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16. Abstract

Headlamps with high-intensity discharge (HID) sources have been available on vehicles sold in the U.S. for a little over ten years. Although estimates of the proportion of HID headlamps in the vehicle fleet can be made based on sales data, there are uncertainties in those estimates because of lack of comprehensive compilation of data, unknown retention rates in the fleet, and complex regional differences in sales. Furthermore, number of vehicles sold and/or registered is not necessarily predictive of vehicles in use because of possible differences in overall driving rates or, most importantly, in nighttime driving rates.

This study was therefore designed to obtain direct measurements of the proportion of vehicles with HID headlamps in nighttime traffic. Eight sites (two in each of four metropolitan areas) were selected, and traffic at those sites was video recorded between the hours of 7:00 p.m. and 10:00 p.m. The observations were made in late February and early March 2008, when those evening hours were dark and virtually all vehicles had their headlamps on. Video recording was done with diffraction gratings mounted on the cameras so that the type of headlamps—HID or tungsten-halogen (TH)—could be easily discriminated by the spectrally dispersed headlamp images. Investigators later scored the videos, counting the numbers of vehicles (except for motorcycles) in terms of headlamp type (HID or TH), and number of headlamps on (both, one, or none).

The proportions of vehicles with HID headlamps varied by more than an order of magnitude, from 0.0151 to 0.200, across the eight sites. The proportion of HID headlamps did not vary over time within the three-hour observation periods. The proportions of TH-equipped vehicles with one headlamp not functioning varied from 0.0018 to 0.0129 across the eight sites.

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Introduction

Headlamps with high-intensity discharge (HID) sources have been available on vehicles sold in the U.S. for a little over ten years (Moore, 1998). Although estimates of the proportion of HID headlamps in the vehicle fleet can be made based on sales data, there are uncertainties in those estimates because of lack of comprehensive compilation of data, unknown retention rates in the fleet, and complex regional differences in sales. Furthermore, number of vehicles sold and/or registered is not necessarily predictive of vehicles in use because of possible differences in overall driving rates or, most importantly, in nighttime driving rates.

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The observation sites were not meant to provide a systematic or comprehensive survey of headlamp use in the entire U.S. Rather, they comprised a sample of convenience that appeared to be sufficient to provide initial estimates of local and, to a limited extent, national conditions. The metropolitan areas were selected on the basis of several criteria, including that they should be broadly dispersed across the country, and that they should be in areas relatively free of winter weather that could interfere with scheduling or make outdoor observations generally difficult. Because there were not strong technical criteria for choosing some metropolitan areas over others, the decisions were strongly influenced by the availability of inexpensive transportation and accommodations. Coastal California was the only area that was selected for strong substantive reasons (the expected high proportion of imported vehicles).

We decided to make observations in the winter for several reasons, all having to do with early sunset. Vehicle density is higher earlier in the evening, as illustrated in Figure 1 by data from the 2001 National Household Travel Survey (NHTS, 2001). This means that to observe the highest number of headlamps in operation, it helps to make observations as early as possible in the evening. Also, it may be that the mix of vehicles changes over hours of the day, and at least some changes may happen early in the evening. In particular, drivers who try to avoid driving at night, including many older drivers, may often still be in the driving population early in the evening but drop out quickly after sunset. Any tendency for those drivers to continue to drive after sunset may be stronger in the winter, when driving in the early hours of darkness is harder to avoid.

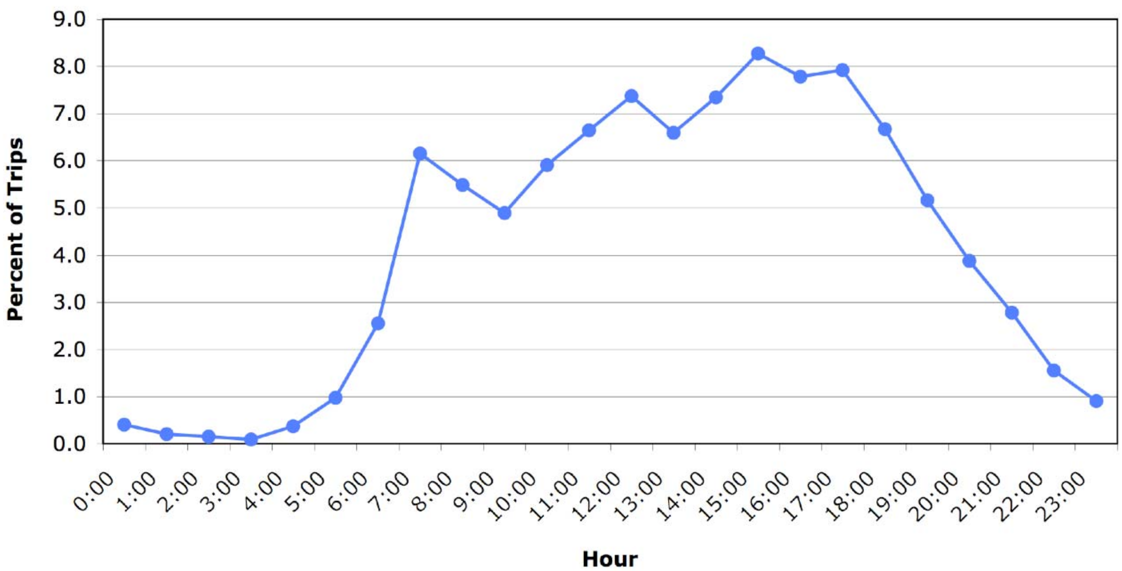

Figure 1. Percent of trips by hour in which they began (NHTS, 2001).

Method

Observation sites, dates, and times

Eight sites (two locations within each of four metropolitan areas in the United States) were selected for nighttime video recording of traffic. The metropolitan areas were Charleston, SC; Orange County, CA; Phoenix, AZ; and Sarasota, FL. The specific sites within each metropolitan area are shown on maps in the Appendix. The location of the video camera was at the tip of the yellow arrow on each map, and the flow of traffic that was recorded by the camera is show by the direction of the arrow. The sites were major arterial roads consisting of either two or three lanes of traffic. Posted speed limits ranged from 35 to 50 mph.

In each metropolitan area, video recording occurred over two nights, one night at each of the two sites. Video recording occurred in late February and early March 2008. The recording dates were chosen so that the end of civil twilight, when the sun is 6 degrees below the horizon, would occur prior to 7:00 p.m. local time. This ensured that virtually all vehicles would have their headlamps on by the beginning of the planned observation period, which was from 7:00 p.m. to 10:00 p.m. local time. On each night, the recording began approximately fifteen minutes before sunset and continued at least until 10:00 p.m. local time. Local sunset times for the days on which the recording took place are listed in Table 1.

Table 1
Local sunset times for each night at the sampled sites.

Location	Sunset (local time)	
	First night	Second night
Charleston, SC	6:19 p.m.	6:21 p.m.
Orange County, CA	5:45 p.m.	5:46 p.m.
Phoenix, AZ	6:17 p.m.	6:18 p.m.
Sarasota, FL	6:29 p.m.	6:30 p.m.

Video recording

Digital camcorders were used to video record traffic. Diffraction gratings were placed over the lenses of the camcorders so that, in addition to recording normal video images, the camera would record spectrally dispersed images. The cameras were aimed so that the normal images of passing headlamps would appear in the upper portion of the camera field of view, and spectral images of those lamps would appear in the lower portion of the camera field of view.

