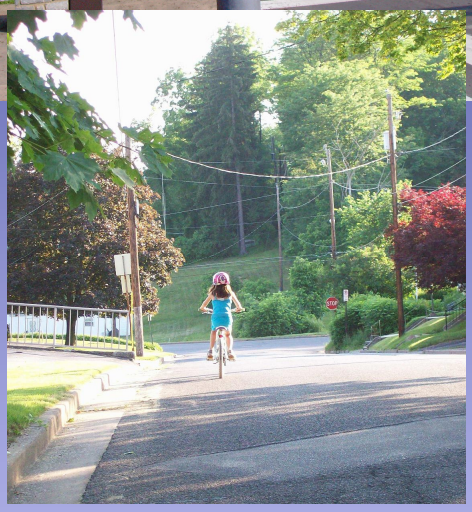

Comprehensive Pedestrian and Bicycle Program for the Borough of State College, Centre County

Part I – Prioritization of Areas of Concern
Final Report

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October 23, 2008

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EXECUTIVE SUMMARY

Part I of the Comprehensive Pedestrian and Bicycle Program for the Borough of State College is the development of a prioritized list of areas of concern. This report (Part I) provides background information on pedestrian safety history in the Borough, it identifies the areas of concern based upon crash analysis techniques, and it provides recommendations to improve safety at the top five sites based on a detailed engineering study. Part II of the Comprehensive Pedestrian and Bicycle Program includes the development of a comprehensive educational, engineering, and enforcement program to address pedestrian and bicycle safety in the Borough of State College.

A review of the pedestrian – vehicle crash history encompassed Borough-wide statistics of both reportable and non-reportable crashes for the years of 1989 through 2007 (excluding 3 intermediate years). Based upon crash analysis the top five areas of concern for pedestrian – vehicle crashes in the Borough of State College are the intersections of:

1. Beaver Avenue (SR 0026) & Atherton Street (SR 3014);
2. College Avenue (SR 0026) & Atherton Street;
3. College Avenue & Allen Street;
4. College Avenue & Burrowes Street;
5. Beaver Avenue & Locust Lane.

For each location a detailed engineering study was performed to identify engineering countermeasures to reduce pedestrian – vehicle crashes. The countermeasures included the following strategies:

- Fully implement the leading pedestrian interval (LPI), especially at the top two intersections of concern;
- Construct curb extensions (pedestrian nodes) for applicable crosswalks for the top five intersections;
- Implement a physical barrier for mid-block crossings along Atherton Street between College and Beaver Avenues using decorative drop-chain-style fencing.

A before-after analysis was performed on the implementation of the LPI at ten downtown traffic signals. The results show a nearly 50 percent reduction in pedestrian-vehicle crashes at the locations where the LPI was installed. Based upon these findings, the implementation of the LPI at the top two areas of concern in the Borough -- Beaver Avenue & Atherton Street and College Avenue & Atherton Street -- is recommended.

INTRODUCTION

Part I of the Comprehensive Pedestrian and Bicycle Program for the Borough of State College includes a prioritized list of areas of concern. This report (Part I) provides background information on pedestrian safety, it identifies the areas of concern based upon crash analysis techniques, and it provides recommendations to improve safety at the top five sites based on a detailed engineering study. Part II of the Comprehensive Pedestrian and Bicycle Program includes the development of a comprehensive educational, engineering, and enforcement program to address pedestrian and bicycle safety in the Borough of State College.

BACKGROUND

Several efforts have been made in the recent past to address pedestrian safety in the Borough of State College. In 2001, the Borough created an educational task force for pedestrian safety education. The task force performed a detailed review of pedestrian – vehicle crashes for the previous two years and created educational materials to address unsafe behaviors for pedestrians and motorists.

In 2002, a graduate transportation safety course at Penn State University investigated pedestrian – vehicle crashes in the Borough from 1989 through 2002. Two reports were prepared, *Pedestrian – Vehicle Accident Study* (1), and *Pedestrian Safety in State College* (2). The reports contain descriptive statistics on pedestrian – vehicle crashes, and discussions of pedestrian behavioral observations from task and causal analyses. Recommendations from the reports included improving lighting, creating wide sidewalks, installing curb extensions, reducing traffic signal cycle lengths, adjusting vehicle stop bar locations to create pseudo-leading pedestrian intervals, installation of barriers to prevent mid-block crossings, develop education programs on safe crossing and driving behaviors, and enforce existing traffic laws on yielding the right-of-way and mid-block crossings.

In 2008, the graduate transportation safety course was held again at Penn State University. During the course, sites with promise (SWiP) were identified using the Empirical Bayes (EB) method of estimation for pedestrian – vehicle crashes. In addition, a pedestrian exposure model for the entire Borough was developed based on spatial analyses and land use patterns.

OBJECTIVES

The purpose of Part I of the Comprehensive Pedestrian and Bicycle Program is to identify prioritized areas of concern based upon crash history. Following the identification of prioritized areas of concern, a detailed engineering study (DES) is performed at each location to recommend safety improvements. The majority of the analysis for Part I involves pedestrian – vehicle crashes since they are the prevalent form of vehicle vs. non-motorized vehicle crash in the Borough.

SCOPE OF STUDY

A review of the pedestrian – vehicle crash history encompassed Borough-wide statistics, not just focused on the central business district (CBD). A data set of both reportable and non-reportable crashes was provided by the State College Borough Police Department for years 1989 through 2007. Due to changes in databases and reporting methods, the data set excludes years 1998, 1999, and 2002. In total, 16 years of complete crash data were analyzed for the Borough.

METHODOLOGY

To develop a prioritized list of areas of concern five analysis methods were used to rank all locations in the Borough where a pedestrian – vehicle crash had occurred in the 16 analysis years. Developing a combined ranking based on different analysis techniques attempts to account for the various factors which influence pedestrian-vehicle crashes and the various motivations for ranking one site higher than another in terms of "concern".

For this project, sites were ranked based upon crash frequency, crash rates per vehicle exposure, crash rates per pedestrian exposure, severity index, and empirical Bayes (EB) network screening. The final overall ranking was developed by creating an overall score for a site based upon the five analysis methods. The following section describes the results from the five analysis methods.

TOP FIVE AREAS OF CONCERN ANALYSIS METHODS

CRASH FREQUENCY ANALYSIS

The analysis period for crash frequency included years 1989 to 2007, inclusive, excluding years 1998, 1999, and 2002. Pedestrian-vehicle crashes were obtained and matched to the respective intersections. The total pedestrian-vehicle crash frequency was then calculated for each intersection for the analysis period and sorted from greatest to least. Table 1 indicates the top ten intersections with respect to pedestrian-vehicle crash frequency.

Almost all intersections are located along College Avenue or Beaver Avenue. College Ave. and Beaver Ave. carry relatively large volumes of pedestrian and vehicle traffic, which increases the risk of pedestrian-vehicle crashes. The intersection with the greatest crash frequency is Beaver Ave. and Atherton St., where 27 crashes occurred during the analysis period (1.69 crashes/year).

Table 1. *Top Sites by Crash Frequency.*

Rank	Street 1	Street 2	Crash Frequency 1989 - 2007	Score
1	Beaver Ave.	Atherton St.	27	10
2	College Ave.	Atherton St.	20	9
3	College Ave.	Allen St.	14	8
4	College Ave.	Burrowes St.	12	7
5	College Ave.	Garner St.	10	6
5	Beaver Ave.	Locust Ln.	10	6
7	Beaver Ave.	Allen St.	8	4
7	Calder Way	Garner St.	8	4
9	College Ave.	Pugh St.	7	2
10	Beaver Ave.	Garner St.	6	1
10	Beaver Ave.	McAllister St.	6	1
10	Calder Way	Pugh St.	6	1

CRASH RATE ANALYSIS (VEHICLE EXPOSURE)

Simple frequency counts of crashes can be misleading because they ignore the characteristics of the sites from which the statistics arise. Crash rates are an attempt to quantify risk on a comparative basis and exposure-based rates attempt to account for the amount of conflict that is susceptible to crash occurrence due to high traffic volumes (3). The crash rate was computed for each intersection using Equation 1. The equation produces an estimate of the number of crashes per million entering vehicles (MEV). Nearly complete ADT data were available for the year 2003; therefore, these data were used as an estimate of vehicle exposure. While the traffic volumes change from year to year, they typically change at approximately the same rate within an area (e.g., within the Borough). To compute relative crash rates, it was not necessary to adjust the traffic volumes across the multiple years because the volumes would have been adjusted at the same rate.

$$\text{Crash Rate}_i = (X_i * 10^6)/(ADT_i * 365 * 16) \quad \ldots\ldots\ldots(1)$$

Where:
X_i = total crashes for intersection *i* for analysis period.
ADT_i = Total entering vehicles per day for intersection *i*.

Table 2 shows the top ten intersections with respect to crash rate. These top ten intersections are nearly identical to those presented in Table 1 where intersections are ranked by crash frequency. The order of the top ten intersections changes slightly when comparing the two tables. For crash rate, the intersection of College Ave. and Allen St. ranks at the top of the list (0.1937 crashes per MEV). The only intersection that appears

in Table 2, but not in Table 1, is the intersection of Allen St. and Mitchell St.; likely due to the relatively low traffic volume.

Table 2. *Top Sites by Crash Rate (Vehicle Exposure).*

Rank	Street 1	Street 2	Crash Rate 1989 – 2007 (per MEV)	Score
1	College Ave.	Allen St.	0.1937	10
2	Allen St.	Mitchell St.	0.1875	9
3	College Ave.	Burrowes St.	0.1830	8
4	Beaver Ave.	Atherton St.	0.1537	7
5	Calder Way	Garner St.	0.1352	6
6	Beaver Ave.	Locust Ln.	0.1338	5
7	College Ave.	Pugh St.	0.1304	4
8	College Ave.	Garner St.	0.1083	3
9	College Ave.	Atherton St.	0.1051	2
10	Beaver Ave.	McAllister St.	0.0889	1

CRASH RATE ANALYSIS (PEDESTRIAN EXPOSURE)

For pedestrian exposure crash rate calculations, total entering pedestrians were used as the surrogate exposure measure. The pedestrian-related crash rate was computed for each intersection using Equation 2. The equation produces an estimate of the number of crashes per total entering pedestrians. Nearly complete pedestrian data were available for the year 2008; therefore, these data were used as an estimate of pedestrian exposure. The pedestrian volume data was used from the pedestrian flow model developed by the 2008 Penn State University transportation safety class. The pedestrian volumes represent a specific period during the day and not total daily volumes. While the pedestrian volumes may change from year to year, they typically change at approximately the same rate. To compute relative crash rates, it was not necessary to adjust the pedestrian volumes for multiple years because the volumes would have been adjusted at the same rate.

$$\text{Crash Rate}_i = (X_i)/(P_i) \quad \ldots\ldots (2)$$

Where:
X_i = total crashes for intersection i for analysis period.
P_i = Total entering pedestrians during count period for intersection i.

Table 3 shows the top ten intersections with respect to pedestrian-based crash rate. Many of the top ten intersections are similar to those presented in Tables 1 and 2 where intersections are ranked by crash frequency and vehicle-related crash rate. About half of the top ten intersections, ranked by pedestrian-related crash rate, do not appear on the other lists. This is likely due to relatively low pedestrian volumes at these intersections, where a small number of crashes will result in a relatively large crash rate if the exposure

is low. For the pedestrian-related crash rate, the intersection of Park Ave. and Atherton St. ranks at the top of the list (0.1250 crashes per relative pedestrian exposure (RPE)).

Table 3. *Top Sites by Crash Rate (Pedestrian Exposure).*

Rank	Street 1	Street 2	Crash Rate 1989 – 2007 (per RPE)	Score
1	Park Ave.	Atherton St.	0.1250	10
2	Atherton St.	Hillcrest St.	0.1000	9
3	College Ave.	Atherton St.	0.0784	8
4	Atherton St.	Westerly Pkwy.	0.0625	7
5	Beaver Ave.	Atherton St.	0.0475	6
6	Calder Way	Garner St.	0.0471	5
7	University Dr.	Royal Rd..	0.0417	4
8	Allen St.	Mitchell St.	0.0323	3
9	Beaver Ave.	Locust Ln.	0.0307	2
10	Atherton St.	Branch St.	0.0303	1
10	Pugh St.	Fairmount St.	0.0303	1

SEVERITY INDEX

The fourth analysis technique to rank the top sites with pedestrian – vehicle crashes is by severity index. The severity index is a number which represents the type of crashes which have occurred at each intersection and scales the severity based upon the amount of injury from the crash. The severity index was computed for each intersection using Equation 3. The equation produces an estimate of the relative severity of crashes occurring at each intersection.

$$\text{Severity Index}_i = (\text{No Injury}_i * W_1) + (\text{Injury}_i * W_2) + (\text{Fatal}_i * W_3) \quad \ldots (3)$$

Where:
No Injury$_i$ = total non-injury crashes for intersection *i* for analysis period.
Injury$_i$ = total injury crashes for intersection *i* for analysis period.
Fatal$_i$ = total fatal crashes for intersection *i* for analysis period.
W_1 = weighting factor for non-injury crash.
W_2 = weighting factor for injury crash.
W_3 = weighting factor for fatal crash.

The severity factors were determined using the Federal Highway Administration (FHWA) report *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (4). Both comprehensive and human capital cost estimates are provided in the report. Comprehensive cost estimates include not only the monetary losses associated with medical care, other resources used, and lost work, but also non-monetary costs related to the reduction in the quality of life. Comprehensive crash costs are generally used in safety analyses because human capital costs do not

capture the full burden of injury. The report provides these costs by severity level, location (i.e., intersection or non-intersection), and speed limit (i.e., < 50mph or ≥ 50mph). Thus, the comprehensive crash cost estimates for intersections with speed limit less than 50 mph were used to develop weighting factors for the three severity levels. The non-injury level was used as the baseline. To compute the weighting factors, the crash cost for a particular severity level was divided by the crash cost for a non-injury crash. The comprehensive crash costs and weighting factors are shown in Table 4.

