5 foot cement and wooden 600+ person spectator area topped with a 9 foot press/broadcast box
- building new access road between Beauvoir School and football stadium
- lowering the sloped ground on the east side of Pilgrim Road approximately 10 feet to accommodate the baseball field
- creating a 2-level entry plaza with parking lane area for pick-up and drop-offs off Pilgrim Road
- building an outdoor swimming pool structure between Pilgrim Road and proposed football field/track that appears to be located about 10 feet below grade level; and

WHEREAS the current plans call for the demolition of 177 trees, including nearly all of the trees south of Beauvoir School to Garfield Street and east to 34th Street, as well as all the trees on the east side of Pilgrim Road from Garfield Street to the service drive:

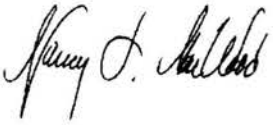
THEREFORE BE IT RESOLVED that Advisory Neighborhood Commission 3C (ANC 3C) supports in concept the proposed plans to build an academic building and an underground performing arts center as compatible with the historic character of the Close, but reserves the right to review the redesign of the tower structure; and

BE IT RESOLVED that ANC 3C urges the HPRB to require the retention of any hardwood trees that could be saved with appropriate protections during construction of the buildings, a detailed landscape plan to augment the general plan submitted to ANC 3C that should include large hardwood trees in keeping with the Olmsted vision of creating a "venerable permanency of aspect"; and

BE IT RESOLVED that ANC 3C conditions its support for the athletic field expansion and reconfiguration on

- The creation of a perimeter fencing plan for 34th Street and Garfield Street to replace or front the chain link fencing, which substantially detracts from the landmark, and to require that the material and design enhance the landmark and be compatible with the historic character of the landmark;
- The development of a landscape plan as a central feature of the reconfiguration of the athletic fields and not just outside the fencing, and that it include a serious effort:
  - To preserve mature hardwood trees, which are central to Olmsted's vision and plan for the Close,
  - To weave hardwood trees into the layout of the fields so as to soften the appearance of terraced, flat surfaces, which are antagonistic to the hilly, informal character of the Close, and
  - To landscape the east edge of Pilgrim Road so that the athletic fields and buildings are secondary to the experience of approaching the Cathedral through a wooded drive that gradually reveals the architecture of the structure; and
- The lowering of the proposed height of the football/track stadium so that it
- Does not compete with the views of the Cathedral and camouflaging, to the extent possible, the amount of athletic surfaces and the prominence of Beauvoir with a plant and tree selection that connects the southeast quadrant of the Close, with its majestic views of the Cathedral, to the mature and elegant Olmsted landscaping found throughout the Close; and
- The examination of the need for an access road and, if one is necessary, locating it where it is not visible from a distant perspective and constructing it of permeable material; and

BE IT FURTHER RESOLVED that the Chair or her designee, is authorized to represent the Commission on this matter.

Attested by  Chair, on May 17, 2005

Nancy J. MacWood

This resolution was unanimously approved by a vote of 8-0 by ANC 3C at its publicly noticed monthly meeting on May 16, 2005, at which a quorum of 8 of 8 members was present.

G

St. Albans School

Performing Arts Center, Loading Dock and Athletic Fields

Hydrological Impact Assessment

St. Albans School

Performing Arts Center, Loading Dock and Athletic Fields

Hydrological Impact Assessment

January 2005

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Job number 130437-60

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EXECUTIVE SUMMARY

A hydrological study has been carried out to assess the impact of proposed below ground structures for St. Albans School, Washington DC. The proposed works consist of:

- A reconfigurations of the Athletics Fields in the area of the existing baseball field and tennis courts
- New Wing Addition and a new Loading Dock adjacent to the existing New Wing and Lane-Johnston Building
- A new Performing Arts Center adjacent to the Trapier Theatre, New Wing and Senior Circle.

To assess the impact of the proposed works on the existing ground water flow, the existing hydrological environment was studied, incorporating the results of ground water monitoring around the Close since 1999 and previous studies carried out for the area of Olmstead Woods.

The results of this study conclude that no part of the permanent below ground structures extend below the highest recorded ground water levels, and the proposed structures will not impact the existing hydrological environment.

Temporary sheet pile retaining walls will extend below the ground water surface and will have an impact on the natural ground water flow in the immediate vicinity of the below ground works. These sheet pile walls are required to provide temporary support for the basement and Loading Dock excavations. Once the excavations are complete, the permanent concrete bases and w alls are constructed and the sheet pile walls will be extracted.

Whilst the sheet pile walls are installed in the ground, they will form a barrier to the ground water flow in locations where the sheet pile walls run perpendicular to the direction of water flow. To determine the impact on the ground water flow, a 2-dimensional numerical analysis has been carried out. Conservative assumptions have been adopted for the parameters within the model and therefore the results represent an upper bound assessment of the impact of the sheet pile walls on the ground water flow. The results of the analyses indicate that, at the location of the sheet piles, the damming effect of the sheet pile wall will cause the ground water surface to rise by up to 4ft behind the wall and drop by a maximum of 4ft in front of the wall. At a distance of 80ft from the wall, the ground water surface will be unaffected and will remain at the natural level.

The results of these analyses therefore confirm that the installation of temporary sheet pile walls will cause a small impact on the ground water levels. This effect is localized to within 140ft of the wall location and the impact for the wider site area is negligible. Once the sheet pile walls are extracted at the end of the construction period, the ground water levels will revert to their original levels, with no residual impact on the ground water levels in the area.

1. INTRODUCTION

Arup was commissioned by St. Albans School, Washington DC, to assess the impact on ground water of new above and below ground developments on the school site.

The study had the following objectives:

- Produce a conceptual model of ground water conditions under pre and post construction conditions.
- Assess the impact of temporary and permanent below ground construction works.
- Assess the impact of the development on Olmsted Woods.
- If the conceptual model suggests unacceptable impacts undertake numerical modelling to further define the extent and severity.
- Suggest mitigation measures to ensure no unacceptable impacts.

The following approach was adopted to achieve these objectives:

- Data collation.
- Site Walkover (25 October 2004, St. Albans School buildings, Olmsted Woods, Athletic fields).
- Develop an understanding of the environmental setting and produce a conceptual model.
- Review proposed development to identify potential impacts.
- Assess hydrological changes as a result of new development.
- Consider other developments that have had an adverse impact on hydrology.
- Carry out numerical modelling to quantify potential impacts.
- Assess significance of predicted impacts and identify possible mitigation measures.