Figure 2 shows an example of how the headlamp images looked. The video frame is from one of the sites in Charleston, SC. Three pairs of headlamps are visible in the frame. The normal images of the headlamps appear in the upper half of the frame, and their spectrally dispersed counterparts appear in the lower half, each just below the corresponding normal image. At the extreme left, there is a vehicle with TH headlamps. The continuous spectral images that are characteristic of TH lamps are visible in the lower half of the frame, also at the extreme left, below the normal headlamp images. Halfway across the frame is a second vehicle with TH headlamps, and just to the right of that vehicle is one with HID headlamps. The spectrally dispersed images of the HID lamps have a characteristic "beaded" appearance that results from the strong concentrations of power near certain wavelengths in the light emitted by the HID sources. In several places in the frame there are images of streetlights. The spectrally dispersed images of those luminaires also show the beaded appearance, as one would expect since most of the light sources used in street lighting also have strong spectral lines.

At each site, the camera was located a short distance from the road, and aimed at about a 45 degree angle relative to the road. This arrangement allowed the camera to record the passing vehicles when they were reasonably close, so as to produce clear images. It also allowed each vehicle to be recorded over a reasonably long path. In virtually all cases, this path was long enough to ensure that both headlamps of each vehicle were visible during at least part of the vehicle's movement though the camera field of view. Although vehicles in the more distant lanes were at times partially obscured by closer vehicles, the variation in viewing angle across the field of view, as well as changes in relative positions because of differences in vehicle speeds, helped to make the headlamps visible.

Figure 2. An example video frame, illustrating the appearance of normal and spectrally dispersed headlamp images of TH and HID headlamps. Three pairs of headlamps and their spectra are visible: a TH pair near the left edge, a TH pair near the middle, and an HID pair just to the right of middle. See text for details.

Video coding

The digital video recorded at each of the field sites was later viewed by specially trained coders in a laboratory setting at UMTRI. While viewing the video, the coders kept separate counts for vehicles with each of the various headlighting conditions that are described below. All video that was recorded between 7:00 p.m. and 10:00 p.m. local time at each of the eight sites was analyzed (a total of 24 hours of video). Coders viewed the video with software that allowed both continuous, real-time playback as well as forward and backward frame-by-frame stepping. They used a strategy that involved real-time playback for relatively simple, low-volume traffic flow, and slower, more detailed examination for complex traffic (e.g., high-volume traffic involving partial obscuration of some vehicles).

All motorized vehicles, with the exception of motorcycles, were included in the counts reported here. The following vehicle types were counted, and the counts were recorded for each five-minute interval of video:

1. Vehicles equipped with TH headlamps, both of which were on
2. Vehicles equipped with HID headlamps, both of which were on
3. Vehicles equipped with TH headlamps, only one of which was on
4. Vehicles equipped with HID headlamps, only one of which was on
5. Vehicles with both headlamps off

Three coders performed the video analysis. Each coder viewed 12 hours of video, so that 12 of the 24 hours of video were analyzed by two coders. The coders knew that about half of the video would be coded twice to check for consistency across coders, but they worked separately and did not know which portions that would be. The agreement in the various counts across coders for the doubly coded video was very good. For example, the average correlation across coders for HID-equipped vehicles as a proportion of all vehicles, analyzed at the level of counts for five-minute intervals, was .996.

Results and Discussion

For the 24 hours of video recorded across all eight sites, the total count of vehicles was 19,103. Of those, 1,810 (about 9.5%) had HID headlamps. However, the proportion of HID-equipped vehicles varied greatly across sites, so that a single overall estimate for the eight sites sampled in this study must be interpreted cautiously.

Table 2 shows the counts for each of the vehicle types and each of the eight sites. The sites averaged 2,388 vehicles for the three-hour observation period (796 vehicles/hour). Across the sites, there was about a two-to-one range of traffic flow (from 484 to 1,023 vehicles/hour).

Table 3 gives results for two key proportions: HID-equipped vehicles as a proportion of all vehicles (excluding the few vehicles that had both lamps off, and for which lamp type therefore could not be determined); and TH-equipped vehicles with only one lamp on as a proportion of all TH-equipped vehicles (again, excluding vehicles with both headlamps off). The proportions of HID-equipped vehicles varied from 0.0151 (for the PH1 site) to 0.2000 (for the OC2 site). The proportions of TH-equipped vehicles with only one lamp on varied from 0.0018 (for the SA2 site) to 0.0129 (for the OC2 site).

Table 2
Vehicle counts at the eight locations surveyed.

Metropolitan area	Site	Vehicle headlighting type and condition					Totals
		TH, both on	HID, both on	TH, only one on	HID, only one on	Both off	
Charleston, SC	CH1	1,659	99	12	0	1	1,771
Charleston, SC	CH2	2,837	133	22	1	1	2,994
Orange County, CA	OC1	1,235	203	15	0	0	1,453
Orange County, CA	OC2	1,990	502	26	2	4	2,524
Phoenix, AZ	PH1	2,134	32	17	1	1	2,185
Phoenix, AZ	PH2	2,449	313	24	0	4	2,790
Sarasota, FL	SA1	2,107	200	9	0	2	2,318
Sarasota, FL	SA2	2,738	324	5	0	1	3,068
Totals		17,149	1,806	130	4	14	19,103

Table 3

Vehicle proportions at the eight locations surveyed.

Metropolitan area	Site label	HID [1]	TH, only one lamp on [2]
Charleston, SC	CH1	0.0559	0.0072
Charleston, SC	CH2	0.0448	0.0077
Orange County, CA	OC1	0.1397	0.0120
Orange County, CA	OC2	0.2000	0.0129
Phoenix, AZ	PH1	0.0151	0.0079
Phoenix, AZ	PH2	0.1123	0.0097
Sarasota, FL	SA1	0.0864	0.0043
Sarasota, FL	SA2	0.1056	0.0018
Totals		0.0948	0.0075

[1] Numerator is the count of all HID-equipped vehicles, with one or both lamps on; denominator is the count of all vehicles except those with both lamps off.
[2] Numerator is the count of TH-equipped vehicles with only one lamp on; denominator is the count of all TH-equipped vehicles, with one or both lamps on.

Figure 3 shows the HID proportion results form Table 3 graphically, along with 95% confidence intervals. The data are strong enough to show a clear separation of the HID proportions across the eight sites. The sites within metropolitan areas are similar, except for the two Phoenix sites, which show a marked disparity. The sampling in this study is not broad enough to reach a clear conclusion about the extent to which HID proportion is determined by metropolitan area, or region of the country. It is certainly possible that there is a complicated pattern of variations both across and within broad regions of the country.

Figure 4 shows the data on proportion of TH-equipped vehicles with only one lamp on, also with 95% confidence intervals. As with the HID proportions, there are clear differences across the eight sites, and there is at least some suggestion that the differences are consistent for metropolitan areas. Although, again, the sampling in this study is not broad enough to permit clear conclusions on that issue.