Table 4. *Crash Costs and Severity Weighting Factors.*

Injury Level	Mean Comprehensive Crash Cost	Weighting Factor
No Injury	$10,249	1.0
Injury	$129,418	12.6
Fatal	$3,234,016	315.5

Note: all costs are related to vehicle-pedestrian crashes at an intersection with speed limit < 50 mph.

Table 5 shows the top ten intersections with respect to severity index. All of the top ten intersections appear in at least one of the top ten lists previously presented in Tables 1 through 3. For crash severity, the intersection of Beaver Ave. and Atherton St. ranks at the top of the list (severity index 958.6). It is not surprising that the intersection of Beaver Ave. and Atherton St. ranks at the top of the list because this intersection also had the most crashes (27) during the analysis period.

Table 5. *Top Sites by Severity Index.*

Rank	Street 1	Street 2	Severity Index	Score
1	Beaver Ave.	Atherton St.	958.6	10
2	Beaver Ave.	Garner St.	378.5	9
3	University Dr.	Royal Rd.	315.5	8
4	College Ave.	Atherton St.	228.8	7
5	College Ave.	Allen St.	151.2	6
6	College Ave.	Burrowes St.	139.6	5
7	Beaver Ave.	Locust Ln.	114.4	4
8	College Ave.	Garner St.	91.2	3
9	Calder Way	Garner St.	89.2	2
10	Beaver Ave.	Allen St.	77.6	1

EMPIRICAL BAYES NETWORK SCREENING

The Empirical Bayes (EB) method was applied as a final network screening technique. The EB method is used to increase the precision of crash estimates with limited data sets and it corrects for regression-to-the mean bias (5). The EB method uses the observed crash record of a site and the expected crash frequency at similar sites to estimate a weighted long-term average expected crash frequency. The EB method incorporates a

safety performance function (SPF) to predict the expected number of crashes (k) for a particular intersection. The SPF for all Borough intersections was developed using negative binomial regression techniques to predict the expected number of crashes for a site based on the traffic volume, pedestrian volume, and site characteristics. The SPF is shown in Table 6.

Table 6. *Safety Performance Function for EB Ranking.*

Variable	Coefficient	P>|z|
Constant	-0.6603	0.0520
Major Street ADT	0.0000438	0.0570
Minor Street ADT	0.0000423	0.3940
CBD (Y=1, N=0)	0.5445	0.0260
Signalized Intersection (Y=1, N=0)	-0.1669	0.5230
4-Legged Intersection (Y=1, N=0)	0.4157	0.0650
Major Street One-Way (Y=1, N=0)	0.7979	0.0000
Minor Street One-Way (Y=1, N=0)	0.2396	0.4170
Pedestrian Volume (Crossing Major Road)	0.0013	0.0200
Pedestrian Volume (Crossing Minor Road)	0.0001	0.7970
alpha	0.1249	

The EB method combines the expected crash frequency with the observed crash frequency to obtain a weighted average. Equation 4 was used to combine the expected and observed crash frequency.

$$\text{EB Estimate} = w_i k_i + (1-w_i)*X_i \quad \ldots\ldots (4)$$

Where:
w_i = weighting factor for intersection *i*.
k_i = expected number of crashes for intersection *i* based on SPF.
X_i = observed crashes for intersection *i*.

The weighting factor (Equation 5) is calculated for each intersection using alpha from the negative binomial model (Table 6) as well as the expected number of crashes from the SPF.

$$w_i = 1/(1+\text{alpha}*k_i) \quad \ldots\ldots (5)$$

Where:
alpha = 0.1249 from negative binomial model.
k_i = expected number of crashes for intersection *i* based on SPF.

Table 7 presents the top ten intersections ranked by the expected number of crashes from the EB method. The list of the top ten intersections presented in Table 7 is very similar to those intersections identified in the previous ranking procedures. The only intersection that appears in Table 7, but not in the previous tables, is Beaver Ave. and Pugh St. The top intersection, identified by the EB method, is Beaver Ave. and Atherton St., which also appeared at the top of the list based on crash frequency and severity index.

Table 7. *Top Sites by EB Method.*

Rank	Street 1	Street 2	Expected No. Crashes (1989-2007)	Expected Crash Rate (per Year)	Observed Crashes (1989-2007)	Score
1	Beaver Ave.	Atherton St.	21.42	1.34	27	10
2	College Ave.	Atherton St.	15.54	0.97	20	9
3	College Ave.	Garner St.	13.32	0.83	10	8
4	College Ave.	Burrowes St.	10.88	0.68	12	7
5	College Ave.	Allen St.	8.54	0.53	14	6
6	Beaver Ave.	Locust Ln.	7.41	0.46	10	5
7	Beaver Ave.	Allen St.	6.58	0.41	8	4
8	Beaver Ave.	Garner St.	6.30	0.39	6	3
9	College Ave.	Pugh St.	5.61	0.35	7	2
10	Beaver Ave.	Pugh St.	5.20	0.33	5	1

FINAL RANKING – TOP FIVE AREAS OF CONCERN

The rankings from the previous analyses were combined to produce an overall score for each intersection that appeared in a top ten list. There were 20 intersections that appeared on at least one of the five top ten lists. A score was assigned to each intersection based on the original ranking from the frequency analysis, vehicle-exposure crash rate analysis, pedestrian-exposure crash rate analysis, severity index analysis, and EB method analysis. The score was assigned by subtracting the original rank from 11. In essence, those sites ranked number one on each list were assigned a score of ten and those sites ranked last on the list were assigned a score of one. The scores of the five analysis methods were then summed for each intersection and sorted from greatest to least (Table 8). The top five intersections are shown in bold.

Table 8. *Final Combined Ranking of Sites.*

Rank	Street 1	Street 2	Score
1	**Beaver Ave.**	**Atherton St.**	**43**
2	**College Ave.**	**Atherton St.**	**35**
3	**College Ave.**	**Allen St.**	**30**
4	**College Ave.**	**Burrowes St.**	**27**
5	**Beaver Ave.**	**Locust Ln.**	**22**
6	College Ave.	Garner St.	20
7	Calder Way	Garner St.	17
8	Beaver Ave.	Garner St.	13
9	Allen St.	Mitchell St.	12
10	University Dr.	Royal Rd.	12
11	Park Ave.	Atherton St.	10
12	Atherton St.	Hillcrest St.	9
13	Beaver Ave.	Allen St.	9
14	College Ave.	Pugh St.	8
15	Atherton St.	Westerly Pkwy.	7
16	Beaver Ave.	McAllister St.	2
17	Atherton St.	Branch Rd.	1
18	Beaver Ave.	Pugh St.	1
19	Calder Way	Pugh St.	1
20	Pugh St.	Fairmount St.	1

PEDESTRIAN INTERSECTION SAFETY INDEX ANALYSIS

A procedure described in the report *Pedestrian and Bicyclist Intersection Safety Indices* (6) was used to develop a list of prioritized locations for proactive safety improvements. The pedestrian intersection safety index (ISI) is a statistical model based upon expert safety ratings and behavioral data. Indicative variables in the pedestrian ISI model include:

- Intersection control type;
- Number of through lanes;
- 85th percentile speeds;
- Main street through traffic volume; and
- Area type.

The ISI allows the identification of locations with a high-priority for in-depth pedestrian safety evaluations to address *potential* safety problems. In contrast to the first set of analyses, the ISI is not based upon crash history of a site.

The ISI is computed for each crossing, not by total intersection as in the previous analysis. The ISI can be used to identify potentially hazardous crossings (i.e., those that

exhibit characteristics conducive of increased crash risk). These locations should be examined further to identify contributing factors and the need for further action. To provide a ranked list of intersections, the ISI for individual crossing was combined for each intersection based on the procedure described in Carter et al. (2007). The suggested procedure averages the ISI values from all legs. It should be noted that some intersections may have one leg that is a high priority for safety evaluation (high ISI value) and other legs that are a relatively low priority (low ISI values). When the ISI values are averaged, the high priority leg may go unnoticed. Therefore, the ISI is presented for each leg of the intersection in addition to the average ISI for the intersection (Table 9). The top 25 locations in the Borough are shown in Table 9, with a complete listing in the Appendix.

Table 9. *Pedestrian Intersection Safety Index by Approach and Intersection.*

Street 1	Street 2	Major St. X-ing # 1 Ped ISI	Major St. X-ing # 2 Ped ISI	Minor St. X-ing # 1 Ped ISI	Minor St. X-ing # 2 Ped ISI	Average Ped ISI
Atherton	Center	4.58	4.58	1.92	*	3.69
Atherton	Pugh	4.58	4.58	1.92	*	3.69
Calder	Atherton	4.58	4.58	1.59	*	3.58
Atherton	Foster	4.58	4.58	2.10	2.10	3.34
Atherton	Nittany	4.58	4.58	2.10	2.10	3.34
Atherton	Highland	4.58	4.58	1.92	1.92	3.25
Atherton	Logan	4.58	4.58	1.92	1.92	3.25
Beaver	Heister	3.73	3.73	1.92	*	3.13
Beaver	Humes	3.73	3.73	1.92	*	3.13
Beaver	McAllister	3.73	3.73	1.92	*	3.13
College	Heister	3.73	3.73	1.92	*	3.13
College	Locust	3.73	3.73	1.92	*	3.13
College	McAllister	3.73	3.73	1.92	*	3.13
Fraser	Foster	3.67	3.67	1.87	*	3.07
Park	McKee	3.67	3.67	1.87	*	3.07
University	Royal	3.67	3.67	1.69	*	3.01
Calder	Kelly	3.40	3.40	1.92	*	2.90
Calder	McAllister	3.40	3.40	1.92	*	2.90
Beaver	Sowers	3.49	3.49	1.69	*	2.89
College	Hetzel	3.49	3.49	1.69	*	2.89
College	High	3.49	3.49	1.69	*	2.89
College	Sowers	3.49	3.49	1.69	*	2.89
Westerly	O'Bryan	3.49	3.49	1.69	*	2.89
Beaver	Locust	3.73	3.73	1.92	1.92	2.83
Calder	Garner	3.73	3.73	1.92	1.92	2.83

The ranked locations in Table 9 show the relative potential for pedestrian safety problems based upon the pedestrian ISI model. When evaluating locations for long term capital improvements to improve pedestrian safety, the ranking in Table 9 should prove as a valuable starting point.

SUMMARY STATISTICS ON PEDESTRIAN – VEHICLE CRASHES

Unless otherwise noted, the analysis period for the following summary statistics is 1989 to 2007, inclusive, excluding 1998, 1999, and 2002.

Figure 1 shows the total number of pedestrian-vehicle crashes by year in the Borough of State College. The figure shows a relatively random fluctuation in pedestrian-vehicle crashes over the analysis period (i.e., there is no definite increasing or decreasing trend). The maximum occurred in 1995 (37 crashes) and the minimum occurred in 2005 (14 crashes).

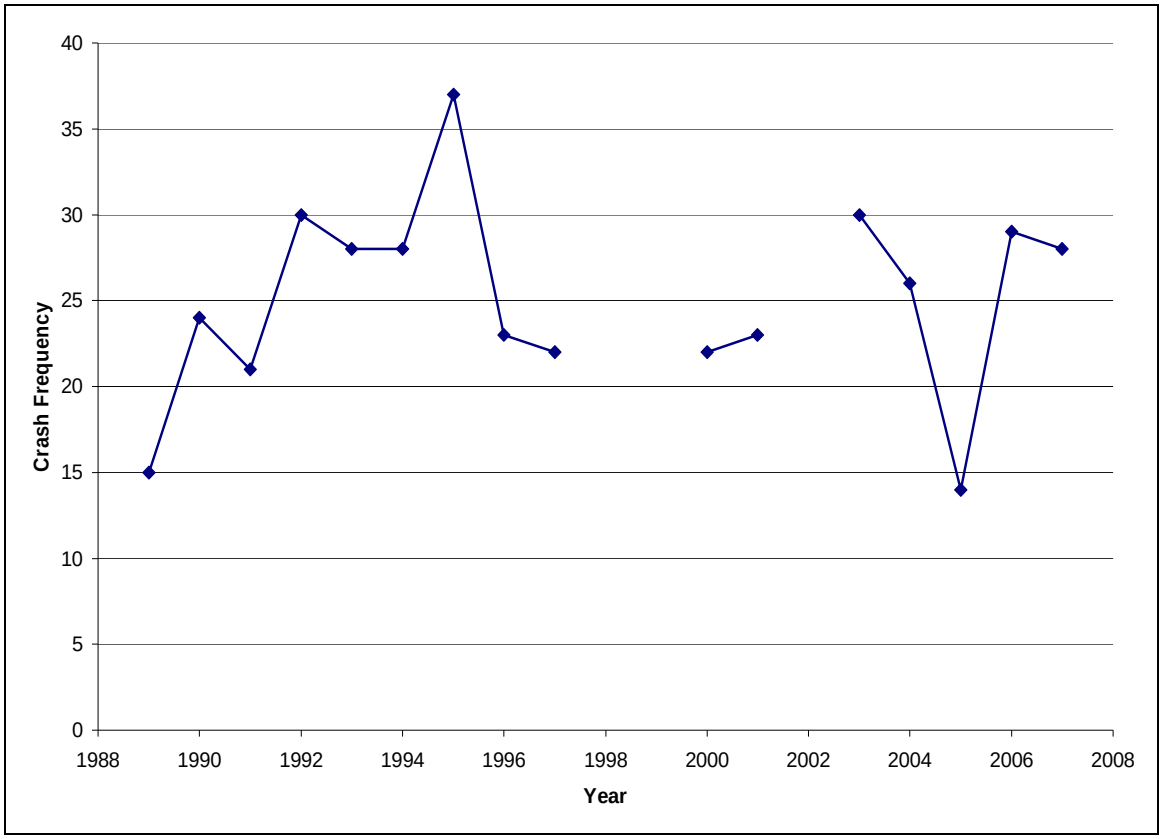


Figure 1. *Crash Frequency by Year.*

Table 10 presents the total number of crashes by intersection and control type. The signalized intersections experience a greater number of crashes per site than the unsignalized intersections, which is not surprising due to the fact that the signalized intersections are associated with greater traffic volumes and typically greater pedestrian volumes (i.e., greater exposure). For both signalized and unsignalized intersections, the four-legged intersections experience a greater number of crashes per site than the respective three-legged intersections. This is also not surprising because four-legged intersections have more conflict points (i.e., more opportunities for a collision). Based on these points, it is obvious that four-legged, signalized intersections experience the most pedestrian-vehicle crashes.