ENVIRONMENTAL SETTING

1 Site Description

The National Cathedral Close is located in Northwest Washington, DC. The site of approximately 60 acres is bounded by Woodley Road to the north, 34th Street to the east, Garfield Street to the south and Wisconsin Avenue to the west. The Cathedral Close has a number of existing structures comprising the Washington National Cathedral in the northeast, St. Albans School buildings in the southwest, Beauvoir School buildings in the east, the National Cathedral School (NCS) in the northwest, athletic fields and light structures in the southeast and a permanently drained underground athletics facility, the NCS Field House, in the northeast. An area of mixed woodland, known as Olmsted Woods, is located in the center of the site (Figure 1).

The National Cathedral building works were completed in 1990. This structure has significant foundations extending to a maximum depth of 26.5 feet.

The St. Albans School buildings are understood to have shallow foundations, with the exception of Martin Gym which is understood to be supported on piled foundations.

The NCS Field House in the northeast part of Cathedral Close was constructed in 1999/2000 and extends 40 feet below ground.

2 Previous Ground Investigations

Several geotechnical investigations have been carried out on the site. The following have been reviewed as part of this study:

Geo-Technology Associates (2000). *Report of Hydrogeologic Evaluation – Washington National Cathedral, Washington, DC*

Schnabel Engineering North LLC (2003). *Ground Water Hydrology Study Report, Cathedral Close, N.W. Washington DC*

Schnabel Engineering North LLC (2004a). *Geotechnical Engineering Subsurface Investigation Report. National Cathedral Close, Northwest, Washington, DC*

Schnabel Engineering North LLC (2004b). *Geotechnical Data Report, St. Albans School, Commons and Performing Arts Center, National Cathedral Close, Northwest, Washington, DC*

In addition to these studies, Schnabel performed site investigations at the School in 2004 for the proposed Performing Arts Center, Loading Dock and Athletic Fields, 1994 for the Lucas Building addition and 1976 for the Martin Gym. Schnabel also performed a geotechnical investigation on the National Cathedral in 2002. The investigations cited above included 31 geotechnical borings and the installation of 16 water observation wells (Figure 2). Geo-Technology Associates carried out a hydrogeological assessment of the center of the site in 2000 producing estimates of hydraulic conductivity of the geological units encountered in the proposed development areas.

3 Topography

A topographic plan showing pre-development contours across the site in 1884 has been used to assess natural drainage patterns.

The topography of the site in 1884 comprises a ridge trending west to east along the northern half of the site descending from a maximum elevation of 390ft in the northwest to El 290ft in the northeast. Ground elevation in the southern half of the site slopes down from the ridge and is incised with four valleys oriented north-south, evenly spaced across the site. The three easternmost valleys converge in the center of the southern site boundary. Ground elevation along the southern boundary varies between El 360ft in the west and El 280ft in the east.

The National Cathedral is situated on a topographical ridge which is oriented southwest-northeast at a level between El 385 and 375ft. The site generally slopes down from this ridge to the southeast with elevations varying between a maximum of 385ft in the northwest and a minimum of 270ft in the southeast. Ground levels along the southern boundary display evidence of engineering with a steep embankment between the St. Albans School buildings and Garfield Street which rises from El 330 to 360ft at the western end tapering out to a ground elevation of 310ft at the eastern end. An embankment oriented approximately southeast-northwest is present between the Beauvoir School buildings and the present athletic fields. The height of this embankment drops from El 315 to 305ft from northwest to southeast with a ground surface elevation of 300ft in the northwest and 295ft in the southeast. The athletic fields are bounded on the western side by a slope running north-south parallel with the access road, tapering out to the north from 10ft above ground level at the southern end with a ground surface elevation of 298ft.

The main topographic features of the southern part of the Cathedral Close are three valleys, two in Olmsted Woods oriented north-south and one running east-west between the St. Albans School buildings and the athletic fields. These valleys are shown in Figure 3 as the western valley, eastern valley and southern valley. In previous studies (Schnabel, 2003) the eastern and southern valleys were identified to be channelling water from springs (Figure 3). Following the completion of the National Cathedral increased runoff caused erosion of the eastern valley channel prompting studies to assess remedial measures to be commissioned. A topographic map of the site topography dating from 1884 shows the presence of two further valleys. One valley located below current St. Albans School buildings linked the western and southern valleys; the other was situated below the athletic fields in the southeast of the site and oriented north-south. Both valleys have been filled since 1884 but may continue to influence hydrology.

2.4 Geology

The site is located in the Valley and Ridge Province of Maryland in the Great Valley (locally known as the Hagerstown Valley) formed on Cambrian and Ordovician limestone and dolomite. The site itself is underlain by the Georgetown Intrusive Suite of early Ordovician age, specifically a biotite-hornblende tonalite, a medium to coarse grained, massive to foliated rock (MGS, 1981).

Published geological maps suggest the majority of the site is covered by a thin layer of Tertiary colluvium consisting of sparse pebbles in a clayey matrix. In the east of the site early to middle Miocene sedimentary deposits are indicated on published maps. The oldest sedimentary deposit present is the Tertiary Calvert Formation, a clayey silt and fine grained quartz sand which is diatomaceous where fresh. It was deposited in widespread seas and, where it has become weathered it becomes a very fine grained to medium coarse sand with discoidal quartz pebbles. The Calvert Formation is overlain by a crudely bedded Tertiary gravel, sand, silt, and clay unit.

Previous site investigations have broadly confirmed the published geology establishing the top surface of bedrock at between El 250 and 270ft sloping gently to the east. The Tertiary deposits are more substantial than the geological maps suggest, with a thickness of up to 100 feet. The lower sand and gravel unit consists of clayey and silty sand and gravel interbedded with clay lenses of limited lateral extent. The upper section of this unit is fine to coarse sand, the outcrop of

which is shown on Figure 3. This is overlain by a silt and clay unit formed by sandy silt and clay with some gravel layers near the base of the unit. The upper sand and gravel unit is a poorly graded clayey sand with clayey gravel. The fill material, found predominantly in the filled valleys, consists of clayey and silty sand with gravel, with scattered asphalt and wood fragments (Schnabel, 2004).

2.5 Hydrology and Hydrogeology

2.5.1 Precipitation

Rainfall data for the city of Washington DC was obtained from the National Oceanographic and Atmospheric Administration (NOAA) website (www.noaa.gov) (Figure 4) and the Atlantic Coast Observer Network (ACON) website (www.jhuapl.edu/weather). Average annual precipitation in the city is 44 inches. In 2003 62 inches fell, the highest for 50 years. Storm events deliver roughly one third of the annual rainfall. In 2003 there were approximately 20 days with greater than 1 inch of rainfall recorded. The rainfall records show much higher levels of annual rainfall approximately once every seven years (Figure 4). Schnabel (2003) suggests average annual rainfall between 40 and 45 inches with most storm events only producing 0.5 to 1 inch of rain.