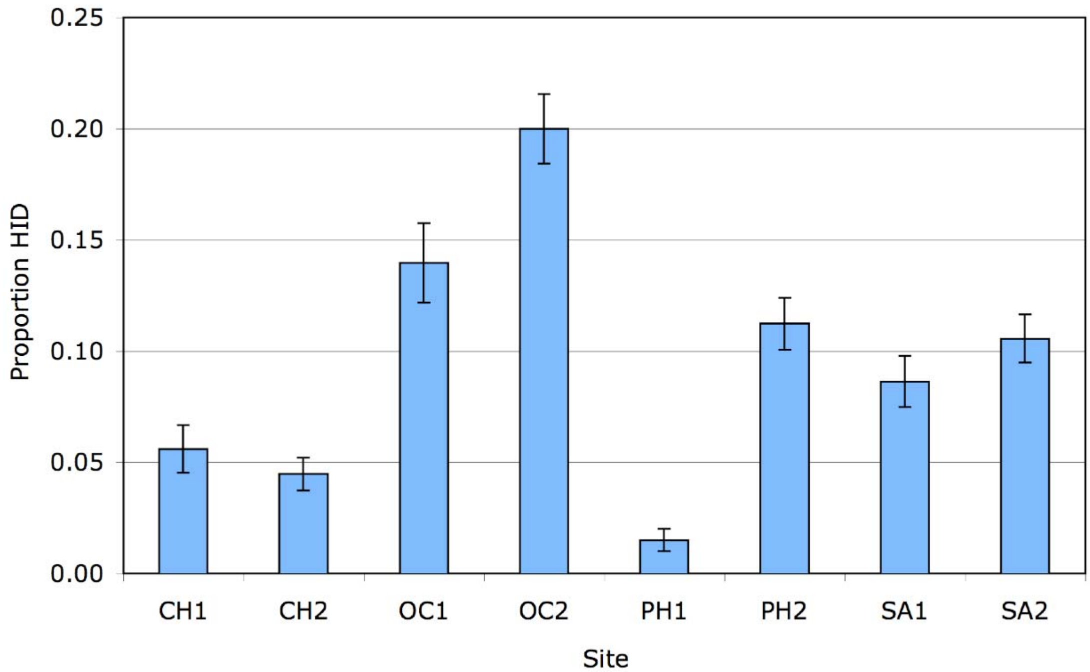

Figure 3. Proportion of vehicles with HID headlamps, for the eight sites surveyed, with 95% confidence intervals.

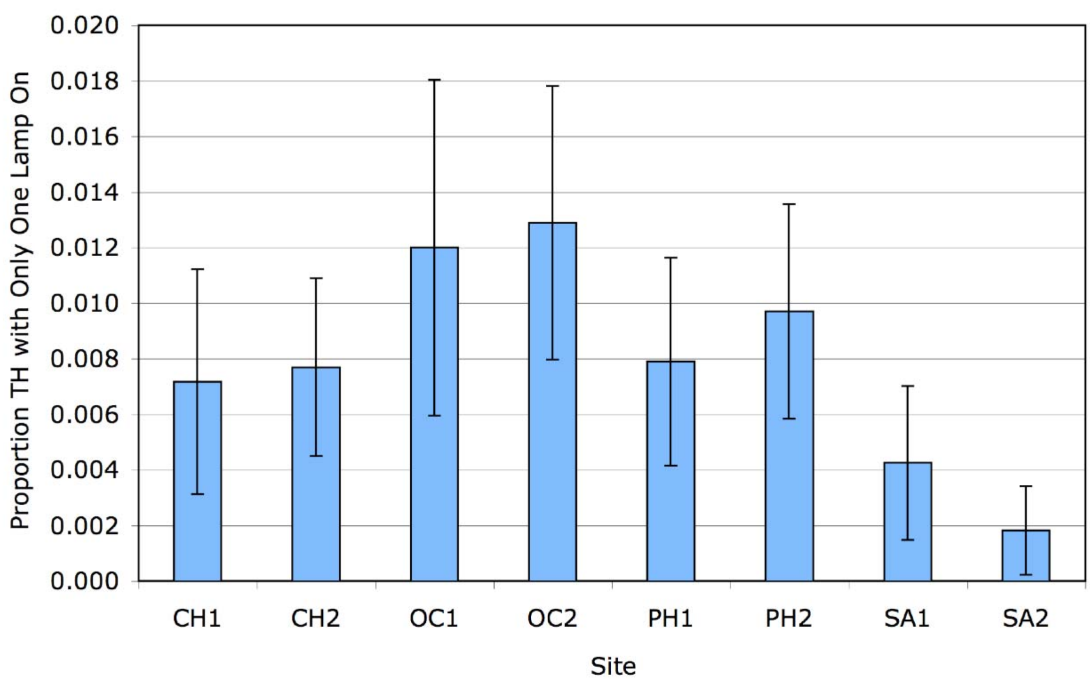

Figure 4. Proportion of vehicles with TH headlamps that had only one lamp on, for the eight sites surveyed, with 95% confidence intervals.

Because HID headlamps are more prevalent in higher-end vehicles, it may be that some of the variation in proportions of HID-equipped vehicles is associated with income levels in the areas surrounding the study sites. Any analysis of this relationship must be considered tentative, both because of the limited sites sampled and because of the ill-defined nature of the areas that can be associated with traffic flow through major arterial roads such as those involved here. However, there is some evidence for the sort of relationship that might be expected. Table 4 presents data on median household income for the zip code areas that contain each of the eight sites. The same data are presented graphically in Figure 5. The overall correlation between income and proportion HID for the eight sites is .78.

We also checked the relationship between income and proportion of TH-equipped vehicles with only one headlamp on. This relationship is shown in Figure 6. As in Figure 5, there is a reasonably high correlation, .58. However, in this case the relationship appears to be opposite what might be expected. For example, because higher incomes are associated with newer vehicles (NHTS, 2001), it might be expected that areas with higher incomes would have fewer vehicles with burned out bulbs. However, the opposite appears to be the case. But, again, any conclusions about relationships in Figure 5 and Figure 6 must be considered tentative.

Table 4

Median household income (1999 dollars) and proportion of vehicles equipped with HID headlamps for each of the sampled locations. Ordered by income.

Metropolitan area	Site	Zip code	Median household income ($)	Proportion HID
Orange County, CA	OC2	92651	76,644	0.2000
Orange County, CA	OC1	92646	69,638	0.1397
Charleston, SC	CH1	29464	57,014	0.0559
Sarasota, FL	SA1	34233	47,811	0.0864
Sarasota, FL	SA2	34231	40,385	0.1056
Charleston, SC	CH2	29407	37,436	0.0448
Phoenix, AZ	PH2	85016	37,031	0.1123
Phoenix, AZ	PH1	85017	28,595	0.0151

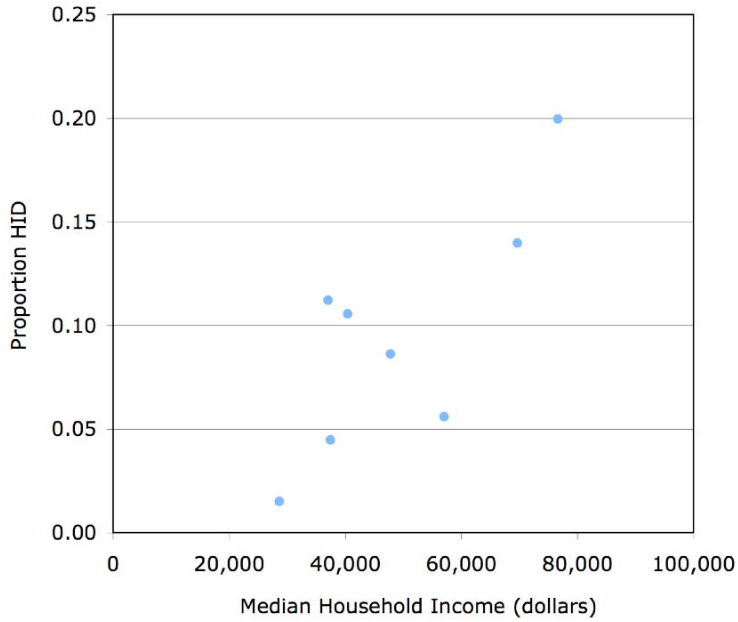

Figure 5. Proportion HID-equipped vehicles and median household income for the zip code areas containing the observation sites.