Table 10. *Crash Frequency by Intersection and Control Type.*

Intersection Type	Control Type	Number of Sites	Crash Frequency 1989 – 2007	Crashes per Site
4-legged	Signalized	17	111	6.53
3-legged	Signalized	7	32	4.57
4-legged	Unsignalized	28	64	2.29
3-legged	Unsignalized	21	43	2.05

Table 11 presents the number of crashes by location (i.e., intersection or mid-block). For the overall analysis period, the majority of crashes occur at intersections (58 percent) compared to mid-block locations (42 percent). This trend holds for all years except 1992 to 1994, inclusive, where mid-block locations experience a greater number of crashes. Crashes per site are not calculated for Table 11 because mid-block locations vary in length and stretch between intersections, where intersections are more isolated locations and easier to quantify.

Table 11. *Crash Frequency by Location (Intersection / Mid-block).*

Year	Crash Frequency				
	Mid-Block	% Mid-Block	Intersection	% Intersection	Total
1989	6	40.0	9	60.0	15
1990	11	45.8	13	54.2	24
1991	8	38.1	13	61.9	21
1992	18	60.0	12	40.0	30
1993	19	67.9	9	32.1	28
1994	17	60.7	11	39.3	28
1995	18	48.6	19	51.4	37
1996	11	47.8	12	52.2	23
1997	11	50.0	11	50.0	22
2000	6	27.3	16	72.7	22
2001	7	29.2	17	70.8	24
2003	7	23.3	23	76.7	30
2004	9	34.6	17	65.4	26
2005	4	28.6	10	71.4	14
2006	7	24.1	22	75.9	29
2007	9	32.1	19	67.9	28
Total	**168**	**41.9**	**233**	**58.1**	**401**

Table 12 presents the number of crashes by area type (i.e., CBD or residential). While there were more crashes in the CBD area, there were also more intersection locations that

experienced crashes in the CBD. Adjusting for the number of sites by area type, the CBD area still experiences more crashes per site than the residential area by about three fold.

Table 12. *Crash Frequency by Area Type.*

Area Type	Number of Sites	Crash Frequency 1989 – 2007*	Crashes per Site
CBD	40	189	4.73
Residential	33	52	1.58

*Note: Includes Intersection Crashes Only

Tables 13 and 14 present the number of crashes by month and year for intersection and mid-block crashes, respectively. Figure 2 depicts the data shown in Tables 13 and 14 graphically. Figure 2 shows the total number of crashes by location and month. From Figure 2, it is evident that the months with the greatest number of crashes are those months during the fall semester at Penn State University (September through December). The months during the spring semester (January through April) show a substantial reduction in crashes compared to the fall semester and the summer months (May through August) show another substantial reduction in crashes. While the number of students remains relatively constant between the fall and spring semesters, there are a number of factors that may lead to the increased crashes during the fall months. One reason may be the relative number of new students arriving during the fall. Many of the freshmen are not familiar with the area (driving or walking) and this could lead to increased risk. Another, and perhaps more significant, reason for the increased pedestrian-vehicle crashes in the fall is Penn State football games. The football weekends attract thousands of visitors to the area, which increases the pedestrian and vehicle exposure.

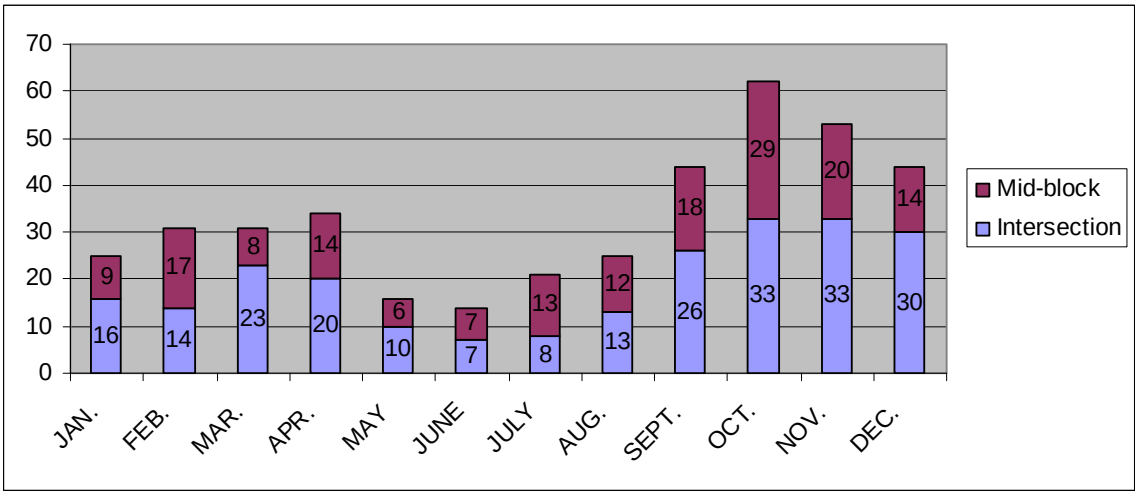


Figure 2. *Pedestrian-Vehicle Crashes by Month and Location.*

Table 13. *Pedestrian-Vehicle Crashes by Monthly Distribution (Intersections).*

	Month											
Year	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
1989	0	0	0	0	0	0	2	2	1	0	2	2
1990	0	2	1	0	0	0	0	1	1	2	4	2
1991	1	0	1	0	0	0	2	3	0	1	4	1
1992	0	0	1	2	0	1	0	0	0	3	3	2
1993	1	2	0	1	2	0	0	0	0	3	0	0
1994	0	0	0	1	2	0	0	1	1	1	4	1
1995	0	2	1	1	0	0	0	4	5	4	1	1
1996	0	1	1	1	0	0	0	0	3	3	1	2
1997	2	0	1	0	0	1	0	0	1	2	2	2
2000	3	1	1	2	2	0	1	0	1	1	2	2
2001	3	0	3	0	0	1	0	0	2	3	2	3
2003	0	2	5	2	1	2	1	1	0	3	3	3
2004	0	2	3	2	0	1	0	0	3	1	2	3
2005	1	1	3	1	0	1	1	0	1	0	0	1
2006	3	1	1	3	1	0	0	0	5	4	2	2
2007	2	0	1	4	2	0	1	1	2	2	1	3
Total	**16**	**14**	**23**	**20**	**10**	**7**	**8**	**13**	**26**	**33**	**33**	**30**
Average	**1.0**	**0.9**	**1.4**	**1.3**	**0.6**	**0.4**	**0.5**	**0.8**	**1.6**	**2.1**	**2.1**	**1.9**
Standard Deviation	1.2	0.9	1.4	1.2	0.9	0.6	0.7	1.2	1.6	1.3	1.3	0.9

Table 14. *Pedestrian-Vehicle Crashes by Monthly Distribution (Mid-Block).*

	Month											
Year	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
1989	0	0	0	0	0	0	0	2	0	3	0	1
1990	1	0	0	2	0	1	0	0	0	3	3	1
1991	0	1	1	0	0	0	1	0	1	3	0	1
1992	1	2	1	1	0	1	5	0	1	4	2	0
1993	0	3	0	0	1	1	1	3	2	2	3	3
1994	0	1	1	3	2	0	0	3	3	1	0	3
1995	0	2	1	1	0	2	1	1	2	2	5	1
1996	1	1	0	1	2	1	1	0	1	0	3	0
1997	1	2	0	2	0	1	1	0	1	2	1	0
2000	1	0	1	0	0	0	1	1	0	1	1	0
2001	0	1	0	0	0	0	1	1	1	2	0	0
2003	0	1	1	2	0	0	0	1	1	0	0	1
2004	1	2	0	0	1	0	0	0	2	2	1	0
2005	0	0	1	1	0	0	1	0	0	1	0	0
2006	2	0	0	0	0	0	0	0	1	2	1	1
2007	1	1	1	1	0	0	0	0	2	1	0	2
Total	**9**	**17**	**8**	**14**	**6**	**7**	**13**	**12**	**18**	**29**	**20**	**14**
Average	**0.6**	**1.1**	**0.5**	**0.9**	**0.4**	**0.4**	**0.8**	**0.8**	**1.1**	**1.8**	**1.3**	**0.9**
Standard Deviation	0.6	0.9	0.5	1.0	0.7	0.6	1.2	1.1	0.9	1.1	1.5	1.0

Table 15 presents the number of crashes by severity for each year of the analysis period. Figure 3 illustrates these data graphically. Unlike vehicle-vehicle crashes, where the severity is heavily skewed toward non-injury, pedestrian-vehicle crashes are skewed toward injury crashes. This is due to the vulnerability of pedestrians. The likelihood of an injury increases as the speed of the vehicle increases. There were four reported pedestrian fatalities during the analysis period and over 200 injuries that resulted from pedestrian-vehicle crashes.

Figure 4 shows the severity distribution by year. Three of the four fatal crashes occurred recently (since 2001). It also appears that the number of injury crashes has increased over the years.

Table 15. *Severity Distribution by Year.*

Year	No Injury	Injury	Fatal
1989	0	9	0
1990	1	13	0
1991	2	11	1
1992	1	11	0
1993	2	8	0
1994	3	8	0
1995	2	13	0
1996	3	8	0
1997	4	8	0
2000	1	15	0
2001	4	13	1
2003	2	21	1
2004	2	18	0
2005	0	10	0
2006	1	24	1
2007	0	19	0
Total	**28**	**209**	**4**