2.5.2 Surface water

On the day of the site visit (October 25th 2004) the only observed surface water was at the emergence and the eastern end of the southern spring. No running water was noted, however Schnabel (2003) identify springs in the southern and eastern valleys. The western valley displays evidence of surface water flow with pipes beneath roads and structures such as the amphitheater stage but was dry during the site walkover. A boggy area was observed at the location shown on Figure 3. It is reported that the valleys channel surface runoff during storm events and water emerges at the springs when the water table rises sufficiently.

2.5.3 Drainage Management

Construction of the National Cathedral permanently altered the hydrology of the Cathedral Close increasing runoff and reducing infiltration as a result of large areas of hard standing, such as the Cathedral roof, roads and parking areas. The runoff is directed beneath Pilgrim Road and into the Eastern Ravine where it has caused increased erosion. The associated reduction in infiltration may have resulted in a fall in ground water levels beneath the cathedral.

Several studies have been commissioned by the Cathedral Close management and it is understood that works have been implemented to reduce the impacts of increased runoff. The Cathedral Close management has indicated that a retention tank has been installed to store storm runoff from the National Cathedral and allow it to infiltrate into the aquifer beneath Olmsted Woods. The capacity of the tank is not known at the time of reporting, however the Cathedral Close management has indicated that there is an overflow pipe from this tank directed into the eastern valley.

During construction of the Martin Gym it is understood that water was encountered above the founding level resulting in a drainage network being emplaced below the gym building discharging into the Southern Valley. The Lawrence Pool building has suffered from flooding in the past. It is understood that surface water is piped beneath the Service Road to the north of the Martin Gym, beneath the gym and into the Southern Valley. It is understood that there is a drain in the southeast of the site, beneath the intersection of Garfield Street and 34th Street.

2.5.4 Ground water levels

Ground water levels are measured regularly by the Cathedral Close staff with boreholes W1, W2 and W3 dipped monthly since November 1999, and boreholes W4, W5, W6, W7, W8 and W9 dipped quarterly since August 2003 and boreholes W10 and W11 dipped monthly since August 2003. These data were used to produce hydrographs representing water level variation across the site (Appendix A). Levels to the southeast of the Cathedral ridge show little variation between mid 2003 and 2004 with levels in W4 to W9 fluctuating over a maximum of 4 feet. Ground water levels in the vicinity of the Cathedral (W1, W2 and W3) display a sharp rise of up to 12 feet between late 2003 and early 2004 (Figure 5), falling again in late spring 2004 and to a lesser extent this peak is observed in the other monitoring wells across the Close. This rise may be associated with the unusually high precipitation experienced during 2003 (Figure 5), the highest for 50 years. The hydraulic gradient across the site broadly reflects topography with a typical value of 0.05.

Ground water contours for maximum (peak), average and minimum conditions (Figures 6, 7, 8) have been produced based on available monitoring data from boreholes W1-11. The seasonal variation in ground water levels is less than +/- 5 feet, with most pronounced range in the vicinity of the Cathedral. Beneath St. Albans School the observed variation is approximately +/- 2 feet (from August 2003 to October 2004 in W4).

Records of ground water encountered during drilling and stabilized ground water levels from 51 borehole logs have been tabulated (Appendix B) and used to assess the presence of perched water levels. Perched water is an isolated pocket of ground water within a stratified soil, bounded by zones of lower permeability strata, and is not indicative of the general ground water surface in the area. The level at which water is encountered during drilling of the borehole may not be representative of the stable water table elevation due to the drilling process or perched water levels. A large proportion of the records near the National Cathedral and beneath the current athletic field show evidence of perched water. Few boreholes beneath the St. Albans School buildings suggest perched water is present.

2.5.5 Hydraulic characteristics

The ease with which water is able to pass through a geological formation is described by its hydraulic conductivity (K). Due to the depositional environment of the Tertiary sediments ground water flows more readily horizontally than vertically resulting in a higher horizontal hydraulic conductivity (K_H) than vertical hydraulic conductivity (K_V). The horizontal hydraulic conductivity of unconsolidated sediments is usually assumed to be approximately ten times greater than the vertical hydraulic conductivity, if no site-specific data is available.

The main water-bearing unit on site is the lower sand and gravel. Geo-Technology Associates (2000) undertook field falling head tests to assess vertical and horizontal permeability. The upper 4 to 5 feet of the lower sand and gravel was considered the most permeable section of the geological profile with a K_H of 42m/d, while the unit has an average K_H of 8.64m/d and a K_V of 0.2m/d. Field testing of the silt and clay which overlies the lower sand and gravel indicated the unit has a much lower hydraulic conductivity, with a K_H of 0.8m/d and a K_V of $4x10^{-3}$ m/d. The upper sand and gravel K_V from field testing was indicated to be 0.02m/d (K_H was not assessed).

2.6 NCS Field House

Arup has learned that there were community concerns about the construction of the NCS Field House, a sub-water table building in the northeast of Cathedral Close, in 1999-2000. In particular, there were concerns regarding the impact of the construction on ground water levels

and the consequences for neighboring properties. The building has a permanent integral ground water drainage system.

The impact of the NCS Field House construction on the hydrology can be assessed from the comparison of ground water contours now, as shown on Figure 2, and those estimated as pre-construction ground water levels in Figure 3. The pre-construction ground water levels have been determined from observation of the general ground water characteristics in the area. It can be seen that the change in ground water levels is localized in the northeast corner of the Close and there is negligible impact on the ground water flow in the areas of study for this report.

The presence of the NCS Field House and the associated ground water drainage system is therefore not considered further within this hydrological impact assessment.

3. PROPOSED DEVELOPMENT

3.1 Performing Arts Center and Loading Dock

The largest proposed area of construction on site is around the Trapier Theater and New Wing buildings of St. Albans School, in the southwest corner of the site (Figure 9). A new level loading dock is planned to the south of the existing New Wing building with a final elevation of 312ft. To the north of New Wing and the Trapier Theater, underneath Senior Circle, a new Performing Arts Center will be situated. This will extend below ground and have a multi-level stepped base with final elevations of 329, 327, 319 and 310ft.

During the construction phase temporary underground works will be employed to stabilize the excavations. These temporary works will predominantly consist of sheet pile walls sunk to a depth greater than the final elevation (Figure 10), with a maximum depth of 70feet below ground level (fbgl) in the Performing Arts Center, and 45fbgl in the loading dock. The sheet pile walls are formed by interlocking corrugated steel panels that are driven into the ground to allow for excavation in front of the wall to the required level. Temporary works may be removed following construction.

Permanent subsurface structures are limited with two concrete pile tangent pile walls planned, one along a section of the Performing Arts Center wall running southeast-northwest, the other with the same alignment along the southern wall of the New Wing (Figure 10). The Performing Arts Center building will be founded on shallow footings.