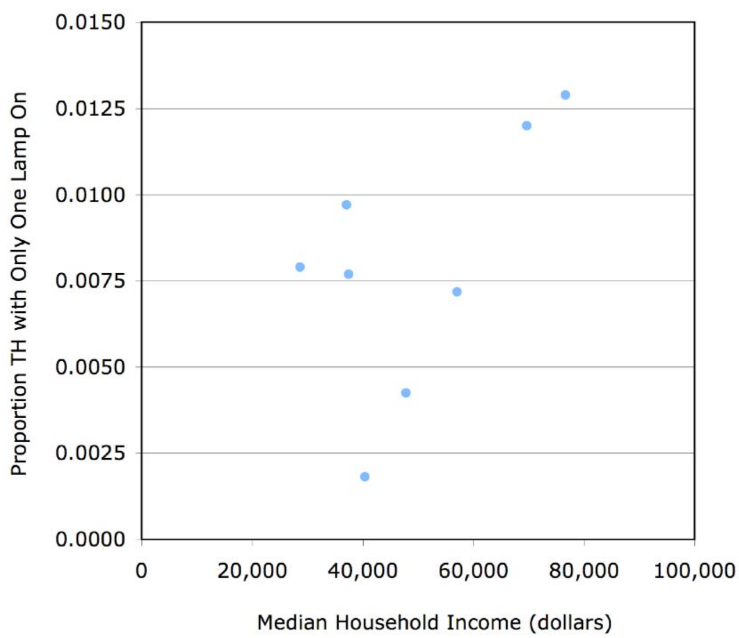

Figure 6. Proportion of TH-equipped vehicles that had only one lamp on and median household income in the zip code areas containing the observation sites.

Figure 7 presents results for the proportion of HID-equipped vehicles across the three hours of the evening that were observed. There is little if any evidence for a change in the proportion of HID-equipped vehicles. If anything, there is a slight increase in the HID proportion through the evening, opposite what would be expected if owners of HID vehicles, who are likely to be somewhat more affluent and older than other drivers, drive less later at night. However, the pattern might be different if the observation window was extended to very late at night.

Trends through the evening are also shown in Figure 8, which shows total vehicle count at the eight sites at 15-minute intervals. As expected, there is a reduction in traffic through the evening, although somewhat less than expected from the comprehensive national data in Figure 1. Figure 9 shows the proportion of HID-equipped vehicles for the same intervals. The data are noisy at this level of resolution, but the stability of the proportion of HID-equipped vehicles that is evident in Figure 7 appears to hold up reasonably well at all eight sites.

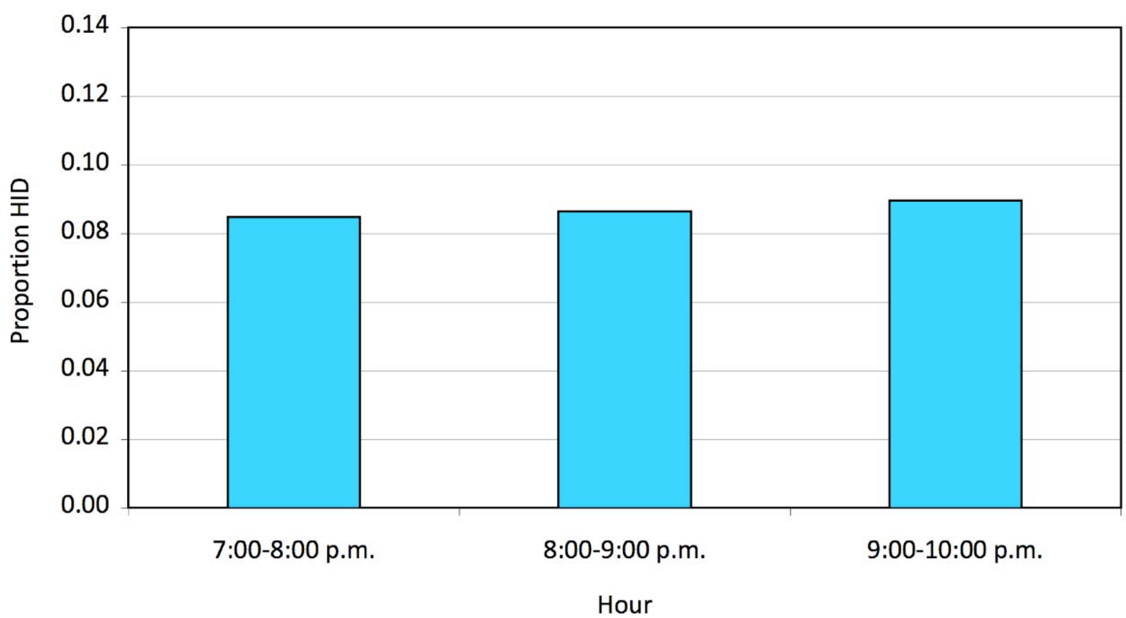

Figure 7. Proportion HID-equipped vehicles for each of the three hours of the observation periods, combined over all eight sites.

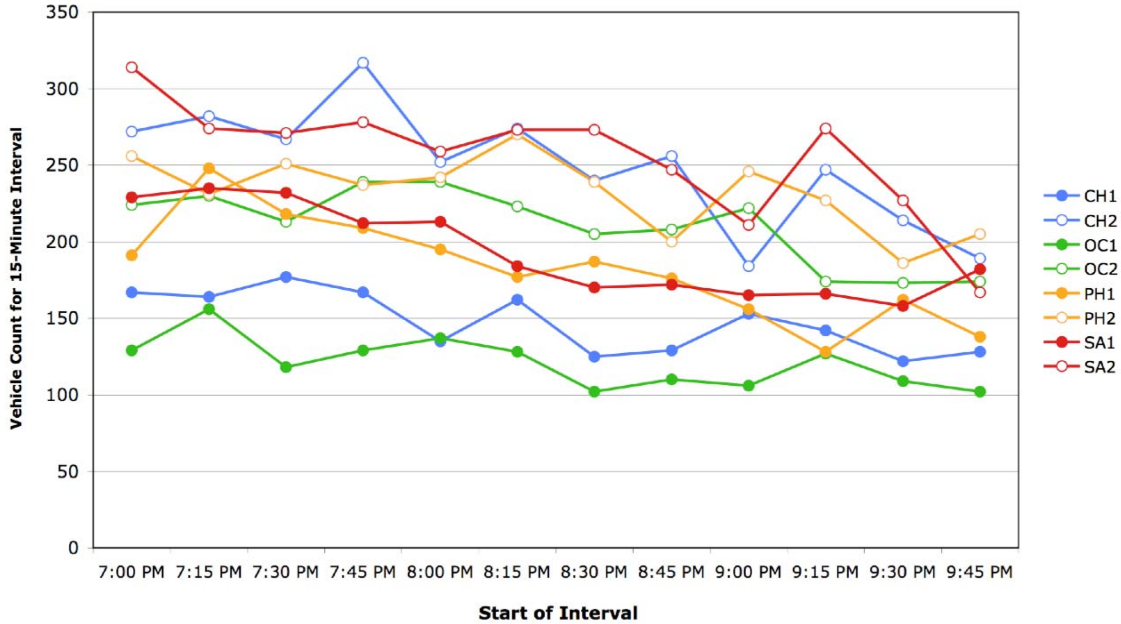

Figure 8. Vehicle counts for the eight sites, in 15-minute intervals.