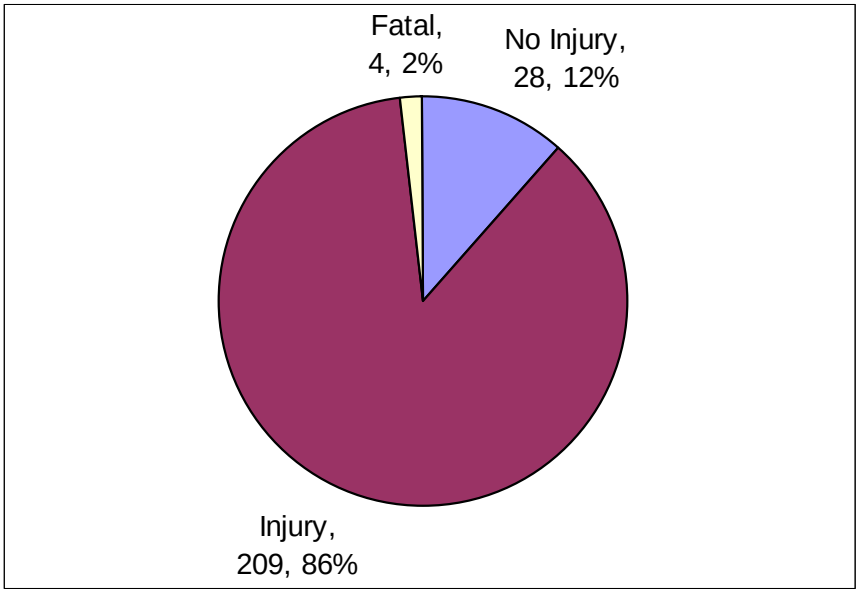


Figure 3. *Severity Distribution for Pedestrian-Vehicle Crashes.*

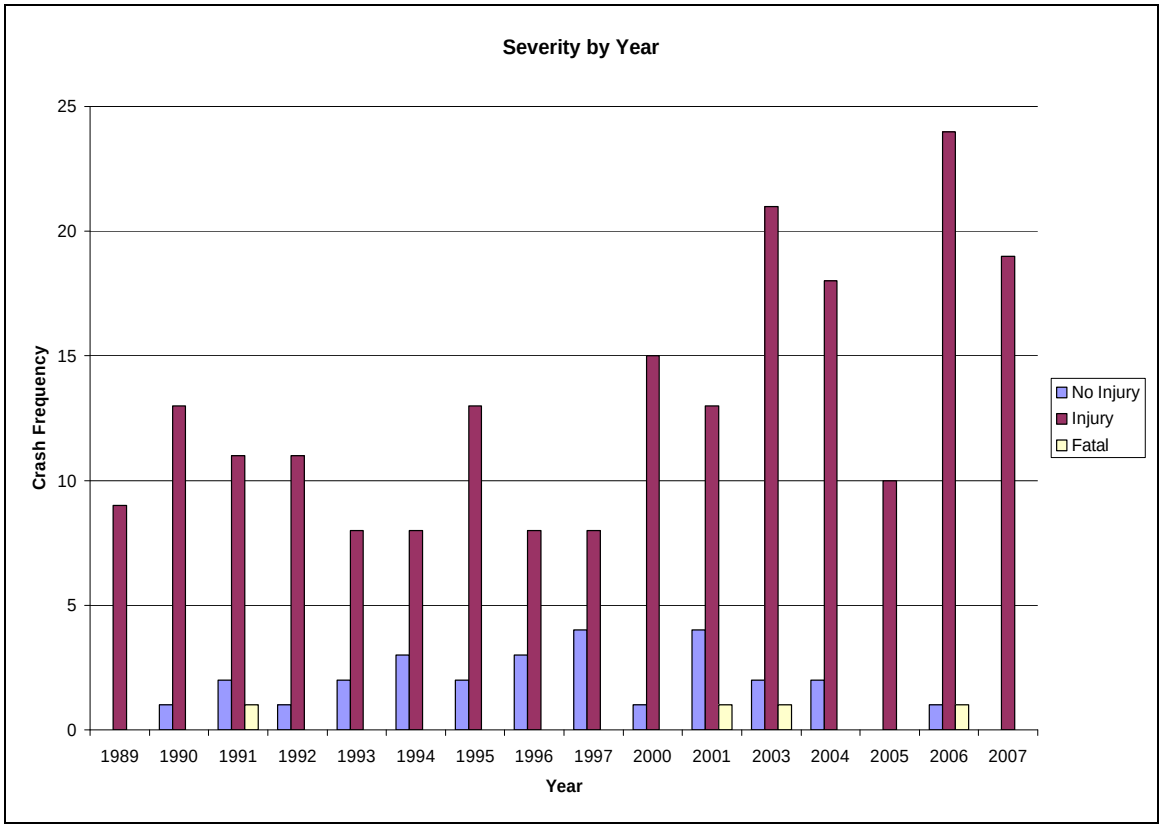


Figure 4. *Yearly Distribution for Pedestrian-Vehicle Crashes by Severity.*

Table 16 presents the number of crashes by time of day for intersection and mid-block locations separately. Figure 5 depicts these data graphically. It should be noted that these data only represent years 1989 through 2007 and 2000 through 2001.

For the majority of hours during the day, the number of crashes fluctuate around 10 crashes. There is, however, a notable increase from 12pm to 6pm and another spike from 9pm to 10pm. There is a significant decrease in crashes in the early morning hours (3am to 8am), likely due to the reduced exposure in pedestrian and vehicle traffic.

Table 16. *Pedestrian-Vehicle Crashes by Time of Day.*

Time of Day	Intersection Crashes*	Mid-block Crashes*	Total Crashes*
0:01-1:00	9	3	12
1:01-2:00	6	7	13
2:01-3:00	2	10	12
3:01-4:00	0	1	1
4:01-5:00	0	1	1
5:01-6:00	0	1	1
6:01-7:00	1	0	1
7:01-8:00	2	1	3
8:01-9:00	5	6	11
9:01-10:00	6	6	12
10:01-11:00	4	3	7
11:01-12:00	5	6	11
12:01-13:00	10	4	14
13:01-14:00	8	7	15
14:01-15:00	10	9	19
15:01-16:00	11	11	22
16:01-17:00	13	11	24
17:01-18:00	5	12	17
18:01-19:00	7	4	11
19:01-20:00	7	6	13
20:01-21:00	6	6	12
21:01-22:00	11	9	20
22:01-23:00	8	4	12
23:01-0:00	5	4	9

*Note: Only includes crashes from 1989-1997 and 2000-2001

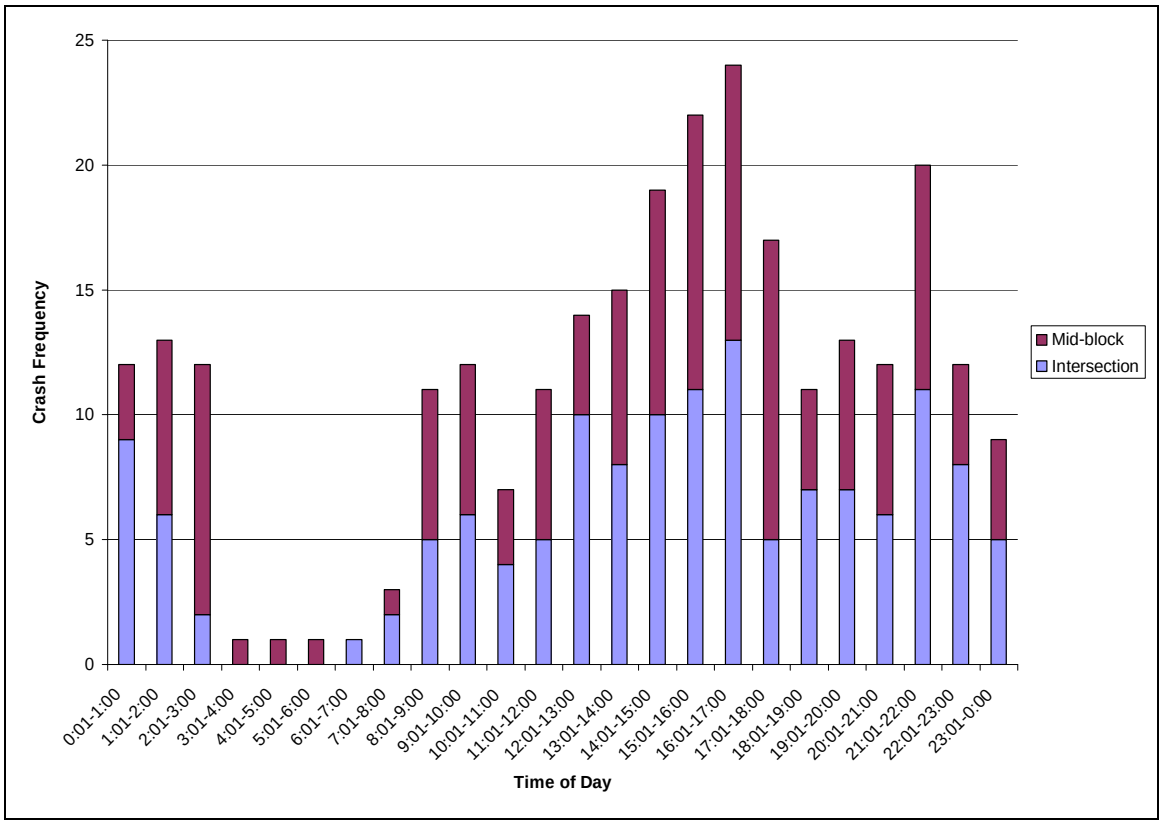


Figure 5. *Pedestrian-Vehicle Crashes by Time of Day and Location.*

Table 17 presents the number of crashes by age for drivers and pedestrians. Figures 6 and 7 depict these data graphically for drivers and pedestrians, respectively. It should be noted that these data only represent crashes from 2000 to 2001, inclusive. The overwhelming majority of crashes involve drivers and pedestrians ages 17 to 24, inclusive. This is not surprising due to the relatively large student population at Penn State and the number of young drivers from the local high schools.

Table 17. *Crash Frequency by Age.*

	Driver		Pedestrian	
Age Range	**Intersection Crashes**	**Mid-block Crashes**	**Intersection Crashes**	**Mid-block Crashes**
< 8	0	0	1	1
9-16	0	0	2	0
17-24	12	6	17	8
25-32	3	1	4	0
33-40	0	0	1	0
41-48	6	0	1	1
49-56	2	2	3	1
57-64	0	0	2	0
65-72	1	1	1	0
> 72	1	2	0	2

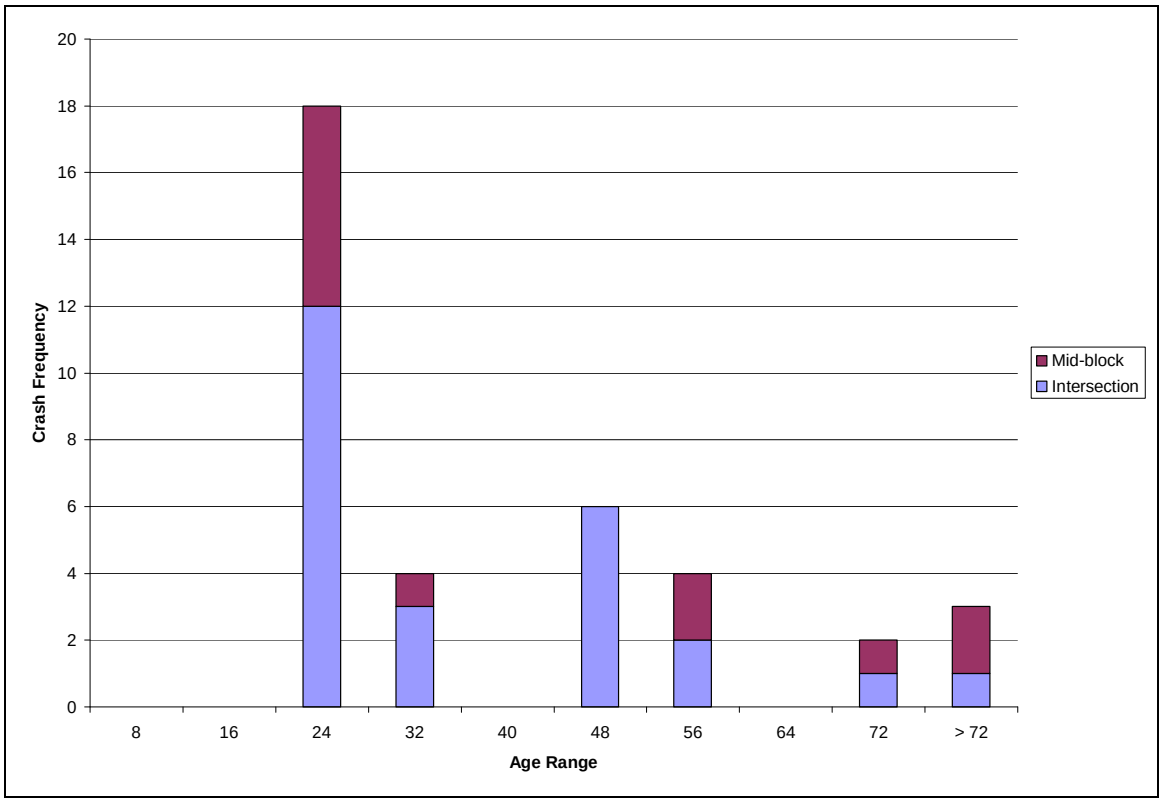


Figure 6. *Crash Frequency by Driver Age and Location.*

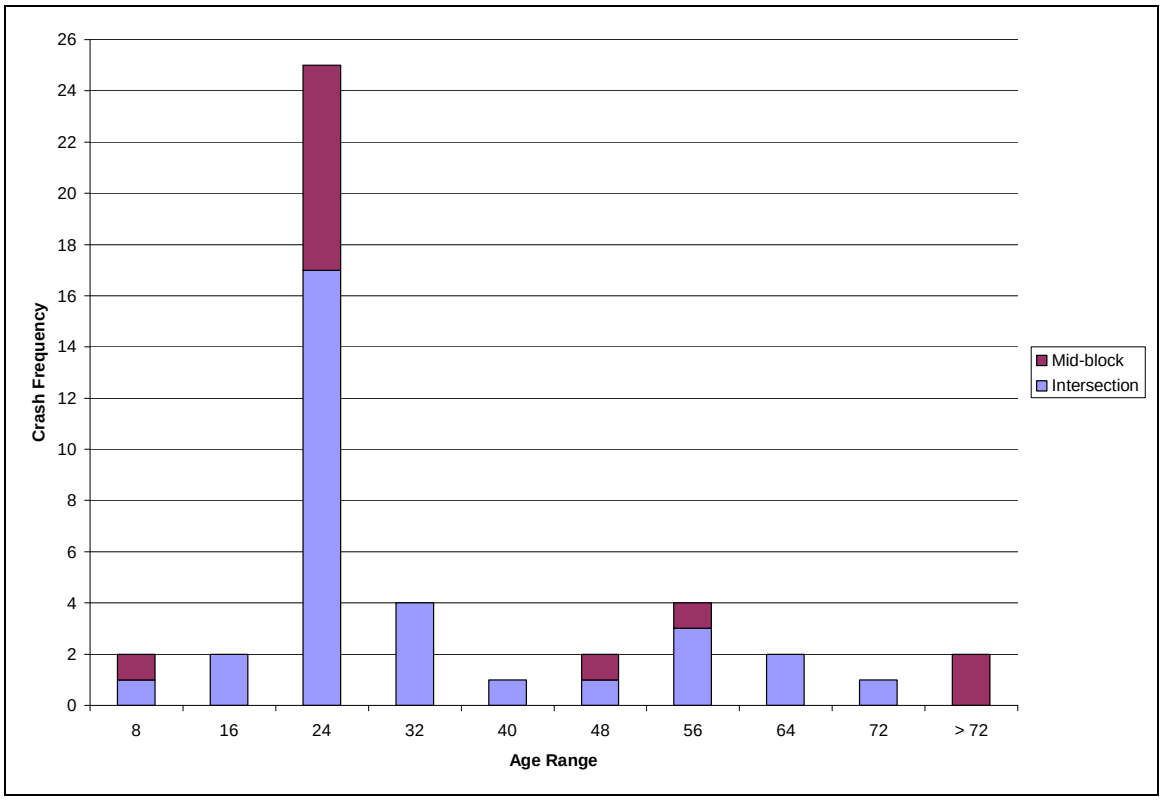


Figure 7. *Crash Frequency by Pedestrian Age and Location.*

Table 18 presents the number of crashes by day of week for intersection and mid-block locations. Figure 8 depicts these data graphically. It should be noted that these data only represent crashes from 2000 to 2001, inclusive. The day of week with the greatest number of crashes is Monday (10 crashes) followed by Friday (9 crashes). Saturday and Sunday show a significant reduction in crashes. This may be attributed to a reduced exposure (both vehicle and pedestrian traffic) on the weekend; however, this should be verified before further conclusions are drawn.