3.2 Reconfigured Athletic Fields

A reconfiguration of the existing surface Athletics Fields in the eastern part of the site is proposed (Figure 9). A new permanent seating area is also to be constructed which will be cut into the embankment and require the relocation of the Beauvoir Pool. The ground level adjacent to the seating area is to be raised by 10 feet using fill material to form a northern athletic field. The southern area of the Athletic Fields will be at a lower level, with tennis courts located on terraced levels over the southeast of the site. The cut and fill operations for the Athletic Fields will be balanced to minimize the transport of materials to and from the site.

The boundary between the upper and lower fields may be constructed using some form of retaining wall structure, but it is not planned to extend below the final ground level for the southern athletic field of about El 290ft. An arcade structure has been schematically designed to run along the interface of the lower and upper fields. This structure may require piled foundations, typically at 15ft spacings.

The reconfiguration of the new Athletic Fields is therefore largely superficial and has limited sub surface works (Figure 11). Any piled foundations for the arcade structure are widely spaced and these isolated elements in the ground will not impact on ground water flow in the area.

3.3 Other Developments

In addition to the Performing Arts Center, Loading Dock and reconfigured Athletic Fields, more development is planned on the Close, the impacts of which are not assessed in this study. The lawn to the north of the National Cathedral is to have an underground parking facility constructed beneath it with works due to commence in spring 2005. The structure is to be a 4-level parking garage with the lowest level founded at an elevation of 345ft. The structure will therefore be

located above the ground water level in this area and the flow of ground water from the north of the site should not be affected. The potential increase in runoff due to this construction may be significant and should be addressed in the drainage design.

4. IMPACT ASSESSMENT

4.1 Approach

Plans outlining the proposed areas of development and the extent of the work to be undertaken were made available to Arup by the St. Albans School and the design team. This information combined with geological maps and ground water monitoring data allowed cross sections through the new development areas to be constructed with a view to assessing the potential impact of the temporary and permanent sub surface works on the flow of ground water across the site. A conceptual model was developed for each structure incorporating historical, geological and hydrogeological data and used to assess the potential impact of each area on the flow of ground water. Areas where the new developments may impact on ground water flow were numerically modelled to assess the extent of the effects.

4.2 Conceptual Model

4.2.1 Reconfigured Athletic Fields

The Athletic Fields project is a redevelopment of the existing facility in the eastern area of the site (Figure 9). The proposed works consist of relatively minor, superficial works to construct a permanent seating area, and re-profile the area to provide upper and lower athletic fields and tennis courts on terraced areas in the extreme southeast of the site. The new seating area will require limited excavation of the lower sand and gravel unit to a maximum depth of 7 feet, with up to 15 feet of fill material used to achieve the final elevation of the upper athletic field. The fill for the upper field will be obtained from the reduction in ground levels in the southern area of the site to produce a balanced cut and fill operation.

The limited excavation work to be undertaken will occur in the lower sand and gravel unit as shown on Figure 11. There are no planned works below the maximum recorded water level and the depth of excavation is at least 20 feet above the average water table. A pool building on the site of the seating area will be demolished and rebuilt nearby but the existing structure is not thought to have extensive foundations.

The surcharging work to raise ground levels is not expected to have any adverse impact on ground water levels, as ground conditions are not identified as loose and compression sufficient to cause a significant decrease in hydraulic conductivity is not predicted.

If piled foundations are required for the arcade structure at the boundary of the upper and lower fields, these will be placed at 15ft intervals along the line of the arcade. Steel H-piles are envisaged, with a typical width of about 10". Therefore, along the line of the arcade, the piles will present an obstruction to the ground water flow over 5% of the length of the arcade. 95% of the area is therefore unaffected and the overall impact of the piled foundations on the ground water flow is insignificant.

In summary there are no predicted ground water impacts associated with the proposed works for the reconfigured Athletic Fields.

4.2.2 Performing Arts Center and Loading Dock

The Performing Arts Center is a multi-level development to be constructed under Senior Circle on the St. Albans School site. The area the building will occupy is approximately 20,000 sf, to the northeast of the New Wing and Trapier Theater, shown on Figure 9. Sections through the

proposed Performing Arts Center excavation showing final elevations for the base of the structure, geology and water level are presented as Figures 12 and 13.

The loading dock to the south of the New Wing will have a final elevation of 308ft, and cover an area of approximately 15,000 sf. A cross section through the loading dock showing final elevation, geology and water levels is presented as Figure 14.

As shown in Figures 12 and 13 the Performing Arts Center excavation is principally through the upper sand and gravel unit, with most of the final foundation, at between El 327 and 329ft, penetrating the silt and clay unit. Two basement sections at El 310 and 319ft lie in the lower sand and gravel unit however these do not extend below the maximum recorded water level. The northern end of the Performing Arts Center excavation, shown in Figure 13, may encounter perched water associated with the presence of a clay lens between 11 and 16fbgl. The loading dock excavation is almost entirely in the lower sand and gravel unit with the foundation level above the maximum recorded water table elevation.

The sheet pile walls (SPWs), as described in Section 3.1, to be used during the construction phase locally extend below the average water table and have the potential to impede ground water flow across the site by acting as a dam. Although they are not designed to be water tight there will be a degree of modification to the natural flow system associated with the SPW. Notably the deepest basement area of the Performing Arts Center, which is already close to the ground water table, has a SPW which reaches approximately 25 feet below the water table. This will impede flow during the period the SPW is in place. If the SPW is left in situ post-construction the flow of ground water will continue to be affected. However long term impacts would be negligible if the SPWs are removed following construction. Ground water flow would return to original conditions soon after removal.

Permanent sub-ground water works in the Performing Arts Center and loading dock development comprise only two tangent pile walls (TPWs) oriented northwest-southeast, one on a section of the Performing Arts Center wall and the other along the southern wall of the New Wing. The foot of these structures is at El 285ft, which at both locations is below the average water table elevation. The TPWs are not designed to be water tight but potentially could impact on ground water flow by acting as a dam. However both TPWs are aligned with their long axes parallel to the direction of flow which will minimize the impact on ground water. Slight alterations in the flow pattern and water table elevation near the walls will be observed but the effects will be negligible with relation to both the large scale flow across the site and water levels impacting on the new construction.