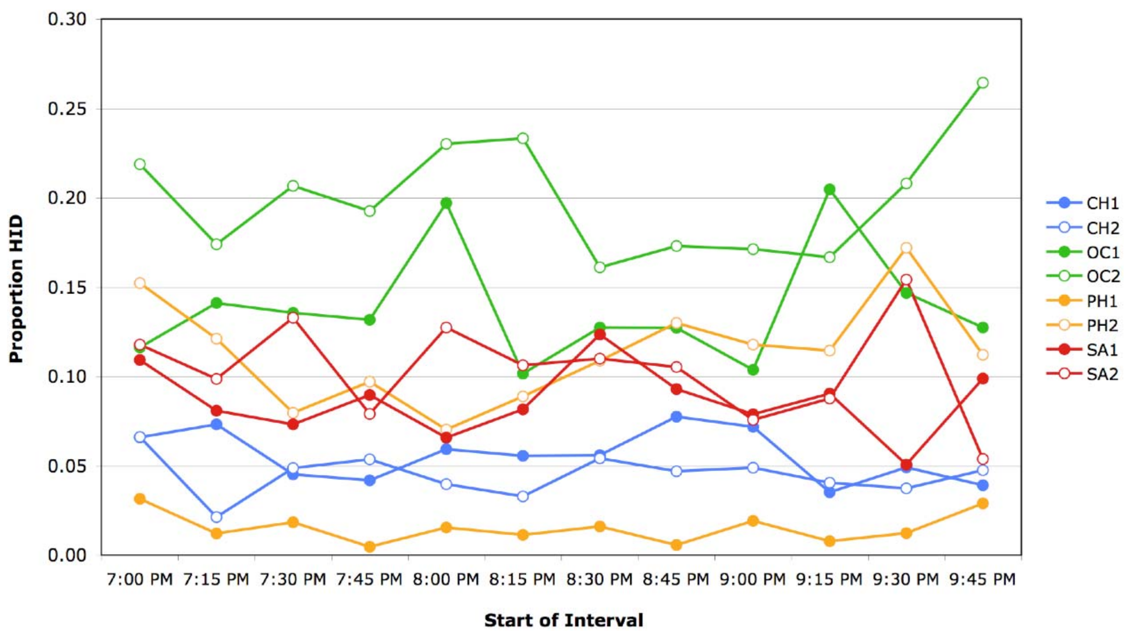

Figure 9. Proportion of HID-equipped vehicles for each of the eight sites, based on counts for 15-minute intervals.

Summary and Conclusions

The proportions of vehicles with HID headlamps at the eight sites surveyed varied by more than an order of magnitude, from 0.0151 to 0.200. The proportion of HID vehicles did not appear to vary with time within the observation window, which ran from 7:00 p.m. to 10:00 p.m. However, extending observations later into the night, perhaps after midnight, might still reveal a change. Making estimates of vehicle proportions later in the evening would require more investment in data collection because overall traffic volume is greatly diminished late at night. The strategy that we used in this study was to make observations in the winter, when we could observe headlamps in use relatively early in the evening because of early sunsets. That strategy is most appropriate for addressing the possibility that the vehicle mix changes early on, perhaps between commuters and evening shoppers. However, based on the present results, any changes in traffic mix early in the evening do not seem to affect the proportion of HID-equipped vehicles.

The proportions of vehicles reported here apply to *all* vehicles—including passenger cars, light trucks and vans, as well as large commercial vehicles. Proportions of HIDs among passenger vehicles are likely to be higher than the corresponding proportions for all vehicles because it is unlikely that many commercial vehicles were equipped with HID headlamps.

The large regional variation in proportion of HID headlamps that was evident in these results has several consequences. First, it means that estimating the proportion of HID headlamps for vehicles in use for the U.S. as a whole would be difficult. A much more elaborate stratified sampling strategy than the one employed here would have to be devised. Such a survey would probably involve many more sites, both within and across metropolitan areas. Second, it suggests that attempts to understand differences in HID usage might benefit from making use of the regional variations that apparently exist within the U.S. For example, studies of the safety consequences of HID headlamps might include comparisons between regions with high and low HID rates. Third, it raises the question of whether similar differences exist within other countries, or within regions such as Europe.

Although a comprehensive survey of lighting in use in the U.S. would be difficult, the regional differences in the current results might be extended relatively easily by combining them with other sources of information about the mix of vehicle makes and models in various regions. Although most of the sources available would not directly provide estimates of vehicles in use, some alternatives worth considering include vehicle sales and registrations, as well as crash data.

The proportions of HID-equipped vehicles at the various observation sites are correlated with local median household income, in terms of income data for the zip code areas in which the sites were located. However, the pattern is not particularly strong, and the limited regional sampling in the current study means that any conclusions should be considered tentative.

The proportion of TH-equipped vehicles that had only one lamp on varied from 0.0018 to 0.0129 across the eight sites surveyed. The regional differences in nonfunctioning lamps do not seem to be easily explained by income data, which may be correlated with average vehicle age. Perhaps more direct measures of vehicle age would be worth investigating. Interestingly, all of the estimates in the current study are lower than the value of 0.023 that was estimated for the U.S. as a whole from a survey in the early 1990s (Rys, Konz, & Russell, as cited in Sivak, Flannagan, & Miyokawa, 1999). It is not entirely clear how to explain the difference. It is possible that the overall reliability of headlamps has improved between the surveys, but it is also possible that the discrepancy is due to differences in the actual sites surveyed. In either case, both the possible change over time and the regional differences in the current results appear to be strong enough to be worth further investigation.