Table 18. *Crash Frequency by Day of Week.*

Day of Week	Intersection Crashes(1)	Mid-block Crashes(1)	Total Crashes(1)
MON.	7	3	10
TUES.	6	0	6
WED.	5	2	7
THURS.	5	3	8
FRI.	7	2	9
SAT.	2	2	4
SUN.	1	1	2

(1) Only includes crashes from 2000-2001

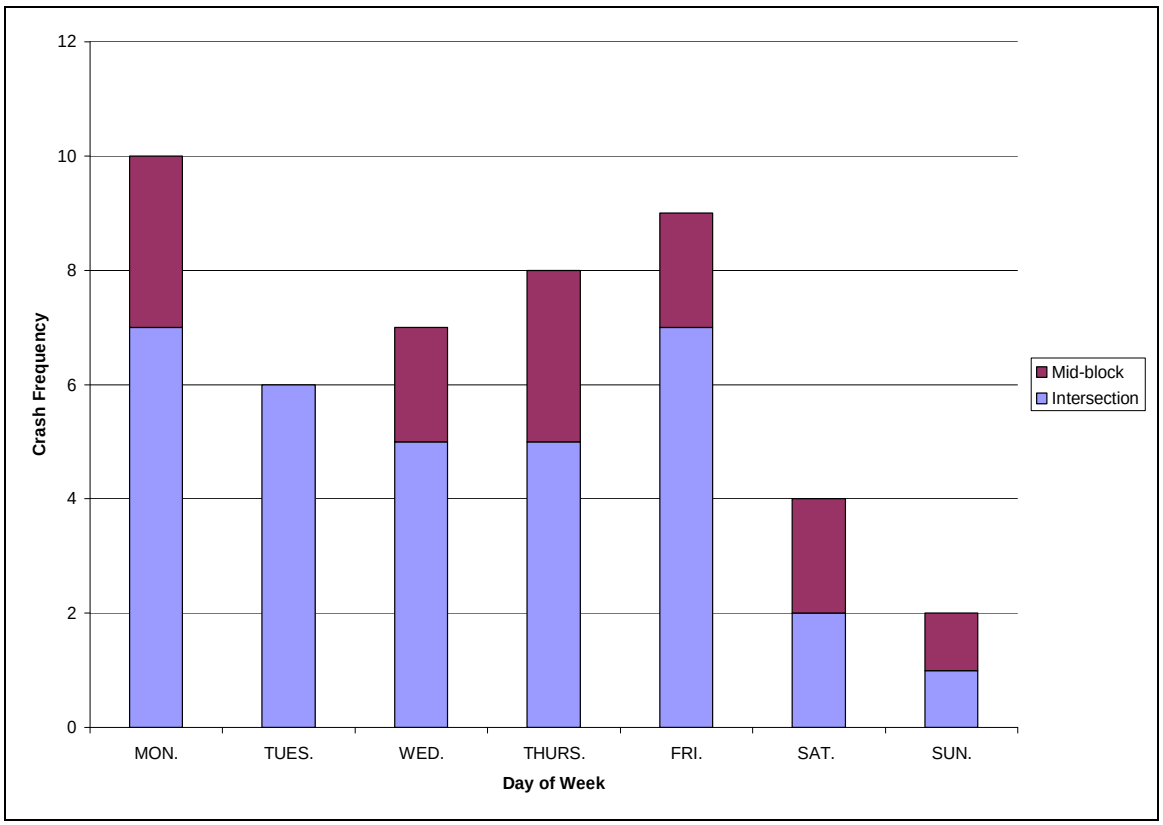


Figure 8. *Crash Frequency by Day of Week and Location.*

EVALUATION OF PAST PEDESTRIAN ENHANCEMENTS

For the entire analysis time period a number of pedestrian enhancements have been implemented in the Borough of State College. Table 19 lists some of the recent pedestrian enhancements and the period which they were implemented.

Table 19. *Selected Pedestrian Enhancements.*

Location	Enhancement	Implementation Date
College Ave. & Pugh St.	Curb Extension (Ped. Node)	June 1999
Beaver Ave. & Garner St.	Curb Extension (Ped. Node)	July 2003
Beaver Ave. & Allen St.	Curb Extension (Ped. Node)	July 2004
Beaver Ave. & Atherton St.	Curb Extension (Ped. Node)	August 2004
10 CBD traffic signals	Leading Pedestrian Interval	March 2005
College Ave. & Allen St.	Countdown Ped. Signal	June 2005
Beaver Ave. & Allen St.	Countdown Ped. Signal	June 2005
Beaver Ave. & Atherton St.	Intersection Lighting	October 2005
Beaver Ave. to College Ave. along Atherton St.	Street Lighting	October 2005

The most widespread enhancement was the leading pedestrian interval (LPI) implementation which was installed at 10 traffic signals in the downtown CBD. The LPI was installed at:

- College Avenue & Garner St. / Shortlidge Rd.
- College Avenue & Pugh St.
- College Avenue & Allen St.
- College Avenue & Fraser St.
- College Avenue & Burrowes St.
- Beaver Avenue & Burrowes St.
- Beaver Avenue & Fraser St.
- Beaver Avenue & Allen St.
- Beaver Avenue & Pugh St.
- Beaver Avenue & Garner St.

The LPI is a 3 second advance walk indication that is given to pedestrians prior to the circular green indication given to vehicles. The LPI is intended to reduce conflicts with pedestrians and turning vehicles by allowing pedestrians to begin and, in some cases, substantially complete the street crossing maneuver before vehicles receive a green indication at the start of a signal phase. The number of crosswalks with LPI varies based upon the existing configuration of the intersection. Locations with protected left turn phases do not have the LPI implemented since there would be a conflict with signal indications.

In order to determine the effectiveness of the LPI, an EB before-after analysis was completed for the downtown intersections with LPI. The EB method increases the precision of estimation and corrects for regression-to-the mean bias. A safety performance function is developed to determine the expected number of crashes at the sites had there been no improvements made (no LPI).

In the empirical Bayes (EB) approach, the change in safety for a given crash type at a site is given by Equation 6.

$$\Delta = \lambda - \pi \tag{6}$$

Where,
Δ = change in safety (number of crashes),
λ = expected number of crashes that would have occurred in after period without treatment, and
π = actual number of reported crashes in the after period.

The expected number of crashes (λ) was estimated by a safety performance function (SPF). An SPF explicitly accounts for the effects of regression-to-the-mean and changes in traffic volume. SPFs were developed using data from untreated sites (reference sites) and applying multiple logistic regression techniques that relate crash frequency to traffic flow and other relevant factors. Yearly indicators were included in the SPF to account for potential temporal effects on safety (e.g., variation in weather, demography, and crash reporting). The estimated SPF is shown in Table 20.

In the EB method, the SPF is used to first estimate the number of crashes that would be expected in each year of the before period at locations with traffic volumes and other characteristics similar to the treatment sites being analyzed (i.e., reference sites). The sum of these annual SPF estimates (P) is then combined with the actual count of crashes (x) in the before period at a treatment site to obtain an estimate of the expected number of crashes (m) before treatment. The estimate of m is calculated using Equation 7.

$$m = w_1(x) + w_2(P) \tag{7}$$

Where,
m = expected number of crashes before the treatment,
w_1 = weighting factor for actual number of crashes,
w_2 = weighting factor for sum of annual SPF estimates,
x = actual number of crashes before the treatment, and
P = sum of annual SPF estimates.

Table 20. *SPF for LPI Analysis.*

Variable	Coefficient	St. Err.	P>|z|
Constant	-6.487639	0.769	0.000
y1990	0.775735	0.539	0.150
y1991	0.762551	0.539	0.158
y1992	0.548234	0.558	0.326
y1993	0.282780	0.586	0.629
y1994	0.519435	0.559	0.352
y1995	0.791941	0.534	0.138
y1996	0.488515	0.559	0.383
y1997	0.577551	0.550	0.294
y2000	0.301760	0.575	0.600
y2001	0.688354	0.539	0.201
y2003	1.053926	0.516	0.041
y2004	0.926615	0.523	0.077
y2005	-0.061820	0.615	0.920
y2006	0.914102	0.524	0.081
y2007	0.969776	0.521	0.063
Total Entering Vehicles	0.000044	0.000	0.020
CBD (1 = yes; 0 = no)	0.618603	0.208	0.003
Signal (1 = yes; 0 = no)	0.218798	0.269	0.415
Approaches (1 = 4; 0 = 3)	0.902823	0.186	0.000
Major 1-way (1 = yes; 0 = no)	0.781088	0.192	0.000
ln(Total Entering Pedestrians)	0.421876	0.117	0.000
Dispersion Parameter	1.000000		

The weights, w_1 and w_2, are estimated from the mean and variance of the SPF by Equations 8 and 9.

$$w_1 = \frac{P}{P + 1/k} \tag{8}$$

$$w_2 = \frac{1}{k\left(P + 1/k\right)} \tag{9}$$

Where,
w_1 = weighting factor for actual number of crashes,
w_2 = weighting factor for sum of annual SPF estimates,
k = dispersion parameter for a given model, estimated from SPF calibration process

A factor is then applied to *m* to account for the length of the after period and differences in traffic volumes between the before and after periods. This factor is the sum of the

annual SPF predictions for the after period divided by the sum of these predictions for the before period (P). The result, after applying this factor, is an estimate of λ. The procedure also produces an estimate of the variance of λ. The estimate of λ is then summed over all sites in a treatment group of interest (λ_{sum}) and compared with the count of crashes during the after period in that group (π_{sum}). The variance of λ is also summed over all sites in the treatment group to obtain Var(λ_{sum}). The Index of Effectiveness (θ) is estimated from Equation 10.

$$\theta = \frac{\pi_{sum} / \lambda_{sum}}{1 + \left(Var(\lambda_{sum}) / \lambda_{sum}^2 \right)} \tag{10}$$

Where,
θ = Index of effectiveness,
π_{sum} = sum of observed crashes in after period,
λ_{sum} = sum of expected crashes in after period, and
Var(λ_{sum}) = sum of the variance of expected crashes in after period.

The standard deviation of θ is given by Equation 11.

$$StDev(\theta) = \sqrt{\frac{\theta^2 \left(\frac{Var(\pi_{sum})}{\pi_{sum}^2} + \frac{Var(\lambda_{sum})}{\lambda_{sum}^2} \right)}{\left(1 + \frac{Var(\lambda_{sum})}{\lambda_{sum}^2} \right)^2}} \tag{11}$$

Where,
Var(π_{sum}) = sum of the variance of observed crashes in after period and
All other terms are as previously defined.

The percent change in crashes is calculated from Equation 12. Thus a value of $\theta = 0.7$ with a standard deviation of 0.12 indicates a 30 percent reduction in crashes with a standard deviation of 12 percent.

$$Percent\ Change\ in\ Crashes = 100 * (1 - \theta) \tag{12}$$

The results of the EB analysis (Table 21) indicate that the implementation of the LPI at the 10 sites in downtown State College resulted in nearly a 50 percent reduction in pedestrian-vehicle crashes. A 95 percent confidence interval for the expected reduction in crashes, after implementing the LPI, is 20.5 percent to 80.6 percent. The confidence interval does not include zero; therefore, the reduction is significant at the 95 percent confidence level. While the results are statistically significant at the 95 percent confidence interval, they are based on a relatively small sample of locations and limited after period. In an EB analysis, the sample size is related to the number of crashes in the

before and after period. As this analysis is based on pedestrian-vehicle crashes, there are relatively few observed crashes in the before and after periods. This could result in the over-estimation of the effectiveness of the treatment (i.e., LPI). Despite the small number of treated sites and limited crash data, the LPI appears to be an effective countermeasure for reducing pedestrian-vehicle crashes at signalized intersections.

Table 21. *Results of the LPI Before-After Analysis.*

Sites	EB expected crashes in after period without treatment	Crash count observed in after period	θ (standard error)	% Reduction (standard error)
10	23.5	12	**0.505** (0.153)	**49.5%** (15.3)

Note: Bold numbers indicate a statistically significant change at the 95 percent confidence level.

DETAILED ENGINEERING STUDY FOR THE TOP FIVE AREAS OF CONCERN

A detailed engineering study (DES) was performed for the top five areas of concern to formulate cost-effective strategies to improve safety. The DES includes a review of site-specific conditions and a detailed review of past site crash characteristics. For each location characteristics such as traffic data, geometric data, operational data, pedestrian behavioral observations, and crash data were summarized.

Average daily traffic (ADT) values were reported from the Pennsylvania Department of Transportation (PennDOT) iTMS system. For local roads, the ADT values were measured through past traffic engineering studies or estimated from 2008 peak hour turning movement counts.

Peak hour entering pedestrian volumes reflect pedestrian counts from April 2008 during the 5 PM to 6 PM hour. The values can be considered relative since they were all conducted on the same time basis. At Beaver Avenue & Locust Lane the hourly pedestrian entering volume is based on the pedestrian flow model developed by the Penn State graduate transportation safety class in 2008. Levels of service reflect year 2010 forecasted values from traffic engineering studies in the project area (7).

Pedestrian behavioral observation data was collected in April 2008. A pedestrian behavioral study was performed in accordance with the *Manual of Transportation Engineering Studies* (8). One observer was used to record all pedestrian behavioral observations in 2008 to reduce inter-observer bias. Crash data in the following Tables reflects the most recent crash information from year 2000 through 2007, excluding 2002 when no crash data was available.