In summary:

- None of the proposed excavations extend below maximum (peak) ground water levels in the Performing Arts Center and loading dock development.
- Two tangent pile walls, shown on Figure 10, are predicted to extend below ground water levels. However as both walls are parallel to predicted ground water flow direction as determined from the contours of current ground water levels, impact is predicted to be negligible and no numerical modelling has therefore been undertaken.
- Five sheet pile walls, shown on Figure 10, are predicted to extend below ground water levels. These SPWs are required for temporary stabilization of excavations only, but may be left in place following construction. These SPWs are not designed to be water tight and will allow some flow of ground water. One of the sheet pile walls, SPW B, is approximately parallel to ground water flow direction, resulting in negligible impact. The potential impacts of SPWs

A, C, D and E to ground water levels have been considered further by numerical modelling discussed below.

4.3 Numerical Model

4.3.1 Base case models

The impact on ground water levels of sheet pile walls extending below the maximum ground water table in the Performing Arts Center and loading dock (SPWs A, C, D and E on Figure 10) has been assessed using numerical modelling techniques.

The most appropriate modelling approach, considering the available data, is a 2-dimensional cross-section 'slice' model through the proposed development, specifically the sub-water table sheet pile walls. SEEP/W (1999) was used to model the each section of SPW which extends below the average water table. SEEP/W is an industry-standard 2-dimensional seepage analysis graphical software program that models both saturated and unsaturated flow.

Four cross sectional models were developed representing SPWs A, C, D and E – the sheet pile walls that penetrate the ground water surface by a significant distance. All models used input parameters in Table 1 in the 'base case'. The modelled initial conditions and modelled output for each scenario is included in Appendix C. Sensitivity analyses were subsequently carried out to assess variability of output to sensitive input parameters.

The system was assumed to be in steady state with an initial water table set at the maximum observed ground water elevation. Fixed head boundary conditions were set at a sufficient distance from the SPW to ensure the flow near the SPW was not influenced by boundary conditions.

To enable modelling using SEEP/W the SPWs are represented using an extremely low permeability zone of 10^{-13}m/s to represent effectively impermeability. It is assumed in the model that the SPWs are of infinite lateral extent as the system is simplified to two dimensions. The model assumes bedrock is impermeable. These assumptions introduce conservatism into the model. The predicted change in water levels will therefore be overestimated as, in reality, water can flow around the ends of the SPWs and some leakage through the SPWs is likely.

The results of the modelling are presented in Table 2. The largest calculated rise in water levels from the models occur up flow of SPWs C and D with an increase of 4 feet adjacent to the SPW.

The model output has been analysed to assess the distance from the SPW that the change in groundwater level is less than 6 inches. Considering the uncertainties and conservatism inherent in the model a 6 inch change predicted by the model is considered negligible. The distance from the SPW to negligible change in groundwater levels is presented in Table 2 and has a maximum value of 140 feet for SPW C. In plan view the area of change in groundwater levels will be elliptical and will reach a maximum perpendicular to the centrepoint of the SPW. At the ends of the SPW the distance to the point of negligible change in groundwater levels will be significantly less. The change in groundwater levels is predicted to have a negligible impact on Olmsted Woods.

4.3.2 Sensitivity analysis

As many of the input parameters in the modelling are uncertain or spatially variable, sensitivity analysis was undertaken to assess confidence in the model output. The sensitivity of the predicted head change across the SPW to variation, within realistic bounds, of the following uncertain parameters was assessed:

- Vertical hydraulic conductivity (K_V) of lower sand and gravel
- Horizontal hydraulic conductivity (K_H) of lower sand and gravel
- Thickness of lower sand and gravel.

The sensitivity of the model outputs to vertical hydraulic conductivity (permeability) of the lower sand and gravel was assessed. The field measurement of K_v in the lower sand and gravel gave a value of less than 3% of K_H (Geo-Technology Associates, 2000). This value is atypically low for this type of formation, 10% being a more typical value.

In the sensitivity analysis K_v was increased to 10% of K_H. This resulted in a slight reduction of calculated impact. The impact of increasing K_v to 10% of K_H on model output is presented in Table 2.

The water table is located in the lower sand and gravel unit and the hydraulic conductivity of this unit was estimated from one field test performed some distance from the site. In order to assess the sensitivity of the model outputs to hydraulic conductivity the input value was reduced by one order of magnitude. This reduced hydraulic conductivity was applied to the reduced thickness of lower sand and gravel to give the most conservative case. This resulted in the same change in ground water level upgradient and downgradient as the base case model but the effects were more local to the SPW.

The thickness of the lower sand and gravel is a relatively uncertain parameter as all borings in the southwest of the site are too shallow to encounter bedrock. Depth to bedrock was extrapolated from site investigation borings in the southwest of the site that encounter bedrock. The sensitivity of the model to thinner lower sand and gravel was assessed. The sensitivity analysis assumed that the minimum possible thickness at each SPW was the depth of the deepest boring plus 5 feet (an assumed thickness to represent permeable weathered bedrock). The sensitivity analysis showed that the modelled reduction in thickness of the lower sand and gravel unit had no significant effect on the model outputs, and therefore the predicted impacts remained the same as the base case models.

Table 1 Input parameters for numerical modelling

Parameter	Source	Value and Comment
Hydraulic conductivity of Upper Sand and Gravel	Geo-Technology Associates (2000)	K_V value of 0.02m/d. Value from field tests performed by Geo-Technology Associates (2000). K_H value of 0.2m/d, assumed $K_v = 10\% K_H$
Hydraulic conductivity of Silt and Clay	Geo-Technology Associates (2000)	K_H value of 0.8m/d and K_v value of 4×10^{-3} m/d. Values from field tests performed by Geo-Technology Associates (2000).
Hydraulic conductivity of Lower Sand and Gravel	Geo-Technology Associates (2000)	K_H value of 8.6m/d and Kv value of 0.2m/d. Values from field tests performed by Geo-Technology Associates (2000).
Hydraulic conductivity of SPW	Arup-selected value	Set at 5.5×10^{-13}m/s to be effectively impermeable, a conservative assumption.
Thickness of Lower Sand and Gravel	Borehole logs from Schnabel (2003 and 2004)	Bedrock is assumed to be impermeable, which is conservative as there will be a permeable weathered zone. Borehole logs used to estimate bedrock at ~El 250ft across the site.
Initial Water Table Elevation	Water level monitoring data, from Cathedral Close staff and Arup site walkover	Maximum water levels assumed.