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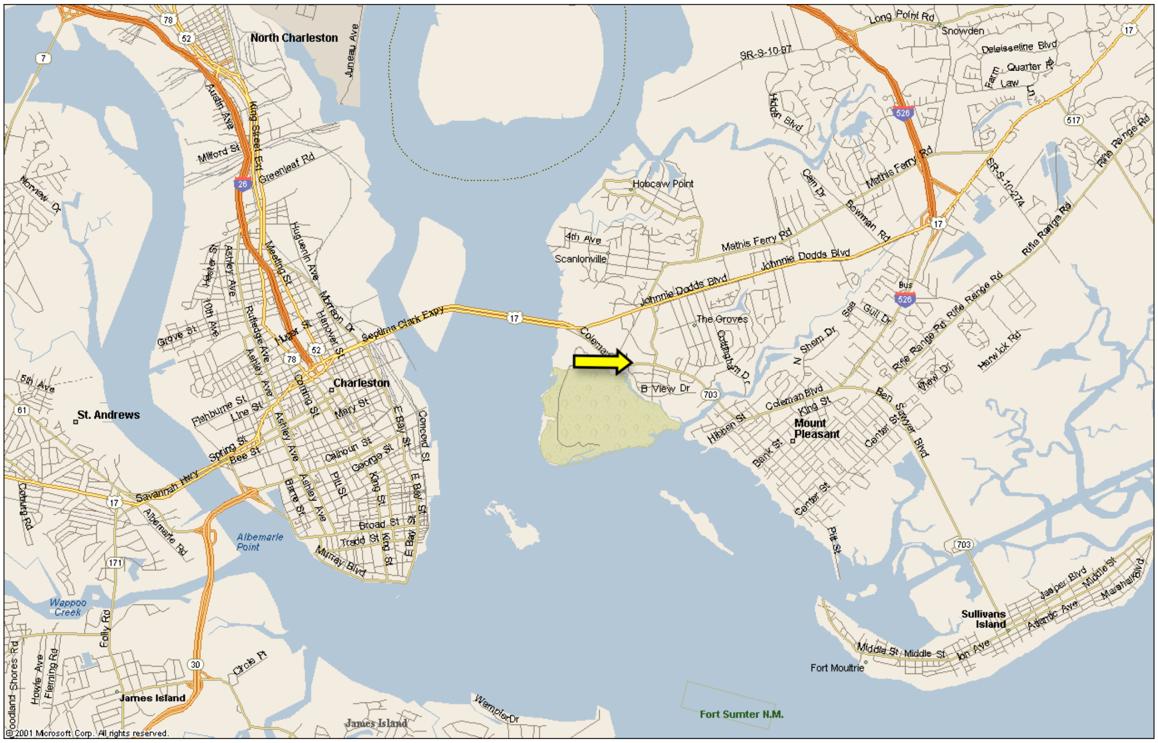
Appendix

The following eight maps show the sites at which video recordings were made. On each map, the tip of the yellow arrow shows the location of the observation point, and the direction of the arrow shows the movement of the flow of traffic that was observed.



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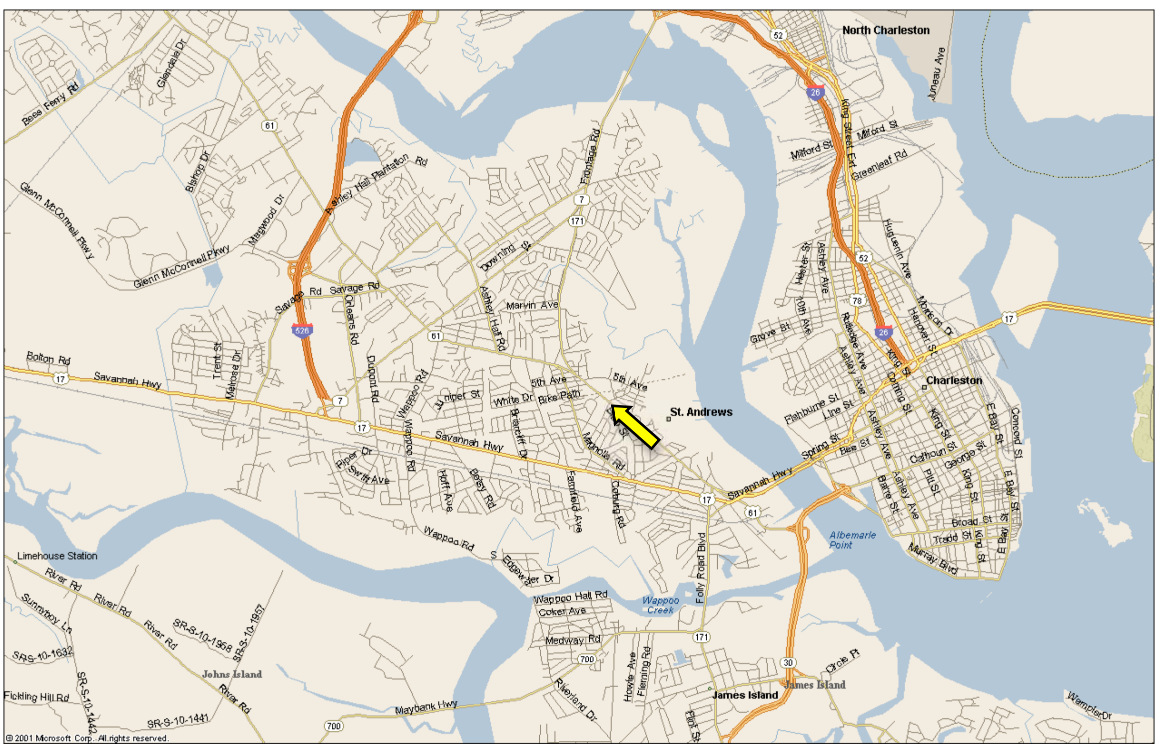

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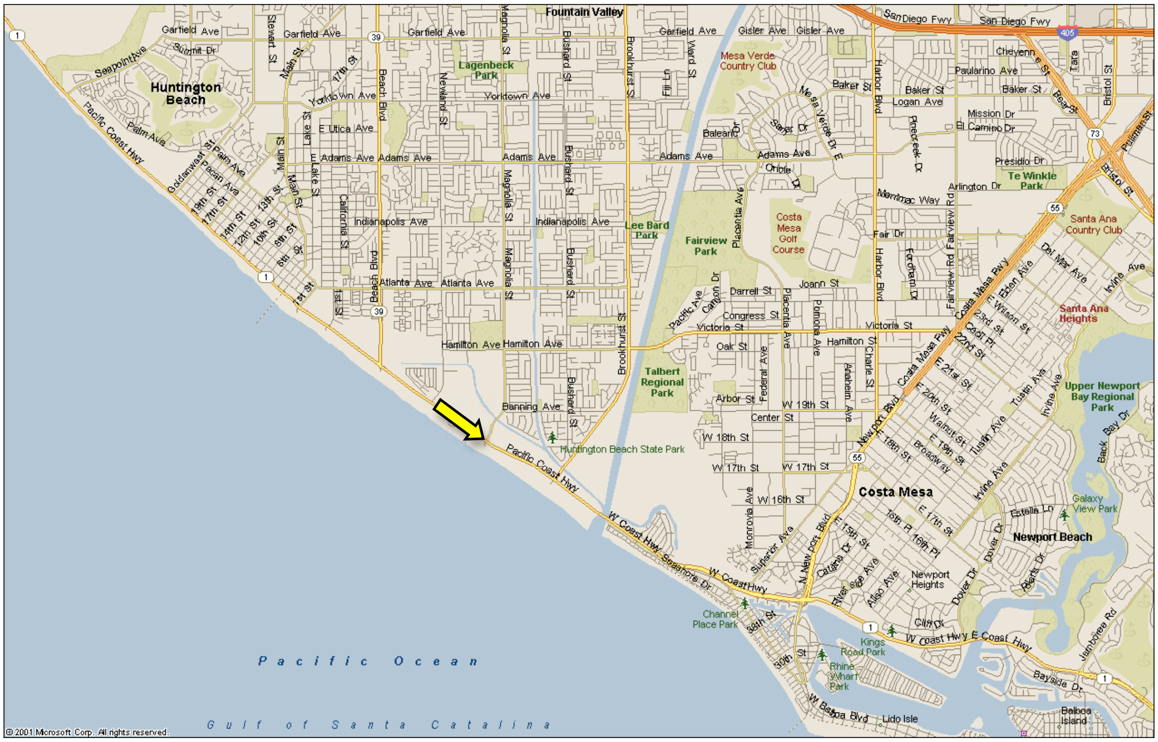