BEAVER AVENUE AND ATHERTON STREET

Existing site characteristics are given in Table 22. The current condition diagram is shown in the Appendix.

Table 22. *Beaver Avenue & Atherton Street Existing Site Characteristics.*

	Major Street	Minor Street	Total
Traffic Data	***Atherton Street***	***Beaver Avenue***	
Functional Classification	Urban Principal Arterial Highway	Urban Principal Arterial Highway	--
ADT	20,100 vpd	5,800 vpd	--
Posted Speed Limit	35 mph	25 mph	--
Entering Pedestrian Volume (peak hourly)	--	--	150
Geometric Data			
Number of Approaches	2	1	3
Number of Lanes	4	2	6
Number of Crosswalks	2	2	4
Crosswalk Length (ft.)	55	35	--
Approach Grades	+,- 2%	0 %	
Operational Data			
LPI	None	None	None
AM Peak Hour LOS	C / A	C	C
PM Peak Hour LOS	C / D	C	D
Behavioral Observations (Total Intersection)	**2008 Data**	**2002 Data**	
Peds crossing against signal	21%	39%	
Observed midblock crossing	12%	NA	
High crash-risk crossing behaviors	11%	NA	
Crash Data	**Total Crashes 2000-2007 ex.2002**	**Percentage**	
Crash Type Grouping	Number of Crashes		
Turning vehicle hits pedestrian	5	83%	
Through vehicle hits pedestrian	1	17%	

The intersection of Beaver Avenue & Atherton Street is characterized by heavy pedestrian and vehicle volumes. With Atherton Street posted at 35 mph, the intersection

has one of the highest approach speed limits of the top five areas of concern. The maximum crosswalk length is also one of the longest of the top five areas of concern due to the multi-lane cross section of Atherton Street. A relatively significant percentage of pedestrians were observed crossing mid-block in the vicinity of the intersection and the majority of recent crashes have involved turning vehicles hitting pedestrians.

Based upon a detailed site review the following engineering recommendations are offered to reduce pedestrian-vehicle crashes at the intersection:

1. ***Implement the LPI;***
2. ***Install a barrier (i.e. decorative drop chain fence, etc.) along Atherton Street from Beaver Avenue to College Avenue.***
3. ***Install a curb extension (pedestrian node) on the south-east corner of the intersection shadowing the parking lane on Beaver Avenue;***

The LPI has shown to be a significant improvement to pedestrian safety by reducing pedestrian-vehicle crashes at other traffic signals in State College. In addition, the LPI is intended to reduce the types of crashes that have in fact occurred at this intersection in the past – "turning vehicle hitting pedestrian crashes".

The installation of a barrier to discourage mid-block crossings of Atherton Street between Beaver Avenue and College Avenue will likely reduce the overall pedestrian – vehicle crash rate. Mid-block crossings were readily observed at this location. Due to the curvature, number of lanes, speed, and traffic volume on Atherton Street, a midblock crossing attempt between Beaver Avenue and College Avenue is a very dangerous maneuver for a pedestrian.

The geometry of the intersection allows for the installation of a curb extension on the south-east corner and this would reduce the crossing distance for pedestrians and reduce their exposure to vehicles at the intersection.

COLLEGE AVENUE AND ATHERTON STREET

Existing site characteristics are given in Table 23. The current condition diagram is shown in the Appendix.

Table 23. *College Avenue & Atherton Street Existing Site Characteristics.*

	Major Street	**Minor Street**	**Total**
Traffic Data	***Atherton Street***	***College Avenue***	
Functional Classification	Urban Principal Arterial Highway	Urban Principal Arterial Highway	--
ADT	20,100 vpd	8,000 vpd	--
Posted Speed Limit	35 mph	25 mph	--
Entering Pedestrian Volume (peak hourly)	--	--	470

Geometric Data	***Atherton Street***	***College Avenue***	***Total***
Number of Approaches	2	1	3
Number of Lanes	4	3	6
Number of Crosswalks	2	2	4
Max. Crosswalk Length (ft.)	65	40	--
Approach Grades	+,- 5%	+2 %	--
Operational Data			
LPI	None	None	None
AM Peak Hour LOS	B / B	C	C
PM Peak Hour LOS	B / C	B	C
Behavioral Observations (Total Intersection)	**2008 Data**		
Peds crossing against signal	17%		
Observed midblock crossing	15%		
High crash-risk crossing behaviors	2%		
Crash Data	**Total Crashes 2000-2007 ex.2002**	**Percentage**	
Crash Type Grouping	Number of Crashes		
Turning vehicle hits pedestrian	4	57%	
Vehicle – Pedestrian Sideswipe	1	14%	
Unknown	2	29%	

The intersection of College Avenue & Atherton Street is also characterized by heavy pedestrian and vehicle volumes. With Atherton Street posted at 35 mph, the intersection also has one of the highest approach speed limits of the top five areas of concern. The maximum crosswalk length is also the longest of the top five areas of concern due to the intersection skew and the multi-lane cross section of Atherton Street. A relatively significant percentage of pedestrians were observed crossing mid-block in the vicinity of the intersection and the majority of recent crashes have involved turning vehicles hitting pedestrians. The site characteristics for this intersection are similar to Beaver Avenue & Atherton Street.

Based upon a detailed site review the following engineering recommendations are offered to reduce pedestrian-vehicle crashes at the intersection:

1. ***Implement the LPI;***
2. ***Install a barrier (i.e. decorative drop chain fence, etc.) along Atherton Street from Beaver Avenue to College Avenue.***

The LPI has shown to be a significant improvement to pedestrian safety by reducing pedestrian-vehicle crashes at other traffic signals in State College. In addition, the LPI is intended to reduce the types of crashes that have in fact occurred at this intersection in the past – "turning vehicle hitting pedestrian crashes".

The installation of a barrier to discourage mid-block crossings of Atherton Street between College Avenue and Beaver Avenue will likely reduce the overall pedestrian – vehicle crash rate for the Borough. Mid-block crossings were readily observed at this location. Due to the curvature, number of lanes, speed, and traffic volume on Atherton Street, a midblock crossing attempt between College Avenue and Beaver Avenue is a very dangerous maneuver for a pedestrian.

COLLEGE AVENUE AND ALLEN STREET

Existing site characteristics are given in Table 24. The current condition diagram is shown in the Appendix.

Table 24. *College Avenue & Allen Street Existing Site Characteristics.*

	Major Street	**Minor Street**	**Total**
Traffic Data	***College Avenue***	***Allen Street***	
Functional Classification	Urban Principal Arterial Highway	Local Road	--
ADT	8,000 vpd	2,200 vpd	--
Posted Speed Limit	25 mph	25 mph	--
Entering Pedestrian Volume (peak hourly)	--	--	1,500
Geometric Data			
Number of Approaches	1	1	2
Number of Lanes	2	2	4
Number of Crosswalks	2	1	3
Max. Crosswalk Length (ft.)	38	30	--
Approach Grades	-2%	+4%	--
Operational Data			
LPI	Yes	Yes	--
AM Peak Hour LOS	A	B	A
PM Peak Hour LOS	A	D	B
Behavioral Observations (Total Intersection)	**2008 Data**		
Peds crossing against signal	21%		

Behavioral Observations (Total Intersection)	**2008 Data**		
Observed midblock crossing	0%		
High crash-risk crossing behaviors	10%		
Crash Data	**Total Crashes 2000-2007 ex.2002**	**Percentage**	
Crash Type Grouping	Number of Crashes		
Turning vehicle hits pedestrian	2	29%	
Ped exiting vehicle hit	1	14%	
Unknown	4	57%	

College Avenue and Allen Street has the highest total pedestrian volume of the top five areas of concern. Pedestrian behaviors at this intersection are similar to the other intersections observed in the Borough. The cause of the majority of pedestrian-vehicle crashes were due to unusual circumstances which could not be classified by the traditional crash type groupings.

Based upon a detailed site review the following engineering recommendation is offered to reduce pedestrian-vehicle crashes at the intersection:

1. ***Install a curb extension or pedestrian node on the north side of the intersection for both College Avenue crosswalks.***

The geometry of the intersection allows for the installation of a curb extension which would reduce the crossing distance for pedestrians and reduce their exposure to vehicles at the intersection. The curb extension would provide greater visibility for pedestrians, especially at the near side-bus stop location on the north side of College Avenue at Allen Street. A curb extension would reduce bus maneuverability directly adjacent to the intersection, but this could be mitigated by allowing more separation between the curb extension and the first bay of the bus pull-off.

COLLEGE AVENUE AND BURROWES STREET

Existing site characteristics are given in Table 25. The current condition diagram is shown in the Appendix.

Table 25. *College Avenue & Burrowes Street Existing Site Characteristics.*

	Major Street	**Minor Street**	**Total**
Traffic Data	***College Avenue***	***Burrowes Street***	
Functional Classification	Urban Principal Arterial Highway	Local Road	--
ADT	8,000 vpd	6,300 vpd	--
Posted Speed Limit	25 mph	25 mph	--
Entering Pedestrian Volume (peak hourly)	--	--	560
Geometric Data			
Number of Approaches	1	2	3
Number of Lanes	2	2/3	4/5
Number of Crosswalks	2	2	4
Max. Crosswalk Length (ft.)	40	33	--
Approach Grades	+1%	+,- 5%	--
Operational Data			
LPI	Partial	Yes	--
AM Peak Hour LOS	A	B/D	B
PM Peak Hour LOS	C	B/E	D
Behavioral Observations (Total Intersection)	**2008 Data**		
Peds crossing against signal	24%		
Observed midblock crossing	3%		
High crash-risk crossing behaviors	11%		
Crash Data	**Total Crashes 2000-2007 ex.2002**	**Percentage**	
Crash Type Grouping	Number of Crashes		
Turning vehicle hits pedestrian	3	33%	
Ped non-compliance with signal	1	11%	
Unknown	5	56%	

The intersection of College Avenue and Burrowes Street is characterized by relatively high vehicle volumes due to the two-way traffic on Burrowes Street. The intersection also includes a northbound protected left turn signal phase which precludes the installation of the LPI for the west crosswalk at the intersection. Other traffic engineering studies in the project area have shown that the protected left turn phase is not warranted based upon engineering criteria (7).

Based upon a detailed site review the following engineering recommendations are offered to reduce pedestrian-vehicle crashes at the intersection:

1. ***Install a curb extension or pedestrian node on the west side of the intersection on the north and south sides of College Avenue.***
2. ***Remove the protected northbound left turn signal phase and implement the LPI at for the west crosswalk.***

The LPI has shown to be a significant improvement to pedestrian safety by reducing pedestrian-vehicle crashes at other traffic signals in State College.

The geometry of the intersection allows for the installation of curb extensions on the north-west and south-west corners and this would reduce the crossing distance for pedestrians and reduce their exposure to vehicles at the intersection.

BEAVER AVENUE AND LOCUST LANE

Existing site characteristics are given in Table 26. The current condition diagram is shown in the Appendix.

Table 26. *Beaver Avenue & Locust Lane Existing Site Characteristics.*

	Major Street	**Minor Street**	**Total**
Traffic Data	***Beaver Avenue***	***Locust Lane***	
Functional Classification	Urban Principal Arterial Highway	Local Road	--
ADT	5,800 vpd	1,500 vpd	--
Posted Speed Limit	25 mph	25 mph	--
Entering Pedestrian Volume (est. peak hourly)	--	--	560
Geometric Data			
Number of Approaches	1	2	3
Number of Lanes	2	2/1	4/3
Number of Crosswalks	2	2	4
Max. Crosswalk Length (ft.)	37	35	--
Approach Grades	+1%	+,- 5%	--
Operational Data			
Control Type	Uncontrolled	Stop Controlled	
Crash Data	**Total Crashes 2000-2007, ex.2002**	**Percentage**	
Crash Type Grouping	Number of Crashes		
Unknown	2	100%	

Beaver Avenue and Locust Lane is the only unsignalized intersection in the top five areas of concern. The crash data indicate few crashes in the most recent analysis period—the majority of crashes occurred at this intersection in the 1990's.

Based upon a detailed site review the following engineering recommendation is offered to reduce pedestrian-vehicle crashes at the intersection:

1. ***Install a curb extension or pedestrian node on the south-east and south-west side of the intersection.***

The geometry of the intersection allows for the installation of curb extensions on the south-east and south-west corners and this would reduce the crossing distance for pedestrians and reduce their exposure to vehicles at the intersection.

CONCLUSIONS

The top five areas of concern for pedestrian – vehicle crashes were identified for the Borough of State College. Through a robust analysis using five ranking methodologies the top five sites were identified as:

1. Beaver Avenue & Atherton Street;
2. College Avenue & Atherton Street;
3. College Avenue & Allen Street;
4. College Avenue & Burrowes Street;
5. Beaver Avenue & Locust Lane.