Table 2 Predicted impacts on ground water levels from numerical modelling

SPW (Figure 10)	Depth of penetration below average water table	Predicted change in ground water level - base case models	Predicted change in ground water level using $K_v = 0.1K_H$	Distance (feet) from SPW to negligible change in water level
A	~6 feet	1 feet rise in water level immediately up flow of SPW, 1foot fall down flow.	1 foot rise in water level immediately up flow of SPW, 1 foot fall down flow	25
C	~19 feet	4 feet rise in water level immediately up flow of SPW, 2 feet drop down flow.	4 feet rise in water level immediately up flow of SPW, 2 feet drop down flow.	140
D	~18 feet	4 feet rise in water level immediately up flow of SPW, 4 feet fall down flow.	3 feet rise in water level immediately up flow of SPW, 3 feet drop down flow.	80
E	~9 feet	3 feet rise in water level immediately up flow of SPW, 2 feet fall down flow.	3 feet rise in water level immediately up flow of SPW, 1.5 feet drop down flow.	70

4.4 Potential Impacts and Mitigation

No excavations associated with the proposed development of the Performing Arts Center and loading dock extend below maximum (peak) ground water levels. Therefore the only predicted impacts to ground water levels associated with the proposed development of the Performing Arts Center and loading dock are associated with four sheet pile walls that extend below the main excavations, labelled A, C, D and E on Figure 10. Table 2 identifies the changes in ground water levels predicted by the numerical models at these sheet piles walls. There are no predicted hydrological impacts at the reconfigured Athletic Fields.

The SPWs are required as temporary support for excavations only, and may be removed as part of the construction works. If the piles are removed residual ground water impacts from the developments are predicted to be negligible.

If the SPWs remain in place there will be a local upgradient increase and down gradient decrease in ground water level at the SPWs. The magnitude of the step change in ground water level across the sheet piles is predicted by numerical modelling as shown in Table 2. It is likely that the magnitude of the ground water change will be less than predicted by the model due to the conservatism of the models discussed in Section 4.3. Considering this conservatism and the relatively steep topography and ground water contours any changes in ground water level are likely to be highly localized.

No change to spring flows in Olmsted Woods is predicted. A slight change in ground water levels (steepening of ground water gradient) at the western edge of Olmsted Woods northeast of the Performing Arts Center is predicted. This change is unlikely to have any resulting ecological impacts.

The reconfiguration of the Athletics Fields will not directly affect ground water levels or flow.

In summary, for the proposed works over the entire study area, no mitigation measures are required as no unacceptable hydrological impacts from the proposed subsurface construction are predicted. The only impact is due to the presence of the temporary sheet pile walls and, if these are removed after construction, the hydrological change as a result of construction would be reduced to negligible levels.

5. CONCLUSIONS

This study has assessed the likely impact on ground water levels and flows resulting from subsurface construction works to develop a Performing Arts Center, Loading Dock and reconfigured Athletic Fields at St. Albans School, Cathedral Close, Washington DC.

The study has involved review of available geotechnical and hydrological studies relating to the close and a site walkover on 25 October 2004. A conceptual understanding of current ground water levels and flows has been developed, and has considered the proposed subsurface construction works and the potential impacts of the development.

None of the proposed excavations at the Performing Arts Center, Loading Dock or Athletic Fields extend below ground water levels. The only predicted impacts to ground water levels associated with the proposed development are where four sheet pile walls (each less than 100 feet in length) extend below the main excavations and penetrate the water table. These SPWs are required as temporary support for excavations only, and may be removed as part of the construction program. If the piles are removed residual ground water impacts from the developments are predicted to be negligible.

Numerical modelling techniques have been applied to enable quantified prediction of changes to the ground water regime if the SPWs are not removed. The model predicts that for the 'worst case' of the four SPWs there will be a maximum local upgradient increase in ground water level of 4 feet and down gradient decrease in ground water level of 2 feet at the SPW. The numerical modelling includes several conservative assumptions and the model results are considered to show more pronounced ground water level changes than will actually result from emplacement of the SPWs. Considering this conservatism and the relatively steep topography and ground water contours any local ground water level changes are predicted to be highly localized to the vicinity of the SPWs.

No change to spring flows in Olmsted Woods is predicted. A slight change in ground water levels (steepening of ground water gradient) at the western edge of Olmsted Woods northeast of the Performing Arts Center is predicted. This change is unlikely to have any resulting ecological impacts.

No mitigation measures are required as no unacceptable hydrological impacts from the proposed subsurface construction are predicted. However if the SPWs were removed after construction the hydrological change as a result of construction would be reduced to negligible levels.

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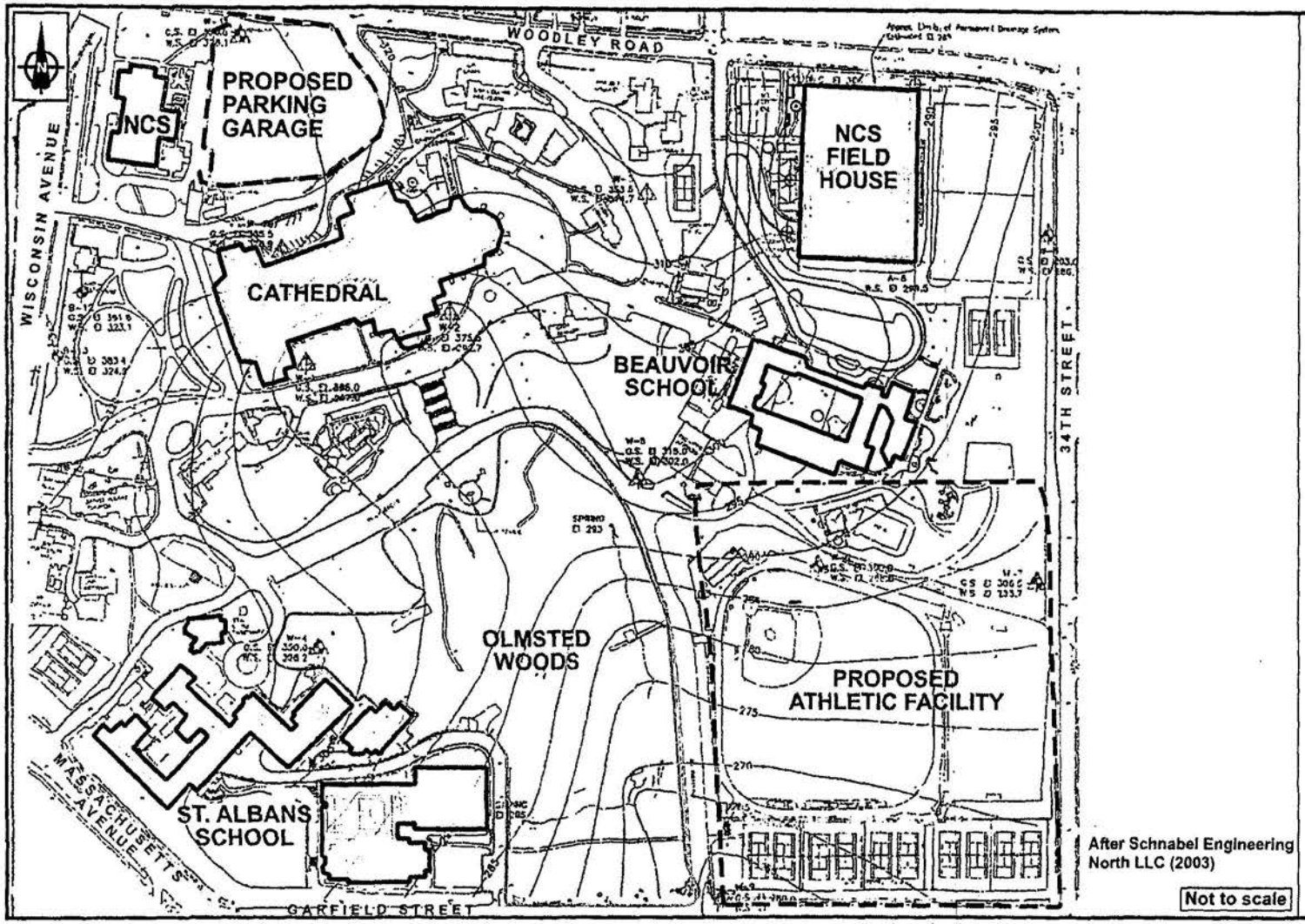
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FIGURES