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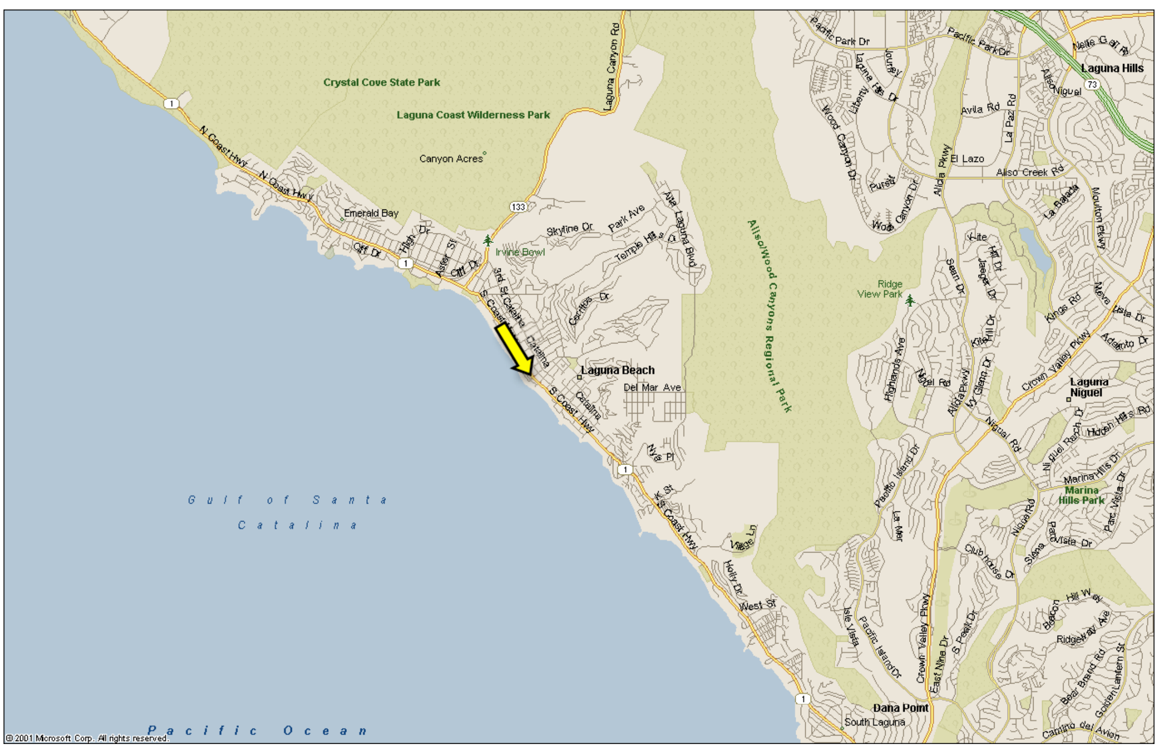

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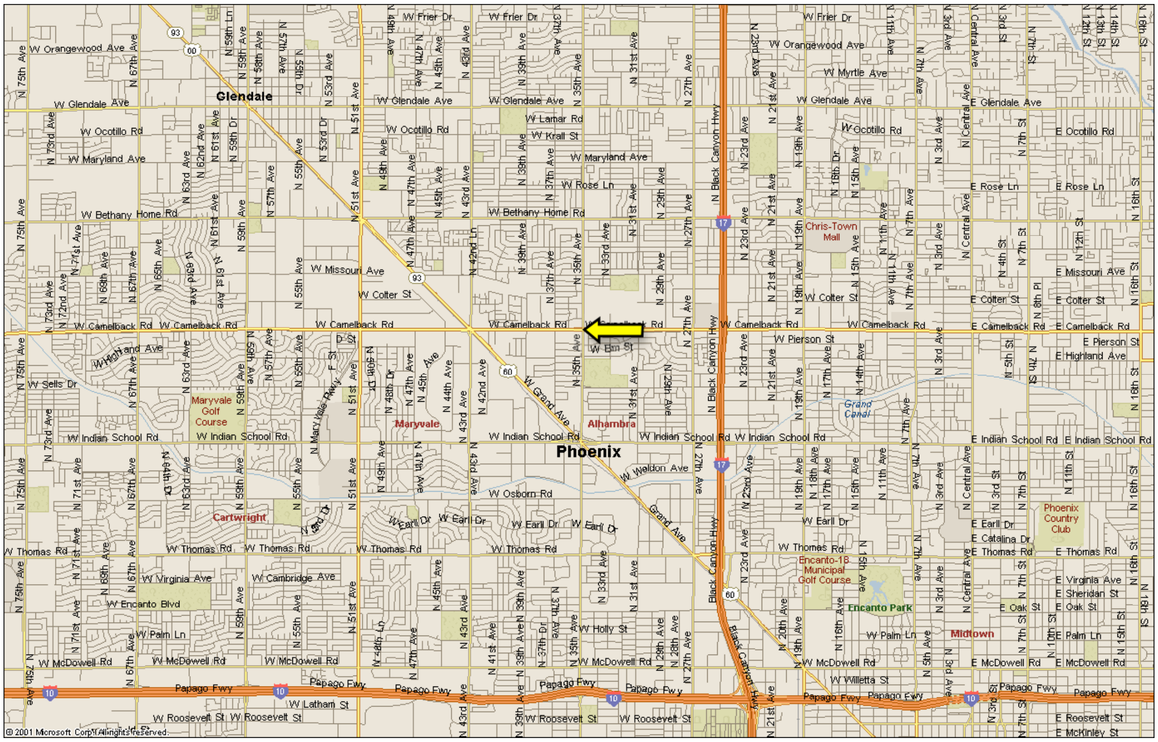