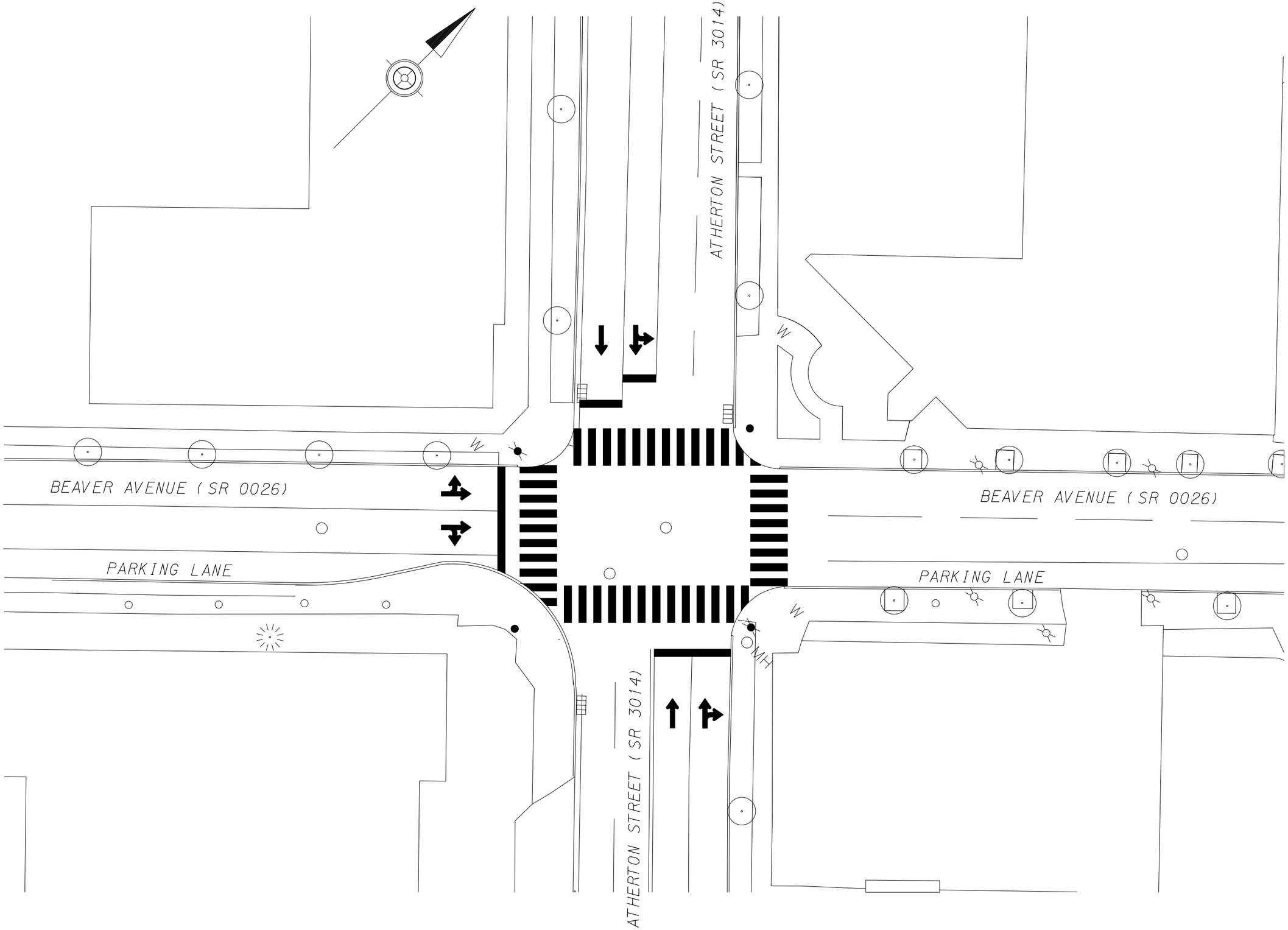
A detailed review of each site has produced a list of engineering recommendations for implementation. Recommendations on educational and enforcement strategies will be discussed in Part II of the Comprehensive Pedestrian and Bicycle Program.

In addition to the top five areas of concern identified in this report, all locations in the Borough should be approached with the following guiding principles to address pedestrian – vehicle crashes and conflicts (9):

- Reduce pedestrian exposure to vehicular traffic;
- Improve sight distance and visibility for motor vehicles and pedestrians;
- Reduce the speed of motor vehicles;
- Improve pedestrian and motorist safety awareness and behavior.

Implementation of the recommendations identified in Part I of the Comprehensive Pedestrian and Bicycle Program for the Borough of State College should have a positive effect by reducing the pedestrian-vehicle crash rate in the Borough. Continual monitoring of pedestrian-vehicle crashes and proactive improvements at locations with high pedestrian ISI scores will provide for improved safety for pedestrians throughout the Borough.

APPENDIX A – INTERSECTION CONDITION DIAGRAMS



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DESIGNER_____
PROJ. MANAGER_____

DATE DESCRIPTION
REVISIONS

PROJECT NAME
STATE COLLEGE BOROUGH PEDESTRIAN AND BICYCLE SAFETY MASTER PLAN

SHEET NAME
BEAVER AVENUE & ATHERTON STREET CONDITION DIAGRAM

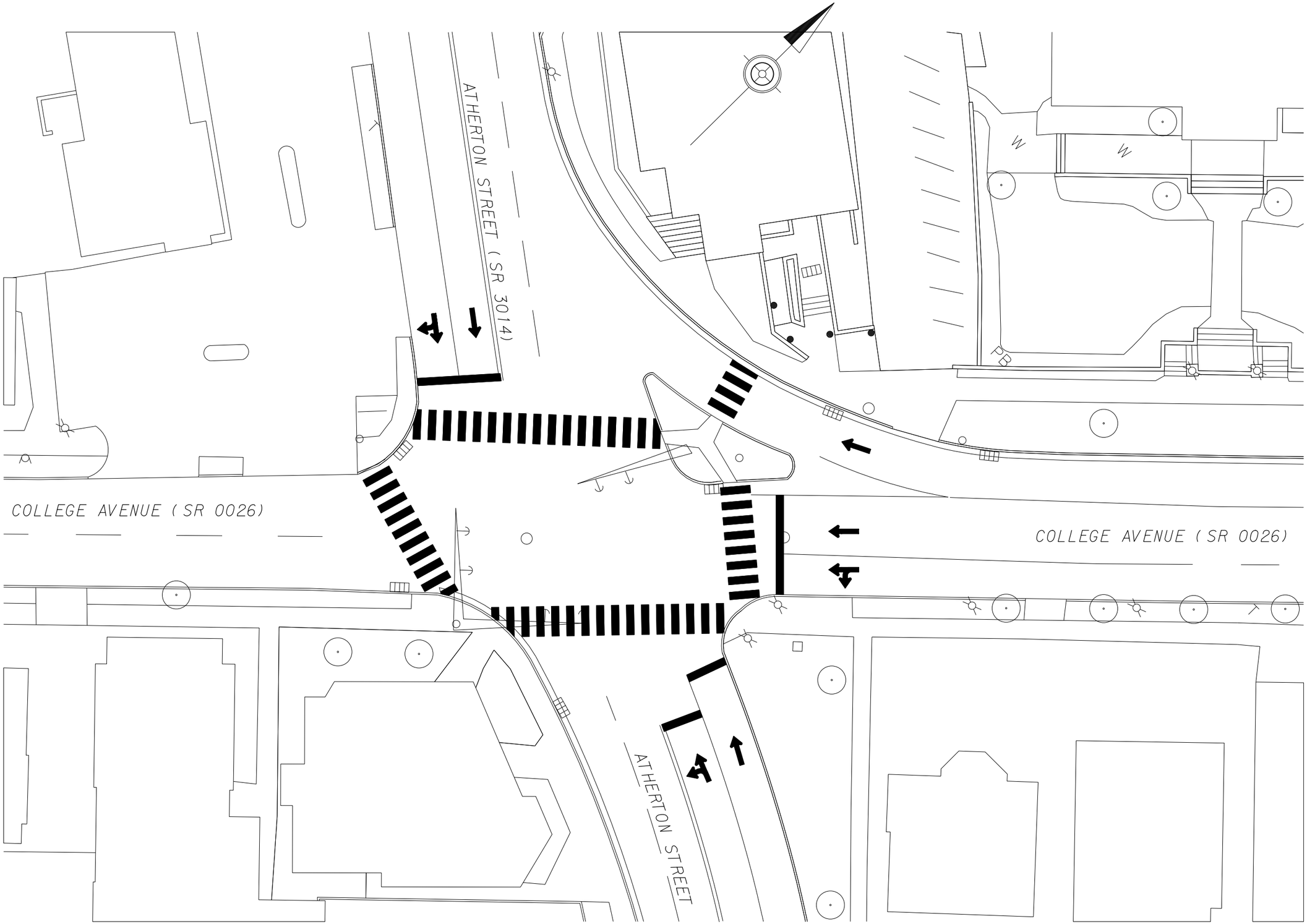
PROJECT NO.
STATE01-08-030

DATE
JUNE 10, 2008

SCALE	SHEET NO.
1"=25'	A-1

PLOTTED: 6/13/2008

FILE NAME: 08-030 Beaver & Atherton Plan Sh01.dgn



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SHEET NAME

COLLEGE AVENUE & ATHERTON STREET CONDITION DIAGRAM

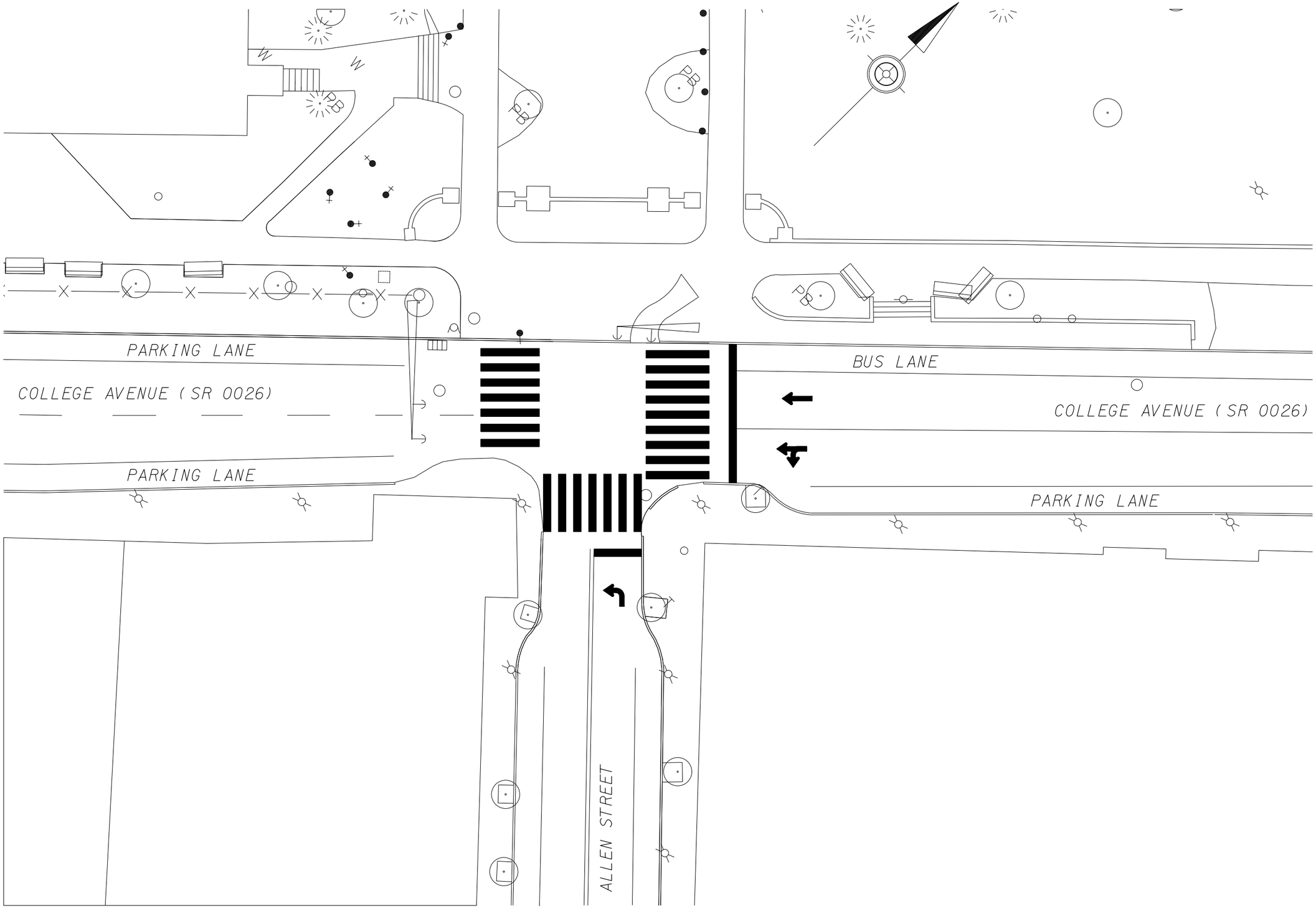
PROJECT NO.
STATE01-08-030

DATE
JUNE 10, 2008

SCALE	SHEET NO.
1"=25'	A-2

PLOTTED: 6/13/2008

FILE NAME: 08-030 College & Atherton Plan Sh01.dgn



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PROJECT NAME
STATE COLLEGE BOROUGH PEDESTRIAN AND BICYCLE SAFETY MASTER PLAN