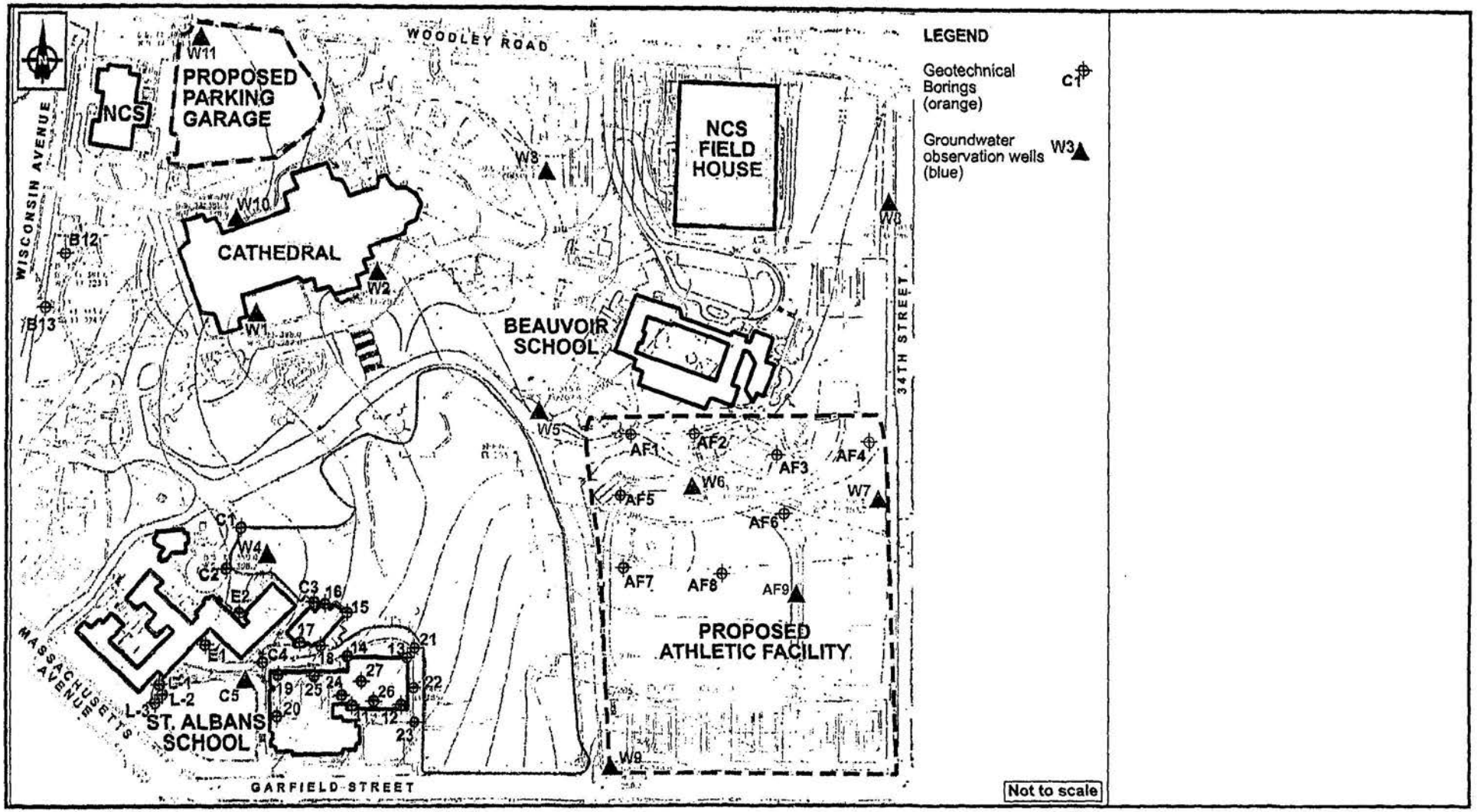


ARUP

St. Albans School Performing Arts Center, Loading Dock and New Athletic Facility
Hydrological Impact Assessment
SITE PLAN