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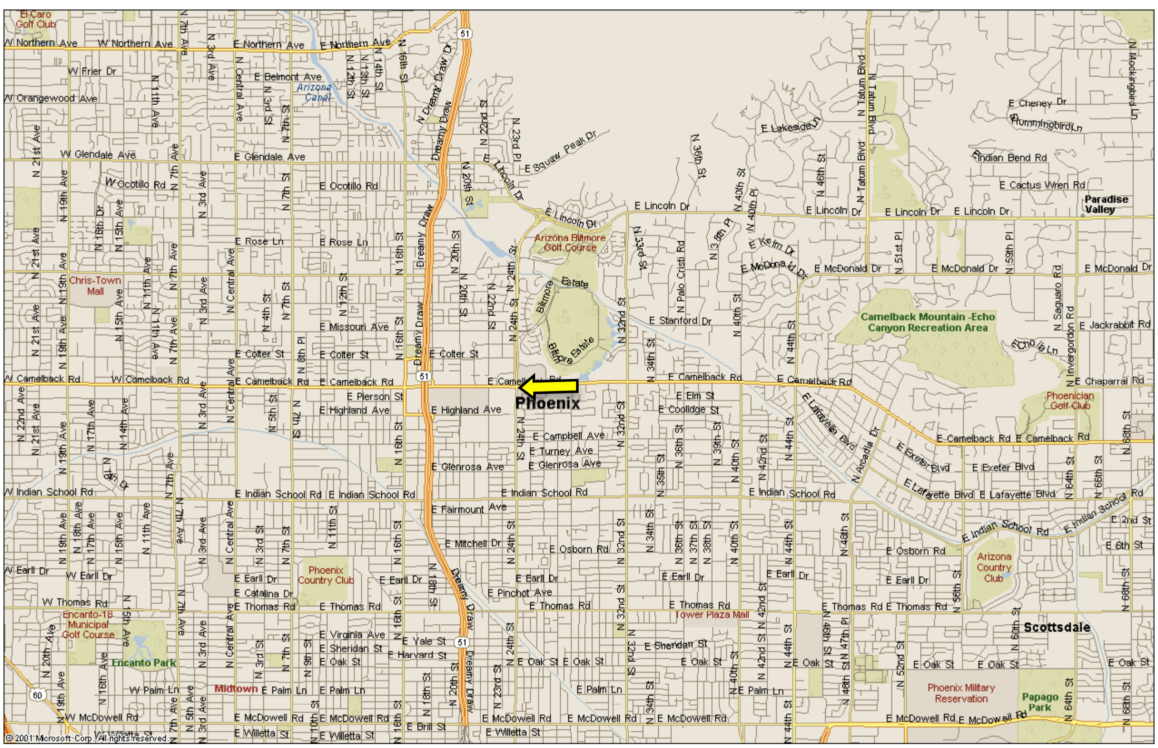
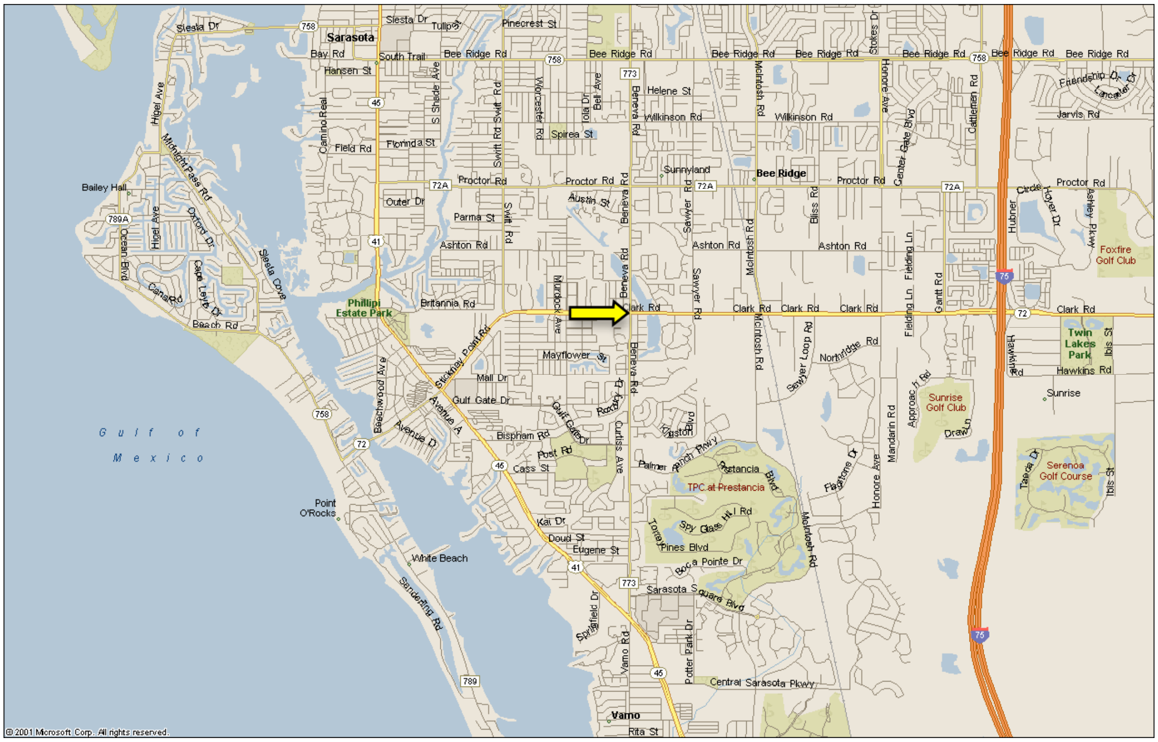
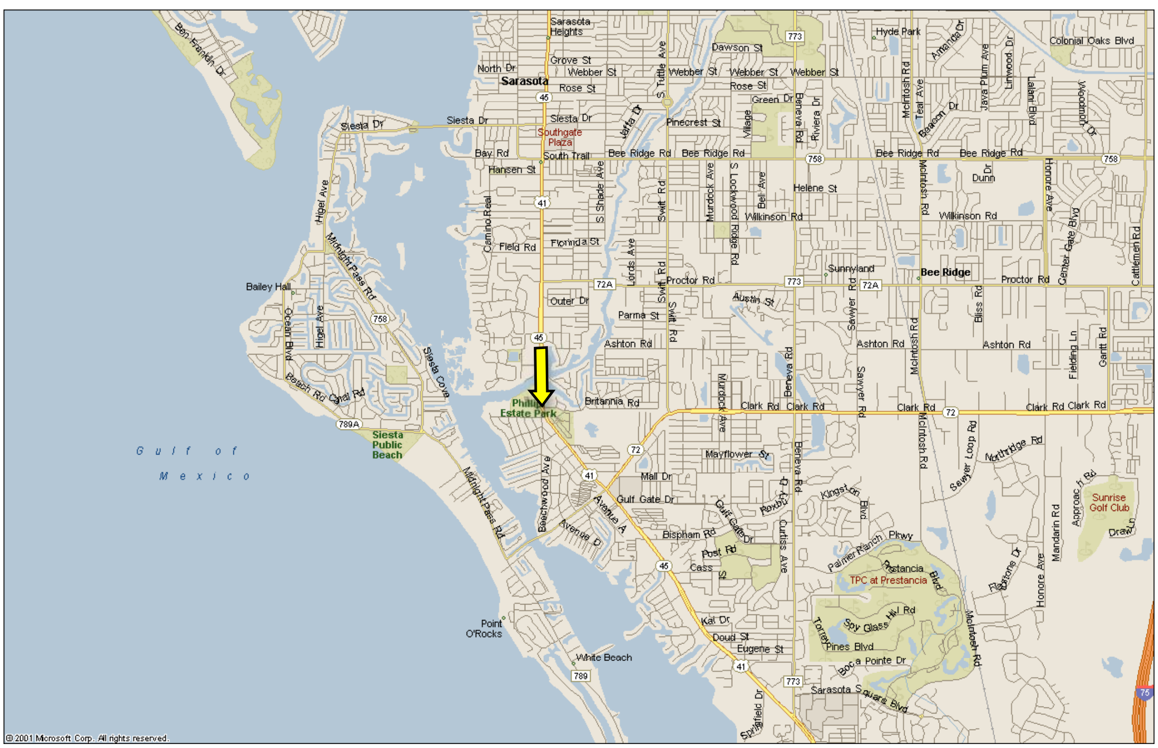


Site PH2 Phoenix, AZ



Site SA1 Sarasota, FL



Site SA2 Sarasota, FL