SHEET NAME
COLLEGE AVENUE & ALLEN STREET CONDITION DIAGRAM

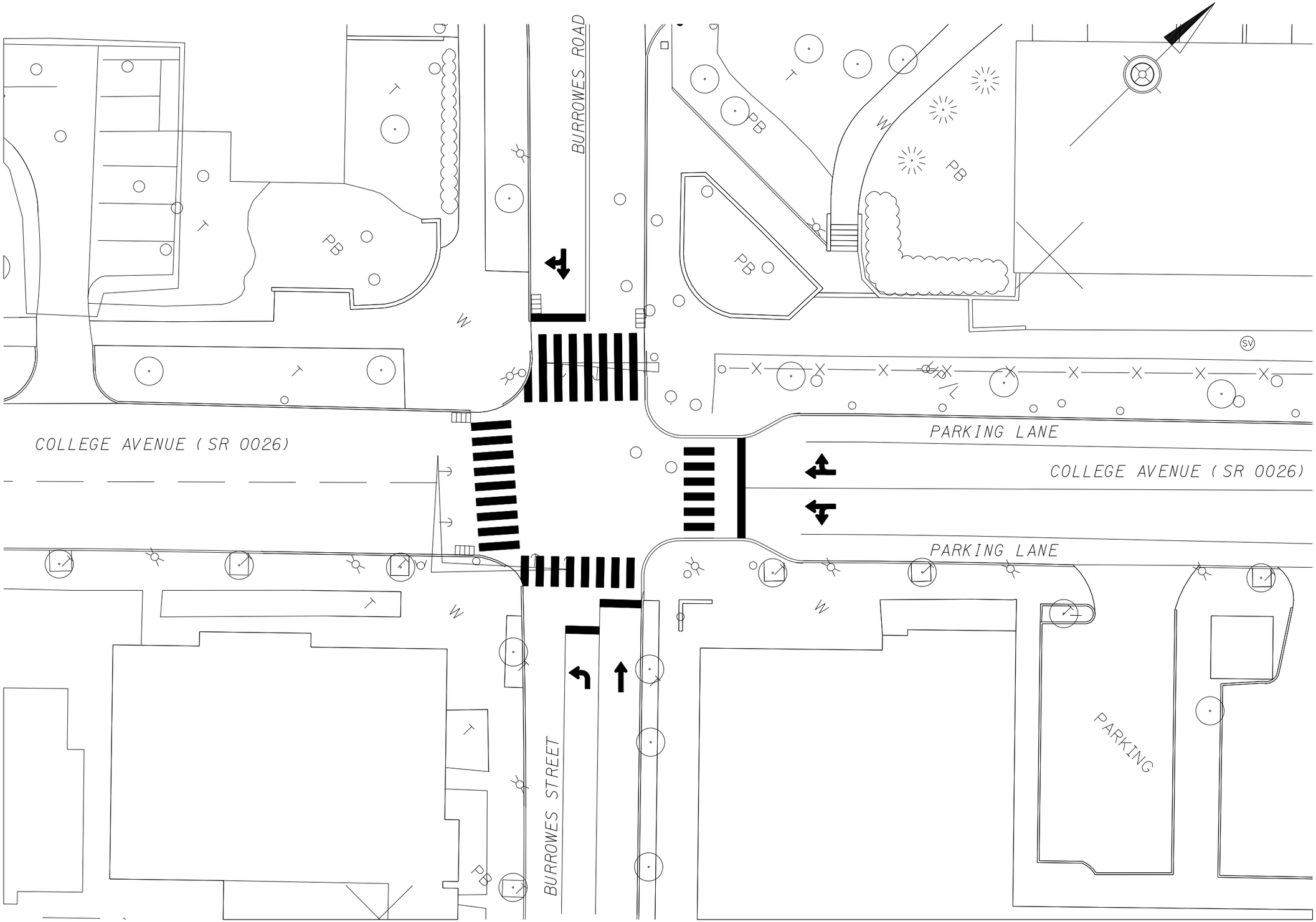
PROJECT NO.
STATE01-08-030

DATE
JUNE 10, 2008

SCALE	SHEET NO.
1"=25'	A-3

PLOTTED: 6/13/2008

FILE NAME: 08-030 College & Allen Plan Sh01.dgn



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PROJECT NAME

STATE COLLEGE BOROUGH PEDESTRIAN AND BICYCLE SAFETY MASTER PLAN

SHEET NAME

COLLEGE AVENUE & BURROWES STREET CONDITION DIAGRAM

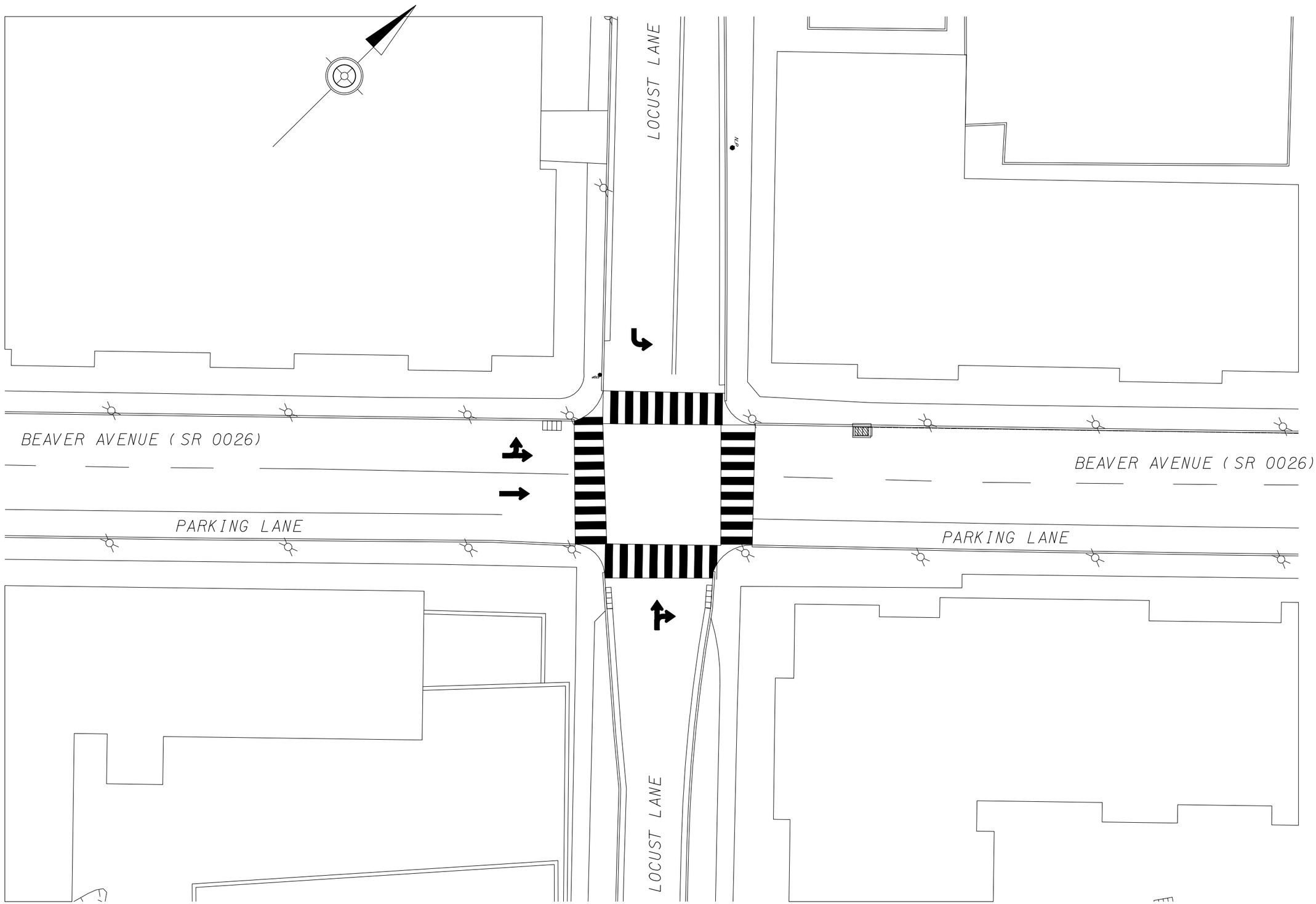
PROJECT NO.
STATE01-08-030

DATE
JUNE 10, 2008

SCALE	SHEET NO.
1"=25'	A-4

PLOTTED: 6/13/2008

FILE NAME: 08-030 College & Burrowes Plan Sh01.dgn



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FILE NAME: 08-030 Beaver & Locust Plan Sh01.dgn

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REVISIONS

PROJECT NAME

STATE COLLEGE BOROUGH PEDESTRIAN AND BICYCLE SAFETY MASTER PLAN

SHEET NAME

BEAVER AVENUE & LOCUST LANE CONDITION DIAGRAM

PROJECT NO.
STATE01-08-030

DATE
JUNE 10, 2008

SCALE	SHEET NO.
1"=25'	A-5

APPENDIX B – PEDESTRIAN INTERSECTION SAFETY INDICES

Street 1	Street 2	Major St. X-ing #1 Ped ISI	Major St. X-ing #2 Ped ISI	Minor St. X-ing #1 Ped ISI	Minor St. X-ing #2 Ped ISI	Average Ped ISI
Atherton	Center	4.58	4.58	1.92	*	3.69
Atherton	Pugh	4.58	4.58	1.92	*	3.69
Calder	Atherton	4.58	4.58	1.59	*	3.58
Atherton	Foster	4.58	4.58	2.10	2.10	3.34
Atherton	Nittany	4.58	4.58	2.10	2.10	3.34
Atherton	Highland	4.58	4.58	1.92	1.92	3.25
Atherton	Logan	4.58	4.58	1.92	1.92	3.25
Beaver	Heister	3.73	3.73	1.92	*	3.13
Beaver	Humes	3.73	3.73	1.92	*	3.13
Beaver	McAllister	3.73	3.73	1.92	*	3.13
College	Heister	3.73	3.73	1.92	*	3.13
College	Locust	3.73	3.73	1.92	*	3.13
College	McAllister	3.73	3.73	1.92	*	3.13
Fraser	Foster	3.67	3.67	1.87	*	3.07
Park	McKee	3.67	3.67	1.87	*	3.07
University	Royal	3.67	3.67	1.69	*	3.01
Calder	Kelly	3.40	3.40	1.92	*	2.90
Calder	McAllister	3.40	3.40	1.92	*	2.90
Beaver	Sowers	3.49	3.49	1.69	*	2.89
College	Hetzel	3.49	3.49	1.69	*	2.89
College	High	3.49	3.49	1.69	*	2.89
College	Sowers	3.49	3.49	1.69	*	2.89
Westerly	O'Bryan	3.49	3.49	1.69	*	2.89
Beaver	Locust	3.73	3.73	1.92	1.92	2.83
Calder	Garner	3.73	3.73	1.92	1.92	2.83
Burrowes	Fairmount	3.67	3.67	1.87	1.87	2.77
Garner	Easterly	3.83	3.83	1.69	1.69	2.76
Pugh	Easterly	2.02	2.02	3.49	3.49	2.76
Calder	Fraser	3.73	3.73	1.59	1.92	2.74
Allen	Fairmount	3.49	3.49	1.87	1.87	2.68
Allen	Foster	3.49	3.49	1.87	1.87	2.68
Allen	Logan	3.49	3.49	1.87	1.87	2.68
Allen	Mitchell	3.49	3.49	1.87	1.87	2.68
Allen	Nittany	3.49	3.49	1.87	1.87	2.68
Beaver	Barnard	3.49	3.49	1.87	1.87	2.68
Beaver	Gill	3.49	3.49	1.87	1.87	2.68
College	Barnard	3.49	3.49	1.87	1.87	2.68
College	Patterson	3.49	3.49	1.87	1.87	2.68
Pugh	Fairmount	3.49	3.49	1.87	1.87	2.68
Pugh	McCormick	3.49	3.49	1.87	1.87	2.68
Pugh	Nittany	3.49	3.49	1.87	1.87	2.68

Street 1	Street 2	Major St. X-ing #1 Ped ISI	Major St. X-ing #2 Ped ISI	Minor St. X-ing #1 Ped ISI	Minor St. X-ing #2 Ped ISI	Average Ped ISI
Calder	Sowers	3.16	3.16	1.69	*	2.67
Calder	Thrush	3.16	3.16	1.69	*	2.67
Calder	Allen	3.73	3.73	1.59	1.59	2.66
Calder	Locust	3.73	3.73	1.59	1.59	2.66
Calder	Pugh	3.73	3.73	1.59	1.59	2.66
Allen	Hamilton	3.49	3.49	1.69	1.69	2.59
College	Sparks	3.49	3.49	1.69	1.69	2.59
Pugh	Highland	3.49	3.49	1.69	1.69	2.59
Atherton	Branch	2.80	2.80	2.07		2.56
Atherton	Westerly	2.85	2.85	2.23	2.23	2.54
Atherton	Railroad	2.85	2.85	1.86	*	2.52
Atherton	White Course	2.85	2.85	1.86	*	2.52
Park	Atherton	2.85	2.85	2.10	1.77	2.39
College	Atherton	2.83	2.83	1.91	1.91	2.37
Beaver	Atherton	2.83	2.83	1.90	1.90	2.36
Atherton	Hillcrest	2.85	2.85	1.87	1.87	2.36
Atherton	Allen	2.80	2.80	1.88	1.88	2.34
University	Curtin	2.53	2.53	1.64	1.64	2.09
University	Hastings	2.53	2.53	1.63	1.63	2.08
Beaver	Burrowes	1.92	1.92	2.06	2.06	1.99
College	Garner	1.92	1.92	1.91	1.91	1.91
Beaver	Garner	1.92	1.92	1.90	1.90	1.91
Beaver	Allen	1.92	1.92	1.90	1.90	1.91
College	Allen	1.91	1.91	1.90		1.90
College	Burrowes	1.91	1.91	1.90	1.90	1.90
Beaver	Pugh	1.92	1.92	1.88	1.88	1.90
College	Pugh	1.91	1.91	1.89		1.90
College	Fraser	1.91	1.91	1.89		1.90
Beaver	Fraser	1.92	1.92	1.88	1.88	1.90
Park	Shortlidge	1.92	1.92	1.63	1.63	1.77
Beaver	Hetzel	1.68	1.68	1.63		1.66
Beaver	Sparks	1.66	1.66	1.64	1.64	1.65

APPENDIX C – REFERENCES

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