130437-61

Figure 1

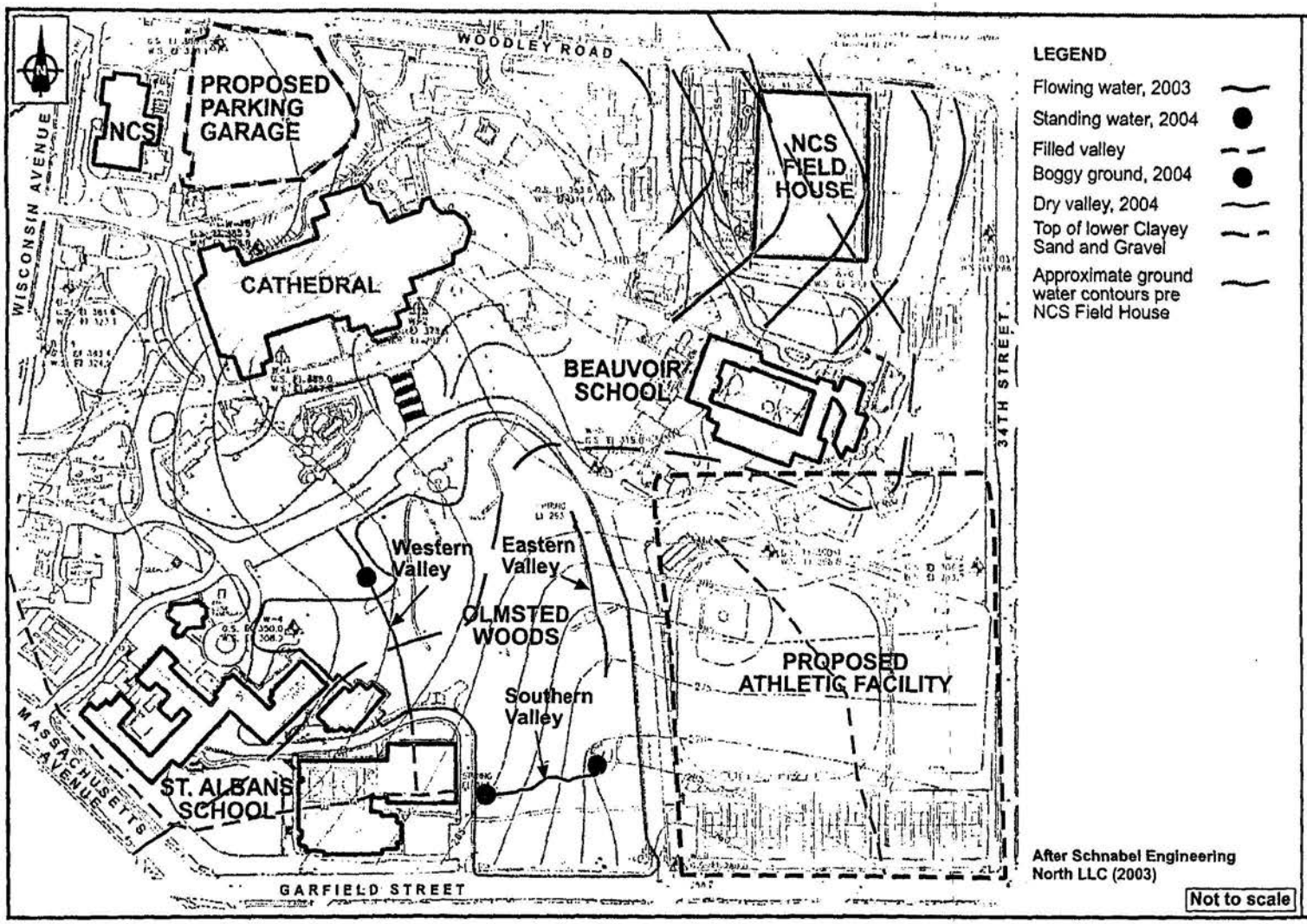


ARUP

St. Albans School Performing Arts Center,
Loading Dock and New Athletic Facility
Hydrological Impact Assessment
ALL EXPLORATORY HOLE LOCATIONS

130437-61

Figure **2**

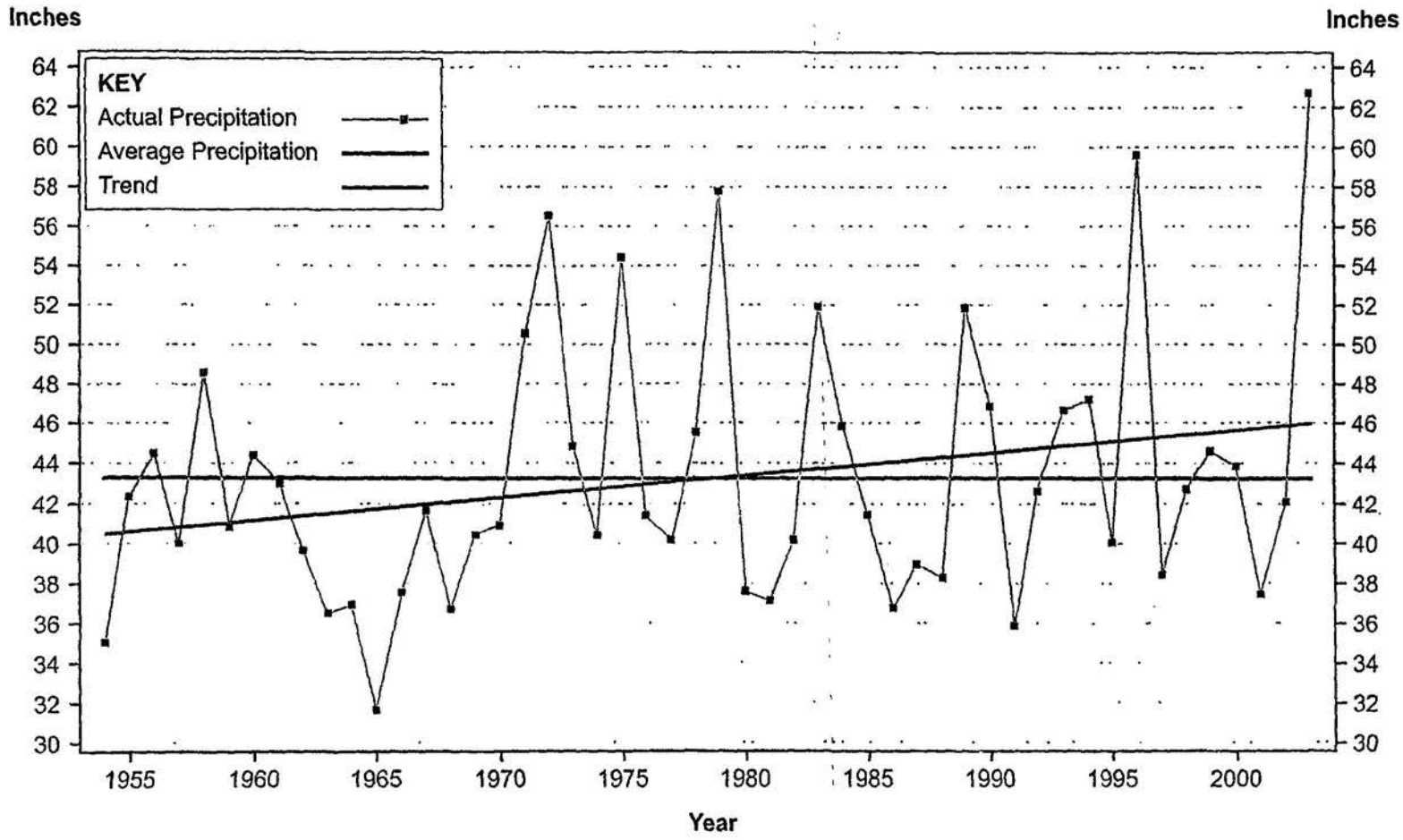


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St. Albans School Performing Arts Center, Loading Dock and New Athletic Facility
Hydrological Impact Assessment
WATER FEATURES MAP

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Figure 3



ARUP

St. Albans School Performing Arts Center,
Loading Dock and New Athletic Facility
Hydrological Impact Assessment
HISTORICAL ANNUAL PRECIPITATION FOR WASHINGTON DC

130437-61

Figure 4